Evolution of Galaxy Light Distributions in Galaxy Clusters

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Motivation

- What is the main physical mechanism for the observed evolution and/or properties of galaxy clusters?
  (cooling-flow / environmental effects / metal distribution)

- How can we observe the “main physical mechanism”?

- Galaxy clusters consist of galaxies (observed in optical), intergalactic hot gas (observed in X-ray), and dark matter.
  We should see the interaction between galaxies and plasmas to understand the evolution/properties of galaxy clusters.
  (by Prof. Makishima)

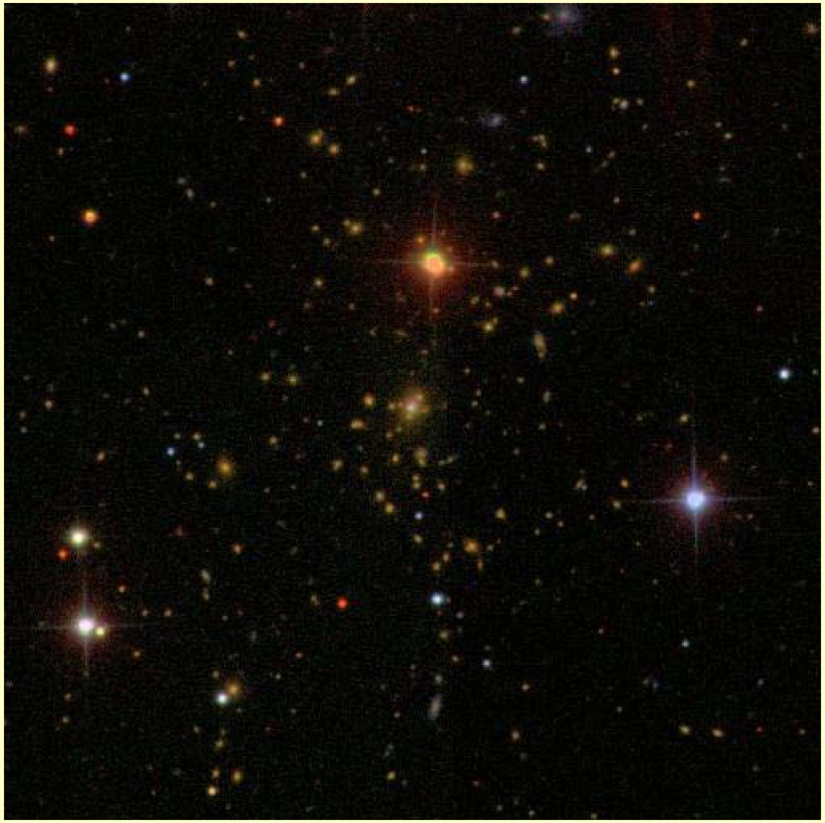
Contents:
- optical observation for galaxy clusters.
- X-ray observation for galaxy clusters.
- physical mechanism for cluster properties.
- preliminary result.

What is “Cluster of Galaxies”

cluster of galaxies:

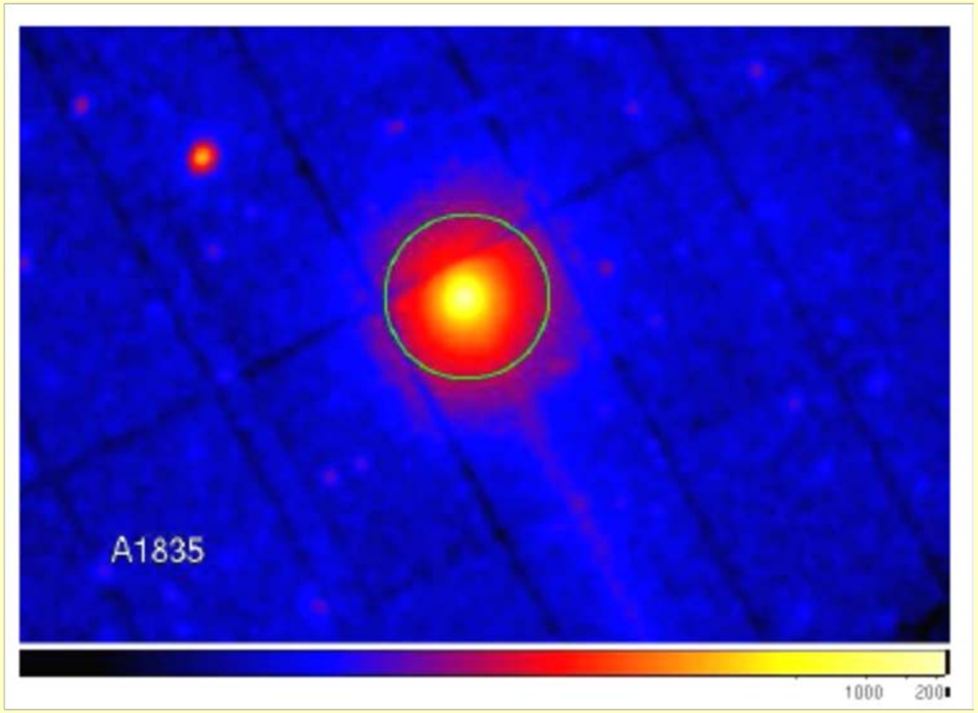
a large system (object) with more than ~50 gravitationally bounded galaxies in a region of a few Mpc diameter.

