Transport mechanisms in the intracluster medium

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OUTLINE

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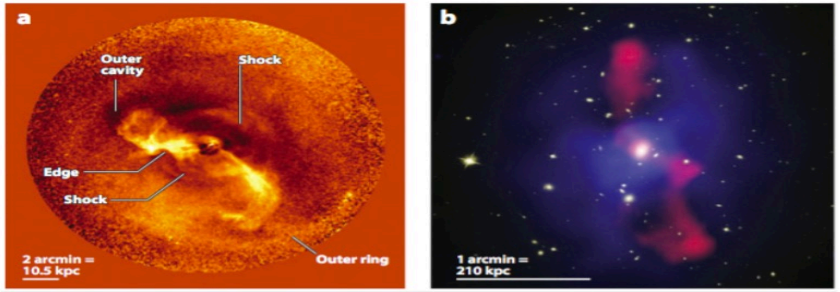
BACKGROUND

Intracluster medium (ICM): plasma gas

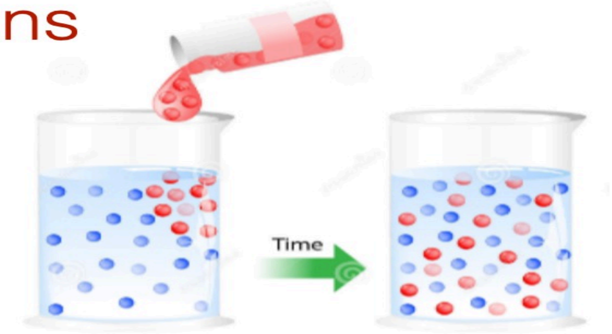
Typical temperature: 10^7K ;

Density: 10^{-3} particles per cubic centimeter.

ICM turbulent motions: an essential piece of puzzle for many astrophysical questions

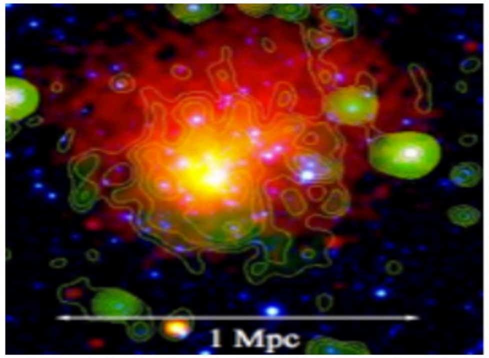


kinetic AGN feedback; the cooling flow problem

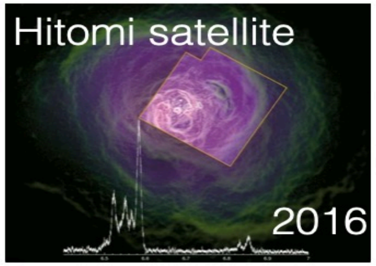


diffusion of chemical elements and heat

galaxy - ICM interaction



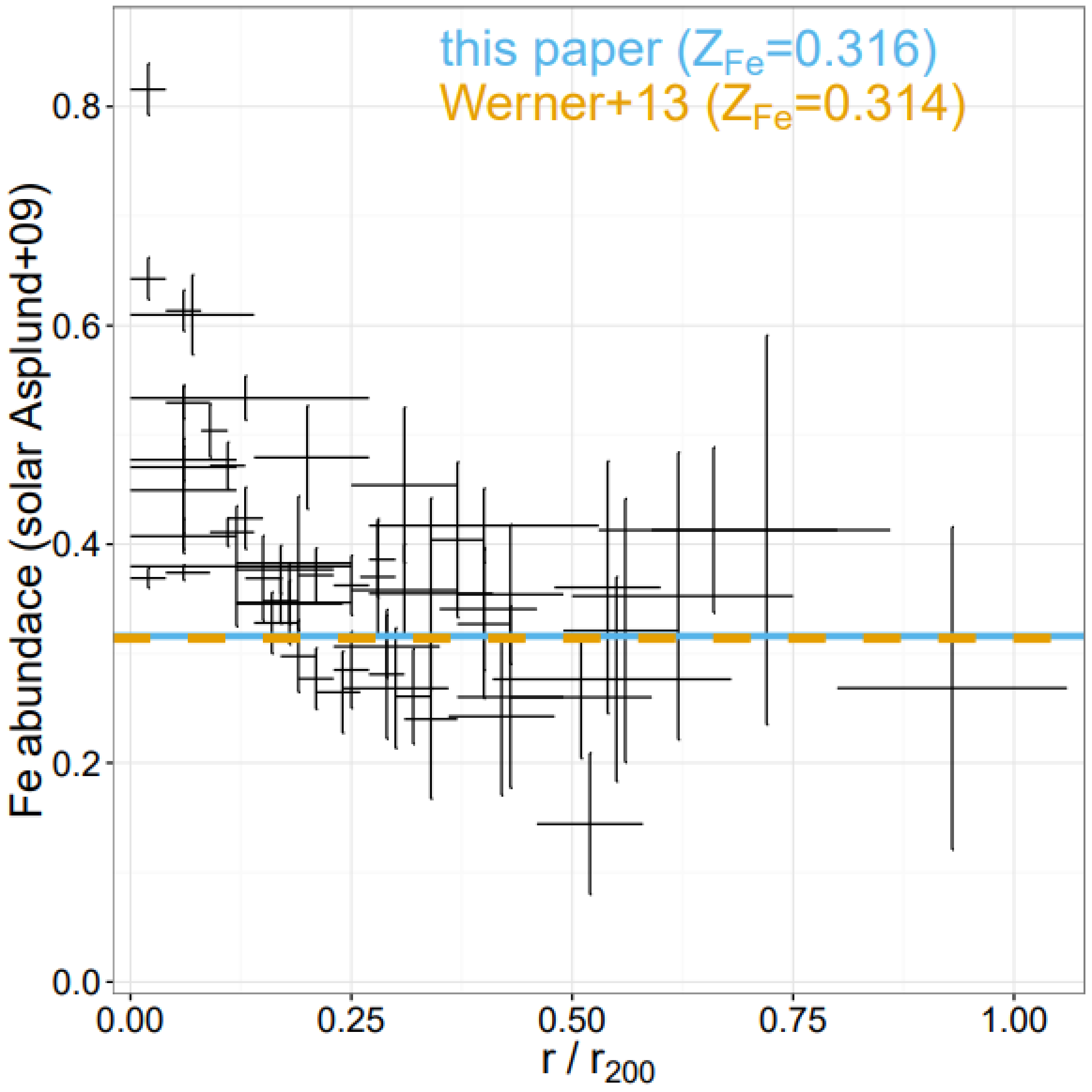
magnetic fields, cosmic rays and the radio emissions



