OBSERVING SIMULATED GALAXY CLUSTERS: THE PROSPECTS OF VELOCITY DIAGNOSTICS

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“Galaxy clusters as giant cosmic laboratories”
OUTLINE

• Motivation
• Phox: structure of the code
• Application, perspectives
• Summary
CLUSTERS OF GALAXIES:
AT THE TOP OF THE COSMIC HIERARCHY

- Crossroads of cosmology and astrophysics

- Hot diffuse plasma (ICM), $T \sim 10^7$-$10^8$ K: \textbf{X-rays}

> Use X-ray observations of the ICM to trace intrinsic structure & total mass

Hydrostatic Equilibrium

$$\frac{1}{\rho} \frac{dP}{dr} = -\frac{GM}{r^2}$$

- Spherical symmetry
- Gas pressure support only due to thermal motions

\textbf{X-RAY MASS:}

$$M(<r) = -\frac{k_B T_{\text{gas}}}{G \mu m_p} r \left( \frac{d \ln \rho_{\text{gas}}}{d \ln r} + \frac{d \ln T_{\text{gas}}}{d \ln r} \right)$$
Reliable? Valid assumptions? What about non-thermal motions?

\[ \frac{1}{\rho} \frac{dP}{dr} = -\frac{GM}{r^2} \]

where

\[ P = P_{\text{thermal}} + P_{\text{non-thermal}} \]

e.g. turbulence, bulk motions (streaming, rotation)
[Fang et al. 09; Lau et al. 09; Zhuravleva et al. 10; Biffi, Dolag, Böhringer 2011]

✓ possible to constrain directly with hydro-simulations!

(possibly) detectable spectral signatures: velocity broadening of emission lines

Required faithful comparison between hydro-simulations and X-ray observations
A NEW X-RAY PHOTON SIMULATOR

hydro-simulation

Gas element ~ single-temperature emitting plasma

Emission in the X rays: spectrum → photons

mock observation

$$(x,v)_i$$

$$(n,T,Z)_i$$
For each gas element in the simulation output compute a model spectrum. Calculate total number of photons from spectrum, assuming $A_{\text{fid}}, \tau_{\text{obs,fid}}$. Populate the current spectrum with a distribution of photons. Output files with photon packages. For each package position, velocity and a list of photon energies are stored.

**UNIT 1:** generation of the ideal virtual cube of photons

Choose l.o.s. direction. Select subregion of interest. Correct photon energies for Doppler Shift along l.o.s. Filter according to desired collecting area and observing time. Photon list (arrival time, direction and energy).

**UNIT 2:** geometrical selection and projection along l.o.s.

Use any external software explicitly designed to simulate a specific X-ray instrument (e.g., XISSIM). Convolve the simulated photon list with the response of a desired X-ray instrument.

**UNIT 3:** convolution with a real instrumental response.

Synthetic X-ray event file.

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Biffi, Dolag, Böhringer, Lemson 2012, MNRAS
RECONSTRUCTING GLOBAL PROPERTIES: THE $L_X$-$T$ RELATION

“MAGNETICUM” hydro-simulation:
- box size of 352 Mpc/h
- $\sim 4 \times 10^8$ particles
- $z_{\text{snap}} = 0.2$

- sample of simulated clusters: 43 halos

✓ mock Chandra observations obtained with PHOX
ICM VELOCITY DIAGNOSTICS: $L_X$-T RELATION

Biffi, Dolag, Böhringer 2012, to be submitted
preserve high spatial and energy resolution: predict X-ray observational results achievable with upcoming instruments, study of gas non-thermal velocity field from high-precision spectroscopic data; effect of velocity field on mass determination and scaling relations;

perform very efficiently mock X-ray observations of large cosmic volumes;

process very efficiently large catalogues of clusters, from a single photon cube for a given simulation output;
THANKS!

This starlight falls on our eyes after a journey across trillions of miles—dying here at last, so far from home, all so we can see some pretty dots.

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