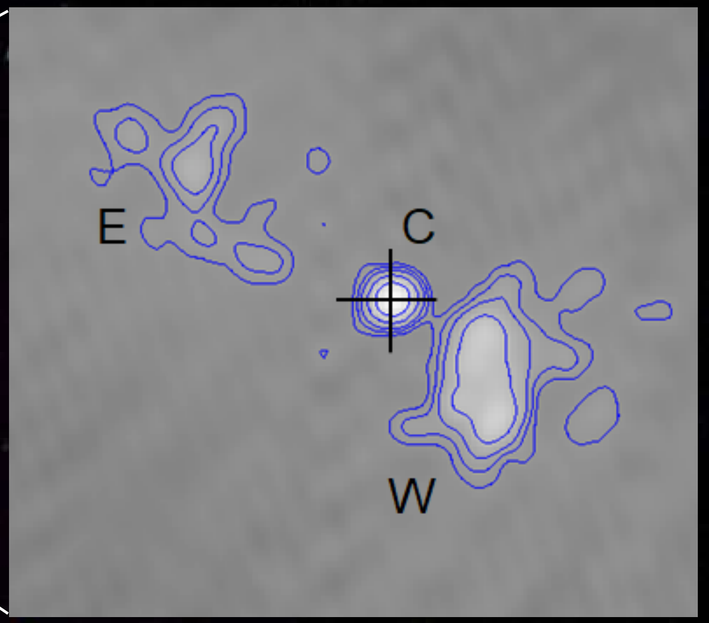
# 1321+045: a CSS source in a cool-core galaxy cluster




Ewan O'Sullivan, M. Kunert-Bajraszewska, A. Siemiginowska, D.J. Burke, F. Combes, P. Salomé & S. Giacintucci
(see O'Sullivan et al. 2021, arXiv:2104.04548)

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# Introduction

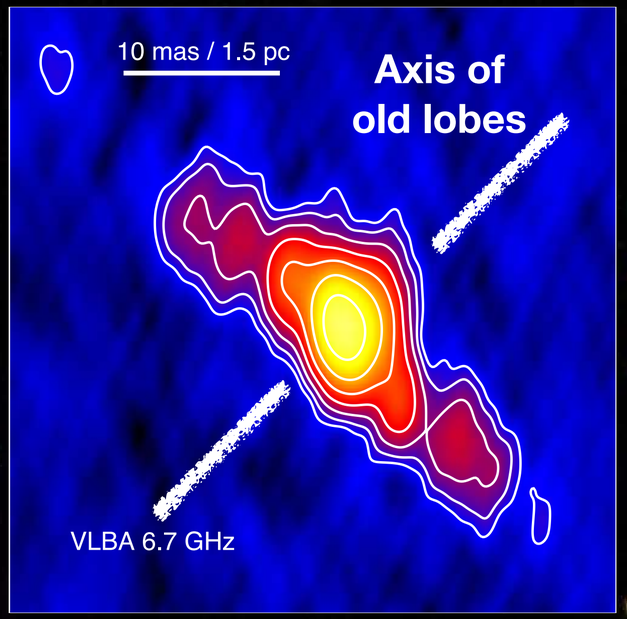
- Cluster-dominant galaxies are a special location for AGN
  - Host most massive black holes
  - ~10x more likely to host radio AGN than non-central galaxies (Best et al. 2007)
  - Cooling from ICM fuels repeated periods of jet activity

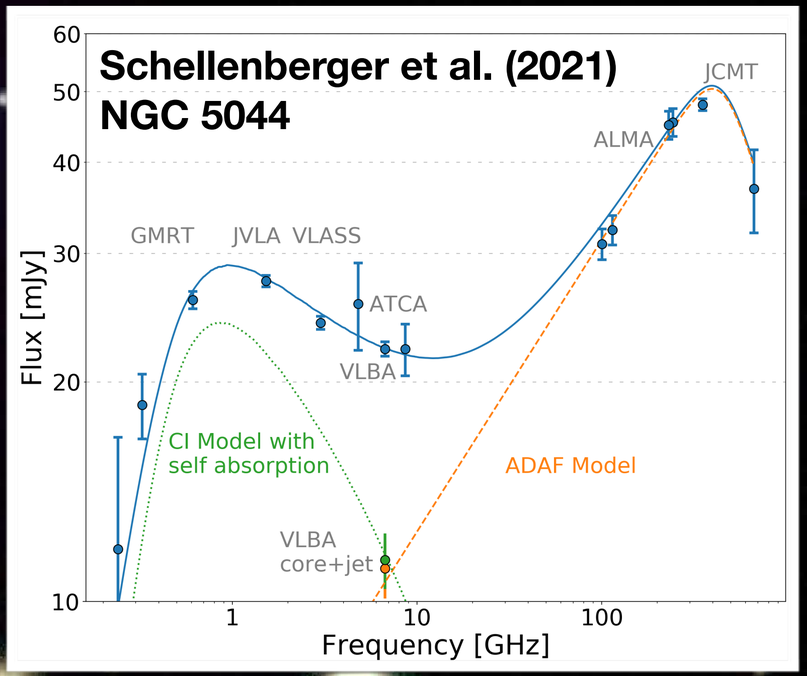
- Observations of surrounding ICM can help us study radio sources (fuelling, jet power, particle content, etc.)

