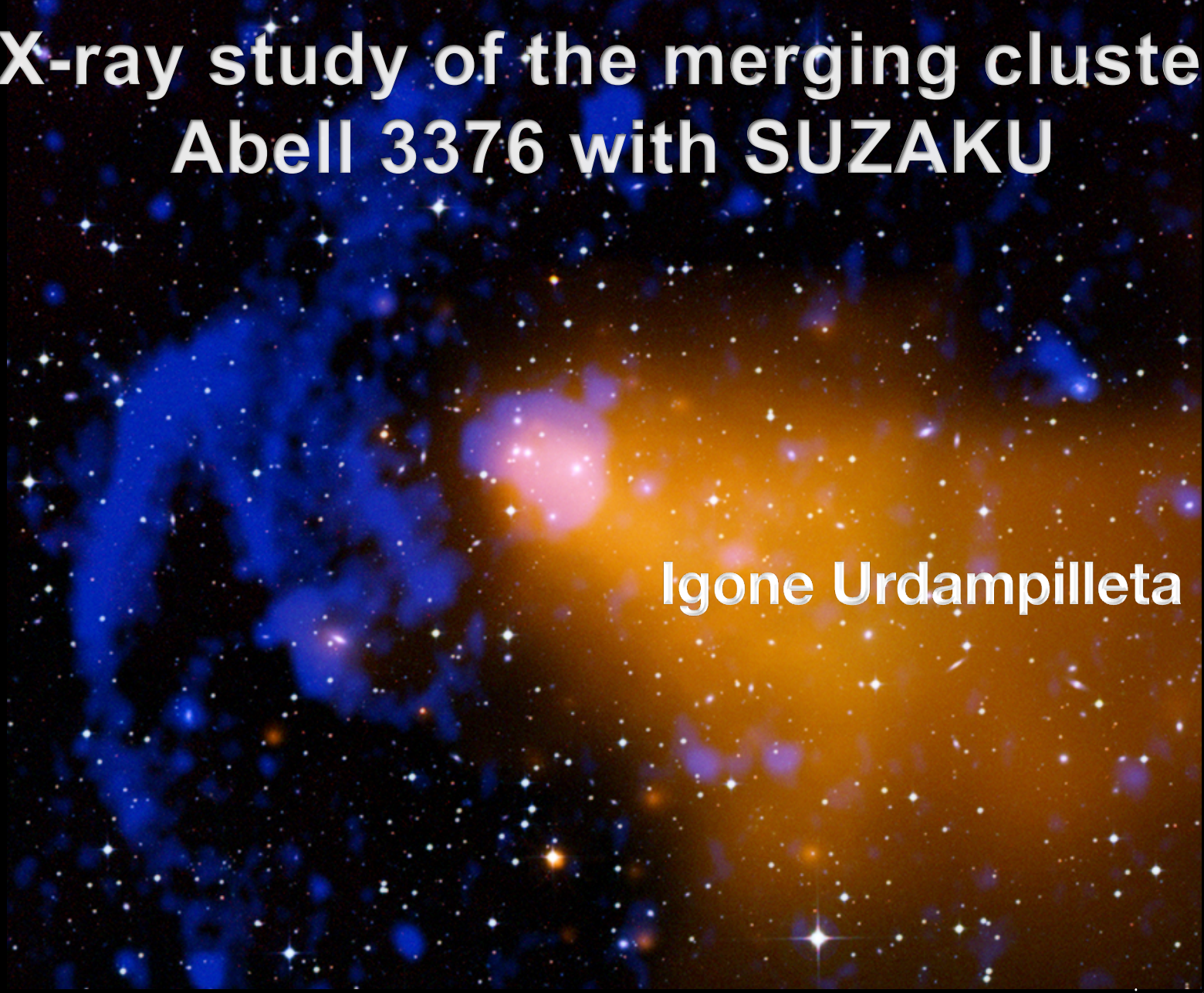
X-ray study of the merging cluster Abell 3376 with SUZAKU

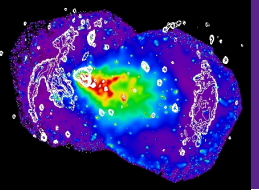


Igone Urdampilleta

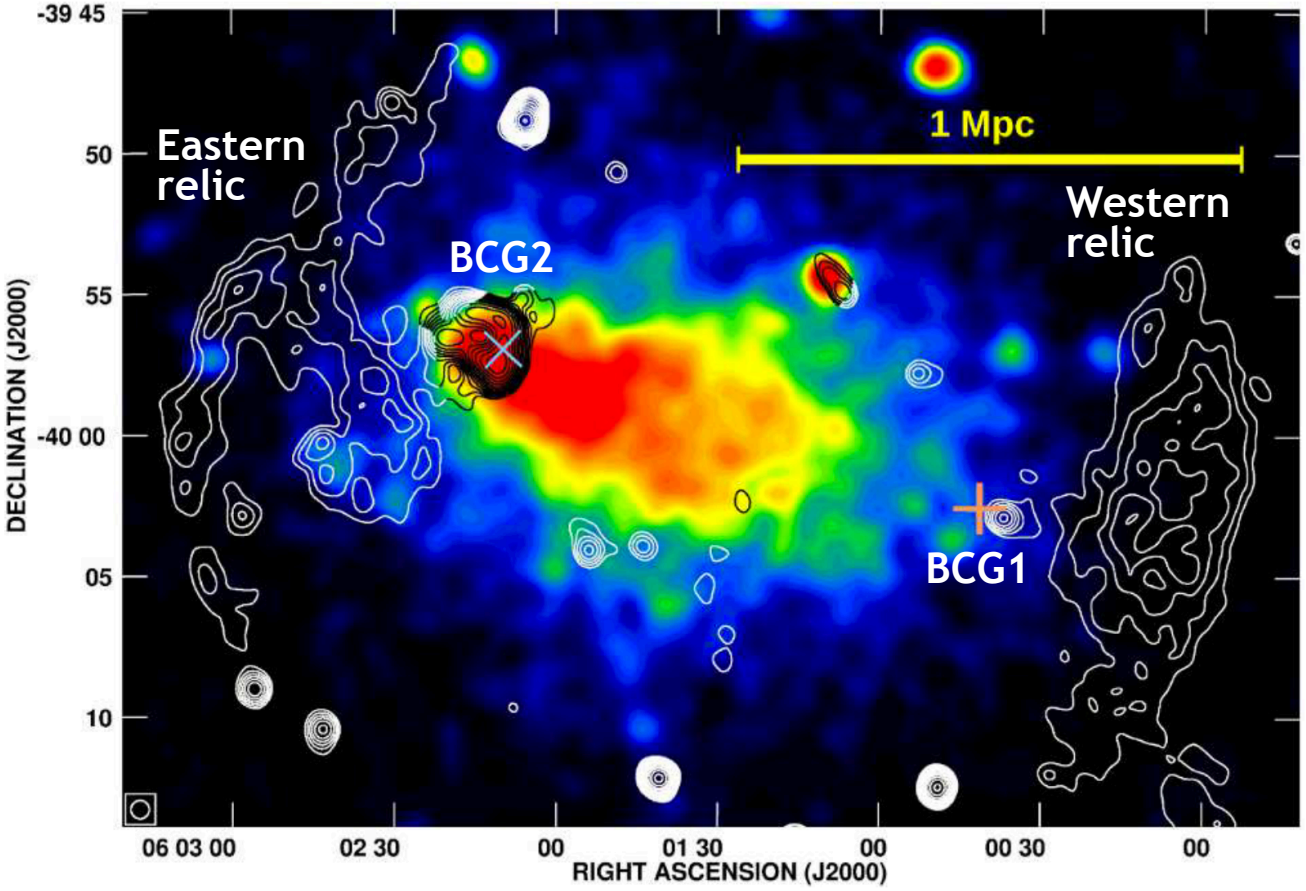
SRON
Netherlands Institute for Space Research

H. Akamatsu, F. Mernier, J. S. Kaastra, J. de Plaa,
T. Ohashi, Y. Ishihsaki & H. Kawahara

Sterrewacht Leiden



Abell 3376



X-ray (ROSAT)

Radio (GMRT 325 MHz)

