Bullet Cluster:

Wide-band Interferometer measurement of the Sunyaev Zeldovich Effect

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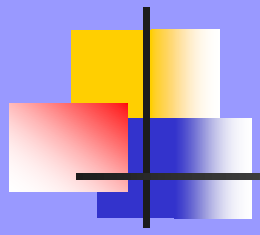
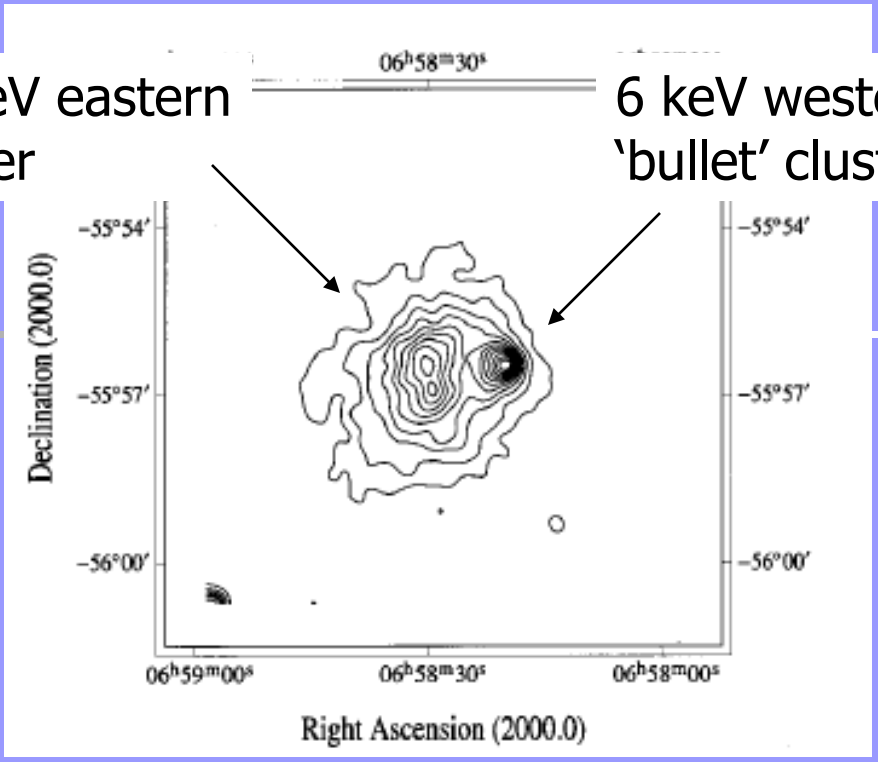


- Bullet cluster = 1E 0657−56 / RJ J0658−5557
- Redshift z = 0.3
- 4 arcmin = 1 Mpc proper length

- ROSAT PSPC X-ray image



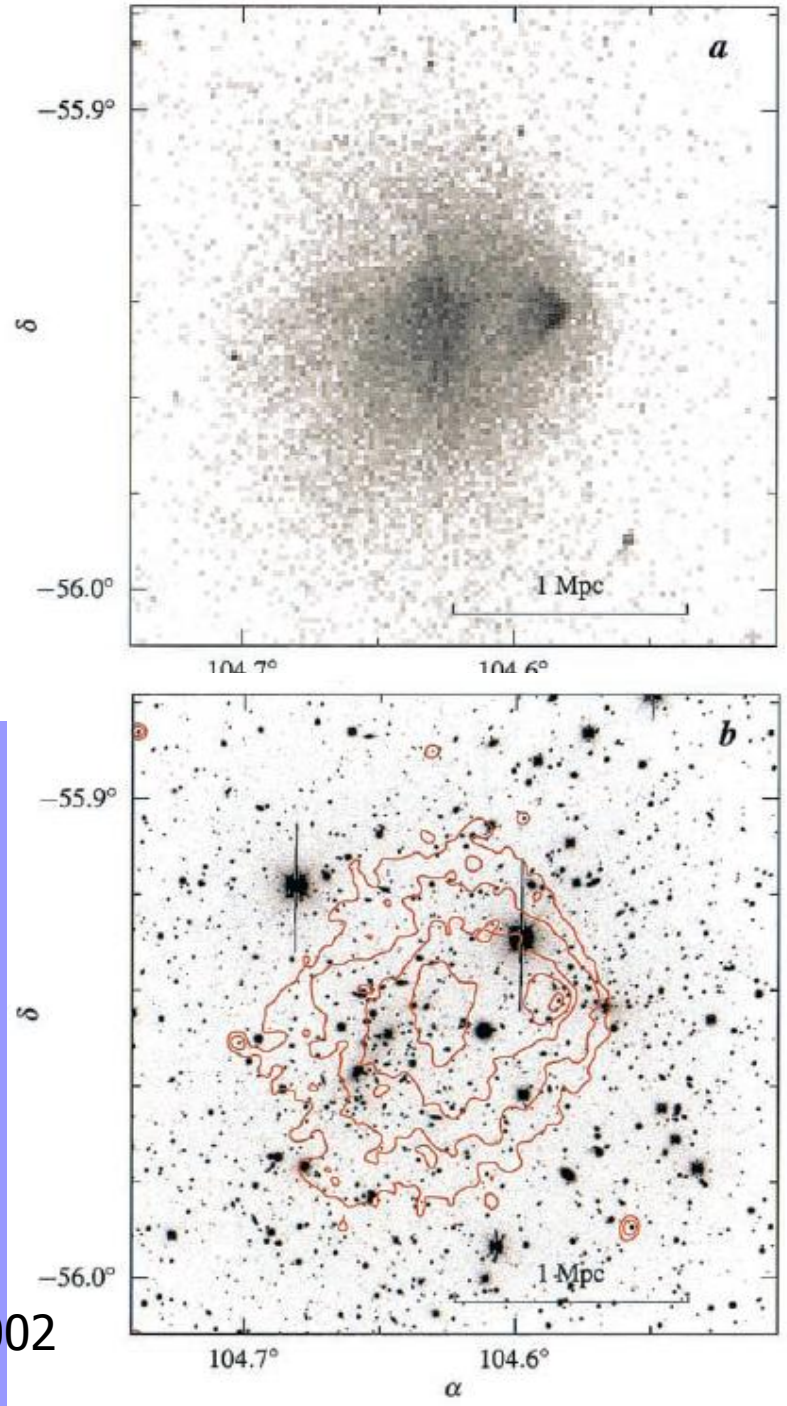
- Two sub-clusters with mass ratio 10:1 in the act of merging: the western 'bullet' has passed through the eastern cluster
- The western sub-cluster is the hottest known cluster of galaxies (14 keV)