First direct measurement of ICM turbulence

high-res X-ray spectra: a new window

Measurements of metal abundance in the outskirts are extremely challenging



From O. Urban et al(2017), *Suzaku*

With Suzaku few clusters have measurements reaching the virial radius

How do metals spread in galaxy clusters?

Study the particle transport during major mergers in ICM:

1. Look for possible coherent transport mechanism.
2. Use pair dispersion statistics to study the effect of particle transport at various epochs of the cluster assembly history.
3. Investigate how merger influences ICM transport.

SIMULATION

Daisuke Nagai' s group

Lagrangian tracer particle re-simulation of the non-radiative run of Omega500 cosmological simulation to study the dynamical process in ICM using galaxy cluster

λCDM cosmology with WMAP five-year (WMAP5) cosmological parameters:

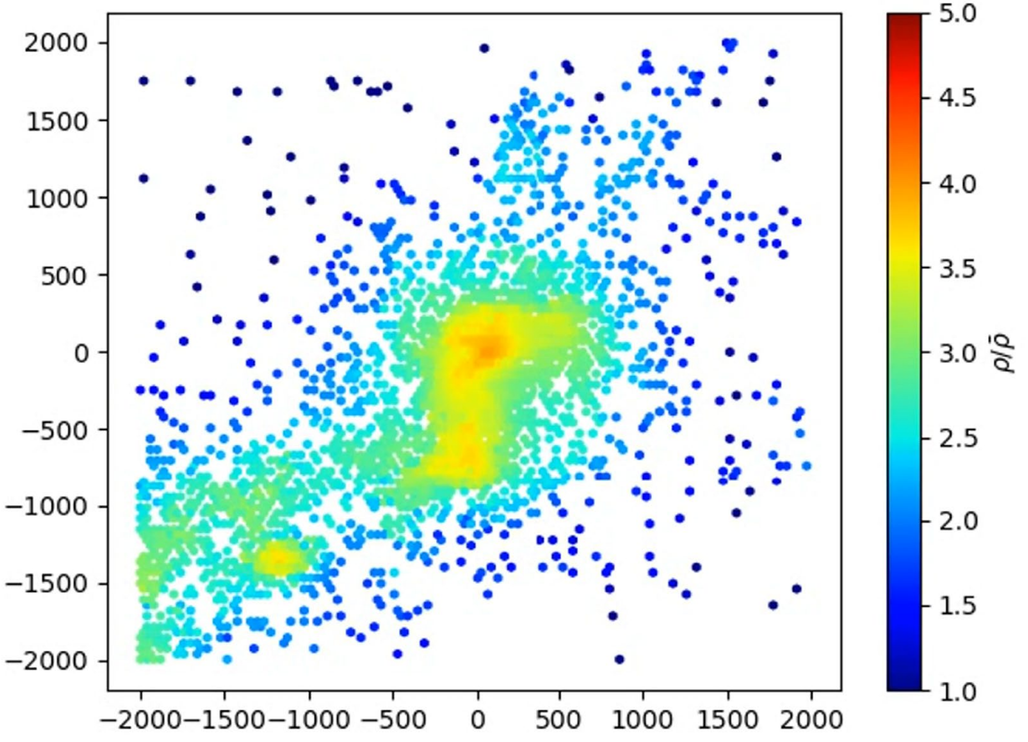
$\Omega_m = 0.27, \Omega_b = 0.0469, h = 0.7, \sigma_8 = 0.8$.

