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Gas Flows in Galaxy Clusters

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Galaxies and clusters are embedded in gaseous hot atmospheres that serve as repositories of unused fuel for galaxy formation, ejecta from evolved stars, and mechanical energy released by supermassive black holes. The hot gas located within the central galaxy is expected to cool and fuel star formation. Yet most giant elliptical galaxies are "red and dead." Instead, cooling is suppressed by powerful radio jets that periodically heat the gas in a self-regulating feedback loop. Radio-mechanical feedback may explain the the dearth of luminous, blue galaxies predicted by standard Lambda-CDM models and the excess of hot baryons in the Universe. I will discuss recent studies showing that radio-mechanical feedback also drives hot outflows at rates of tens of solar masses per year from central cluster galaxies. I will highlight new results from the Atacama Large Millimeter Array (ALMA) showing that the hot gas that has cooled resides in nascent molecular gas disks and plumes of molecular gas clouds flying in and out of the galaxy. The ALMA data for the Abell 1835 BCG indicate a molecular outflow at a rate of ~200 solar masses per year behind a pair of buoyantly rising radio/X-ray bubbles. Apparently, X-ray bubbles couple efficiently to molecular clouds, and this may have broader implication for the evolution of galaxies and supermassive black holes.

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