High-resolution SZE observations of RX J1347.5-1145 as a case study for ALMA

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Outline

Obs. of the most X-ray-luminous cluster at 150 & 350GHz

⇒ Highest resolution (～15”) SZE images

Implications on cluster physics

Prototype of high resolution/frequency studies by ALMA

Collaborators

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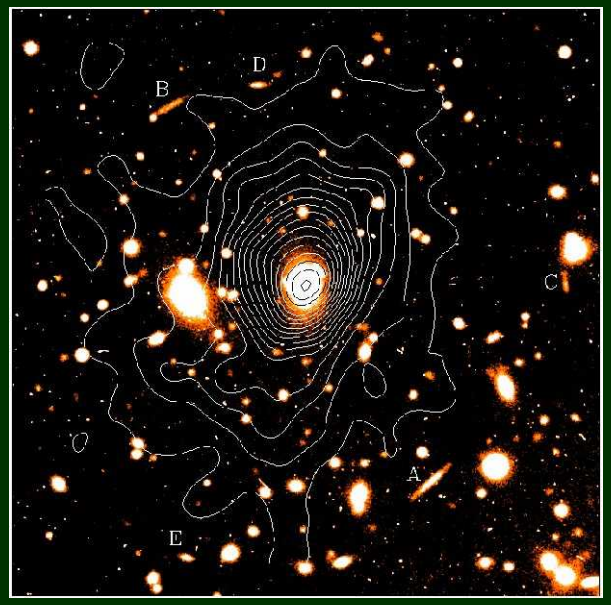
References

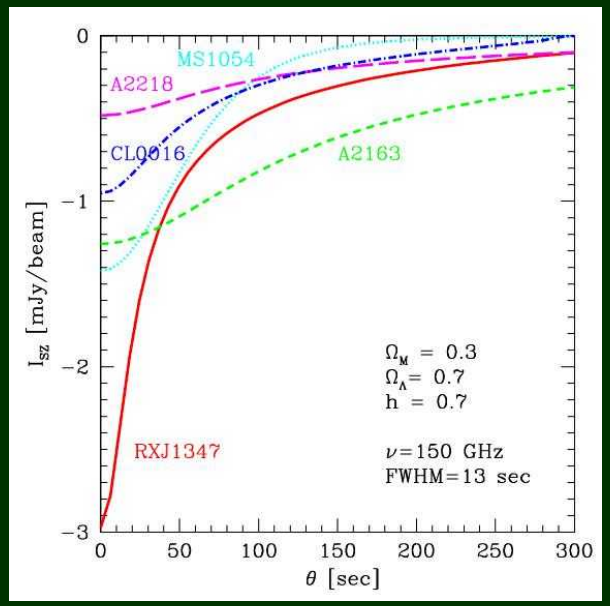
Komatsu et al. (1999) ApJ 516, L1
Komatsu et al. (2001) PASJ 53, 57
Kitayama et al. (2004) PASJ 56, 17

Why RX J1347.5-1145 ?

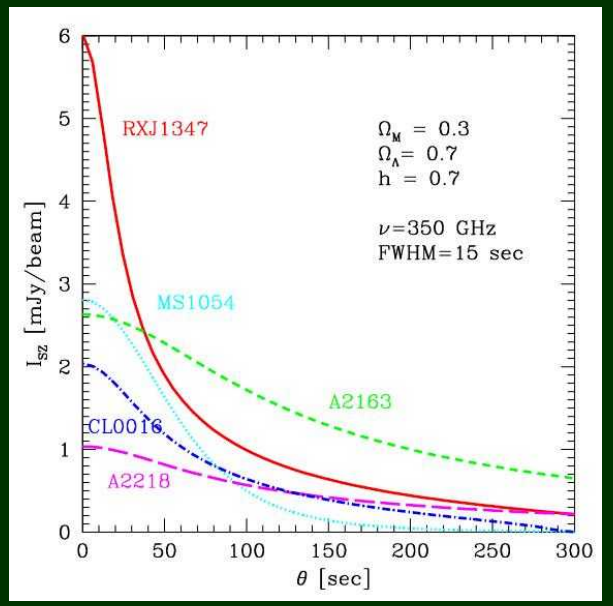
The most X-ray luminous galaxy cluster known



ROSAT & R-band
(Schindler et al. 1997)