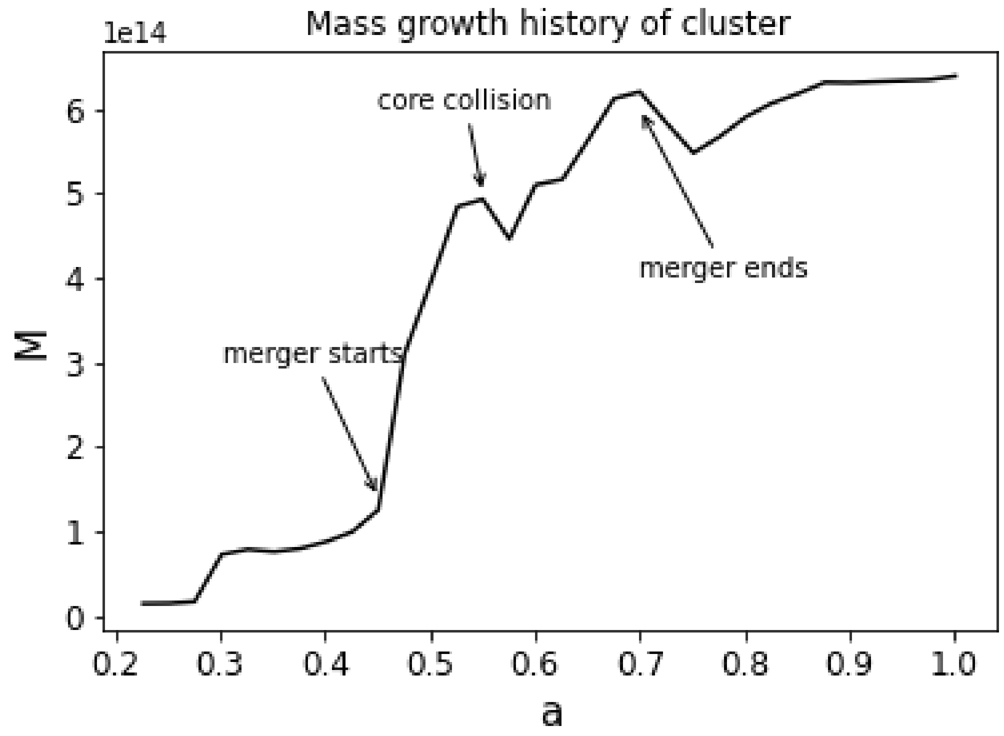
Simulation box size: 500 h^{-1} Mpc, maximum comoving spatial resolution is 3.8 h^{-1} kpc.

