Surveying and Imaging Clusters with AMI

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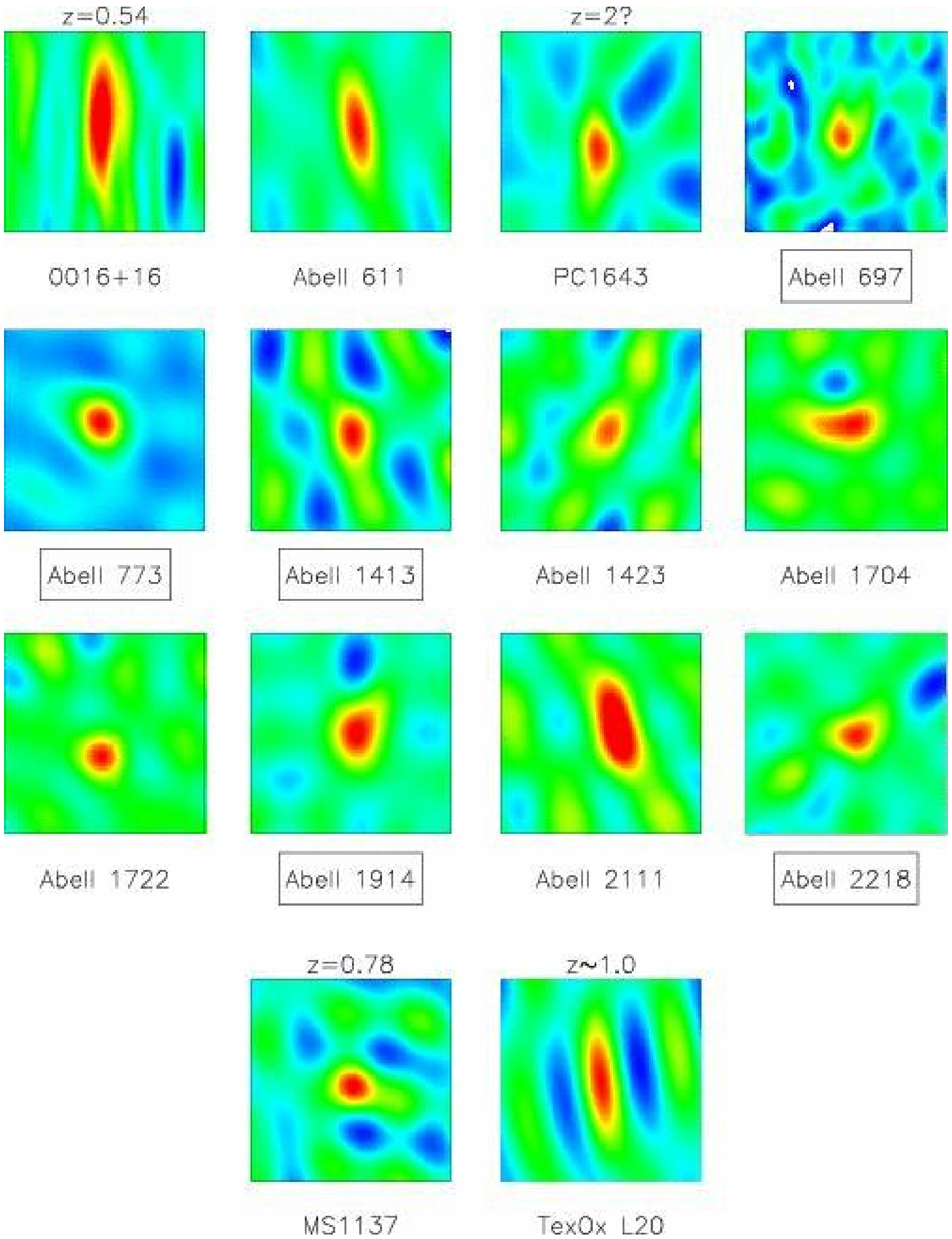
ALMA SZ meeting, IAS Orsay, 7 April 2005

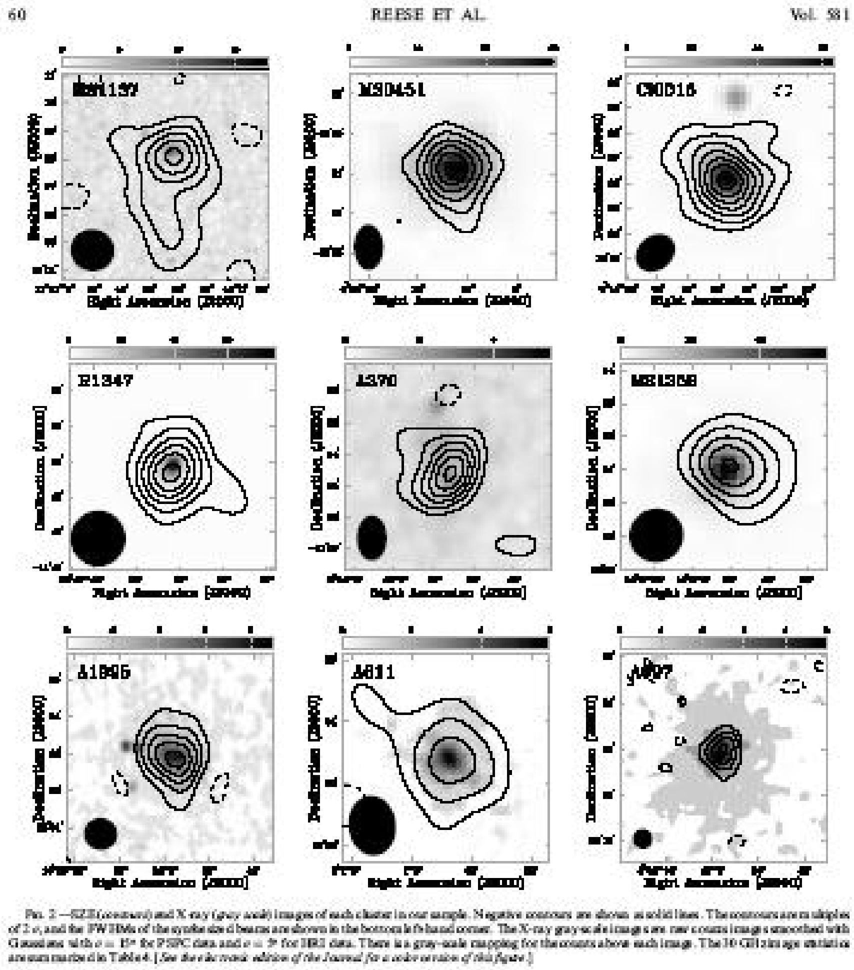
Arcminute Micro-Kelvin Imager (AMI)

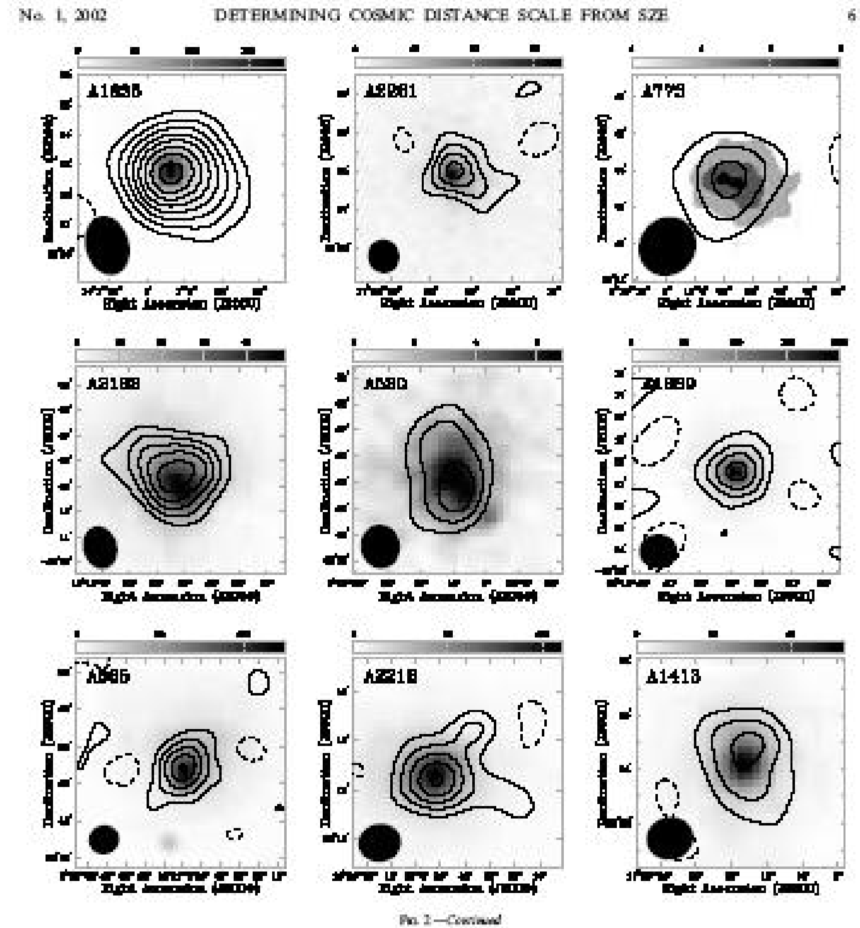
- instrument / status
- expectations for the survey
- imaging capability



SZ clusters observed with the Ryle Telescope ($z = 0.1$–1).