Model SZE profile
150GHz



Model SZE profile
350GHz

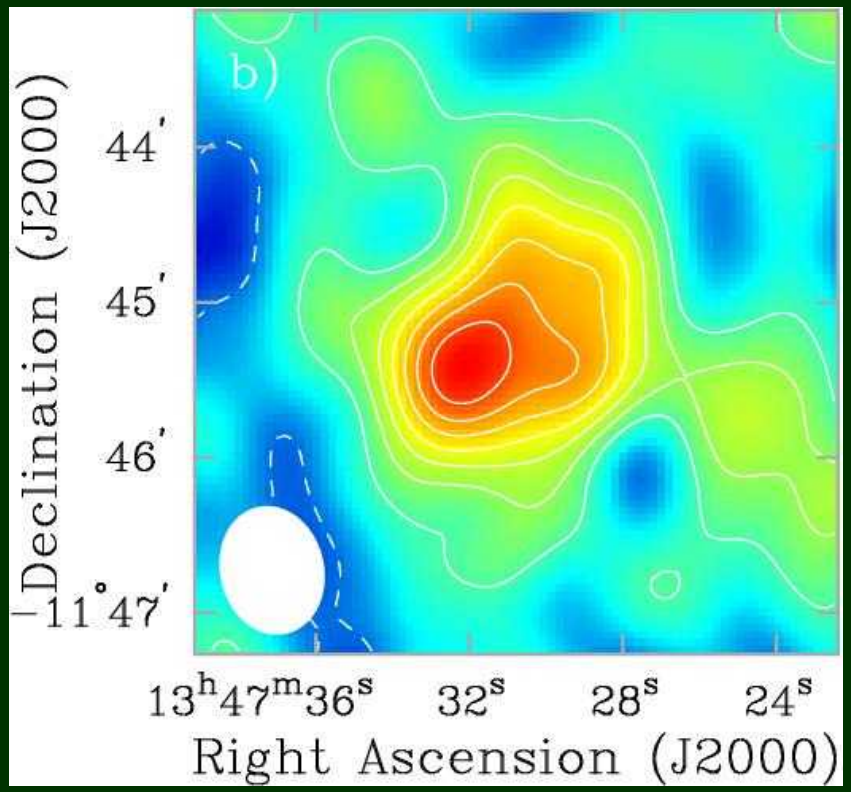
z=0.451

<kT> = 9.3 keV

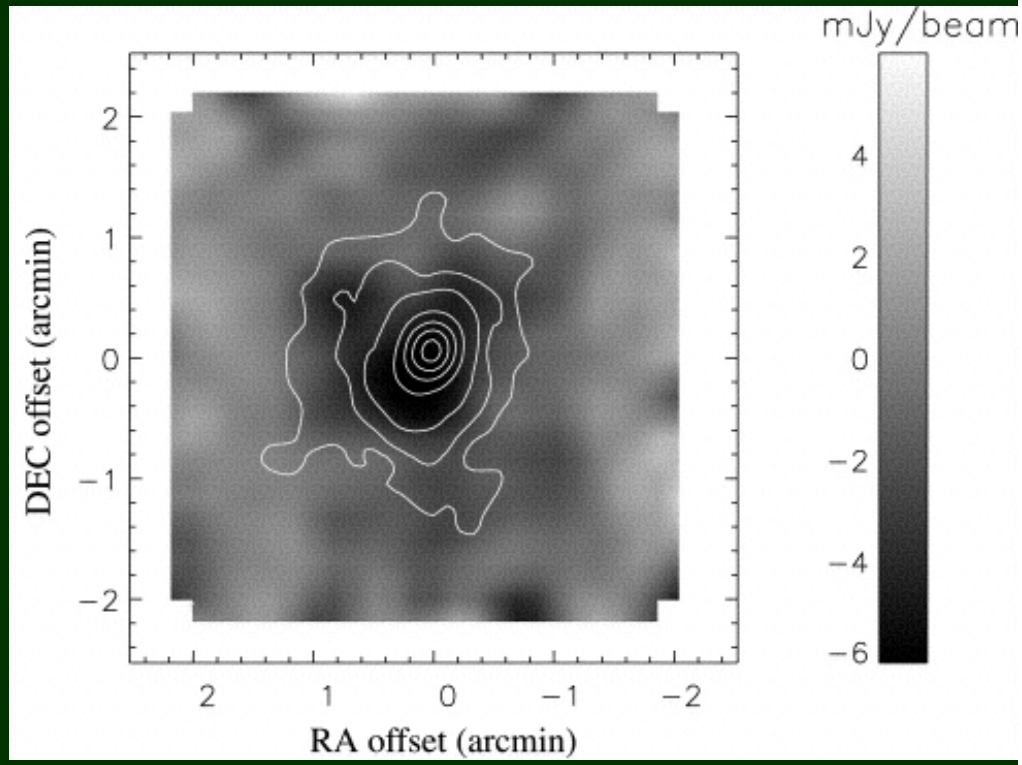
$y_0 = 8.0 \times 10^{-4}$

Strongest & very compact SZE
"best" target for high resolution studies

SZE maps of RX J1347.5-1145 (1)



28.5GHz, BIMA/OVRO
40”x50” beam
(Carlstrom et al. 2002;
Reese et al. 2002)



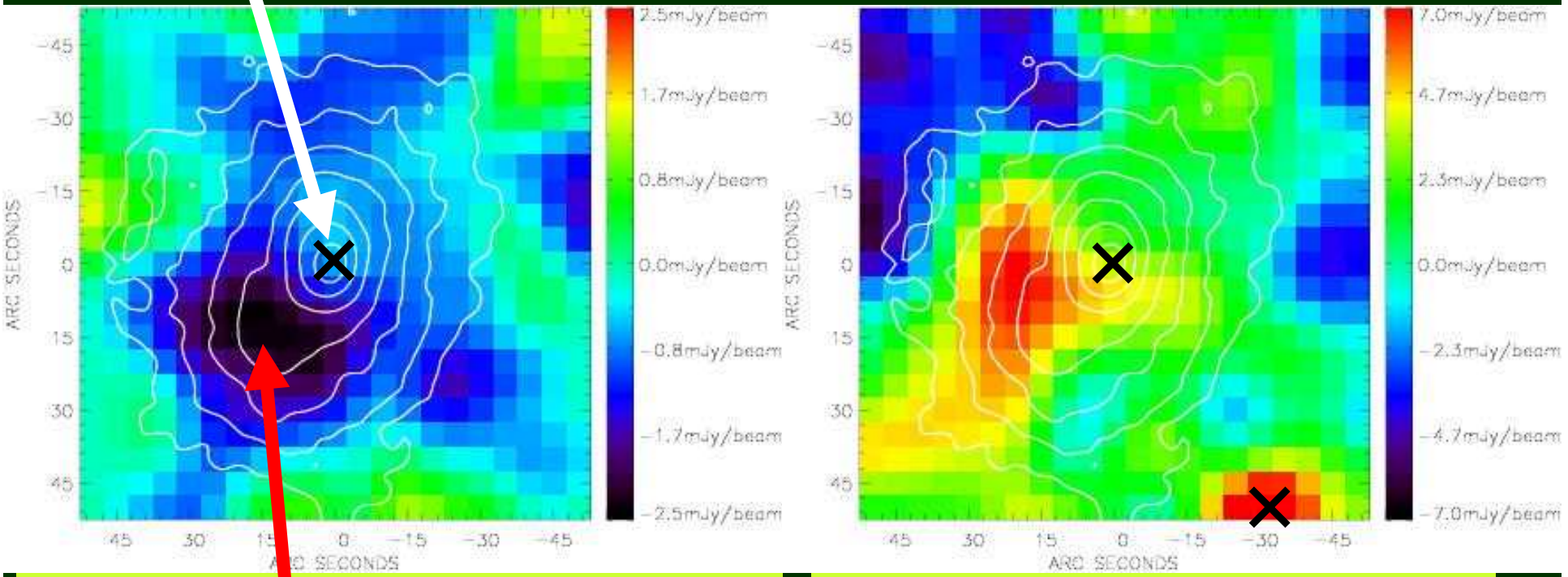
143GHz, Diabolo on IRAM 30m
22” beam, 20” smoothing
Contours: ROSAT X-ray
(Pointecouteau et al. 1999; 2001)

