Prospects for ASTRO-H from Cosmological Viewpoints

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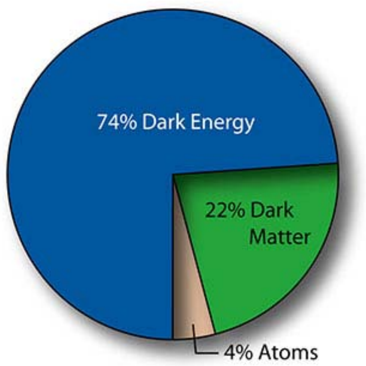
Further Challenges in Cosmology

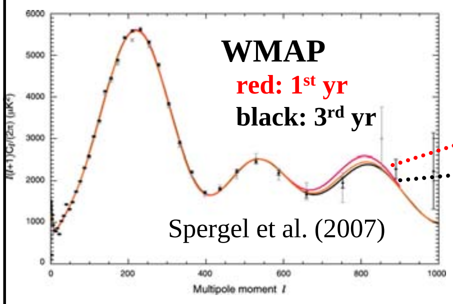


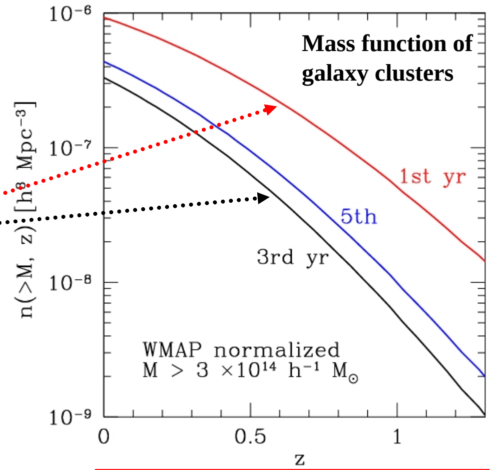
http://map.gsfc.nasa.gov/resources/

A great progress has been made, yet,,,

1. **Only less than 5% is understood.**
   What are DE & DM (DB) ?
   Why this fraction?
2. **Unknown systematics?**
   observationally or theoretically
3. **Compatible with formation/evolution of astronomical objects?**

CMB and Structure Formation

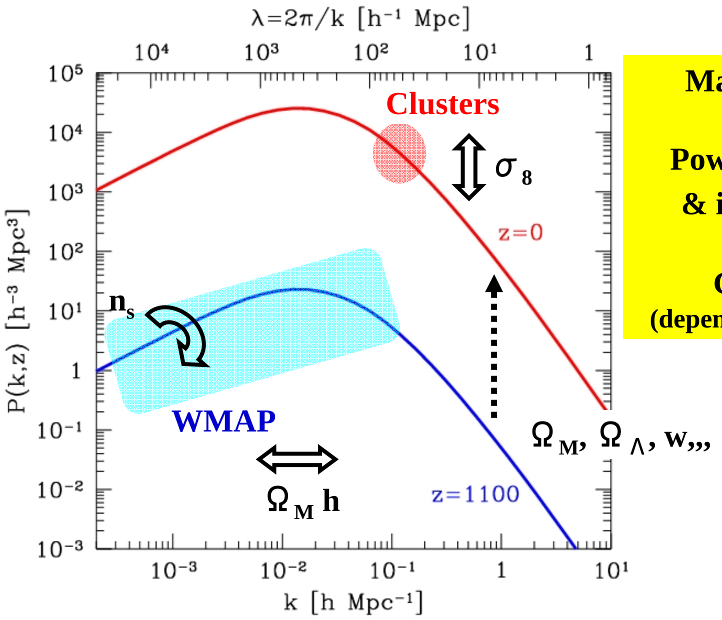




1st yr	3rd yr
Ω_m=0.28	Ω_m=0.24
h=0.72	h=0.73
σ_8=0.92	σ_8=0.76
n_s=0.99	n_s=0.96

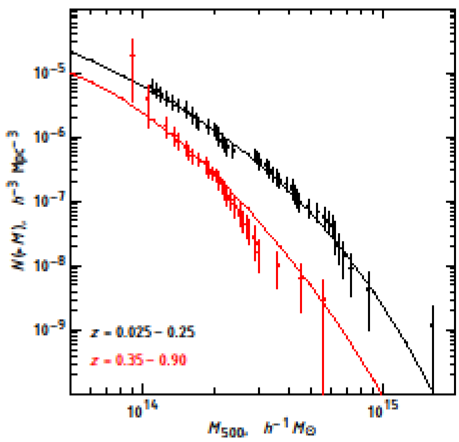
Also, the number of objects with T_{vir}>10^4K changes by ~100 at z=15 (Alvarez et al. 2006)