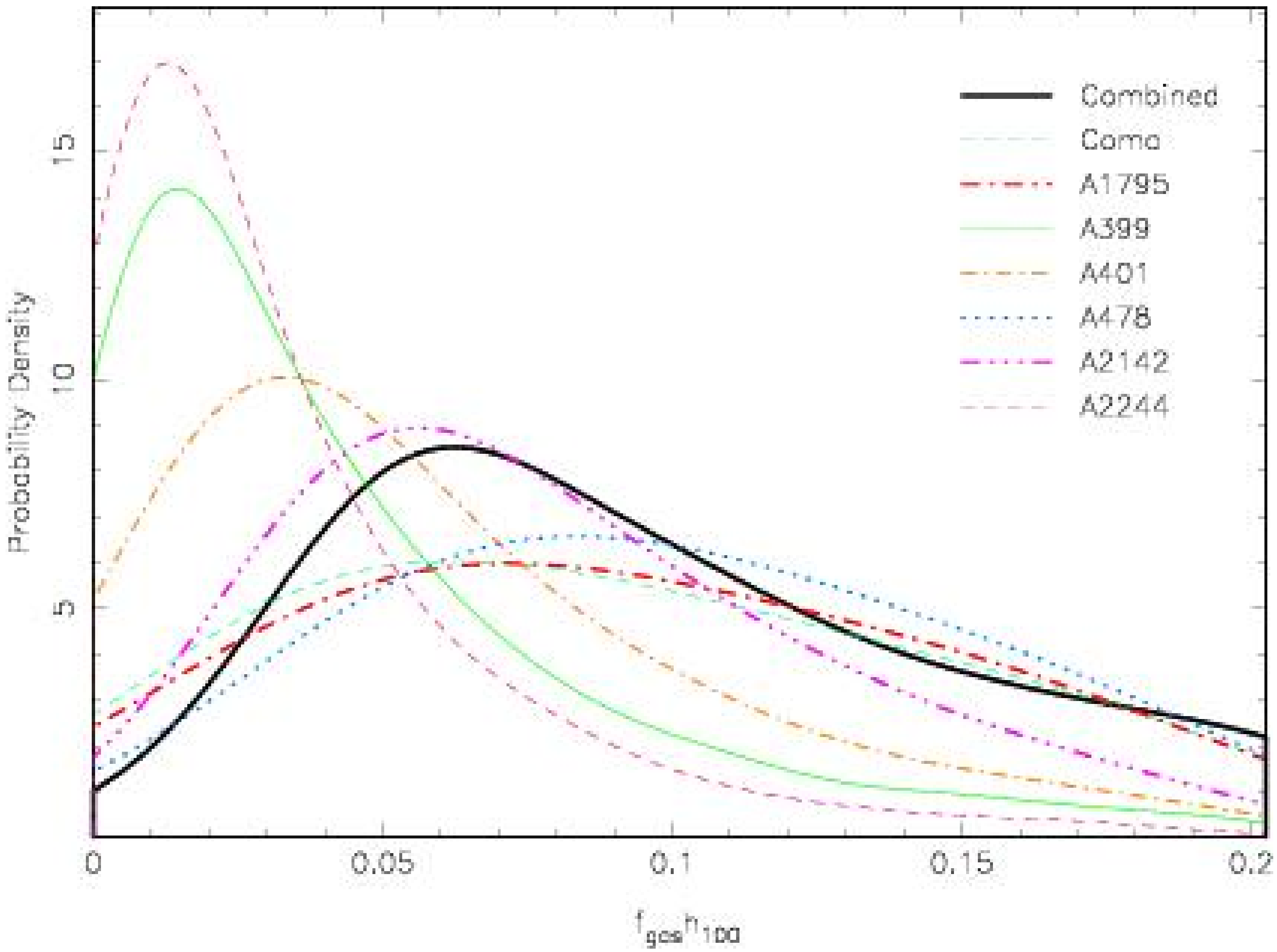
OVRO / BIMA cluster sample





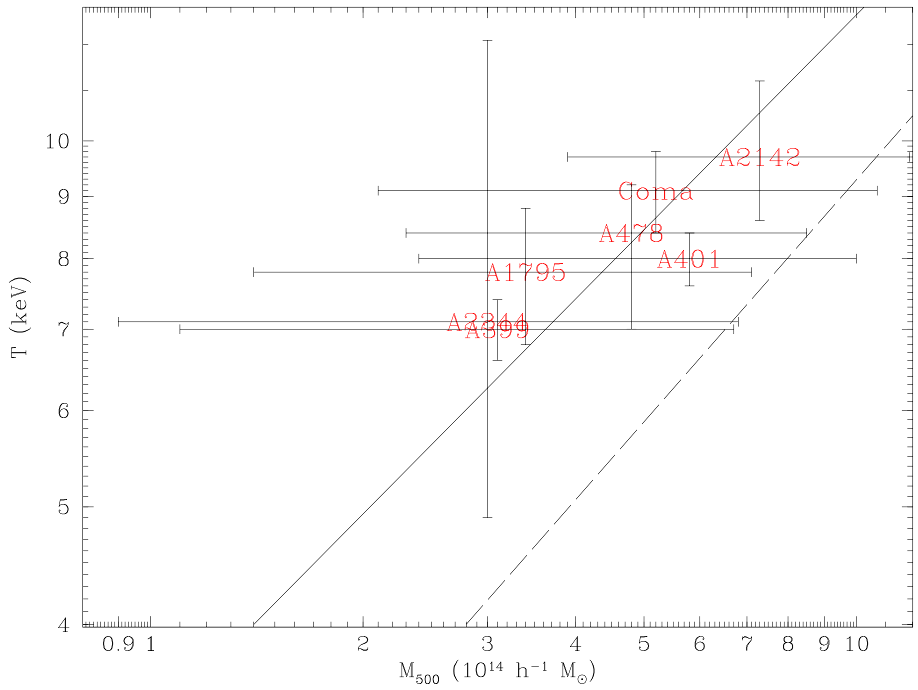
Weighted sample averages $H_0 = 66 \pm 10$ km s^{-1} Mpc^{-1} (Jones et al.), $60 \pm 4^{+13}_{-18}$ (Reese et al.).
see also Mason & Myers (OVRO, 5.5 m), Grego et al., Udomprasert et al. (CBI), Benson et al. (SuZIE), Lancaster et al. (VSA) etc.

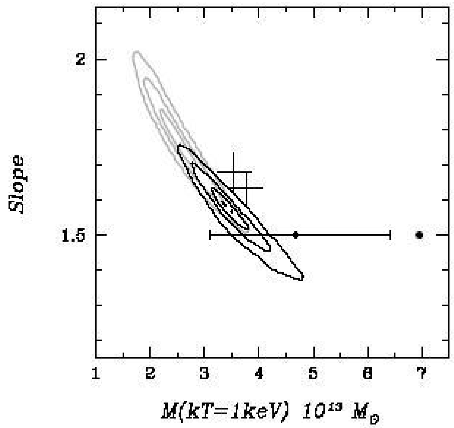
Gas fraction measurement from VSA SZ data



Combined constraints (from significant detections - see evidence) on the gas fraction $f_g = 0.08^{+0.06}_{-0.04} h^{-1}$ (Lancaster et al., astro-ph/0405582)

A mass - temperature relation from VSA SZ data

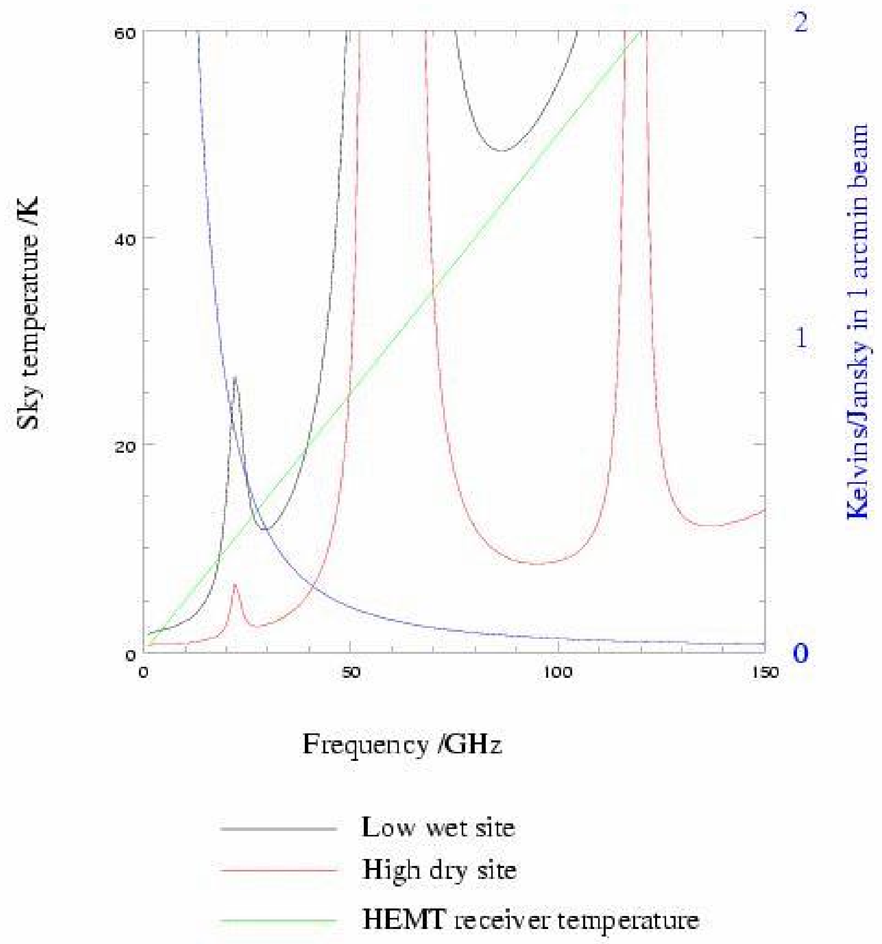




In agreement with X-ray determinations, disagreement with predictions from adiabatic simulations - interesting, given the differences between X-ray and SZ.

