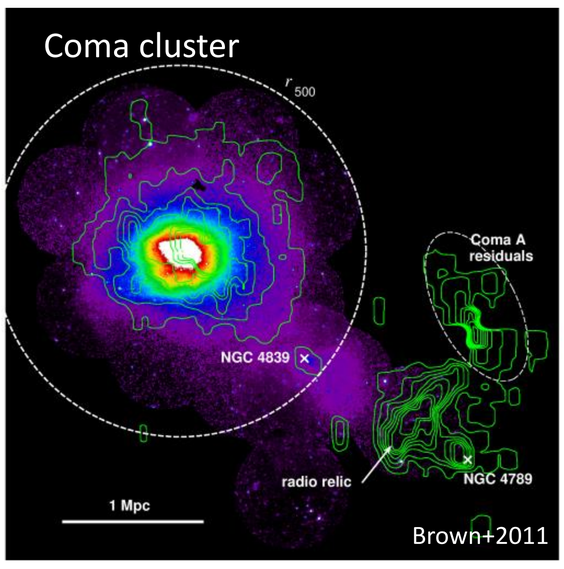
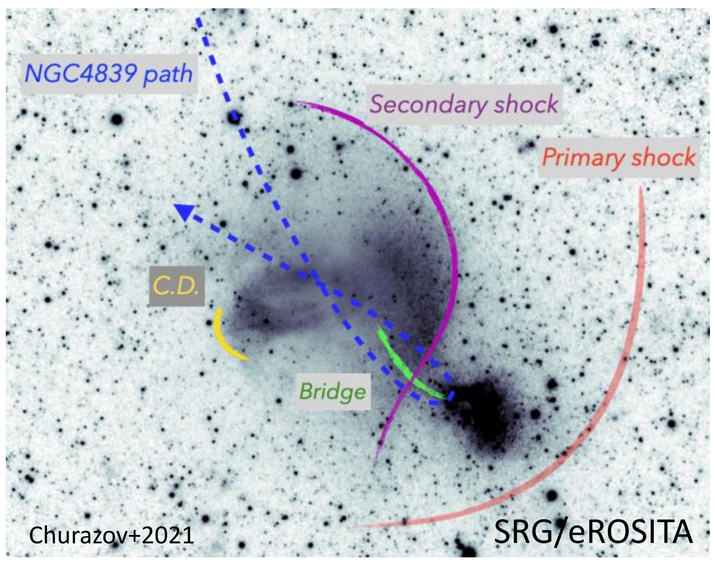
Outskirts of Galaxy Clusters beyond a Self-similar Picture

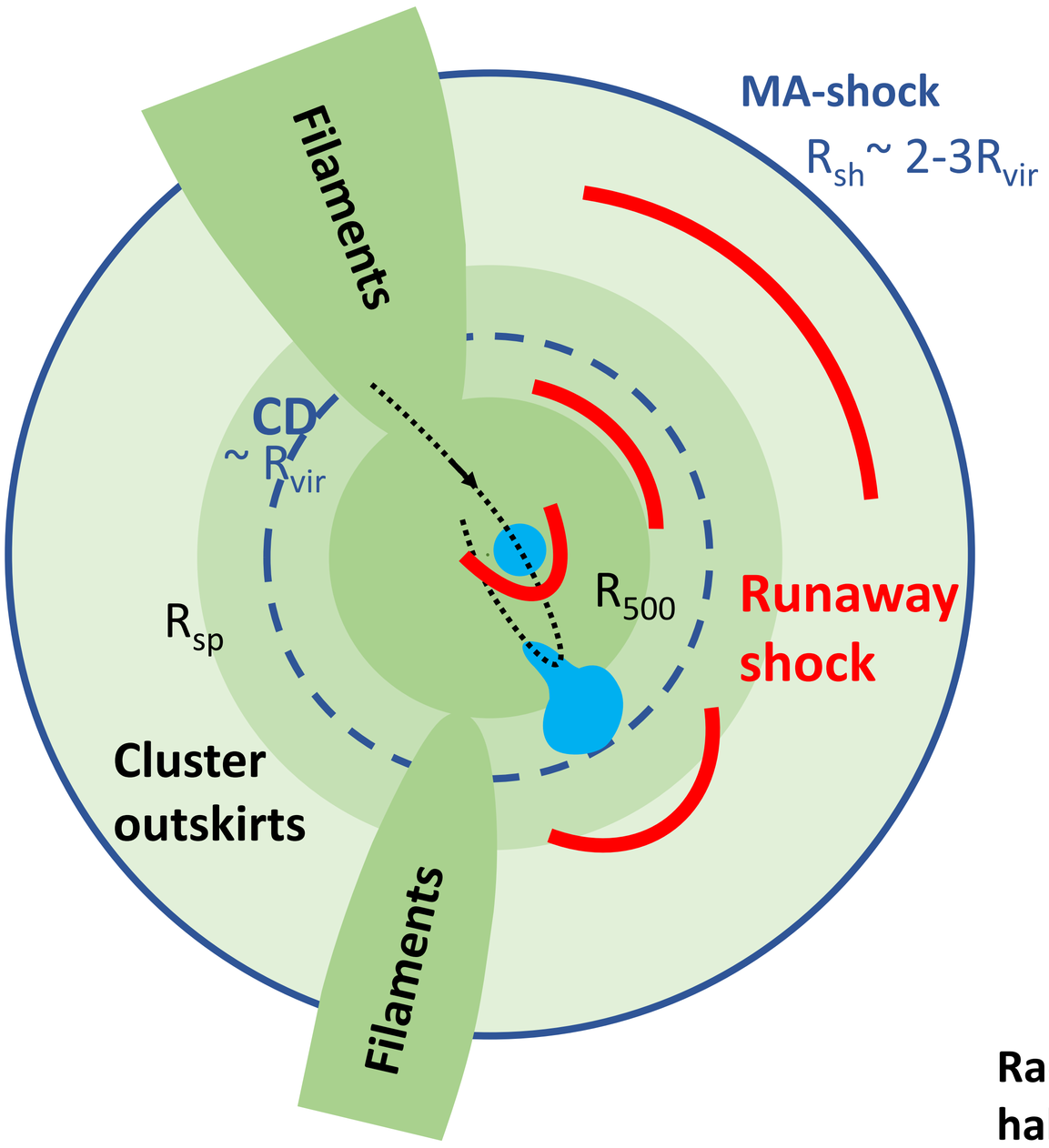
Congyao Zhang (*UChicago*),* Irina Zhuravleva (*UChicago*), Eugene Churazov (*MPA*), Klaus Dolag (*USM*), William Forman (*CfA*), and Andrey Kravtsov (*UChicago*)