- Identifying young radio sources could help us examine conditions that trigger feedback in clusters

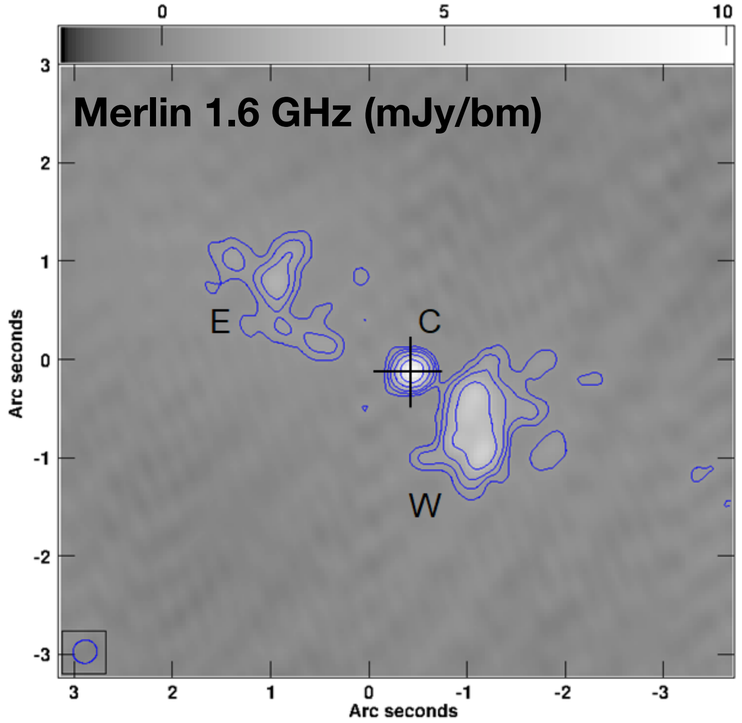
# Cluster-central CSS/GPS

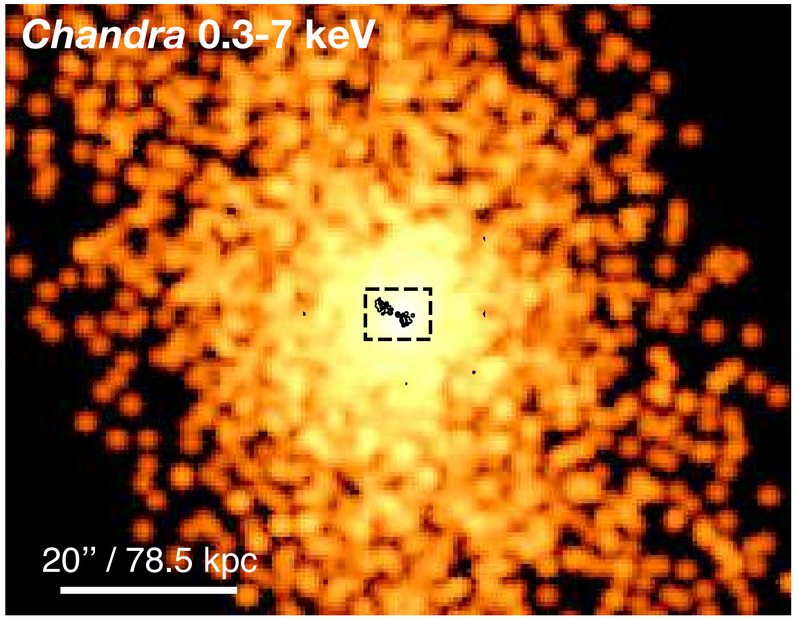
- Relatively few have been studied:
- ~8.5% of BCGs in cool core clusters have GPS-like spectral features (Hogan et al. 2015)
- New cycle of activity in NGC 5044 is GPS-like: 4.5pc jets, self-absorbed spectrum peaking at 1GHz (Schellenberger et al. 2021)
- CSS sources in clusters:
  - 3C186: QSO in 8 keV cool-core cluster at z=1.06 (Siemiginowska et al. 2005, 2010, Migliori et al. 2012)
  - IRAS F15307+3252: QSO in 2 keV group at z=0.93 (Hlavacek-Larrondo et al. 2017)
  - 1321+045: in 4.4 keV cluster at z=0.263