Understanding L_{SZ} - M relation, ie. M-T and f_g, will be essential for the blind SZ surveys.

The Ryle Telescope (80's technology) is too slow for surveying / no imaging of faint clusters.

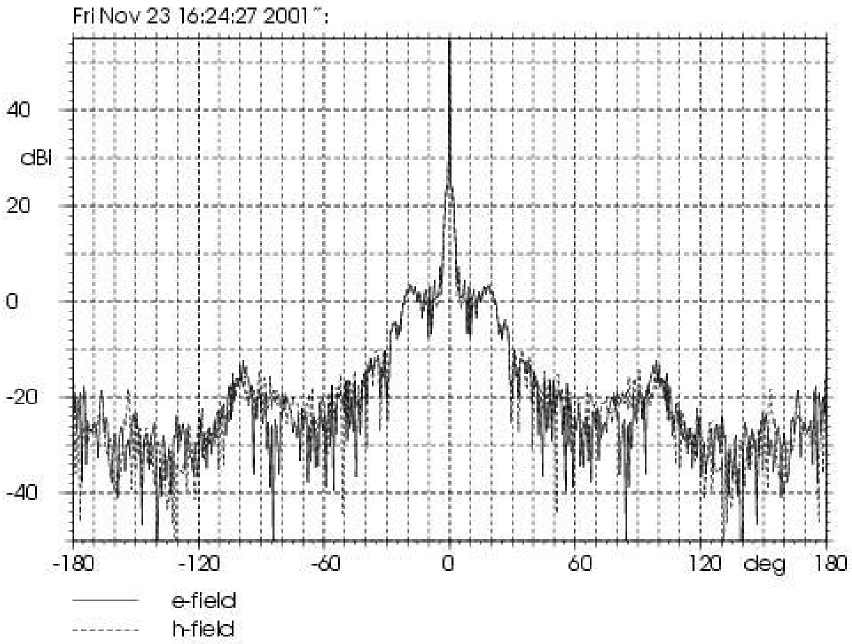


Design of AMI uses **large collecting area** to build SZ survey instrument at low frequency

- **Low** T_{sys} (atmosphere / receivers; 55K $\rightarrow$ 25K) + use **highest bandwidth** possible (0.35 GHz $\rightarrow$ 6 GHz)
- Move 3 distant Ryle antennas to gain **N-S resolution** and sensitivity
- **Infrastructure** of Lord's Bridge site
- Add **compact array of 3.7-m dishes**: Minimum baseline to **not resolve cluster** $\sim 200\lambda$ @ 2 cm (RT with 650λ resolves 90% of cluster flux)
- At 15 GHz **radio sources** are bright $\rightarrow$ **subtract** using Ryle antennas / surveys at neighbouring lower frequencies available

Antennas:

- 3.7-m Cassegrain, off-the-shelf single-piece paraboloidal primary
- shaped, over-size secondary gives $\eta \simeq 0.8$ over 12–18 GHz
- rim baffle and ground screen gives $T_{\rm spill} < 1$ K



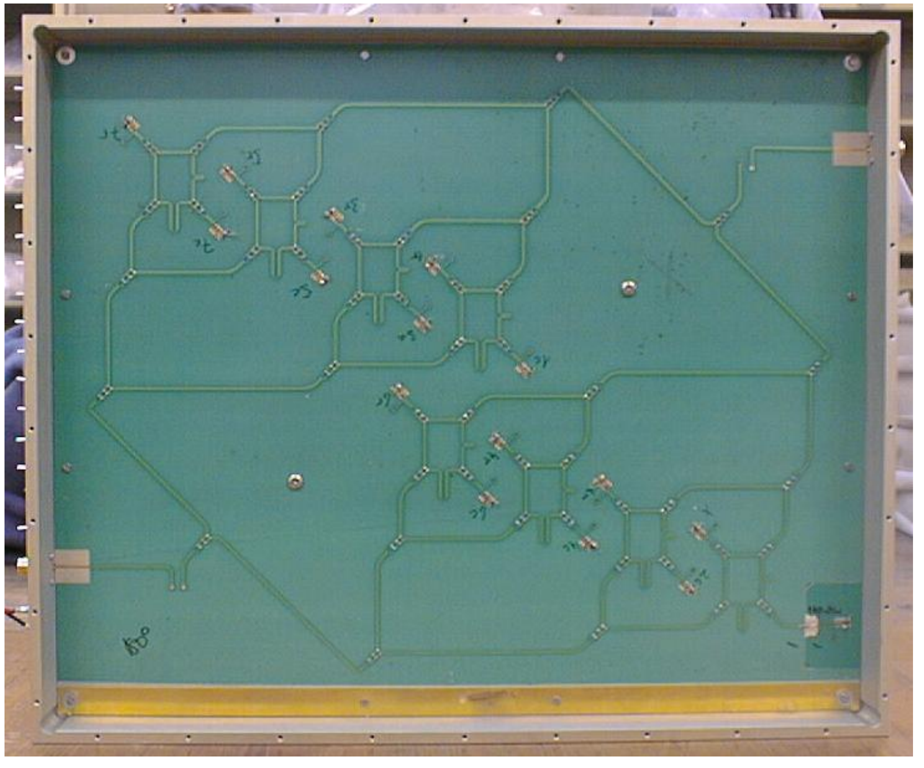
Receivers:

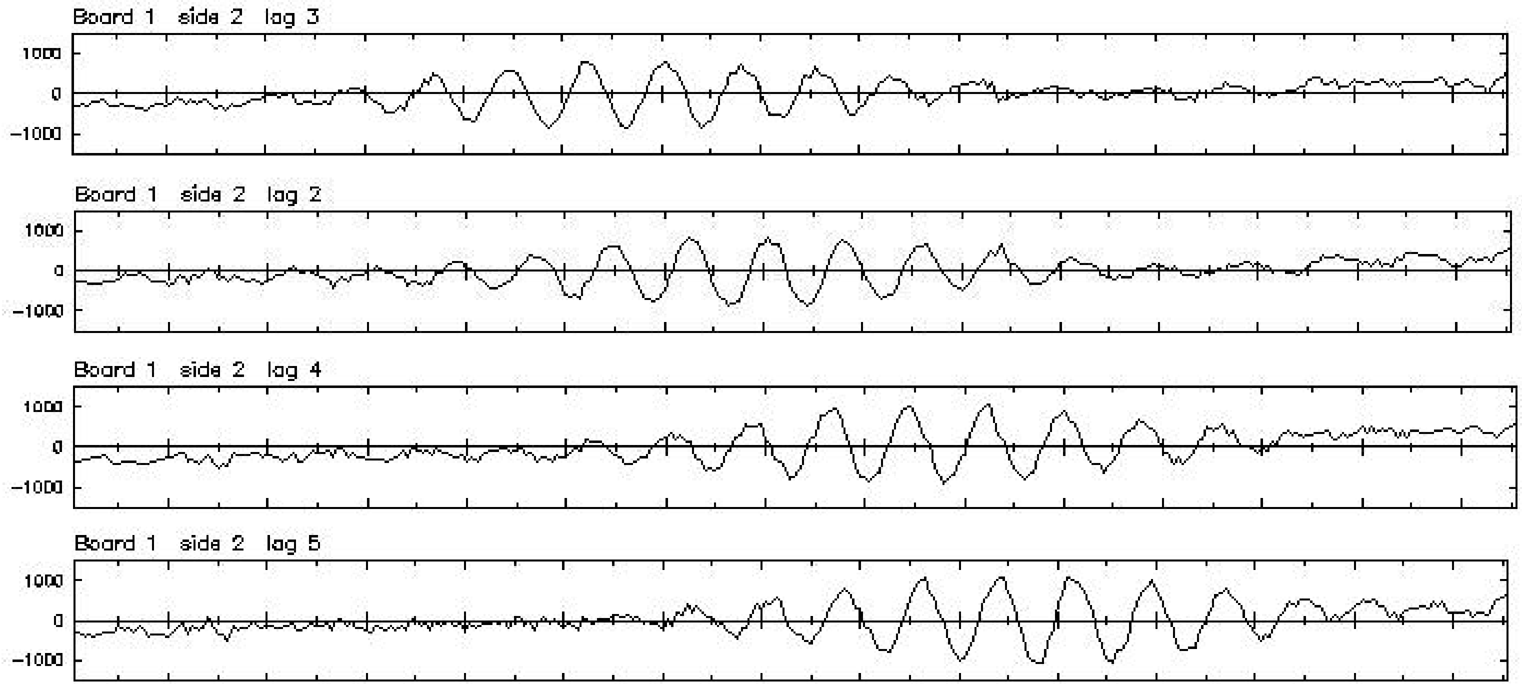
- NRAO 8–18 GHz amplifiers, $T_{\mathsf{amp}} = 6$ K
- fully cooled feedhorn

IF system: downconverters, amplifiers, filters, path compensator, gain control units for 6–12 GHz.

