The Connection between Cluster Equilibrium and X-ray Merger Signatures

Marios Chatzikos (Univ. of Kentucky); Craig Sarazin (Univ. of Virginia); Brian O'Shea (Michigan State Univ.)

Abstract:

I use the *S*imulation *L*ibrary of *A*strophysical galaxy cluster *M*ergers (SLAM) database to quantify the connection between X-ray substructure measures and the true dynamical state of the system. SLAM consists of a set of 156 adiabatic simulations of binary galaxy cluster mergers, that covers 2 dex in mass. I have quantified the substructure using center shifts and power ratios. Mergers of intermediate mass contrasts, 2:1 and 5:1, produce substructure signals that can persist in X-ray images for at least 1–2 sound crossing times. The amplitude of both measures depends strongly on the initial mass contrast. However, the measures for major mergers (mass contrast <3) are generally independent of the system mass. Neither measure follows the true dynamical state of the system closely, although the center shifts appear to be a better proxy. Comparisons with the virial and hydrostatic disequilibrium parameters reveal that there is no value of either substructure measure that unambiguously distinguishes merging from relaxing systems.

SLAM Description:

156 simulations of binary cluster mergers done with Gadget-2. The set spans a factor of 200 in the primary mass; uses mass ratios 1, 2, 5, and 10; and spin parameters λ = 0, 0.025, 0.05, and 0.075. Minimum cluster mass: 10^{13} $M_{\odot}$. Time integration: 10 Gyr.

Centroid Shifts:

Centroids iteratively determined as in Jeltema+08. The shifts are computed as the standard deviation of the displacements between the position of the emission-weighted center within an aperture and the formal centroid. The aperture size varies in (0.05–1) R_{500} in steps $0.05R_{500}$.

$$\langle w \rangle = \frac{1}{R_{500}} \left[\frac{1}{N-1} \sum (\Delta_i - \overline{\Delta}) \right]^{1/2}$$

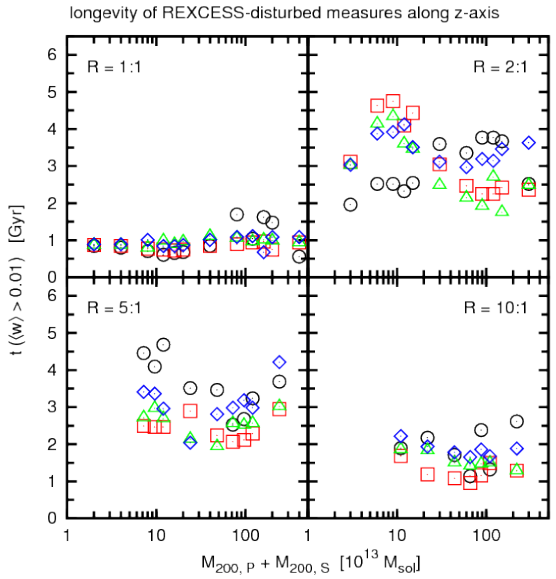

Figure 1: Longevity of centroid shifts in excess of 0.01 R_{500}, the limit favored by the REXCESS team (Bohringer+10, Pratt+10). Symbols are: circles for λ=0; squares for λ=0.025; triangles for λ=0.05; and diamonds for λ=0.075.

Hydrostatic Offset:

Also known as the hydrostatic disequilibrium parameter, it measures the deviation from hydrostatic equilibrium (HEQ), and it is equivalent to the error in 3D mass introduced by the assumption of HEQ.

$$H(r) = 1 + \frac{r^2\, dP/dr}{\rho G M(<r)} = 1 - \frac{M_{\rm HS}}{M(<r)}$$

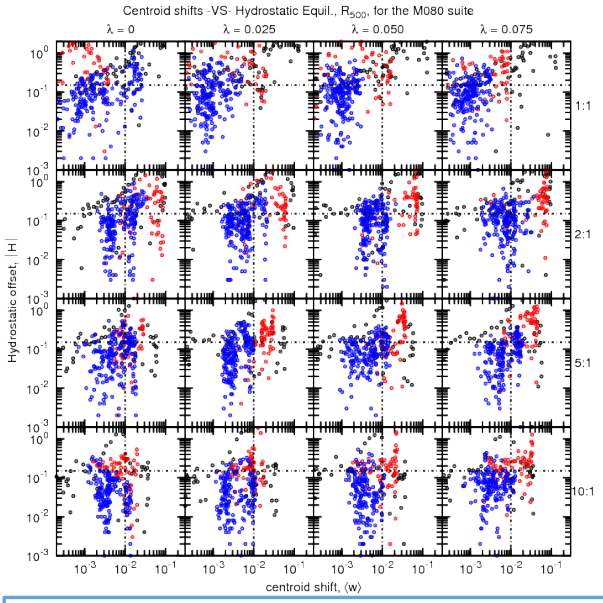

Figure 2: Correlation of center shifts and hydrostatic offset. Symbols: red circles for time between 1st and 2nd approach; and blue for after 2nd approach. Dashed lines are 15% HEQ error, and REXCESS center shift limit. Ideally, the merger should not be found in the top left or bottom right quadrants.

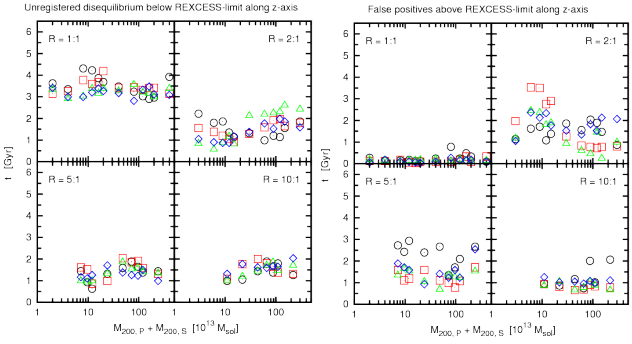

Figure 3: (left) Time that mergers spend in the upper left quadrant on the w-H plane, i.e., with significant hydrostatic offsets, but no discernible X-ray substructure. (right) Time that mergers spend in the lower right quadrant, in HEQ, but with significant X-ray substructure signatures. Symbols as in Fig. 1.

References:

Böhringer et al. 2010, A&A, 514, A32 • Jeltema et al. 2008, ApJ, 681, 167 • Pratt et al. 2010, A&A, 511, A85