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Heating and Acceleration at Galaxy Cluster Shocks: Insights from NuSTAR

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Mergers between galaxy clusters drive weak shock fronts into the intracluster medium, capable of both heating the gas and accelerating relativistic particles. Measurements of the high temperature gas and non-thermal inverse Compton (IC) emission that result from these shocks most benefit from sensitive observations at hard X-ray energies. NuSTAR observations of the Bullet cluster, Abell 2163, Abell 665, and most recently, Abell 2146–all massive merging clusters–lead to improved measurements of both the thermal and IC components in these clusters. NuSTAR temperature constraints at shock fronts are used to test competing models of electron heating, namely whether electrons are heated directly by the shock or if they reach the shock temperature further behind the front through interactions with ions. In order to resolve the small angular scales necessary to distinguish these models, we develop a joint Chandra-NuSTAR forward-fitting approach of image data, allowing Chandra to determine the density distribution of the gas while NuSTAR constrains its temperature. Interestingly, we measure temperatures in between the predictions of the two models for the Mach 3 shocks in the Bullet cluster and Abell 665, in contrast with temperature constraints from Chandra data alone. In Abell 2146, the temperatures of its two shock fronts are constrained; we find the bow shock temperature to be in good agreement with the Chandra measurement, but the upstream shock–more consistent with expectations–is significantly lower. We will also present constraints on the flux of IC emission from the electrons producing radio halos in all four clusters.

Topic

Hot and diffuse baryons

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