

# A Herschel Space Observatory Spectral Line Survey of Local Luminous Infrared Galaxies from 194 to 671 Microns\*

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## ABSTRACT

We describe a *Herschel Space Observatory* 194-671  $\mu\text{m}$  spectroscopic survey of a sample of 121 local luminous infrared galaxies and report the fluxes of the CO  $J$  to  $J-1$  rotational transitions for  $4 \leq J \leq 13$ , the [N II] 205  $\mu\text{m}$  line, the [C I] lines at

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609 and  $370\,\mu\text{m}$ , as well as additional and usually fainter lines. The CO spectral line energy distributions (SLEDs) presented here are consistent with our earlier work, which was based on a smaller sample, that calls for two distinct molecular gas components in general: (i) a cold component, which emits CO lines primarily at  $J \lesssim 4$  and likely represents the same gas phase traced by CO (1–0), and (ii) a warm component, which dominates over the mid- $J$  regime ( $4 < J \lesssim 10$ ) and is intimately related to current star formation. We present evidence that the CO line emission associated with an active galactic nucleus is significant only at  $J > 10$ . The flux ratios of the two [C I] lines imply modest excitation temperatures of 15 to 30 K; the [C I]  $370\,\mu\text{m}$  line scales more linearly in flux with CO (4–3) than with CO (7–6). These findings suggest that the [C I] emission is predominately associated with the gas component defined in (i) above. Our analysis of the stacked spectra in different far-infrared (FIR) color bins reveals an evolution of the SLED of the rotational transitions of  $\text{H}_2\text{O}$  vapor as a function of the FIR color in a direction consistent with infrared photon pumping.

*Subject headings:* infrared: galaxies — galaxies: star formation — galaxies: active — galaxies: ISM — ISM: molecules — submillimeter: galaxies

## 1. Introduction

Luminous Infrared Galaxies (LIRGs, defined to have an  $8\text{--}1000\,\mu\text{m}$  total infrared luminosity  $L_{\text{IR}} \geq 10^{11} L_{\odot}$ ; Sanders & Mirabel 1996), and ultra-luminous galaxies (ULIRGs,  $L_{\text{IR}} > 10^{12} L_{\odot}$ ) dominate the cosmic star formation (SF) at  $z \gtrsim 1$  (Le Flóch et al. 2005; Caputi et al. 2007; Magnelli et al. 2009, 2011; Gruppioni et al. 2013). For  $z \sim 1$  up to 3, these galaxies are mixtures of two populations based on the dominant “SF mode”: (i) mergers dominated by nuclear starburst with warm far-infrared (FIR) colors and a high SF efficiency (SFE) similar to that of local ULIRGs, and (ii) gas-rich disk galaxies with SF extended over their disk and an SFE comparable to local spirals (e.g., Daddi et al. 2010; Genzel et al. 2010). Most ULIRGs at  $z \sim 1 - 3$ , as defined purely by their luminosities, belong to group (ii), the so-called “main-sequence” (MS) population (Muzzin et al. 2010; Elbaz et al. 2011), with FIR colors in the range occupied by typical local LIRGs (Rujopakarn et al. 2011). Due to their proximity, local LIRGs can be studied in much more detail than distant counterparts, and therefore provide valuable insights into the star formation process and its interplay with dense interstellar gas in the galaxy population that dominates the cosmic star formation at high redshifts. For this reason, the flux-limited sample of local LIRGs in the Great Observatories All-Sky LIRG Survey (GOALS; Armus et al. 2009) has been the focus of a large number of observational surveys, including imaging and/or spectroscopy in X-ray (e.g., Iwasawa et al. 2011; U et al. 2012), ultra-violet (e.g., Howell et al. 2010; Petty et al. 2014), optical/near-IR (e.g., Haan et al. 2011), mid- to far-IR (e.g., Petric et al. 2011; Díaz-Santos et al. 2010, 2011; Stierwalt et al. 2013, 2014; Inami et al. 2013) and radio continuum (e.g., Murphy et al. 2013). More recently, the GOALS sample was observed with the *Herschel Space Observatory*

(hereafter *Herschel*; Pilbratt et al. 2010) in a broad-band photometric survey at 70, 100, 160, 250, 350 and 500  $\mu\text{m}$  (PI: D. B. Sanders; see Chu et al. 2017, in preparation) and a spectroscopic survey targeting some of the major FIR gas cooling lines (PI: L. Armus; see Díaz-Santos et al. 2013, 2014, 2017).

(U)LIRGs are all known to be rich in molecular gas (Sanders & Mirabel 1996), which is the fuel necessary for their above-average SF rates (SFRs). The CO (1–0)<sup>1</sup> line, which is associated with a critical density ( $n_c$ ) on the order of  $10^3 \text{ cm}^{-3}$  and an excitation temperature ( $T_{\text{ex}}$ ) of 5.5 K, has been widely used to trace the total molecular gas content. However, SF occurs mainly in the denser parts of molecular clouds as evidenced by correlations in local (U)LIRGs between  $L_{\text{IR}}$  and dense gas tracers such as HCN (1–0) (e.g., Gao & Solomon 2004; Wu et al. 2005; Pricon et al. 2015), and heats up the surrounding dense molecular gas substantially. The resulting warm dense gas can be better traced by a mid- $J$  CO line transition, such as CO (6–5), which has  $n_c \sim 10^5 \text{ cm}^{-3}$  and  $T_{\text{ex}} = 116 \text{ K}$  (Carilli & Walter 2013). This prediction was already suggested by limited ground-based CO data (e.g., Bayet et al. 2009) prior to the advent of *Herschel*. In general, a CO line of a higher  $J$  corresponds to higher  $n_c$  and  $T_{\text{ex}}$ . This unique property of the CO rotational transitions allows one to immediately make ballpark estimates on both the gas density and temperature of the underlying molecular gas based on the  $J$  value at the peak of the CO spectral line energy distribution (SLED) observed.

By combining our own observations with archival data, we analyzed the 194–671  $\mu\text{m}$  spectra of 121 LIRGs obtained with the Fourier transform spectrometer (FTS) of the Spectral and Photometric Imaging REceiver (SPIRE; Griffin et al. 2010; Swinyard et al. 2014) onboard *Herschel*. These galaxies belong to a complete, IR flux-limited sample of 123 LIRGs from GOALS as detailed in §2. One of our primary goals is to study the CO SLED in the mid- $J$  regime, i.e.,  $4 < J \lesssim 10$ , which was anticipated to be closely related to on-going SF. Indeed, our earlier analysis of the CO SLEDs on a subset of this sample (Lu et al. 2014) suggests that a simple picture that can adequately describe the molecular gas properties in the majority of (U)LIRGs involves two gas components: (a) a cold, moderately dense gas phase, which emits CO lines primarily at  $J < 4$  and is not directly related to current SF, and (b) a warm and dense component, which emits CO lines mainly in the mid- $J$  regime. For the vast majority of the SF-dominated (U)LIRGs, the ratios of the total luminosity of the warm CO line emission to  $L_{\text{IR}}$  show a well defined characteristic value, suggesting strongly that current SF is the power source for both the warm CO and IR dust emissions in these galaxies. This framework was further confirmed by our high angular resolution mapping of the CO (6–5) line emission in some representative local LIRGs with the Atacama Large Millimeter/submillimeter Array (ALMA; Xu et al. 2014, 2015; Zhao et al. 2016b). As a result, Lu et al. (2015) analyzed the CO (7–6) data from the current paper and showed that a single mid- $J$  CO line, such as CO (7–6), can serve as a good SFR tracer for galaxies both in the local universe and at high redshifts.

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<sup>1</sup>Throughout this paper, we use  $J$  to refer to the upper energy level of the CO rotational transition from  $J$  to  $J - 1$ . For example, CO (1–0) is the rotational transition from  $J = 1$  to  $(J - 1) = 0$ .



As a SFR tracer, CO (7–6) has advantages over some conventional SFR tracers such as the luminosity of the [C II] line at  $158\mu\text{m}$  and  $L_{\text{IR}}$ . The [C II] line luminosity to  $L_{\text{IR}}$  (or SFR) ratio decreases steeply as the FIR color increases (e.g., Díaz-Santos et al. 2013, Lu et al. 2015). Since the FIR color is fundamentally driven by the average intensity of the dust heating radiation field (e.g., Draine & Li 2007) and scales empirically with the average SFR surface density in disk galaxies (e.g., Liu et al. 2015; Lutz et al. 2016), this implies that, the higher the SFR surface density of a galaxy is, the less relevant (energetically) the [C II] line becomes. This runs counter to what constitutes a good SFR tracer. In contrast, the CO (7–6) to IR luminosity ratio depends little on the FIR color (Lu et al. 2014, 2015).  $L_{\text{IR}}$  is regarded as a reliable SFR tracer for active star-forming galaxies as dust grains are very effective in absorbing far-UV photons and reradiating the energy in the infrared. For high- $z$  galaxies, however, this usually requires multiple photometric measurements covering a wide wavelength range, as illustrated in the recent studies of 3 galaxies at  $z \sim 5$ –6 (Riechers et al. 2013; Gilli et al. 2014; Rawle et al. 2014). Furthermore, as  $z$  increases, accurate continuum photometry in sub-mm becomes challenging due to a relatively bright background and an increasing Cosmic Microwave Background (CMB; da Cunha et al. 2013). In comparison, using CO (7–6) as the SFR tracer involves only one line flux measurement and is less impacted by CMB due to the high line excitation temperature. In addition, as further shown in this paper, the CO (7–6) line emission could also be largely free from the influence of AGN.

In this paper we tabulate and study in more detail the SPIRE/FTS fluxes of the CO emission lines of  $4 \leq J \leq 13$  for the whole sample. The CO data presented here can be further combined with existing ground-based CO lines of  $1 \leq J \leq 3$  (e.g., Sanders et al. 1991; Gao & Solomon 1999; Yao et al. 2003; Leech et al. 2010; Papadopoulos et al. 2012) to construct a “full” CO SLED that can be used to gain important insights into the physical conditions of molecular gas in (U)LIRGs and how different gas phases evolve along a merger sequence. This can be done either by modeling the observed CO SLED in a non-local thermodynamic equilibrium (non-LTE) condition, which has been applied to many individual galaxies with SPIRE/FTS data (e.g., Panuzzo et al. 2010; van der Werf et al. 2010; Rangwala et al. 2011; Spinoglio et al. 2012; Meijerink et al. 2013; Kamenetzky et al. 2012; Pereira-Santaella et al. 2013; Pellegrini et al. 2013; Rigopoulou et al. 2013; Papadopoulos et al. 2014; Rosenberg et al. 2014a, 2014b, 2015; Schirm et al. 2014; Wu et al. 2015; Xu et al. 2015), or by empirical correlation analyses with data from other wavebands (e.g., Lu et al. 2014, 2015; Greve et al. 2014; Liu et al. 2015; Kamenetzky et al. 2016).

Besides the CO lines, our other main targeted spectral lines include the fine-structure line of singly-ionized nitrogen at  $205\mu\text{m}$  (i.e.,  $^3P_1 \rightarrow ^3P_0$  at 1461.134 GHz; hereafter referred to as [N II]  $205\mu\text{m}$  or the [N II] line) and the two fine-structure transitions of neutral carbon in its ground state at  $609\mu\text{m}$  (i.e.,  $^3P_1 \rightarrow ^3P_0$  at 492.1607 GHz; hereafter [C I]  $609\mu\text{m}$ ) and  $370\mu\text{m}$  (i.e.,  $^3P_2 \rightarrow ^3P_1$  at 809.3435 GHz; hereafter [C I]  $370\mu\text{m}$ ). Statistical analyses of our data on the [N II] line, which probes mainly low-ionization and low-density ionized gas, can be found in Zhao et al. (2013, 2016a) who also carefully derived a local luminosity function of this line. A detailed analysis of the [C I] line data will be presented elsewhere. The current paper describes our survey and presents the

spectral lines detected. The remainder of this paper is organized as follows: We present our galaxy sample in §2. In §3 we describe our spectroscopic survey and data reduction, present the resulting spectra, and tabulate the fluxes of the detected spectral lines. In §4 we consider possible data systematics that may be relevant for certain future science application of the data sets given here. In §5 we present statistical analyses of the CO and [C I] lines, as well as spectral lines from H<sub>2</sub>O vapor and hydrogen fluoride (HF) molecules. Finally, in §6 we summarize our results.

## 2. Sample

### 2.1. Sample Selection

We selected our targets for the SPIRE/FTS survey from the GOALS sample (Armus et al. 2009). The GOALS sample consists of 202 LIRGs complete to a flux density of 5.24 Jy at 60  $\mu$ m as measured by the *Infrared Astronomical Satellite* (*IRAS*). For a target in a multiple galaxy system, its  $L_{\text{IR}}$  was determined based on a flux partition between the individual galaxies at either 70 or 24  $\mu$ m, following the scheme described in Díaz-Santos et al. (2010, 2011). Fig. 1a is a plot of the 202 GOALS galaxies in terms of  $\log L_{\text{IR}}$  versus  $F_{\text{IR}}$ , where  $F_{\text{IR}}$  is the 8-1000  $\mu$ m IR flux as defined in Sanders & Mirabel (1996). The conversion between  $F_{\text{IR}}$  and  $L_{\text{IR}}$  was done using the luminosity distance given in Table 1 below. The horizontal dotted line stands for the  $L_{\text{IR}}$  cutoff for LIRGs. The vertical dotted line stands for  $F_{\text{IR}} = 6.5 \times 10^{-13} \text{ W m}^{-2}$ , which was the cutoff for the initial 124 targets selected for our SPIRE/FTS survey, including 7 ULIRGs. This flux cutoff was applied to achieve a balance between the sample size and the telescope time required to achieve our desired sensitivity. Our sample selection included one object (IRAS 05223+1908) that we now no longer consider to be an LIRG based on the new SPIRE/FTS data here (see §3.3). After excluding this source, the complete, IR flux-limited LIRG sample intended for our SPIRE/FTS survey consists of 123 sources.

While SPIRE/FTS observations of ULIRGs were also obtained by other groups, our program is the only one that provides adequate coverage of LIRGs with  $L_{\text{IR}}$  of  $10^{11}$  to  $\sim 10^{11.5} L_{\odot}$ , where the LIRG population displays the largest diversity in physical properties (Armus et al 2009). Fig. 1b plots the FIR color,  $C(60/100)$ , defined in this work as the *IRAS* 60-to-100  $\mu$ m flux density ratio, as a function of  $F_{\text{IR}}$ . For a galaxy in a multiple galaxy system unresolved by *IRAS*, its FIR color used here is the same as for the system as a whole except for the cases where the 60 and 100  $\mu$ m flux densities of the individual galaxies were available. Fig. 1b shows that the  $C(60/100)$  color range covered by our FTS sample is representative of the parent sample. Fig. 1c plots the *IRAS* 60  $\mu$ m flux density against  $F_{\text{IR}}$ , with the horizontal dotted line standing for the 60  $\mu$ m flux density cutoff of the GOALS sample. This plot illustrates that our FTS sample is effectively limited only by our flux cutoff in  $F_{\text{IR}}$ .

## 2.2. Basic Galaxy Parameters

Of the 123 LIRGs in our complete, IR flux-limited sample, a total of 121 were observed with SPIRE/FTS (with VV 250a and IC 4686 being the 2 objects that were not observed). In addition, we also observed two non-LIRG galaxies, NGC 5010 and the aforementioned IRAS 05223+1908. All 123 observed targets are listed in Table 1 with the following columns: Column (1) is the name of the target spatially closest to the actual pointing of the SPIRE/FTS observation. These names follow an updated naming scheme detailed in Mazzarella et al. (2017, in preparation) with notes given in Appendix A for those galaxies with known companions. Columns (2) and (3) are the J2000 RA and Dec. of the actual pointing of the SPIRE/FTS observation. Column (4) gives the systematic pointing offset in arcseconds, as of the calibration version 11 in the *Herschel* Interactive Processing Environment (HIPE; Ott 2010), between the actual pointed position and the requested pointing position. The latter is always the nuclear position of the target specified in Column (1). This pointing offset includes a  $1.7''$  SPIRE-specific offset applicable to the *Herschel* observational days (OD) earlier than OD 1110, but not any *Herschel*-wide absolute pointing error that could be up to  $2''$ . Column (5) is the adopted  $L_{\text{IR}}$  relevant to the target of the SPIRE/FTS observation. For a target in a multiple system of 2 or more galaxies, this value is followed by a “(\*)” with its derivation explained in Appendix A. In many cases, this is a 24 or  $70\,\mu\text{m}$  flux-scaled luminosity from the *IRAS* total  $L_{\text{IR}}$  of the galaxy system. In addition, due to the updated  $L_{\text{IR}}$ , a few of our targets (e.g., NGC 0876, NGC 2341, NGC 6285) now have  $L_{\text{IR}}$  slightly less than  $10^{11} L_{\odot}$ . These galaxies are still kept in our LIRG sample. Column (6) is the FIR color,  $C(60/100)$ . For most of the targets involved in a multiple system (see Appendix A), their  $C(60/100)$  values are simply that for their galaxy system, which should be dominated by the brightest member galaxy that is usually our SPIRE/FTS target. Columns (7) and (8) are respectively the luminosity distance in Mpc and heliocentric velocity in  $\text{km s}^{-1}$ , taken from Table 1 in Armus et al. (2009). Column (9) is the SPIRE/FTS observation identification number (OBSID). The observations with an OBSID  $\leq 1342245858$  were done prior to OD 1110, and thus were impacted by the SPIRE-specific  $1.7''$  pointing offset mentioned above<sup>2</sup>. Column (10) gives the on-target integration time of the FTS observation. Finally, column (11) identifies the original FTS program in which the observation was carried out. For example, “OT1\_nlu\_1” refers to our own SPIRE/FTS program.

For each target in Table 1 (except for NGC 1068), estimates of the AGN fractional contribution to the total bolometric luminosity have been recently updated by Díaz-Santos et al. (2017) using a number of independent estimators, including the line ratios  $[\text{Ne V}]/[\text{Ne II}]$  and  $[\text{O IV}]/[\text{Ne II}]$ , mid-IR continuum slope, equivalent width of Polycyclic Aromatic Hydrocarbon (PAH) emission bands and the diagram of Laurent et al. (2000), following the formulation prescribed in Veilleux et al. (2009). If we denote  $f_{\text{AGN}}$  as the unweighted average for the fractional contribution by AGN to the total bolometric luminosity, from these various independent estimates, there are a total of 6

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<sup>2</sup>Note that, since the observations of the SPIRE/FTS point-source flux calibrators in the early ODs also suffered this  $1.7''$  systematic offset, this offset has no net effect on the point-source flux calibration.

targets with  $f_{\text{AGN}} > 50\%$ , meaning that there is a high likelihood, with a good consistency among the different estimators, that the AGN could be the dominant source powering the observed  $L_{\text{IR}}$  in these galaxies. Although the classic Seyfert galaxy NGC 1068 is not included in Díaz-Santos et al. (2017), alternative analyses suggest  $f_{\text{AGN}} \gtrsim 50\%$  for this galaxy (Telesco & Decher 1988; Lu et al. 2014). We therefore refer to these 7 galaxies (i.e., NGC 1068, UGC 02608, NGC 1275, IRAS F05189-2524, UGC 08058 (= Mrk 231), MCG -03-34-064, and NGC 7674) as the (sub)sample of dominant AGNs in the remainder of this paper.

These 7 galaxies represent the cases where the AGN clearly dominates the bolometric luminosity. While it is known that star formation dominates the bolometric luminosity of most LIRGs (Petric et al. 2011, Stierwalt et al. 2013), there are certainly additional sources in our sample in which the AGN contribution to the bolometric luminosity is non-negligible according to one or more individual mid-IR diagnostics, such as the one based on the equivalent width of the  $6.2\mu\text{m}$  PAH feature (Stierwalt et al. 2013). However, in this paper, we have chosen to isolate those sources where the average fractional AGN bolometric contribution is above 50%, in order to identify galaxies where the AGN might be expected to have the largest impact on the molecular ISM. We refer the reader to Díaz-Santos et al. (2017) for details on individual AGN diagnostics and their relationship to the average AGN fraction value we used here.

### 3. Observations, Data Reduction and Spectral Line Results

#### 3.1. SPIRE/FTS Spectroscopy

The SPIRE/FTS (Griffin et al. 2010) uses two bolometer arrays of 37 and 19 detectors for spectral imaging in a Spectrometer Short Wavelength (SSW) coverage from 194 to  $313\mu\text{m}$  and a Spectrometer Long Wavelength (SLW) coverage from 303 to  $671\mu\text{m}$ , respectively. The incoming light from the telescope is split into two beams. An internal moving mirror regulates the optical path difference between the two beams before they are re-combined to form an interference pattern that is split again and focused onto the 2 detector arrays located behind their respective, broad-band filters. The detectors are arranged in a hexagonally close-packed pattern with the spacing between them set at  $\sim 33''$  for SSW and  $\sim 51''$  for SLW. These are roughly equal to two beam widths. Therefore, there is always a gap of one beam width between the neighboring detectors.

Ninety-one galaxies in our complete flux-limited sample were observed in our own program (program ID: OT1\_nlu\_1; PI: N. Lu) with the SPIRE/FTS operating in its high-resolution (HR), staring (i.e., “sparse”) mode, targeted at the nuclear position of each galaxy. The resulting spectra have a frequency-independent resolution of 1.2 GHz ( $\delta\nu$ ). This corresponds to  $\lambda/\delta\lambda \sim 1218$  (or a velocity resolution of  $\sim 296\text{ km s}^{-1}$ ) at the frequency (i.e., 1461.1 GHz) of the NII line near the blue end of the FTS frequency coverage, and to  $\lambda/\delta\lambda \sim 480$  (or  $\sim 750\text{ km s}^{-1}$ ) at the frequency (576.2 GHz) of CO (5–4) near the long-wavelength end. For a spectrally unresolved line, the line profile is a sinc function and the effective Full Width at Half Maximum (FWHM) is  $1.207\delta\nu$  or

1.44 GHz (hereafter, referred to as  $\Delta\nu_{\text{FWHM}}^{\text{FTS}}$ ). In addition to our own observations, a total of 31 sample galaxies were observed with SPIRE/FTS by other groups in a similar way, except for NGC 4418 which was observed in a mapping mode. The data from the central pointing of the mapping observation was used for NGC 4418. The FTS data of these targets were downloaded from the *Herschel* science archive. As noted in Column (11) of Table 1, these observations are mostly from the open-time key project “HerCULES” (*Herschel* program ID: KPOT\_pvanderw\_1; see van der Werf et al. 2010; Rosenberg et al. 2015), with only a few from other programs (i.e., KPGT\_cwilson01\_1, see Rangwala et al. 2011, Kamenetzky et al. 2012 and Spinoglio et al. 2012; GT1\_lspinogl\_2, see Pereira-Santaella et al. 2013; KPGT\_esturm\_1, see Rosenberg et al. 2015; OT1\_pogle\_01\_1, PI: P. Ogle).

In order to cover (i) as large a sample of LIRGs as possible for better statistics and (ii) more intrinsically faint LIRGs, our own observing program was designed to ensure detection of the mid- $J$  CO lines, e.g.,  $5 \leq J < 10$ , in particular, CO (6–5) and CO (7–6). The on-target integration time varied from 1,332 to 7,992 sec, set to detect the anticipated CO (6–5) flux at  $S/N > 5$ . This line flux was estimated using the M 82 SPIRE/FTS spectrum (Panuzzo et al. 2010) plus an apparent correlation between the CO (3–2) luminosity and the FIR luminosity ( $L_{\text{FIR}}$ , over 40 to 120  $\mu\text{m}$ ) for LIRGs from Yao et al. (2003). As a result, our detection rate of the CO lines at  $J \geq 10$  is relatively low. In contrast, many of the archival observations targeted the brightest local LIRGs and used longer integration times (see Table 1), and therefore have significantly better detection rates on the high- $J$  CO lines.

### 3.2. Data Reduction

All the data, both our own and from the *Herschel* archive, were homogeneously reduced using HIPE version 11, which offers a line flux accuracy on the order of 6% (Swinyard et al. 2014). (The SPIRE/FTS flux calibration accuracy for spectral lines has remained largely unchanged since HIPE version 11.) The angular extent of the majority of our targets is such that the flux is largely contained within the central detector of the SSW and/or SLW arrays, with no significant flux detected in off-axis detectors. We therefore extracted a spectrum from the central detectors based on a point-source flux calibration and used it for all our subsequent spectral line detection and analysis.

A SPIRE/FTS continuum inherits a residual signal from the bright emission of the 80 K telescope in an additive way. Under the HIPE 11 calibration, this residual signal is on the order of 0.5 Jy. However, this systematic effect has no impact on the detection and flux derivation of spectral lines. The SPIRE/FTS continuum fluxes are used in this paper only when we discuss the HF spectral line near the end of §5, where we describe how we tried to further remove this telescope residual from the continuum (see §5.7.2).

All of our targets have been observed with the *Herschel* Photodetector Array Camera and

Spectrometer (PACS; Poglitsch et al. 2010) at  $70\,\mu\text{m}$  (Chu et al. 2017). Based on the PACS images, some of our targets are more extended at  $70\,\mu\text{m}$  than the SPIRE beam relevant to the frequency of a particular spectral line under consideration. Since both the  $70\,\mu\text{m}$  emission from warm dust (e.g., Helou 1986; Buat & Deharveng 1988) and mid- $J$  CO line emission in LIRGs are traced to the same star-forming regions, in such cases, the line flux from the point-source calibrated spectrum represents a lower limit on the total line flux of the target, and an appropriate aperture flux correction is needed. Since the cold dust continuum in a SPIRE/FTS spectrum may have a different spatial scale than a mid- $J$  CO line from warm molecular gas in star-forming regions, we chose not to do the aperture flux correction for an observed CO line by minimizing the continuum gap between the SSW and SLW spectral segments as prescribed in Wu et al. (2013). Instead, we provide a line flux aperture correction factor  $f_{70\mu\text{m}}^{-1}(\theta)$ , where  $f_{70\mu\text{m}}(\theta)$  is the fractional  $70\,\mu\text{m}$  continuum flux within a Gaussian beam of  $\theta$  (FWHM). This was done by convolving the PACS  $70\,\mu\text{m}$  image to the Gaussian beam of  $\theta$  following the convolution algorithm in Aniano et al. (2011; see Zhao et al. 2016a for more details). In Table 2, we list the SPIRE/FTS FWHM beam sizes (see the SPIRE Handbook) for all our main targeted spectral lines. We have calculated the values of  $f_{70\mu\text{m}}(\theta)$  for representative beam sizes of  $\theta = 17''$ ,  $30''$  and  $35''$  (see Table 4) for each galaxy and discuss these parameters in depth later (see §4.2).

### 3.3. Spectra

Fig. 2 displays the final SPIRE/FTS spectra in the reference frame of Local Standard of Rest (LSR), after the continuum was fit by a polynomial and subsequently removed (as detailed below). The expected frequencies of the CO lines, the [C I] lines, a few rotational transitions of  $\text{H}_2\text{O}$  vapor, and HF (1–0) are marked and labelled in each spectral plot. The brightest line in each spectral plot is almost always [N II]  $205\,\mu\text{m}$ , and it is not marked as it can be unambiguously recognized. For each target, the SSW spectrum is in the upper panel, followed by the SLW spectrum and then by the corresponding PACS  $70\,\mu\text{m}$  image of  $3' \times 3'$  in size, overlaid with the two SPIRE/FTS FWHM beam sizes at  $250\,\mu\text{m}$  and  $500\,\mu\text{m}$ , respectively. This PACS image should be used only as a quick visual guide as to whether the target is significantly extended with respect to the FTS beams. We refer the reader to Chu et al. (2017) for a more detailed analysis of the PACS images.

The SPIRE/FTS spectrum of *IRAS* 05223+1908 is dominated by a set of strong CO lines, which can be best fit with a heliocentric velocity of  $100\,\text{km s}^{-1}$ . A close inspection of the PACS images of this target reveals three distinct objects. As explained in Appendix A, the spectral lines in the SPIRE/FTS spectrum are dominated by the emission from the northern object in the field, which is likely a Galactic source. The data for this target, as well as for the non-LIRG galaxy NGC 5010 we observed, are included in this paper (i.e., in Tables 1, 3 and 5) for completeness, however not used in any analyses.

For targets close to the Galactic plane, the Galactic [N II]  $205\,\mu\text{m}$  line emission could be present in their spectra, usually at a frequency close to CO (13–12). ESO 099-G004 and *IRAS* 08355-4944

in Fig. 2 are two such examples.

### 3.4. Line Detection, Flux Derivation and Identification

Tabulated in Table 3 is a list of the spectral lines (in emission or absorption) detected in one of the deep SPIRE/FTS spectra of Arp 220 (a ULIRG; Rangwala et al. 2011), M82 (a starburst; Kamenetzky et al. 2012) and NGC 1068 (an AGN; Spinoglio et al. 2012). We then searched for these lines in each of our sample galaxies. We opted for this approach, rather than a blind search for lines, because of the consideration that many of our spectra are sensitive enough to detect only our primary targeted lines. This approach minimizes the number of spurious line detections. On the other hand, a potential drawback from this approach is that we might miss spectral lines that are not in Table 3, but would have been detected purely based on a  $S/N$  ratio criterion. In practice, this is only a potential issue in the cases of the highest- $S/N$  spectra obtained in the HerCULES program (see Table 1): indeed, a few spectral lines additional to those compiled in Table 3 have been possibly detected in some HerCULES spectra (P. van der Werf 2016, private communication).

The determination of the continuum emission is a two-step process. Firstly we fit a polynomial (of order 5) to the observed SSW or SLW spectrum. A global channel-to-channel r.m.s. noise was calculated after subtracting the polynomial fit from the spectrum. Then all the spectral features (either in emission or absorption) with a peak signal to noise ratio greater than 3 were identified and further masked out using a box car of 10 (3.0 GHz; for SLW) or 14 (4.2 GHz; for SSW) sample points. A new polynomial fit of order 5 was then applied to all the remaining data samples, resulting in our final continuum fit.

The detection of a candidate spectral line in Table 3 was done in 2 steps. Firstly we calculated an average noise,  $\sigma_{\text{local}}^r$ , from the noise spectrum provided as part of the SPIRE/FTS pipeline product, but within a spectral window of 20 times  $\Delta\nu_{\text{FWHM}}^{\text{FTS}}$ , centered at the redshifted frequency of the spectral line under consideration. The line was deemed as a tentative detection if there was a signal peak within  $\pm\Delta\nu_{\text{FWHM}}^{\text{FTS}}$  of the expected line frequency, and with an amplitude of  $> 2.5 \times \sigma_{\text{local}}^r$ . The quantity  $\sigma_{\text{local}}^r$  reflects mainly the random noise, and is usually equal to or somewhat smaller than the total noise in the spectrum. The latter includes systematic noise due to imperfect FTS calibration. Therefore this tentative detection criterion is more relaxed than a true  $S/N = 2.5$  criterion. Once all the tentatively detected lines were identified, these lines were fit simultaneously. For each feature, we used either a sinc or a sinc-Gaussian convolved line profile, plus a local linear function for any possible residual continuum limited to the data points within a frequency window of  $20 \Delta\nu_{\text{FWHM}}^{\text{FTS}}$  in width, centered at the frequency of the feature peak. The sinc function in either case always had a fixed width (in frequency) equal to that of the SPIRE/FTS instrumental resolution profile. The Gaussian component of the sinc-Gaussian function had a free width parameter to reflect the unknown velocity dispersion of a spectral line. The collective model fit to all the tentatively detected features was obtained using an Interactive Data Language (IDL) nonlinear least-squares fitting procedure as prescribed by Markwardt (2009) and was subsequently removed from the target

spectrum. The resulting “line-free” residual spectrum was used to calculate a refined local (total) noise,  $\sigma_{\text{local}}^t$ , for each tentatively detected spectral line. This noise was the r.m.s. value (after further removing the fitted local residual continuum) within a frequency window of  $20 \Delta\nu_{\text{FWHM}}^{\text{FTS}}$  in length, centered on the fitted central frequency of the spectral line under consideration. Finally, all tentative detected lines with a fitted peak flux density greater than  $3\sigma_{\text{local}}^t$  were retained as being the formal line detections. In the remainder of this paper, the  $S/N$  ratio of a line always refers to the ratio of the line peak signal to  $\sigma_{\text{local}}^t$ .

In principle, the sinc profile always underestimates the flux of a line because the line always has some intrinsic width (see §4 for more details on this). However, a sinc-Gaussian line profile is usually less robust than that using a sinc-only profile as the former line template is more sensitive to the wings of a spectral line. As a result, one usually requires a very high  $S/N$  ratio in order to obtain a reliable line fit using a sinc-Gaussian profile if the line is unresolved or only marginally resolved, which should be the cases for the mid- $J$  CO lines in all our galaxies (but NGC 6240). As a result, we used a sinc-only line profile for all the detected lines (except for the [N II] line), with the frequency width of the sinc function set to the SPIRE/FTS spectral resolution. (The resulting line flux could underestimate the real flux if the line significantly resolved. We address this potential systematic effect in more detail in §4.) For the [N II] line, we always tried to fit a sinc-Gaussian profile if possible. This choice is not only practical because the [N II] line was usually detected at a high  $S/N$  ratio, but also logical since the line is near the blue end of the SPIRE/FTS spectral coverage. In a few cases, we used the sinc-only profile to fit the [N II] line as this resulted in a better fit. For NGC 6240, its CO and [C I] lines are quite broad and have high  $S/N$  ratios (see Table 4). We fit each of these lines with a sinc-Gaussian profile as well.

For each detected line, we assign a quality flag  $Q$ . This flag depends on the  $S/N$  ratio and a velocity criterion that measures how well the heliocentric velocity ( $V_{\text{obs}}$ ) inferred from the fitted line central frequency matches a fiducial velocity ( $V_{\text{fiducial}}$ ) adopted for the target. Fig. 3 shows the observed r.m.s. value of the velocity difference,  $(V_{\text{obs}} - V_{\text{[NII]}})$ , for all those lines that have been detected at  $S/N \geq 7$  in at least 3 targets, where  $V_{\text{[NII]}}$  is the inferred heliocentric velocity from the fitted central line frequency of the [N II] line. For a given spectral line, this r.m.s. value was calculated over the number of the qualifying targets. With such a high  $S/N$  ratio cutoff, we were looking for any potential systematic trend of these r.m.s. velocity differences as a function of frequency, for example, as a result of decreasing velocity resolution with decreasing frequency; no obvious trend is seen in Fig. 3. The maximum value of this r.m.s. velocity difference across all the lines shown in Fig. 3 is  $\sigma_V \sim 70 \text{ km s}^{-1}$ . We therefore assigned a good quality flag to a detected line if  $|V_{\text{obs}} - V_{\text{fiducial}}| < 210 \text{ km s}^{-1}$  (i.e.,  $3\sigma_V$ ), where  $V_{\text{fiducial}}$  was set to the inferred velocity of the [N II] line. In a rare case in which the [N II] line was not detected,  $V_{\text{fiducial}}$  was set to the averaged velocity of the detected CO lines. Additional details on the  $Q$  flag are given in Table 4. We found no cases in which one particular suite of lines, e.g., CO, have consistent velocities among themselves, but differ in velocity from that of the [N II] line at a significance of  $3\sigma_V$  or larger.

Fig. 4 shows examples of CGCG 049-057 and NGC 6240. The sinc line profiles were used to



fit all lines but (i) the [N II]  $205\,\mu\text{m}$  line in the spectra of both galaxies and (ii) the CO and [C I] lines in the spectrum of NGC 6240. The lines specified in (i) and (ii) were fit with sinc-Gaussian profiles.

### 3.5. Results

Table 4 tabulates the derived line fluxes and other properties of the CO rotational transitions of  $J = 4$  to 13, the two [C I] lines and the [N II] line. The table columns are:

Column (1) is the target name from Table 1.

Columns (2)-(14) contain the data for each of these spectral lines, in 9 rows, where

Row 1 – The spectral line flux or upper limit in units of  $10^{-17}\,\text{W m}^{-2}$ . A positive number indicates that the line is detected, whilst a negative number represents a non-detection with its absolute value being the  $3\sigma$  upper limit, where  $\sigma$  was set using a sinc line profile together with the local r.m.s. noise around the expected line frequency. For CO (4–3), a flux value of zero means that the line is redshifted out of the low frequency end of the SLW coverage. This is the case for a total of 17 targets with  $V_h \leq 9,558\,\text{km s}^{-1}$ . Note that the flux values given here (as well as in Table 5) were derived assuming a point-source case. See §4.2 for a discussion on how to use the  $f_{70\mu\text{m}}(\theta)$  factors in Column (15) of Table 4 for a possible flux aperture correction if the target is more extended than a point source. Row entries 2 to 9 are relevant only if the line is detected.

Row 2 – The line flux uncertainty in units of  $10^{-17}\,\text{W m}^{-2}$ . This is the uncertainty from the line-fitting procedure. For most of the spectral lines fitted with a sinc profile, this was found to be comparable to  $F/(S/N)$ , where  $F$  is the total line flux in Row 1 and  $S/N$  is the ratio of the line peak to  $\sigma_{\text{local}}^t$ , given in Row 7 in this table. This local noise  $\sigma_{\text{local}}^t$ -based estimator tends to overestimate the real line flux uncertainty because the line flux fitting was done over multiple data points. Near the long wavelength ends of both SLW and SSW, the spectral noise appears to be more “spiky” than Gaussian noise due to some systematic noise. Therefore  $\sigma_{\text{local}}^t$  could be systematically larger than the line flux uncertainty quoted in Row 2 here. The spectral lines that are susceptible to this potential issue include CO (4–3), [C I]  $609\,\mu\text{m}$ , and possibly CO (9–8).

Row 3 – The observed central frequency of the line, in GHz, in the Local Standard of Rest.

Row 4 – The uncertainty of the observed line central frequency, in GHz, from the line profile fit.

Row 5 – The difference in GHz between the observed line central frequency and the expected line frequency based on the heliocentric velocity of the target in Table 1.

Row 6 – The peak line flux density in Jy.

Row 7 – The  $S/N$  ratio of the peak line flux density to the local r.m.s. noise  $\sigma_{\text{local}}^t$ .

Row 8 – A quality flag,  $Q$ , assigned for a detected line, with  $Q = 1$ : a robust detection with a  $S/N \geq 5$  and a satisfaction of our velocity criterion of  $|V_{\text{obs}} - V_{\text{fiducial}}| < 210\,\text{km s}^{-1}$  (as defined in §3.4 above);  $Q = 2$ : a less robust detection with  $3 \leq S/N < 5$  but still satisfying our velocity criterion;  $Q = 3$ : a good detection with  $S/N > 5$ , but a possible line identification with the inferred line velocity being just short of satisfying our velocity criterion; or  $Q = 4$ : a detection of  $3 \leq S/N < 5$  and only a possible line identification with the inferred line velocity being just short

of satisfying our velocity criterion.

Row 9 – The FWHM of the Gaussian component in  $\text{km s}^{-1}$  when a sinc-Gaussian profile was used for the line fitting.

Column (15) gives the data of  $f_{70\mu\text{m}}(\theta)$  for three different values of  $\theta$ :

Row 1 –  $f_{70\mu\text{m}}(35'')$ , appropriate for the SPIRE/FTS beam sizes of the CO (5–4), CO (7–6) or [C I] 370 lines.

Row 2 –  $f_{70\mu\text{m}}(30'')$ , appropriate for the SPIRE/FTS beam size of the CO (6–5) line.

Row 3 –  $f_{70\mu\text{m}}(17'')$ , appropriate for the SPIRE/FTS beam size of the [N II] line and the higher- $J$  CO lines covered by the SSW spectral segment.

Table 5 lists those targets with one or more additional lines detected. These lines, which are listed in Column (2) of the table, are usually fainter than our main targeted lines in Table 4 and include, for example, a set of rotational transitions of  $\text{H}_2\text{O}$  vapor and HF (1–0).

With the frequency coverage of SSW starting at  $\sim 957$  GHz and that of SLW ending at  $\sim 989$  GHz, the two arrays have a frequency coverage overlap of  $\sim 32$  GHz. As noted in Table 3, up to 2 of the following targeted spectral lines could be seen in both arrays depending on the source heliocentric velocity: CO (9–8) and  $\text{OH}^+$  ( $1_{12}-0_{12}$ ) if  $V_h$  is greater than 14,660 and 13,510  $\text{km s}^{-1}$ , respectively;  $\text{OH}^+$  ( $1_{22}-0_{11}$ ) and  $\text{H}_2\text{O}$  ( $2_{02}-1_{11}$ ) if  $V_h$  is less than 4,640 and 9,695  $\text{km s}^{-1}$ , respectively. For each of these lines, the line detection was performed on each detector array independently. If the line was detected in both SSW and SLW, the detection of the higher S/N ratio was chosen in the end. The fluxes of the CO (9–8) and  $\text{OH}^+$  ( $1_{12}-0_{12}$ ) lines were all measured in the SSW array. For the other two lines, their fluxes given in Table 5 end with suffix “L” (for SLW) or “S” (SSW) to indicate from which detector array the flux was taken.

## 4. Consideration of Systematic Effects

### 4.1. Partially Resolved Lines

Some of the CO lines, especially those in the SSW spectral segment, may be partially resolved by the SPIRE/FTS instrumental spectral resolution. As a result, a sinc profile-based line flux derivation may underestimate the true line flux. In many cases, these lines are either undetected or detected at a modest  $S/N$  ratio, precluding an accurate line fit using a sinc-Gaussian profile.

Fig. 5 plots the theoretical prediction of the ratio of the line flux of a sinc-Gaussian line profile to the flux of a sinc profile with the same peak flux density, as a function of the line frequency for a number of velocity widths (FWHM) of the Gaussian component. In both cases, the width of the sinc function was fixed in frequency to correspond to that of the SPIRE/FTS instrumental resolution. It is clear that, near the blue end of the SSW spectral coverage, a line velocity dispersion of 200 to 300  $\text{km s}^{-1}$  (in FWHM) could result in a significant flux underestimate if the sinc-only profile is used to derive the line flux. On the other hand, Fig. 5 shows that, for CO (7–6), the line

flux from the sinc profile fitting may underestimate the line flux by less than 20% if the intrinsic line FWHM is under  $400 \text{ km s}^{-1}$ .

The majority of the archival spectra have quite high  $S/N$  ratios for CO (6–5), CO (7–6), [C I]  $370 \mu\text{m}$  and the [N II] lines. We have fit both sinc-only and sinc-Gaussian profiles to these lines in 31 archival spectra, of which the average  $S/N$  ratios are 34, 30, 26 and 45 for these 4 spectral lines, respectively. The resulting flux ratios are shown in Fig. 6 as a function of the fitted Gaussian FWHM expressed in GHz, where the dotted curve is a 3rd-order polynomial representation of the theoretical prediction from Fig. 5, given in eq. (1):

$$R_{\text{theoretical}} = 1.013 - 0.074W + 0.301W^2 - 0.0307W^3, \quad (1)$$

and the solid curve is a 3rd-order polynomial fit to the data points in Fig. 16, given in eq. (2):

$$R_{\text{fit}} = 1.051 - 0.110W + 0.315W^2 - 0.0283W^3. \quad (2)$$

In both equations,  $W$  is the FWHM (in GHz) of the Gaussian component and  $R$  stands for the (sinc-Gaussian to sinc) line flux ratio. The r.m.s. residual (along the Y-axis) between the data points and the solid curve is 0.03. This plot shows that, for example, for an intrinsic line with of 1.0 GHz (equivalent to  $\sim 434$  and  $372 \text{ km s}^{-1}$  for CO (6–5) and CO (7–6), respectively), the sinc-only profile-based fluxes may underestimate the real flux by  $\sim 20\%$  for both of these lines.

## 4.2. Flux Aperture Corrections

The SPIRE/FTS beam depends on frequency in a non-trivial way (Swinyard et al. 2014). Table 2 lists the Gaussian FWHM beam sizes at the rest-frame frequencies of all our main targeted lines (see the SPIRE Handbook). This Gaussian approximation of the SPIRE/FTS beam should be adequate for any target that is either a true point source or is only modestly extended with respect to the SPIRE/FTS beam. All our targets fall in one of these cases. For lines covered in the SLW spectral segment, the smallest FWHM beam size is  $\sim 30''$  (i.e., for CO (6–5)). For CO (7–6), the relevant beam size is  $\sim 35''$ . For lines covered by the SSW part, a representative FWHM beam size is  $\sim 17''$  as the beam size only weakly depends on frequency. For each target, we therefore list in table 4 the values of  $f_{70\mu\text{m}}(\theta)$  for  $\theta = 35''$ ,  $30''$  and  $17''$ , respectively.

Fig. 7 shows how  $f_{70\mu\text{m}}(\theta)$  varies with either  $C(60/100)$  or  $L_{\text{IR}}$  for  $\theta = 30''$  (top panel) and  $17''$  (bottom panel). While the former  $\theta$  value is a conservative choice for all the spectral lines in the SLW spectral segment, the latter case is appropriate for the [N II] line and other lines in the SSW segment. The dotted lines in both plots indicate  $f_{70\mu\text{m}}(\theta) = 0.8$ . For the FIR coldest (i.e.,  $C(60/100) \leq 0.6$ ) or least luminous ( $L_{\text{IR}} < 10^{11.3} L_{\odot}$ ) sample galaxies, about 85% and 50% of them pass the criteria  $f_{70\mu\text{m}}(30'') \geq 0.8$  and  $f_{70\mu\text{m}}(17'') \geq 0.8$ , respectively. When considering the ratio of a SPIRE/FTS spectral line flux from this paper to the total IR or FIR flux, one could either (a) divide  $f_{70\mu\text{m}}(\theta)$  into the line flux in this paper as an effective aperture correction or (b) multiply

the total IR or FIR flux by this factor to arrive at an estimate on the flux within the SPIRE/FTS beam. Neither option is free from possible systematics. However, for a mid- $J$  CO line, (a) is likely a better option because both the  $70\mu\text{m}$  dust emission and the warm CO line emission originate from more or less the same region while the spectral energy distribution of the dust emission behind the value of  $L_{\text{IR}}$  or  $L_{\text{FIR}}$  is expected to vary significantly from the nucleus to the outer disk of a star-forming galaxy. In the remainder of this paper, we use the point-source calibrated line fluxes in all analyses, but only include those galaxies with  $f_{70\mu\text{m}}(\theta) \geq 80\%$  when we consider a line-to-IR luminosity ratio where  $\theta = 30''$  or  $17''$ , depending on whether the line is covered in the SLW or SSW segment. In this manner the line fluxes used will always be less than 20% underestimated compared to their actual value.

### 4.3. Line Detection Rate

Panels (b) to (n) in Fig. 8 are plots of the fractional detection rates of the spectral lines tabulated in Table 4 in a number of bins of  $F_{\text{IR}}$ , indexed numerically from 1 to 7. The bins are delineated at the following flux values:  $7.5, 10, 15, 22, 35$  and  $120 \times 10^{-13} \text{ W m}^{-2}$ . For example, the first bin of index 1 is for  $6.5 \leq F_{\text{IR}} < 7.5 \times 10^{-13} \text{ W m}^{-2}$ , the second bin for  $7.5 \leq F_{\text{IR}} < 10 \times 10^{-13} \text{ W m}^{-2}$ , and the last bin of index 7 for  $F_{\text{IR}} > 120 \times 10^{-13} \text{ W m}^{-2}$ . Only the detections with a quality flag of  $Q = 1$  and 2 are used here. As a comparison, panel (a) in Fig. 8 shows the number distribution of the observed LIRGs, with the galaxy number in each flux bin marked explicitly. It is clear that we have achieved a detection completeness of better than  $\sim 90\%$  at all flux levels for CO (6–5), CO (7–6), [C I]  $370\mu\text{m}$  and [N II]  $205\mu\text{m}$ . The next best cases are for CO (5–4) and CO (8–7), for which the detection rates are still more than  $\sim 60\%$  even in the faintest flux bins.

Fig. 9 shows similar plots for selected fainter spectral lines based on detections tabulated in Table 5. It is clear that the detection rate is rather low for any of these lines except in the three brightest flux bins, where the number of galaxies is low. To alleviate this shortcoming, we use stacked spectra created by summing over the spectra of individual sources to study some of these fainter lines.

## 5. Data Analysis and Discussion

### 5.1. CO SLEDs

Fig. 10 is a comparison of the observed CO SLEDs among the brightest galaxies in each of the following 3 FIR color bins: (a) eleven “FIR-cold” galaxies (in red) of  $0.50 < C(60/100) \leq 0.65$ , which are brighter than  $f_{\nu}(60\mu\text{m}) = 8.1 \text{ Jy}$ , (b) eleven “FIR-intermediate” galaxies (in black) of  $0.75 < C(60/100) \leq 0.90$  and brighter than  $f_{\nu}(60\mu\text{m}) = 12.0 \text{ Jy}$ , and (c) ten “FIR-warm” galaxies (in blue) of  $C(60/100) \geq 1.0$  and brighter than  $f_{\nu}(60\mu\text{m}) = 10.7 \text{ Jy}$ .

These represent the brightest sample galaxies in their respective FIR color bin. All satisfy  $f_{70\mu\text{m}}(17'') > 0.8$ , which means that the shape of each CO SLED should not deviate by more than 20% from the true shape across the plotted range of  $J$  values, even if the target is not point-like with respect to the SPIRE/FTS beam sizes in SSW. All the CO SLEDs in Fig. 10 are normalized to unity at  $J = 6$ . They are arranged from the top left to bottom right in an increasing order of  $L_{\text{IR}}$ . These plots together reinforce the previous finding (Lu et al. 2014; Rosenberg et al. 2015) that the overall shape of a CO SLED is more fundamentally correlated with the FIR color than with  $L_{\text{IR}}$ . For example, NGC 4418 has only a modest  $L_{\text{IR}}$ , but one of the warmest FIR colors known in the local universe. Its CO SLED appears even “warmer” than that of Mrk 231, which is more than 10 times more IR luminous. Since the FIR color is driven in turn by the spatially averaged intensity of the dust heating radiation field (e.g., Draine & Li 2007), this finding suggests that it is the radiation field intensity that shapes the overall CO excitation condition over  $4 < J < 13$ .

A few CO SLEDs in Fig. 10 show an apparent “kink,” with the integrated line flux of a CO line (most often CO (9–8)) being lower than the value from a smooth interpolation from the neighboring data points. Such examples include Mrk 231, IRAS F05189-2524 and ESO 286-IG 019. However, these “out-of-line” data points are mostly at a significance no greater than  $3\sigma$  based on the error bars shown here. Furthermore, the CO (9–8) line is near the long wavelength end of SSW. As we mentioned before, the error bars plotted here (from Table 4, Row 2 in Column 7) are from the line fitting procedure and might somewhat underestimate the true line flux uncertainty for CO (9–8). Therefore this CO (9–8) kink phenomenon is likely to be an artifact.

In Fig. 11 we plot the individual CO SLEDs from Fig. 10 separately for the three FIR color bins. The individual CO SLEDs are plotted in various colors. For clarity, only the detected lines are included. Within each FIR color bin, we derived a median flux value at each  $J$  using the detected lines only and also plotted the “median CO SLED” synthesized from these median flux values as a thick black curve. Since the upper limits were not used in calculating these median values, some caution should be exercised when interpreting the significance of a median flux value when there are many upper limits, e.g., near the high- $J$  end in Fig. 11a. Nevertheless, these median CO SLEDs, given numerically in Table 6, are still useful in illustrating the systematic change in the shapes of CO SLEDs as the FIR color increases. There is also an indication that the variance of the CO SLED shapes also increases as the FIR color increases. Since all the CO SLEDs are normalized to 1 at  $J = 6$ , this variance manifests itself in the scatter of the individual CO SLEDs at the high- $J$  end in each plot. In particular, a large variance is seen in the warmest FIR color bin. This may suggest that the local condition of the radiation field and gas density become so complicated or extreme that the spatially averaged FIR color becomes less accurate in predicting the shape of a CO SLED. We labelled in Fig. 11c the 3 individual galaxies associated with some of the warmest CO SLEDs in our sample. One of them, NGC 4418, is known to be among the most compact extragalactic IR sources known (e.g., Sakamoto et al. 2013).

To confirm that the systematic variation in SLED shape seen for the brightest galaxies of the sample in Figs. 10 and 11 is not dependent on their  $60\mu\text{m}$  flux densities, we show the entire sample

in Fig. 12 by plotting each CO line luminosity, normalized by that of CO (6–5), as a function of the FIR color. For  $J = 4$  or  $J \gtrsim 9$ , there are now significant numbers of non-detections. We therefore focus on the overall trend and whether the upper limits are consistent with the trend. To this end, in each plot the horizontal dotted line marks where the normalized line flux equals 1 and the two vertical dashed lines separate the three color bins used in Figs. 10 and 11. The individual sources belonging to the dominant AGN subsample defined earlier are shown in red. For the CO lines of  $J \geq 9$  (covered in SSW), we only used those sources with  $f_{70\mu m}(17'') \geq 0.8$  in order to control the effect on the normalized line fluxes from the SPIRE/FTS beam size difference between SSW and SLW. For  $C(60/100) \lesssim 0.7$ , the CO SLEDs tend to be brightest at  $J < 6$ . In contrast, at  $C(60/100) \sim 1.0$ , the observed CO SLEDs become nearly flat across all  $J$  levels or even show somewhat increasing normalized line fluxes towards higher  $J$ . At the FIR colors in between, the CO SLEDs tend to peak around  $J \sim 6$  or 7. These observations are all consistent with the data of the brightest sample galaxies shown in Figs. 10 and 11.

Furthermore, there is no obvious segregation between the dominant AGNs and the rest of the sample in any plot in Fig. 12. With the caveat that our AGN sample size is small, this implies that the presence of an energetic AGN in a LIRG has little or only marginal effect on the shape of the CO SLED over the  $J$  levels shown here. This is in general agreement with other recent studies on the mid- $J$  CO line emissions in individual AGNs (e.g., Pereira-Santaella et al. 2013; Zhao et al. 2016b). We discuss the subject of AGN gas heating in more detail in §5.3.

## 5.2. Star Formation and Molecular Gas Heating

The simplest model for explaining the systematic change in the shapes of the CO SLEDs shown in the previous figures is to assume a single molecular gas phase that gets warmer and denser when the FIR color becomes warmer. However, we showed earlier (Lu et al. 2014) that one generally requires at least two distinct CO gas phases to explain the observed CO SLEDs. We explore this important finding further using the full galaxy sample here, which is twice the size of the sample used in Lu et al. (2014).

Fig. 13 shows how a CO line luminosity, normalized by  $L_{\text{IR}}$ , varies as a function of the FIR color for the entire sample. As in Fig. 12, those dominant AGNs are shown in red. All the plots in Fig. 13 span 2.0 dex vertically to facilitate direct comparison. The horizontal dotted line in each plot indicates the value of -4.88, the average logarithmic CO (7–6)/IR luminosity ratio identified by Lu et al. (2015) on a combined set of the LIRGs from the current sample and additional ULIRGs from the *Herschel* archive. This line serves as a fiducial level to help identify the most energetic CO line across all  $J$  values at a given  $C(60/100)$ . If one focuses first on the mid- $J$  CO lines of  $J = 6$  or 7 in Fig. 13, the line-to-IR luminosity ratios appear to only weakly depend on  $C(60/100)$  and show apparently the smallest scatters among all the lines plotted in Fig. 13. In fact, the ratios shown in panel (J) in Fig. 13 are for the combined CO (6–5) and CO (7–6) line fluxes. Excluding the AGNs and the outlier NGC 6240, the ratios of the remaining galaxies show very little dependence

on  $C(60/100)$  across the entire FIR color range covered here. On the other hand, the first two panels in Fig. 13 show that, as  $C(60/100)$  becomes smaller, CO (4–3) or even CO (5–4) becomes relatively stronger. As pointed out in Lu et al. (2014), a single gas phase model can not explain these observations. One needs at least two gas components: A warm and dense component, which emits the CO lines primarily in the mid- $J$  (i.e.,  $5 \lesssim J \lesssim 10$ ) with a general peak around  $J \approx 6$  or 7 and correlates energetically with the dust emission, is mainly responsible for the observed constant ratio seen around  $J = 6$  or 7. Since the dominant heating source for the IR emission in the majority of LIRGs is unambiguously current SF, the same ongoing SF should be also responsible for this warm CO gas component although the exact or dominant heating mechanism is still controversial (see Lu et al. 2014 for a list of possible mechanisms). The other gas component is a cold gas phase of a moderate density, which emits CO lines primarily at  $J \lesssim 4$  and is *not directly* related to current SF that powers  $L_{\text{IR}}$  in LIRGs.

This two-component picture has been supported by other independent studies, with many of the recent studies on non-LTE modeling of observed CO SLEDs in LIRGs and star-forming galaxies pointing to at least 2 distinct gas phases (e.g., Panuzzo et al. 2010; van der Werf et al. 2010; Rangwala et al. 2011; Spinoglio et al. 2012; Kamenetzky et al. 2012; Pereira-Santaella et al. 2013; Pellegrini et al. 2013; Rigopoulou et al. 2013; Papadopoulos et al. 2014; Rosenberg et al. 2014a, 2014b; Schirm et al. 2014; Xu et al. 2015). A few of our sample galaxies have also been directly imaged in CO (6–5) at a high angular resolution. The resulting CO (6–5) line emission shows a very different spatial scale than either CO (1–0) or CO (2–1) (e.g., Xu et al. 2014, 2015). This further supports our two component picture.

### 5.3. AGN and Molecular Gas Heating

We showed in Fig. 12 that the presence of a dominant AGN in a galaxy does not appear to have a significant impact on the *shape* of a CO SLED up to  $J \sim 10$ , and in Fig. 13 that most of the dominant AGNs in our sample tend to show a lower mid- $J$  CO to IR ratio. We explore possible physics behind these phenomena here.

Fig. 14 is a plot of the log of the ratio of the CO line luminosity summed over CO (6–5) and CO (7–6) to  $L_{\text{IR}}$  as a function of  $f_{\text{AGN}}$  for the same set of galaxies shown in Fig. 13j. We have offset the Y-axis by the sample median log value of -4.53 for the SF-dominated galaxies. The color coding scheme is the same as in Fig. 13, except for the upper limits shown here in green now for the sake of visual clarity. The average  $f_{\text{AGN}}$  value and its uncertainty (= the standard deviation of the mean) plotted as an error bar here are, as described in §2.2, from Díaz-Santos et al. (2017). The distribution of the data points in Fig. 14 indicates a possible trend that points to a lower Y-axis value on average as  $f_{\text{AGN}}$  increases. For example, the Y-axis median value is near zero for the sources with  $f_{\text{AGN}} \leq 0.25$ . This median value would be about -0.1 over  $0.25 < f_{\text{AGN}} \leq 0.5$  if the two upper limits in this bin were also taken into consideration. For  $f_{\text{AGN}} > 0.5$ , there are 5 data points. The resulting median value is -0.31, equal to about  $2.6\sigma$ , where  $\sigma$  is the r.m.s. scatter

of the sample sources with  $f_{\text{AGN}} < 0.25$ . We explain in detail the solid curves in Fig. 14 below.

Another useful way to gain insights into AGN heating of molecular gas is to compare the CO SLEDs between well-known AGNs and starbursts by extending their CO SLEDs from our SPIRE/FTS observations to even higher  $J$  levels using PACS spectroscopic data. Lu et al. (2014) singled out Mrk 231 ( $f_{\text{AGN}} = 0.77$ ; Díaz-Santos et al. 2017) and NGC 1068 ( $f_{\text{AGN}} \gtrsim 0.50$ ; Telesco & Decher 1988, Lu et al. 2014) as two representative AGN-dominated galaxies that display a lower CO (7–6) to IR ratio than the typical ratios seen in the SF-dominated galaxies in our sample. These AGNs are known to have significant hot CO gas emissions at  $J > 10$  (González-Alfonso et al. 2014a; Hailey-Dunsheath et al. 2012), which could be associated with the AGN-powered X-ray dissociated regions (XDR) (van der Werf et al. 2010; Spinoglio et al. 2012). In Fig. 15 we show the expanded CO SLEDs of these two dominant AGNs, along with those of M 82, Arp 220 (= UGC 09913) and IC 0694 (= UGC 06472 or Arp 299A), by making use of the PACS spectroscopic data from Mashian et al. (2015). M 82 is an archetypical starburst. With  $f_{\text{AGN}} \sim 0.12$  (Díaz-Santos et al. 2017), Arp 220 is also dominated by a starburst. The last galaxy, IC 0694, is controversial as to whether it harbors a strong AGN, with both positive evidence for (e.g., Sargent & Scoville 1991; Henkel et al. 2005; Tarchi et al. 2007; Della Ceca et al. 2002; Alonso-Herrero et al. 2013; Rosenberg et al. 2014b) and against (e.g., Alonso-Herrero et al. 2000) it. Both Arp 220 and Mrk 231 are compact enough to be practically point sources for both SPIRE and PACS. IC 0694 is itself a compact source and its SPIRE and PACS fluxes were based on a point-source case. The mid- $J$  CO line emission of NGC 1068 is shown to be extended and dominated by the circumnuclear SF based on a SPIRE/FTS mapping observation (Spinoglio et al. 2012). The total SPIRE/FTS CO line fluxes in Table 1 of Spinoglio et al. (2012) were used here. As shown in Spinoglio et al. (2012) and Mashian et al. (2015), the PACS part of the CO SLED is dominated by the central compact source. M 82 is somewhat extended with respect to both SPIRE and PACS beams (Kamenetzky et al. 2012; Mashian et al. 2015). Its PACS line fluxes were integrated over the PACS field of view of  $47'' \times 47''$ . We therefore used the SPIRE/FTS CO line fluxes within a constant aperture of comparable size from Kamenetzky et al. (2012).

If one focuses on the mid- $J$  regime, there is an apparent scatter in CO SLED shape between the individual sources. In particular, the CO SLED shape of NGC 1068 appears to be different from that of any of the other sources. However, this could be largely expected given the fact that the mid- $J$  CO SLED shape depends on  $C(60/100)$  (see Fig. 11). NGC 1068 has a relatively mild FIR color at  $C(60/100) = 0.76$ . In comparison, IC 0694, M 82 and Mrk 231 all have very warm FIR colors, with  $C(60/100) = 1.01, 1.08$  and  $1.04$ , respectively. With  $C(60/100) = 0.90$ , Arp 220 falls in between. As a result, at least part of the mid- $J$  differences among the galaxies seen in Fig. 15 should be due to their FIR color differences. In fact, if we “convert” the observed CO SLEDs of NGC 1068 and Arp 220 to what one would have seen if they had  $C(60/100) > 1.0$ , the results would be those shown in the insert in Fig. 15. This conversion was done by multiplying the observed SLED by the ratio of two of the median CO SLEDs in the 3 FIR color bins in Fig. 11 (or Table 6) based on the FIR color of the target. For Arp 220, this ratio equals Col. (4) divided by Col. (3)



in Table 6; for NGC 1068, it is Col. (4) divided by the average value of Cols. (2) and (3) in Table 4 as its FIR color falls between the FIR color ranges associated with the latter two columns. This exercise illustrates an important point of Fig. 15: (A) there is no significant (systematic) difference over  $5 \lesssim J \lesssim 10$  (i.e., the mid- $J$  regime) between the AGNs and starbursts considered here after one has accounted for the FIR color dependence of the mid- $J$  CO SLED shape. Another important point of Fig. 15 is that (B) the two dominant AGNs, Mrk 231 and NGC 1068, show significant excess of the CO line emission at higher  $J$  (i.e.,  $J > 13$ ) in comparison with the two starburst-dominated galaxies, M 82 and Arp 220.

(A) is the same conclusion we drew in Fig. 12, i.e., the mid- $J$  CO SLED shape is not impacted by the presence of an AGN in any obvious and significant way. There are 2 possible explanations for (A): (i) that SF and AGN gas heating produce more or less the same CO SLED shape in the mid- $J$  regime, or (ii) that the gas cooling associated with AGN gas heating occurs mainly at  $J > 10$ . We reject the scenario (i) by different arguments, depending on whether the observed gas cooling at  $J > 10$  is due to AGN heating. If the observed gas cooling at  $J > 10$  is due to AGN heating, this implies that the dense CO gas surrounding the AGN is very hot, no matter whether the actual gas heating is via the X-ray radiation alone or via a combined X-ray and far-UV radiation field from the AGN. Therefore, it is unrealistic for the mid- $J$  CO SLED shape to be similar to that in a pure starburst case. On the other hand, if the observed gas cooling at  $J > 10$  were not related to AGN, most of the gas cooling associated with AGN heating would be limited to within the mid- $J$  regime. In this case, the lower mid- $J$  CO-to-IR flux ratios of AGNs seen in Fig. 13 or 14 would conflict with the fact that AGN should be more effective in heating the gas than the dust regardless of whether it is via X-ray or AGN-driven shocks, leading to a mid- $J$  CO to IR flux ratio higher than those of SF-dominated galaxies. Therefore (ii) is the most likely explanation. Namely, the lower mid- $J$  CO-to-IR luminosity ratios associated with those dominant AGNs are due to the fact that the SPIRE/FTS spectral coverage does not sample most of the CO gas cooling associated with the AGN heating. This conclusion is also consistent with the theoretical prediction (e.g., Spaans & Meijerink 2008) that gas temperatures in XDRs can be much higher than those found photon-dominated regions (PDRs) powered by the far-UV radiation of young, massive stars.

The conclusion drawn above leads to 2 important corollaries. One is that the mid- $J$  CO line emission of a (U)LIRG is entirely powered by star formation, regardless of whether an AGN is present or not. This lays the foundation for a mid- $J$  CO line, such as CO (7–6), to be used as a robust SFR tracer, both locally and at high redshifts (Lu et al. 2015). The other corollary is that, as shown in Lu et al. (2014), the expected Y-axis position of an AGN in Fig. 14 is given by

$$\delta[\log(\text{CO}/\text{IR})] = \log(1 - L_{\text{IR}}^{\text{AGN}}/L_{\text{IR}}), \quad (3)$$

where  $L_{\text{IR}}^{\text{AGN}}$  is the IR luminosity attributed to the AGN (i.e., excluding the SF in the host galaxy). To relate eq. (3) to  $f_{\text{AGN}}$ , one has to relate the two IR luminosities on the right hand side of the equation to their respective bolometric luminosities. It is relatively secure to establish (via observations) a mean relationship between  $L_{\text{IR}}$  and the bolometric luminosity,  $L_{\text{bolo}}$ , for the galaxy as a whole. Veilleux et al. (2009) proposed an average of  $L_{\text{bolo}}/L_{\text{IR}} = 1.15$  for ULIRGs. We adopt

this ratio also for our LIRGs. In contrast, it is not observationally straightforward to establish such a relationship for the AGN itself, i.e., separating the AGN from its host galaxy. This would require high spatial resolution observations in the mid- to far-infrared. If we denote the quantity  $L_{\text{IR}}^{\text{AGN}}/L_{\text{bolo}}^{\text{AGN}}$  by  $\epsilon$ , then we have

$$\delta[\log(\text{CO}/\text{IR})] = \log(1 - 1.15\epsilon f_{\text{AGN}}). \quad (4)$$

The solid curves in Fig. 14 are from eq. (4) with  $\epsilon = 50\%$ ,  $65\%$  and  $80\%$ , respectively, and illustrate that eq. (4) can follow the overall distribution of the AGN data points in Fig. 14 with some reasonable value of  $\epsilon$ .

Under the framework presented here, IC 0694 clearly harbors an energetic AGN, perhaps, a heavily dust-enshrouded one as suggested by some authors (Della Ceca et al. 2002; Alonso-Herrero et al. 2013). This galaxy is not included in Fig. 14 because it has  $f_{70\mu\text{m}}(30'') < 0.8$  (see Table 4). However, all mid-IR AGN diagnostics point to a low AGN fractional contribution to its bolometric luminosity, at  $f_{\text{AGN}} \sim 0.05$  (Díaz-Santos et al. 2017).

Despite the convincing picture of AGN heating of molecular gas unveiled here, we restrict our discussion by pointing out that the sample size of the dominant AGNs presented here is *small*. As a result, the claims drawn here are in principle still subject to small number statistics.

#### 5.4. Shocks and Molecular Gas Heating

NGC 6240 stands out as the only clear outlier in our sample in terms of the mid- $J$  CO/IR ratio. The starburst superwinds in NGC 6240 are believed to power large-scale diffuse ionized gas (e.g., Heckman et al. 1987) and shock-excited  $\text{H}_2$  line emission (e.g., Max et al. 2005). Its SPIRE/FTS CO SLED has been modeled in detail and its excitation was shown to be likely due to shocks (Meijerink et al. 2013). However, there is some difficulty with a stellar shock, which is in turn driven by the SF process, being the main heating mechanism behind the high CO/IR ratios observed, because the same SF process should have a far-UV radiation component that is proportional in some way to the mechanical energy of the shock. Whilst the shock itself would heat the gas, the far-UV component would heat the dust which in turn would radiate in the IR. One would therefore expect both the CO line emission and the IR emission to be impacted by the superwinds and shocks, and therefore that the CO to IR luminosity might not be significantly elevated. Indeed, all other well-known superwind galaxies (e.g., M 82, Arp 220) show “normal” CO to IR luminosity ratios. In fact, a supernova or stellar wind driven shock has been the most favored gas heating scenario in many recent studies of the mid- $J$  CO SLEDs of LIRGs and star-forming galaxies (see Lu et al. 2014 for a list of references). Therefore, shock gas heating does not necessarily raise the CO/IR luminosity ratio as long as the shock energy is ultimately derived from SF.

The gas in the nuclear region of NGC 6240 is known to be highly turbulent (Tacconi et al. 1999), with strong molecular gas outflows (Feruglio et al. 2013a, 2013b). Recent ALMA imaging in

HCN (4–3) and CS (7–6) has shown that the dense gas is concentrated along the ridge between the two nuclei in NGC 6240 (Scoville et al. 2015). ALMA imaging in CO (6–5) would reveal directly whether shocks associated with this nuclear gas component could be responsible for the elevated CO/IR ratio.

Objects such as NGC 6240 are likely to be rare as none of the other galaxies in our sample are like it. Lu et al. (2014) showed two more galaxies from the *Herschel* archive that resemble NGC 6240 in terms of an elevated CO/IR luminosity ratio. They are NGC 1266 and 3C 293, both of which are known to have significant, non-SF driven shocks such as shocks driven by an AGN-related outflow or radio jet (Alatalo et al. 2011; Ogle et al. 2010; Lanz et al. 2015).

### 5.5. On Local CO Line Luminosity Functions

In §5.2 we have shown that a mid- $J$  CO line, e.g., CO (7–6), is potentially a robust tracer of SFR. This opens up the new possibility of characterizing galaxy SFRs at high redshifts by measuring only the flux of CO (7–6). With a modern facility such as ALMA, this may become practically a routine. The luminosity function (LF) of CO (7–6) could therefore develop as a powerful tool to characterize the cosmic evolution of SFR. To this end, one needs to know the present-day CO (7–6) LF to serve as the local benchmark. While there are no observational data on such a LF, Lagos et al. (2012) derived a CO (7–6) LF based on a galaxy formation model coupled with a PDR framework for gas heating dominated by far-UV photons.

For most LIRGs, both  $L_{\text{IR}}$  and a mid- $J$  CO line emission trace the same SFR. For lower luminosity galaxies,  $L_{\text{IR}}$  may no longer be dominated by young, massive stars. As a result, these two quantities are expected to decouple from each other when  $L_{\text{IR}}$  is low enough. Liu et al. (2015) analyzed a large SPIRE/FTS sample consisting of LIRGs and normal star-forming galaxies and found that  $L_{\text{CO}(7-6)}$  and  $L_{\text{IR}}$  are coupled nearly linearly down to about  $L_{\text{FIR}} \sim 10^9 L_{\odot}$  (roughly equivalent to  $L_{\text{IR}} \approx 2 \times 10^9 L_{\odot}$ ), with an overall scatter increasing only to  $\sim 0.2$  dex at the low luminosity end. In their study, Liu et al. also applied an aperture correction to  $L_{\text{IR}}$  that is similar to  $f_{70\mu\text{m}}(35'')$  defined in this paper. Their result therefore lends support to extending the luminosity limit, above which the CO (7–6)/IR ratio remains constant, to  $L_{\text{IR}} \sim 2 \times 10^9 L_{\odot}$ .

This constancy of the CO (7–6)/IR ratio allows one to derive a local LF of the CO (7–6) emission from the well-characterized local LF of  $L_{\text{IR}}$ . We show in Fig. 16 the log of such a CO (7–6) LF (hereafter referred to as  $\text{LF}_{\text{CO}(7-6)}^{\text{IR-scaled}}$ ) as a function of  $\log L_{\text{CO}(7-6)}$ , where  $\text{LF}_{\text{CO}(7-6)}^{\text{IR-scaled}}$  is expressed as  $dN/d\log(L_{\text{CO}(7-6)}/L_{\odot})/d(V/\text{Mpc}^3)$ , with  $N$  standing for number of galaxies. This function was scaled from the two-power law fitted infrared LF of Sanders et al. (2003) by adopting a constant luminosity scale factor of  $\langle \log(L_{\text{IR}}/L_{\text{CO}(7-6)}) \rangle = 4.88 \pm 0.01$  for (U)LIRGs from Lu et al. (2015). For comparison we also plotted the model-based CO (7–6) LF (hereafter  $\text{LF}_{\text{CO}(7-6)}^{\text{model}}$ ) from Lagos et al. (i.e., from the solid black curve for  $z = 0$  in their Fig. 5). To have a rough assessment of the uncertainty of  $\text{LF}_{\text{CO}(7-6)}^{\text{IR-scaled}}$ , we note that  $\log(dN/d\log L_{\text{CO}(7-6)}) = \log(dN/d\log L_{\text{IR}}) +$

$\log(d \log L_{\text{IR}}/d \log L_{\text{CO}(7-6)})$ . The error of the first term on the right hand side of the above expression can be set to the typical error of 0.08 for the log of the power-law fit of the LF of  $L_{\text{IR}}$  in Sanders et al. (see their Table 6). The error of the second term on the right hand side of the expression can be set to 0.07, the formal  $1\sigma$  error of  $\langle \log(L_{\text{FIR}}/L_{\text{CO}(7-6)}) \rangle$  given in the study of Liu et al. The square root of the quadratic sum of these two errors is 0.11, which we take as an estimate on the uncertainty of the log of  $\text{LF}_{\text{CO}(7-6)}^{\text{IR-scaled}}$ .

There are some significant differences between the two curves in Fig. 16. Firstly,  $\text{LF}_{\text{CO}(7-6)}^{\text{model}}$  from Lagos et al. predicts fewer counts for all luminosity values covered in Fig. 16. Secondly, the turnover of  $\text{LF}_{\text{CO}(7-6)}^{\text{IR-scaled}}$  occurs at  $L_{\text{CO}(7-6)} \approx 10^{5.6} L_{\odot}$ , which is about 0.8 dex lower than the turnover luminosity of  $\text{LF}_{\text{CO}(7-6)}^{\text{model}}$ . This difference is larger than any that could arise from a systematic underestimate in the SPIRE/FTS CO (7–6) line fluxes (i.e., as a result of our choice of sinc line profile; see Fig. 5). Another difference is that  $\text{LF}_{\text{CO}(7-6)}^{\text{model}}$  is much steeper than  $\text{LF}_{\text{CO}(7-6)}^{\text{IR-scaled}}$  at  $L_{\text{IR}} \gtrsim 10^{11.5} L_{\odot}$ . Both these differences may reflect the fundamental uncertainty as to whether far-UV photon gas heating that is the backbone of all PDR models is the main heating mechanism behind the mid- $J$  CO line emission in galaxies. For example, recent studies on modeling of the CO SLEDs of galaxies tend to favor a mechanical heating via shocks (see Lu et al. 2014 for a discussion on this). In view of this uncertainty, an  $L_{\text{IR}}$ -scaled LF such as the one shown in Fig. 16 might be a more practical choice for the LF of a mid- $J$  CO line emission, at least for luminous galaxies.

## 5.6. Neutral Carbon Line Emission

The ground state of neutral carbon has a simple 3-level, fine-structure system with the upper and middle energy levels at 62.5 K ( $^3P_2$ ) and 23.6 K ( $^3P_1$ ) above the bottom level ( $^3P_0$ ). The  $^3P_1 \rightarrow ^3P_0$  transition (i.e., [C I] 609  $\mu\text{m}$ ) has  $n_c \approx 470 \text{ cm}^{-3}$  and the  $^3P_2 \rightarrow ^3P_1$  transition ([C I] 370  $\mu\text{m}$ ) has  $n_c \approx 1.2 \times 10^3 \text{ cm}^{-3}$  (assuming collisions with  $\text{H}_2$  and a gas temperature of 100 K; see Table 1 in Carilli & Walter 2013). The latter critical density is similar to that of CO (1–0). In the optically thin case, the ratio of the two [C I] lines depends only on the excitation temperature ( $T_{\text{ex}}$ ) between the energy levels  $^3P_2$  and  $^3P_1$ . If the gas density is high enough so that the neutral carbon ground system is nearly thermalized, the  $T_{\text{ex}}$  from the [C I] line ratio should be close to the gas kinetic temperature. In the thermalized case, the observed [C I] fluxes can also be used to infer the total neutral carbon column density. Prior to the advent of *Herschel*, the [C I] line observations were available for a small number of nearby galaxies (e.g., Büttgenbach et al. 1992; Harrison et al. 1995; Schilke et al. 1993; Stutzki et al. 1997; Gerin & Phillips 2000; Israel & Baas 2002; Papadopoulos & Greve 2004) and for some high-redshift galaxies (see references in Carilli & Walter et al. 2013).

We plot in Fig. 17a the line flux ratio of [C I] 370  $\mu\text{m}$  to [C I] 609  $\mu\text{m}$  as a function of the FIR color for the whole SPIRE/FTS sample, overlaid with implied excitation temperatures ( $T_{\text{ex}}$ ) assuming an optically thin case (Stutzki et al. 1997). The relevant excitation temperature range

for our LIRGs appears to be from  $\sim 15$  and 30 K. This is in agreement with similar findings on some IR active galaxies in the literature (e.g., Weiß et al. 2003). NGC 6240 has the highest  $T_{\text{ex}}$  at 40.7 K, among all the sample sources with both [C I] lines detected. Most observations of the [C I] lines in the literature indicate optically thin cases (e.g., Ojha et al 2001; Weiß et al. 2003). If this assumption does not hold, the true excitation temperatures would be somewhat higher than those shown in Fig. 17a.

In the classical picture of PDRs (e.g., Kaufman et al. 1999), the [C I] line emission arises from a thin transition layer (of  $A_V \sim 1$  to a few) in a gas cloud, between  $\text{C}^+$  and CO. Recent observations indicated good spatial correspondence between the [C I] 609  $\mu\text{m}$  line emission and some low- $J$  rotational transitions from either CO or  $^{13}\text{CO}$  in molecular clouds in our Galaxy (e.g., Ojha et al. 2001; Ikeda et al. 2002; Beuther et al. 2014). This suggests that neutral carbon may be found more ubiquitously throughout a molecular cloud than previously thought, opening up the possibility of using one of the [C I] lines as an alternative tracer for the mass of molecular gas in distant galaxies (e.g., Papadopoulos & Greve 2004; Papadopoulos et al. 2004). Fig. 17c shows that, for our LIRGs, the [C I] 370  $\mu\text{m}$  to CO (7–6) ratio is strongly anti-correlated with  $C(60/100)$  over the full FIR color range explored here. This ratio drops by at least a factor of 5 when  $C(60/100)$  increases from 0.4 to 1.2. In contrast, the [C I] 370  $\mu\text{m}$  to CO (4–3) ratio in Fig. 17b has a much weaker overall dependence on  $C(60/100)$  based on those sources with both [C I] 370  $\mu\text{m}$  and CO (4–3) lines detected, albeit with increased scatter. In general, as  $J$  decreases, the ratio of [C I] 370  $\mu\text{m}$  (or [C I] 609  $\mu\text{m}$ ) to the CO line of the upper energy level  $J$  becomes less dependent on  $C(60/100)$ . This would be evident if one had replaced CO (7–6) in Fig. 17c with CO (5–4) or CO (6–5). This overall trend can also be seen in our stacked spectra discussed later (see Fig. 21 or Table 7). These statistical results suggest that the [C I] line emission in our LIRGs comes predominantly from regions of molecular gas of moderate densities and temperatures, which collectively represent the bulk of the molecular gas mass. It is therefore promising to use the [C I] lines as an alternative molecular gas mass tracer for galaxies at high redshifts.

In Fig. 17c, the dominant AGNs on average show a higher [C I] 370  $\mu\text{m}$  to CO (7–6) ratio than the star formation-dominated galaxies at a given  $C(60/100)$ . However, such a systematic difference is not evident in Fig. 17c, which is a plot of the [C I] 370  $\mu\text{m}$  line to IR luminosity ratio as a function of  $C(60/100)$ . This suggests that the “elevated” [C I] 370  $\mu\text{m}$  to CO (7–6) ratios seen in the dominant AGNs are likely due to the fact that these dominant AGNs have relatively “depressed” CO (7–6) to IR luminosity ratios as discussed in §5.3.

### 5.7. Spectral Stacking and Fainter Lines

In view of the low detection rates of the fainter spectral lines, we also co-added individual SPIRE/FTS spectra (after registering them all in the rest-frame using a spline interpolation along with the redshift inferred from the observed frequency of the [N II] line) to increase sensitivity. Shown in Figs. 18 to 20 (i.e. top panel) are respectively the stacked spectra within 3 different FIR

color bins. These are unweighted median spectra, obtained in the frequency domain, where the instrumental resolution is frequency independent. Since most of the spectral lines are expected to be unresolved, there is little systematic effect from shifting a line in frequency. The weighted median spectra would look similar when the weight used was the inverse of the square of the average noise in SSW or SLW. We prefer the median method over a weighted or unweighted averaging method in order to be less biased to the brightest galaxies in each FIR color bin. We marked the frequency locations of all the main targeted lines and some of the fainter lines in each spectrum, along with the sample standard deviation (middle panel) and the number of individual spectra (bottom panel) used in the stacking process at a given frequency.

In Table 7, we give the peak line flux densities (or the  $3\text{-}\sigma$  upper limits), in units of relative Jy, for the CO, [N II] and [C I] lines as well as a set of the H<sub>2</sub>O line transitions and HF (1-0). For an unresolved line, this peak flux density is proportional to its line flux. The error bars at  $1\sigma$  were estimated from the noise in the stacked spectrum, and therefore do not reflect the dispersion (shown in Panel (b) in Figs. 18 to 20) among the individual spectra that went into the stacking process. Our stacking procedure was carried out using the point-source calibrated spectra of individual sources regardless of angular sizes. The frequency-dependent SPIRE/FTS beam could in principle imprint its signature on the relative line fluxes across the frequency range, especially between SSW and SLW, even though the median filtering method we employed should reduce this effect by filtering out those very extended sources that tend to have smaller point-source line fluxes. To check on this systematic effect, we performed the same stacking process on a subset of the sources that are “compact” enough to satisfy  $f_{70\mu\text{m}}(17'') > 0.80$  to see if this would result in a significantly different CO or H<sub>2</sub>O SLED shape. This additional selection process threw out about half of the targets in the FIR cold color bin (i.e., Fig. 18), but only a few sources in the FIR warm color bin (Fig. 20). We found that the two stacking processes produced similar CO and H<sub>2</sub>O SLED shapes in each color bin.

Using Table 7, we show in Fig. 21 plots of the line intensity, normalized by that of CO (6–5), as a function of the rest-frame line frequency for the CO lines (in red), the two [C I] lines (black), the [N II] line (magenta), as well as a suite of H<sub>2</sub>O lines (blue) and HF (1–0) (green) from the 3 stacked spectra shown in Figs. 18 to 20, respectively. A detected line is plotted as a filled square whereas an undetected line is shown either as an upper limit if it is a CO line or as a range of  $\pm 3\sigma$  if it is a H<sub>2</sub>O line or HF (1–0). The CO (4–3) and CO (14–13) lines are excluded here as both of them were stacked over fewer individual spectra. Note that the [N II] line is not shown in (a) or (b), as the line is too bright to fit within the plot. As a comparison, we also plot, in each color bin, the CO SLED (in red crosses) from the stacking of the subset of targets with  $f_{70\mu\text{m}}(17'') > 0.80$ . For clarity, the crosses were manually offset in frequency by -10 GHz. There appears to be no significant difference between the two sets of CO SLEDs shown here, especially in (a) and (b). The difference is apparently larger for the warm FIR color bin in (c), but this is largely due to the fact that the intrinsic scatter in individual CO SLED shape is large in the first place (see Fig. 11). The same conclusion could have been drawn if we had done a similar comparison on the H<sub>2</sub>O SLEDs

here. As a result, the relative CO and H<sub>2</sub>O line fluxes in Table 7 are not significantly affected by the fact that the SPIRE/FTS beam varies significantly across SSW and SLW.

The CO SLEDs from the stacked spectra in Fig. 21 are consistent with their corresponding median CO SLEDs based on the brightest sample galaxies (see Fig. 11 and Table 6). This confirms that the average CO SLED shape is indeed correlated primarily with the FIR color, not significantly influenced by apparent flux or luminosity. Also note in Fig. 21 that, while the relative flux strength between [C I] 370  $\mu$ m and CO (7–6) varies greatly across the 3 FIR colors, that between [C I] 370  $\mu$ m and CO (5–4) varies much less so. This reinforces our earlier conclusion that the ratio of [C I] 370  $\mu$ m to a CO line of the upper energy level  $J$  becomes less dependent on  $C(60/100)$  as  $J$  decreases (see Figs. 17b and 17c). As a further application of the stacked spectra, we use Fig. 21 to study below how the relative strengths of H<sub>2</sub>O lines vary as FIR color increases.

#### 5.7.1. H<sub>2</sub>O Vapor Lines

While H<sub>2</sub>O is an abundant molecular species in the ISM, it remains mostly as ice on dust grains (e.g., van Dishoeck et al. 2011). Only in warm molecular gas does it exist in vapor form and can be detected in terms of its rotational transitions in emission or absorption depending on the background continuum. These lines were detected by the *Infrared Space Observatory* in a small number of galaxies, including Arp 220 (González-Alfonso et al. 2004), NGC 253 and NGC 1068 (Goicoechea et al. 2005), and Mrk 231 (González-Alfonso et al. 2008). With the improved sensitivity of *Herschel*, the sample of galaxies with H<sub>2</sub>O line detections has been expanded to include additional bright galaxies and (U)LIRGs (e.g., van der Werf et al. 2010; Weiß et al. 2010; González-Alfonso et al. 2010, 2012, 2013; Rangwala et al. 2011; Spinoglio et al. 2012; Kamenetzky et al. 2012; Appleton et al. 2013). Yang et al. (2013) collected a sample of 176 galaxies with either published or unpublished SPIRE/FTS spectra and examined simple flux-flux correlations between the luminosity of a water line and  $L_{\text{IR}}$  for a subset of 45 galaxies with at least one water line detected. They found that, in general, the water line luminosity scales nearly linearly with  $L_{\text{IR}}$  and favored the IR pumping plus collisional excitation model proposed by González-Alfonso et al. (2010). However, if the water lines from highly excited energy levels in (U)LIRGs are dominated by IR photon pumping, one would expect that the shape of the SLED of the H<sub>2</sub>O line emission to be highly sensitive to the FIR color or dust temperature  $T_{\text{dust}}$  (or IR photon density) (González-Alfonso et al. 2014b). However, such a trend was not observed by Yang et al. (2013). We investigate this subject further here.

Since the H<sub>2</sub>O lines were only detected in a fraction of our sample galaxies, we chose to make use of the data in Table 7 from the stacked spectra. As shown in Fig. 21, only two individual H<sub>2</sub>O lines, H<sub>2</sub>O (2<sub>02</sub>–1<sub>11</sub>) and H<sub>2</sub>O (2<sub>20</sub>–2<sub>11</sub>), are detected in all 3 stacked spectra. Both these lines show only small variations in their CO (6–5)-normalized line fluxes: 0.28 to 0.34 for H<sub>2</sub>O (2<sub>02</sub>–1<sub>11</sub>) and 0.16 to 0.19 for H<sub>2</sub>O (2<sub>20</sub>–2<sub>02</sub>). These two lines are characterized by their relatively low upper energy levels of  $E_{\text{up}} = 100$  to 200 K. In contrast, such variations are much larger for water lines with higher  $E_{\text{up}}$ . For example, the CO (6–5)-normalized flux of H<sub>2</sub>O (3<sub>21</sub>–3<sub>12</sub>) (with  $E_{\text{up}} = 305$  K)

increases from a value less than 0.15 in the FIR cold subsample to a value of 0.35 in the FIR warm subsample. Since the CO (6–5) line luminosity traces the total SFR well, this quantitative observation suggests that, as  $C(60/100)$  increases, only  $\text{H}_2\text{O}$  emission lines associated with a high-enough  $E_{\text{up}}$  are enhanced above the average line luminosity per SFR.

We explore the above phenomenon further in Fig. 22, where we show the resulting  $\text{H}_2\text{O}$  SLEDs from each of the 3 stacked spectra by plotting the strength of a  $\text{H}_2\text{O}$  line, relative to that of  $\text{H}_2\text{O}(2_{02}-1_{11})$ , as a function of the upper level energy of that line. The  $\text{H}_2\text{O}$  SLEDs of the 3 FIR color bins are differentiated by different colors. (One can connect the data points of the same color to see more clearly the differences between the individual SLEDs.) It is evident that the  $\text{H}_2\text{O}$  SLED of the warmest FIR color bin of  $0.9 \leq C(60/100) < 1.4$  (shown in blue) is “tilted” more towards the high- $E_{\text{up}}$  lines than the  $\text{H}_2\text{O}$  SLED of the least warm FIR color bin of  $0.3 \leq C(60/100) < 0.6$  (shown in red). In other words, as the FIR color increases, the strengths of the water lines with  $E_{\text{up}} > 200$  K are increasingly enhanced relative to those of the water lines with  $E_{\text{up}} \lesssim 200$  K. The clearest difference among the different FIR color bins is seen in  $\text{H}_2\text{O}(3_{21}-3_{12})$  with  $E_{\text{up}} \sim 300$  K, where the vertical displacement between the successive FIR color bins has a significance of at least 2.5 times the uncertainty inferred from the error bars shown. However, the most significant point is that the observed pattern in Fig. 22 is consistent with the IR pumping model predictions by González-Alfonso et al. (2014b) who showed that an increasing  $T_{\text{dust}}$  enhances the relative strengths of the  $\text{H}_2\text{O}$  lines of  $E_{\text{up}} > 200$  K (see their Fig. 3).

The  $\text{H}_2\text{O}$  line of the lowest  $E_{\text{up}}$  is  $\text{H}_2\text{O}(1_{11}-0_{00})$  at 1113.3 GHz. This line is in absorption in more than half of the detections, with the strong absorption case in Arp 220 (see Fig. 2) being a good example. In contrast, the  $\text{H}_2\text{O}$  lines of the highest  $E_{\text{up}}$  are almost always in emission in our sample, e.g.,  $\text{H}_2\text{O}(3_{21}-3_{12})$  and  $\text{H}_2\text{O}(5_{23}-5_{14})$ . This contrast supports the picture that lower-energy water lines are overall not significantly affected by the IR pumping.

### 5.7.2. $\text{HF}(1-0)$

Despite its relatively low abundance in the ISM, Fluorine (F) can react with molecular hydrogen ( $\text{H}_2$ ) to form HF, which locks up most F atoms. If the F/H abundance ratio is more or less fixed, the formation process of HF involving  $\text{H}_2$  implies that its number density may scale with that of  $\text{H}_2$ , thus can serve as an alternative tracer of the total molecular mass (Neufeld et al. 2005). The lowest rotational transition,  $\text{HF}(1-0)$ , has a frequency of 1232.476 GHz, which is within the SPIRE/FTS frequency coverage. The critical density for collisional excitation of this transition with  $\text{H}_2$  is quite high, at about  $5 \times 10^{10} \text{ cm}^{-3}$  (Neufeld et al. 2005). As a result, the line is typically observed in absorption in the Milky Way (e.g., Phillips et al. 2010, Sonnentrucker et al. 2010, 2015; Neufeld et al. 2010; Monje et al. 2011). With the assumption that most HF is in its ground rotational state, the observed absorption line strength of  $\text{HF}(1-0)$  has been used to infer the column density of HF along the line of sight, thus that of  $\text{H}_2$  indirectly (e.g., Neufeld et al. 2005; Monje et al. 2011, 2014). Recent *Herschel* observations of Mrk 231 (van der Werf et al. 2010), NGC 7130 (Pereira-



Santaella et al. 2013), and the Orion Bar in our own Galaxy (van der Tak et al. 2012) revealed that this line could be predominately in emission. Possible excitation mechanisms for the emission have been discussed in the literature, including near-infrared radiative pumping, chemical pumping, and collision with electrons (van der Tak et al. 2012; Pereira-Santaella et al. 2013), but with no consistent picture emerging at this point. The observational fact that HF (1–0) can be either in emission or absorption at a galactic level suggests that it might be not straightforward to use the observed flux of this line to infer the total molecular gas content of a galaxy.

We can look to see whether there are any trends in the ratio of the HF (1–0) flux to  $F_{\text{IR}}$  or the underlying continuum for our galaxy sample. To this end, we used a continuum flux based on the more recent HIPE 14 flux calibration. While the line flux calibration improved very marginally since HIPE 11, the continuum flux calibration has improved significantly. We further estimated the telescope residual continuum signal by fitting a polynomial of order 5 to the median spectrum of the surrounding detectors (i.e., for SLW, these are the 5 detectors in the first detector ring; for SSW, these are the 5 detectors in the 2nd detector ring that also co-align spatially with the aforementioned 5 SLW detectors; see Swinyard et al. 2014). We can calculate the value of this polynomial function at any given frequency. For our galaxy sample, the mean value is about 0.1 Jy over the SSW frequency range, with a sample standard deviation of  $\sim 0.2$  Jy. (This residual telescope signal is much less in SLW.) This polynomial fit of the telescope residual continuum was then subtracted from the target spectrum extracted from the central detectors before any continuum flux was measured. We then measured the median continuum flux densities in two line-free frequency ranges: 1169 to 1221 GHz and 1273 to 1305 GHz (in the rest-frame), which bracket the HF line in frequency. The continuum flux density at the frequency of the HF line, derived as a linear interpolation of these two flux densities, was used to calculate the line equivalent width (EW).

If the HF (1–0) line was detected for a galaxy, its integrated line flux was calculated using a sinc line profile and tabulated in Table 5, where a negative flux denotes a line in absorption; in the case of a non-detection we derived a  $3\sigma$  upper limit for the flux amplitude using the local noise level in the spectrum. In Fig. 23 we plot, as a function of the FIR color, (a) the ratio of the absolute HF (1–0) luminosity to  $L_{\text{IR}}$  and (b) the EW of the absolute HF (1–0) line flux or its  $3\sigma$  upper limit for our sample galaxies. For a detected line, we use different colors to separate an emission case (in red) from an absorption case (in blue). The dominant AGNs as defined in §2.2 are further circled in magenta. In either plot, there is no clear segregation trend between the emission and absorption cases as  $C(60/100)$  increases, nor any significant difference between the strong AGNs and those dominated by SF. The emission and absorption cases appear to be roughly equally represented in our sample so that HF (1–0) is either undetected or only marginally detected in our stacked spectra (see Fig. 21). One conjecture is that the observed HF (1–0) line is a net of individual emission and absorption sites along the line of sight and could be in either emission or absorption depending on whether the emission sites collectively outnumber the absorption sites. Without a good understanding of the physical picture behind the integrated HF (1–0) line flux, it is rather

uncertain to use the observed HF line flux to infer the molecular gas mass of a galaxy, especially at high redshift where the spatial resolution is usually poor.

There could be possibly a weak trend for a lower absolute HF (1–0) luminosity to  $L_{\text{IR}}$  ratio on average at a higher  $C(60/100)$  in Fig. 23a. However, the fact the emission and absorption cases of HF (1–0) are well mixed in Fig. 23a makes it challenging to draw any meaningful inference from such a trend. Fig. 23a shows that, of all the emission cases we detected, the  $L_{\text{HF}}/L_{\text{IR}}$  is the largest ( $\approx 1.3 \times 10^{-5}$ ) in the case of IRAS 05442+1732. On the other hand, the strongest absorption case in Fig. 23b is NGC 0023, which has an EW of  $106 (\pm 16) \text{ km s}^{-1}$ .

## 6. Summary

In this paper we presented a *Herschel* SPIRE 194–671  $\mu\text{m}$  spectroscopic survey of 121 galaxies belonging to a complete, flux-limited sample of 123 LIRGs down to a total IR flux of  $6.5 \times 10^{-13} \text{ W m}^{-2}$ , selected from the Great Observatories All-Sky LIRG Survey (GOALS). This program complements the other two *Herschel* surveys on the GOALS sample: a broadband photometric survey at 70, 100, 160, 250, 350 and 500  $\mu\text{m}$  (Chu et al. 2017) and a spectroscopic line survey of some major FIR fine-structure lines (Días-Santos et al. 2013).

From the SPIRE spectra presented here, we derived and tabulated the integrated line fluxes or upper limits for (a) the CO rotational transitions of  $J$  to  $J-1$  over  $4 \leq J \leq 13$ , being most complete for the CO lines in the mid- $J$  regime (i.e.,  $5 \leq J \leq 10$ ), (b) the fine-structure [N II] line at 205  $\mu\text{m}$ , with a detection completeness at nearly 100%, and (c) the two fine-structure lines of the neutral carbon in its ground state, [C I] at 609 and 370  $\mu\text{m}$ , with a very high detection completeness for the 370  $\mu\text{m}$  line. We also tabulated additional (usually fainter) spectral lines detected in many individual targets, such as some of the rotational transitions of  $\text{H}_2\text{O}$  vapor and HF (1–0), the  $J = 1$  to 0 rotational transition of hydrogen fluoride. The [N II] data presented here have been statistically analyzed in detail in Zhao et al. (2013, 2016a).

We found that the overall shape of a CO SLED over  $4 \leq J \leq 13$  is much better correlated with FIR color than with IR luminosity  $L_{\text{IR}}$ . From this we inferred that the intensity of the dust heating radiation field is the main determinant of the overall excitation temperature of dense molecular gas in these galaxies. The CO line to IR luminosity ratios presented here confirm our earlier analysis (Lu et al. 2014), calling for a minimum of two distinct galactic molecular gas components: (i) a cold component, which emits the CO lines primarily at  $J \lesssim 4$  and likely represents the same gas phase as traced by CO (1–0), and (ii) a warm and dense gas component, dominant over the mid- $J$  regime ( $4 < J \lesssim 10$ ), which is intimately related to current star formation.

Based on a quantitative estimate of the fractional contribution of AGN to the bolometric luminosity,  $f_{\text{AGN}}$ , we singled out a set of 7 dominant AGNs with  $f_{\text{AGN}} > 50\%$ . The mid- $J$  CO SLEDs of these dominant AGNs are statistically identical to those of the galaxies dominated by star formation, but on average have a lower mid- $J$  CO to IR luminosity ratio. Considering the

galaxy sample as a whole (excluding NGC 6240), we observe an overall trend towards a falling mid- $J$  CO to IR luminosity ratio with increasing  $f_{\text{AGN}}$ . Combining our SPIRE/FTS data with CO data of  $J > 13$  from the literature, we further illustrated that the lower mid- $J$  CO to IR ratios of these dominant AGNs are likely a result of an excess of CO emission in the  $J > 10$  CO lines, likely associated with AGN heating of molecular gas. As a result, the mid- $J$  CO line emission in a LIRG is predominantly powered by star formation, irrespective of whether the galaxy harbors an energetic AGN or not.

NGC 6240 is a clear outlier in our sample with a mid- $J$  CO to IR luminosity ratio much higher than that of any other galaxy in the sample. We argued that the likely gas heating scenario in NGC 6240 involves shocks unrelated to current star formation.

The relatively tight correlation between the mid- $J$  CO line emission and the total IR emission for our LIRGs implies that the shape of the local luminosity function (LF) of a mid- $J$  CO line should be close to that of  $L_{\text{IR}}$  except for a constant scale factor in luminosity. The CO (7–6) LF determined this way differs significantly from a PDR-model based luminosity function, suggesting either that the PDR heating mechanism may need to be revised or that it may not be the dominant heating mechanism for this warm molecular gas phase.

The ratios of the two neutral carbon lines imply a relatively modest excitation temperature, ranging from 15 to 30 K. This, together with the fact that the [C I] line flux scales more linearly with CO (4–3) than with a higher- $J$  CO line (e.g., CO (7–6)), suggests that the [C I] line emission is physically more related to the cold CO component (i) defined above.

To better measure some of the fainter lines in the SPIRE spectra, we derived stacked spectra of 3 subsamples of different FIR colors. Our results indicate an evolution of the H<sub>2</sub>O SLED as the FIR color becomes warmer in a direction that is consistent with an IR photon pumping framework suggested by González-Alfonso et al. (2014b).

The HF (1–0) line was detected in emission in some sources, but in absorption in others. No correlation with the FIR color was identified. This, together with the fact that HF (1–0) is only barely detected in our stacked spectra, suggests that both emission and absorption may be present in any given galaxy. As a result, it is not straightforward to use the observed HF (1–0) line strength (in either absorption or emission) to estimate the total molecular gas mass in a galaxy.

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### A. Notes on Infrared Luminosities of Targets with Companions

The targets in Table 1 with their  $L_{\text{IR}}$  value marked by “(\*)” are all in a (either physical or projected) system of multiple galaxies based on optical and near-IR imaging data (see Howell et al. 2010; and for an updated work on this, see Mazzarella et al. 2017). When the angular separations from the galaxy targeted by our SPIRE/FTS observation to the companions are all (a) larger than the largest *IRAS* beam (i.e.,  $\sim 4'$ ) or (b) smaller than or comparable to the smallest beam size of SPIRE/FTS (i.e.,  $\sim 17''$ ), we used the *IRAS*-measured total  $L_{\text{IR}}$  for our target. For a case in between (a) and (b), we used a reduced  $L_{\text{IR}}$  scaled from the *IRAS* total  $L_{\text{IR}}$  using either the *Spitzer Space Observatory* (hereafter *Spitzer*)  $70\,\mu\text{m}$  or  $24\,\mu\text{m}$  fluxes of the individual galaxies (Díaz-Santos et al. 2010, 2011). If the individual galaxies in the system are separated in the *Spitzer*  $70\,\mu\text{m}$  image, the  $70\,\mu\text{m}$  flux-scaled luminosities were always preferred. In this appendix, we describe how we derived  $L_{\text{IR}}$  in each of these cases. Note that, regardless of how  $L_{\text{IR}}$  was derived, the FIR color,  $C(60/100)$ , is still based on the *IRAS* total fluxes unless specified otherwise. Therefore, the adopted value of  $C(60/100)$  is dominated by the brightest individual galaxy in the system. In most case, this brightest galaxy is the target in our SPIRE/FTS observation.

**NGC 0034:** This is a LIRG in a galaxy pair with NGC 0035 (a non-LIRG) at an angular separation of  $318''$ . We used the *IRAS* total  $L_{\text{IR}}$  for our target.

**MCG -02-01-051:** This is a LIRG in a galaxy pair with MCG -02-01-052 (a non-LIRG) at an angular separation of  $64''$ . We used a  $24\,\mu\text{m}$  flux scaled  $L_{\text{IR}}$  for our target, which accounts for 91% of the *IRAS* total  $L_{\text{IR}}$ .

**NGC 0232:** This is a LIRG in a pair with NGC 0235 (a non-LIRG) at an angular separation of  $121''$ . The  $L_{\text{IR}}$  and the FIR color of this target was derived from *IRAS* high-resolution data in Surace et al. (2004).

**NGC 0317B:** This is a LIRG in a pair with NGC 0317A (a non-LIRG) at an angular separation of  $33''$ . We used a  $24\,\mu\text{m}$  flux scaled  $L_{\text{IR}}$  for the target, which accounts for 98% of the *IRAS* total  $L_{\text{IR}}$ .

**IC 1623:** This refers to the galaxy pair involving IC 1623A and IC 1623B, separated by  $12''$ . We used the *IRAS* total  $L_{\text{IR}}$  here.

**ESO 244-G012:** This refers to a galaxy pair involving two galaxies, one LIRG and one non-LIRG, separated by  $17''$ . We used *IRAS* total  $L_{\text{IR}}$  here.

**NGC 0876:** This is in a pair with NGC 0877 at an angular separation of  $123''$ . We used a  $70\text{ }\mu\text{m}$  flux scaled  $L_{\text{IR}}$  for our target, which accounts for 75% of the *IRAS* total  $L_{\text{IR}}$ . Note that the resulting  $L_{\text{IR}}$  is just below the threshold for being a LIRG.

**MCG +02-08-029:** This is in a pair with MCG +02-08-030 (a non-LIRG) at an angular separation of  $22''$ . We used a  $24\text{ }\mu\text{m}$  flux scaled  $L_{\text{IR}}$  for our target, which accounts for 98% of the *IRAS* total  $L_{\text{IR}}$ .

**UGC 02608:** This is in a projected pair with a much fainter galaxy UGC 02612 with an angular separation of  $247''$ . We used the *IRAS* total  $L_{\text{IR}}$  for our target.

**IRAS 05223+1908:** The CO lines in the SPIRE/FTS spectrum of this target can be best fit with a heliocentric velocity of  $100\text{ km s}^{-1}$ . The PACS image at  $100\text{ }\mu\text{m}$  (Chu et al. 2017) reveals 3 separate sources within  $\sim 40''$  of the targeted position of our SPIRE/FTS observation: Object 1 (at  $\text{RA} = 5^{\text{h}}25^{\text{m}}16.69^{\text{s}}$ ,  $\text{Dec.} = 19^{\circ}10'48.7''$ ; J2000), Object 2 ( $5^{\text{h}}25^{\text{m}}17.75^{\text{s}}$ ,  $19^{\circ}10'12.2''$ ), and Object 3 ( $5^{\text{h}}25^{\text{m}}16.40^{\text{s}}$ ,  $19^{\circ}10'35.9''$ ). Our SPIRE/FTS observation was pointed at Object 1. At  $39''$  away from Object 1, Object 2 is largely outside the SPIRE/FTS beam. Object 3 is only at  $13''$  from Object 1 and should contribute to the observed SPIRE/FTS spectrum. However, Object 3 is very red in color with PACS flux densities of 0.12, 0.81 and  $2.72\text{ Jy}$  at  $70$ ,  $100$  and  $160\text{ }\mu\text{m}$ , respectively. Our checks of the archived images from the *Hubble Space Telescope*, the *Two-Micron All Sky Survey* and *Spitzer* in some near- to mid-IR bands between  $1.6$  to  $8\text{ }\mu\text{m}$  in wavelength revealed no detections of this source, with quite stringent near-IR upper limits (e.g., a  $3\sigma$  limit of  $27\text{ mJy}$  at  $3.6\text{ }\mu\text{m}$ ). All these findings suggest that Object 3 is unlikely to be a Galactic source. Therefore, the CO lines detected in our SPIRE/FTS spectrum should be largely from Object 1, which should then be a Galactic source. If Object 3 is indeed an extragalactic object, its extremely red FIR color calls for a very high redshift (e.g.,  $\gtrsim 3$ ). However, this inference seems to conflict with its relatively high PACS fluxes. Object 2 shows a quiescent FIR color based on its PACS flux densities of 1.97, 2.95 and  $3.38\text{ Jy}$  at  $70$ ,  $100$  and  $160\text{ }\mu\text{m}$ , respectively. The IRAS 05223+1908 system was detected in HI 21 cm line emission at a heliocentric velocity of  $8867\text{ km s}^{-1}$  with the Arecibo radio telescope (Lu et al. 1990). This HI emission might come from Object 2 as the  $3.2'$  Arecibo beam enclosed all the three objects here.

**IRAS 05442+1732:** This is a pair with UGC 03356 (a non-LIRG) at an angular separation of  $85''$ . We used a  $70\text{ }\mu\text{m}$  flux scaled  $L_{\text{IR}}$  for our target, which accounts for 88% of the *IRAS* total  $L_{\text{IR}}$ .

**UGC 03410:** This is in a pair with UGC 03405 (a non-LIRG) at an angular separation of  $124''$ . We used a  $70\text{ }\mu\text{m}$  flux scaled  $L_{\text{IR}}$ , which accounts for 83% of the *IRAS* total  $L_{\text{IR}}$ .

**ESO 255-IG 007:** This refers to two galaxies in a triple galaxy system. In terms of the  $24\,\mu\text{m}$  flux scaled  $L_{\text{IR}}$ , these galaxies are (a)  $6.04 \times 10^{11} L_{\odot}$  (position: R.A. =  $6^{\text{h}}27^{\text{m}}21.70^{\text{s}}$ , Dec. =  $-47^{\circ}10'36.2''$ ; J2000), (b)  $1.19 \times 10^{11} L_{\odot}$  (position:  $6^{\text{h}}27^{\text{m}}22.55^{\text{s}}$ ,  $-47^{\circ}10'47.3''$ ), (c)  $6.63 \times 10^{10} L_{\odot}$  (position:  $6^{\text{h}}27^{\text{m}}23.09^{\text{s}}$ ,  $-47^{\circ}11'02.6''$ ). Our SPIRE/FTS observation was pointed at the brightest galaxy (a). The galaxies (b) and (c) are  $14''$  and  $30''$  off our pointing, respectively. We therefore used the summed luminosity of the two LIRGs (a) and (b) in Table 1.

**NGC 2341:** This is in a pair with NGC 2342 at an angular separation of  $144''$ . We used the *IRAS* high resolution data in Surace et al. (2004) to calculate the  $L_{\text{IR}}$  and FIR color for this target.

**NGC 2342:** See the note on **NGC 2341** above.

**NGC 2388:** This target has two companion galaxies: NGC 2389 at an angular offset of  $202''$  and NGC 2385 at  $323''$  off. We used the *IRAS* total  $L_{\text{IR}}$  for our target.

