AGN WINGS: UNRAVELLING THE MYSTERY OF CROSS-SHAPED X-RAY EMISSION

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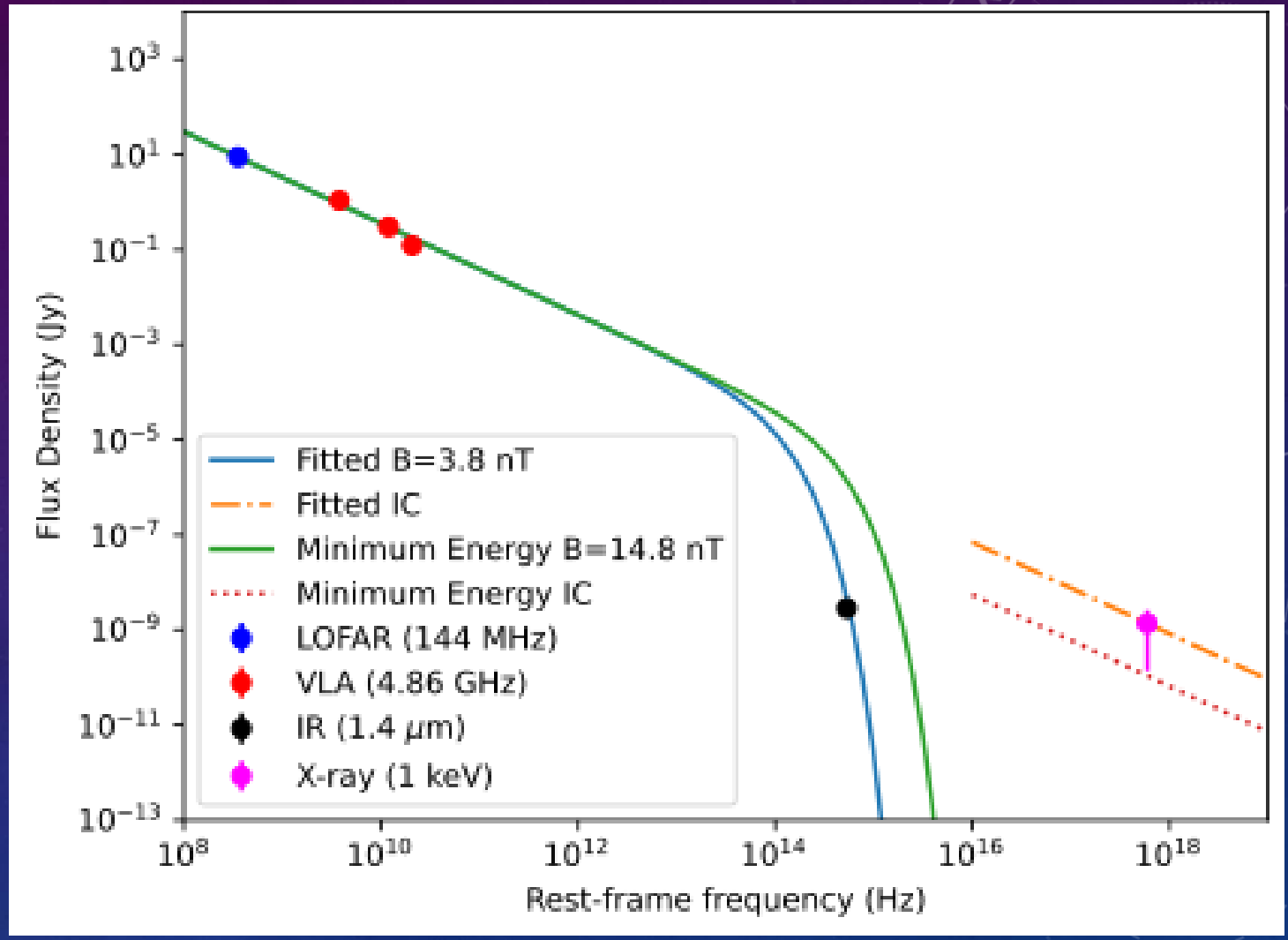
X-RAY OBSERVATIONS OF RADIO JETS

- Multiple Chandra observations have shown jets at X-ray energies e.g. PKS 0637-75 [Schwartz+2000]
- Combining X-ray and Radio fluxes, can be used to find the magnetic field without relying on minimum energy assumptions
- Results have shown B-field in jet related regions often knots and hot spots to be a factor of a few away from minimum energy.
- To the right is an example of an iC/CMB dominated X-ray emission from a QSO jet with jet power: 6.8×10^{47} erg s^{-1}



Example jet lobe for 3CR 14

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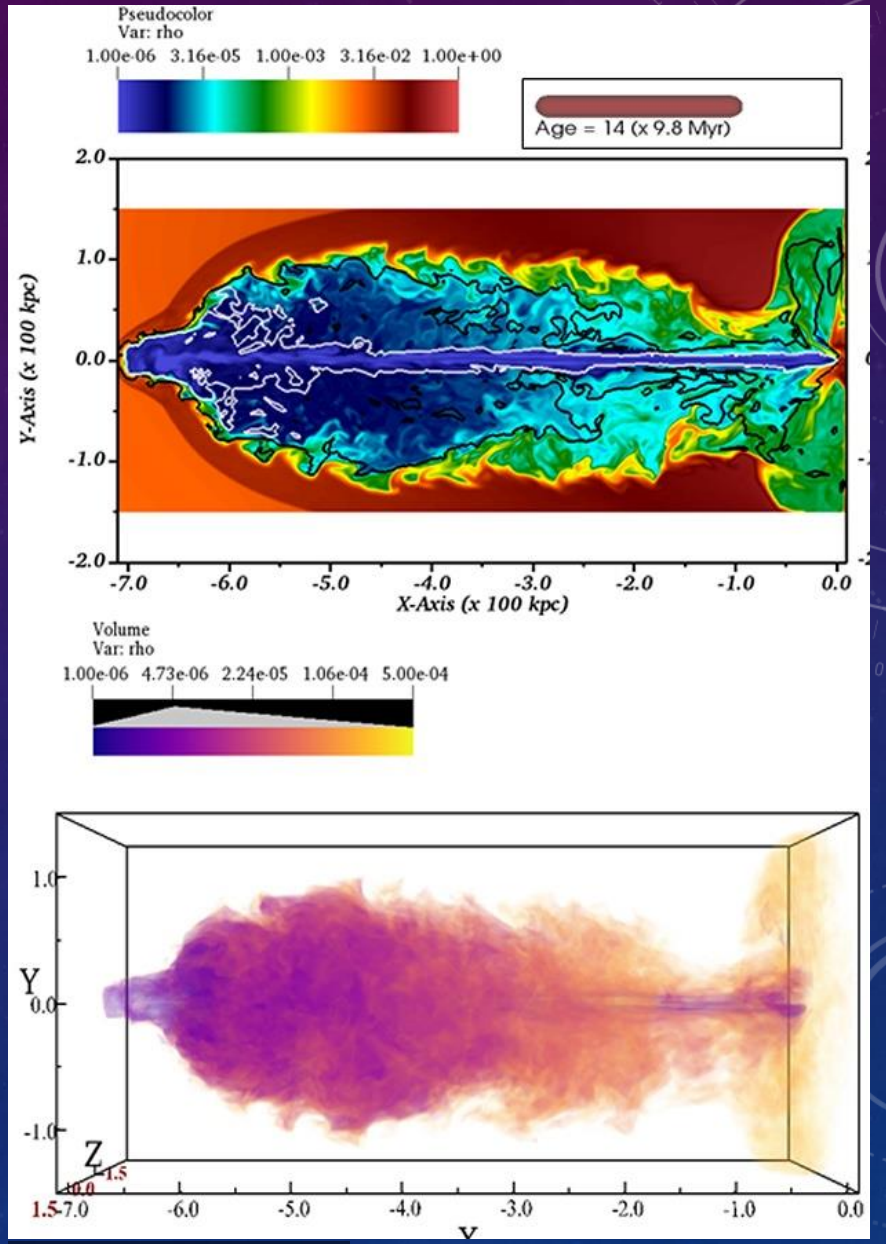
EVOLUTION OF AGN WINGS