Kale et al. 2011

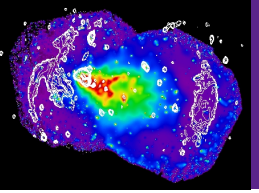
$z = 0.046$

$M \sim 4\text{-}5.10^{14}\, M_{\odot}$

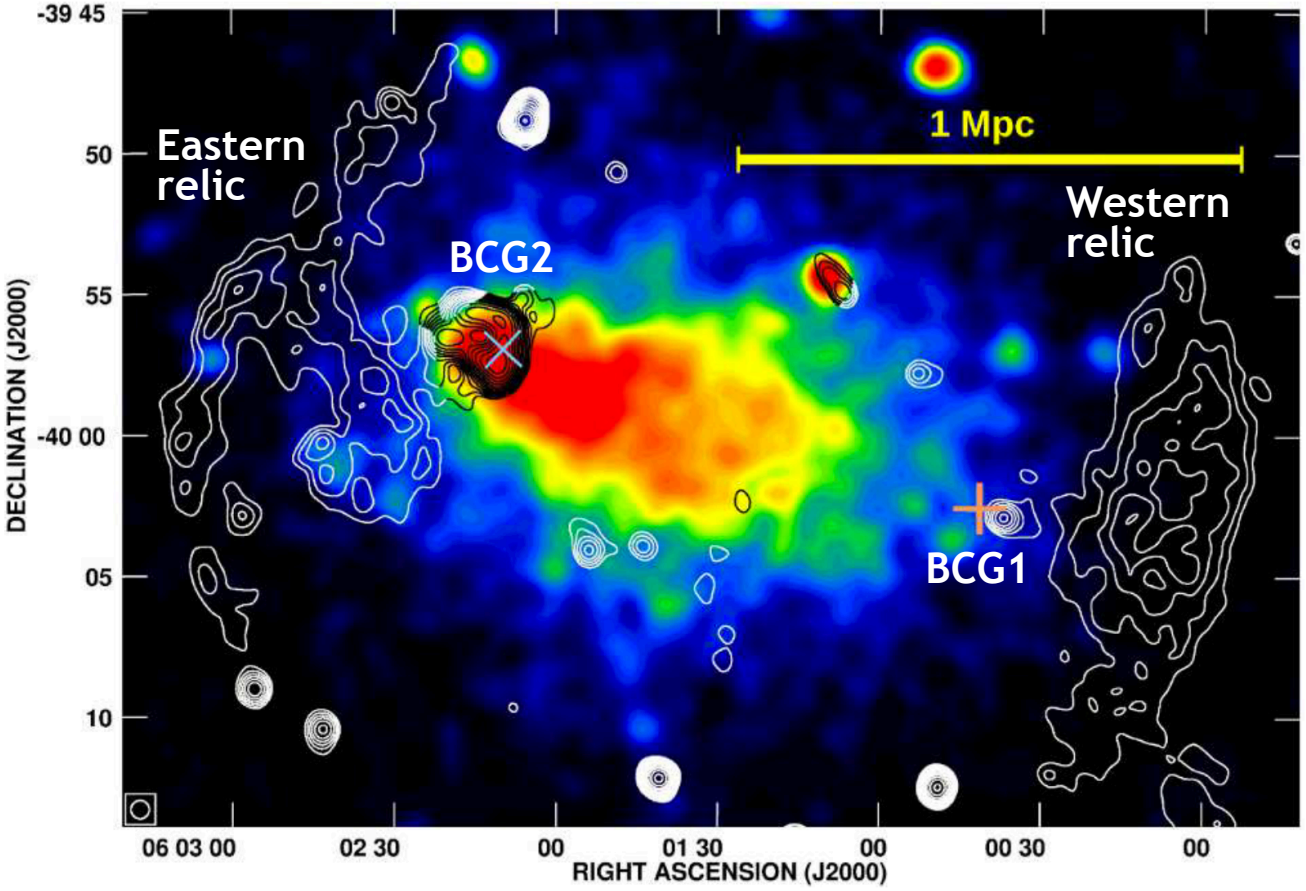
$\langle kT \rangle \sim 4.2$ keV

Two giant arc-like (~2 x 1.6 Mpc) radio relics

Discovered by Bagchi et al. 2006



Abell 3376



X-ray (ROSAT)

Radio (GMRT 325 MHz)

Kale et al. 2012

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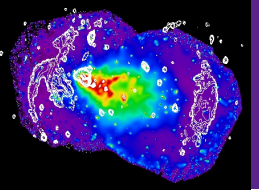
$\langle kT \rangle \sim 4.2$ keV

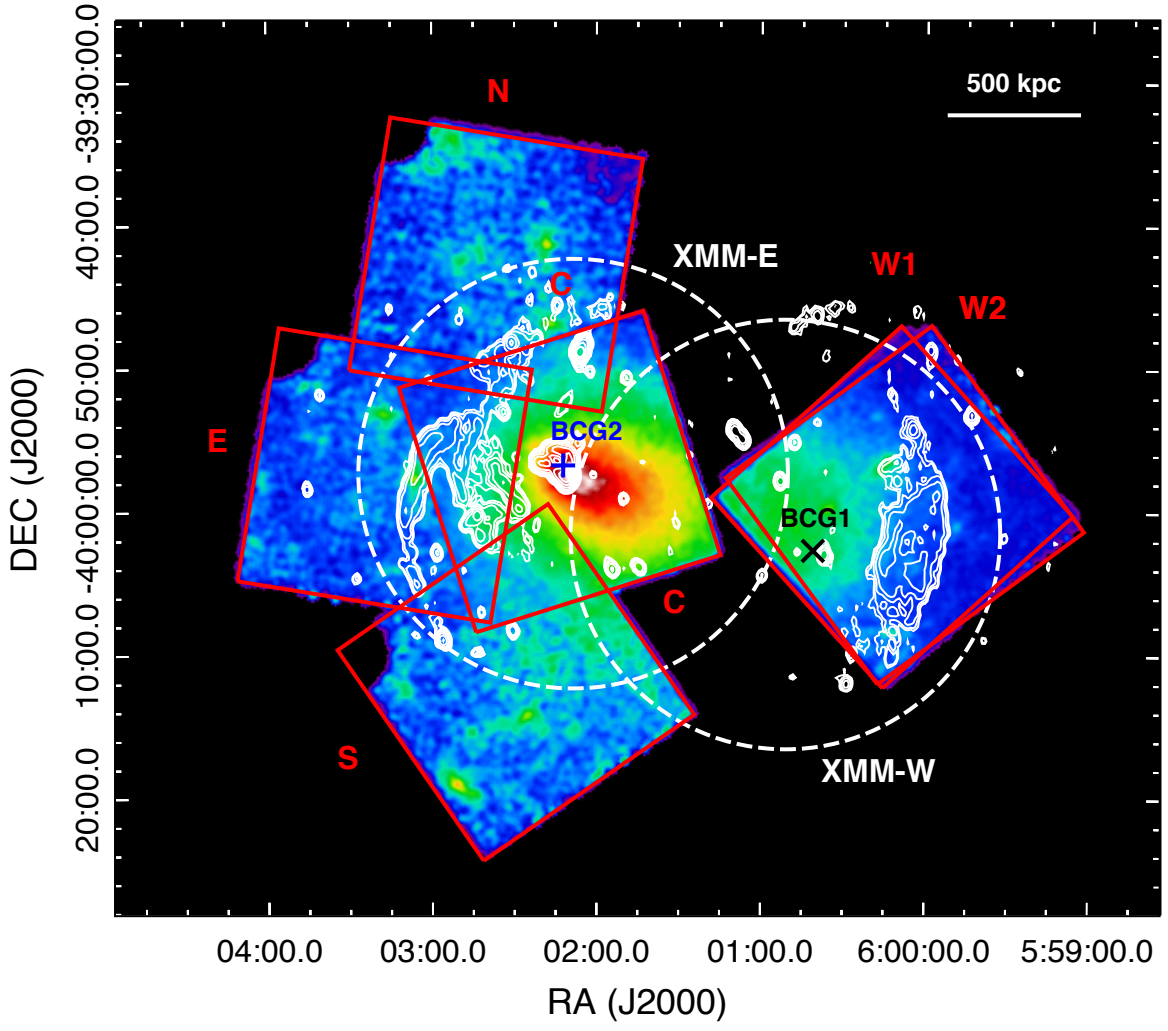
Smaller and denser A3376E crosses more massive A3376W, disrupting the core.

Two giant arc-like (~2 x 1.6 Mpc) radio relics

Discovered by Bagchi et al. 2006



Abell 3376 observations



Obtain the spatial distribution of X-ray and radio component

-Suzaku:

Western relic: **C,W1 & W2**

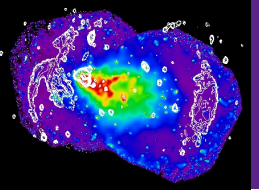
Eastern relic: **C,N, E, S**

-XMM-Newton:

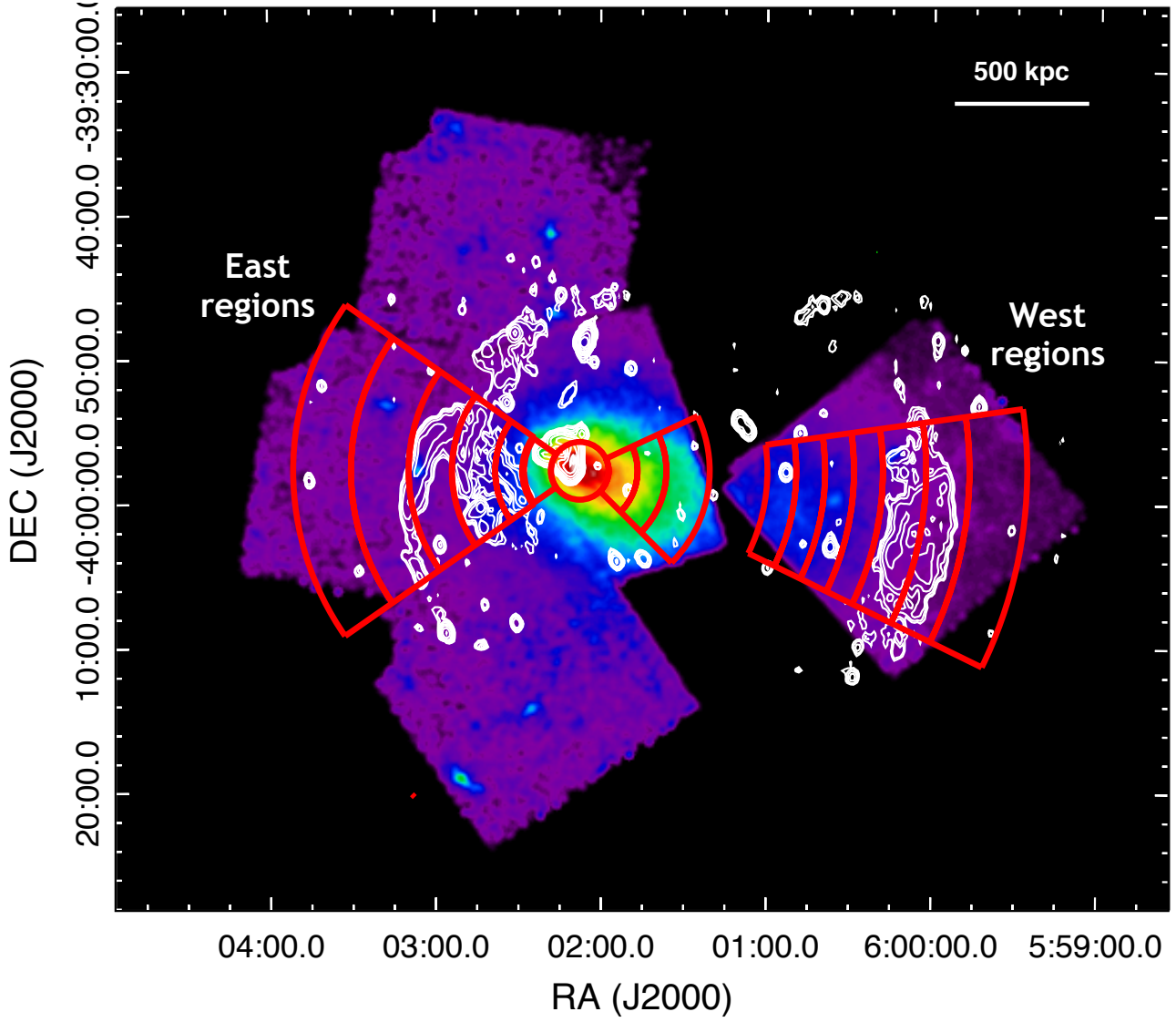
Point sources

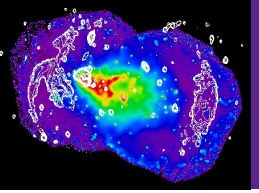
SB profiles

RADIO VLA *(Kale, R.)*

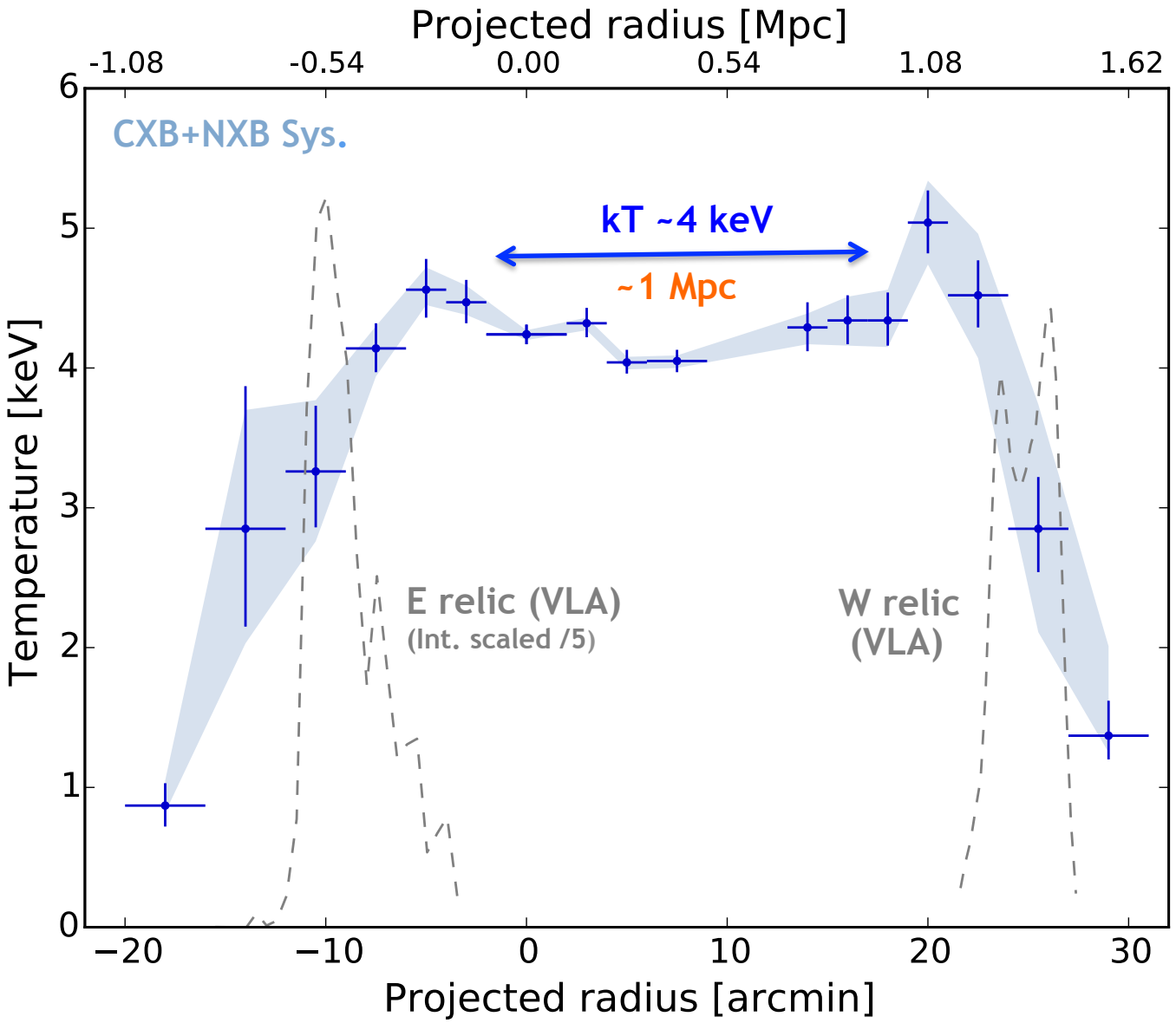


E & W Regions


500 kpc
East regions
West regions
DEC (J2000)
20:00.0
10:00.0 -40:00:00.0
50:00.0
40:00.0 -39:30:00.0
04:00.0
03:00.0
02:00.0
01:00.0
6:00:00.0
5:59:00.0
RA (J2000)

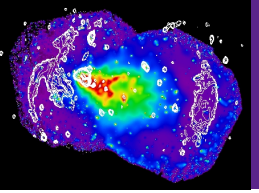


E & W T radial profile

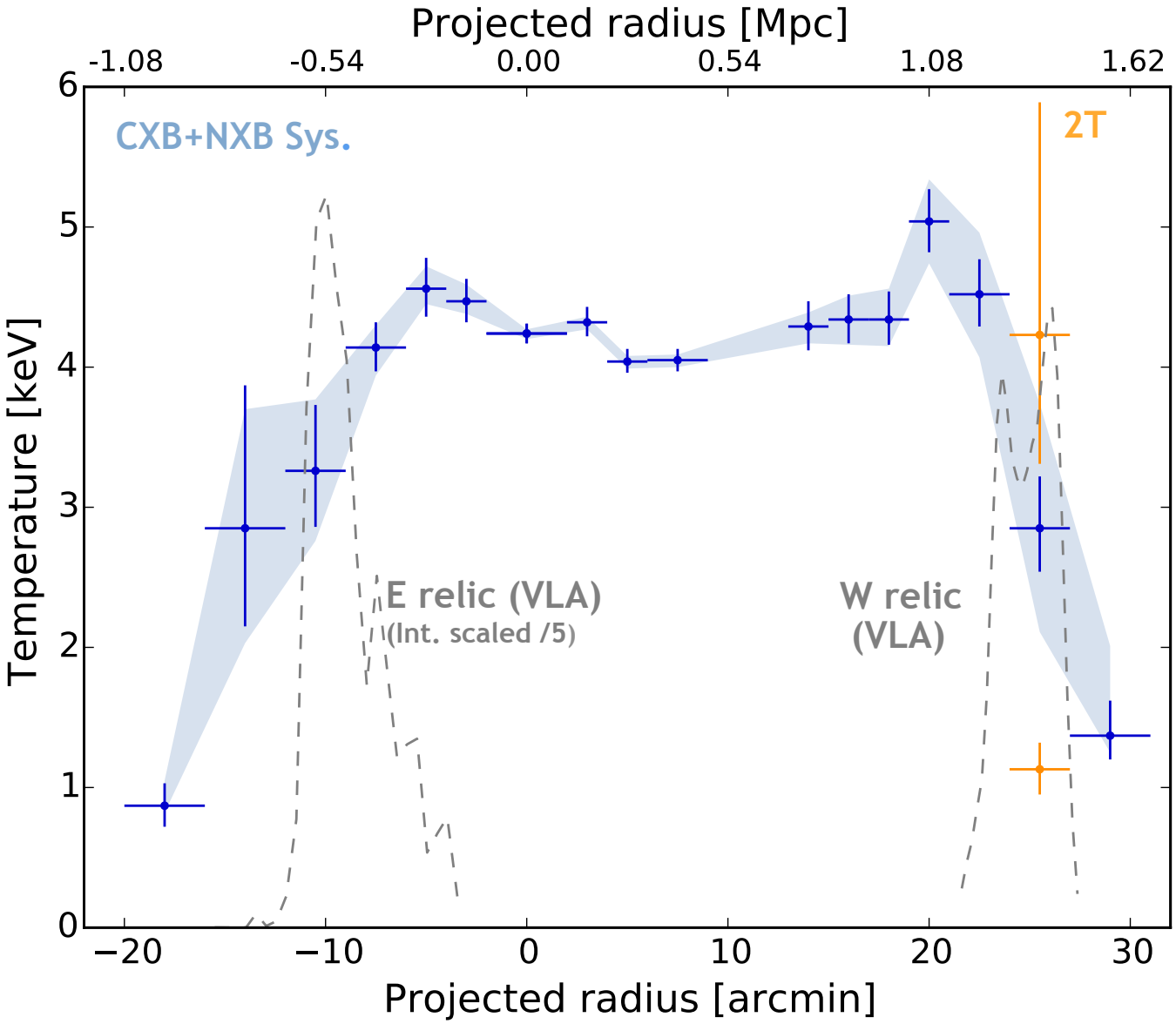


-kT ~4 keV in the center along ~1 Mpc

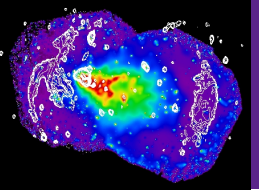
-T decreases along radio relics at West and East