Correlator:

- 16-lag analogue correlator $\rightarrow$ 8 complex frequency channels
- detect phase-switched power with Schottky diodes

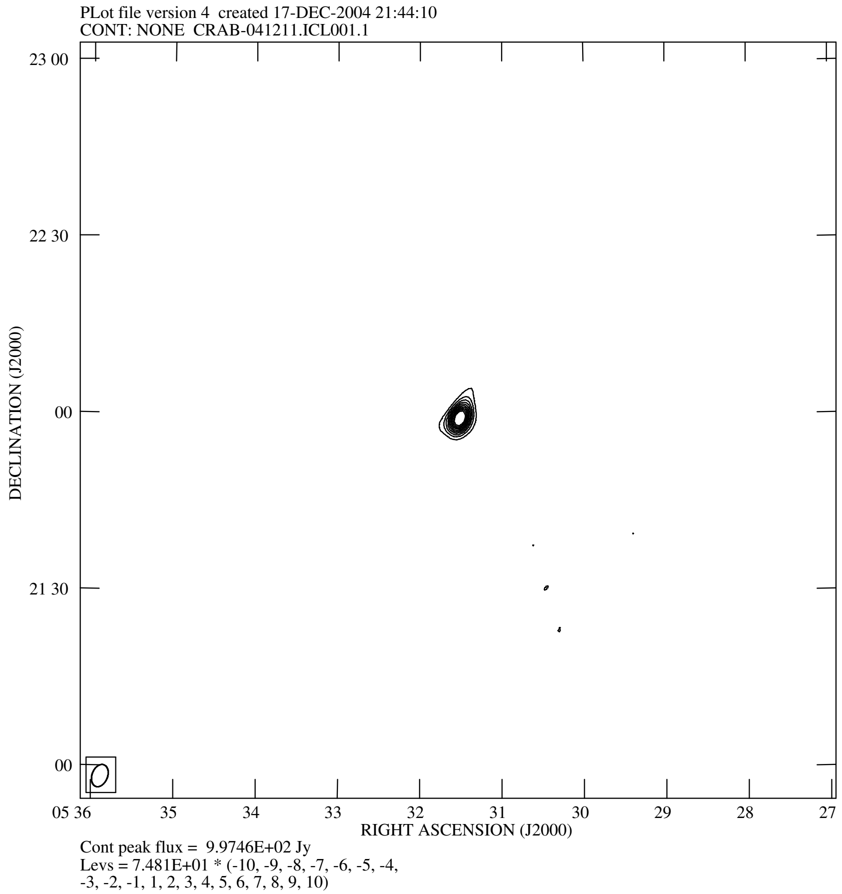




Single baseline fringes from Crab Nebula. Output by correlator lag – FT to get frequency

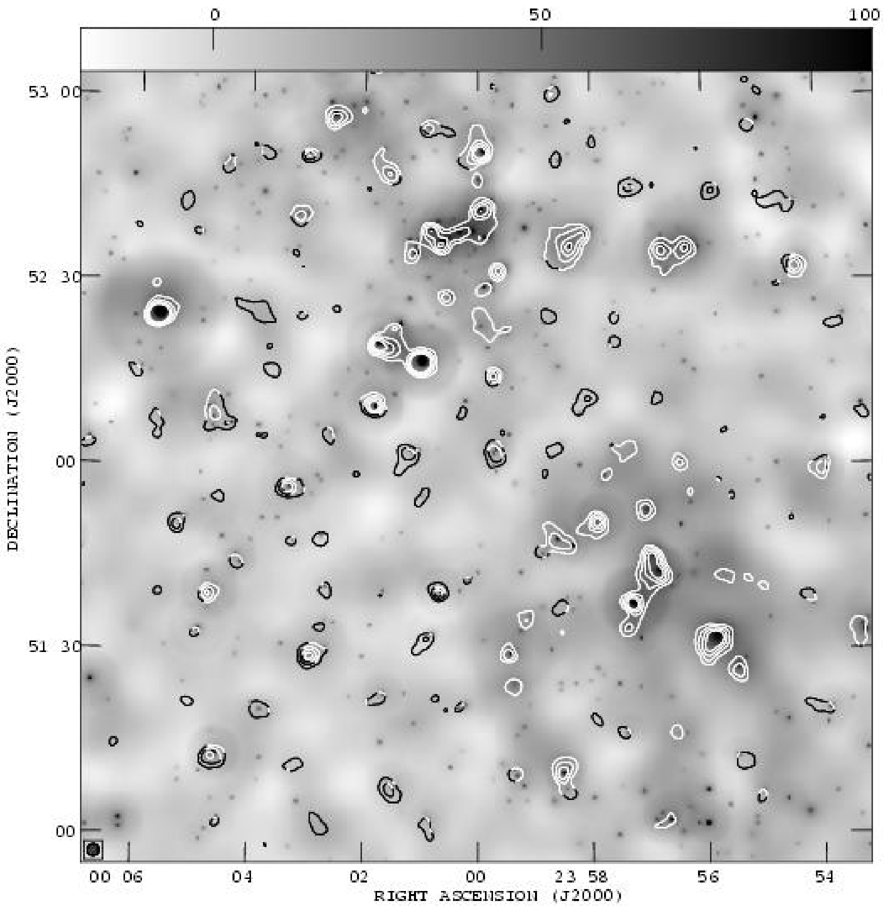
Compact Array, May 2004

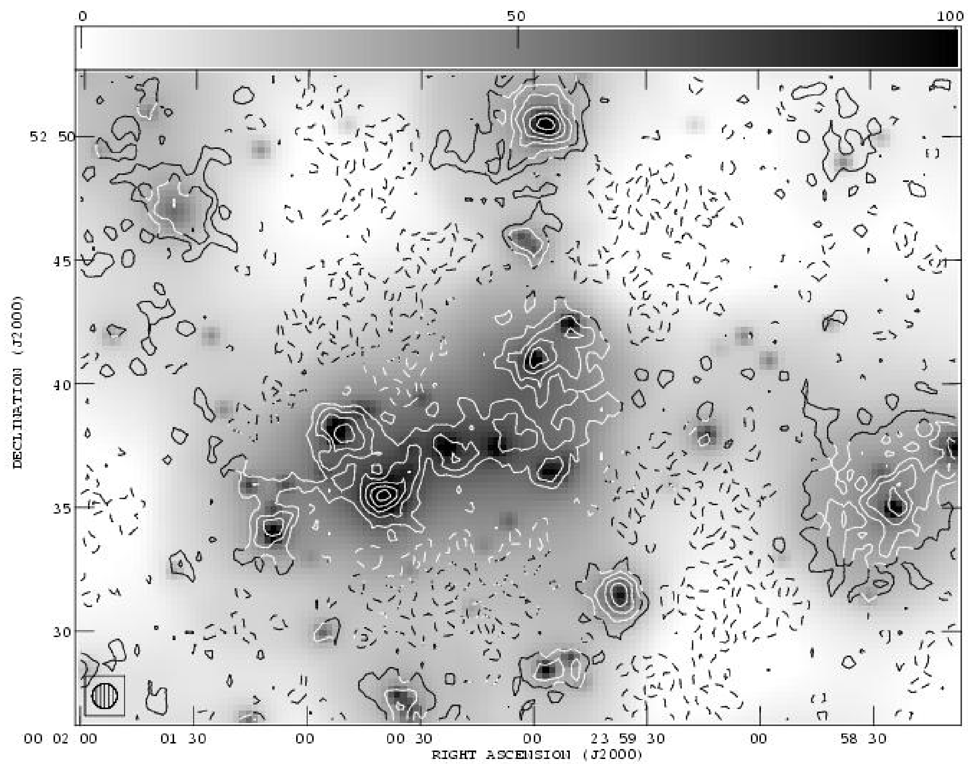
Roger Boysen, Tony Brown, Mike Crofts, Tom Culverhouse, Roger Dace, Peter Duffett-Smith, Ken Duggan, Will Flynn, Keith Grainge, Will Grainger, Jörn Geisbüsch, Richard Hills, Mike Hobson, Christian Holler, Roy Jilley, Mike Jones, Tak Kaneko, Rüdiger Kneissl, Anthony Lasenby, Ian Northrop, Guy Pooley, Vic Quy, Richard Saunders, Jack Schofield, Paul Scott, Clive Shaw, Angela Taylor, Dave Titterington, Marko Velic, Simon West, Brian Wood, Jonathan Zwart



First image from AMI compact array (of the Crab Nebula, Dec 2004);
4 (10) antennae, 6 (45) baselines, 1 (8) frequency channels

AMI cluster survey

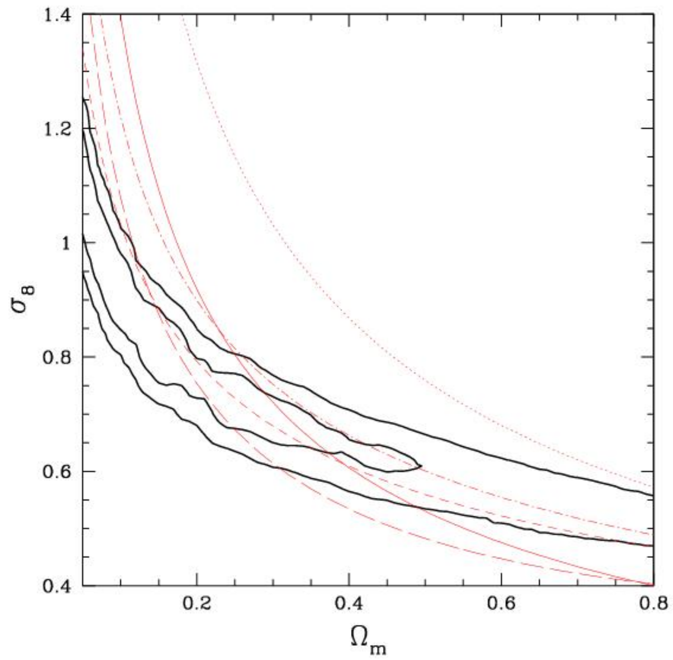




Grayscale image: Virgo cluster positions with scaled β model clusters, plus CMB
Contour overlay: 6 months survey, 2 arcmin resolution. Sources subtracted!