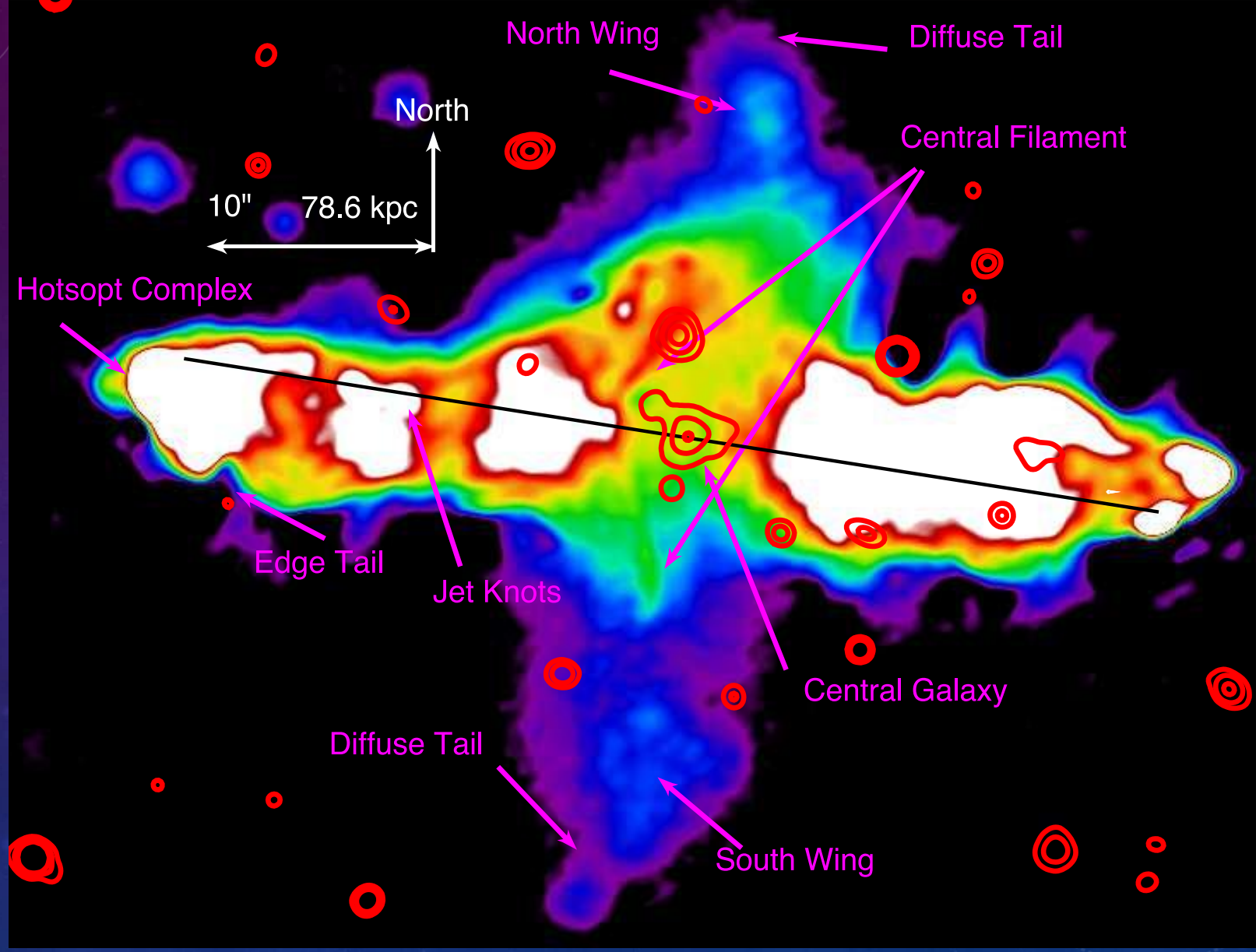
- In radio observations hundreds of AGN have been observed to have emission along two separate axes, often appearing perpendicular [see Bera+20].
- This emission, appearing Cross-shaped, has led to the categorisation of XRGs or sometimes ZRGs.
- There are a few different mechanisms, which include:
  - A merger or binary/dual AGN scenario [e.g. Merrit & Ekers, 02; Lal+19]
  - A backflow model where plasma follows favourable pressure gradients to form wings [See Leahy & Williams, 1984; Gillone+16; Giri+25]



Giri+ 2025

3C 34 (Z=0.69)

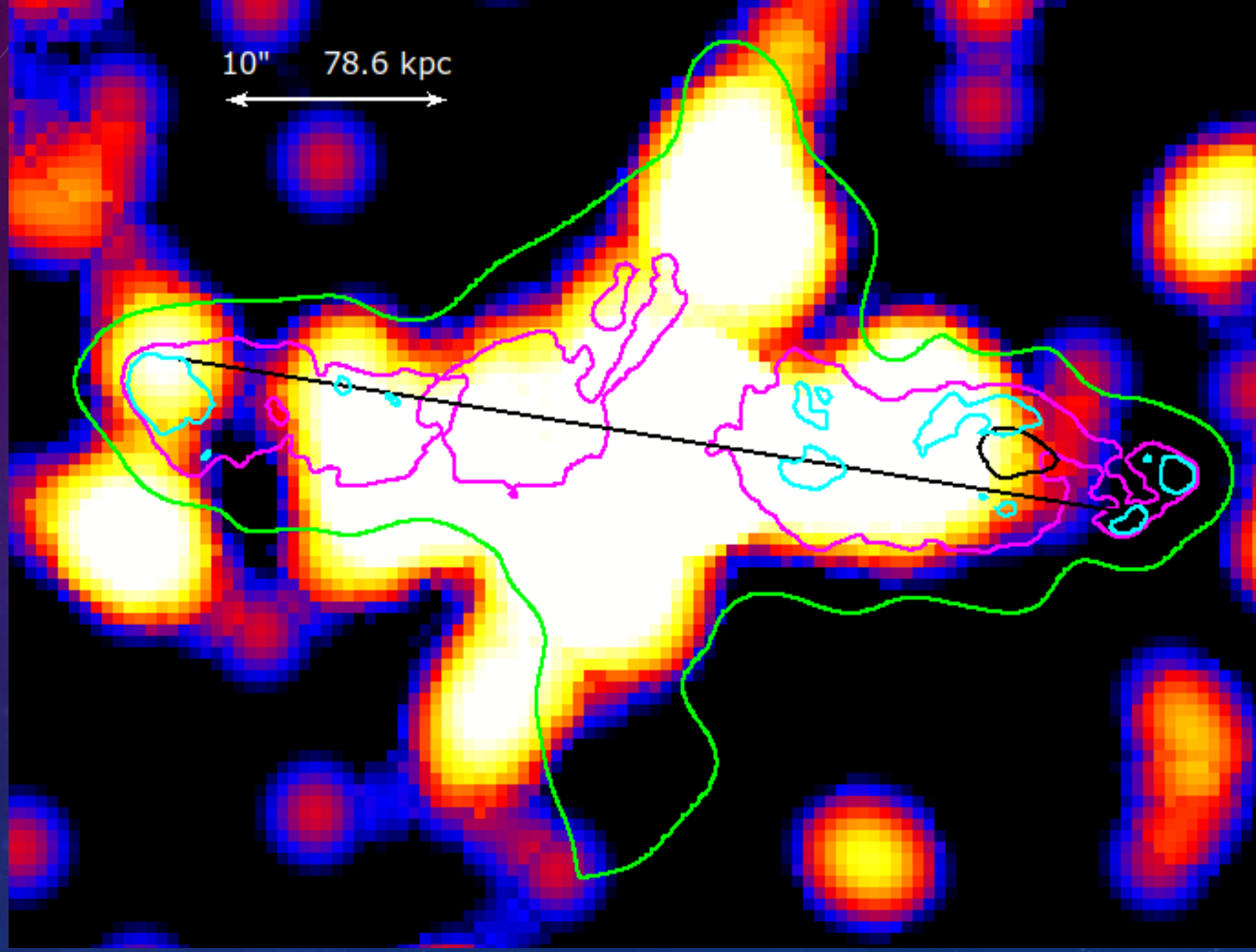
- LOFAR 144 mHz image with red HST optical contours
- LOFAR resolution is 0.3”
- Projected 380 kpc length
- Large central filament ~ 100 kpc feeding ~ 125 kpc wings
- Best model is plasma backflow [Mahatma+2023]



Mahatma+23 & Best+97

3C 34 (Z=0.69)

- Smoothed Chandra image with LOFAR Contours
- Evidence of X-ray emission to match the LOFAR-observed Wings
- X-ray emission along the jet axis



