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Science Validation of the Spitzer Source List

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Abstract. The Spitzer Science Center will produce a source list (SL) of photometry for a large subset of imaging data in the Spitzer Heritage Archive (SHA). The list will enable a large range of science projects. The primary requirement on the SL is very high reliability — with areal coverage, completeness and limiting depth being secondary considerations. The SHA at the NASA Infrared Science Archive (IRSA) will serve the SL as an enhanced data product. The SL will include data from the four channels of IRAC (3–8 microns) and the 24 micron channel of MIPS. The Source List will include image products (mosaics) and photometric data for Spitzer observations of about 1500 square degrees and include around 30 million sources. We describe ongoing science validation of the Spitzer Source List, and discuss the range of use cases which will be supported

The Spitzer Science Center (SSC) will produce a source list (SL) of photometry for a large subset of imaging data obtained by the IRAC and MIPS instruments onboard the *Spitzer Space Telescope* (Werner et al. 2004) during its recently-completed cryogenic mission. The SL will enable a large range of science projects, but is not intended to meet the standards of a mission wide catalog (e.g. 2MASS). The primary requirement on the SL is very high reliability, even at the cost of completeness. The Spitzer Heritage Archive (SHA) at the NASA/IPAC Infrared Science Archive (IRSA) will serve the SL as an enhanced data product and will ensure that appropriate caveats and warnings are prominently placed. The SL products are planned for public release in late 2011. Details of the SL requirements and construction were given in the proceedings of the 2009 ADASS.

This SL will ensure high reliability by including only a subset of Spitzer data that is well behaved and can be processed and verified autonomously. This means observing programs must meet a minimum set of requirements for processing by the SL pipeline. These minimum requirements include data obtained with IRAC channels 1–4 (3–8 microns) in high-dynamic range or mapping mode and MIPS channel 1 (24 microns) in scan or photometry mode. In these proceedings, we present possible science use cases that may be used for SL validation.

1. Galactic Science I. Dust Extinction in Dark Clouds from UKIDSS and Spitzer

Knowledge of the wavelength dependence of interstellar dust grain extinction gives a constraint on the dust size and composition, and improves estimates of the true colors of objects behind dust. Studies of dust extinction in galactic molecular clouds typically show changes in the wavelength dependence of the extinction compared to dust in the diffuse interstellar medium, usually ascribed to grain growth (e.g. Flaherty et al. 2007; Chapman et al. 2009).

The UKIDSS (Lawrence et al. 2007) includes a Galactic Plane Survey about 3 mag deeper than 2MASS at K (2.2 μm). By combining UKIDSS data with Spitzer data one can get the dust extinction law deep into dark clouds through the IRAC 8 μm band (to MIPS 24 μm in some cases).

As an example of the kind of science one might do with the Spitzer source list, we chose a patchy dark cloud, L673, seen against a dense stellar background (galactic coordinates $l = 46°$,

$b = -1°$). Parts of the cloud were observed with Spitzer by the "c2d" Legacy survey (Evans et al. 2007). For this example, we used the objects identified in their catalog as likely to be photospheres and matched these to UKIDSS sources.

The extinction at K in mag, A(K), for each object was estimated from the UKIDSS data by assuming a power-law for $A(\lambda)$ between J (1.25 μm), H (1.63 μm), and K (2.2 μm), and assuming a mean intrinsic color for the background stars of $J - H = 0.7$ and $H - K = 0.3$ from off-cloud regions, in a similar manner as Lombardi & Alves (2001). The relative extinctions in IRAC bands were then calcuated assuming photospheres. Values in separate bins in A(K) were fit with a robust linear fit and mean fit values in low and high extinction bins are plotted in Figure 1.

While strong conclusions are not possible from just this small region, the trend appears consistent with what's been seen in other dense clouds: flatter extinction in IRAC bands relative to K when looking towards the high extinction areas, compared to lower extinction regions, which are more like the diffuse ISM. Though ice bands contribute to this effect, grain growth is probably dominant, according to McClure (2009).

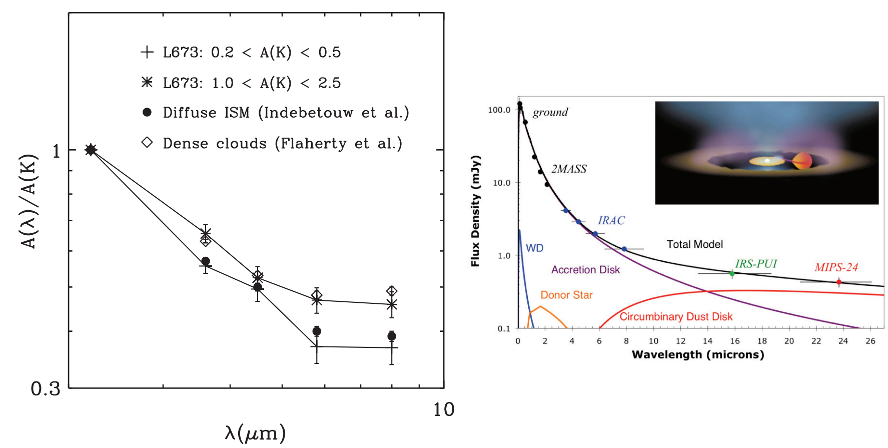

Figure 1. **Left:** Dust extinction law in low and high extinction regions of L673, compared to other lines of sight. The Indebetouw et al. (2005) values are those adjusted by Flaherty et al. (2007) and do not include the uncertainty in A(H)/A(K). **Right:** Spectral energy distribution of the bright, nearly face-on cataclysmic variable V592 Cas, along with a multi-component model. Infrared data from pointed observations with the Spitzer Space Telescope were crucial to discovering the presence of a circumbinary dust disk that surrounds this close binary star (see artistic depiction in inset panel). For details, see Hoard et al. (2009).