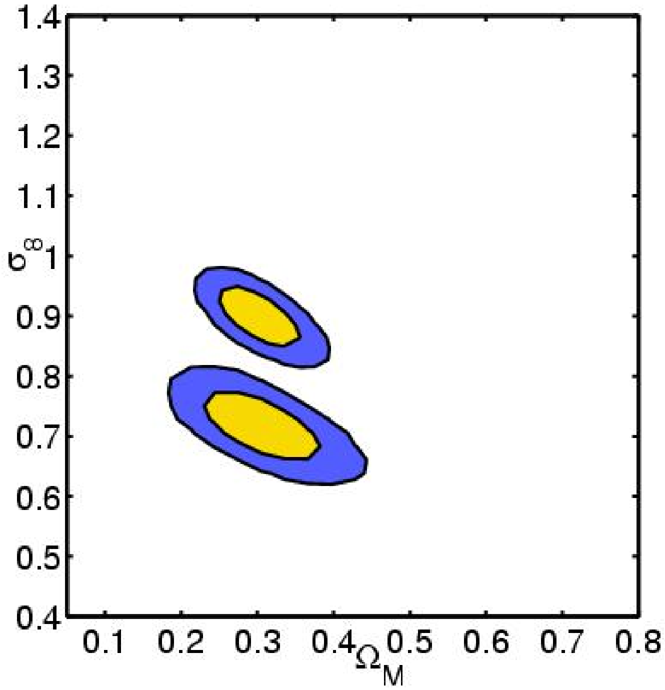
Parameter estimation

- Two cases considered: $\sigma_8 = 0.9$ and $\sigma_8 = 0.7$ ($\Omega_M = 0.3$)
- M-T relation is changed consistently with X-ray data
- Size of the error is roughly given by cluster numbers (300 and 150 clusters)
- Other cosmological parameters held fixed (e.g. $h = 0.72$ and $w = -1$)
- Follow-up: redshifts with $\Delta z = 0.1$ out to $z = 2$
- Well-determined cluster scaling relations (e.g. $\Delta f_g \sim$ 10%, $\Delta\beta \sim$ 10%)
- See Weller, Battye, RK (2002) for the method



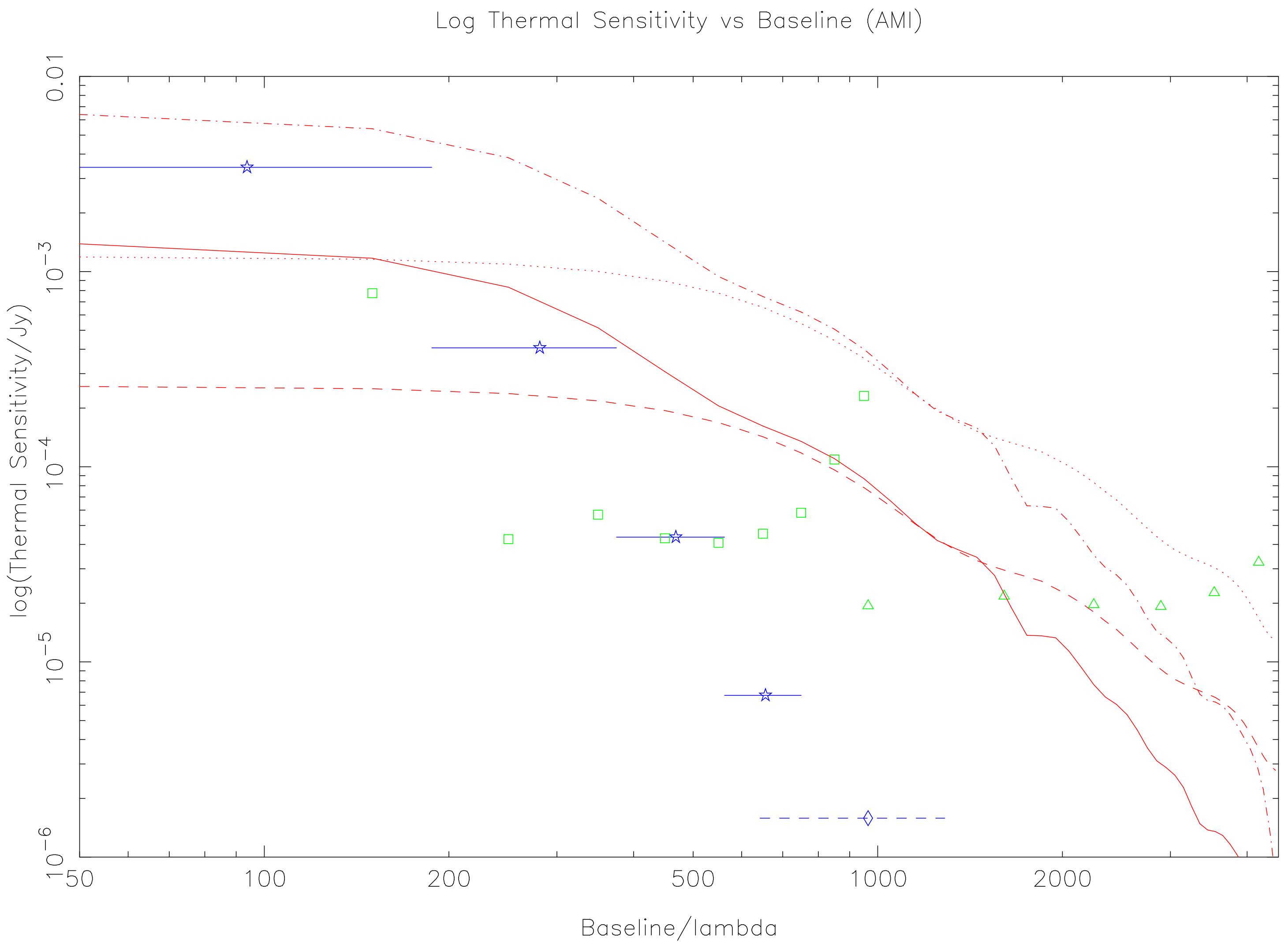
X-ray cluster abundance

(compilation from Allen et al. 2002)