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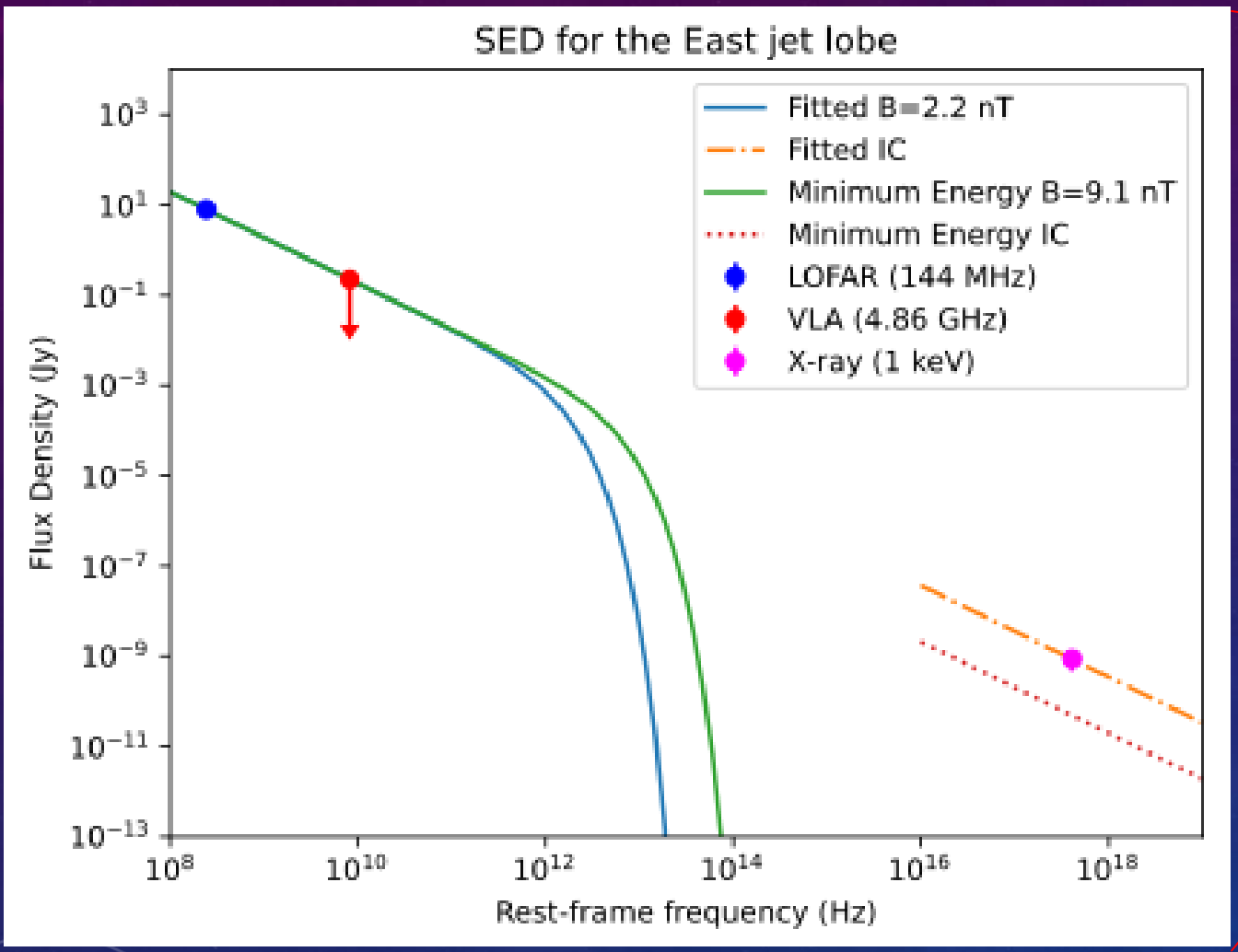

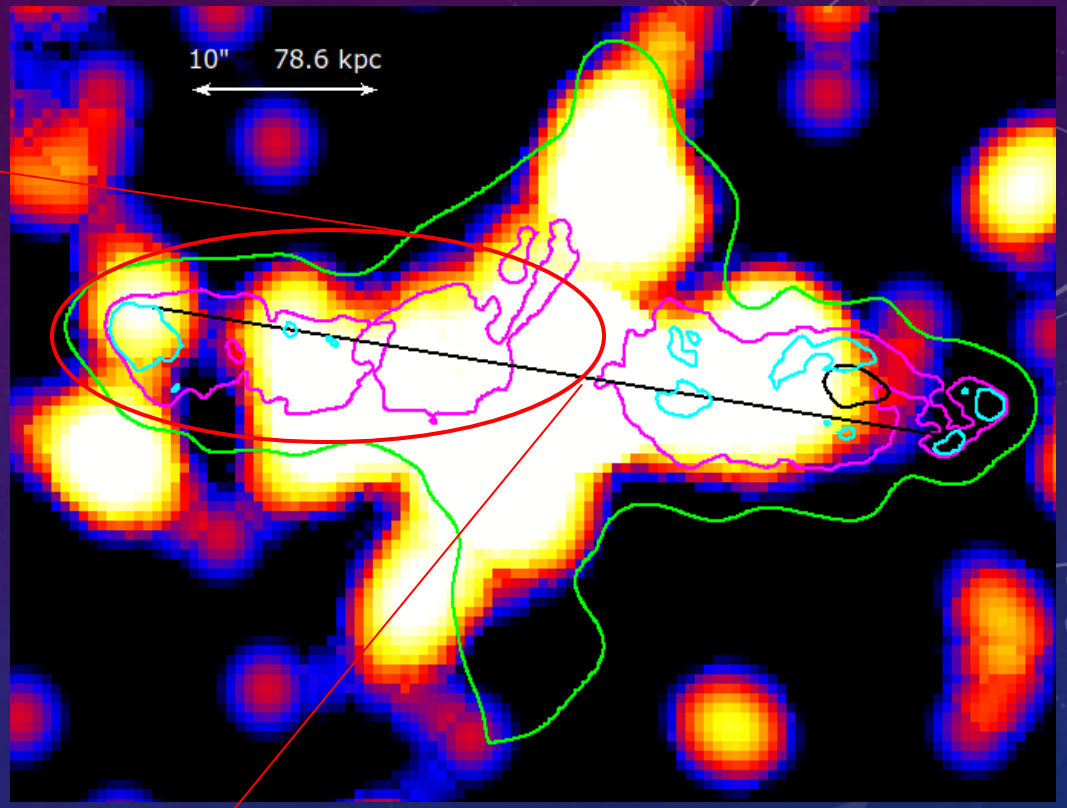

- Model gives a magnetic field discrepancy of a factor of 4
- Consistent with general jet observations