Point source-subtracted images

SZE maps of RX J1347.5-1145 (2)

point source

100”, 600 kpc

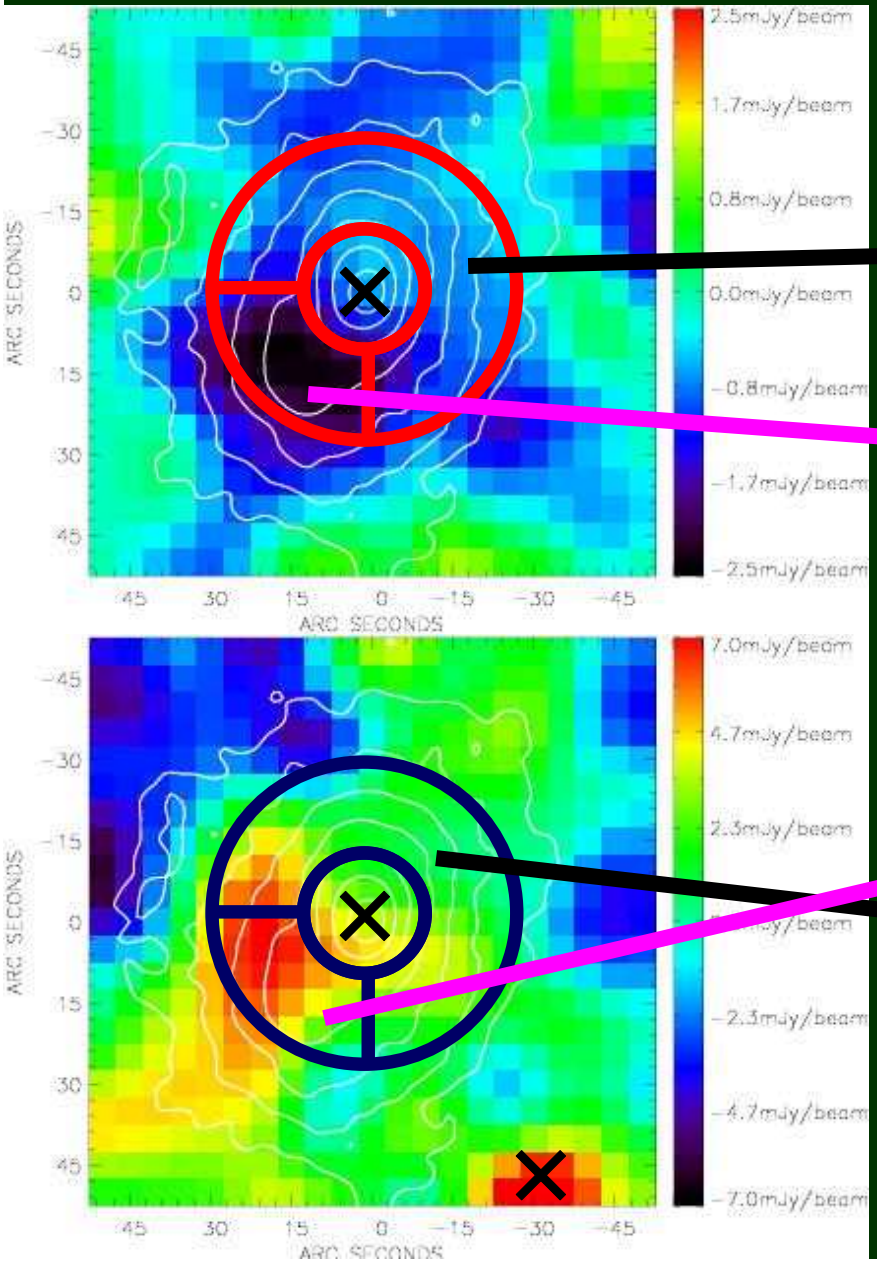


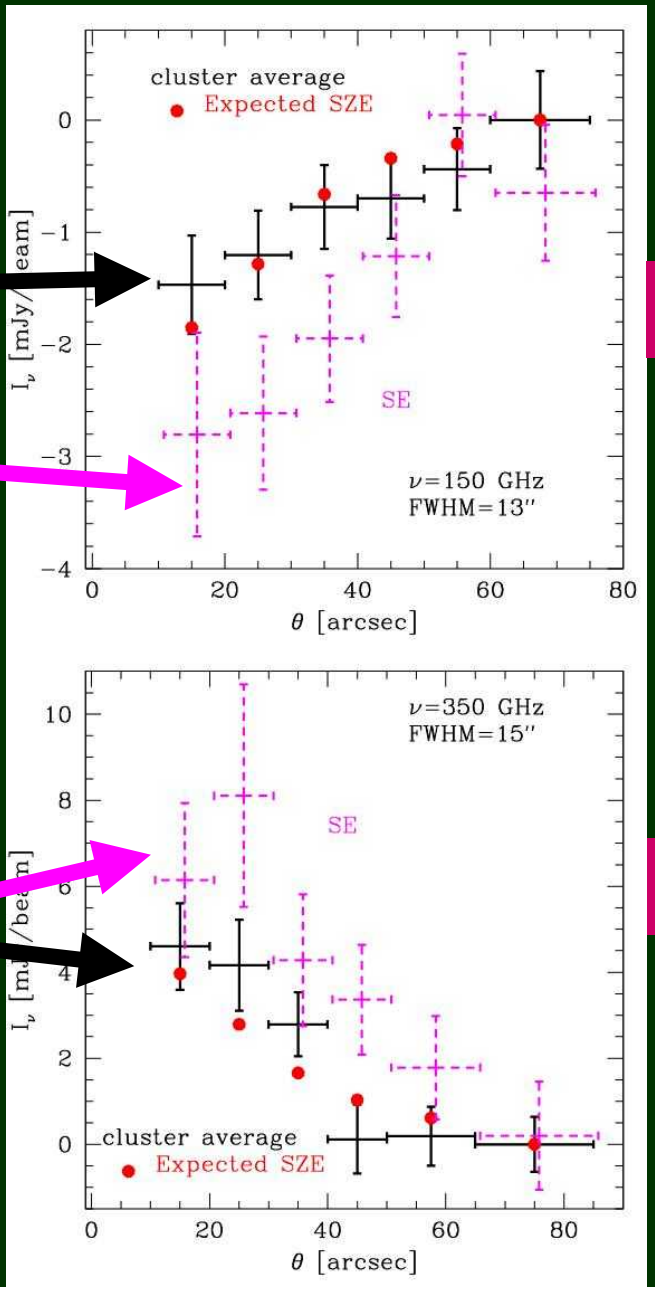
150GHz, NOBA on Nobeyama 45m
13” beam, 16” smoothing
1 **σ** =0.6mJy/beam in the smoothed image
(Komatsu et al. 2001)
Contours: Chandra X-ray (Allen et al. 2002)