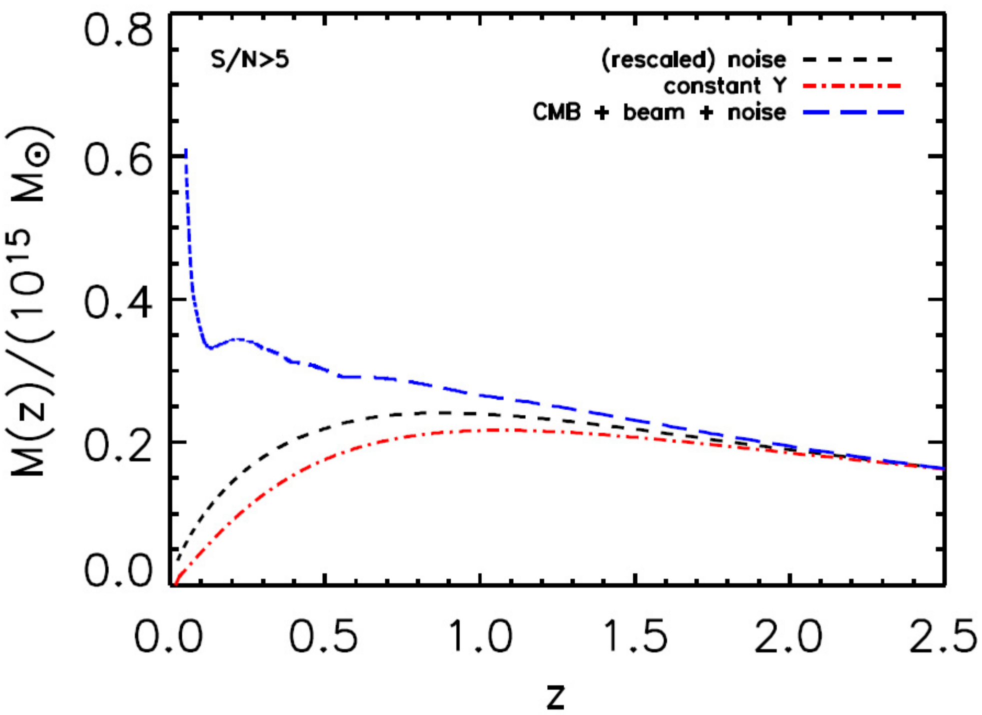
1-year AMI survey of 100 deg^2

Sensitivity and CMB Confusion

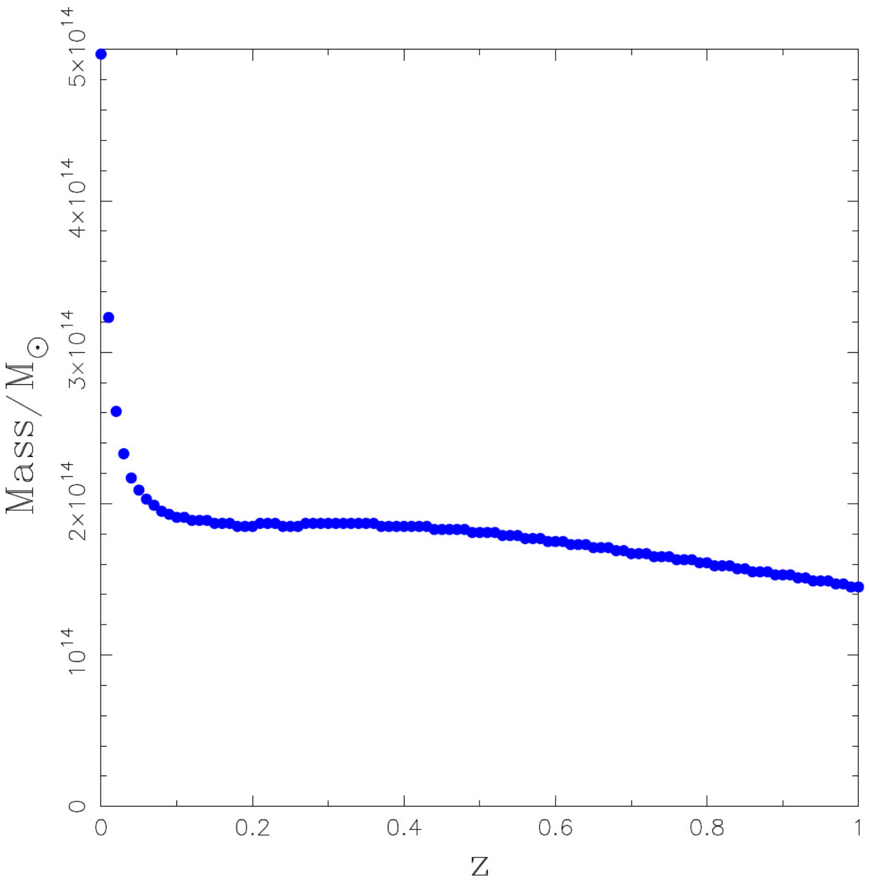


Thermal flux sensitivity (6 $\times$ 8-hours; within a 21 arcmin aperture) of the compact array 3.7-m and large array 13-m dishes compared to primordial CMB and 4 clusters with masses of $M = 2 / 5 \times 10^{14} M_{\odot}$ and at redshifts $z = 0.15/0.8$.

SZ selection function

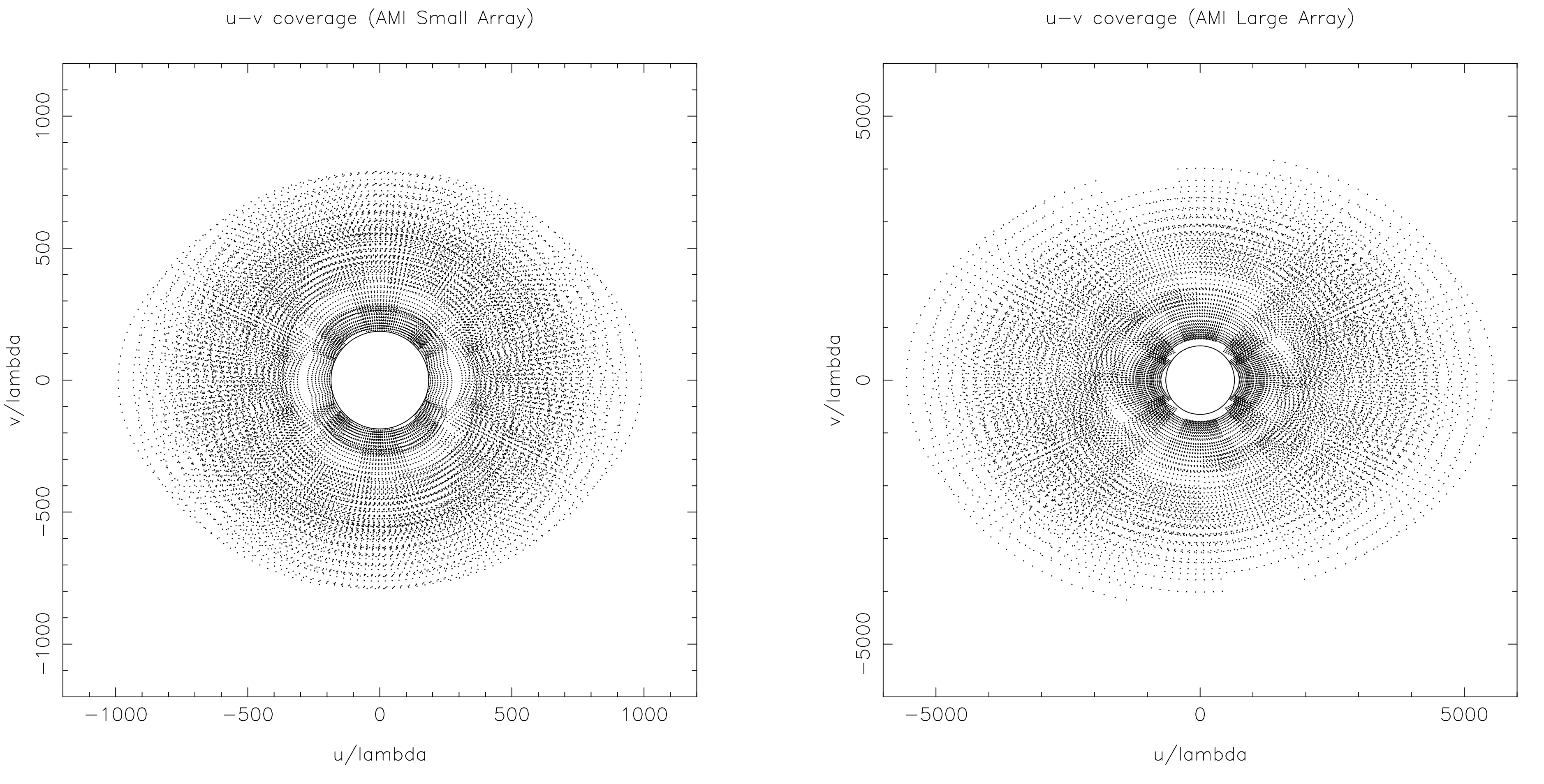


Melin, Bartlett, Delabrouille
(astro-ph/0409564)



Culverhouse
(Moriond 2004)

U-V coverage for compact array and up-graded Ryle Telescope



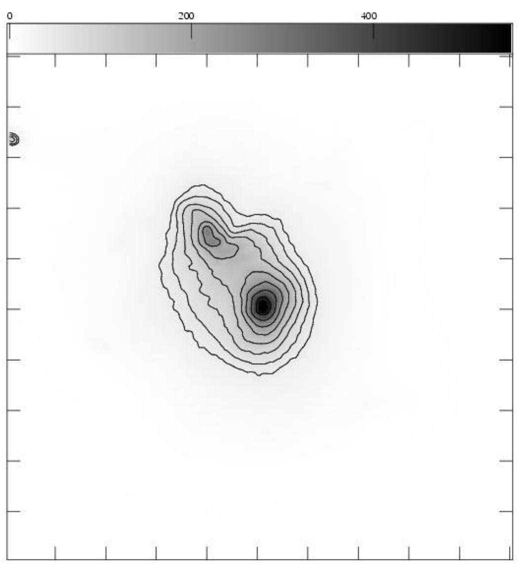
Move of Ryle antennae (Oct-Dec 2004)