RESULTS OF THE PROJECT

The formation history of a selected massive galaxy cluster

a=0.2-1.0

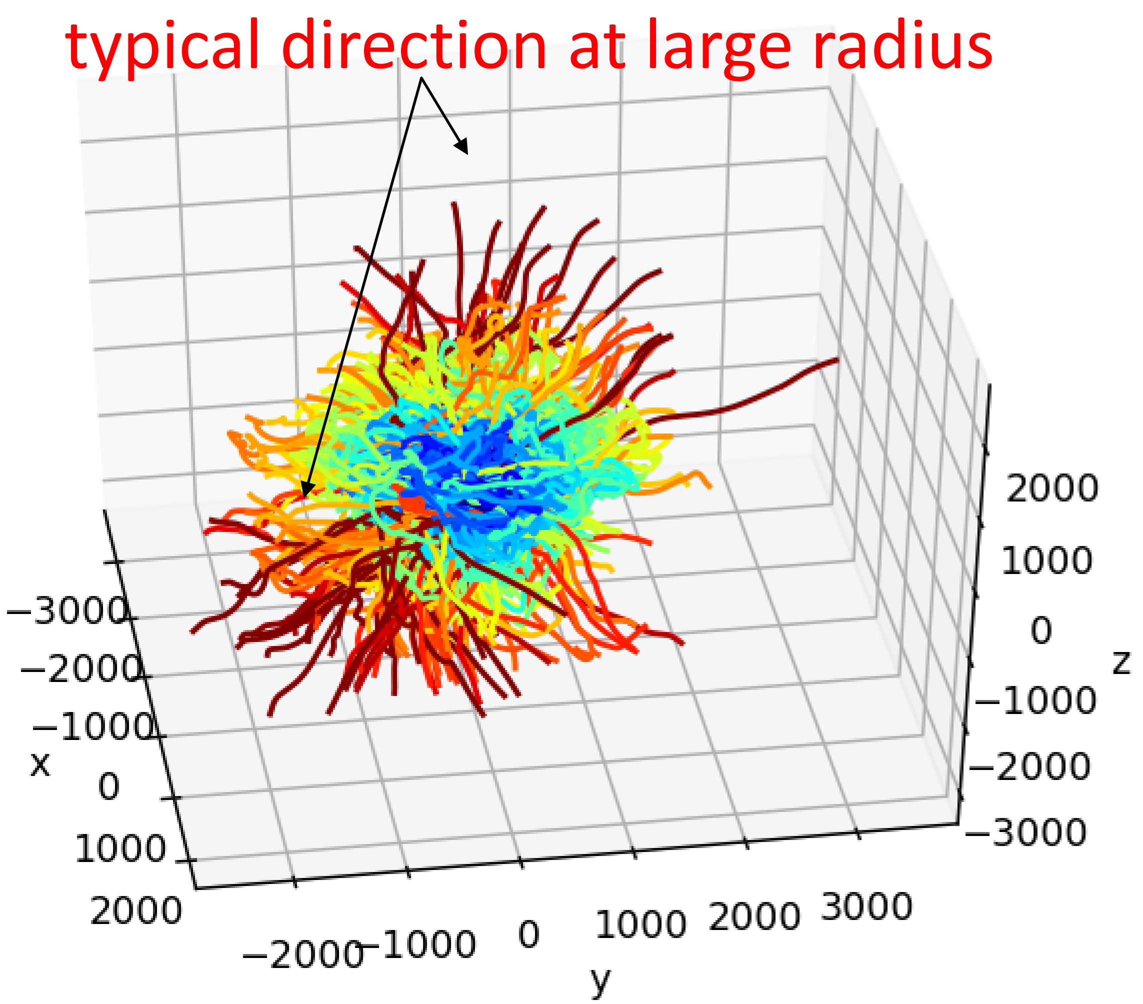




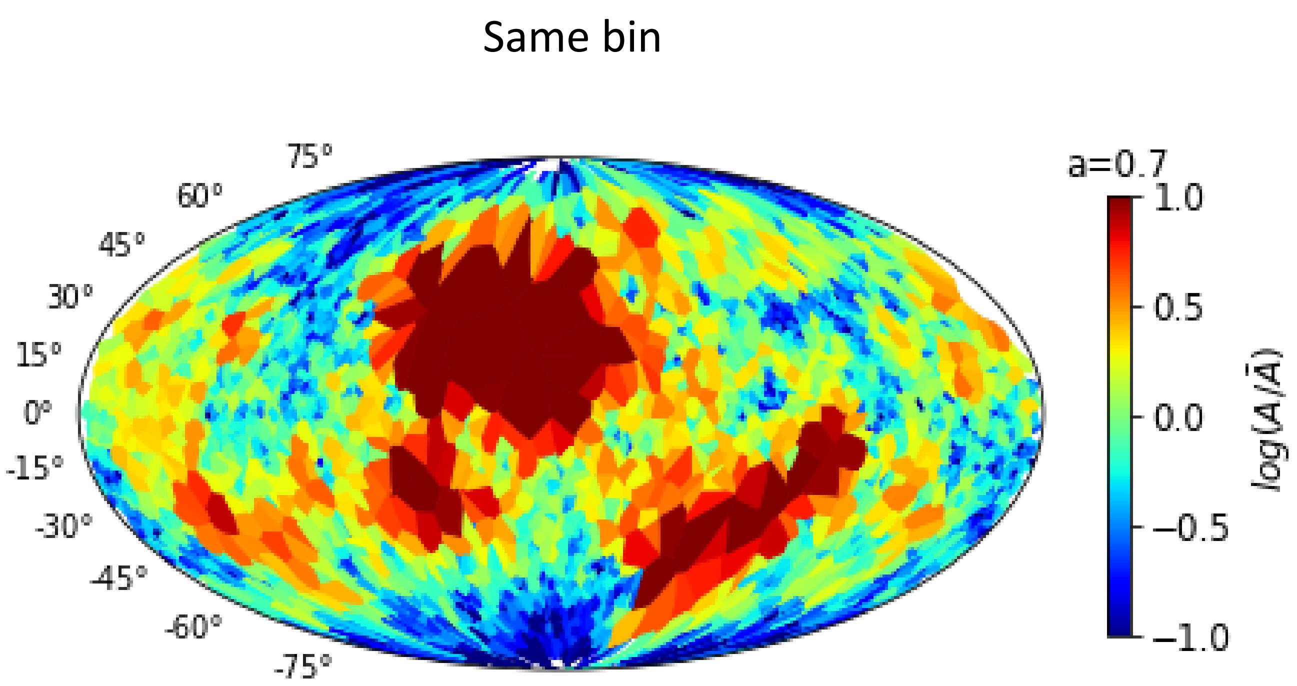
The particle density distribution of the galaxy cluster change with scale factor(a) which in the range of 0.2-1.0

The major merger starts at a=0.45, ends at a=0.7. Core collision happens at a=0.55. The mass of cluster at a=1 is M_{500c} = 6.39 $\times$ $10^{14} M_{\odot}$.

COHERENT TRANSPORT



3D path of particles during the major merger.