350GHz, SCUBA on JCMT 15m
15” beam, 16” smoothing
1 **σ** =2.5mJy/beam in the smoothed image
(Komatsu et al. 1999)

Highest resolution SZE images, point sources un-subtracted
Hot substructure at ~20” (120 kpc) off center, discovered by SZE

SZE signals of RX J1347.5-1145



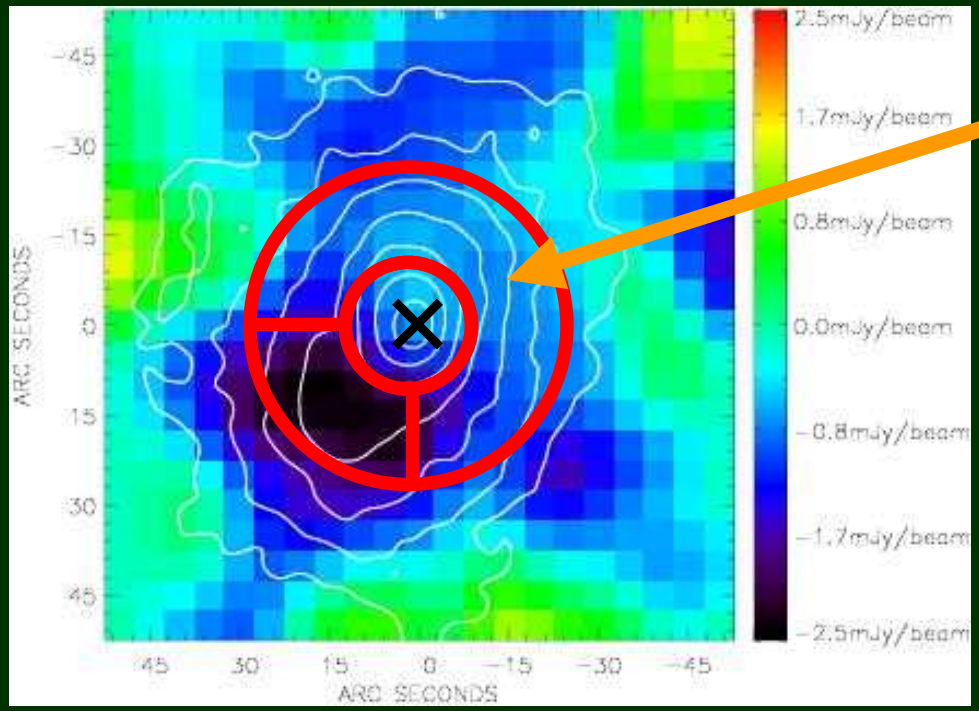


150GHz

350GHz

Applications of high resolution SZE data (1)

(Kitayama et al. 2004)

