Investigating the ‘Deficit’: Probing the High Redshift CII Signal of Star Forming Galaxies with ALMA

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PHYS 641 Observational Methods in Modern Astrophysics

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December 11, 2022

1 Abstract

While the 158 μm fine structure transition of singly ionized carbon (CII) has been propelled as a reliable star formation rate (SFR) indicator for low redshift (z > 5) star forming galaxies, the constraints on that relationship sparks a lot of controversy at higher redshift, with many surveys reporting a systematic ‘CII deficit’ starting from z = 5, while others argue that the low redshift relationship persists in that range. In an effort to investigate the question, we request 70 hours of observing time using the ALMA telescope targeting 118 z > 5 star forming galaxies drawn from the COSMOS and ECDFS fields.

2 Scientific Justification

2.1 [CII] Cosmology

Galaxy formation and star forming processes at high redshift, crucial to the history of our modern Universe, are becoming the focus point of many astrophysical observational endeavours in the advent of the necessary observing tools to start probing distant galaxies. One of the target frequencies of this investigation is the 158 μm rest-frame [CII] line. As a major coolant of the neutral atomic gas of the interstellar medium, the [CII] signal is proportional to the heating rate and the fraction of atomic gas. Additionally, it is the strongest emission line of star forming galaxies at rest-frame far-infrared wavelength, which makes it the ideal tracer for galactic star formation rate (SFR) [1, 2].

Observations of local galaxies have revealed a linear scaling relationship the [CII] luminosity L_{CII} and SFR [e.g., 3]. At higher redshifts ($z > 5$), various small scale surveys have yielded divergent results: some report that the linear scaling from the lower redshifts persists [e.g., 4], while others report a systematic decrease of the [CII] luminosity, the so-called "CII deficit" [e.g., 5]. Hence, it is important in order to shed light on this problem to perform a systematic observation of a large selection of $z > 5$ star forming galaxies to study the relationship between the strength of the [CII] signal and the star formation rate of these galaxies. An instrument who matches the sensitivity for this task is the ALMA telescope [6].

2.2 ALMA

The Atacama Large Millimeter/sub-millimeter Array (ALMA) is an interferometer consisting of a large configuration of 12-m antennas, whose bandwidth, ranging from approximately 84 GHz to 950 GHz, allows the detection of the redshifted [CII] line in our range of interest ($z \sim 5 - 8$). Next we discuss the selection of 118 sources for the proposed survey, and how they are to produce a significant observation of the [CII] signal we are looking after. [6]

3 Technical Justification

3.1 Selection Process

Our selection of galaxies is based off of COSMOS and ECDFS survey samples. They need to have a reliable spectroscopic redshift, roughly between 5 and 7. This redshift range is within the band 7 of ALMA (275 - 373 GHz). The [CII] sensitivity of the instrument in that range is shown in Figure 1. They are UV selected with $L_{UV} > 0.6L^*$ to include most of the star formation traced by the [CII] signal, redshifted to UV, while excluding type I AGNs. The accurate redshifts of the sources are retrieved from the VLT and Keck. [6, 7]

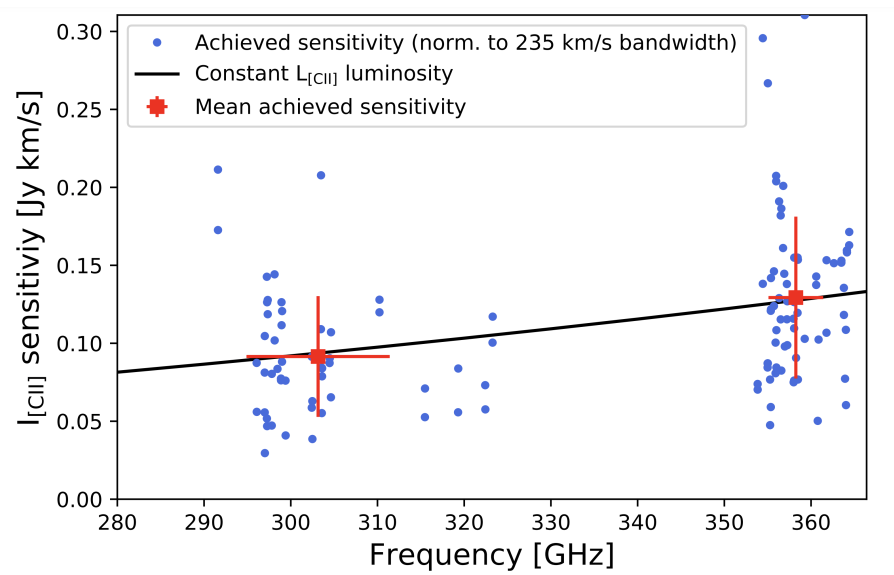

Figure 1: Achieved [CII] RMS sensitivity with ALMA in the 275 - 373 GHz bandwidth (from [7]).

To better detect the [CII] line, the observation will prioritize detection over spatial resolution. The ALMA array can be set in a C43-1 or C43-2 configuration, which should allow for a beam size of order ~ 1 arcsec [7].