No quantitative definition.



galaxies: ~3% of M_{total}

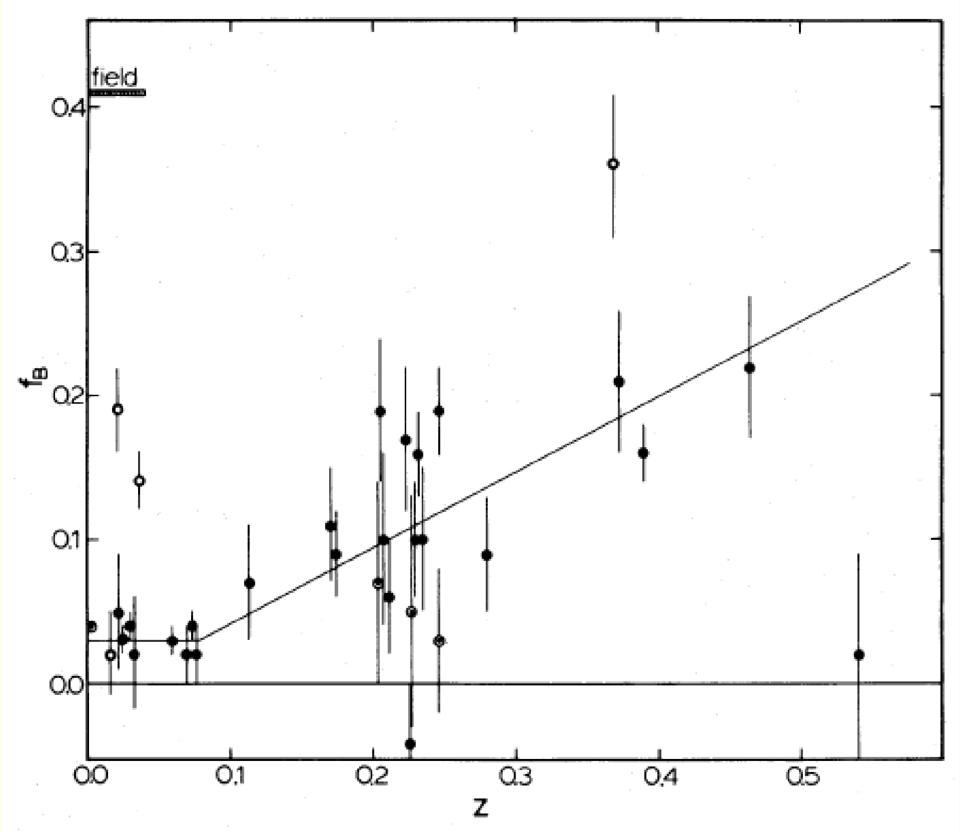
Random motion



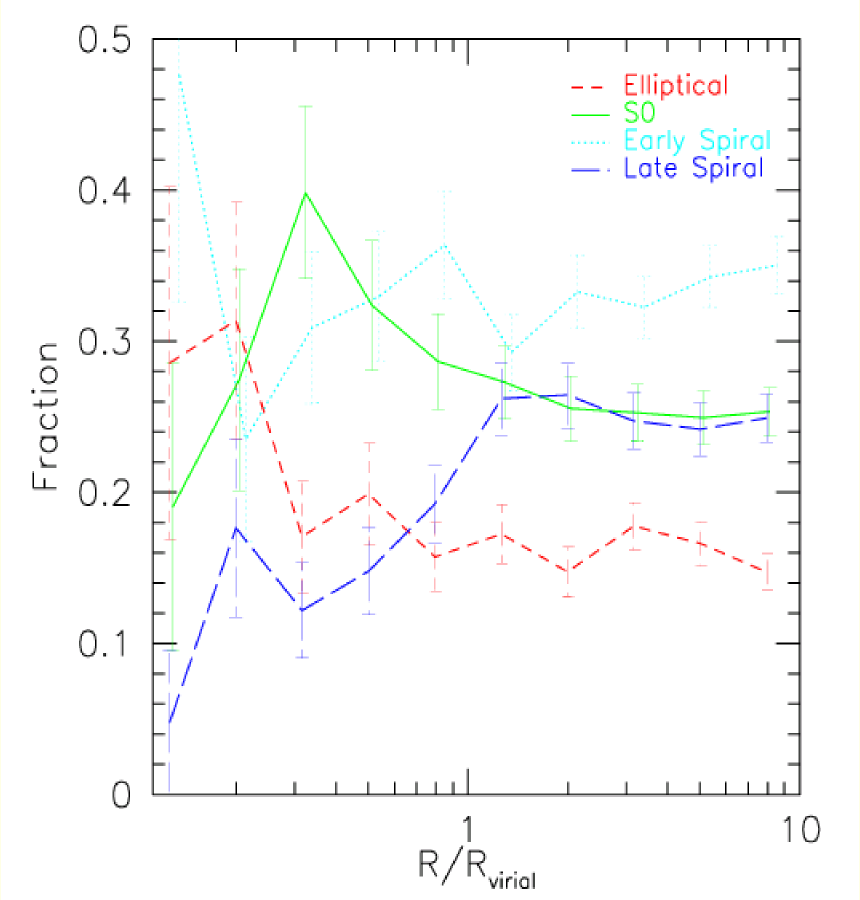
ICM: ~12% of M_{total}

kT_e ~ 2-15 keV

Properties of Galaxy Clusters in Optical



(Butcher & Oemler 1984)