Tucker et al. 1998

- Chandra ACIS 0.5-5 keV
  ESO-NTT R-band optical

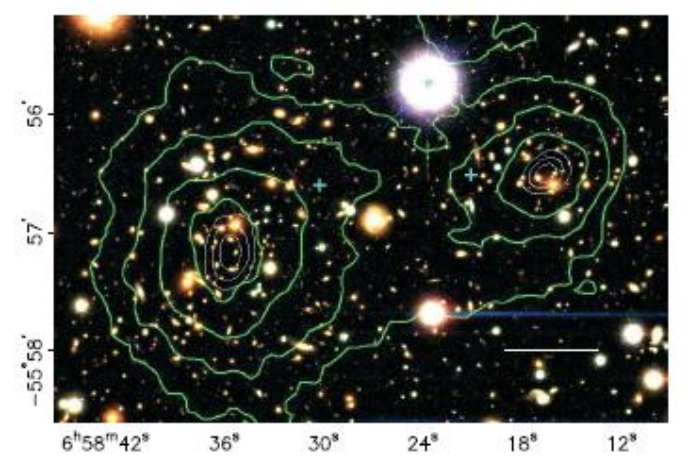
- Bow shock behind the gas bullet.

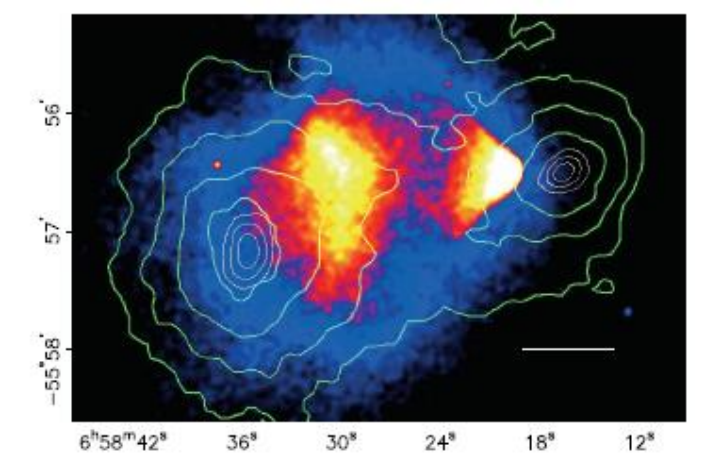
- Sub-cluster of galaxies seen leading the ‘bullet’