**MCG -02-33-098:** This refers to a pair system of one LIRG and one non-LIRG, separated by  $11''$ . The LIRG component accounts for 70% of the *IRAS* total  $L_{\text{IR}}$ . we used the *IRAS* total  $L_{\text{IR}}$  here.

**NGC 5653:** There is a companion galaxy at about  $10''$  west of NGC 5653, but the companion is much fainter. We used the *IRAS* total  $L_{\text{IR}}$  here.

**NGC 5734:** This is in a pair with NGC 5743 (a non-LIRG) with an angular separation of  $158''$ . We used the *IRAS* high resolution data in Surace et al. (2004) to calculate the  $L_{\text{IR}}$  and FIR color for this target.

**VV340a:** This is in a pair with VV340b at an angular separation of  $39''$ . Both galaxies are LIRGs. We used a  $70\,\mu\text{m}$  flux scaled  $L_{\text{IR}}$  for our target, which accounts for 82% of the *IRAS* total  $L_{\text{IR}}$ .

**IC 4518A:** This is in a pair with IC 4518B (a non-LIRG) at an angular separation of  $45''$ . We used a  $70\,\mu\text{m}$  flux scaled  $L_{\text{IR}}$  for our target, which accounts for 84% of the *IRAS* total  $L_{\text{IR}}$ .

**VV 705:** This refers to a pair of two LIRGs with an angular separation of  $7''$ . We used the *IRAS* total  $L_{\text{IR}}$  here.

**CGCG 052-037:** This is in a pair with 2MASX J16381338-6827170 (a non-LIRG) at an angular separation of  $68''$ . We used a  $70\,\mu\text{m}$  flux scaled  $L_{\text{IR}}$  for our target, which accounts for 97% of the *IRAS* total  $L_{\text{IR}}$ .

**NGC 6285:** In a pair with NGC 6286 (a LIRG) with an angular separation of  $91''$ . We used the *IRAS* high resolution fluxes from Surace et al. (2004) to calculate the  $L_{\text{IR}}$  and FIR color for this target. The resulting  $L_{\text{IR}}$  suggests that NGC 6285 is just short of being a LIRG.

**NGC 6286:** In a pair with NGC 6285 (a non-LIRG) with an angular separation of  $91''$ . We used the *IRAS* high resolution fluxes from Surace et al. (2004) to calculate the  $L_{\text{IR}}$  and FIR color for this target.

**IRAS 17578-040:** This has two non-LIRG companions: 2MASX J18003399-0401443 (at  $60''$  off our SPIRE/FTS pointing) and 2MASX J18002449-040023 (at  $113''$  off). We used a  $70\mu\text{m}$  flux scaled  $L_{\text{IR}}$  for our target, which accounts for 83% of the *IRAS* total  $L_{\text{IR}}$  for the system.

**NGC 6621:** This is in the Arp 81 galaxy group involving two other non-LIRG galaxies: NGC 6621SE (at  $25''$  off our SPIRE/FTS pointing) and NGC 6622 (at  $41''$  off). We used a  $24\mu\text{m}$  flux scaled  $L_{\text{IR}}$  for our target, which accounts for 97% of the *IRAS* total  $L_{\text{IR}}$ .

**IC 4687:** This is in a galaxy system involving 2 other galaxies: IC 4689 (a non-LIRG at  $84''$  off our SPIRE/FTS pointing) and IC 4686 (a LIRG at  $28''$  off). We used a  $24\mu\text{m}$  flux scaled  $L_{\text{IR}}$  for our target, which accounts for 54% of the *IRAS* total  $L_{\text{IR}}$  for the system.

**MCG +04-48-002:** This is in a pair with NGC 6921 (a non-LIRG) at an angular separation of  $91''$ . We used a  $70\mu\text{m}$  flux scaled  $L_{\text{IR}}$  for our target, which accounts for 78% of the *IRAS* total  $L_{\text{IR}}$ .

**CGCG 448-020:** This refers to a triple galaxy system consisting of 2 LIRGs (CGCG 448-020SEsw at R.A. =  $20^{\text{h}}57^{\text{m}}24.09^{\text{s}}$ , and Dec. =  $+17^{\circ}07'35.2''$ , J2000; CGCG 448-020SEne at  $20^{\text{h}}57^{\text{m}}24.38^{\text{s}}$  and  $+17^{\circ}07'39.2''$ ) and a non-LIRG galaxy (CGCG 448-020NE at  $20^{\text{h}}57^{\text{m}}23.65^{\text{s}}$  and  $+17^{\circ}07'44.1''$ ). All the galaxies are within  $12''$  of each other. We used the *IRAS* total  $L_{\text{IR}}$  for this target.

**NGC 7469:** In a pair with IC 5283 (a non-LIRG) at an angular separation of  $79''$ . We used a  $70\mu\text{m}$  flux scaled  $L_{\text{IR}}$  for our target, which accounts for 86% of the *IRAS* total  $L_{\text{IR}}$ .

**NGC 7592:** This refers to a galaxy pair consisting of NGC 7285E and NGC 7592W at an angular separation of  $12''$ . Both galaxies are LIRGs based on their  $24\mu\text{m}$  fluxes. We used the *IRAS* total  $L_{\text{IR}}$ .

**NGC 7674:** This is in a pair with NGC 7674A (a non-LIRG) at an angular separation of  $34''$ . We used a  $24\mu\text{m}$  flux scaled  $L_{\text{IR}}$  for our target, which accounts for 96% of the *IRAS* total  $L_{\text{IR}}$ .

**NGC 7679:** This is in a pair with NGC 7678 at an angular separation of  $271''$ . We used the *IRAS* total  $L_{\text{IR}}$  for our target.

**NGC 7771:** This is in a triple galaxy system with NGC 7769 and NGC 7770. Only NGC 7771 is a LIRG based on the  $24\mu\text{m}$  imaging photometry. NGC 7769 is too far away to have meaningful contribution to the *IRAS* fluxes. The separation between NGC 7771 and NGC 7770 is  $61''$ . We therefore split the *IRAS* total  $L_{\text{IR}}$  between these two galaxies based on their  $24\mu\text{m}$  fluxes. The resulting  $L_{\text{IR}}$  of NGC 7771 accounts for 76% of the *IRAS* total  $L_{\text{IR}}$ .

**Mrk 331:** This is in a pair with UGC 12812 (a non-LIRG) at an angular separation of  $118''$ . We used a  $24\mu\text{m}$  flux scaled  $L_{\text{IR}}$  for our target, which accounts for 99% of the *IRAS* total  $L_{\text{IR}}$ .

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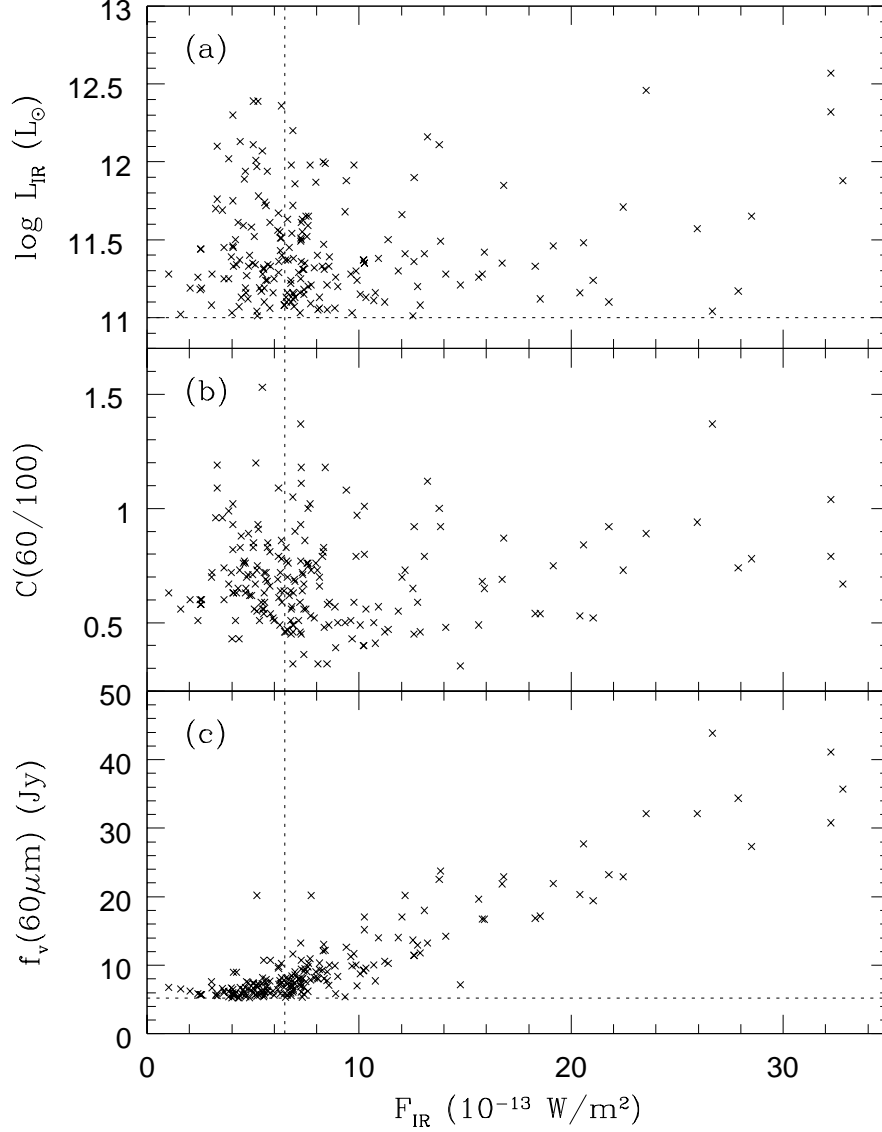


Fig. 1.— Plots of (a) logarithmic  $L_{\text{IR}}$ , (b) *IRAS* 60-to-100  $\mu\text{m}$  flux density ratio or the FIR color  $C(60/100)$ , and (c) *IRAS* 60  $\mu\text{m}$  flux density as a function of the total IR flux,  $F_{\text{IR}}$ , for the GOALS sample of 202 LIRGs. The  $L_{\text{IR}}$  and  $C(60/100)$  are the values used at the time of the sample selection. The vertical dotted line across all the plots indicates our FTS sample selection of  $F_{\text{IR}} > 6.5 \times 10^{-13} \text{ W m}^{-2}$ . The horizontal dotted lines in (a) and (c) indicate  $L_{\text{IR}} = 10^{11} L_{\odot}$  and  $f_{\nu}(60 \mu\text{m}) = 5.24 \text{ Jy}$ , respectively.

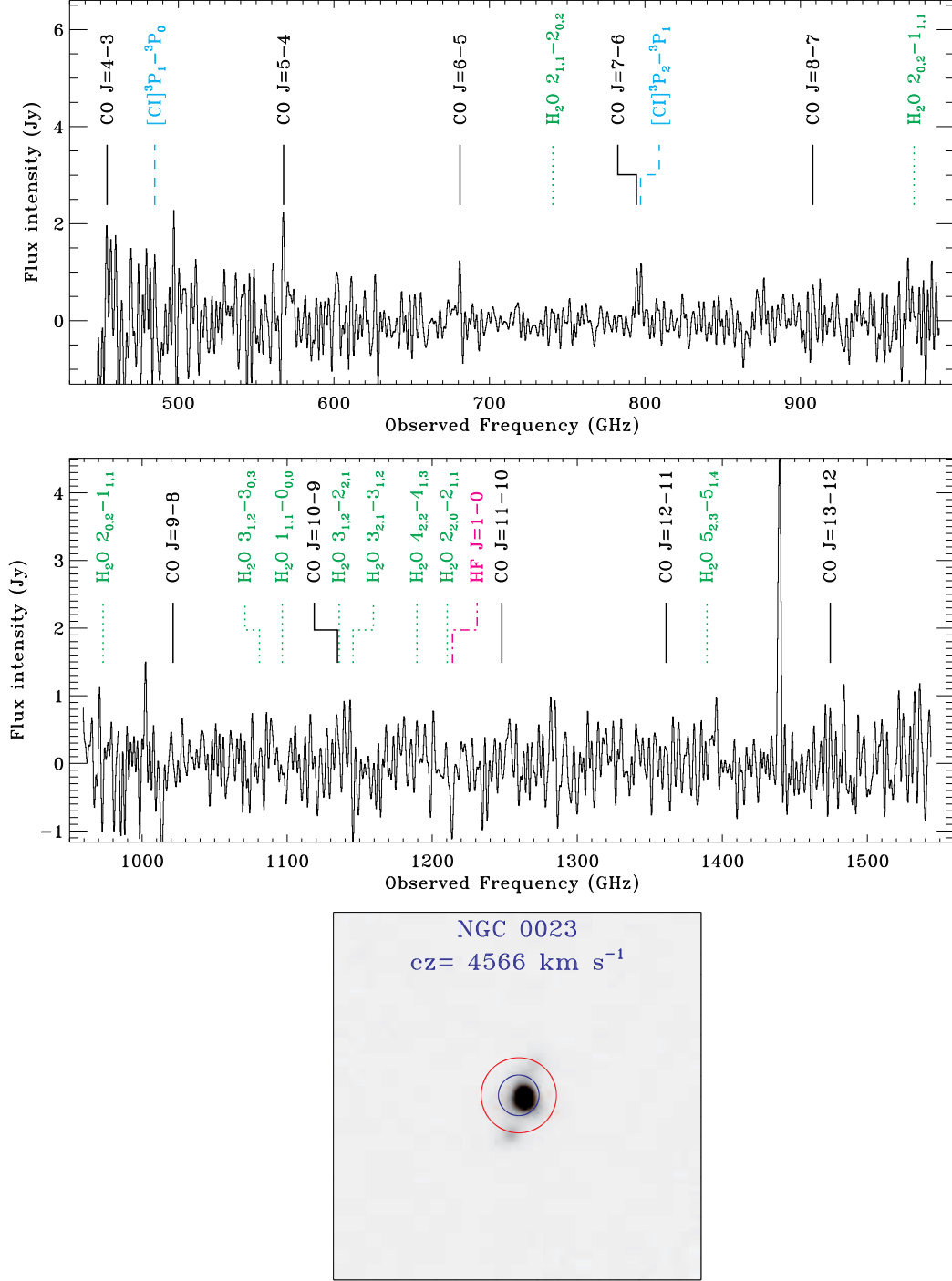


Fig. 2.— Continuum subtracted spectra in the Local Standard of Rest (LSR), with expected frequencies of the spectral lines discussed in the text marked, for the sample galaxies. The brightest feature is almost always the [N II] 205  $\mu$ m line, which is not marked, but can be easily identified. The gray-scale image shown is the corresponding PACS 70  $\mu$ m image ( $3' \times 3'$ ; North up and East to the left) overlaid with the two SPIRE/FTS FWHM beam sizes at 250  $\mu$ m (in blue) and 500  $\mu$ m (red). The gray scale was set between the intensities above which 99.5% and 15% pixels lie, respectively. The target name and its heliocentric velocity are also labelled.

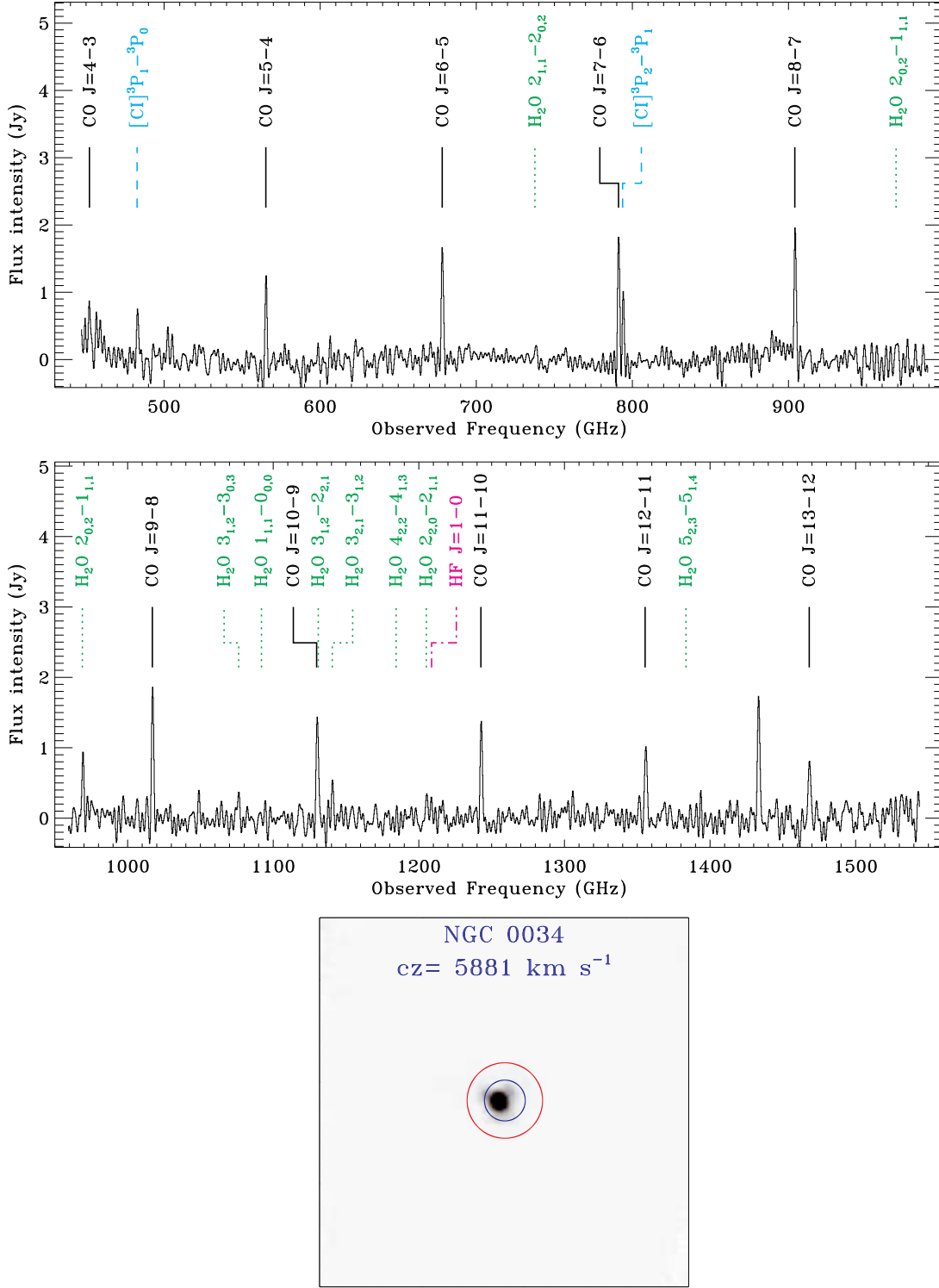


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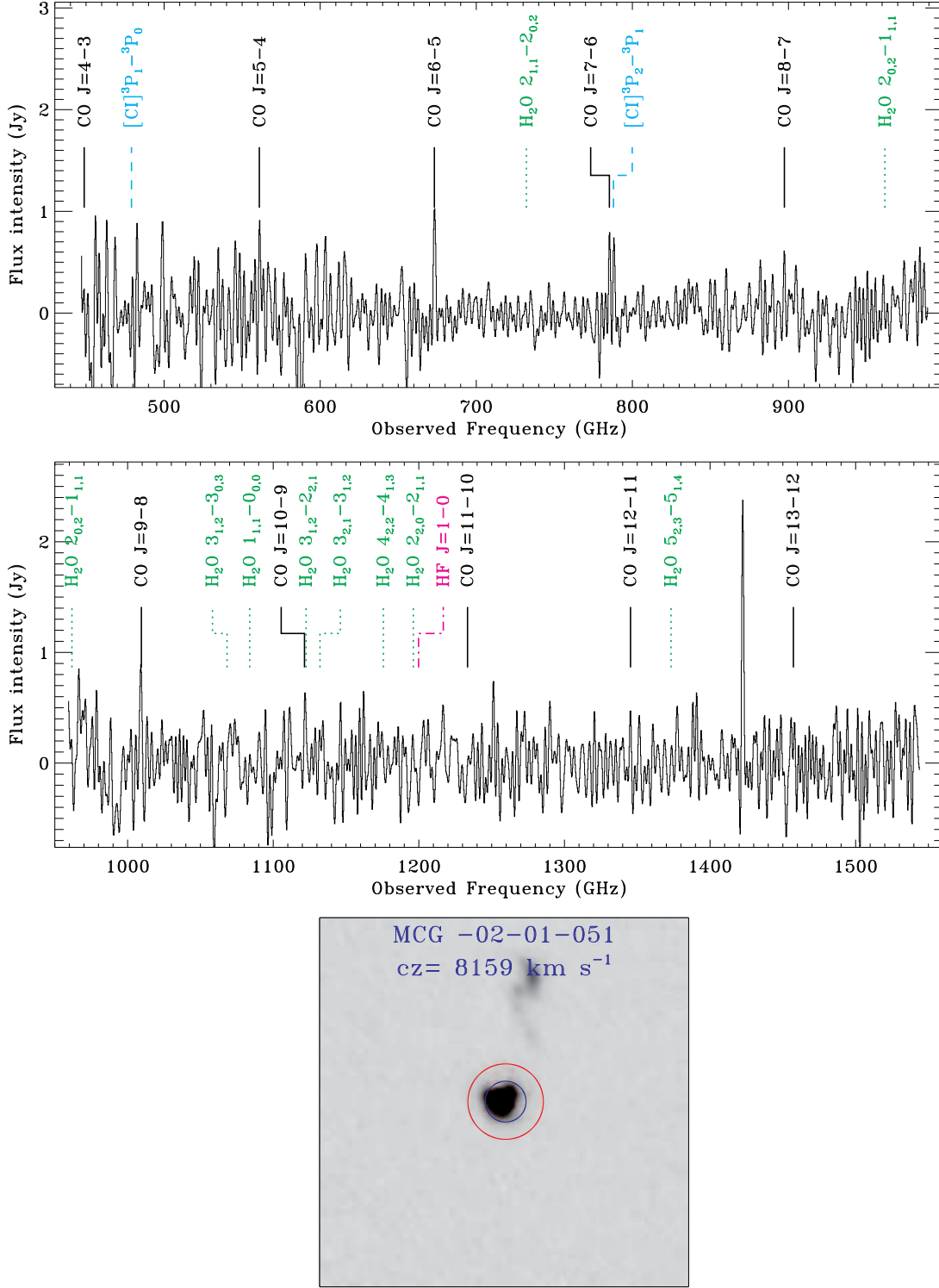


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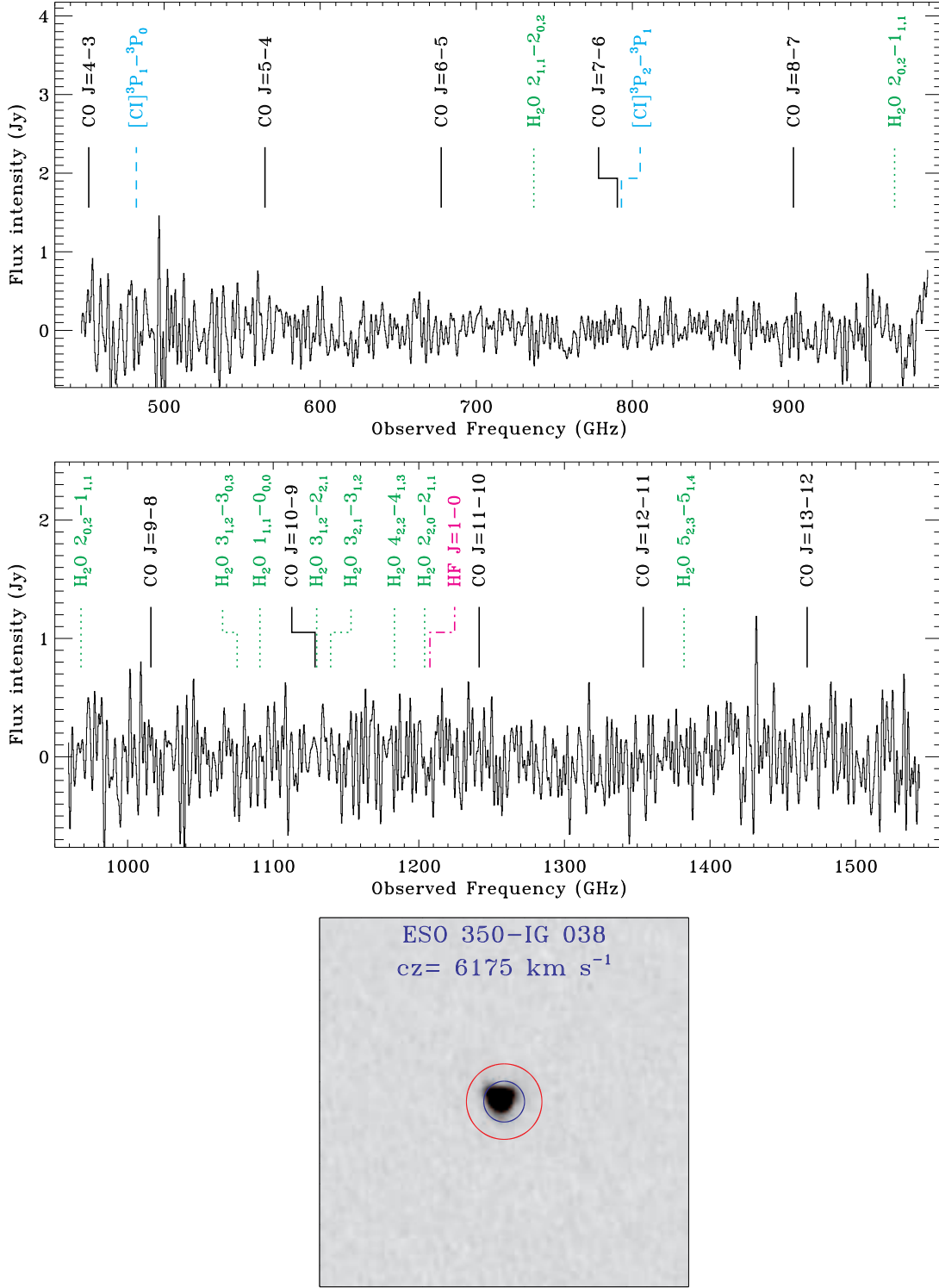


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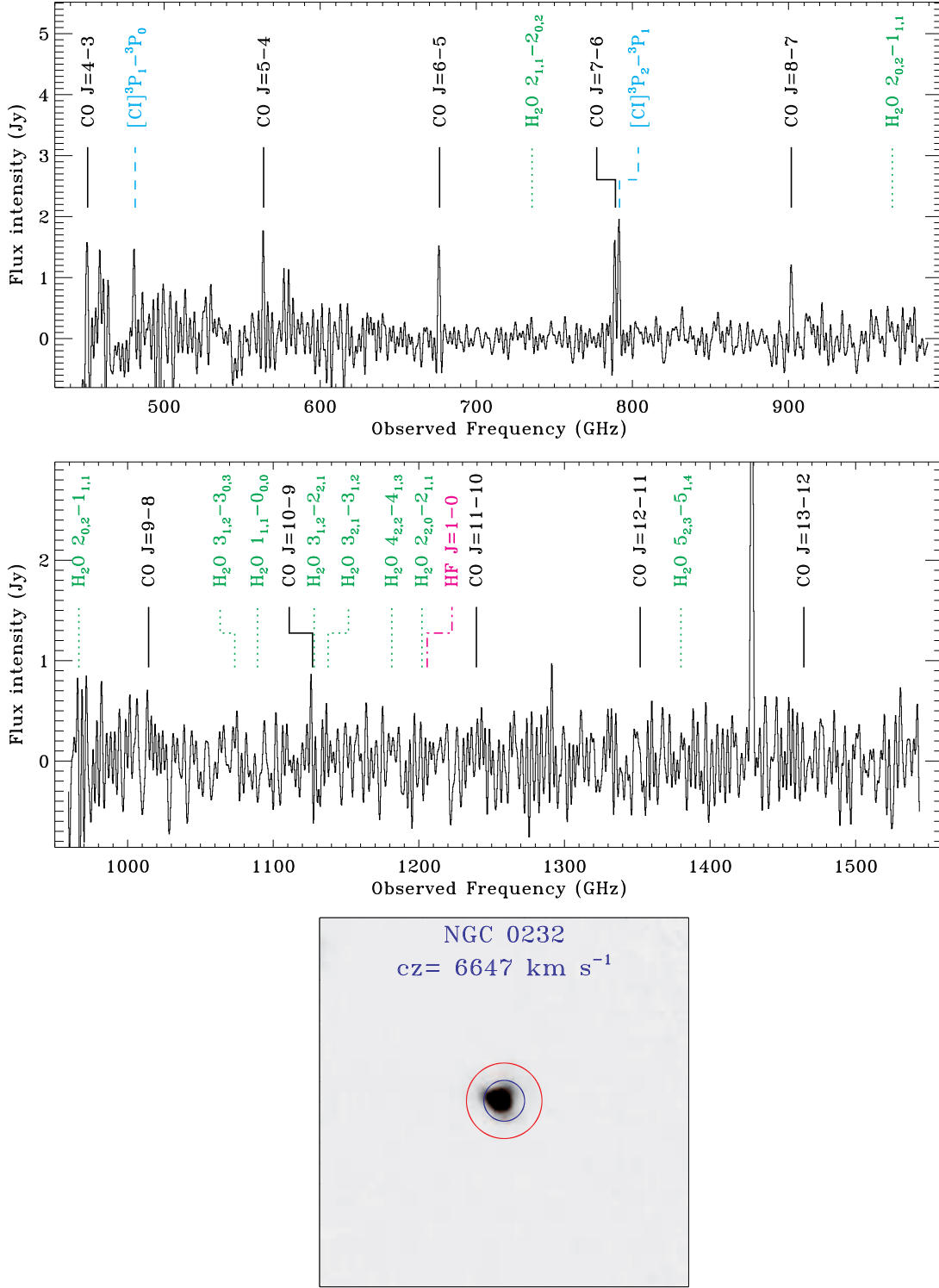


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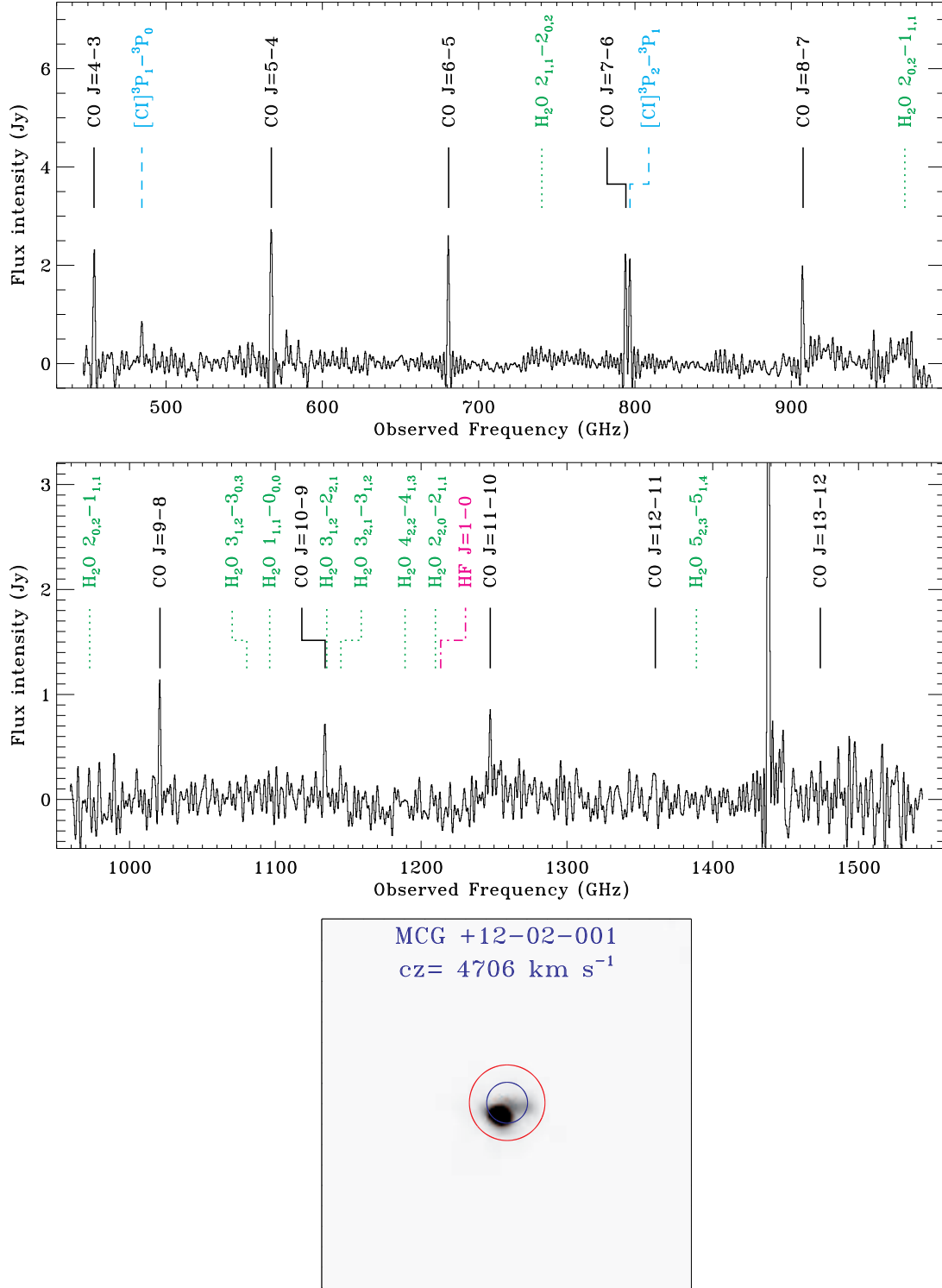


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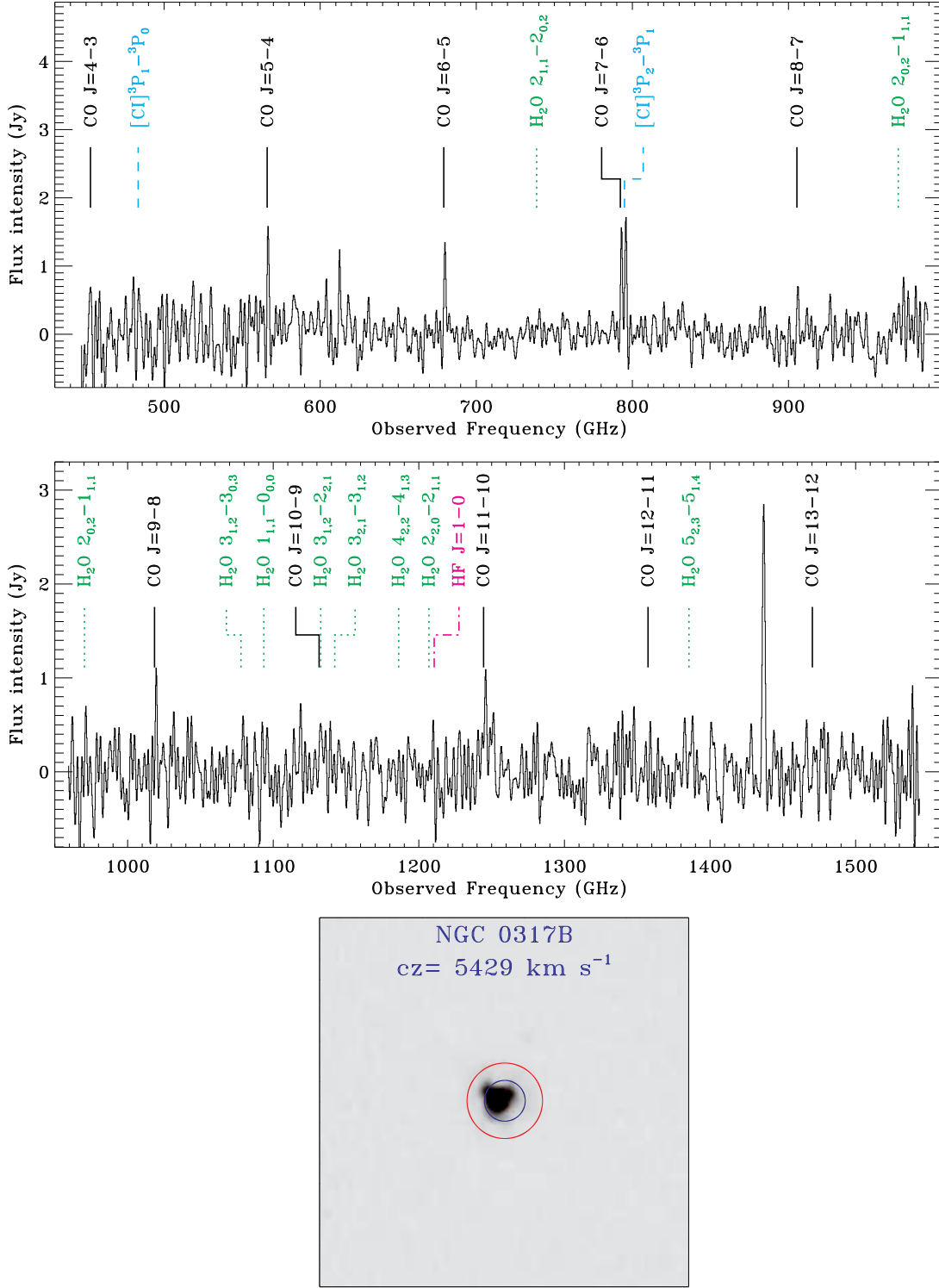


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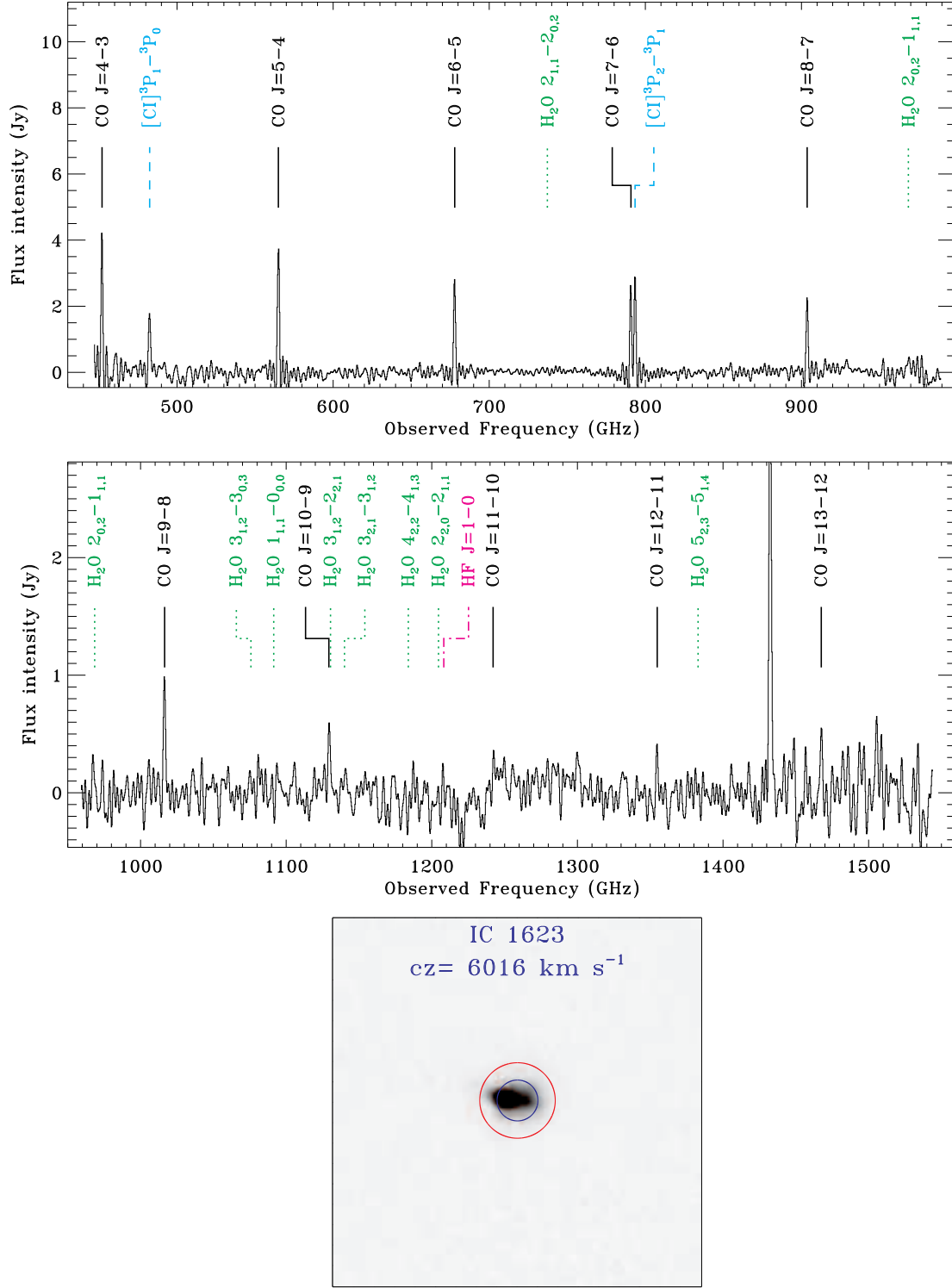


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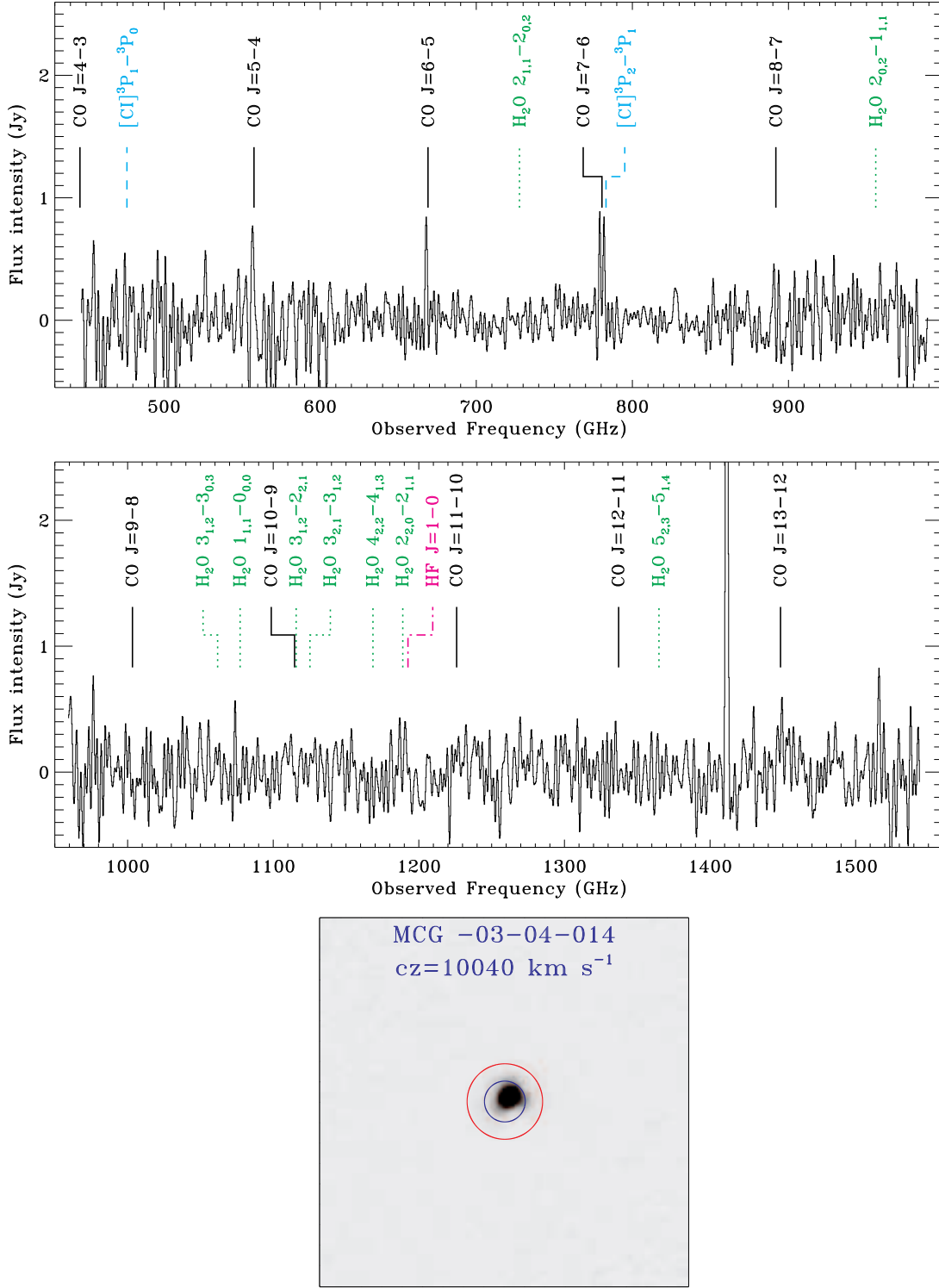


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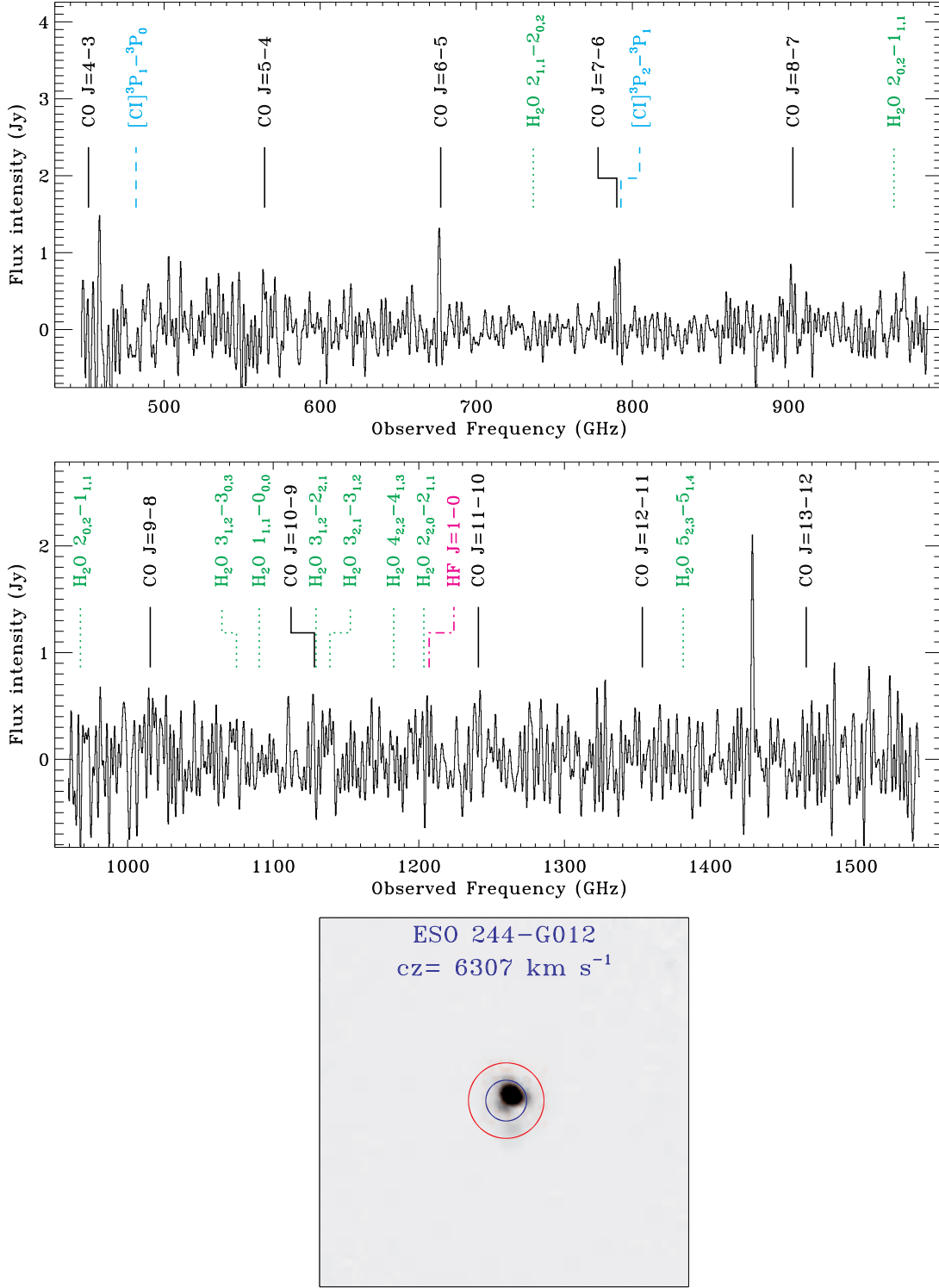


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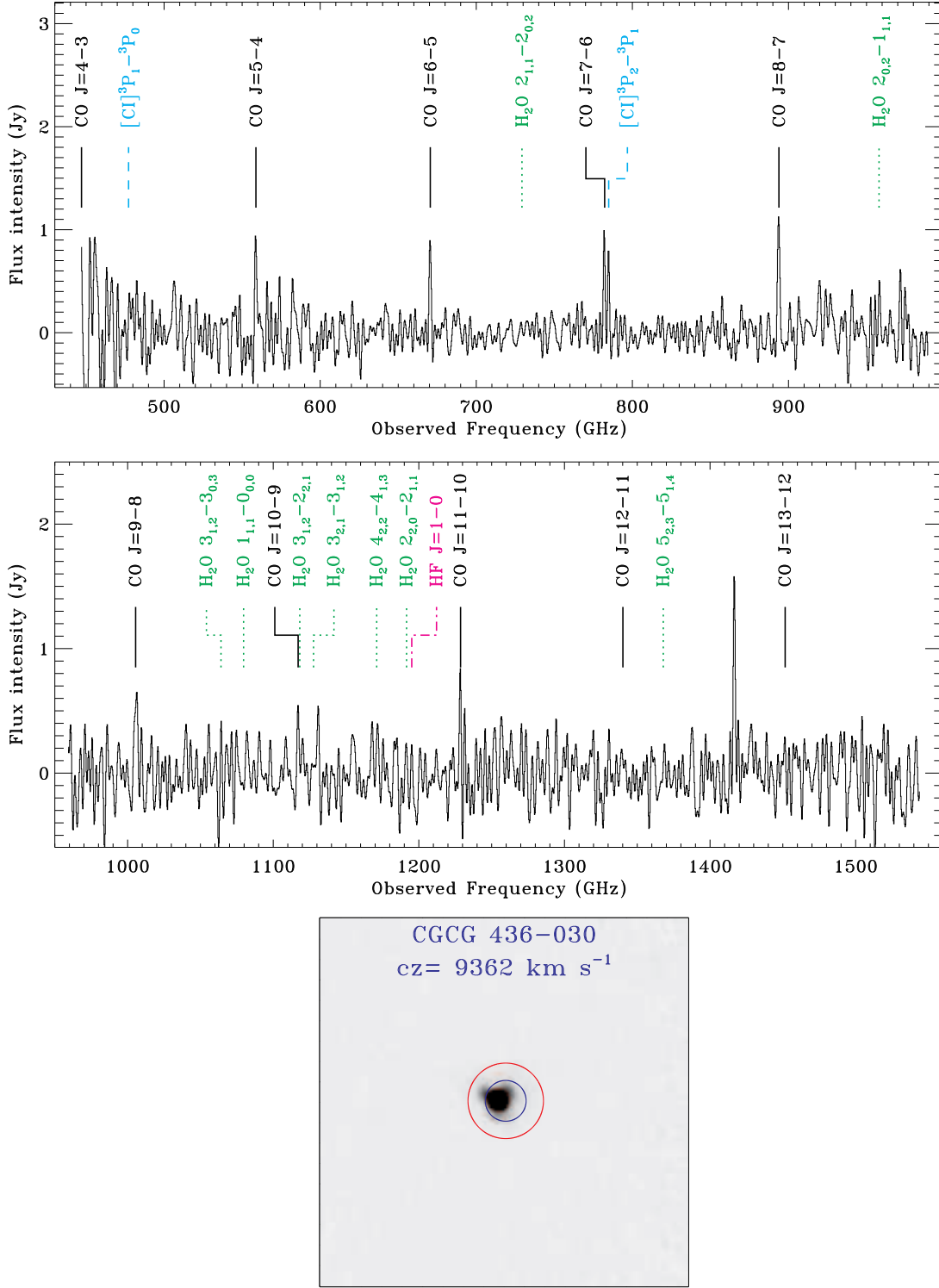


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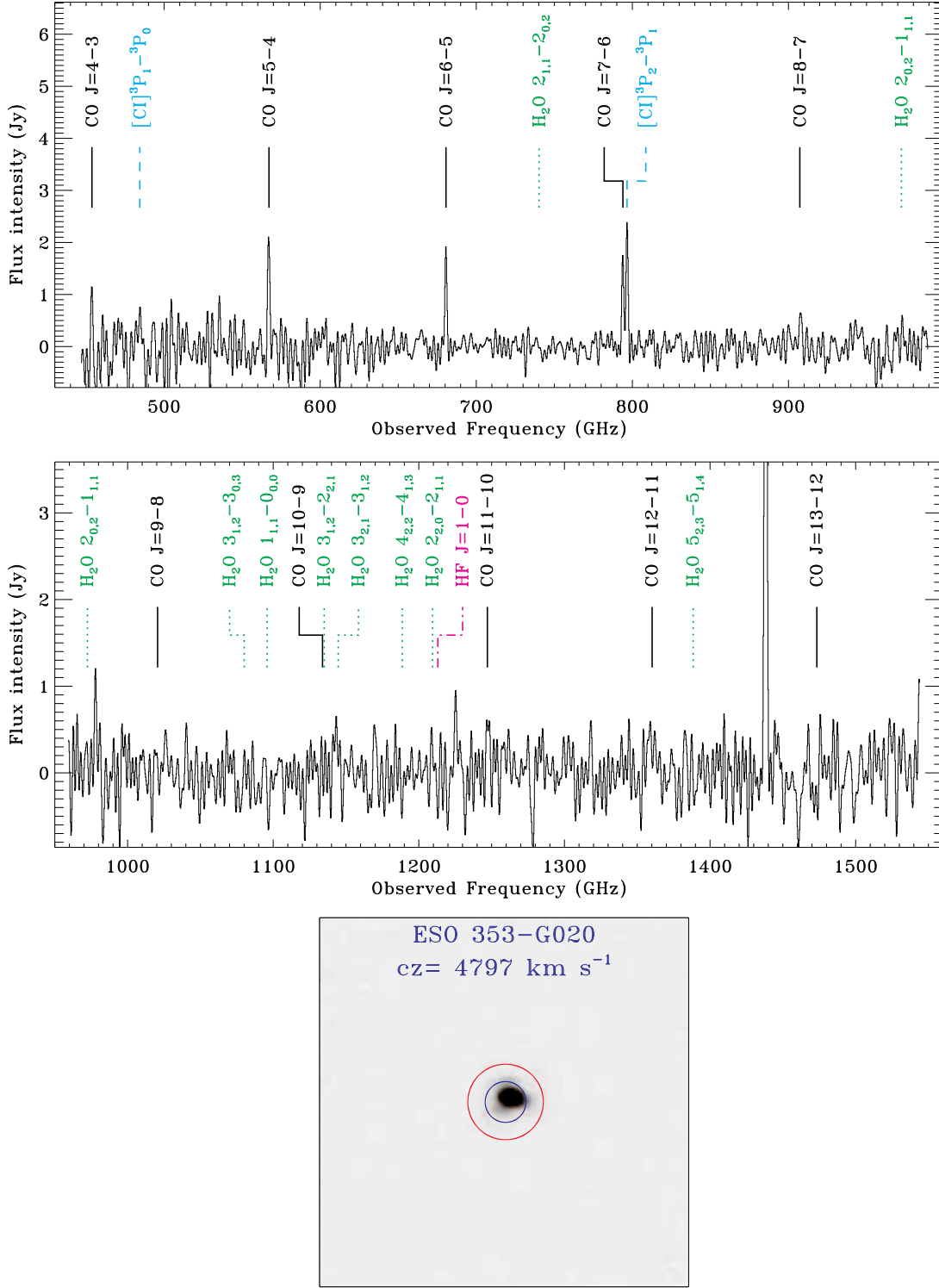


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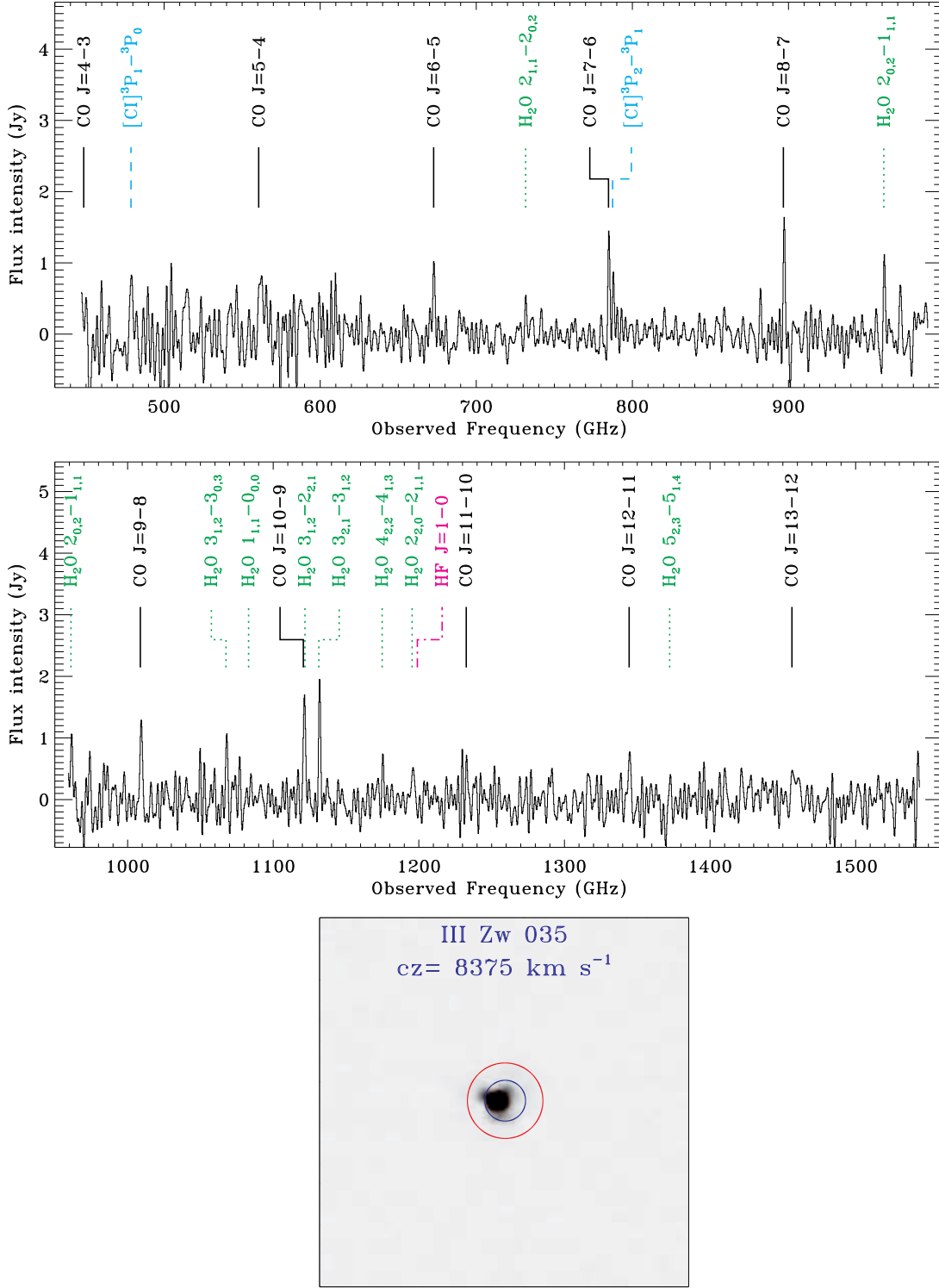


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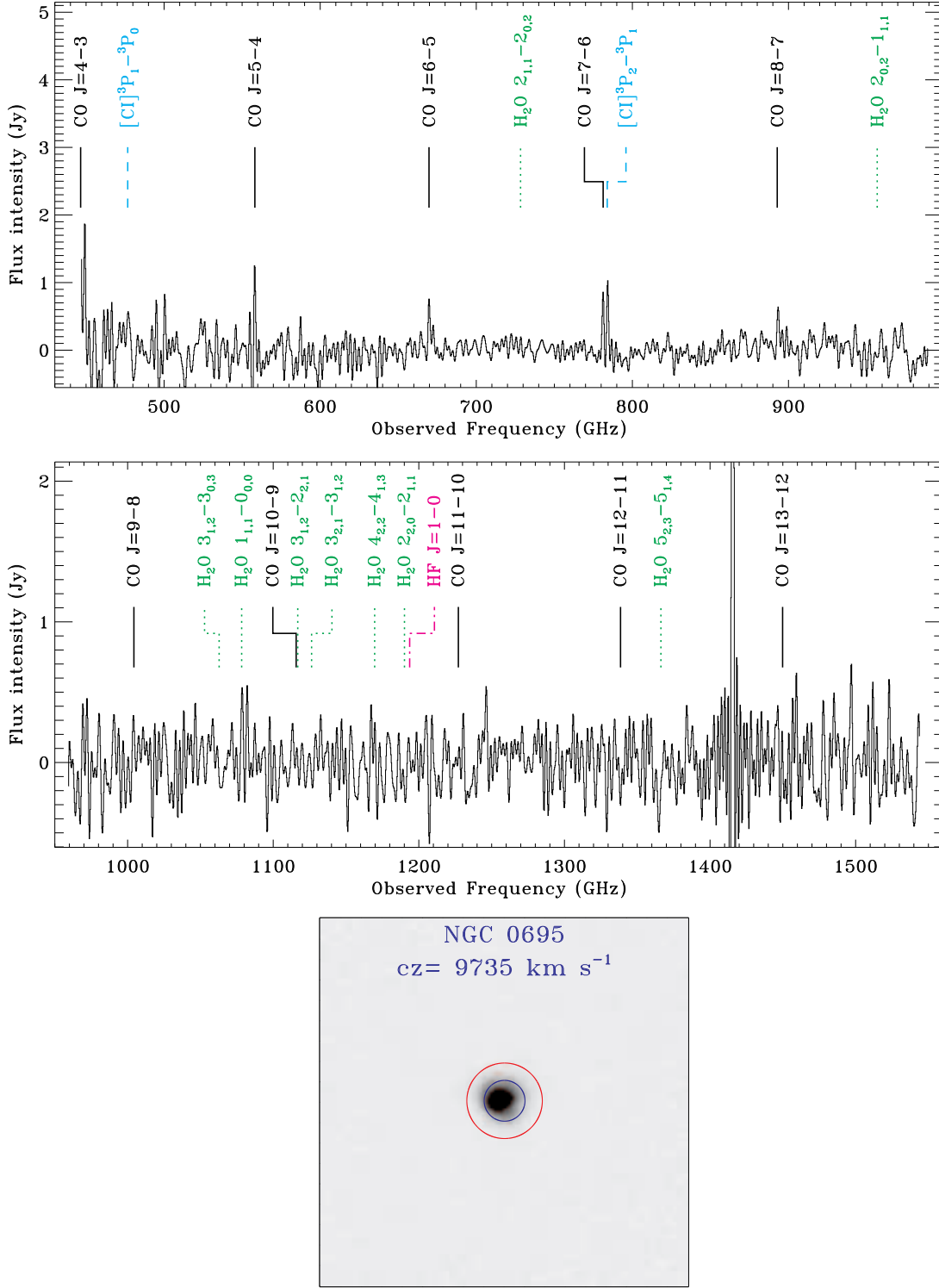


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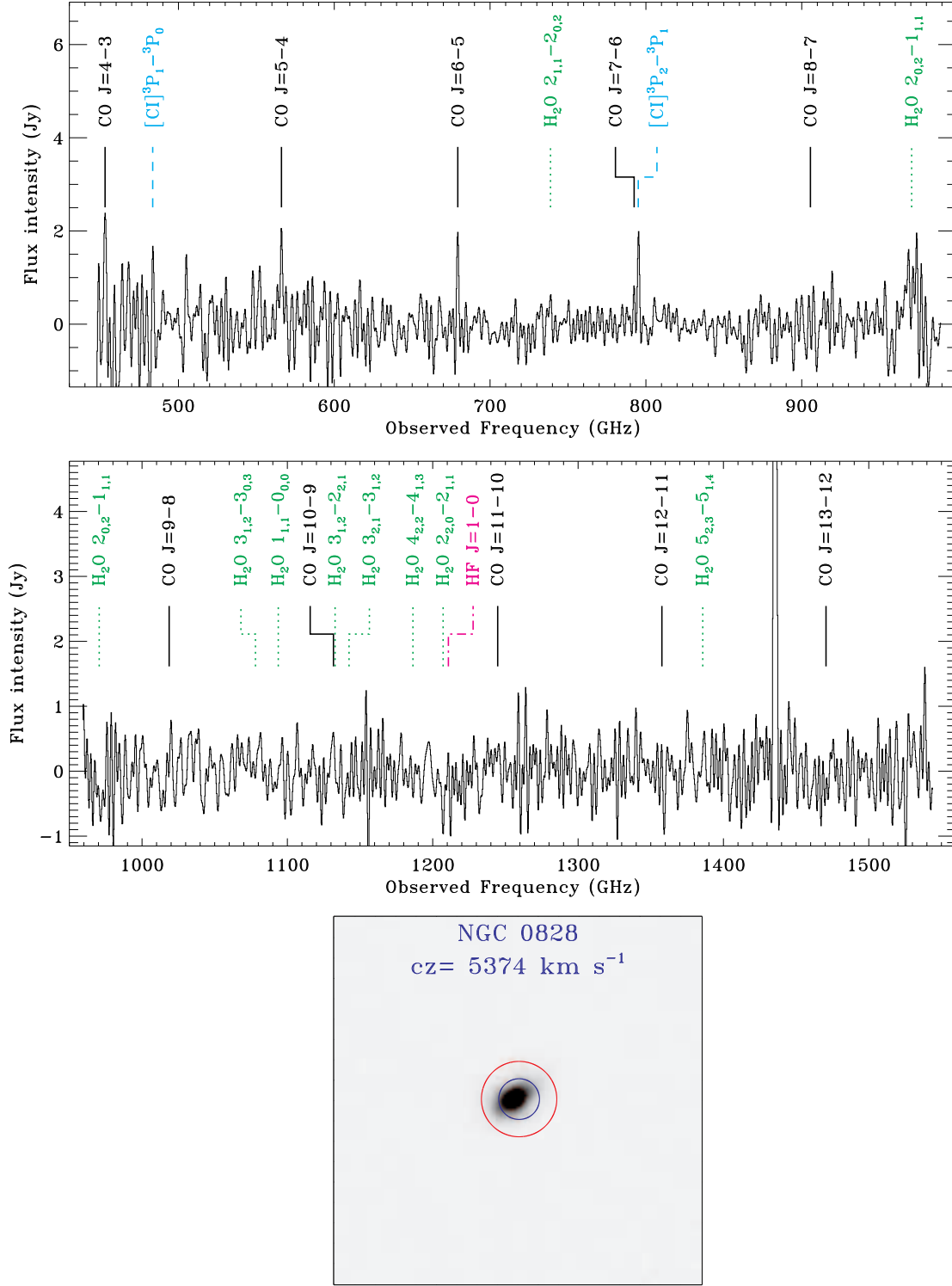


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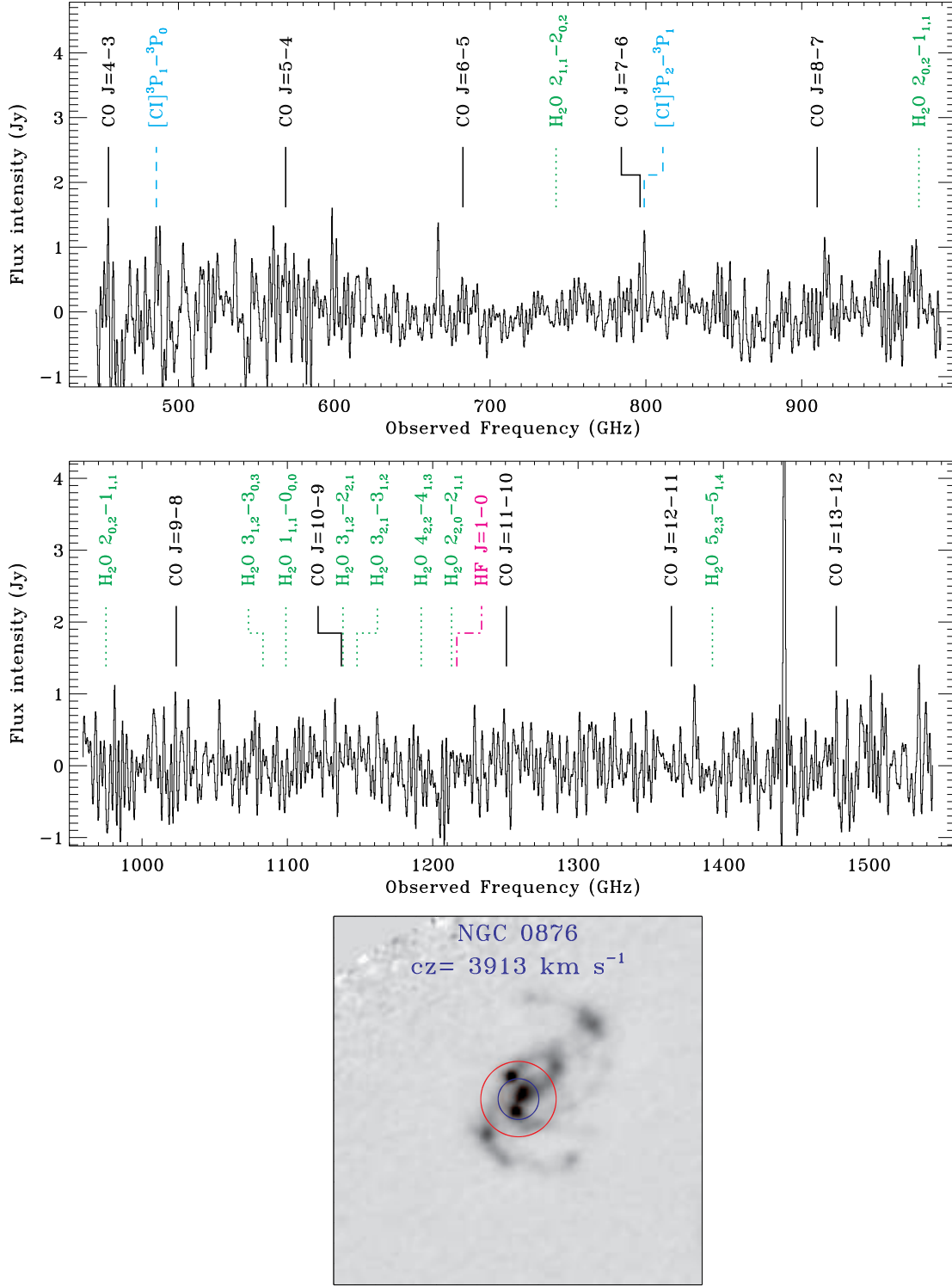


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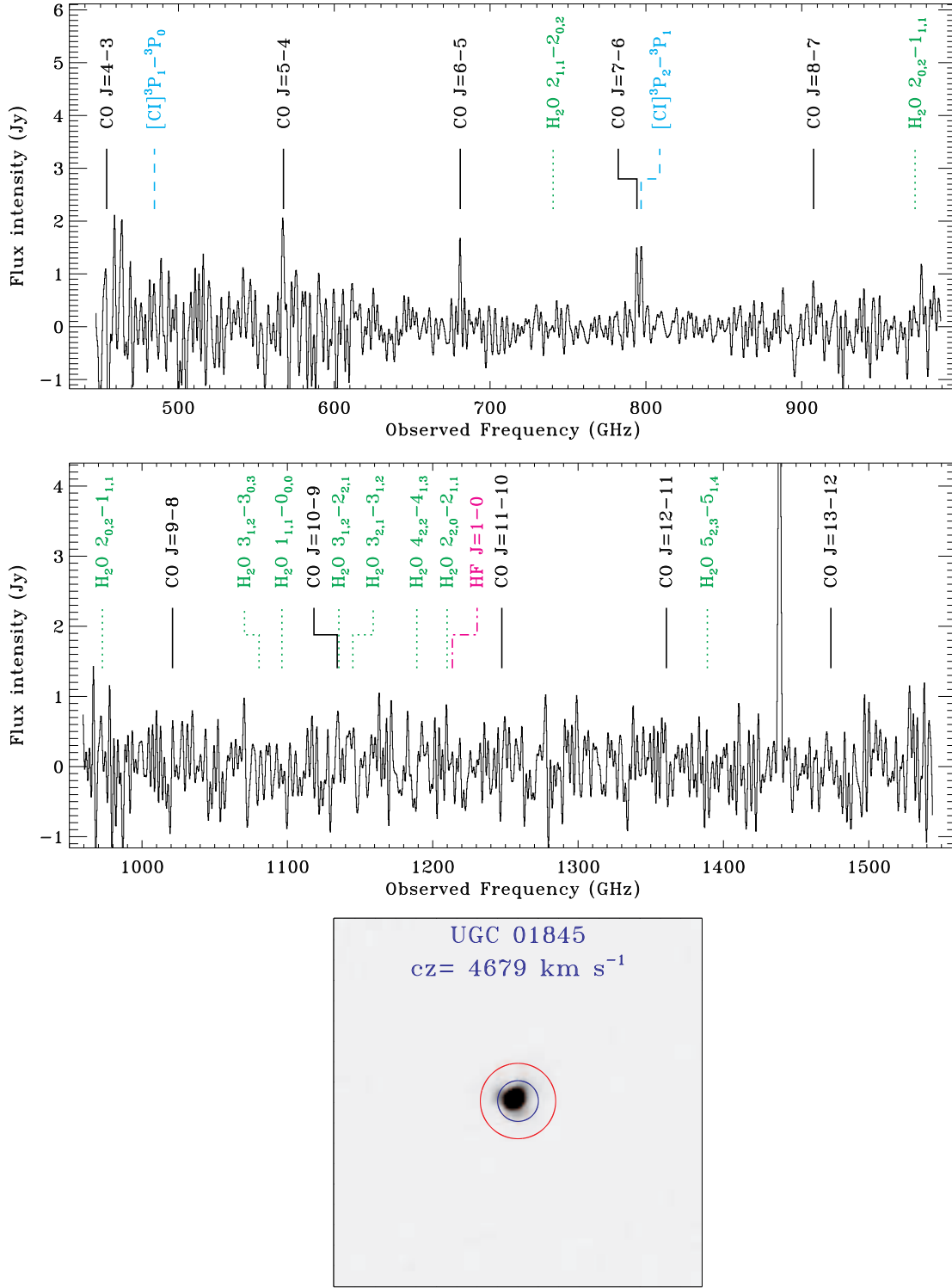


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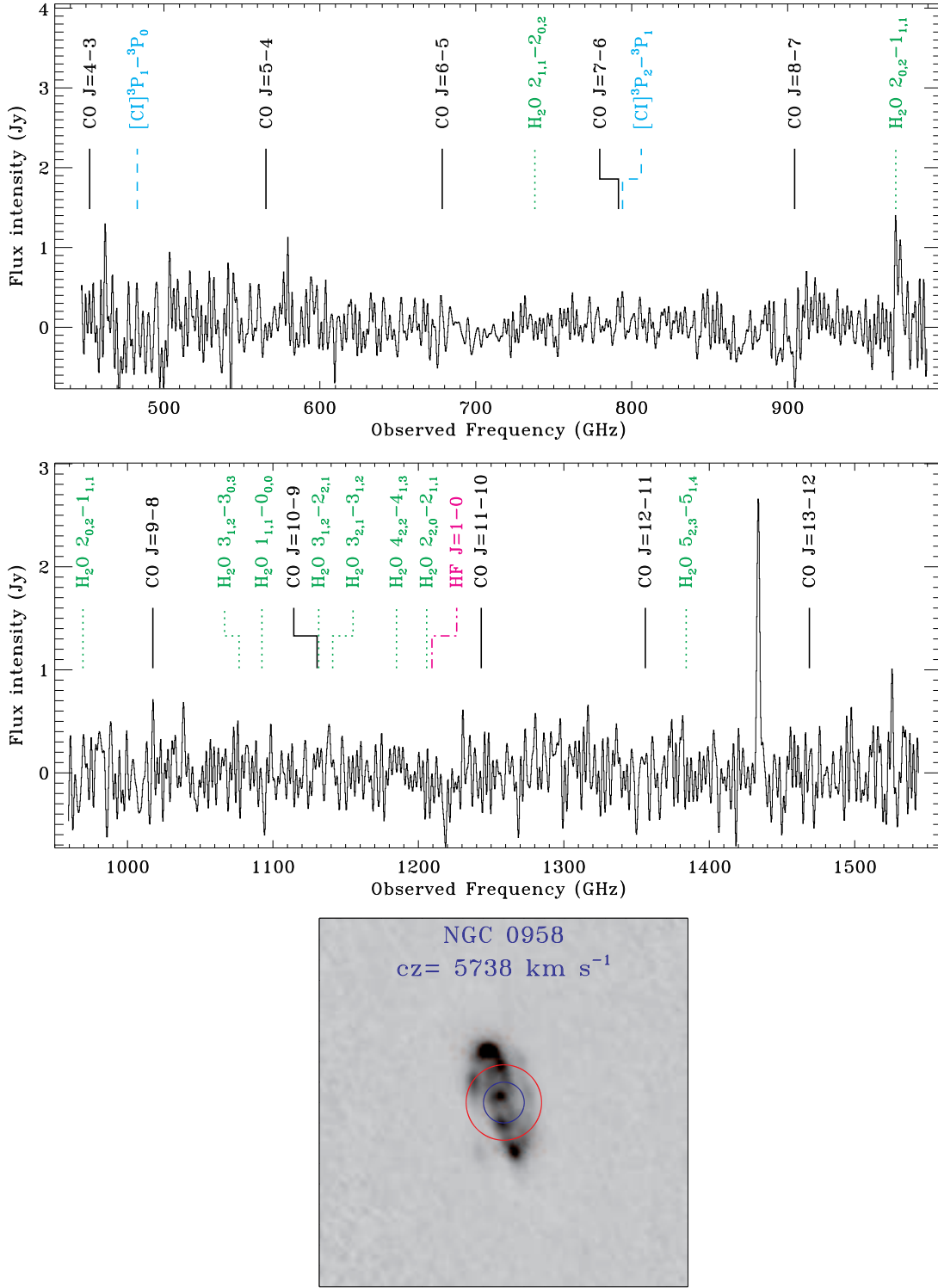


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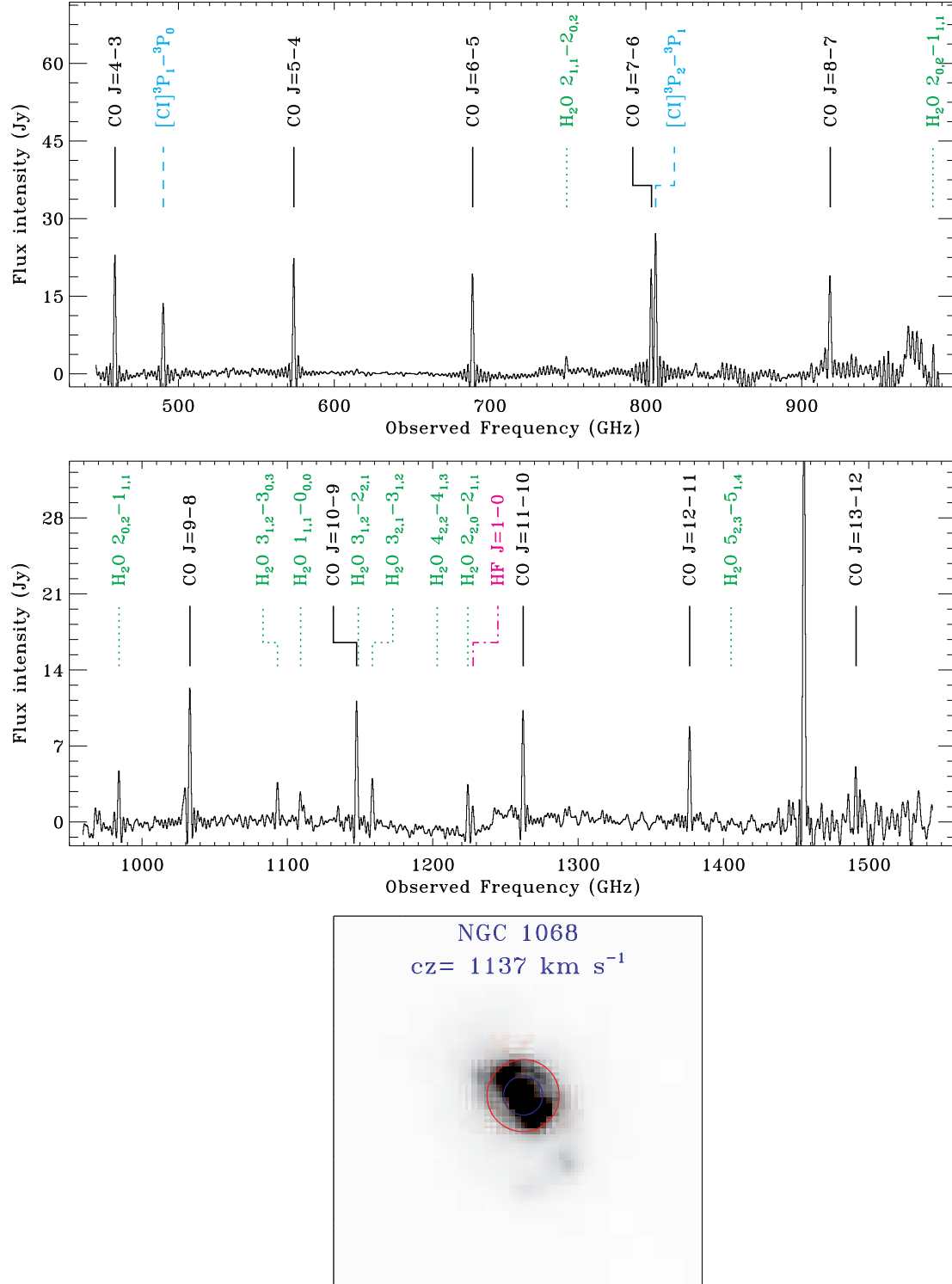


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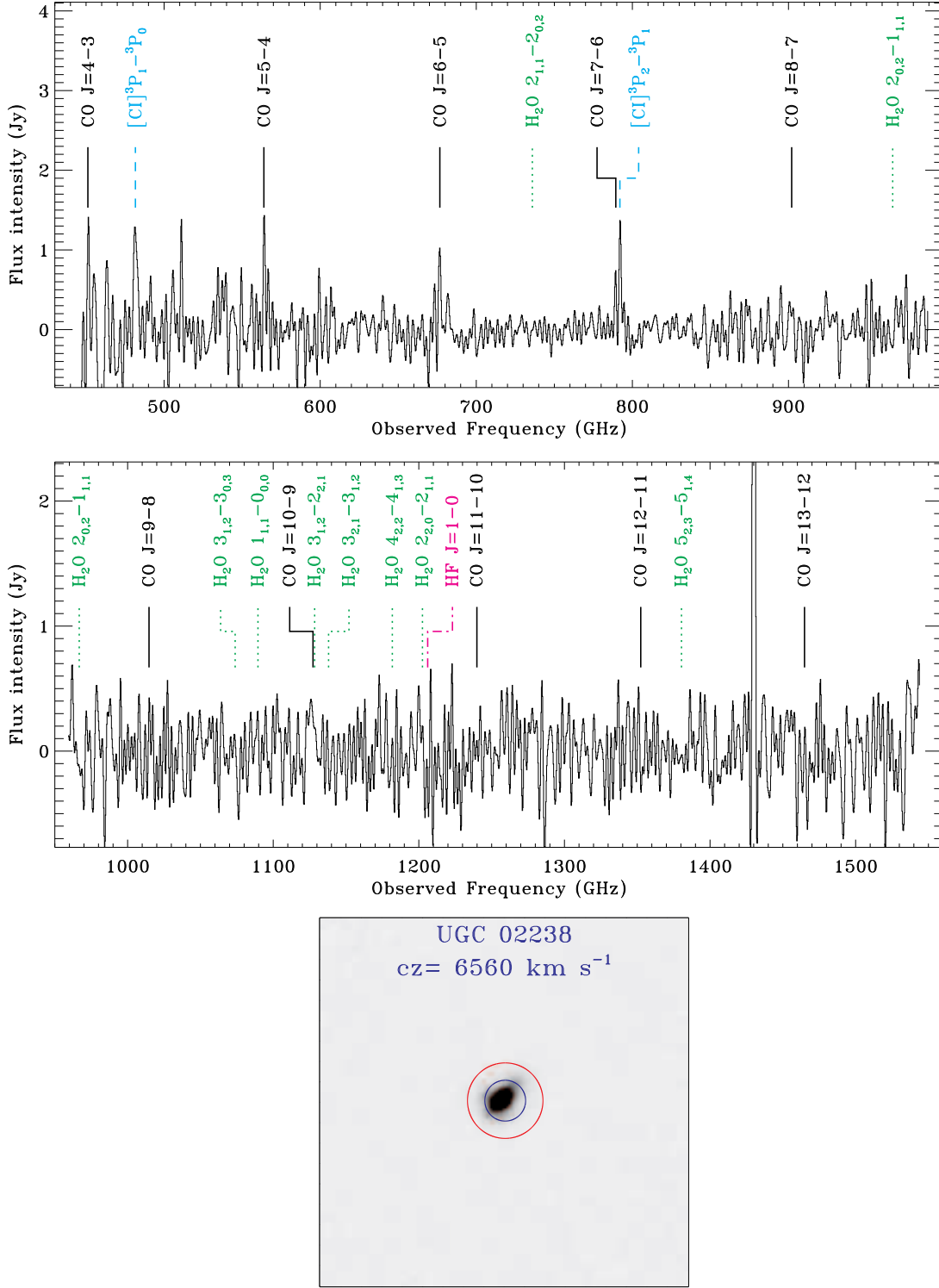


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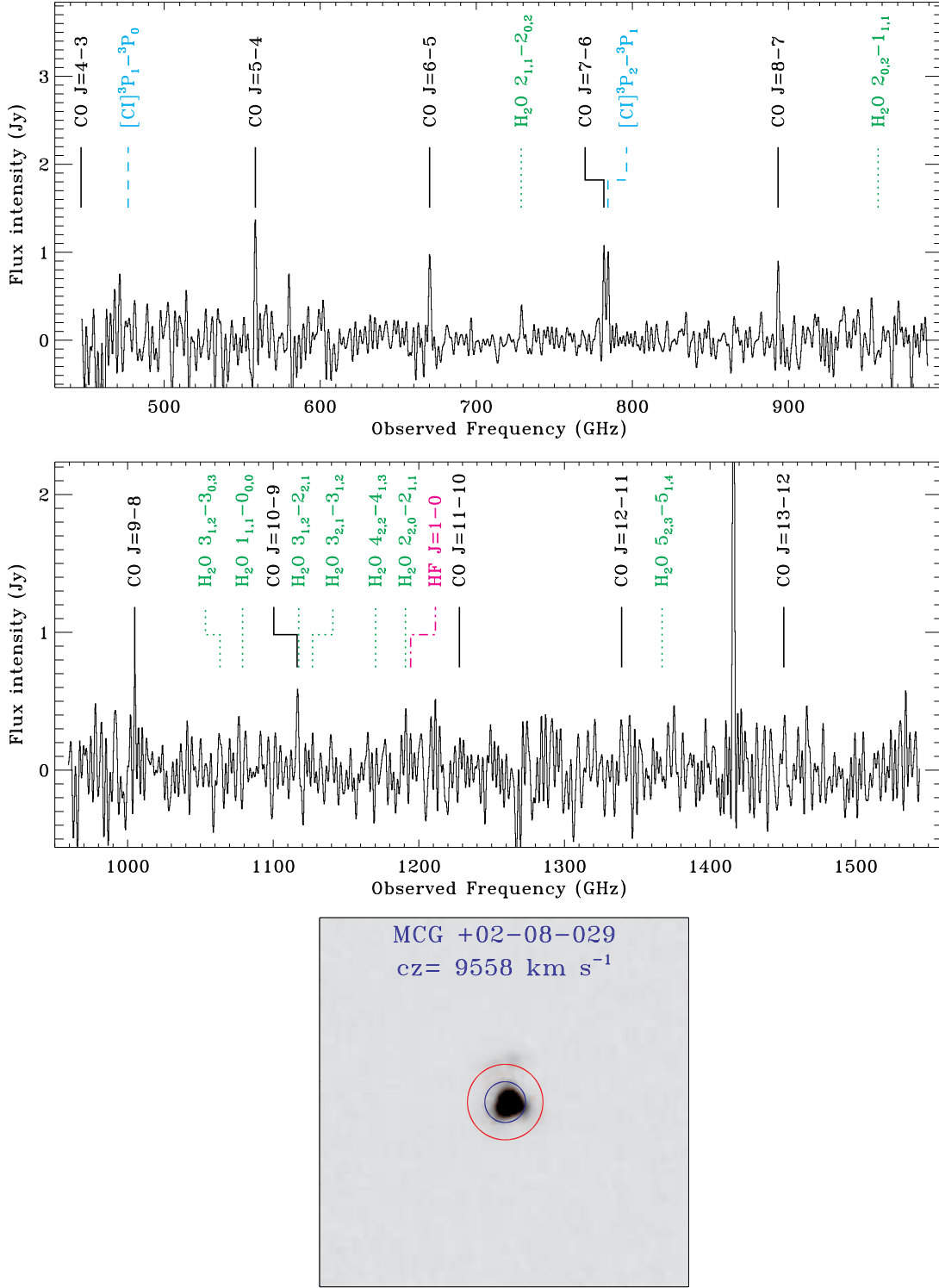


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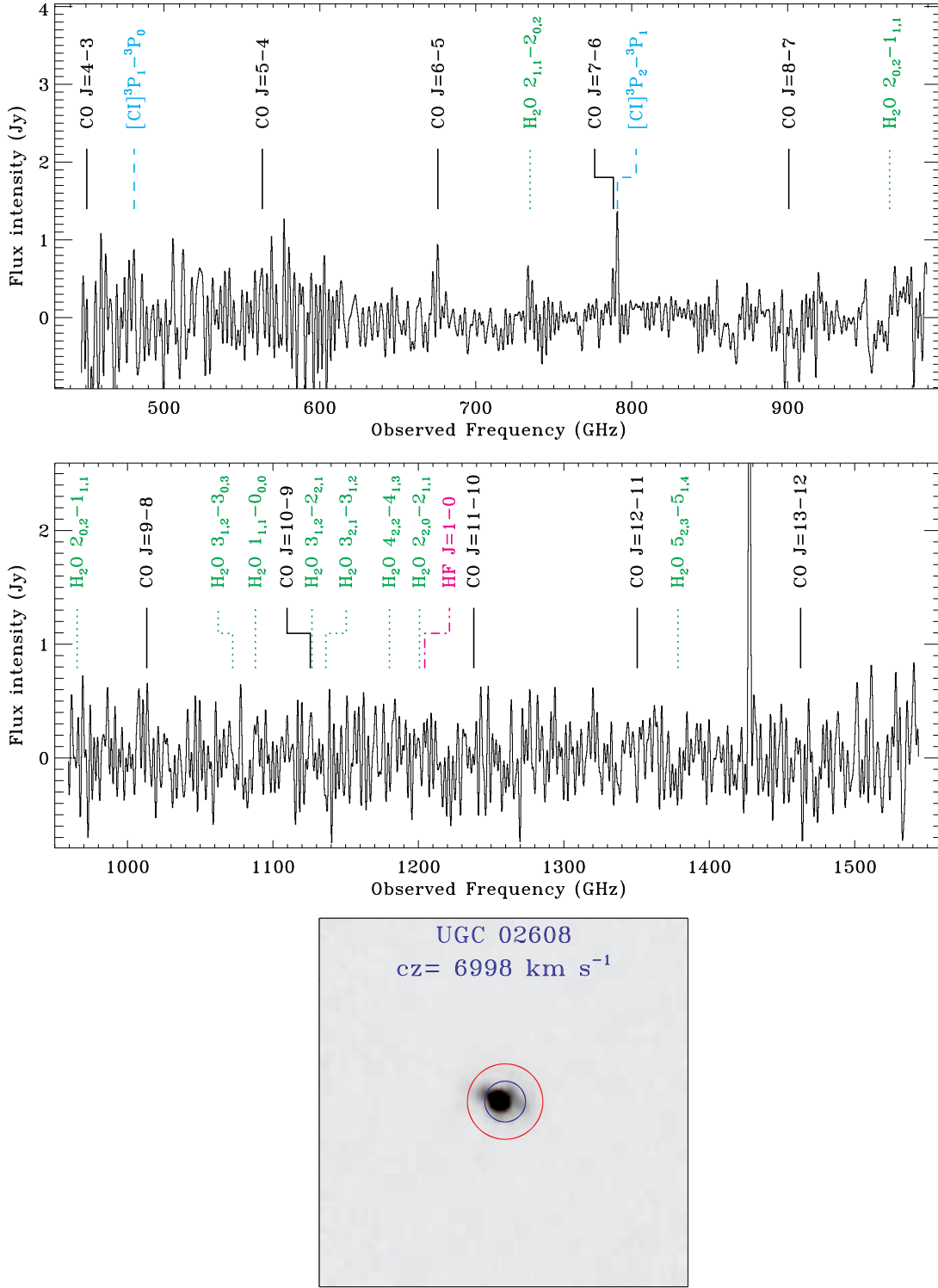


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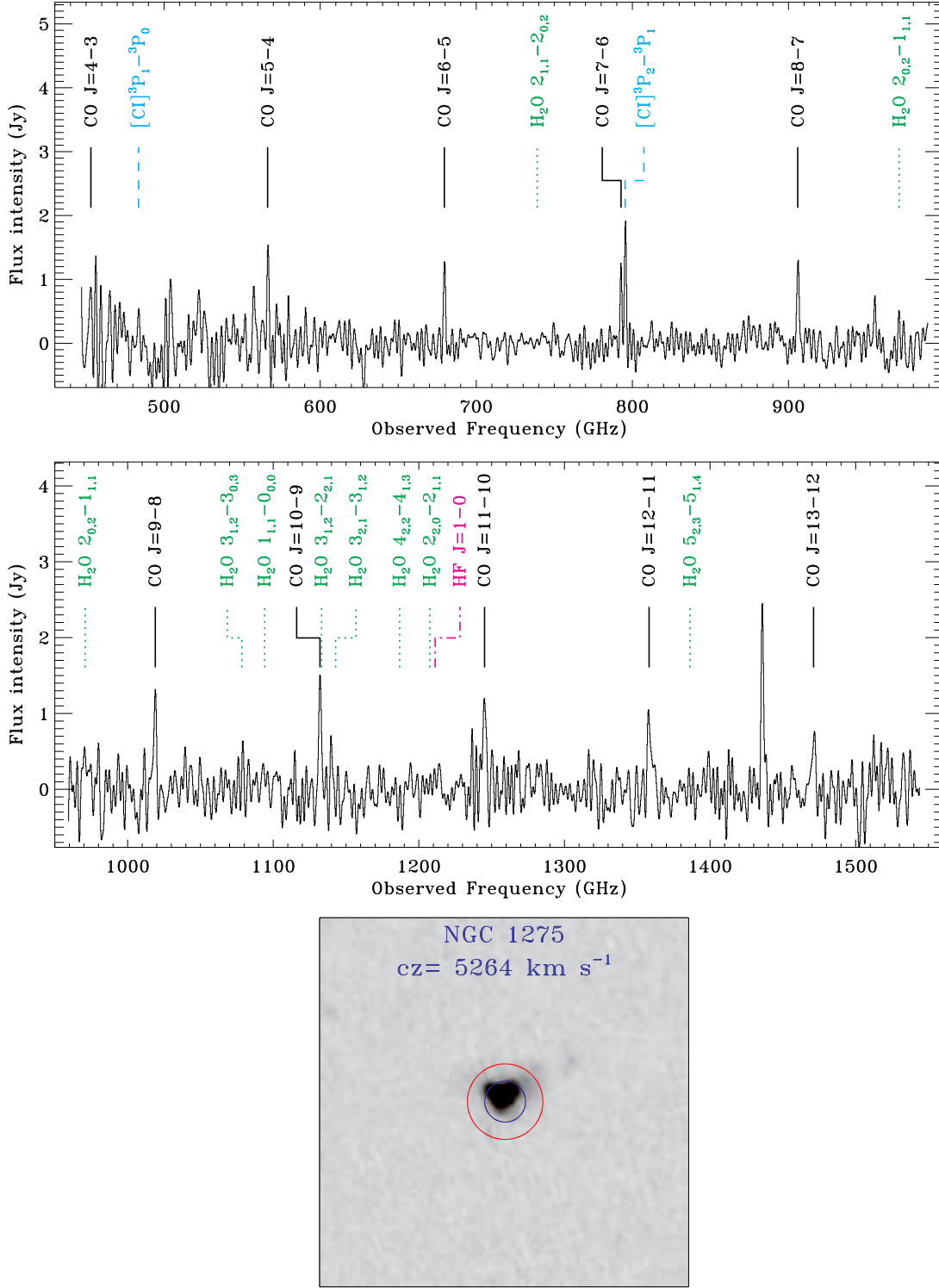


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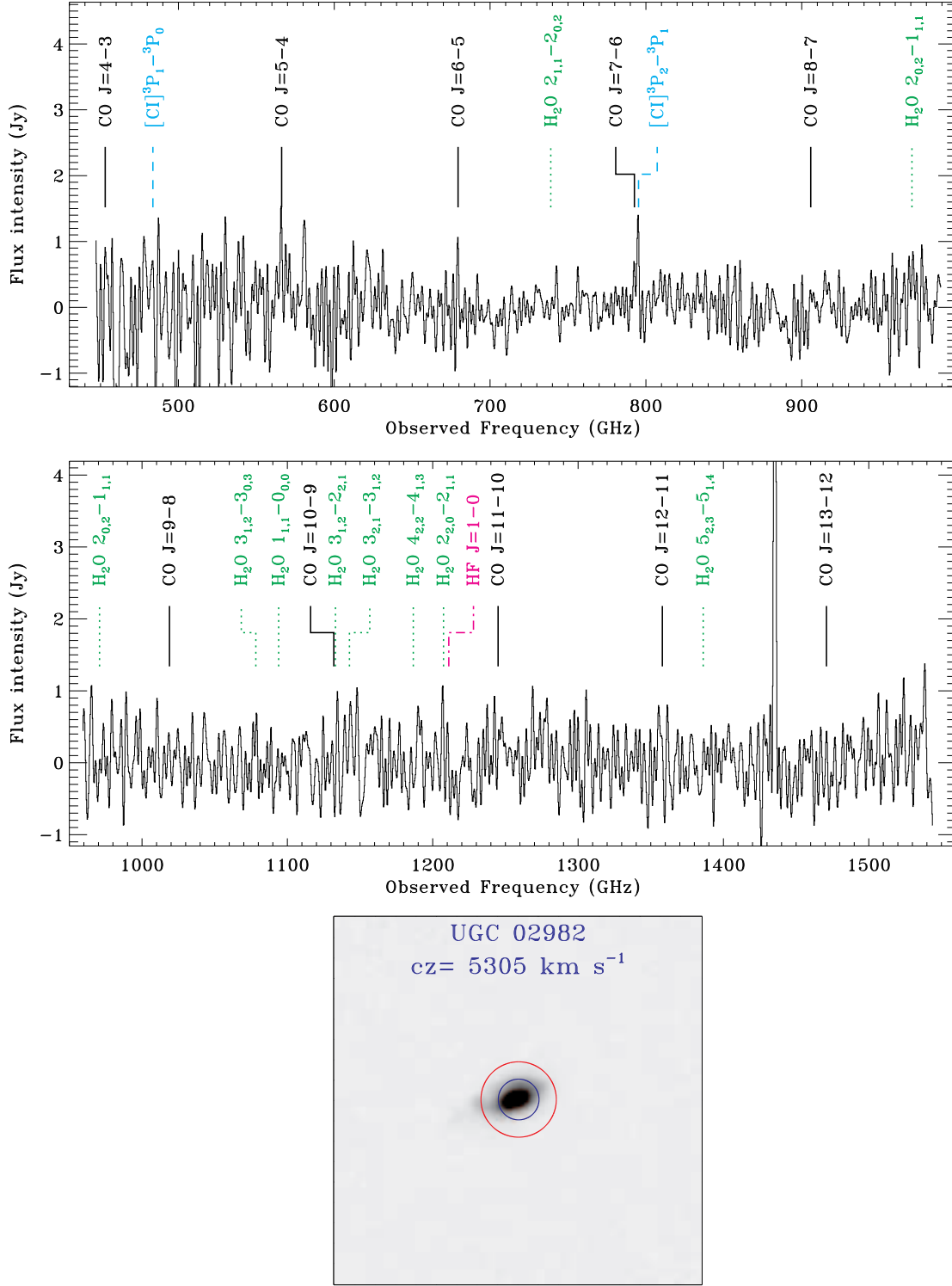


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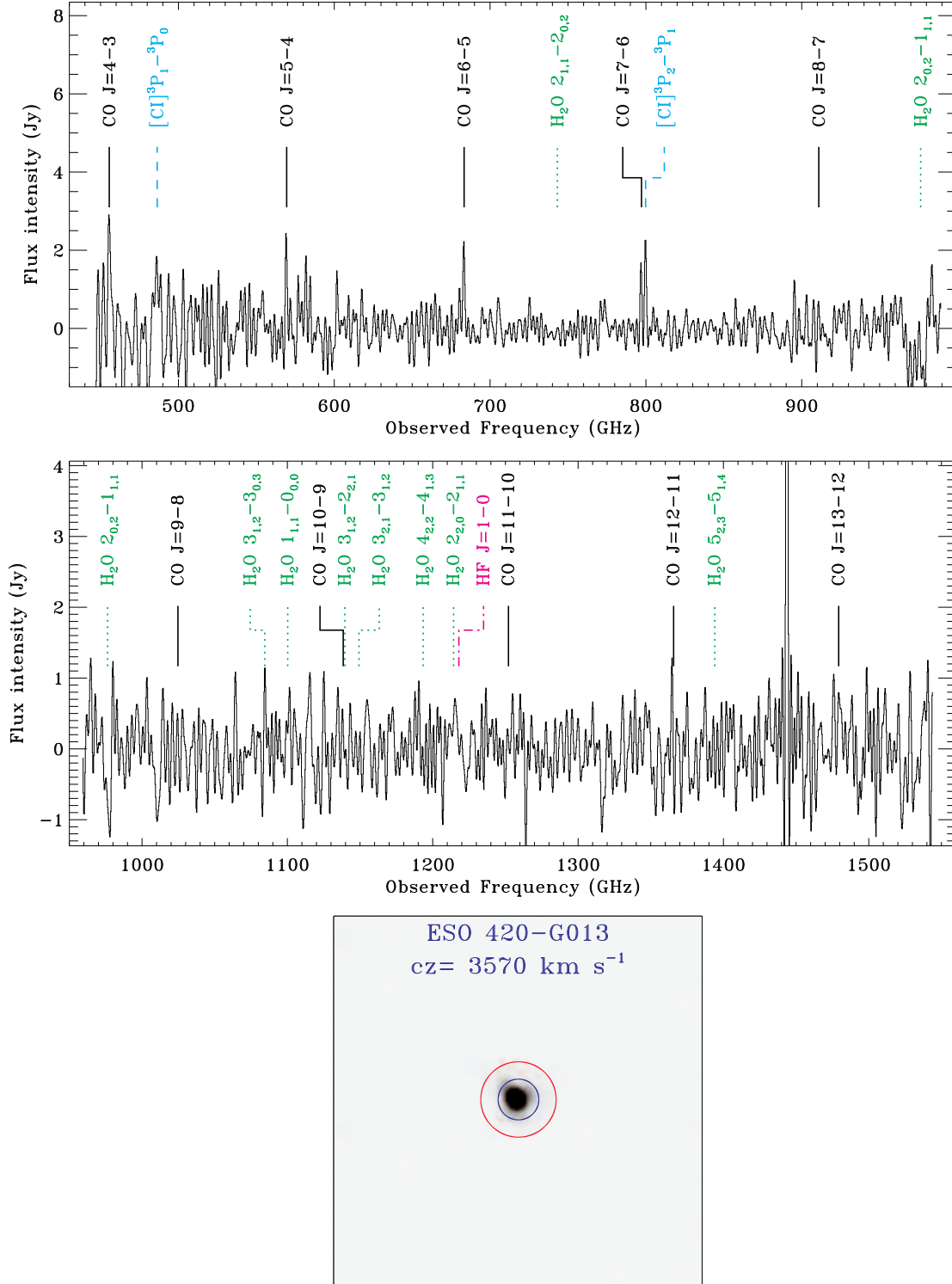


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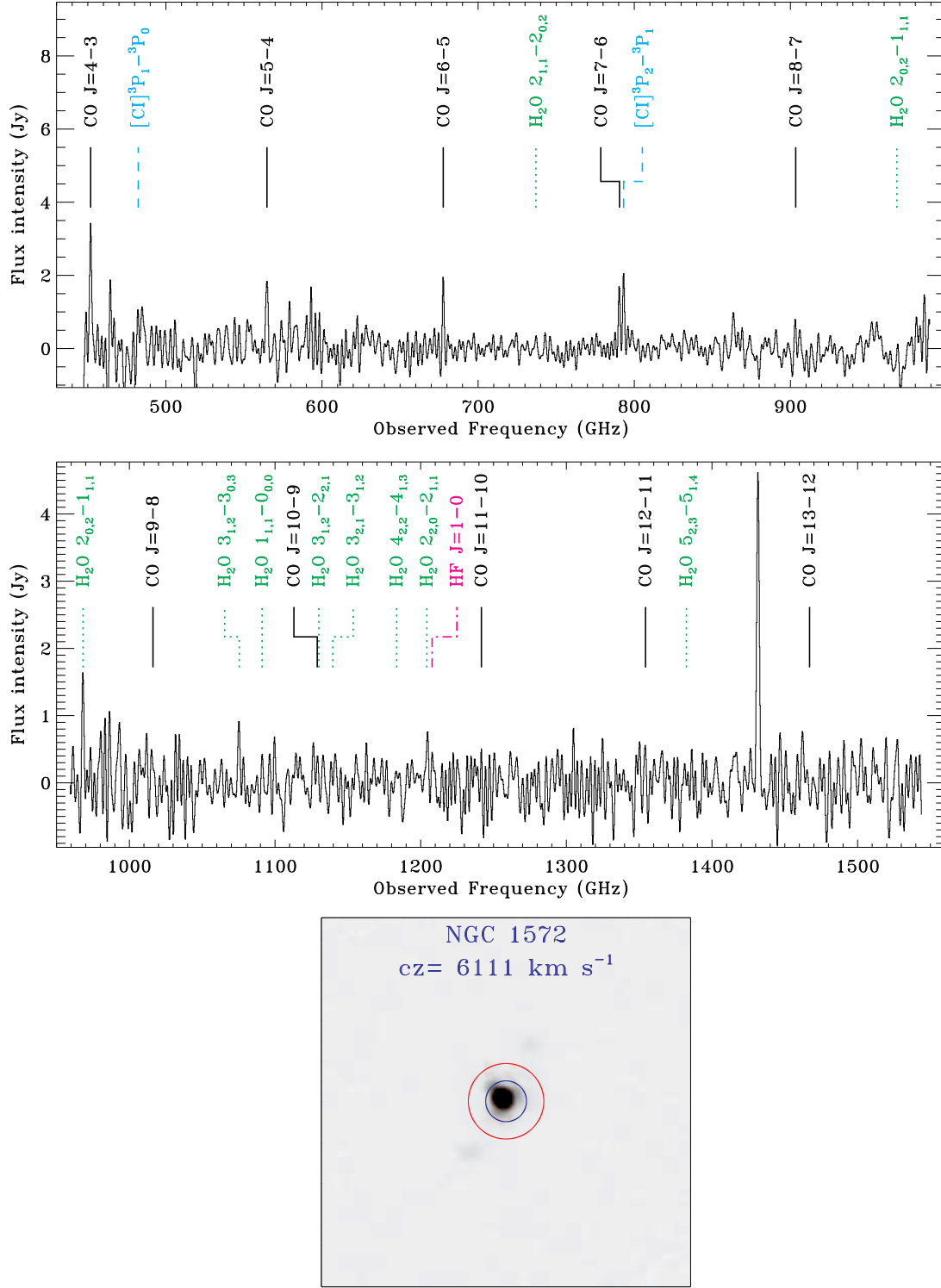


