Identifying Protoclusters in Distant Universe

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Abstract

Properties of galaxies appear to be associated with the environment in which they are immersed. To investigate how the environment-galaxy relation is established, we study protoclusters — numerically-dense environments of galaxies in the early Universe, that give rise to galaxy clusters today. In this work, we use submillimetric galaxies (SMGs) - dusty and distant galaxies with copious infrared emission redshifted to the submillimetric bands - as lampposts to trace potential sites of protocluster regions. To gauge galaxy overdensities around SMGs, we search in their vicinity for more typical star-forming galaxies through their Lyman-**α** emission ("Lyman-**α** emitters" or LAEs). We investigate 4 potential protocluster sites in the redshift range z~1-5, which corresponds to > 4 Giga years. With this, we seek to understand how the environment-galaxy relation evolves within a growing cluster structure. We focus here on structures within the COSMOS field.

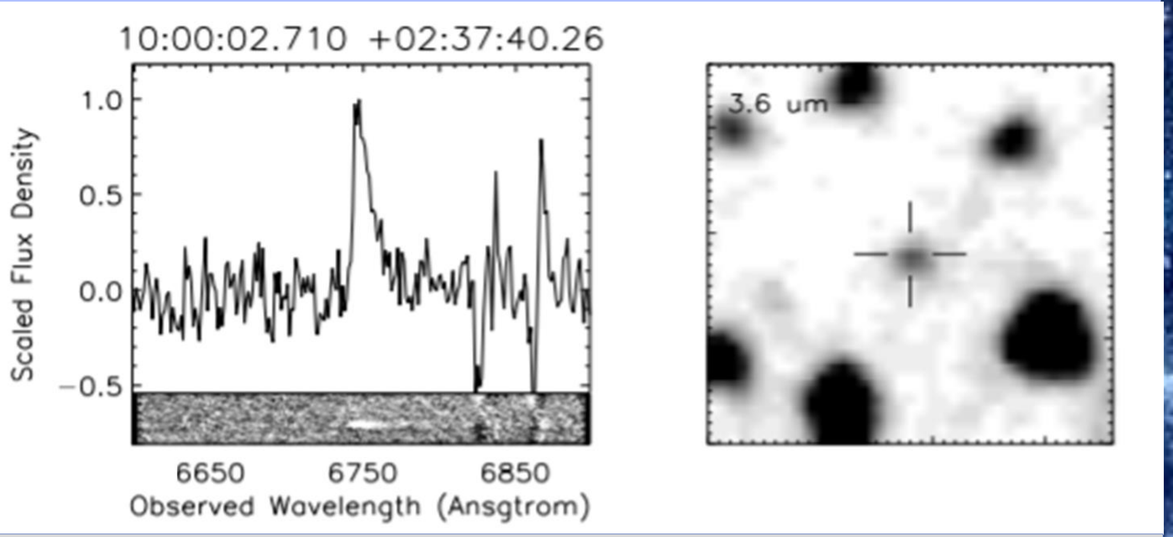
SMGs as lampposts for protoclusters regions

Studies show that SMGs inhabit massive dark matter halos (~10^{14} M_{Sun}; Blain+04) or even more typical modest-mass regions going through active episodes of star formation (Chapman+09). SMGs thus allow us to probe different kinds of environments, providing us with a more representative view of galaxy clusters at high redshifts. Our goals here are:

- **Identify galaxies around SMGs — do they correspond to galaxy overdensities in the early universe?**
- **Study properties of individual protocluster members and probe for spatial segregation within each structure.**
- **Analyse how galaxy properties vary within protoclusters at different redshifts, to trace any evolution in the galaxy-environment relation as a function of protocluster maturity.**