Basic Idea

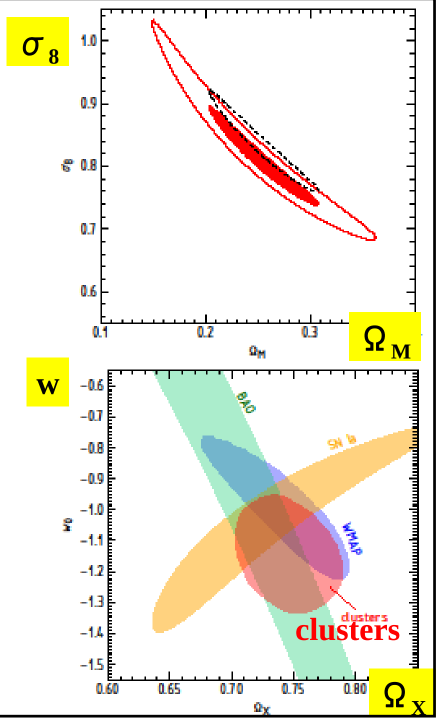


Mass function
⇕
Power spectrum
& its evolution
+
Geometry
(depending on method)

Recent Results



Vikhlinin et al. (2008)
ROSAT selected & Chandra
49 clusters with <z>∼0.05
37 clusters with <z>∼0.55



Systematics !

1. Direct mass measurements

－departure from equilibrium, spherical sym.
－non-thermal pressure, bulk motion, turbulence,,,
－local inhomogeneities

2. Indirect mass estimates

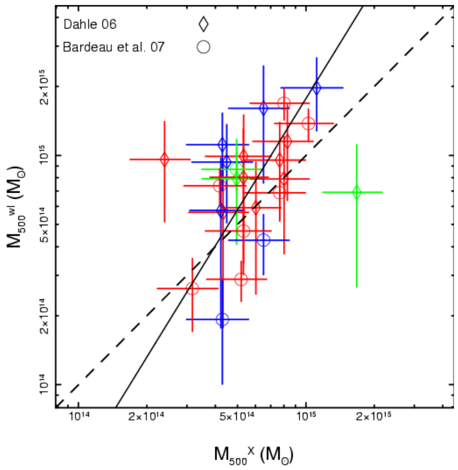
－Mass-observable relation (L, T, M_{gas}, Y) ;
offset, scatter, evolution, selection bias,,,

3. Theory

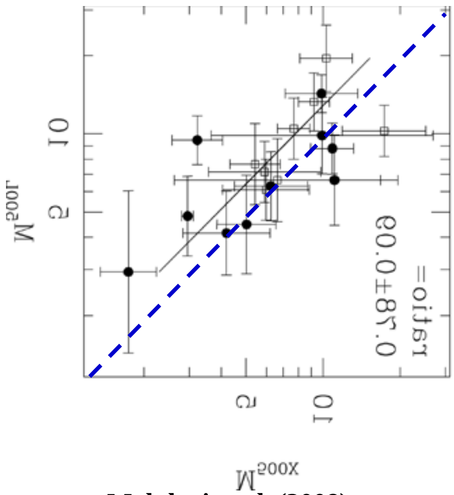
－incomplete understanding of cluster evolution
－non-Gaussianity

etc.

X-ray vs. lensing masses

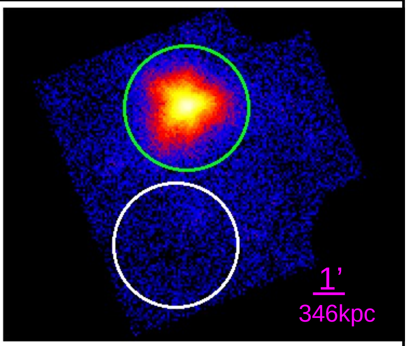


Zhang et al. (2008)
ROSAT selected, XMM data
M_L/M_X increases with mass(?)