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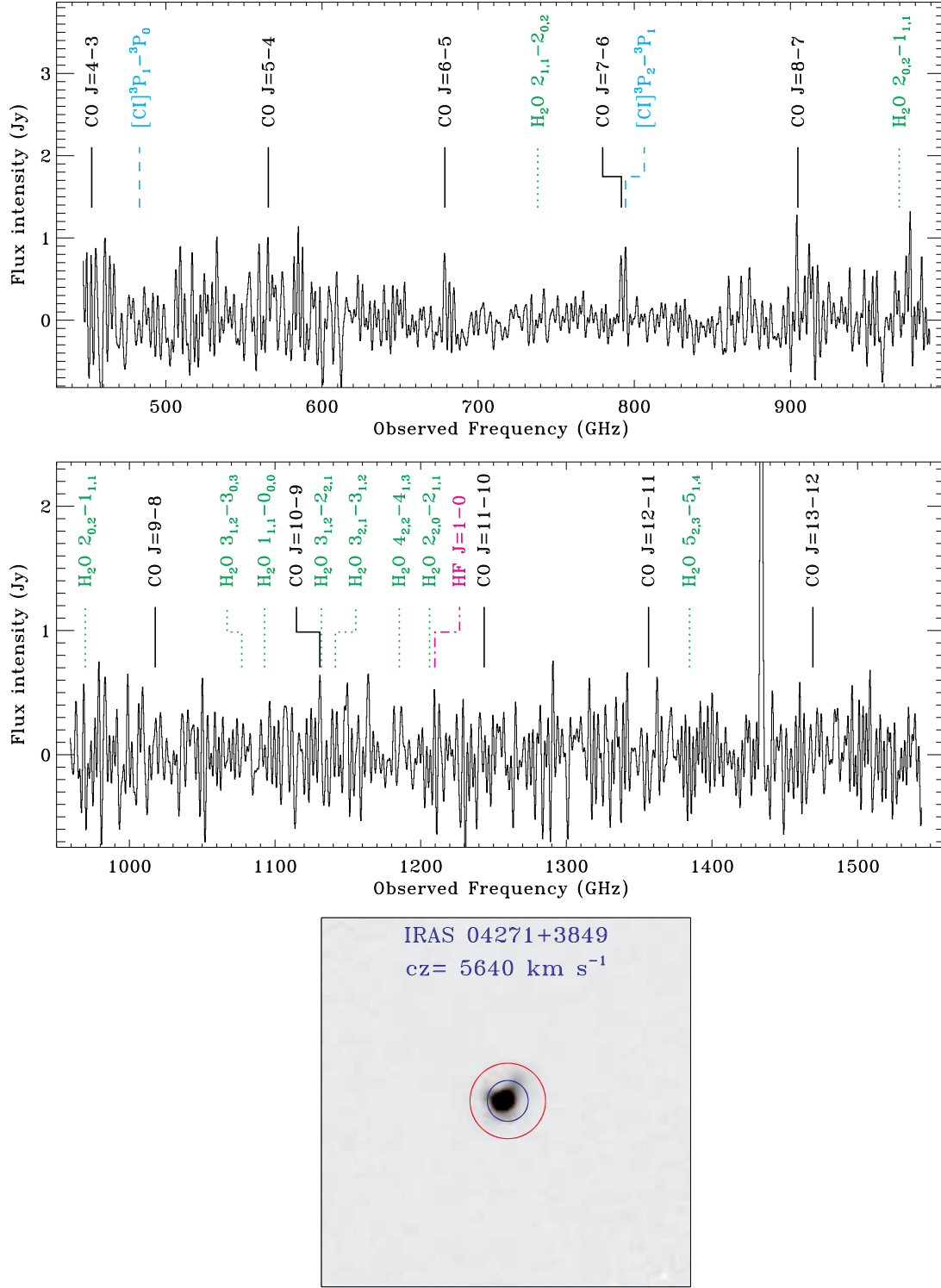


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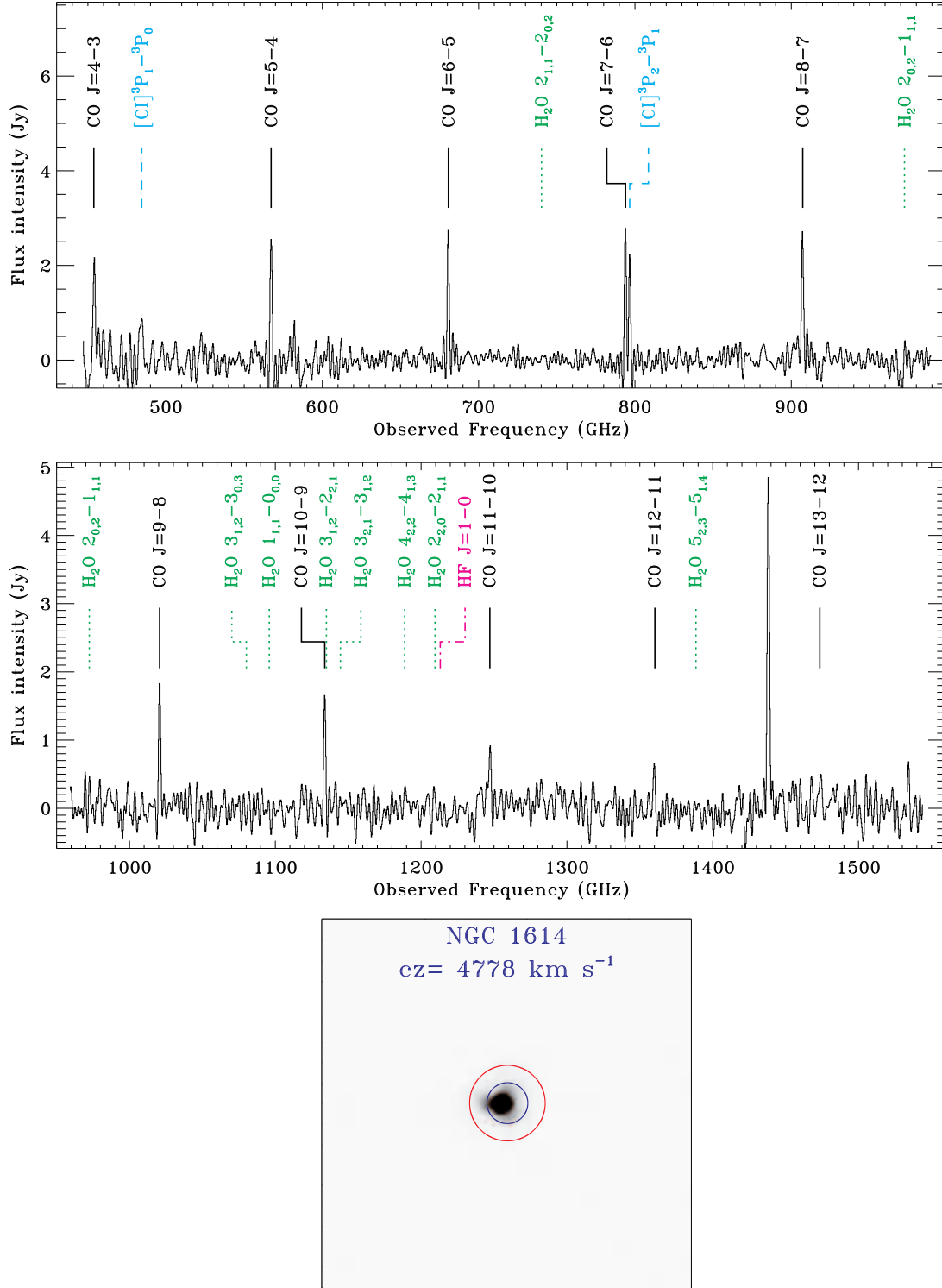


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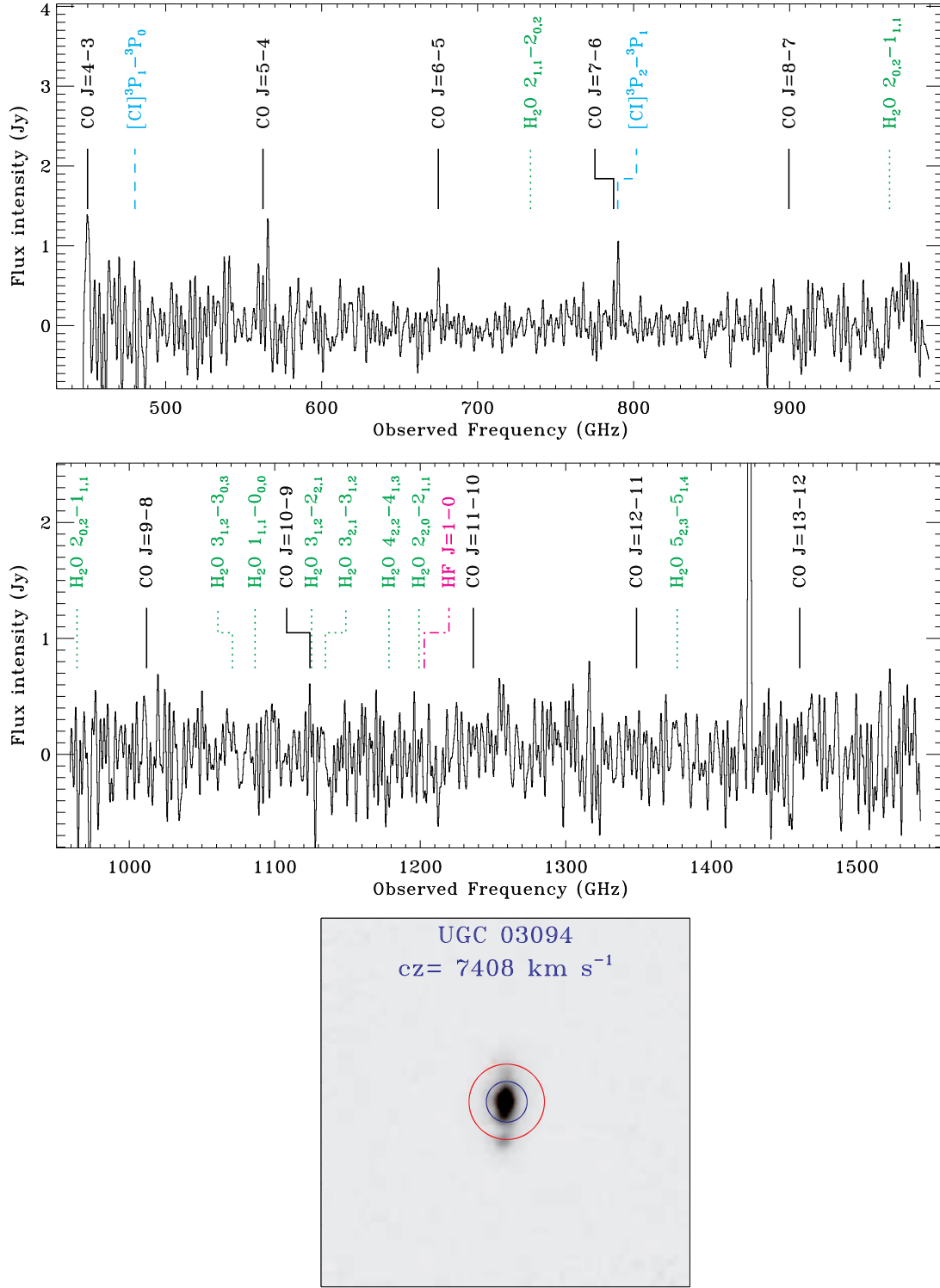


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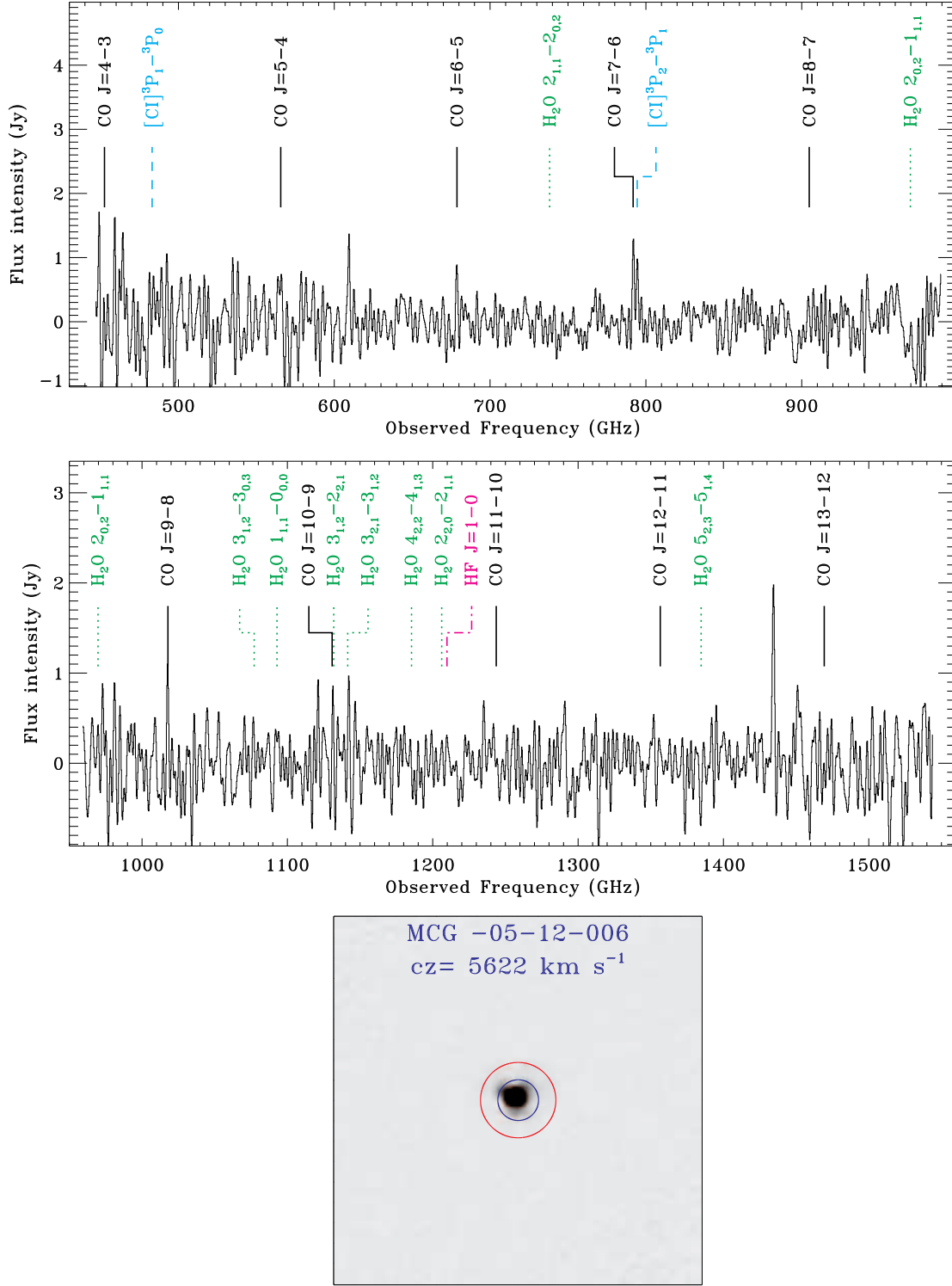


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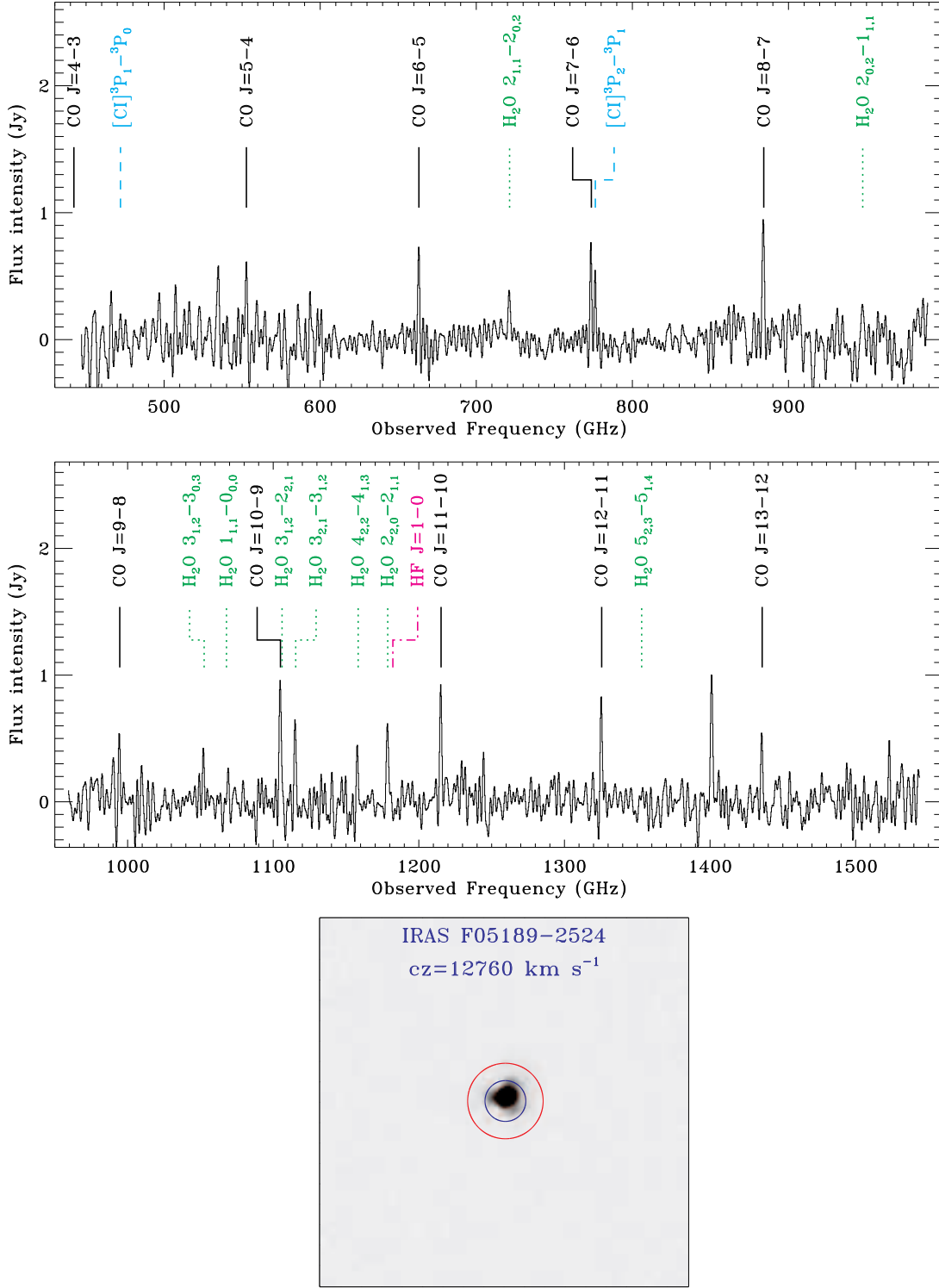


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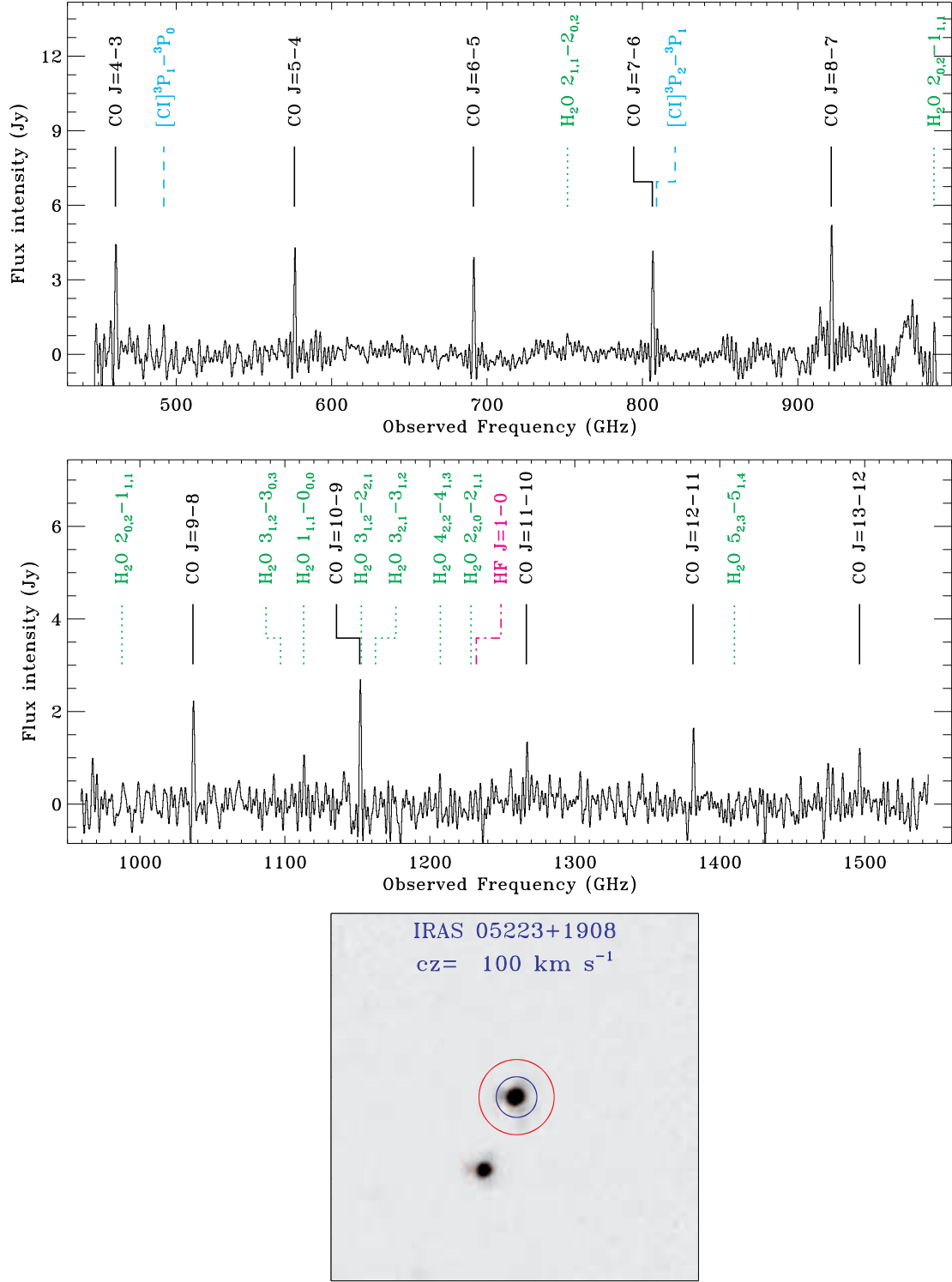


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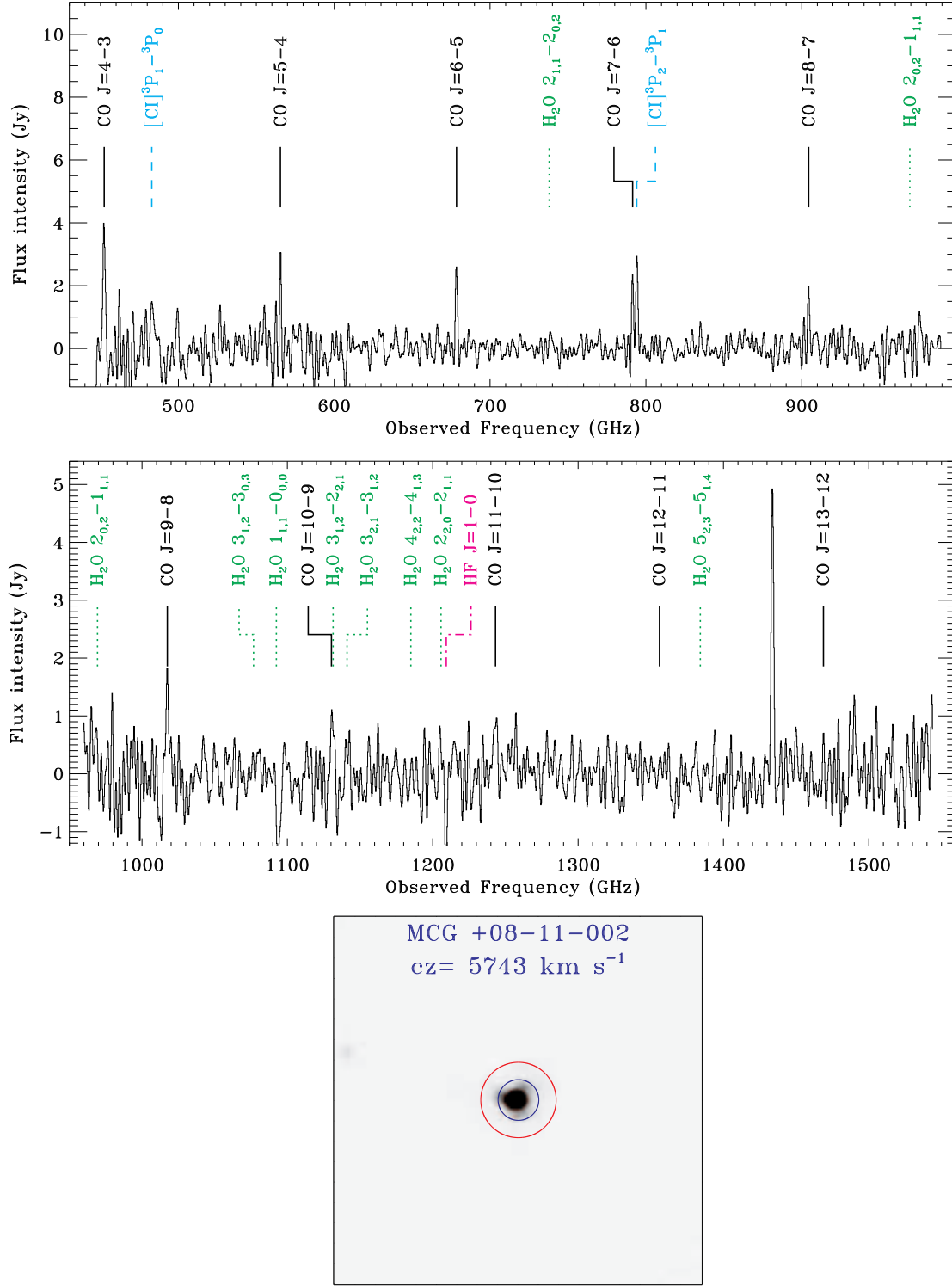


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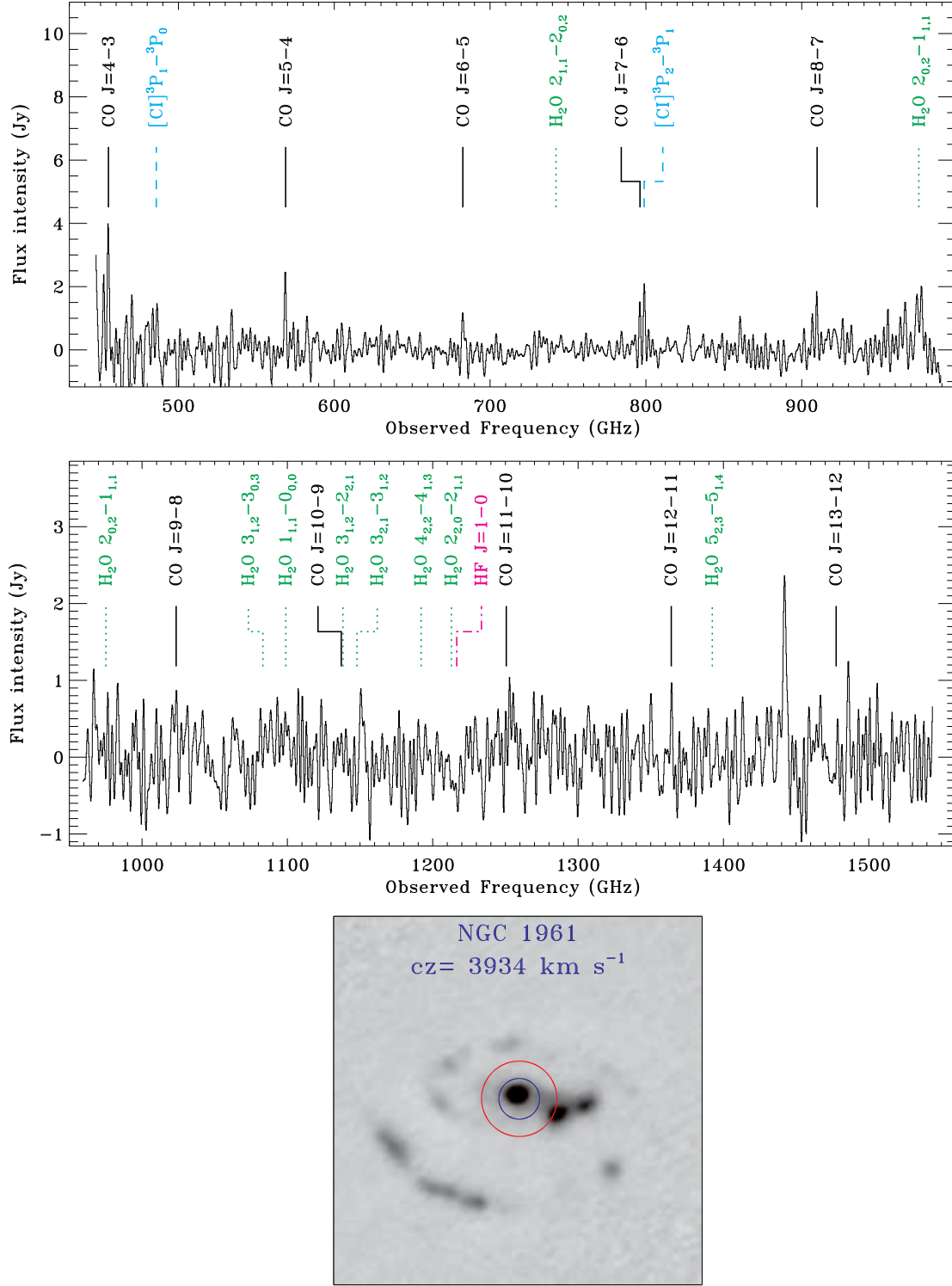


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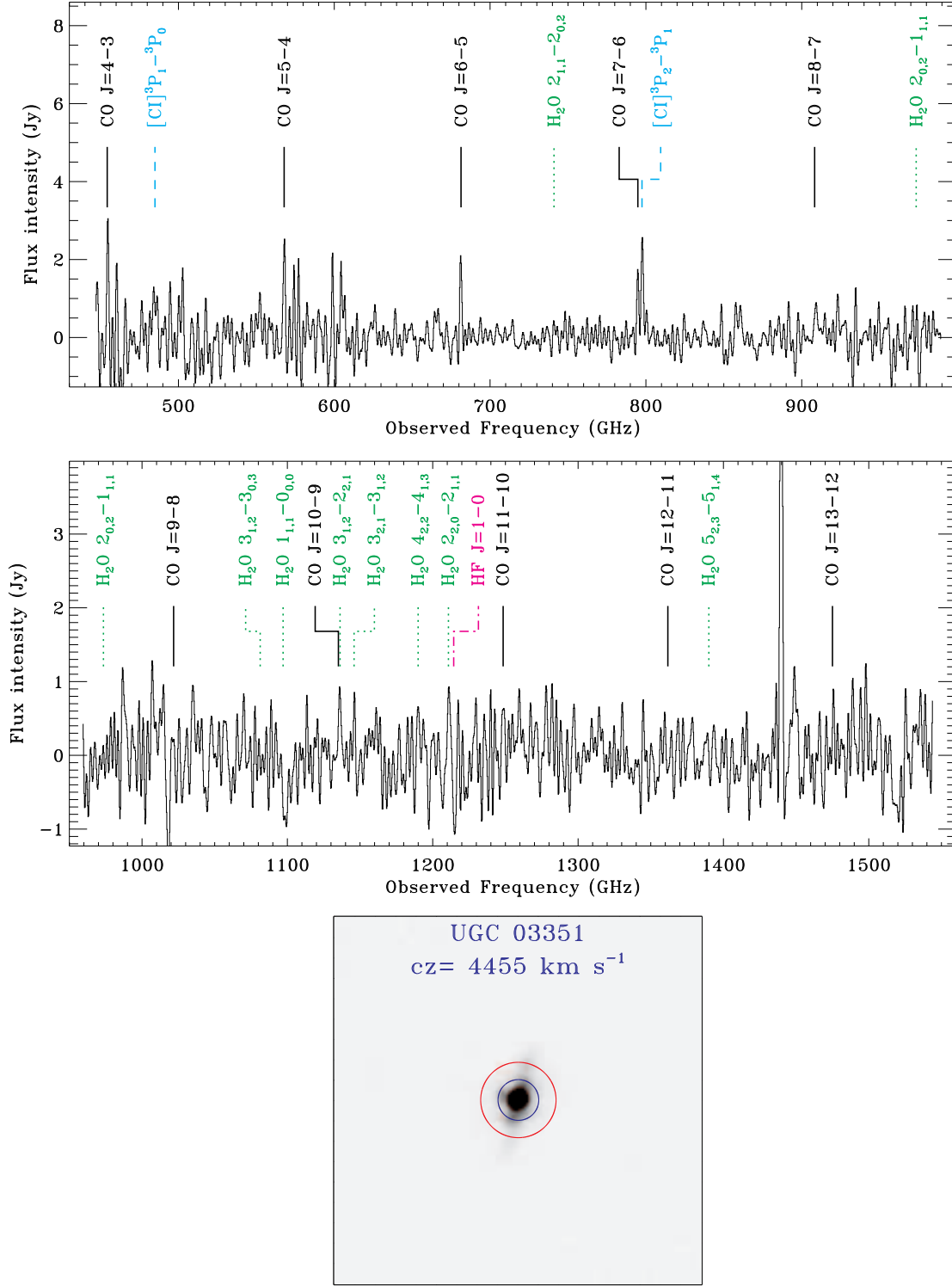


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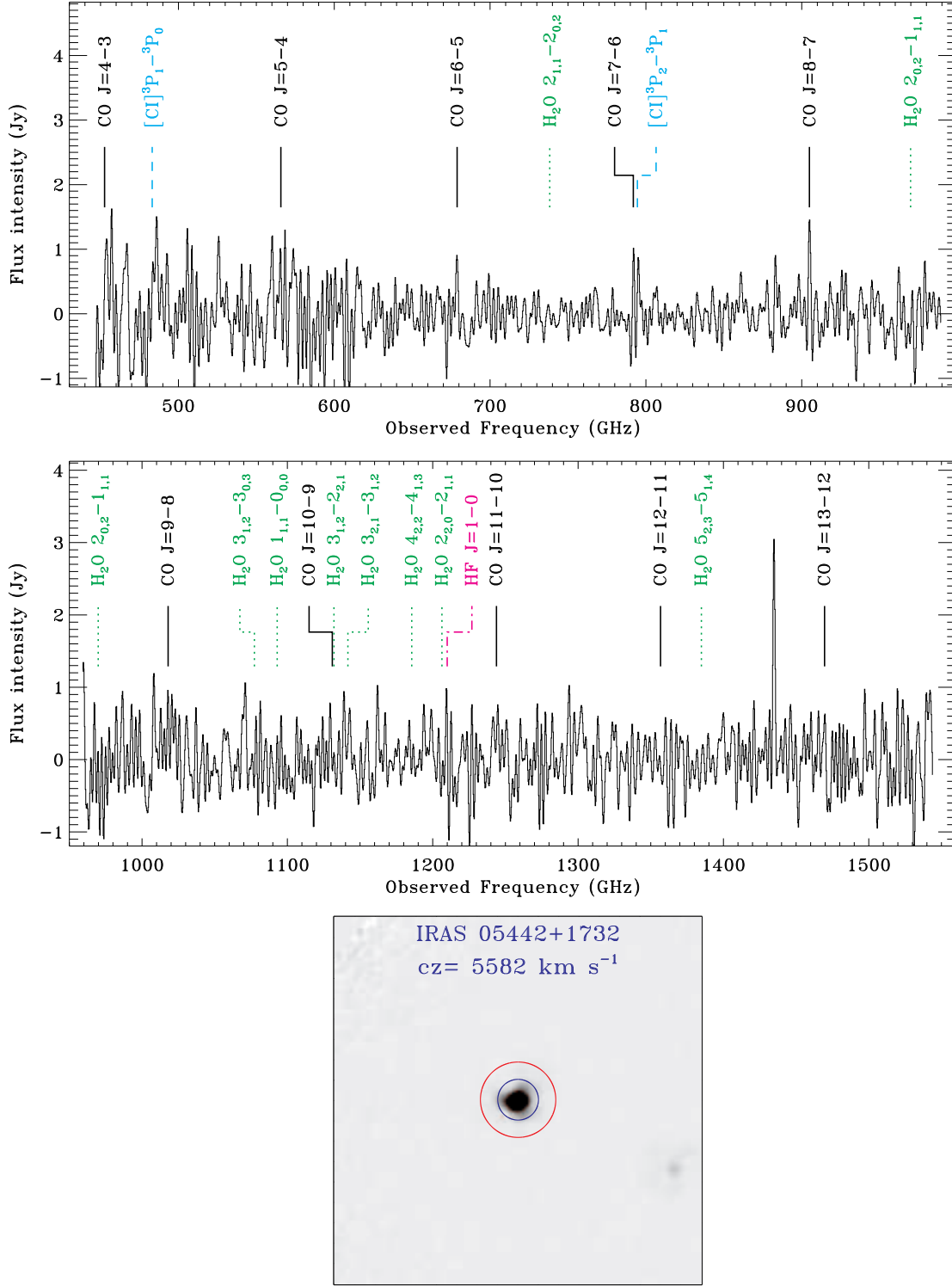


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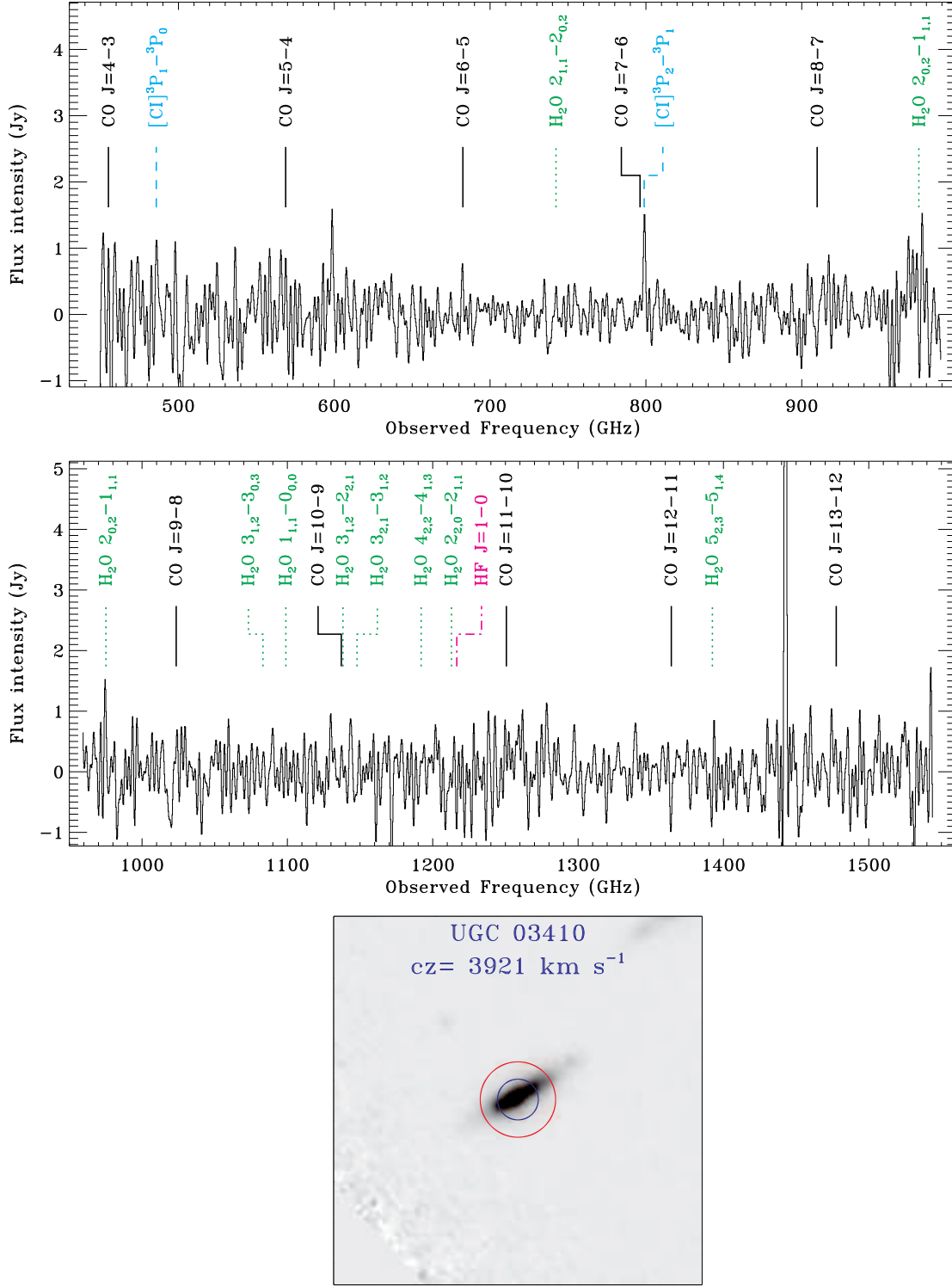


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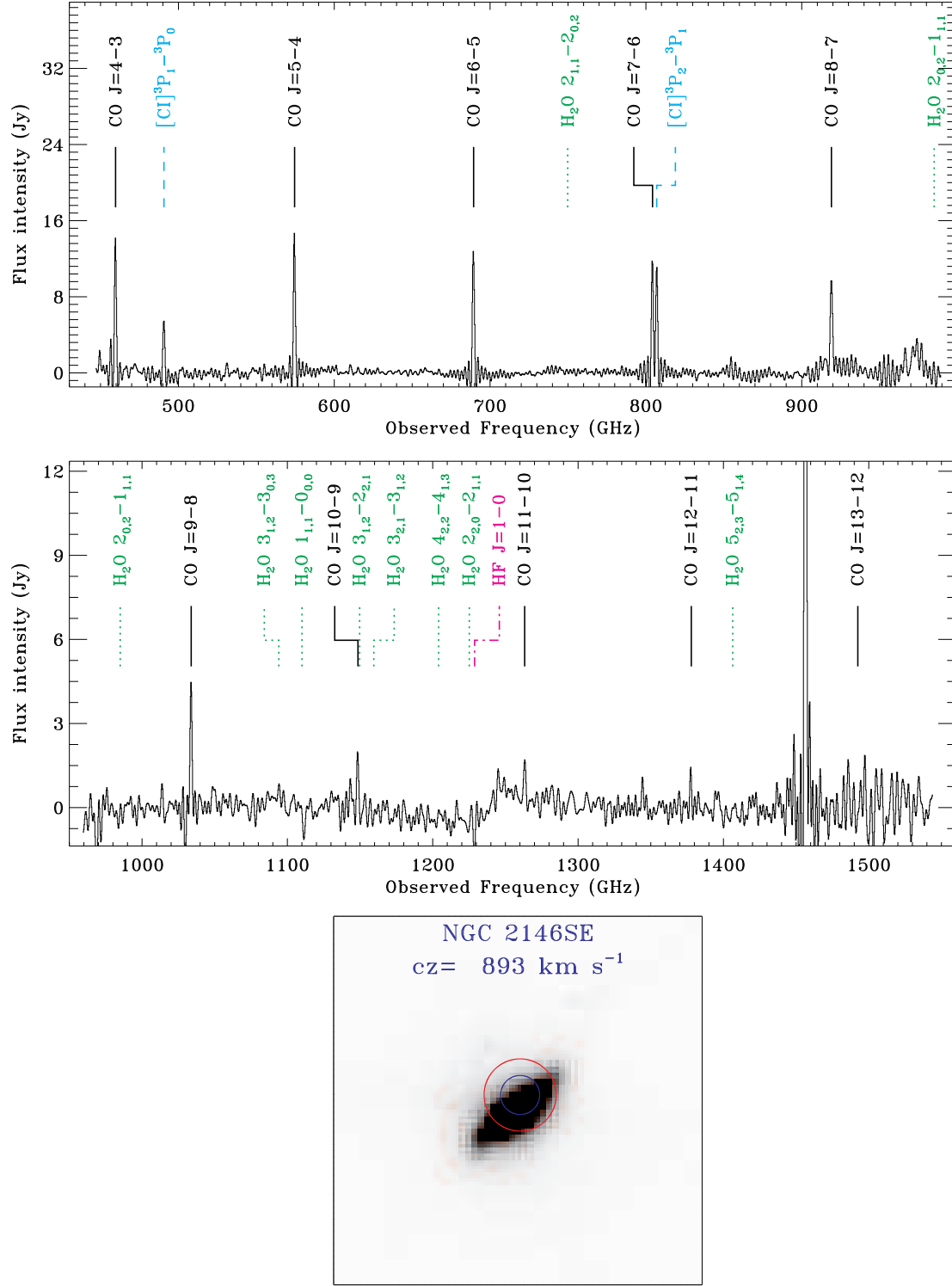


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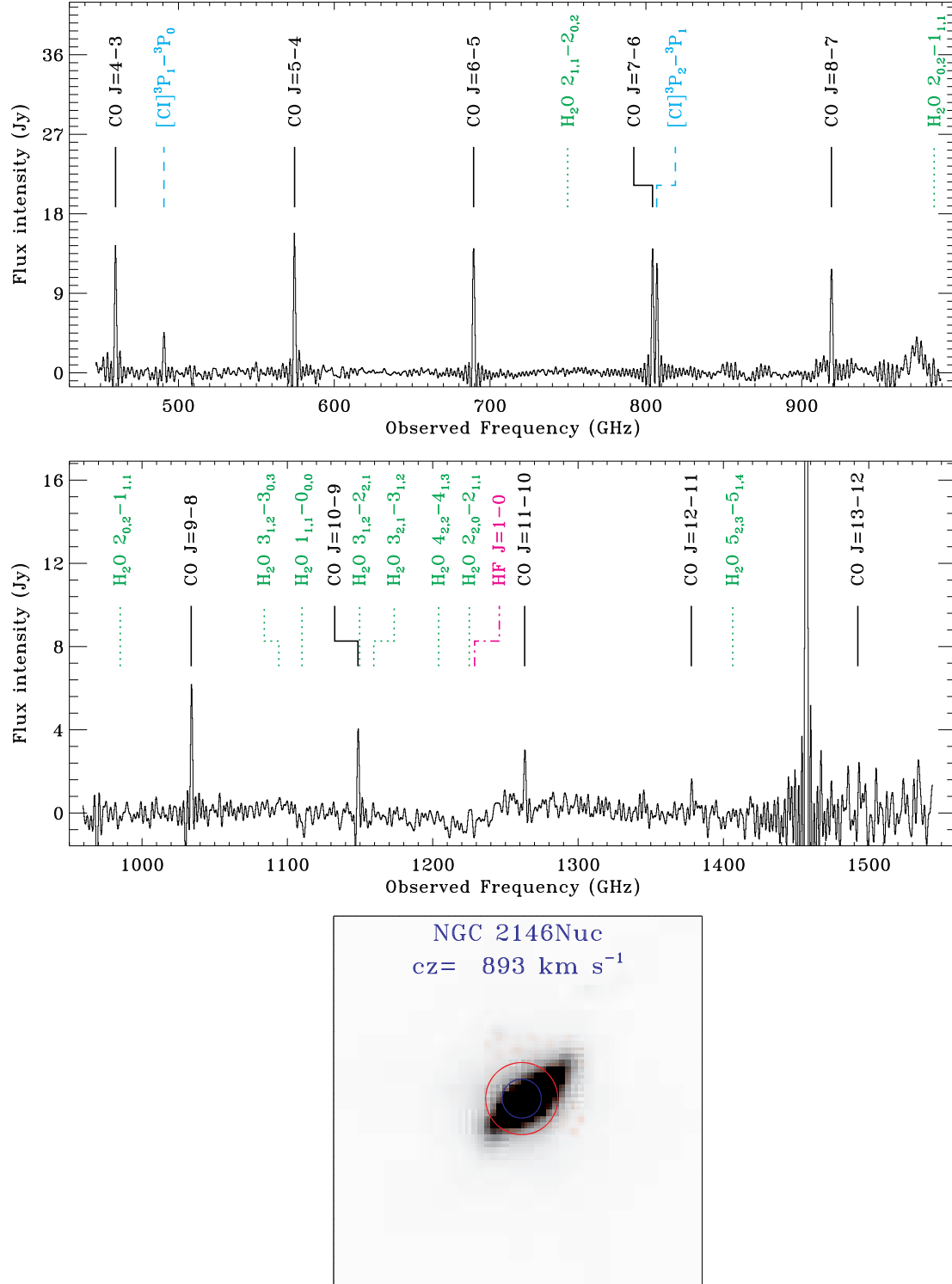


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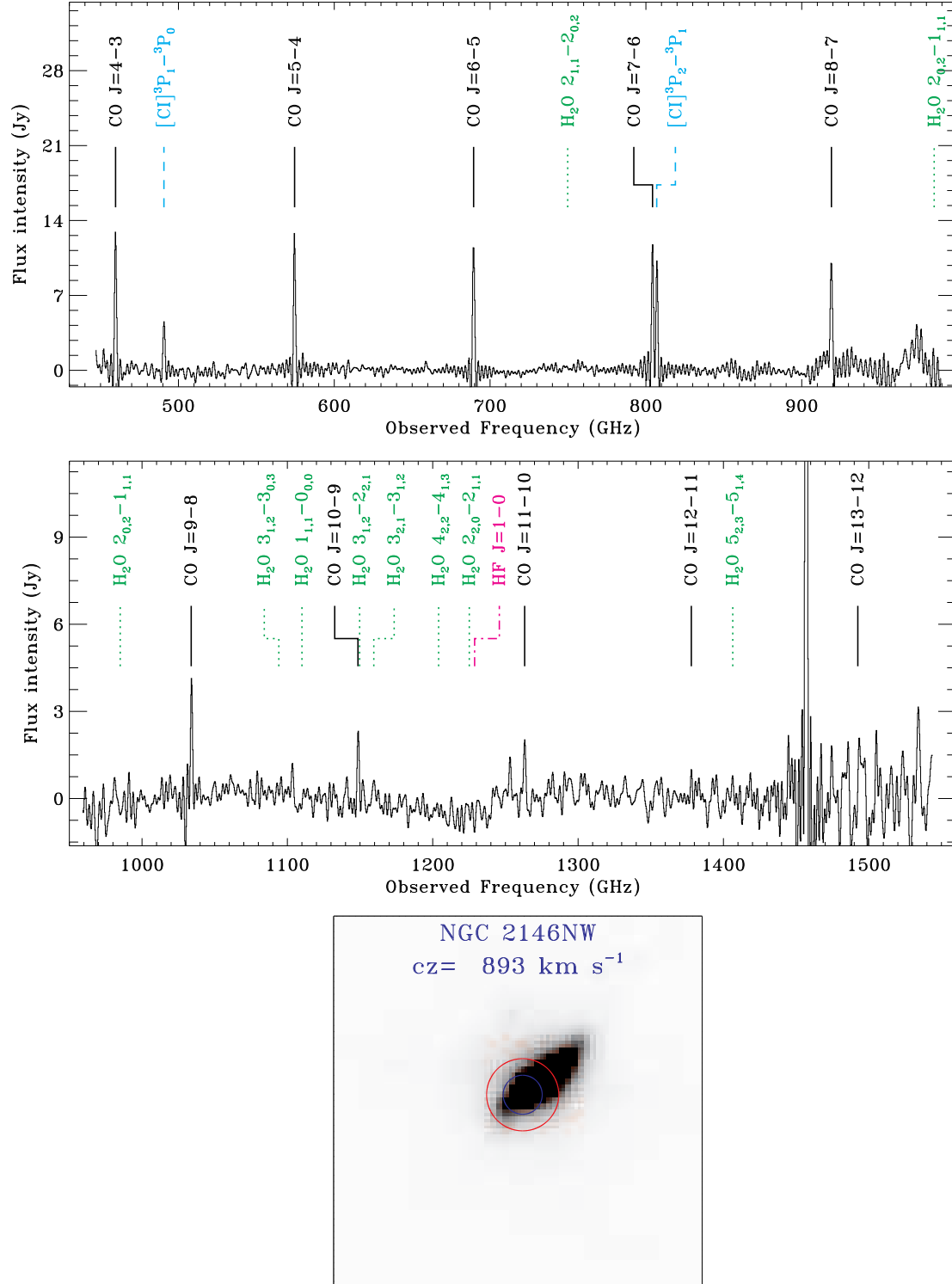


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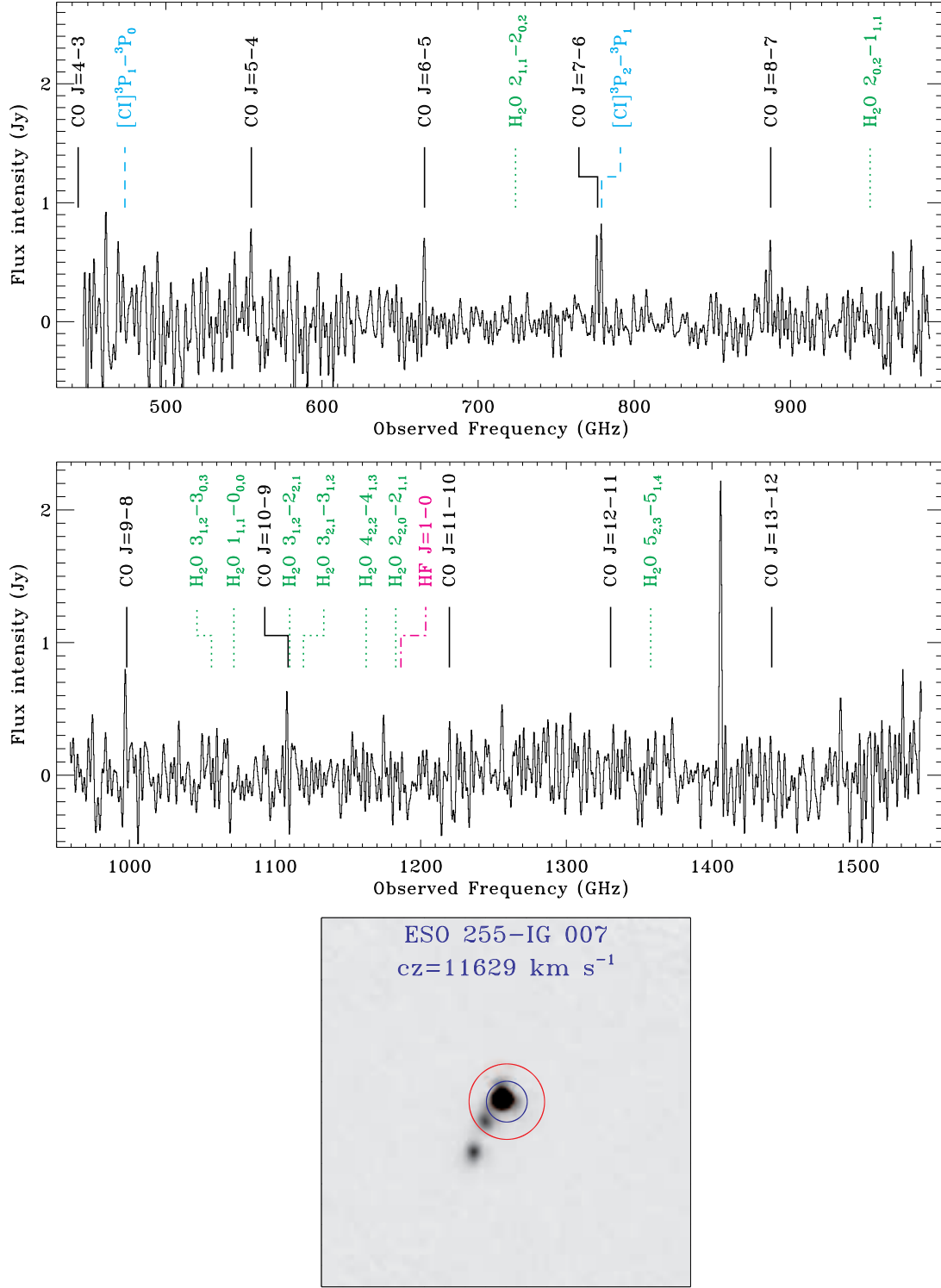


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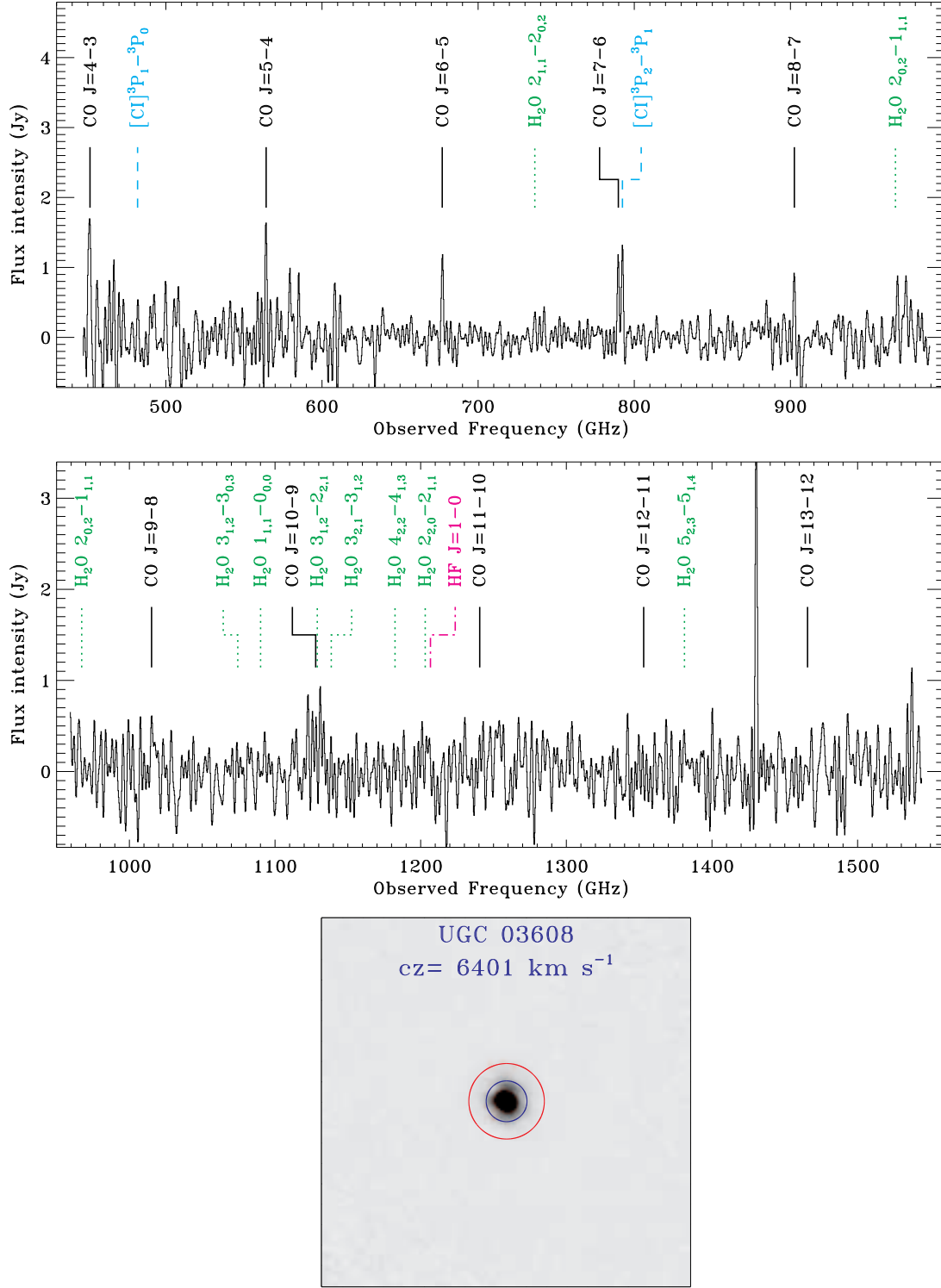


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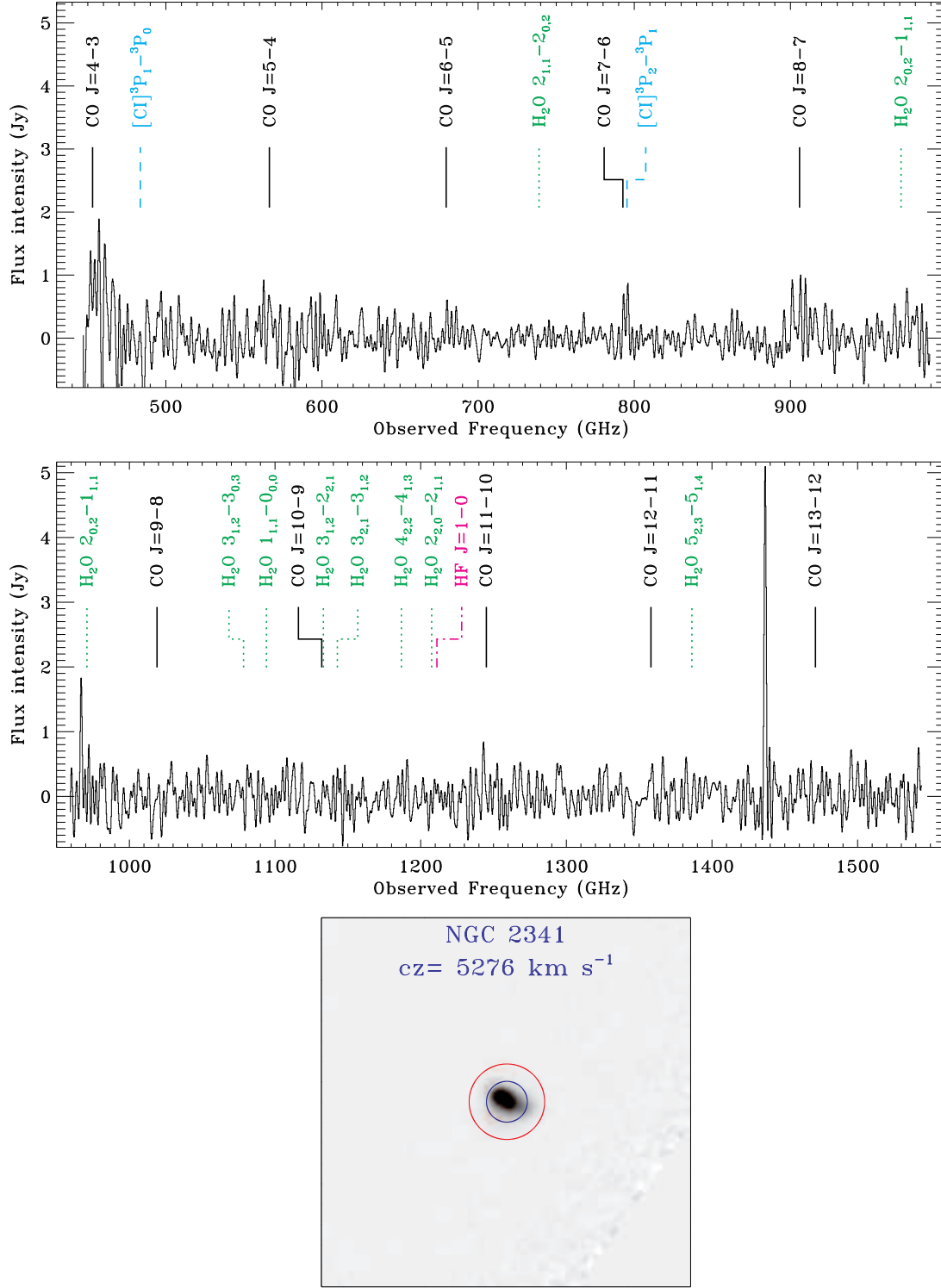


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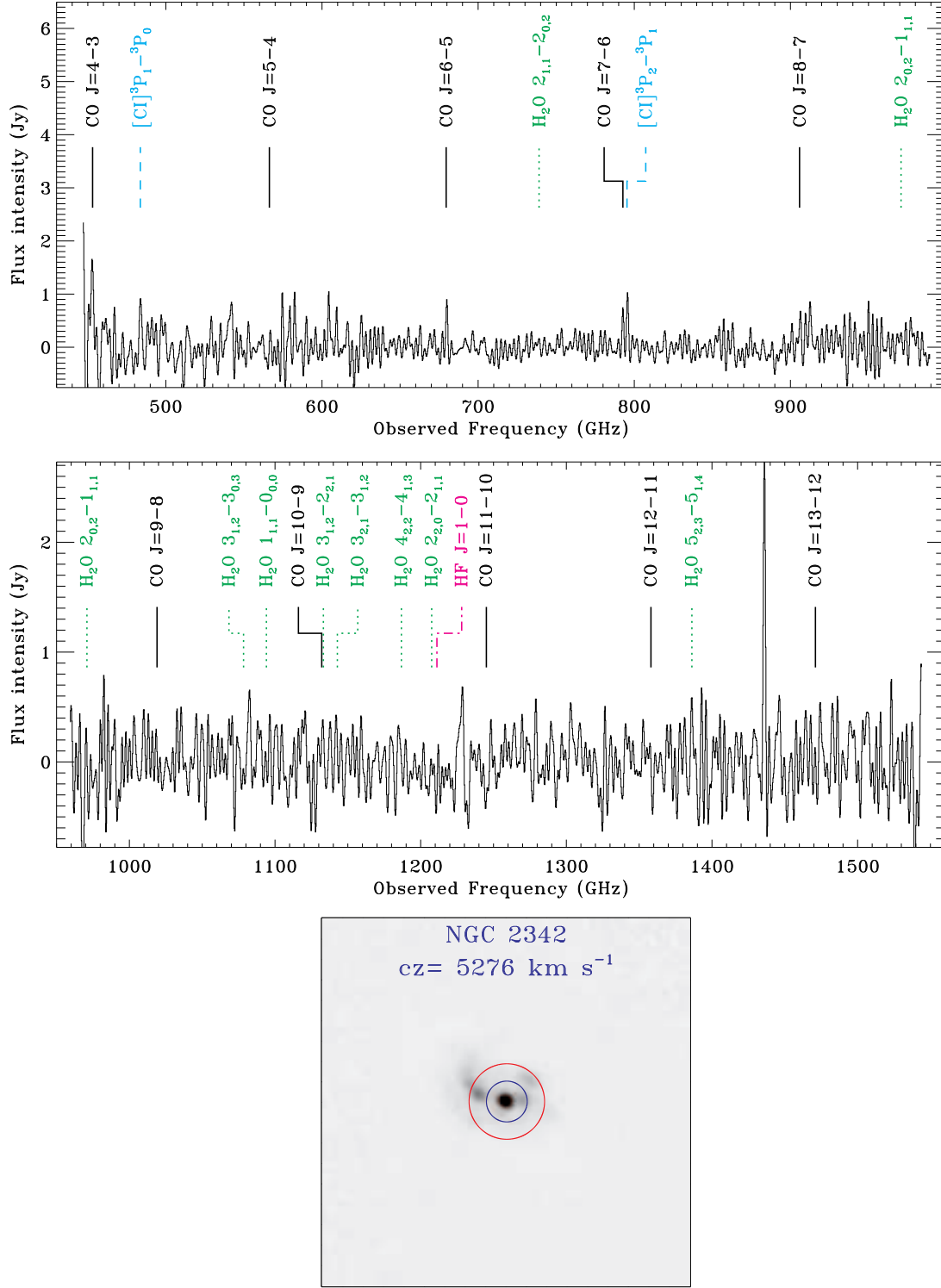


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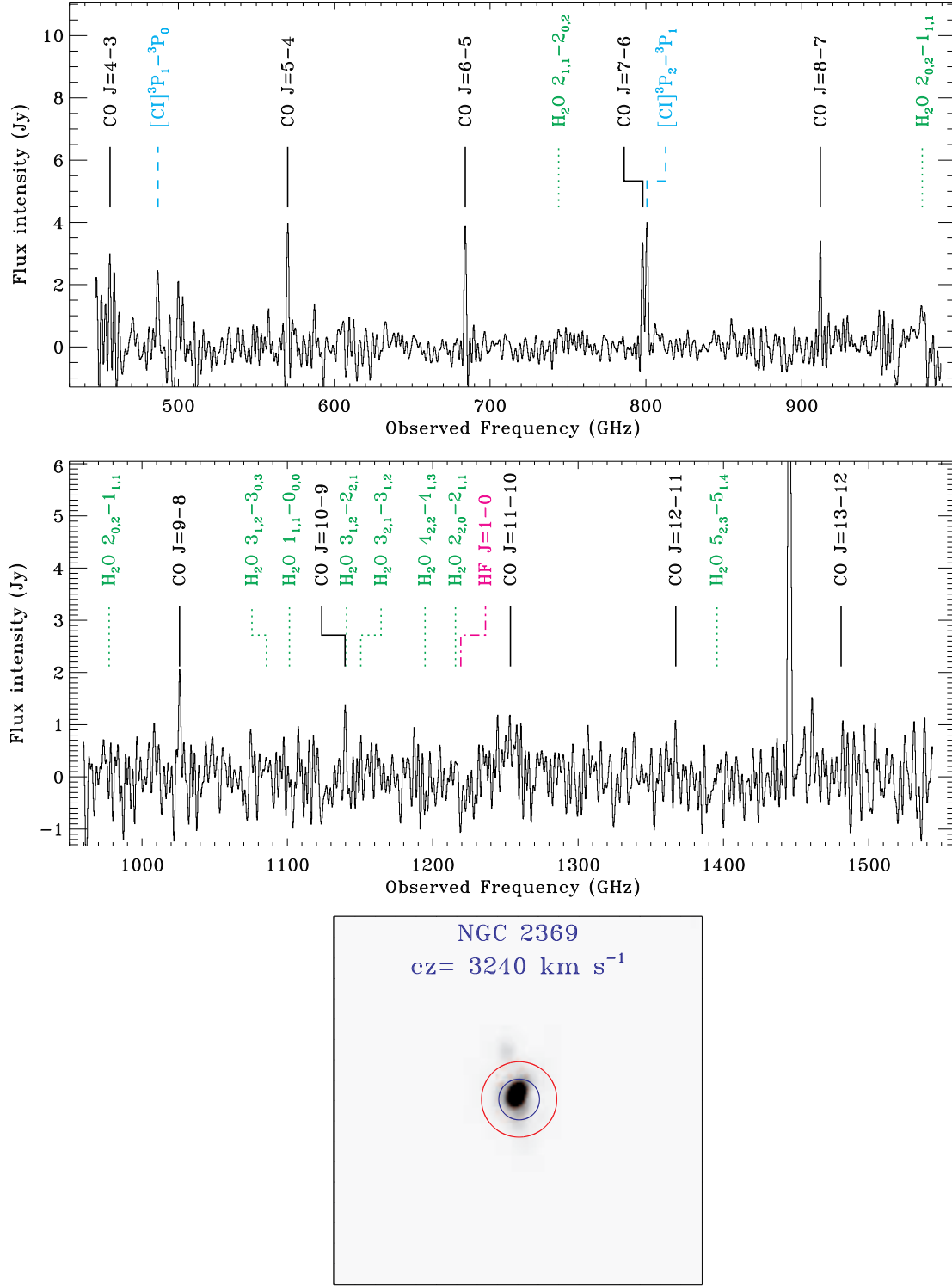


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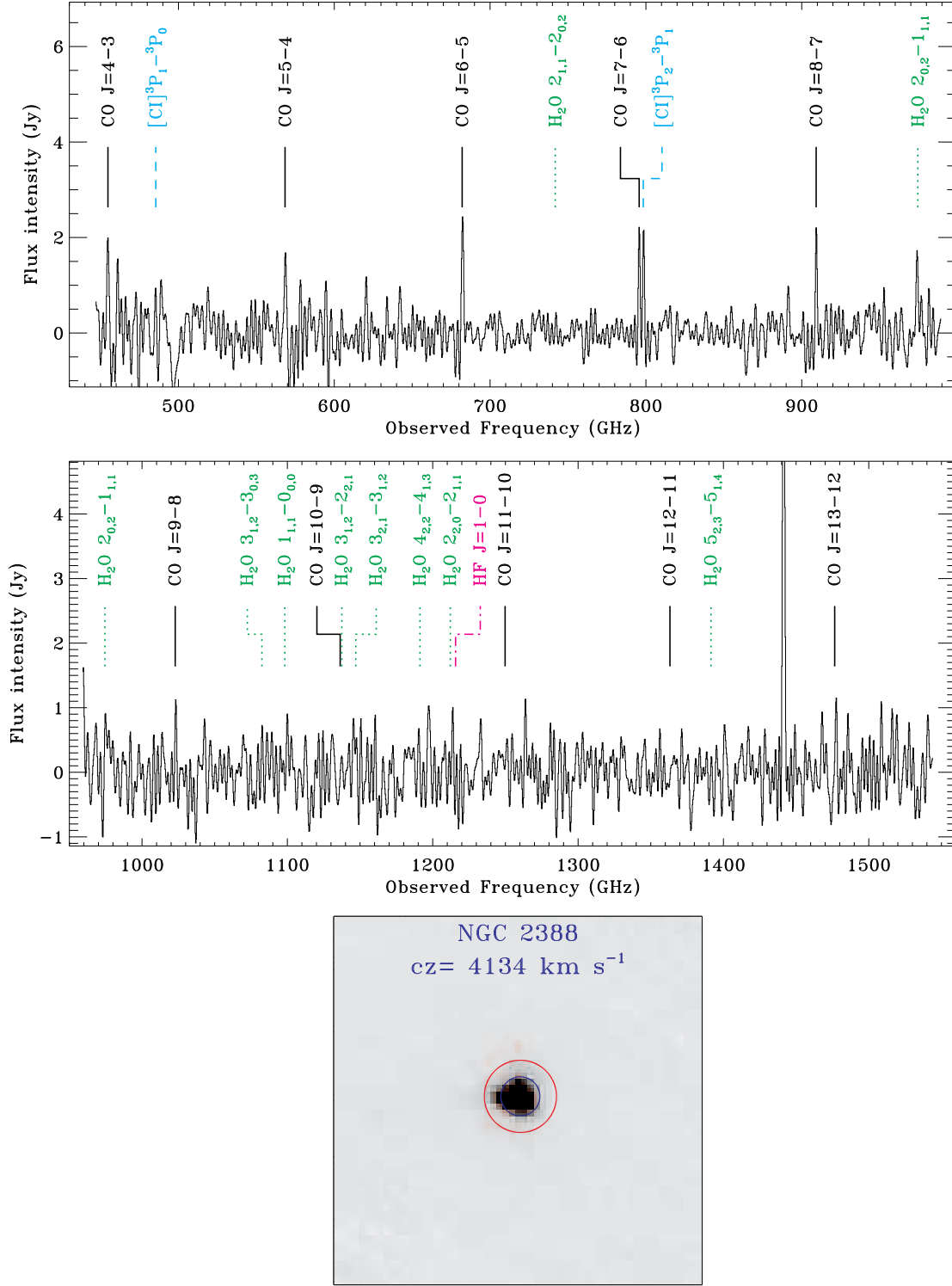


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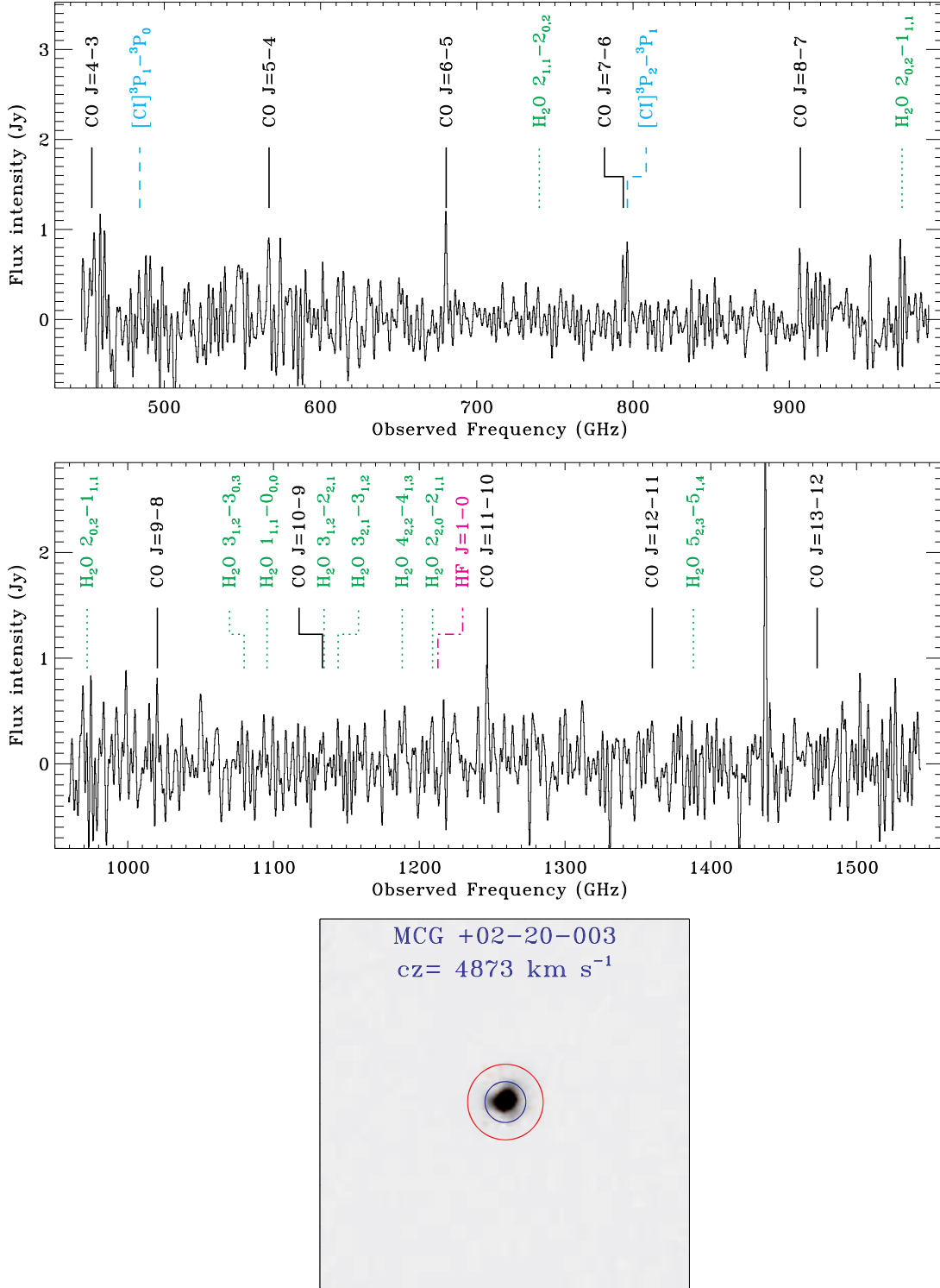


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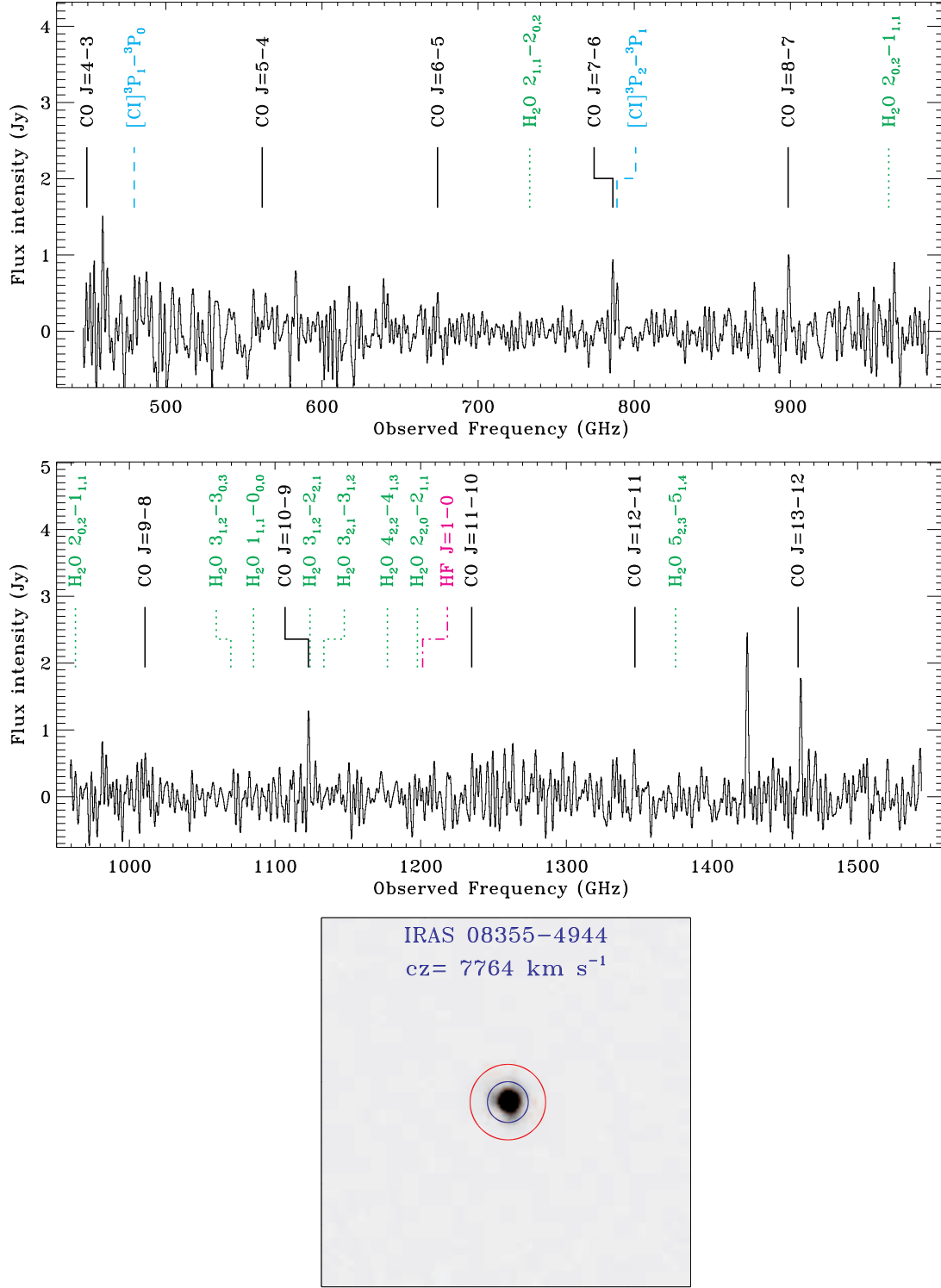


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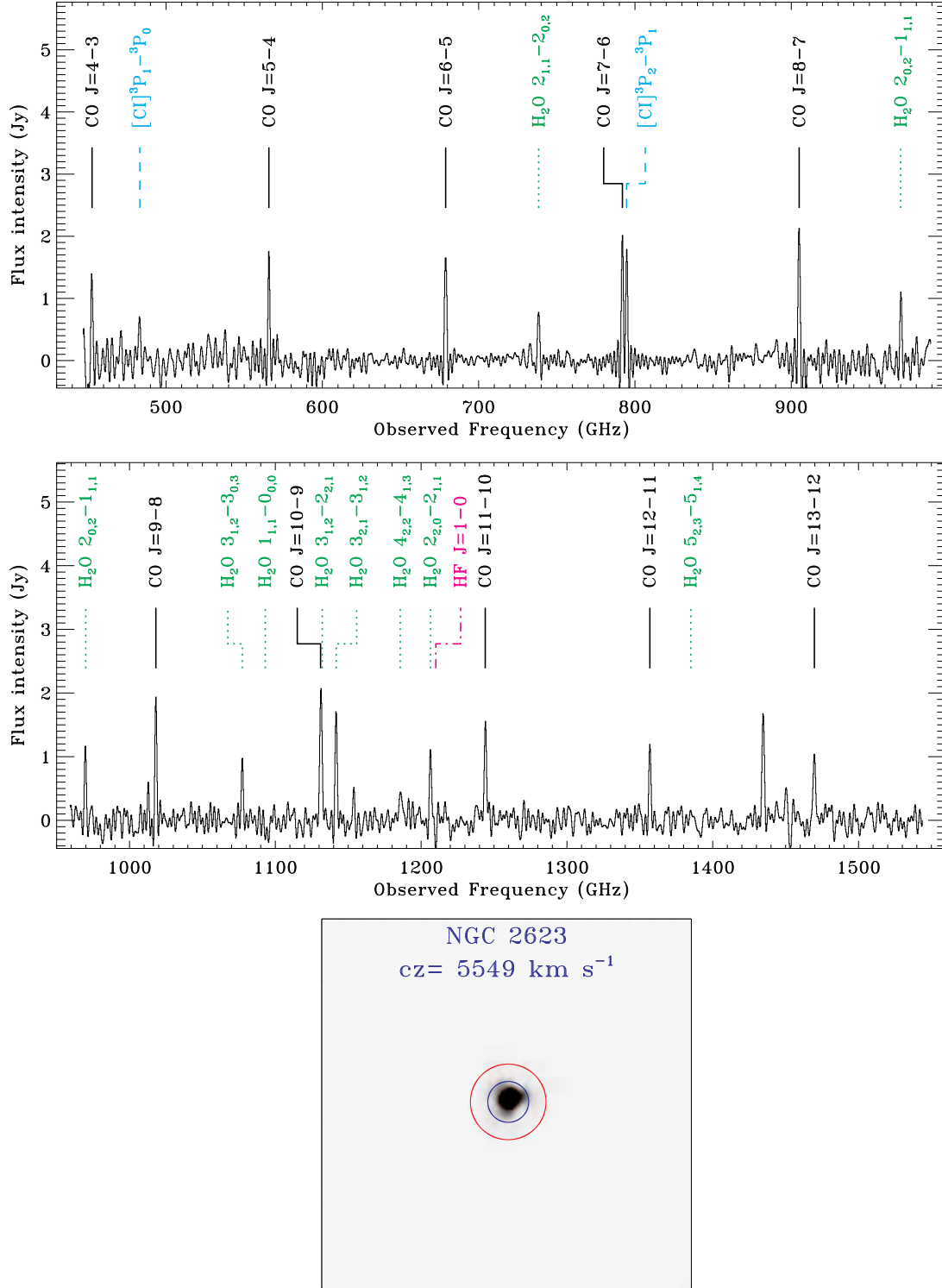


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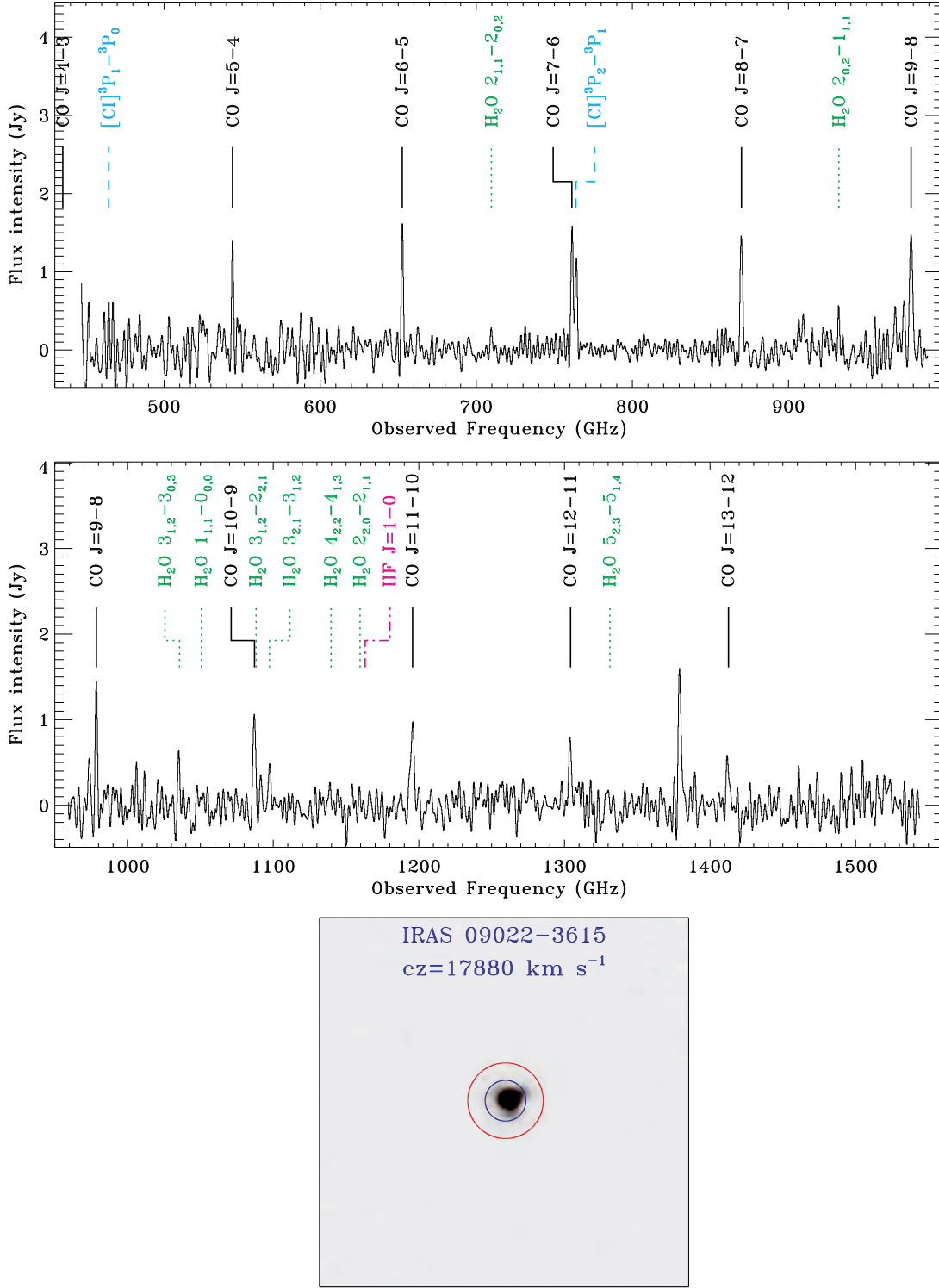


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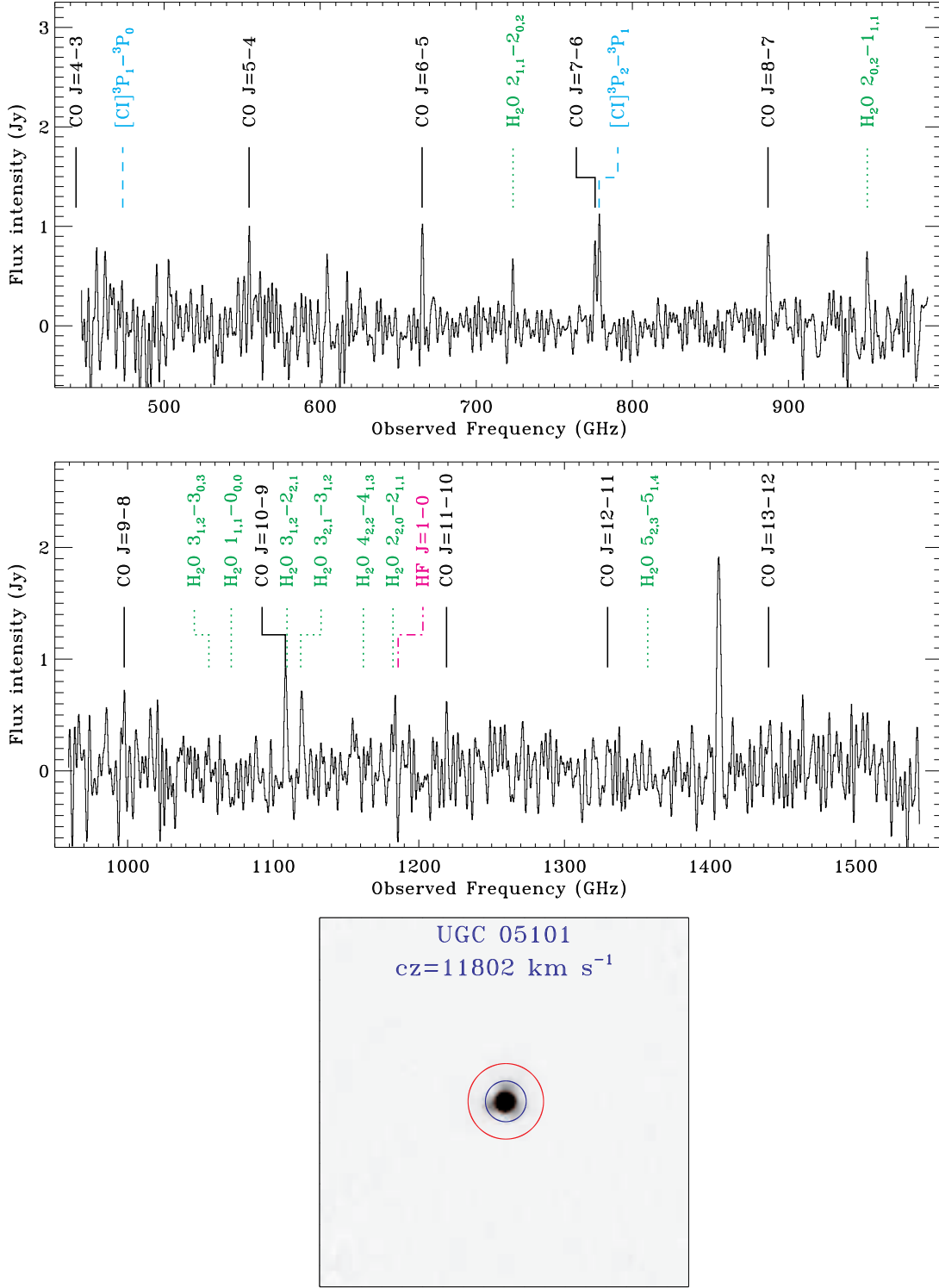


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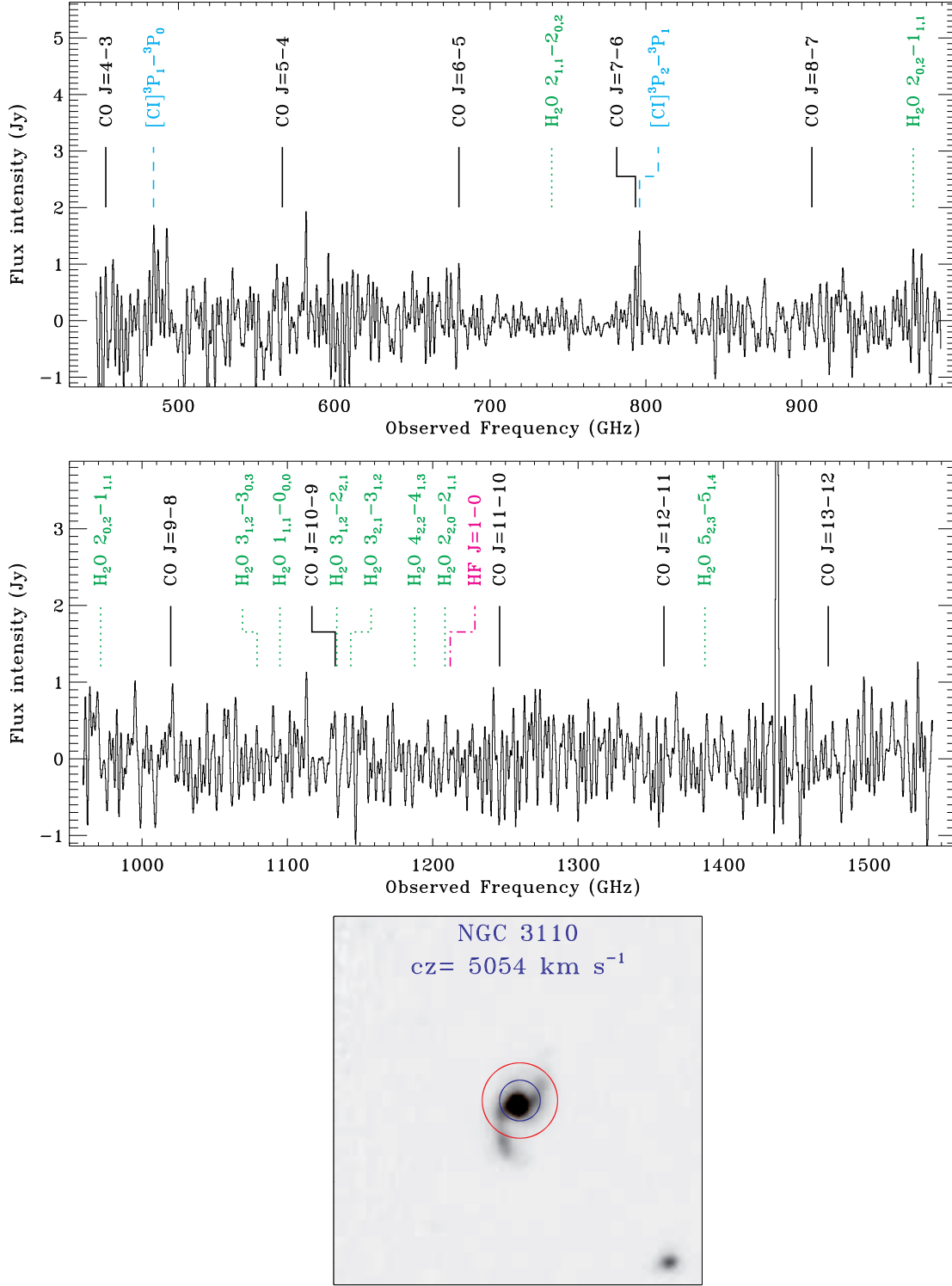


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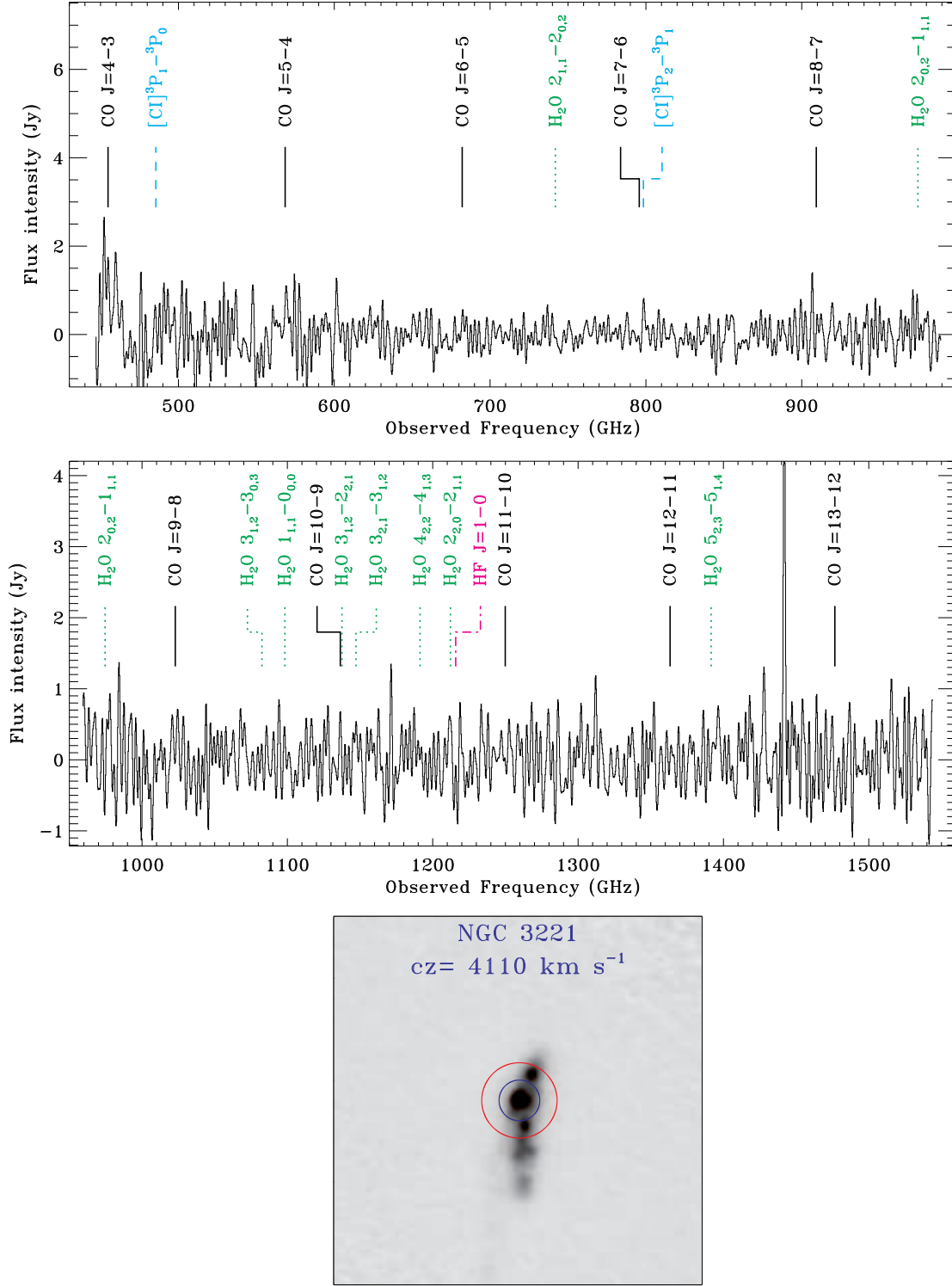


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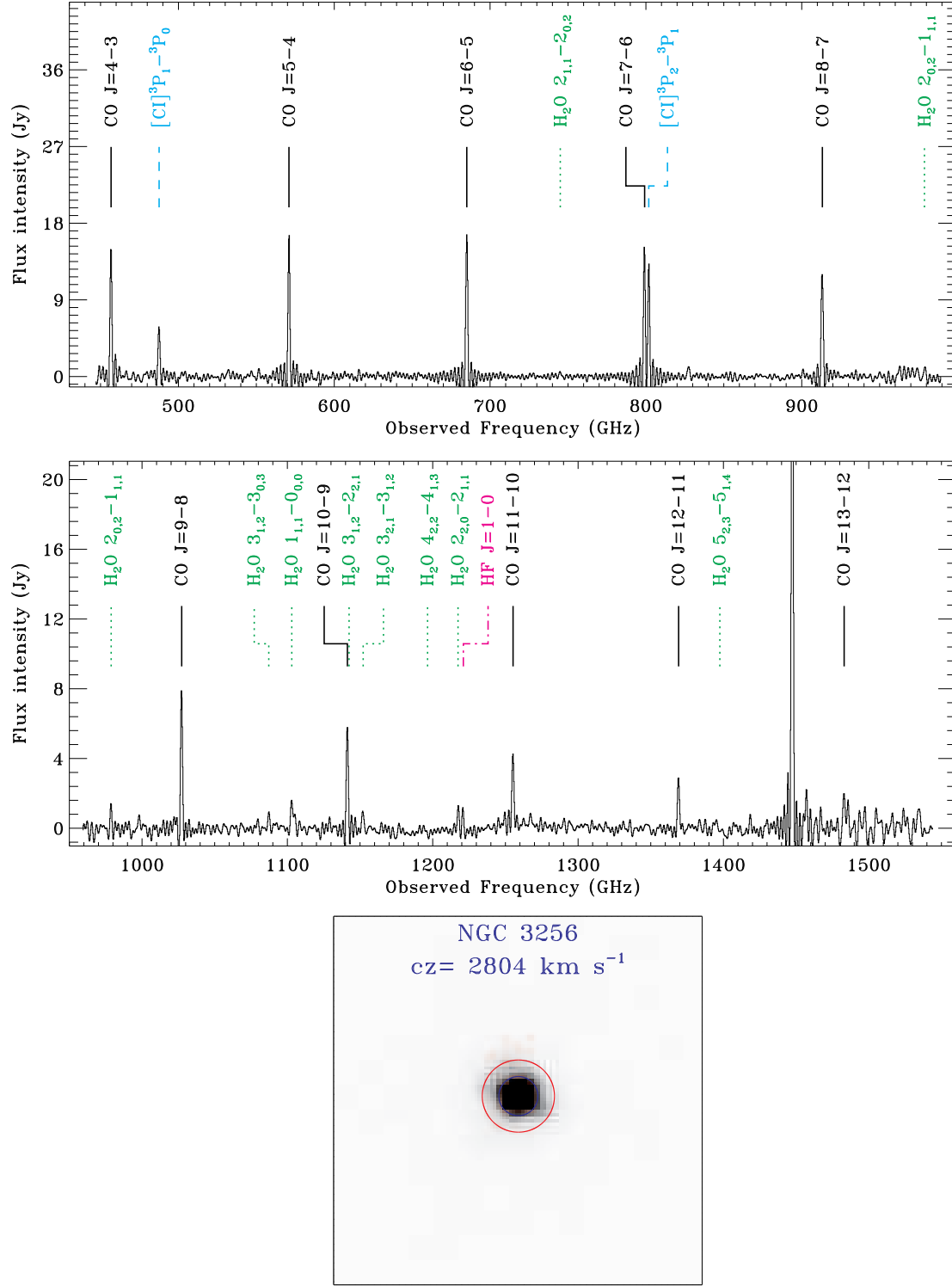


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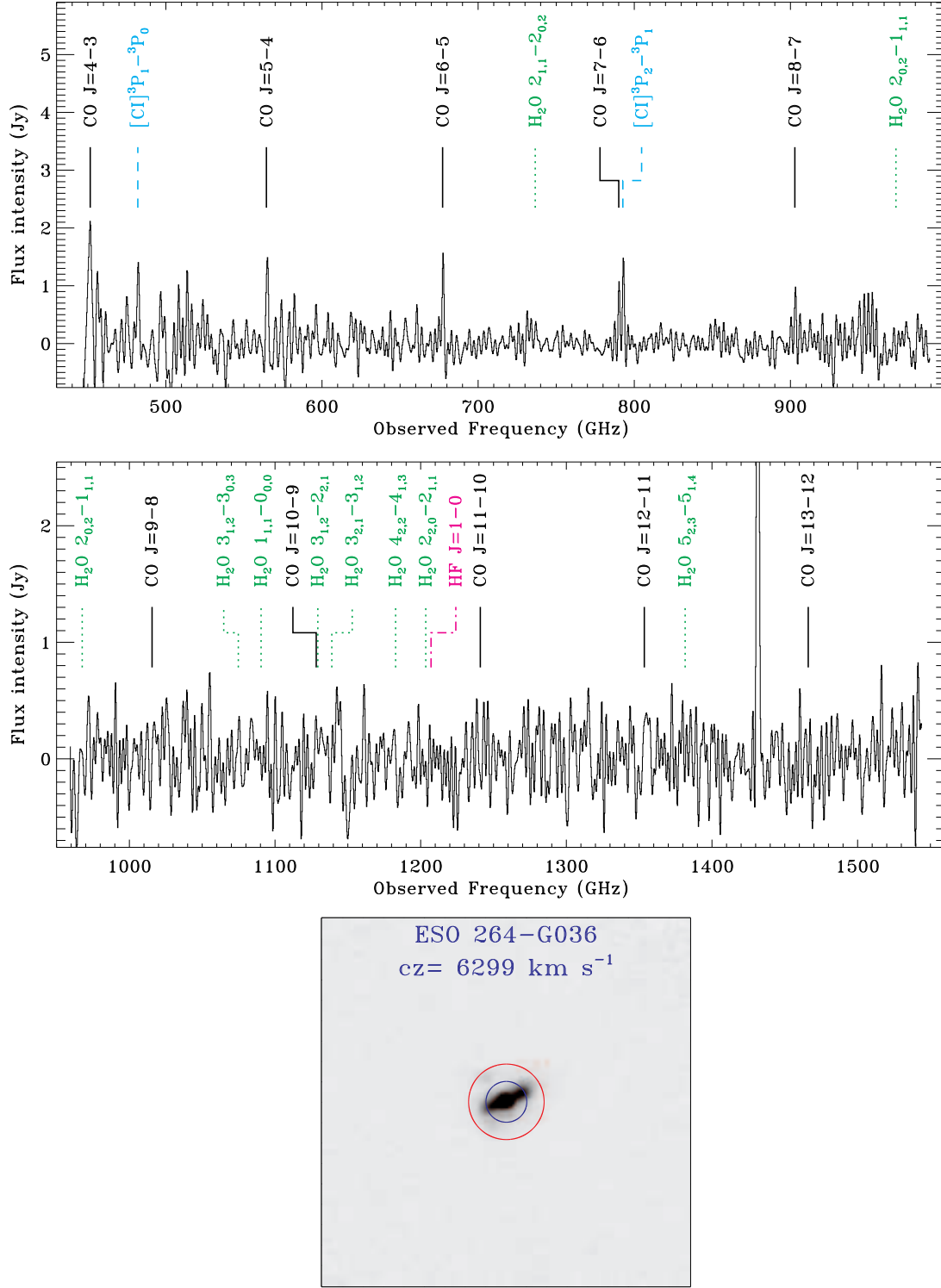


