Revealing A Highly Dynamic Cluster Core in Abell 1664 with Chandra

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Abstract

We present new, deep (240 ks) Chandra X-ray observations of the galaxy cluster Abell 1664 (z=0.126). These data reveal rich structure, including cold fronts in the NE-SW direction, suggesting that the hot gas is sloshing in the gravitational potential. The central active galactic nucleus (AGN) appears to have recently undergone a mechanical outburst, as evidenced by our detection of cavities, which may explain the motion of cold molecular clouds previously observed with the Atacama Large Millimeter Array (ALMA). The estimated mechanical power of the AGN may be enough to drive the molecular gas flows. Finally, the most rapidly cooling gas is mostly coincident with the molecular gas reservoir, and may be fueling cold accretion onto the central black hole.

Origin of the Giant Molecular Clouds

Abell 1664 hosts a giant reservoir (~10^9 M☉) of cold molecular gas flows, first detected by Edge et al. (2003), and later resolved with ALMA by Russell et al. (2014). Our deeper Chandra observations are motivated by trying to determine the origin of these reservoirs. Studies have shown that the local cooling time of the intracluster medium (ICM), as well as some missing mass, appears to correlate with the presence of such thermal instabilities (e.g. Gaspari et al. 2012, McNamara et al. 2016, Voit et al. 2017). In this study, we focused on two major mechanisms which could be responsible for mixing of the ICM gas sloshing and AGN feedback.

The Most Rapidly Cooling X-ray Gas

The specific details of how thermal instabilities in the ICM develop are still being investigated, but we can address whether there is sufficient cooling to fuel the massive cold gas reservoir in Abell 1664's central galaxy. To this end, we map temperature variations on the same spatial scale as the molecular gas and find that the most rapidly cooling gas is mostly coincident with the molecular gas. This potentially establishes a link between the cluster atmosphere on tens of kpc scales to the central black hole on which the cold molecular gas could be accreting and fueling the AGN (Pizzolato & Soker 2010).

X-ray Cavities Carved Out by the AGN

McNamara et al. (2016; see also Voit et al. 2017) suggest that uplift by buoyantly-rising radio bubbles, inflated by a central AGN, promotes thermally unstable cooling leading to the formation of cold filaments. Our deeper X-ray data enabled us to detect the X-ray cavities carved out by such radio bubbles. Just as in a dozen other systems observed by ALMA, the molecular clouds in Abell 1664 lie predominantly in filaments projected behind these X-ray cavities. Based on the p^2 work done by these cavities on their surroundings, we estimate the mechanical power of the AGN to be (1.1 ± 1.0) x 10^47 erg/s, which may be enough to drive the molecular gas flows.

Core Sloshing on Multiple Scales

Careful analysis of the surface brightness profiles along certain directions reveal sharp edges that are consistent with density discontinuities behaving as a local, broken power law. While the density drops sharply, the temperature at each discontinuity rises sharply, but in such a way that the pressure remains smooth, indicating the presence of cold fronts (see Markovčič & Viklinčič 2007).

Cold Fronts: Temperature View

Cold fronts are caused by galaxy mergers as infalling subhaloes are stripped of their gas and change the shape of the gravitational potential (Ascasibar & Markovic 2008). As a result, the cluster core oscillates and causes changes in ram pressure, giving the infalling gas some angular momentum and resulting in a characteristic spiral pattern about the cluster core. The cold fronts revealed above are clearly visible here at various radii, where there is high temperature contrast between adjacent regions. These sloshing perturbations may also be responsible for the North-South molecular gas reservoir reported recently by Olivier & al. (2019), which is perpendicular to the gas flows studied here as well as the jet-axis axis. Abell 1664 could thus provide an ideal laboratory for testing the relative importance of these mechanisms in the creation of thermal instabilities.

References