Mahdavi et al. (2008)
Chandra data
M_L/M_X ～1.3 within r_{500}

Suzaku observation of RX J1347.5－1145 at z=0.45
（Ota et al. 2008）

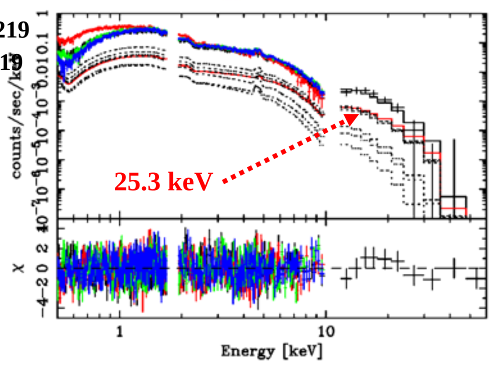


Mass discrepancy between Chandra & XMM (Gitti et al. 2007; Bradac et al. 2008)

① **Broadband (XIS+HXD) spectrum (150 ks) & spatially resolved Chandra spectra**
⇒ **hard component**
$kT_{ex}=25.3^{+6.1}_{-4.5}$[keV] χ^2/dof=1311/1219
or $\Gamma=1.45^{+0.03}_{-0.04}$ χ^2/dof=1317/1219

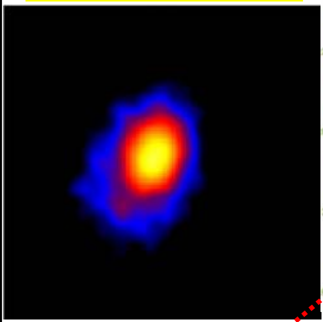
② **HXD only**
Detection at 9σ statistically, but limited by NXB systematics
$F_{cl}<8\times10^{-12}$ [ergs/s/cm²] in 15-60 keV

if IC & radio synchrotron flux (Gitti et al. 2007)
⇒ **B＞0.007 μG**

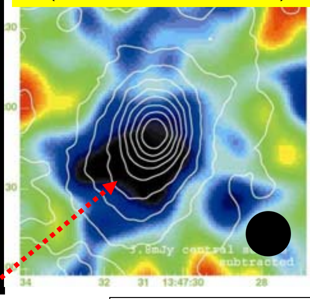


X-ray and SZE images of RX J1347.5－1145

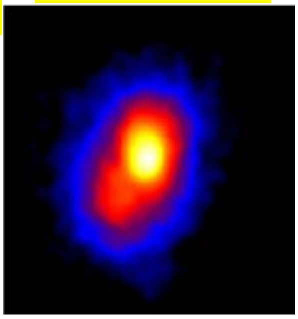
ROSAT 0.2-2 keV (Schindler et al. 1997)



Nobeyama SZE 150 GHz point-source subtracted (Komatsu et al. 2001)



Chandra 0.5-7 keV (Allen et al. 2002)



Hot substructure at ～120 kpc off-center

Discovered due to higher sensitivity of SZE to T_{gas}

SZE & Chandra (TK et al. 2004)

kT=28.5±7.3 keV

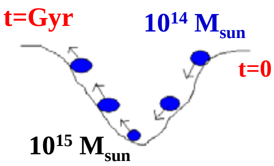
※ If merger shock,

→ v_{pre} ～3900 km/s,

v_{post}～1600 km/s (shock frame)

SZE and X-ray images in cluster merger simulations

(Takizawa 2005)



kT_{max} ～30 keV

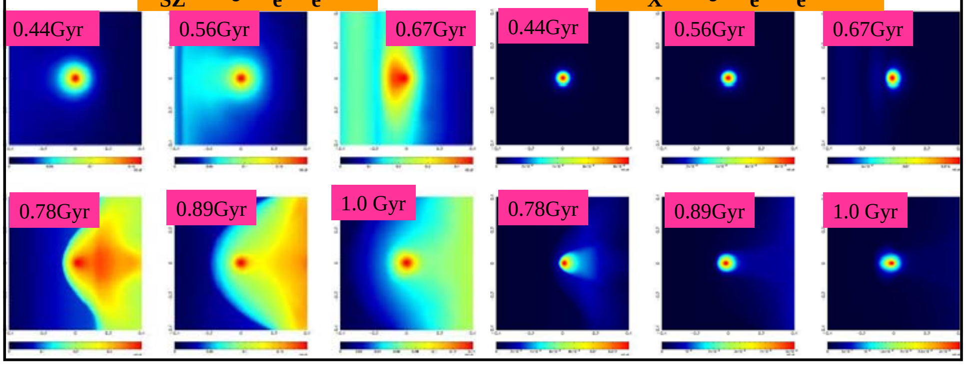
V_{max} ～4000 km/s

$\Delta\tau$ ～0.1 Gyr

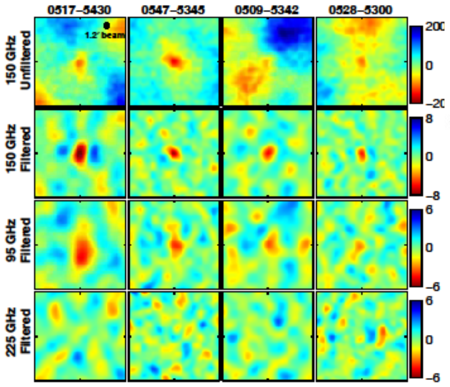
Complementary probe of cluster structures

