Uncovering Early Galaxy Evolution in the ALMA and JWST Era
Proceedings IAU Symposium No. 352, 2019
E. da Cunha, J. Hodge, J. Afonso, L. Pentericci & D. Sobral, eds.

doi:10.1017/S1743921319009475

The molecular gas content in a protocluster at z = 1.7: Star formation and AGN feedback

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Abstract. A large-scale structure has been recently discovered at z = 1.7, around a powerful FRII radio galaxy. Eight Star Forming Galaxies (SFGs) have been discovered within $\Delta z \approx 0.0095$ and at <1 Mpc from the FRII, indicating that this is a signpost of a protocluster. Furthermore, a significant X-ray diffuse emission overlapping the Eastern lobe of the FRII has been detected. Protoclusters are the ideal targets to investigate the complex assembly processes leading to the formation of local galaxy clusters. We will exploit new ALMA CO(2-1) observations (PI: R. Gilli) of the entire region around the FRII galaxy to trace the molecular gas content, in order to discover new protocluster members. Coupling these measurements with the multi-wavelength data coverage available for this field, we aim at placing constrains on the physical conditions in which star formation occurs, and ultimately infer the role of the radio jets in triggering it.

Keywords. galaxies clusters, quasars, supermassive black holes, shock waves, high-redshift

VLT/MUSE data show an overdensity of 6 SFGs in the redshift range 1.6871–1.6967 (Fig. 1, green circles). From a subsequent spectroscopic follow-up carried out with LBT/LUCI we measured the spectroscopic redshift z = 1.6987 for the FRII optical host, and serendipitously discovered an additional protocluster member candidate, at z = 1.6966 (Fig. 1, blue circles). We also estimated the photometric redshift of the additional radio source North of the Eastern lobe of the FRII, obtaining a redshift estimate between z = 1.4 and z = 1.9 at 68% confidence level. We obtained new ALMA observation of the region covered by the FRII (Fig. 1, cyan rectangle) down to $L'_{CO(2-1)} = 2 \times 10^{10}$ K km/s pc^{-2} in order to detect new members of the protocluster and measure their position, gas mass, gas fraction and Star Formation Rate (SFR). Deep Chandra observations reveal a diffuse X-ray emission (Fig. 2), in particular around the FRII Eastern lobe. Four out of six the VLT/MUSE sources are distributed at the edge of such emission, with three of them in an arc-like shape. We speculate that the diffuse X-rays trace shock-heated gas by positive AGN feedback, promoting star formation by compression of the cold gas. Based on the number density of field CO emitters with $L'_{CO} \geqslant 3 \times 10^9$ K km/s pc^{-2} (Decarli+16, ApJ, 833, 69), from the CO (2-1) observation we expect to detect ∼10 new galaxies of the protocluster. Based on their location we will infer whether the SF is related to the FRII activity. In Fig. 3, right-top corner,

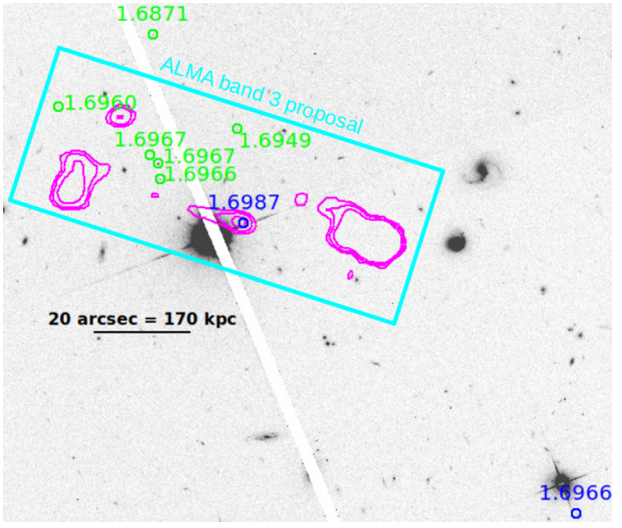

Figure 1. HST-ACS F850LP image of the field around the FRII. North is up and East is to left. The magenta contours show the 1.4 GHz emission at the 3σ, 5σ, 10σ level, respectively. An additional radio source (possible part of the protocluster) is also labeled in magenta. The green circles mark the VLT/MUSE protocluster candidates, labeled with their spectroscopic redshift. The two LBT/LUCI possible members, including the FRII are marked with the blue circles. The cyan rectangle covers the ALMA proposal region.