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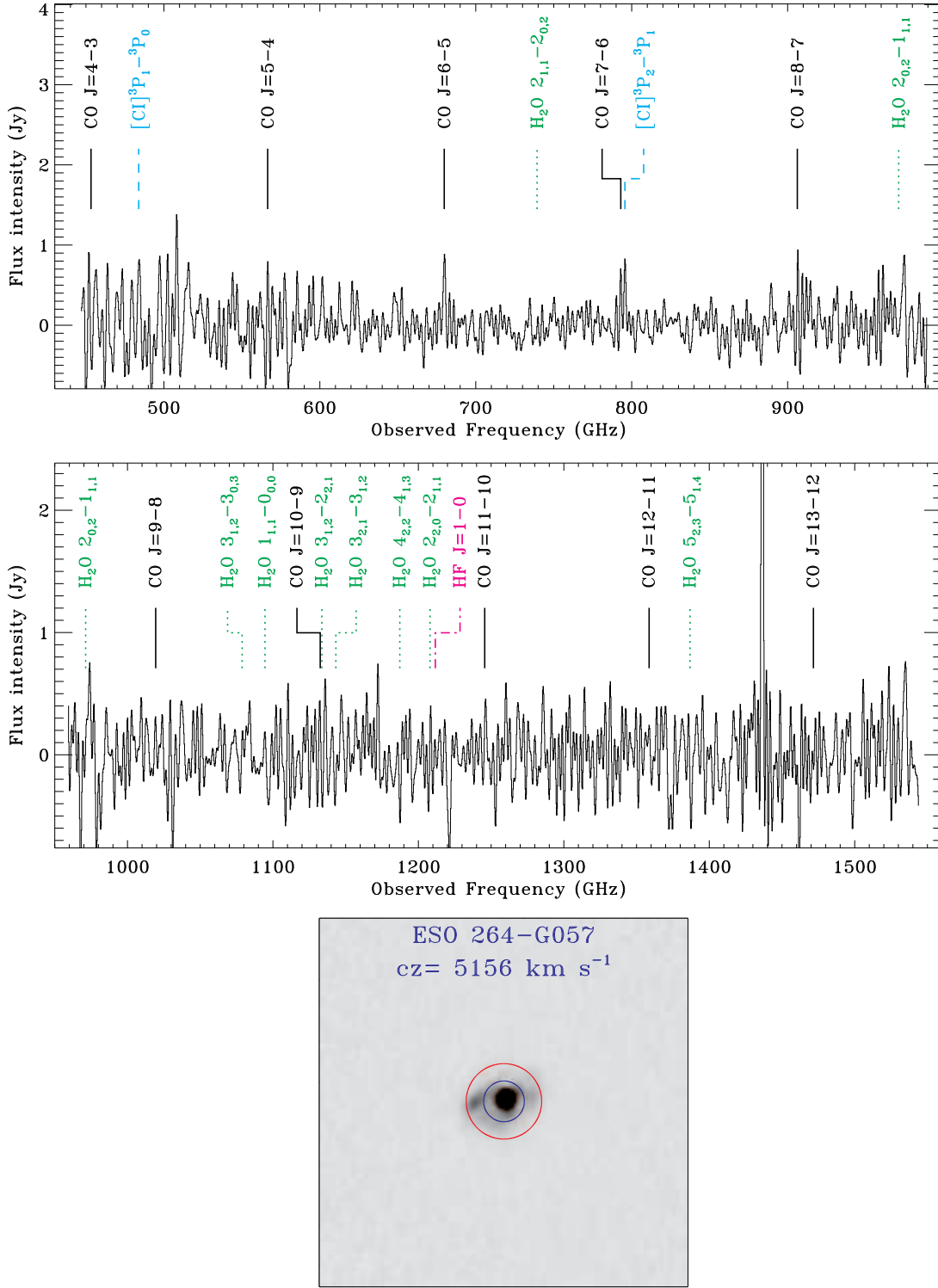


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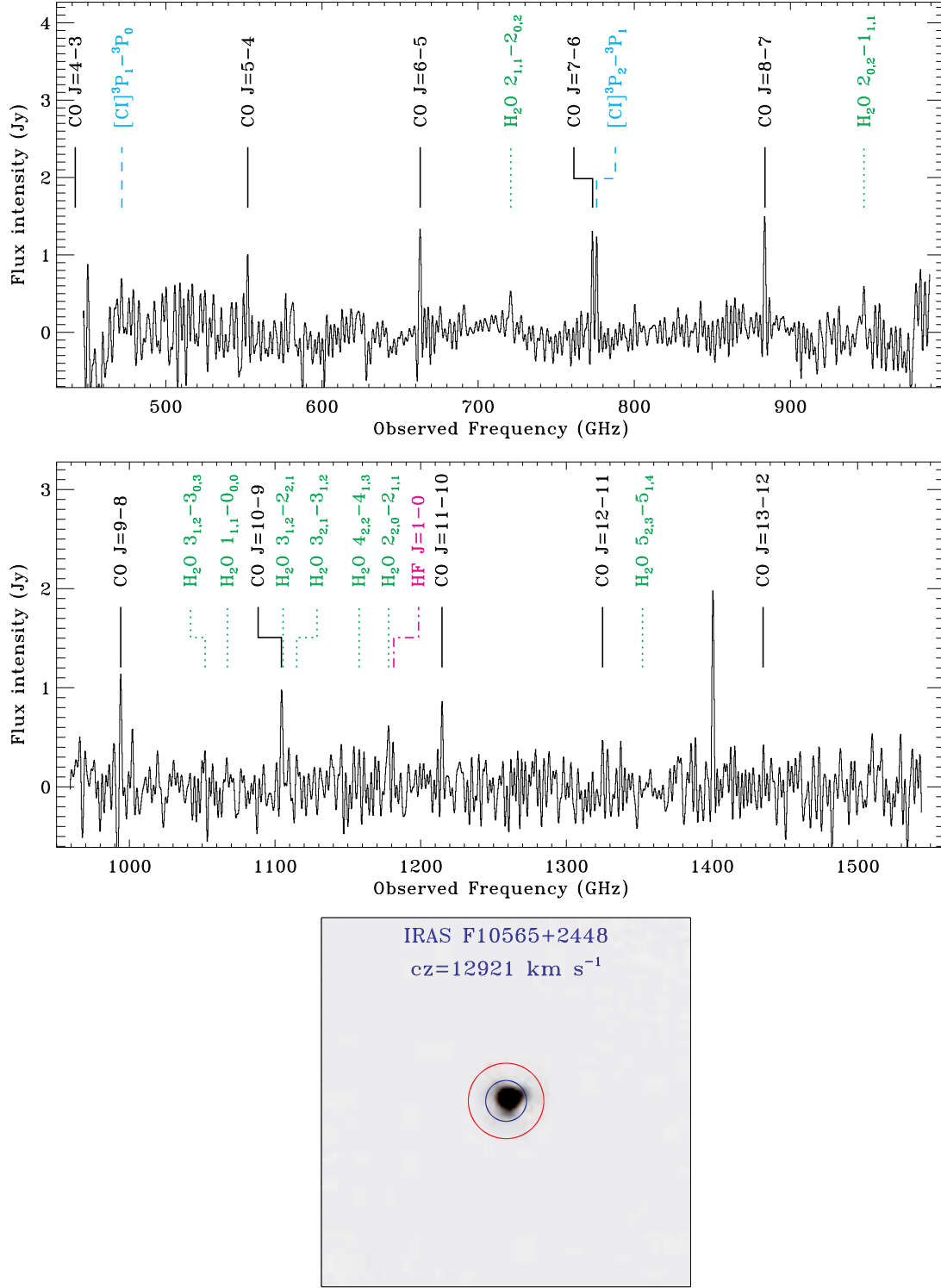


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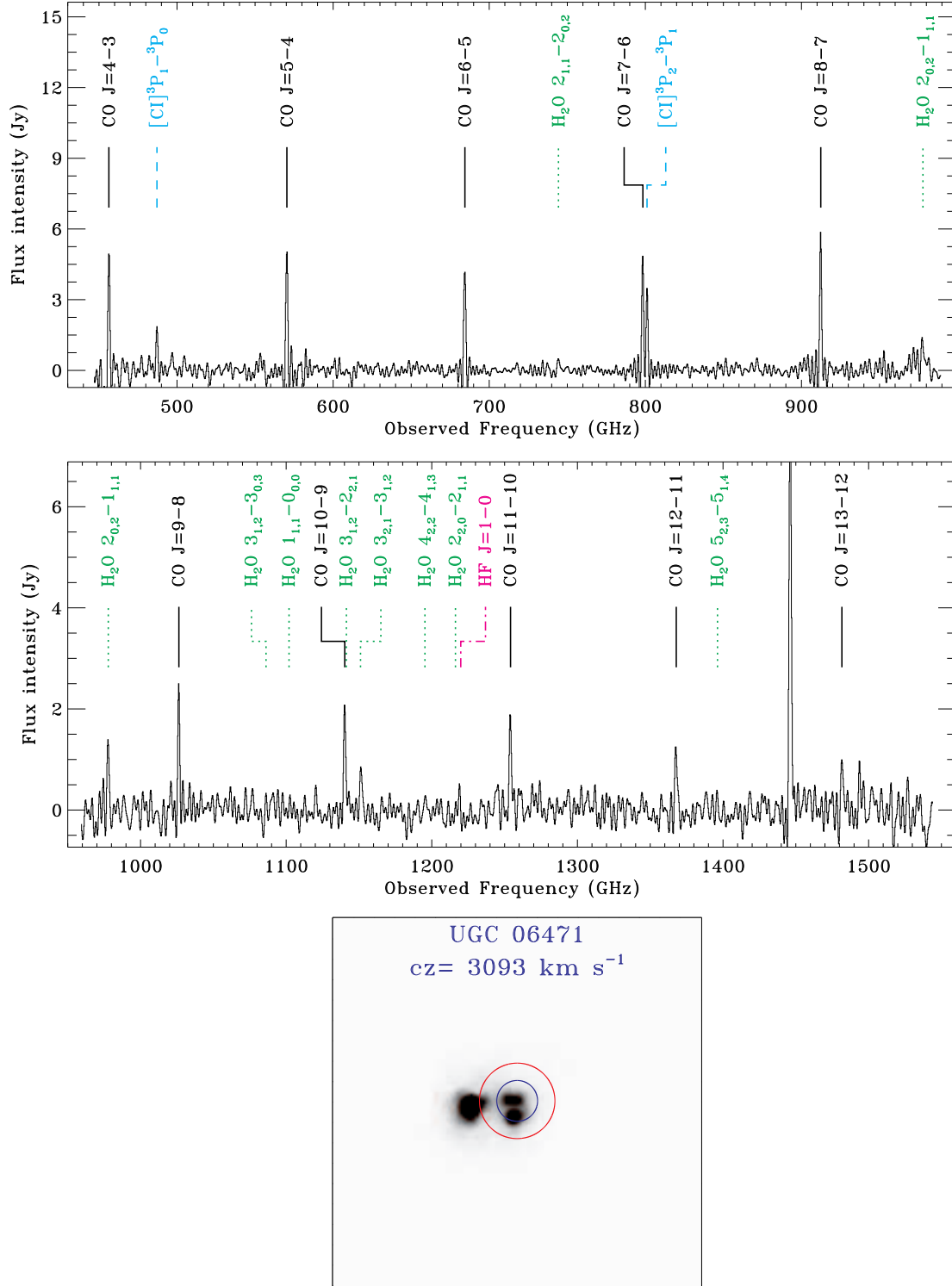


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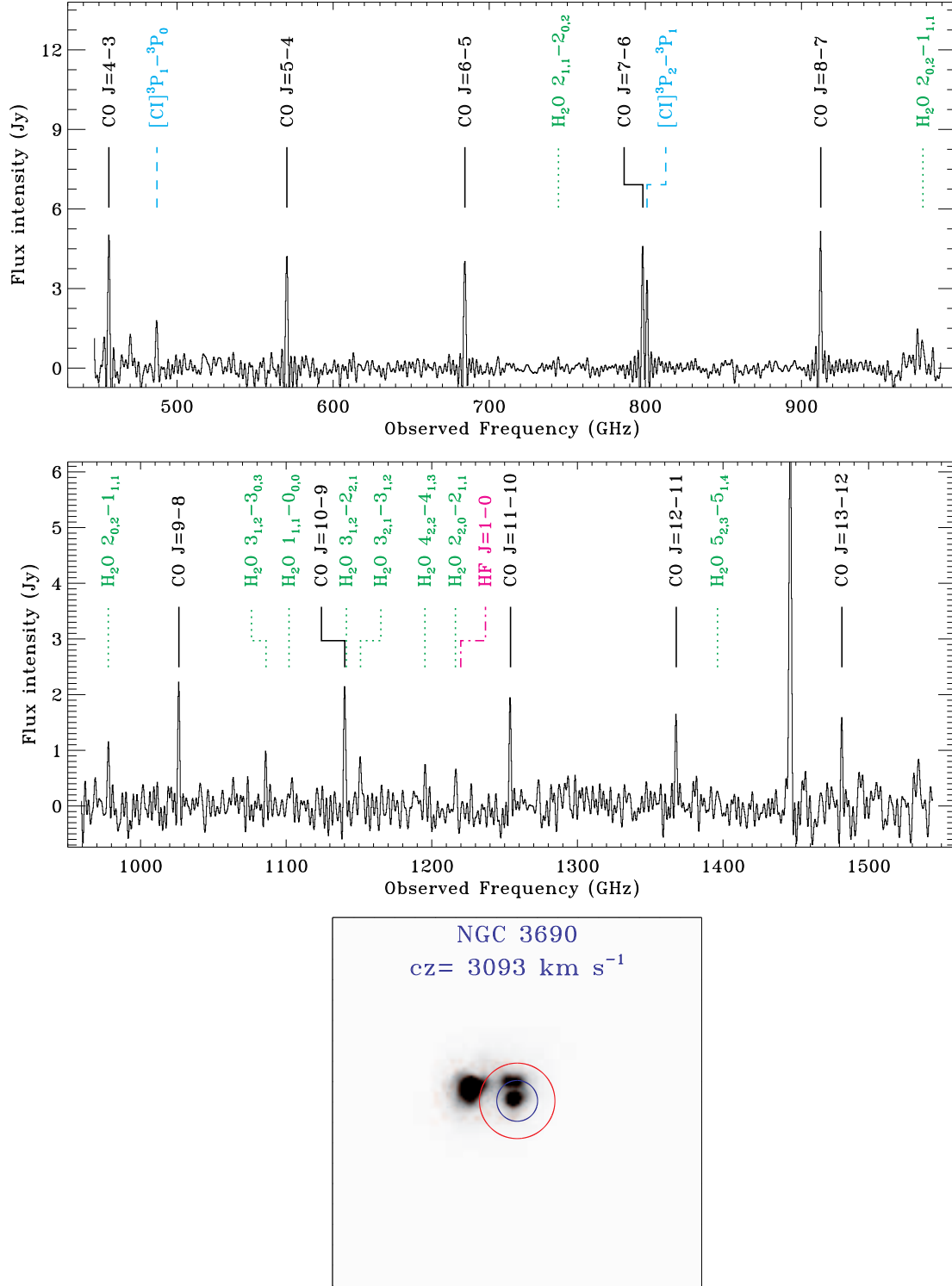


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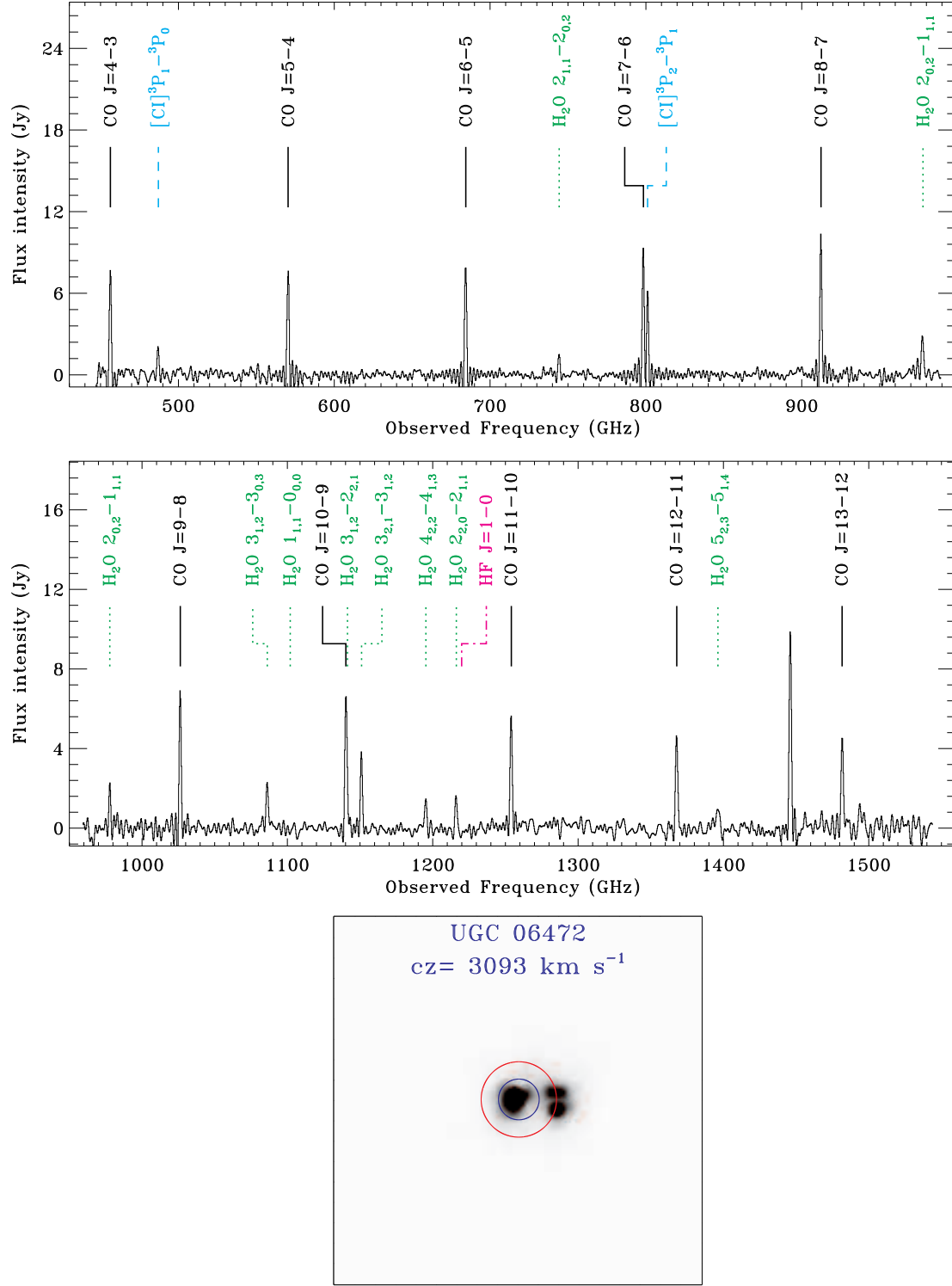


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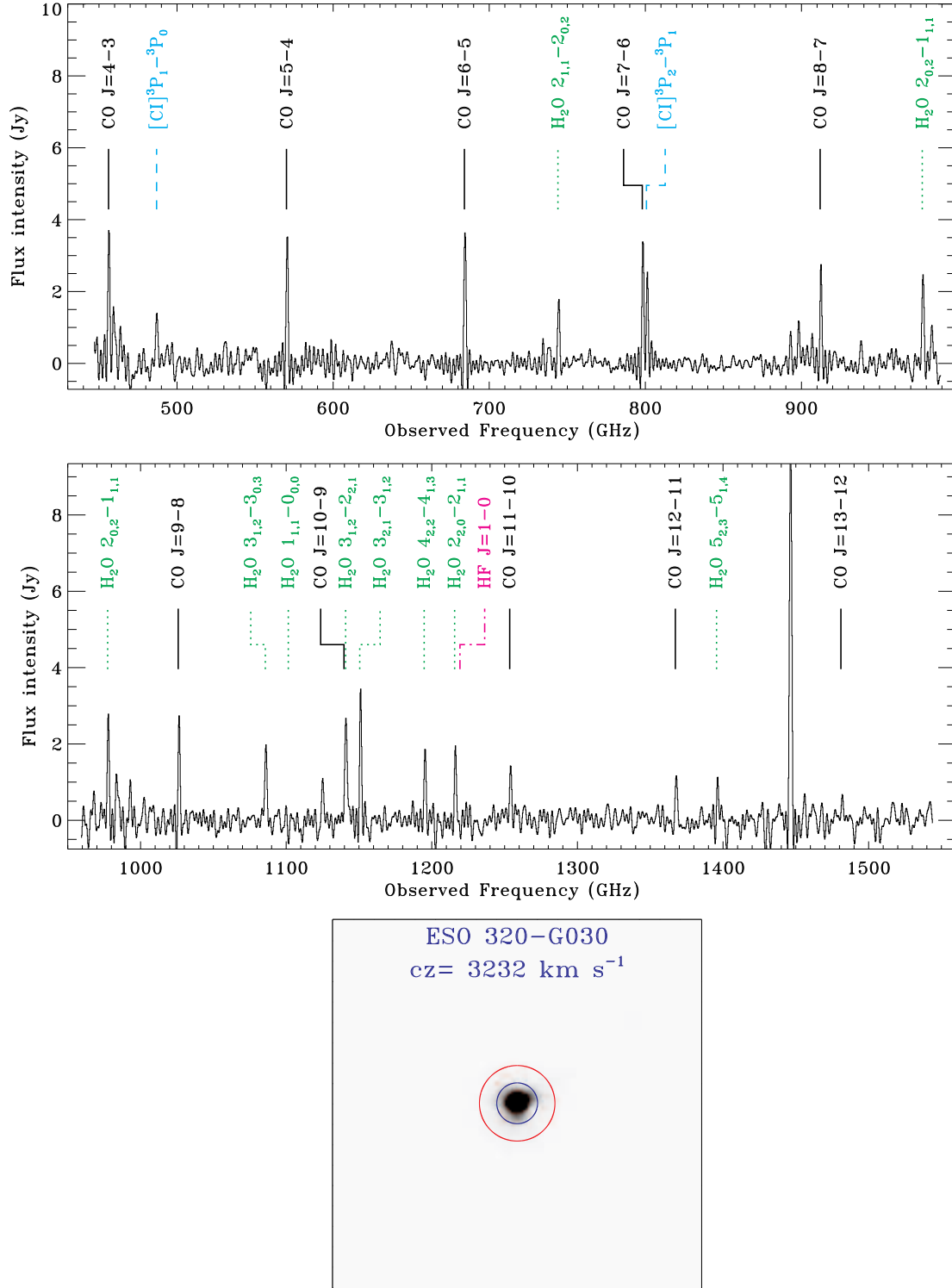


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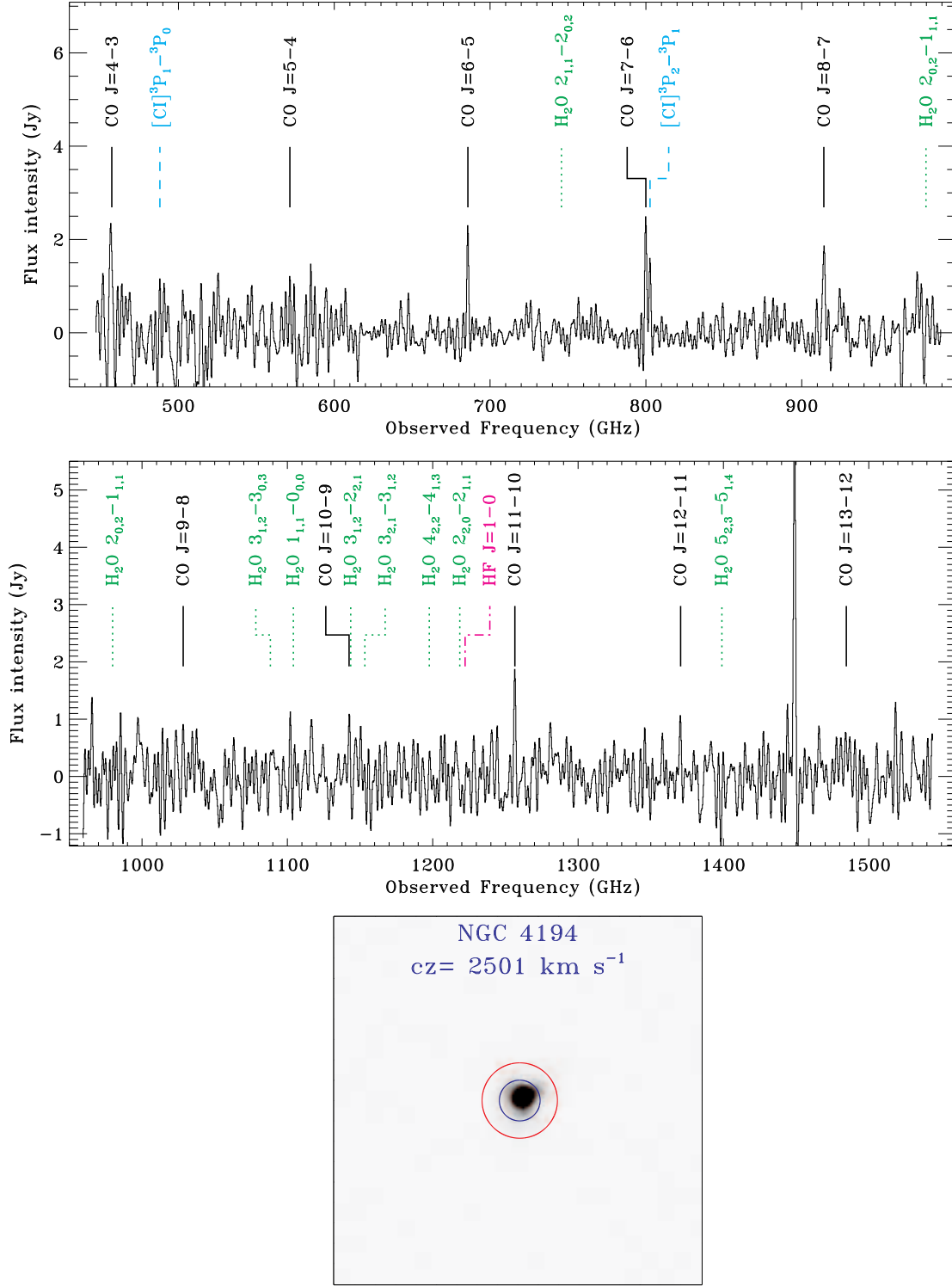


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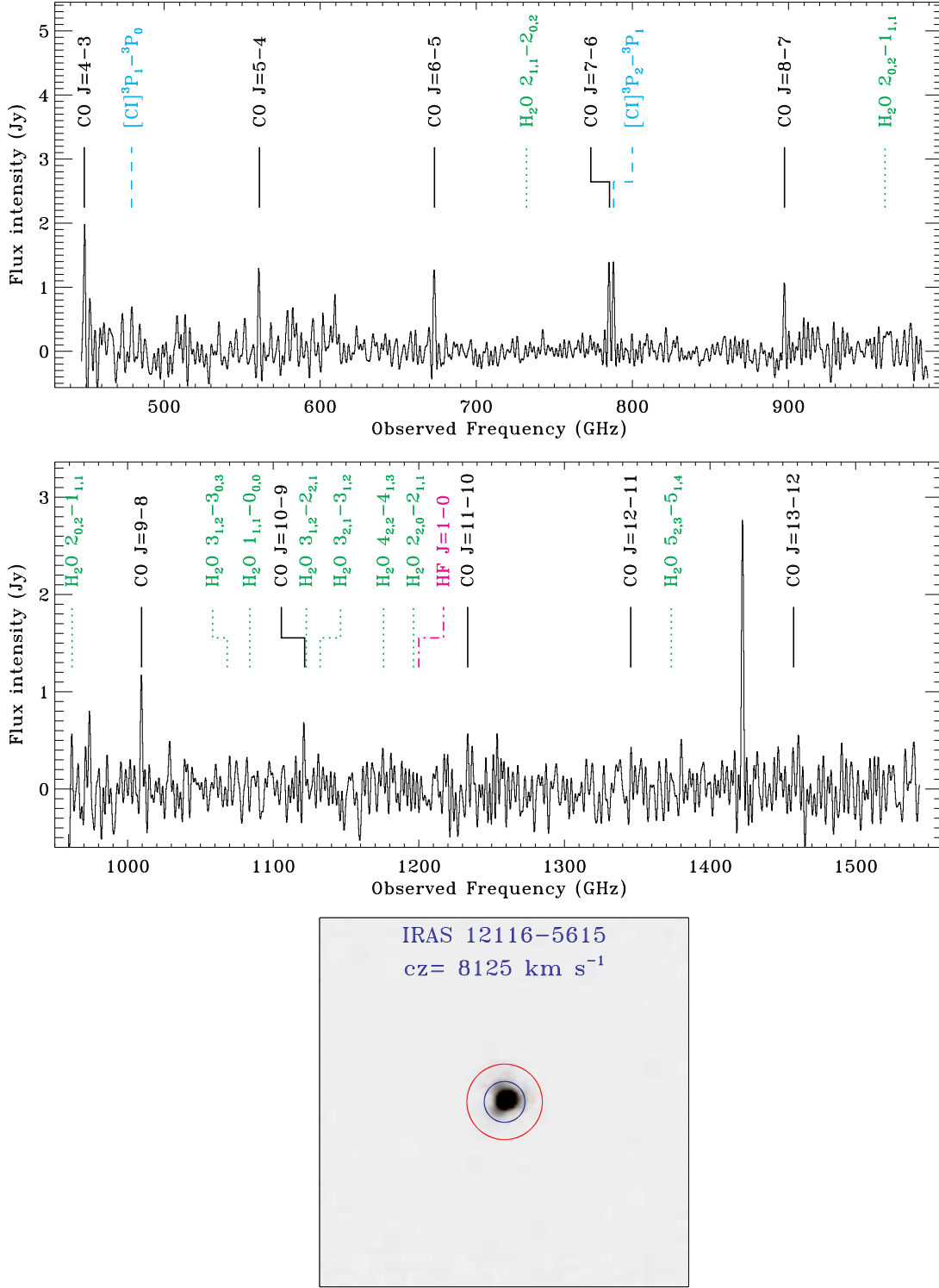


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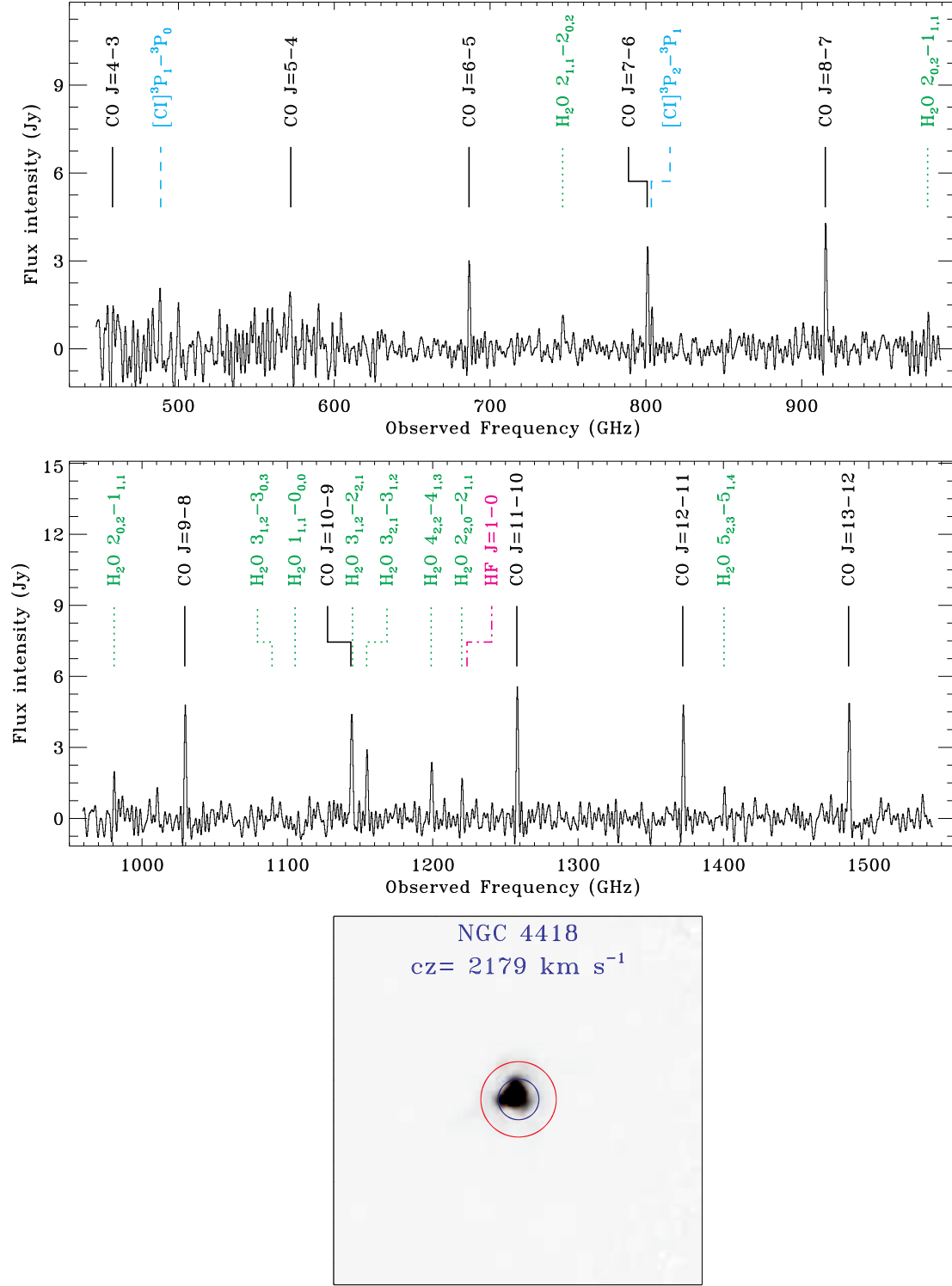


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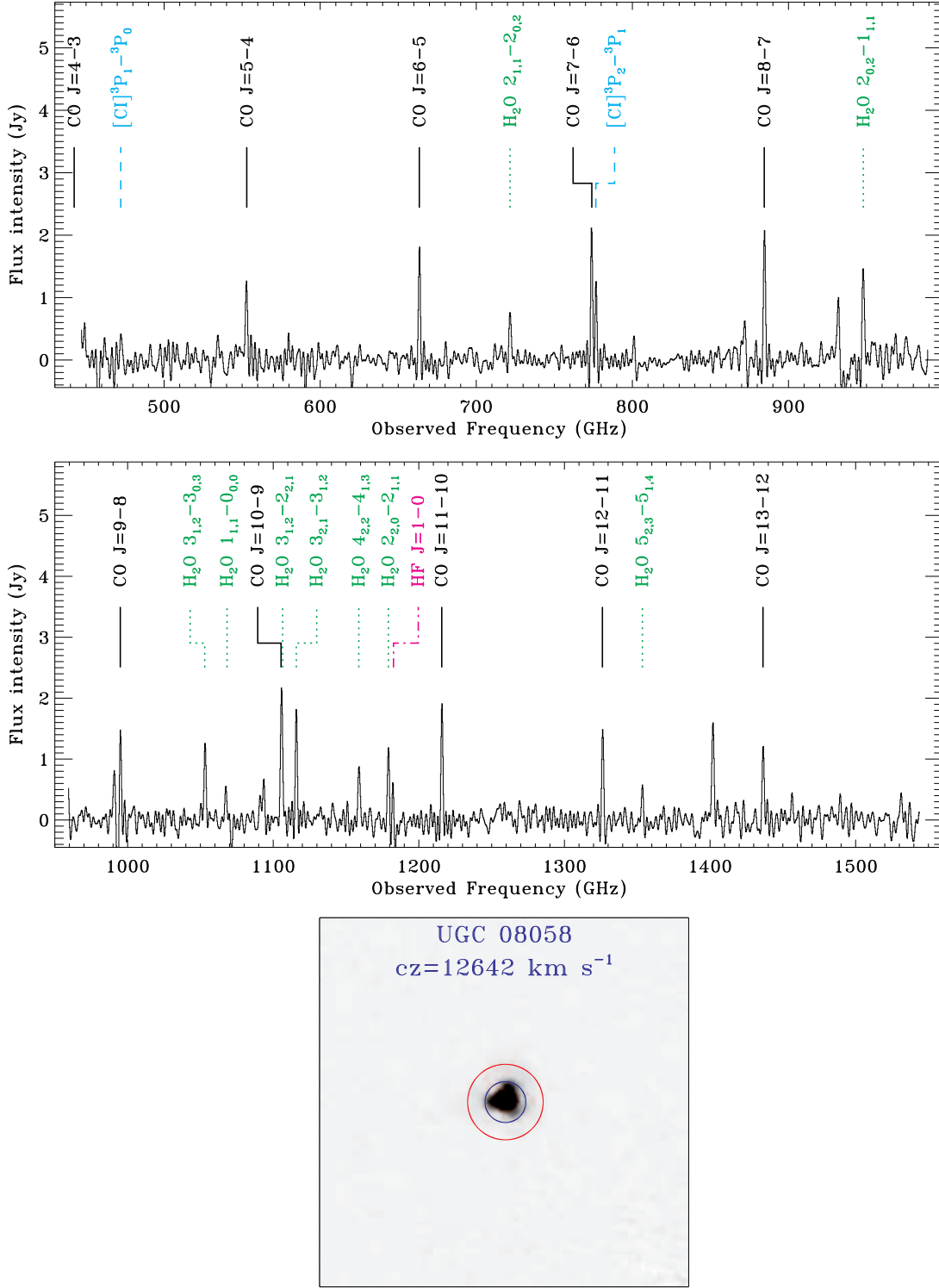


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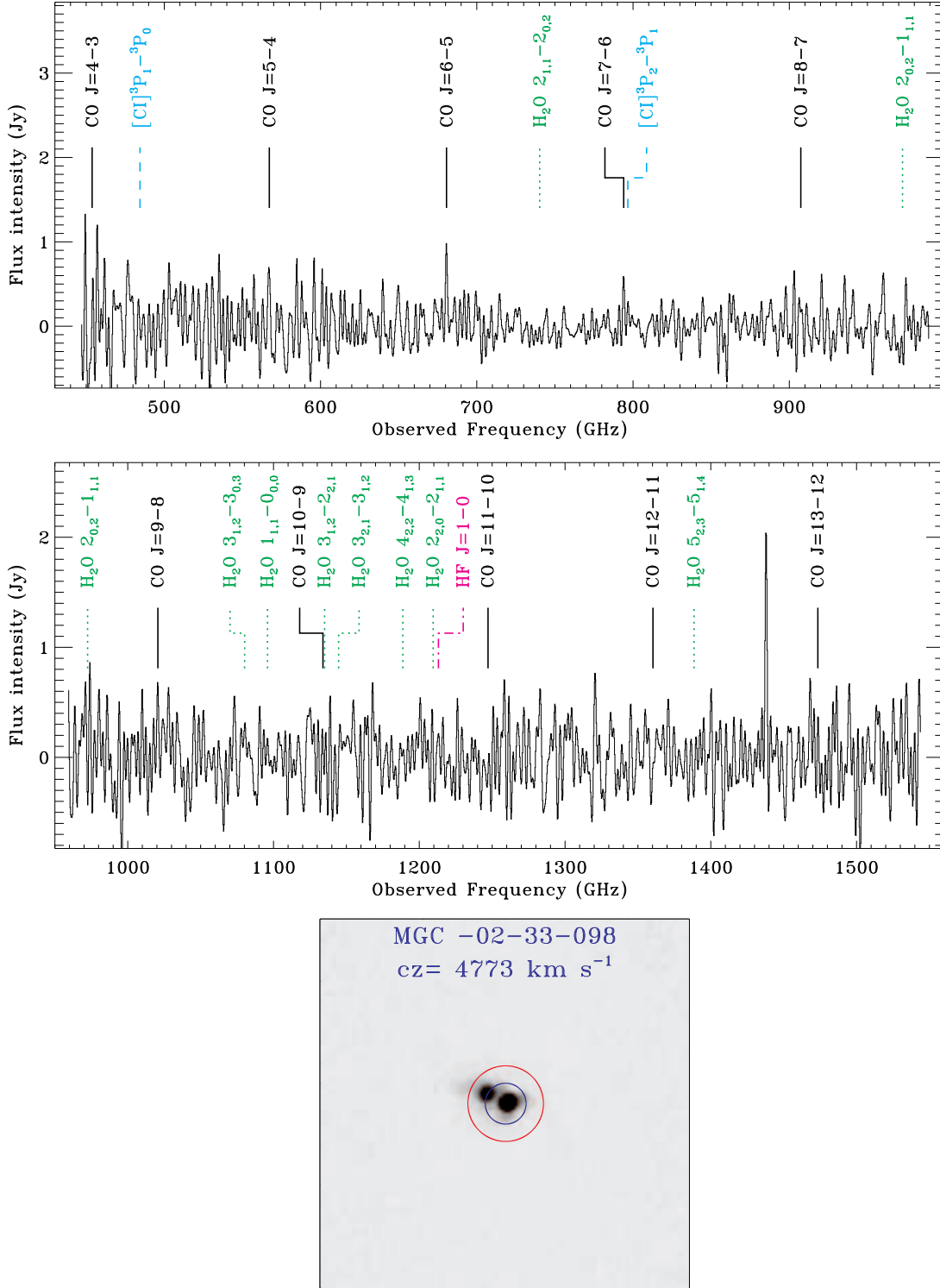


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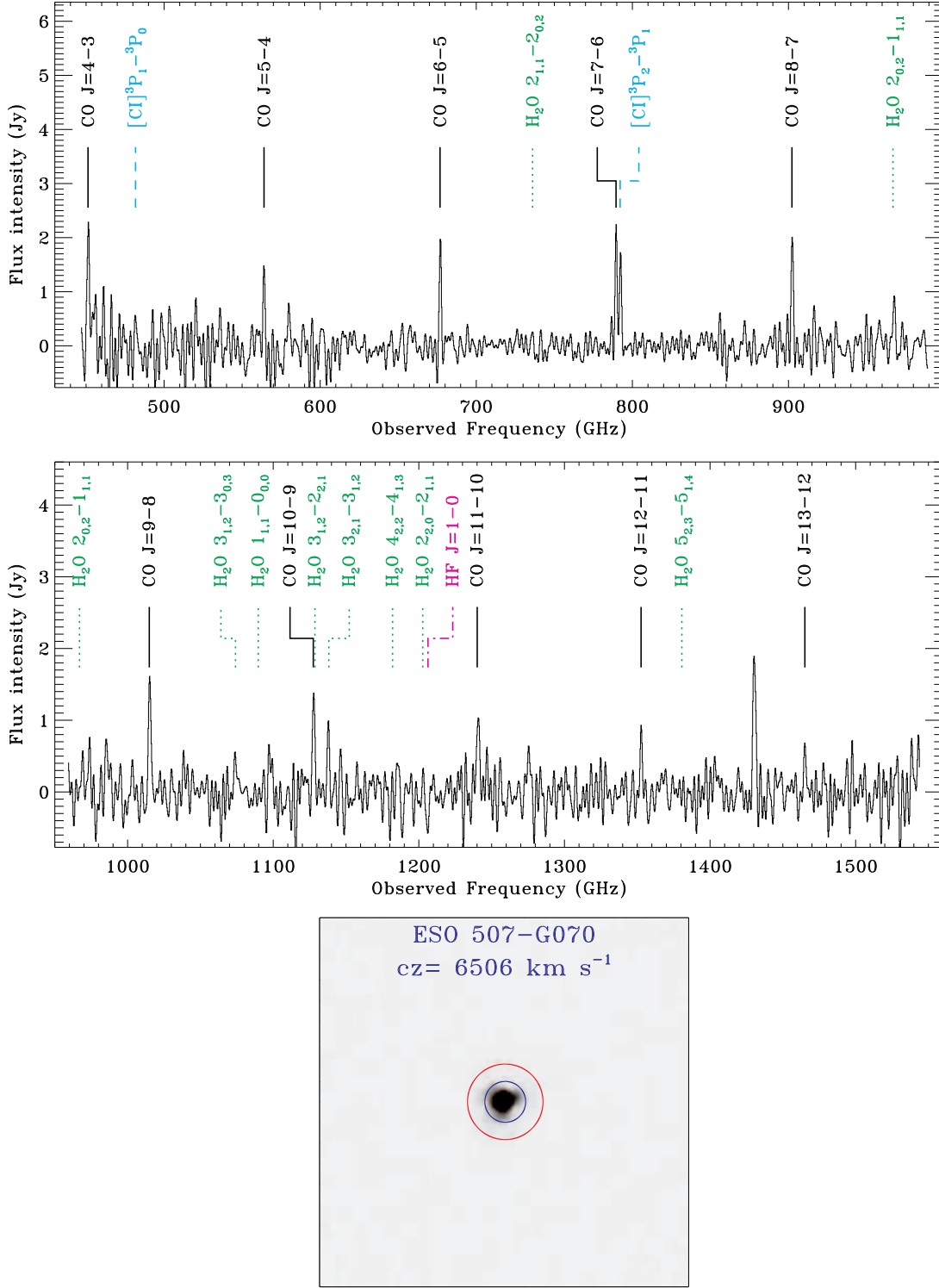


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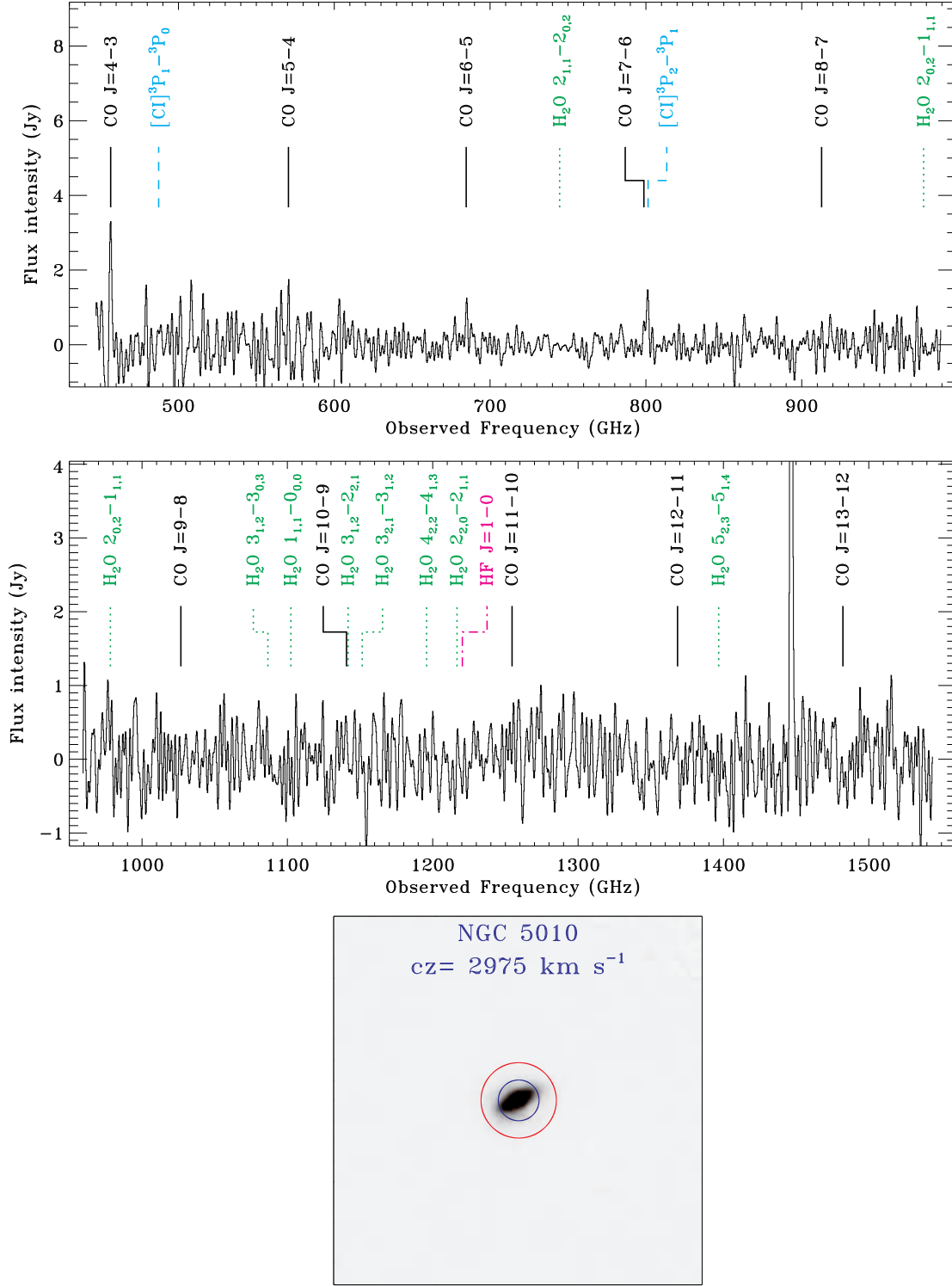


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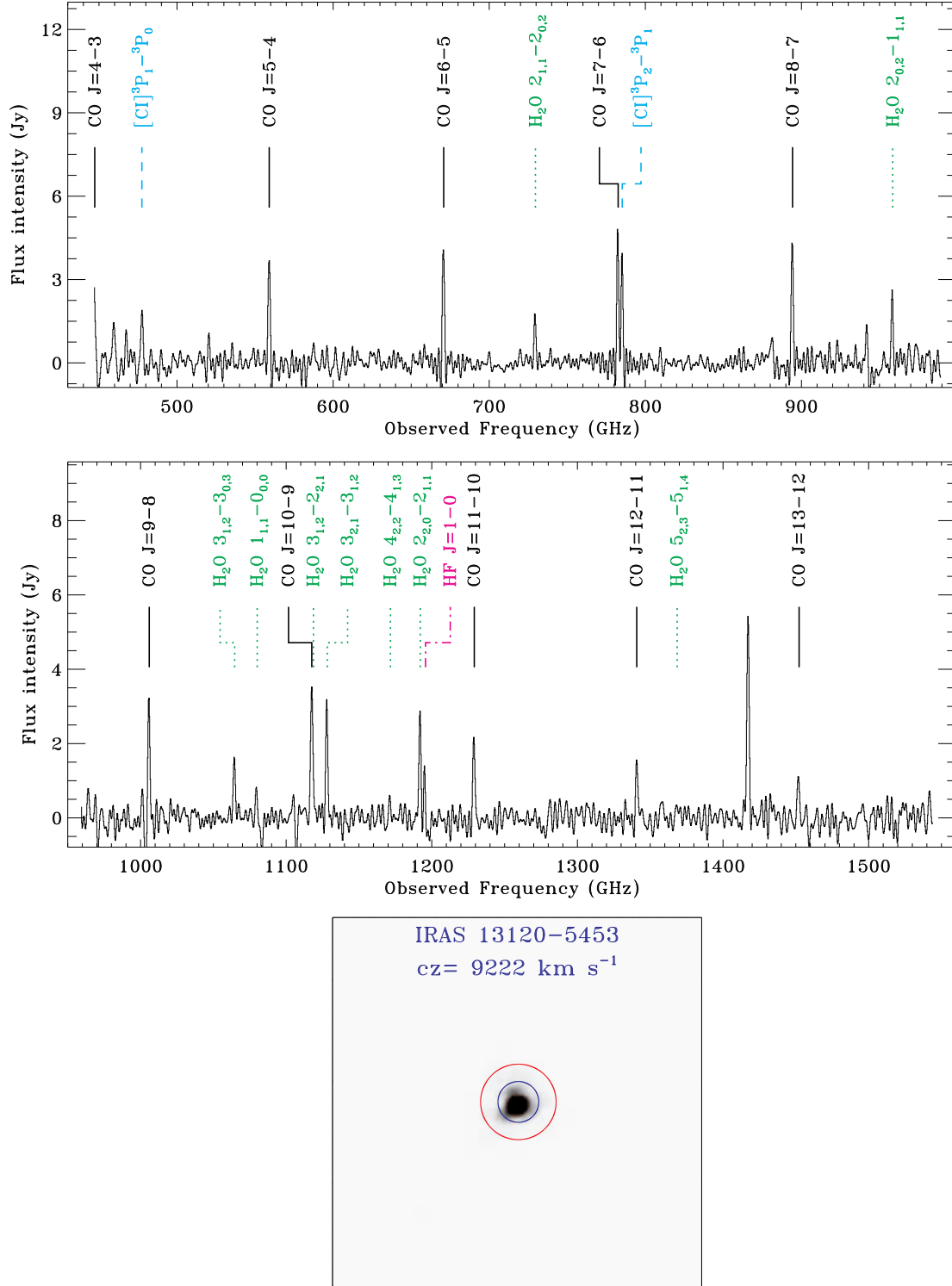


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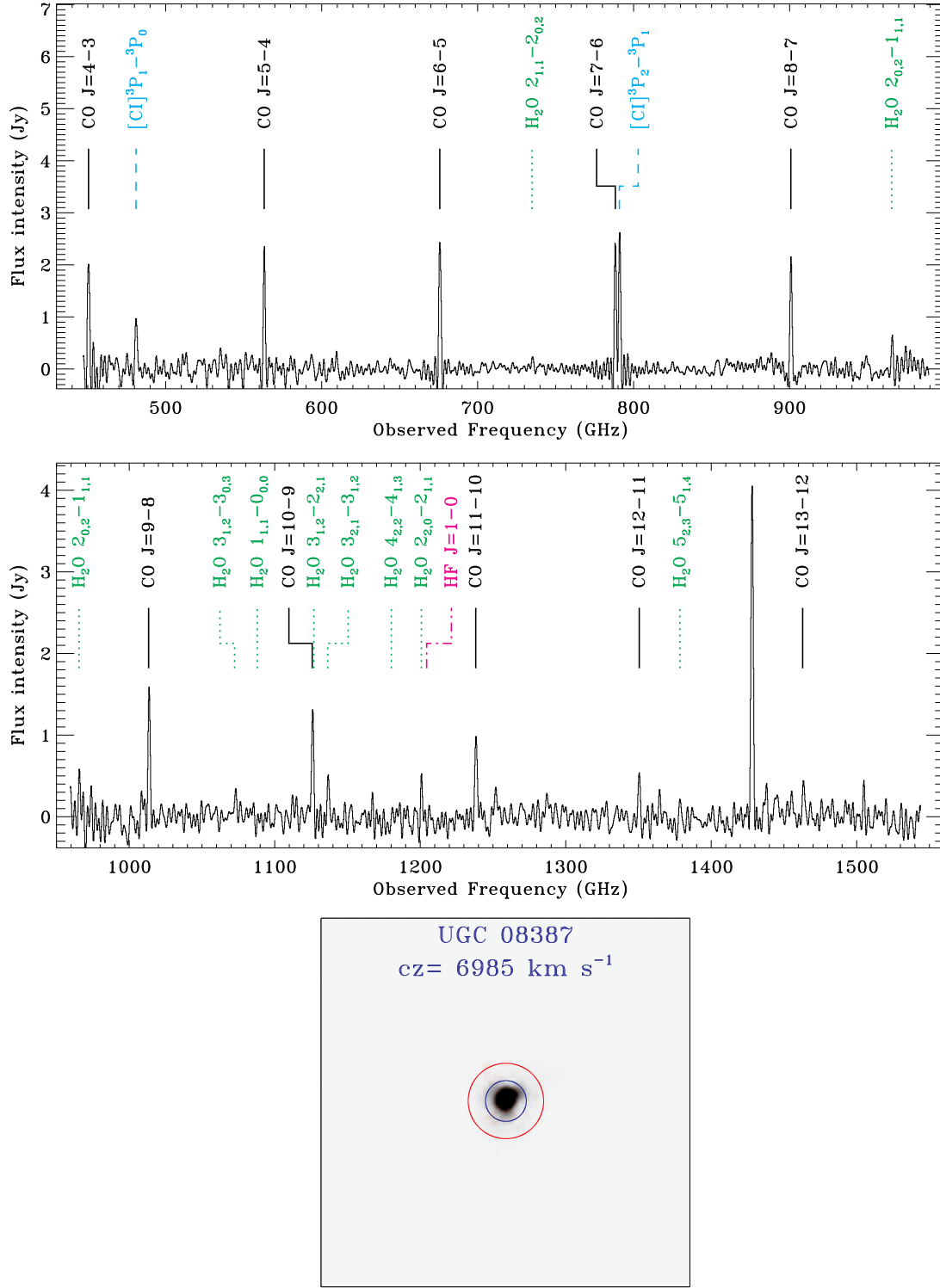


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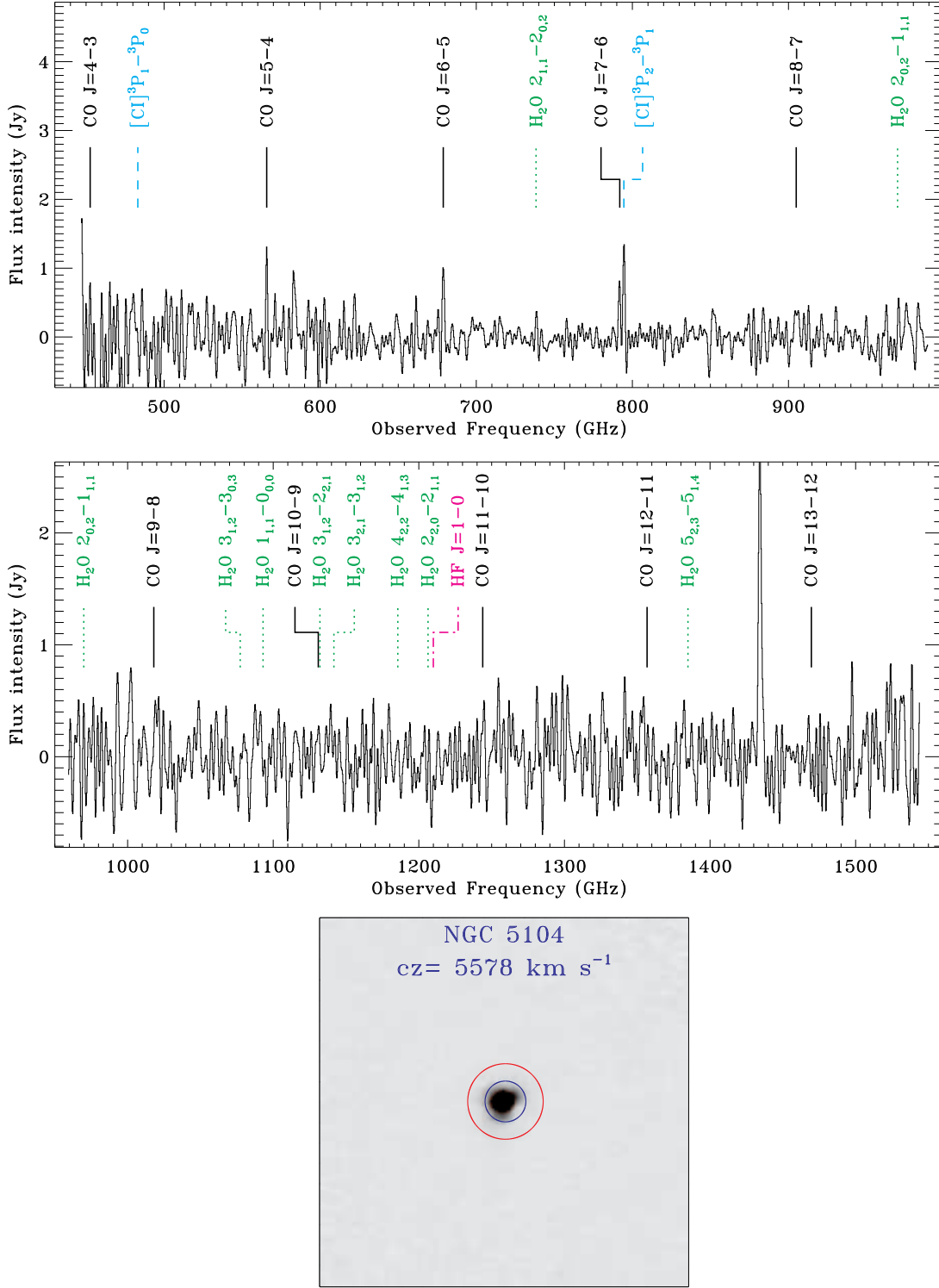


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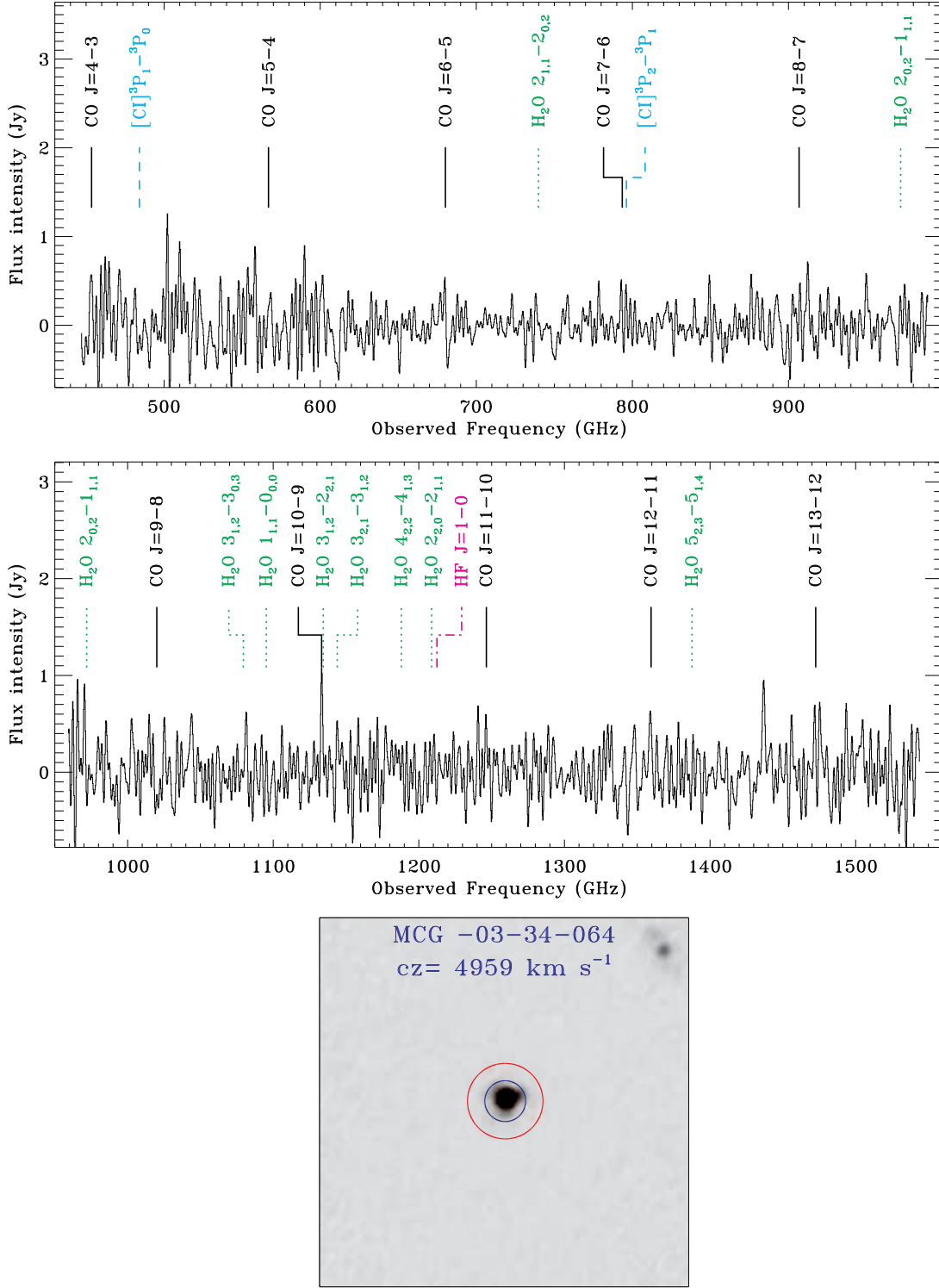


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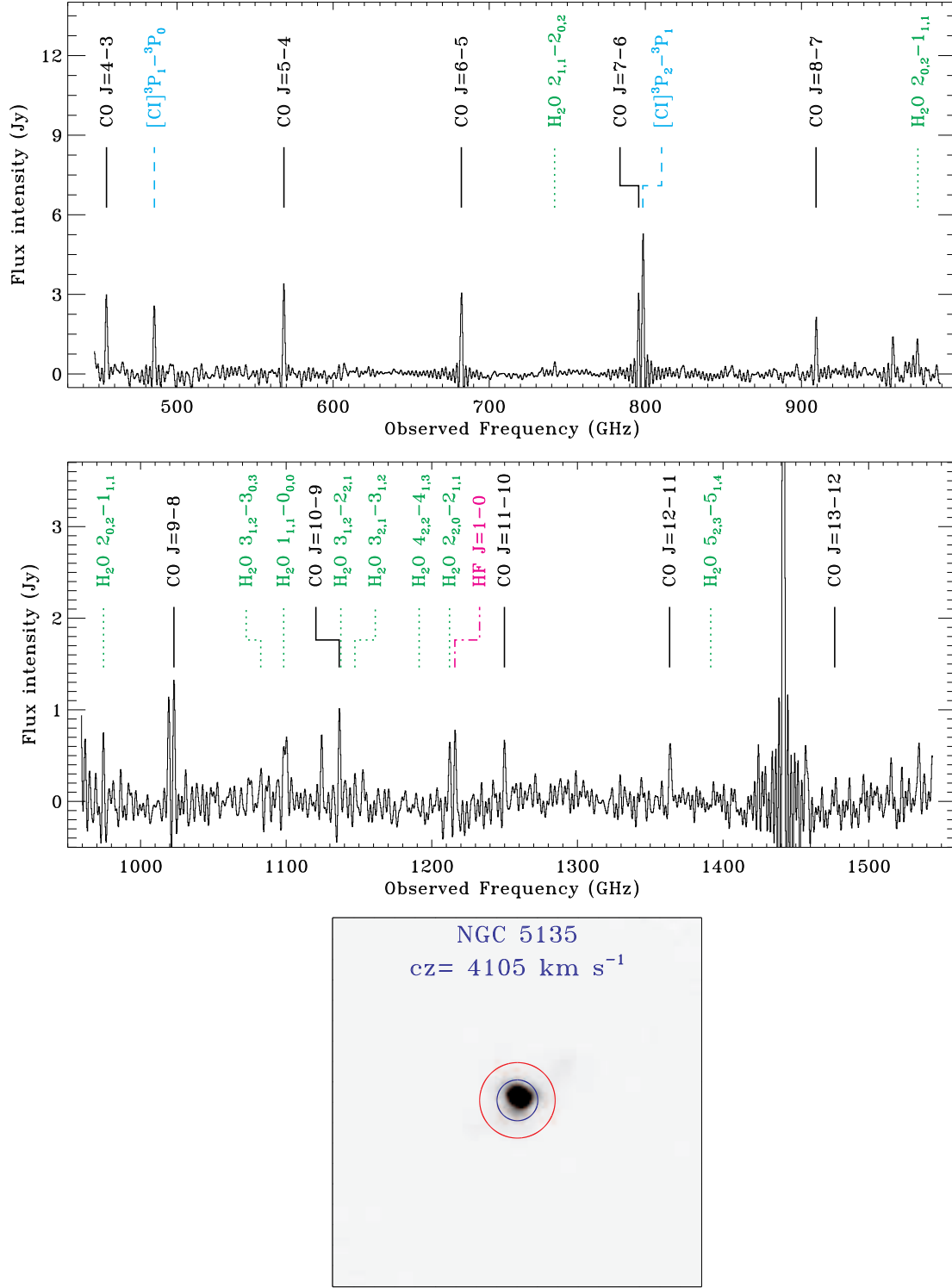


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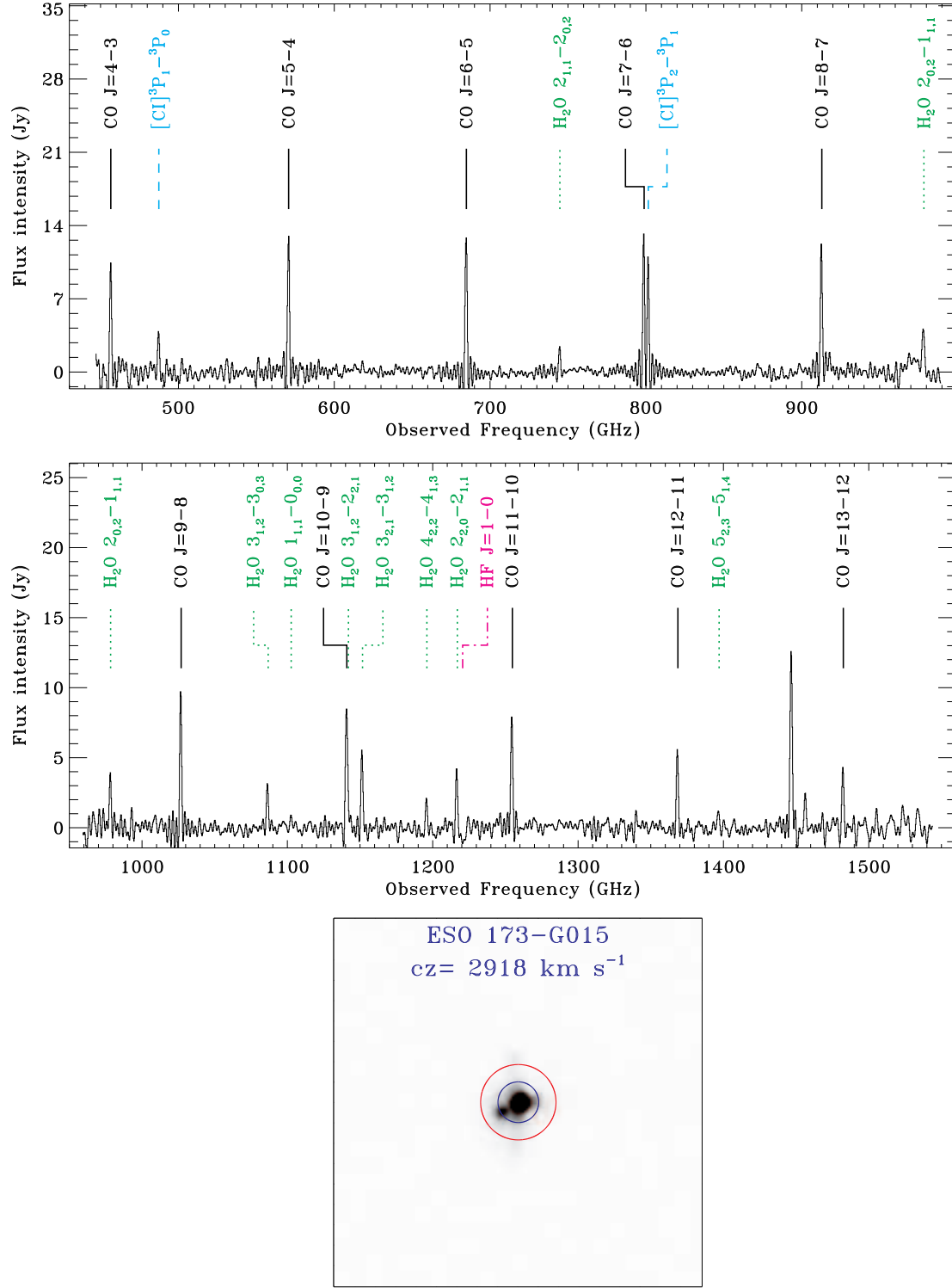


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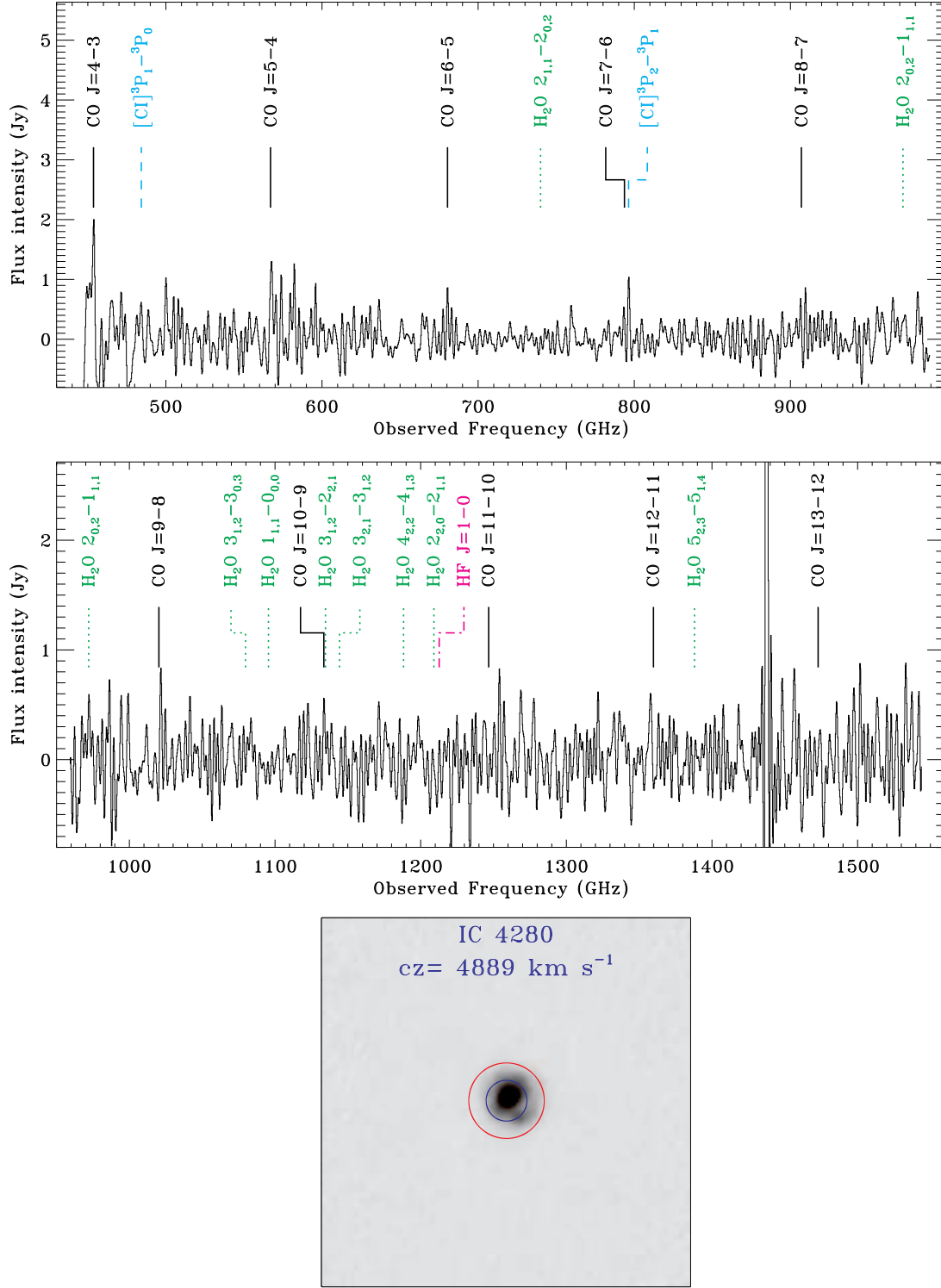


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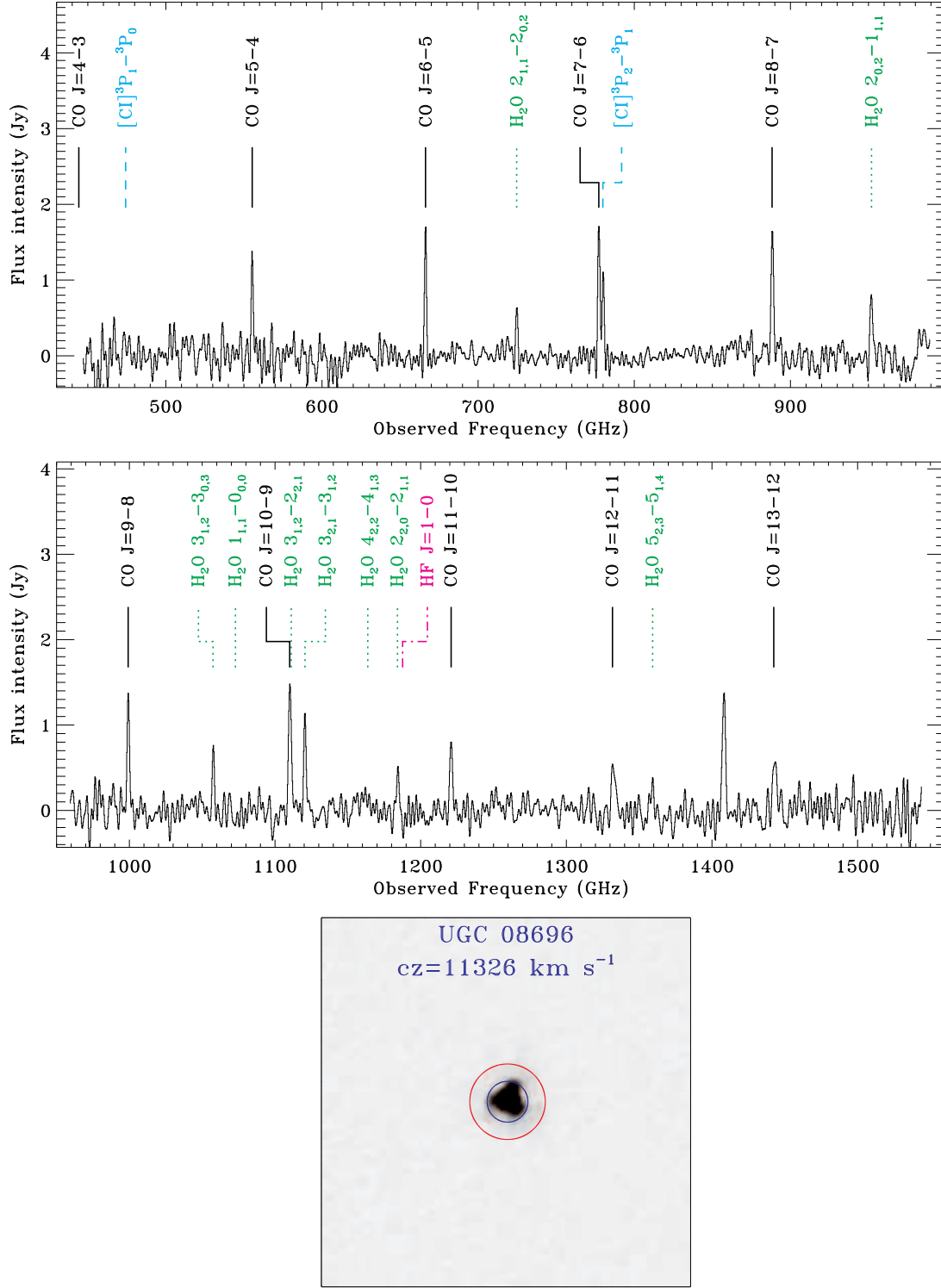


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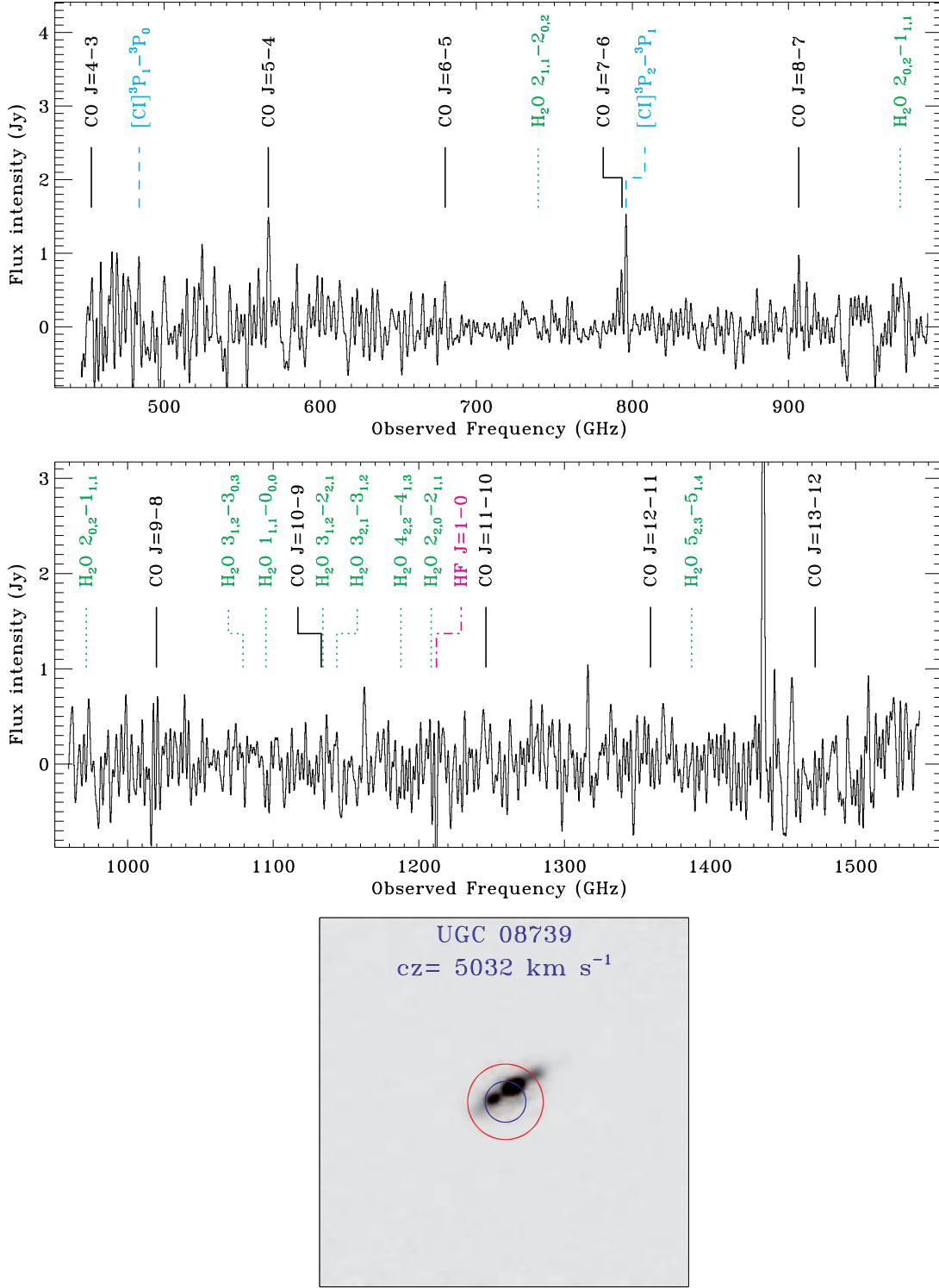


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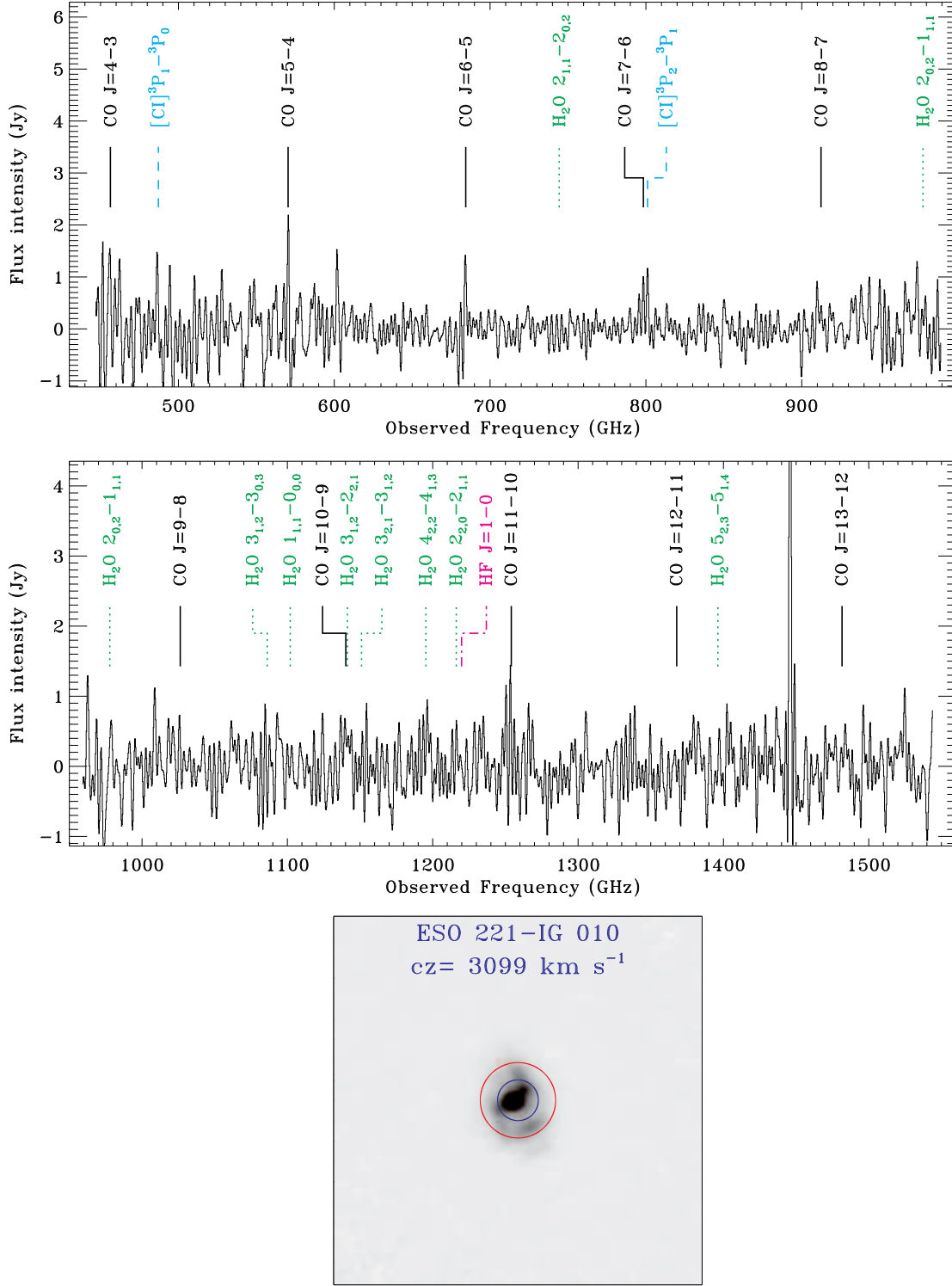


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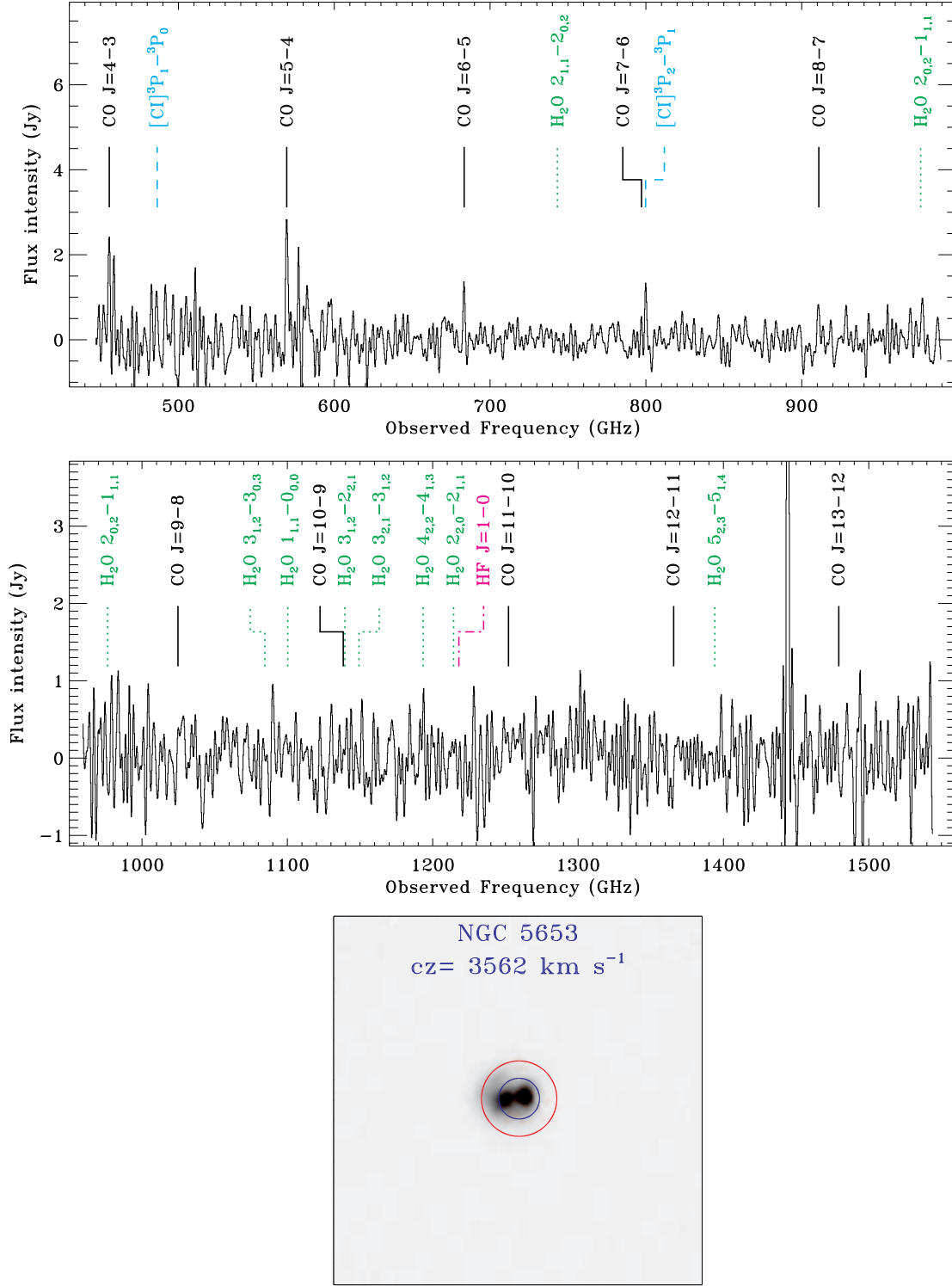


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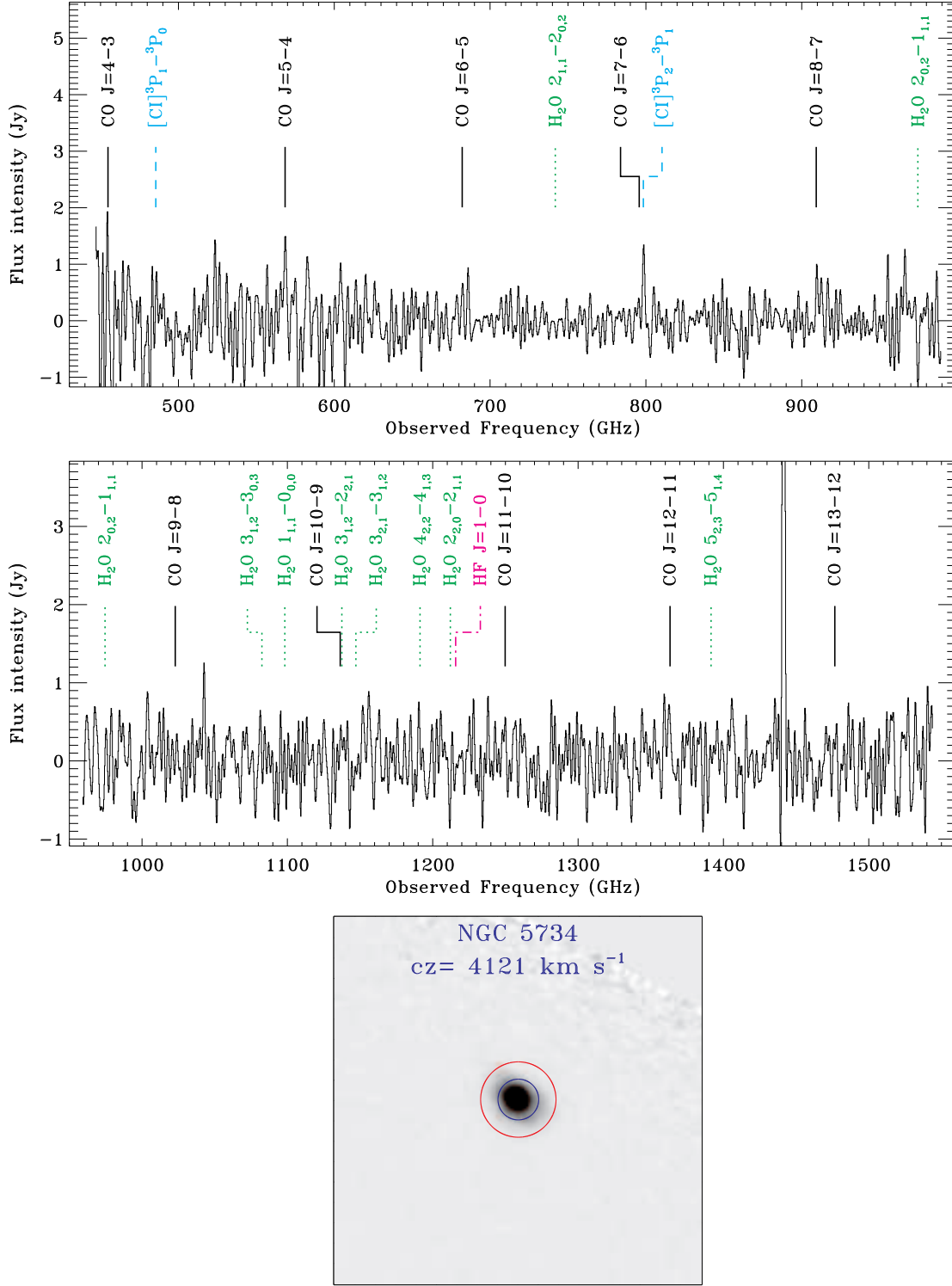


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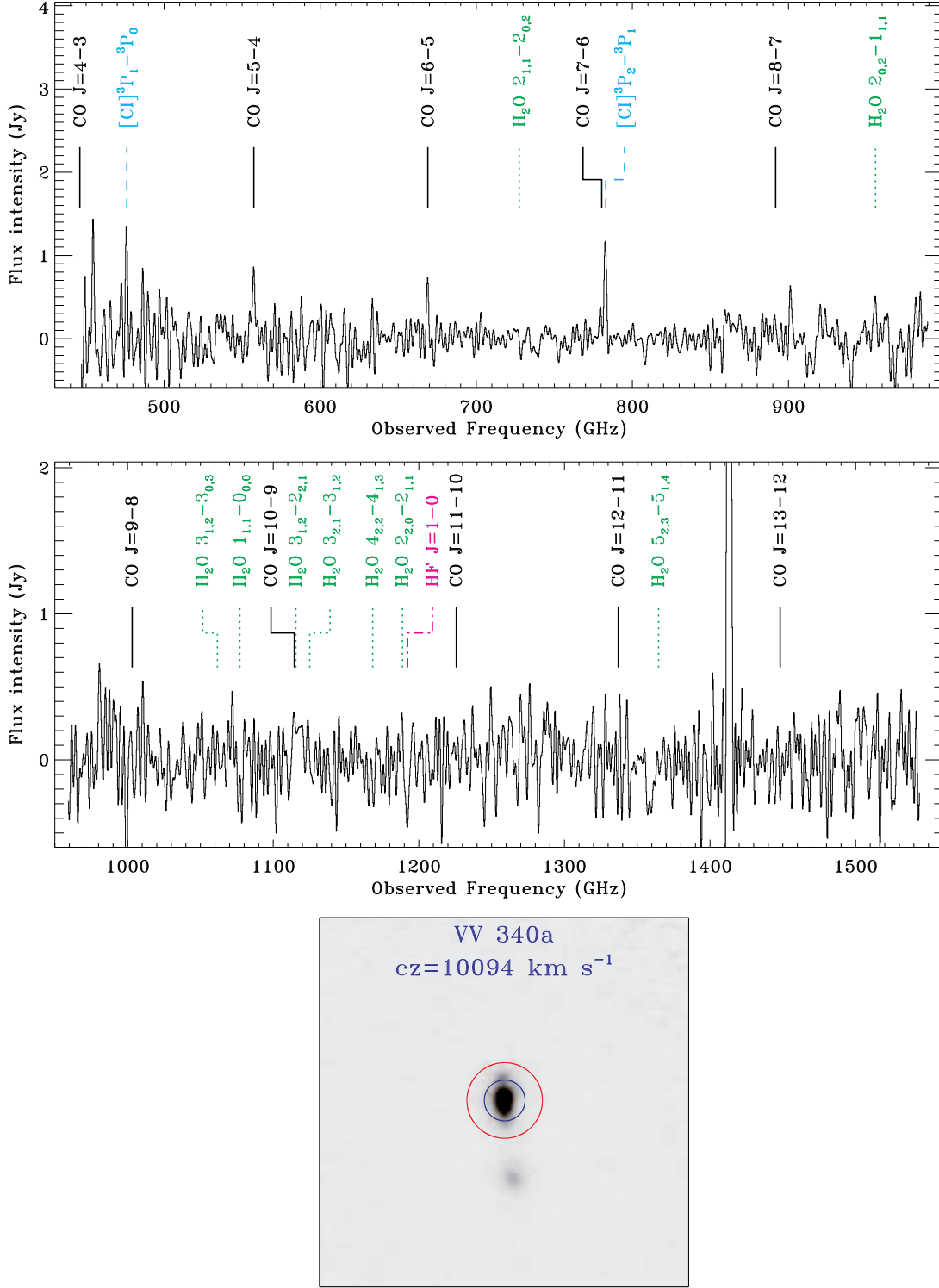


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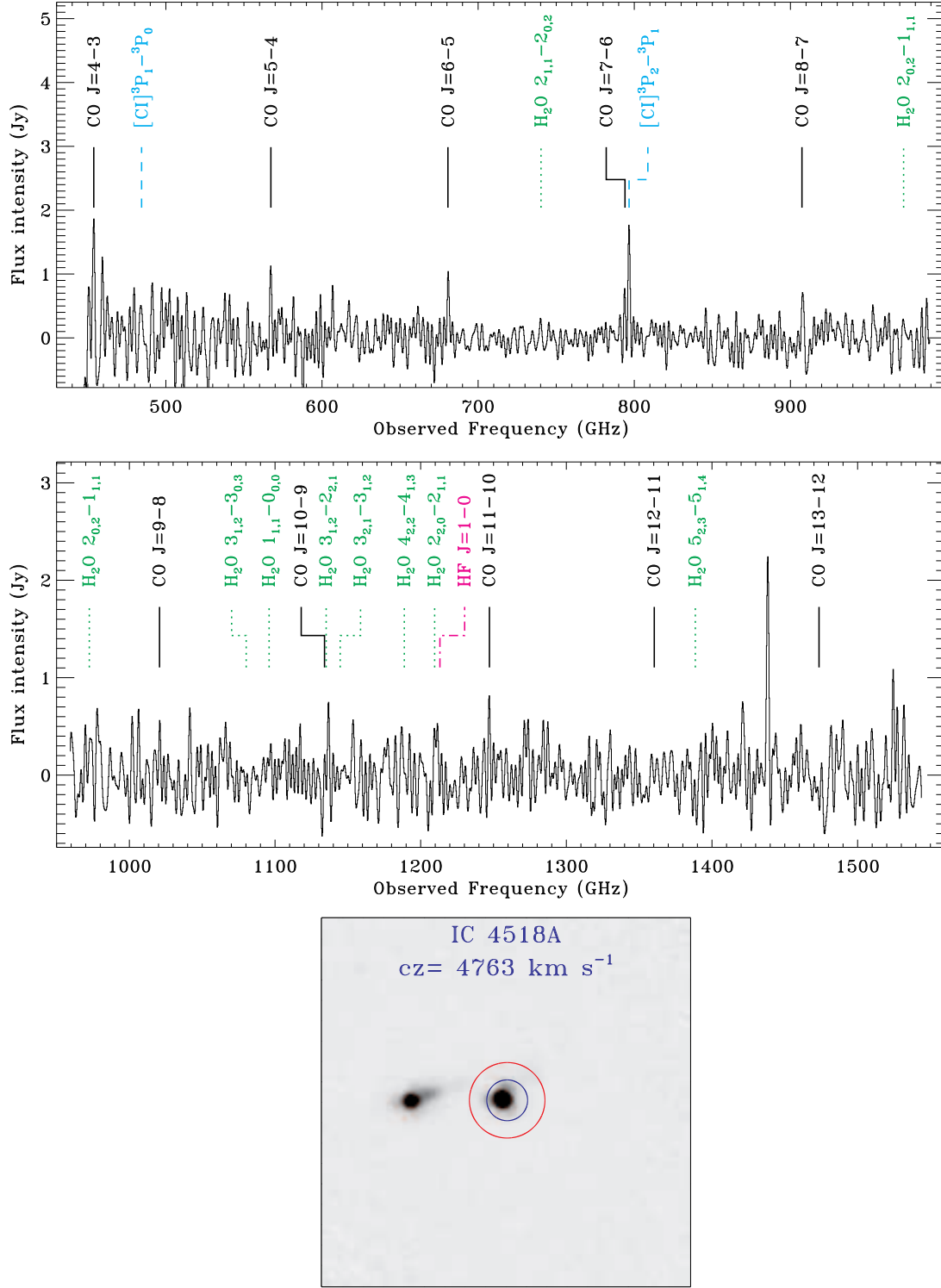


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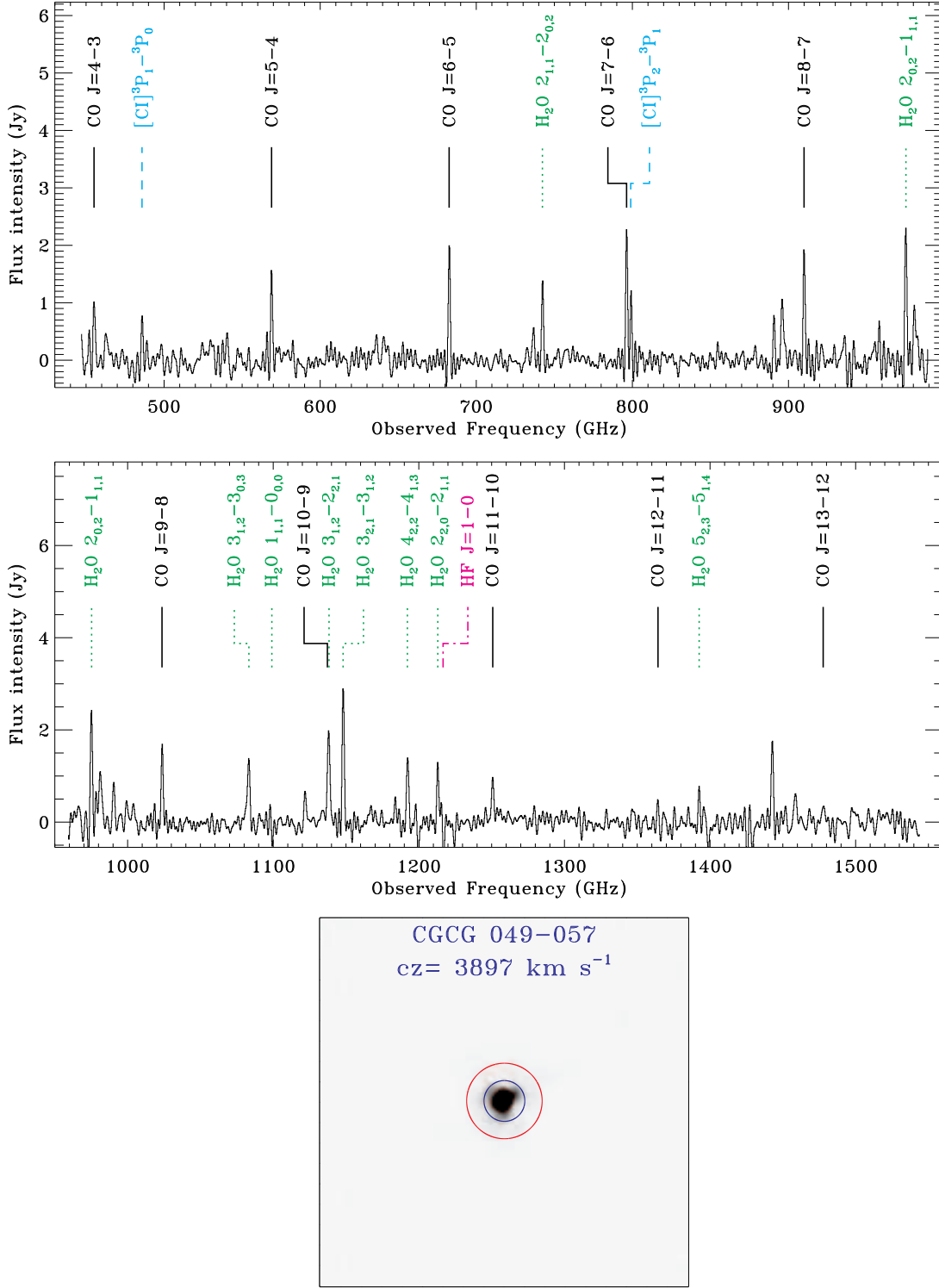


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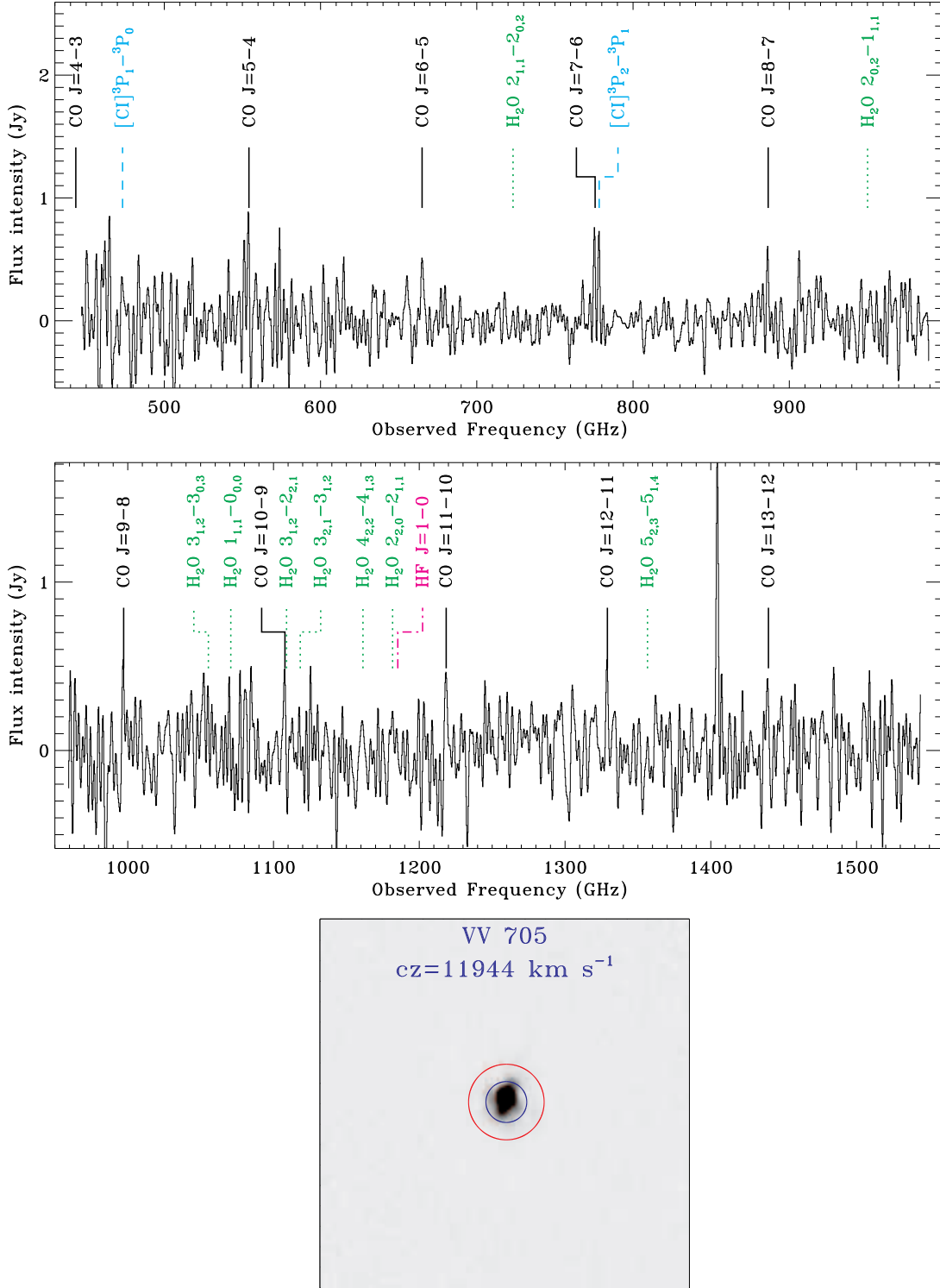


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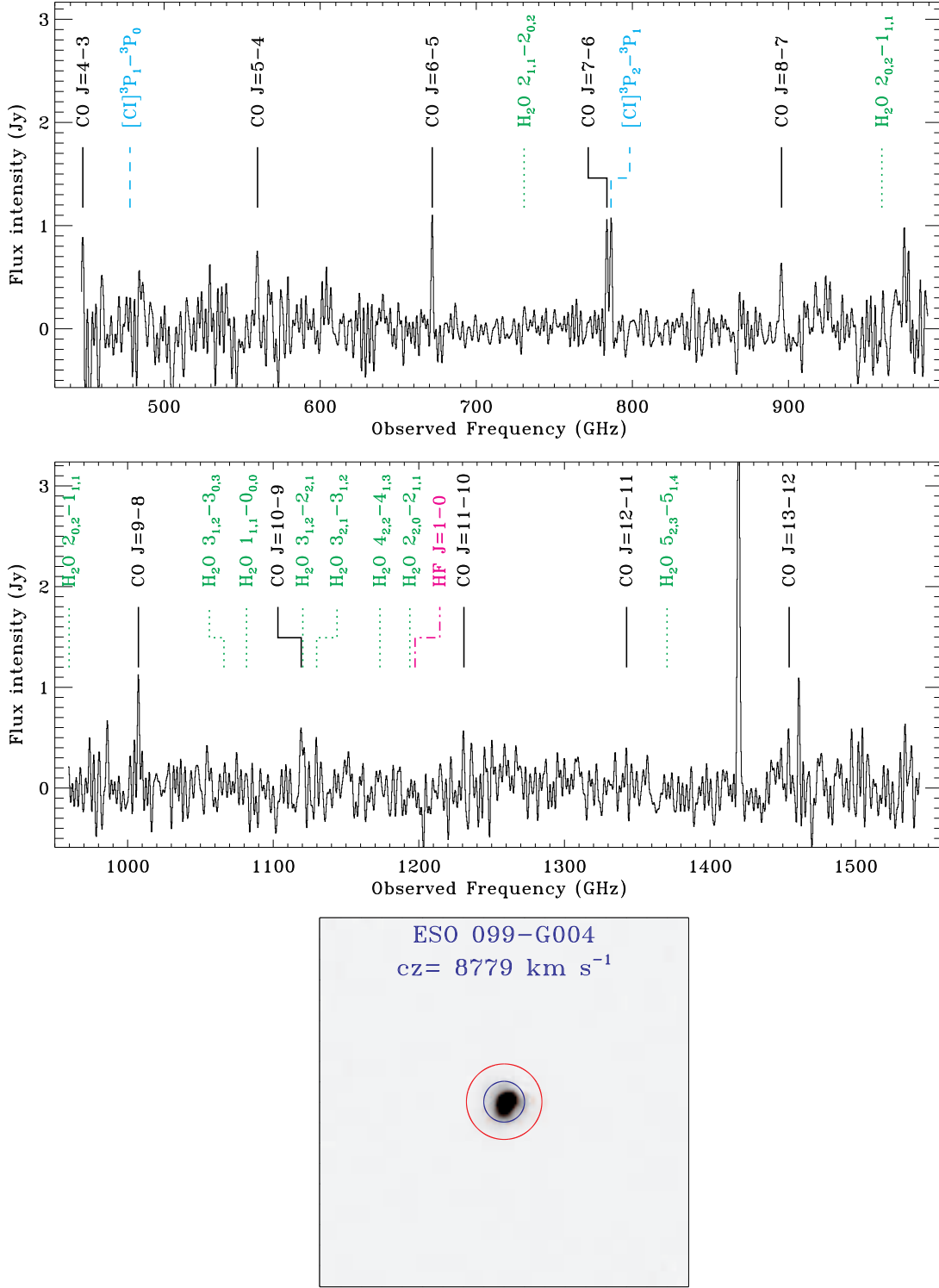