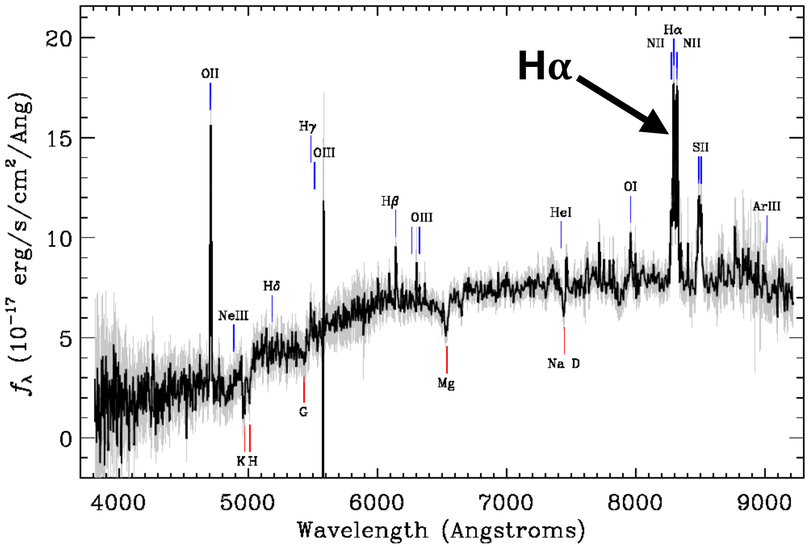


# 1321+045: previous studies



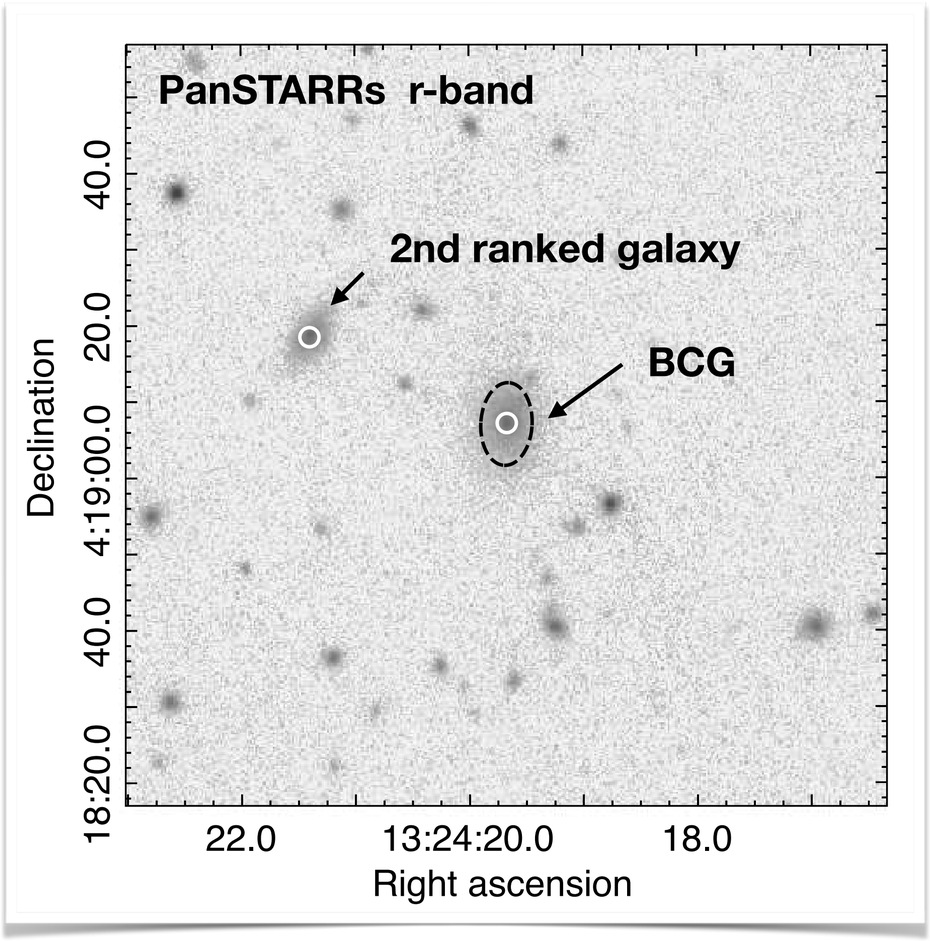



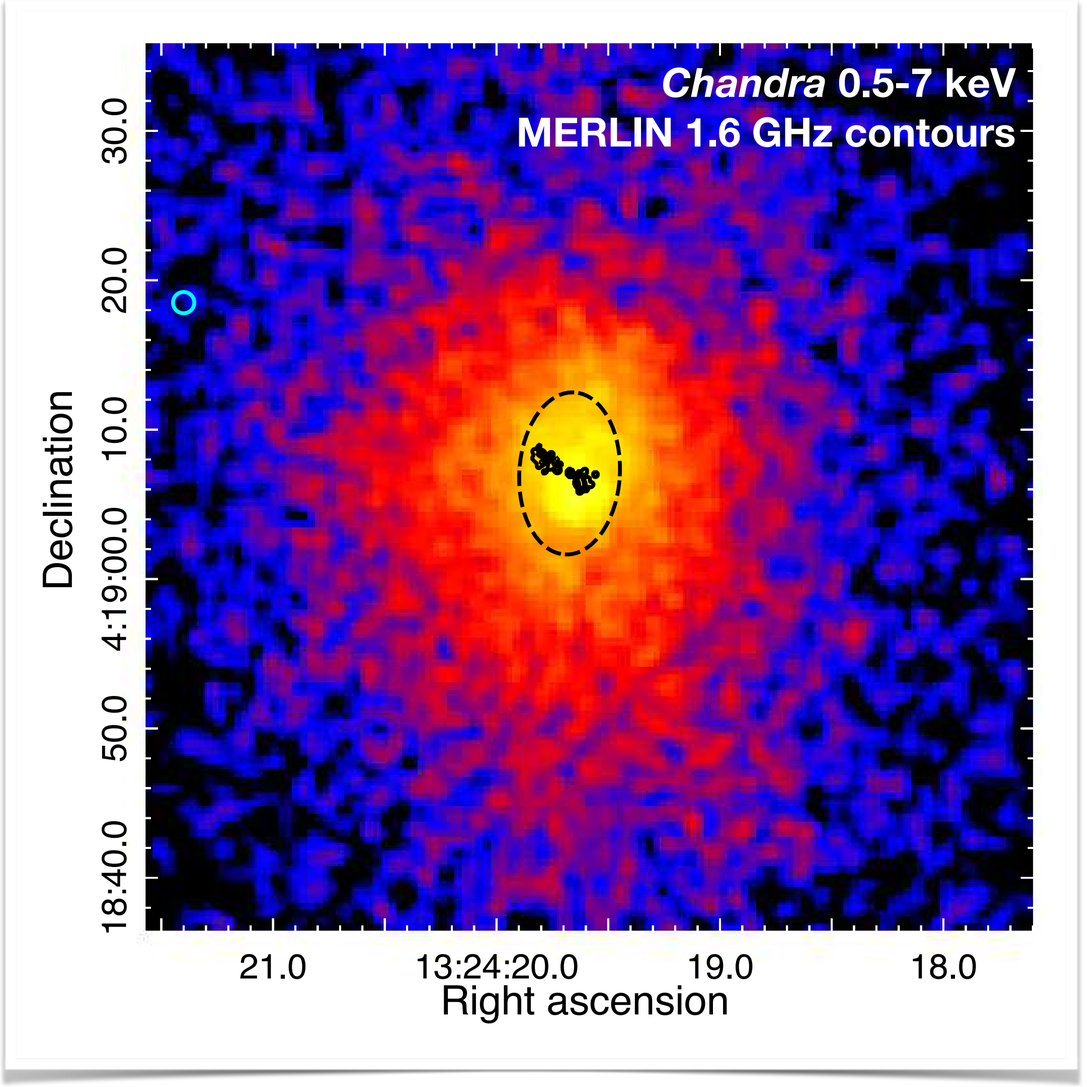




**SDSS spectrum**

- FR-I with ~16kpc lobes, spectral index $\alpha$=-0.95 (Kunert-Bajraszewska et al. 2010)
- *Chandra* 9ks snapshot shows 4.4 keV cluster with cool core (K-B et al. 2013)
- Lobes over-pressured by factor ~2 compared to ICM
- Relaxed cluster galaxy population (Wen & Han 2013)
- $L_{H\alpha}$=4.5x$10^{41}$ erg/s (Liu et al. 2012) similar to cooling H$\alpha$ nebulae in low-z clusters

