The Spectacular Merger Event in A3411: Shock Fronts and Radio Relics

Felipe Andrade-Santos[1], Reinout van Weeren[1], Christine Jones[1], Georgiana Ogrean[1], William Forman[1], William Dawson[2], Stephen Murray[1], Kevin Fogarty[3]

[1]Harvard-Smithsonian Center for Astrophysics, [2]Lawrence Livermore National Laboratory, [3]Johns Hopkins University

Introduction: The study of galaxy cluster merger events is of major astrophysical interest as they have a profound and long-lasting impact on the thermodynamic evolution of the ICM. Observed as part of our *Chandra* program on the *Planck* ESZ sample, we discovered that the cluster A3411 (z=0.17) is undergoing a spectacular merger event (see Figs. 1 and 2).

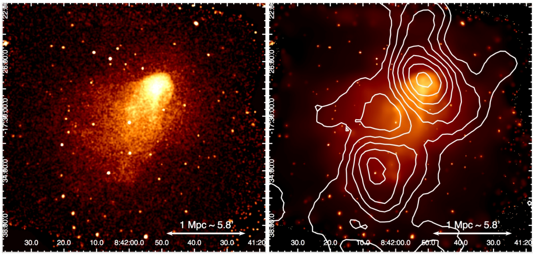

Fig. 1.— Left: 0.5-2.0 keV X-ray (*Chandra*). Right: galaxy isodensity contours in A3411 (north) and A3412 (south).

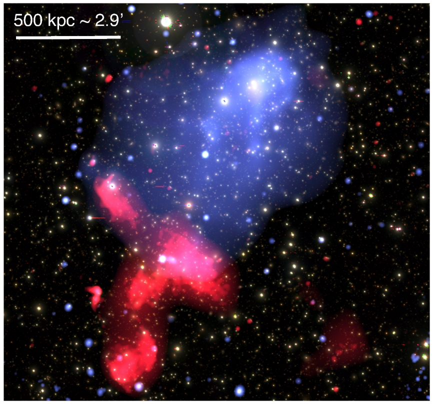

Fig. 2. — Composite image of the A3411/A3412 field: optical (Subaru), 0.5-2.0 keV X-ray (*Chandra* – in blue), and 325 and 610 MHz radio (GMRT – in red).

X-ray — Cold Front and Shock: We measure the surface brightness profile in a wedge towards the north of A3411, centered on the bright northern cool core. Left panel of Fig. 3 shows the cold front signature, as modeled by a β-model and a power law. Center panel of Fig. 3 shows what suggests to be the bow shock, 2′.8 (0.5 Mpc) upstream from the cold front, with the density modeled as a broken power law. The density jump is 1.47 ± 0.32, which implies a Mach number $M = 1.32 \pm 0.22$, if we interpret this density discontinuity as a shock front.

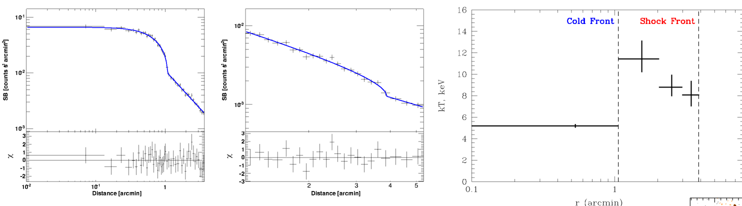

Fig. 3. — Left: surface brightness profile towards the north of A3411. Center: same as for the left panel, except for larger distances from the core. Right: Temperature profile in the direction of the cold front and of the possible shock front (from the same wedge used for extraction of the surface brightness profiles showed in the left and center panels).

Optical — Galaxy Distribution: The optical spectroscopy (Subaru) suggests that the cluster is a merger with a mass ratio 1:1, occurring primarily in the plane of the sky.

Radio — Relics: Giant radio relics are likely the signatures of electrons being (re)accelerated by large-scale shocks (e.g., Ensslin et al. 1998; van Weeren et al. 2010, 2012). Fig. 4 shows the GMRT 610 MHz image of the relic in A3411. Using *Chandra* data, we find hints of a shock in the south of A3411, at the location of the northern part of the relic, which is suggestive of (re)acceleration of electrons.

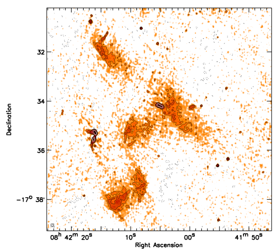

Fig. 4. — GMRT 610 MHz image of the radio relic in A3411.

Conclusions: Although the statistics are insufficient to determine the strength of the southern shock, we know it cannot be too strong given the measured low Mach number in the north. This implies that even low-Mach number shocks are capable of producing bright radio relics. This result indicates that our understanding of particle acceleration at shocks is incomplete (Guo et al. 2014), or that the production of relics requires a pre-existing fossil electron population.

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References: Ensslin, T. A., Biermann, P. L., Klein, U., & Kohle, S. 1998, A&A, 332, 395; van Weeren, R. J., R.ttgering, H. J. A., Brüggen, M., & Hoeft, M. 2010, Science, 330, 347; van Weeren, R. J., R.ttgering, H. J. A., Intema, H. T., et al. 2012, A&A, 546, A124; Guo, X., Sironi, L., & Narayan, R. 2014, ApJ, 794, 153