E & W T radial profile

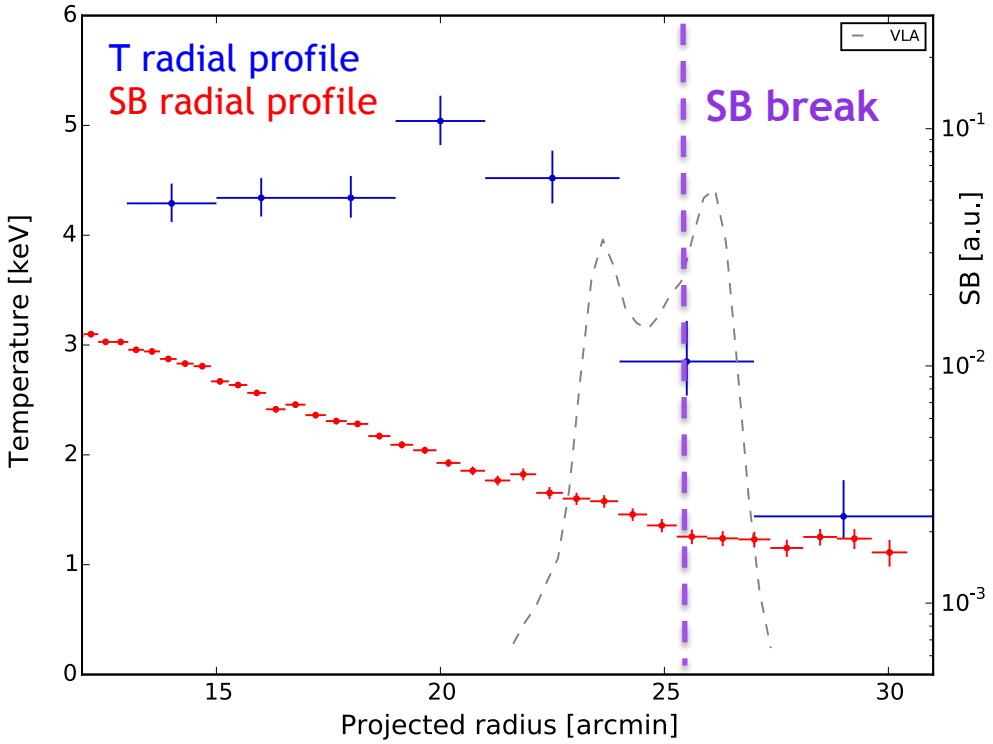


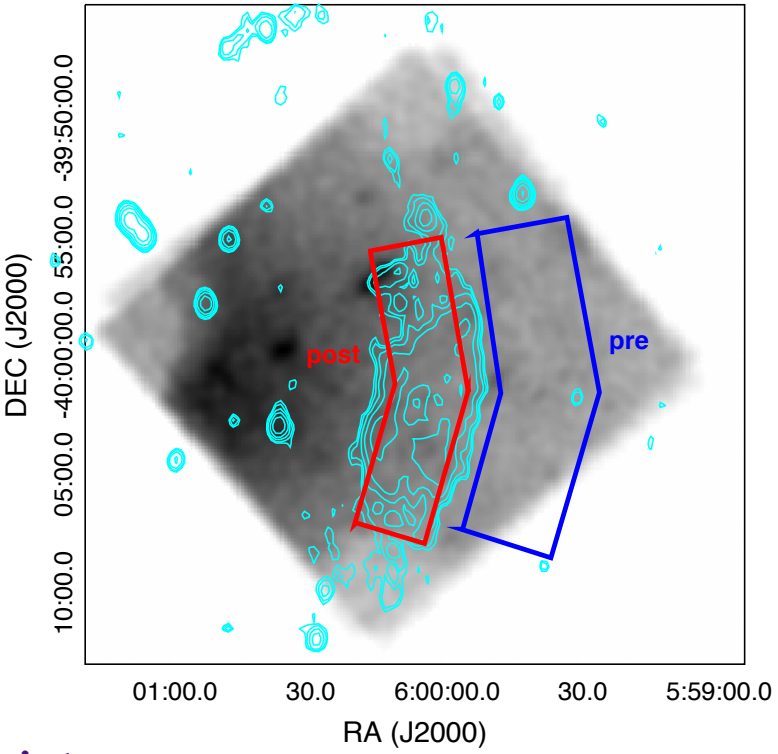
2T structure
found at radio relic



Western shock

SB profile break found with XMM observations at radio relic





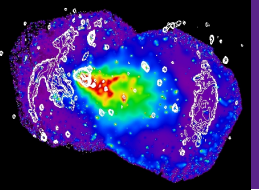
Rankine-Hugoniot

$T_{post} = 4.2 \pm 0.3$

$T_{pre} = 1.3 \pm 0.3$

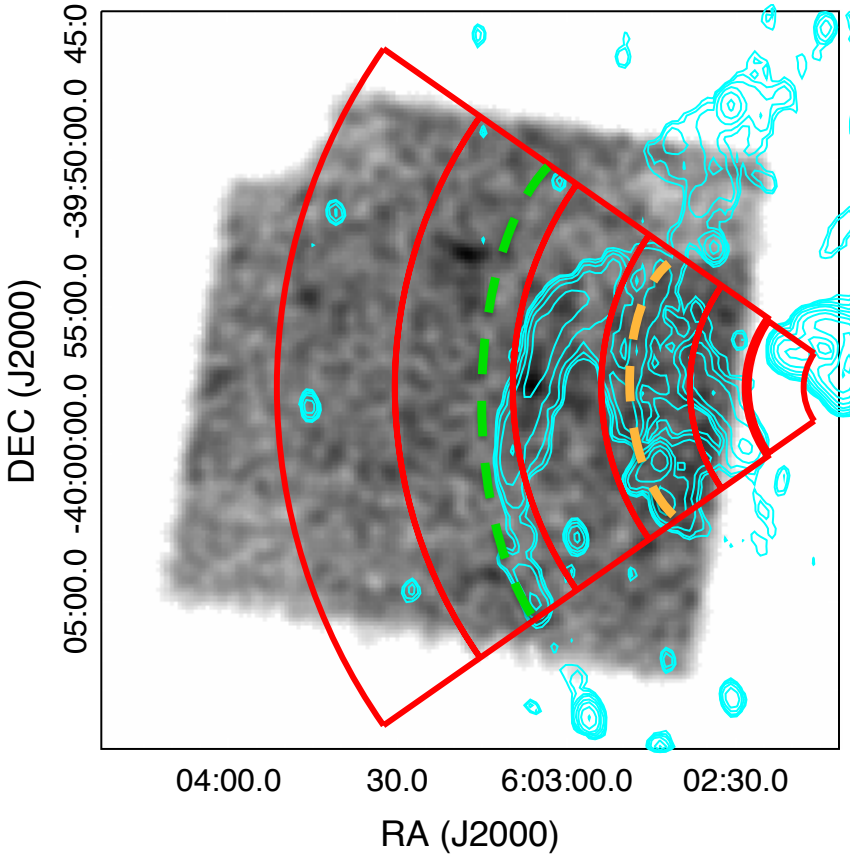
$M_W \sim 2.8 \pm 0.4$