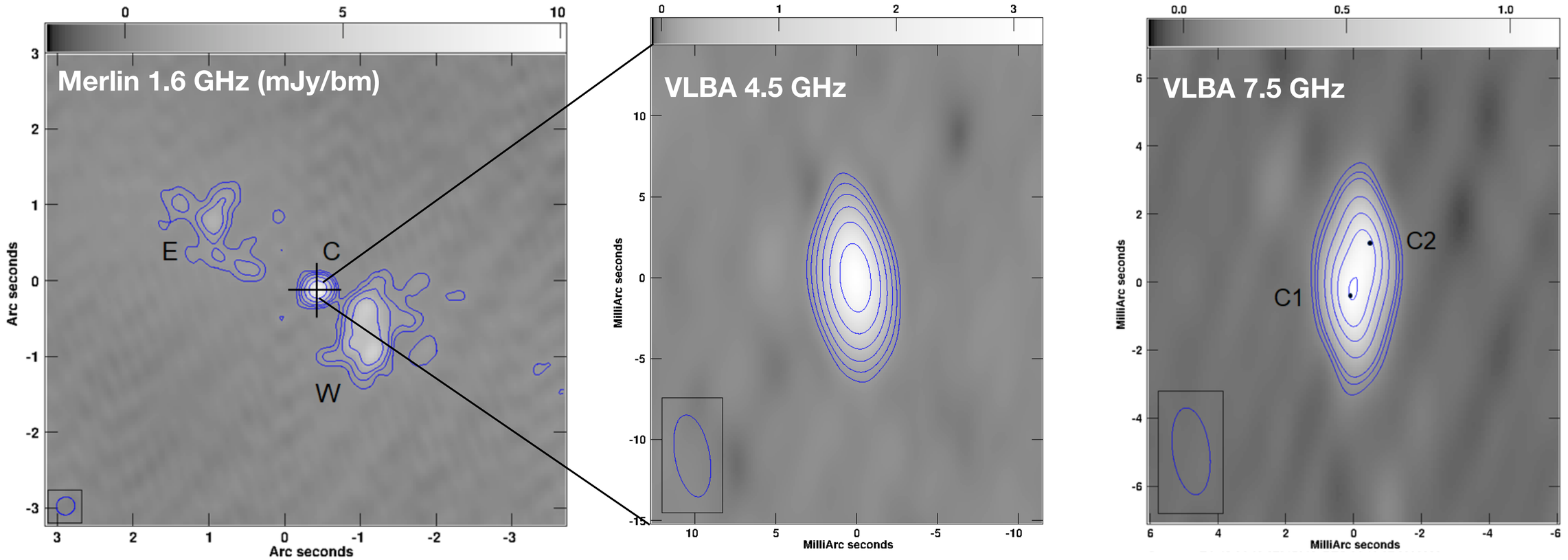
# 1321+045: new observations




- 80ks Chandra X-ray observation
- 2.5hr VLBA C-band (+1.5min archival VLA)
- 12hr IRAM 30m CO(1-0) & (3-2): non-detection, $M_{H2} \lesssim 6 \times 10^9\ M_\odot$

# VLA and VLBA data




- Archival VLA 4.9 GHz confirms MERLIN 1.6 GHz morphology
- VLBA reveals 20pc jet in core, ~90º offset between jet axes
- Expansion timescale of 20pc jet = ~few hundred years

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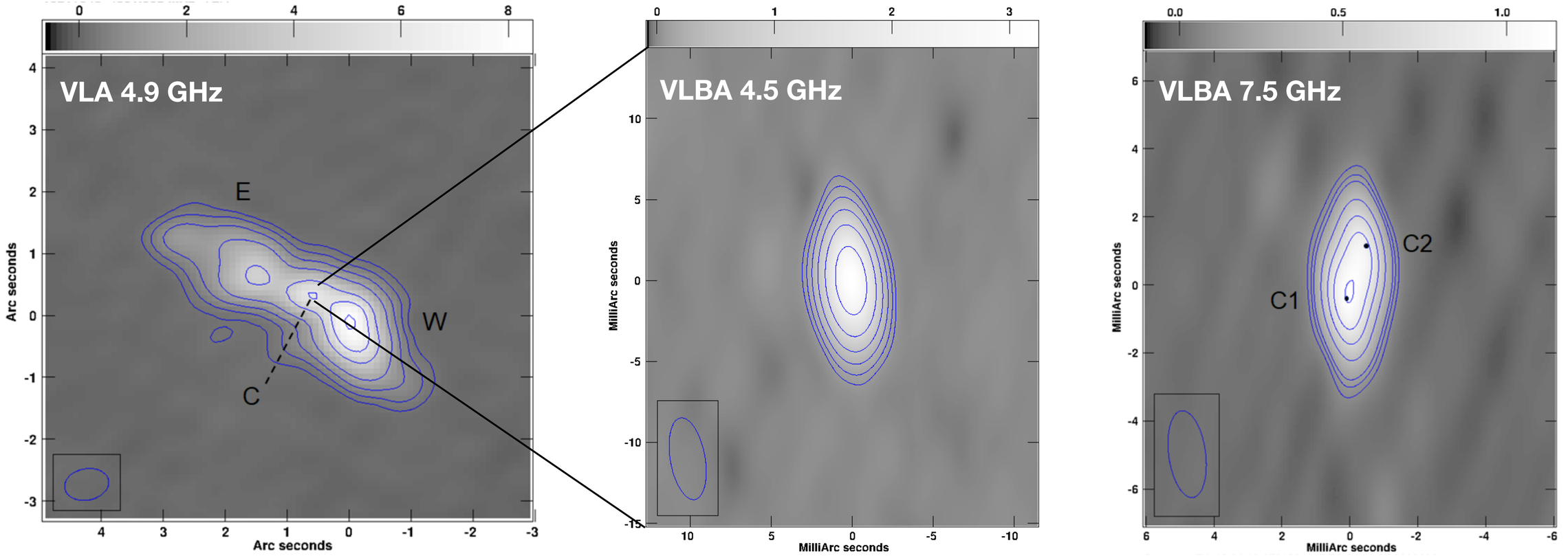