INTRODUCTION A large portion of a galaxy cluster extends beyond its virial radius R_{vir}, whose detection is a frontier in large-scale structure studies. Self-similar spherical collapse model predicts a dark matter (DM) splashback and accretion shock in the outskirts of galaxy clusters while missing a key ingredient of structure formation – processes associated with mergers. We built a theoretical framework describing how mergers drive Mpc-scale outflows in galaxy clusters and shape gas and DM distributions in their outskirts.

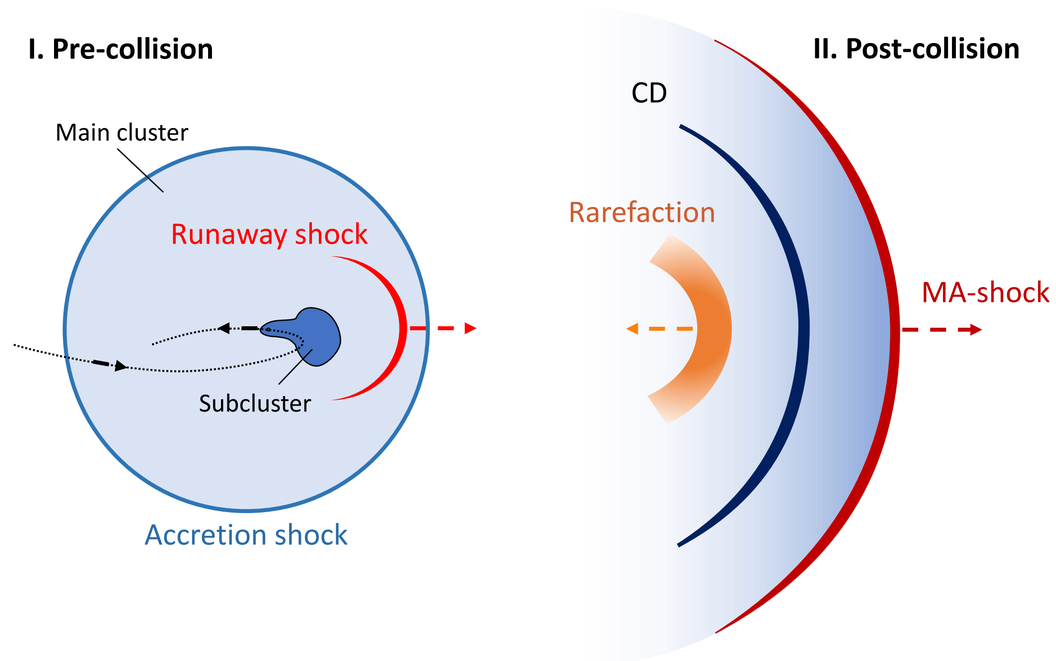
Runaway merger shock scenario: It describes a late-stage evolution of merger shocks driven by infalling substructures (e.g., groups and small clusters) in the intracluster medium (ICM; Zhang+2019). These runaway shocks show unique *N*-shape waveform and presumably associate with the outer radio relics found in a number of clusters. The Coma cluster provides a beautiful example of the runaway shock supporting our theoretical prediction (Lyskova+2019, Churazov+2021).