Markevitch et al. 2002

Dark matter from weak lensing



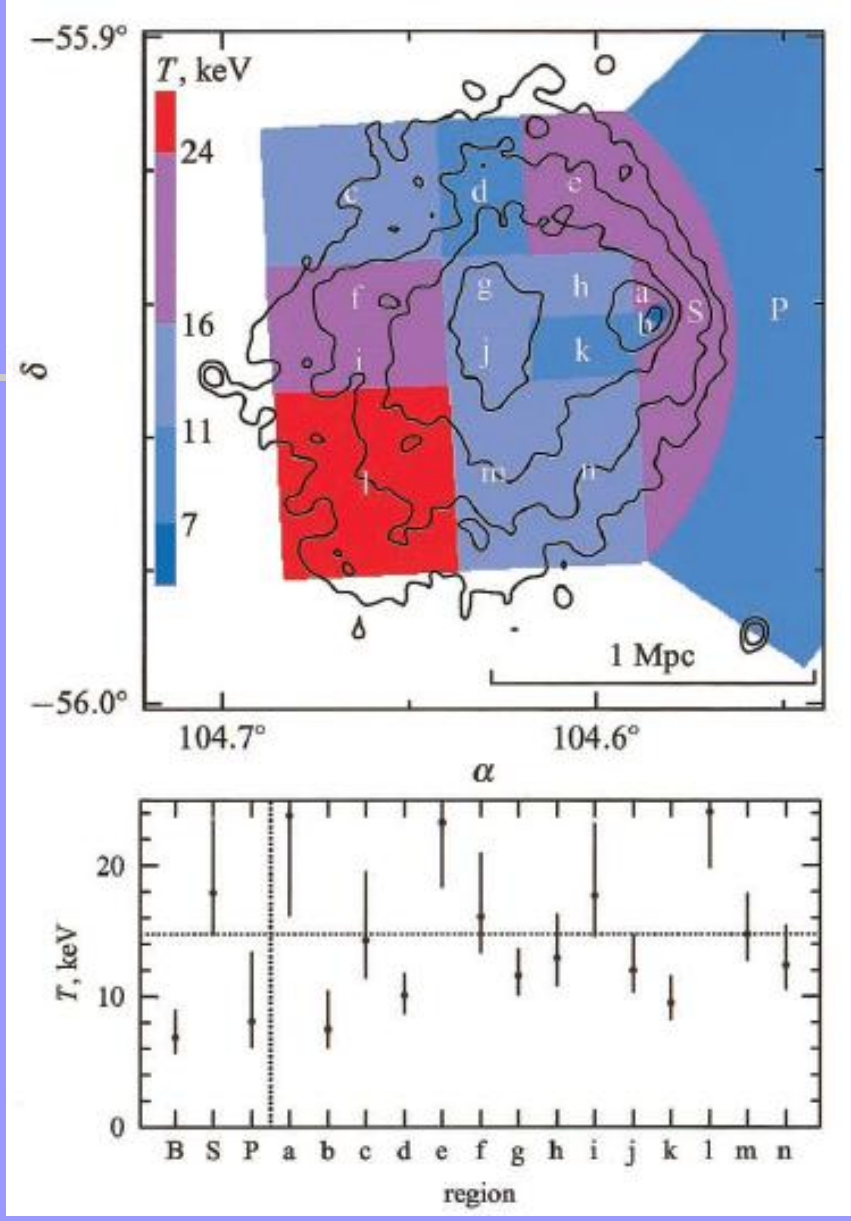


DM centres are coincident with where the bright galaxy clusters are located.

Clowe et al. 2006

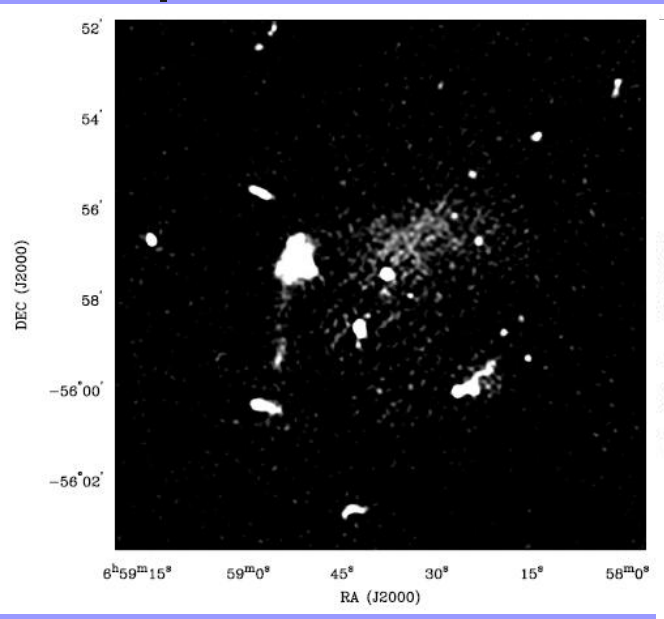
Temperature from Chandra ACIS spectral energy in 0.9-9.5 keV band

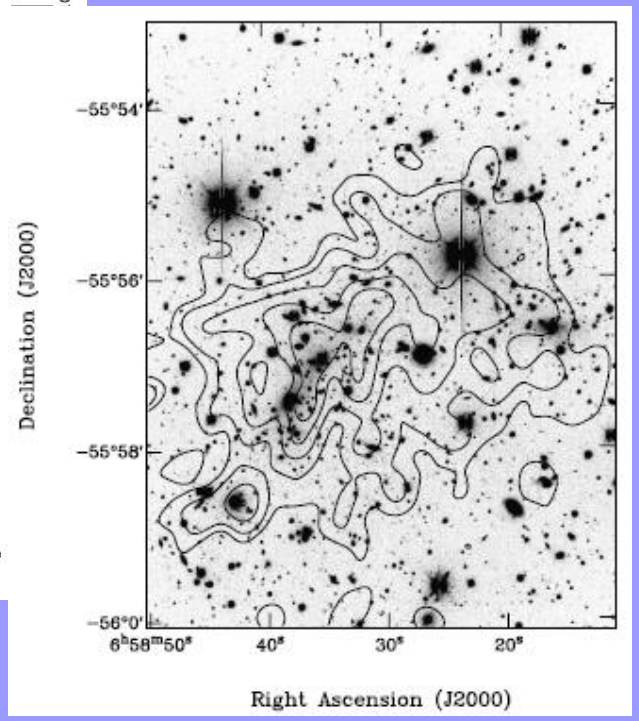
- Coolest part is the gas in the bullet : 7 keV
- Hottest part is to SE : >24 keV where there are several bright galaxies
- There is a temperature and density jump (3-4) at the shock and at the contact discontinuity between the bullet and ambient gas
- Bullet Mach number 2-3 (4700 km/s): collision 100 Myr ago.