Imaging cluster substructure

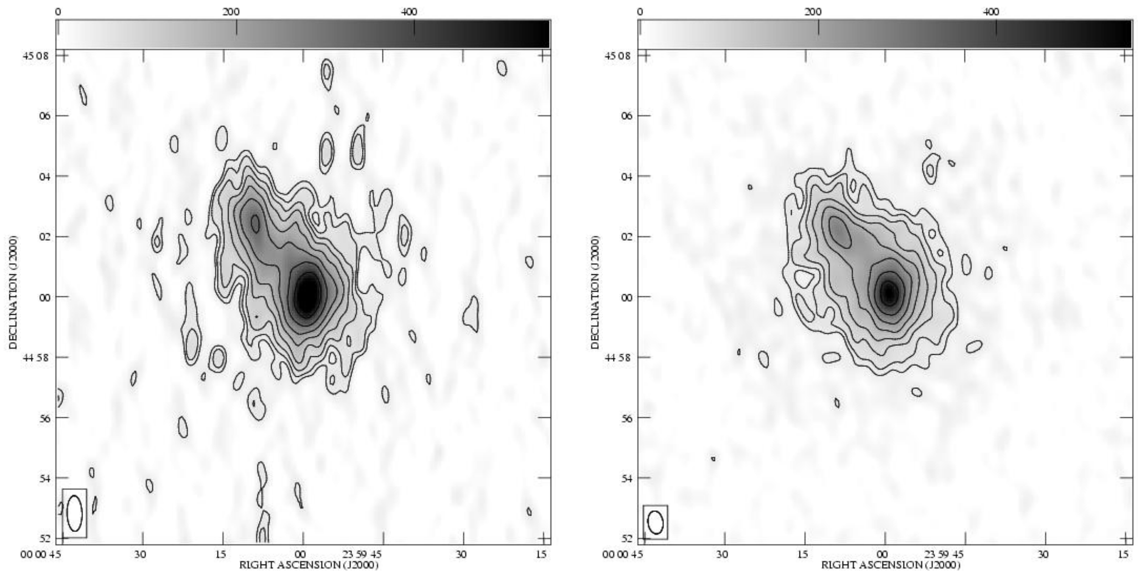
Construction phase 3: Compactifying the Ryle telescope

current wide East-West alignment

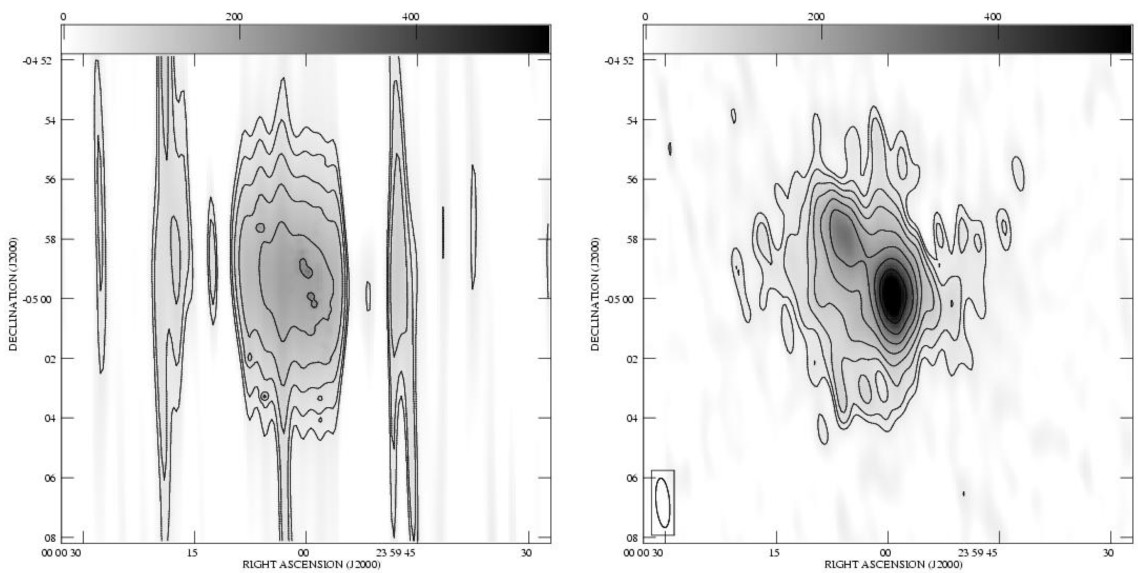
more compact array with improved North-South resolution



Hydrosimulation: 5×10^{14} $M_{\odot}$ merging cluster at $z = 0.155$.

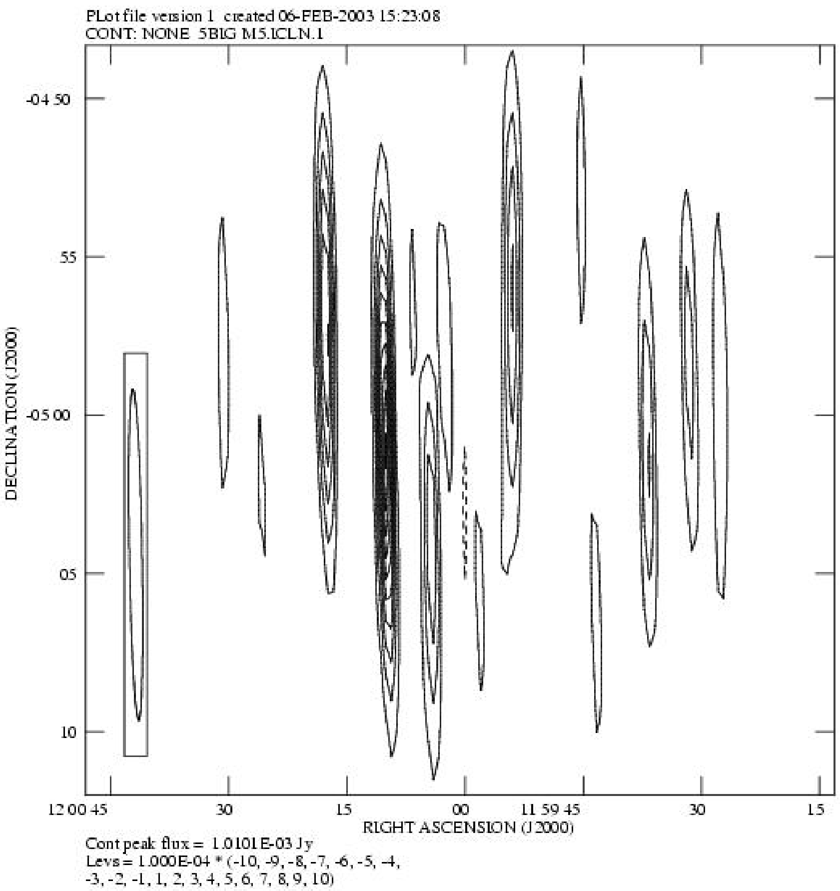


high declination (45 deg)

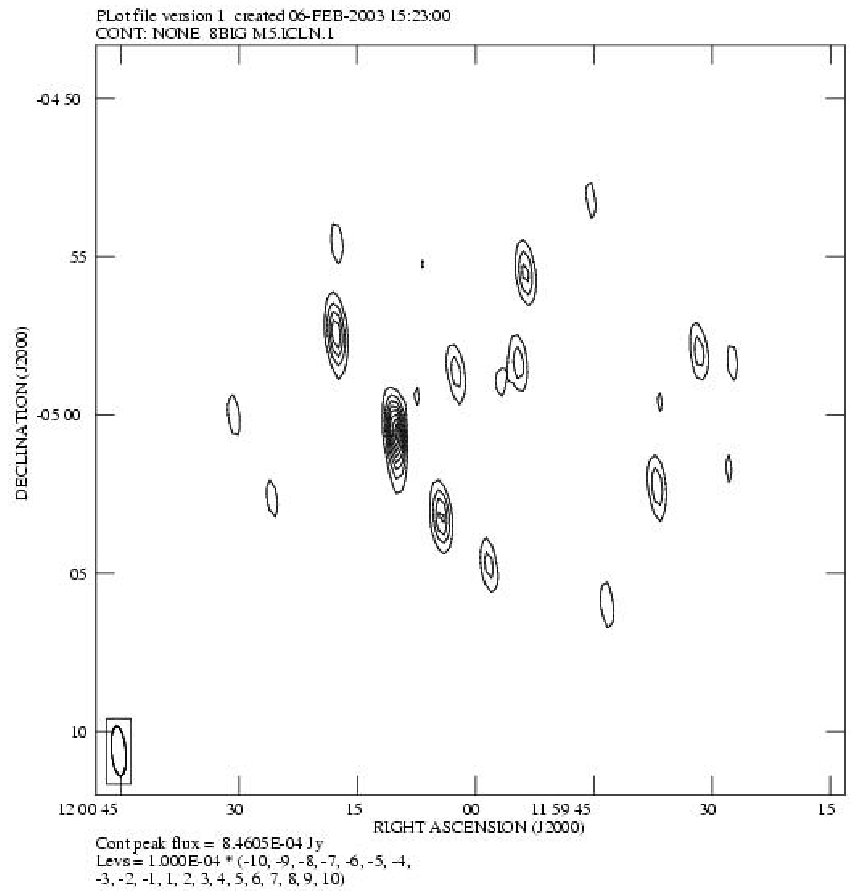


low declination (-5 deg)