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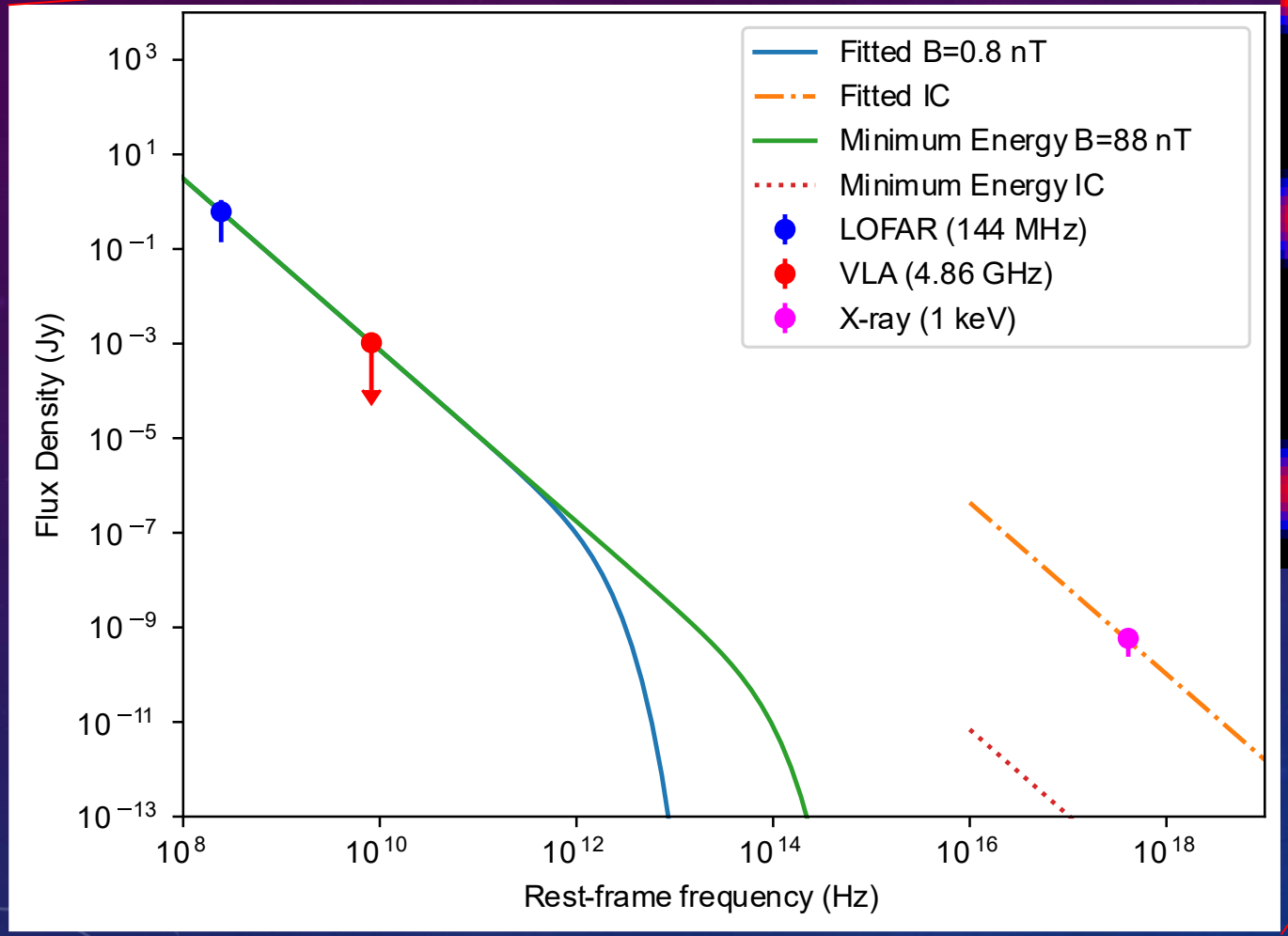
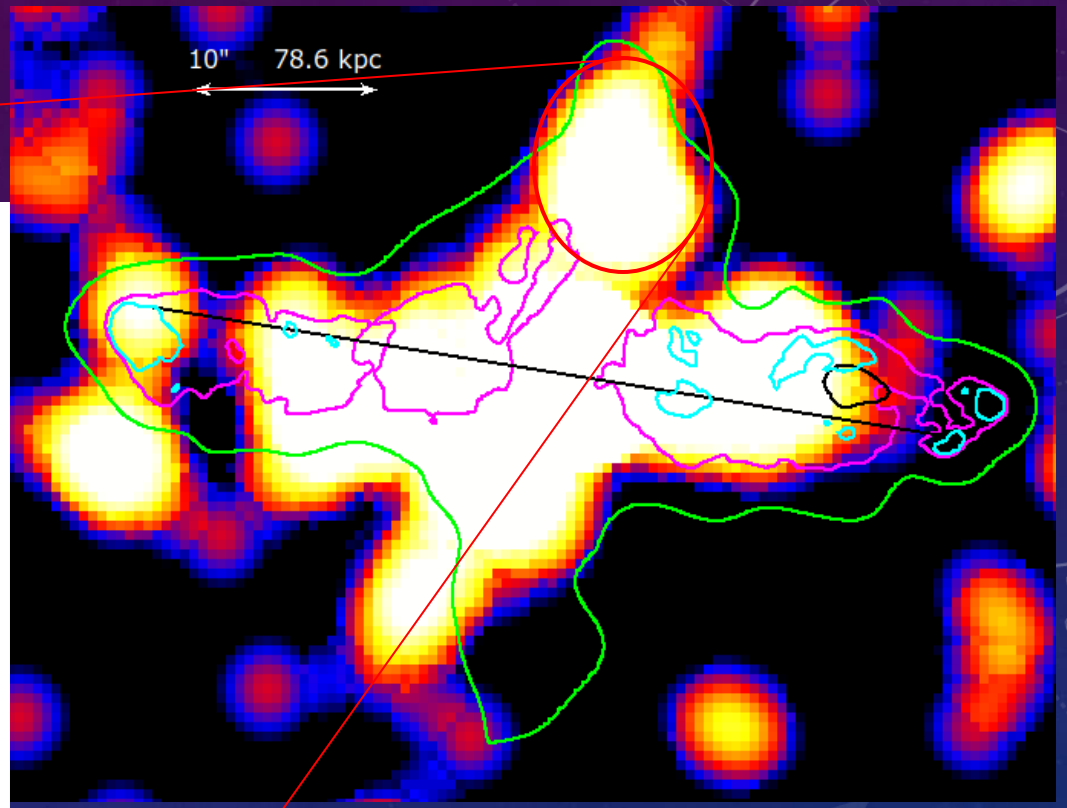
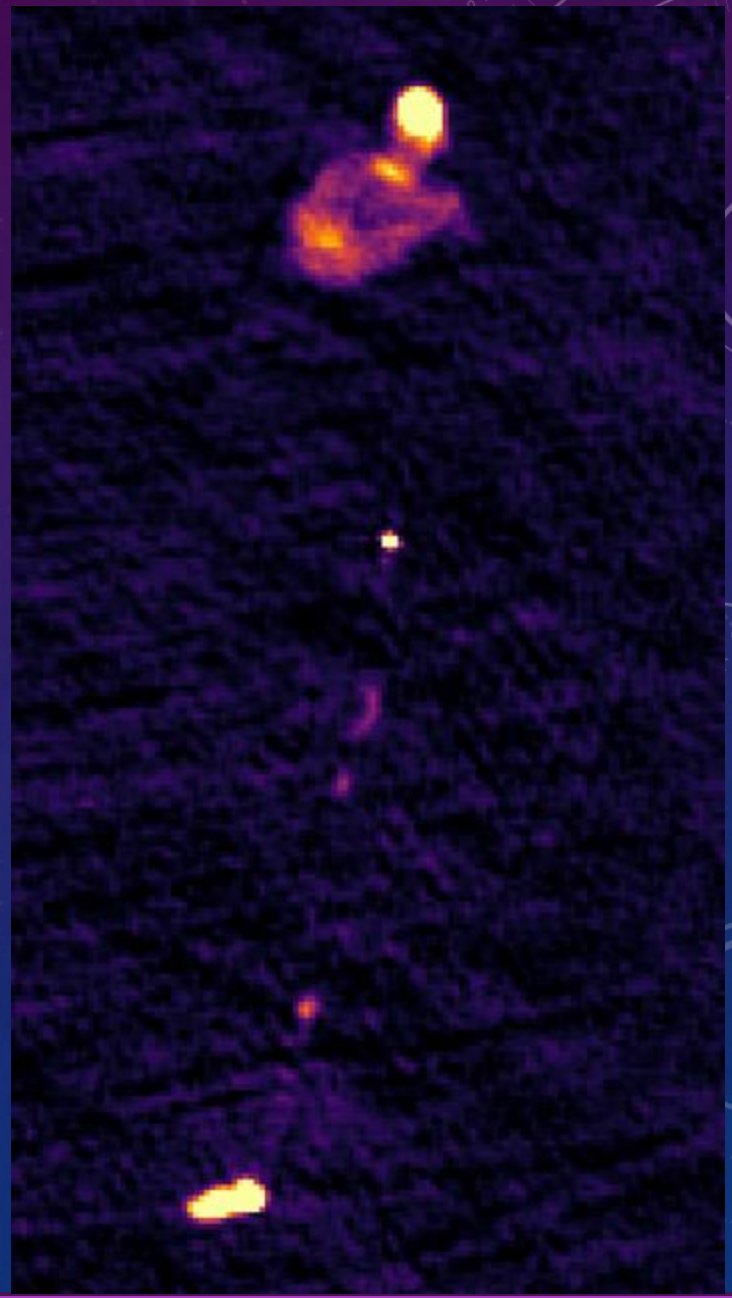




- Model gives a magnetic field discrepancy of a factor of about 100
- Likely a thermal model is needed to explain a majority of the X-ray emission

3C 14 (Z=1.469)

- Deprojected Jet length ~ 300 kpc.
- Some jet knots seen along South jet and a leading-edge feature trailing the northern hot spot on the plane of the sky.
- No clear evidence of emission perpendicular to the jet axis at 8.44 GHz.



VLA 8.44 GHz image of 3CR 14 from Bowden [Private Communication]

