Thesis subject

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Subject's title: Carbon as a tracer of the interstellar medium of the first massive galaxies in the Universe

Subject description:

Understanding the early assembly of massive galaxies remains a challenge for modern astrophysics. We still do not well understand how gas is accreted by galaxies, cool down, and is finally used as fuel for star formation. For instance, very massive galaxies have been found extremely early in the Universe (e.g., Strandet et al. 2017, Marrone et al. 2018). Some of these objects are an order of magnitude more massive than the Milky Way less than a gigayear after the recombination and the mechanisms leading to their incredibly fast assembly are poorly known. Of course, the bulk of stars at high redshift are not form in these monsters. However, at these early times (z>3), a significant fraction of the stars was formed in already massive galaxies (>10^{10} Msun) hosting very high star formation rates (SFR > 10 Msun/yr and >100 Msun/yr for the most massive ones, e.g. Schreiber et al. 2015).

How can we explain that the stellar mass of these galaxies was assembled so early and so fast? Recent observations have shown that the gas fraction increases quickly from z=0 to z=3 (e.g., Magdis et al. 2012, Béthermin et al. 2015a) contributed to the emergence of a new scenario, where the intense star formation in these objects is driven mainly by cosmic accretion of cold gas onto early-assembled dark matter halos (e.g., Dekel et al. 2006). Until recent years, most of our constraints on the star formation at z>3 were essentially coming from the UV light from young stars escaping the galaxies (e.g., Madau & Dickinson 2014), but we had very few information on their gas content, except in bright lensed quasars and extreme starbursts. Since ALMA has reached its final capabilities, a new era is opening, and we can finally detect the cold gas reservoirs of galaxies at z>3. These new observations will be crucial to finally understand the mechanisms leading to the early assembly of the massive galaxies. This PhD project aims to put new constraints on the interstellar medium (ISM) of high-z galaxies using the carbon fine-structure lines ([CII] and [CI]).

The South Pole Telescope Sub-millimeter Galaxies (SPT SMG) collaboration is a coordinated international effort (~25 active members) to study an unprecedented sample of ~100 gravitationally-magnified dusty star-forming galaxies with ALMA, HST, *Spitzer*, *Herschel*, APEX, ATCA, VLT (e.g., Vieira et al. 2013). During this thesis project, we will analyze a large sample of ~40 detections of [CI] from z=2.5 to z=7 obtained serendipitously during the ALMA redshift-search campaigns and during additional follow up campaigns with APEX. This line is a promising tracer of the total gas mass of distant galaxies (Papadopoulos & Greve 2004, Bothwell et al. 2016). This unprecedently large sample at high redshift will allow us to test the relation between [CI] and various physical parameters of these galaxies.

In complement to this large sample, we obtained ALMA high-resolution observations of two of these objects in [CI], CO, and the dust continuum, which will allow us to compare the spatial distribution of these various tracers of the ISM and understand possible systematic effects in our methods to estimate the gas content of a galaxy. Thanks to the velocity measurements performed using these lines, we will also determine the dynamical and gas mass of these galaxies and compare it with the estimates based on line luminosities.

In addition to these lines, many other tracers have been observed in the SPT SMG sample as far-IR fine-structure lines ([CII], [OI]. [OIII], [NII]) and dense-gas rotational lines (CO, HCN, HCO+, HNC). We will develop a chemical modeling approach, based on existing gas-grain chemistry models, but specific to these high-redshift objects for which we start to detect a large variety of lines but have very few geometrical information. The impact of the much higher CMB temperature at this epoch will also be considered both in the chemistry and in the emission lines of the observed species.

Bibliography:

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