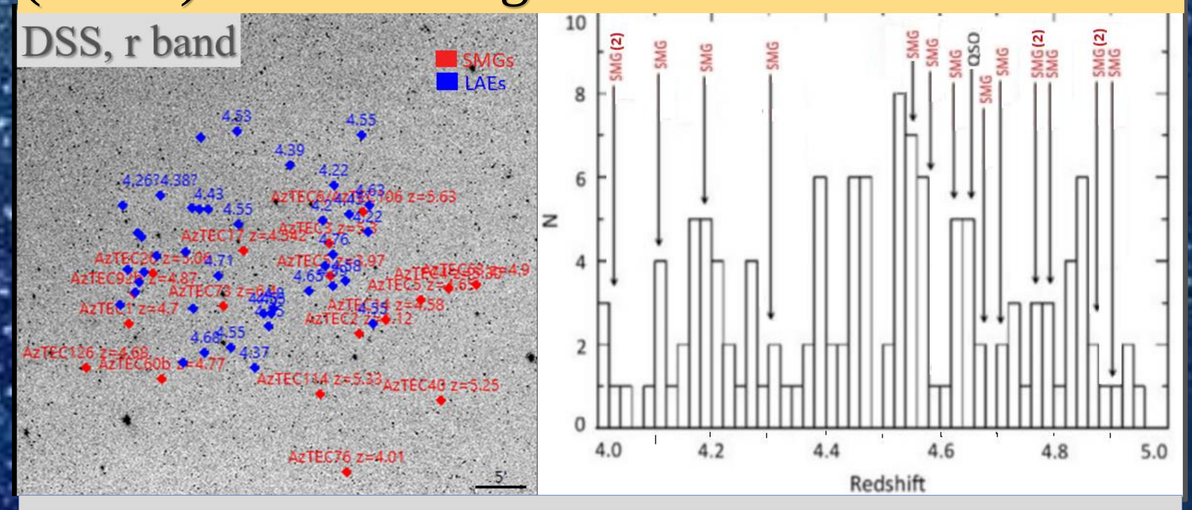
Identifying Protoclusters Members Through Lyα Emission

We combine deep imaging and spectroscopic observations to identify LAEs. We identified more than 300 LAEs candidates in 4 potential protocluster regions. Of these ~200 have already been spectroscopically-confirmed to be at the SMGs redshifts ($\Delta v \leq 2000$ km/s) within a few Mpc in projected distance. This is consistent with them being part of the same structure.



Left: Example of a LAE spectroscopic detection with the IMACS instrument on Baade, Las Campanas Observatory (Chile). Right: Archival multi-band imaging opens up the possibility of tracing individual galaxy properties (e.g., stellar mass, AGN content). Here, mid-IR counterpart in Spitzer/IRAC archival imaging

Protocluster candidates in the COSMOS field (z~4-5) — First insights



Left: Potential protocluster regions at z > 4, identified through LAEs around SMGs in the COSMOS field. Red symbols show the location of SMGs with spectroscopic redshifts (Brisbin+17); blue, our LAEs. Right: Redshift distribution of LAEs, with SMGs redshifts locations highlighted.

Our analysis of the LAE distribution within the COSMOS region at SMG redshifts z~4-5 is still underway. We note that:

- The region extension corresponds to a physical distance of ~10Mpc, which is consistent with protocluster extensions (Overzier+18).
- LAE and SMG redshift distribution shows that SMGs appear to coincide with peaks in the galaxy redshift distribution. However, they are also found in less populated regions.
- Further characterization of these region number densities (compared to the field) will unveil what kind of environment we are probing.

Next Steps

- Characterize overdensity (number of galaxies per unit volume) around SMGs by comparing with studies of LAEs in the field at the same redshift (Rhoads et al. 2000, for z~4.5).
  Do SMG regions correspond to protoclusters?
- Study LAEs properties (e.g., mass, SFR, presence of AGN) exploiting multi-band public data archives.
  Do we find spatial segregation of LAE properties?
- Analyse how the distribution of galaxy properties inside protoclusters varies at different stages of protocluster evolution.
  Do we trace changes in the galaxy-environment relation?

References

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