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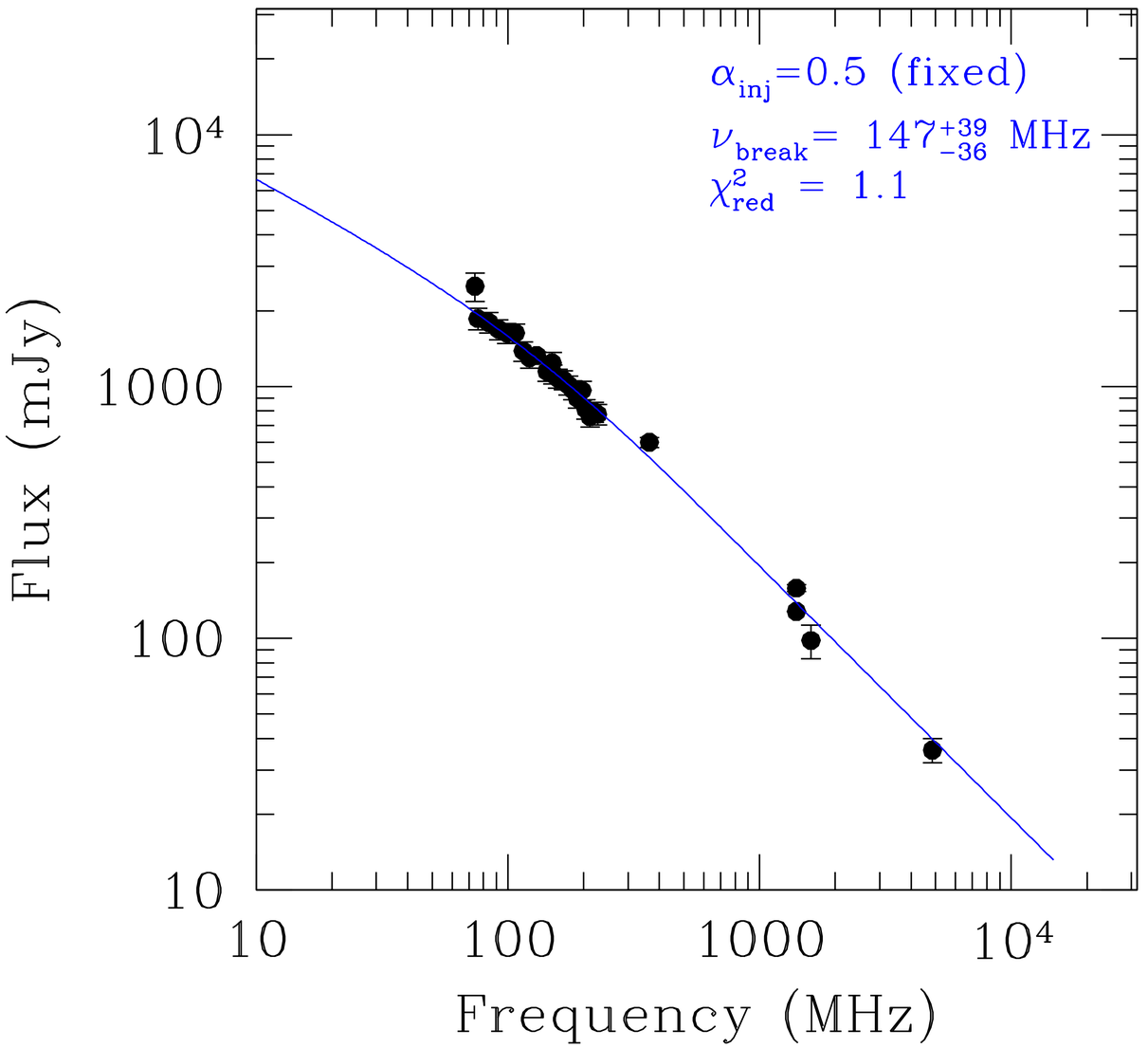
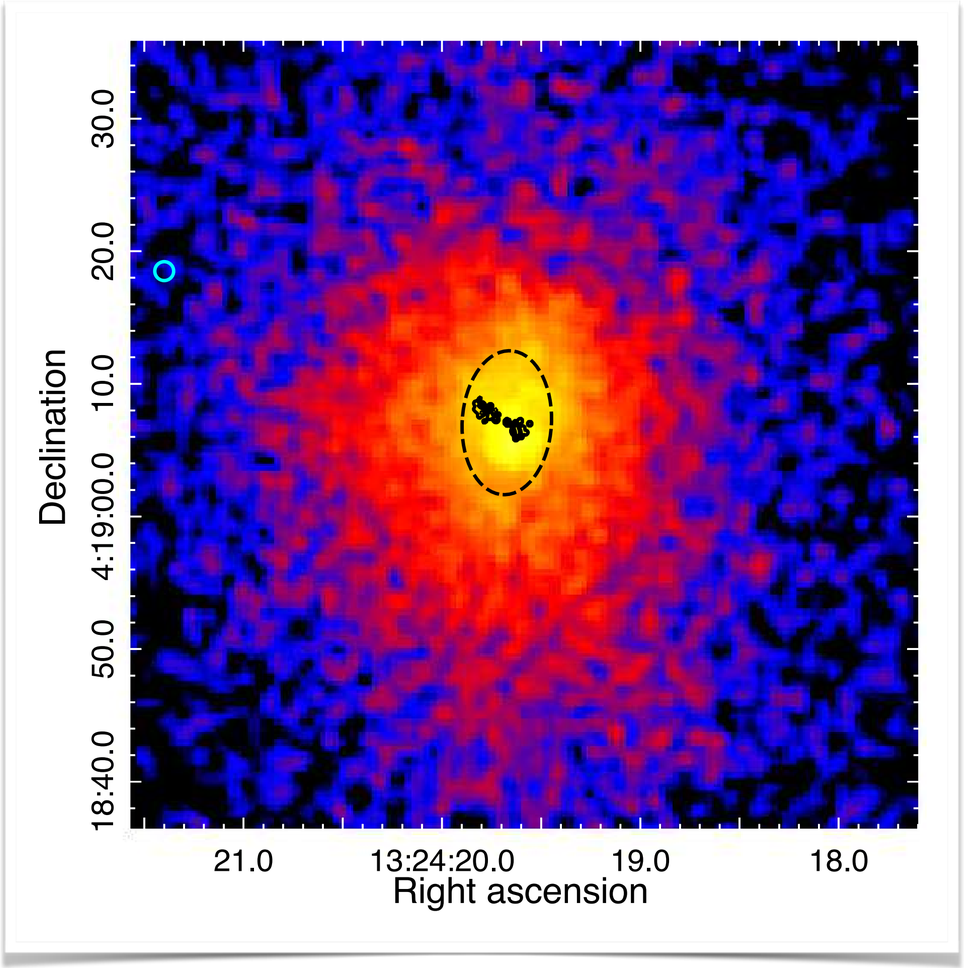
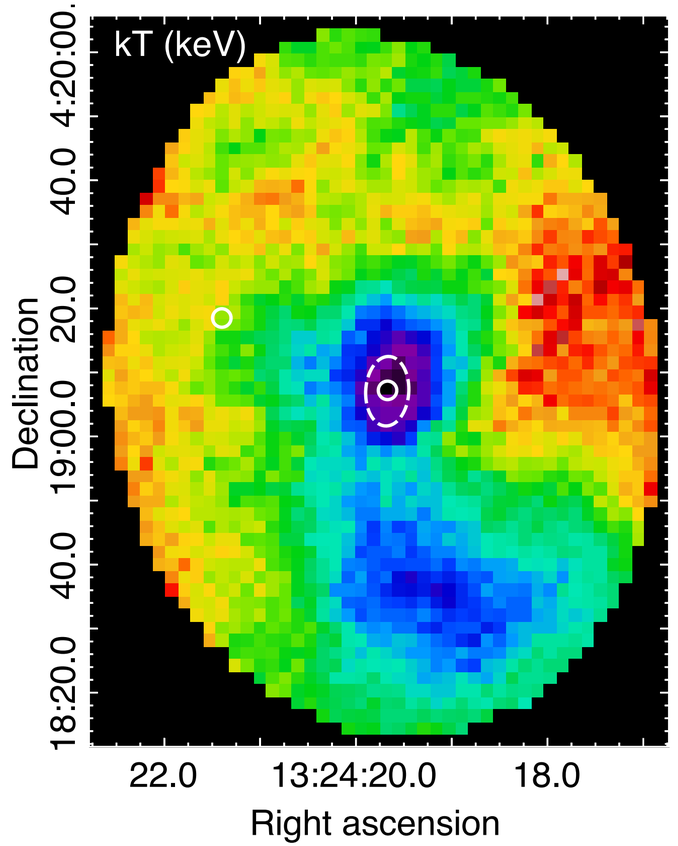
# Radio spectrum