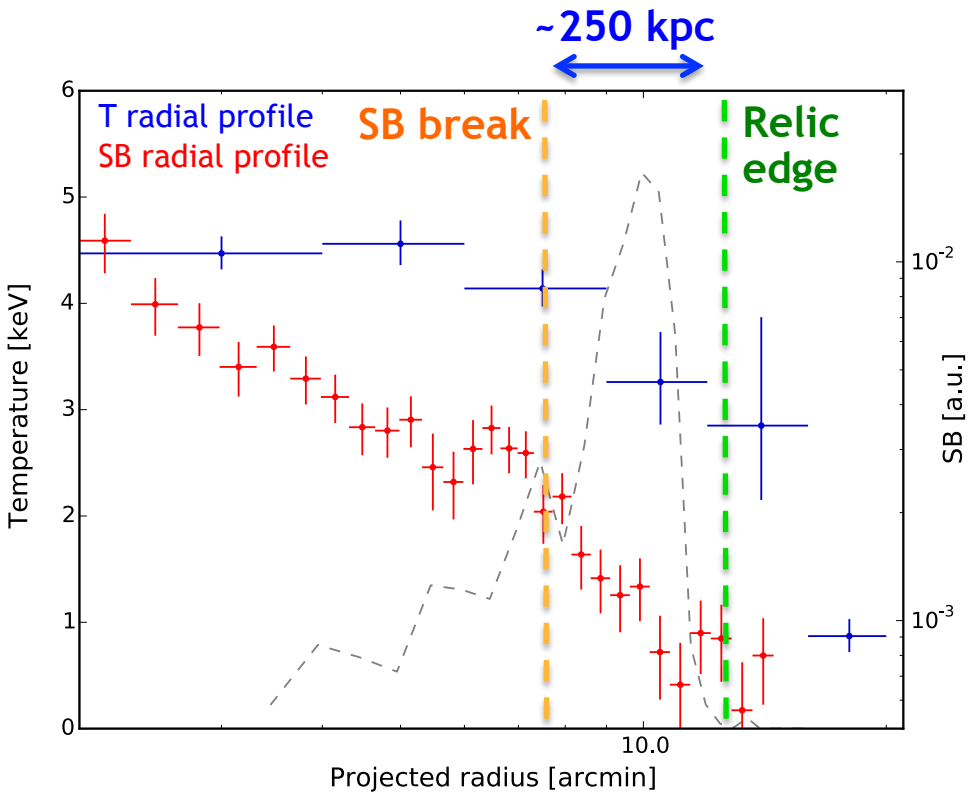
$v_{sW} \sim 1630 \pm 250$ km/s

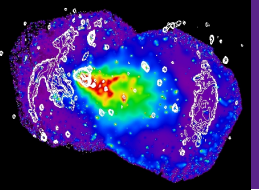


Eastern shock

SB profile break found with XMM displaced from relic outer edge







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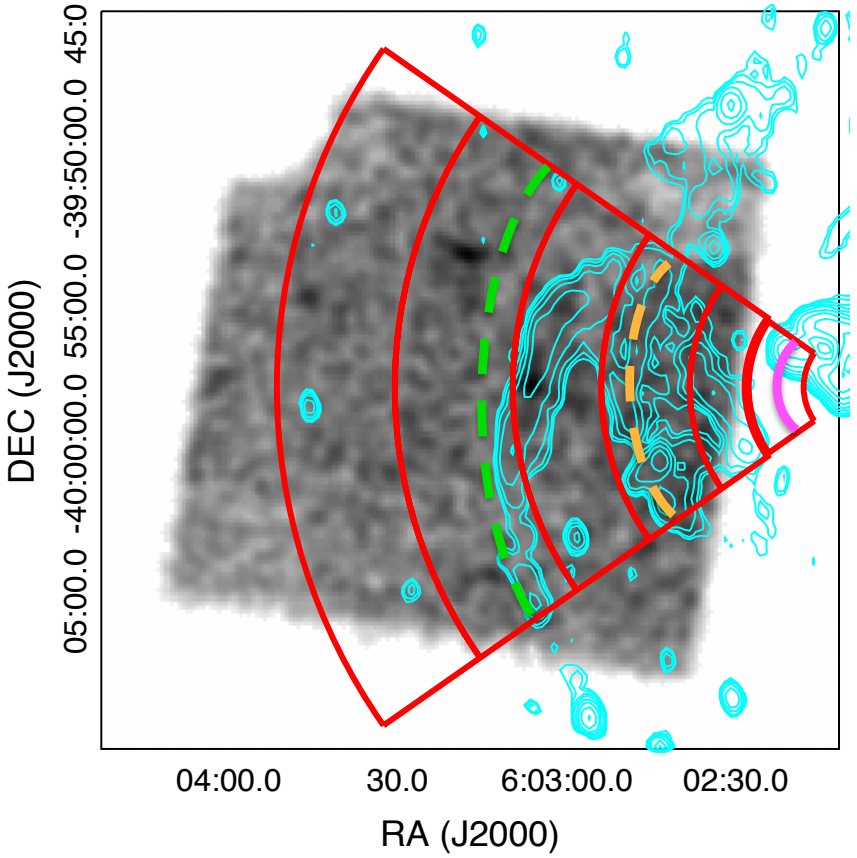
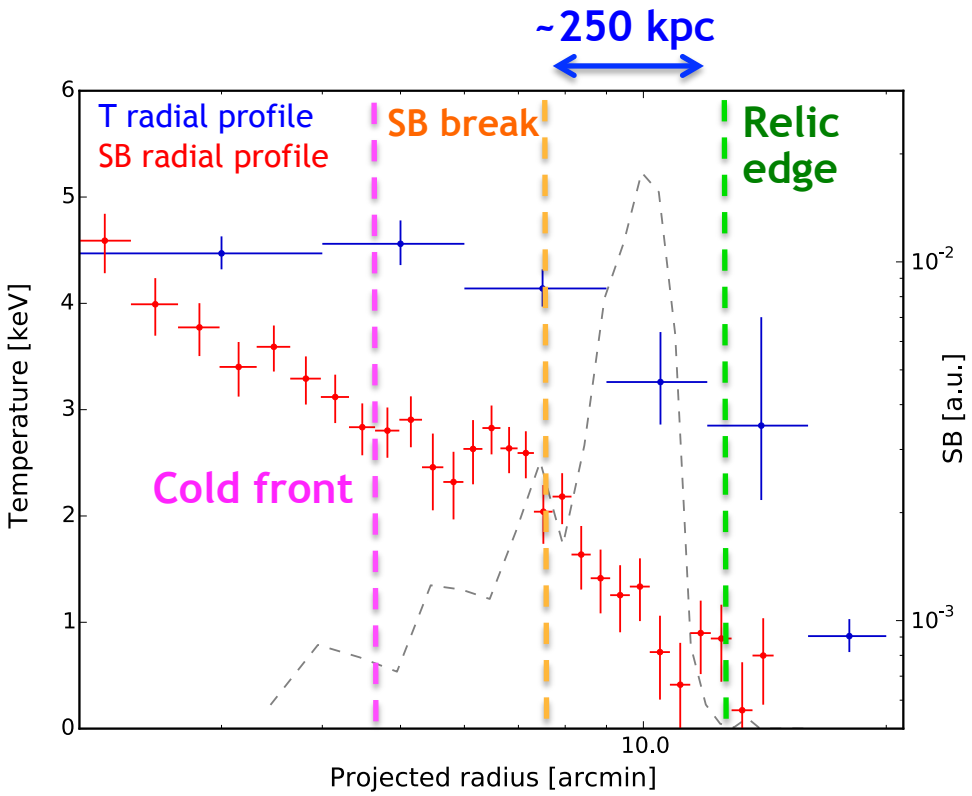
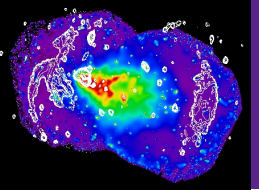
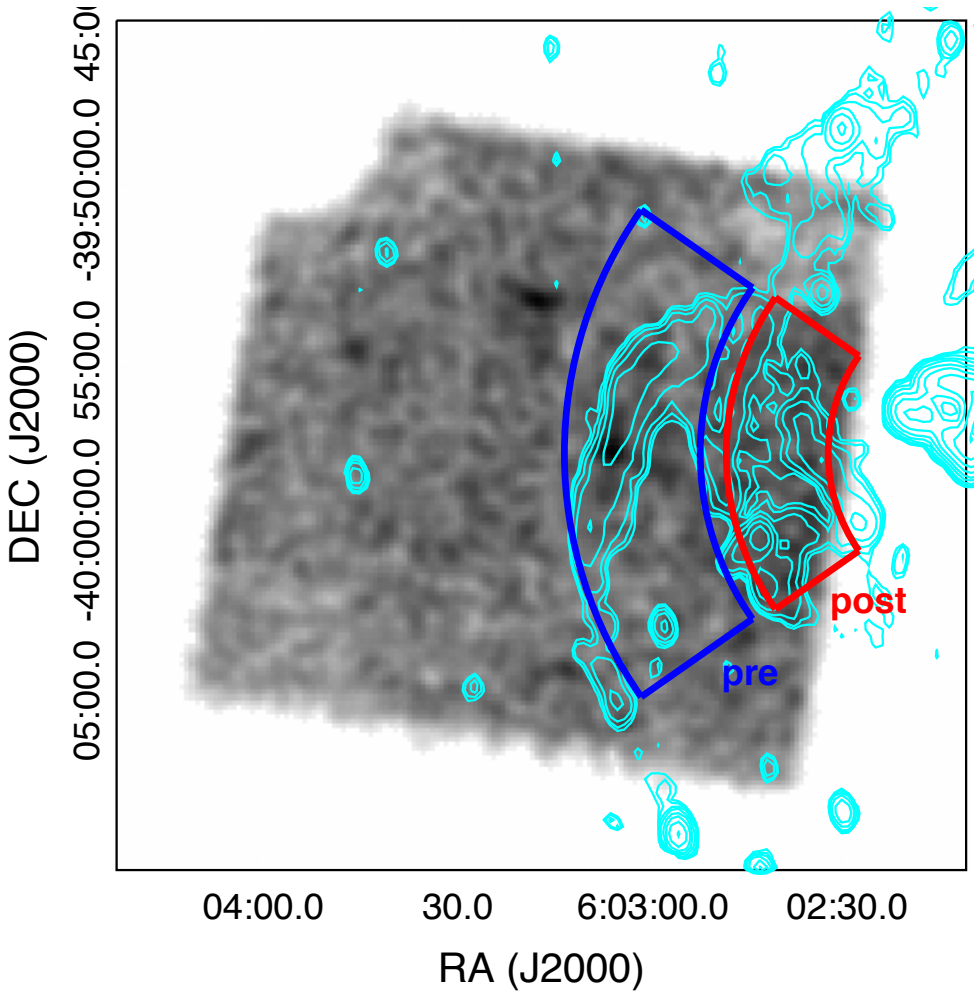