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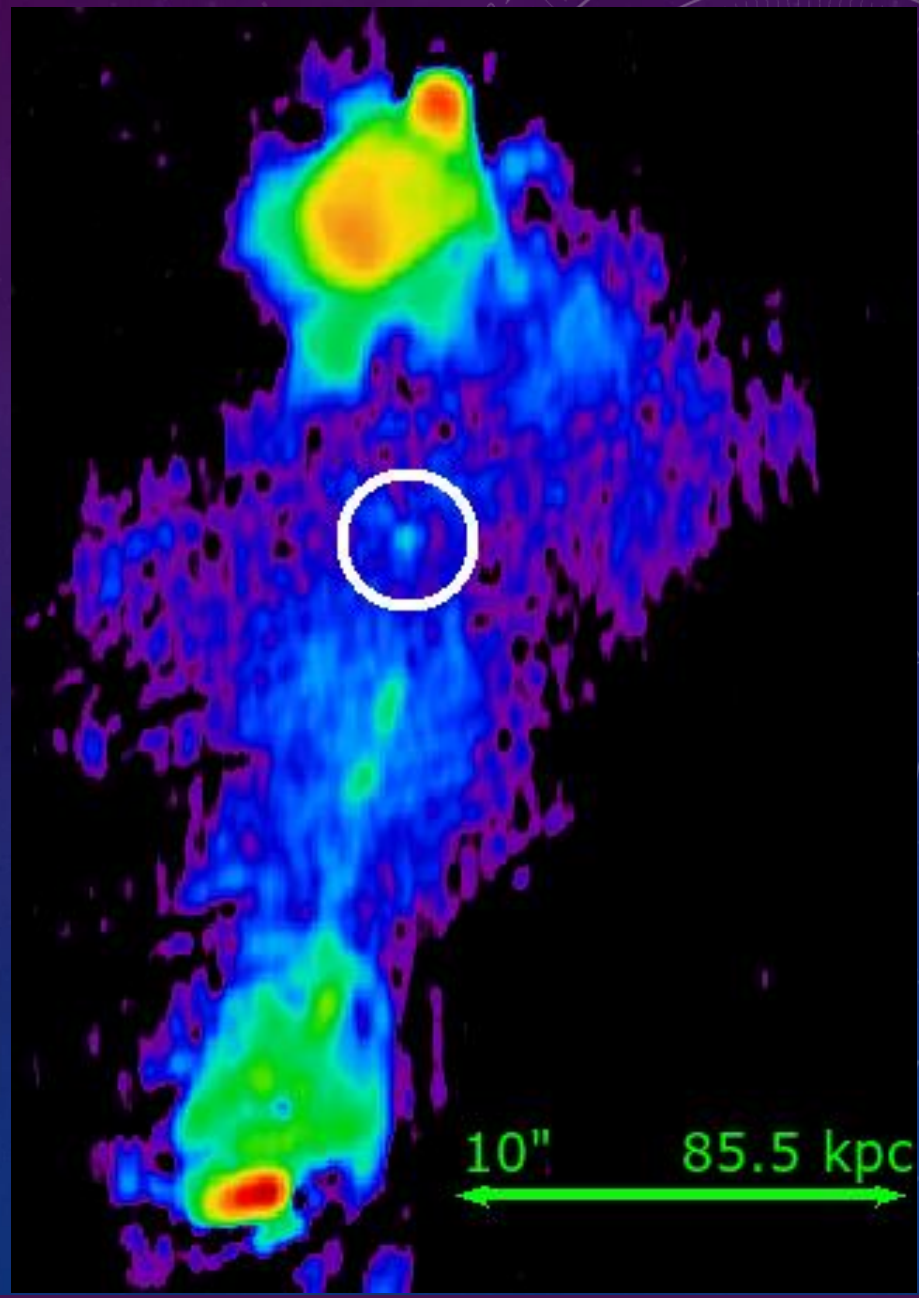

LOFAR 144 MHz image of QSO 3CR 14 with a 1.5” circle over the core to indicate the Chandra PSF size.

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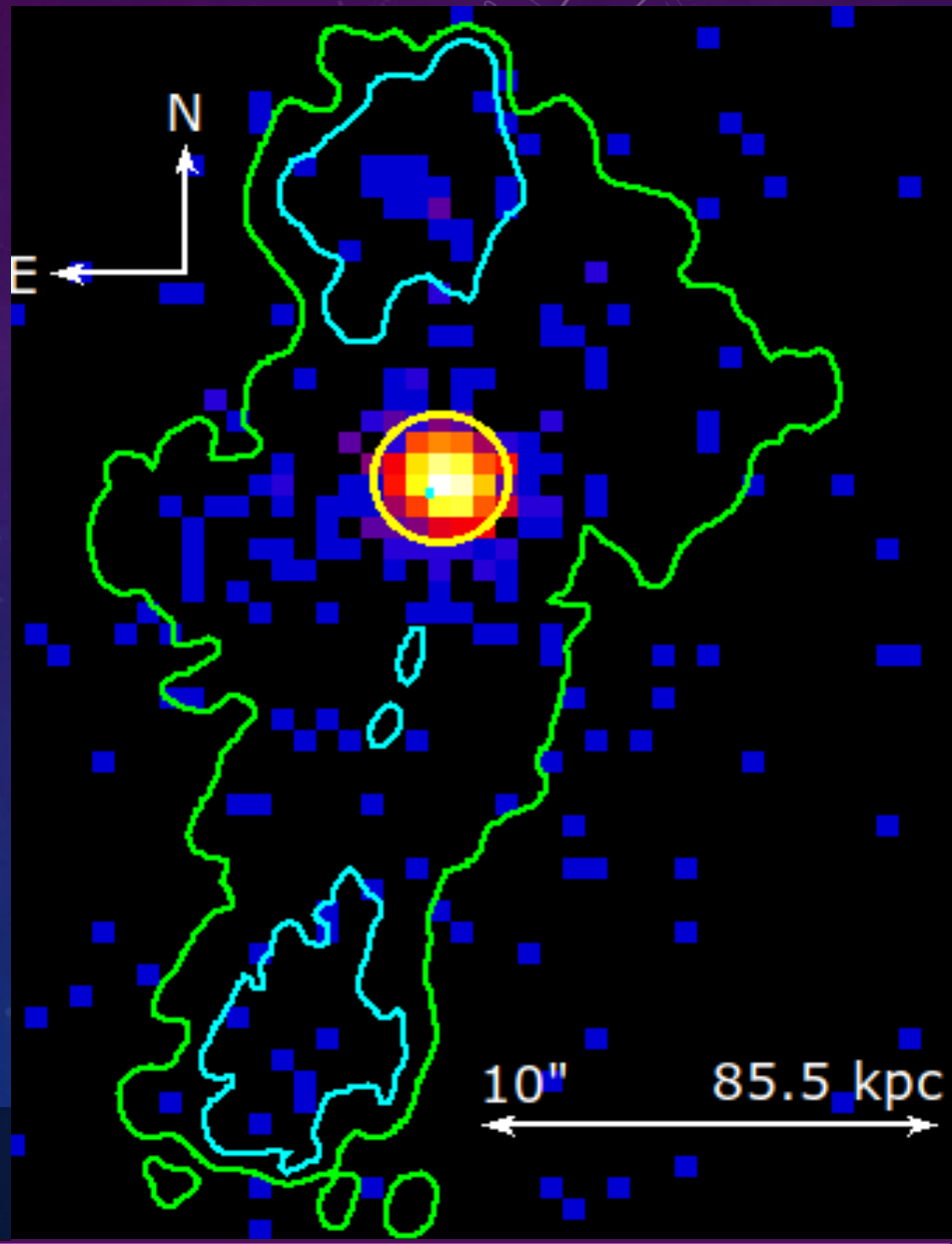
- Evidence of wings emerging perpendicular to the jet axis from LOFAR.
- X-ray emission is seen faintly along the jet axis.
- Stronger evidence of X-ray detection from the leading-edge feature from the north jet.
- X-ray emission to the east of the core, significantly detected above the background and core PSF.



Chandra native pixel image of 3CR 14 with LOFAR contours in green and cyan. The Chandra 90% PSF is circled in yellow.