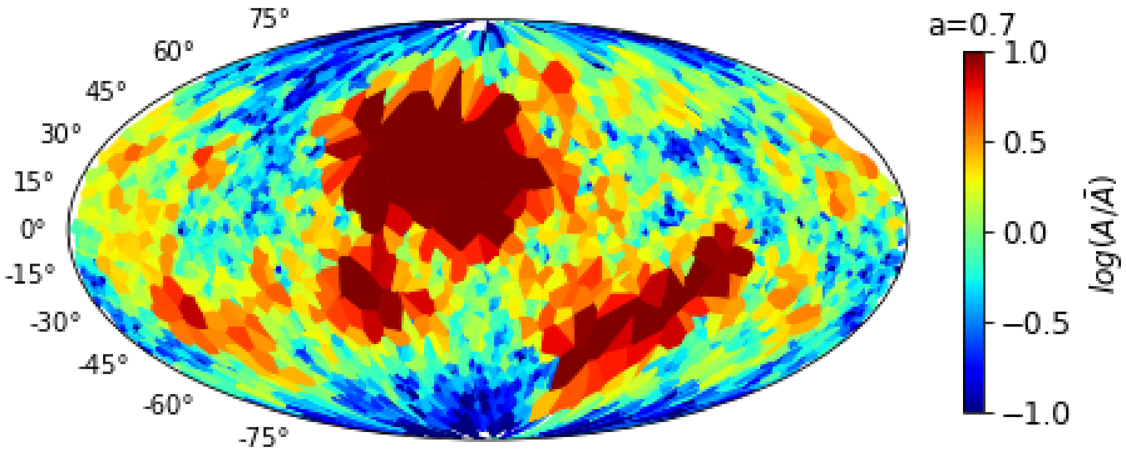


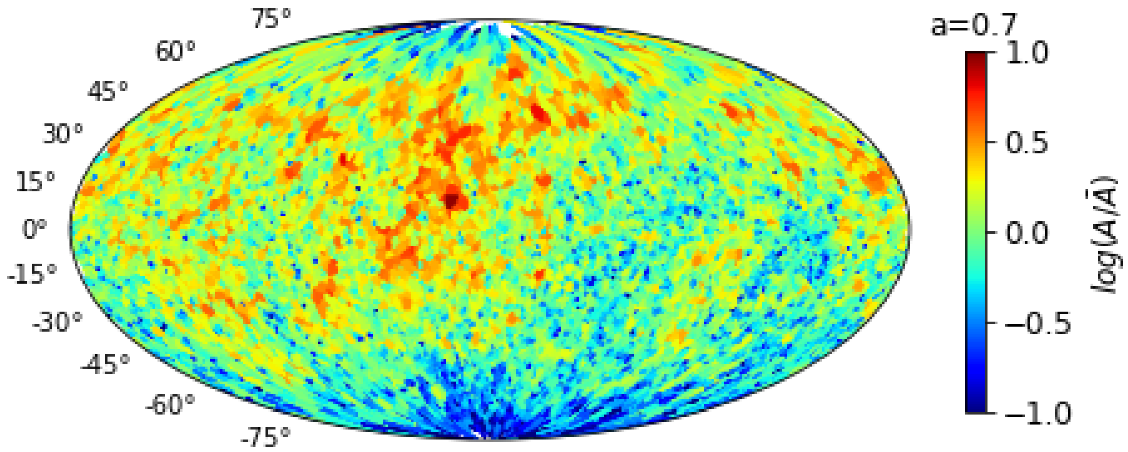
Distribution of particles at 4π.

Different radius

0.88-1.77 R_{500}

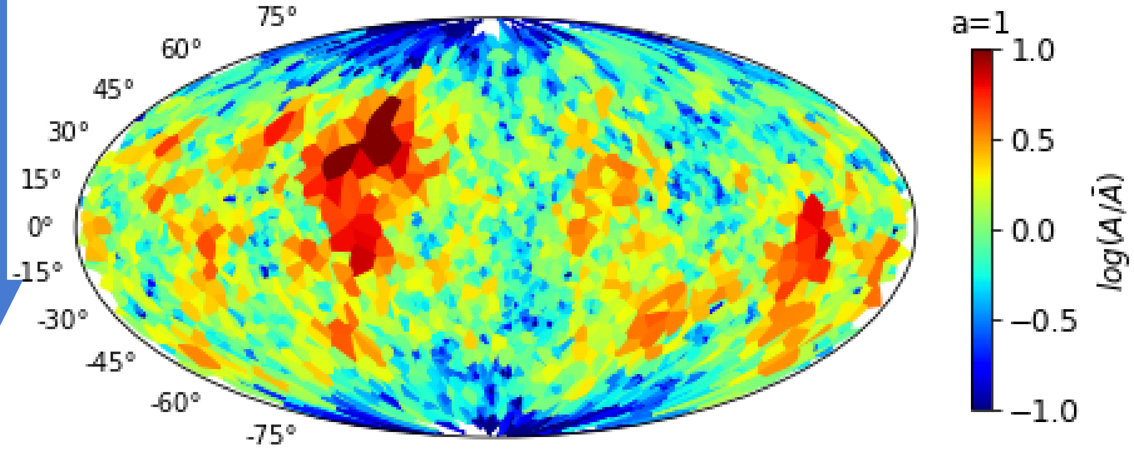
0-0.88 R_{500}





Time

Coherence weakens with time(turbulence influence)