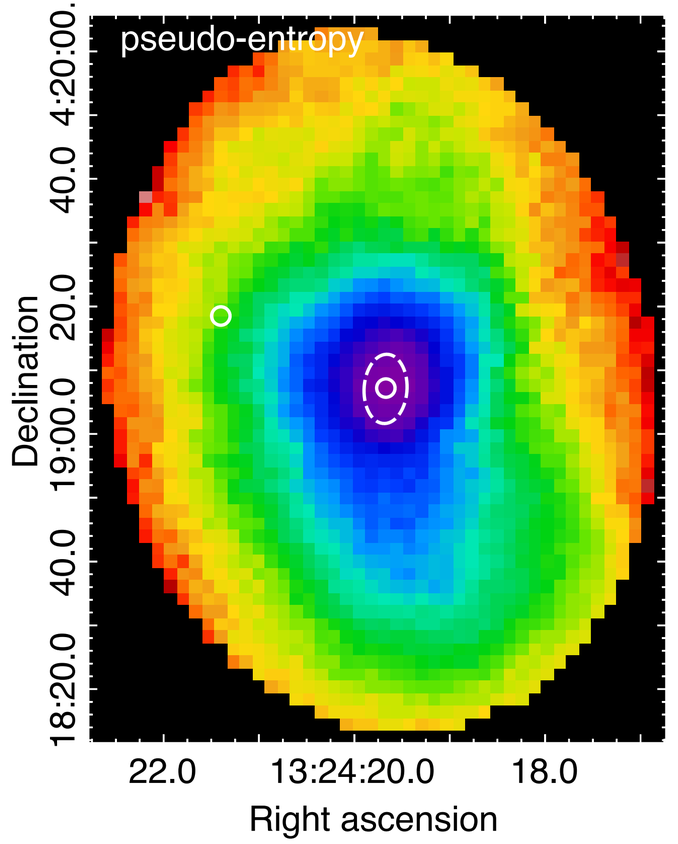
- Continuous Injection model a good fit to 74 MHz - 4.9 GHz
- GLEAM survey points show break at 147 MHz
  => Lobe age ~2 Myr
- CI+off model: cutoff frequency poorly constrained, >290 GHz
- Lobes either still powered by jets, or only shut down <$10^5$ yr ago?