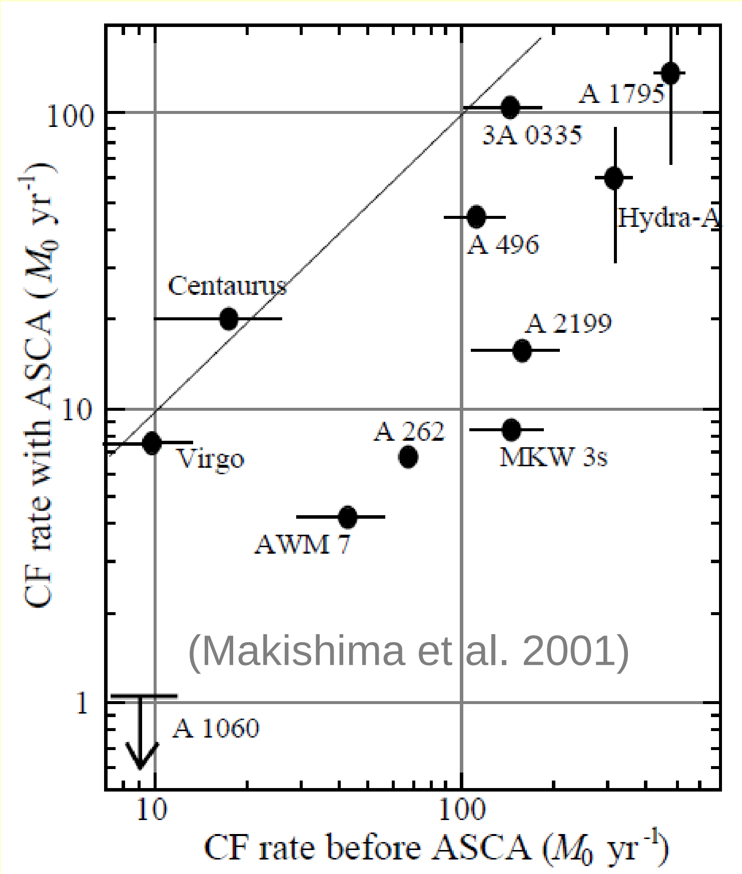


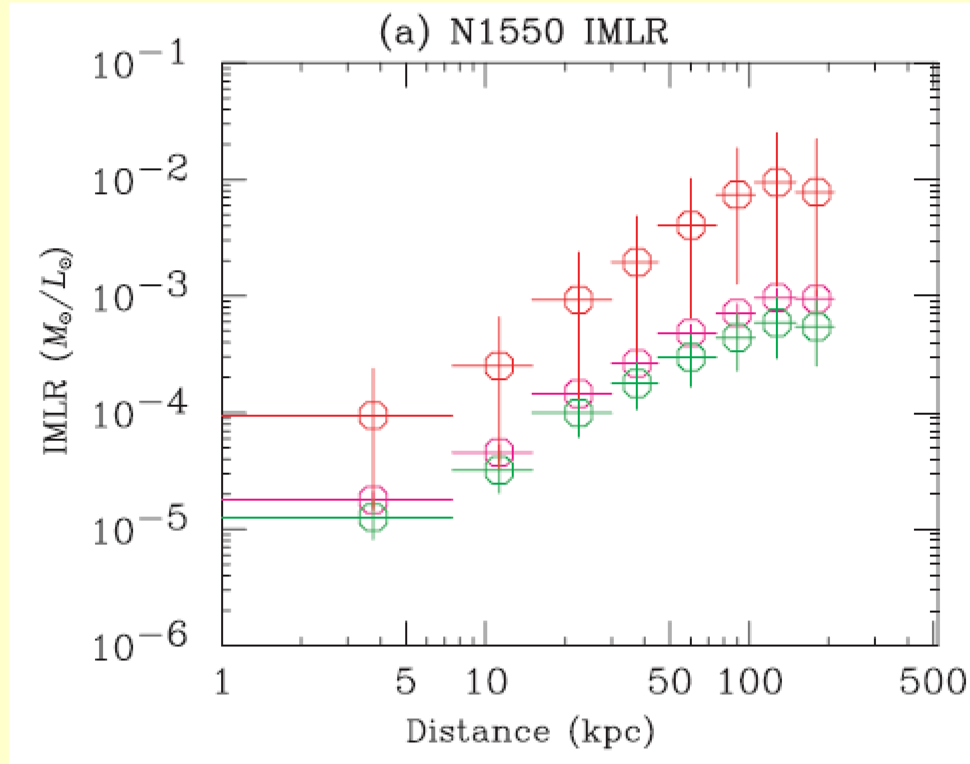
(Goto et al. 2003)

Fraction of blue galaxy (star-forming spiral / irregular) is higher in high redshift clusters.

Elliptical galaxies are dominant in center (denser) regions of Galaxy clusters.

Properties of Galaxy Clusters in X-ray





(Kawaharada et al. 2009)

radiative cooling at center ⇒ pressure decreasing ⇒ ICM flows to center (cooling flow).

<u>much smaller cooling flow from ASCA observation.</u>

<u>metal mass to light ratio is not constant.</u>

expansion of metals??

galaxies falling to the cluster center??

Physical Mechanism for Properties of Galaxy Clusters

From the observational properties of galaxy clusters ….

- Butcher-Oemler Effect and morphology-density relation. why galaxy have such distributions ??
- why $\beta < 1$ in beta-model ?? (hot gas distribution is more extended than that of dark matter, what is the reason ??)
- why metal distribution is more extended than galaxy (luminosity) distribution ??
- what is the source of ICM heating ??

One simple interpretation may be that galaxies moving in ICM lose their kinetic energy (through interactions of interstellar media & ICM and magnetic field reconnection of MHD turbulence) and gradually fall to the cluster center with evolving their color & morphology and providing metals to surrounding hot gas (through ram-pressure stripping).

How Can We Observe "Dynamical Friction"?

galaxies falling to center, with keeping (or expanding) ICM distribution.