2. Galactic Science II. Cataclysmic Variables in the Infrared

Recent infrared observations, particularly from the Spitzer Space Telescope, of white dwarfs, cataclysmic variables (CVs), and other interacting compact binaries, have revealed the presence of dust in many systems (for example, see Figure 1). Cataclysmic variables, in particular, are important astrophysical laboratories for the study of mass transfer and accretion processes. These play key roles in a wide range of astrophysical scenarios, from the formation of stars and planets to the central engines of quasars and AGN. The recent, and surprising, discovery of dust in CVs has also highlighted the importance of these systems for expanding the understanding of post-main sequence stellar evolution, as well as the eventual fate of planetary systems.

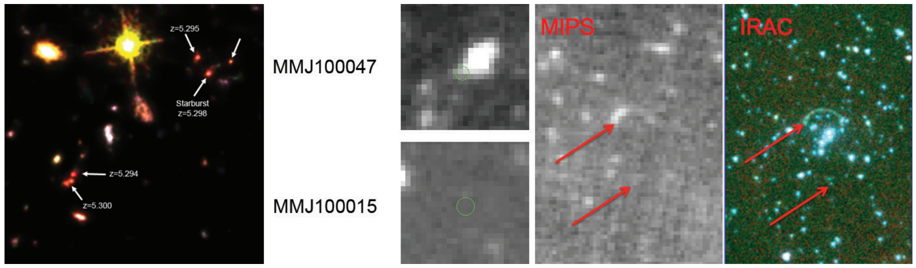

Figure 2. **Left:** The core of a proto-cluster at z=5.3 with spectroscopically confirmed sources marked. The source list photometry was confirmed to be accurate enough to measure masses for these objects. **Center:** IRAC Ch1 cutouts around optically faint sub-mm bright galaxies are shown (Aravena et al. 2010) with the mm positions marked by a 1″ radius green circle. Note the lack of a clear detection for either source. **Right:** Source list images for an extended gravitational lens and counter image (indicated with red arrows) reported by Wuyts et al. (2010). Note the 24μm emission is resolved in this $z = 1.7$ lensed galaxy.

Up to now, the Spitzer observations of CVs have targeted only about two dozen systems (out of 2500+ known CVs) in pointed programs. We will use the Spitzer Source List, with a recently updated, comprehensive target list for all known cataclysmic variables (CVs), to complete the census of mid-infrared photometry of CVs.

Prior to our observational confirmation of their existence, circumbinary dust disks had been proposed as an additional angular momentum loss mechanism to help rectify theories and observational constraints for the secular evolution of CVs. We have already shown that the total masses of dust appear to be many orders of magnitude too small to agree with the proposed evolutionary models. However, many important questions remain; for example, what is the origin and formation mechanism for the dust? The Spitzer observations to date have given clues to the answer for this question, such as the general lack of a 10-micron emission feature (indicating that the dust grains are likely relatively large), but a complete answer awaits a full exploration of parameter space for the dust in CVs. Even such a basic question as the true ubiquity of dust in CVs remains unanswered. The data to support such an undertaking will be found in the Spitzer Source List. In addition, when combined with upcoming results from the all sky infrared survey by WISE, we will be able to examine the infrared spectral energy distributions of CVs for variability on time scales of several years. This will allow us to address questions relating to the ongoing formation and longevity of dust in these systems.

3. Extragalactic Science

Statistical surveys of the sky at all wavelengths have become the backbone of modern extragalactic astronomy and are set to become even more essential in the next decade as new survey facilities come online. Novel re-analysis of this survey data often results in valuable and surprising findings, especially if the data are cross correlated with existing data at other wavelengths. Here we give three examples of such science that made use of the SL pipeline. In all cases, a more careful analysis by the science team confirmed the SL results.

A massive proto-cluster was recently confirmed around a sub-mm system at z=5.3 (Capak et al. 2011, Figure 2 Left). The mass of the galaxies in the system was determined using IRAC 3.6 & 4.5μm data obtained in both the Cryogenic and Warm missions. The IRAC images and photometry for this cluster were analyzed using the source list pipeline. The results were checked with a manual re-reduction of the mosaics and Point Spread Function (PSF) fitting of the IRAC source photometry. The images were essentially identical and the photometry was consistent for isolated sources.

In a recent paper (Aravena et al. 2010) the Sub-Millimeter Array (SMA) was used to localize two potentially high-redshift sub-mm systems found with the IRAM 30m telescope. Neither of these sources have significant optical or near-Infrared counterparts. Even in very deep IRAC observations reduced with the SL pipeline no clear counterpart is visible (Figure 2 Center).

Finally, the Red Sequence Cluster Search (RCS) recently reported the discovery of a very extended strongly lensed galaxy (Wuyts et al. 2010, Figure 2 Right). Analysis of the lensing arcs shows the 24μm emission is isolated to one side of the extended arc, and is significantly weaker in a similarly magnified, but un-extended counter-arcs. This indicates the 24μm emission is coming from a very compact region within the galaxy that is more apparent when the emission is resolved by the lensing.

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