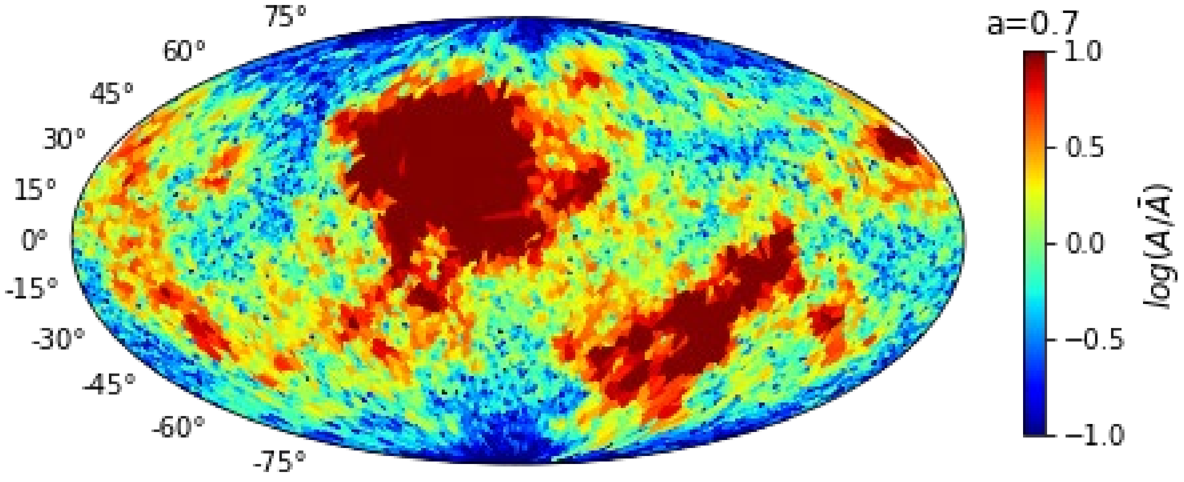


The coherent transport mechanism is transient and discontinuous

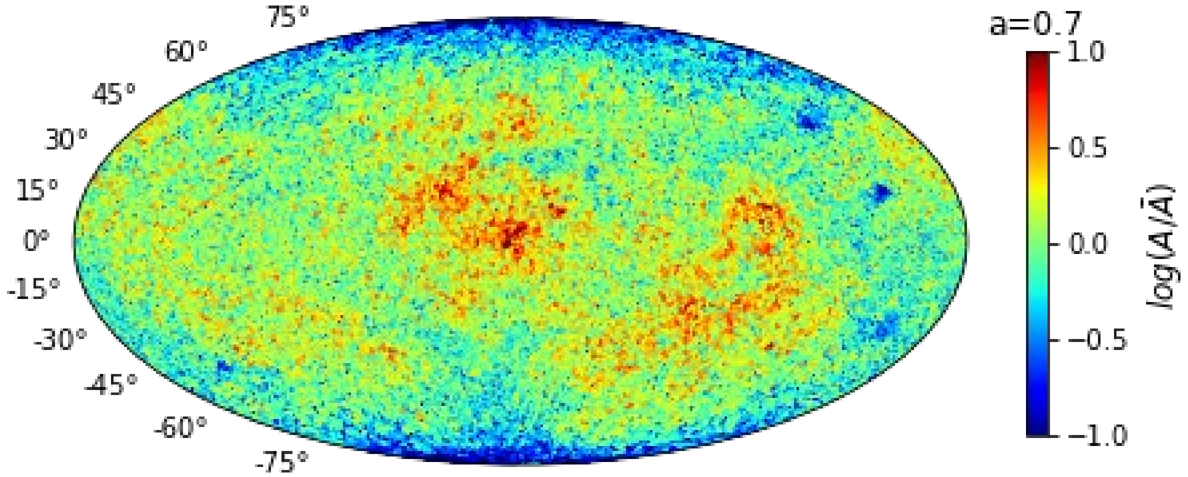
Reason:

The particles began to fall back during the transportation process, so that the particles did not reach the periphery. The turbulent intensity in the interior disrupts the coherent transport.