# ICM: disturbed structures

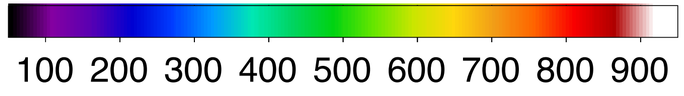




**Temperature (keV)**




**pseudo-entropy (arbitrary units)**

Although ICM looks relaxed at first glance, several

=> Recent minor merger, S tail and E spur = gas stripped from infalling subcluster?

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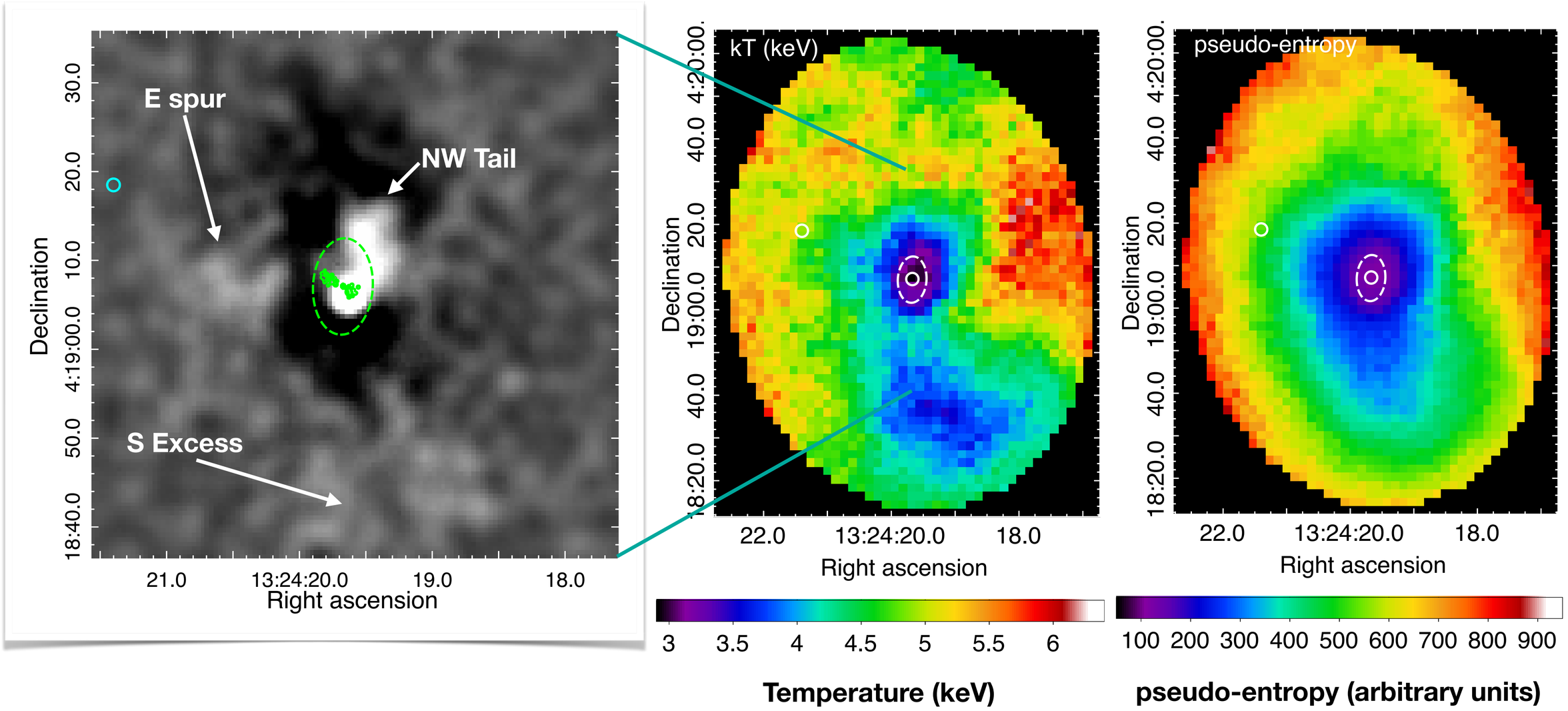