3.2 Sources' characteristics

Drawing from the COSMOS and ECDFS catalogs star forming galaxies, 118 sources are selected for a z_{spec} range of $4.4 < z_{spec} < 5.9$. The typical FWHM is $\sim 235km/s$. The coarse resolution of the instrument in our band (about $\sim$ 30 MHz) should be sufficient to resolve our [CII] lines at Δv = 25 - 35 km/s [6]. Table 1 presents the positions and z_{spec} of a few of the 118 selected sources, while Table 2 presents the distribution of all sources' SFR with respect to their masses:

Table 1: Excerpt table of the catalogue of selected sources (118 total) with indicated position and z_{spec} (from [6]):

ALPINE ID	α_{2000}	δ_{2000}	z_{spec}
CANDELS GOODS 12	53.22551	-27.8336	4.4297
CANDELS GOODS 14	53.0788	-27.8841	5.5630
CANDELS GOODS 21	53.0497	-27.6992	5.5780
CANDELS GOODS 32	53.0708	-27.6871	4.4140
DEIMOS COSMOS 274035	149.8853	1.7017	4.48200
DEIMOS COSMOS 308643	150.3612	1.7573	4.5270
DEIMOS COSMOS 351640	150.3712	1.8248	5.7070
DEIMOS COSMOS 357722	149.9668	1.8349	5.7380
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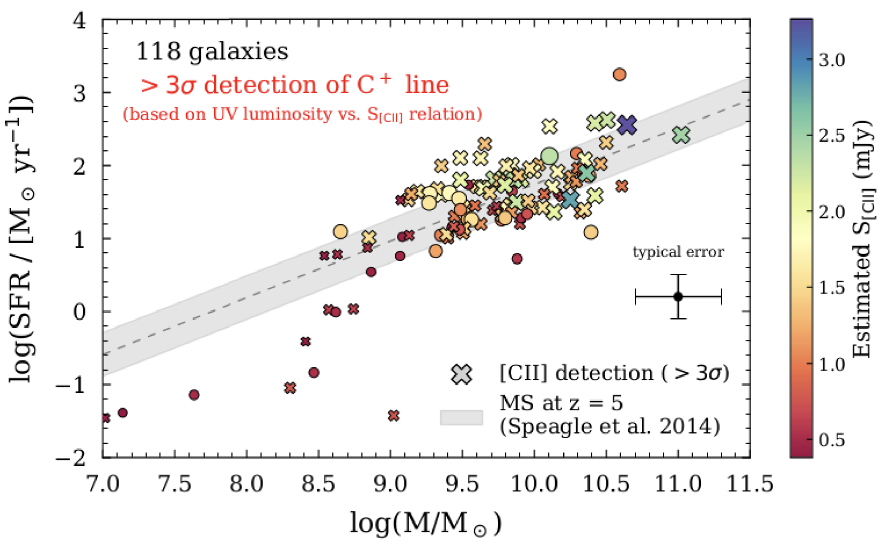

Figure 2: Distribution of the SFR of our sample of 118 galaxies (from [6]).

Simulations tell that an SNR $> 3.5\sigma$ would allow to detect the [CII] signal at 95% probability. With a total observing time of 70 hours, with 30 minutes per target and up to one hour in integration time, we would be able to detect the [CII] signal for about 65% of our catalog using this cutoff [6]. Figure 3 displays the distribution of SNR with the 3.5σ line that such an observation would entail:

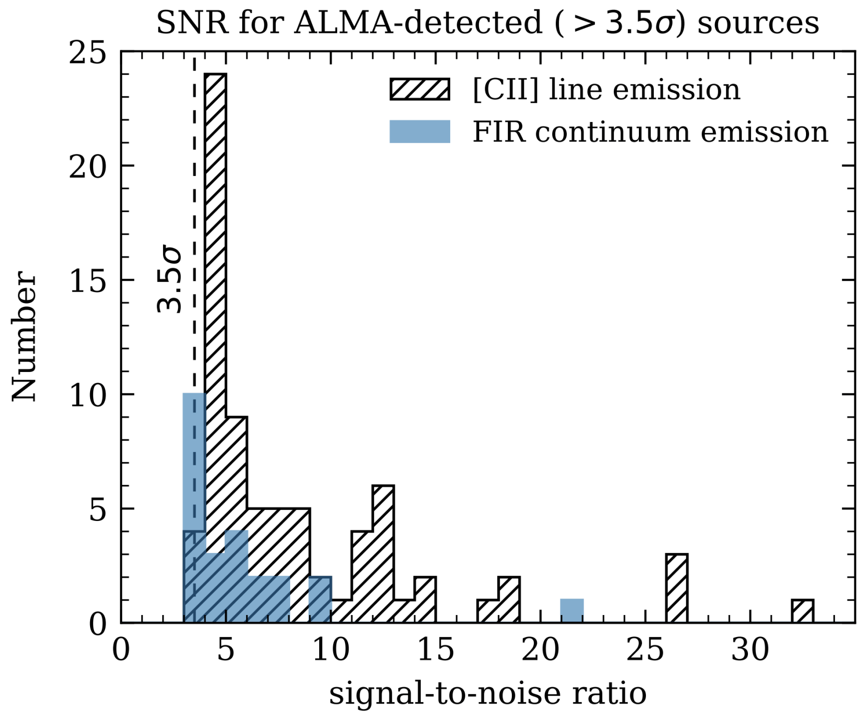

Figure 3: Distribution of the SNR of our sample of 118 galaxies (from [9]).

Hence, ALMA could detect the [CII] line of numerous star forming galaxies with a redshift $4.4 < z_{spec} < 5.9$. By correlating this signal to SFR information, this survey could put further constraints on the $L_{[CII]}$/SFR relationship at high redshift, furthering the pathway towards understanding in more details the process of galaxy & star formation.

4 References

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