Confirmed Clusters and Proto-clusters at $1.4 < z < 2.8$

Investigating their Star Formation Activity

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WASHINGTON, DC - March 18-23, 2018

Confirmed high-redshift clusters

- We followed-up the 20 densest CARLA cluster candidates with HST.
- **CARLA**: 200 cluster candidates selected as overdense fields of $z > 1.3$ Spitzer color-selected galaxies around $1.3 < z < 3.2$ Radio-Loud AGN (RLAGN). Wylezalek et al. 2013, 2014.
- **CARLA** samples the previously largely unexplored transition epoch between proto-cluster and cluster environments.

- We obtained 2 orbits/orientations of HST G141 grism slitless spectroscopy and F140W imaging per field, allowing us to confirm star-forming members only, within $0.5$ Mpc physical scale around the RLAGN.

- We confirm 16 of the 20 cluster candidates, covering $z = 1.4 - 2.8$.

- Figures on the right-hand side show the redshift and spatial distributions of CARLA J2039-2514 members, confirmed at $\langle z_{cl} \rangle = 1.999$. All members are identified based on [OIII] detections. This cluster also exhibits a red-sequence of passive candidate members.

Accelerated evolution of massive member galaxies?

- In Noirot et al. (2018), we demonstrate that our 16 spectroscopically confirmed CARLA clusters and proto-clusters at $1.4 < z < 2.8$ are as rich as spectroscopically confirmed $z \sim 1.4$ SPT and ISCS clusters in terms of $z > 1.3$ Spitzer color-selected galaxies.

- We estimate member galaxy stellar masses from their Spitzer IRAC fluxes, and show that massive confirmed members are located below their star-forming main-sequences up to $z = 2.0$.

- $A_V$ dust attenuations of 2 (4) mag for $10^{10}$ ($10^{11}$) $M_\odot$ members at $z \sim 1.5$ would be required to be consistent with their main-sequence. Unless significantly dust-obscured, this suggests that massive CARLA members, residing in rich environments, already followed an accelerated evolution compared to the field at these early epochs.

A reversed star-formation rate - density relation

- We also investigate the dependence of the star-formation rates (SFRs) of $z = 1.4 - 2.0$ confirmed members with their distance from the RLAGN. We find a decrease in individual SFRs with distance, for both Hα and [OIII] SFR tracers up to $z \sim 1.7$.

- Average cluster SFR densities, as seen on the right-hand side, decrease with distance from the RLAGN for all redshifts and SFR tracers. As opposed to local clusters, this indicates that at these early epochs cluster centers are the main sites of star formation.

- Consistent with the lower redshift work by Brodwin et al. (2013), our higher redshift results show that $z \sim 1.4$ represent the onset of the reversal of the SFR - density relation.

- This CARLA–HST survey represents a unique and large homogenous sample of spectroscopically confirmed structures at high redshifts, ideal to further study galaxy cluster physics, star-formation, quenching mechanisms, and AGN feedback.