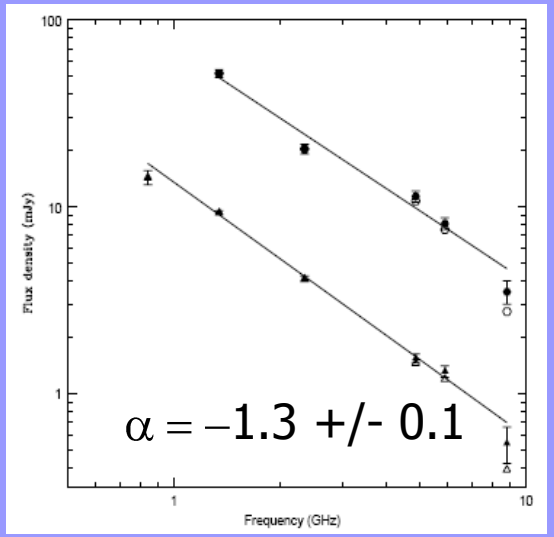


Markevitch et al. 2002

Radio halo in the bullet cluster



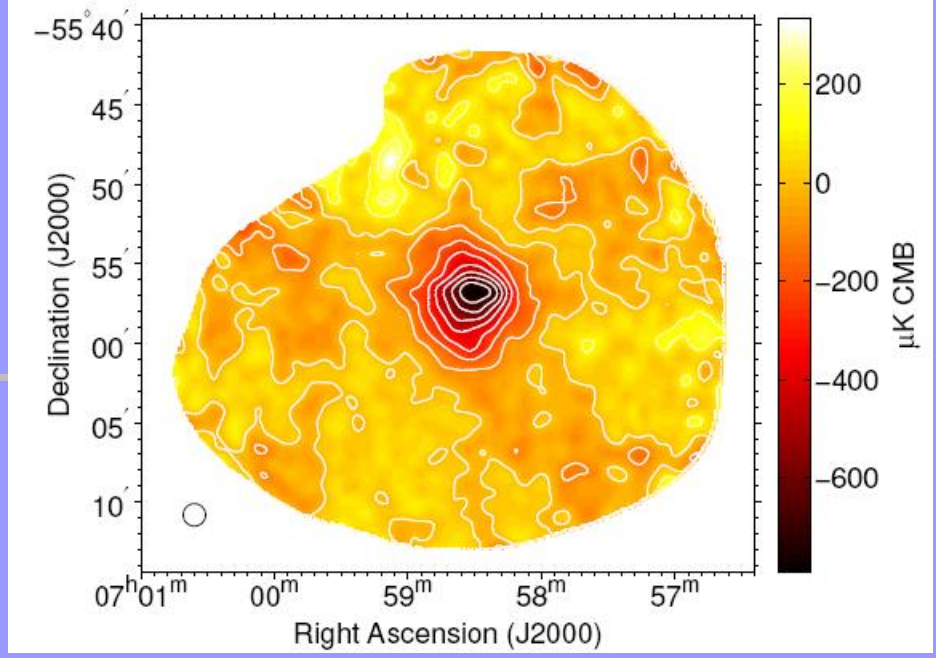


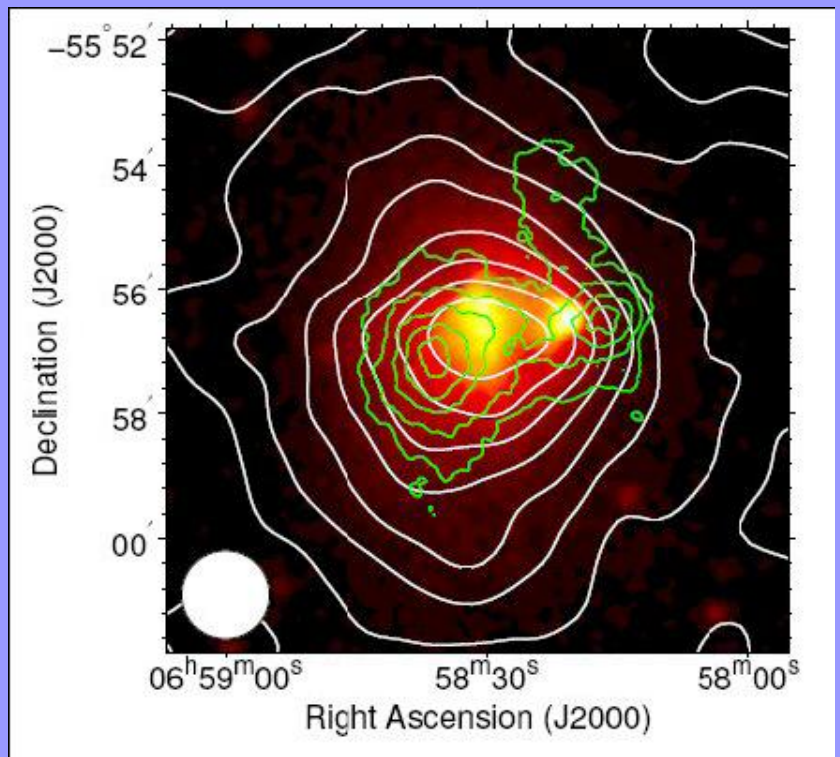


Liang et al. 2000

Sunyaev-Zeldovich Effect

- SZE image with APEX-SZ bolometer array at 150 GHz
- 85 arcsec beam
- 0.88 mK decrement