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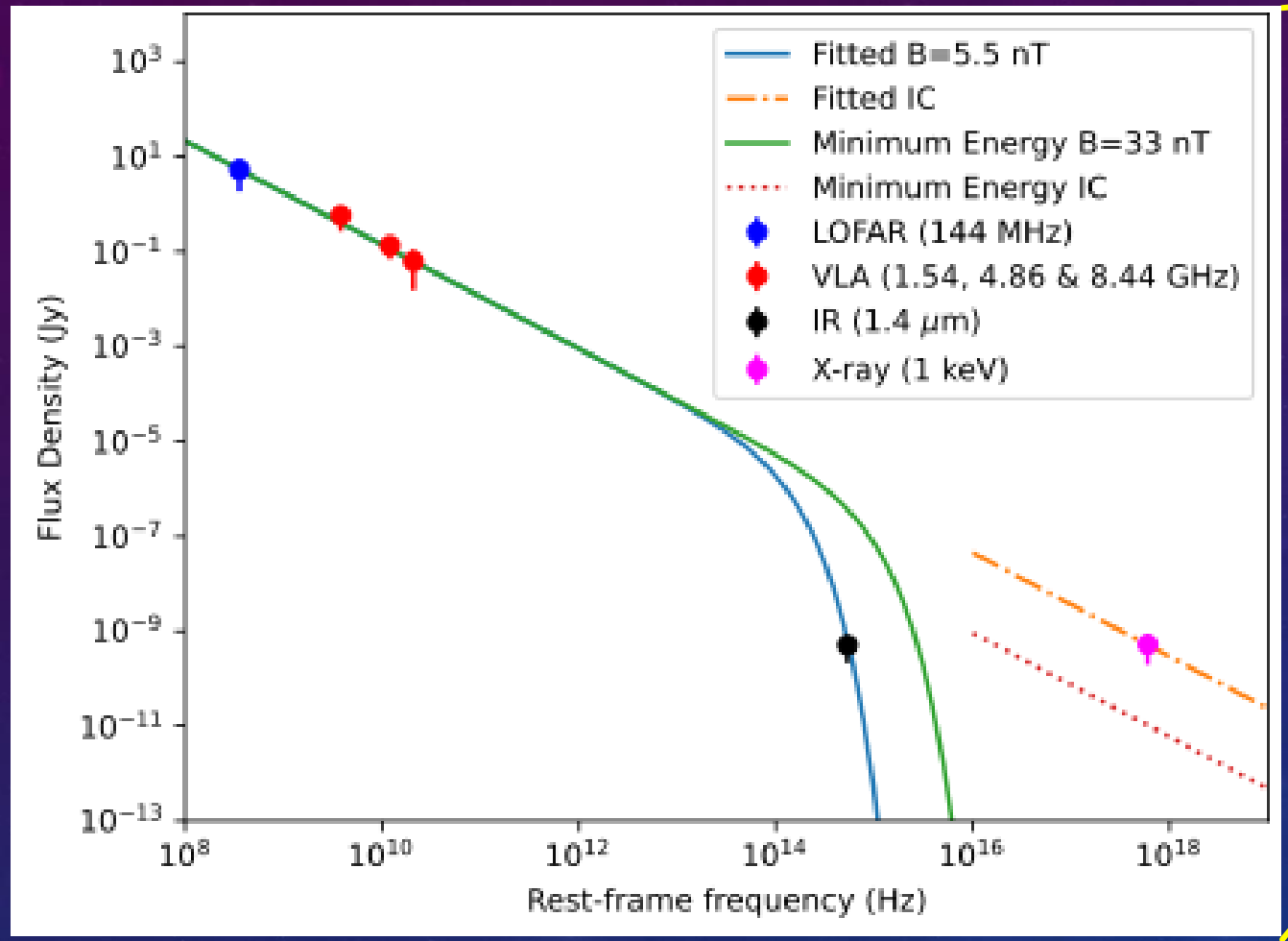
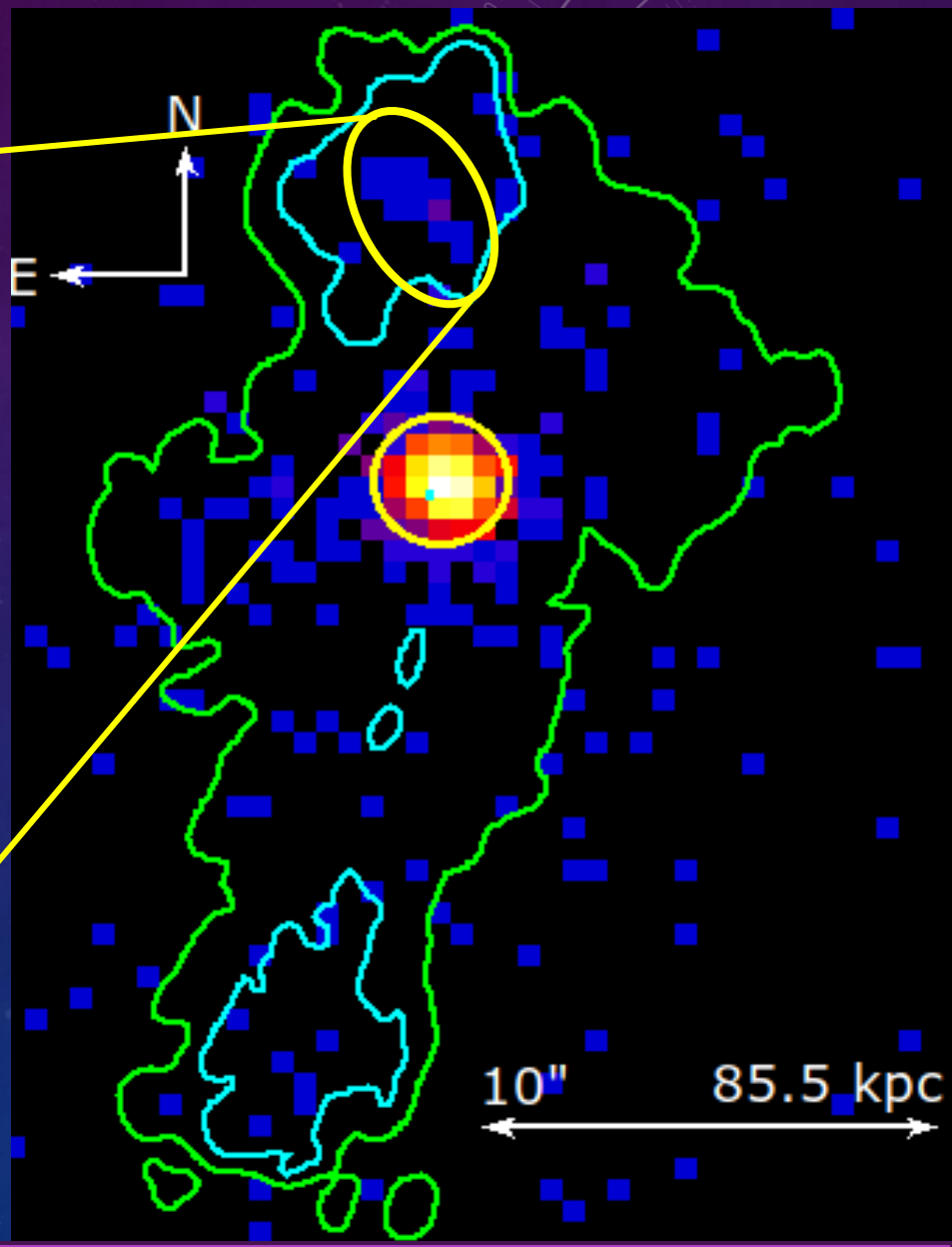
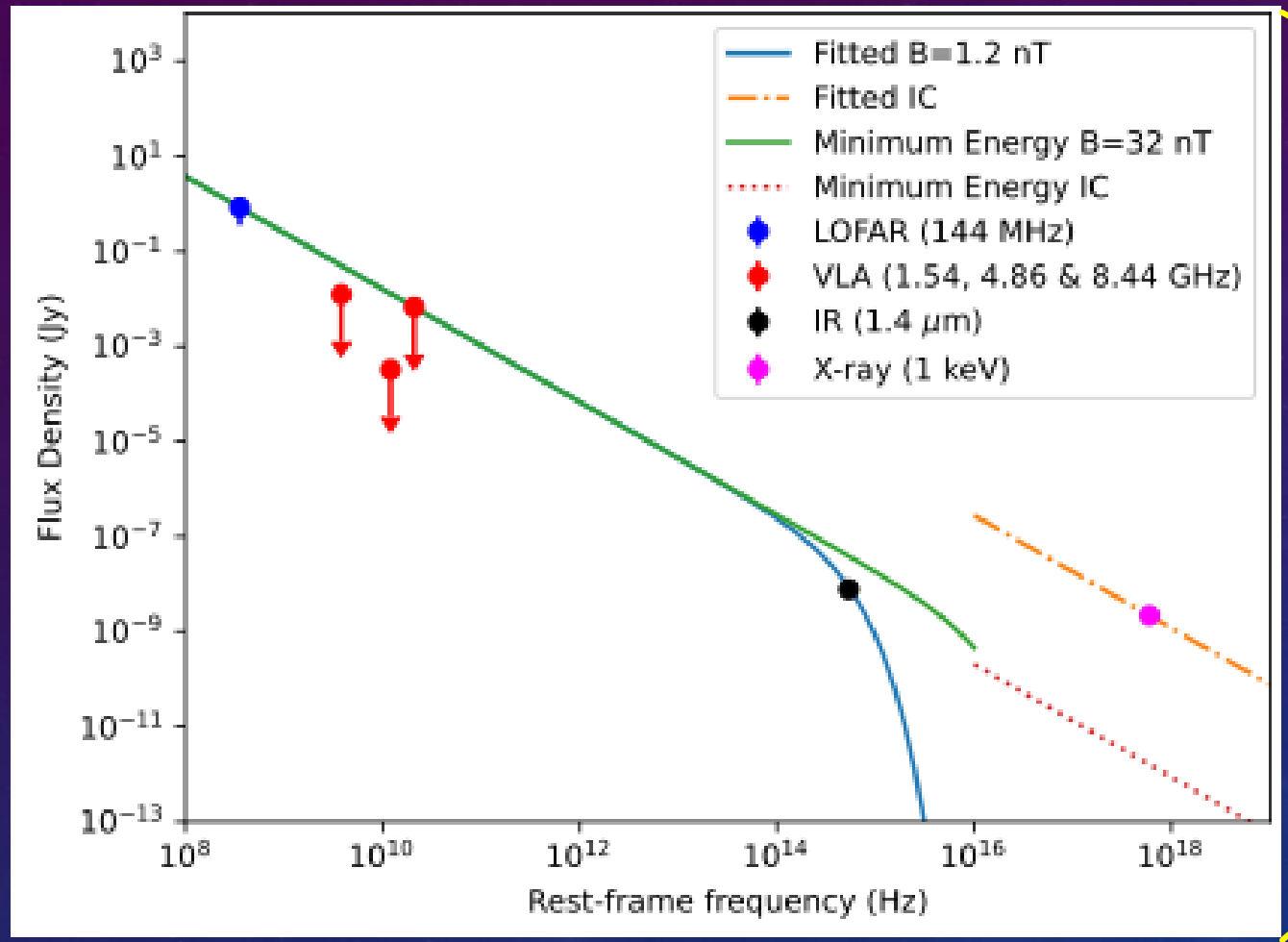
3C 14 (Z=1.469)