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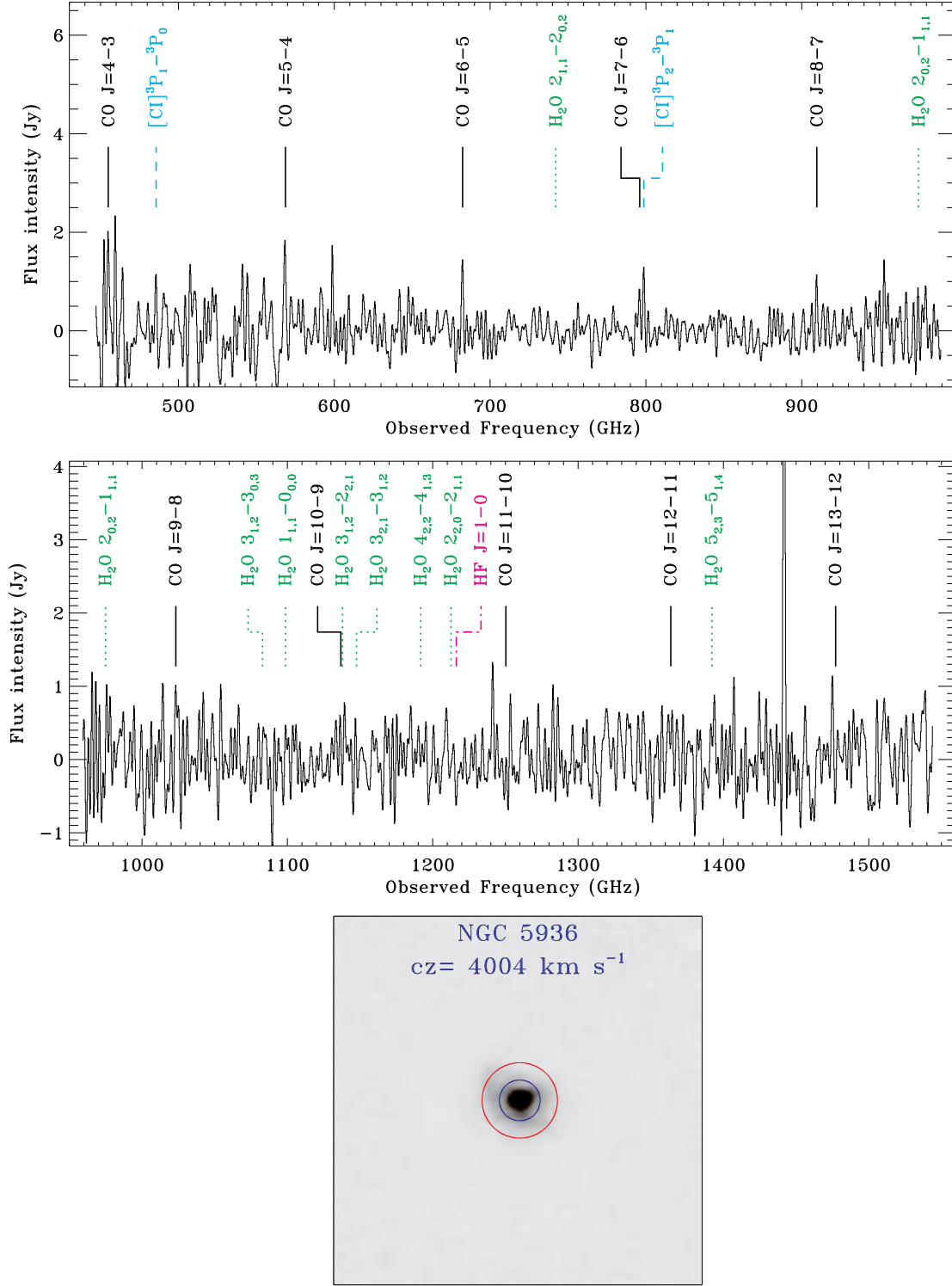


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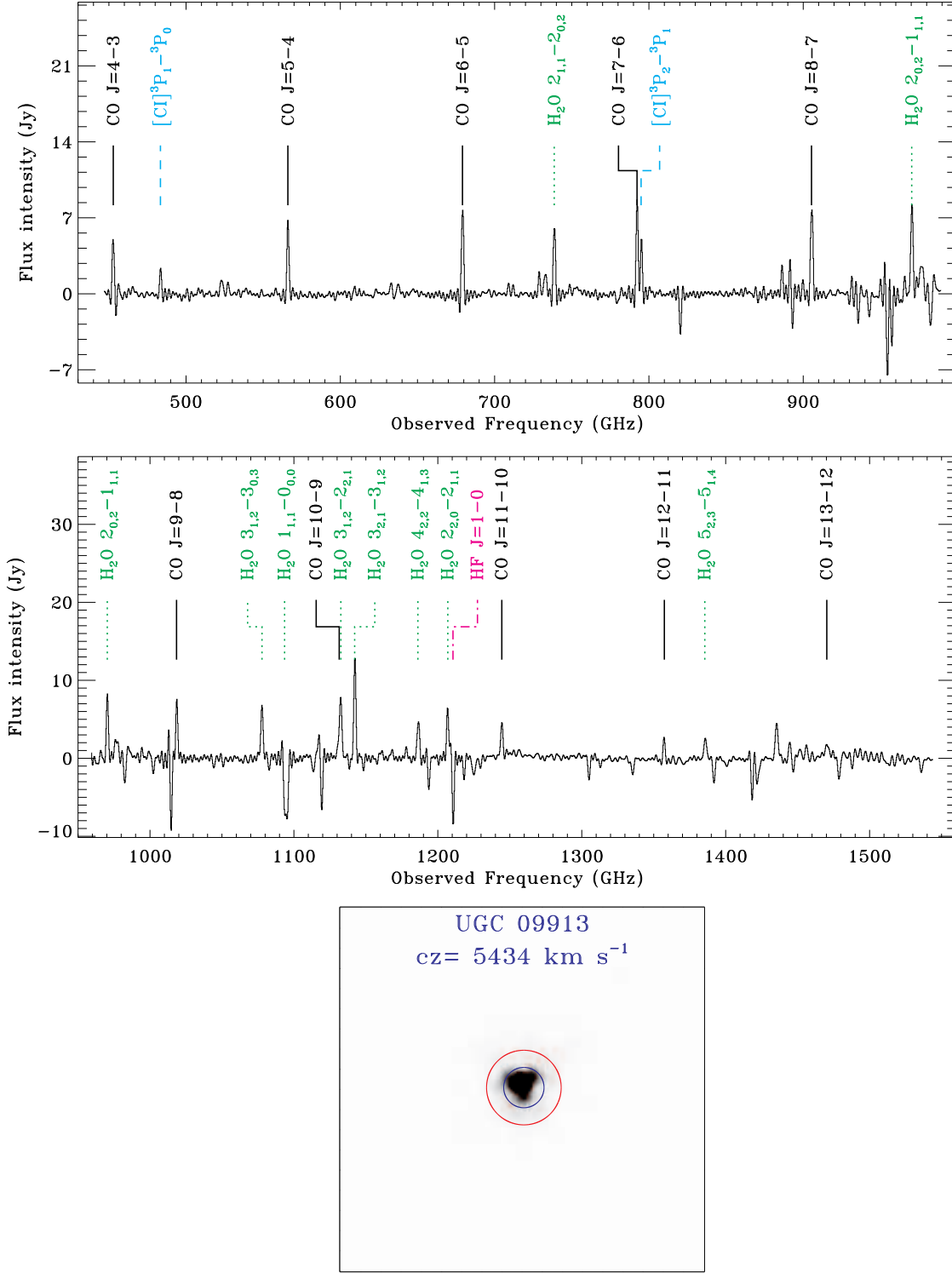


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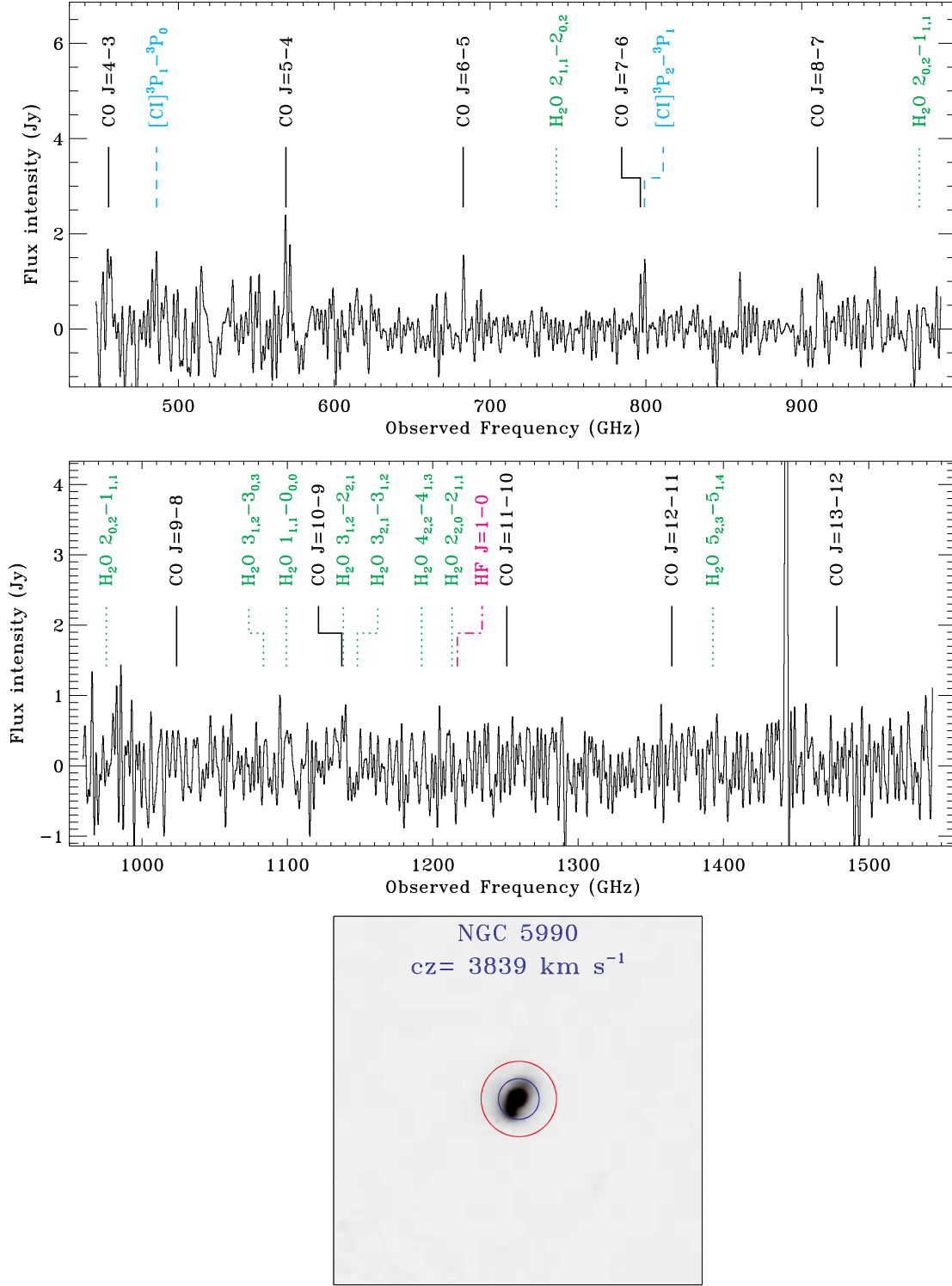


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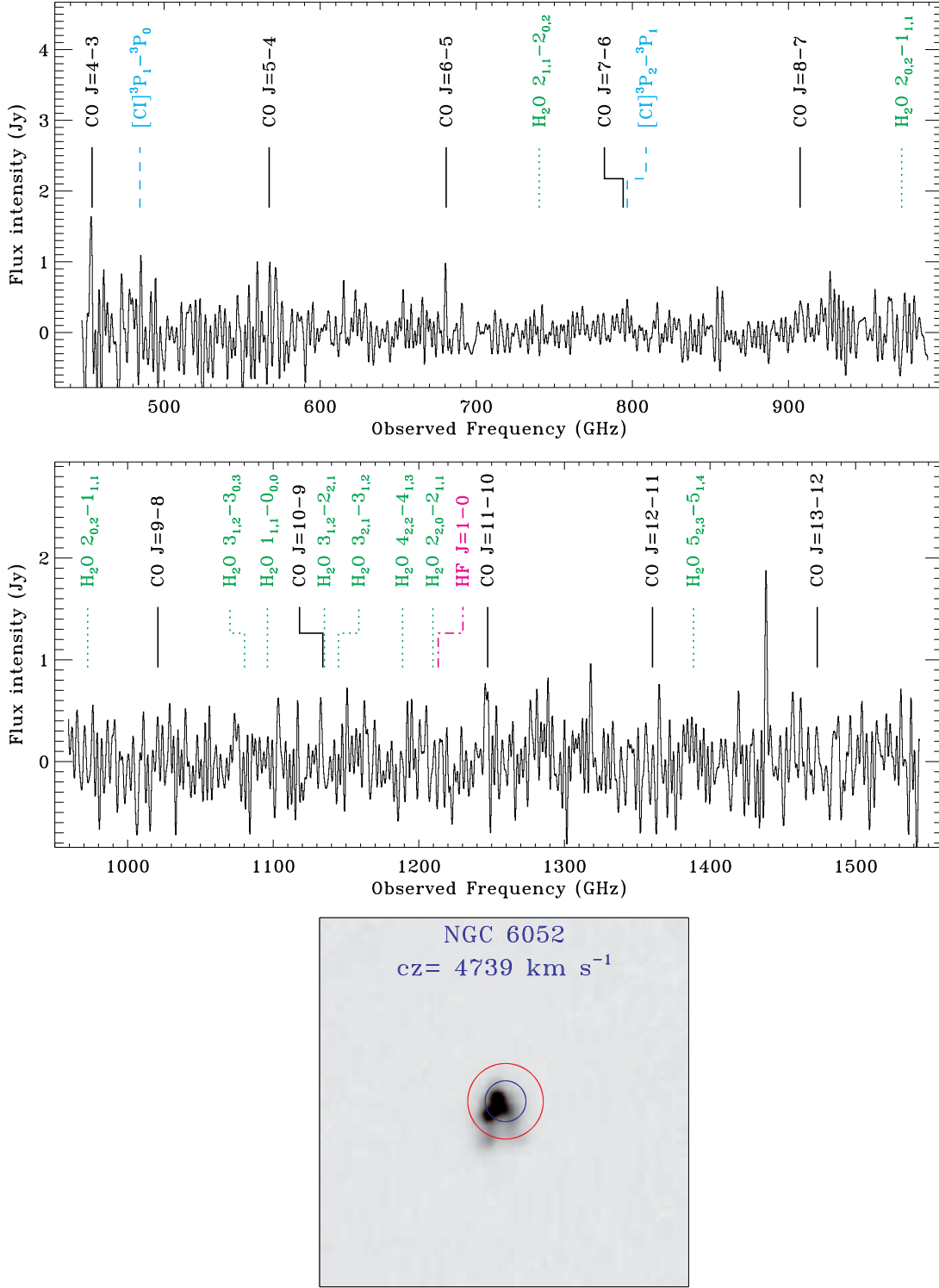


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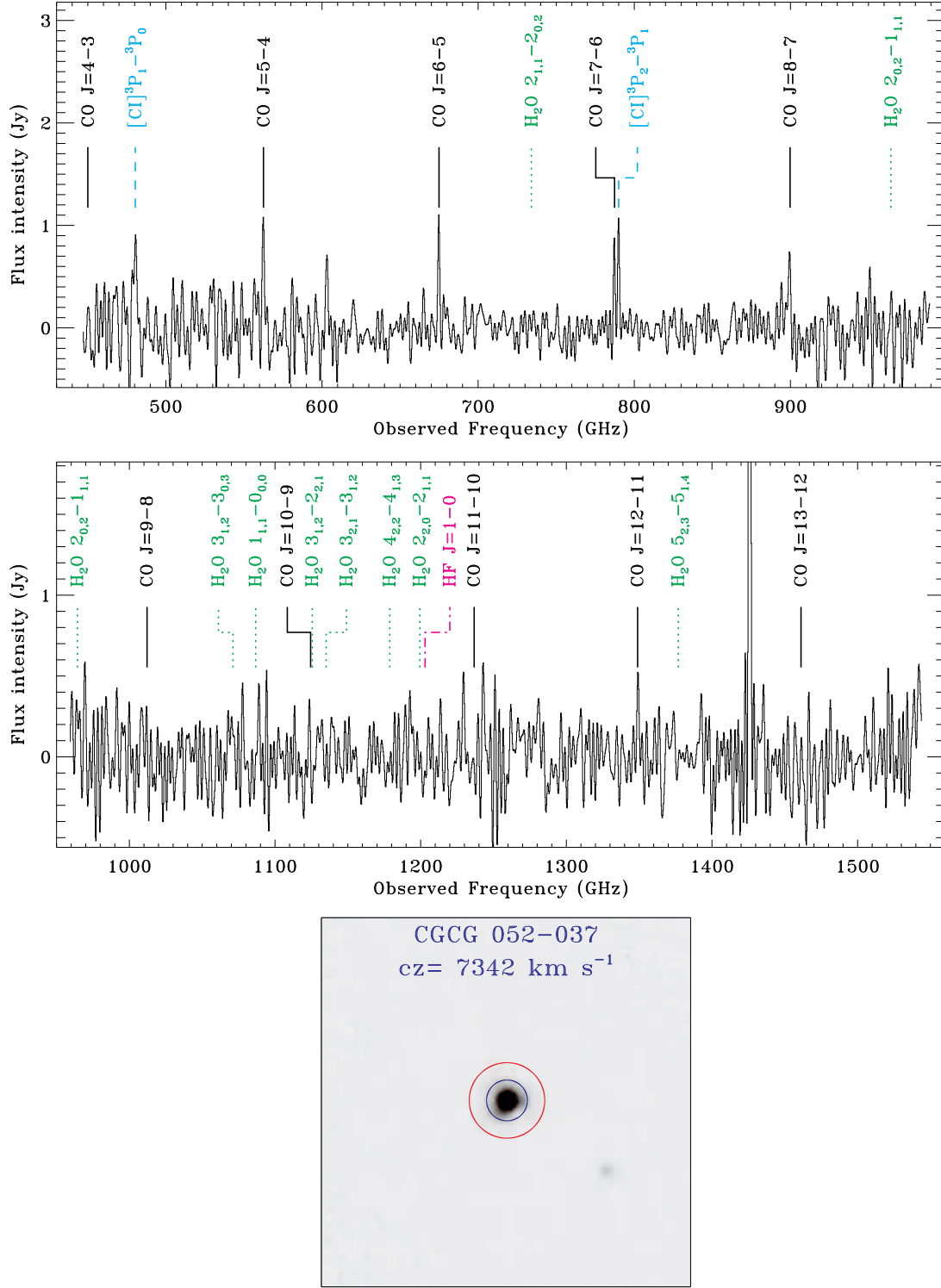


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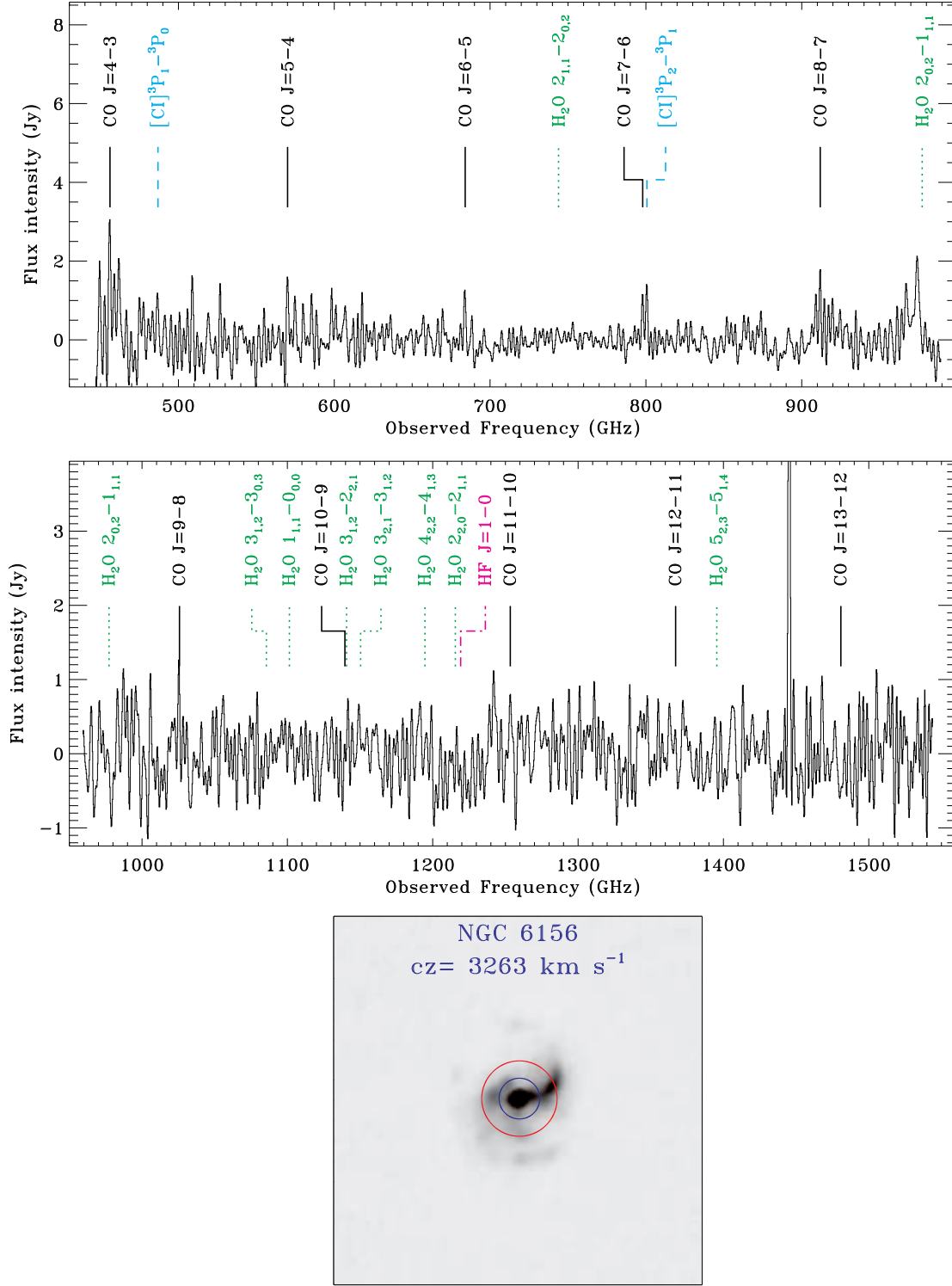


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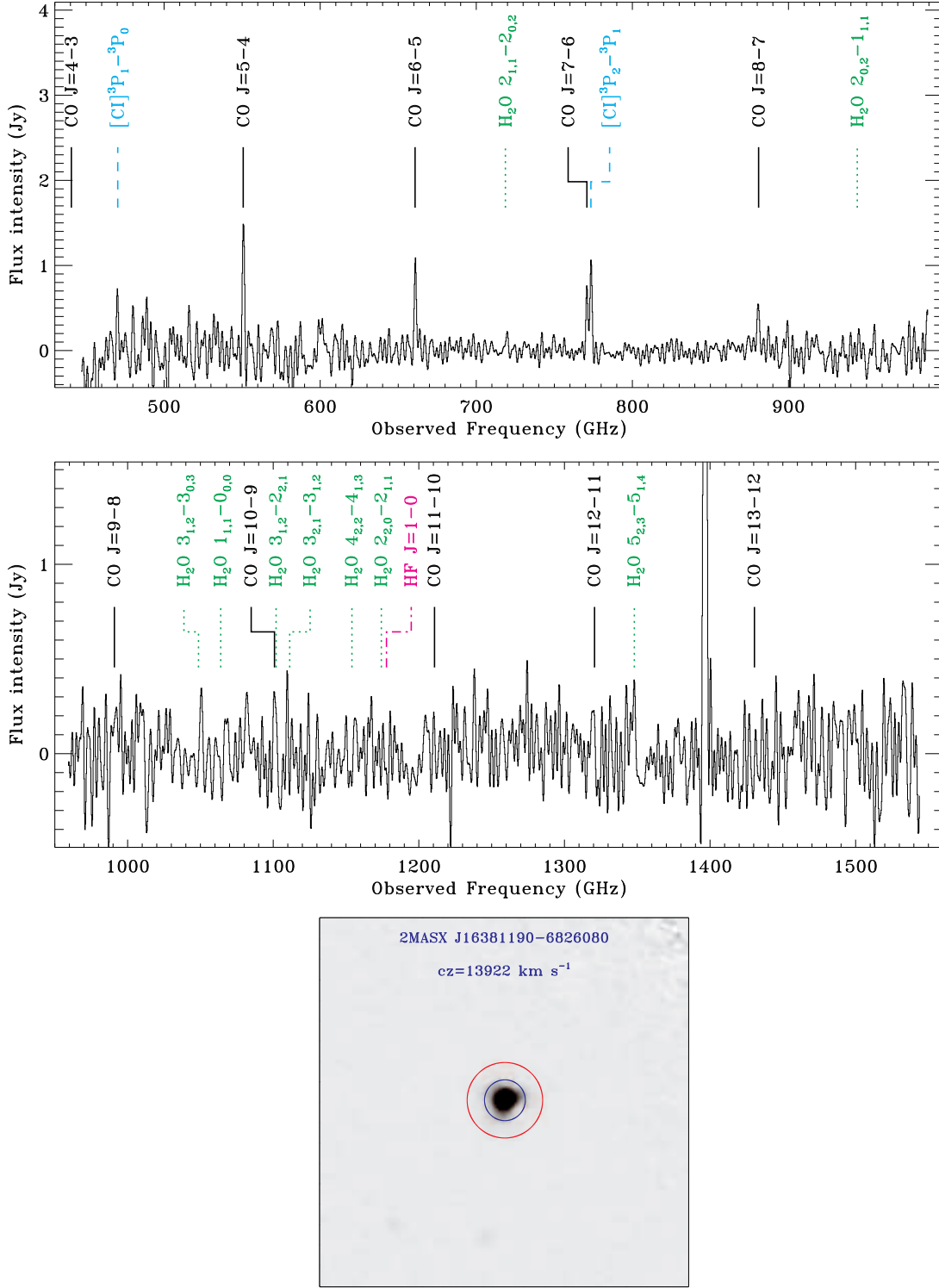


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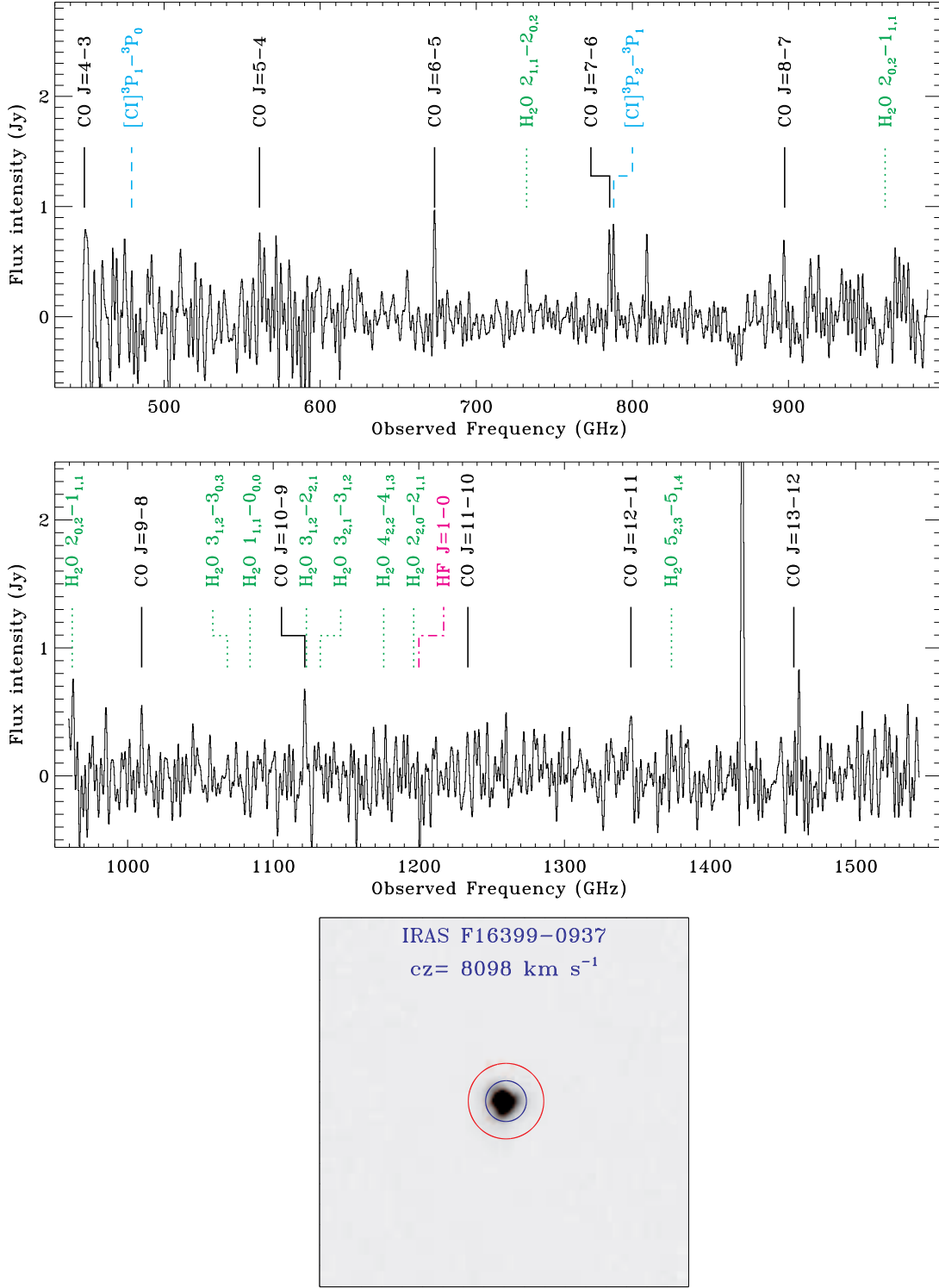


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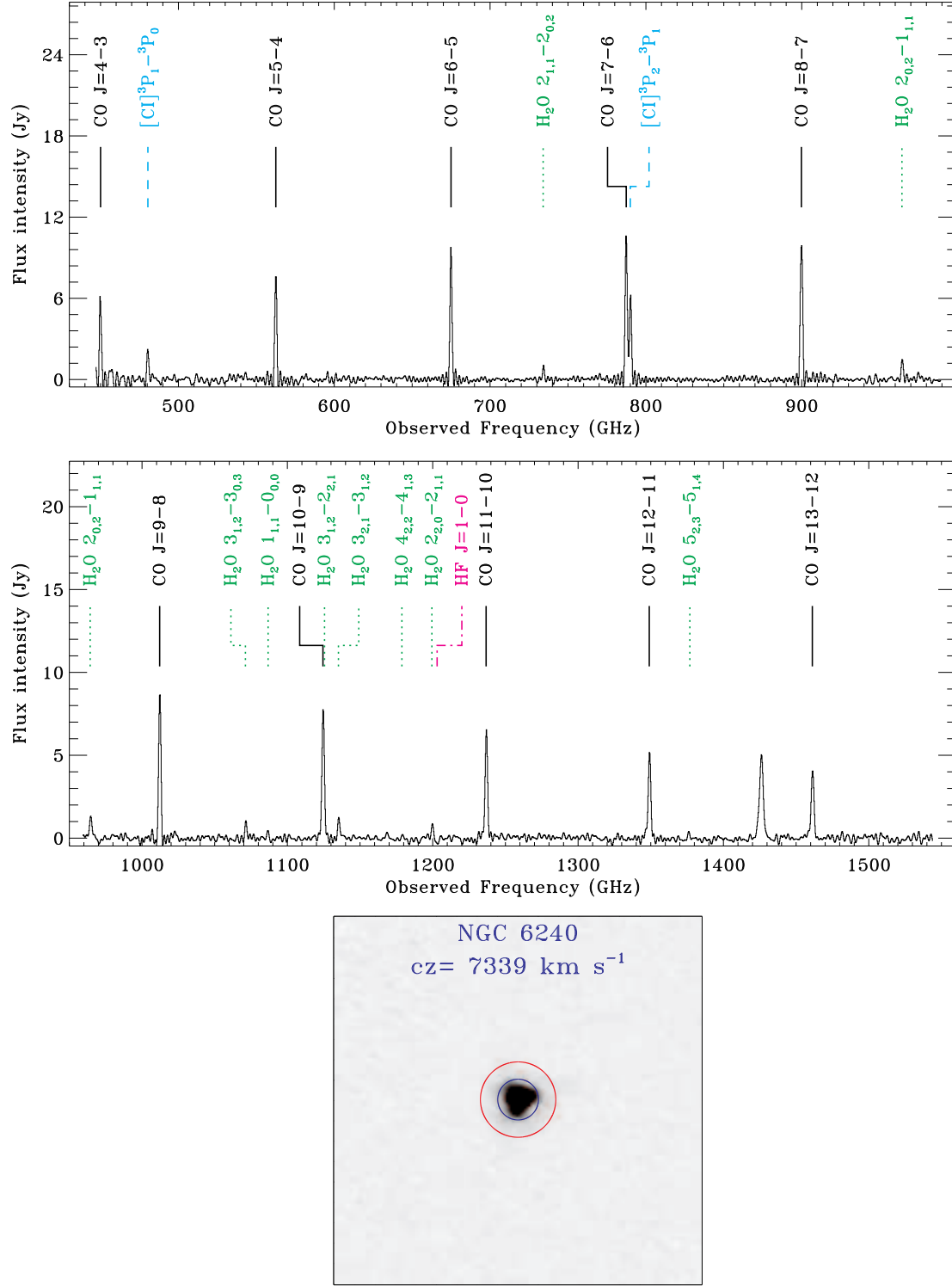


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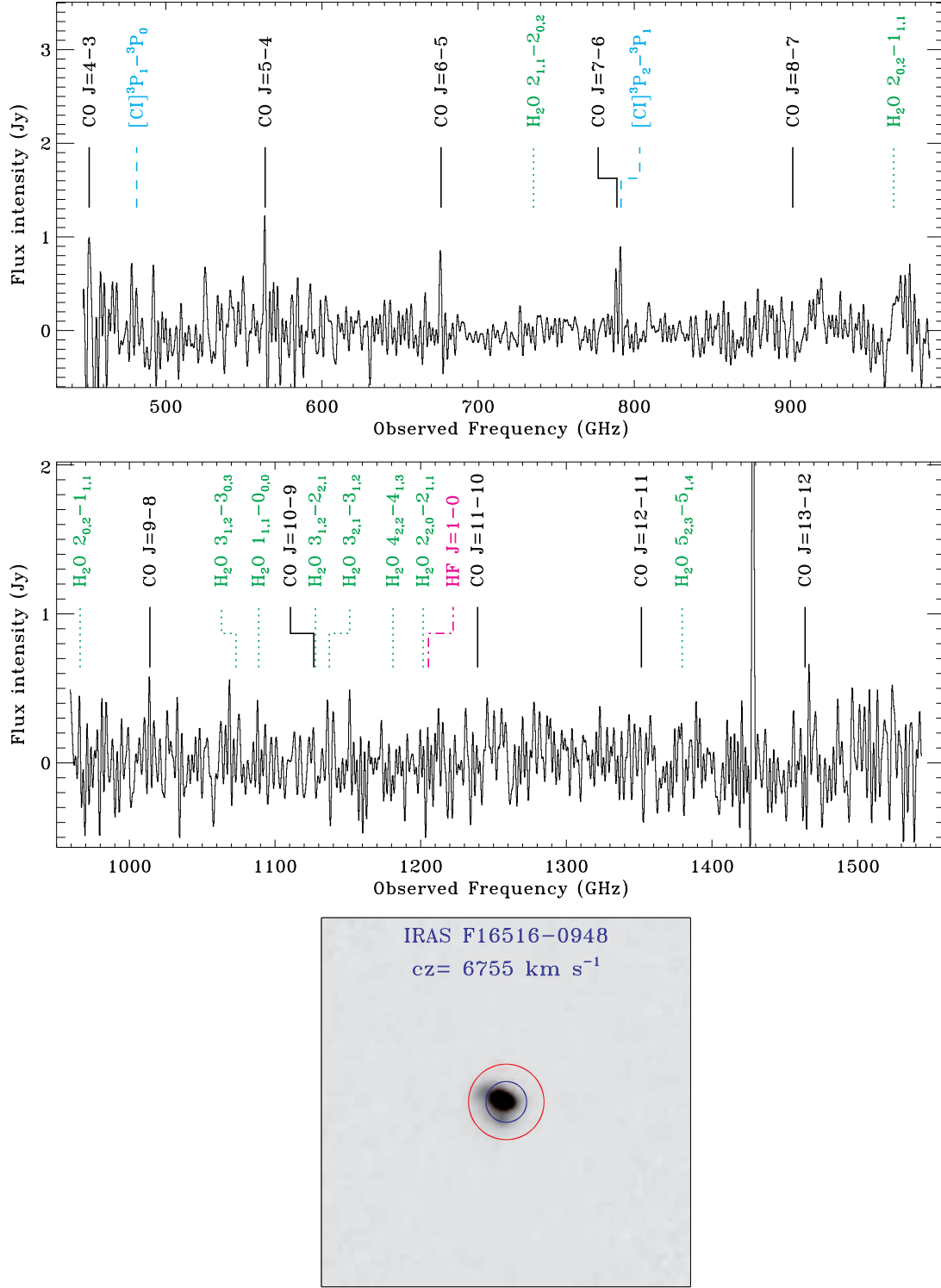


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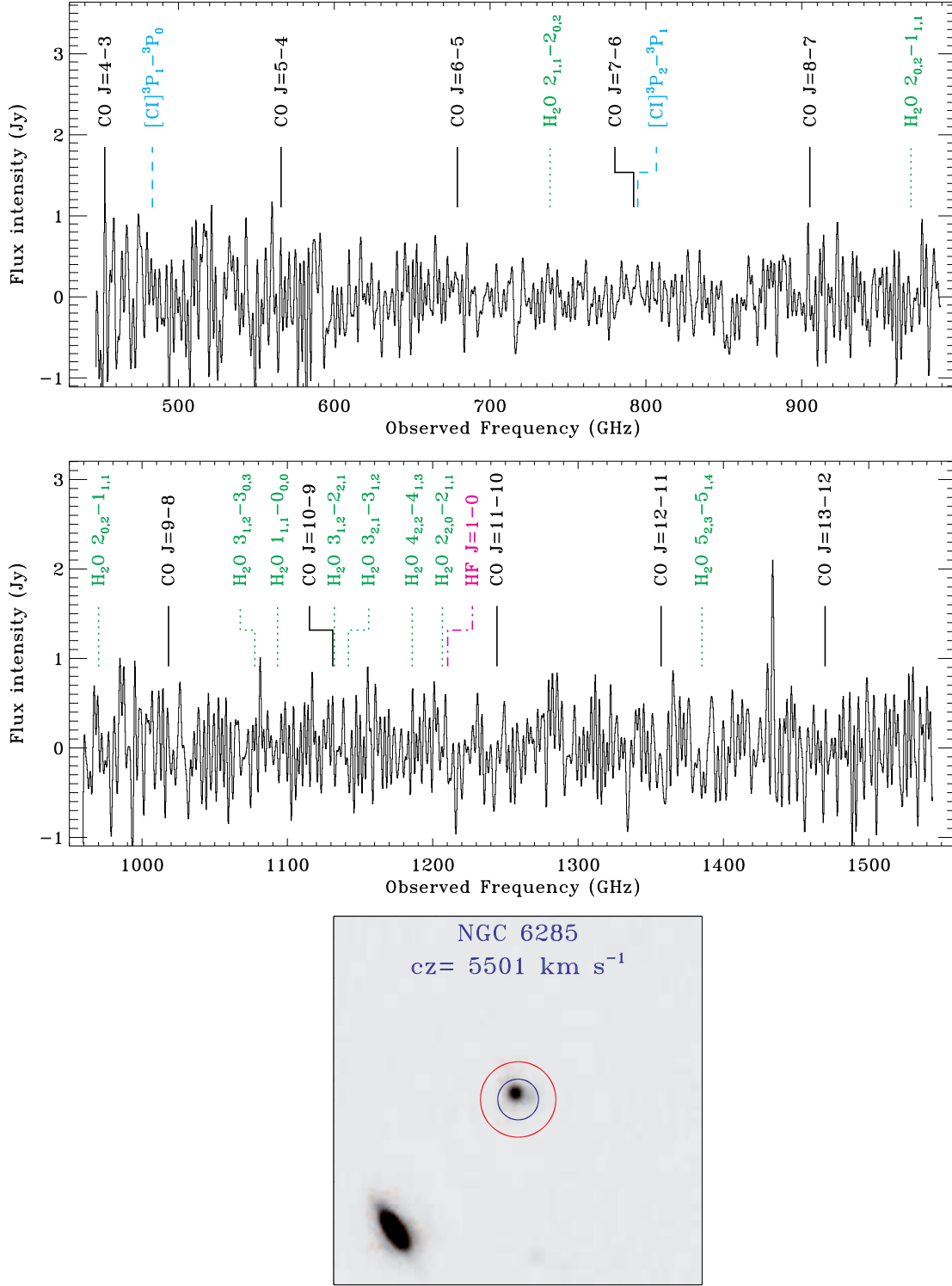


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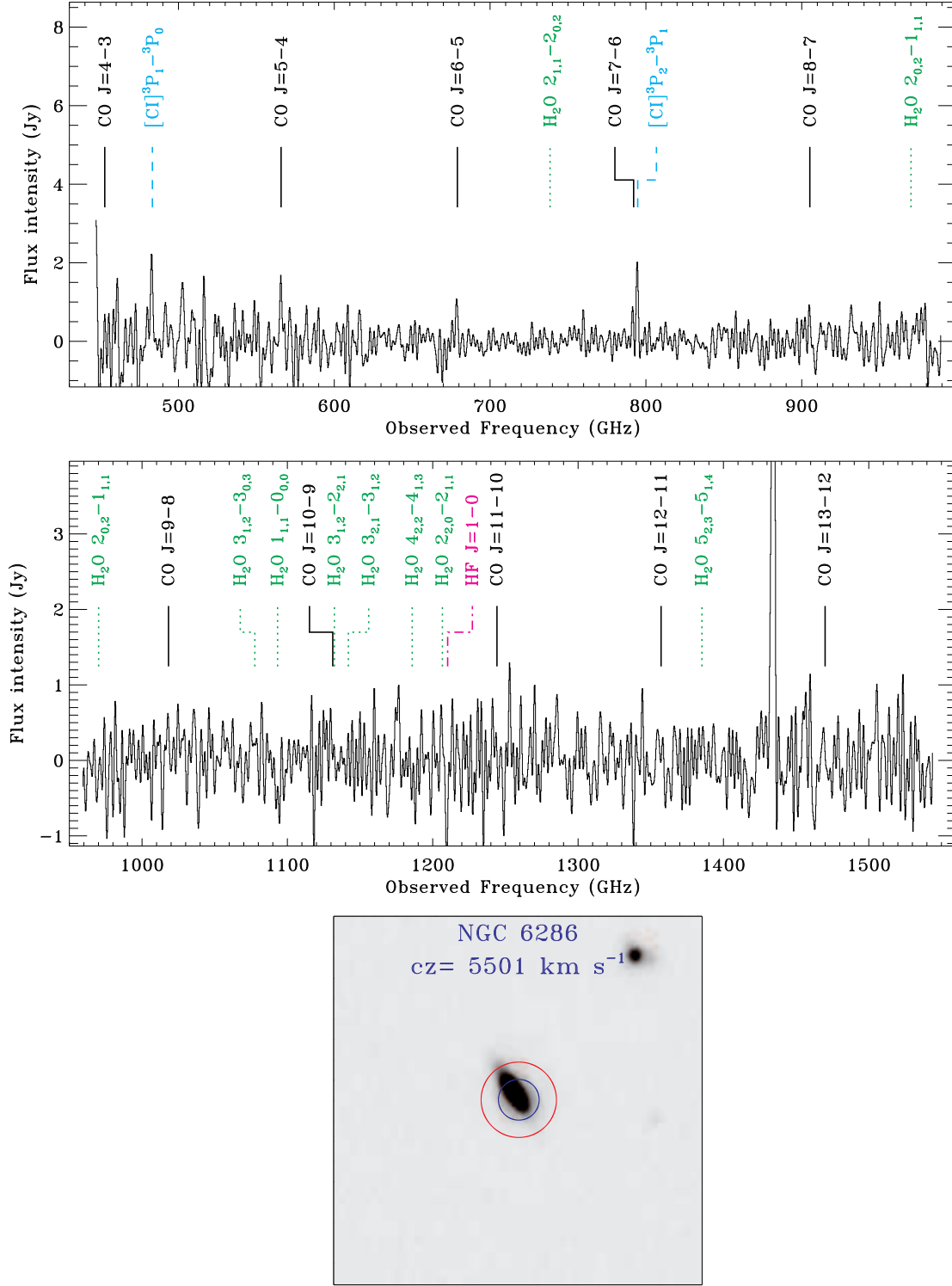


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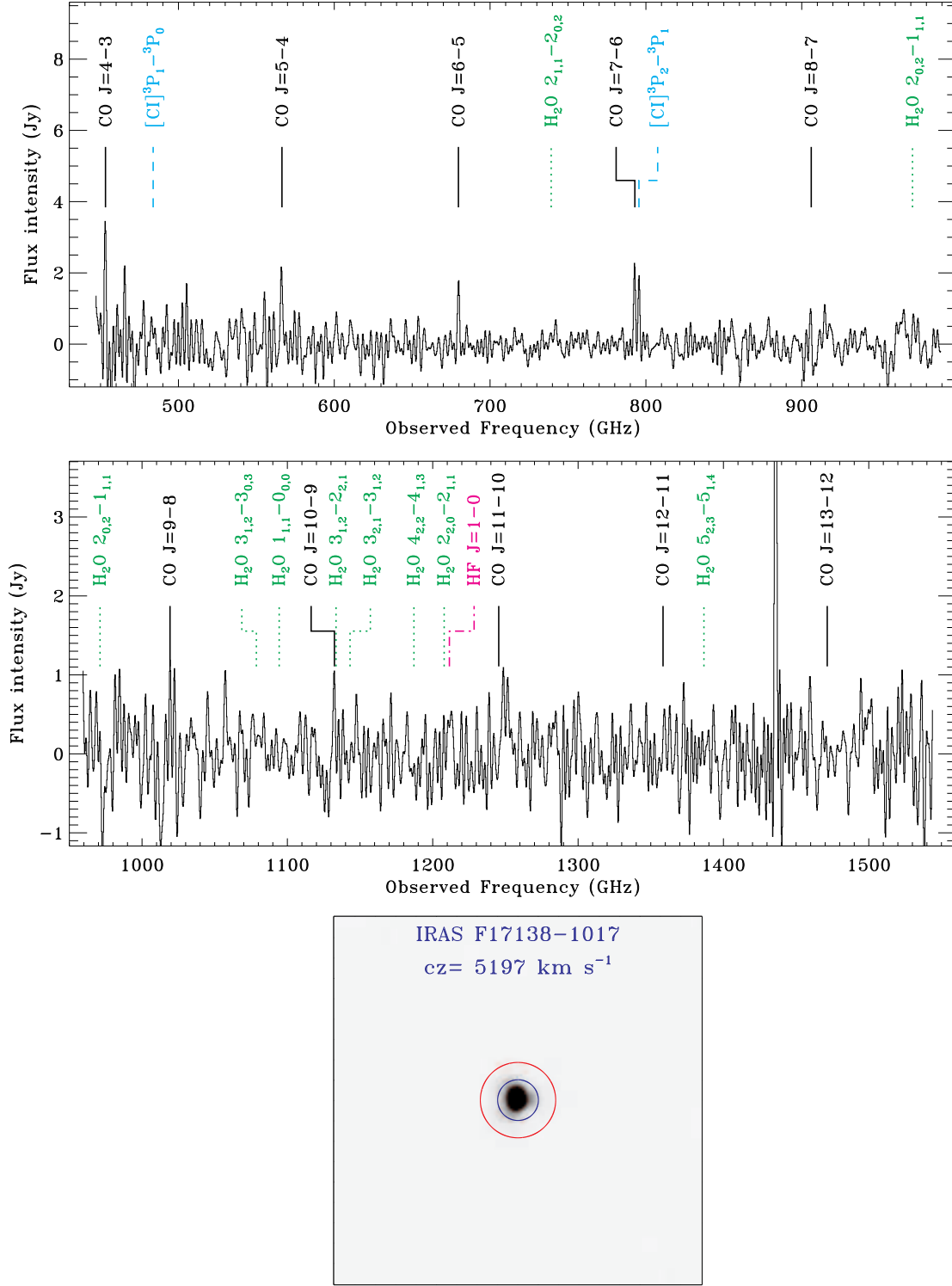


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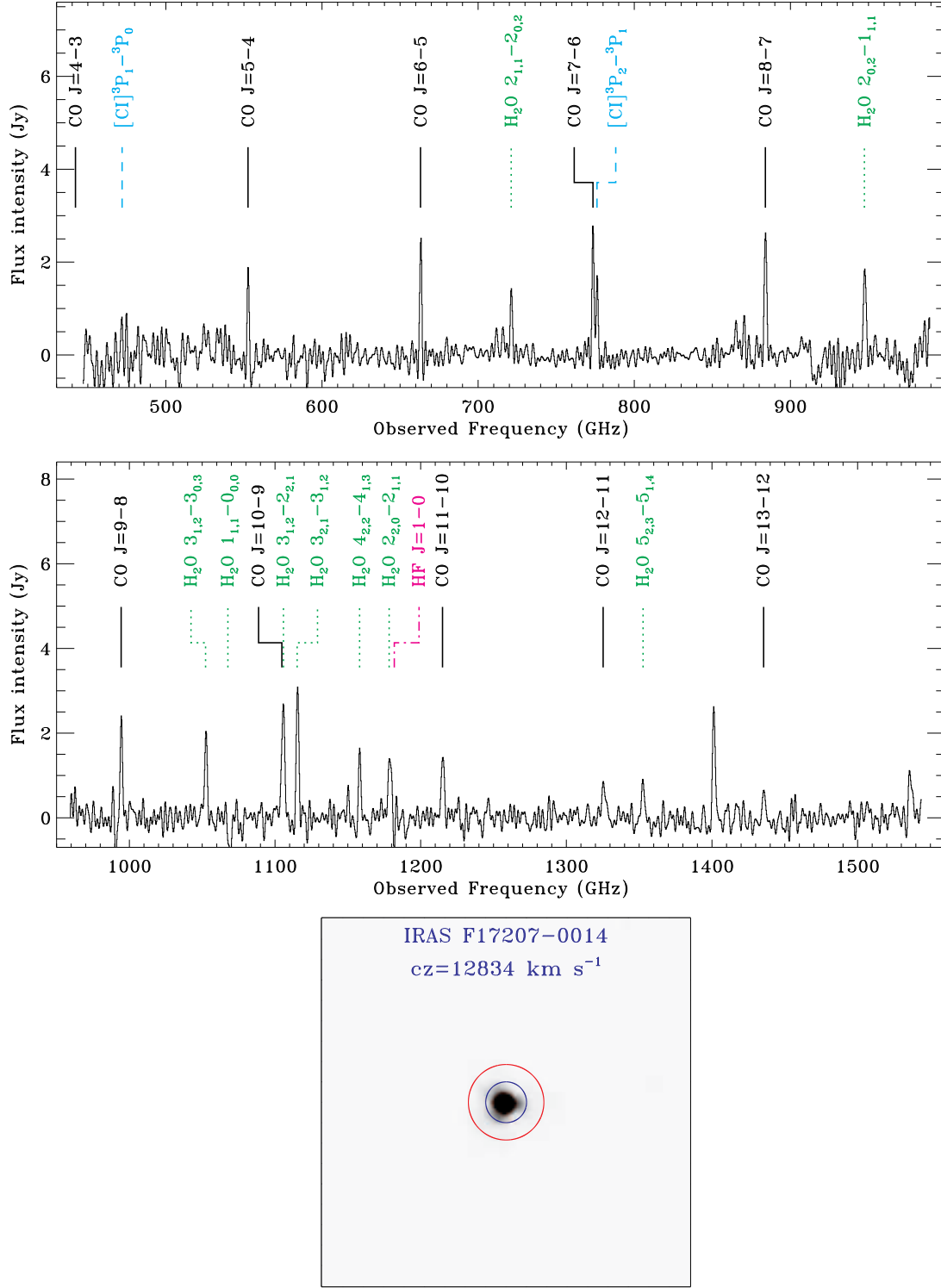


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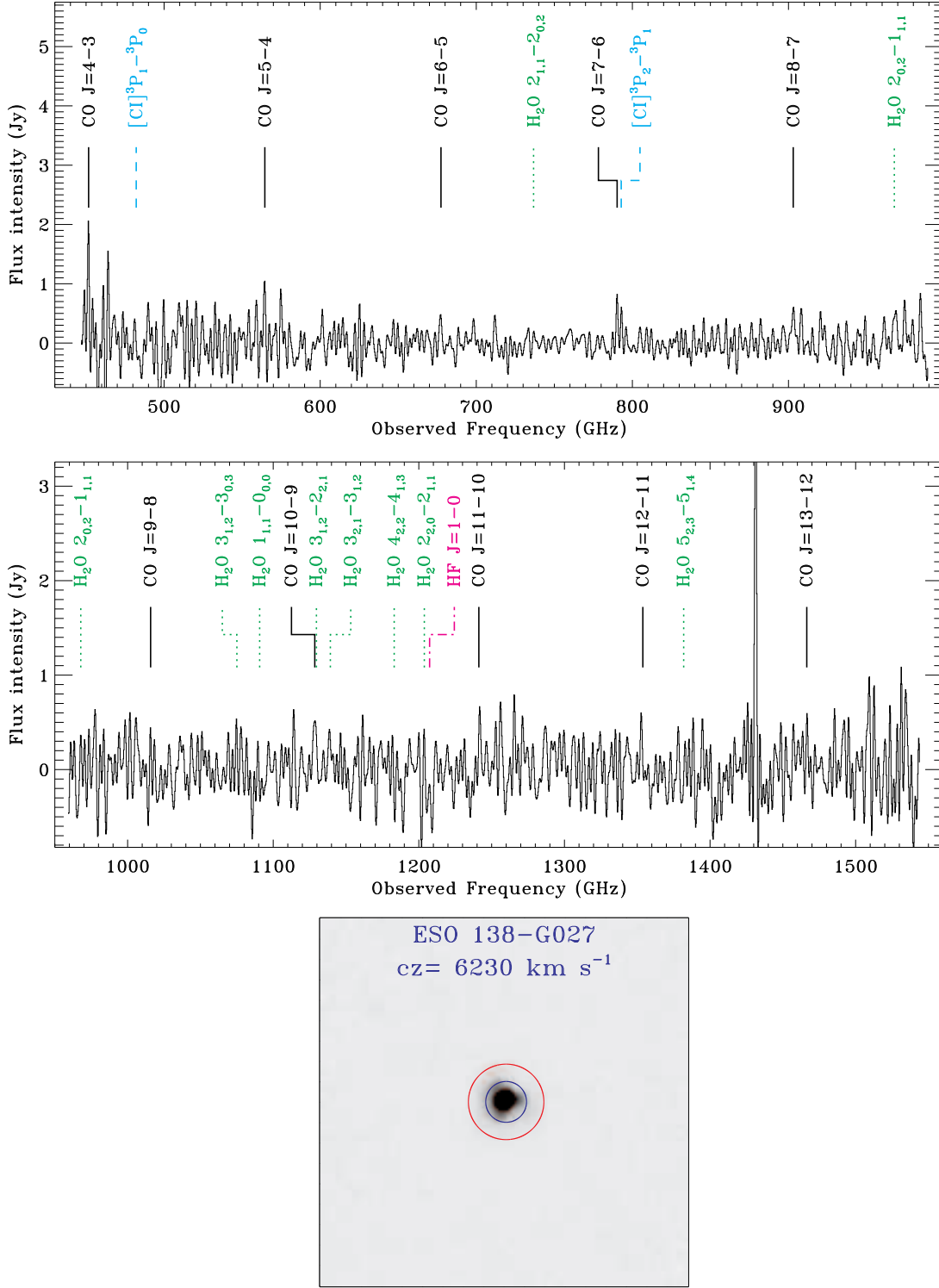


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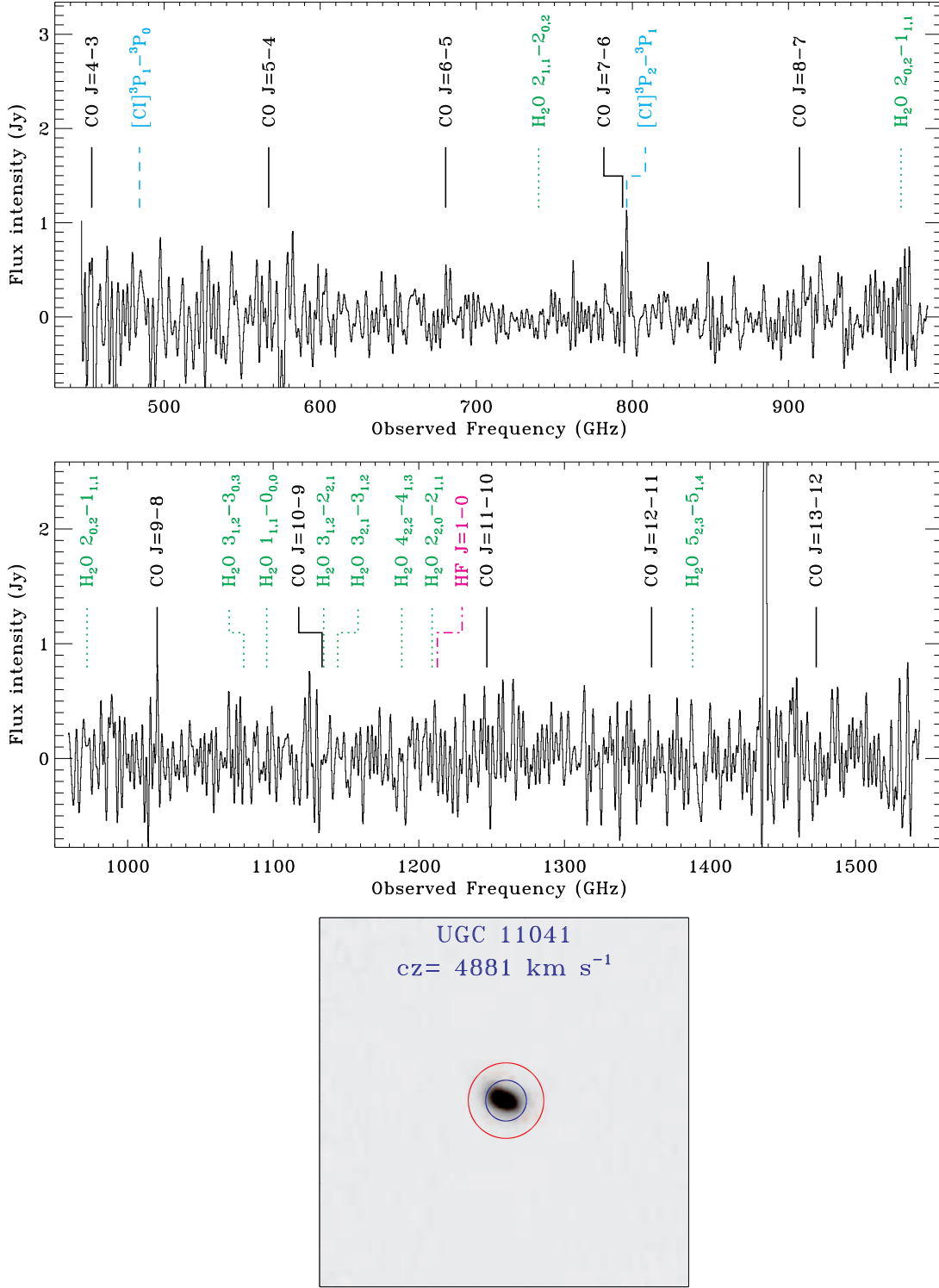


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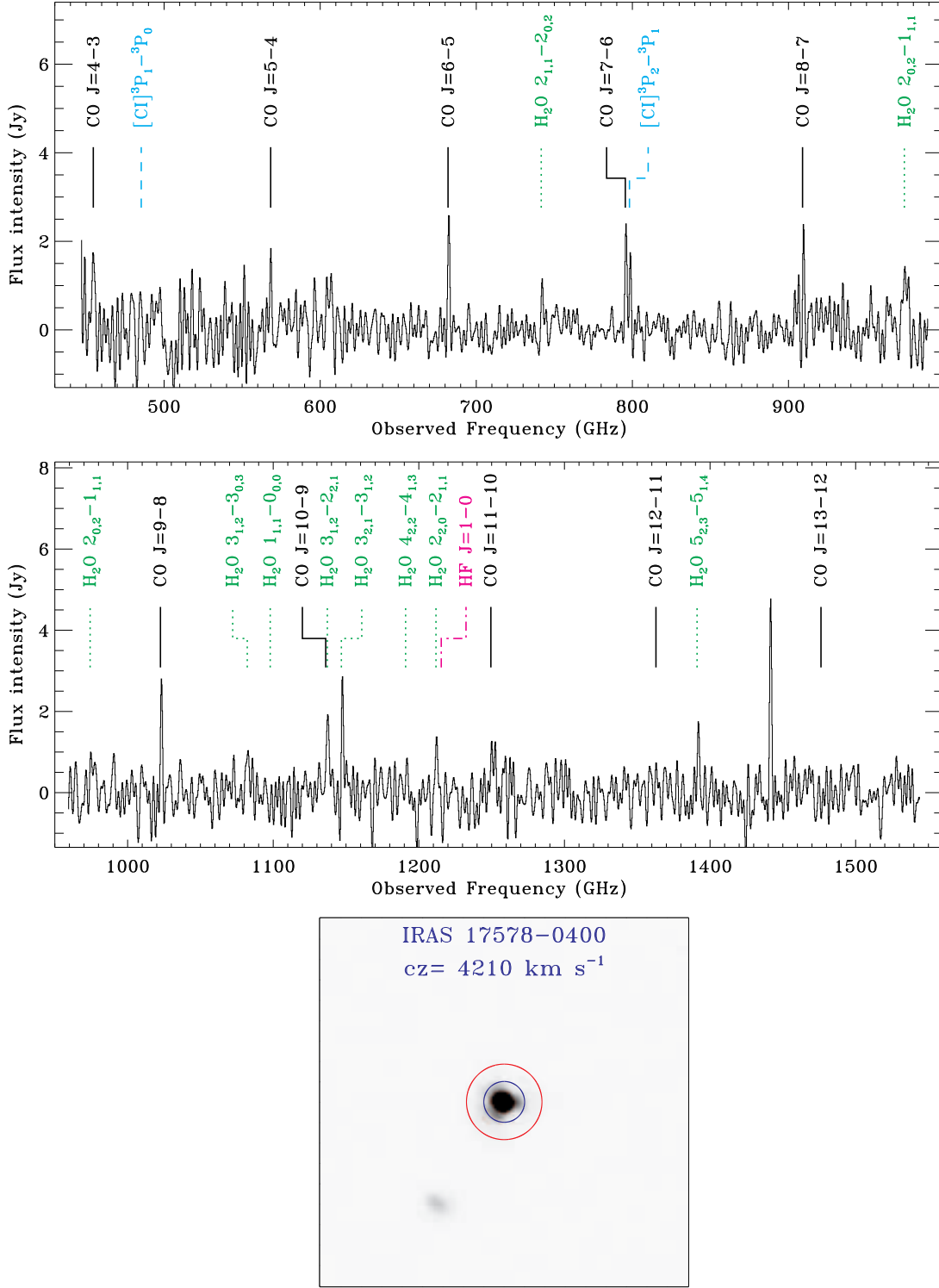


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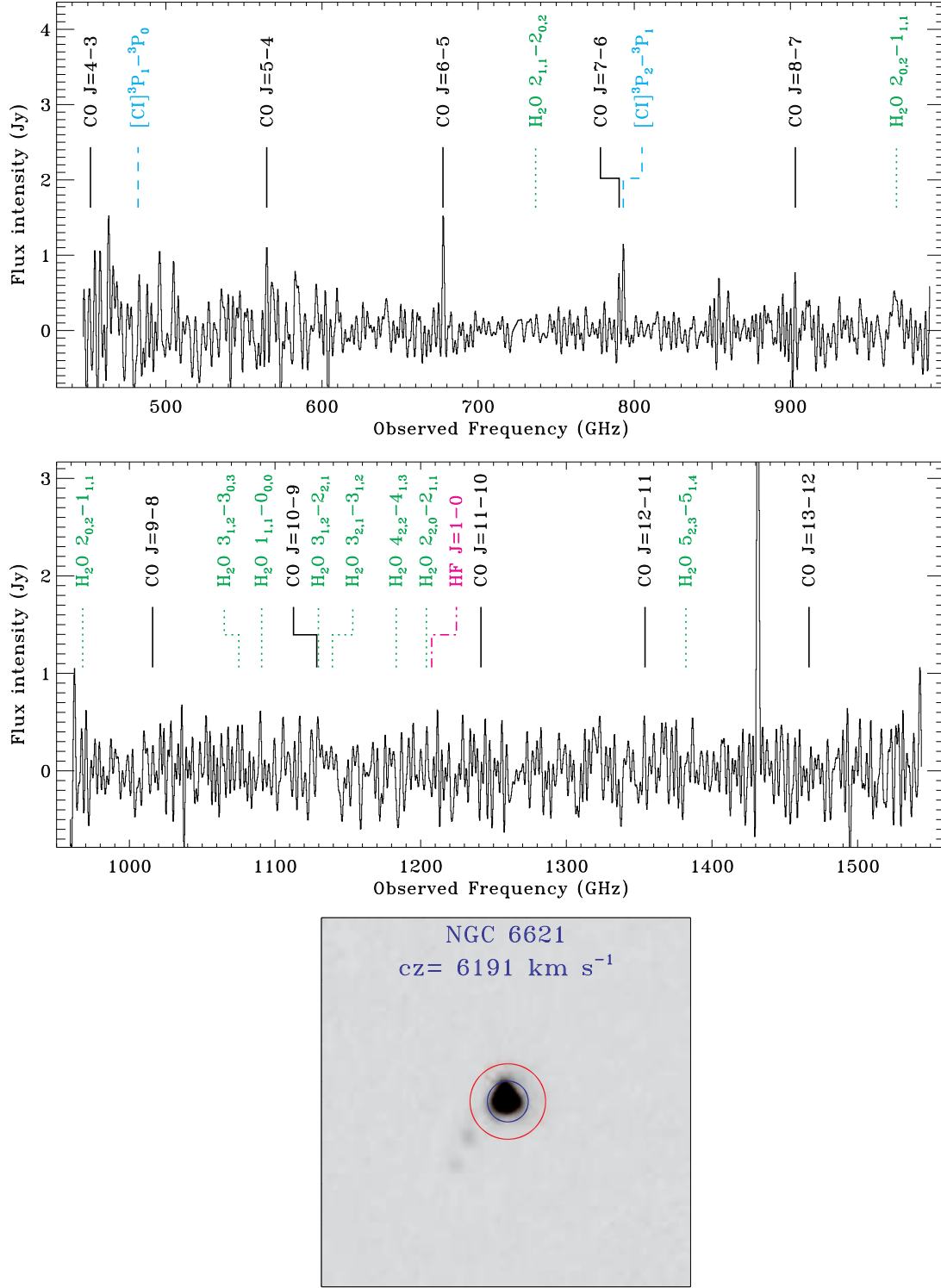


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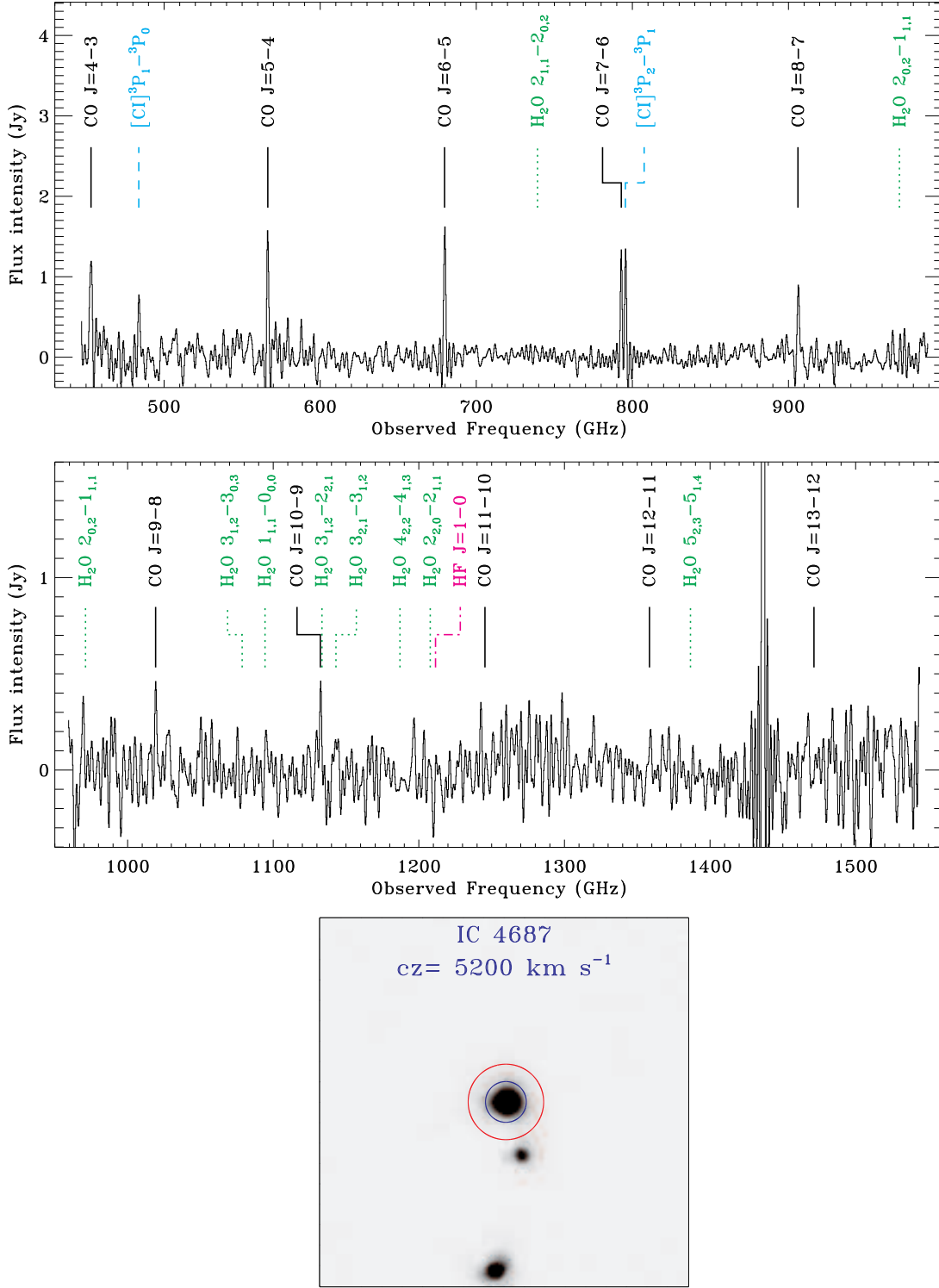


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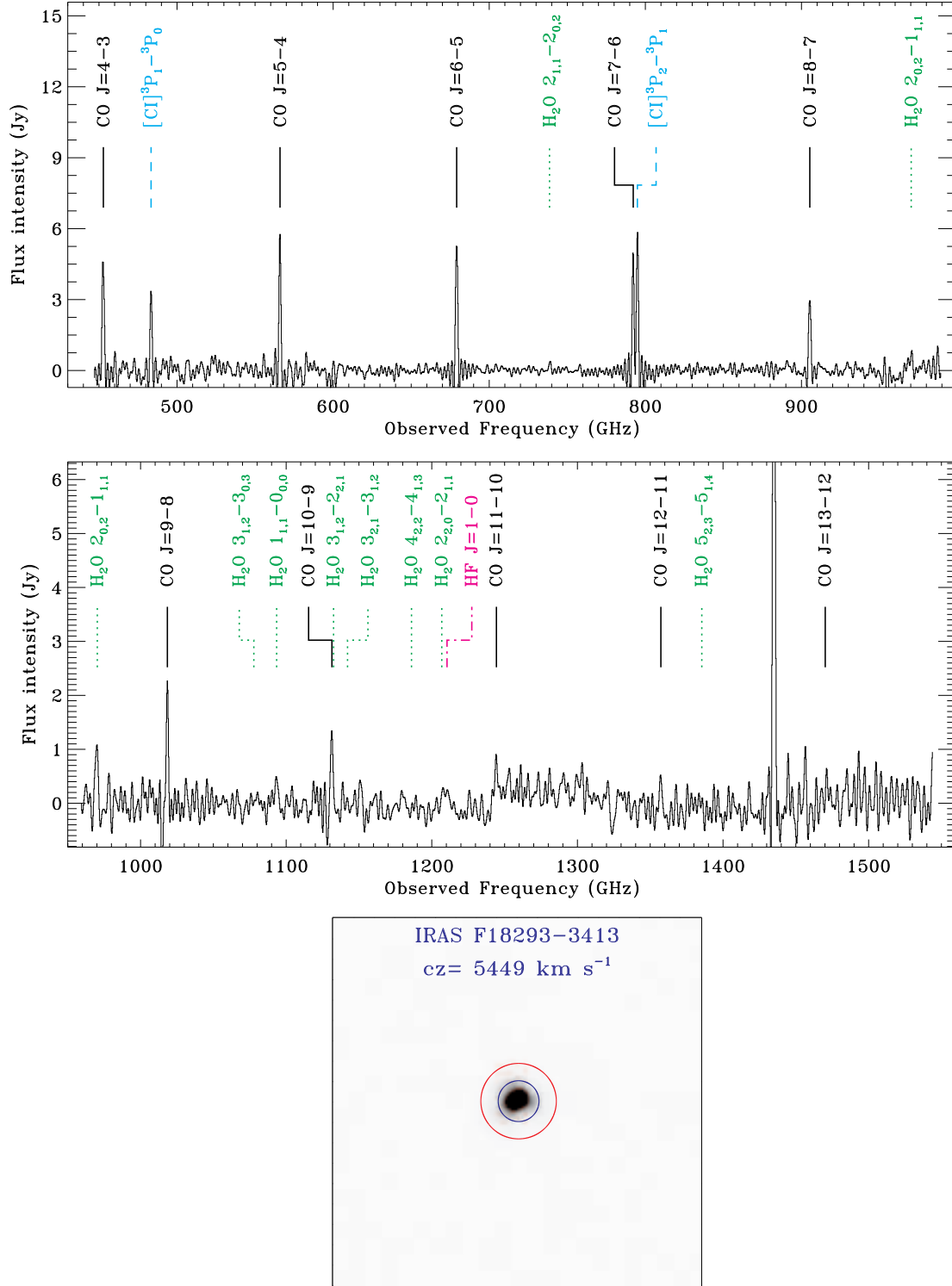


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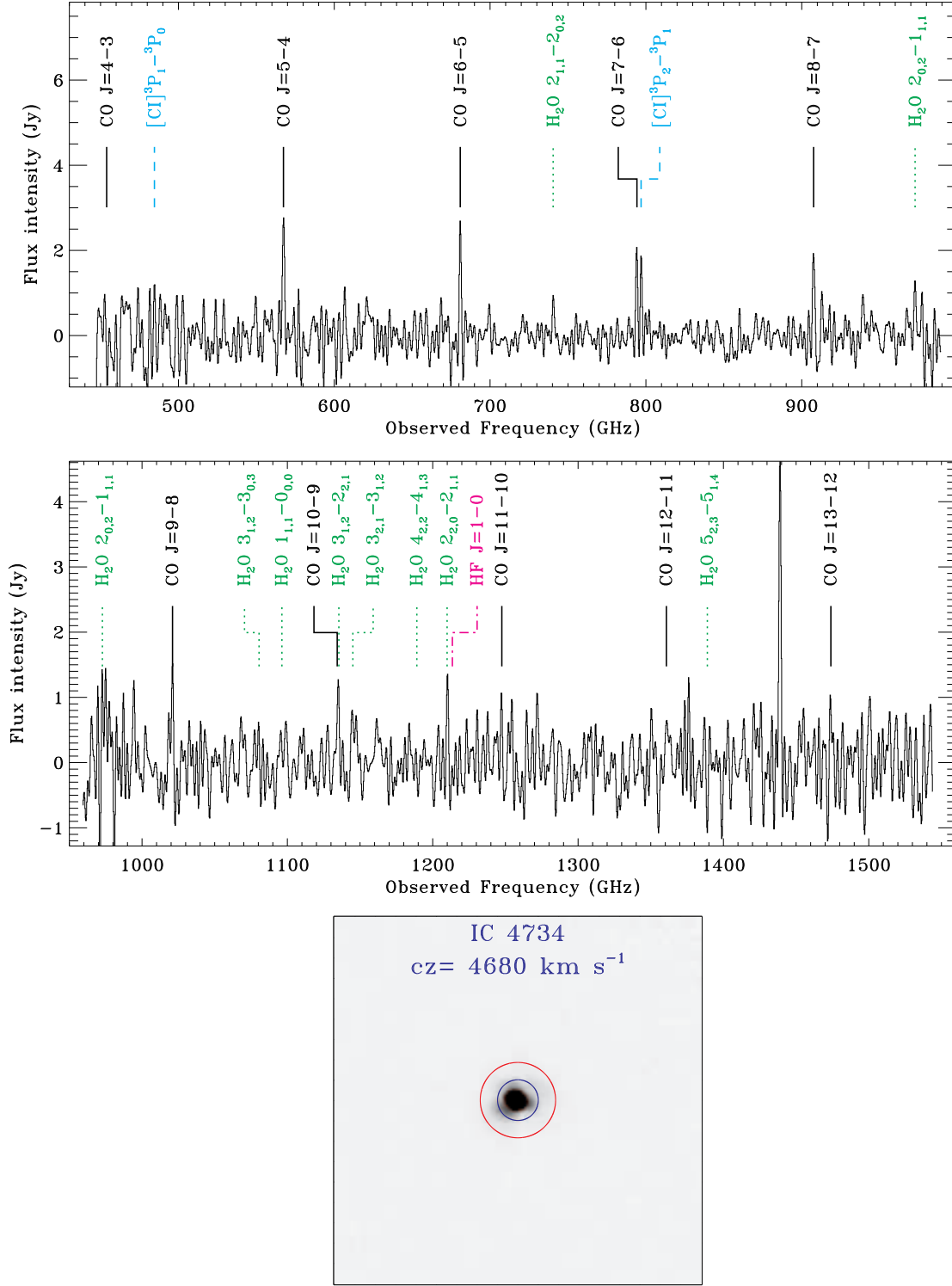


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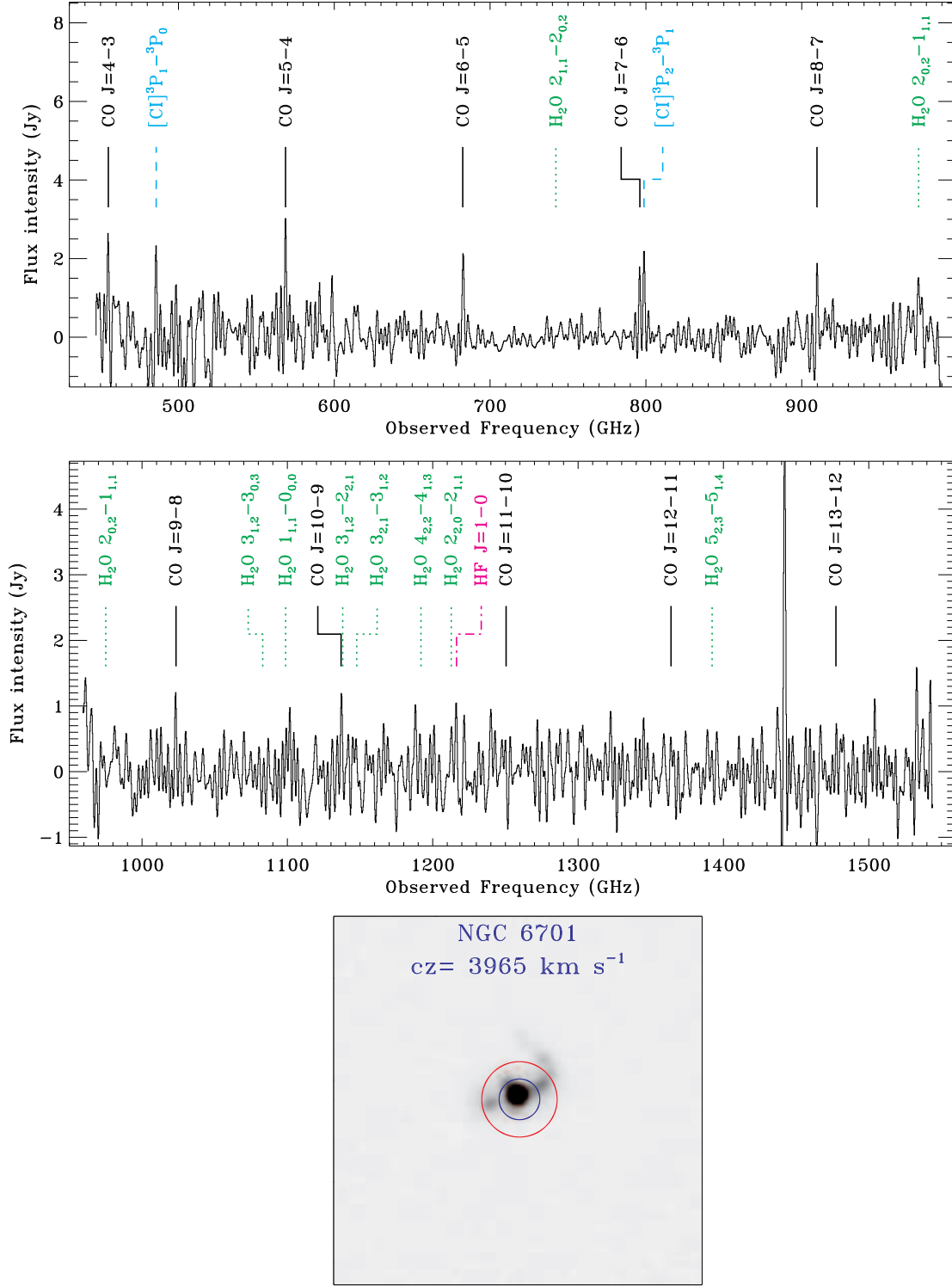


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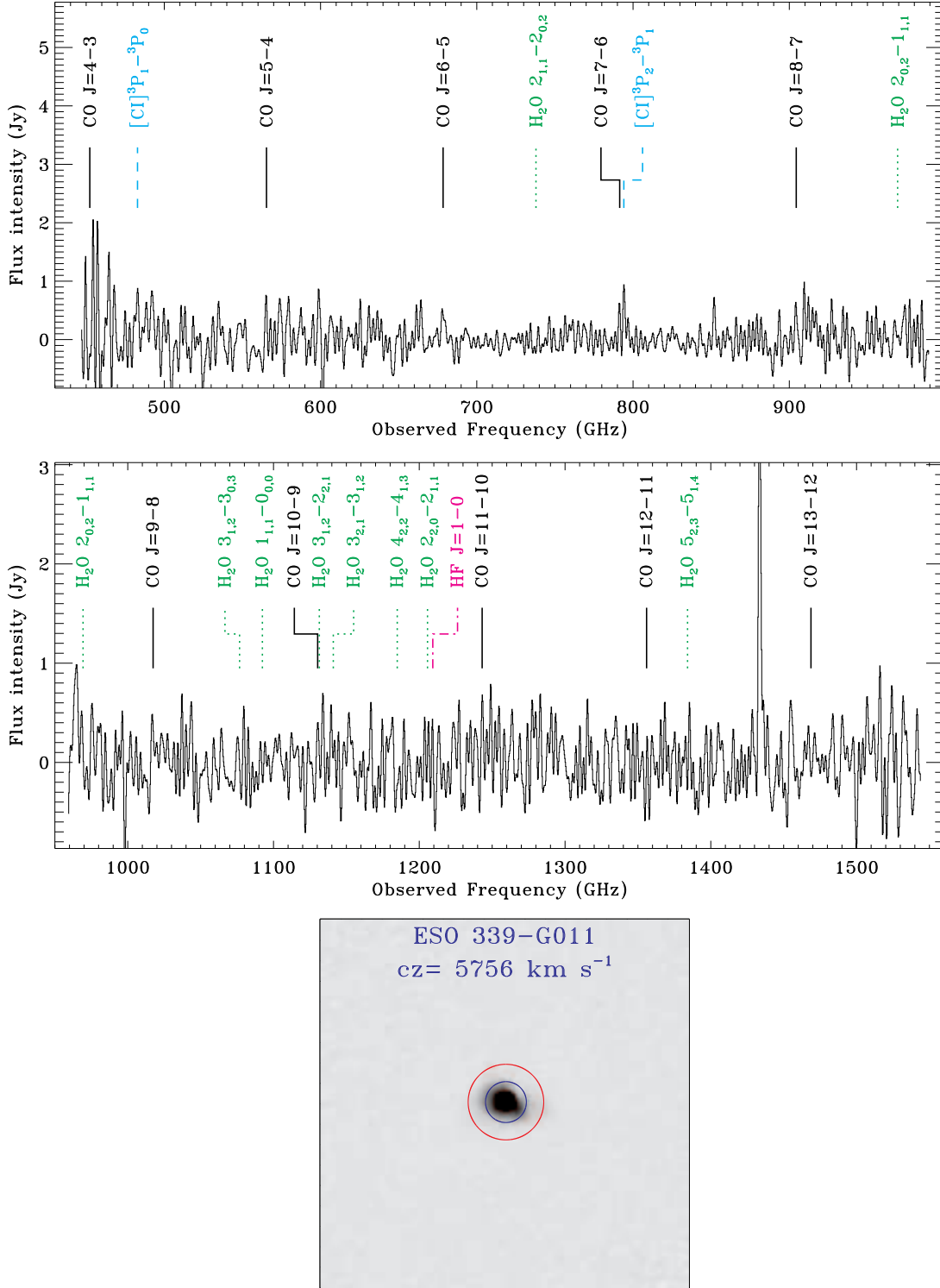


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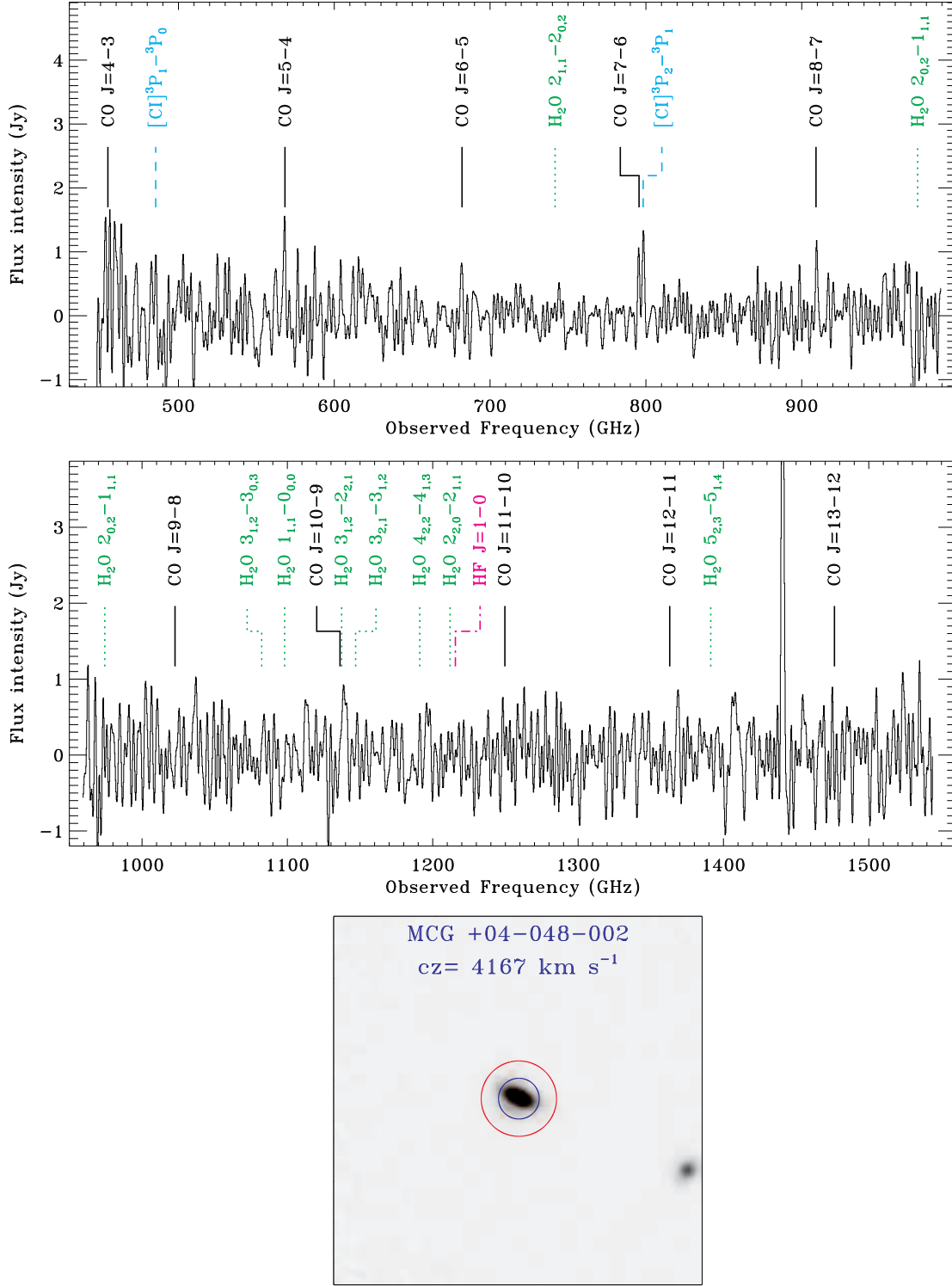


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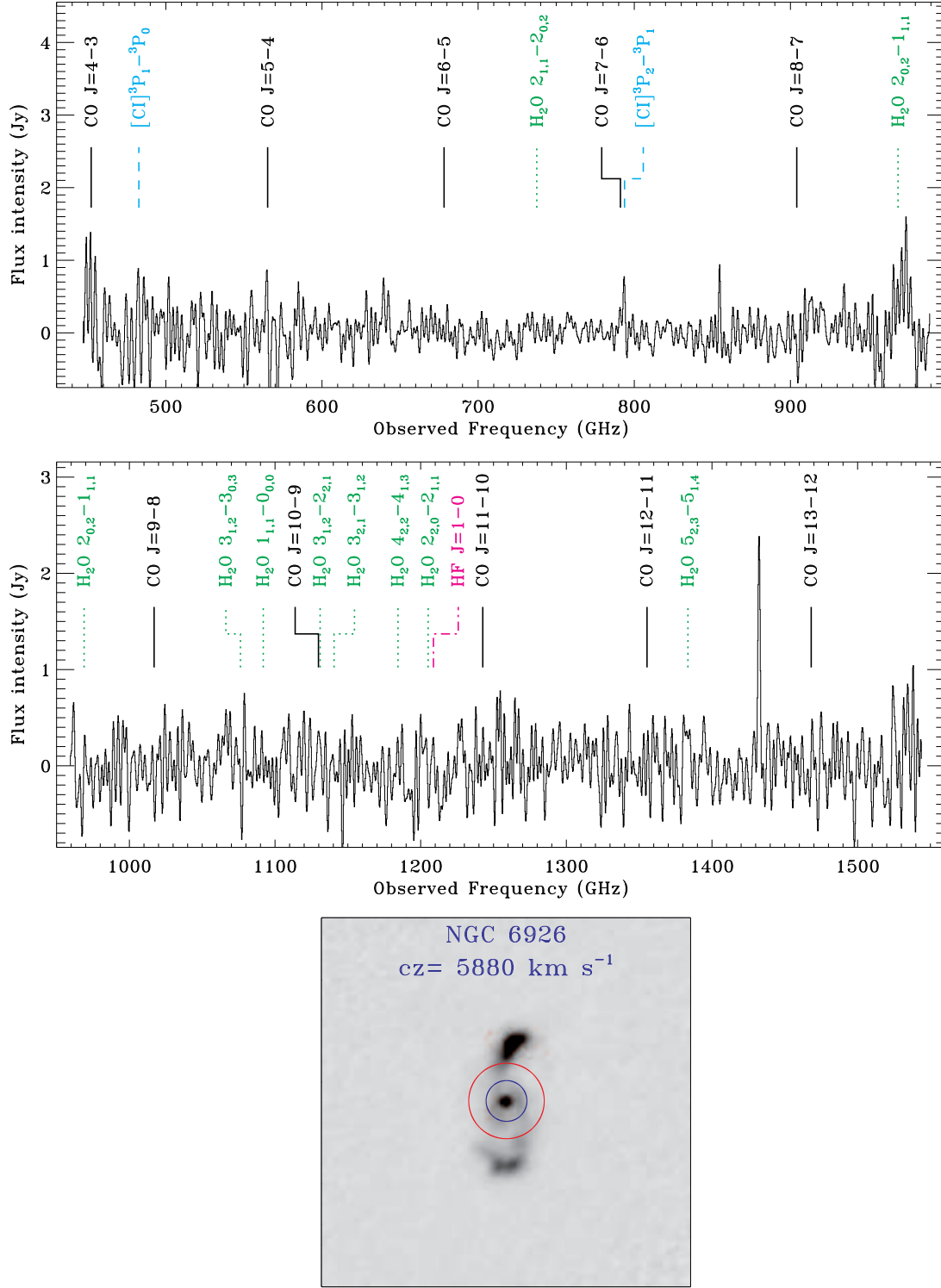


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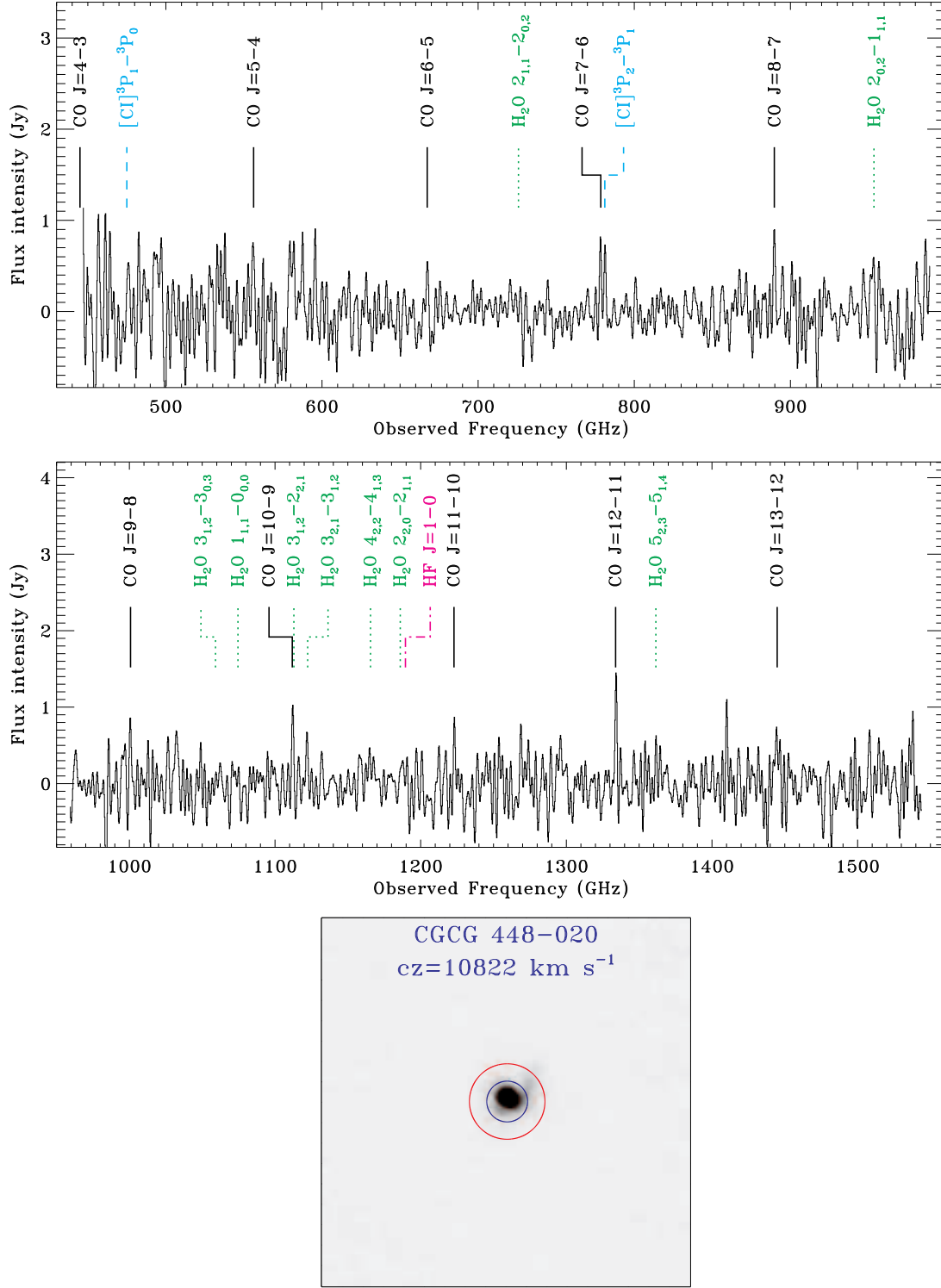


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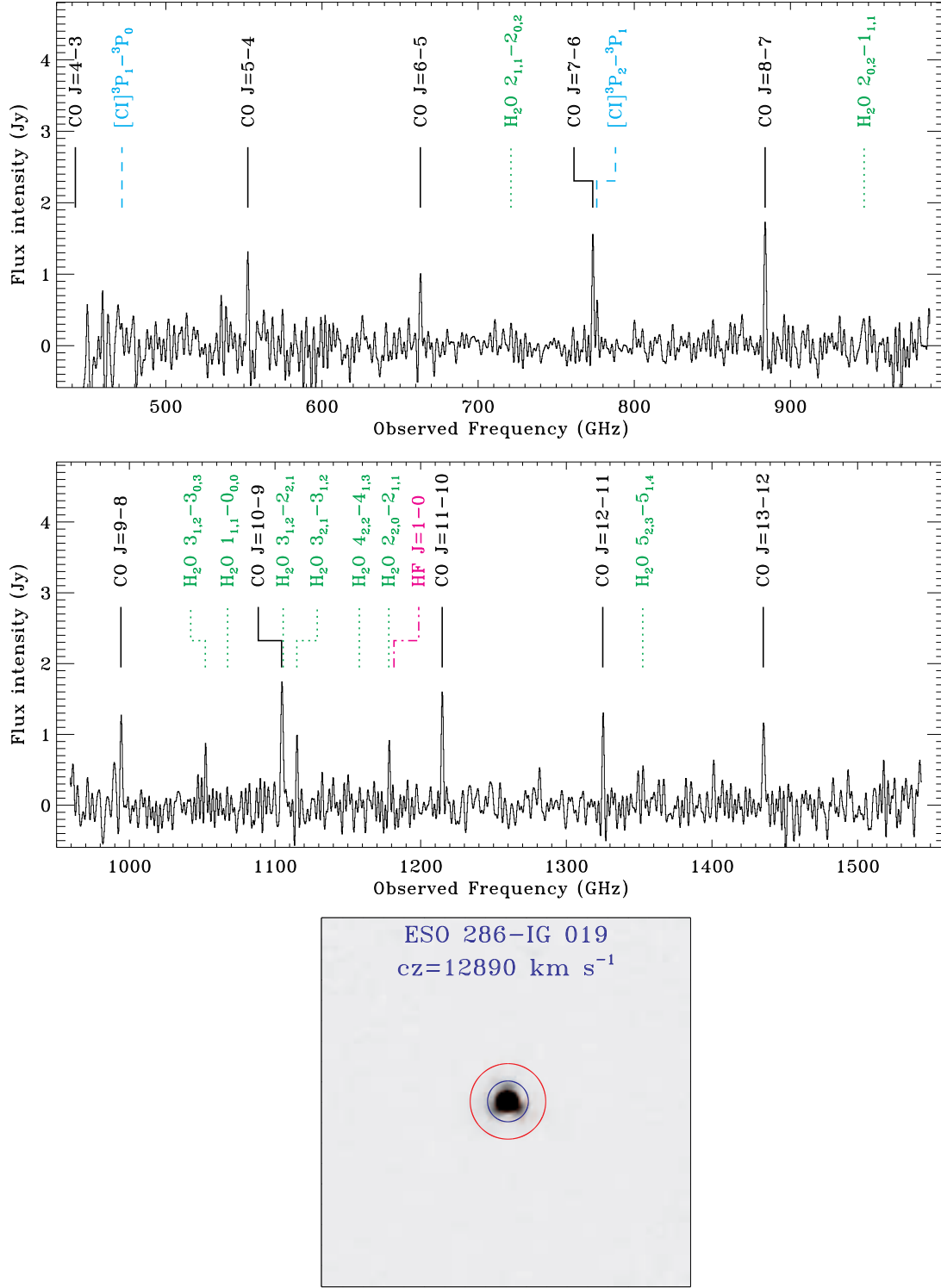


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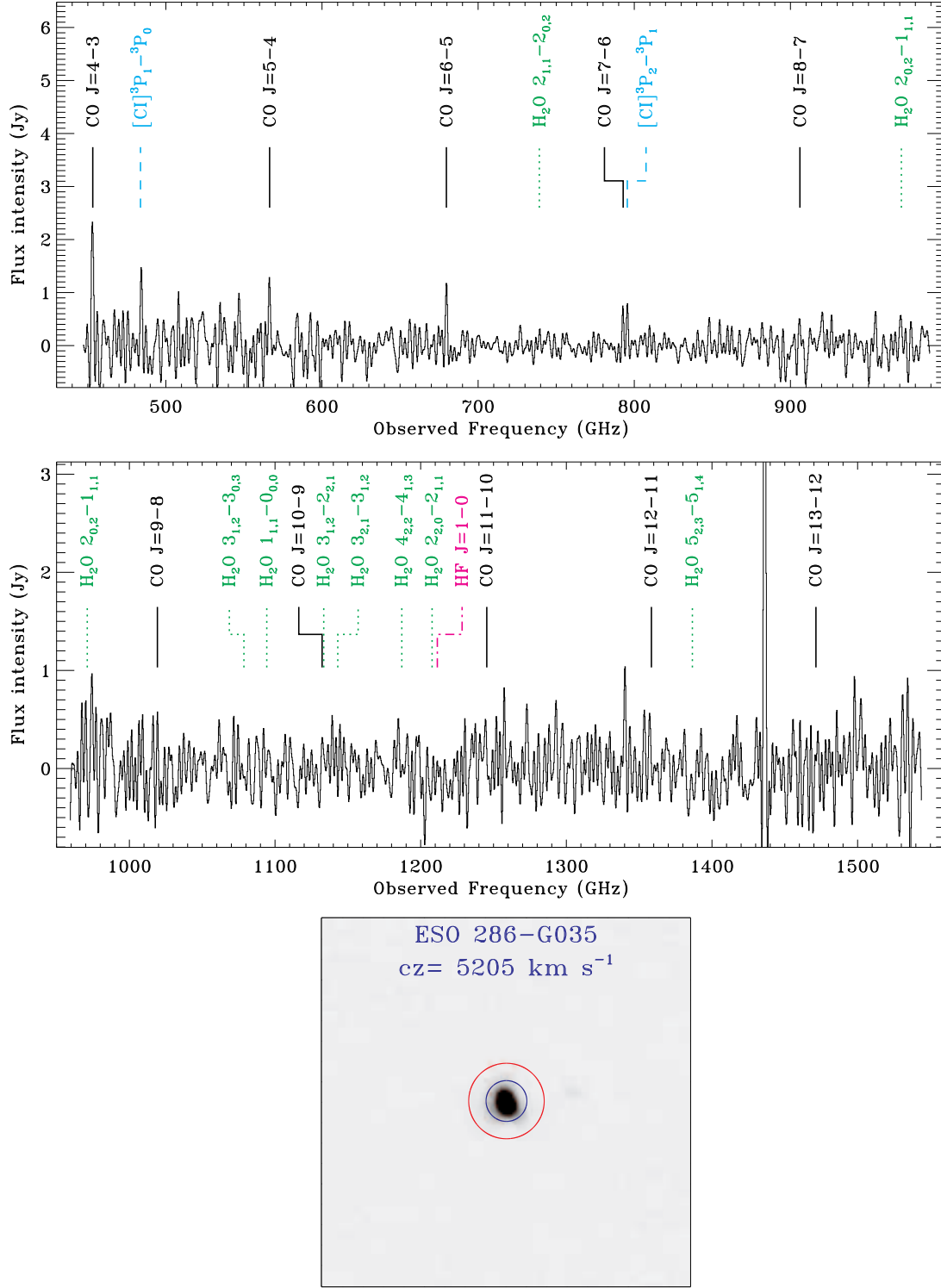


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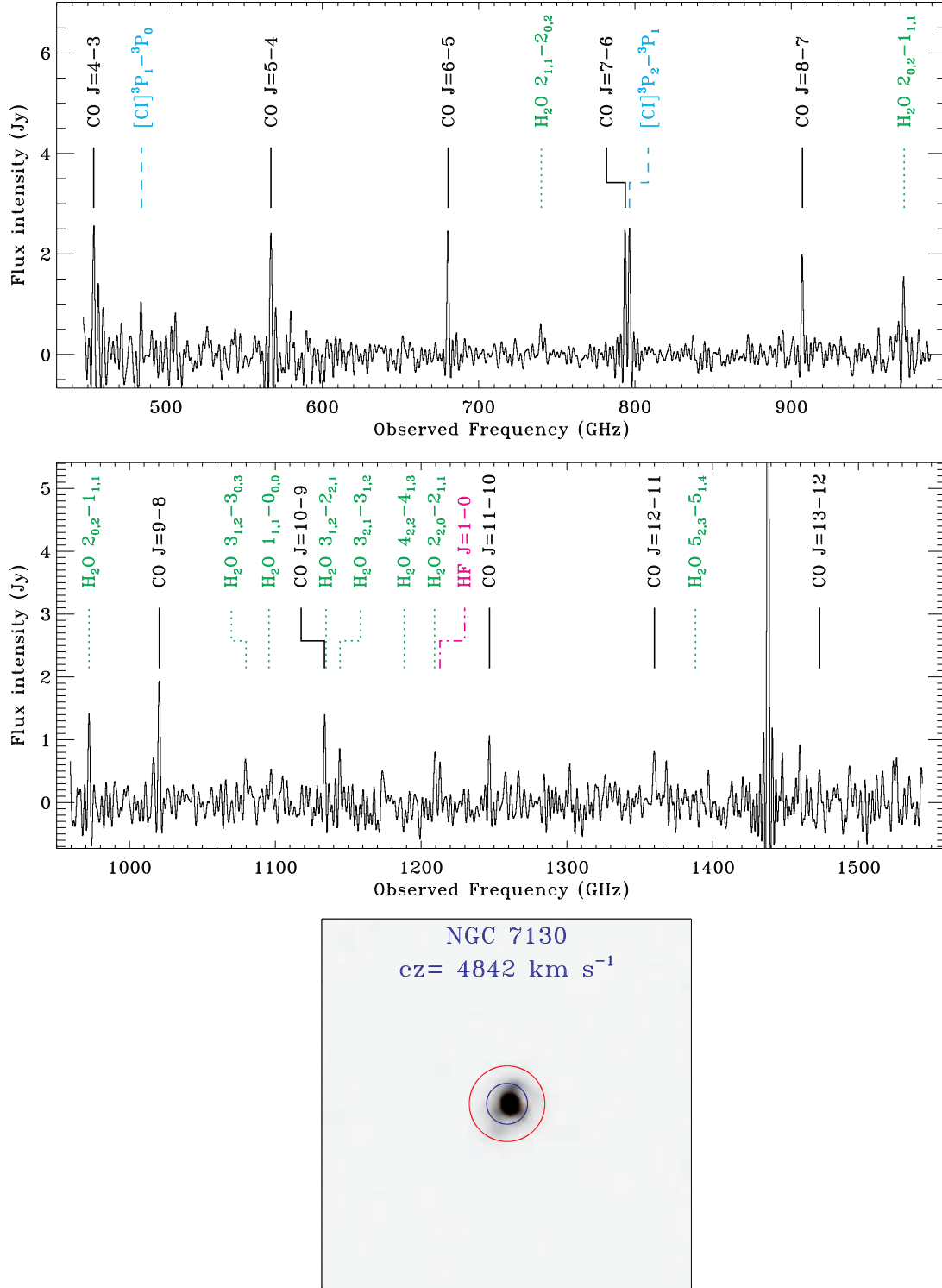