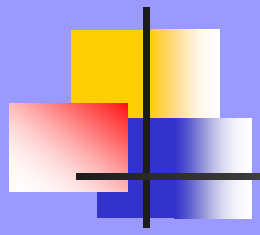




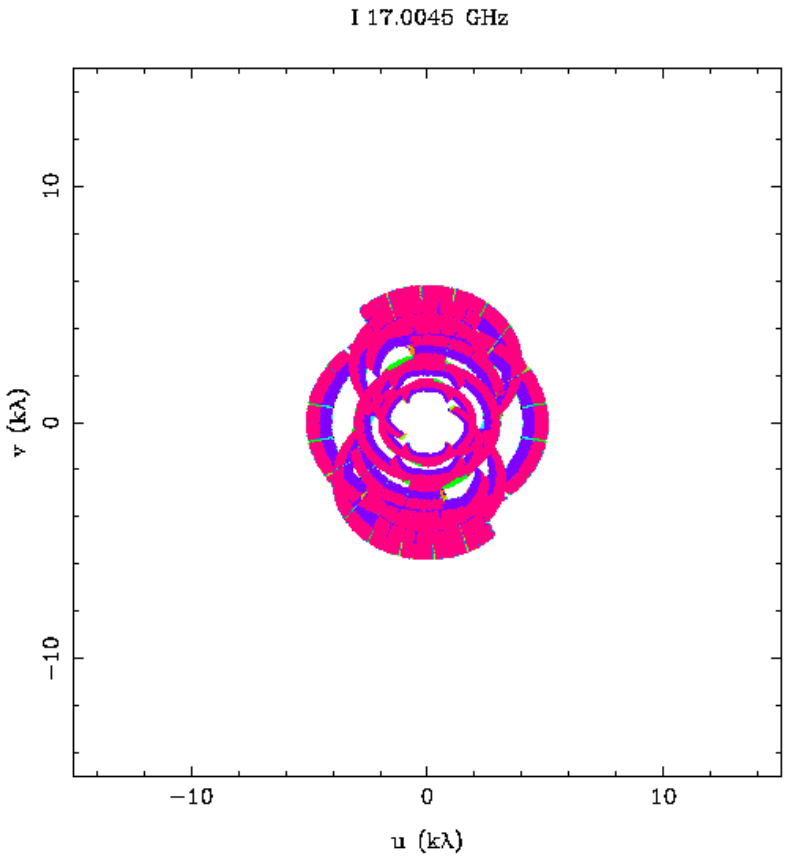
Halverson et al. 2009

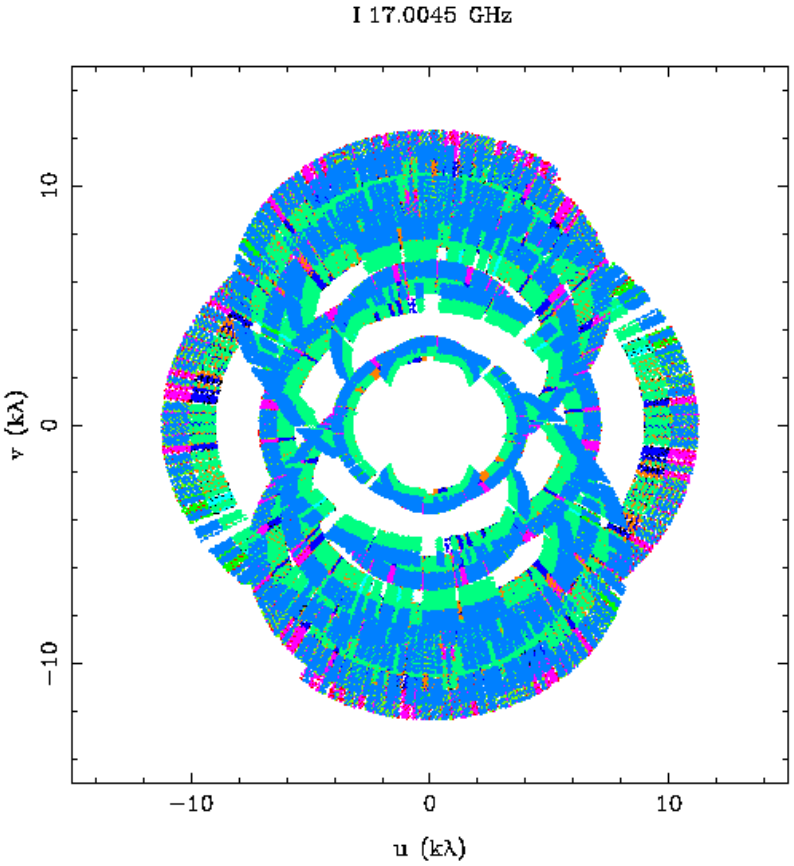
ATCA obs: Siddharth Malu, D Narasimha, Mark Wieringa, RS

- 5 x 22m antennas
- 2 x 2 GHz bands
  @ 17 & 19 GHz
- 2048 frequency channels
  in each band
- 2.6 arcmin antenna FWHM
- Full polarization
- 3x8 hrs in 75-m array; 2x12hr in 168m array
- 2 pointing centres at the X-ray peaks – separation 1.5 arcmin