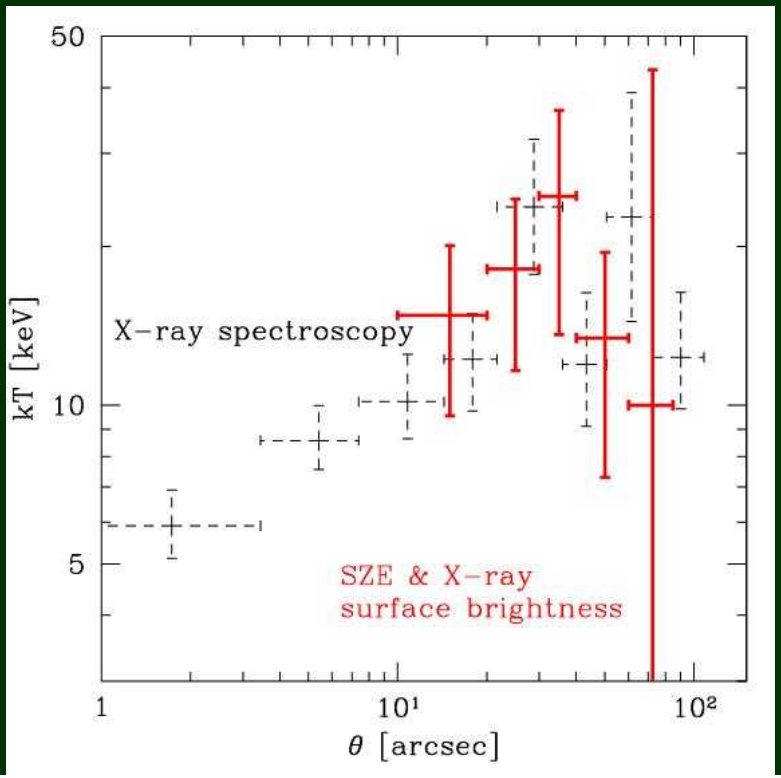


Temperature deprojection by imaging data only

$I_{SZ} \propto \int n(r)T(r)\, dl$

$I_X \propto \int n^2(r)\, T^{1/2}(r)\, dl$

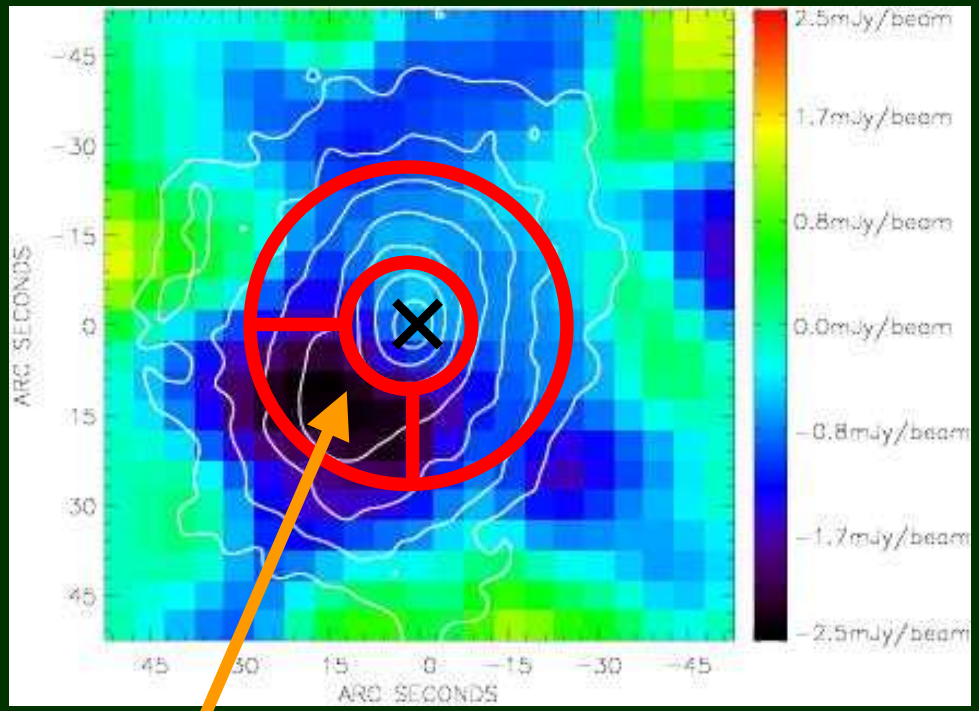
assuming V=0, spherical symmetry



- Can **mask** point sources & inhomogeneous regions
- Probe of **temperature structures** even for clusters with **no X-ray spectroscopy**

Applications of high resolution SZE data (2)

(Kitayama et al. 2004)



Unique tool to spatially resolve very hot gas with **kT>20 keV**

cf. current X-ray imagers **E<10keV**

Properties of hot substructure:

n_{ex} = (1.45 ± 0.58) x 10^{-2} cm^{-3}

L_{ex} = 250 ±190 kpc (l.o.s. extent)

kT_{ex} = 28.5 ± 7.3 keV

cf. X-ray spectra: kT_{ex}>21.5 keV

※ merger shock?

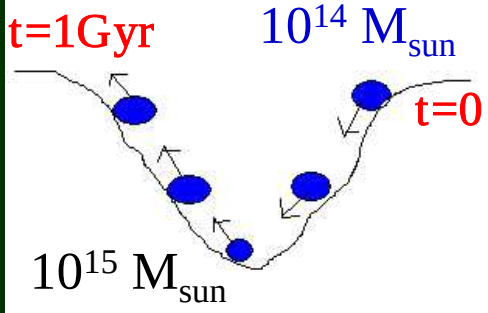
⇒ Mach number ～ 2.1

$v_{preshock}$ ～3900 km/s,

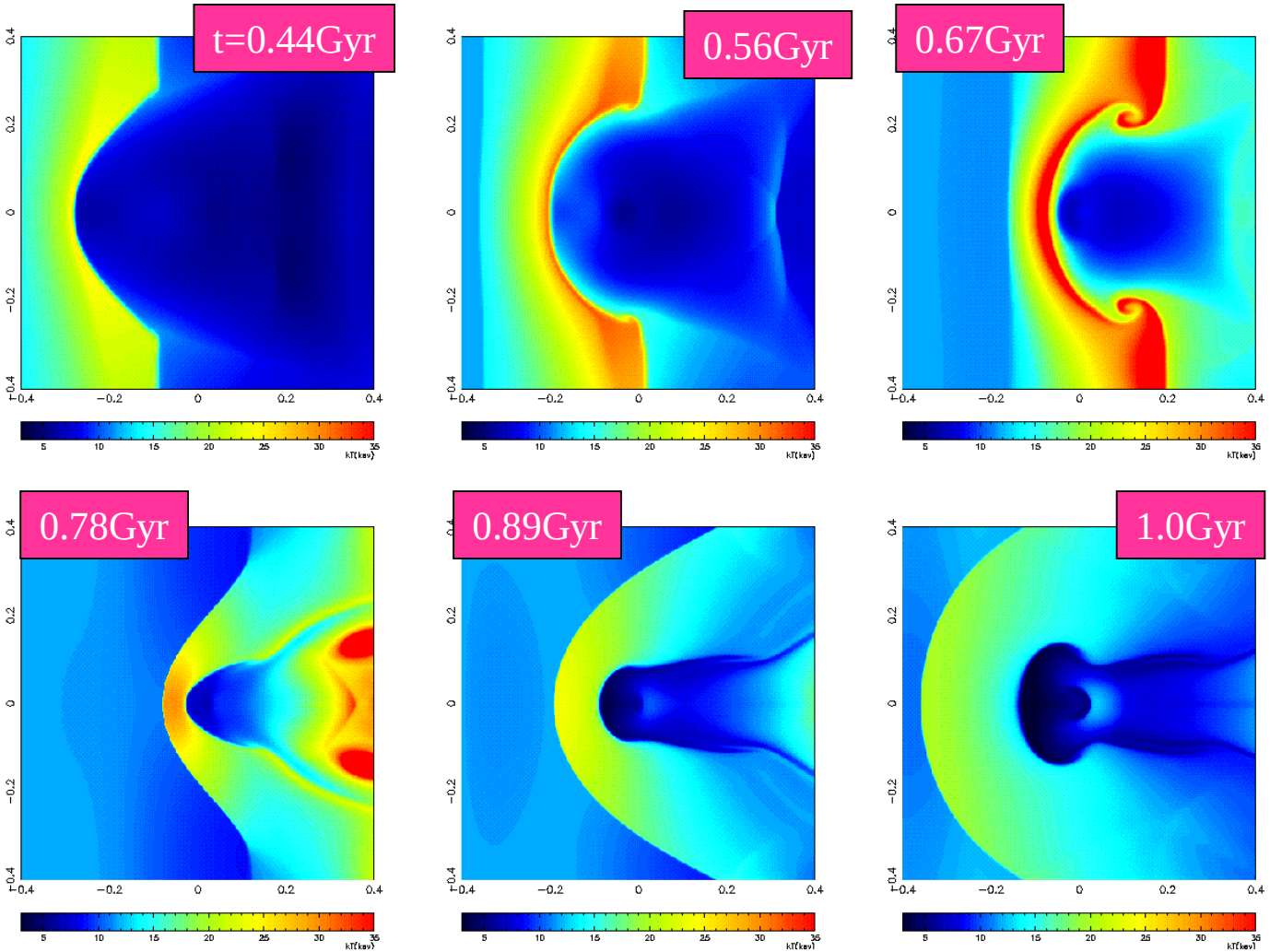
$v_{postshock}$ ～1600 km/s (shock frame)