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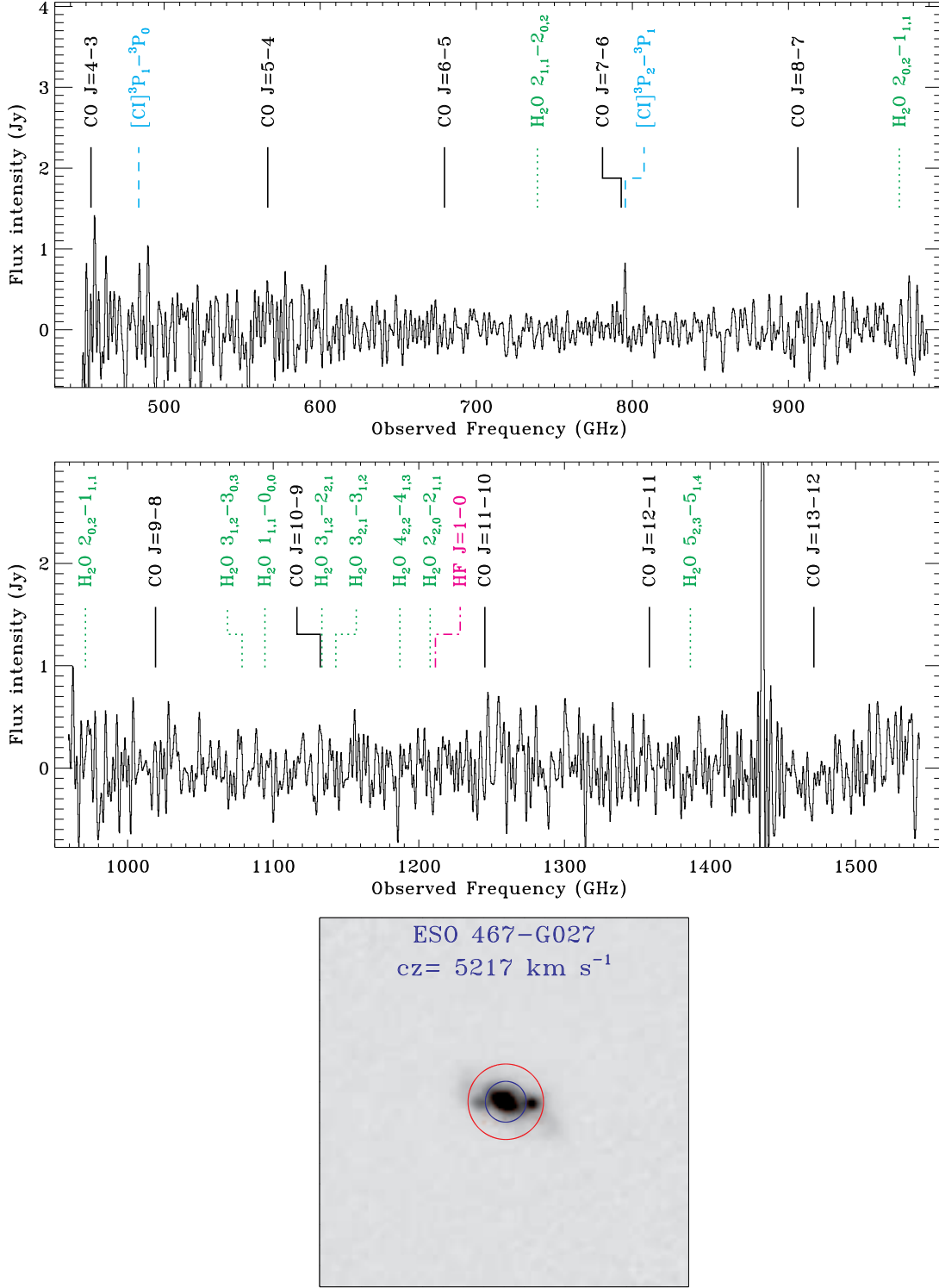


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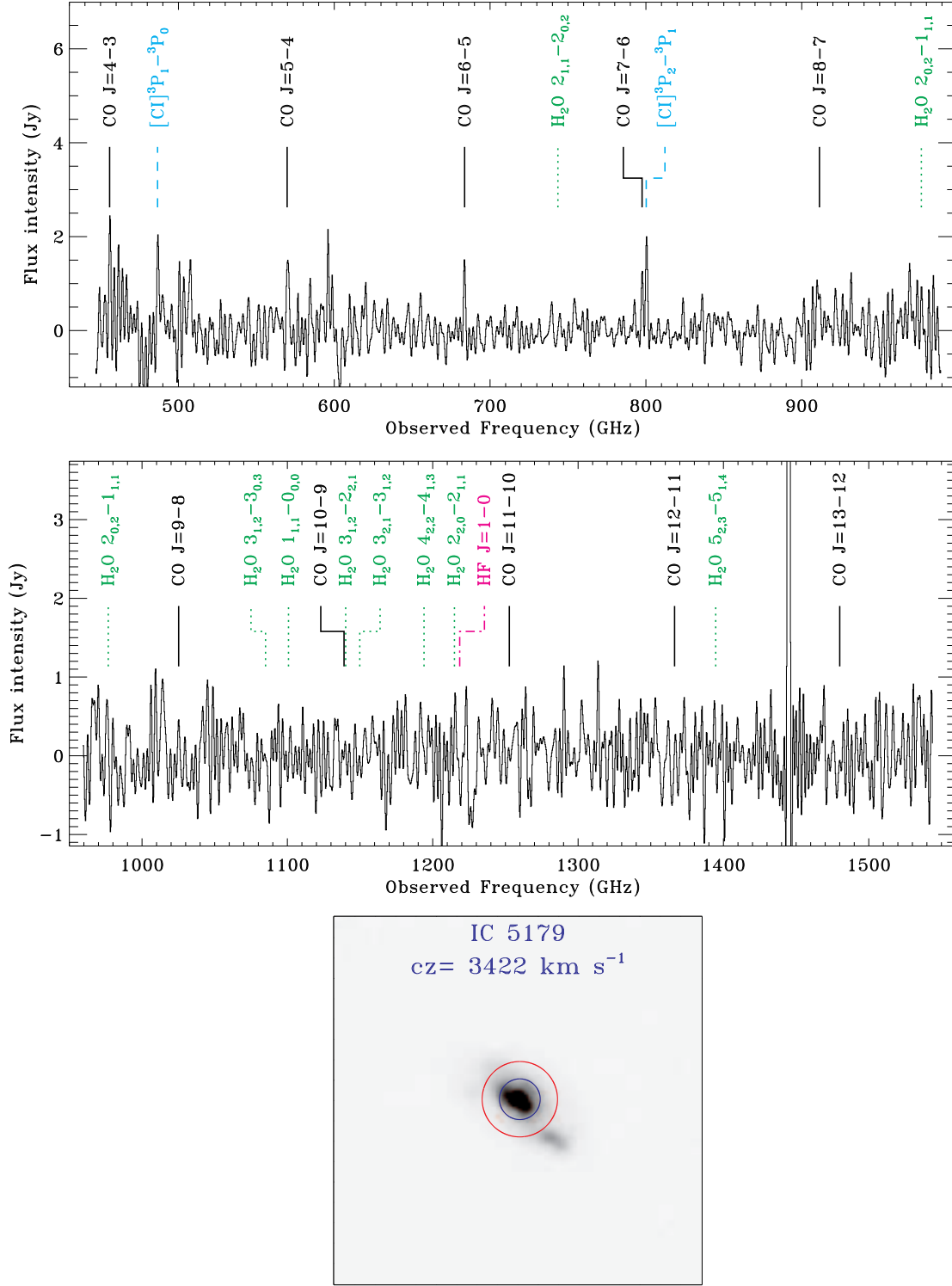


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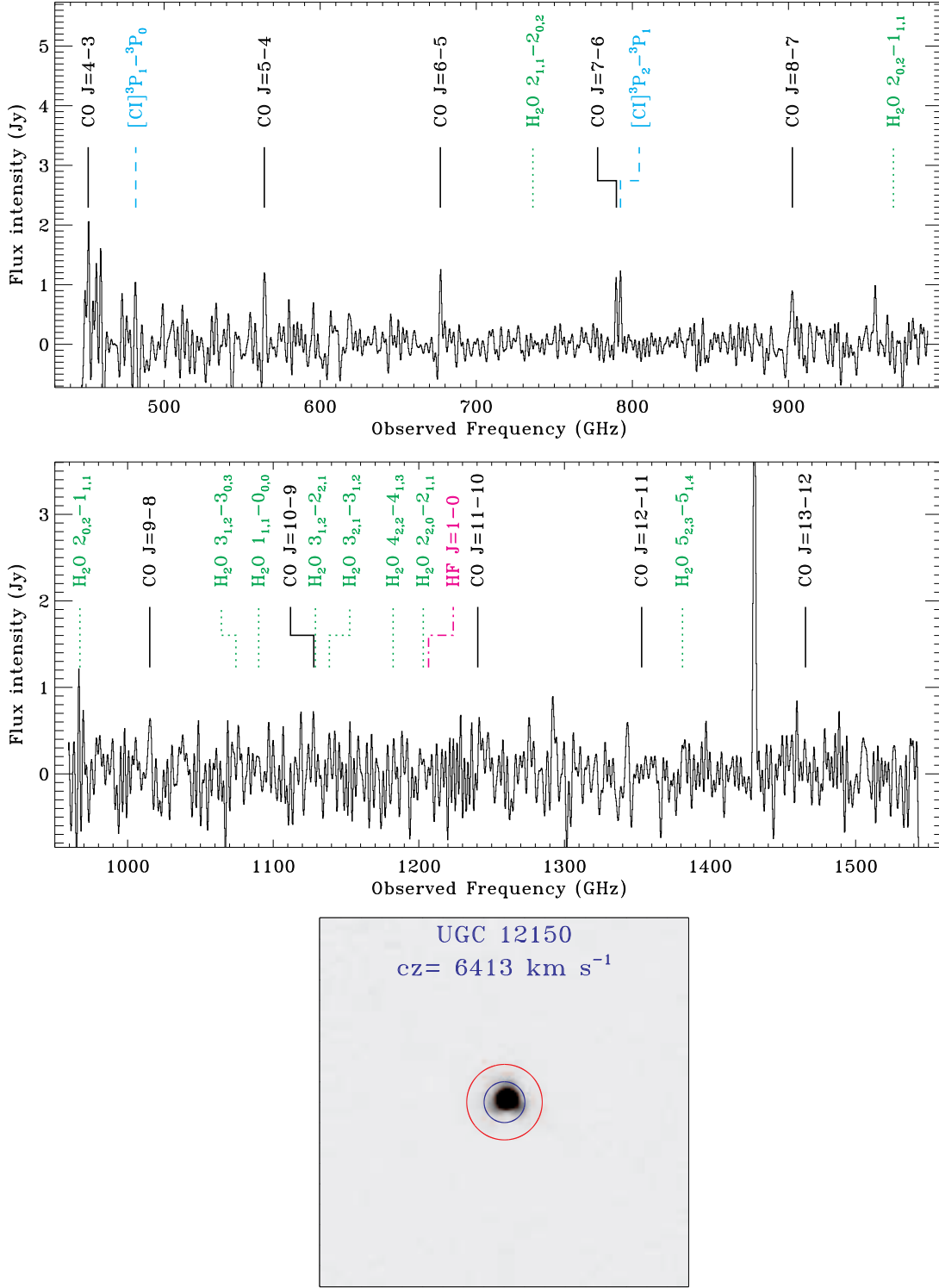


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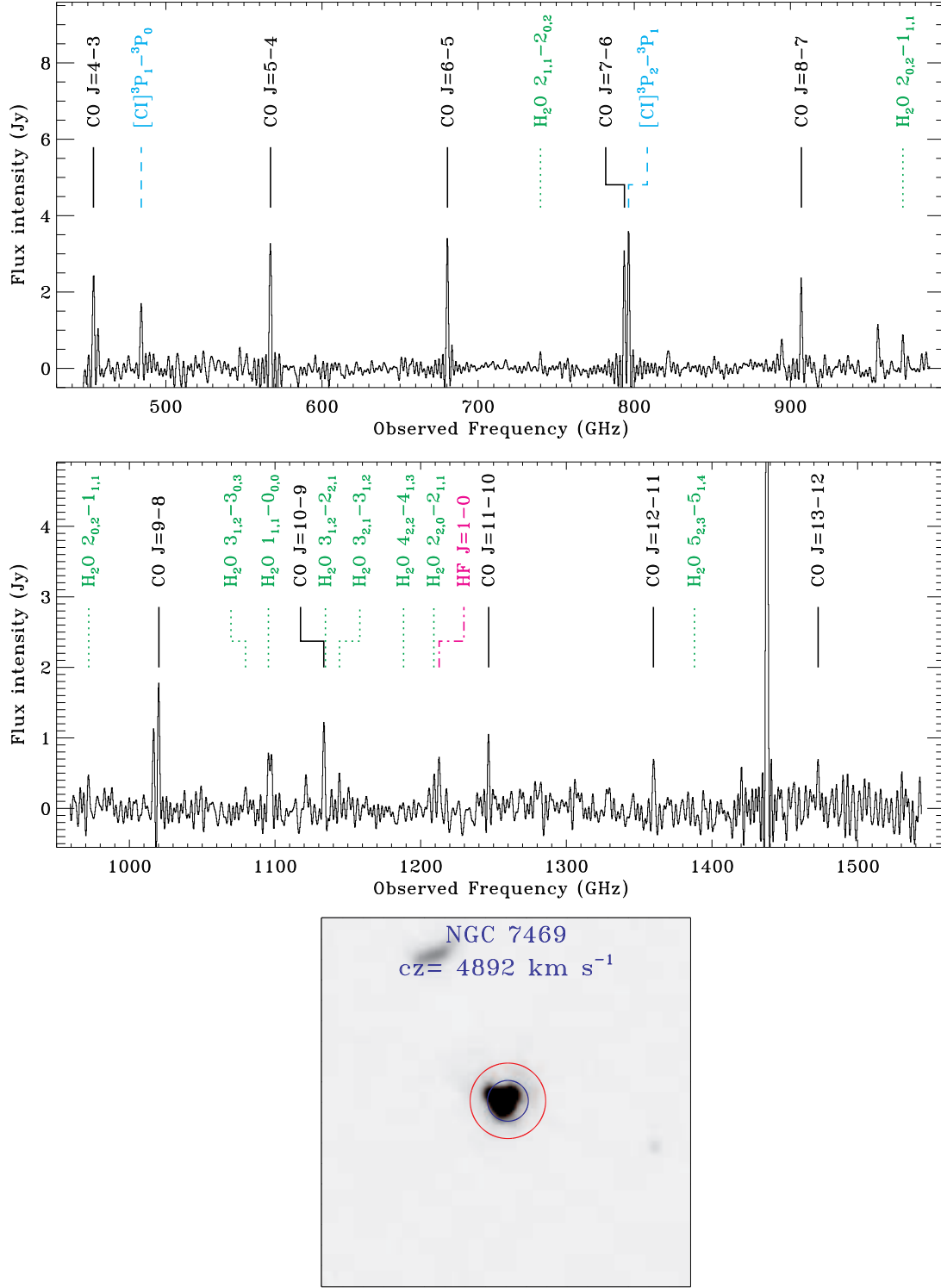


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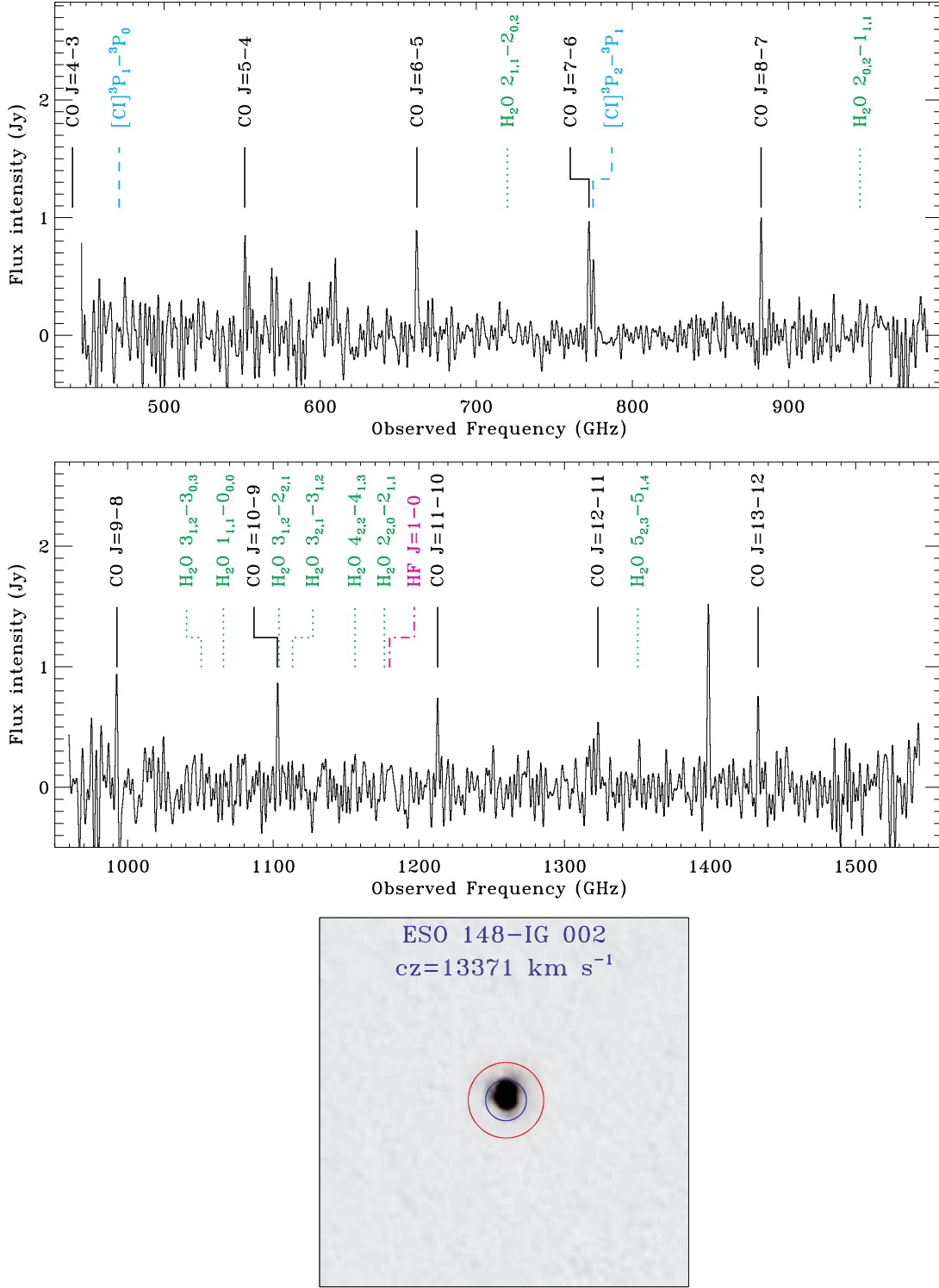


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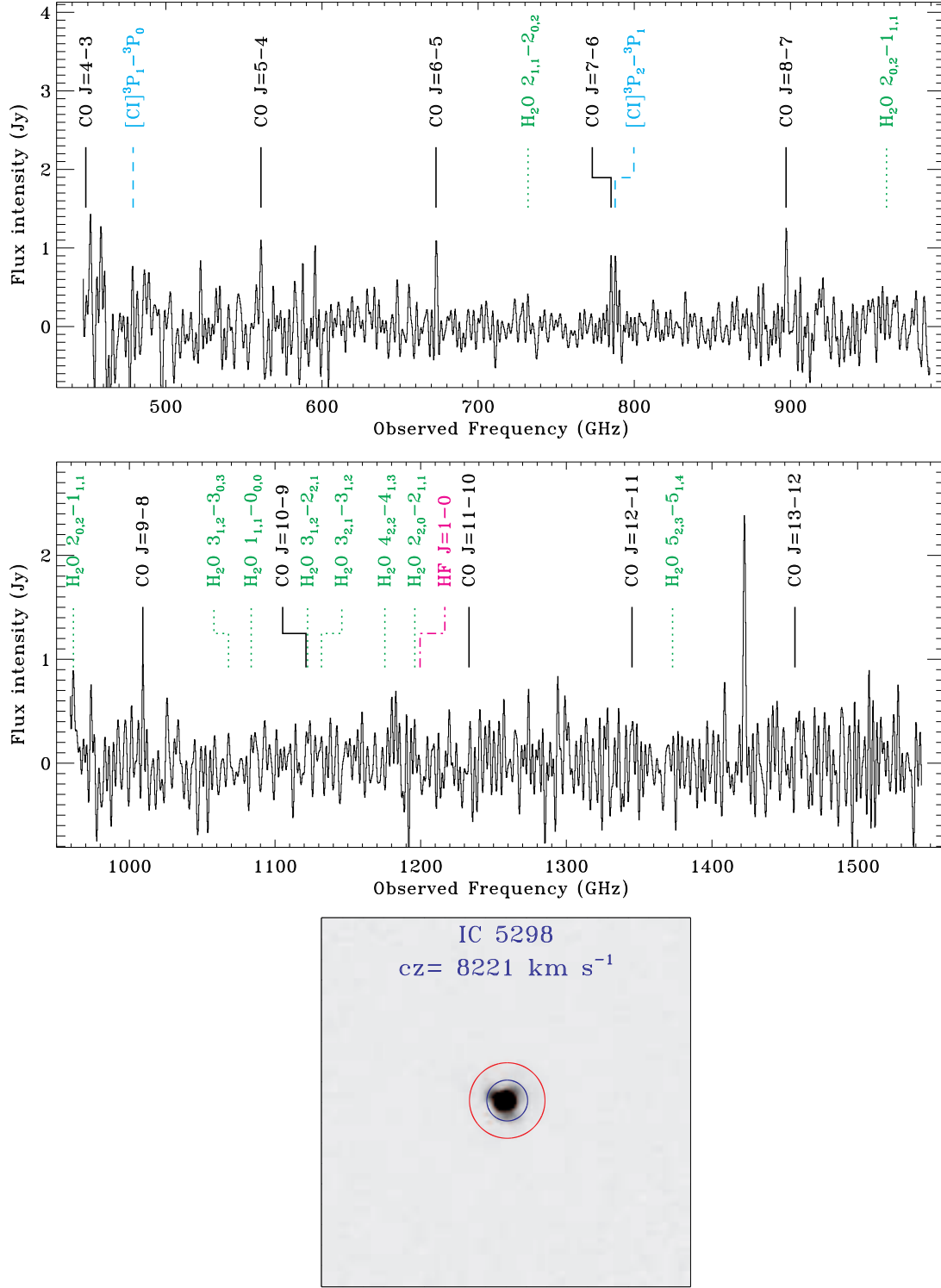


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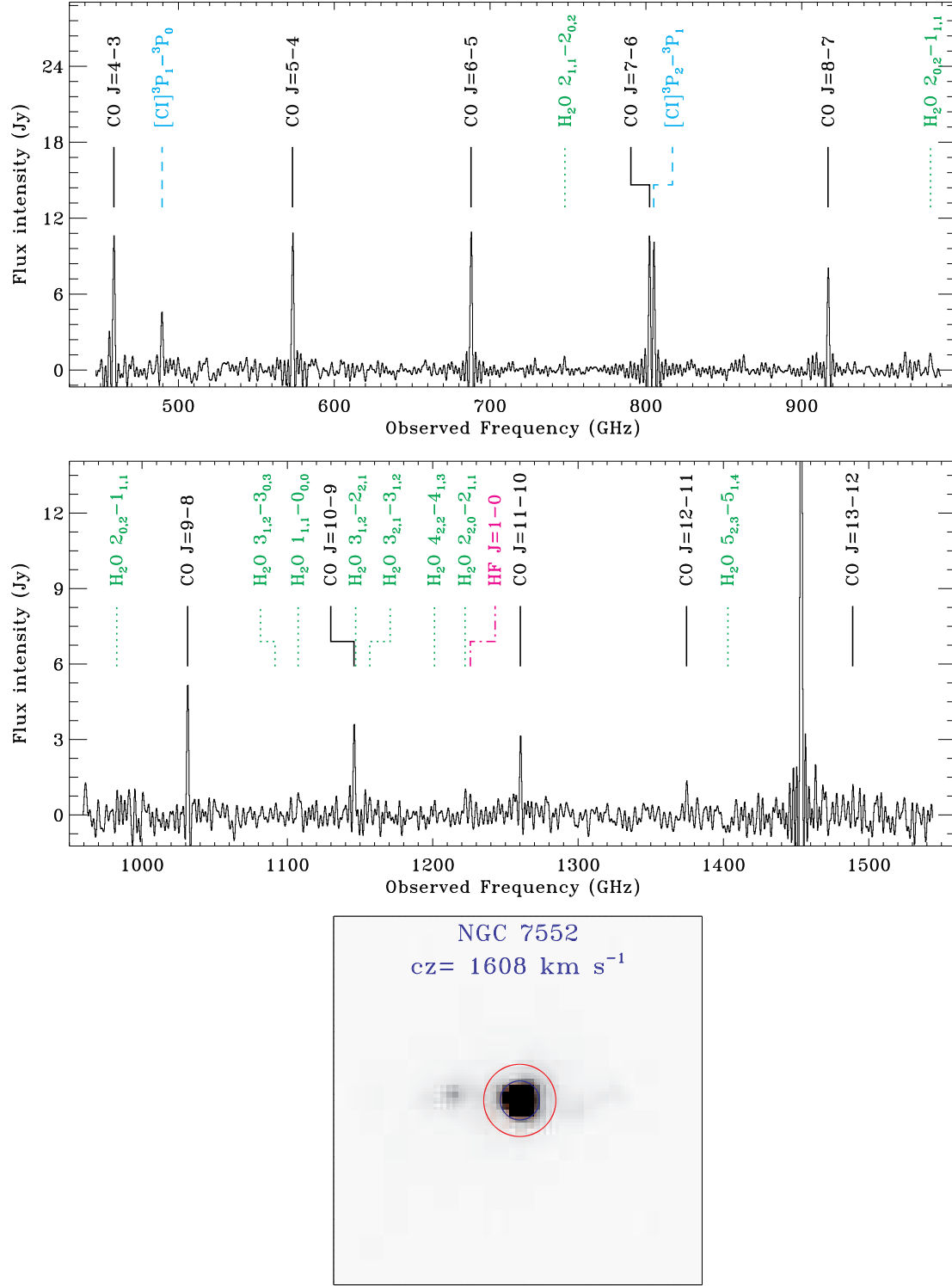


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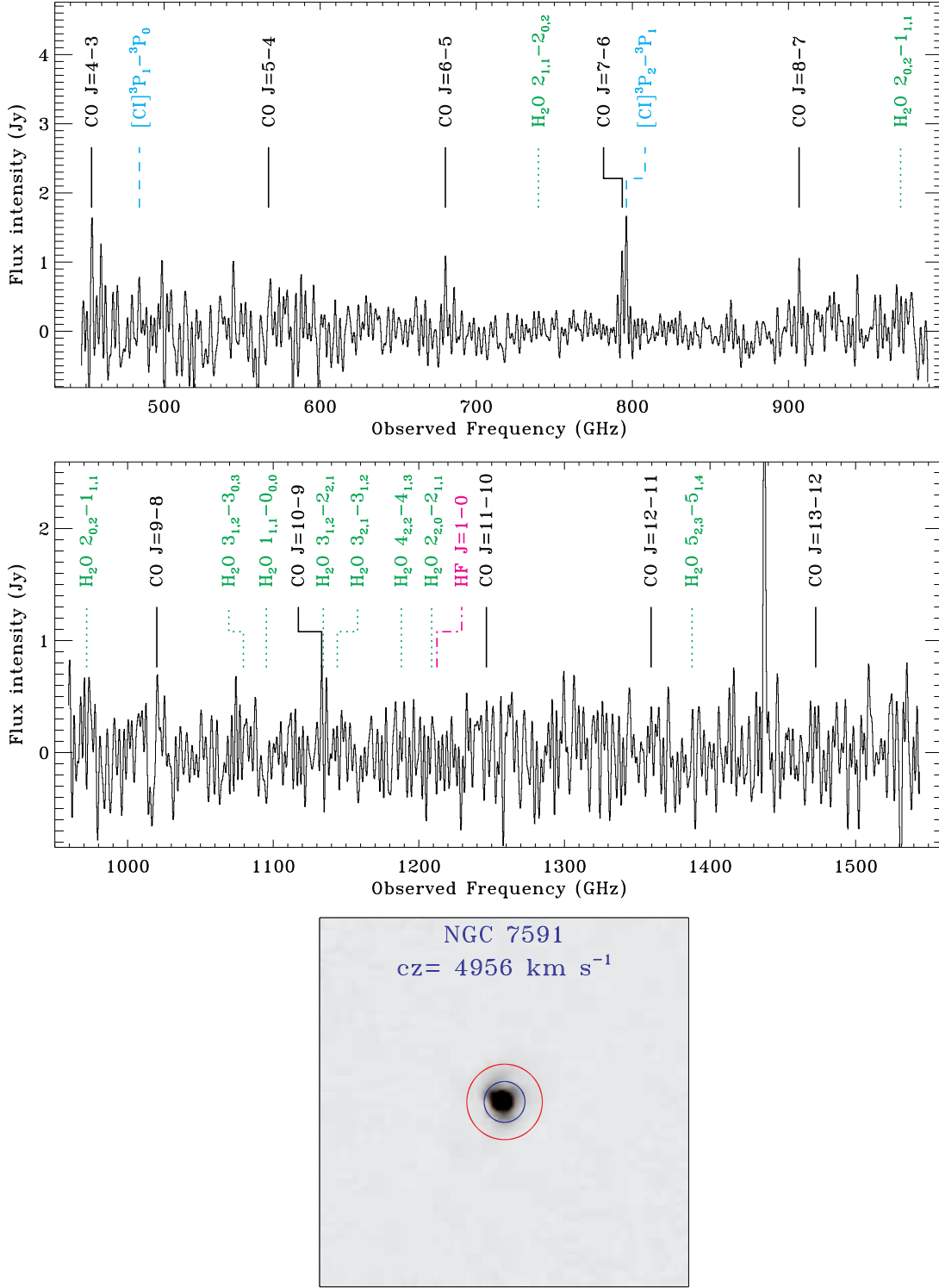


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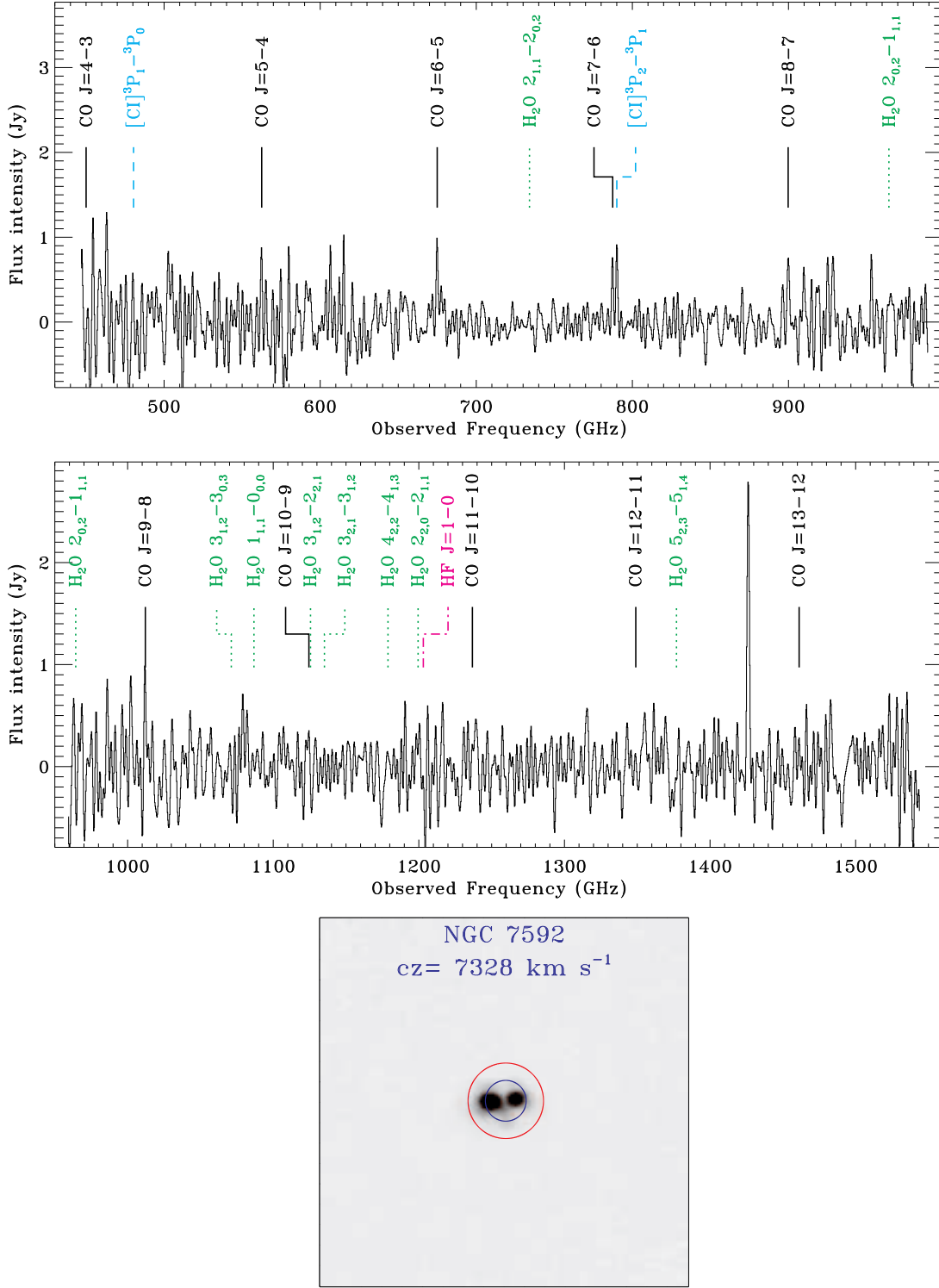


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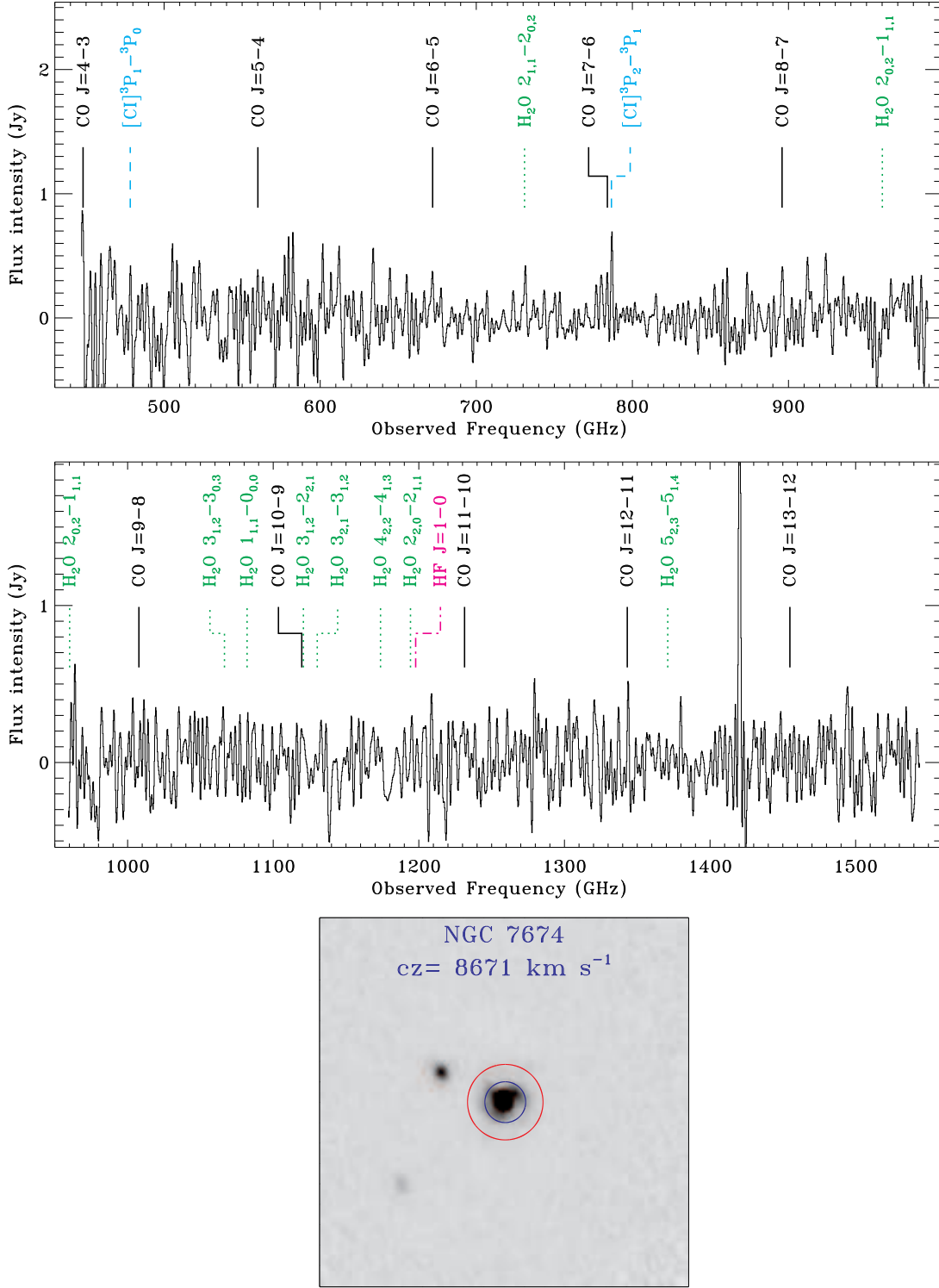


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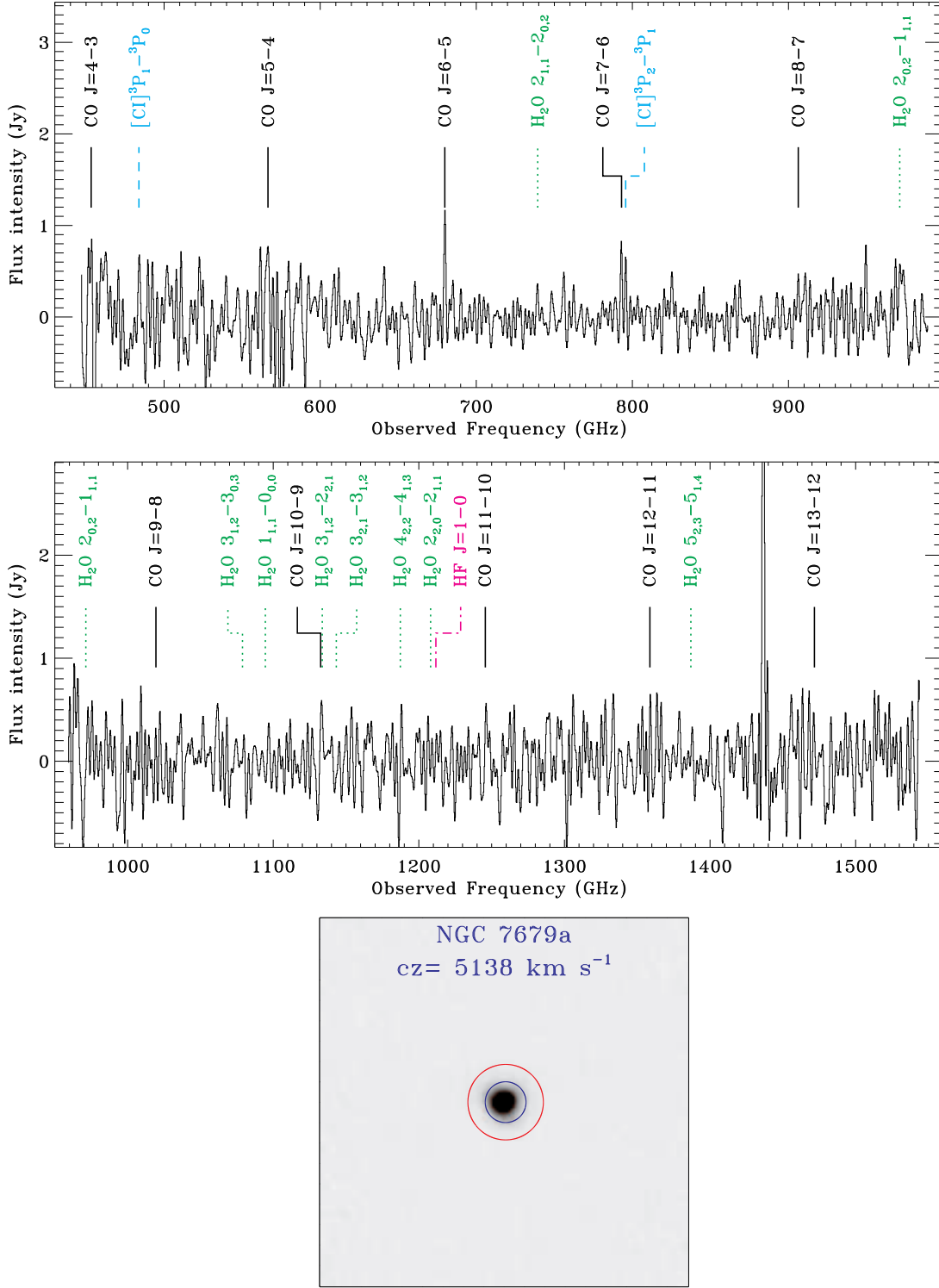


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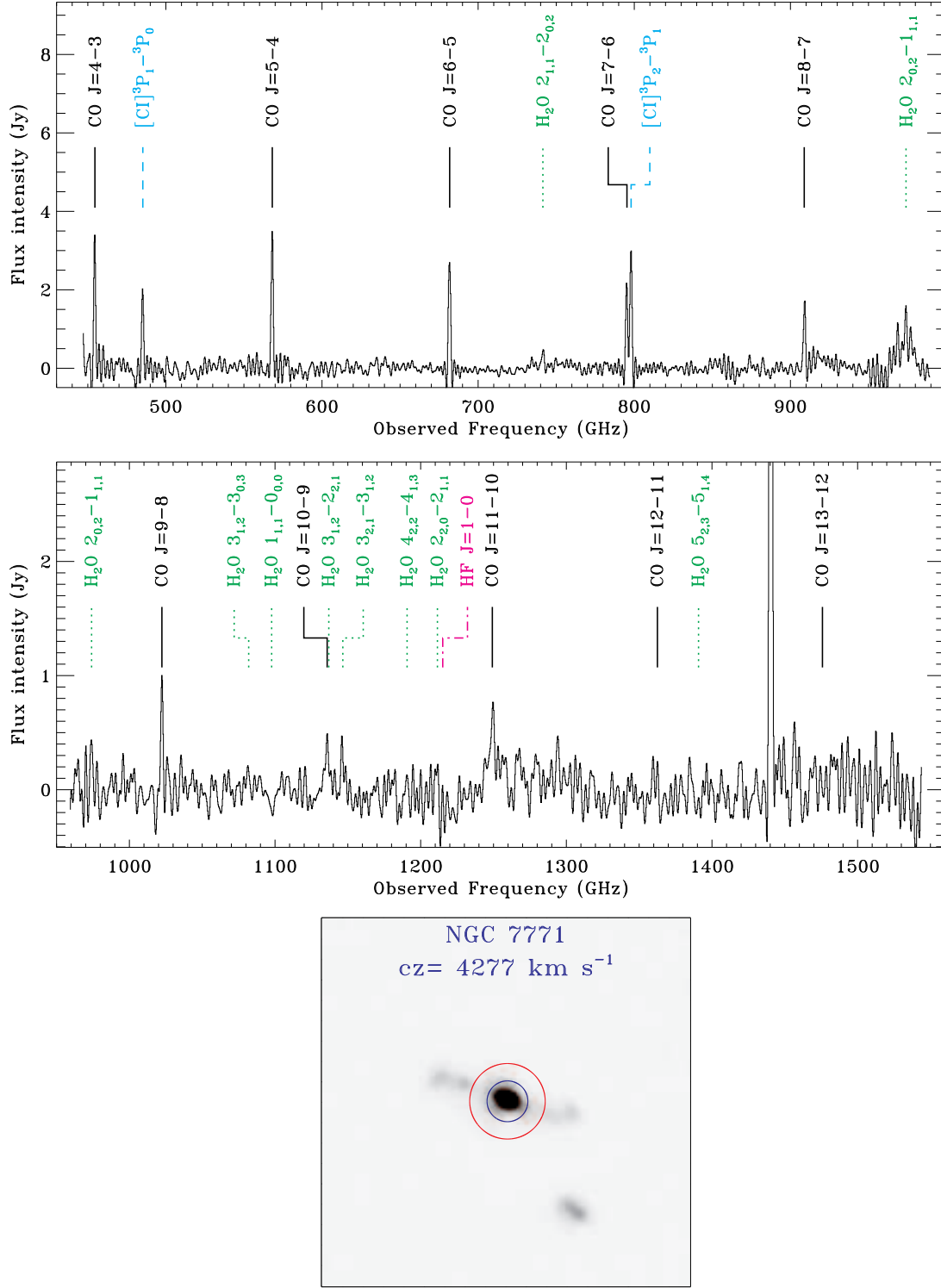


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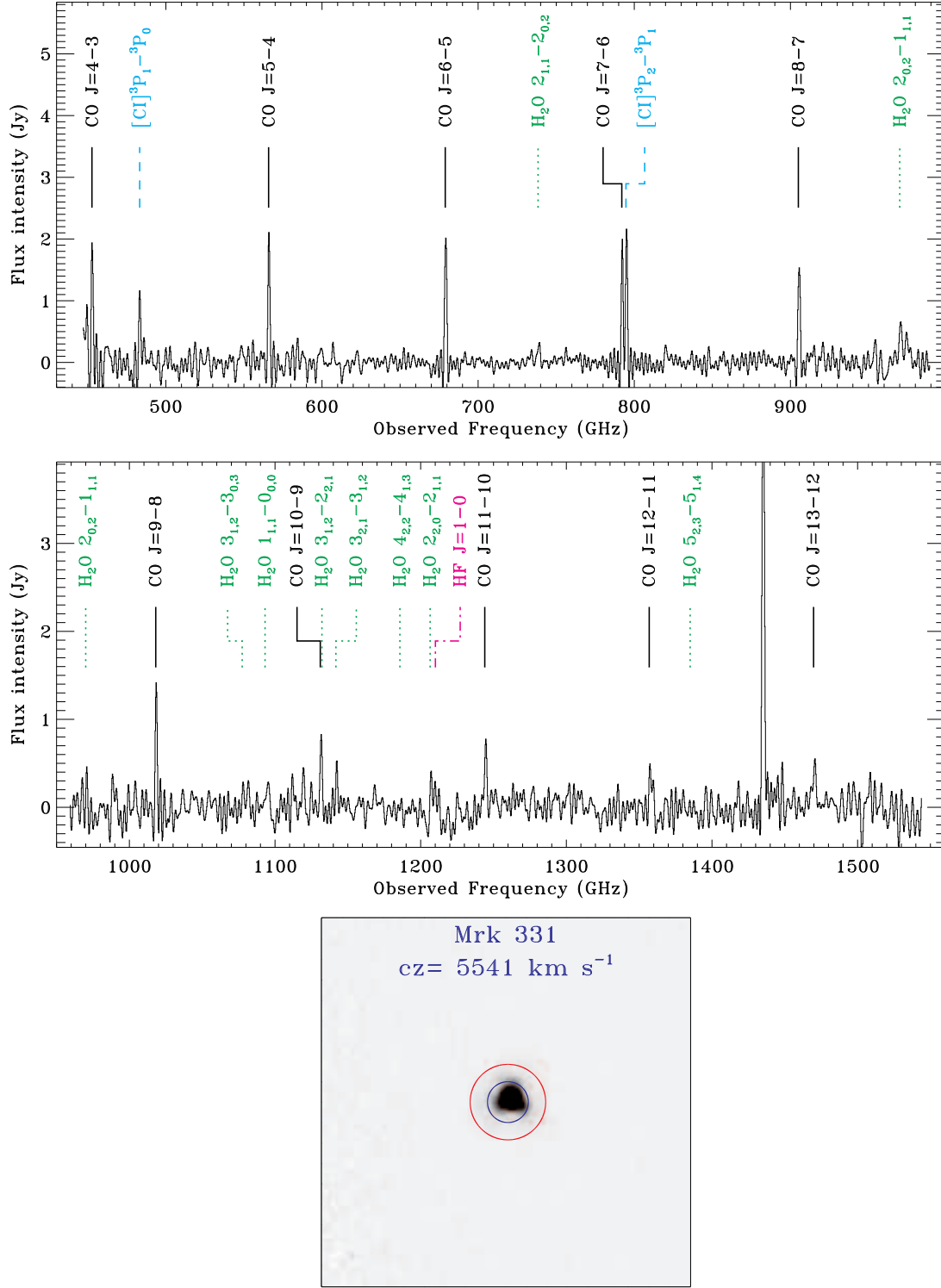


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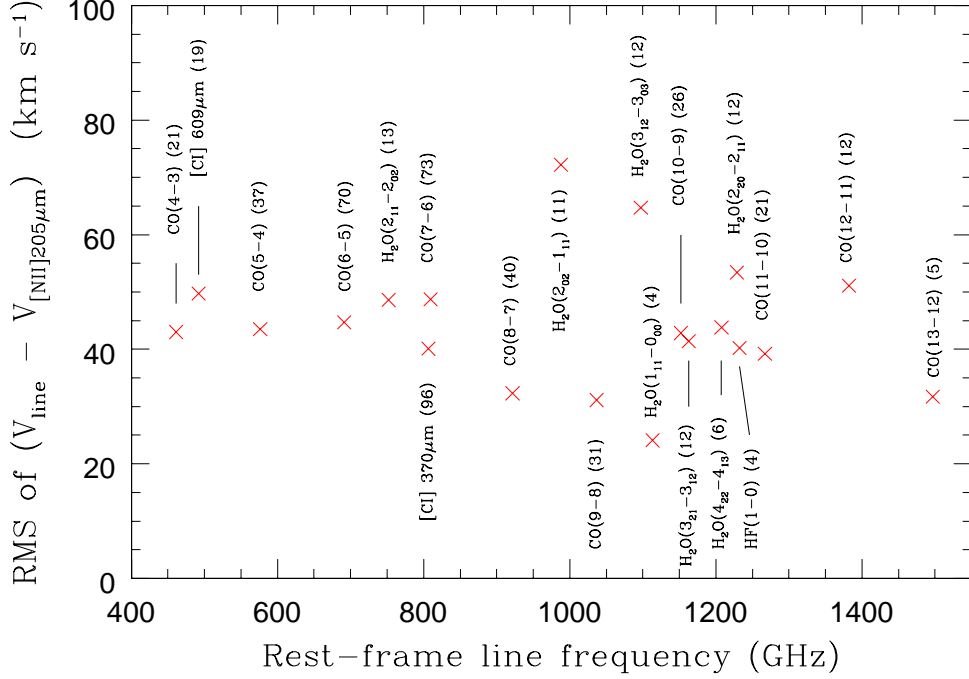


Fig. 3.— Plot of the r.m.s. value of  $(V_{\text{line}} - V_{[\text{NII}]})$  of a spectral line as a function of the line frequency, where  $V_{\text{line}}$  is the inferred heliocentric velocity of the spectral line and  $V_{[\text{NII}]}$  is the similar velocity of the  $[\text{N II}]$  line. The r.m.s. value was calculated using all the targets in which the line was detected at  $S/N \geq 7$ . Only the spectral lines that were detected at  $S/N \geq 7$  for at least 3 targets are plotted here. For each spectral line, the number of targets used in the calculation of this r.m.s. value is given in parentheses next to the label of the line.

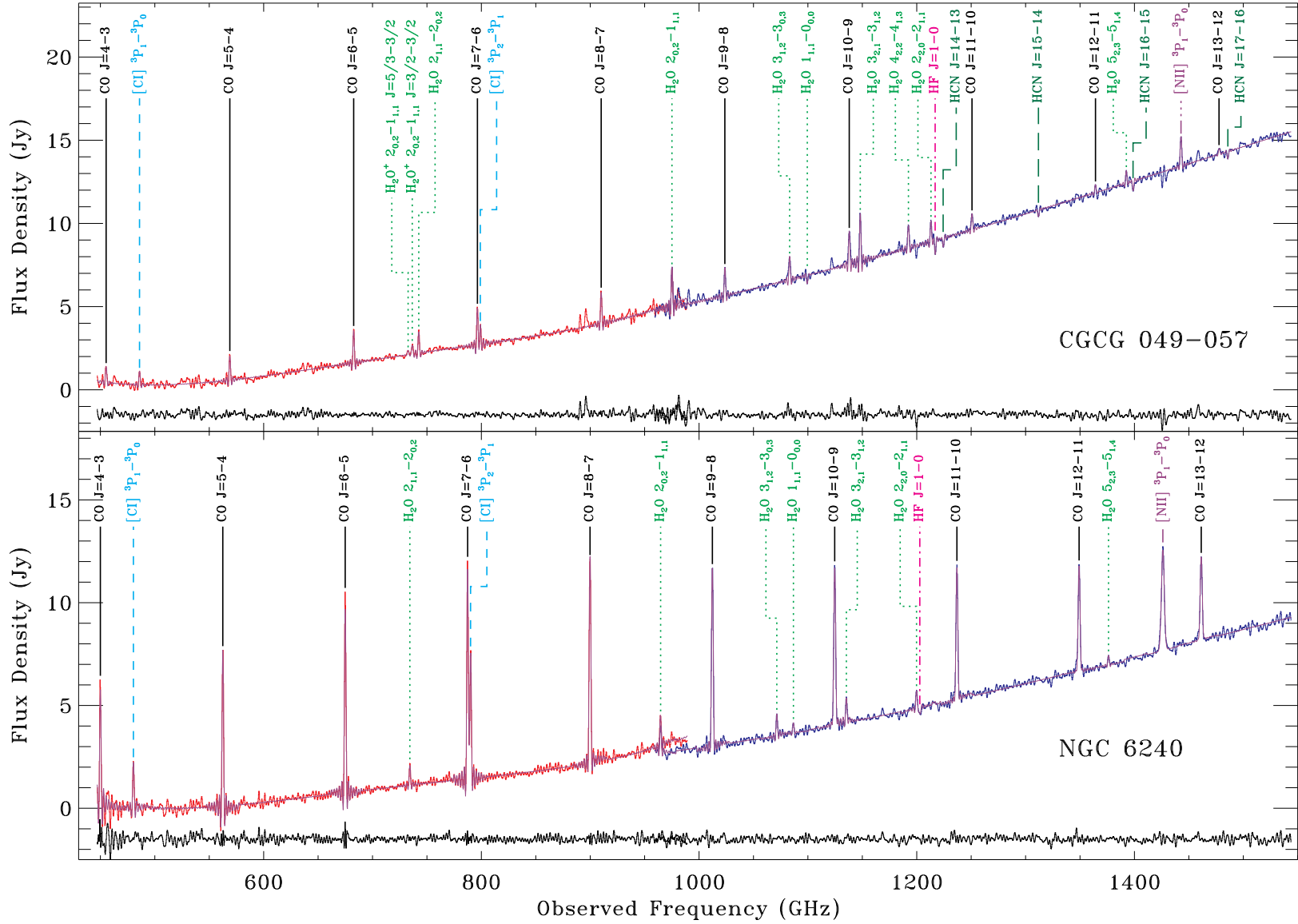


Fig. 4.— Examples of our line fitting results for CGCG 049-057 (top) and NGC 6240 (bottom). In each case, we show the observed spectrum (in red or blue), overlaid with the fitted model continuum and line profiles (black), as well as their difference spectrum (also in black). The [N II] lines in both cases were fit using a sinc-Gaussian profile. All the other lines were fit using sinc-only profiles, except for the CO and [C I] lines in the case of NGC 6240 for which sinc-Gaussian profiles were used.

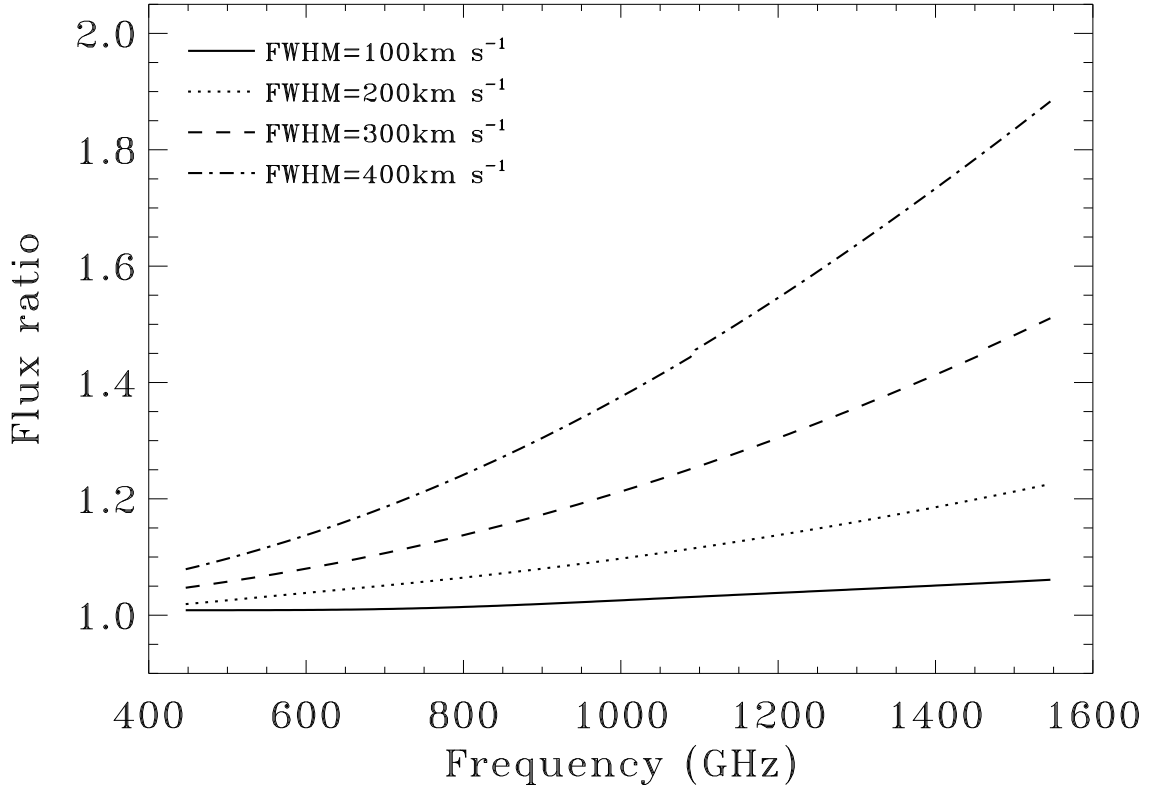


Fig. 5.— Theoretically predicted ratio of the flux of a sinc-Gaussian line profile to the flux of a sinc-only line profile as a function the line central frequency. The width of the sinc function in each line profile is fixed at the SPIRE/FTS spectral resolution. The results are shown for 4 different FWHM values (as noted in the legend) of the Gaussian component of the sinc-Gaussian profile. Both line profiles have the same central frequency and peak flux density.

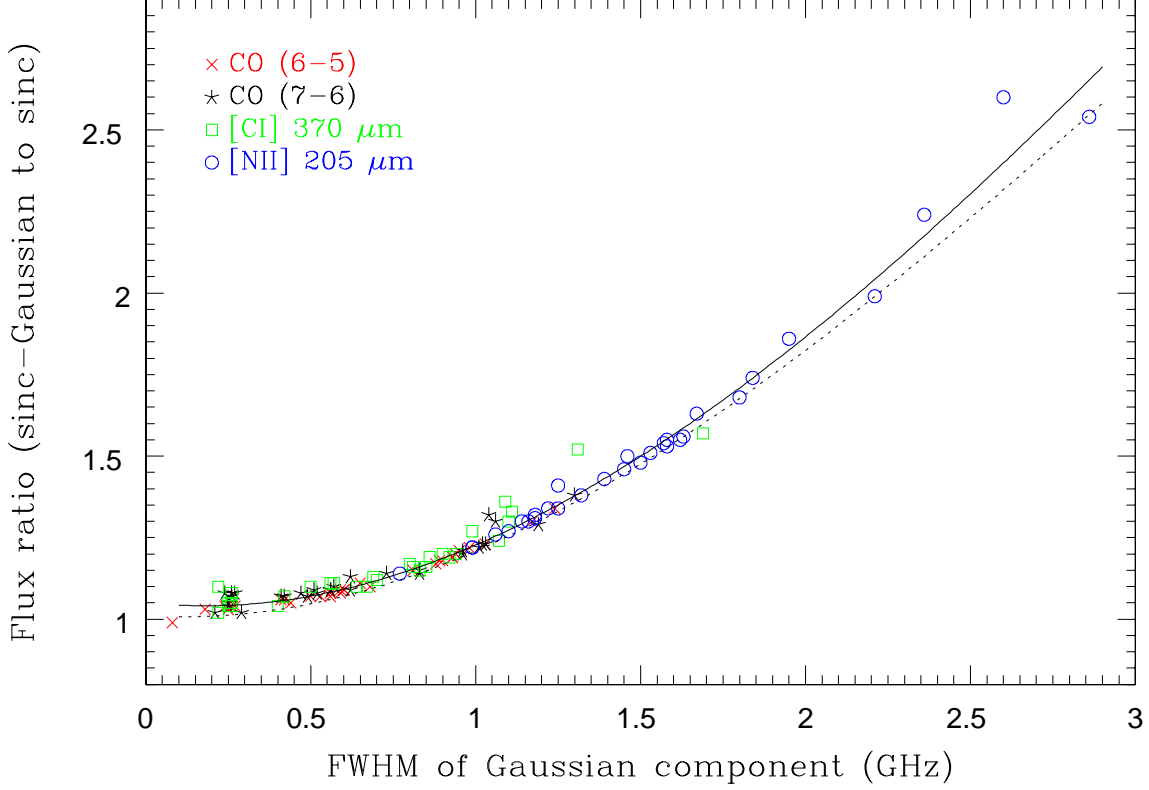


Fig. 6.— Plot of the line flux ratio of a line fit with a sinc-Gaussian profile to the same line fit with a sinc-only profile as a function of the fitted FWHM (in GHz) of the Gaussian component for the [N II] line, CO (7–6), CO (6–5) and [C I] 370  $\mu\text{m}$  detected at high  $S/N$  ratios in 31 archival spectra, . The different spectral lines are color coded as explained in the legend. The dotted curve is a 3rd-order polynomial representation of the theoretical prediction from Fig. 5. The solid curve is a 3rd-order polynomial fit to the data points here. The overall vertical r.m.s. residual between the data points and the solid curve is 0.03.



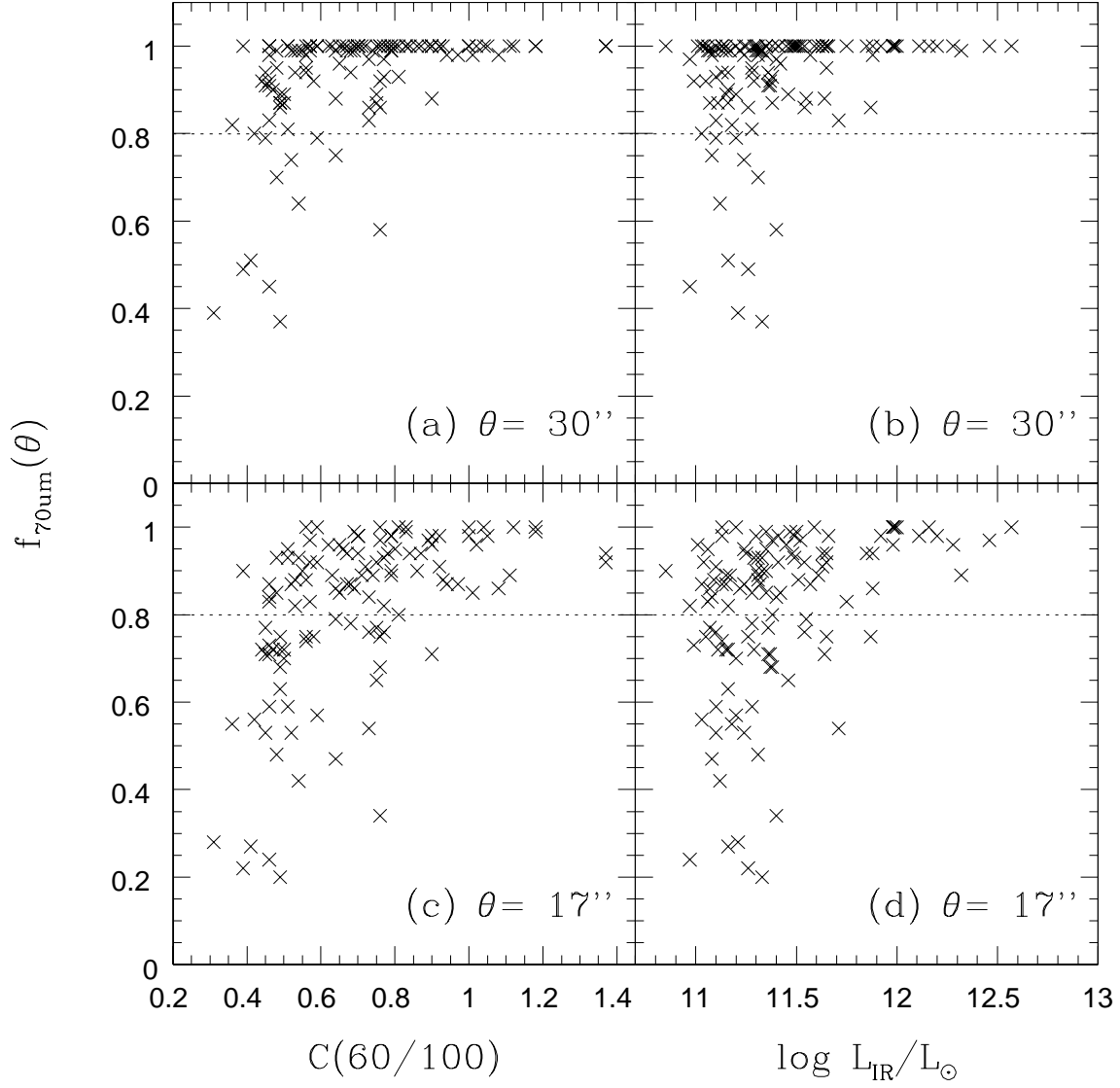


Fig. 7.— Plots of  $f_{70\mu\text{m}}(\theta)$ , the fractional  $70\mu\text{m}$  flux within a Gaussian beam of FWHM  $\theta$ , as a function of  $C(60/100)$  or  $L_{\text{IR}}$  for  $\theta = 30''$  (top panels) and  $17''$  (bottom panels). The dotted line in each plot indicates  $f_{70\mu\text{m}}(\theta) = 0.8$ .

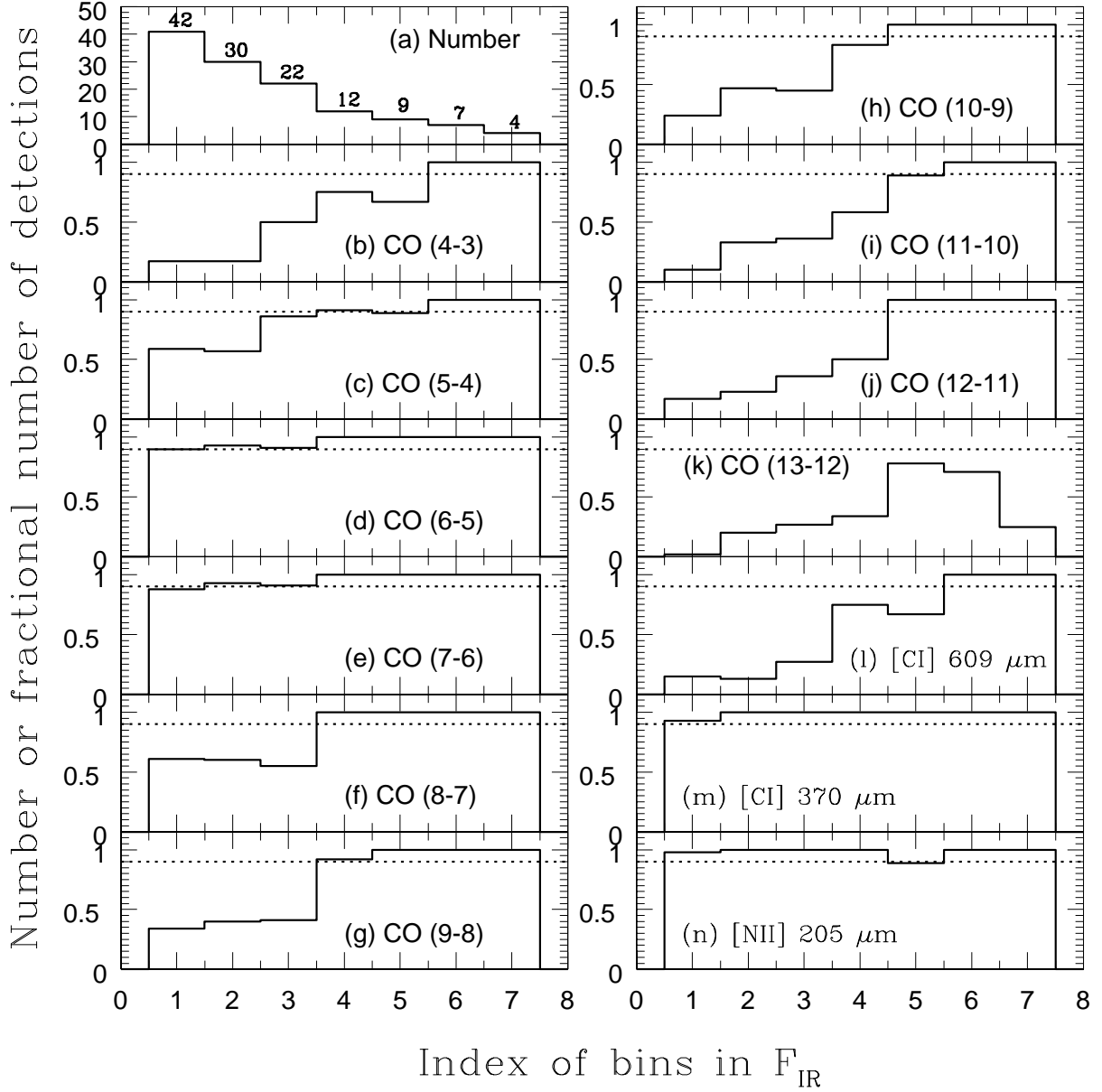


Fig. 8.— Panels (b) to (n) show respectively the fractional detection rates of the main targeted spectral lines in a number of bins of the total IR flux  $F_{\text{IR}}$ , where the flux bins are delineated at the following values:  $7.5, 10.0, 15.0, 22, 35$  and  $120 \times 10^{-13} \text{ W m}^{-2}$ . For example, the first bin (i.e., index = 1) has  $6.5 \leq F_{\text{IR}} < 7.5 \times 10^{-13} \text{ W m}^{-2}$ , the second bin has  $7.5 \leq F_{\text{IR}} < 10 \times 10^{-13} \text{ W m}^{-2}$  and the last bin is for  $F_{\text{IR}} > 120 \times 10^{-13} \text{ W m}^{-2}$ . The subject spectral line and the 90% completeness level are marked in each plot. As a comparison, panel (a) shows the similar distribution of the total observed galaxies, with the number of the galaxies in each flux bin explicitly marked. The multiple entries of the NGC 3690 and NGC 2146 in Table 1 were counted separately here.

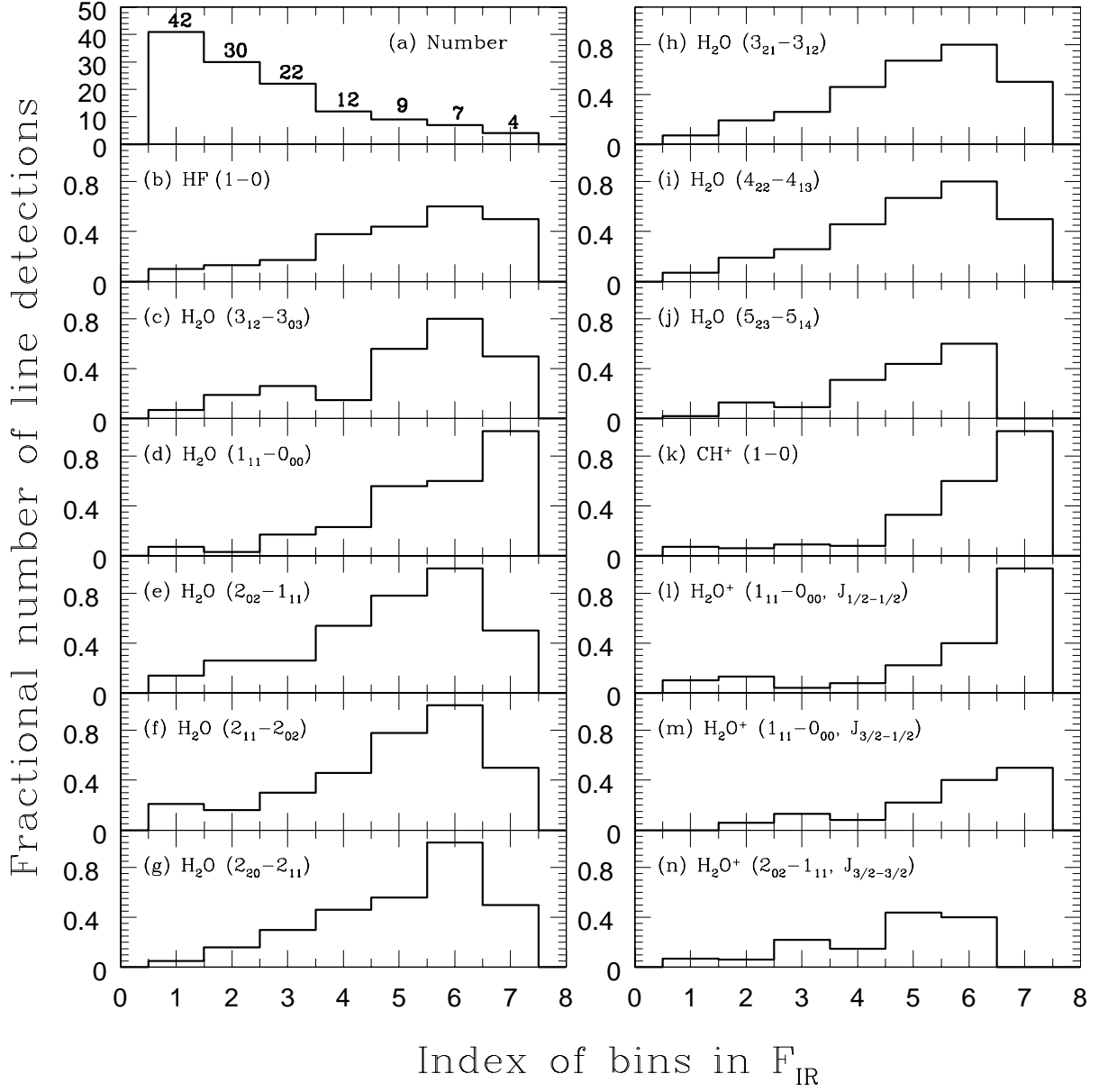


Fig. 9.— Plots similar to those in Fig. 8, but of the fractional detection (in either emission or absorption) rates of selected fainter spectral lines. The subject spectral line is labelled in each plot.

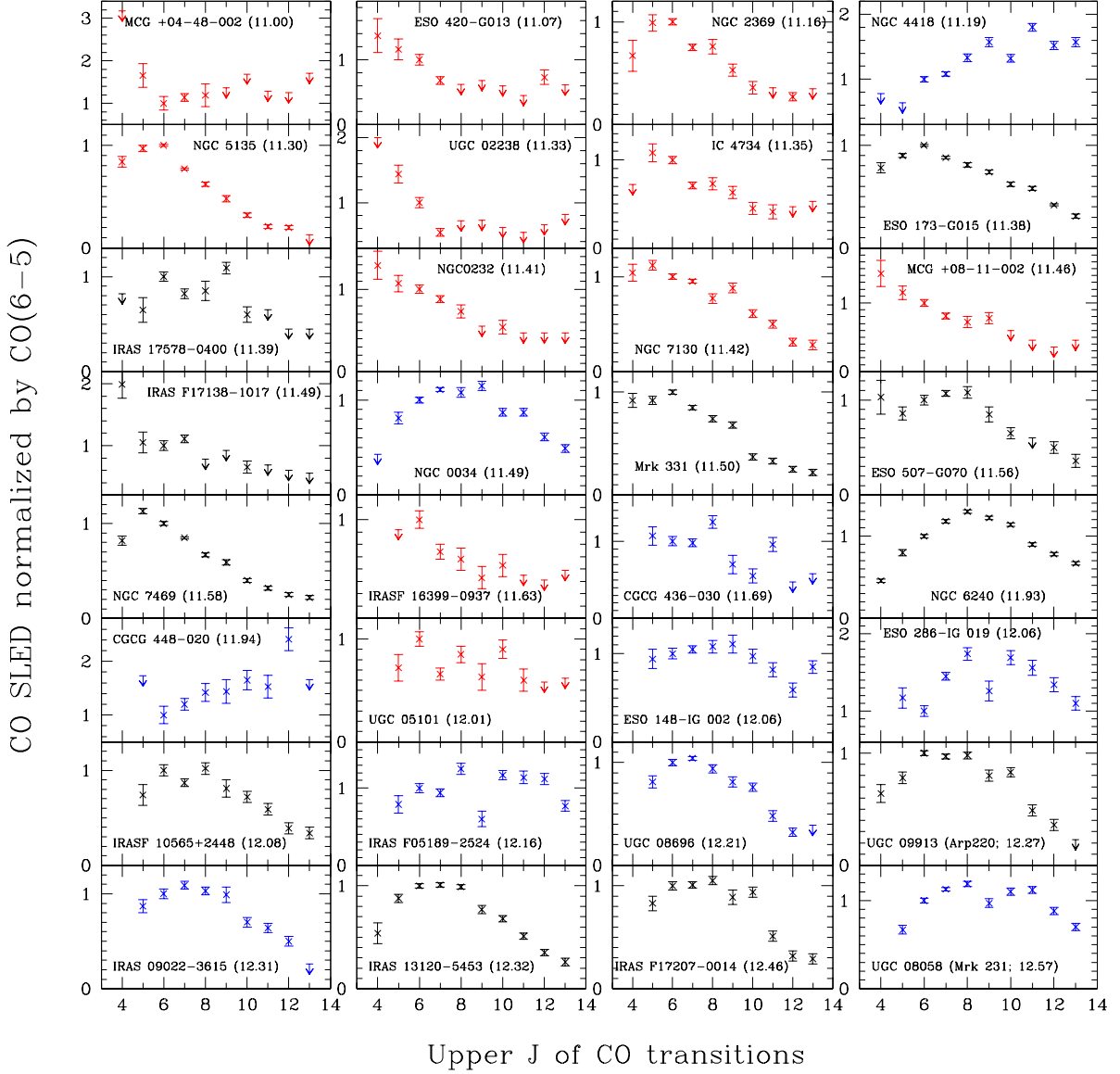


Fig. 10.— Individual CO SLEDs, each normalized to 1 at  $J = 6$ , of the brightest sample galaxies in each of the three FIR color bins: Those in red for the 11 FIR-cold galaxies with  $0.50 < C(60/100) \leq 0.65$  and  $f_\nu(60\mu\text{m}) > 8.1\text{ Jy}$ , those in black for the 11 galaxies with  $0.75 < C(60/100) \leq 0.90$  and  $f_\nu(60\mu\text{m}) > 12.0\text{ Jy}$ , and those in blue for the 10 FIR-warm galaxies with  $C(60/100) \geq 1.0$  and  $f_\nu(60\mu\text{m}) > 10.7\text{ Jy}$ . All the galaxies shown here satisfy  $f_{70\mu\text{m}}(17'') > 0.8$ . The individual SLEDs are arranged in increasing order of  $L_{\text{IR}}$  from the top left to the bottom right. The galaxy name and logarithmic  $L_{\text{IR}}$  in solar units (in parentheses) are noted in each panel.

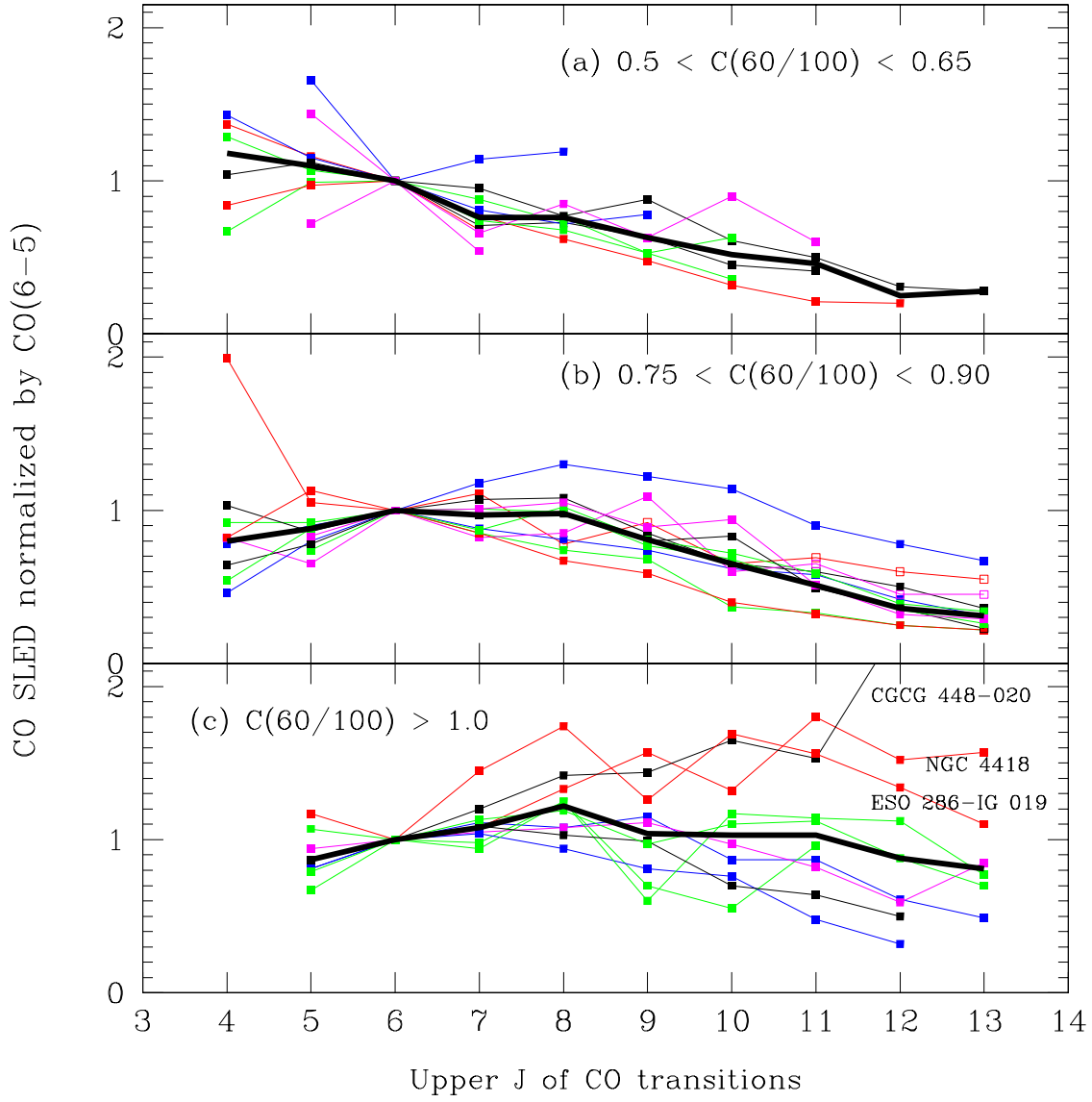


Fig. 11.— Plots of the individual CO SLEDs (connected squares in various colors) from Fig. 10, along with the median CO SLED (the thick curve in black) they generate, for each of the three FIR color bins (as labelled in the plots). The 3 galaxies with the warmest CO SLEDs are labelled in the bottom panel.

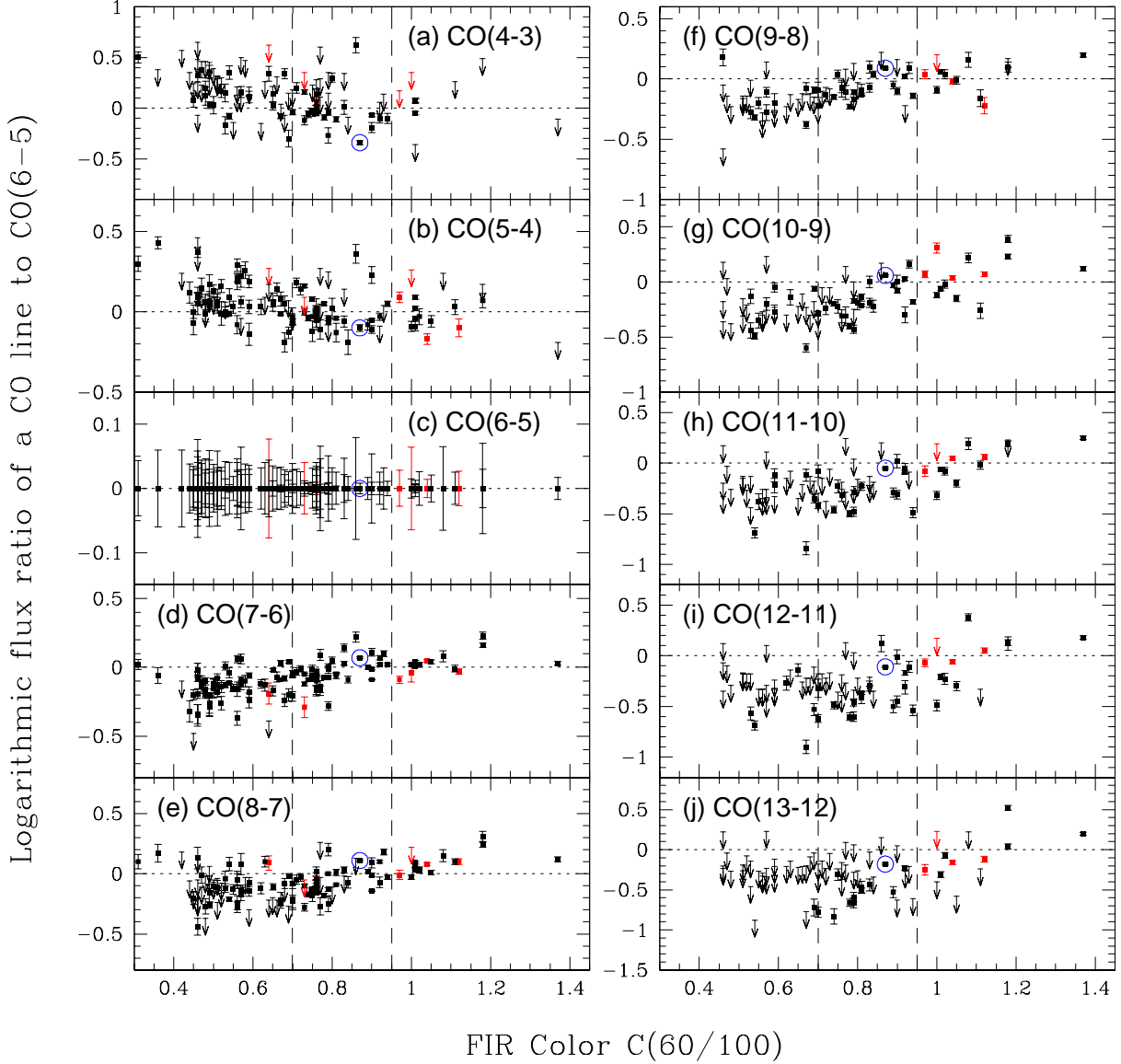


Fig. 12.— Plots of the log of the flux ratio of a CO line of the upper level  $J$  to CO (6–5) as a function of  $C(60/100)$  for the sample galaxies detected in CO (6–5) and for  $J$  from 4 to 13 (as labelled in each plot). The horizontal dotted line in each plot marks where the logarithmic line ratio equals 0. The two vertical dashed lines separate the 3 subsamples used in Figs. 10 and 11. For the CO lines covered in SSW (i.e.,  $J \geq 9$ ), we further limited the data plotted here to those galaxies with  $f_{70\mu\text{m}}(17'') > 0.8$ . The AGNs are shown in red and NGC 6240 is further circled in blue. For the plot of CO (6–5), it shows the relative line flux uncertainty.

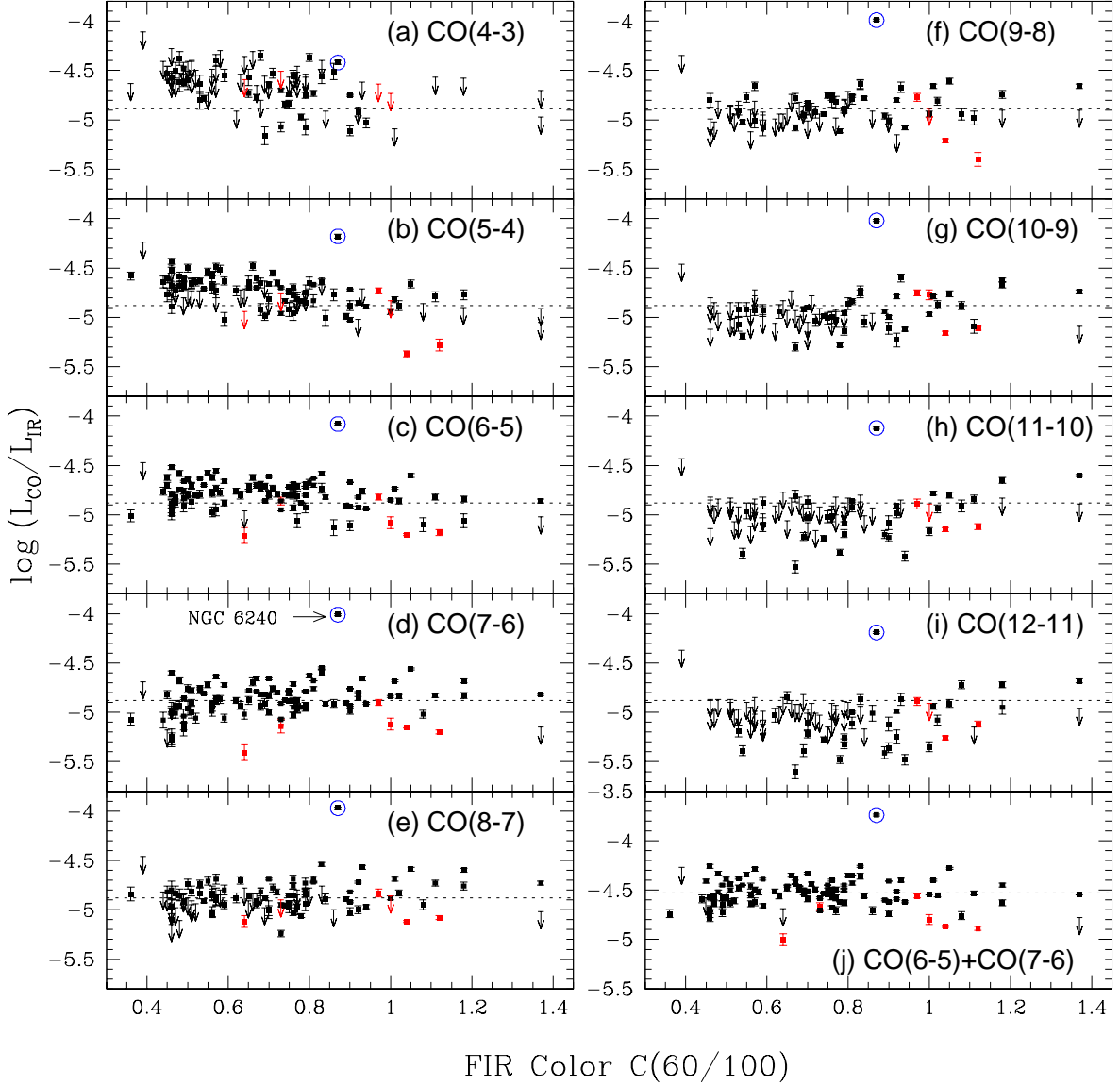


Fig. 13.— Panels (a) to (i) are plots of the log of the luminosity of a CO line of the upper level  $J$ , divided by  $L_{\text{IR}}$ , as a function of  $C(60/100)$  for our sample galaxies and for  $J$  from 4 to 12, respectively. For  $J < 9$  (i.e., with the CO line detected in the SLW array), only the targets with  $f_{70\mu\text{m}}(30'') > 0.8$  are plotted; for  $J \geq 9$  (i.e., detected in SSW), only those with  $f_{70\mu\text{m}}(17'') > 0.8$  are shown here. The red data points are the dominant AGNs that also satisfy our FTS beam size-based selection criterion. The galaxy NGC 6240 is further circled in blue. Panel (j) is for the sum of CO (6–5) and CO (7–6). The horizontal dotted lines in panels (a) to (i) indicate the average logarithmic ratio of  $-4.88$  adopted for CO (7–6) in Lu et al. (2015). The dotted line in (j) indicates a value of  $-4.53$ , the median ratio for the galaxies plotted in (j), excluding the AGNs and NGC 6240.

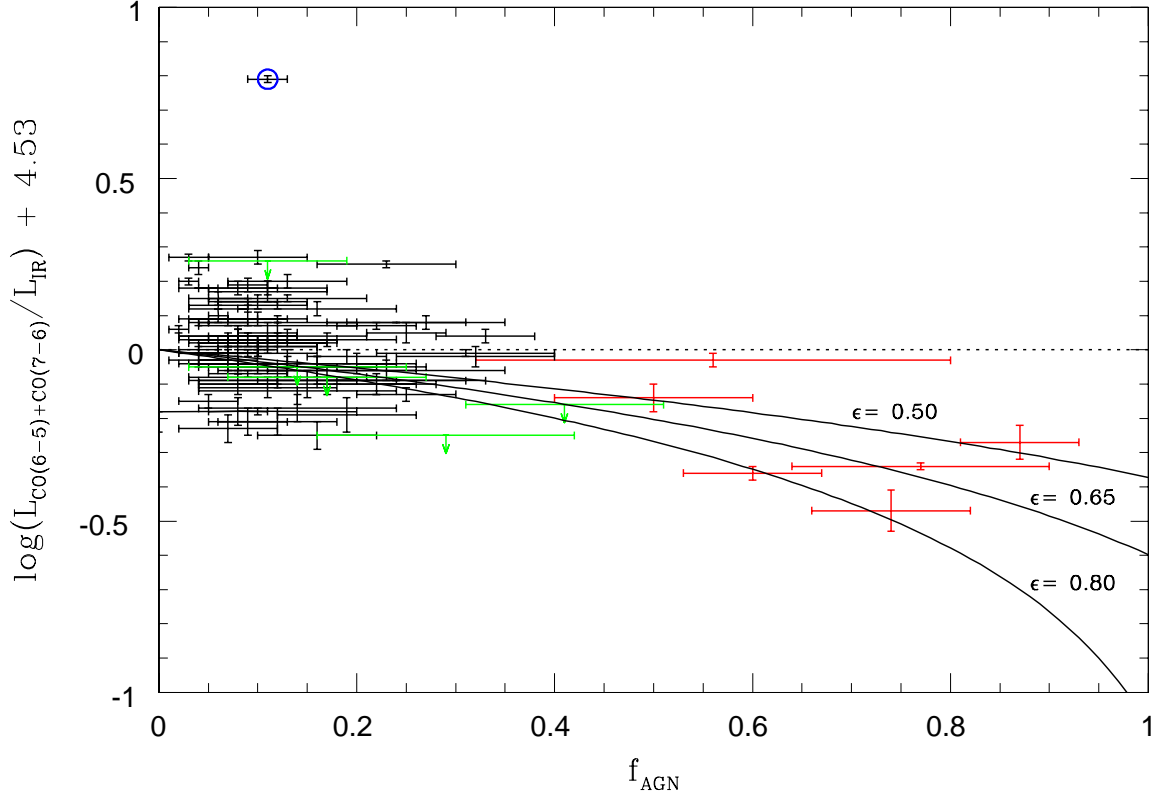


Fig. 14.— Plot of the logarithmic ratio of the luminosity of the sum of the CO (6–5) and CO (7–6) line emission to  $L_{\text{IR}}$  as a function of  $f_{\text{AGN}}$  for the same set of galaxies as in Fig. 13j. The luminosity ratios plotted are offset by the sample median log value of -4.53 marked in Fig. 13j. The color coding scheme is the same as in Fig. 13, except for the upper limits shown here in green for clarity. A few galaxies without an  $f_{\text{AGN}}$  value are not plotted here. The solid curves stand for the function of  $\log(1 - 1.15\epsilon f_{\text{AGN}})$  with  $\epsilon = 50\%$ ,  $65\%$  and  $80\%$ , respectively, which are further explained in the text.



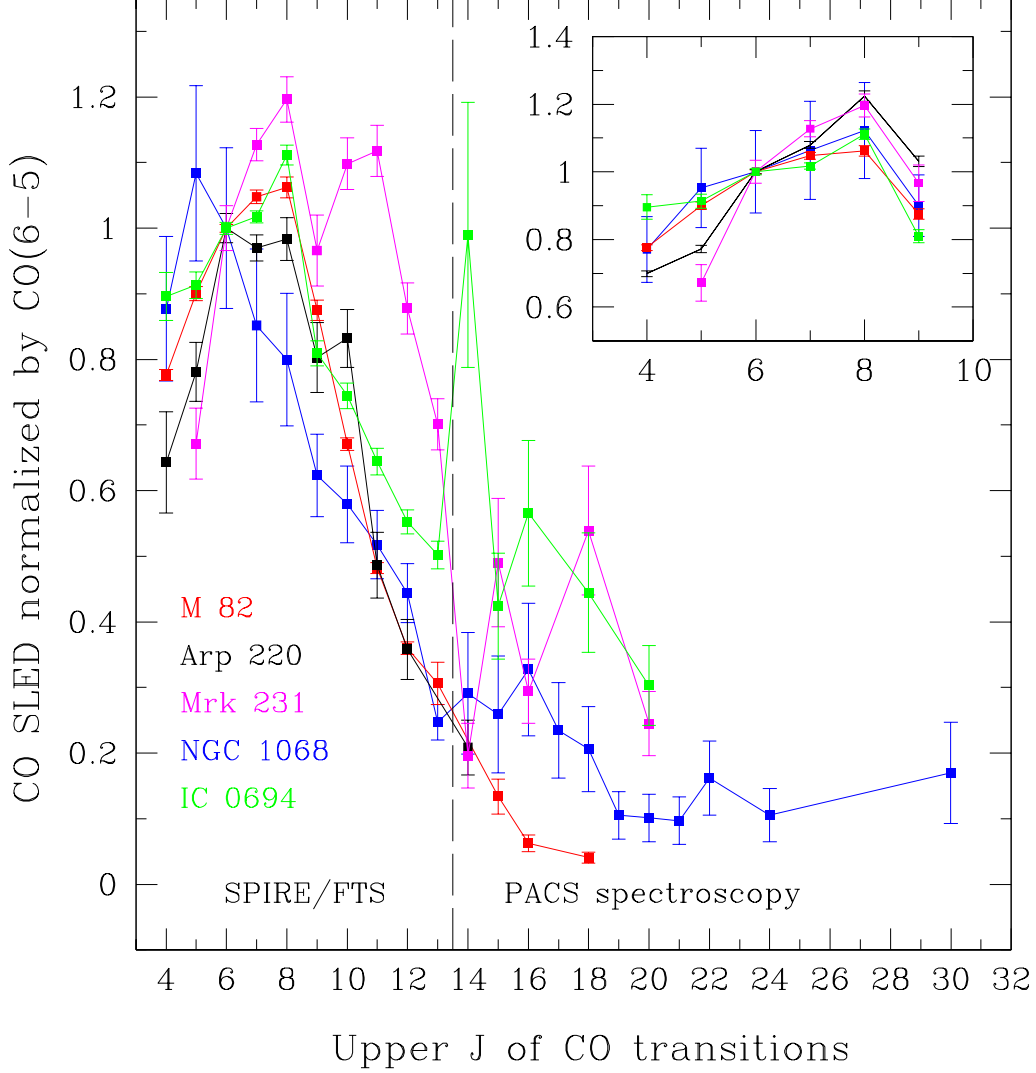


Fig. 15.— CO SLEDs, all normalized to 1 at  $J = 6$ , of a few well-known starbursts and AGNs (as labelled in plot). These were constructed by combining the SPIRE/FTS data in this paper (or from the literature in the cases of M 82 and NGC 1068) with the higher- $J$  CO line fluxes from the PACS data in Mashian et al. (2015). The vertical dashed line separates the SPIRE/FTS frequency side from the PACS side. The small insert shows the sections of these CO SLEDs over  $4 \leq J < 10$ , after “removing” a systematic dependence of the mid- $J$  CO SLED shape on the FIR color. (See the text for more details.)

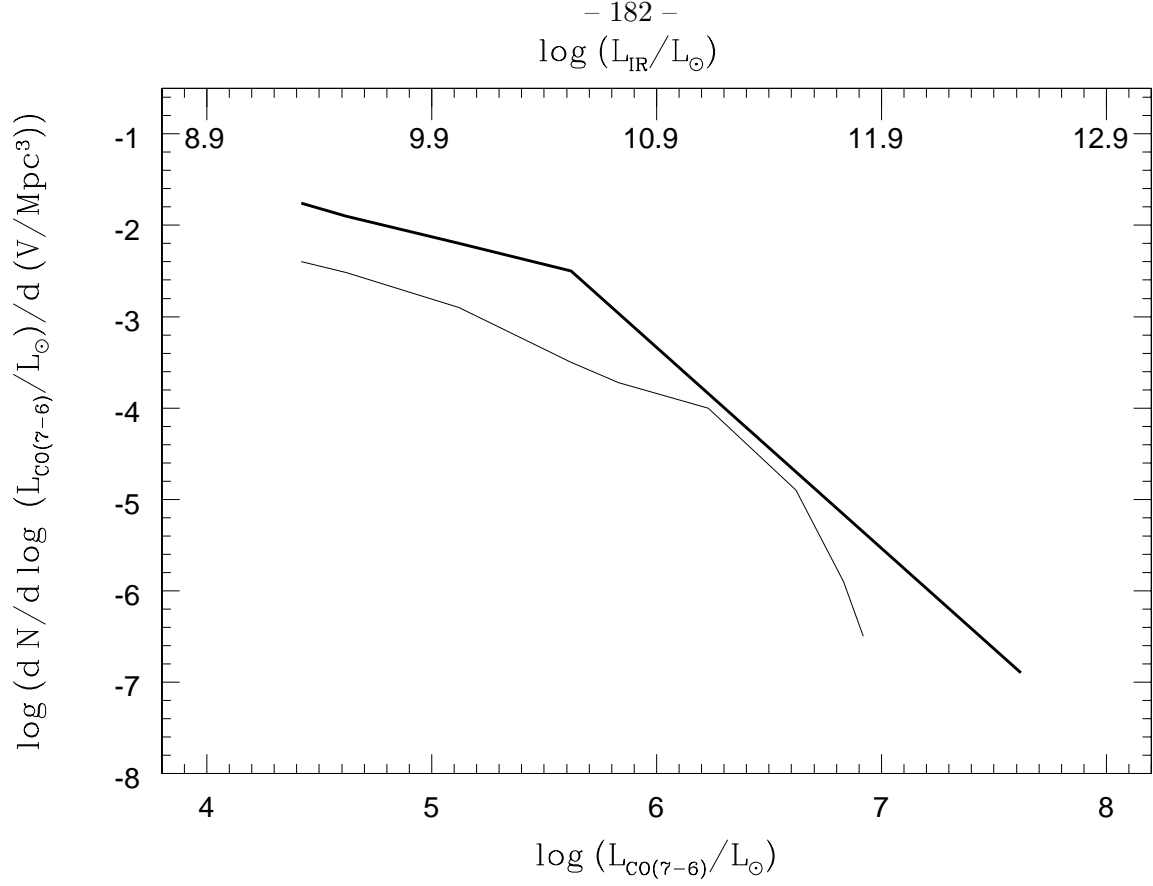


Fig. 16.— Comparison of our CO (7–6) LF scaled from the infrared LF of Sanders et al. (2003) (thick curve) and a local CO (7–6) LF of Lagos et al. (2012) based on a PDR model (thin curve) for  $L_{\text{IR}} > 2 \times 10^9 L_{\odot}$ , with the logarithmic  $L_{\text{IR}}$  scale shown at the top of the plot. The typical uncertainty for our CO (7–6) LF is on the order of 0.11 dex (see the text).

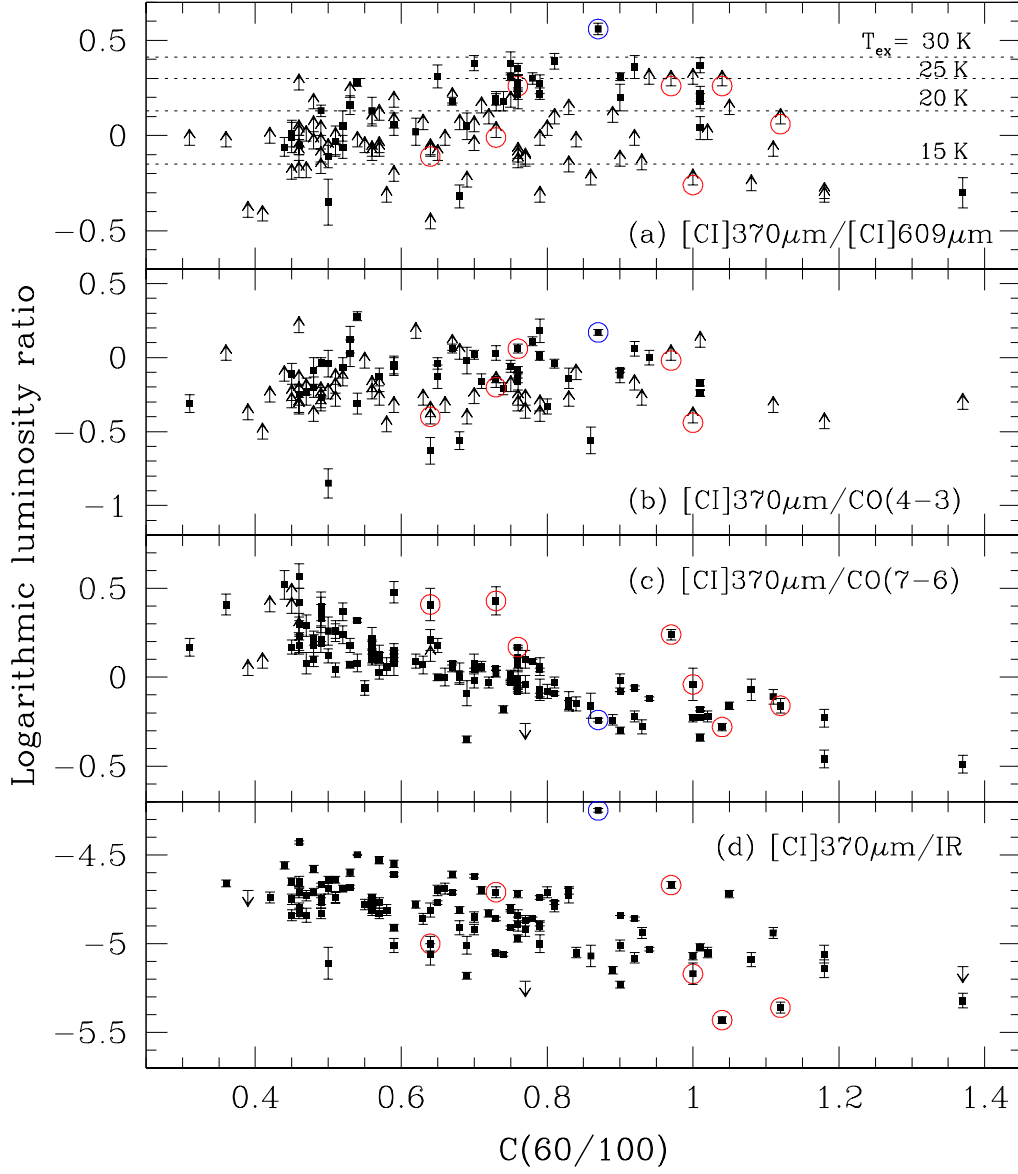


Fig. 17.— Plots of various [C I] line-related luminosity ratios as a function of the FIR color for our galaxy sample: (a) [C I]  $370 \mu\text{m}$  to [C I]  $609 \mu\text{m}$ , (b) [C I]  $370 \mu\text{m}$  to CO (4–3), (c) [C I]  $370 \mu\text{m}$  to CO (6–5), and (d) [C I]  $370 \mu\text{m}$  to the total IR emission. In each plot, arrows indicate the  $3\sigma$  limits when one line involved in the ratio was undetected; the cases where both lines in the ratio were undetected are not included here. NGC 6240 and the known AGNs are further circled in blue and red, respectively. The dotted lines in (a) show the implied gas excitation temperatures from the line ratio using an optically thin case. In (d), only those sources with  $f_{70\mu\text{m}}(35'') > 0.8$  are included.

