Cold and massive filaments in cool core clusters and groups.

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Understanding the origin of the multi-phase filamentary structures around galaxy clusters is key to gain insight into the AGN-feedback phenomenon. To progress in this topic, we observed with ALMA the cold molecular gas distributions and kinematics in three cluster cores: Centaurus, Abell S1101, and RXJ1539.5. We also gathered ALMA and MUSE data for a sample of 15 systems.

Almost all those observations show clumpy, massive and long, 3--25 kpc, molecular filaments and two objects show nuclear molecular disks. We found that the warm ionized and cold molecular gas are co-spatial and have similar dynamics, consistent with the optical nebula tracing the warm envelopes of cold molecular filaments. The filaments are located preferentially around the radio bubbles inflated by the AGN. Surprisingly, the radial profile of the Halpha/CO flux ratio is roughly constant for most of the objects. This suggests that local processes are responsible for exciting the filamentary emission. If optical emission line nebulae are the surfaces of the molecular clouds then we estimate that between 1.2 to 6 times more cold molecular gas is present than we have detected with ALMA observations.

We found that projected velocities of molecular gas fall in the range of 100 – 400 km/s, generally showing disturbed kinematics but sometimes with coherent velocity gradients. This is likely due to the mixing in projection of several thin filaments yet unresolved. The velocity fields could also be continuously stirred by turbulence induced by bubbles, jets or merger-induced sloshing. The velocity dispersion of the gas is generally low. Overall the velocities and widths of the molecular lines are below the escape velocity of the cluster and the clouds should eventually fall back towards the center of the gravitational potential, fueling the AGN.

Recently, we traced, for the first time, the distribution and kinematics of the warm gas in a sample of 17 galaxy groups core by using several optical emission lines from MUSE observations (Olivares et al. in prep). Galaxy groups provide an excellent opportunity to study AGN-feedback, given that the impact of AGN outburst is more prominent in low-mass systems due to their shallow gravitational potentials. Our preliminary results suggest that cold gas in galaxy groups cores is complex, with a variety of morphologies. The warm gas, in general, is distributed in filamentary structures, but these filaments in projection seem to be shorter than those seen in the galaxy clusters. I also found rare examples of rotating disks and rings, in contrast to the galaxy clusters where the filaments are ubiquitous.

[1] V. Olivares, P. Salome, F. Combes, et al., A&A 631, A22 (2019)