Fitted B=5.5 nT
Fitted IC
Minimum Energy B=33 nT
Minimum Energy IC
LOFAR (144 MHz)
VLA (1.54, 4.86 & 8.44 GHz)
IR (1.4 μm)
X-ray (1 keV)
Flux Density (Jy)
Rest-frame frequency (Hz)


N
E
10"
85.5 kpc

3C 14 (Z=1.469)


Fitted B=1.2 nT
Fitted IC
Minimum Energy B=32 nT
Minimum Energy IC
LOFAR (144 MHz)
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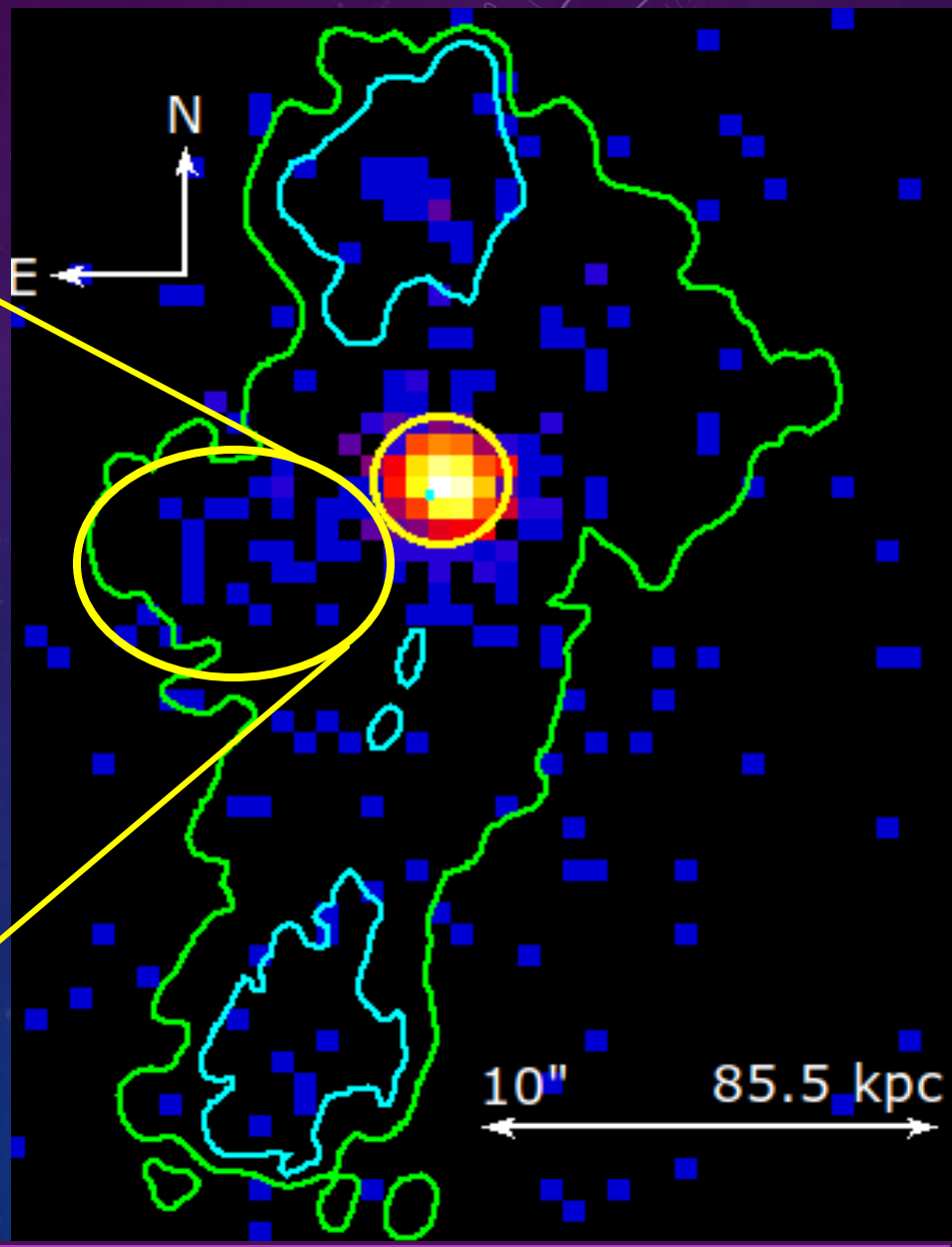
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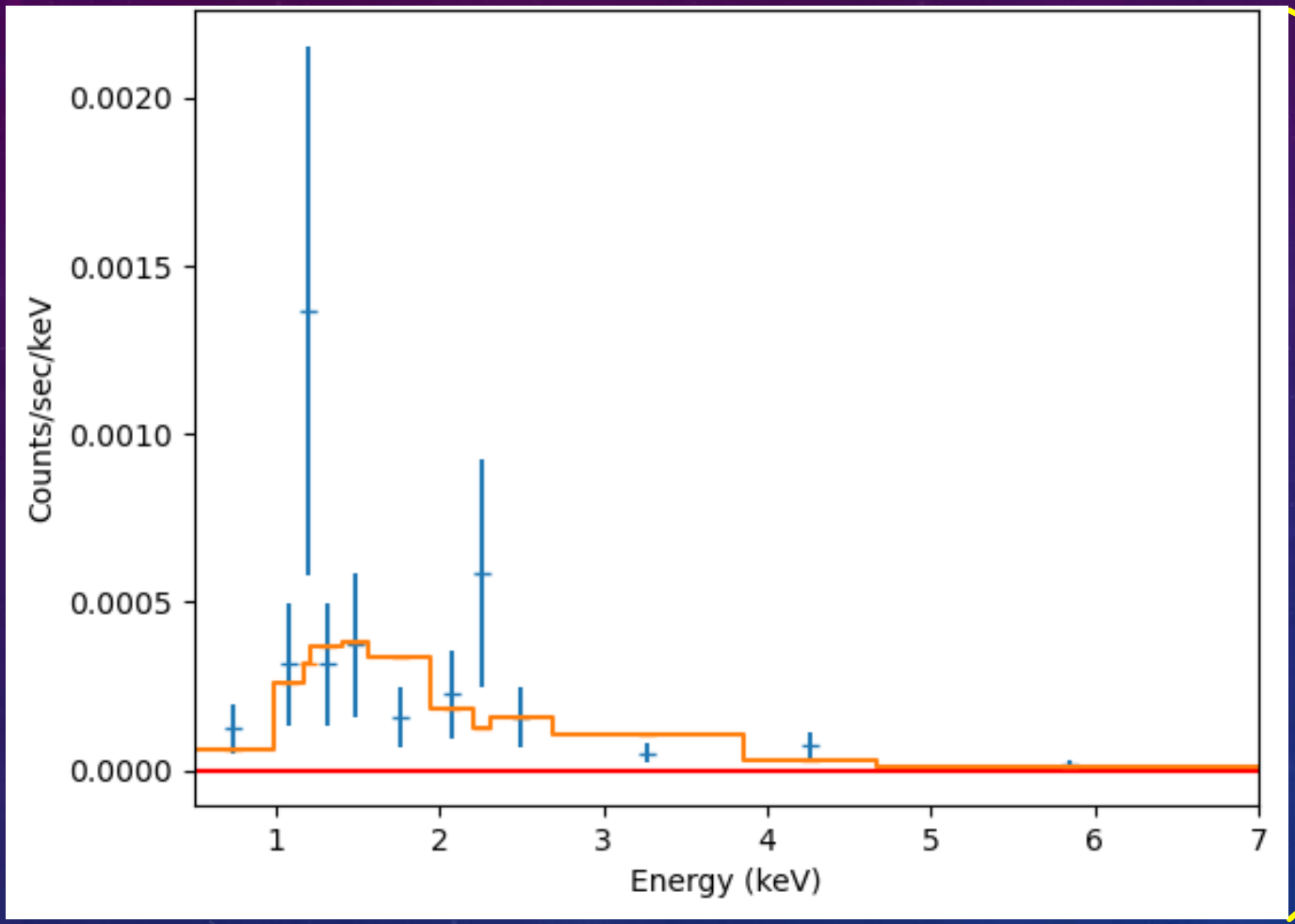