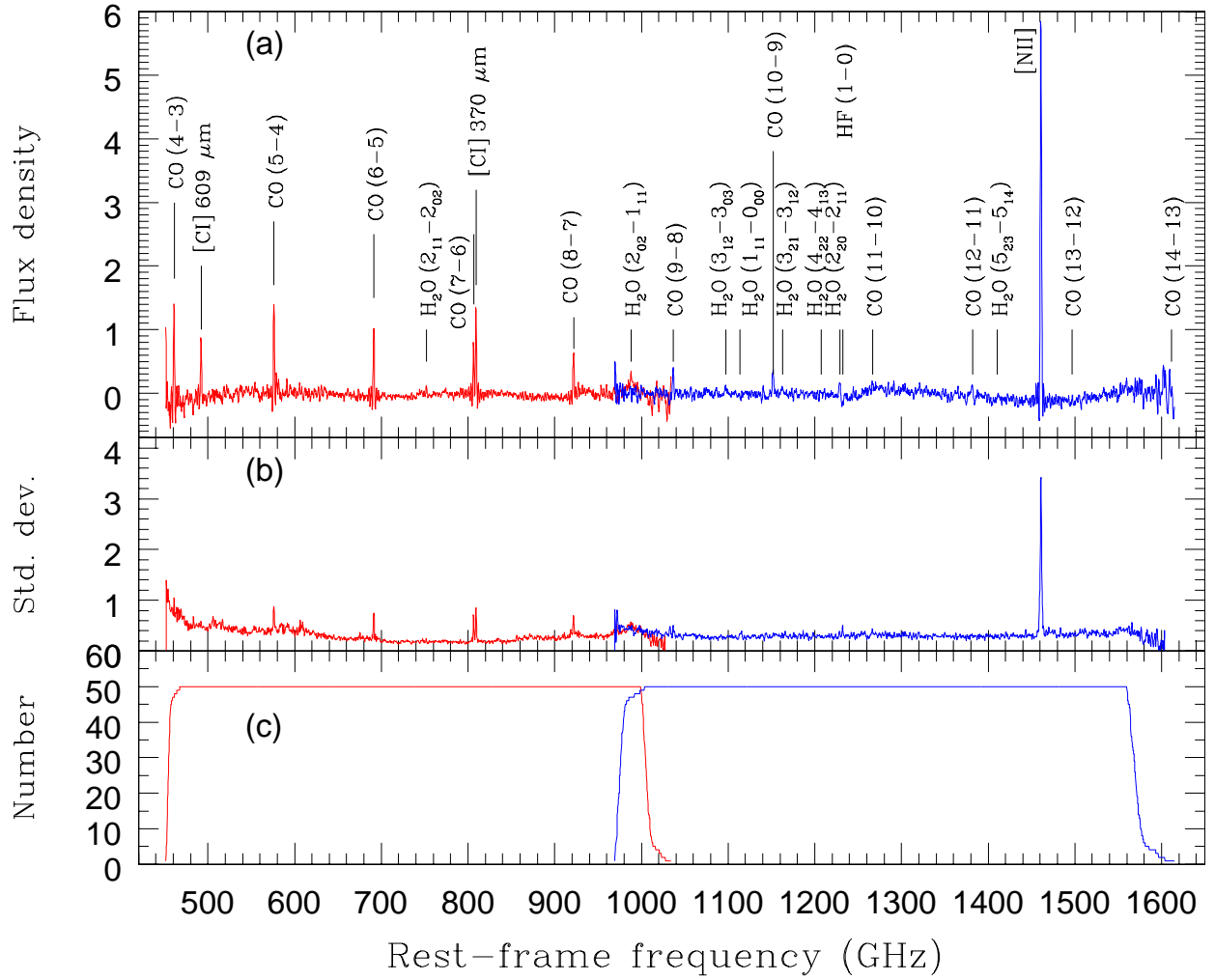


Fig. 18.— Results from stacking individual SPIRE/FTS spectra of galaxies with  $0.3 \leq C(60/100) < 0.6$ : (a) the rest-frame, unweighted median spectrum, (b) the sample standard deviation as a function of frequency, and (c) the number of spectra used in the stacking as a function of frequency. The frequency locations of our main targeted lines as well as a number of H<sub>2</sub>O lines and HF (1–0) are marked in (a).

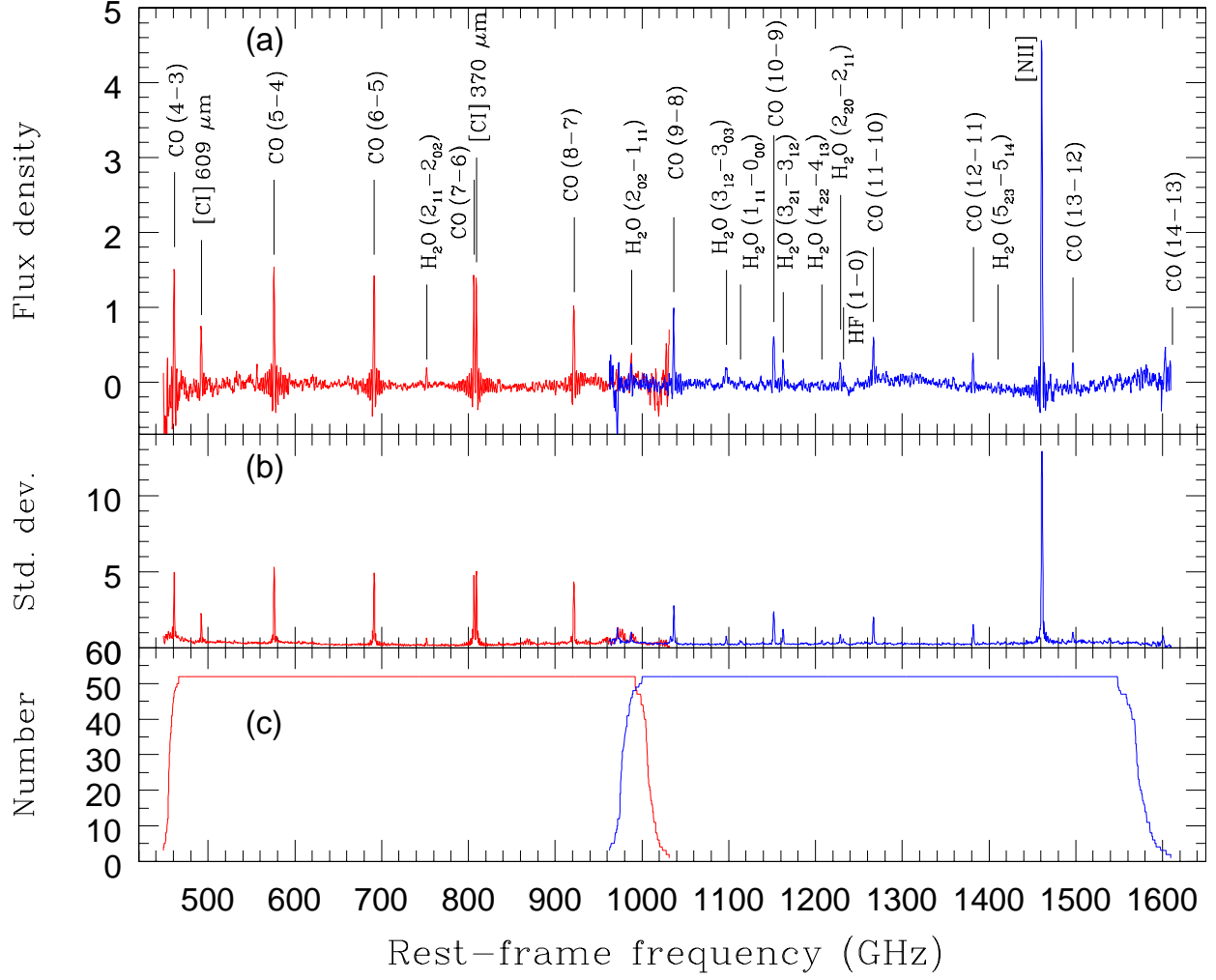


Fig. 19.— Same as Fig. 18, but using the sample galaxies with  $0.6 \leq C(60/100) < 0.9$ .

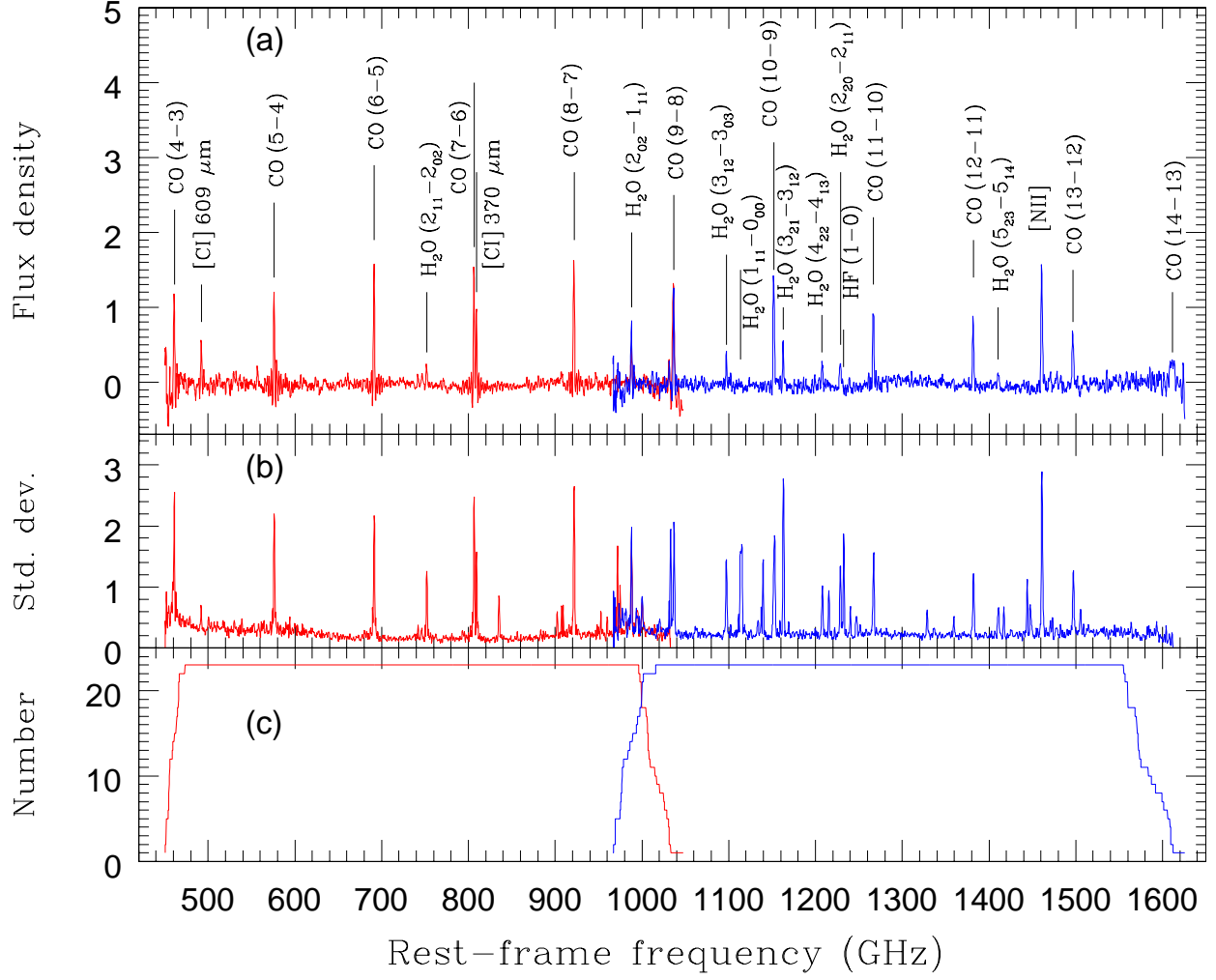


Fig. 20.— Same as Fig. 18, but using the sample galaxies with  $0.9 \leq C(60/100) < 1.4$ .

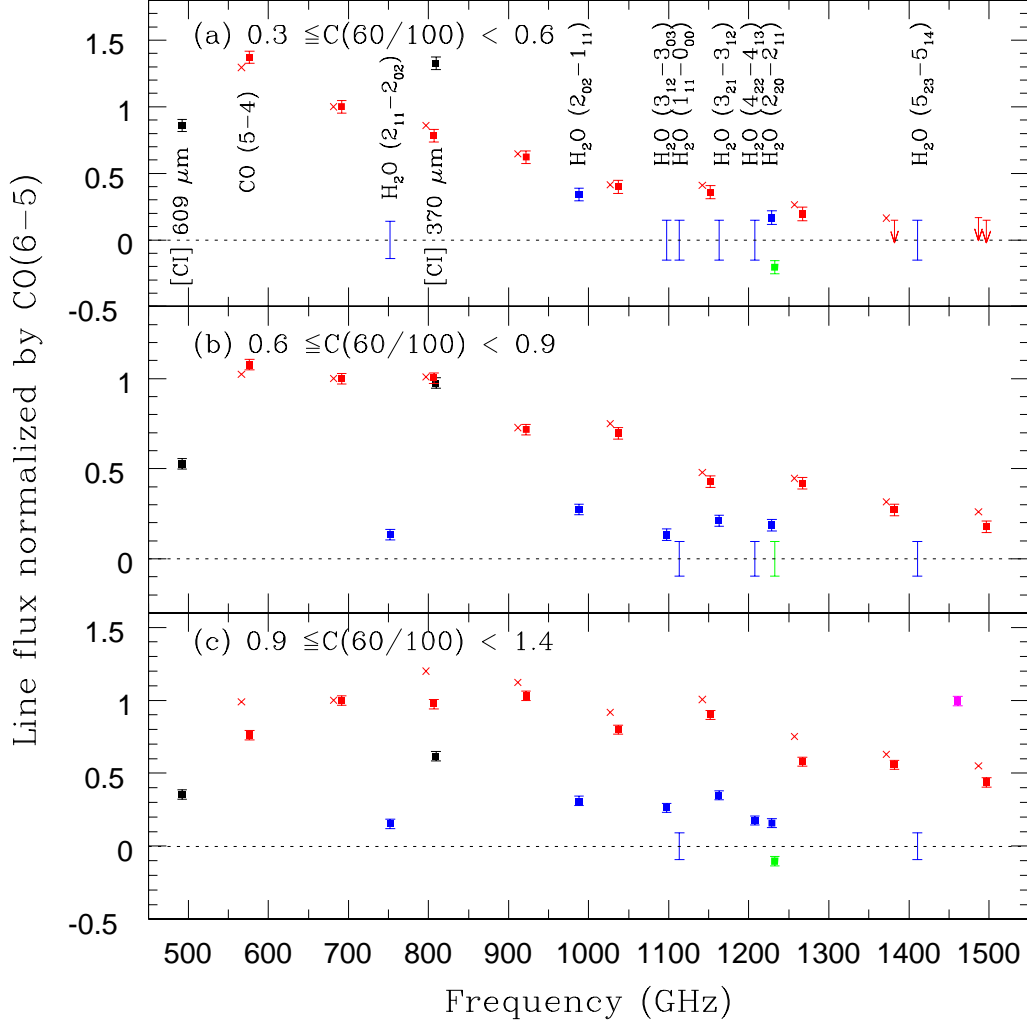


Fig. 21.— Panels (a) to (c) are plots of the line intensity or its upper limit, normalized by the intensity of CO(6–5), as a function of the line frequency, for the CO lines (in red), the two [C I] lines (black), the [N II] line (magenta), as well as a suite of H<sub>2</sub>O lines (blue) and HF(1–0) (green) from the 3 stacked spectra shown in Figs. 18 to 20, respectively. The normalized [N II] line fluxes are 5.72, 3.20 and 1.00 in (a), (b) and (c), respectively. Therefore this line is off the scale in both (a) and (b). Detected lines are shown as filled squares. For an undetected CO line, its  $3\sigma$  upper limit is plotted; for an undetected H<sub>2</sub>O or HF(1–0) line, its  $\pm 3\sigma$  range is shown to enclose both emission and absorption possibilities. Some of the lines are labelled in (a) to guide line identifications. For the CO lines, we also show the results (in red crosses) from a similar stacking procedure, but limited to the subset of “compact” targets with  $f_{70\mu\text{m}}(17'') > 0.80$ . For clarity, this second CO data set is offset by –10 GHz along the frequency axis in each plot.

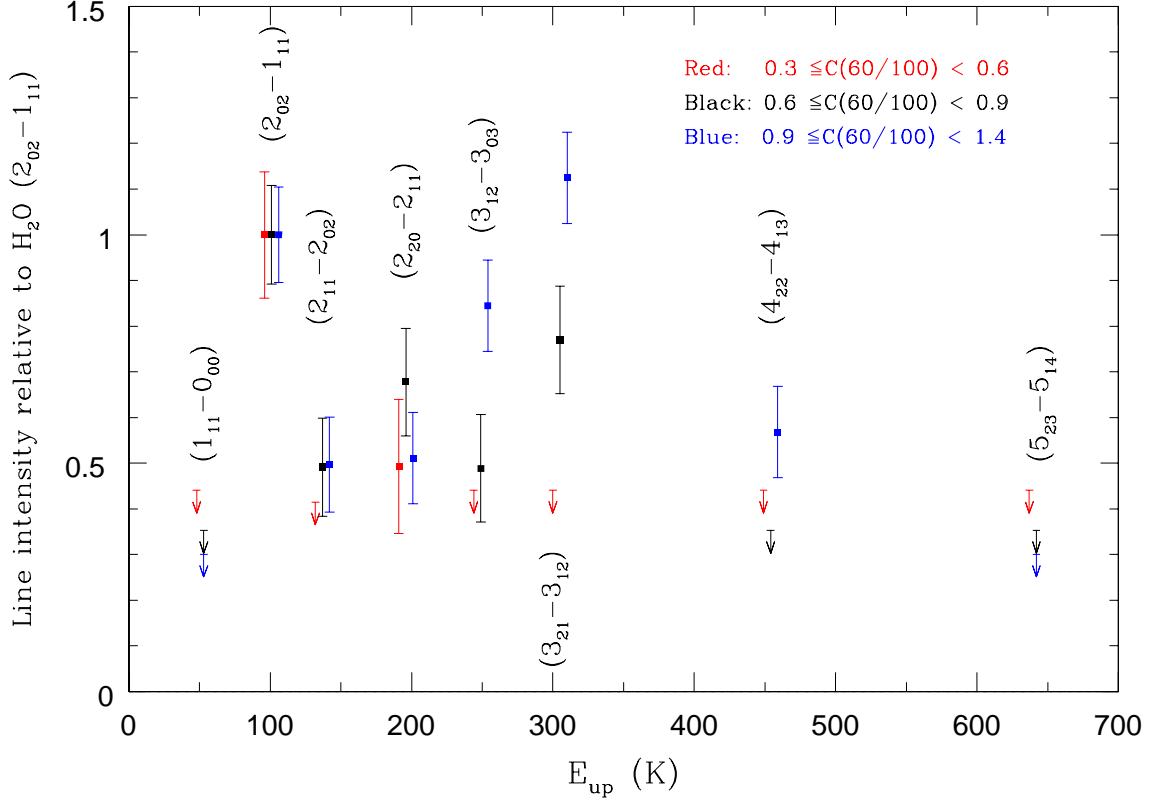


Fig. 22.— Plot of the line intensity as a function of the line upper level energy for the  $\text{H}_2\text{O}$  lines listed in Table 7. As noted in the legend, the data points are color coded to differentiate which of the 3 stacked spectra they belong to. The intensity of each line plotted has been normalized by that of  $\text{H}_2\text{O}$  ( $2_{02}-1_{11}$ ) at 987.927 GHz from the same stacked spectrum. For visual clarity, a small offset along the X-axis was placed between the data sets shown in different colors. The individual  $\text{H}_2\text{O}$  transitions are labelled in the plot. Note that the  $3\sigma$  upper limit shown for a non detection also constrains the amplitude of the subject line if it is in absorption.



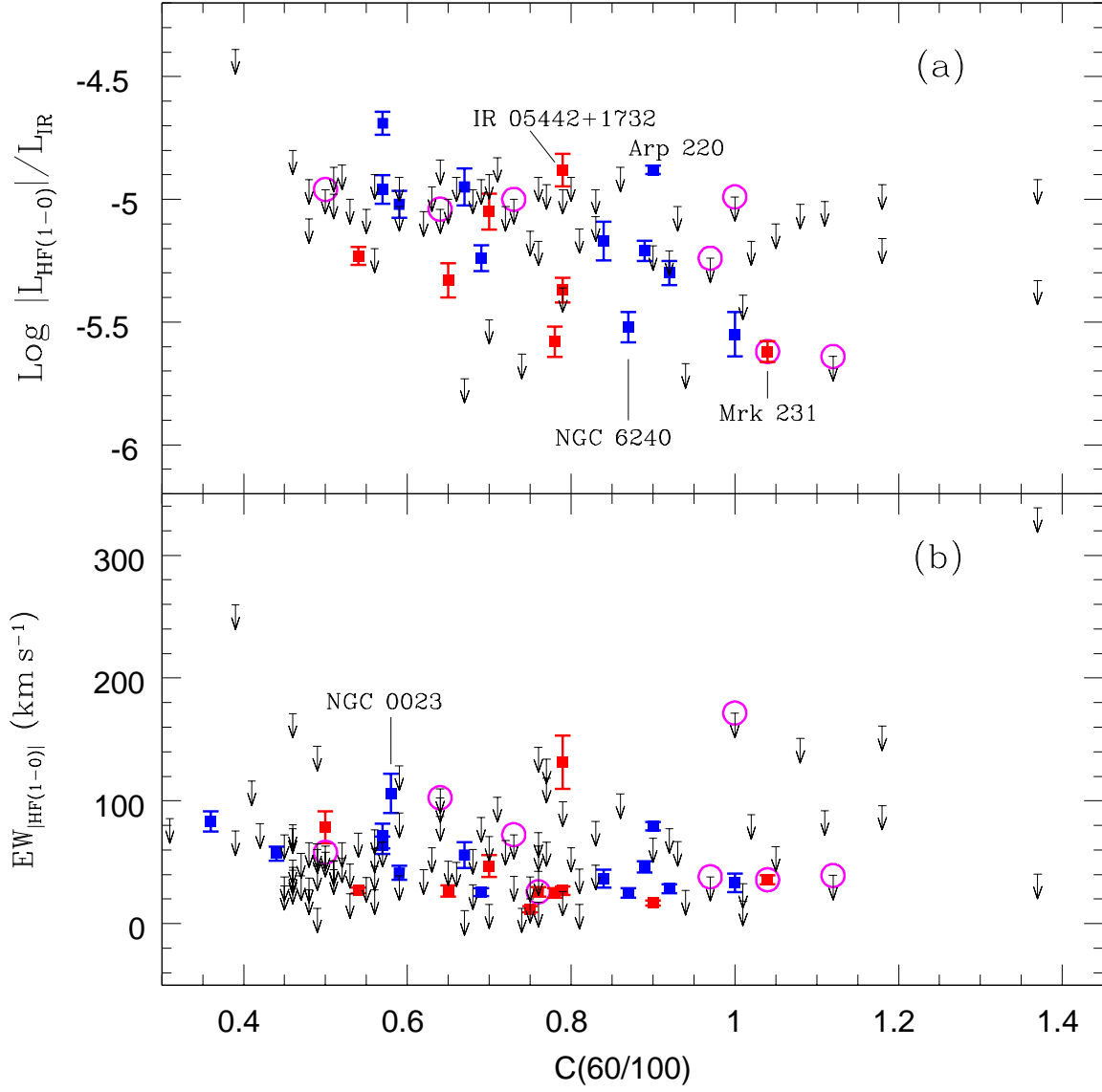


Fig. 23.— Plots as a function of the FIR color of (a) the ratio of the absolute HF (1–0) luminosity to  $L_{\text{IR}}$  and (b) the equivalent with (EW) of the absolute HF (1–0) line flux for our sample galaxies. The emission and absorption cases of detections are shown in red and blue, respectively. For non-detections, the  $3\sigma$  upper limits are shown in black. The dominant AGNs are further circled in magenta. In (a), only those targets compact enough (i.e., with  $f_{70\mu\text{m}}(17'') > 0.8$ ) are plotted; in (b) the whole sample is shown. Two galaxies (IRAS 05442+1732 and NGC 23), which are discussed in the text, as well as a few well known individual galaxies are labelled in the plots.

Table 1. SPIRE/FTS Observations

Name	R.A.	Dec.	$\delta r$	$L_{\text{IR}}$	$C_{\text{FIR}}$	$D_{\text{lum}}$	$V_h$	OBSID	Exp	FTS Program
(1)	(J2000)	(J2000)	( $''$ )	( $\log L_{\odot}$ )	(6)	(Mpc)	( $\text{km s}^{-1}$ )	(9)	(sec)	(11)
NGC 0023	0h09m53.4s	25d55m26s	0.2	11.11	0.58	65.2	4566	1342247622	1584	OT1_nlu_1
NGC 0034	0h11m06.6s	-12d06m24s	2.9	11.49(*)	1.01	84.1	5881	1342199253	14832	KPOT_pvanderw_1
MCG -02-01-051	0h18m50.9s	-10d22m38s	0.1	11.44(*)	0.77	117.5	8159	1342247617	2936	OT1_nlu_1
ESO 350-IG038 (= Haro 11)	0h36m52.5s	-33d33m17s	0.0	11.28	1.37	89.0	6175	1342246978	2936	OT1_nlu_1
NGC 0232	0h42m45.9s	-23d33m39s	3.1	11.41(*)	0.59	95.2	6647	1342221707	2936	OT1_nlu_1
MCG +12-02-001	0h54m03.4s	73d05m09s	3.1	11.50	0.75	69.8	4706	1342213377	14428	KPOT_pvanderw_1
NGC 0317B	0h57m40.3s	43d47m33s	0.3	11.18(*)	0.67	77.8	5429	1342239358	2936	OT1_nlu_1
IC 1623	1h07m46.7s	-17d30m27s	5.3	11.71(*)	0.73	85.5	6016	1342212314	13346	KPOT_pvanderw_1
MCG -03-04-014	1h10m08.8s	-16d51m11s	2.0	11.65	0.70	144.0	10040	1342213442	5640	OT1_nlu_1
ESO 244-G012	1h18m08.3s	-44d27m39s	4.2	11.38(*)	0.79	91.5	6307	1342221708	2936	OT1_nlu_1
CGCG 436-030	1h20m02.5s	14d21m41s	2.2	11.69	1.11	134.0	9362	1342213443	5640	OT1_nlu_1
ESO 353-G020	1h34m51.3s	-36d08m15s	0.1	11.06	0.46	68.8	4797	1342247615	2936	OT1_nlu_1
III Zw 035	1h44m30.5s	17d06m09s	0.2	11.64	0.93	119.0	8375	1342239343	2936	OT1_nlu_1
NGC 0695	1h51m14.4s	22d34m56s	1.5	11.68	0.56	139.0	9735	1342224767	5640	OT1_nlu_1
NGC 0828	2h10m09.5s	39d11m25s	0.2	11.36	0.45	76.3	5374	1342239357	1584	OT1_nlu_1
NGC 0876	2h18m00.1s	14d32m34s	0.2	10.97(*)	0.46	54.6	3913	1342239342	1584	OT1_nlu_1
UGC 01845	2h24m07.9s	47d58m11s	0.3	11.12	0.66	67.0	4679	1342240022	1584	OT1_nlu_1
NGC 0958	2h30m42.8s	-2d56m24s	0.2	11.20	0.39	80.6	5738	1342239339	2936	OT1_nlu_1
NGC 1068 <sup>a</sup>	2h42m40.8s	-0d00m48s	2.1	11.40	0.76	15.9	1137	1342213445	5041	KPGT_cwilso01_1
UGC 02238	2h46m17.5s	13d05m45s	0.1	11.33	0.52	92.4	6560	1342239340	2936	OT1_nlu_1
MCG +02-08-029	2h54m01.8s	14d58m14s	0.1	11.66(*)	0.72	136.0	9558	1342239341	5640	OT1_nlu_1
UGC 02608 <sup>a</sup>	3h15m01.2s	42d02m09s	0.2	11.38(*)	0.73	100.0	6998	1342239356	2936	OT1_nlu_1
NGC 1275 <sup>a</sup>	3h19m48.2s	41d30m42s	0.3	11.26	0.97	75.0	5264	1342249054	3612	OT1_pogle01_1
UGC 02982	4h12m22.5s	5d32m50s	0.1	11.20	0.50	74.9	5305	1342240021	1584	OT1_nlu_1
ESO 420-G013	4h13m49.6s	-32d00m24s	0.2	11.07	0.65	51.0	3570	1342242590	1584	OT1_nlu_1
NGC 1572	4h22m42.8s	-40d36m03s	0.3	11.30	0.48	88.6	6111	1342242588	2936	OT1_nlu_1
IRAS 04271+3849	4h30m33.2s	38d55m49s	1.2	11.11	0.63	80.8	5640	1342227786	2936	OT1_nlu_1
NGC 1614	4h33m59.8s	-8d34m45s	1.7	11.65	0.94	67.8	4778	1342192831	6720	KPOT_pvanderw_1
UGC 03094	4h35m33.8s	19d10m19s	1.4	11.41	0.49	106.0	7408	1342227522	2936	OT1_nlu_1
MCG -05-12-006	4h52m05.0s	-32d59m26s	0.2	11.17	0.83	81.3	5622	1342242589	2936	OT1_nlu_1
IRAS F05189-2524 <sup>a</sup>	5h21m01.3s	-25d21m46s	2.3	12.16	1.12	187.0	12760	1342192832	16996	KPOT_pvanderw_1
IRAS 05223+1908 <sup>b</sup>	5h25m16.8s	19d10m49s	2.4	.....(*)	....	....	100	1342228738	2936	OT1_nlu_1
MCG +08-11-002	5h40m43.8s	49d41m43s	1.8	11.46	0.57	83.7	5743	1342230414	1584	OT1_nlu_1

Table 1—Continued

Name	R.A. (J2000)	Dec. (J2000)	$\delta r$ ( $''$ )	$L_{\text{IR}}$ ( $\log L_{\odot}$ )	$C_{\text{FIR}}$	$D_{\text{lum}}$ (Mpc)	$V_h$ ( $\text{km s}^{-1}$ )	OBSID	Exp (sec)	FTS Program
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
NGC 1961	5h42m04.7s	69d22m43s	1.8	11.06	0.31	59.0	3934	1342228708	1584	OT1_nlu_1
UGC 03351	5h45m48.2s	58d42m05s	1.8	11.28	0.48	65.8	4455	1342230415	1584	OT1_nlu_1
IRAS 05442+1732	5h47m11.3s	17d33m48s	1.8	11.24(*)	0.79	80.5	5582	1342230413	1584	OT1_nlu_1
UGC 03410	6h14m30.1s	80d27m01s	1.7	11.02(*)	0.42	59.7	3921	1342231072	1584	OT1_nlu_1
NGC 2146NW <sup>c</sup>	6h18m36.0s	78d21m32s	2.2	11.12	0.76	17.5	893	1342219554	3070	KPOT_pvanderw_1
NGC 2146Nuc <sup>c</sup>	6h18m38.6s	78d21m25s	1.1	11.12	0.76	17.5	893	1342204025	3070	KPOT_pvanderw_1
NGC 2146SE <sup>c</sup>	6h18m39.8s	78d21m16s	2.2	11.12	0.76	17.5	893	1342219555	3070	KPOT_pvanderw_1
ESO 255-IG 007	6h27m21.8s	-47d10m36s	1.8	11.86(*)	0.76	173.0	11629	1342231084	5640	OT1_nlu_1
UGC 03608	6h57m34.6s	46d24m12s	2.3	11.34	0.71	94.3	6401	1342228744	2936	OT1_nlu_1
NGC 2341	7h09m12.2s	20d36m13s	1.5	10.97(*)	0.77	78.0	5276	1342228730	2936	OT1_nlu_1
NGC 2342	7h09m18.1s	20d38m10s	1.5	11.03(*)	0.48	78.0	5276	1342228729	2936	OT1_nlu_1
NGC 2369	7h16m37.8s	-62d20m35s	1.8	11.16	0.53	47.6	3240	1342231083	1584	OT1_nlu_1
NGC 2388	7h28m53.6s	33d49m09s	1.8	11.28(*)	0.68	62.1	4134	1342231071	1584	OT1_nlu_1
MCG +02-20-003	7h35m43.5s	11d42m36s	1.3	11.13	0.70	72.8	4873	1342228728	2936	OT1_nlu_1
IRAS 08355-4944	8h37m02.0s	-49d54m29s	1.8	11.62	1.18	118.0	7764	1342231975	2936	OT1_nlu_1
NGC 2623	8h38m24.0s	25d45m17s	0.8	11.60	0.92	84.1	5549	1342219553	12534	KPOT_pvanderw_1
IRAS 09022-3615	9h04m12.8s	-36d27m00s	1.9	12.31	1.05	271.0	17880	1342231063	8344	OT1_nlu_1
UGC 05101	9h35m51.9s	61d21m11s	2.1	12.01	0.59	177.0	11802	1342209278	5098	GT1_lspinogl_2
NGC 3110	10h04m02.2s	-6d28m28s	1.7	11.37	0.51	79.5	5054	1342231971	1584	OT1_nlu_1
NGC 3221	10h22m20.4s	21d34m21s	3.1	11.09	0.41	65.7	4110	1342221714	1584	OT1_nlu_1
NGC 3256	10h27m51.3s	-43d54m15s	1.7	11.64	0.90	38.9	2804	1342201201	5234	KPOT_pvanderw_1
ESO 264-G036	10h43m07.7s	-46d12m45s	0.3	11.32	0.45	100.0	6299	1342249044	2936	OT1_nlu_1
ESO 264-G057	10h59m01.8s	-43d26m26s	0.3	11.14	0.47	83.3	5156	1342249043	2936	OT1_nlu_1
IRAS F10565+2448	10h59m18.2s	24d32m34s	0.0	12.08	0.81	197.0	12921	1342247096	5640	OT1_nlu_1
UGC 06471 <sup>d</sup>	11h28m30.6s	58d33m39s	3.6	11.93	1.01	50.7	3093	1342199249	4964	KPOT_pvanderw_1
NGC 3690 <sup>d</sup>	11h28m30.6s	58d33m48s	3.6	11.93	1.01	50.7	3093	1342199250	4964	KPOT_pvanderw_1
UGC 06472 <sup>d</sup>	11h28m33.2s	58d33m45s	3.6	11.93	1.01	50.7	3093	1342199248	4964	KPOT_pvanderw_1
ESO 320-G030	11h53m11.7s	-39d07m50s	1.0	11.17	0.74	41.2	3232	1342210861	6044	KPOT_pvanderw_1
NGC 4194	12h14m09.8s	54d31m35s	1.7	11.10	0.92	43.0	2501	1342231069	1584	OT1_nlu_1
IRAS 12116-5615	12h14m22.1s	-56d32m33s	0.3	11.65	0.76	128.0	8125	1342249462	5640	OT1_nlu_1
NGC 4418	12h26m54.6s	-0d52m39s	0.0	11.19	1.37	36.5	2179	1342210848	9491	KPGT_esturm_1
UGC 08058 <sup>a</sup> (= Mrk 231)	12h56m14.5s	56d52m26s	2.4	12.57	1.04	192.0	12642	1342210493	14292	KPOT_pvanderw_1
MCG -02-33-098	13h02m19.8s	-15d46m04s	0.1	11.16(*)	0.77	78.7	4773	1342247567	2936	OT1_nlu_1

Table 1—Continued

Name	R.A.	Dec.	$\delta r$	$L_{\text{IR}}$	$C_{\text{FIR}}$	$D_{\text{lum}}$	$V_h$	OBSID	Exp	FTS Program
(1)	(J2000)	(J2000)	( $''$ )	( $\log L_{\odot}$ )	(6)	(Mpc)	( $\text{km s}^{-1}$ )	(9)	(sec)	(11)
ESO 507-G070	13h02m52.3s	-23d55m18s	0.1	11.56	0.83	106.0	6506	1342248421	2936	OT1_nlu_1
NGC 5010 <sup>e</sup>	13h12m26.5s	-15d47m51s	1.6	10.82	0.47	44.4	2975	1342236996	1584	OT1_nlu_1
IRAS 13120-5453	13h15m06.3s	-55d09m23s	0.5	12.32	0.79	144.0	9222	1342212342	4152	KPOT_pvanderw_1
UGC 08387	13h20m35.5s	34d08m23s	1.9	11.73	0.70	110.0	6985	1342209853	14832	KPOT_pvanderw_1
NGC 5104	13h21m23.1s	0d20m33s	0.1	11.27	0.51	90.8	5578	1342247566	2936	OT1_nlu_1
MCG -03-34-064 <sup>a</sup>	13h22m24.4s	-16d43m43s	0.1	11.17	1.00	82.2	4959	1342249041	2936	OT1_nlu_1
NGC 5135	13h25m44.0s	-29d49m60s	1.4	11.30	0.54	60.9	4105	1342212344	14832	KPOT_pvanderw_1
ESO 173-G015	13h27m23.7s	-57d29m23s	0.8	11.38	0.81	34.0	2918	1342202268	1988	KPOT_pvanderw_1
IC 4280	13h32m53.3s	-24d12m26s	0.1	11.15	0.49	82.4	4889	1342249042	2936	OT1_nlu_1
UGC 08696	13h44m42.3s	55d53m10s	3.3	12.21	1.00	173.0	11326	1342209850	13616	KPOT_pvanderw_1
UGC 08739	13h49m14.3s	35d15m20s	0.0	11.15	0.36	81.4	5032	1342247123	2936	OT1_nlu_1
ESO 221-IG 010	13h50m56.9s	-49d03m19s	0.2	11.22	0.59	62.9	3099	1342249461	1584	OT1_nlu_1
NGC 5653	14h30m09.9s	31d12m56s	0.1	11.13(*)	0.46	60.2	3562	1342247565	1584	OT1_nlu_1
NGC 5734	14h45m09.0s	-20d52m13s	0.1	10.99(*)	0.46	67.1	4121	1342248417	1584	OT1_nlu_1
VV 340a	14h57m00.8s	24d37m05s	1.5	11.66(*)	0.46	157.0	10094	1342238241	5640	OT1_nlu_1
IC 4518A	14h57m41.1s	-43d07m56s	0.1	11.16(*)	0.59	80.0	4763	1342250514	2936	OT1_nlu_1
CGCG 049-057	15h13m13.2s	7d13m29s	3.2	11.35	0.69	65.4	3897	1342212346	14832	KPOT_pvanderw_1
VV 705	15h18m06.3s	42d44m45s	1.5	11.92(*)	0.90	183.0	11944	1342238712	5640	OT1_nlu_1
ESO 099-G004	15h24m57.7s	-63d07m30s	1.8	11.74	0.75	137.0	8779	1342230419	5640	OT1_nlu_1
NGC 5936	15h30m00.8s	12d59m22s	0.2	11.14	0.49	67.1	4004	1342249046	1584	OT1_nlu_1
UGC 09913 (= Arp 220)	15h34m57.2s	23d30m12s	1.5	12.27	0.90	87.9	5434	1342190674	10445	KPGT_cwilso01_1
NGC 5990	15h46m16.4s	2d24m55s	0.2	11.13	0.56	64.4	3839	1342240016	1584	OT1_nlu_1
NGC 6052	16h05m12.9s	20d32m37s	0.2	11.09	0.64	77.6	4739	1342212347	2936	OT1_nlu_1
CGCG 052-037	16h30m56.6s	4d04m59s	0.2	11.43(*)	0.62	116.0	7342	1342251284	5640	OT1_nlu_1
NGC 6156	16h34m52.3s	-60d37m08s	1.8	11.14	0.54	48.0	3263	1342231041	1584	OT1_nlu_1
2MASX J16381190-6826080	16h38m11.5s	-68d26m08s	1.8	11.97(*)	0.56	212.0	13922	1342231040	8344	OT1_nlu_1
IRAS F16399-0937	16h42m40.1s	-9d43m13s	0.2	11.63	0.57	128.0	8098	1342251334	5640	OT1_nlu_1
NGC 6240	16h52m59.1s	2d24m04s	3.5	11.93	0.87	116.0	7339	1342214831	13346	KPOT_pvanderw_1
IRAS F16516-0948	16h54m23.8s	-9d53m21s	0.2	11.31	0.46	107.0	6755	1342251335	5640	OT1_nlu_1
NGC 6285	16h58m23.9s	58d57m19s	1.7	10.85(*)	0.39	85.7	5501	1342231068	1584	OT1_nlu_1
NGC 6286	16h58m31.4s	58d56m17s	5.4	11.29(*)	0.44	85.7	5501	1342221715	1584	OT1_nlu_1
IRAS F17138-1017	17h16m35.7s	-10d20m42s	1.7	11.49	0.80	84.0	5197	1342230418	1584	OT1_nlu_1
IRAS F17207-0014	17h23m22.0s	-0d17m00s	1.3	12.46	0.89	198.0	12834	1342192829	6720	KPOT_pvanderw_1

Table 1—Continued

Name	R.A.	Dec.	$\delta r$	$L_{\text{IR}}$	$C_{\text{FIR}}$	$D_{\text{lum}}$	$V_h$	OBSID	Exp	FTS Program
(1)	(J2000) (2)	(J2000) (3)	( $''$ ) (4)	( $\log L_{\odot}$ ) (5)	(6)	(Mpc) (7)	( $\text{km s}^{-1}$ ) (8)	(9)	(sec) (10)	(11)
ESO 138-G027	17h26m43.1s	-59d55m56s	1.8	11.41	0.86	98.3	6230	1342231042	2936	OT1_nlu_1
UGC 11041	17h54m51.7s	34d46m33s	1.7	11.11	0.46	77.5	4881	1342231061	2936	OT1_nlu_1
IRAS 17578-0400	18h00m31.8s	-4d00m54s	1.7	11.39 <sup>(*)</sup>	0.84	68.5	4210	1342231047	1584	OT1_nlu_1
NGC 6621	18h12m55.1s	68d21m46s	1.2	11.27 <sup>(*)</sup>	0.56	94.3	6191	1342221716	2936	OT1_nlu_1
IC 4687	18h13m39.7s	-57d43m30s	1.2	11.36 <sup>(*)</sup>	0.73	81.9	5200	1342192993	14562	KPOT_pvanderw_1
IRAS F18293-3413	18h32m41.3s	-34d11m26s	2.3	11.88	0.67	86.0	5449	1342192830	5640	KPOT_pvanderw_1
IC 4734	18h38m25.6s	-57d29m25s	0.2	11.35	0.55	73.4	4680	1342240013	1584	OT1_nlu_1
NGC 6701	18h43m12.5s	60d39m10s	1.7	11.12	0.50	62.4	3965	1342231994	1584	OT1_nlu_1
ESO 339-G011	19h57m37.5s	-37d56m10s	1.7	11.20	0.64	88.6	5756	1342231990	2936	OT1_nlu_1
MCG +04-48-002	20h28m35.1s	25d44m03s	2.9	11.00 <sup>(*)</sup>	0.57	64.2	4167	1342221682	1584	OT1_nlu_1
NGC 6926	20h33m06.0s	-2d01m40s	1.7	11.32	0.49	89.1	5880	1342231050	2936	OT1_nlu_1
CGCG 448-020	20h57m24.4s	17d07m38s	1.4	11.94 <sup>(*)</sup>	1.08	161.0	10822	1342221679	2936	OT1_nlu_1
ESO 286-IG 019	20h58m26.8s	-42d39m01s	0.0	12.06	1.18	193.0	12890	1342245107	5640	OT1_nlu_1
ESO 286-G035	21h04m11.2s	-43d35m31s	3.1	11.20	0.68	79.1	5205	1342216901	2936	OT1_nlu_1
NGC 7130	21h48m19.4s	-34d57m04s	1.5	11.42	0.65	72.7	4842	1342219565	5098	GT1_lspinogl_2
ESO 467-G027	22h14m39.8s	-27d27m50s	0.1	11.08	0.45	77.3	5217	1342245108	2936	OT1_nlu_1
IC 5179	22h16m09.1s	-36d50m37s	0.1	11.24	0.52	51.4	3422	1342245109	1584	OT1_nlu_1
UGC 12150	22h41m12.3s	34d14m56s	0.9	11.35	0.51	93.5	6413	1342221699	2936	OT1_nlu_1
NGC 7469	23h03m15.9s	8d52m30s	5.7	11.58 <sup>(*)</sup>	0.78	70.8	4892	1342199252	12400	KPOT_pvanderw_1
ESO 148-IG 002	23h15m46.7s	-59d03m15s	0.0	12.06	1.02	199.0	13371	1342245110	7396	OT1_nlu_1
IC 5298	23h16m00.9s	25d33m26s	3.6	11.60	0.76	119.0	8221	1342221700	2936	OT1_nlu_1
NGC 7552	23h16m10.8s	-42d35m05s	1.0	11.11	0.75	23.5	1608	1342198428	1988	KPOT_pvanderw_1
NGC 7591	23h18m16.3s	6d35m09s	0.0	11.12	0.53	71.4	4956	1342257346	2936	OT1_nlu_1
NGC 7592	23h18m22.3s	-4d24m57s	2.7	11.40 <sup>(*)</sup>	0.76	106.0	7328	1342221702	2936	OT1_nlu_1
NGC 7674 <sup>a</sup>	23h27m56.7s	8d46m44s	0.0	11.54 <sup>(*)</sup>	0.64	125.0	8671	1342245858	5640	OT1_nlu_1
NGC 7679	23h28m46.6s	3d30m43s	1.3	11.11 <sup>(*)</sup>	0.69	73.8	5138	1342221701	2936	OT1_nlu_1
NGC 7771	23h51m24.7s	20d06m41s	3.6	11.27 <sup>(*)</sup>	0.49	61.2	4277	1342212317	14832	KPOT_pvanderw_1
Mrk 331	23h51m26.6s	20d35m09s	3.1	11.50 <sup>(*)</sup>	0.79	79.3	5541	1342212316	13616	KPOT_pvanderw_1

<sup>a</sup> A member of the subsample of powerful AGNs defined in §2.2.<sup>b</sup> IRAS 05223+1908 consists of three objects. The SPIRE/FTS spectrum is likely dominated by the brightest northern object, which is a Galactic source at a heliocentric velocity of 100 km/s (see Appendix A for more details). While the SPIRE/FTS data of this target are included here, this target was not used in our statistical analysis.

<sup>c</sup> NGC 2146 has 3 independent observations, placed at the galaxy center and two offset positions, respectively. The total IRAS  $L_{\text{IR}}$  is listed for each observation in the table.

<sup>d</sup> These 3 independent observations targeted the 3 surface brightness peaks of the interacting galaxy pair system NGC 3690. In the literature, UGC 06471 may also be referred to as NGC 3690 or Arp 299B, and UGC 06472 as IC 0694 or NGC 3690A or Arp 299A, The total IRAS  $L_{\text{IR}}$  of the system is listed for each individual observation in the table.

<sup>e</sup> NGC 5010 was included in the SPIRE/FTS sample based on its  $L_{\text{IR}}$  from Sanders et al. (2003), where its systemic velocity used is incorrect. While the SPIRE/FTS data of this target are still documented here, this target was not used in any statistical analysis in this paper.

Table 2. FWHM Beam Sizes at Selected Line Frequencies

Line	Freq. (GHz)	Wavelength ( $\mu\text{m}$ )	FWHM (arcsec)	Detector
CO (4–3)	461.041	650.7	42.8	SLWC3
[C I] 609 $\mu\text{m}$	492.161	609.1	38.6	SLWC3
CO (5–4)	576.268	520.2	35.2	SLWC3
CO (6–5)	691.473	433.6	31.2	SLWC3
CO (7–6)	806.652	371.7	35.9	SLWC3
[C I] 370 $\mu\text{m}$	809.342	370.4	36.0	SLWC3
CO (8–7)	921.800	325.2	40.1	SLWC3
CO (9–8)	1036.912	289.1	19.0	SSWD4
CO (10–9)	1151.985	260.4	17.4	SSWD4
CO (11–10)	1267.014	236.8	17.3	SSWD4
CO (12–11)	1381.995	217.1	16.9	SSWD4
[N II] 205 $\mu\text{m}$	1461.132	205.2	16.6	SSWD4
CO (13–12)	1496.922	200.4	16.6	SSWD4

Table 3. Rest-frame Frequencies of Known Spectral Lines within the SPIRE/FTS Frequency Coverage

Line in SLW	Frequency (GHz)	Line in SSW	Frequency (GHz)
CO (4–3)	461.041	OH <sup>+</sup> (1 <sub>12</sub> –0 <sub>12</sub> ) <sup>b</sup>	1033.118
[C I] (1–0)	492.161	CO (9–8) <sup>b</sup>	1036.912
HCN (6–5)	531.716	HCN (12–11)	1062.980
HCO <sup>+</sup> (6–5)	536.828	H <sub>2</sub> O (3 <sub>12</sub> –3 <sub>03</sub> )	1097.365
<sup>13</sup> CO (5–4)	550.926	H <sub>2</sub> O (1 <sub>11</sub> –0 <sub>00</sub> )	1113.343
CO (5–4)	576.268	H <sub>2</sub> O+ (1 <sub>11</sub> –0 <sub>00</sub> , $J_{3/2-1/2}$ )	1115.204
HCO <sup>+</sup> (7–6)	624.208	H <sub>2</sub> O+ (1 <sub>11</sub> –0 <sub>00</sub> , $J_{1/2-1/2}$ )	1139.561
<sup>13</sup> CO (6–5)	661.067	CO (10–9)	1151.985
CO (6–5)	691.473	H <sub>2</sub> O (3 <sub>12</sub> –2 <sub>21</sub> )	1153.127
H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> –1 <sub>11</sub> , $J_{5/3-3/2}$ )	742.033	H <sub>2</sub> O (3 <sub>21</sub> –3 <sub>12</sub> )	1162.912
H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> –1 <sub>11</sub> , $J_{3/2-3/2}$ )	746.194	H <sub>2</sub> O (4 <sub>22</sub> –4 <sub>13</sub> )	1207.639
H <sub>2</sub> O (2 <sub>11</sub> –2 <sub>02</sub> )	752.033	H <sub>2</sub> O (2 <sub>20</sub> –2 <sub>11</sub> )	1228.789
<sup>13</sup> CO (7–6)	771.184	HF (1–0)	1232.476
CO (7–6)	806.652	HCN (14–13)	1239.890
[C I] (2–1)	809.342	CO (11–10)	1267.014
CH <sup>+</sup> (1–0)	835.079	HCN (15–14)	1328.302
<sup>13</sup> CO (8–7)	881.273	CO (12–11)	1381.995
OH <sup>+</sup> (1 <sub>01</sub> –0 <sub>12</sub> )	909.159	H <sub>2</sub> O (5 <sub>23</sub> –5 <sub>14</sub> )	1410.618
CO (8–7)	921.800	HCN (16–15)	1416.683
OH <sup>+</sup> (1 <sub>22</sub> –0 <sub>11</sub> ) <sup>a</sup>	971.805	[N II] (1–0)	1461.134
H <sub>2</sub> O (2 <sub>02</sub> –1 <sub>11</sub> ) <sup>a</sup>	987.927	CO (13–12)	1496.923
		HCN (17–16)	1505.030
		CO (14–13)	1611.793

<sup>a</sup>These lines could also be seen in the SSW array if the source heliocentric velocity is low enough, i.e., less than about 4,640 and 9,695 km s<sup>–1</sup> for OH<sup>+</sup> (1<sub>22</sub>–0<sub>11</sub>) and H<sub>2</sub>O (2<sub>02</sub>–1<sub>11</sub>), respectively.

<sup>b</sup>These lines could also be seen in the SLW array if the source heliocentric velocity is high enough, i.e., greater than about 13,510 and 14,660 km s<sup>–1</sup> for OH<sup>+</sup> (1<sub>12</sub>–0<sub>12</sub>) and CO (9–8), respectively.



Table 4. Fluxes of the CO, [C I] and [N II] Lines

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
NGC 0023	-4.22	2.57	1.43	1.14	-1.34	-1.14	-1.31	-1.35	-1.22	-1.33	-2.98	1.32	10.94	0.95
	...	0.32	0.13	0.12	...	...	...	...	...	...	...	0.11	0.66	0.92
	...	567.39	681.02	794.86	...	...	...	...	...	...	...	797.44	1439.42	0.75
	...	0.09	0.06	0.09	...	...	...	...	...	...	...	0.06	0.04	
	...	-0.23	-0.08	0.31	...	...	...	...	...	...	...	0.24	0.20	
	...	2.17	1.20	0.96	...	...	...	...	...	...	...	1.12	5.00	
	...	4.43	4.62	4.80	...	...	...	...	...	...	...	5.33	18.52	
	...	2	2	2	...	...	...	...	...	...	...	1	1	
NGC 0034	...	...	...	...	...	...	...	...	...	...	...	...	428.10	
	-0.83	1.54	1.91	2.11	2.05	2.20	1.66	1.66	1.17	0.93	0.88	0.97	3.52	1.00
	...	0.11	0.06	0.05	0.09	0.09	0.08	0.08	0.07	0.08	0.13	0.05	0.23	0.98
	...	565.28	678.33	791.24	904.36	1017.21	1130.22	1242.87	1355.98	1468.29	482.98	794.20	1433.43	0.85
	...	0.04	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.06	0.10	0.03	0.03	
	...	0.10	0.17	0.11	0.29	0.25	0.40	0.24	0.57	0.17	0.29	0.43	0.40	
	...	1.30	1.61	1.78	1.73	1.85	1.40	1.40	0.99	0.79	0.74	0.82	1.88	
	...	10.83	14.64	22.25	11.53	13.21	8.24	12.73	7.07	4.65	5.69	11.71	15.67	
MCG -02-01-051	...	1	1	1	1	1	1	1	1	2	1	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	368.10	
	-1.81	1.10	1.41	0.94	0.75	1.10	0.68	-0.71	-0.76	-0.90	-1.23	0.86	3.33	1.00
	...	0.16	0.11	0.08	0.13	0.16	0.15	...	...	...	...	0.07	0.70	1.00
	...	561.27	673.28	785.45	897.36	1009.07	1121.82	...	...	...	...	788.18	1422.48	0.93
	...	0.10	0.05	0.06	0.12	0.10	0.13	...	...	...	...	0.07	0.03	
	...	0.27	0.13	0.17	-0.02	-0.37	0.36	...	...	...	...	0.28	0.06	
	...	0.93	1.19	0.80	0.63	0.92	0.58	...	...	...	...	0.73	3.50	
ESO 350-IG038	...	3.21	8.50	6.67	3.15	4.00	3.41	...	...	...	...	6.08	21.88	
	...	2	1	1	2	2	2	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	188.80	
	-1.45	-0.88	-0.69	-0.51	-0.68	-0.90	-0.59	-0.93	-0.79	-0.77	-1.43	-0.53	1.55	1.00
	...	...	...	...	...	...	...	...	...	...	...	...	1.29	1.00
	...	...	...	...	...	...	...	...	...	...	...	...	1431.81	0.94
	...	...	...	...	...	...	...	...	...	...	...	...	0.07	
	...	...	...	...	...	...	...	...	...	...	...	...	0.16	
	...	...	...	...	...	...	...	...	...	...	...	...	2.13	

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
NGC 0232	...	...	...	...	...	...	...	...	...	...	...	...	7.89	
	...	...	...	...	...	...	...	...	...	...	...	...	1	
	...	...	...	...	...	...	...	...	...	...	...	...	143.70	
	2.55	2.12	1.98	1.75	1.44	-1.10	1.07	-0.93	-0.93	-0.94	1.94	2.23	10.12	1.00
	0.35	0.21	0.10	0.07	0.17	...	0.16	...	...	...	0.27	0.08	0.43	1.00
	450.66	563.54	676.11	788.80	901.73	...	1125.97	...	...	...	480.76	791.32	1428.72	0.92
	0.10	0.07	0.03	0.03	0.07	...	0.10	...	...	...	0.09	0.02	0.02	
	-0.38	-0.23	-0.36	-0.35	-0.08	...	-1.02	...	...	...	-0.72	-0.47	-0.72	
	2.16	1.79	1.67	1.47	1.22	...	0.90	...	...	...	1.64	1.88	5.05	
	4.15	6.63	11.93	9.19	5.55	...	4.09	...	...	...	6.07	11.75	21.04	
MCG +12-02-001	2	1	1	1	1	...	2	...	...	...	3	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	394.60	
	2.71	3.56	2.98	2.44	2.23	1.30	0.85	0.87	-0.48	-0.61	0.99	2.35	8.60	0.93
	0.25	0.11	0.07	0.05	0.10	0.09	0.09	0.09	...	...	0.15	0.05	0.32	0.89
	453.98	567.26	680.61	794.04	907.26	1020.70	1133.91	1247.38	...	...	484.51	796.64	1438.17	0.65
	0.06	0.02	0.01	0.02	0.03	0.04	0.07	0.07	...	...	0.09	0.02	0.01	0.80
	0.07	-0.10	-0.17	-0.14	-0.30	-0.19	-0.27	-0.05	...	...	-0.05	-0.20	-0.39	1
	2.29	3.01	2.52	2.06	1.88	1.10	0.72	0.73	...	...	0.83	1.98	6.67	
	11.45	18.81	42.00	25.75	11.06	10.00	8.00	7.30	...	...	6.92	24.75	33.35	
	1	1	1	1	1	1	1	1	...	...	1	1	1	
NGC 0317B	...	...	...	...	...	...	...	...	...	...	...	...	253.60	
	-1.66	1.82	1.50	1.63	0.91	1.25	-0.88	1.15	-0.90	-0.94	-1.26	1.85	6.04	1.00
	...	0.20	0.12	0.08	0.15	0.16	...	0.16	...	...	...	0.08	0.44	0.99
	...	566.64	679.86	793.21	905.99	1019.63	...	1245.97	...	...	...	795.72	1436.86	0.87
	...	0.07	0.05	0.03	0.11	0.08	...	0.08	...	...	...	0.03	0.04	
	...	0.62	0.68	0.91	0.59	1.16	...	1.49	...	...	...	0.78	1.71	
	...	1.53	1.27	1.37	0.77	1.06	...	0.97	...	...	...	1.56	3.11	
	...	6.65	8.47	11.42	4.05	5.89	...	3.88	...	...	...	13.00	13.52	
	...	1	1	1	2	1	...	2	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	381.10	
IC 1623	4.47	4.54	3.12	2.78	2.51	1.13	0.66	-0.59	0.59	0.73	2.01	3.13	7.30	0.88
	0.22	0.10	0.06	0.05	0.09	0.09	0.09	...	0.08	0.10	0.15	0.05	0.27	0.83
	451.90	564.90	677.80	790.74	903.63	1016.38	1129.52	...	1354.63	1467.63	482.33	793.33	1432.41	0.54
	0.03	0.02	0.01	0.01	0.02	0.05	0.08	...	0.09	0.08	0.04	0.01	0.02	

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
MCG -03-04-014	-0.07	-0.03	-0.07	-0.04	-0.03	-0.13	0.19	...	-0.18	0.15	-0.15	-0.09	0.02	1.00 1.00 0.94
	3.77	3.83	2.64	2.34	2.12	0.96	0.56	...	0.49	0.62	1.70	2.64	3.93	
	13.46	27.36	24.00	21.27	16.31	8.00	5.60	...	7.00	4.13	10.63	24.00	28.07	
	1	1	1	1	1	1	1	...	1	2	1	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	365.10	
	0.00	1.01	1.09	0.97	0.65	-0.64	-0.46	-0.55	0.52	-0.72	-0.89	0.93	9.80	
	0.00	0.13	0.07	0.06	0.08	...	...	...	0.12	...	...	0.06	0.31	
	...	556.58	667.94	779.24	890.69	...	...	...	1335.10	...	...	781.66	1411.46	
	...	0.09	0.05	0.04	0.09	...	...	...	0.15	...	...	0.04	0.02	
	...	-1.01	-1.13	-1.27	-1.24	...	...	...	-2.11	...	...	-1.46	-2.32	
ESO 244-G012	0.00	0.86	0.92	0.82	0.55	...	...	...	0.44	...	...	0.79	5.25	1.00 1.00 0.90
	...	3.44	9.20	9.11	3.24	...	...	...	3.14	...	...	8.78	30.88	
	0	2	1	1	2	...	...	...	2	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	372.40	
	-2.37	-1.41	1.68	0.89	0.95	-1.29	-0.95	-0.99	-0.78	-0.88	-1.15	1.03	3.36	
	...	...	0.10	0.07	0.16	...	...	...	...	...	...	0.09	0.52	
	...	...	676.23	788.84	901.62	...	...	...	...	...	...	791.81	1429.12	
	...	...	0.04	0.06	0.10	...	...	...	...	...	...	0.06	0.05	
	...	...	-0.99	-1.20	-1.18	...	...	...	...	...	...	-0.86	-1.91	
	...	...	1.42	0.75	0.80	...	...	...	...	...	...	0.87	2.49	
CGCG 436-030	...	...	7.89	5.77	3.20	...	...	...	...	...	...	6.69	10.83	1.00 1.00 0.89
	...	...	1	1	2	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	267.10	
	-1.97	1.17	1.09	1.07	1.37	0.76	0.60	1.05	-0.51	-0.64	-1.08	0.84	1.86	
	...	0.13	0.06	0.06	0.08	0.13	0.10	0.10	...	...	...	0.06	0.09	
	...	558.65	670.48	782.05	893.64	1006.38	1117.02	1228.44	...	...	...	784.62	1416.63	
	...	0.08	0.04	0.04	0.04	0.11	0.11	0.07	...	...	...	0.05	0.03	
	...	-0.17	-0.06	-0.17	-0.24	0.86	-0.08	-0.21	...	...	...	-0.21	-0.26	
	...	0.99	0.92	0.90	1.15	0.64	0.50	0.88	...	...	...	0.71	1.57	
	...	4.95	10.22	11.25	7.19	3.20	3.33	5.18	...	...	...	8.87	11.21	
ESO 353-G020	...	2	1	1	1	4	2	1	...	...	...	1	1	1.00 1.00
	...	...	...	...	...	...	...	...	...	...	...	...	...	
	-1.84	2.68	2.17	1.81	0.78	-0.58	-0.95	-1.02	-0.97	-1.28	-1.57	2.72	17.68	
	...	0.18	0.11	0.09	0.14	...	...	...	...	...	...	0.09	0.50	1.00

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
III Zw 035	...	567.02	680.58	794.11	907.80	...	...	...	...	...	...	796.52	1438.17	0.87
	...	0.05	0.03	0.04	0.13	...	...	...	...	...	...	0.02	0.02	
	...	-0.18	-0.01	0.16	0.51	...	...	...	...	...	...	-0.08	0.05	
	...	2.26	1.83	1.53	0.66	...	...	...	...	...	...	2.29	8.05	
	...	8.69	12.20	9.00	3.30	...	...	...	...	...	...	13.47	28.75	
	...	1	1	1	2	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	430.30	
	-1.78	-1.41	1.28	1.62	1.96	1.58	1.85	-1.04	0.99	-0.79	-1.28	0.85	-0.82	1.00
	...	...	0.10	0.08	0.12	0.17	0.16	...	0.13	...	...	0.07	...	1.00
	...	...	672.96	785.05	897.25	1009.31	1121.46	...	1344.91	...	...	787.69	...	0.88
	...	...	0.06	0.03	0.04	0.07	0.05	...	0.09	...	...	0.06	...	
	...	...	0.28	0.32	0.50	0.58	0.78	...	0.47	...	...	0.34	...	
	...	...	1.08	1.37	1.65	1.33	1.56	...	0.83	...	...	0.71	...	
	...	...	6.75	9.79	11.79	5.54	6.50	...	3.61	...	...	5.07	...	
NGC 0695	...	...	1	1	1	1	1	...	2	...	...	1	...	
	...	...	...	...	...	...	...	...	...	...	...	...	...	
	0.00	1.54	0.79	0.91	0.70	-0.70	-0.47	-0.56	-0.67	-0.70	-1.01	1.14	10.52	0.98
	0.00	0.14	0.09	0.06	0.08	...	...	...	...	...	...	0.05	0.67	0.95
	...	558.08	669.81	781.19	893.37	...	...	...	...	...	...	784.17	1415.52	0.75
	...	0.06	0.07	0.04	0.08	...	...	...	...	...	...	0.03	0.01	
	...	-0.06	0.09	-0.09	0.56	...	...	...	...	...	...	0.28	0.34	
	0.00	1.30	0.67	0.77	0.59	...	...	...	...	...	...	0.96	11.72	
	...	8.12	6.09	9.62	4.92	...	...	...	...	...	...	12.00	78.13	
	0	1	1	1	2	...	...	...	...	...	...	1	1	
NGC 0828	...	...	...	...	...	...	...	...	...	...	...	...	179.10	
	-4.39	2.15	2.52	-0.83	-1.80	-1.25	-1.18	-1.20	-0.91	-1.15	2.30	2.26	30.17	0.96
	...	0.39	0.21	...	...	...	...	...	...	...	0.45	0.15	0.68	0.94
	...	566.24	679.20	...	...	...	...	...	...	...	483.61	795.27	1435.52	0.77
	...	0.11	0.05	...	...	...	...	...	...	...	0.13	0.04	0.02	
	...	0.12	-0.10	...	...	...	...	...	...	...	0.12	0.18	0.12	
	...	1.81	2.13	...	...	...	...	...	...	...	1.94	1.91	13.95	
	...	3.85	7.89	...	...	...	...	...	...	...	3.18	8.68	29.06	
	...	2	1	...	...	...	...	...	...	...	2	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	424.30	
	...	...	...	...	...	...	...	...	...	...	...	...	...	
	...	...	...	...	...	...	...	...	...	...	...	...	...	

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
NGC 0876	-3.19	-2.02	-0.93	0.78	-1.26	-1.58	-1.14	-1.24	-0.80	1.32	-2.19	1.34	9.48	0.52
	...	...	...	0.15	...	...	...	...	...	0.25	...	0.16	1.29	0.45
	...	...	...	795.60	...	...	...	...	...	1477.72	...	799.12	1441.82	0.24
	...	...	...	0.12	...	...	...	...	...	0.12	...	0.07	0.02	
	...	...	...	-0.66	...	...	...	...	...	0.09	...	0.21	-0.49	
	...	...	...	0.66	...	...	...	...	...	1.11	...	1.13	10.63	
	...	...	...	3.30	...	...	...	...	...	3.36	...	7.53	27.97	
	...	...	...	2	...	...	...	...	...	2	...	1	1	
UGC 01845	...	...	...	...	...	...	...	...	...	...	...	...	174.80	
	-3.98	2.74	1.97	1.66	-1.17	-1.50	-1.54	-1.21	-1.08	-1.21	-1.88	1.68	15.09	1.00
	...	0.27	0.15	0.15	...	...	...	...	...	...	...	0.14	0.76	1.00
	...	567.03	680.79	794.32	...	...	...	...	...	...	...	796.84	1438.57	0.95
	...	0.07	0.05	0.05	...	...	...	...	...	...	...	0.05	0.03	
	...	-0.38	-0.06	0.07	...	...	...	...	...	...	...	-0.06	-0.11	
	...	2.32	1.66	1.40	...	...	...	...	...	...	...	1.42	7.01	
	...	4.64	8.30	6.09	...	...	...	...	...	...	...	6.17	28.04	
NGC 0958	...	2	1	1	...	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	421.10	
	-1.28	-0.86	-0.73	-0.48	-1.23	0.91	-0.69	-0.79	-0.81	-0.82	-1.32	0.49	6.33	0.58
	...	...	...	...	...	0.14	...	...	...	...	...	0.07	0.43	0.49
	...	...	...	...	...	1017.60	...	...	...	...	...	794.11	1433.73	0.22
	...	...	...	...	...	0.11	...	...	...	...	...	0.11	0.04	
	...	...	...	...	...	0.16	...	...	...	...	...	-0.03	0.04	
	...	...	...	...	...	0.77	...	...	...	...	...	0.41	2.74	
NGC 1068	...	...	...	...	...	3.85	...	...	...	...	...	3.42	16.12	
	...	...	...	...	...	2	...	...	...	...	...	2	1	
	...	...	...	...	...	...	...	...	...	...	...	...	454.40	
	25.58	23.20	22.10	20.13	20.20	14.69	12.80	11.47	9.88	5.51	16.36	29.57	74.26	0.64
	1.77	1.05	0.53	0.40	0.72	0.43	0.37	0.36	0.35	0.39	1.01	0.44	1.52	0.58
	459.19	573.99	688.75	803.50	918.15	1032.92	1147.64	1262.14	1376.72	1491.02	490.21	806.16	1455.43	0.34
	0.04	0.03	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.05	0.04	0.01	0.01	
	-0.11	-0.10	-0.11	-0.11	-0.17	-0.08	0.01	-0.09	-0.05	-0.24	-0.09	-0.12	-0.18	
	21.58	19.57	18.64	16.98	17.04	12.39	10.80	9.68	8.33	4.65	13.80	24.94	46.28	
	31.28	40.77	66.57	25.73	11.92	45.89	30.00	16.98	18.51	4.43	49.29	38.37	45.37	

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
	1	1	1	1	1	1	1	1	1	2	1	1	1	
UGC 02238	...	...	...	...	...	...	...	...	...	...	...	...	312.30	
	-2.48	1.79	1.24	0.68	-0.90	-0.91	-0.77	-0.67	-0.81	-1.02	1.41	1.60	16.33	1.00
	...	0.17	0.10	0.08	...	...	...	...	...	...	0.28	0.07	0.43	0.99
	...	564.14	676.48	789.21	...	...	...	...	...	...	481.43	792.13	1430.06	0.87
	...	0.07	0.06	0.08	...	...	...	...	...	...	0.12	0.03	0.01	
	...	0.21	-0.18	-0.17	...	...	...	...	...	...	-0.19	0.11	0.21	
	...	1.51	1.05	0.57	...	...	...	...	...	...	1.19	1.35	9.70	
MCG +02-08-029	...	6.04	4.77	5.70	...	...	...	...	...	...	3.22	13.50	33.45	
	...	1	2	1	...	...	...	...	...	...	2	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	331.30	
	0.00	1.65	1.21	1.17	1.13	0.89	0.69	-0.51	-0.72	-0.71	-0.95	1.10	5.18	1.00
	0.00	0.13	0.07	0.06	0.09	0.13	0.10	...	...	...	...	0.06	0.46	1.00
	...	558.50	670.30	782.02	893.41	1004.98	1116.72	...	...	...	...	784.28	1416.11	0.91 <sub>l</sub>
	...	0.05	0.04	0.03	0.05	0.09	0.09	...	...	...	...	0.03	0.02	
UGC 02608	...	0.04	0.19	0.29	0.09	0.10	0.33	...	...	...	...	-0.06	0.12	
	0.00	1.39	1.02	0.99	0.95	0.75	0.59	...	...	...	...	0.93	4.90	
	...	7.32	7.29	12.38	8.64	3.95	4.54	...	...	...	...	11.63	32.67	
	0	1	1	1	1	2	2	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	211.00	
	-2.51	-1.40	1.12	0.58	-1.01	-0.92	-1.00	-0.97	-0.75	-1.00	-1.63	1.58	6.87	0.99
	...	...	0.11	0.11	...	...	...	...	...	...	...	0.11	0.47	0.97
NGC 1275	...	...	675.64	788.36	...	...	...	...	...	...	...	790.71	1427.62	0.84
	...	...	0.07	0.11	...	...	...	...	...	...	...	0.04	0.03	
	...	...	-0.06	0.11	...	...	...	...	...	...	...	-0.17	-0.19	
	...	...	0.95	0.49	...	...	...	...	...	...	...	1.33	4.59	
	...	...	5.28	4.90	...	...	...	...	...	...	...	13.30	22.95	
	...	...	1	2	...	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	297.50	
NGC 1275	-2.24	1.84	1.51	1.24	1.46	1.66	1.75	1.27	1.28	0.84	-1.16	2.13	5.04	0.99
	...	0.15	0.10	0.08	0.13	0.15	0.13	0.16	0.12	0.14	...	0.08	0.47	0.98
	...	566.64	679.61	792.90	906.01	1019.10	1132.25	1244.84	1357.68	1471.63	...	795.47	1435.94	0.87
	...	0.06	0.04	0.04	0.06	0.06	0.05	0.08	0.07	0.11	...	0.02	0.05	
	...	0.31	0.07	0.17	0.12	0.08	0.14	-0.31	-0.46	0.53	...	0.09	0.01	

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
UGC 02982	...	1.55	1.27	1.04	1.23	1.40	1.48	1.07	1.08	0.71	...	1.80	2.60	
	...	4.70	8.47	7.43	7.24	5.19	4.77	3.15	3.86	4.44	...	13.85	13.00	
	...	2	1	1	1	1	2	2	2	2	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	379.40	
	-3.51	-1.77	1.42	1.00	-1.20	-1.09	-1.57	-1.10	-1.56	-1.24	-2.31	1.83	17.53	0.93
	...	...	0.13	0.18	...	...	...	...	...	...	...	0.15	0.74	0.89
	...	...	679.22	792.76	...	...	...	...	...	...	...	794.85	1435.31	0.70
	...	...	0.07	0.11	...	...	...	...	...	...	...	0.06	0.02	
	...	...	-0.23	0.14	...	...	...	...	...	...	...	-0.42	-0.42	
	...	...	1.20	0.84	...	...	...	...	...	...	...	1.55	10.69	
ESO 420-G013	...	...	4.14	4.67	...	...	...	...	...	...	...	9.12	29.69	
	...	...	2	2	...	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	321.70	
	3.38	2.86	2.46	1.68	-1.54	-1.67	-1.48	-1.11	1.79	-1.50	-3.42	2.52	11.59	1.00
	0.65	0.40	0.20	0.15	...	...	...	...	0.28	...	...	0.16	0.26	1.00
	455.48	569.20	683.17	796.88	...	...	...	...	1364.63	...	...	799.71	1443.62	0.96
	0.14	0.08	0.05	0.07	...	...	...	...	0.10	...	...	0.04	0.02	0.96
	-0.14	-0.29	-0.16	-0.28	...	...	...	...	-1.10	...	...	-0.10	-0.32	0.96
	2.85	2.41	2.08	1.42	...	...	...	...	1.51	...	...	2.12	9.77	0.96
	3.06	5.36	6.71	7.89	...	...	...	...	4.08	...	...	11.16	30.53	0.96
NGC 1572	2	1	1	1	...	...	...	...	2	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	...	
	3.48	2.15	2.19	1.75	1.17	-1.29	-0.92	-1.21	-1.12	-1.18	-2.10	2.19	10.01	1.00
	0.57	0.27	0.15	0.11	0.19	...	...	...	...	...	...	0.12	0.56	0.99
	451.75	564.64	677.65	790.53	903.05	...	...	...	...	...	...	793.06	1431.61	0.93
	0.10	0.09	0.04	0.04	0.11	...	...	...	...	...	...	0.04	0.04	
	-0.08	-0.11	-0.01	-0.00	-0.33	...	...	...	...	...	...	-0.11	-0.34	
	2.94	1.81	1.85	1.47	0.99	...	...	...	...	...	...	1.85	4.87	
	4.14	4.76	8.81	9.19	3.54	...	...	...	...	...	...	11.56	18.73	
	2	2	1	1	2	...	...	...	...	...	...	1	1	
IRAS 04271+3849	...	...	...	...	...	...	...	...	...	...	...	...	404.60	
	-2.00	-1.34	1.10	0.82	1.39	-0.80	0.80	-0.92	-0.79	-0.80	-0.90	0.96	9.29	1.00
	...	...	0.11	0.09	0.15	...	0.14	...	...	...	...	0.08	0.39	1.00
	...	...	678.58	791.58	904.11	...	1130.80	...	...	...	...	794.38	1433.89	0.89









Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
NGC 2146Nuc <sup>b</sup>	24.27	29.46	53.77	27.97	13.24	15.29	7.24	6.06	4.45	...	14.61	24.17	48.96	
	1	1	1	1	1	1	1	1	2	...	1	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	253.00	
	15.33	17.23	17.10	14.86	13.42	6.87	5.08	3.37	1.74	-3.66	5.61	12.65	102.50	0.78
	0.86	0.42	0.19	0.18	0.31	0.35	0.31	0.28	0.28	...	0.46	0.19	1.23	0.73
	459.66	574.57	689.48	804.35	919.17	1034.07	1148.72	1263.45	1378.17	...	490.72	807.04	1456.99	0.52
	0.03	0.02	0.01	0.01	0.02	0.03	0.04	0.05	0.09	...	0.05	0.01	0.00	
	-0.01	0.01	0.06	0.09	0.11	0.23	0.15	0.20	0.28	...	0.02	0.10	0.20	
	12.93	14.54	14.42	12.54	11.32	5.80	4.29	2.84	1.47	...	4.73	10.67	85.83	
	23.51	33.05	60.08	48.23	21.77	26.36	14.79	7.47	5.25	...	12.45	41.04	111.47	
NGC 2146SE <sup>b</sup>	1	1	1	1	1	1	1	1	1	...	1	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	231.90	
	15.26	15.45	15.04	12.65	10.51	4.81	2.36	1.65	1.65	-2.98	6.90	11.47	69.91	0.60
	0.77	0.50	0.20	0.19	0.24	0.29	0.23	0.27	0.25	...	0.49	0.17	1.13	0.52
	459.56	574.46	689.30	804.23	919.08	1033.65	1148.35	1263.31	1377.44	...	490.59	806.82	1456.36	0.23
	0.03	0.02	0.01	0.01	0.02	0.04	0.07	0.11	0.10	...	0.05	0.01	0.01	
	-0.11	-0.10	-0.12	-0.03	0.02	-0.18	-0.21	0.06	-0.45	...	-0.11	-0.12	-0.44	
	12.87	13.03	12.68	10.67	8.87	4.06	1.99	1.39	1.39	...	5.82	9.68	52.06	
	20.43	30.30	79.25	28.08	11.23	18.45	6.63	4.09	6.32	...	16.17	25.47	51.54	
	1	1	1	1	1	1	1	2	1	...	1	1	1	
ESO 255-IG 007	...	...	...	...	...	...	...	...	...	...	...	...	261.10	
	0.00	0.87	0.94	0.74	0.76	0.95	0.81	-0.67	-0.54	-0.62	-1.13	0.86	3.91	0.88
	0.00	0.14	0.08	0.06	0.07	0.12	0.11	...	...	...	...	0.05	0.33	0.86
	...	554.43	665.42	776.05	887.10	997.15	1108.14	...	...	...	...	778.77	1405.91	0.75
	...	0.10	0.06	0.06	0.07	0.09	0.09	...	...	...	...	0.05	0.03	
	...	-0.32	-0.23	-0.48	-0.28	-1.04	-0.83	...	...	...	...	-0.35	-0.66	
	0.00	0.73	0.79	0.62	0.64	0.80	0.68	...	...	...	...	0.73	2.62	
	...	3.32	8.78	6.89	4.57	4.71	5.23	...	...	...	...	8.11	18.71	
	0	2	1	1	2	2	1	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	299.90	
UGC 03608	2.16	2.09	1.37	1.29	1.23	-1.10	-1.23	-0.97	-0.91	-0.99	-1.12	1.48	5.52	1.00
	0.27	0.16	0.10	0.08	0.11	...	...	...	...	...	...	0.07	0.85	1.00
	450.95	564.12	677.05	789.84	902.46	...	...	...	...	...	...	792.26	1430.39	0.89
	0.09	0.05	0.04	0.04	0.06	...	...	...	...	...	...	0.03	0.03	

Table 4—Continued

Name (1)	(4−3) (2)	(5−4) (3)	(6−5) (4)	(7−6) (5)	(8−7) (6)	(9−8) (7)	(10−9) (8)	(11−10) (9)	(12−11) (10)	(13−12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
NGC 2341	-0.45	-0.11	0.03	0.05	-0.07	...	...	...	...	...	...	-0.17	-0.20	
	1.82	1.76	1.16	1.09	1.04	...	...	...	...	...	...	1.25	5.63	
	3.87	6.77	7.73	10.90	5.47	...	...	...	...	...	...	11.36	28.15	
	4	1	1	1	1	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	193.70	
	-2.78	-1.30	0.69	0.86	-1.25	-0.84	-0.95	-1.21	-0.94	-0.86	-1.52	1.07	7.95	0.99
	...	...	0.11	0.08	...	...	...	...	...	...	...	0.09	0.57	0.97
	...	...	680.04	793.38	...	...	...	...	...	...	...	795.71	1436.53	0.82
	...	...	0.10	0.06	...	...	...	...	...	...	...	0.05	0.02	
	...	...	0.53	0.68	...	...	...	...	...	...	...	0.37	0.67	
NGC 2342	...	...	0.58	0.72	...	...	...	...	...	...	...	0.90	6.48	
	...	...	3.62	5.54	...	...	...	...	...	...	...	6.92	24.92	
	...	...	2	1	...	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	241.60	
	-3.00	-1.09	1.05	0.73	-1.00	-0.71	-0.99	-0.76	-0.63	-0.90	-1.31	1.11	4.28	0.76
	...	...	0.12	0.10	...	...	...	...	...	...	...	0.08	0.59	0.70
	...	...	679.90	792.71	...	...	...	...	...	...	...	795.69	1435.98	0.48
	...	...	0.07	0.09	...	...	...	...	...	...	...	0.05	0.04	
	...	...	0.38	0.01	...	...	...	...	...	...	...	0.35	0.11	
	...	...	0.89	0.61	...	...	...	...	...	...	...	0.93	3.62	
NGC 2369	...	...	7.42	5.08	...	...	...	...	...	...	...	8.45	15.74	
	...	...	1	1	...	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	232.60	
	3.25	4.80	4.85	3.63	3.70	2.56	1.75	-1.77	1.31	-1.69	2.95	4.31	25.06	0.96
	0.71	0.37	0.17	0.16	0.32	0.31	0.31	...	0.21	...	0.37	0.14	0.72	0.94
	455.97	570.14	684.09	798.05	911.86	1026.04	1139.80	...	1366.97	...	486.66	800.45	1445.37	0.82
	0.13	0.05	0.03	0.03	0.05	0.08	0.10	...	0.11	...	0.09	0.02	0.02	
	-0.14	0.03	0.01	0.02	-0.08	0.22	0.13	...	-0.25	...	-0.24	-0.24	-0.14	
	2.74	4.05	4.09	3.06	3.12	2.16	1.48	...	1.11	...	2.49	3.64	11.01	
	3.11	10.95	15.15	10.55	10.40	4.80	5.29	...	3.70	...	3.95	12.55	29.76	
NGC 2388	2	1	1	1	1	2	1	...	2	...	2	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	443.60	
	-2.51	1.89	2.92	2.42	2.42	1.55	-1.44	-1.01	-1.10	1.43	-2.27	2.43	14.59	0.97
	...	0.28	0.15	0.11	0.25	0.24	...	...	...	0.26	...	0.09	0.61	0.94

Table 4—Continued

Name (1)	(4−3) (2)	(5−4) (3)	(6−5) (4)	(7−6) (5)	(8−7) (6)	(9−8) (7)	(10−9) (8)	(11−10) (9)	(12−11) (10)	(13−12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
MCG +02-20-003	...	568.68	682.31	795.82	909.34	1023.26	...	...	...	1477.62	...	798.40	1441.41	0.78
	...	0.10	0.03	0.03	0.05	0.09	...	...	...	0.11	...	0.03	0.01	
	...	0.25	0.25	0.14	0.07	0.45	...	...	...	1.06	...	0.07	0.15	
	...	1.59	2.46	2.04	2.04	1.30	...	...	...	1.20	...	2.05	9.84	
	...	3.24	9.84	12.75	6.58	4.33	...	...	...	3.16	...	12.81	36.44	
	...	2	1	1	1	2	...	...	...	2	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	291.50	
	-1.99	-1.28	1.31	0.81	0.81	1.06	-0.72	1.10	-0.87	-0.63	-1.17	0.97	4.15	1.00
	...	...	0.12	0.07	0.18	0.16	...	0.17	...	...	...	0.08	0.92	1.00
	...	...	680.21	793.65	906.67	1020.13	...	1246.39	...	...	...	796.18	1437.43	0.98
IRAS 08355-4944	...	...	0.05	0.06	0.11	0.09	...	0.10	...	...	...	0.06	0.03	
	...	...	-0.20	-0.10	-0.38	-0.19	...	-0.36	...	...	...	-0.22	-0.33	
	...	...	1.10	0.68	0.68	0.89	...	0.93	...	...	...	0.82	4.57	
	...	...	7.86	5.67	3.24	3.87	...	4.04	...	...	...	6.83	24.05	
	...	...	1	1	2	2	...	2	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	178.20	
	-1.93	-0.93	0.63	1.07	1.27	-0.92	1.56	-1.07	0.83	2.09	-1.37	0.64	4.14	1.00
	...	...	0.11	0.07	0.13	...	0.12	...	0.14	0.14	...	0.07	0.48	1.00
	...	...	674.05	786.26	898.92	...	1123.04	...	1346.63	1461.05	...	788.91	1424.22	0.99
	...	...	0.11	0.05	0.06	...	0.05	...	0.12	0.04	...	0.09	0.04	
NGC 2623	...	...	0.04	-0.03	0.39	...	0.13	...	-0.48	1.92	...	-0.00	-0.03	
	...	...	0.53	0.90	1.07	...	1.31	...	0.70	1.76	...	0.54	2.99	
	...	...	3.12	8.18	5.35	...	6.24	...	3.18	6.52	...	4.91	17.59	
	...	...	2	1	1	...	1	...	2	3	...	2	1	
	...	...	...	...	...	...	...	...	...	...	...	...	275.80	
	1.70	1.97	2.12	2.23	2.70	2.23	2.27	1.71	1.43	1.24	0.85	1.93	2.99	1.00
	0.18	0.10	0.05	0.05	0.08	0.09	0.08	0.08	0.08	0.08	0.12	0.04	0.27	1.00
	452.57	565.81	678.89	792.01	905.06	1018.07	1131.22	1244.07	1356.92	1469.74	483.04	794.64	1434.60	0.98
	0.07	0.03	0.02	0.01	0.02	0.03	0.02	0.03	0.04	0.04	0.10	0.02	0.03	
	-0.09	0.01	-0.02	0.02	0.02	0.01	0.17	0.08	0.04	0.02	-0.18	0.00	0.02	
	1.43	1.66	1.79	1.88	2.27	1.88	1.92	1.44	1.20	1.04	0.71	1.63	1.88	
	5.72	12.77	22.38	37.60	15.13	13.43	8.73	12.00	10.00	6.50	4.18	32.60	20.89	
	1	1	1	1	1	1	1	1	1	1	2	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	314.00	

Table 4—Continued

Name (1)	(4−3) (2)	(5−4) (3)	(6−5) (4)	(7−6) (5)	(8−7) (6)	(9−8) (7)	(10−9) (8)	(11−10) (9)	(12−11) (10)	(13−12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
IRAS 09022-3615	0.00	1.51	1.73	1.89	1.79	1.71	1.21	1.10	0.86	-0.46	-1.02	1.31	3.57	1.00
	0.00	0.13	0.08	0.06	0.07	0.13	0.09	0.09	0.09	...	...	0.06	0.28	1.00
	...	543.90	652.59	761.43	869.82	978.50	1086.96	1195.84	1303.88	...	...	763.66	1379.20	0.98
	...	0.05	0.03	0.02	0.03	0.05	0.05	0.06	0.07	...	...	0.03	0.05	
	...	0.06	0.04	0.18	-0.10	-0.05	-0.18	0.14	-0.33	...	...	-0.13	0.30	
	0.00	1.27	1.46	1.59	1.51	1.44	1.02	0.93	0.73	...	...	1.10	1.69	
	...	8.47	12.17	14.45	10.07	7.20	5.37	6.20	5.21	...	...	11.00	9.94	
	0	1	1	1	1	1	1	1	1	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	431.00	
UGC 05101	0.00	0.93	1.29	0.85	1.09	0.81	1.16	0.77	-0.75	-0.80	-1.09	1.20	6.12	1.00
	0.00	0.16	0.09	0.08	0.10	0.16	0.12	0.14	...	...	...	0.07	0.44	1.00
	...	554.53	665.41	776.31	887.00	997.71	1108.42	1219.07	...	...	...	778.68	1406.13	1.00
	...	0.10	0.05	0.05	0.06	0.13	0.07	0.11	...	...	...	0.04	0.06	
	...	0.09	0.13	0.22	0.12	0.07	0.07	0.05	...	...	...	-0.01	0.34	
	0.00	0.79	1.09	0.72	0.92	0.68	0.98	0.65	...	...	...	1.01	2.14	
	...	3.95	9.08	5.54	6.13	3.40	4.67	3.42	...	...	...	7.21	11.26	
	0	2	1	1	1	2	2	2	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	572.90	
NGC 3110	-2.65	-1.78	1.30	0.96	-1.18	-1.27	-1.35	-1.51	-1.39	-1.10	-2.23	1.77	15.19	0.85
	...	...	0.19	0.13	...	...	...	...	...	...	...	0.12	0.74	0.81
	...	...	680.04	793.37	...	...	...	...	...	...	...	795.85	1436.86	0.59
	...	...	0.08	0.09	...	...	...	...	...	...	...	0.05	0.02	
	...	...	0.03	0.09	...	...	...	...	...	...	...	-0.07	-0.05	
	...	...	1.10	0.81	...	...	...	...	...	...	...	1.49	10.79	
	...	...	3.67	4.76	...	...	...	...	...	...	...	8.76	30.83	
	...	...	2	2	...	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	277.40	
NGC 3221	-3.12	-2.09	-0.94	-0.79	-1.51	-1.29	-1.17	-1.09	-1.18	-1.69	-2.51	0.88	6.98	0.58
	...	...	...	...	...	...	...	...	...	...	...	0.14	1.23	0.51
	...	...	...	...	...	...	...	...	...	...	...	798.50	1441.85	0.27
	...	...	...	...	...	...	...	...	...	...	...	0.10	0.00	
	...	...	...	...	...	...	...	...	...	...	...	0.10	0.48	
	...	...	...	...	...	...	...	...	...	...	...	0.74	7.31	
	...	...	...	...	...	...	...	...	...	...	...	3.36	17.83	

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
NGC 3256	...	...	...	...	...	...	...	...	...	...	...	2	1	
	...	...	...	...	...	...	...	...	...	...	...	...	187.20	
	16.59	17.59	19.62	16.05	14.13	9.18	6.90	4.65	3.41	2.72	6.67	13.48	47.33	0.91
	0.51	0.26	0.13	0.12	0.20	0.18	0.18	0.18	0.15	0.25	0.29	0.12	0.69	0.88
	456.69	570.88	685.00	799.10	913.15	1027.17	1141.21	1255.12	1369.04	1482.92	487.48	801.77	1447.38	0.71
	0.02	0.01	0.00	0.00	0.01	0.01	0.02	0.03	0.03	0.05	0.03	0.01	0.00	
	-0.08	-0.05	-0.06	-0.07	-0.11	-0.13	-0.10	-0.15	-0.15	-0.13	-0.12	-0.08	-0.22	
	14.00	14.84	16.55	13.54	11.92	7.74	5.82	3.92	2.88	2.30	5.62	11.37	37.02	
	26.92	37.10	61.30	50.15	44.15	22.76	30.63	14.00	14.40	5.23	22.48	42.11	90.29	
	1	1	1	1	1	1	1	1	1	1	1	1	1	
ESO 264-G036	...	...	...	...	...	...	...	...	...	...	...	...	250.00	
	2.14	1.78	1.77	1.11	1.12	-0.84	-0.74	-0.81	-0.84	-0.90	1.62	1.65	11.99	0.95
	0.36	0.18	0.12	0.10	0.15	...	...	...	...	...	0.28	0.10	0.42	0.91
	451.27	564.88	677.56	790.39	903.22	...	...	...	...	...	482.31	793.01	1431.48	0.71
	0.11	0.07	0.04	0.05	0.09	...	...	...	...	...	0.11	0.04	0.02	211
	-0.28	0.47	0.32	0.33	0.39	...	...	...	...	...	0.28	0.32	0.41	
	1.81	1.50	1.49	0.94	0.95	...	...	...	...	...	1.36	1.39	6.34	1
	3.07	4.55	8.76	8.55	5.59	...	...	...	...	...	4.12	12.64	37.29	
	4	2	1	1	1	...	...	...	...	...	2	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	372.20	
ESO 264-G057	-1.70	-1.35	1.01	0.79	0.99	-0.85	-0.95	-0.74	-0.85	-0.74	-1.60	0.96	7.67	0.93
	...	...	0.09	0.09	0.17	...	...	...	...	...	...	0.08	0.72	0.90
	...	...	679.88	793.16	906.51	...	...	...	...	...	...	795.58	1436.40	0.72
	...	...	0.07	0.08	0.10	...	...	...	...	...	...	0.06	0.02	
	...	...	0.10	0.14	0.29	...	...	...	...	...	...	-0.08	-0.03	
	...	...	0.85	0.67	0.83	...	...	...	...	...	...	0.81	7.55	
	...	...	4.72	6.09	3.46	...	...	...	...	...	...	6.75	29.04	
	...	...	2	1	2	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	199.90	
	0.00	1.22	1.65	1.43	1.68	1.34	1.19	0.97	0.64	0.56	-1.16	1.35	2.77	1.00
IRAS F10565+2448	0.00	0.18	0.10	0.07	0.10	0.15	0.09	0.10	0.10	0.11	...	0.08	0.57	1.00
	...	552.41	662.77	773.30	883.57	994.16	1104.52	1214.68	1324.90	1435.36	...	775.79	1400.69	1.00
	...	0.09	0.04	0.03	0.04	0.07	0.06	0.07	0.11	0.13	...	0.04	0.03	
	...	-0.05	-0.13	-0.02	-0.15	0.09	0.13	0.02	0.00	0.29	...	-0.11	-0.07	

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
UGC 06471 <sup>c</sup>	0.00	1.03	1.39	1.21	1.42	1.13	1.00	0.82	0.54	0.47	...	1.14	2.93	
	...	4.68	9.93	10.08	15.78	5.95	5.88	6.83	3.18	3.36	...	10.36	17.24	
	0	2	1	1	1	1	1	1	2	2	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	190.70	
	5.81	5.23	4.98	5.05	5.45	2.49	2.54	2.36	1.87	2.16	2.19	3.32	14.36	0.50
	0.31	0.16	0.08	0.08	0.15	0.13	0.12	0.12	0.12	0.15	0.19	0.06	0.39	0.42
	456.31	570.25	684.35	798.31	912.24	1026.24	1140.17	1253.82	1367.70	1481.49	486.93	800.93	1446.16	0.24
	0.03	0.02	0.01	0.01	0.02	0.03	0.03	0.04	0.04	0.04	0.06	0.01	0.01	
	-0.02	-0.14	-0.06	-0.10	-0.15	-0.09	-0.05	-0.26	-0.18	-0.15	-0.20	-0.15	-0.05	
	4.90	4.41	4.20	4.26	4.60	2.10	2.14	1.99	1.57	1.82	1.85	2.80	7.49	
NGC3690 <sup>c</sup>	11.14	17.64	26.25	38.73	27.06	15.00	9.73	15.31	7.48	9.10	7.71	28.00	32.57	
	1	1	1	1	1	1	1	1	1	1	1	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	373.30	
	6.12	6.27	5.14	5.35	6.30	2.85	2.36	2.13	1.52	1.11	2.11	3.50	14.89	0.50
	0.32	0.16	0.08	0.08	0.13	0.14	0.13	0.14	0.12	0.15	0.21	0.07	0.43	0.42
	456.35	570.27	684.34	798.34	912.28	1026.23	1140.17	1253.89	1367.55	1481.44	487.11	800.94	1446.15	0.22
	0.03	0.02	0.01	0.01	0.01	0.03	0.04	0.04	0.05	0.09	0.06	0.01	0.01	
	0.01	-0.12	-0.07	-0.07	-0.11	-0.09	-0.05	-0.18	-0.33	-0.20	-0.03	-0.14	-0.07	
	5.16	5.29	4.34	4.51	5.32	2.41	1.99	1.79	1.29	0.94	1.78	2.96	8.71	
	11.47	16.53	31.00	30.07	19.70	12.05	11.71	8.14	6.79	3.03	7.74	19.73	37.87	
UGC 06472 <sup>c</sup>	1	1	1	1	1	1	1	1	1	2	1	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	332.80	
	8.87	9.04	9.90	10.07	11.00	8.01	7.37	6.38	5.47	4.97	2.54	5.93	18.00	0.79
	0.36	0.20	0.09	0.09	0.15	0.19	0.19	0.20	0.18	0.21	0.24	0.09	0.69	0.75
	456.28	570.31	684.32	798.33	912.28	1026.24	1140.37	1253.95	1367.74	1481.67	486.87	800.95	1446.02	0.60
	0.03	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.06	0.01	0.01	
	-0.06	-0.07	-0.09	-0.09	-0.11	-0.09	0.15	-0.13	-0.15	0.03	-0.27	-0.13	-0.19	
	7.48	7.63	8.35	8.50	9.28	6.76	6.21	5.38	4.62	4.20	2.14	5.01	11.37	
	16.62	28.26	59.64	32.69	32.00	18.27	11.29	16.81	13.20	8.08	7.38	19.27	40.61	
	1	1	1	1	1	1	1	1	1	1	1	1	1	
ESO 320-G030	...	...	...	...	...	...	...	...	...	...	...	...	310.20	
	4.01	4.15	4.55	3.71	3.05	3.24	2.88	1.59	1.47	0.68	1.60	2.44	18.93	1.00
	0.32	0.17	0.09	0.08	0.15	0.14	0.12	0.13	0.12	0.16	0.20	0.07	0.47	0.99
	456.33	570.52	684.49	798.52	912.51	1026.47	1141.03	1254.19	1367.95	1481.95	486.98	801.12	1446.45	0.89



Table 4—Continued

Name (1)	(4−3) (2)	(5−4) (3)	(6−5) (4)	(7−6) (5)	(8−7) (6)	(9−8) (7)	(10−9) (8)	(11−10) (9)	(12−11) (10)	(13−12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
NGC 4194	0.05	0.02	0.01	0.01	0.03	0.03	0.03	0.06	0.05	0.14	0.08	0.02	0.01	
	0.21	0.40	0.39	0.47	0.54	0.61	1.33	0.69	0.70	1.00	0.07	0.41	0.90	
	3.38	3.50	3.84	3.13	2.58	2.73	2.43	1.34	1.24	0.57	1.35	2.06	11.21	
	8.24	16.67	25.60	34.78	11.22	13.65	9.35	7.88	6.53	3.80	6.14	25.75	44.84	
	1	1	1	1	1	1	1	1	1	2	1	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	328.90	
	-2.97	-2.10	2.56	3.01	2.18	-1.54	1.29	2.27	1.24	-1.36	-2.02	1.80	10.24	1.00
	...	...	0.15	0.11	0.23	...	0.23	0.26	0.21	...	...	0.14	0.79	1.00
	...	...	685.67	800.02	914.22	...	1142.65	1256.43	1370.32	...	...	802.39	1448.90	0.91
	...	...	0.03	0.03	0.06	...	0.12	0.07	0.12	...	...	0.05	0.03	
IRAS 12116-5615	...	...	-0.08	0.04	0.05	...	0.20	-0.10	-0.24	...	...	-0.25	-0.14	
	...	...	2.16	2.54	1.84	...	1.09	1.92	1.05	...	...	1.52	7.46	
	...	...	11.37	16.93	5.26	...	3.03	5.65	4.04	...	...	9.50	16.58	
	...	...	1	1	1	...	2	1	2	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	268.10	
	2.09	1.51	1.57	1.47	1.31	1.32	0.77	0.75	-0.64	-0.68	0.86	1.45	4.03	1.00
	0.30	0.15	0.07	0.06	0.10	0.14	0.11	0.11	...	...	0.18	0.06	0.46	1.00
	448.96	560.76	673.10	785.13	897.37	1009.45	1121.01	1233.55	...	...	479.29	787.82	1422.32	1.00
	0.09	0.06	0.03	0.03	0.05	0.06	0.09	0.09	...	...	0.13	0.03	0.02	
	0.08	-0.31	-0.12	-0.24	-0.11	-0.10	-0.57	-0.03	...	...	0.11	-0.16	-0.26	
NGC 4418	1.77	1.27	1.32	1.24	1.11	1.11	0.65	0.63	...	...	0.72	1.22	3.64	
	5.21	7.47	9.43	15.50	8.54	7.93	4.33	3.15	...	...	3.13	13.56	22.75	
	1	1	1	1	1	1	2	2	...	...	2	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	220.30	
	-2.85	-2.35	3.67	3.96	4.86	5.77	4.85	6.59	5.56	5.77	2.52	1.27	-1.16	1.00
	...	...	0.15	0.13	0.23	0.26	0.24	0.23	0.22	0.25	0.41	0.14	...	1.00
	...	...	686.68	801.16	915.44	1029.77	1144.33	1258.24	1372.43	1486.56	488.23	803.81	...	0.92
	...	...	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.10	0.08	...	
	...	...	0.20	0.33	0.29	0.34	0.66	0.37	0.41	0.44	-0.38	0.31	...	
	...	...	3.09	3.34	4.10	4.87	4.09	5.56	4.69	4.87	2.12	1.07	...	
UGC 08058	...	...	12.87	15.18	11.39	14.76	9.30	18.53	16.75	10.36	3.16	4.86	...	
	...	...	1	1	1	1	1	1	1	1	4	2	...	
	...	...	...	...	...	...	...	...	...	...	...	...	...	
	0.00	1.37	2.04	2.30	2.44	1.97	2.24	2.28	1.79	1.43	-0.66	1.20	2.65	1.00

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
(= Mrk 231)	0.00	0.11	0.07	0.05	0.07	0.11	0.08	0.08	0.08	0.08	...	0.05	0.26	1.00
	...	552.80	663.56	774.00	884.63	995.04	1105.66	1215.88	1326.26	1436.47	...	776.59	1402.00	1.00
	...	0.05	0.02	0.01	0.02	0.04	0.02	0.02	0.03	0.04	...	0.03	0.04	
	...	-0.15	0.06	-0.02	0.13	0.09	0.29	0.13	0.18	0.12	...	-0.01	-0.01	
	0.00	1.16	1.72	1.94	2.06	1.66	1.89	1.93	1.51	1.21	...	1.02	1.81	
	...	8.92	19.11	27.71	15.85	11.07	11.81	17.55	13.73	8.64	...	14.57	13.92	
	0	1	1	1	1	1	1	1	1	1	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	295.00	
MCG -02-33-098	-1.96	-1.12	1.00	0.72	-0.92	-0.98	-1.10	-0.99	-0.77	-1.04	-1.17	-0.40	2.46	0.96
	...	...	0.11	0.08	...	...	...	...	...	...	...	...	0.14	0.93
	...	...	680.57	793.94	...	...	...	...	...	...	...	...	1437.96	0.76
	...	...	0.06	0.07	...	...	...	...	...	...	...	...	0.04	
	...	...	-0.07	-0.07	...	...	...	...	...	...	...	...	-0.27	
	...	...	0.84	0.61	...	...	...	...	...	...	...	...	2.08	
	...	...	5.25	5.55	...	...	...	...	...	...	...	...	11.56	
	...	...	1	1	...	...	...	...	...	...	...	...	1	
ESO 507-G070	...	...	...	...	...	...	...	...	...	...	...	...	...	
	2.30	1.93	2.24	2.39	2.42	1.91	1.46	-1.35	1.12	0.81	-1.31	1.67	4.97	1.00
	0.40	0.16	0.12	0.07	0.14	0.17	0.14	...	0.14	0.15	...	0.09	0.45	1.00
	451.38	564.06	676.92	789.62	902.41	1015.07	1127.77	...	1352.75	1465.12	...	792.33	1430.41	0.99
	0.11	0.06	0.03	0.02	0.04	0.06	0.06	...	0.07	0.12	...	0.04	0.06	
	0.13	0.04	0.13	0.10	0.19	0.19	0.26	...	0.11	-0.01	...	0.18	0.32	
	1.94	1.63	1.89	2.02	2.04	1.61	1.23	...	0.95	0.68	...	1.41	2.13	
	3.88	5.82	11.12	10.63	7.85	6.44	7.24	...	5.00	4.25	...	7.42	10.14	
NGC 5010	2	1	1	1	1	1	1	...	2	2	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	460.10	
	3.41	1.99	1.42	1.04	-1.12	-1.03	-1.53	-1.34	-1.12	-1.31	-2.14	2.02	20.73	0.99
	0.70	0.29	0.15	0.13	...	...	...	...	...	...	...	0.14	0.76	0.97
	456.07	570.65	684.94	799.18	...	...	...	...	...	...	...	801.08	1446.64	0.83
	0.13	0.10	0.07	0.09	...	...	...	...	...	...	...	0.05	0.02	
	-0.44	0.04	0.26	0.45	...	...	...	...	...	...	...	-0.31	-0.14	
	2.88	1.68	1.20	0.88	...	...	...	...	...	...	...	1.70	10.59	
	3.20	3.05	5.22	6.29	...	...	...	...	...	...	...	13.08	27.87	
	4	2	1	1	...	...	...	...	...	...	...	1	1	

Table 4—Continued

Name (1)	(4−3) (2)	(5−4) (3)	(6−5) (4)	(7−6) (5)	(8−7) (6)	(9−8) (7)	(10−9) (8)	(11−10) (9)	(12−11) (10)	(13−12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
IRAS 13120-5453	...	...	...	...	...	...	...	...	...	...	...	...	381.30	
	2.75	4.53	5.14	5.18	5.09	3.97	3.51	2.63	1.79	1.32	2.21	4.15	10.10	1.00
	0.54	0.20	0.11	0.09	0.12	0.18	0.16	0.15	0.15	0.18	0.24	0.09	0.46	0.99
	447.32	559.03	670.62	782.43	894.08	1005.64	1117.57	1228.85	1340.73	1451.65	477.54	784.96	1417.15	0.89
	0.12	0.03	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.09	0.07	0.01	0.02	
	0.04	-0.04	-0.22	-0.15	-0.21	-0.33	-0.04	-0.35	-0.03	-0.60	0.07	-0.23	-0.37	
	2.32	3.82	4.34	4.37	4.30	3.35	2.96	2.22	1.51	1.11	1.87	3.50	5.89	
	4.14	15.28	19.73	24.28	17.20	9.85	6.73	9.65	6.86	5.29	4.92	19.44	29.45	
	2	1	1	1	1	1	1	1	1	1	2	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	341.00	
UGC 08387	2.74	2.63	3.00	2.62	2.47	1.81	1.54	1.13	0.73	0.50	1.21	2.89	7.70	1.00
	0.17	0.10	0.05	0.04	0.08	0.08	0.07	0.07	0.06	0.08	0.13	0.05	0.21	1.00
	450.58	563.23	675.85	788.43	900.90	1013.65	1126.12	1238.38	1350.52	1463.34	481.00	791.01	1428.12	0.98
	0.05	0.02	0.01	0.01	0.02	0.03	0.03	0.04	0.06	0.10	0.07	0.01	0.01	
	0.04	0.09	0.12	0.14	0.09	0.35	0.36	0.21	-0.01	0.50	0.05	0.10	0.26	
	2.31	2.22	2.53	2.21	2.09	1.52	1.30	0.96	0.61	0.42	1.02	2.44	4.47	
	12.16	14.80	23.00	18.42	13.93	11.69	10.83	6.40	6.10	3.82	7.85	18.77	49.67	
	1	1	1	1	1	1	1	1	1	2	1	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	339.60	
	-2.71	1.51	1.31	0.85	-0.76	-0.95	-0.65	-0.92	-0.85	-0.72	-1.69	1.55	7.47	1.00
NGC 5104	...	0.19	0.09	0.07	...	...	...	...	...	...	...	0.07	0.50	1.00
	...	565.74	678.85	791.81	...	...	...	...	...	...	...	794.59	1434.28	0.95
	...	0.08	0.05	0.06	...	...	...	...	...	...	...	0.04	0.05	
	...	-0.01	0.01	-0.11	...	...	...	...	...	...	...	0.03	-0.16	
	...	1.28	1.10	0.72	...	...	...	...	...	...	...	1.31	3.00	
	...	4.92	7.33	7.20	...	...	...	...	...	...	...	13.10	13.04	
	...	2	1	1	...	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	488.60	
	-1.40	-1.12	0.62	0.56	-1.03	-0.98	1.27	-0.96	-0.92	-1.07	-0.93	0.51	2.12	1.00
	...	...	0.10	0.09	...	...	0.14	...	...	...	...	0.08	0.44	1.00
MCG -03-34-064	...	...	679.81	792.80	...	...	1133.29	...	...	...	...	795.96	1436.80	1.00
	...	...	0.10	0.09	...	...	0.07	...	...	...	...	0.10	0.12	
	...	...	-0.41	-0.72	...	...	0.05	...	...	...	...	-0.22	-0.56	
	...	...	0.52	0.48	...	...	1.07	...	...	...	...	0.43	1.04	
	...	...	...	...	...	...	...	...	...	...	...	...	...	