↓

Galaxy (optical light) distribution divided by hot gas distribution should evolve with redshift (should become centrally-concentrated toward lower redshifts).

time scale:

dynamical time scale ⇒ $(R_{vir}^3/GM_{vir})^{1/2}$ ~ 1.4 Gyr < t_H

Kinetic energy of a galaxy ⇒ ~10^{60} erg
dynamical friction ⇒ ~10^{43} erg/sec
time scale of energy loss ⇒ ~10^{17} sec < t_H
(time scale of energy loss) = (a few) x (dynamical time scale)

c.f. from z = 0.4 to z = 0.1 ⇒ ~3.0 Gyr (in standard cosmology)

Preliminary Study: Target and Optical Data

<u>target for our preliminary study:</u>
6 galaxy clusters with $0.073 < z < 0.282$ in the **SDSS** data, which have sufficient quality **XMM-Newton** archival data and similar X-ray temperatures.

for each cluster ….

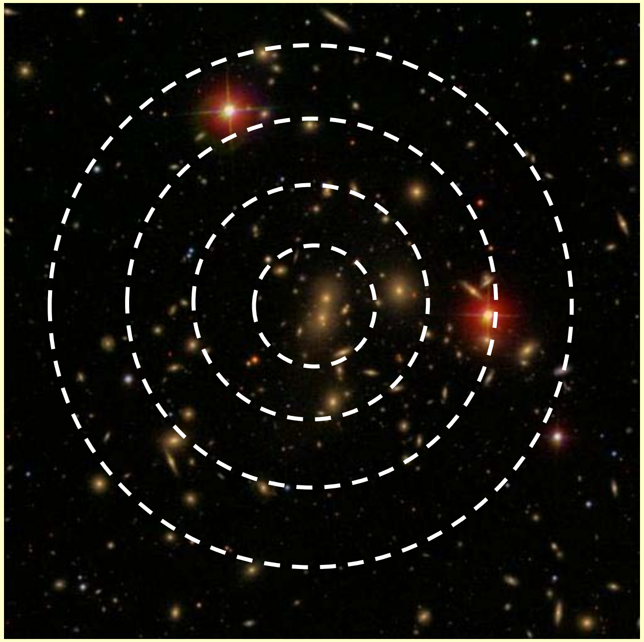
1. select extended objects with *i*-band magnitudes of $i_{BCG} < i < i_{lim}$ in a region with a physical radius of 2.5 Mpc measured from the X-ray center. i_{lim} is defined to be $M_{*}+1$ ($M_{*} = -21.7$).

2. integrate fluxes of these extended objects in a circle with an increasing radius in a step of 100 kpc, and then subtract the background flux derived from field galaxies around the cluster. We normalize the luminosity profile to the flux in the central central bin, and physical distances from the X-ray center to the virial radius (R_{vir}) of the cluster.