Eastern shock



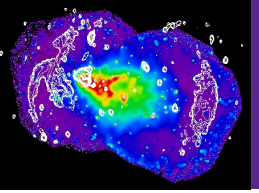
$T_{post} = 4.7 \pm 0.4$

$T_{pre} = 3.3 \pm 0.4$

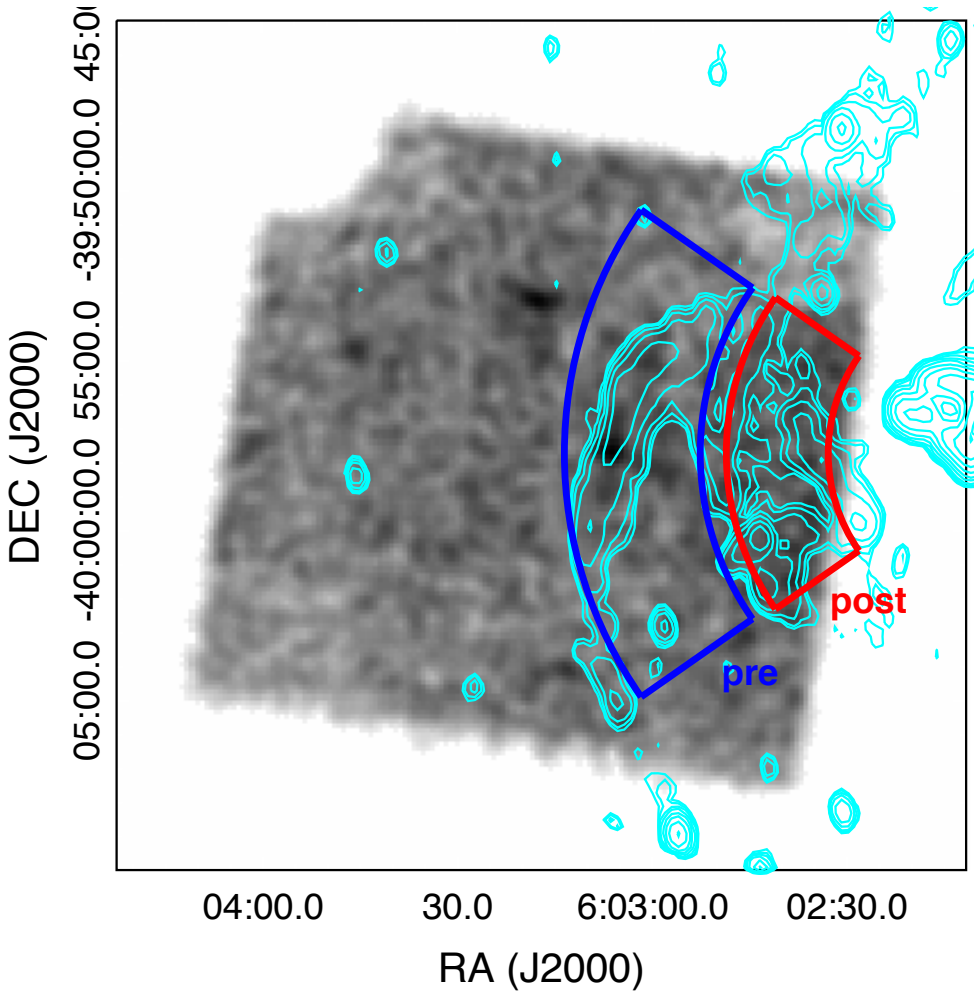
$M_E \sim 1.5 \pm 0.1$

$v_{sE} \sim 1450 \pm 150$ km/s

d shocks ~1.9 Mpc:
$t_{core\ passage} \sim 0.6$ Gyr



Eastern shock



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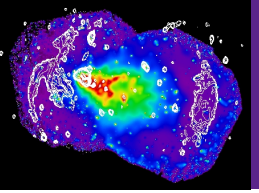
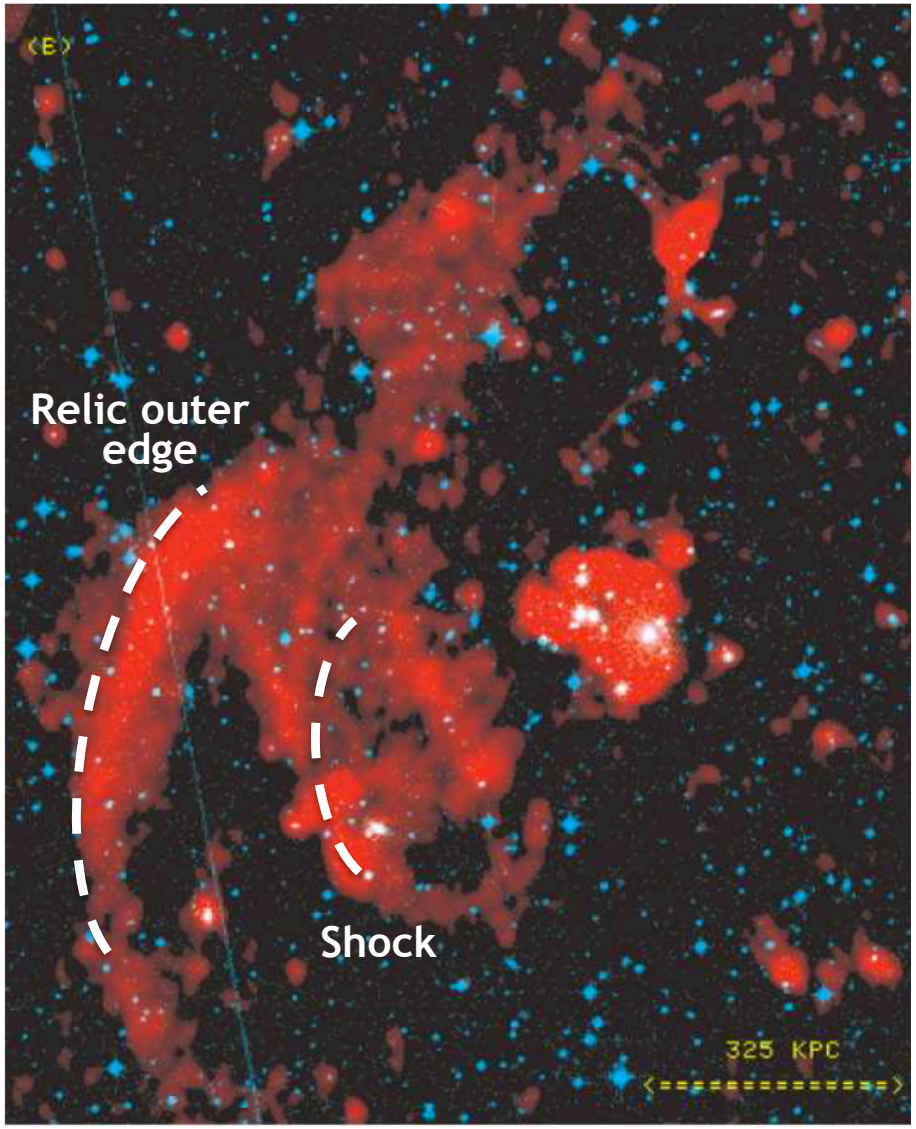
Still evolving merging galaxy cluster



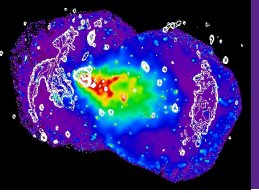
Eastern shock/relic



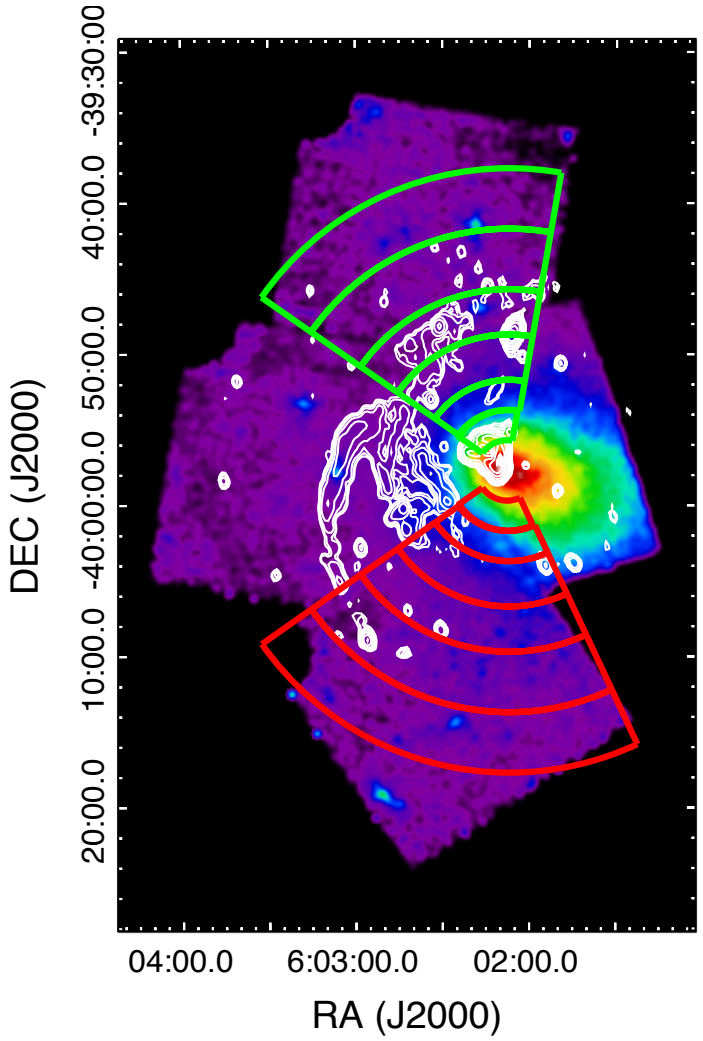
- ✓ Complex radio relic structure:
  - -Northern E-relic
  - -Elongated E-relic
  - -Notch
- ✓ No X-ray SB break at relic outer edge limited by low SB emission

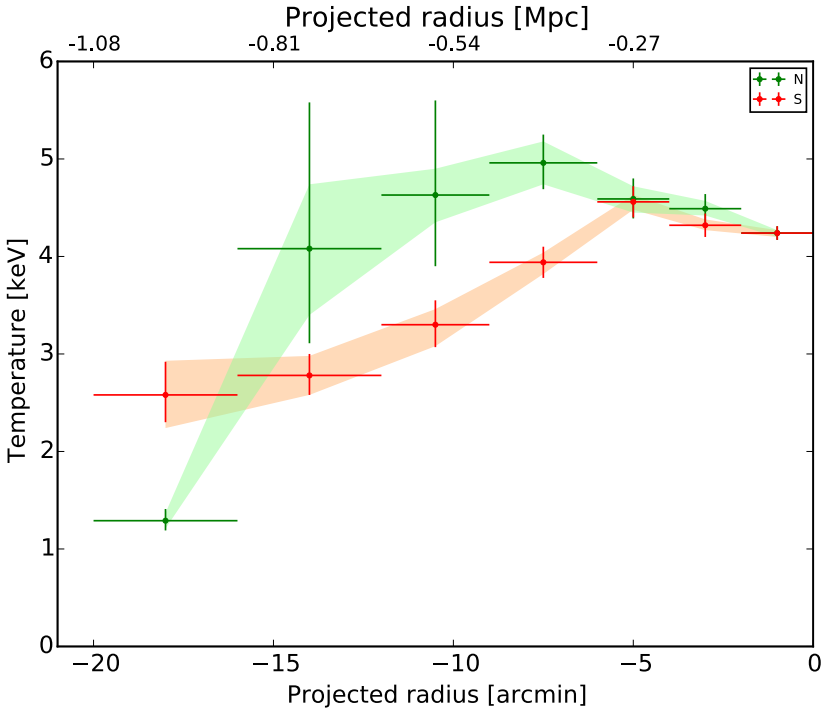
High-sensitivity X-ray images needed with Athena

Radio (VLA 1.4 GHz)
(Bagchi et al. 2006)