Simulations of sub-cluster mergers

(Takizawa 2005)



Temperature maps at the central surface



- -Eulerian mesh
- N=400^3
- L=0.8 Mpc

kT_{max} ～30 keV

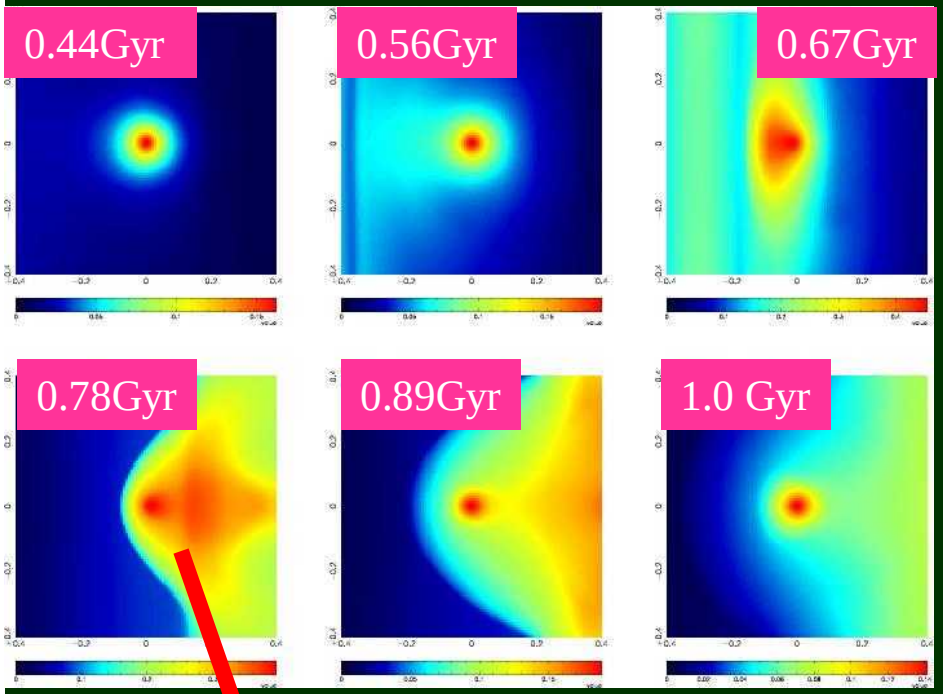
V_{max} ～4000 km/s

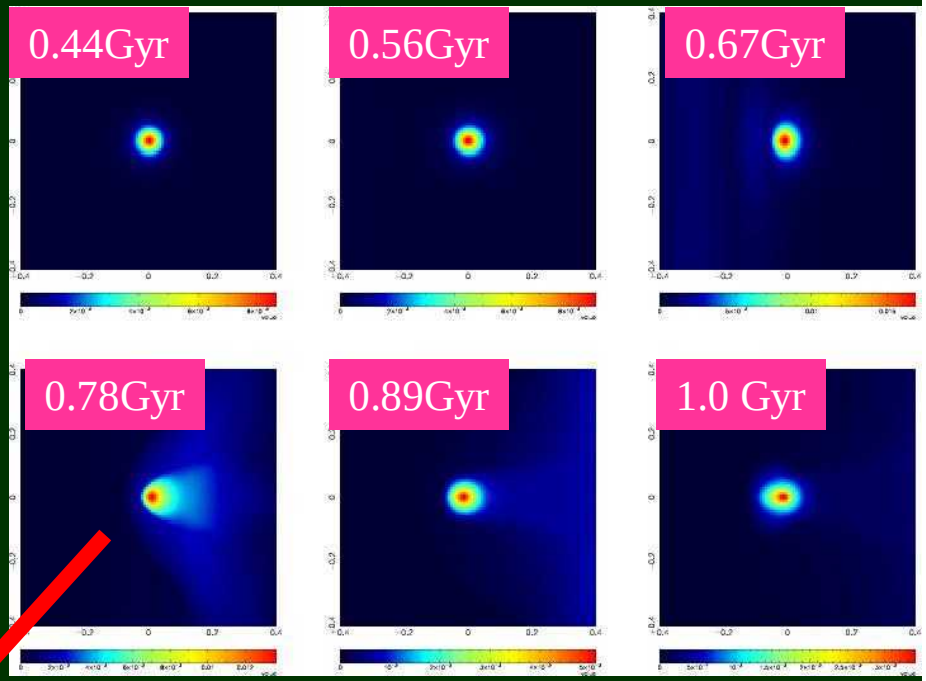
$\Delta\tau$ ～0.1 Gyr

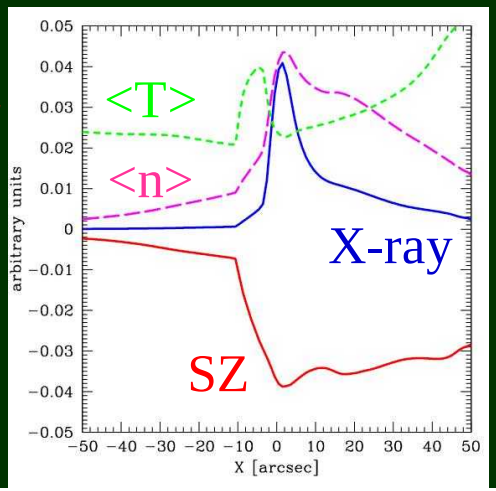
Simulations of sub-cluster mergers (Takizawa 2005)