Picked particles in 0.8-1.7 R_{500}



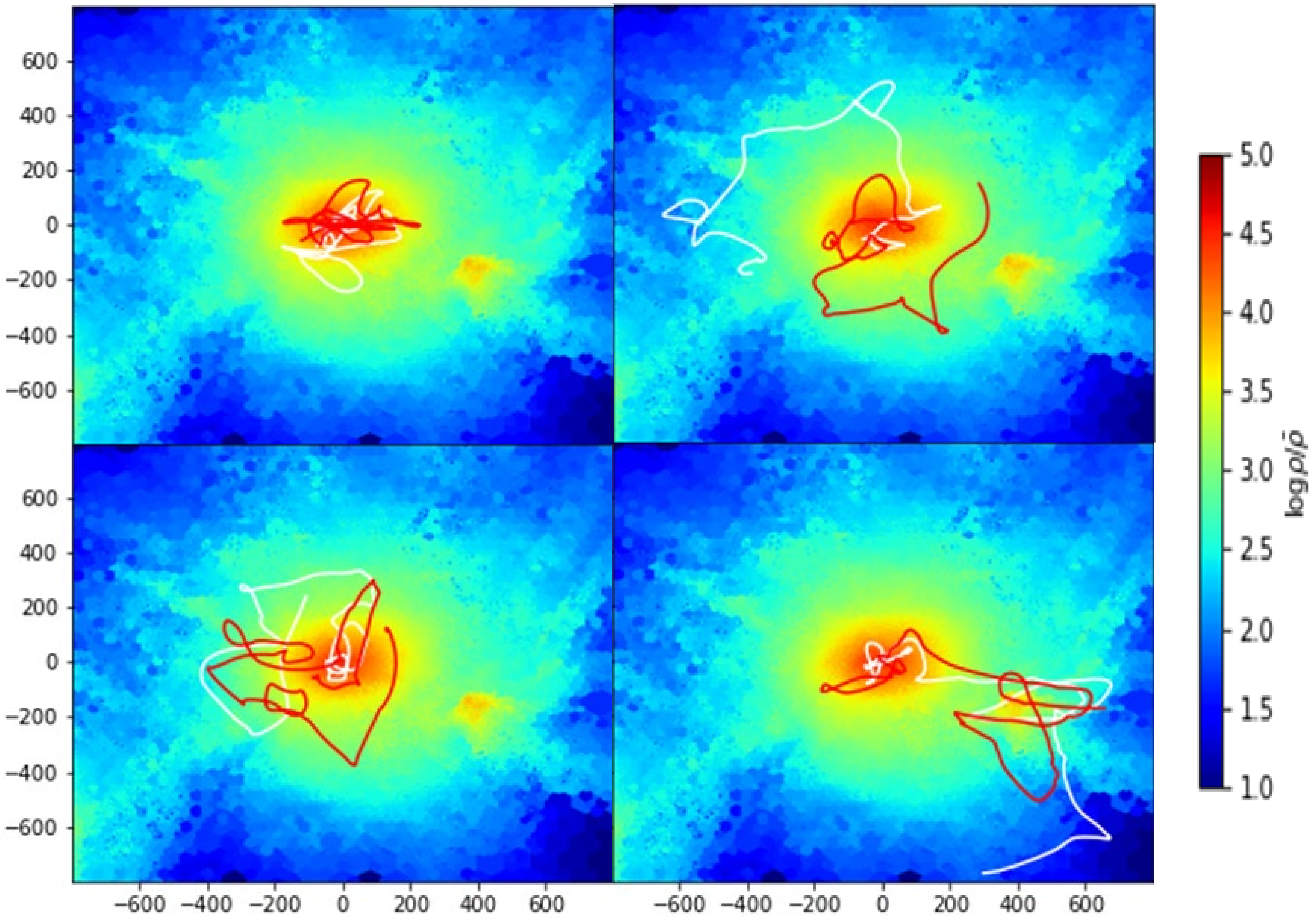
All particles in 0.8-1.7 R_{500}



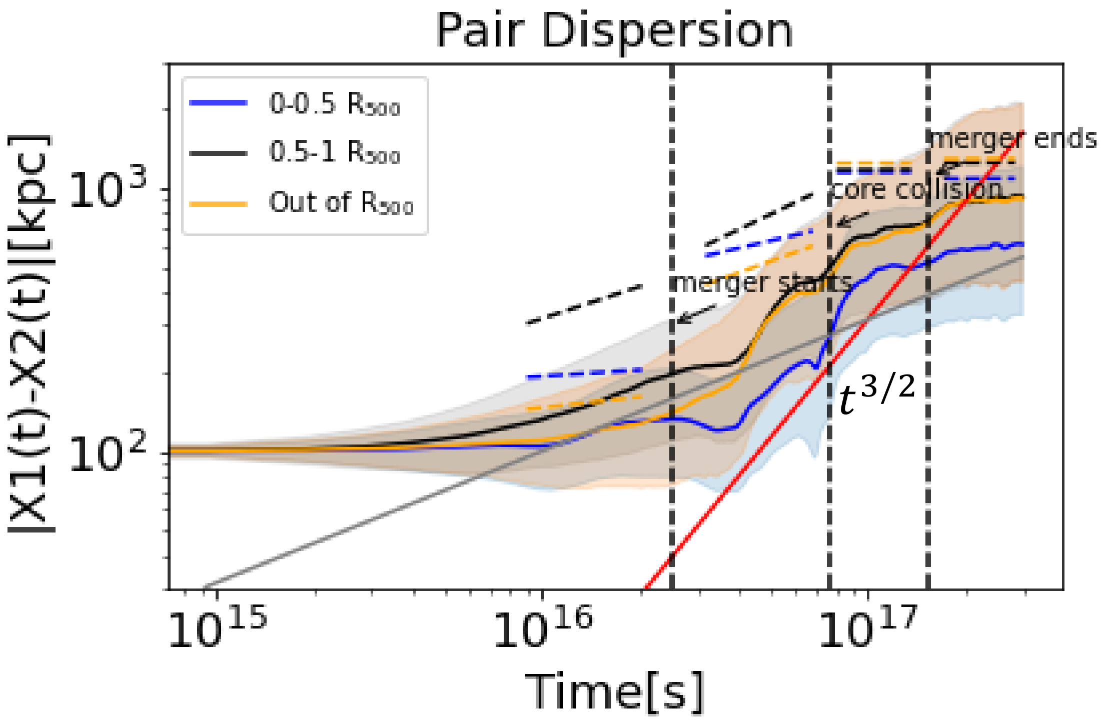
Distribution of particles at 4π.

Coherent transport contribute a little to whole distribution of particles

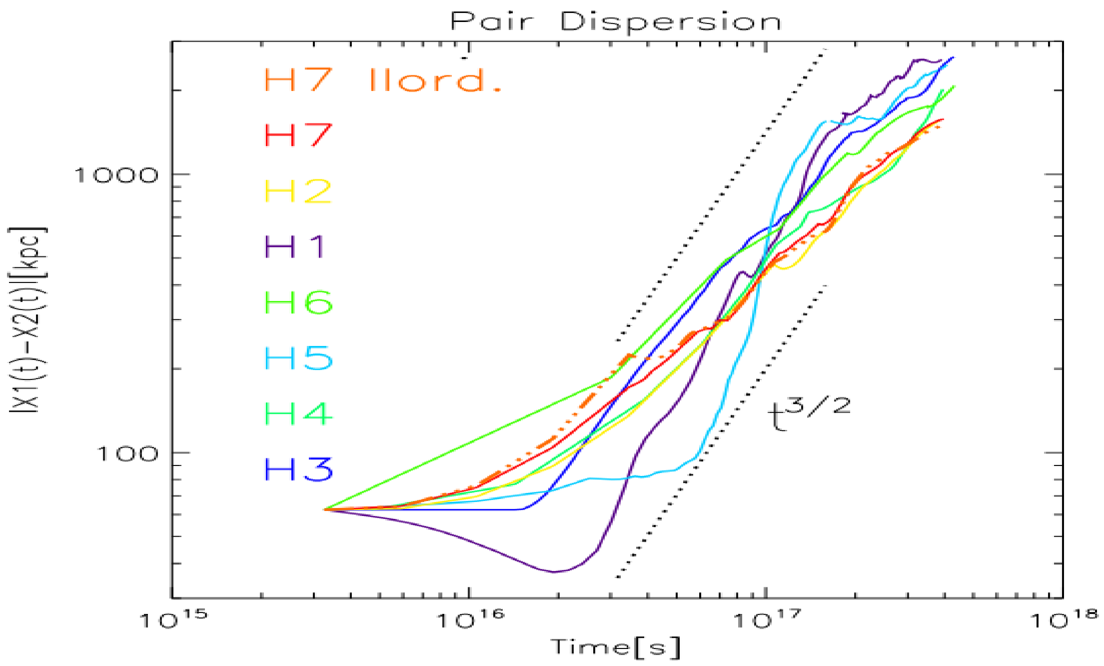
PAIR DISPERSION



2D pair dispersion evolved from a = 0.4 to 1



Pair dispersion of particles in three bins(the radial direction) at a = 0.4.