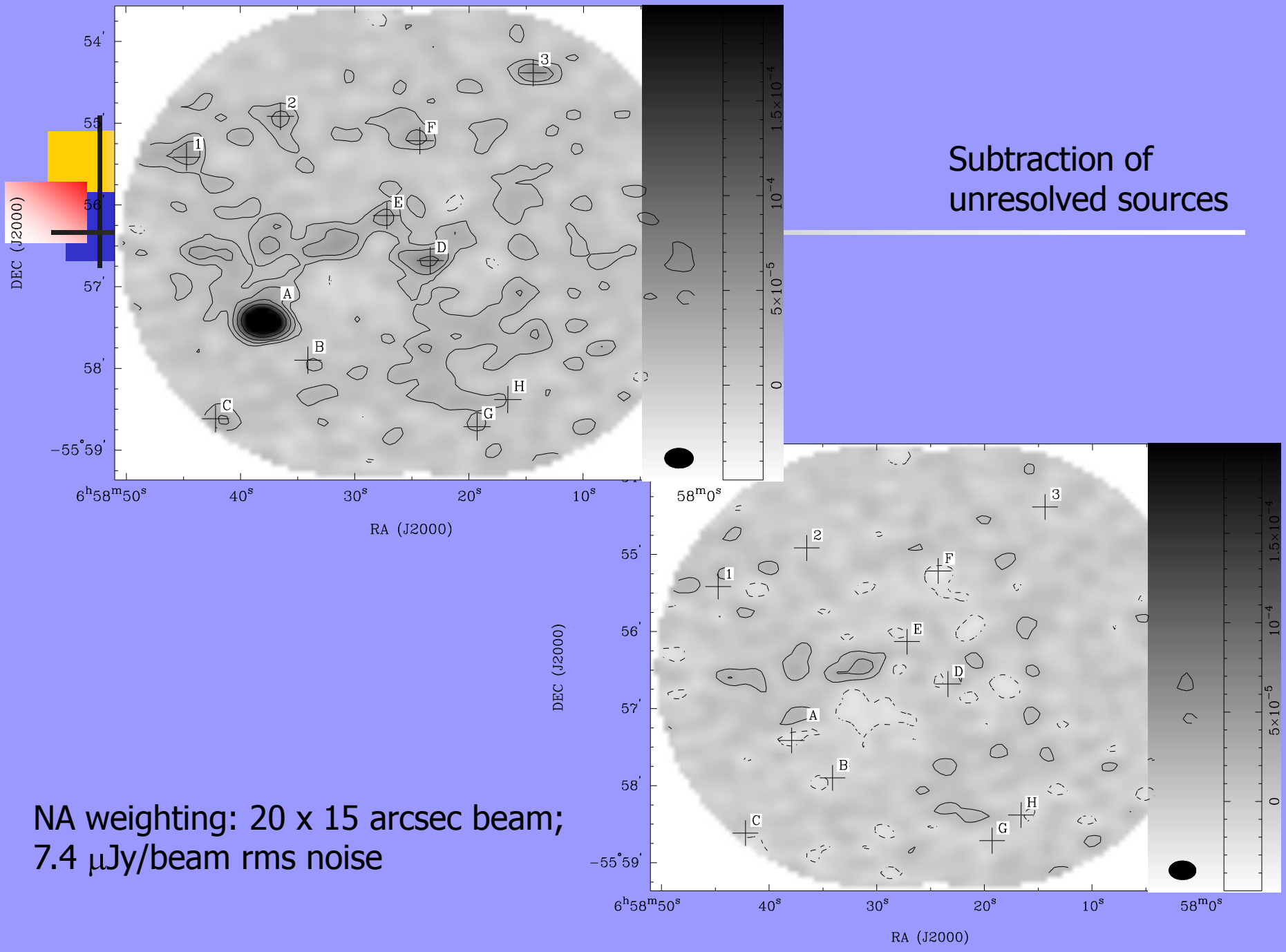


- Bullet cluster pointing centres observed alternately every 80 sec
- PKS B0742-56 every 10 min for amplitude & phase calibration
- PKS B0537-441 every 1 hr for antenna pointing update: 5-point pattern
- PKS B1934-638 once every day for absolute flux scale and bandpass (spectral index $\alpha = -1.33$)
- Visibilities recorded with 10-sec averaging; 1 MHz channels averaged to 10 MHz after editing & calibration.