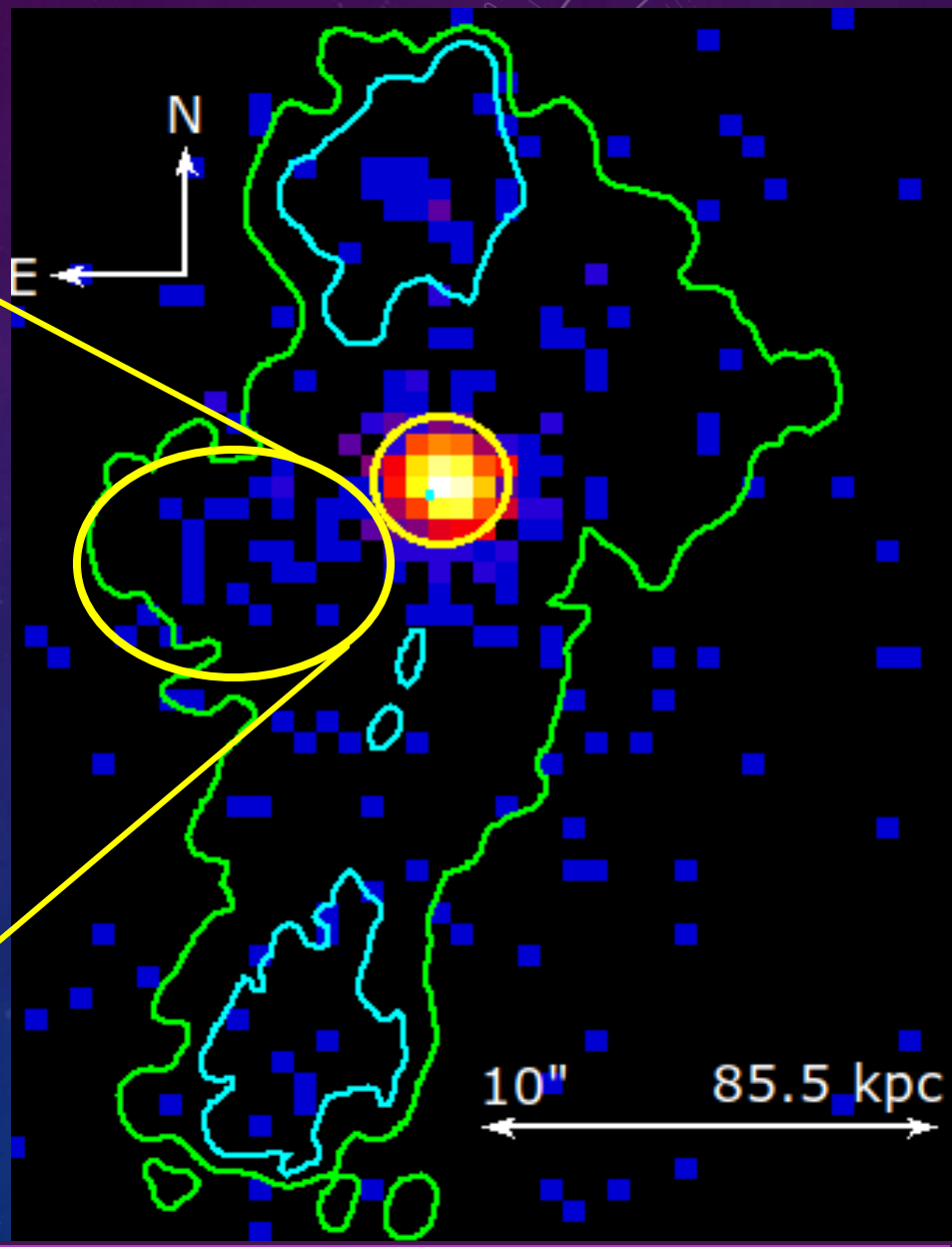

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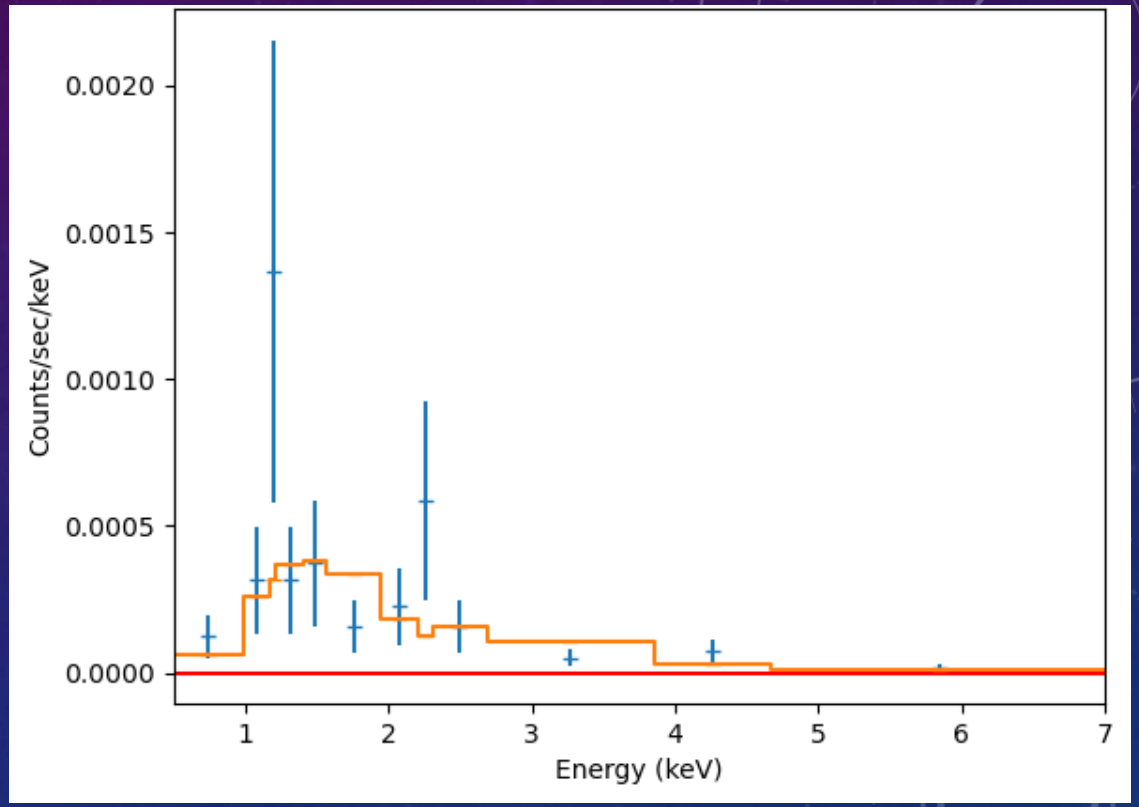
THERMAL EMISSION

Key Values:

- Temperature: 5.7 ± 2.7 keV
- Electron Density: $n_e = 6.2 \pm 0.1$ cm^{-3}
- Thermal Pressure: $P_T = (1.1 \pm 0.5) \times 10^{-9}$ erg cm^{-3}.
- Age: ~ 50 Myr

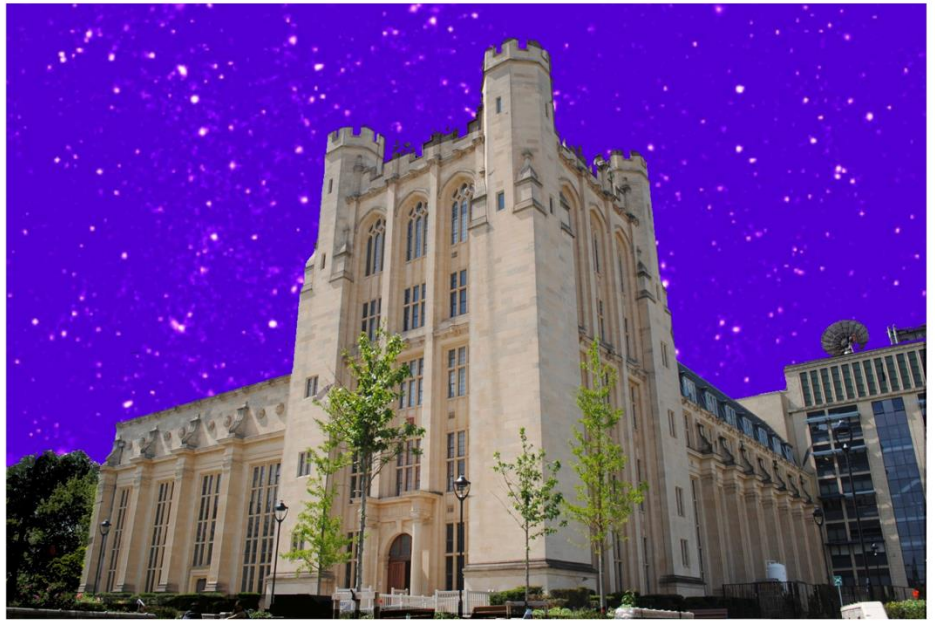


SUMMARY

- XRGs have different morphologies and origin histories
- X-ray emission needs to be inspected carefully, even in regions outside of high-frequency radio emission
- In the case of 3CR 14, Thermal emission dominates X-rays production in the LOFAR wing region

New Results in X-ray Astronomy & NewAthena

University of Bristol, 4–5 September 2025



X-ray background above Bristol physics

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