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[CII] Emission from Low Redshift Analogs of Epoch of Reionization Galaxies

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Abstract. We present Herschel/PACS far-infrared spectroscopy of a population of ~20 local ($z < 0.2$) star-forming galaxies identified in the Sloan Digital Sky Survey and whose specific star-formation rates and extreme emission line properties make them very similar to $z > 5$ Lyman-break galaxies. We detect [CII] emission in about half the sample, with [CII]/ L_{IR} ratios which lie between 1.6×10^{-4} and 1.6×10^{-3}. We find that [CII]/L_{IR} ratios in mergers are lower by a factor of $\sim 2-3$; however we do not find evidence for a metallicity dependence. We predict based on these measurements that ALMA spectroscopy of $z > 5$ Lyman-break galaxies should reveal median [CII]/L_{IR} ratios of 6×10^{-4} and maybe even as high as 10^{-3}, depending on whether mergers or cold gas accretion powers star-formation.

1. Motivation

More than 70% of z>5 galaxies show evidence for strong nebular line emission, particularly Hα, but also [OIII] (Chary et al. 2005, Shim et al. 2011, Stark et al. 2013). The origin of this strong nebular emission appears to be due to a population of hot ,young stars which are responsible for a high ionization parameter (i.e. ionizing photons/baryon in the galaxies). Fitting the nebular line strength along with the stellar mass and ages, requires an IMF which at least in some galaxies, has a functional form of $dN/dM \propto M^{-1.7}$ i.e. top-heavy (Chary 2008).

The [CII] line at 157.7μm is an important coolant of the warm interstellar medium and can account for ~0.1−1% of the bolometric luminosity L_{TIR} (e.g. Malhotra et al. 2001, Ivison et al. 2010). An ISM which is subjected to a high UV radiation field density would have photoelectrons ejected from the dust which would heat the gas in the surrounding photodissociation region. If the gas density is high, for a constant UV radiation field, the strength of the [CII] line will therefore be lower. For a constant gas density, as the ionizing radiation field increases, the efficiency of photoelectron heating may decrease as the dust grains become positively charged. This would also weaken the strength of the [CII] line. Thus, the strength of [CII] emission can provide a constraint on the ionizing radiation density which ALMA is primed to target in $z > 5$ galaxies.

In Shim & Chary (2013), we have found ~300 galaxies in the Sloan Digital Sky Survey (SDSS) with similarly large Hα equivalent width (EW>500Å) as seen in $z > 5$ galaxies. They have lower mass and lower SFR than $z \sim 5$ galaxies; yet their specific

star-formation rates are remarkably similar to the epoch of reionization galaxies discussed in Shim et al. (2011). Although such high EW galaxies are far less abundant in the local Universe as a fraction of the galaxy population compared to the incidence rate of ~70% at high redshift, indications are that they share similar conditions in terms of their ionizing radiation field and gas density based on the properties of their optical spectra seen in SDSS. We undertook Herschel/PACS spectroscopy of 20 of these local Lyman-break analogs, in an attempt to constrain the strength of the [CII] emission in these galaxies.

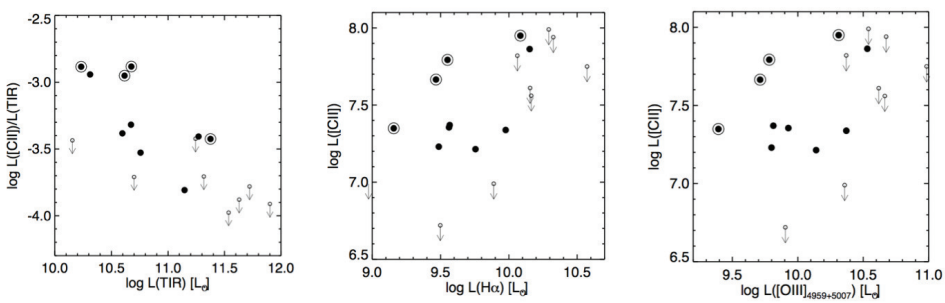

Figure 1. Left: [CII]/L_{TIR} ratios of the low redshift Lyman-break analogs plotted against their L_{TIR}. The dots are mergers, the dots with surrounding circles are non-mergers while the open circles are non-detections. Clearly, non-mergers have higher ratios than mergers with similar L_{TIR}, presumably due to their lower gas densities. Middle and Right: [CII] strengths plotted against Hα and [OIII] line luminosities respectively. Although the strength of [CII] does correlate loosely with ionization parameter for which the nebular lines are a proxy, there is significant scatter.

2. Results

We detect [CII] emission in half the sample with high signal to noise; the median [CII]/L_{TIR} ratio is 6×10^{-4}. 6 of the galaxies are clear mergers while 4 are non-mergers. The strength of [CII] emission correlates loosely with Hα and [OIII] with the strength of [CII] being $\sim10^{-2}$ of the line luminosity arising in Hα and [OIII]. The mergers appear to have a factor of $2-3$ weaker [CII] emission compared to the non-mergers. Since both the mergers and non-mergers span a similar range of L_{TIR}, the implication is that higher gas densities expected in the mergers is responsible for the weakness of [CII]. If the star-formation in $z > 5$ galaxies is driven primarily by accretion of cold-gas rather than by mergers, ALMA may measure their [CII]/L_{TIR} as high as $\sim10^{-3}$, similar to the average seen among the non-mergers in our sample.

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