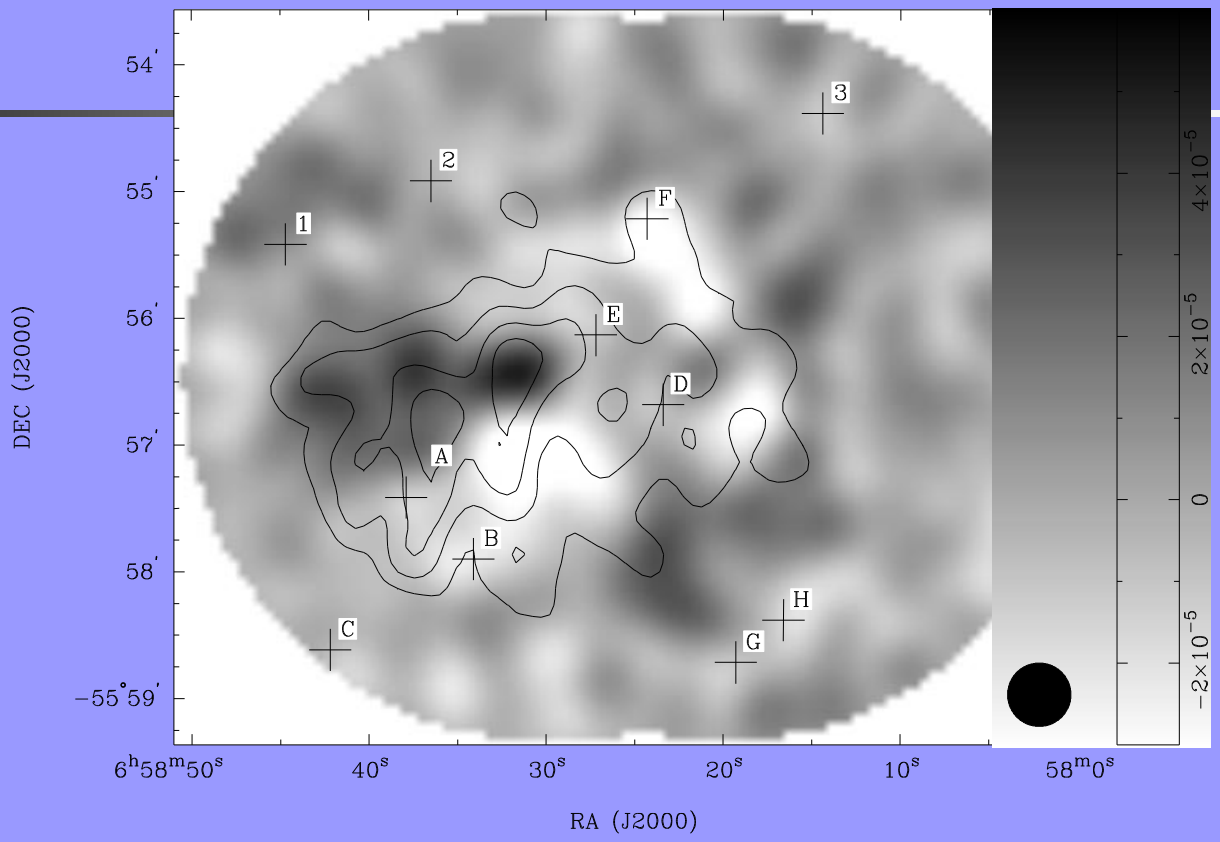

I 17.0045 GHz
v (kλ)
u (kλ)
10
0
−10
−10
0
10


I 17.0045 GHz
v (kλ)
u (kλ)
10
0
−10
−10
0
10

Subtraction of unresolved sources

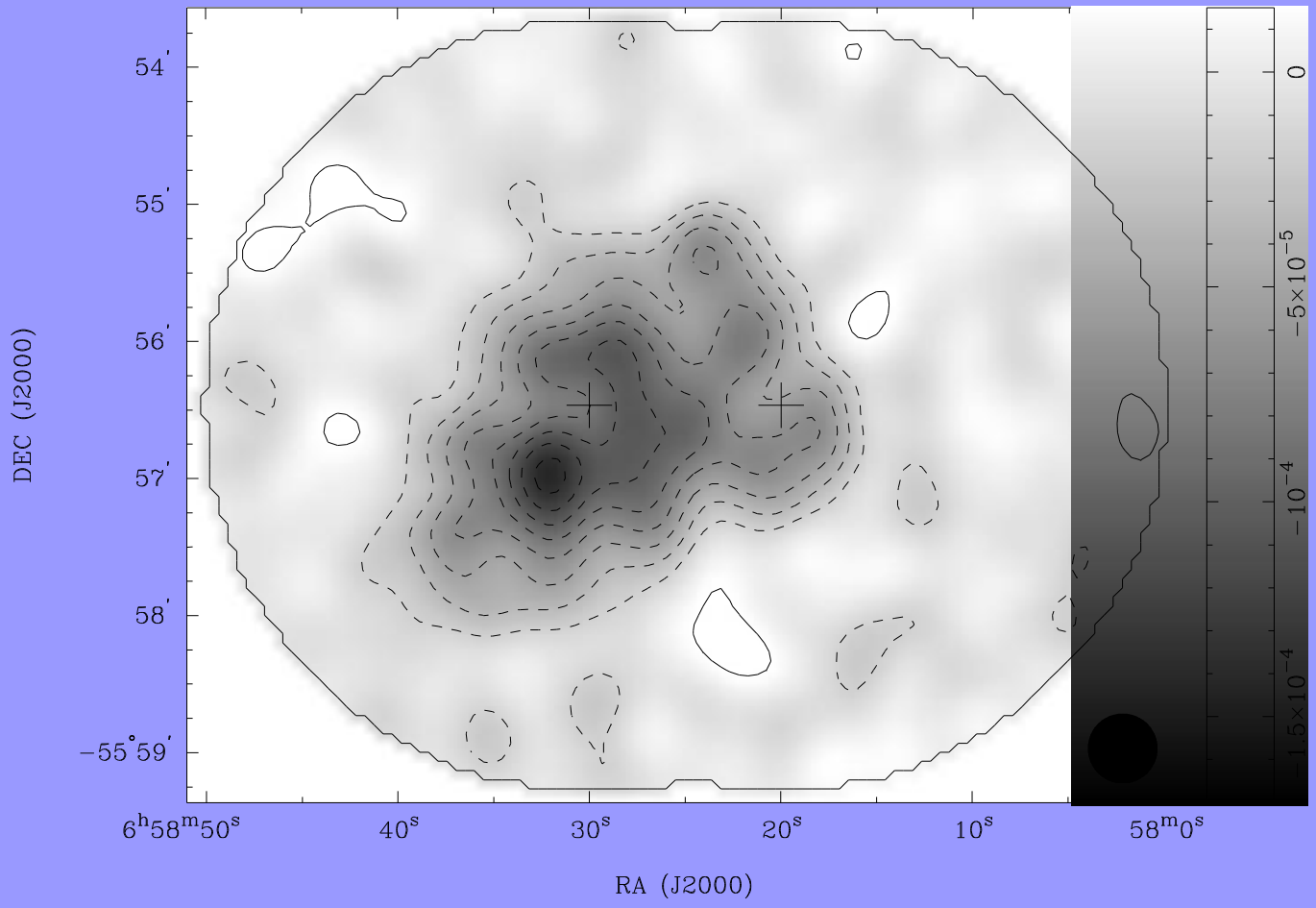


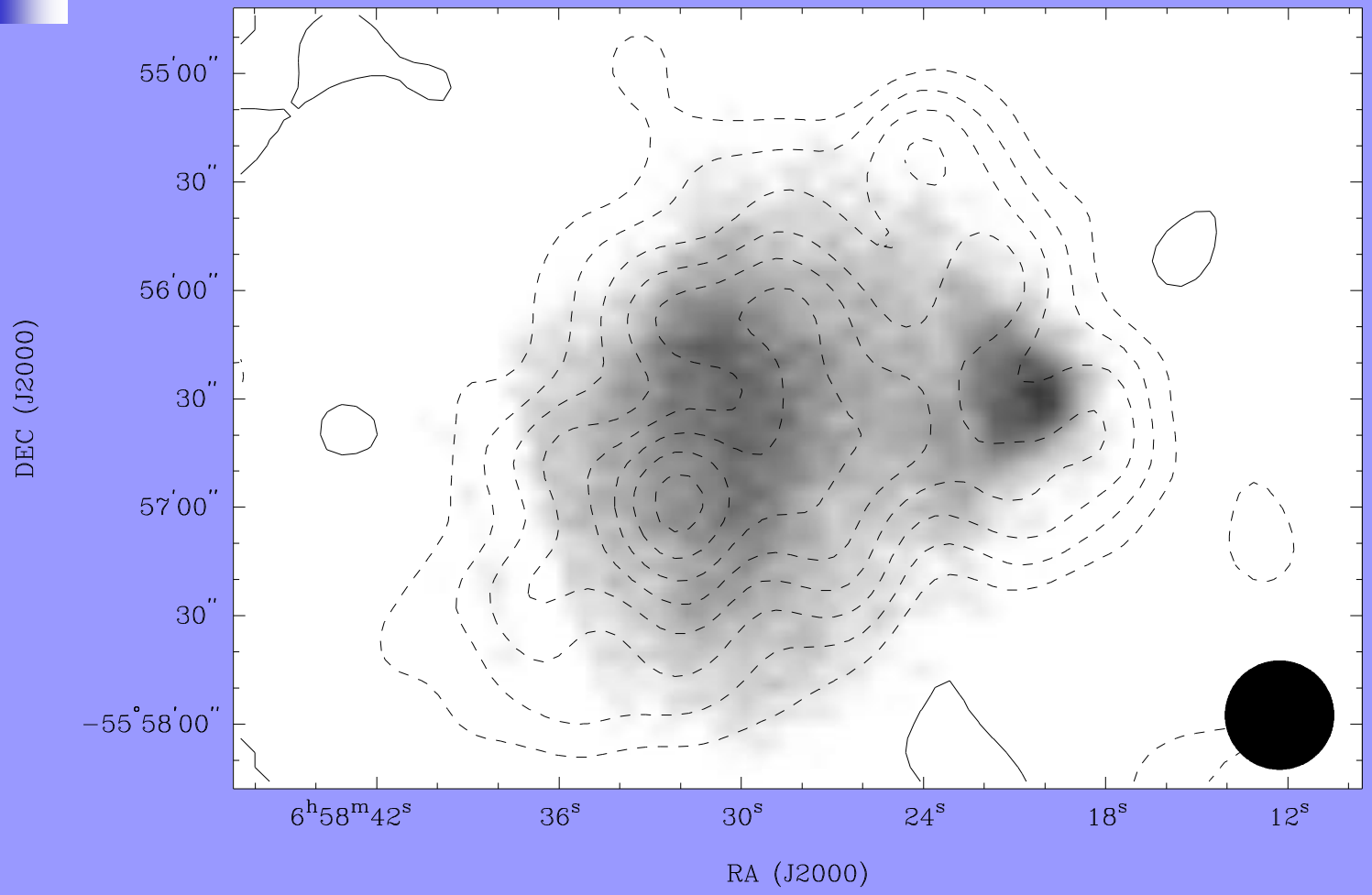
NA weighting: 20 x 15 arcsec beam;
7.4 μJy/beam rms noise

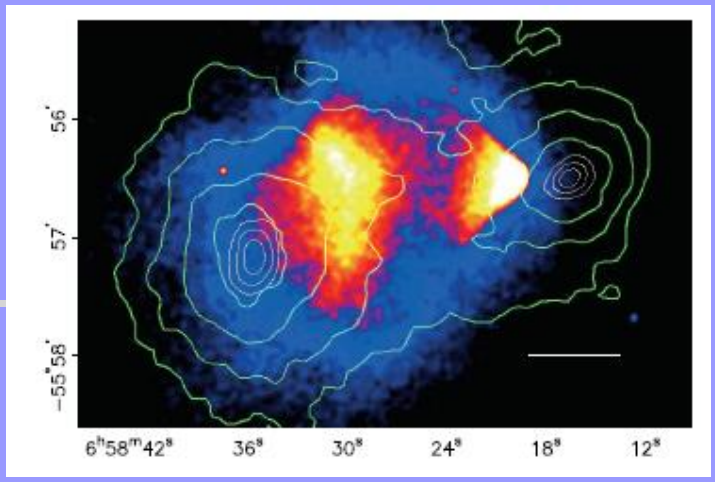


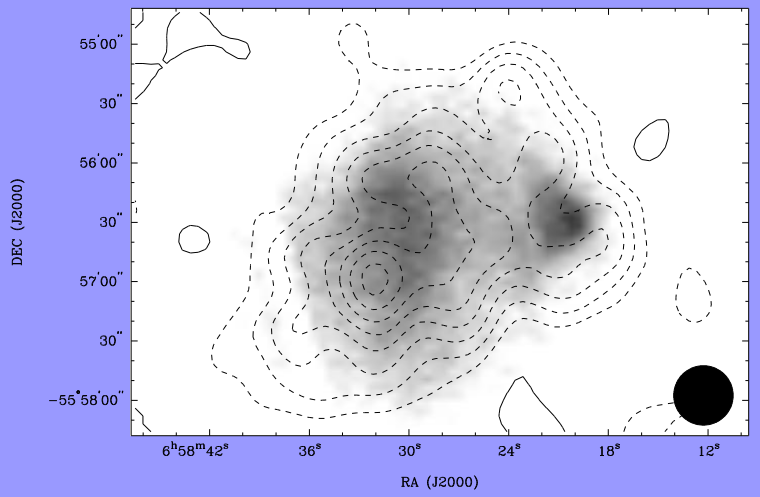
Scaled radio halo + residual 18 GHz image

The SZE is co-located within the radio halo


54′
55′
56′
57′
58′
−55°59′
DEC (J2000)
6h58m50s
40s
30s
20s
10s
58m0s
RA (J2000)
0
−5×10−5
−10−4
−1.5×10−4


55′00″
30″
56′00″
30″
57′00″
30″
−55°58′00″
DEC (J2000)
6h58m42s
36s
30s
24s
18s
12s
RA (J2000)





Summary:

Merging clusters may have compact features and substructure in SZE.

Interesting? Unexpected?

SZE science with the EVLA – ALMA interferometers