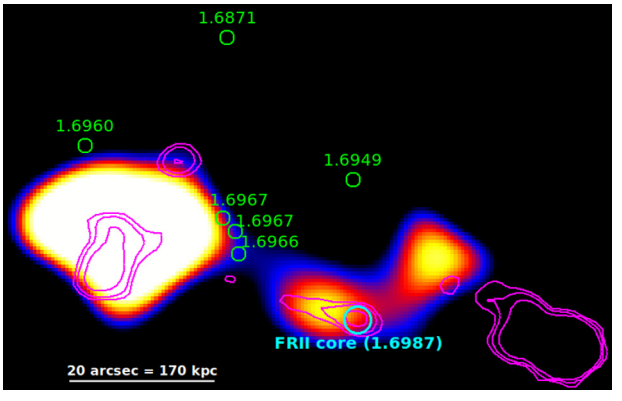

Figure 2. Point-source subtracted and smoothed Chandra image in the 0.5-7 KeV band, overlaid with 1.4 GHz contours (magenta). We mark the protocluster galaxies with green circles, labeled with their redshift. The FRII core position is indicated with a cyan circle.

we report the serendipitous discovery of a CO emitter located close (projected distance <50 kpc, spectral shift <300 km/s) to the FRII core, which is one of the best candidates as new protocluster member. The host of the FRII was found to be a strong CO emitter with a complex kinematic structure, as visible from the double-peaked shape of the line (Fig. 3, left-top corner), that could be ascribed either to a rotating system or even to two separated, but spatially unresolved, galaxies.

https://doi.org/10.1017/S1743921319009475 Published online by Cambridge University Press

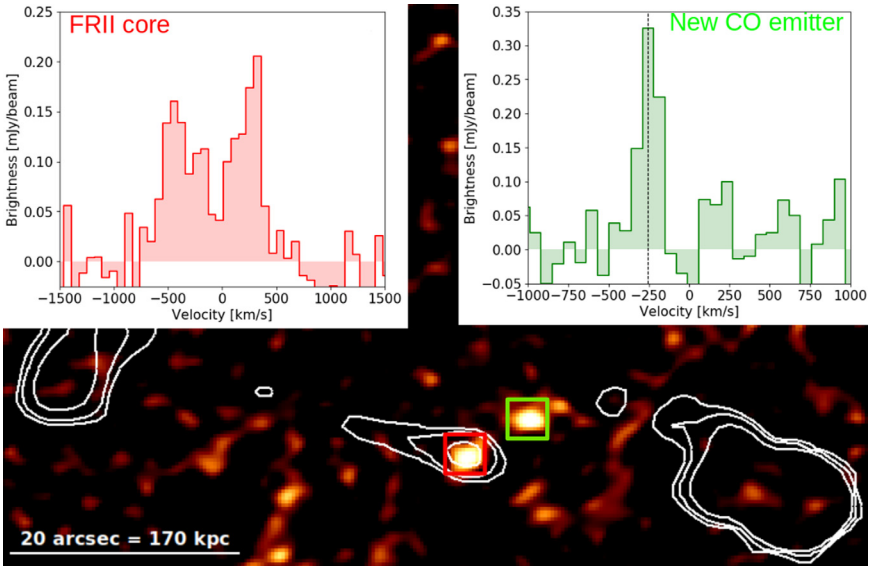

Figure 3. Continuum-subtracted image of the CO(2-1) emission, overlaid with 1.4 GHz contours in white. The spectrum of the serendipitous source (highlighted by the green box) is reported in the right-top corner, in which the black dashed line indicates the channel corresponding to the image (∼-255 km/s). In the left-top corner we report the spectrum of the FRII host (in the red box). The spectrum velocity is centered at the FRII rest-frame, the channel width is 70 km/s.

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