Cooking a 'Sausage': the impact of merger shocks in cluster gas and galaxy evolution

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Abstract

Galaxy clusters mainly grow through mergers with other clusters and groups. Major mergers give rise to important astrophysical phenomena such as the segregation of dark and luminous matter and the formation of cluster-wide traveling shocks and also drive galaxy evolution. The observable effects of shock waves can be seen at radio wavelengths as relics: elongated, diffuse synchrotron emitting areas located at the periphery of merging clusters. Despite the great interest in relics, candidates with simple geometry, undisturbed morphology and high surface brightness are scarce. The 'Sausage' cluster hosts an extraordinary Mpc-wide relic, which enables us to study to study particle acceleration and the effects of shocks on cluster galaxies. We use a unique combination of facilities (INT, WHT, Keck, Subaru, CFHT, GMRT, WSRT, AMI) to obtain the first cluster-wide, multi-wavelength, multi-method analysis aimed at giving a complete picture of a merging cluster with relics. Using the radio data, we derive shock properties and the magnetic field structure for the relic. Using spectral modeling, we test acceleration and electron energy-loss mechanisms and resolve the discrepancy between the Mach number calculated from the radio and X-rays. Our results indicate that particles are shock-accelerated, but turbulent re-acceleration or unusually efficient transport of particles in the downstream area and line-of-sight mixing are important effects. We demonstrate the feasibility of high-frequency observations of radio relics, by presenting a 16 GHz detection of the 'Sausage' relic. The radio analysis is complemented by H mapping of the cluster volume, aimed at providing the first direct test as to whether the shock drives or prohibits star formation. We find numerous H emitting galaxies in close proximity to the radio relic which are extremely massive, metal-rich, mostly star-forming with evidence for gas mass loss though outflows. We speculate that the complex interaction between the merger, the shock wave and gas is a fundamental driver in the evolution of cluster galaxies from gas rich spirals to gas-poor ellipticals.