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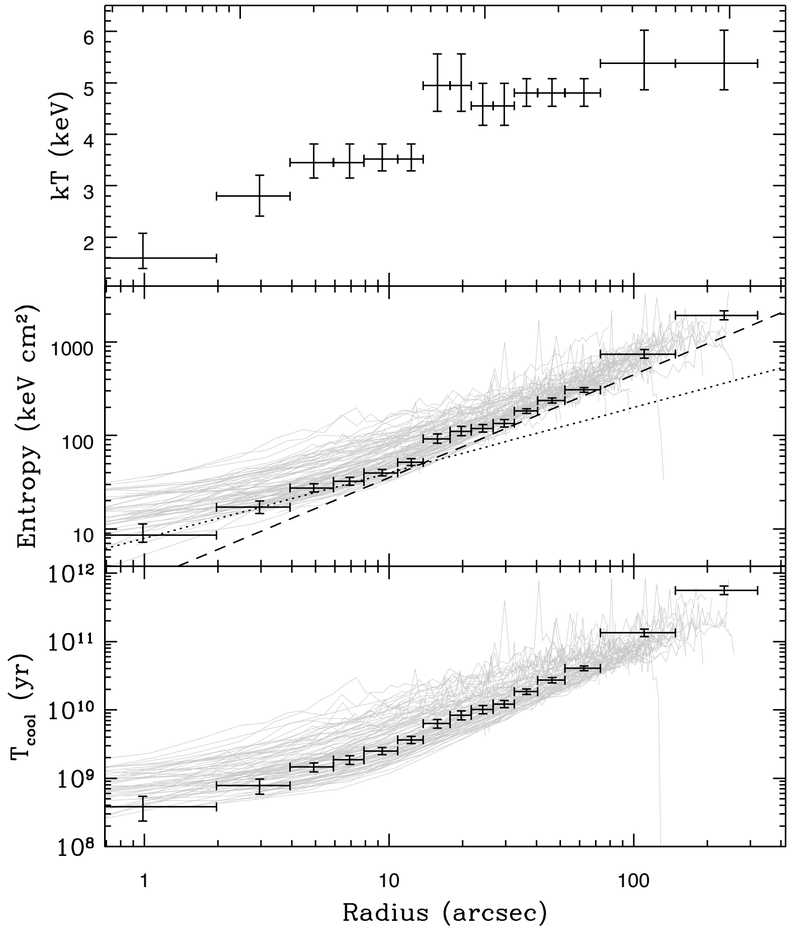
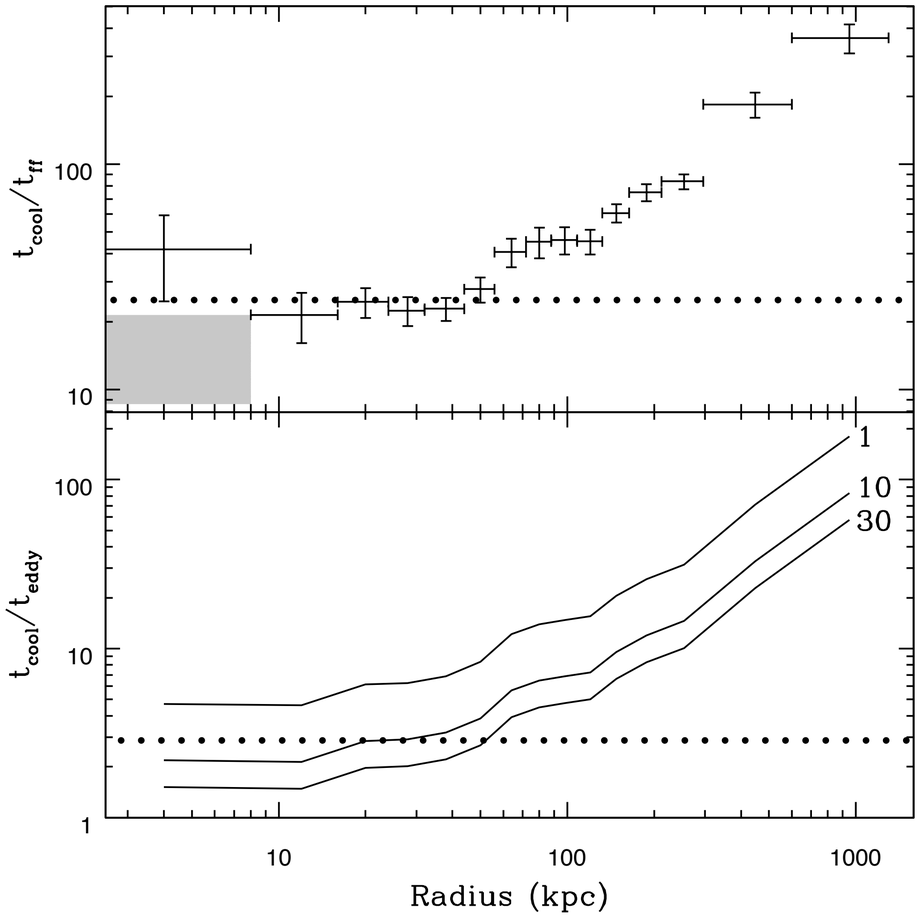
# ICM: radial profiles




- ICM properties similar to other cool-clusters (e.g., ACCEPT sample, Cavagnolo et al. 2009)
- Thermal instability indicators ($t_{cool}/t_{ff}$, $t_{cool}/t_{eddy}$) suggest ~45kpc cooling/condensation region
- $L_{cool}$ (within $t_{cool}$<7.7Gyr) ~3.1x$10^{44}$ erg/s, Jet power ~1.4x$10^{44}$ => close to thermal balance

# Conclusions

- 1321+045 is hosted by a cluster with properties similar to strong cool-core systems at low redshift.
- Evidence of recent minor cluster merger - triggering event for AGN?
- Outer 16kpc lobes are ~2Myr old, probably capable of balancing ICM cooling if they are still powered by the jets.
- Inner 20pc VLBA jet few x100 yr old, ~90° offset from axis of older lobes.

**Two possible scenarios:**

1) Lobes and inner jet represent two outbursts, AGN jet axis has changed
   - reorientation timescale for the AGN is very short, $\lesssim 10^5$ yr
2) Jets/lobes aligned close to line of sight, precession and bent jets explain apparent axis difference
   - inner jet is one-sided, W lobe significantly brighter than E
   - no detection of the AGN nucleus in X-ray, $L_{2\text{-}10keV} < 1.5 \times 10^{43}$ erg/s