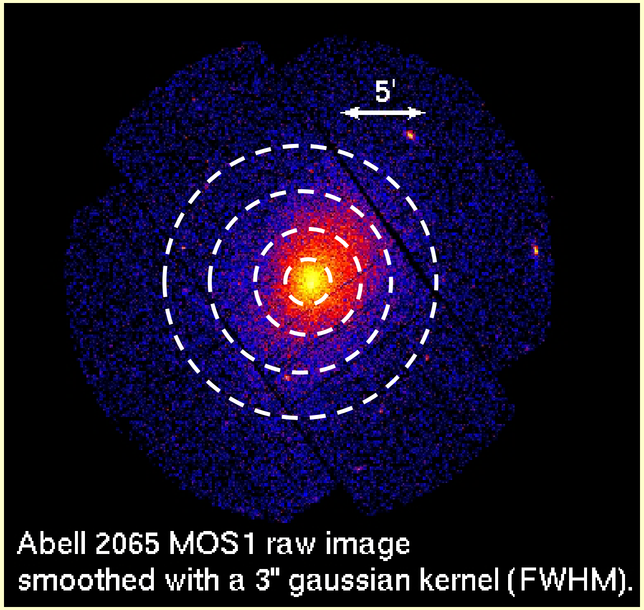
Preliminary Study: X-ray Data

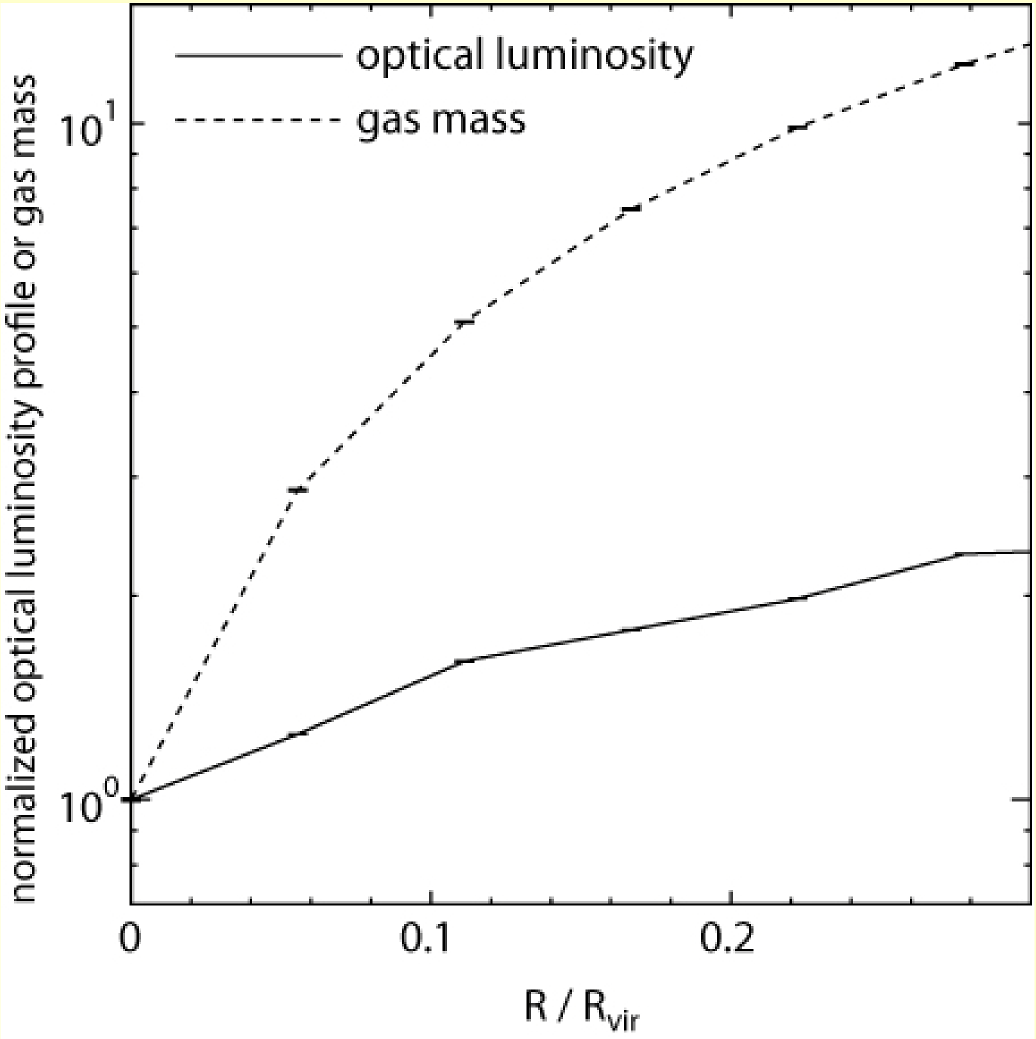
1. We first make a background-subtracted 0.5-10 keV MOS1 image. We use the public blank sky image in the official XMM-Newton website as a background.
2. We divide it by its exposure map. X-ray surface brightnesses are square-rooted so that the profiles are nearly proportional to electron number (and hence gas mass) within each projected radius, and then integrated in a circle with an increasing radius of 100 kpc.
3. Gas mass profile is also normalized to the value in the central bin, and physical distances from the X-ray center are normalized to the virial radius (R_{vir}) of the cluster.
4. The hot gas distribution, which traces the dark matter, is indispensable to compensate for the effect of various dark matter profiles among different clusters.