Radio source confusion



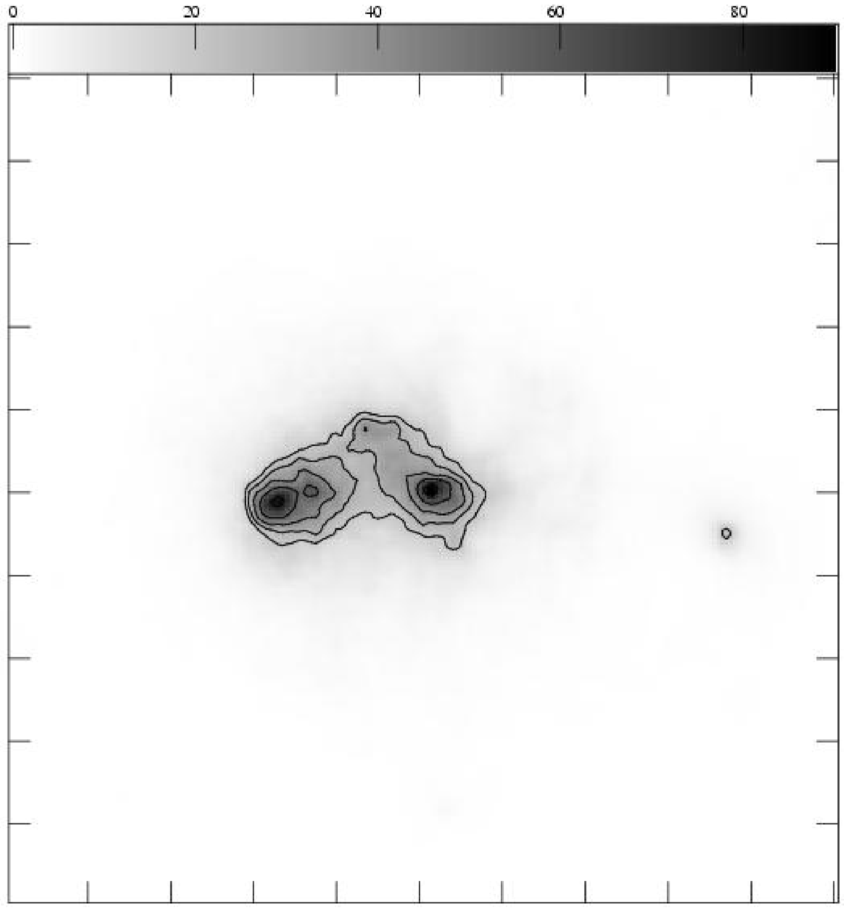
five 13-m dishes



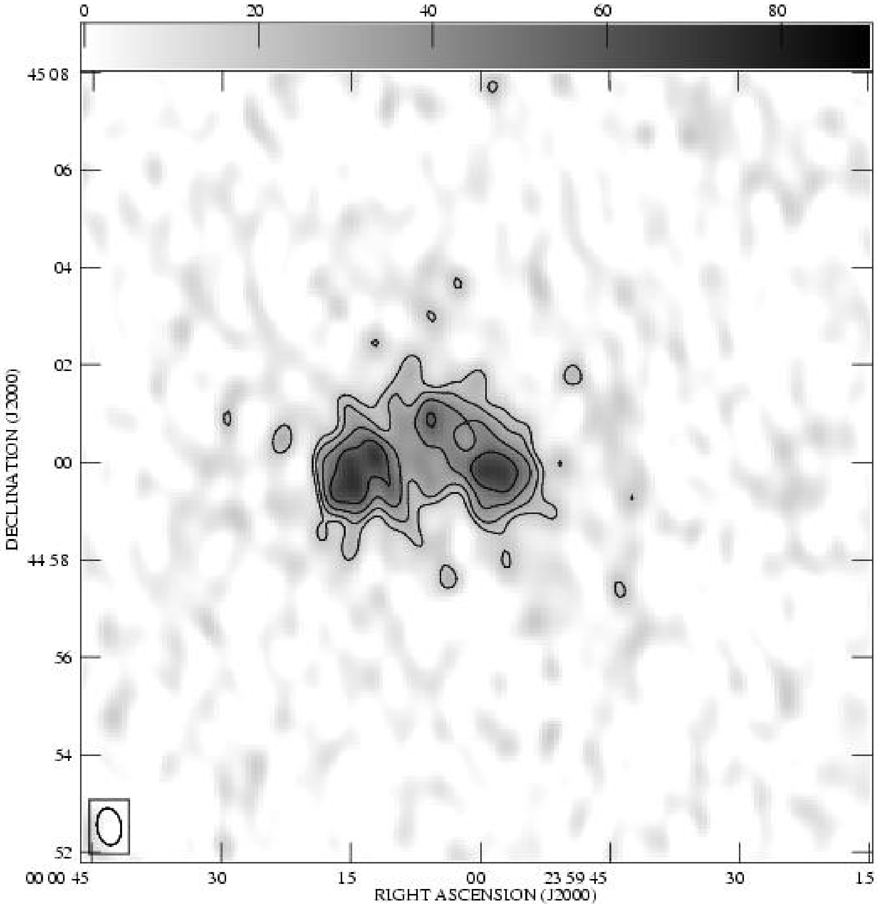
eight 13-m dishes

Simulated source survey observation at DEC -5 with 4 hour total integration time at each pointing. Can subtract sources $> 50\mu$Jy.

Pointed high redshift cluster observations



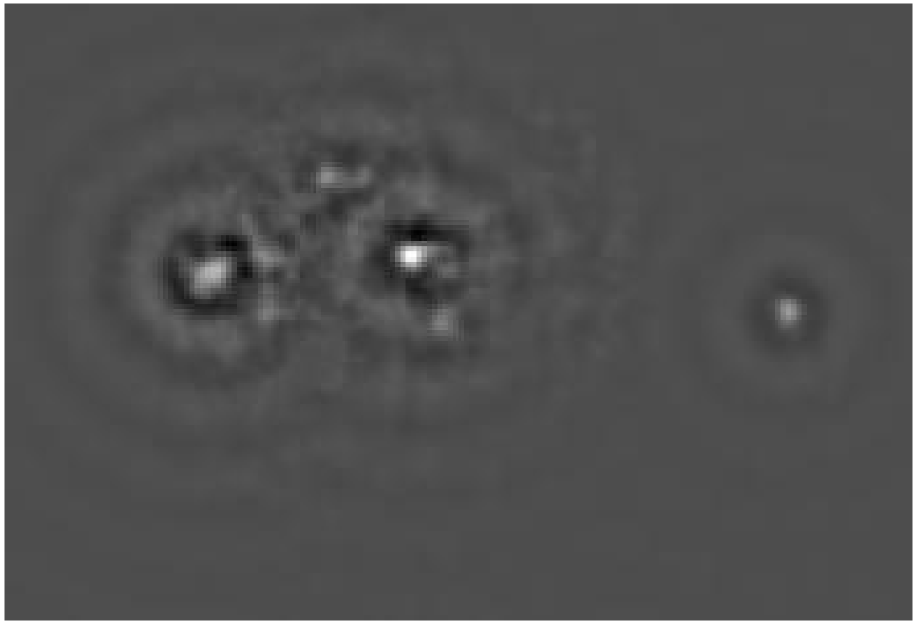
Cluster merger at redshift 1.5 of total mass 2×10^{14} $M_\odot$ from a hydrodynamical simulation (G. Tormen); in y-units of 10^{-6}.



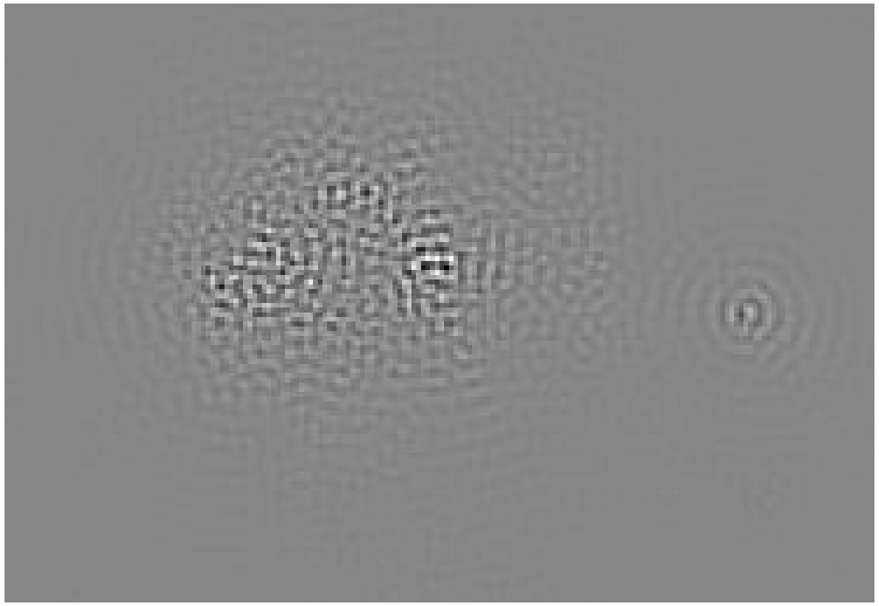
Simulated $14 \times 8{-}$h observation with compact array and Ryle mosaic; in μJy beam^{-1}.

Cluster imaging with ALMA - an example

assume 90 GHz, no noise (1-σ sensitivity is $457\mu\text{K}\sqrt{\text{s}}\,(10''/\Theta)^2$), no CLEANing, could COMBine with lower resolution data, min/max baseline, no baseline projection / shadowing / realistic uv-coverage, . . .



7200–43200 λ, 24–144 m
$\Delta T_{\text{max}} = 100\mu$K,
For 5-σ need 10 min



21600–43200 λ, 72–144 m
6.7 μK,
1.5 days

Conclusions

- AMI cluster survey expected to begin this summer
- expect to find $\sim$ 100 clusters per year
- interesting constraints on σ_8, $\Omega_{\rm M}$, w
- imaging also expected to be interesting - evolution of gas fraction, M–T relation, etc.
- how will ALMA take this further ? - detailed cluster study: cluster sources, features from gas processes (merging, AGN activity, etc.); use high-resolution simulations / Chandra images to check
- plenty of target clusters, also at high z, available for ALMA by 2010