Anisotropic Thermal Conduction as a Possible Origin of the Mach Number Discrepancy in Radio Relics

○Matsuno Nana[1, 2] Yokoyama Takaaki[3] Brunetti Gianfranco[4] Vazza Franco[4, 5] Nishiwaki Kosuke[4] Machida Mami[1, 2]
(1.SOKENDAI 2.NAOJ 3.Kyoto University 4.INAF-IRA 5.University Bologna)

Galaxy cluster mergers drive shocks in the intracluster medium (ICM). These shocks are observed as discontinuities in X-ray brightness and temperature, as well as synchrotron radio emission from shock-accelerated electrons, known as radio relics. A long-standing issue is that Mach numbers inferred from X-ray observations, M_X, are often systematically lower than those derived from radio spectra, M_{radio} (e.g., Botteon et al. 2016). Several explanations have been proposed, including the re-acceleration of pre-existing cosmic-ray electrons (e.g., Markevitch et al. 2005) and spatial variations in shock strength along the shock surface (e.g., Wittor et al. 2021).

In this work, we investigate whether anisotropic thermal conduction along magnetic field lines can contribute to this discrepancy. We perform one-dimensional MHD simulations with anisotropic thermal conduction, initializing the upstream and downstream states from the MHD shock jump conditions. We then estimate Mach numbers from the resulting conduction-modified shock jumps under the adiabatic jump assumption commonly adopted in observations.

We find that, when the magnetic field is nearly aligned with the shock normal, heat is transported to the upstream region, smoothing the jump profile and forming a conductive precursor. As a result, the Mach number inferred from the temperature jump becomes smaller than those inferred from the velocity jumps, consistent with the observed trend $M_X < M_{radio}$. We also survey the far-upstream Mach number and magnetic-field orientation. Although inferred Mach numbers vary with these parameters, the temperature-based Mach number remains below the velocity-based value. The resulting Mach-number phase diagram can separately constrain the intrinsic shock strength and field orientation by comparing it with observationally inferred X-ray and radio Mach numbers. These results suggest that anisotropic thermal conduction may contribute to the Mach number discrepancy in radio relic shocks.