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Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
NGC 5135	...	...	3.06	4.00	...	...	7.13	...	...	...	...	3.91	6.12	
	...	...	2	2	...	...	1	...	...	...	...	2	1	
	...	...	...	...	...	...	...	...	...	...	...	...	400.40	
	3.09	3.60	3.69	2.84	2.28	1.77	1.20	0.76	0.75	-0.48	3.08	5.89	18.17	1.00
	0.20	0.11	0.05	0.05	0.09	0.09	0.08	0.09	0.08	...	0.13	0.04	0.44	0.99
	454.80	568.46	682.18	795.82	909.45	1023.06	1136.59	1249.95	1363.66	...	485.45	798.50	1441.51	0.93
	0.04	0.02	0.01	0.01	0.02	0.03	0.04	0.08	0.07	...	0.03	0.00	0.00	
	-0.01	-0.02	0.05	0.06	0.10	0.16	0.16	0.05	0.33	...	-0.06	0.09	0.11	
	2.60	3.03	3.11	2.40	1.92	1.50	1.01	0.64	0.63	...	2.60	4.96	18.10	
	14.44	18.94	38.87	40.00	19.20	15.00	7.21	5.33	6.30	...	14.44	82.67	139.23	
ESO 173-G015	1	1	1	1	1	1	1	1	1	...	1	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	197.00	
	12.28	14.21	15.73	13.88	12.74	11.60	9.72	9.19	6.66	4.81	4.58	11.23	21.80	0.95
	0.73	0.31	0.16	0.15	0.26	0.27	0.24	0.28	0.20	0.33	0.39	0.15	0.89	0.93
	456.46	570.60	684.61	798.64	912.60	1026.59	1140.68	1254.37	1368.27	1482.12	487.17	801.32	1446.60	0.80
	0.03	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.04	0.05	0.01	0.01	
	-0.14	-0.11	-0.20	-0.24	-0.31	-0.32	-0.20	-0.43	-0.41	-0.37	-0.25	-0.22	-0.45	
	10.36	11.99	13.27	11.71	10.75	9.79	8.20	7.76	5.62	4.06	3.87	9.47	14.54	
	12.48	20.32	41.47	53.23	32.58	22.25	12.62	18.05	16.06	9.02	7.30	45.10	34.62	
	1	1	1	1	1	1	1	1	1	1	1	1	1	
IC 4280	...	...	...	...	...	...	...	...	...	...	...	...	293.50	
	2.27	1.48	1.00	0.52	-0.96	1.04	-0.87	-1.20	-0.79	-1.01	-1.42	1.22	14.64	0.92
	0.36	0.22	0.11	0.10	...	0.16	...	...	...	...	...	0.10	0.70	0.87
	453.73	567.52	680.39	793.24	...	1021.59	...	...	...	...	...	796.54	1437.55	0.63
	0.10	0.10	0.07	0.11	...	0.09	...	...	...	...	...	0.05	0.01	
	0.08	0.50	0.02	-0.47	...	1.32	...	...	...	...	...	0.18	-0.14	
	1.92	1.25	0.85	0.44	...	0.88	...	...	...	...	...	1.03	13.27	
	3.37	3.29	4.25	3.14	...	5.50	...	...	...	...	...	7.92	53.08	
	2	4	2	2	...	3	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	217.00	
UGC 08696	0.00	1.57	1.93	2.01	1.81	1.57	1.47	0.93	0.62	-0.76	-0.64	1.17	3.99	1.00
	0.00	0.12	0.07	0.04	0.07	0.10	0.09	0.09	0.08	...	...	0.05	0.29	1.00
	...	555.28	666.25	777.44	888.43	999.26	1110.14	1221.01	1331.73	...	...	779.79	1408.19	0.98
	...	0.05	0.02	0.02	0.02	0.04	0.04	0.06	0.09	...	...	0.03	0.06	

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
UGC 08739	...	-0.01	-0.05	0.16	0.18	0.09	0.09	0.12	0.05	...	...	-0.09	0.25	0.87 0.82 0.55
	0.00	1.33	1.63	1.69	1.52	1.32	1.24	0.78	0.52	...	...	0.99	1.50	
	...	7.82	20.38	15.36	10.86	8.25	5.17	5.20	3.47	...	...	9.00	13.64	
	0	1	1	1	1	1	1	1	2	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	533.10	
	-1.70	1.94	0.71	0.63	1.06	0.82	-0.89	-0.88	-1.03	-0.81	-1.85	1.62	10.41	
	...	0.18	0.11	0.09	0.20	0.17	...	...	...	...	...	0.09	0.48	
	...	566.99	679.84	793.04	906.67	1020.70	...	...	...	...	...	795.95	1436.57	
	...	0.06	0.10	0.10	0.10	0.14	...	...	...	...	...	0.04	0.02	
	...	0.24	-0.22	-0.29	0.08	0.91	...	...	...	...	...	-0.03	-0.44	
ESO 221-IG 010	...	1.64	0.60	0.53	0.90	0.69	...	...	...	...	...	1.36	6.52	0.84 0.79 0.57
	...	4.56	3.33	4.08	4.29	3.29	...	...	...	...	...	10.46	20.38	
	...	4	2	2	2	4	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	315.00	
	-2.90	2.80	1.80	1.03	-0.91	-0.97	-1.43	1.67	-1.21	-1.24	-2.17	1.25	11.74	
	...	0.26	0.15	0.14	...	...	...	0.18	...	...	...	0.12	1.05	
	...	570.46	684.12	798.45	...	...	...	1253.42	...	...	...	800.95	1445.89	
	...	0.06	0.05	0.08	...	...	...	0.08	...	...	...	0.07	0.02	
	...	0.09	-0.28	0.05	...	...	...	-0.63	...	...	...	-0.11	-0.29	
	...	2.36	1.52	0.86	...	...	...	1.41	...	...	...	1.05	11.04	
NGC 5653	...	5.13	6.61	5.06	...	...	...	3.62	...	...	...	6.18	30.67	0.88 0.83 0.59
	...	1	1	1	...	...	...	2	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	207.90	
	2.98	3.33	1.42	0.63	-1.26	-1.08	-1.24	-1.02	-1.01	-1.32	-2.24	1.65	18.63	
	0.46	0.24	0.17	0.13	...	...	...	...	...	...	...	0.12	0.87	
	455.56	569.56	683.27	797.26	...	...	...	...	...	...	...	799.87	1444.23	
	0.12	0.05	0.07	0.14	...	...	...	...	...	...	...	0.05	0.01	
	-0.07	0.06	-0.08	0.08	...	...	...	...	...	...	...	0.03	0.26	
	2.51	2.81	1.20	0.53	...	...	...	...	...	...	...	1.40	14.75	
	6.12	5.11	5.45	3.31	...	...	...	...	...	...	...	9.33	37.82	
NGC 5734	1	1	1	2	...	...	...	...	...	...	...	1	1	0.95 0.92
	...	...	...	...	...	...	...	...	...	...	...	...	247.50	
	-3.69	-2.35	0.82	-0.87	1.11	-1.04	-1.23	-1.06	-1.19	-1.20	-1.98	1.56	21.63	
	...	...	0.16	...	0.26	...	...	...	...	...	...	0.12	0.71	

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
VV 340a	...	...	682.21	...	909.79	...	...	...	...	...	...	798.55	1441.38	0.73
	...	...	0.13	...	0.14	...	...	...	...	...	...	0.05	0.01	
	...	...	0.12	...	0.49	...	...	...	...	...	...	0.19	0.06	
	...	...	0.69	...	0.94	...	...	...	...	...	...	1.32	12.86	
	...	...	3.14	...	3.13	...	...	...	...	...	...	5.50	42.87	
	...	...	2	...	2	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	328.50	
	0.00	0.94	0.84	0.38	-0.52	-0.75	-0.56	-0.52	-0.71	-0.53	1.60	1.42	15.86	1.00
	0.00	0.16	0.08	0.07	...	...	...	...	...	...	0.18	0.07	0.43	1.00
	...	557.40	668.73	779.05	...	...	...	...	...	...	475.88	782.73	1412.77	0.83
	...	0.11	0.06	0.11	...	...	...	...	...	...	0.07	0.03	0.02	
	...	-0.10	-0.22	-1.32	...	...	...	...	...	...	-0.25	-0.25	-0.77	
	0.00	0.79	0.71	0.32	...	...	...	...	...	...	1.35	1.19	5.47	
	...	4.16	5.46	2.91	...	...	...	...	...	...	4.50	13.22	12.43	
IC 4518A	0	2	1	4	...	...	...	...	...	...	2	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	578.40	
	2.31	1.42	1.26	0.67	0.96	-0.80	-0.75	0.96	-0.60	-0.97	-1.43	2.03	3.93	0.00
	0.35	0.17	0.11	0.09	0.15	...	...	0.15	...	...	...	0.09	0.46	0.00
	453.72	567.17	680.90	794.00	907.99	...	...	1247.05	...	...	...	796.64	1438.26	0.87
	0.10	0.09	0.05	0.09	0.11	...	...	0.10	...	...	...	0.03	0.04	
	-0.11	-0.08	0.24	-0.04	0.60	...	...	-0.15	...	...	...	-0.05	-0.02	
	1.95	1.20	1.06	0.57	0.81	...	...	0.81	...	...	...	1.72	2.64	
	3.75	5.71	6.62	5.18	4.50	...	...	4.26	...	...	...	15.64	12.57	
	2	1	1	1	2	...	...	2	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	293.40	
	1.16	1.71	2.30	2.51	2.20	1.87	2.02	1.02	0.68	0.44	1.00	1.12	2.74	1.00
	0.25	0.15	0.07	0.06	0.11	0.11	0.11	0.11	0.10	0.12	0.16	0.06	0.42	1.00
	455.26	568.91	682.70	796.40	910.09	1023.71	1137.97	1250.77	1364.20	1477.72	485.96	799.02	1442.75	0.99
CGCG 049-057	0.14	0.05	0.02	0.01	0.03	0.04	0.03	0.07	0.09	0.17	0.10	0.03	0.04	
	0.14	0.03	0.10	0.10	0.12	0.10	0.77	0.02	-0.06	0.00	0.11	0.07	0.37	
	0.98	1.44	1.94	2.12	1.86	1.58	1.71	0.86	0.57	0.37	0.85	0.94	2.26	
	5.44	11.08	32.33	26.50	12.40	17.56	6.58	8.60	3.80	3.08	6.07	13.43	14.13	
	1	1	1	1	1	1	1	1	2	2	1	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	237.60	

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
VV 705	0.00	1.05	0.62	0.81	0.76	-0.90	0.62	0.66	0.61	-0.70	-1.13	0.78	2.91	1.00
	0.00	0.14	0.08	0.05	0.08	...	0.10	0.11	0.11	...	...	0.06	0.37	1.00
	...	553.81	665.01	775.30	886.12	...	1107.61	1218.23	1328.77	...	...	778.06	1404.42	0.98
	...	0.09	0.09	0.05	0.07	...	0.11	0.11	0.12	...	...	0.05	0.04	
	...	-0.38	0.03	-0.45	-0.36	...	-0.24	-0.24	-0.27	...	...	-0.27	-0.73	
	0.00	0.88	0.53	0.68	0.64	...	0.52	0.55	0.52	...	...	0.65	2.08	
	...	3.83	3.53	9.71	4.92	...	4.33	3.44	3.71	...	...	10.83	13.00	
	0	2	2	1	1	...	2	2	2	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	281.60	
	...	...	...	...	...	...	...	...	...	...	...	...	...	
ESO 099-G004	-2.06	0.92	1.22	1.18	0.80	1.35	0.74	0.72	-0.54	0.60	-0.86	1.21	8.45	1.00
	...	0.15	0.09	0.07	0.10	0.11	0.11	0.11	...	0.11	...	0.06	0.32	1.00
	...	559.48	671.68	783.79	895.40	1007.38	1119.01	1230.61	...	1453.89	...	786.17	1419.60	0.92
	...	0.11	0.04	0.04	0.08	0.06	0.09	0.11	...	0.12	...	0.04	0.02	
	...	-0.39	-0.12	0.09	-0.17	-0.03	-0.20	-0.36	...	-0.45	...	-0.15	0.03	
	...	0.78	1.03	1.00	0.68	1.14	0.62	0.61	...	0.50	...	1.02	4.40	
	...	3.25	8.58	9.09	5.23	6.71	3.65	3.05	...	2.94	...	9.27	44.00	
	...	4	1	1	1	1	2	2	...	2	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	380.90	
	...	...	...	...	...	...	...	...	...	...	...	...	...	
NGC 5936	-3.41	2.07	1.77	0.91	1.23	-1.66	-1.09	-1.21	-1.37	-1.12	-1.47	1.47	10.71	0.93
	...	0.28	0.12	0.15	0.23	...	...	...	...	...	...	0.11	0.97	0.89
	...	568.28	682.22	795.93	909.51	...	...	...	...	...	...	798.52	1441.70	0.72
	...	0.08	0.06	0.11	0.12	...	...	...	...	...	...	0.06	0.02	
	...	-0.39	-0.14	-0.09	-0.15	...	...	...	...	...	...	-0.15	-0.18	
	...	1.75	1.49	0.77	1.04	...	...	...	...	...	...	1.24	8.86	
	...	3.37	5.96	4.81	3.85	...	...	...	...	...	...	7.29	30.55	
	...	2	1	2	2	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	237.10	
	...	...	...	...	...	...	...	...	...	...	...	...	...	
UGC 09913 (= Arp 220)	6.16	7.48	9.58	9.29	9.42	7.69	7.97	4.66	3.43	-2.23	2.99	4.69	10.99	1.00
	0.74	0.43	0.21	0.19	0.31	0.51	0.42	0.48	0.44	...	0.49	0.17	1.36	1.00
	452.81	566.05	679.23	792.40	905.55	1018.52	1132.48	1244.47	1357.24	...	483.49	794.98	1435.42	0.96
	0.08	0.04	0.01	0.01	0.02	0.04	0.03	0.07	0.08	...	0.11	0.03	0.08	
	-0.02	0.04	0.06	0.11	0.16	0.07	1.00	0.02	-0.15	...	0.09	0.05	0.30	
	5.20	6.31	8.08	7.84	7.95	6.49	6.72	3.93	2.89	...	2.52	3.95	4.80	
	13.00	19.12	35.13	16.33	11.69	12.25	5.21	8.93	9.32	...	15.75	9.19	8.89	
	...	...	...	...	...	...	...	...	...	...	...	...	...	

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
	1	1	1	1	1	1	1	1	1	...	1	1	1	
NGC 5990	...	...	...	...	...	...	...	...	...	...	...	...	449.40	
	-2.79	2.67	1.73	1.19	1.53	-1.10	-1.22	-1.25	-1.28	-1.27	-2.23	1.65	15.45	0.96
	...	0.33	0.17	0.15	0.27	...	...	...	...	...	...	0.16	0.66	0.94
	...	568.80	683.00	796.73	910.54	...	...	...	...	...	...	799.26	1443.18	0.74
	...	0.08	0.07	0.09	0.12	...	...	...	...	...	...	0.06	0.02	
	...	-0.19	0.27	0.28	0.39	...	...	...	...	...	...	0.15	0.52	
	...	2.25	1.46	1.01	1.29	...	...	...	...	...	...	1.39	9.50	
NGC 6052	...	4.69	4.42	6.31	3.15	...	...	...	...	...	...	7.72	22.09	
	...	2	2	1	2	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	317.50	
	2.39	-1.64	1.10	-0.45	-0.66	-1.10	-0.68	-1.10	-1.16	-0.94	-1.71	0.56	3.13	0.81
	0.43	...	0.12	...	...	...	...	...	...	...	...	0.09	0.62	0.75
	453.23	...	680.32	...	...	...	...	...	...	...	...	796.71	1438.47	0.47
	0.12	...	0.06	...	...	...	...	...	...	...	...	0.10	0.06	
	-0.63	...	-0.39	...	...	...	...	...	...	...	...	-0.04	0.07	
	2.02	...	0.93	...	...	...	...	...	...	...	...	0.47	2.31	
	4.39	...	5.17	...	...	...	...	...	...	...	...	3.92	8.88	
CGCG 052-037	4	...	1	...	...	...	...	...	...	...	...	2	1	
	...	...	...	...	...	...	...	...	...	...	...	...	266.70	
	-0.83	1.24	1.17	0.90	0.89	-0.69	-0.59	-0.83	0.63	-0.72	1.07	1.11	8.51	1.00
	...	0.14	0.09	0.07	0.10	...	...	...	0.11	...	0.18	0.06	0.35	1.00
	...	562.30	674.81	787.28	899.50	...	...	...	1349.19	...	480.60	789.84	1425.89	0.96
	...	0.08	0.04	0.05	0.08	...	...	...	0.11	...	0.11	0.04	0.01	
	...	-0.19	-0.14	-0.09	-0.26	...	...	...	0.24	...	0.20	-0.16	-0.32	
	...	1.05	0.99	0.76	0.75	...	...	...	0.53	...	0.91	0.94	6.27	
	...	5.53	7.62	12.67	4.69	...	...	...	4.08	...	3.25	13.43	33.00	
	...	1	1	1	2	...	...	...	2	...	2	1	1	
NGC 6156	...	...	...	...	...	...	...	...	...	...	...	...	269.60	
	3.49	1.92	1.55	1.40	1.88	1.67	-1.15	-1.58	-1.11	-1.55	-1.96	1.70	11.05	0.71
	0.57	0.26	0.15	0.12	0.25	0.23	...	...	...	...	...	0.13	0.93	0.64
	455.81	569.96	683.82	798.03	911.78	1025.36	...	...	...	...	...	800.43	1445.18	0.42
	0.10	0.10	0.06	0.06	0.08	0.11	...	...	...	...	...	0.06	0.02	
	-0.27	-0.10	-0.21	0.06	-0.09	-0.38	...	...	...	...	...	-0.19	-0.22	



Table 4—Continued

Name (1)	(4−3) (2)	(5−4) (3)	(6−5) (4)	(7−6) (5)	(8−7) (6)	(9−8) (7)	(10−9) (8)	(11−10) (9)	(12−11) (10)	(13−12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
2MASX J16381190 -6826080	2.94	1.62	1.31	1.18	1.59	1.41	...	...	...	...	...	1.44	9.03	
	3.63	4.38	5.04	7.37	4.54	4.27	...	...	...	...	...	9.60	25.08	
	2	2	1	1	2	2	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	239.60	
	0.00	1.88	1.17	0.82	0.62	-0.52	-0.62	-0.52	-0.55	-0.60	0.90	1.23	10.62	1.00
	0.00	0.11	0.07	0.05	0.07	...	...	...	...	...	0.15	0.05	0.30	1.00
	...	550.82	660.91	771.25	880.66	...	...	...	...	...	470.09	773.44	1396.63	1.00
	...	0.04	0.04	0.04	0.07	...	...	...	...	...	0.11	0.03	0.02	
	...	0.12	0.13	0.40	-0.24	...	...	...	...	...	-0.23	0.01	0.34	
	0.00	1.58	0.98	0.69	0.52	...	...	...	...	...	0.76	1.04	3.97	
IRAS F16399-0937	...	10.53	8.91	7.67	5.20	...	...	...	...	...	4.22	11.56	20.89	
	0	1	1	1	1	...	...	...	...	...	4	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	539.90	
	-1.72	-1.16	1.26	0.94	0.86	0.66	0.80	-0.69	-0.65	-0.75	-1.22	1.00	7.26	1.00
	...	...	0.09	0.07	0.11	0.11	0.11	...	...	...	...	0.08	0.30	1.00
	...	...	673.27	785.47	897.06	1009.68	1121.67	...	...	...	...	787.81	1422.19	0.92
	...	...	0.05	0.05	0.09	0.11	0.08	...	...	...	...	0.05	0.02	1
	...	...	-0.02	0.04	-0.50	0.04	-0.01	...	...	...	...	-0.25	-0.52	
	...	...	1.06	0.79	0.73	0.56	0.68	...	...	...	...	0.85	4.05	
	...	...	9.64	9.88	4.29	4.31	4.25	...	...	...	...	10.63	28.93	
NGC 6240	...	...	1	1	2	2	2	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	355.30	
	6.42	11.27	14.08	16.63	18.26	17.13	16.02	12.67	10.99	9.37	2.62	9.48	15.90	1.00
	0.27	0.57	0.26	0.28	0.35	0.30	0.24	0.28	0.24	0.27	0.17	0.28	0.30	1.00
	449.97	562.46	674.92	787.38	899.83	1012.23	1124.63	1236.90	1349.16	1461.34	480.33	790.07	1426.10	0.94
	0.03	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.04	0.01	0.02	
	-0.05	-0.03	-0.03	0.01	0.06	0.09	0.17	0.16	0.19	0.19	-0.07	0.07	-0.12	
	5.42	10.18	10.90	11.61	11.21	9.54	8.04	6.74	5.35	4.15	2.21	6.71	4.90	
	12.04	63.63	72.67	105.55	80.07	63.60	73.09	44.93	44.58	51.88	11.05	61.00	32.67	
	1	1	1	1	1	1	1	1	1	1	1	1	1	
IRAS F16516-0948	...	...	...	...	...	499.50	499.00	428.20	429.20	435.60	...	...	640.30	
	-1.94	1.38	1.07	0.69	-0.68	0.69	-0.57	-0.63	-0.66	-0.84	-1.05	1.04	5.27	0.94
	...	0.14	0.08	0.06	...	0.12	...	...	...	...	...	0.07	0.35	0.91
	...	563.34	675.88	788.36	...	1013.70	...	...	...	...	...	791.04	1428.17	0.71



Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
ESO 138-G027	0.00	0.19	0.11	0.09	0.11	0.21	0.14	0.16	0.14	0.14	...	0.09	0.50	1.00
	...	552.73	663.23	773.67	884.04	994.40	1105.65	1215.25	1325.33	1435.51	...	775.96	1401.33	0.97
	...	0.05	0.03	0.02	0.02	0.05	0.03	0.07	0.10	0.11	...	0.03	0.05	
	...	0.12	0.14	0.14	0.08	0.06	0.95	0.25	0.07	0.04	...	-0.15	0.18	
	0.00	2.03	2.46	2.48	2.58	2.20	2.30	1.26	0.78	0.72	...	1.42	2.82	
	...	11.28	17.57	16.53	9.92	9.17	4.42	4.67	4.11	3.60	...	9.47	14.84	
	0	1	1	1	1	1	4	2	2	2	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	453.50	
	2.31	1.26	0.55	0.91	-0.75	-0.92	-0.81	-0.87	0.72	-0.77	-1.15	0.63	6.15	1.00
	0.44	0.18	0.11	0.08	...	...	...	...	0.15	...	...	0.09	1.00	1.00
	451.43	564.39	677.00	790.28	...	...	...	...	1352.77	...	...	792.89	1431.27	0.90
	0.12	0.09	0.12	0.06	...	...	...	...	0.13	...	...	0.10	0.02	
	-0.22	-0.14	-0.40	0.05	...	...	...	...	-1.09	...	...	0.02	-0.11	
	1.95	1.06	0.47	0.77	...	...	...	...	0.61	...	...	0.53	7.54	
UGC 11041	3.31	3.53	3.13	7.00	...	...	...	...	4.36	...	...	4.82	39.68	
	2	2	2	1	...	...	...	...	4	...	...	2	1	
	...	...	...	...	...	...	...	...	...	...	...	...	161.20	
	-1.97	-1.50	0.66	0.63	-0.93	1.01	-1.01	-0.97	-0.86	-1.10	-1.31	1.26	13.27	1.00
	...	...	0.09	0.08	...	0.17	...	...	...	...	...	0.08	0.46	0.98
	...	...	680.60	793.22	...	1020.43	...	...	...	...	...	796.39	1437.70	0.84
	...	...	0.09	0.08	...	0.10	...	...	...	...	...	0.04	0.01	
	...	...	0.20	-0.51	...	0.13	...	...	...	...	...	0.01	-0.02	
	...	...	0.56	0.53	...	0.85	...	...	...	...	...	1.06	8.73	
	...	...	4.00	3.53	...	4.05	...	...	...	...	...	7.07	32.33	
	...	...	2	2	...	2	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	299.70	
	-2.57	2.02	3.12	2.56	2.66	3.40	1.86	-2.02	-1.39	-1.42	-2.08	1.82	7.29	1.00
	...	0.39	0.14	0.15	0.30	0.20	0.25	...	...	...	...	0.15	1.07	1.00
IRAS 17578-0400	...	568.35	682.37	796.08	909.71	1023.25	1137.44	...	...	...	...	798.56	1441.64	0.94
	...	0.11	0.04	0.04	0.06	0.04	0.09	...	...	...	...	0.05	0.03	
	...	0.06	0.47	0.60	0.67	0.70	1.41	...	...	...	...	0.42	0.74	
	...	1.71	2.63	2.16	2.24	2.87	1.57	...	...	...	...	1.54	6.46	
	...	4.89	10.96	9.00	6.40	6.83	3.93	...	...	...	...	6.42	19.58	
	...	2	1	1	1	1	4	...	...	...	...	1	1	

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Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
NGC 6621	...	...	...	...	...	...	...	...	...	...	...	...	221.00	
	-2.38	1.48	1.78	0.76	1.03	-0.94	-0.89	-0.97	-0.84	-0.83	-1.62	1.25	8.83	0.99
	...	0.21	0.12	0.09	0.15	...	...	...	...	...	...	0.09	0.49	0.98
	...	564.61	677.69	790.23	903.00	...	...	...	...	...	...	793.02	1431.55	0.88
	...	0.09	0.04	0.07	0.09	...	...	...	...	...	...	0.05	0.02	
	...	0.00	0.21	-0.10	-0.15	...	...	...	...	...	...	0.05	-0.02	
	...	1.25	1.50	0.64	0.87	...	...	...	...	...	...	1.06	5.47	
	...	3.91	9.38	4.57	3.48	...	...	...	...	...	...	7.57	23.78	
IC 4687	...	2	1	2	2	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	317.60	
	1.40	1.83	1.85	1.41	0.96	0.53	0.58	-0.43	-0.34	-0.46	0.98	1.49	12.54	0.90
	0.16	0.09	0.05	0.04	0.07	0.08	0.07	...	...	...	0.11	0.04	0.29	0.86
	453.23	566.42	679.77	792.99	906.25	1019.28	1132.64	...	...	...	483.89	795.58	1436.37	0.76
	0.08	0.03	0.02	0.02	0.05	0.10	0.08	...	...	...	0.07	0.02	0.01	— 224
	0.05	-0.02	0.09	0.09	0.17	0.05	0.29	...	...	...	0.12	0.04	0.15	
	1.18	1.54	1.56	1.19	0.81	0.45	0.49	...	...	...	0.82	1.25	10.52	
IRAS F18293-3413	5.90	10.27	17.33	29.75	6.23	4.50	4.45	...	...	...	5.13	31.25	80.92	—
	1	1	1	1	1	2	2	...	...	...	1	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	234.90	
	5.56	6.54	6.61	5.37	3.75	2.76	1.64	0.97	0.84	-1.12	4.25	6.42	26.72	1.00
	0.33	0.17	0.08	0.08	0.13	0.18	0.15	0.15	0.14	...	0.23	0.08	0.48	1.00
	452.71	565.92	679.10	792.27	905.32	1018.35	1131.25	1244.15	1357.15	...	483.36	794.83	1434.95	0.94
	0.04	0.02	0.01	0.01	0.02	0.04	0.06	0.10	0.11	...	0.03	0.01	0.01	
	-0.10	-0.06	-0.03	0.02	-0.02	-0.05	-0.17	-0.25	-0.17	...	-0.02	-0.07	-0.10	
IC 4734	4.69	5.51	5.58	4.53	3.16	2.33	1.39	0.81	0.70	...	3.59	5.41	15.06	
	12.68	19.00	42.92	21.57	16.63	13.71	5.56	3.38	3.68	...	16.32	25.76	62.75	
	1	1	1	1	1	1	1	2	2	...	1	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	348.30	
	-2.27	3.44	3.18	2.26	2.33	2.00	1.41	1.32	-1.48	-1.69	-2.43	1.95	7.82	1.00
	...	0.31	0.14	0.14	0.22	0.23	0.24	0.26	...	...	...	0.13	0.81	0.99
	...	567.40	680.91	794.17	907.65	1020.98	1134.90	1247.32	...	...	...	796.93	1438.91	0.90
	...	0.07	0.03	0.04	0.07	0.08	0.10	0.12	...	...	...	0.05	0.03	
IC 4734	...	-0.01	0.06	-0.09	0.02	0.01	0.62	-0.22	...	...	...	0.02	0.23	
	...	2.90	2.68	1.91	1.96	1.69	1.19	1.11	...	...	...	1.65	5.80	

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
NGC 6701	...	6.74	7.88	11.94	5.16	4.97	3.40	3.17	...	...	...	10.31	13.81	
	...	1	1	1	1	2	2	2	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	265.50	
	2.64	3.33	2.44	1.84	1.93	1.44	1.48	-1.24	-1.18	-1.47	3.10	2.42	7.25	0.90
	0.59	0.31	0.14	0.16	0.23	0.26	0.17	...	...	...	0.43	0.12	1.65	0.87
	454.93	568.77	682.68	796.04	909.91	1023.13	1137.24	...	...	...	485.62	798.73	1442.10	0.72
	0.12	0.06	0.04	0.05	0.08	0.12	0.09	...	...	...	0.08	0.04	0.03	
	-0.09	0.02	0.23	-0.08	0.14	-0.24	0.29	...	...	...	-0.11	-0.04	0.04	
	2.22	2.81	2.06	1.55	1.62	1.22	1.25	...	...	...	2.61	2.04	8.76	
ESO 339-G011	3.76	5.85	8.96	10.33	4.05	4.21	3.79	...	...	...	4.92	13.60	23.68	
	2	1	1	1	2	2	2	...	...	...	2	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	162.20	
	-2.97	-1.32	-0.74	0.65	-1.13	-0.78	-1.01	-1.15	-0.95	-0.73	-1.32	1.05	8.24	1.00
	...	...	...	0.08	...	...	...	...	...	...	...	0.09	0.50	0.99
	...	...	...	791.31	...	...	...	...	...	...	...	794.20	1433.53	0.86
	...	...	...	0.10	...	...	...	...	...	...	...	0.06	0.03	0.99
	...	...	...	-0.14	...	...	...	...	...	...	...	0.10	-0.07	0.99
	...	...	...	0.55	...	...	...	...	...	...	...	0.89	4.51	0.99
MCG +04-48-002	...	...	...	4.58	...	...	...	...	...	...	...	7.42	18.04	
	...	...	...	2	...	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	359.40	
	-3.20	1.67	1.01	1.15	1.20	-1.39	-1.71	-1.30	-1.26	-1.73	-1.96	1.53	14.52	1.00
	...	0.28	0.16	0.09	0.27	...	...	...	...	...	...	0.13	0.74	0.99
	...	567.99	681.66	795.21	909.46	...	...	...	...	...	...	798.45	1440.73	0.83
	...	0.11	0.10	0.07	0.12	...	...	...	...	...	...	0.05	0.03	
	...	-0.37	-0.33	-0.38	0.29	...	...	...	...	...	...	0.20	-0.38	
	...	1.41	0.85	0.97	1.01	...	...	...	...	...	...	1.29	7.34	
NGC 6926	...	4.03	3.40	5.11	3.74	...	...	...	...	...	...	6.14	18.82	
	...	2	2	1	2	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	386.70	
	-1.89	-1.48	-0.59	0.48	-1.00	-0.84	-0.99	-1.14	-0.96	-0.97	-1.59	1.01	4.07	0.44
	...	...	...	0.08	...	...	...	...	...	...	...	0.11	0.56	0.37
	...	...	...	791.38	...	...	...	...	...	...	...	793.44	1432.33	0.20
	...	...	...	0.12	...	...	...	...	...	...	...	0.06	0.05	

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
CGCG 448-020	...	...	...	0.25	...	...	...	...	...	...	...	-0.33	-0.70	
	...	...	...	0.40	...	...	...	...	...	...	...	0.85	2.66	
	...	...	...	4.00	...	...	...	...	...	...	...	8.50	11.57	
	...	...	...	4	...	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	302.40	
	0.00	-1.29	0.75	0.90	1.06	1.08	1.24	1.14	1.80	-1.24	-1.50	0.77	1.31	1.00
	0.00	...	0.12	0.08	0.13	0.16	0.13	0.16	0.16	...	...	0.08	0.13	0.98
	...	...	667.61	778.31	889.64	1000.57	1112.18	1223.10	1334.20	...	...	781.26	1410.10	0.86
	...	...	0.11	0.07	0.08	0.11	0.08	0.10	0.06	...	...	0.08	0.07	
	...	...	0.23	-0.24	-0.05	-0.22	0.33	0.23	0.36	...	...	0.12	-0.13	
ESO 286-IG 019	0.00	...	0.63	0.76	0.90	0.91	1.04	0.96	1.52	...	...	0.65	1.11	
	...	...	3.71	6.91	4.29	3.14	5.78	3.84	7.60	...	...	5.91	4.83	
	0	...	2	1	2	2	1	2	1	...	...	1	2	
	...	...	...	...	...	...	...	...	...	...	...	...	...	
	0.00	1.42	1.21	1.76	2.10	1.53	2.04	1.89	1.62	1.32	-1.38	0.61	0.75	1.00
	0.00	0.16	0.09	0.06	0.09	0.15	0.10	0.12	0.11	0.10	...	0.07	0.11	1.00
	...	552.52	662.98	773.57	883.86	994.27	1104.71	1214.82	1325.29	1435.40	...	775.93	1401.22	1.00
	...	0.07	0.05	0.02	0.03	0.06	0.03	0.04	0.04	0.05	...	0.07	0.09	
	...	0.01	0.01	0.17	0.06	0.11	0.22	0.04	0.27	0.19	...	-0.05	0.32	
	0.00	1.20	1.02	1.48	1.77	1.29	1.72	1.59	1.37	1.12	...	0.51	0.64	
ESO 286-G035	...	5.22	6.80	18.50	11.80	6.79	8.19	11.36	10.54	6.22	...	6.38	4.57	
	0	1	1	1	1	1	1	1	1	1	...	1	2	
	...	...	...	...	...	...	...	...	...	...	...	...	...	
	3.08	1.56	1.40	0.81	-1.14	-1.05	-0.71	-1.05	-0.84	-1.13	1.77	0.85	10.05	1.00
	0.37	0.19	0.10	0.09	...	...	...	...	...	...	0.22	0.08	0.51	0.99
	453.06	566.37	679.66	792.77	...	...	...	...	...	...	484.24	795.47	1436.19	0.87
	0.08	0.08	0.05	0.07	...	...	...	...	...	...	0.09	0.07	0.02	
	-0.11	-0.06	-0.01	-0.12	...	...	...	...	...	...	0.48	-0.06	-0.01	
	2.60	1.32	1.18	0.68	...	...	...	...	...	...	1.50	0.72	7.70	
	7.22	5.50	6.94	6.80	...	...	...	...	...	...	4.55	6.55	38.50	
NGC 7130	1	1	1	1	...	...	...	...	...	...	4	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	257.00	
	2.94	3.17	2.82	2.68	2.18	2.49	153.20	1.40	0.87	0.79	1.33	2.71	13.83	0.98
	0.26	0.14	0.08	0.06	0.13	0.14	6755999.93	0.12	0.12	0.13	0.19	0.07	0.82	0.96

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
ESO 467-G027	453.73	567.11	680.40	793.81	907.09	1020.39	1134.17	1246.81	1359.89	1473.15	483.98	796.40	1437.89	0.85
	0.06	0.03	0.02	0.02	0.03	0.04	-0.00	0.06	0.08	0.11	0.09	0.02	0.01	
	0.01	-0.00	-0.09	-0.02	-0.06	-0.05	0.50	-0.06	-0.14	0.02	-0.35	-0.08	-0.02	
	2.48	2.67	2.38	2.26	1.84	2.10	-1.00	1.18	0.73	0.67	1.12	2.28	16.32	
	6.20	9.89	17.00	32.29	12.27	15.00	-8.33	7.87	5.21	3.19	3.73	32.57	125.54	
	1	1	1	1	1	1	1	1	1	2	4	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	166.60	
	-2.12	-1.34	-0.58	-0.42	-0.88	-0.82	-0.82	-1.11	-0.80	-0.61	-1.66	0.97	10.54	0.84
	...	...	...	...	...	...	...	...	...	...	...	0.08	0.62	0.79
	...	...	...	...	...	...	...	...	...	...	...	795.29	1436.04	0.53
IC 5179	...	...	...	...	...	...	...	...	...	...	...	0.05	0.01	
	...	...	...	...	...	...	...	...	...	...	...	-0.21	-0.11	
	...	...	...	...	...	...	...	...	...	...	...	0.82	9.39	
	...	...	...	...	...	...	...	...	...	...	...	6.83	33.54	
	...	...	...	...	...	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	221.30	
	2.74	1.80	1.85	1.34	-1.55	-1.39	-1.00	-1.31	-1.38	-1.27	2.67	2.33	27.86	0.79
	0.44	0.33	0.12	0.14	...	...	...	...	...	...	0.40	0.13	0.75	0.74
	456.05	570.04	683.62	797.83	...	...	...	...	...	...	486.80	800.35	1444.88	0.53
	0.11	0.12	0.05	0.06	...	...	...	...	...	...	0.10	0.04	0.01	
UGC 12150	0.21	0.28	-0.05	0.28	...	...	...	...	...	...	0.20	0.14	0.24	
	2.31	1.52	1.56	1.13	...	...	...	...	...	...	2.25	1.97	20.24	
	4.20	3.62	7.43	6.28	...	...	...	...	...	...	3.95	10.94	57.83	
	2	2	1	1	...	...	...	...	...	...	2	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	269.70	
	-2.77	1.56	1.43	1.18	1.12	-0.99	-1.01	-1.05	-0.96	-0.92	1.40	1.31	9.99	1.00
	...	0.19	0.11	0.09	0.15	...	...	...	...	...	0.29	0.08	0.52	1.00
	...	564.31	677.11	789.65	902.51	...	...	...	...	...	481.62	792.23	1430.51	0.93
	...	0.08	0.05	0.04	0.09	...	...	...	...	...	0.12	0.04	0.03	
	...	0.11	0.12	-0.11	0.01	...	...	...	...	...	-0.24	-0.16	-0.02	
	...	1.32	1.21	0.99	0.94	...	...	...	...	...	1.18	1.10	5.20	
	...	5.50	6.72	8.25	3.62	...	...	...	...	...	3.47	9.17	30.59	
	...	1	1	1	2	...	...	...	...	...	2	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	378.40	

Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
NGC 7469	3.06	4.21	3.74	3.18	2.49	2.20	1.50	1.18	0.95	0.82	2.00	3.95	13.79	1.00
	0.19	0.10	0.06	0.05	0.09	0.10	0.09	0.09	0.09	0.09	0.13	0.05	0.33	1.00
	453.64	566.98	680.33	793.68	906.97	1020.17	1133.51	1246.56	1359.93	1472.80	484.21	796.34	1437.69	0.94
	0.04	0.02	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.04	0.01	0.01	
	0.00	-0.03	-0.05	-0.02	-0.03	-0.09	0.02	-0.11	0.13	-0.09	-0.05	-0.01	0.02	
	2.58	3.55	3.16	2.68	2.10	1.86	1.27	1.00	0.80	0.69	1.69	3.33	10.76	
	15.18	17.75	45.14	26.80	16.15	23.25	14.11	10.00	5.71	4.60	13.00	33.30	76.86	
	1	1	1	1	1	1	1	1	1	2	1	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	252.40	
	0.00	1.01	1.07	1.13	1.15	1.19	1.04	0.89	0.64	0.92	-0.72	0.68	2.45	1.00
ESO 148-IG 002	0.00	0.12	0.07	0.04	0.07	0.11	0.09	0.09	0.09	0.08	...	0.04	0.32	1.00
	...	551.79	661.91	772.27	882.49	992.46	1103.07	1212.91	1323.14	1433.02	...	774.84	1398.89	0.96
	...	0.07	0.04	0.03	0.04	0.06	0.06	0.07	0.09	0.06	...	0.05	0.04	
	...	0.13	-0.04	0.06	0.05	-0.18	0.27	-0.00	0.15	0.01	...	0.05	0.14	
	0.00	0.85	0.91	0.95	0.97	1.00	0.87	0.75	0.54	0.77	...	0.58	1.79	
	...	5.00	7.00	11.88	10.78	5.56	8.70	5.77	3.60	5.92	...	7.25	14.92	
	0	1	1	1	1	1	1	1	2	1	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	277.40	
	-2.21	1.29	1.44	0.97	1.52	1.20	-0.72	-0.93	-0.92	-0.99	-1.42	0.96	4.25	1.00
	...	0.20	0.10	0.09	0.13	0.21	...	...	...	...	...	0.09	0.50	1.00
IC 5298	...	561.07	673.23	785.25	897.33	1009.24	...	...	...	...	...	787.87	1422.30	0.97
	...	0.10	0.05	0.07	0.06	0.11	...	...	...	...	...	0.07	0.05	
	...	0.18	0.21	0.13	0.13	0.01	...	...	...	...	...	0.13	0.17	
	...	1.09	1.21	0.82	1.28	1.01	...	...	...	...	...	0.81	2.67	
	...	3.89	8.64	6.83	5.33	4.81	...	...	...	...	...	6.75	11.61	
	...	2	1	1	1	2	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	317.50	
	12.33	12.13	12.95	11.35	9.60	6.20	4.24	3.39	1.52	-1.82	5.21	10.64	37.60	0.89
	0.54	0.30	0.14	0.11	0.21	0.27	0.24	0.25	0.20	...	0.29	0.11	1.01	0.87
	458.60	573.32	687.86	802.43	917.01	1031.45	1145.92	1260.48	1374.80	...	489.41	805.09	1453.45	0.77
NGC 7552	0.03	0.02	0.01	0.01	0.01	0.03	0.03	0.05	0.08	...	0.04	0.01	0.00	
	0.02	0.13	0.08	0.08	0.13	0.07	0.08	0.22	0.18	...	-0.12	0.07	0.11	
	10.40	10.23	10.93	9.58	8.10	5.23	3.58	2.86	1.28	...	4.40	8.98	35.66	
	15.52	22.73	47.52	50.42	23.82	15.85	9.42	11.44	4.27	...	11.89	49.89	79.24	



Table 4—Continued

Name (1)	(4–3) (2)	(5–4) (3)	(6–5) (4)	(7–6) (5)	(8–7) (6)	(9–8) (7)	(10–9) (8)	(11–10) (9)	(12–11) (10)	(13–12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu\text{m}}(\theta)$ (15)
	1	1	1	1	1	1	1	1	2	...	1	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	205.20	
NGC 7591	1.78	-1.42	1.25	1.28	1.14	-1.21	0.93	-0.93	-0.84	-0.90	-1.21	1.93	7.01	1.00
	0.41	...	0.13	0.09	0.17	...	0.15	...	...	...	...	0.10	0.54	0.99
	453.72	...	680.27	793.63	906.93	...	1133.35	...	...	...	...	796.02	1437.37	0.88
	0.14	...	0.06	0.05	0.09	...	0.11	...	...	...	...	0.03	0.03	
	0.17	...	0.04	0.10	0.12	...	0.10	...	...	...	...	-0.16	-0.00	
	1.50	...	1.06	1.08	0.96	...	0.79	...	...	...	...	1.63	4.35	
	3.49	...	4.82	9.82	4.36	...	3.95	...	...	...	...	14.82	16.11	
	2	...	2	1	2	...	2	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	316.30	
NGC 7592	-2.04	1.10	1.06	0.75	0.94	1.19	-0.73	-0.90	-0.88	-0.82	-1.35	0.97	5.38	0.96
	...	0.17	0.10	0.09	0.14	0.15	...	...	...	...	...	0.08	0.46	0.92
	...	562.36	674.87	787.38	899.82	1011.89	...	...	...	...	...	789.97	1426.23	0.68
	...	0.12	0.06	0.07	0.10	0.09	...	...	...	...	...	0.05	0.04	
	...	-0.16	-0.10	-0.03	0.02	-0.28	...	...	...	...	...	-0.06	-0.04	
	...	0.93	0.89	0.63	0.79	1.00	...	...	...	...	...	0.82	3.18	
	...	3.21	5.56	7.00	3.59	3.57	...	...	...	...	...	9.11	17.67	
	...	2	1	1	2	2	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	334.30	
NGC 7674	-1.86	-0.83	0.44	0.28	0.55	-0.70	-0.51	-0.66	0.67	-0.53	-0.94	0.73	4.28	0.90
	...	...	0.09	0.06	0.08	...	...	...	0.10	...	...	0.07	0.48	0.88
	...	...	671.89	783.76	896.16	...	...	...	1343.80	...	...	786.87	1420.30	0.79
	...	...	0.12	0.14	0.12	...	...	...	0.10	...	...	0.06	0.02	
	...	...	-0.14	-0.22	0.27	...	...	...	0.65	...	...	0.28	0.24	
	...	...	0.37	0.24	0.46	...	...	...	0.57	...	...	0.62	4.21	
	...	...	3.08	3.00	3.83	...	...	...	4.75	...	...	8.86	26.31	
	...	...	2	2	2	...	...	...	2	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	202.60	
NGC 7679	-1.91	-1.60	1.35	0.85	-0.73	-0.94	-0.89	-0.90	-1.05	-1.23	-1.27	0.68	8.94	1.00
	...	...	0.08	0.09	...	...	...	...	...	...	...	0.08	0.67	0.99
	...	...	679.88	792.99	...	...	...	...	...	...	...	795.69	1436.56	0.86
	...	...	0.04	0.07	...	...	...	...	...	...	...	0.08	0.02	
	...	...	0.06	-0.07	...	...	...	...	...	...	...	-0.01	0.05	

Table 4—Continued

Name (1)	(4−3) (2)	(5−4) (3)	(6−5) (4)	(7−6) (5)	(8−7) (6)	(9−8) (7)	(10−9) (8)	(11−10) (9)	(12−11) (10)	(13−12) (11)	[C I] 609 (12)	[C I] 370 (13)	[N II] (14)	$f_{70\mu m}(\theta)$ (15)
NGC 7771	...	...	1.14	0.71	...	...	...	...	...	...	...	0.57	7.67	
	...	...	6.33	6.45	...	...	...	...	...	...	...	5.18	31.96	
	...	...	1	1	...	...	...	...	...	...	...	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	229.60	
	3.63	3.79	3.40	2.16	1.86	1.13	0.47	0.63	-0.48	-0.63	2.48	3.36	23.54	0.88
	0.28	0.16	0.07	0.06	0.11	0.10	0.10	0.10	...	...	0.17	0.06	0.28	0.86
	454.41	568.07	681.66	795.28	909.00	1022.41	1135.86	1249.70	...	...	485.11	797.79	1440.35	0.75
	0.04	0.02	0.01	0.02	0.04	0.06	0.13	0.10	...	...	0.04	0.01	0.01	
	-0.14	-0.09	-0.09	-0.03	0.17	0.09	0.08	0.51	...	...	-0.13	-0.17	-0.23	
	3.06	3.20	2.87	1.82	1.57	0.96	0.40	0.53	...	...	2.09	2.84	11.12	
Mrk 331	12.75	15.24	31.89	10.71	9.24	7.38	4.00	4.08	...	...	16.08	16.71	61.78	
	1	1	1	1	1	1	2	2	...	...	1	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	414.10	
	2.31	2.31	2.52	2.14	1.87	1.70	0.94	0.84	0.63	0.55	1.41	2.37	10.26	1.00
	0.17	0.09	0.05	0.04	0.06	0.08	0.08	0.09	0.07	0.09	0.11	0.04	0.24	1.00
	452.82	566.02	679.22	792.39	905.55	1018.43	1131.65	1244.72	1357.41	1470.62	483.25	794.95	1435.21	0.98
	0.05	0.02	0.01	0.01	0.02	0.03	0.05	0.07	0.08	0.10	0.05	0.01	0.01	
	0.15	0.21	0.30	0.38	0.48	0.34	0.57	0.70	0.49	0.86	0.02	0.30	0.59	
	1.95	1.95	2.12	1.81	1.58	1.44	0.79	0.71	0.53	0.46	1.19	2.00	5.91	
	8.13	13.93	21.20	22.62	14.36	10.29	9.88	6.45	5.30	5.11	8.50	25.00	49.25	
	1	1	1	1	1	1	1	1	1	1	1	1	1	
	...	...	...	...	...	...	...	...	...	...	...	...	340.50	

<sup>a</sup> The spectrum of IRAS 05223+1908 shows strong CO lines that has an inferred heliocentric velocity of 100 km/s. This velocity was used for other line detections.

<sup>b</sup> These  $f_{70\mu m}(\theta)$  values are all with respect to the total 70  $\mu m$  flux of the galaxy NGC 2146.

<sup>c</sup> These  $f_{70\mu m}(\theta)$  values are all with respect to the integrated 70  $\mu m$  flux of the whole NGC 3690 system.

Table 5. Additional Detected Lines

Name (1)	Line (2)	F <sup>a</sup> (3)	$\sigma_F^b$ (4)	$\nu_{\text{obs}}^c$ (5)	$\sigma_\nu^d$ (6)	$\nu_{\text{diff}}^e$ (7)	$(f\nu)_p^f$ (8)	(S/N) <sup>g</sup> (9)	Q <sup>h</sup> (10)
NGC 0023	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	-1.53	0.17	1145.41	0.09	-0.06	-1.29	4.03	2
	HF (1-0)	-1.39	0.21	1213.74	0.10	-0.24	-1.17	4.50	2
	<sup>13</sup> CO (5-4)	-1.80	0.33	544.18	0.12	1.52	-1.52	3.23	4
	HCN (16-15)	1.14	0.21	1395.89	0.13	0.46	0.96	3.20	2
	HCN (17-16)	1.56	0.24	1483.76	0.10	1.31	1.32	3.30	4
NGC 0034	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.01S	0.12	969.36	0.08	0.44	0.85	7.73	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.28	0.04	738.35	0.11	0.78	0.24	4.80	4
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	0.43	0.08	1205.50	0.12	0.35	0.36	3.27	2
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	0.49	0.07	1076.35	0.10	0.10	0.42	4.20	2
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	0.73	0.07	1140.87	0.06	0.33	0.61	3.59	2
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=3/2-1/2)	0.37	0.08	1094.60	0.13	0.85	0.31	3.88	2
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	0.58	0.09	1013.18	0.10	-0.07	0.49	3.77	2
MCG -02-01-051	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	-0.85	0.14	1109.20	0.11	-0.17	-0.72	3.60	2
	HCO <sup>+</sup> (6-5)	-1.11	0.23	523.67	0.13	1.06	-0.94	4.09	4
ESO 350-IG038	HCN (16-15)	-0.71	0.14	1388.03	0.12	-0.06	-0.60	3.75	2
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	-1.06L	0.14	952.40	0.09	0.21	-0.90	4.74	2
NGC 0232	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	-1.50S	0.25	967.24	0.12	0.75	-1.27	3.17	4
MCG +12-02-001	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	0.40	0.08	1144.74	0.13	-0.20	0.33	3.30	2
NGC 0317B	HF (1-0)	-0.83	0.16	1211.56	0.11	1.01	-0.70	3.68	2
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	-0.85	0.17	1015.63	0.13	0.89	-0.72	4.80	2
IC 1623	OH <sup>+</sup> (1 <sub>01</sub> -0 <sub>12</sub> )	-0.34	0.07	891.67	0.13	0.39	-0.28	3.50	2
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	0.58L	0.09	952.32	0.09	-0.37	0.49	4.45	2
MCG -03-04-014	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	0.59	0.11	1186.83	0.12	-2.14	0.50	3.57	2
	HF (1-0)	0.59	0.11	1190.69	0.12	-1.85	0.50	3.57	2
	<sup>13</sup> CO (8-7)	0.43	0.10	851.83	0.13	-0.88	0.36	3.27	2
ESO 353-G020	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	-0.96	0.17	1121.73	0.11	0.12	-0.81	4.26	2
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	0.45	0.14	732.96	0.29	-1.48	0.38	3.45	4
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=5/3-3/2)	-0.60	0.15	731.78	0.22	1.43	-0.51	4.64	4
	HCO <sup>+</sup> (6-5)	-1.03	0.21	529.30	0.11	0.93	-0.87	3.35	4
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	-1.06L	0.14	956.23	0.09	-0.27	-0.90	3.60	2
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	-0.91	0.20	1016.76	0.13	-0.09	-0.76	4.75	2
III Zw 035	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.35L	0.17	961.43	0.08	0.35	1.14	5.70	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.64	0.08	731.69	0.08	0.09	0.54	3.86	2
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	1.31	0.14	1068.04	0.06	0.50	1.11	4.27	2
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	2.26	0.14	1131.88	0.04	0.57	1.90	8.26	1
	H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	0.85	0.16	1175.32	0.12	0.50	0.71	4.73	2
NGC 0695	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	0.61	0.10	1078.69	0.12	0.36	0.51	3.92	2
	HCN (17-16)	0.77	0.12	1459.29	0.10	1.60	0.65	3.10	4
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	0.49L	0.09	942.70	0.13	1.46	0.41	3.15	4
UGC 01845	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	1.16	0.20	1209.50	0.11	-0.40	0.98	3.27	2
	OH <sup>+</sup> (1 <sub>01</sub> -0 <sub>12</sub> )	-1.16	0.20	895.33	0.12	0.15	-0.98	3.16	2
NGC 0958	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.57L	0.18	969.34	0.07	-0.03	1.33	3.91	2
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=3/2-1/2)	-0.73	0.13	1094.20	0.11	-0.06	-0.61	3.59	2
NGC 1068	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	3.36	0.39	1108.99	0.07	-0.14	2.84	11.36	1
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	6.14S	0.49	984.08	0.05	-0.11	5.18	14.00	1

Table 5—Continued

Name (1)	Line (2)	F <sup>a</sup> (3)	$\sigma_F^b$ (4)	$\nu_{\text{obs}}^c$ (5)	$\sigma_\nu^d$ (6)	$\nu_{\text{diff}}^e$ (7)	$(f_\nu)_p^f$ (8)	(S/N) <sup>g</sup> (9)	Q <sup>h</sup> (10)
UGC 02238 MCG +02-08-029	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	3.45	0.40	749.09	0.08	-0.10	2.91	6.77	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	5.20	0.42	1224.16	0.05	0.01	4.39	9.54	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	4.18	0.35	1093.20	0.05	-0.02	3.53	13.58	1
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	5.59	0.47	1158.55	0.04	0.03	4.72	11.80	1
	HF (1-0)	2.80	0.43	1227.70	0.09	-0.12	2.36	5.36	1
	<sup>13</sup> CO (5-4)	0.82	0.94	548.27	0.74	-0.58	0.69	3.63	4
	CH <sup>+</sup> (1-0)	2.68	0.43	831.76	0.10	-0.16	2.27	9.08	1
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	1.61	0.37	1134.72	0.14	-0.53	1.36	4.39	2
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=3/2-1/2)	2.00	0.40	1110.91	0.12	-0.08	1.69	6.76	1
	HCN (6-5)	1.03	1.11	530.25	0.64	0.54	0.87	3.48	4
	HCO <sup>+</sup> (6-5)	1.10	1.01	534.54	0.57	-0.26	0.93	4.43	2
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	2.27S	0.57	967.98	0.16	-0.15	1.92	3.69	2
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	3.74	0.38	1028.98	0.07	-0.23	3.16	11.70	1
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	-1.03	0.14	951.67	0.10	0.68	-0.87	5.44	2
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.46	0.06	729.05	0.08	0.26	0.39	4.87	2
	HCN (6-5)	-0.81	0.14	515.94	0.12	0.65	-0.68	3.09	4
	OH <sup>+</sup> (1 <sub>01</sub> -0 <sub>12</sub> )	0.40	0.10	882.52	0.15	1.45	0.34	3.78	4
UGC 02608	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.84	0.10	733.40	0.08	-1.48	0.71	3.55	4
NGC 1275	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	0.72L	0.16	970.81	0.15	-0.07	0.61	3.39	2
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	0.71	0.14	1079.07	0.12	0.64	0.60	3.33	2
UGC 02982	HCN (17-16)	-0.85	0.15	1479.24	0.12	0.18	-0.71	3.94	2
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	0.80L	0.15	955.32	0.11	0.28	0.67	4.47	2
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	1.44	0.23	1206.85	0.10	-0.58	1.22	4.21	2
	HCN (16-15)	-1.09	0.22	1393.20	0.13	1.15	-0.92	4.84	4
ESO 420-G013	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	1.41	0.23	1084.46	0.10	0.01	1.19	4.41	2
	HCN (6-5)	-2.47	0.38	524.08	0.09	-1.38	-2.08	3.53	4
NGC 1572	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.91S	0.29	968.11	0.09	-0.08	1.61	5.19	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	0.90	0.18	1204.75	0.13	0.51	0.76	4.00	2
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	1.18	0.16	1075.17	0.09	-0.27	1.00	5.88	1
	<sup>13</sup> CO (8-7)	1.12	0.16	863.51	0.09	-0.16	0.95	3.65	2
NGC 1614	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=5/3-3/2)	-0.60	0.14	726.22	0.14	-0.99	-0.51	3.00	4
	HCO <sup>+</sup> (7-6)	-1.18	0.23	611.45	0.13	-0.29	-0.99	3.00	2
	HCN (6-5)	0.73	0.15	522.56	0.14	-0.82	0.61	3.39	4
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	1.33	0.18	1142.28	0.08	0.77	1.12	3.86	2
MCG -05-12-006	HCN (6-5)	-1.62	0.28	520.86	0.11	-1.07	-1.37	3.81	4
IRAS F05189-2524	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	0.31	0.06	1069.07	0.12	1.18	0.26	3.71	4
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.40	0.04	721.15	0.07	-0.18	0.33	4.71	2
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	0.76	0.06	1178.37	0.05	-0.25	0.64	8.00	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	0.46	0.06	1052.00	0.09	-0.56	0.39	5.57	1
MCG +08-11-002	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	0.88	0.06	1115.09	0.04	-0.35	0.75	7.50	1
	H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	0.62	0.06	1157.65	0.07	-0.69	0.52	7.43	1
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	-0.45	0.08	992.17	0.12	1.23	-0.38	3.45	4
	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	-1.56	0.24	1093.41	0.11	0.99	-1.32	4.71	4
	HF (1-0)	-2.23	0.25	1209.09	0.07	-0.22	-1.88	4.95	2
	HCO <sup>+</sup> (6-5)	1.50	0.36	526.69	0.13	-0.04	1.27	3.26	2

Table 5—Continued

Name (1)	Line (2)	F <sup>a</sup> (3)	$\sigma_F^b$ (4)	$\nu_{\text{obs}}^c$ (5)	$\sigma_\nu^d$ (6)	$\nu_{\text{diff}}^e$ (7)	$(f_\nu)_p^f$ (8)	(S/N) <sup>g</sup> (9)	Q <sup>h</sup> (10)
NGC 1961	OH <sup>+</sup> (1 <sub>22</sub> –0 <sub>11</sub> )	-1.22L	0.25	953.15	0.12	-0.39	-1.03	3.22	2
	<sup>13</sup> CO (7-6)	0.69	0.16	761.56	0.12	0.36	0.58	4.14	2
	HCN (17-16)	1.50	0.28	1486.03	0.11	0.49	1.26	3.82	2
UGC 03351	OH <sup>+</sup> (1 <sub>01</sub> –0 <sub>12</sub> )	-1.29	0.24	895.83	0.12	-0.01	-1.09	3.30	2
	OH <sup>+</sup> (1 <sub>22</sub> –0 <sub>11</sub> )	-1.46L	0.27	957.54	0.14	-0.04	-1.23	3.15	2
	OH <sup>+</sup> (1 <sub>12</sub> –0 <sub>12</sub> )	-2.07	0.27	1018.22	0.09	0.23	-1.74	3.95	2
IRAS 05442+1732	HF (1-0)	1.29	0.21	1209.50	0.13	-0.44	1.09	3.21	2
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	-1.14	0.24	1118.10	0.14	-0.63	-0.96	3.43	4
UGC 03410	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.80S	0.39	974.65	0.13	-0.52	1.52	4.11	4
	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	-1.10	0.22	1391.97	0.14	-0.44	-0.92	3.17	2
	OH <sup>+</sup> (1 <sub>22</sub> –0 <sub>11</sub> )	-1.75L	0.23	959.37	0.09	0.11	-1.47	3.68	2
NGC 2146NW	<sup>13</sup> CO (6-5)	1.06	0.25	659.02	0.15	-0.09	0.89	5.93	1
	OH <sup>+</sup> (1 <sub>22</sub> –0 <sub>11</sub> )	-1.73S	0.49	968.81	0.18	-0.11	-1.46	3.32	2
	OH <sup>+</sup> (1 <sub>12</sub> –0 <sub>12</sub> )	-2.13	0.34	1029.81	0.10	-0.24	-1.80	6.67	2
NGC 2146Nuc	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	-1.22	0.27	1111.42	0.15	1.38	-1.03	3.32	4
	<sup>13</sup> CO (5-4)	1.26	0.45	549.66	0.20	0.37	1.06	3.53	2
	CH <sup>+</sup> (1-0)	-0.66	0.21	832.62	0.19	0.02	-0.55	3.06	2
NGC 2146SE	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	-1.15	0.30	1136.29	0.16	0.11	-0.97	3.88	2
	OH <sup>+</sup> (1 <sub>22</sub> –0 <sub>11</sub> )	-3.56S	0.40	968.95	0.07	0.03	-3.01	9.41	2
	OH <sup>+</sup> (1 <sub>12</sub> –0 <sub>12</sub> )	-2.06	0.34	1030.00	0.10	-0.05	-1.74	8.29	2
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	0.84	0.23	1094.33	0.19	0.23	0.71	3.74	2
	HF (1-0)	-1.63	0.29	1228.60	0.10	-0.22	-1.38	4.76	2
	<sup>13</sup> CO (8-7)	1.07	0.27	879.18	0.16	0.53	0.90	3.10	4
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	-1.21	0.26	1136.49	0.13	0.31	-1.02	4.43	2
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=3/2-1/2)	-1.35	0.24	1111.45	0.11	-0.44	-1.14	5.70	2
	HCN (6-5)	1.22	0.42	530.97	0.23	0.83	1.03	3.68	4
	OH <sup>+</sup> (1 <sub>22</sub> –0 <sub>11</sub> )	-2.73S	0.44	968.67	0.10	-0.25	-2.30	5.75	2
UGC 03608	OH <sup>+</sup> (1 <sub>12</sub> –0 <sub>12</sub> )	-2.32	0.26	1029.83	0.07	-0.22	-1.96	8.17	2
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.05L	0.17	968.55	0.10	1.27	0.89	3.71	4
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.46	0.06	736.27	0.10	-0.04	0.39	3.55	2
	HCO <sup>+</sup> (7-6)	-1.16	0.16	609.82	0.08	-1.34	-0.98	3.77	4
	OH <sup>+</sup> (1 <sub>12</sub> –0 <sub>12</sub> )	-0.83	0.14	1015.24	0.11	-0.01	-0.70	3.18	2
NGC 2341	OH <sup>+</sup> (1 <sub>22</sub> –0 <sub>11</sub> )	-2.18S	0.35	961.66	0.11	0.24	-1.84	6.34	2
NGC 2369	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	2.02L	0.25	974.08	0.09	-0.41	1.70	4.72	2
NGC 2388	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	1.38	0.18	1213.75	0.10	1.67	1.17	4.03	4
	<sup>13</sup> CO (7-6)	-0.78	0.14	760.16	0.12	-0.53	-0.65	3.42	4
	HCN (15-14)	-1.12	0.22	1310.58	0.12	0.34	-0.94	4.48	2
MCG +02-20-003	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.10L	0.16	970.99	0.11	-1.13	0.93	5.17	3
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.46	0.09	739.22	0.11	-0.78	0.39	3.55	4
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=5/3-3/2)	0.44	0.08	731.33	0.11	1.16	0.37	4.11	4
NGC 2623	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	-0.45	0.09	1093.21	0.12	0.10	-0.38	3.80	2
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.32S	0.13	969.67	0.06	-0.30	1.11	7.93	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	1.04	0.04	738.38	0.03	0.01	0.88	12.57	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	1.34	0.09	1206.47	0.04	0.01	1.13	9.42	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	1.15	0.08	1077.31	0.04	-0.11	0.97	10.78	1

Table 5—Continued

Name (1)	Line (2)	F <sup>a</sup> (3)	$\sigma_F^b$ (4)	$\nu_{\text{obs}}^c$ (5)	$\sigma_\nu^d$ (6)	$\nu_{\text{diff}}^e$ (7)	$(f_\nu)_p^f$ (8)	(S/N) <sup>g</sup> (9)	Q <sup>h</sup> (10)
IRAS 09022-3615	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	2.11	0.08	1141.71	0.03	-0.07	1.78	7.74	1
	H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	0.51	0.08	1185.78	0.10	0.09	0.43	3.91	2
	HF (1-0)	-0.71	0.09	1209.90	0.07	-0.18	-0.60	5.45	2
	CH <sup>+</sup> (1-0)	-0.20	0.05	820.39	0.15	0.49	-0.17	3.40	2
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=3/2-1/2)	-0.50	0.08	1095.16	0.11	0.22	-0.43	3.91	2
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	0.30	0.05	732.89	0.10	0.26	0.25	3.57	2
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	0.63L	0.10	932.20	0.10	-0.13	0.53	4.42	2
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.38	0.05	709.57	0.10	-0.13	0.32	4.57	2
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	0.81	0.09	1035.10	0.08	-0.50	0.68	4.53	4
	HCN (17-16)	-0.55	0.08	1420.63	0.11	0.31	-0.46	3.29	2
UGC 05101	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	0.96L	0.11	950.50	0.08	-0.00	0.81	4.05	2
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.67	0.08	723.45	0.07	-0.10	0.57	6.33	1
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	0.90	0.12	1119.54	0.09	0.68	0.76	3.80	2
	HF (1-0)	-0.94	0.13	1185.62	0.09	-0.17	-0.79	4.16	2
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	-0.41	0.08	719.63	0.12	1.70	-0.34	3.40	4
NGC 3221	HCN (12-11)	-0.87	0.12	1022.29	0.10	-0.42	-0.73	3.84	2
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	-0.64L	0.12	935.17	0.12	0.17	-0.54	4.15	2
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	-0.76	0.16	993.84	0.13	-0.15	-0.64	3.20	2
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	0.78	0.17	736.75	0.11	0.64	0.65	3.10	2
	HCN (15-14)	1.41	0.20	1312.11	0.11	1.77	1.19	4.76	4
NGC 3256	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	2.13	0.20	1102.93	0.06	-0.09	1.80	12.86	1
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.77S	0.23	978.59	0.09	-0.19	1.49	6.48	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.63	0.14	745.13	0.11	0.06	0.53	6.62	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	1.54	0.19	1217.57	0.08	0.17	1.30	10.83	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	1.09	0.17	1087.27	0.10	0.08	0.92	6.57	1
ESO 264-G036	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	1.45	0.17	1152.09	0.07	-0.05	1.23	5.86	1
	HF (1-0)	1.53	0.18	1220.78	0.08	-0.28	1.29	11.73	1
	<sup>13</sup> CO (6-5)	0.55	0.15	654.67	0.17	-0.27	0.46	3.83	2
	CH <sup>+</sup> (1-0)	1.62	0.11	827.22	0.05	-0.12	1.37	11.42	1
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	0.68	0.16	1129.18	0.15	0.18	0.58	3.22	2
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=3/2-1/2)	1.29	0.17	1104.73	0.10	-0.14	1.09	7.27	1
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	-0.40	0.13	738.36	0.18	-0.92	-0.34	3.40	4
	HCN (17-16)	-2.06	0.21	1491.83	0.06	0.74	-1.74	3.16	2
	HCO <sup>+</sup> (6-5)	1.14	0.28	531.83	0.14	-0.03	0.96	5.33	1
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	-0.88S	0.28	963.88	0.20	1.08	-0.74	3.52	4
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	-0.84	0.14	1118.06	0.12	1.95	-0.71	3.94	4
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	0.64	0.10	731.45	0.09	0.61	0.54	3.38	2
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	0.48	0.09	734.75	0.11	1.17	0.41	3.73	4
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.53	0.07	721.02	0.09	0.06	0.45	4.50	2
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	0.74	0.11	1177.90	0.10	-0.12	0.63	3.32	2
IRAS F10565+2448	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	-0.64	0.11	1053.53	0.11	1.50	-0.54	3.38	4
	CH <sup>+</sup> (1-0)	0.44	0.07	800.37	0.11	-0.20	0.37	4.63	2
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	-1.04	0.15	991.66	0.09	1.23	-0.88	4.40	4
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.42S	0.19	977.84	0.08	-0.00	1.20	5.71	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.53	0.08	744.26	0.10	-0.09	0.44	4.89	1

Table 5—Continued

Name (1)	Line (2)	F <sup>a</sup> (3)	$\sigma_F^b$ (4)	$\nu_{\text{obs}}^c$ (5)	$\sigma_\nu^d$ (6)	$\nu_{\text{diff}}^e$ (7)	$(f\nu)_p^f$ (8)	(S/N) <sup>g</sup> (9)	Q <sup>h</sup> (10)
NGC 3690	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	0.90	0.12	1216.49	0.08	0.25	0.76	6.33	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	1.20	0.12	1085.95	0.06	-0.20	1.01	7.21	1
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	1.07	0.13	1150.94	0.07	-0.10	0.90	4.09	2
	H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	0.98	0.12	1195.44	0.08	0.13	0.82	5.86	1
	<sup>13</sup> CO (7-6)	0.47	0.08	762.97	0.10	-0.33	0.40	4.44	2
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=3/2-1/2)	0.58	0.10	1104.07	0.13	0.25	0.49	3.50	2
	HCN (14-13)	0.57	0.13	1227.16	0.14	-0.07	0.48	4.00	2
	HCN (17-16)	-1.00	0.13	1490.93	0.08	1.27	-0.84	4.00	4
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.60S	0.20	977.59	0.08	-0.24	1.35	5.63	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.74	0.10	744.19	0.07	-0.16	0.62	7.75	1
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	1.12	0.13	1151.33	0.07	0.30	0.95	5.28	1
	HF (1-0)	0.78	0.13	1219.01	0.10	-0.88	0.66	4.40	2
UGC 06472	<sup>13</sup> CO (8-7)	0.57	0.11	871.43	0.11	-0.84	0.48	3.43	4
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	0.42	0.10	737.58	0.12	-1.00	0.36	4.00	4
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=5/3-3/2)	0.48	0.08	734.11	0.10	-0.35	0.41	4.10	2
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	2.55S	0.25	977.81	0.06	-0.03	2.15	7.41	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	1.89	0.08	744.27	0.03	-0.08	1.59	14.45	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	2.11	0.19	1216.02	0.06	-0.22	1.78	8.09	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	2.53	0.18	1086.09	0.04	-0.07	2.14	9.30	1
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	4.48	0.20	1151.05	0.03	0.01	3.78	7.00	1
	H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	1.79	0.19	1195.23	0.07	-0.07	1.51	7.95	1
	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	1.05	0.19	1395.87	0.11	-0.34	0.88	3.83	2
	<sup>13</sup> CO (6-5)	0.59	0.12	654.37	0.13	0.06	0.50	3.13	2
	<sup>13</sup> CO (7-6)	0.57	0.09	762.99	0.10	-0.32	0.48	3.69	2
ESO 320-G030	<sup>13</sup> CO (8-7)	0.68	0.12	871.49	0.11	-0.78	0.57	3.56	4
	CH <sup>+</sup> (1-0)	0.35	0.09	827.08	0.16	0.53	0.30	3.00	4
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=5/3-3/2)	0.51	0.10	734.40	0.11	-0.06	0.43	3.58	2
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	3.08S	0.20	977.84	0.04	0.45	2.60	7.43	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	2.06	0.10	744.51	0.03	0.50	1.74	19.33	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	2.36	0.14	1216.23	0.04	0.54	1.99	9.48	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	2.28	0.12	1086.09	0.04	0.43	1.92	9.14	1
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	4.03	0.14	1151.11	0.02	0.61	3.40	12.14	1
	H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	2.31	0.13	1195.42	0.04	0.66	1.95	10.83	1
	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	1.22	0.14	1396.34	0.07	0.77	1.03	6.87	1
	<sup>13</sup> CO (7-6)	0.38	0.08	764.32	0.13	1.36	0.32	3.56	4
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	0.61	0.10	738.21	0.09	-0.03	0.52	5.20	1
NGC 4194	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=5/3-3/2)	0.75	0.09	734.49	0.07	0.37	0.63	5.73	1
	HCN (14-13)	-0.59	0.15	1227.75	0.16	1.08	-0.50	3.13	2
	HCN (16-15)	-0.82	0.15	1402.44	0.10	0.86	-0.69	4.06	2
	HCN (17-16)	-0.70	0.16	1490.17	0.14	1.19	-0.59	5.36	2
	HCO <sup>+</sup> (6-5)	0.79	0.18	531.16	0.15	0.06	0.67	3.35	2
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	-1.66L	0.25	978.45	0.11	-1.30	-1.40	4.52	4
	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	-1.48	0.21	1398.22	0.10	-0.73	-1.25	3.68	2
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	-1.95L	0.25	964.27	0.08	0.51	-1.65	5.89	2
	HCN (16-15)	0.63	0.10	1380.22	0.11	0.92	0.53	3.79	4
IRAS 12116-5615	HCN (16-15)	0.63	0.10	1380.22	0.11	0.92	0.53	3.79	4

Table 5—Continued

Name (1)	Line (2)	F <sup>a</sup> (3)	$\sigma_F^b$ (4)	$\nu_{\text{obs}}^c$ (5)	$\sigma_\nu^d$ (6)	$\nu_{\text{diff}}^e$ (7)	$(f\nu)_p^f$ (8)	(S/N) <sup>g</sup> (9)	Q <sup>h</sup> (10)
NGC 4418	HCN (17-16)	-0.75	0.10	1465.26	0.09	-0.06	-0.63	3.32	2
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	2.36S	0.31	980.88	0.08	0.08	1.99	5.53	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	1.29	0.16	746.77	0.08	0.16	1.09	4.95	1
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	3.45	0.25	1154.95	0.04	0.43	2.91	6.61	1
	H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	2.77	0.25	1199.37	0.05	0.45	2.34	6.50	1
	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	1.55	0.29	1400.72	0.09	0.28	1.31	7.28	1
UGC 08058 (= Mrk 231)	HCN (16-15)	-1.17	0.28	1407.32	0.13	0.86	-0.99	5.50	2
	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	0.57	0.08	1067.51	0.09	-0.78	0.48	6.00	3
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.77L	0.07	947.91	0.03	-0.04	1.49	9.93	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.79	0.05	721.66	0.04	0.06	0.67	11.17	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	1.42	0.08	1179.05	0.04	-0.02	1.20	10.00	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	1.37	0.08	1053.23	0.04	0.27	1.16	12.89	1
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	2.15	0.07	1115.88	0.02	0.03	1.82	12.13	1
	H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	1.02	0.08	1158.94	0.05	0.16	0.86	6.62	1
	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	0.77	0.08	1353.62	0.06	0.08	0.65	6.50	1
	HF (1-0)	0.77	0.08	1182.33	0.07	-0.28	0.65	5.91	1
	<sup>13</sup> CO (5-4)	-0.48	0.11	530.06	0.15	1.43	-0.40	3.08	4
	CH <sup>+</sup> (1-0)	0.48	0.05	801.11	0.06	-0.18	0.40	5.71	1
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	0.76	0.08	1093.51	0.06	0.06	0.64	3.76	2
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=3/2-1/2)	-0.61	0.08	1071.37	0.09	1.29	-0.52	6.50	4
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	0.26	0.05	715.80	0.13	-0.20	0.22	3.67	2
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=5/3-3/2)	0.32	0.05	711.96	0.10	-0.05	0.27	4.50	2
	OH <sup>+</sup> (1 <sub>01</sub> -0 <sub>12</sub> )	0.59	0.06	872.02	0.07	-0.35	0.50	3.57	2
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	1.22L	0.08	931.93	0.04	-0.56	1.03	6.87	1
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	1.20	0.11	990.86	0.05	-0.46	1.01	6.31	1
ESO 507-G070	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.11L	0.18	967.81	0.11	0.86	0.93	4.23	2
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	0.70	0.12	1073.72	0.12	-0.33	0.59	3.93	2
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	1.12	0.12	1137.85	0.08	-0.36	0.94	3.62	2
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	-1.39	0.15	1115.44	0.06	0.09	-1.17	6.16	2
	HCN (6-5)	1.08	0.19	520.33	0.13	-0.09	0.92	3.54	2
	HCO <sup>+</sup> (6-5)	-1.11	0.25	526.61	0.13	1.19	-0.94	3.36	4
NGC 5010	<sup>13</sup> CO (7-6)	-0.75	0.10	763.23	0.11	-0.38	-0.63	3.15	2
IRAS 13120-5453	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	1.04	0.14	1079.53	0.08	-0.59	0.88	4.19	2
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	2.85L	0.16	958.09	0.04	-0.35	2.40	9.60	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	1.89	0.10	729.27	0.03	-0.32	1.60	20.00	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	3.16	0.16	1191.84	0.03	-0.27	2.66	12.09	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	1.87	0.14	1064.32	0.05	-0.30	1.58	10.53	1
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	3.54	0.16	1127.82	0.03	-0.38	2.98	7.84	1
	H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	0.71	0.15	1171.12	0.14	-0.48	0.60	3.16	2
	HF (1-0)	1.38	0.17	1195.10	0.08	-0.60	1.17	5.32	1
	<sup>13</sup> CO (5-4)	0.81	0.22	535.49	0.17	1.01	0.69	3.29	4
	CH <sup>+</sup> (1-0)	0.74	0.09	809.71	0.07	-0.45	0.63	4.50	2
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	0.32	0.09	723.74	0.20	-0.19	0.27	3.00	2
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=5/3-3/2)	0.62	0.10	719.76	0.10	-0.13	0.52	5.78	1
	HCN (17-16)	-0.94	0.18	1459.09	0.14	-1.02	-0.79	3.76	2



Table 5—Continued

Name (1)	Line (2)	F <sup>a</sup> (3)	$\sigma_F^b$ (4)	$\nu_{\text{obs}}^c$ (5)	$\sigma_\nu^d$ (6)	$\nu_{\text{diff}}^e$ (7)	$(f_\nu)_p^f$ (8)	(S/N) <sup>g</sup> (9)	Q <sup>h</sup> (10)
UGC 08387	HCO <sup>+</sup> (6-5)	1.28	0.23	520.29	0.12	-0.52	1.08	4.70	4
	OH <sup>+</sup> (1 <sub>01</sub> -0 <sub>12</sub> )	1.08	0.12	881.01	0.08	-1.01	0.91	4.33	4
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	1.93L	0.12	941.86	0.05	-0.94	1.63	6.27	3
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	1.60	0.19	1001.36	0.07	-0.92	1.35	4.35	2
	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	-0.30	0.07	1087.12	0.14	-0.88	-0.25	3.13	4
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	0.68S	0.11	965.69	0.10	0.25	0.58	3.22	2
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.24	0.04	735.07	0.12	0.16	0.20	3.33	2
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	0.68	0.07	1200.90	0.06	0.09	0.57	5.18	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	0.36	0.07	1073.18	0.11	0.80	0.30	4.29	2
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	0.65	0.07	1136.89	0.07	0.46	0.55	5.50	1
NGC 5104	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	0.37	0.07	1378.55	0.12	0.05	0.31	3.88	2
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	0.35L	0.07	949.11	0.14	-0.56	0.30	3.00	4
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.54	0.08	738.50	0.11	0.21	0.46	5.75	1
MCG -03-34-064	CH <sup>+</sup> (1-0)	-0.48	0.09	820.58	0.11	0.76	-0.41	3.73	4
	<sup>13</sup> CO (6-5)	-0.64	0.12	650.80	0.11	0.49	-0.54	4.91	4
NGC 5135	<sup>13</sup> CO (7-6)	0.49	0.08	758.35	0.11	-0.29	0.41	3.42	2
	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	0.87	0.08	1098.51	0.07	0.21	0.73	6.08	1
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	0.98S	0.11	974.50	0.07	-0.08	0.83	4.37	2
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.52	0.05	741.96	0.06	0.08	0.44	5.50	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	0.89	0.09	1212.27	0.06	0.08	0.75	6.82	1
	HF (1-0)	1.08	0.10	1216.13	0.05	0.30	0.91	8.27	1
	CH <sup>+</sup> (1-0)	0.48	0.05	824.07	0.06	0.27	0.41	6.83	1
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	0.85	0.08	1124.38	0.06	0.21	0.72	6.55	1
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=3/2-1/2)	0.94	0.08	1100.25	0.07	0.11	0.80	6.67	1
	OH <sup>+</sup> (1 <sub>01</sub> -0 <sub>12</sub> )	0.47	0.07	897.04	0.10	0.16	0.40	3.64	2
ESO 173-G015	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	1.79L	0.09	958.67	0.03	-0.01	1.51	9.44	1
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	1.46	0.09	1019.26	0.04	0.09	1.23	12.30	1
	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	0.99	0.20	1102.44	0.14	-0.17	0.83	3.61	2
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	4.34S	0.33	978.10	0.05	-0.30	3.66	7.63	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	2.92	0.17	744.63	0.03	-0.16	2.46	10.70	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	5.30	0.28	1216.44	0.03	-0.50	4.47	12.42	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	3.75	0.25	1086.27	0.04	-0.52	3.16	15.05	1
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	6.65	0.31	1151.36	0.03	-0.34	5.61	8.63	1
	H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	2.98	0.26	1195.65	0.05	-0.35	2.51	10.04	1
	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	1.61	0.24	1396.39	0.09	-0.63	1.35	4.35	2
IC 4280	HCN (17-16)	-1.61	0.34	1491.50	0.12	0.98	-1.36	3.16	4
	HCO <sup>+</sup> (6-5)	1.96	0.34	531.13	0.12	-0.53	1.65	4.71	2
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	-2.06S	0.41	961.96	0.13	-0.47	-1.74	3.16	2
	H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	-0.70	0.13	1187.25	0.13	-1.01	-0.59	3.28	4
	<sup>13</sup> CO (7-6)	0.60	0.09	759.79	0.09	0.98	0.50	3.57	4
	HCN (14-13)	-0.90	0.17	1220.97	0.12	0.97	-0.76	4.00	4
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	0.95L	0.08	951.66	0.06	-0.30	0.80	6.15	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.80	0.05	724.81	0.04	0.16	0.67	13.40	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	0.61	0.09	1184.50	0.10	0.45	0.52	5.20	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	0.90	0.08	1057.66	0.06	0.24	0.76	6.33	1

Table 5—Continued

Name (1)	Line (2)	F <sup>a</sup> (3)	$\sigma_F^b$ (4)	$\nu_{\text{obs}}^c$ (5)	$\sigma_\nu^d$ (6)	$\nu_{\text{diff}}^e$ (7)	$(f\nu)_p^f$ (8)	(S/N) <sup>g</sup> (9)	Q <sup>h</sup> (10)
UGC 08739	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	1.34	0.09	1120.55	0.04	-0.03	1.13	5.14	1
	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	0.53	0.09	1359.36	0.11	0.10	0.45	3.46	2
	HF (1-0)	-0.38	0.09	1187.79	0.15	0.18	-0.32	3.20	2
	<sup>13</sup> CO (6-5)	0.32	0.07	636.98	0.14	-0.03	0.27	3.38	2
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	0.23	0.06	718.65	0.14	-0.38	0.19	3.80	4
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=5/3-3/2)	0.22	0.05	715.56	0.15	0.54	0.19	3.80	2
	OH <sup>+</sup> (1 <sub>01</sub> -0 <sub>12</sub> )	0.44	0.07	874.95	0.10	-1.11	0.37	3.08	4
	HF (1-0)	-1.61	0.16	1212.01	0.07	-0.12	-1.36	5.44	2
	<sup>13</sup> CO (7-6)	0.56	0.09	758.33	0.11	-0.12	0.47	3.62	2
	CH <sup>+</sup> (1-0)	-0.51	0.08	821.32	0.11	0.03	-0.43	3.31	2
ESO 221-IG 010	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	-0.96L	0.18	955.60	0.11	-0.16	-0.81	3.24	2
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	-0.96	0.18	1016.09	0.11	0.03	-0.81	3.68	2
	H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	1.12	0.23	1196.21	0.13	0.92	0.94	3.48	4
	OH <sup>+</sup> (1 <sub>01</sub> -0 <sub>12</sub> )	-1.15	0.19	899.84	0.12	-0.02	-0.97	5.39	2
NGC 5734	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	1.57S	0.35	962.63	0.13	0.76	1.32	3.14	4
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	-1.56L	0.30	974.62	0.12	0.09	-1.32	3.30	2
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	-1.10	0.21	1211.78	0.12	-0.35	-0.93	3.88	2
VV 340a	HCN (6-5)	1.75	0.31	523.47	0.13	-1.04	1.47	3.34	4
	CH <sup>+</sup> (1-0)	-0.36	0.07	808.00	0.13	0.12	-0.30	4.29	4
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	-0.58	0.11	1102.05	0.13	-0.39	-0.49	3.27	2
	OH <sup>+</sup> (1 <sub>01</sub> -0 <sub>12</sub> )	-0.55	0.10	879.53	0.11	-0.02	-0.47	3.36	2
CGCG 049-057	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	-0.84L	0.10	940.18	0.08	0.03	-0.71	5.07	2
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	-1.28	0.15	999.12	0.08	-0.34	-1.08	5.14	2
	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	-0.60	0.10	1099.44	0.11	0.38	-0.50	4.17	2
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	2.66S	0.14	975.10	0.04	-0.15	2.25	9.38	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	1.49	0.07	742.47	0.02	0.08	1.25	17.86	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	1.35	0.11	1213.07	0.05	0.05	1.14	12.67	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	1.55	0.10	1083.21	0.04	-0.08	1.31	8.73	1
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	3.39	0.11	1148.09	0.02	0.10	2.86	10.21	1
	H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	1.71	0.11	1192.34	0.04	0.20	1.45	7.63	1
	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	0.82	0.12	1392.56	0.08	0.05	0.69	5.31	1
	HF (1-0)	-0.98	0.12	1216.91	0.09	0.24	-0.82	9.11	2
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	0.59	0.07	736.51	0.07	-0.10	0.50	10.00	1
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=5/3-3/2)	0.32	0.06	732.65	0.12	0.14	0.27	4.50	2
ESO 099-G004	HCN (14-13)	-0.57	0.13	1224.25	0.13	0.27	-0.48	5.33	2
	HCN (15-14)	-0.51	0.10	1311.80	0.13	0.54	-0.43	3.91	2
	HCN (16-15)	-0.59	0.12	1398.72	0.11	0.21	-0.50	3.85	2
	HCN (17-16)	-0.55	0.12	1485.82	0.15	0.11	-0.46	3.07	2
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	-0.56	0.12	1020.35	0.13	0.49	-0.47	5.22	2
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	0.63	0.11	1129.59	0.11	-0.23	0.53	3.12	2
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=3/2-1/2)	-0.53	0.10	1083.84	0.12	0.37	-0.45	3.46	2
	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	-10.99	0.43	1093.70	0.03	0.18	-9.27	30.90	2
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	8.54S	0.59	970.39	0.04	0.05	7.20	9.11	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	6.83	0.20	738.71	0.02	0.07	5.76	19.20	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	6.36	0.49	1207.03	0.05	0.12	5.36	6.46	1
UGC 09913 (= Arp 220)	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	-10.99	0.43	1093.70	0.03	0.18	-9.27	30.90	2
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	8.54S	0.59	970.39	0.04	0.05	7.20	9.11	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	6.83	0.20	738.71	0.02	0.07	5.76	19.20	1

Table 5—Continued

Name (1)	Line (2)	F <sup>a</sup> (3)	$\sigma_F^b$ (4)	$\nu_{\text{obs}}^c$ (5)	$\sigma_\nu^d$ (6)	$\nu_{\text{diff}}^e$ (7)	$(f_\nu)_p^f$ (8)	(S/N) <sup>g</sup> (9)	Q <sup>h</sup> (10)
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	7.57	0.39	1077.87	0.03	0.04	6.38	10.13	1
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	14.29	0.46	1142.28	0.02	0.08	12.05	9.06	1
	H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	6.07	0.45	1186.48	0.05	0.34	5.12	8.13	1
	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	2.14	0.49	1386.09	0.13	0.59	1.80	7.83	1
	HF (1-0)	-10.45	0.45	1210.63	0.03	0.10	-8.81	10.49	2
	CH <sup>+</sup> (1-0)	-4.21	0.20	820.38	0.03	0.16	-3.55	29.58	2
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	-7.70	0.44	1119.35	0.04	0.08	-6.50	6.70	2
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=3/2-1/2)	-11.43	0.46	1095.35	0.03	-0.00	-9.64	34.43	2
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	1.73	0.19	732.88	0.07	-0.03	1.46	6.64	1
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=5/3-3/2)	2.27	0.23	728.98	0.06	0.16	1.92	8.73	1
	HCN (6-5)	1.48	0.49	523.07	0.22	0.82	1.25	7.35	3
	HCN (12-11)	-1.61	0.44	1044.38	0.18	0.32	-1.36	5.67	2
	HCN (15-14)	-3.30	0.46	1305.02	0.09	0.37	-2.78	11.12	2
	HCN (16-15)	-3.21	0.48	1391.73	0.09	0.27	-2.71	11.78	2
	HCN (17-16)	-3.38	0.51	1478.81	0.10	0.57	-2.85	4.13	2
	HCO <sup>+</sup> (6-5)	1.22	0.50	527.21	0.25	-0.06	1.03	5.15	1
	OH <sup>+</sup> (1 <sub>01</sub> -0 <sub>12</sub> )	-4.78	0.25	893.09	0.04	0.12	-4.03	5.30	2
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	-8.36L	0.32	954.58	0.03	0.07	-7.05	7.34	2
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	-11.02	0.49	1014.75	0.03	0.03	-9.30	14.09	2
NGC 6052	HCN (6-5)	-1.35	0.24	524.67	0.11	1.23	-1.14	3.93	4
NGC 6156	HCN (6-5)	1.88	0.33	526.76	0.09	0.77	1.59	4.18	4
	HCO <sup>+</sup> (7-6)	1.22	0.24	617.90	0.11	0.42	1.03	3.12	4
2MASX J16381190	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.27	0.05	719.76	0.12	1.10	0.23	3.83	4
-6826080	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	0.47	0.10	1050.75	0.13	2.09	0.40	4.00	4
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	-0.64	0.12	986.91	0.13	-0.36	-0.54	3.60	2
IRAS F16399-0937	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	0.85S	0.16	962.60	0.11	0.65	0.72	3.00	4
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.50	0.07	732.10	0.10	-0.15	0.42	4.67	2
	HF (1-0)	-0.75	0.11	1200.67	0.09	0.61	-0.63	4.20	4
NGC 6240	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	0.59	0.07	1086.69	0.08	-0.05	0.49	4.08	2
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.45S	0.11	964.68	0.05	0.36	1.23	7.24	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	1.15	0.06	734.29	0.03	0.22	0.97	9.70	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	1.00	0.08	1199.79	0.06	0.36	0.84	7.00	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	1.21	0.08	1071.43	0.04	0.29	1.02	8.50	1
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	1.36	0.09	1135.35	0.04	0.23	1.14	9.50	1
	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	0.53	0.08	1376.17	0.09	-0.74	0.45	5.00	2
	HF (1-0)	-0.51	0.08	1202.79	0.11	-0.23	-0.43	3.58	2
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	0.54L	0.10	947.57	0.12	-1.01	0.45	4.09	4
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	0.65	0.10	1007.26	0.09	-1.17	0.55	4.58	4
IRAS F16516-0948	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	0.49	0.10	1087.98	0.13	-0.83	0.42	3.23	2
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	0.53	0.11	1136.07	0.14	-1.22	0.45	3.46	2
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=5/3-3/2)	0.36	0.07	726.91	0.13	1.23	0.31	3.44	4
	HCO <sup>+</sup> (6-5)	0.95	0.16	525.28	0.11	0.29	0.80	4.44	4
NGC 6286	HF (1-0)	-1.82	0.18	1209.63	0.06	-0.64	-1.54	4.53	2
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	-1.55	0.23	1118.25	0.10	-0.77	-1.31	5.24	2
IRAS F17138-1017	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	-1.53L	0.23	955.15	0.09	-0.10	-1.29	3.39	2

Table 5—Continued

Name (1)	Line (2)	F <sup>a</sup> (3)	$\sigma_F^b$ (4)	$\nu_{\text{obs}}^c$ (5)	$\sigma_\nu^d$ (6)	$\nu_{\text{diff}}^e$ (7)	$(f_\nu)_p^f$ (8)	(S/N) <sup>g</sup> (9)	Q <sup>h</sup> (10)
IRAS F17207-0014	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	-0.98	0.14	1069.49	0.09	1.85	-0.82	3.28	4
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	2.00L	0.14	947.69	0.05	0.32	1.69	6.50	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	1.43	0.10	721.30	0.04	0.14	1.20	10.91	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	1.50	0.15	1178.75	0.07	0.41	1.27	5.08	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	2.27	0.15	1052.65	0.04	0.34	1.91	7.35	1
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	3.63	0.14	1115.48	0.03	0.30	3.06	5.88	1
	H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	2.00	0.15	1158.08	0.05	0.02	1.68	6.72	1
	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	1.11	0.15	1352.57	0.09	-0.14	0.94	4.27	2
	HF (1-0)	-1.47	0.15	1181.80	0.07	-0.08	-1.24	5.39	2
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	0.52	0.09	715.79	0.12	0.23	0.44	5.50	1
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=5/3-3/2)	0.58	0.09	711.88	0.10	0.31	0.49	6.13	1
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	-1.11L	0.14	932.10	0.08	0.19	-0.93	3.72	2
IRAS 17578-0400	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	-1.30	0.21	991.02	0.10	0.31	-1.10	4.40	2
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	1.27	0.12	742.16	0.06	0.54	1.07	4.46	2
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	1.49	0.22	1212.37	0.10	0.59	1.26	3.50	2
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	2.88	0.28	1147.55	0.06	0.74	2.43	5.93	1
	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	2.18	0.18	1392.03	0.06	0.94	1.84	4.97	2
NGC 6621	HF (1-0)	-1.39	0.28	1216.25	0.12	0.84	-1.18	3.47	2
	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	0.79	0.13	1089.93	0.11	-0.89	0.67	3.94	4
IRAS F18293-3413	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	0.61	0.14	1093.22	0.16	-0.25	0.52	3.47	2
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.22S	0.21	969.96	0.11	-0.33	1.03	3.43	2
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.48	0.07	738.74	0.11	0.13	0.41	5.13	1
	<sup>13</sup> CO (7-6)	0.40	0.07	757.68	0.13	0.26	0.34	4.86	2
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	1.05L	0.14	953.23	0.08	-1.23	0.89	3.87	4
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	-1.67	0.17	1014.96	0.06	0.29	-1.41	8.29	2
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.55L	0.29	972.69	0.14	-0.05	1.31	3.05	2
IC 4734	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	1.14	0.13	740.62	0.08	0.14	0.96	4.57	2
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	1.77	0.28	1210.13	0.09	0.23	1.49	4.97	1
	HF (1-0)	1.36	0.22	1216.14	0.10	-0.25	1.15	3.48	2
NGC 6701	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=3/2-1/2)	1.31	0.22	1101.72	0.11	1.07	1.11	3.47	4
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	0.63	0.11	736.46	0.13	0.01	0.54	4.15	2
ESO 339-G011	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	0.82	0.17	1385.39	0.14	1.35	0.69	3.29	4
	HCN (12-11)	0.79	0.15	1043.59	0.15	0.63	0.66	3.00	2
NGC 6926	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	-1.07	0.14	1077.19	0.09	0.93	-0.90	4.29	4
CGCG 448-020	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	0.79	0.15	1121.91	0.12	-0.49	0.66	3.67	2
	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	0.73	0.13	1361.61	0.12	0.14	0.62	3.10	2
ESO 286-IG 019	<sup>13</sup> CO (7-6)	0.50	0.08	744.46	0.11	0.15	0.42	3.00	2
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	1.11	0.10	1178.41	0.06	0.28	0.93	5.81	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	1.02	0.10	1052.37	0.07	0.24	0.86	6.62	1
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	1.18	0.10	1115.15	0.06	0.17	0.99	5.21	1
	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	0.60	0.11	1352.71	0.12	0.24	0.51	3.19	2
	CH <sup>+</sup> (1-0)	0.43	0.06	800.11	0.10	-0.54	0.36	4.50	4
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=5/3-3/2)	0.39	0.07	710.74	0.11	-0.71	0.33	3.30	4
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	0.51L	0.10	931.50	0.13	-0.24	0.43	3.07	2
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	0.85	0.12	989.81	0.10	-0.72	0.72	3.79	4

Table 5—Continued

Name (1)	Line (2)	F <sup>a</sup> (3)	$\sigma_F^b$ (4)	$\nu_{\text{obs}}^c$ (5)	$\sigma_\nu^d$ (6)	$\nu_{\text{diff}}^e$ (7)	$(f_\nu)_p^f$ (8)	(S/N) <sup>g</sup> (9)	Q <sup>h</sup> (10)
ESO 286-G035	HCO <sup>+</sup> (7-6)	-0.72	0.18	612.83	0.15	-0.72	-0.60	3.75	4
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	0.86L	0.17	954.46	0.13	-0.76	0.73	3.84	4
NGC 7130	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.84S	0.17	972.23	0.06	0.00	1.55	6.74	1
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.69	0.06	739.66	0.06	-0.42	0.58	5.80	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	1.01	0.13	1209.43	0.08	0.18	0.86	6.62	1
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	0.75	0.11	1079.50	0.10	-0.43	0.64	3.56	2
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	0.95	0.14	1144.26	0.08	-0.17	0.80	5.00	1
	HF (1-0)	0.75	0.13	1213.12	0.11	0.23	0.63	5.73	1
	OH <sup>+</sup> (1 <sub>01</sub> -0 <sub>12</sub> )	0.52	0.11	894.60	0.14	-0.11	0.44	3.14	2
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	0.79L	0.12	956.00	0.09	-0.36	0.67	3.94	2
IC 5179	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	1.19	0.16	1016.37	0.08	-0.33	1.00	7.69	1
	<sup>13</sup> CO (7-6)	-0.80	0.14	764.13	0.11	1.65	-0.67	3.35	4
	HCN (15-14)	1.36	0.24	1313.80	0.10	0.49	1.15	4.11	2
	HCN (16-15)	-1.34	0.19	1400.74	0.10	0.05	-1.13	4.19	2
UGC 12150	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.56S	0.28	966.50	0.11	-0.74	1.31	3.85	4
	HCN (15-14)	-1.13	0.15	1301.54	0.09	1.06	-0.95	3.28	4
NGC 7469	H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	1.23	0.09	1095.63	0.06	0.17	1.04	10.40	1
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	0.57S	0.12	971.83	0.14	-0.23	0.48	3.69	2
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.53	0.05	739.84	0.06	-0.12	0.44	7.33	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	0.51	0.10	1209.18	0.12	0.12	0.43	4.30	2
	H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	0.41	0.09	1079.58	0.13	-0.16	0.34	3.78	2
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	0.73	0.09	1144.28	0.07	0.04	0.61	6.10	1
	HF (1-0)	0.76	0.12	1212.68	0.08	-0.00	0.64	6.40	1
	<sup>13</sup> CO (6-5)	-0.41	0.06	649.21	0.10	-1.25	-0.34	4.25	4
	<sup>13</sup> CO (7-6)	-0.35	0.05	759.05	0.09	0.25	-0.30	3.33	2
	CH <sup>+</sup> (1-0)	0.67	0.05	821.79	0.05	0.12	0.57	9.50	1
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	0.58	0.09	1121.29	0.09	0.03	0.49	4.90	2
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=3/2-1/2)	1.19	0.09	1097.45	0.06	0.15	1.00	11.11	1
	HCN (14-13)	-0.49	0.12	1219.72	0.13	-0.26	-0.42	3.23	2
	HCN (15-14)	0.44	0.09	1305.89	0.12	-1.09	0.37	3.36	4
	OH <sup>+</sup> (1 <sub>01</sub> -0 <sub>12</sub> )	0.80	0.08	894.47	0.06	-0.09	0.67	5.58	1
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	1.46L	0.09	956.14	0.04	-0.06	1.23	8.79	1
	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	1.41	0.10	1016.48	0.04	-0.05	1.19	14.88	1
ESO 148-IG 002	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.23	0.05	719.81	0.13	-0.11	0.19	3.80	2
	H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	0.49	0.09	1351.47	0.12	1.08	0.42	4.20	4
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	-0.48	0.09	1092.15	0.12	1.25	-0.41	3.73	4
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	0.31	0.05	714.98	0.10	0.65	0.27	4.50	4
	HCO <sup>+</sup> (6-5)	1.10	0.23	522.21	0.13	-0.29	0.92	4.84	2
IC 5298	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	1.79L	0.23	982.56	0.08	-0.10	1.51	4.31	2
NGC 7552	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	1.07	0.12	747.79	0.06	-0.23	0.90	5.29	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	1.19	0.22	1222.50	0.10	0.26	1.01	4.39	2
	HF (1-0)	1.03	0.23	1225.97	0.15	0.06	0.87	3.78	2
	<sup>13</sup> CO (6-5)	0.80	0.16	658.14	0.12	0.60	0.68	2.96	4
	HCN (16-15)	1.15	0.18	1408.83	0.09	-0.30	0.97	3.13	2
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	1.72L	0.27	966.37	0.09	-0.25	1.45	4.39	2

Table 5—Continued

Name (1)	Line (2)	F <sup>a</sup> (3)	$\sigma_F^b$ (4)	$\nu_{\text{obs}}^c$ (5)	$\sigma_\nu^d$ (6)	$\nu_{\text{diff}}^e$ (7)	$(f_\nu)_p^f$ (8)	(S/N) <sup>g</sup> (9)	Q <sup>h</sup> (10)
NGC 7674	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.45	0.07	731.36	0.10	0.47	0.38	3.80	2
	<sup>13</sup> CO (8-7)	0.43	0.09	857.98	0.13	1.48	0.37	3.36	4
NGC 7679	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.50	0.09	739.09	0.12	-0.28	0.42	3.50	2
	H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	-1.03	0.15	1186.28	0.09	-1.01	-0.86	4.53	4
NGC 7771	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	0.56S	0.13	973.79	0.15	-0.24	0.47	3.13	2
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.44	0.07	741.60	0.09	0.15	0.37	4.63	2
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	0.56	0.10	1145.91	0.11	-0.65	0.47	4.27	2
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	0.28	0.07	734.36	0.16	-1.33	0.23	3.83	4
Mrk 331	OH <sup>+</sup> (1 <sub>12</sub> -0 <sub>12</sub> )	-0.45	0.11	1017.65	0.15	-0.93	-0.38	3.17	4
	H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> )	0.60S	0.11	970.73	0.12	0.73	0.51	4.64	2
	H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	0.34	0.04	738.84	0.08	0.45	0.29	5.80	1
	H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	0.57	0.08	1207.14	0.09	0.65	0.48	3.20	2
	H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	0.59	0.08	1142.41	0.09	0.60	0.50	7.14	1
	<sup>13</sup> CO (7-6)	0.17	0.04	756.29	0.16	-0.90	0.14	3.50	4
	CH <sup>+</sup> (1-0)	0.38	0.04	820.18	0.07	0.25	0.32	6.40	1
	H <sub>2</sub> O <sup>+</sup> (1 <sub>11</sub> -0 <sub>00</sub> J=1/2-1/2)	0.56	0.08	1119.59	0.09	0.71	0.47	4.27	2
	H <sub>2</sub> O <sup>+</sup> (2 <sub>02</sub> -1 <sub>11</sub> J=3/2-3/2)	0.18	0.04	734.17	0.14	1.52	0.15	3.00	4
	OH <sup>+</sup> (1 <sub>22</sub> -0 <sub>11</sub> )	0.58L	0.07	954.38	0.08	0.22	0.49	4.45	2

<sup>a</sup> Line flux in  $10^{-17} \text{ W m}^{-2}$ . A negative value here indicates an absorption. Note that the flux derivation assumed a point-source case. See §4.2 for a prescription of flux aperture correction in case the target is moderately extended with respect to the SPIRE/FTS beam. The flux values of the OH<sup>+</sup> (1<sub>22</sub>-0<sub>11</sub>) and H<sub>2</sub>O (2<sub>02</sub>-1<sub>11</sub>) lines end with suffix “S” (standing for SSW) or “L” (SLW) to indicate from which detector array the flux was measured.

<sup>b</sup> Line flux uncertainty in  $10^{-17} \text{ W m}^{-2}$ .

<sup>c</sup> Observed line frequency in GHz.

<sup>d</sup> Uncertainty of the observed line frequency in GHz.

<sup>e</sup> This equals the observed frequency minus the expected line frequency based on the redshift of the target, expressed in units of GHz.

<sup>f</sup> Peak line flux density in Jy. A negative value here also indicates an absorption.

<sup>g</sup> S/N ratio for the peak line flux density.

<sup>h</sup> This is the same quality flag as defined in Table 4.

Table 6. Median CO SLEDs from Brightest Sample Galaxies

Line (1)	Cold <sup>a</sup> (2)	Intermediate <sup>a</sup> (3)	Warm <sup>a</sup> (4)
CO (4-3)	1.18	0.80	...
CO (5-4)	1.10	0.88	0.87
CO (6-5)	1.00	1.00	1.00
CO (7-6)	0.76	0.97	1.08
CO (8-7)	0.76	0.98	1.22
CO (9-8)	0.63	0.81	1.04
CO (10-9)	0.52	0.65	1.03
CO (11-10)	0.46	0.51	1.03
CO (12-11)	0.25	0.36	0.88
CO (13-12)	0.28	0.31	0.81

<sup>a</sup> These columns correspond to the same FIR color bins used in Figs. 10 and 11:  $0.5 < C(60/100) \leq 0.65$  (i.e., “Cold”),  $0.75 < C(60/100) \leq 0.9$  (“Intermediate”), and  $1.0 < C(60/100) \leq 1.4$  (“warm”). Note that the frequency-dependent SPIRE/FTS beam has a minimal effect on the results here as they were derived using galaxies satisfying  $f_{70\mu\text{m}}(17'') > 0.80$

Table 7. Line Intensities from Spectral Stacking using a Median method<sup>a</sup>

Line	Freq. (GHz)	(C(60/100) Peak <sup>b</sup>	= 0.3 rms <sup>b</sup>	to std <sup>b</sup>	0.6) n <sub>pts</sub>	(C(60/100) Peak <sup>b</sup>	= 0.6 rms <sup>b</sup>	to std <sup>b</sup>	0.9) n <sub>pts</sub>	(C(60/100) Peak <sup>b</sup>	= 0.9 rms <sup>b</sup>	to std <sup>b</sup>	1.4) n <sub>pts</sub>
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
CO (4-3)	461.041	1.409	0.048	1.05	47	1.503	0.042	4.97	47	1.179	0.051	2.55	14
[C I] 609 $\mu$ m	492.161	0.877	0.048	0.59	50	0.750	0.042	2.26	52	0.559	0.051	0.70	23
CO (5-4)	576.268	1.399	0.048	0.87	50	1.535	0.042	5.30	52	1.200	0.051	2.20	23
CO (6-5)	691.473	1.020	0.048	0.75	50	1.424	0.042	4.91	52	1.576	0.051	2.16	23
H <sub>2</sub> O (2 <sub>11</sub> -2 <sub>02</sub> )	752.033	<0.144	0.048	0.24	50	0.192	0.042	0.65	52	0.243	0.051	1.25	23
CO (7-6)	806.652	0.800	0.048	0.72	50	1.428	0.042	4.75	52	1.535	0.051	2.47	23
[C I] 370 $\mu$ m	809.342	1.353	0.048	0.86	50	1.389	0.042	5.02	52	0.971	0.051	1.57	23
CO (8-7)	921.800	0.634	0.048	0.70	50	1.021	0.042	4.33	52	1.625	0.051	2.65	23
H <sub>2</sub> O (2 <sub>02</sub> -1 <sub>11</sub> ) <sup>c</sup>	987.927	0.347	0.048	0.58	50	0.391	0.042	1.00	52	0.489	0.051	1.72	23
CO (9-8)	1036.912	0.407	0.051	0.50	50	0.991	0.046	2.76	52	1.257	0.049	2.07	23
H <sub>2</sub> O (3 <sub>12</sub> -3 <sub>03</sub> )	1097.365	<0.153	0.051	0.28	50	0.191	0.046	0.77	52	0.413	0.049	1.45	23
H <sub>2</sub> O (1 <sub>11</sub> -0 <sub>00</sub> )	1113.343	<0.153	0.051	0.35	50	<0.138	0.046	0.51	52	<0.147	0.049	1.65	23
CO (10-9)	1151.985	0.366	0.051	0.36	50	0.611	0.046	2.37	52	1.417	0.049	1.84	23
H <sub>2</sub> O (3 <sub>21</sub> -3 <sub>12</sub> )	1162.912	<0.153	0.051	0.35	50	0.301	0.046	1.22	52	0.550	0.049	2.78	23
H <sub>2</sub> O (4 <sub>22</sub> -4 <sub>13</sub> )	1207.639	<0.153	0.051	0.30	50	<0.138	0.046	0.51	52	0.278	0.049	1.02	23
H <sub>2</sub> O (2 <sub>20</sub> -2 <sub>11</sub> )	1228.789	0.171	0.051	0.40	50	0.265	0.046	0.88	52	0.250	0.049	1.34	23
HF (1-0)	1232.476	-0.208	0.051	0.50	50	<0.138	0.046	0.61	52	-0.163	0.049	1.87	23
CO (11-10)	1267.014	0.199	0.051	0.44	50	0.597	0.046	2.05	52	0.913	0.049	1.56	23
CO (12-11)	1381.995	<0.153	0.051	0.33	50	0.387	0.046	1.54	52	0.880	0.049	1.22	23
H <sub>2</sub> O (5 <sub>23</sub> -5 <sub>14</sub> )	1410.618	<0.153	0.051	0.32	50	<0.138	0.046	0.42	52	<0.147	0.049	0.66	23
[N II] 205 $\mu$ m	1461.134	5.840	0.051	3.42	50	4.563	0.046	12.90	52	1.568	0.049	2.89	23
CO (13-12)	1496.923	<0.153	0.051	0.36	50	0.253	0.046	1.05	52	0.688	0.049	1.26	23

<sup>a</sup>The relative line peak flux densities listed here are from stacking of the point-source calibrated spectra of individual targets regardless of their source extension. However, it is shown in the text (see S5.7) that the shape of the resulting CO and H<sub>2</sub>O SLEDs should not be significantly impacted by the fact that the SPIRE/FTS beam is frequency dependent.

<sup>b</sup>These are respectively the line peak flux density, the r.m.s. noise in continuum, and the sample standard deviation, all in units of relative Jy.

<sup>c</sup>The line flux of H<sub>2</sub>O (2<sub>02</sub>-1<sub>11</sub>) was measured in the SLW spectral segment.