Preliminary Study: luminosity & hot gas distribution

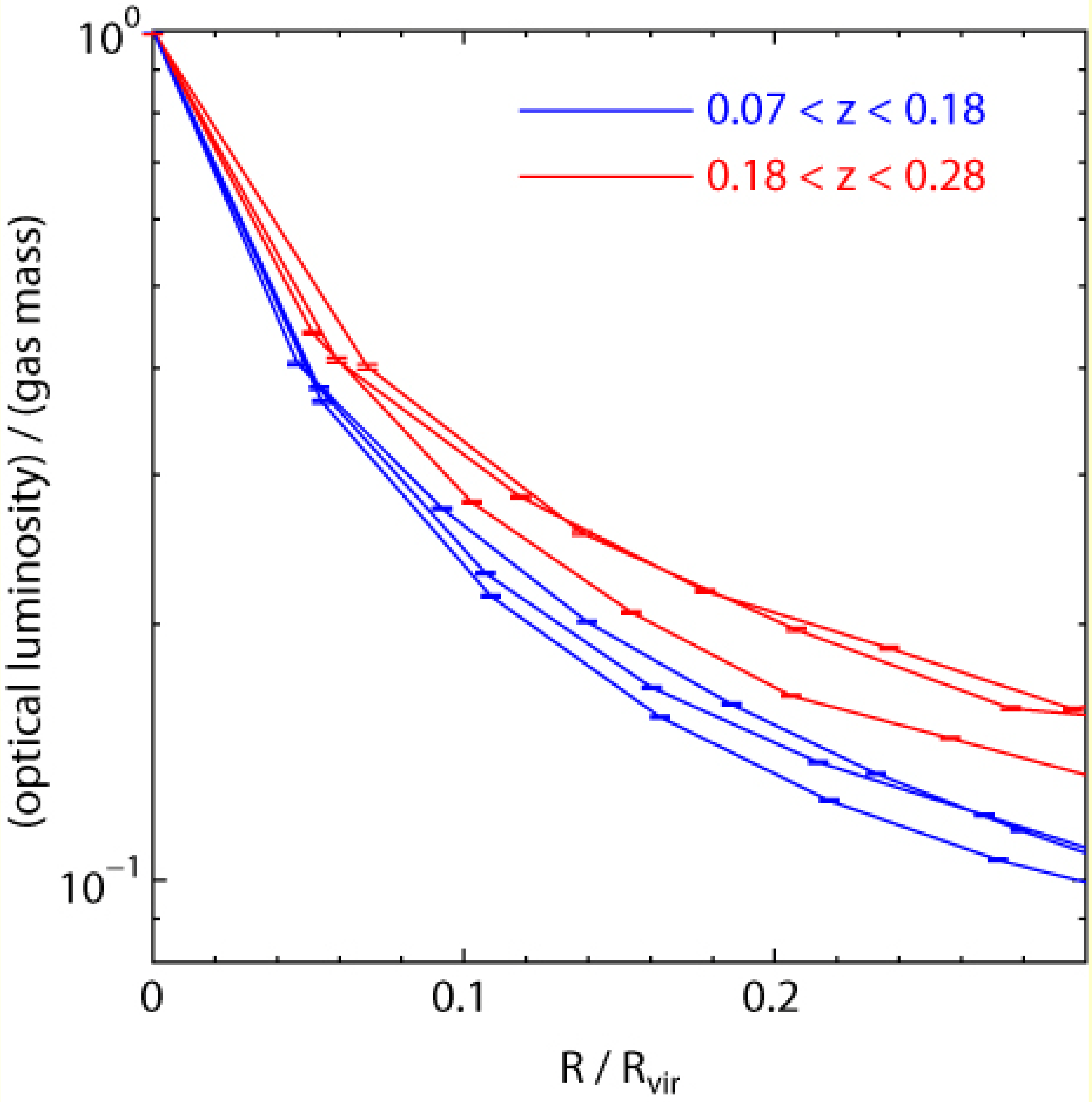


Abell2065 with z = 0.073





Preliminary Study: Result



Summary / Future Works

- From our preliminary result, galaxy light distributions become centrally-concentrated toward lower redshifts.

- We have to increase the number of galaxy clusters. We have optical data of ~30 galaxy clusters (from z = 0.1 to z = 0.8) observed at the UH88 telescope, which have XMM-Newton archival data. (Inada and Konami are now working for this.)

- We definitely need Chandra X-ray data for galaxy clusters with z > ~0.4. (Konami and Inada will be working.)

- Mass-luminosity ratio (in optical)?
  Redshifts do not correspond to the age of clusters?

- The results should be "verified" by simulations?
  (Takahashi will be working?)