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Mass Estimation of Merging Galaxy Clusters

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(Abstract)
We investigate the impact of mergers on the mass estimation of galaxy clusters using N-body + hydrodynamical simulation data. We estimate virial mass from these data and compare it with real mass. When the smaller subcluster's mass is larger than a quarter of that of the larger one, virial mass can be larger than twice of the real mass. The results strongly depend on the observational directions, because of anisotropic velocity distribution of the member galaxies. We also make the X-ray surface brightness and spectroscopic-like temperature maps from the simulation data. The mass profile is estimated from these data on the assumption of hydrostatic equilibrium. In general, mass estimation with X-ray data gives us better results than virial mass estimation. The dependence upon observational directions is weaker than in case of virial mass estimation. When the system is observed along the collision axis, the projected mass tends to be underestimated. This fact should be noted especially when the virial and/or X-ray mass are compared with gravitational lensing results.

Introduction

We have multiple observational ways of cluster mass estimation. However, these methods do not always give us consistent results. Some assumptions are necessary in the mass estimation method. The assumptions used in mass estimation are not very good in clusters during or a few Gyr after mergers. However, it is not trivial how these systems will be overestimated or underestimated. This depends on the phase of mergers, geometry of the system and observational direction, and which mass estimation method we use. In this poster, we investigate the impact of mergers on the cluster mass estimation using N-body+hydrodynamical simulation data. We make mock observational data, and perform ``simulations of mass estimation'' for these mock data, and compare the results with actual mass distribution in the simulation data.

Simulation Data（N-body＋Hydrodynamics）

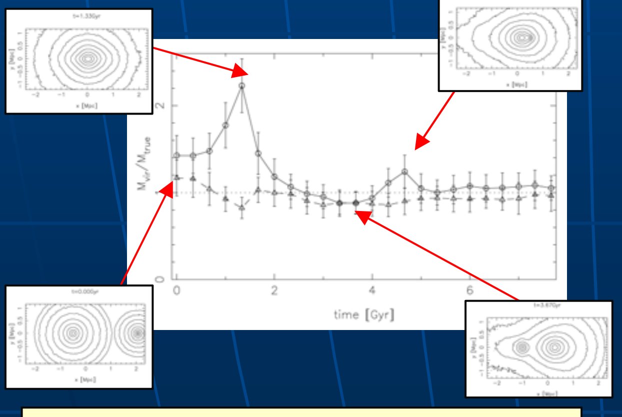
- N-body: Particle Mesh (PM) method
- Hydrodynamics: Roe TVD method
- Self-gravity: FFT with isolated boundary conditions
- Simulation Box: 18Mpc×9Mpc×9Mpc (256×128×128)
- Particle number: N= 256×128×128（～4 millions）

Mass Estimation through the Virial Theorem

- We observe a cluster in the simulation data from a certain direction.
- We randomly choose N_{samp} particles from the N-body one and recognize them as galaxies whose line-of-sight velocity is observed.
- We estimated virial mass using N_{tr} different sets of "member galaxies", and calculate the mean and variance of virial mass.

$$M_{\rm VT} = \frac{3\pi}{G}\sigma_{\rm los}^2\left\langle\frac{1}{r}\right\rangle^{-1}$$

$$\left\langle\frac{1}{r}\right\rangle^{-1} = N_p\left(\sum_{i>j}^{N_p}\frac{1}{r_{ij}}\right)$$



Evolution of the ratio of M_{vir} to M_{true} for 4:1 merger simulation, with snapshots of projected mass distribution.

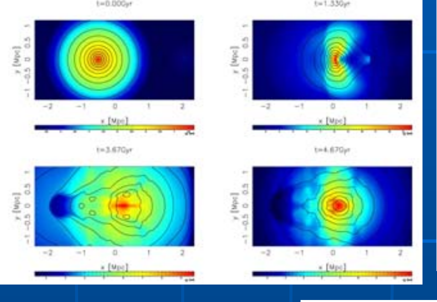
circles＋solid lines: observation along the collision axis
triangles＋dashed lines: observation from the direction perpendicular to the collision axis
N_{samp}=100, N_{tr}=100

Mass Estimation with X-ray Data

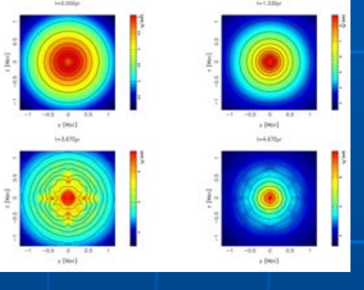
- We made two-dimensional X-ray brightness distribution and spectroscopic-like temperature maps.
- Density profiles are calculated in a standard deprojection procedure.
- Density and temperature profiles are fitted by the β–model function.
- The mass profile is derived assuming hydrostatic equilibrium.

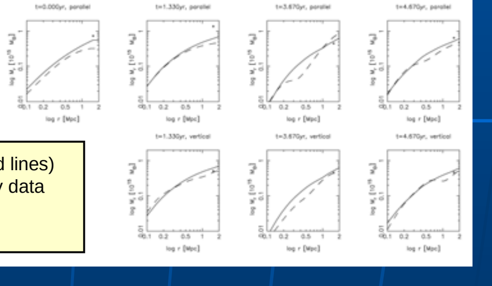
$$M_r = -\frac{k_B T_g r}{G\mu m_p}\left(\frac{d\ln\rho_g}{d\ln r}+\frac{d\ln T_g}{d\ln r}\right)$$

X-ray surface brightness (contours)
Spectroscopic temperature (colors)
Seen from the direction perpendicular to the collision axis



X-ray surface brightness (contours)
Spectroscopic temperature (colors)
Seen from the direction parallel to the collision axis



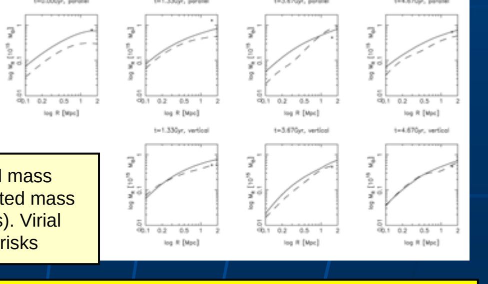


Radial profiles of actual mass (solid lines) and estimated mass from the X-ray data (dashed lines). Virial mass is also represented by asterisks.

$$M_{\rm prj}(R) = \int_0^R 2\pi R'\Sigma(R')dR',$$

$$\Sigma(R) = 2\int_0^{b_{\rm out}}\rho(\sqrt{R^2+b^2})db,$$

$$\rho(r) = \frac{1}{4\pi r^2}\frac{dM}{dr}$$



Radial profiles of actual projected mass (solid lines) and estimated projected mass from the X-ray data (dashed lines). Virial mass is also represented by asterisks

Summary

- We investigate the impact of mergers on the mass estimation of galaxy clusters using N-body + hydrodynamical simulation data.
- We estimated the virial mass from these data. The results strongly depend on the observational directions.
- In general, the mass estimation with X-ray data gives us fairly better results than the virial mass estimation.
- When the systems are observed along the collision axis, the projected mass tends to be underestimated. This fact should be noted when the virial and/or X-ray mass are compared with gravitational lensing results.