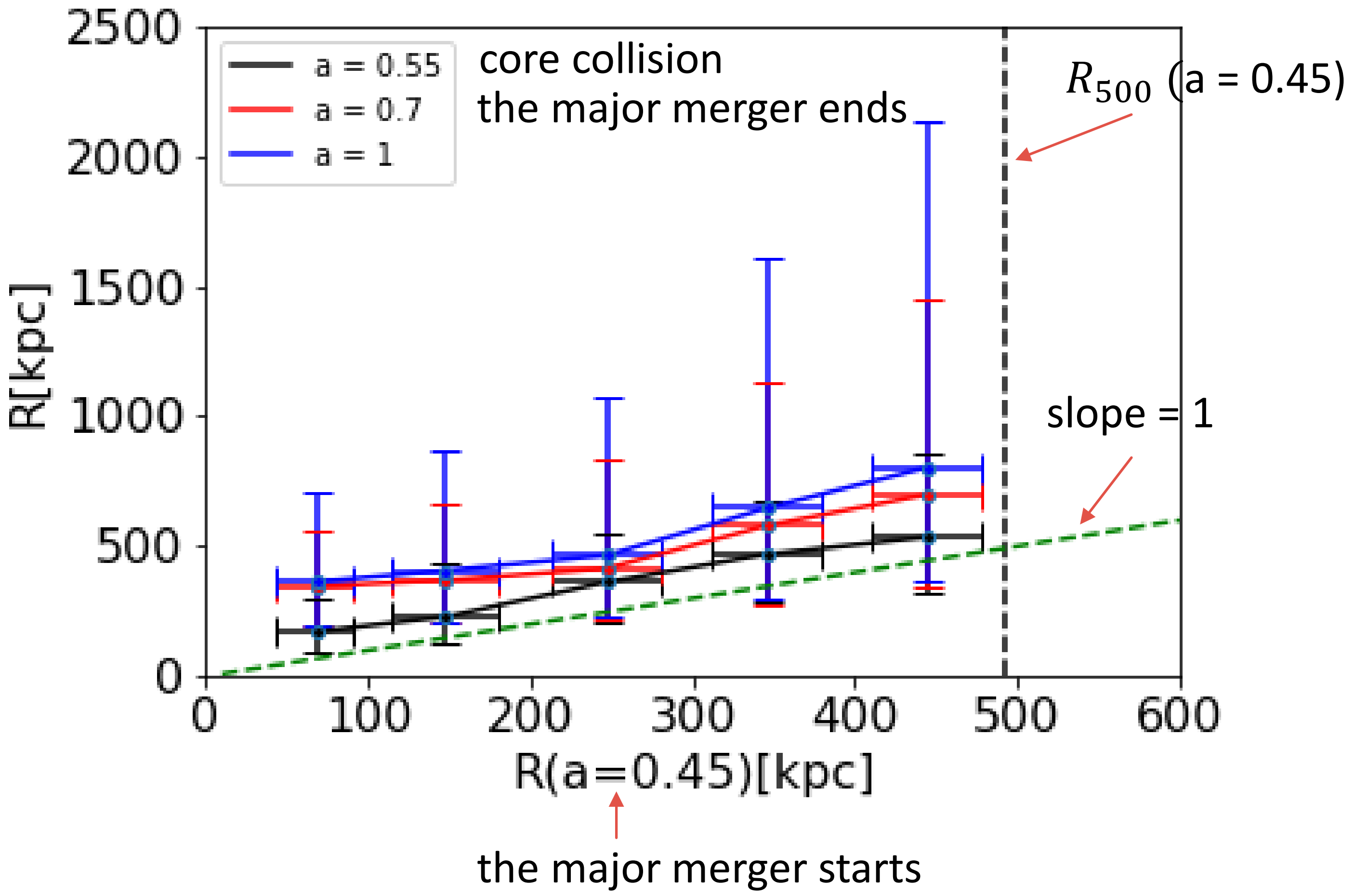


From Vazza et al(2010) , “As soon as the cluster formation starts (i.e. z ≤ 2), the pair dispersion increases following a behavior consistent with a $\sim t^{3/2}$ scaling”

The transport process in the ICM may not have a universal law to obey

Transport depends more on dynamical states of galaxy clusters

MAJOR MERGER



During the major merger, the median value of radius changed a lot.

After the major merger, the median value of radius changed a little but variance increased significantly

Turbulence plays a crucial role after the merger

SUMMARY

We studied the transport mechanisms in the ICM using tracer particle re-simulation of the Omega500 cosmological hydrosimulation, and focused on the particle transport during major mergers.

We used pair dispersion statistics to study the effect of particle transport at various epochs of the cluster assembly history. We found that pair dispersion follows the Richardson scaling during the major merger stage, but is slower before or after it. This means that the transport process in the ICM does not follow a universal law, but depends on the dynamical states of galaxy clusters.

We looked for possible coherent transport during the major merger, and found it to be subdominant compared to turbulence. Turbulence strength is the underlying reason of the varying pair dispersion behavior: while strong turbulence is excited at the major merger, it quickly decays afterwards.

Thanks