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

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

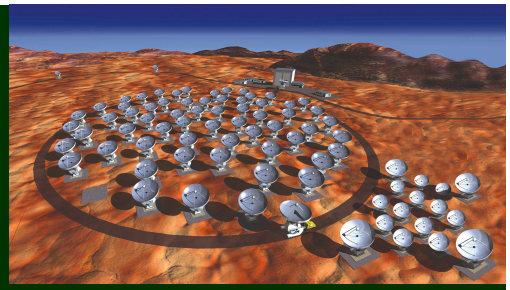




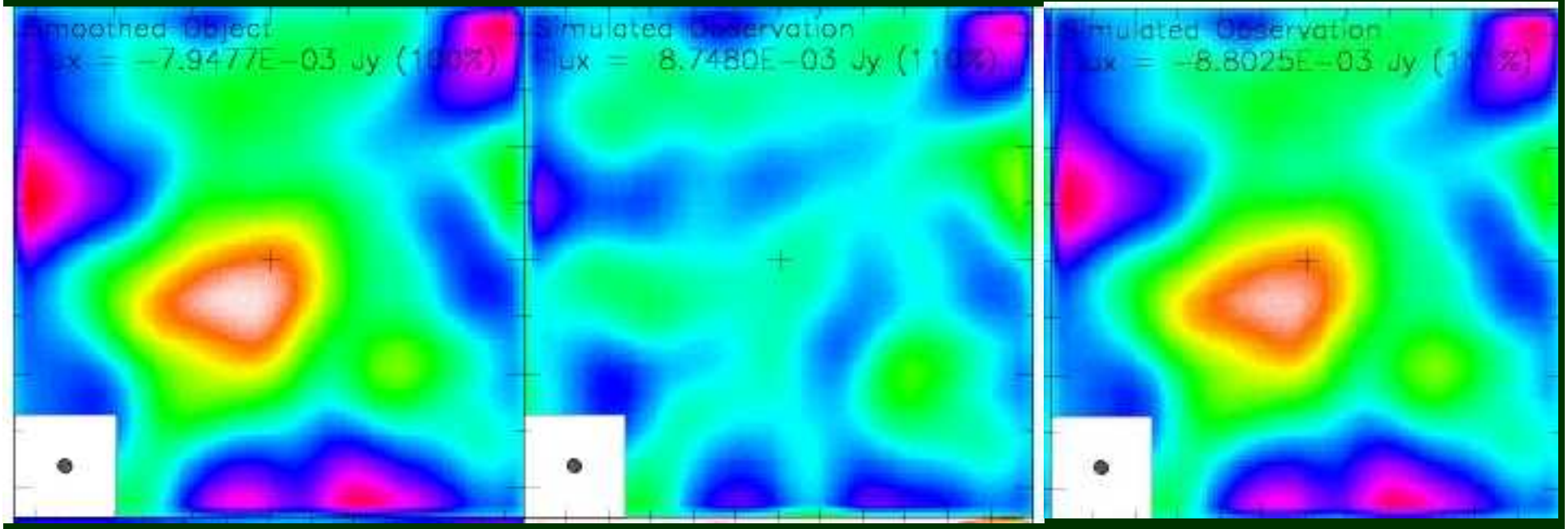


SZE image is highly disturbed,
while X-ray remains compact.
⇒ better tracer of shock front

Feasibility simulations for ALMA by GILDAS (Tsutsumi et al. 2005)



90”



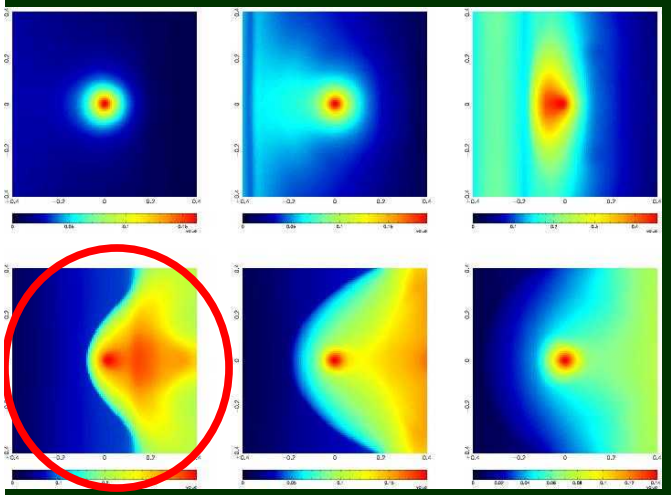
INPUT based on
150GHz data (13”FWHM)
of RX J147.5-1145

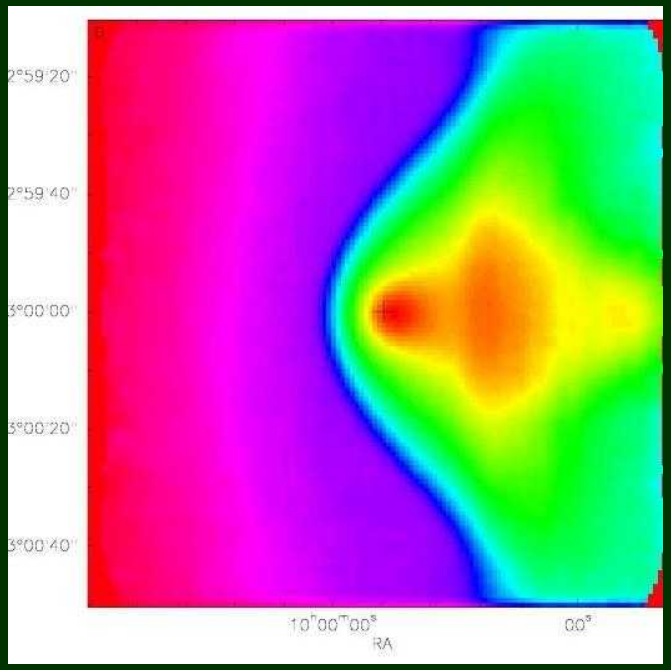
ALMA 64 arrays
longest baseline 150m
13 mosaics, 18 min

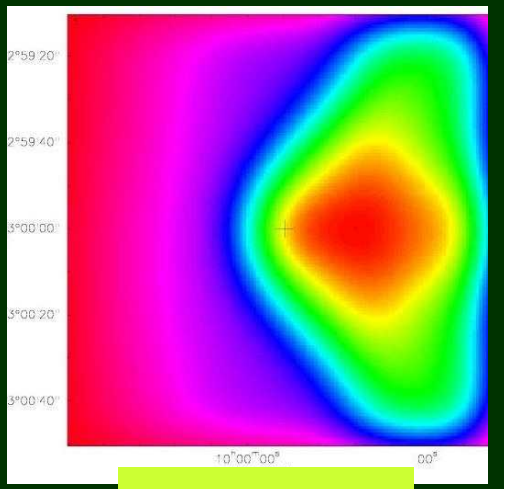
with ACA
longest baseline 30m
13 mosaics, 72 min

1 **σ** =0.03 mJy/beam
peak = -0.22 mJy/beam
FWHM=2.4”

ALMA imaging Simulations







14” FWHM

INPUT:

Snapshot from cluster merger simulations (Takizawa 2005).