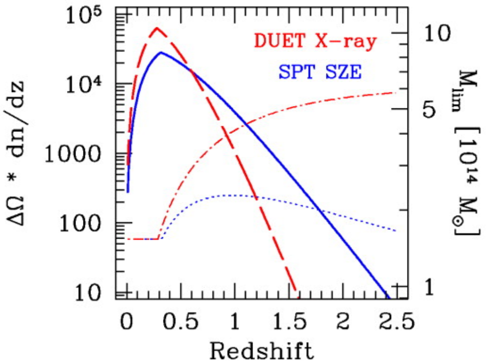
$I_{SZ} \propto \int n_e T_e\, dl$

$I_X \propto \int n_e^2 T_e^{1/2}\, dl$



Impacts of blind SZE survey





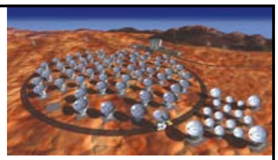
4 clusters detected by SPT
3 are unknown previously
(Staniszewski et al. 2008)

SPT SZE: 4,000 deg^2, F>5 mJy
DUET X-ray: $10^4 deg^2$ F>10^{-13} erg/s/cm^2
(Majumdar & Mohr 2003)

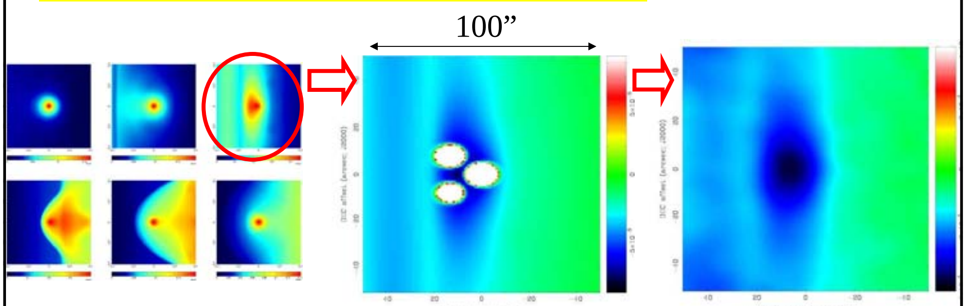
Good for finding high z clusters
Different selection effects

Imaging simulation for ALMA

(Yamada et al. in prep)



ALMA will resolve bright compact clusters with FWHM～10” at 90GHz (& 30GHz)



INPUT:
Cluster merger simulation by Takizawa (2005).
Place at z=1, Dec=-23 deg

Add point sources
10mJy
5mJy
2mJy

Mock obs at 90GHz for 25hrs:
rms=5 μ J/beam
effective FWHM=10.5”
SZ peak=－0.36 mJy/beam
(accuracy ～5%)

Other diagnostics of cosmology

1. H_0 (D_A) measurment by X-ray & SZE (e.g., Birkinshaw 1999)

- $I_X \propto n^2 \Lambda(T) R_{//}$
- $I_{SZ} \propto n\, T\, R_{//}$
- $R_{//} = R_{\perp}$

➡ $$H_0 \propto \frac{1}{D_A} \propto \frac{I_X \theta_\perp T}{I_{SZ}^2 \Lambda(T)}$$

Systematics: asphericity, inhomogeneity, temperature bias,,,

2. Gas mass fraction of clusters (Sasaki 1996; Allen 2002)

- $M_{tot} \propto D_A$
- $M_{gas,\,X} \propto D_A^{5/2}$

➡ $$f_{gas,\,X} \propto D_A^{3/2}$$

Systematics: mass measurement, cooling, evaporation,,,

Free from cosmic distance ladder

Prospects for ASTRO-H

Hard X-ray imaging, high resolution spectroscopy
& multi-wavelength (SZE, lensing,,,)

- Understanding complexity of clusters
  - hard component:
    thermal or non-thermal, amount, origin?
  - turbulence, bulk motion,,,

- Improved application to cosmology
  - direct mass measurement
  - scaling relation and its evolution

- Exploring galaxy-cluster connection
  - high z clusters
  - outskirts of low z clusters