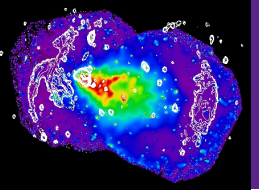


N & S T radial profile

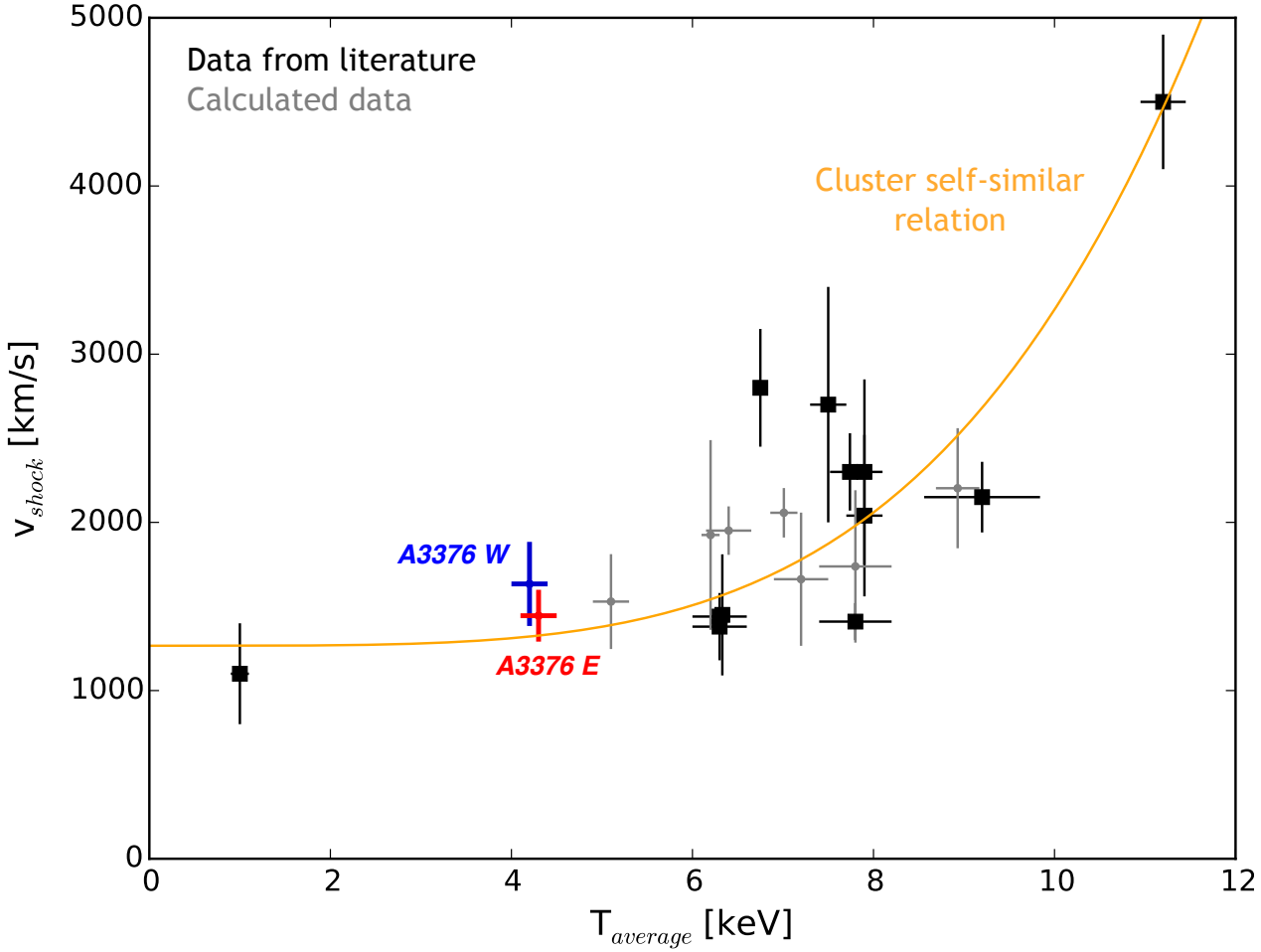




- ✓ Radio features in the North, no X-ray detection due to weakness signal
- ✓ No radio signatures in South
- ✓ South consistent with relaxed cluster *Universal* profile (Burns et al. 2010)



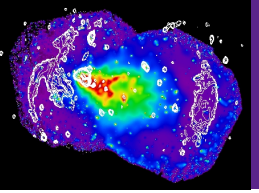
Vshock vs Taverage



$$v_{shock} = M \cdot c_s$$

$$c_s = \sqrt{\frac{\gamma k T_{pre}}{\mu m_p}}$$

v_{shock} appears correlated to $T_{average}$



Summary

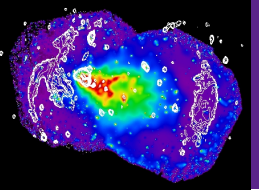
A3376 is an evolving merging galaxy cluster with double giant shocks/radio relics with M~2-3.

Azimuthal T radial distribution in X-ray:
W, E and N consistent with radio relics presence.

- W: shock and radio relic co-spatially located
- E: shock located at the “notch”

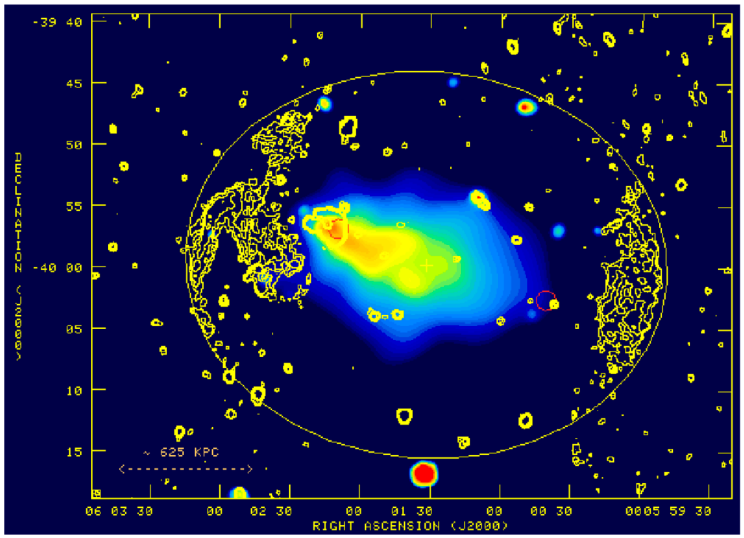
S agrees with relaxed clusters profile.