Place it at z=1, Dec= -23 deg.

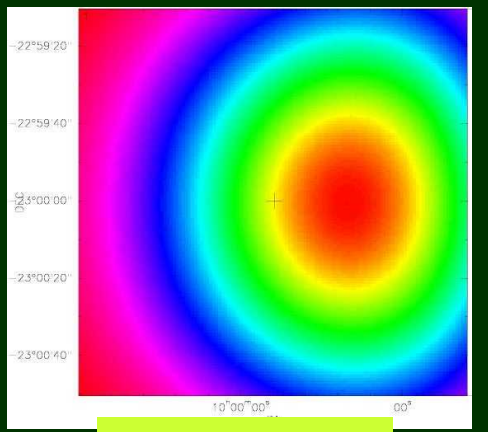
Output:

ALMA 64 arrays + ACA

13 field mosaic, 90min total

no thermal noise (preliminary!)

FWHM=2.4”@150GHz

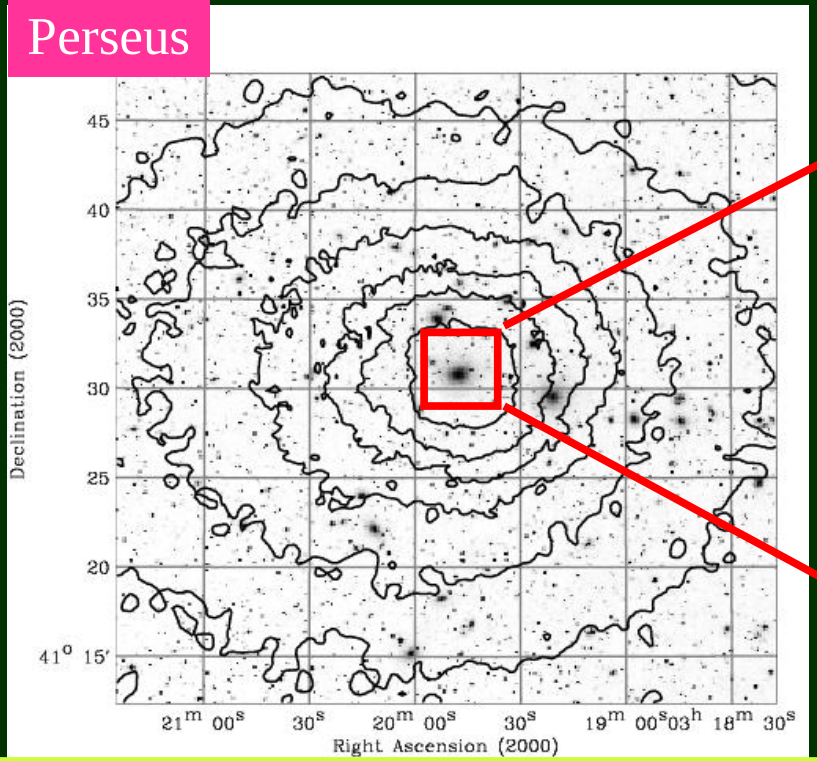


60” FWHM

Impacts of high resolution

X-rays: drastic progress in understanding of ICM

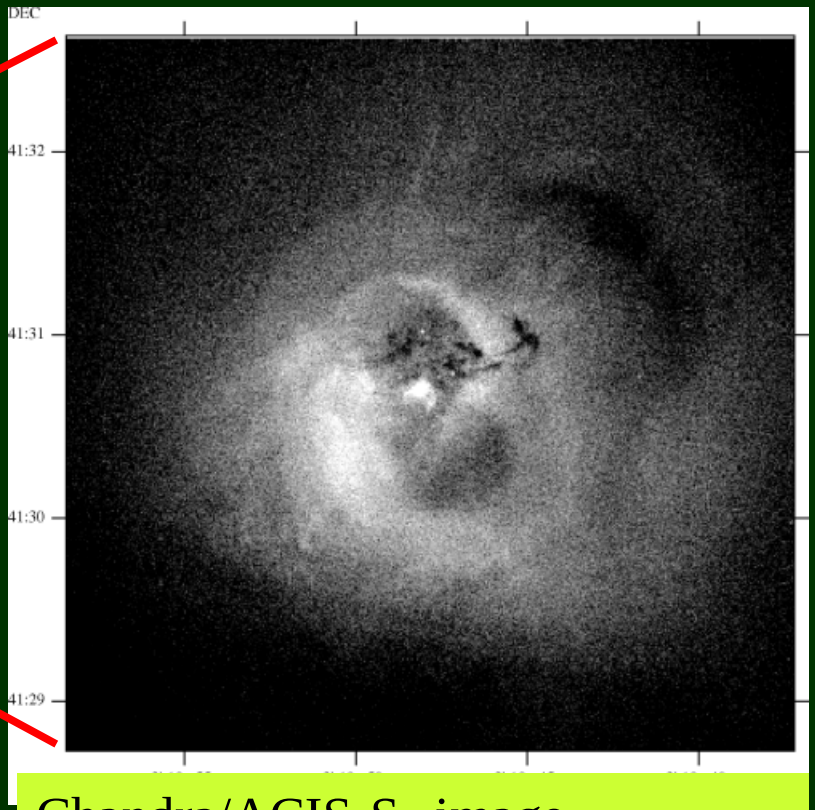
Perseus



ROSAT/PSPC contour + optical image
FWHM～25” (Ettori et al. 1998)

Most of current SZE images
FWHM ～ arcmin

×50



Chandra/ACIS-S image
FWHM～0.5” (Fabian et al. 2003)

ALMA： FWHM ～2“ @ 150GHz

Conclusions

High resolution SZE + X-ray images
⇒ Powerful probe of cluster physics

e.g. RX J1347.5-1145 at z=0.45
strongest SZE & most X-ray luminous

- Temperature profile solely from imaging data

⇒ high z clusters with no X-ray spectroscopy

- Unique tracer of very hot gas with kT>20 keV

cf. current X-ray imagers: E<10 keV

Applicable to a larger number of clusters by ALMA!