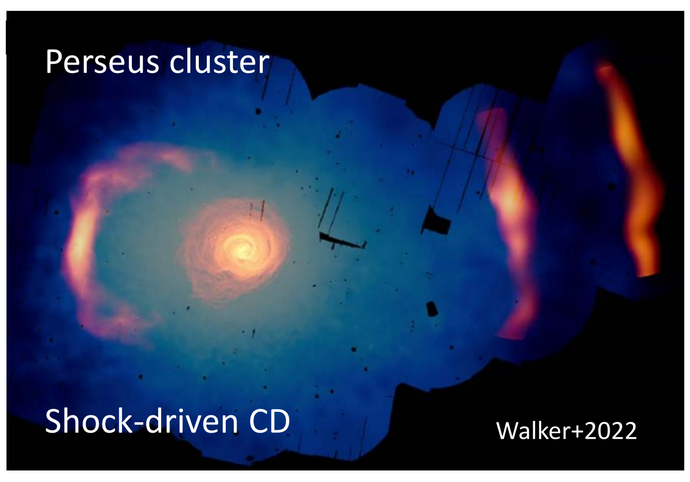




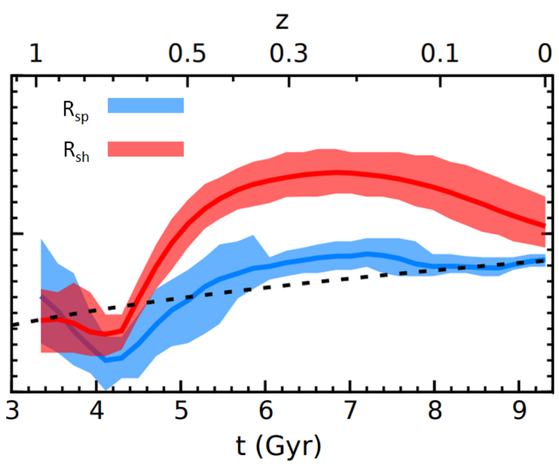
Merger-accelerated Accretion shocks (MA-shocks): Runaway shocks eventually overtake the accretion shock at the boundary of the ICM and expand significantly the gaseous atmospheres of galaxy clusters. The nature of strong external shocks at peripheries of galaxy clusters and groups are MA-shocks formed in such shock collisions (Zhang+2020, 2021) powered by mergers but not accretion.

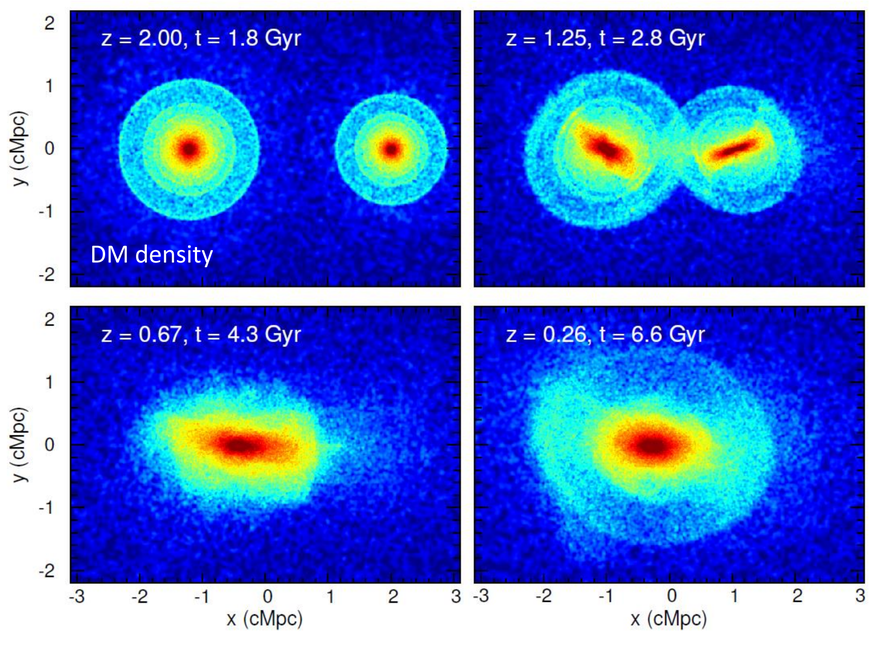


Mpc-scale contact discontinuities near R_{vir}: While colliding between an accretion and runaway shocks, a giant contact discontinuity (CD) is formed near R_{vir}. A candidate of such structures has been identified in the Perseus cluster (Zhang+2020), providing a direct evidence of the past shock collision.



Radial offsets between boundaries of the ICM and DM halos: Mergers could easily generate MA-shock-splashback radial offsets measured in cosmological simulations. We demonstrated this by performing simulations of merging self-similar clusters in an idealized cosmological context and investigating their DM and gas evolution. Our simulations show that clusters rapidly contract during a major merger event and their splashback radius R_{sp} decreases, approaching R_{vir}. MA-shocks reside in regions away from filaments where smooth mass accretion rate is small, revealing significant radial offsets from the DM splashback boundary (Zhang+2021).





Find my papers here

Please contact me if you have any questions

* cyzhang@astro.uchicago.edu