BACK UP

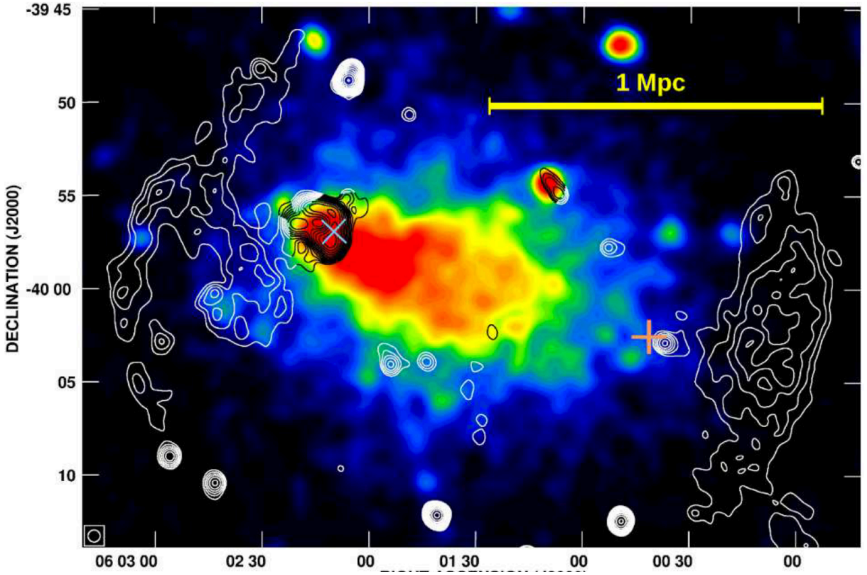


Radio emission

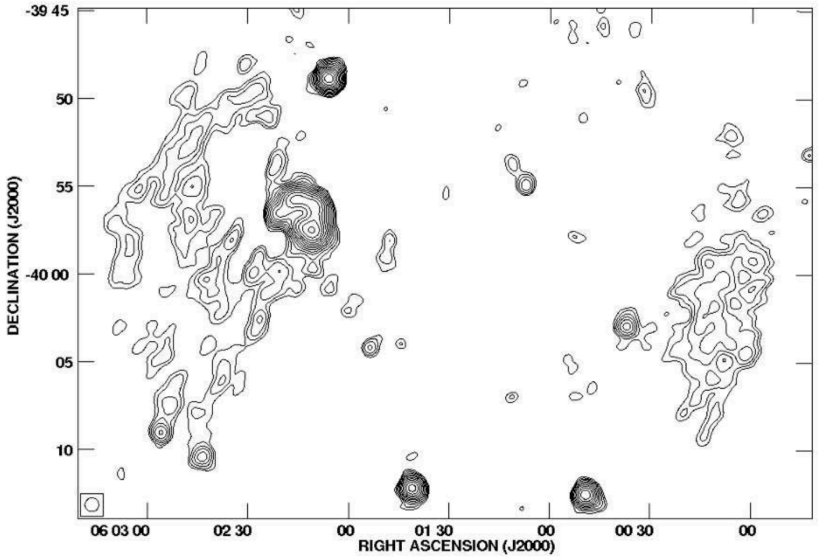
1.4 GHz VLA Bagchi et al



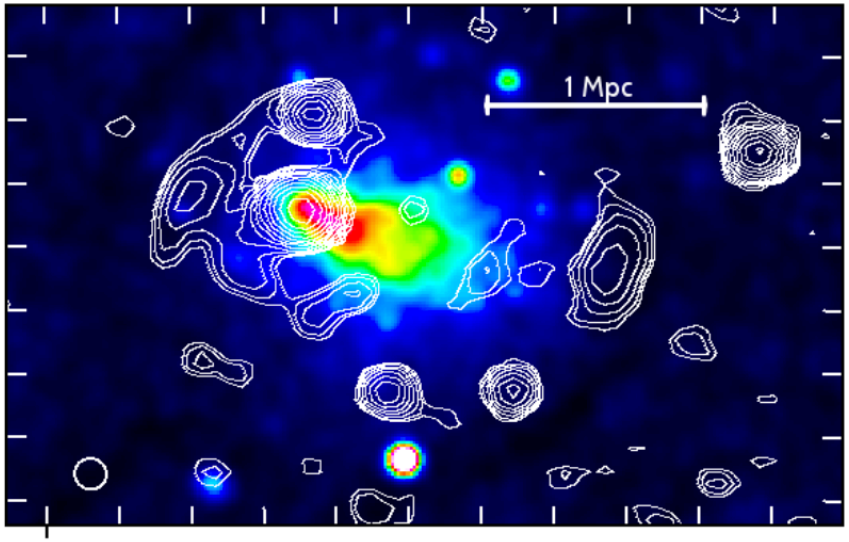
325 MHz GMRT Kale et al

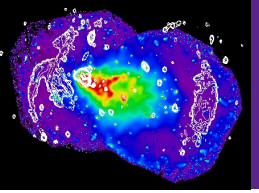


150 MHz GMRT Kale et al



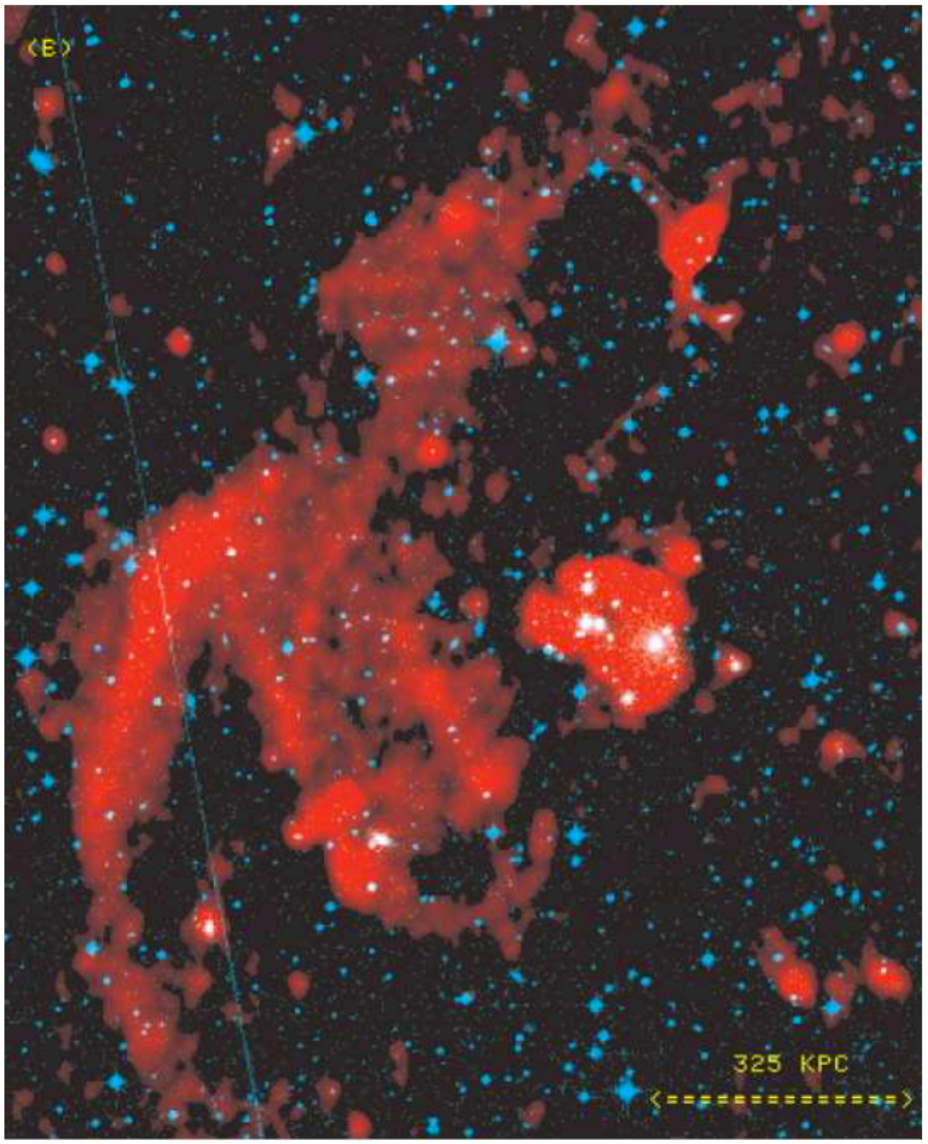
154-215 MHz MWA George et al

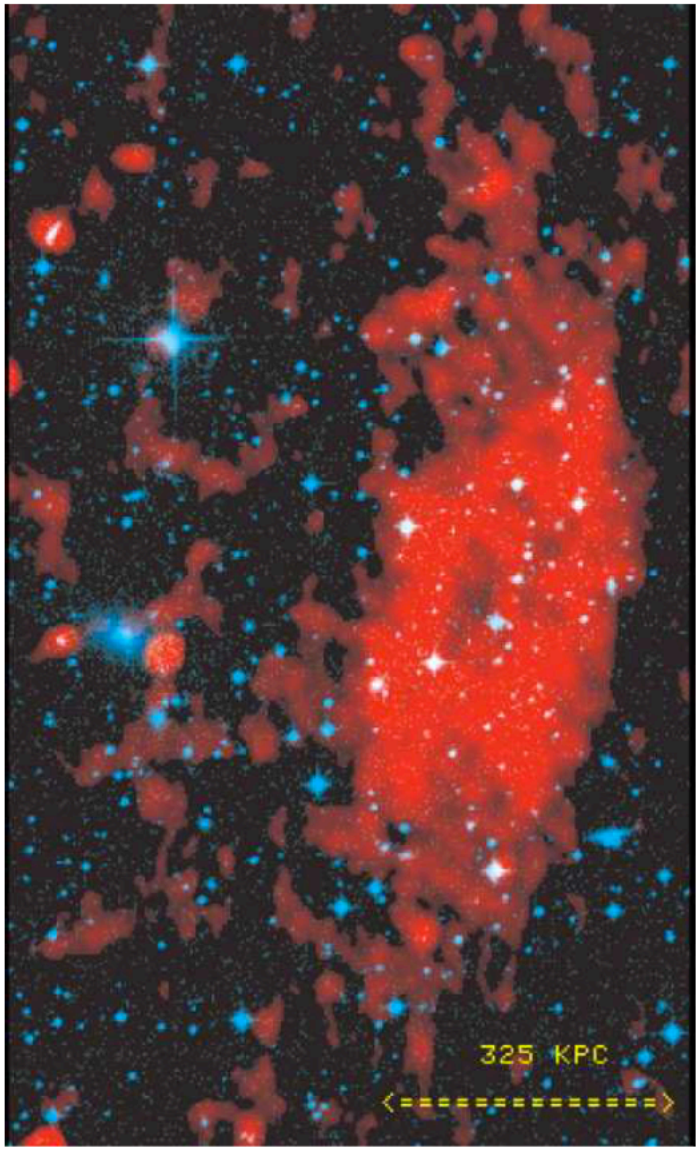


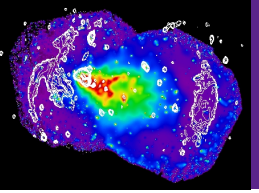


Radio map 1.4 GHz VLA

(Bagchi et al. 2006)







Polarization maps

(Kale et al. 2012)

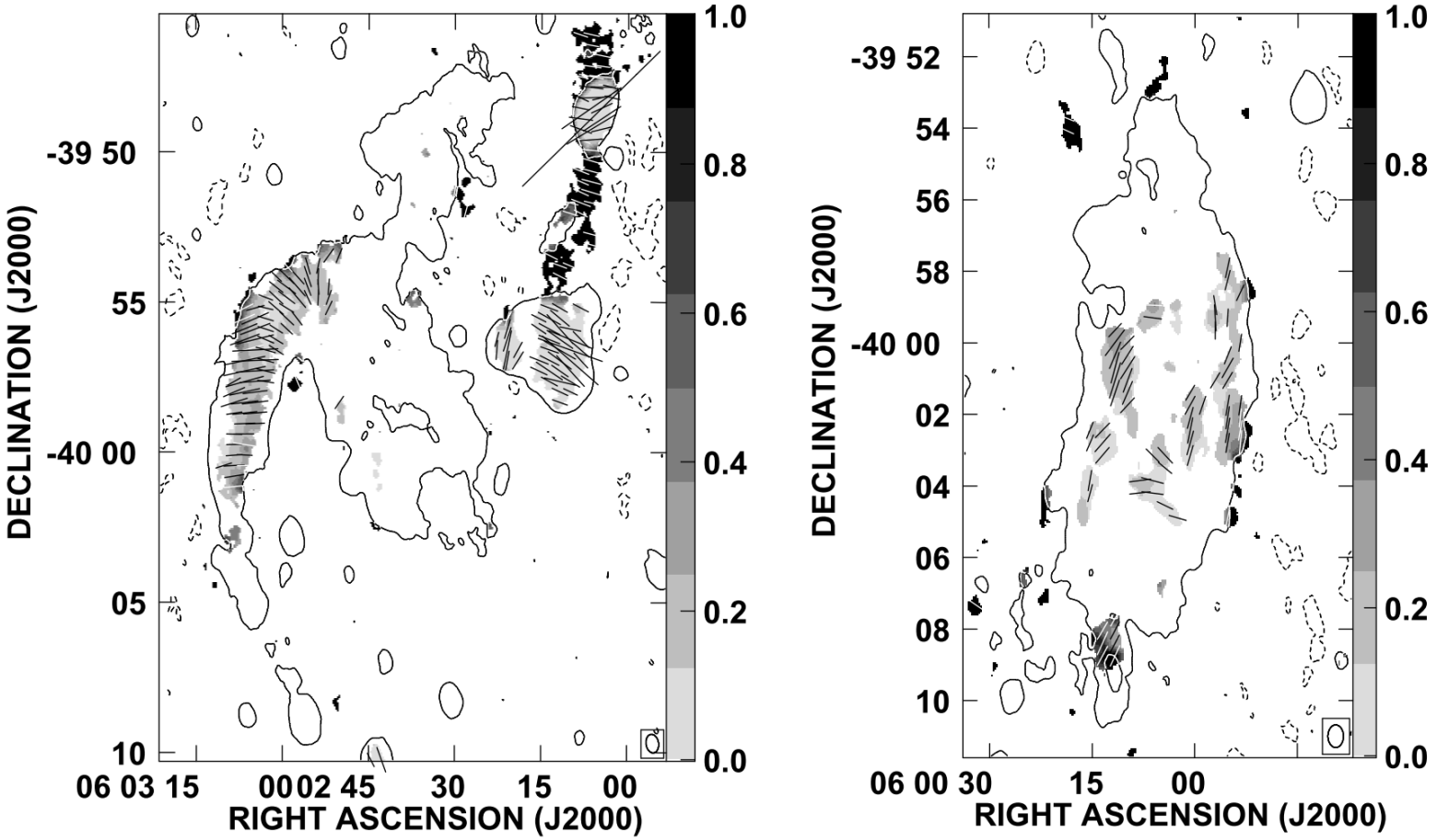
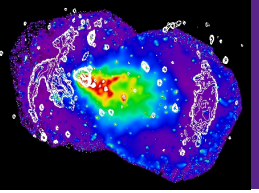


Figure 3. VLA 1400 MHz: Electric field vectors overlaid on fractional polarized intensity shown in grey-scale and Stokes I contours shown at -0.16, 0.16 mJy beam^{-1}. The length of the vectors is proportional to the polarized intensity. The synthesized beam is $37'' \times 25''$ (P. A. 9.22°) in the left panel and $38'' \times 26''$ (P. A. 0.17°) in the right panel.



Radio spectral index map

EAST

(Kale et al. 2012)

WEST

325MHz GMRT
1.4 GHz VLA