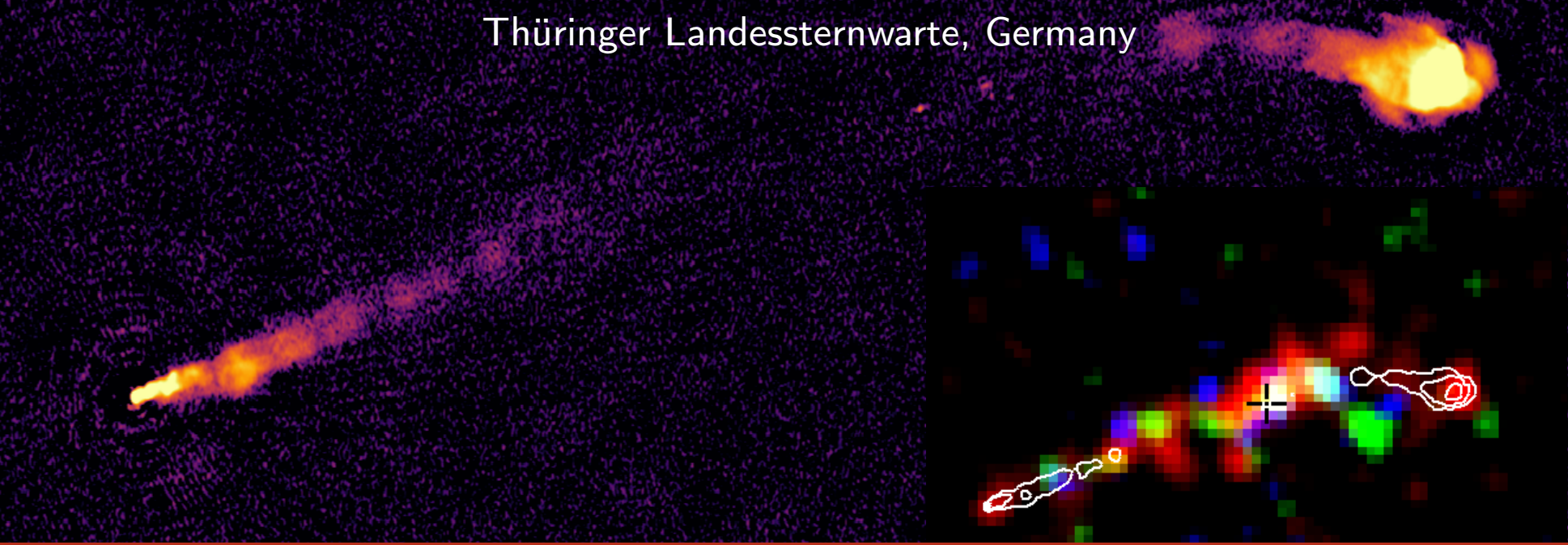
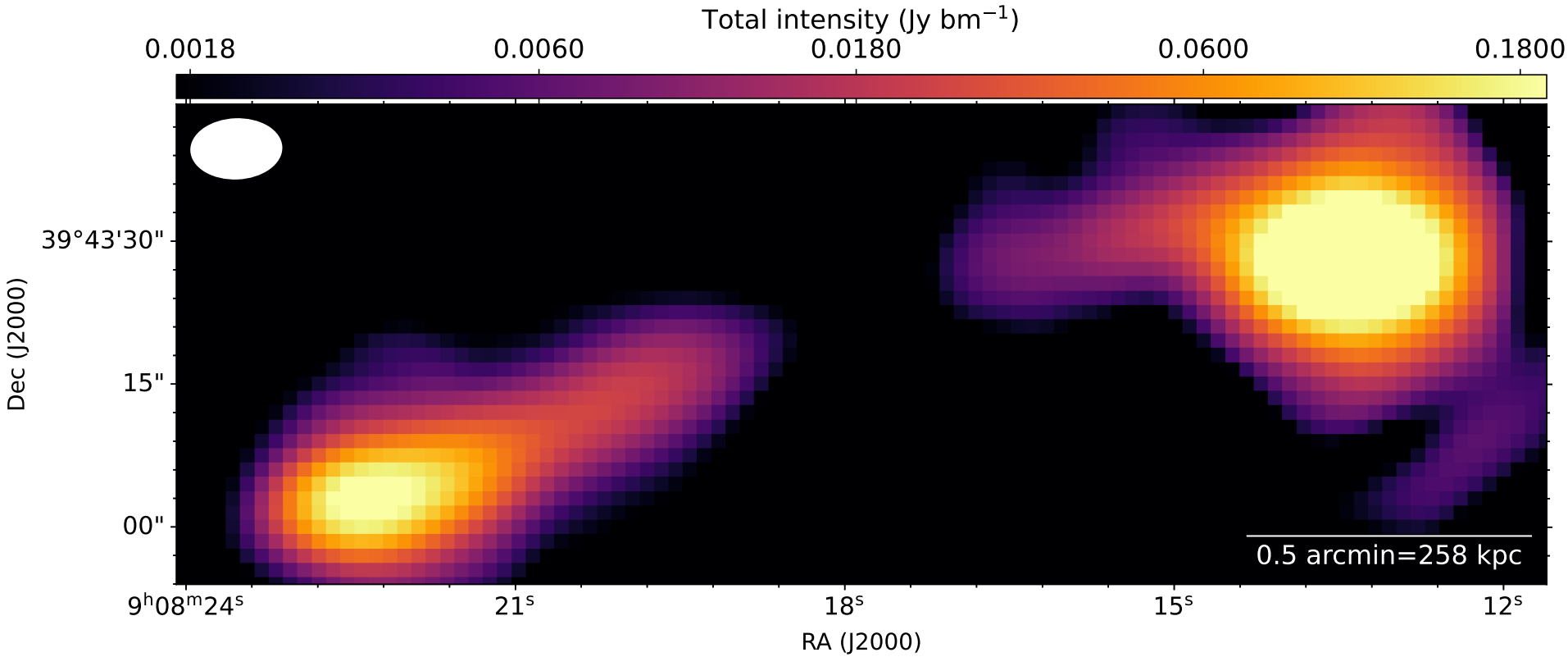
Extended, AGN-induced inverse-Compton emission from the distant, bright radio galaxy 4C 39.24

L. Pfeifer M. Hoeft V. H. Mahatma H. Meusinger G. Lamer (AIP)
A. Drabent H. Andernach

Thüringer Landessternwarte, Germany

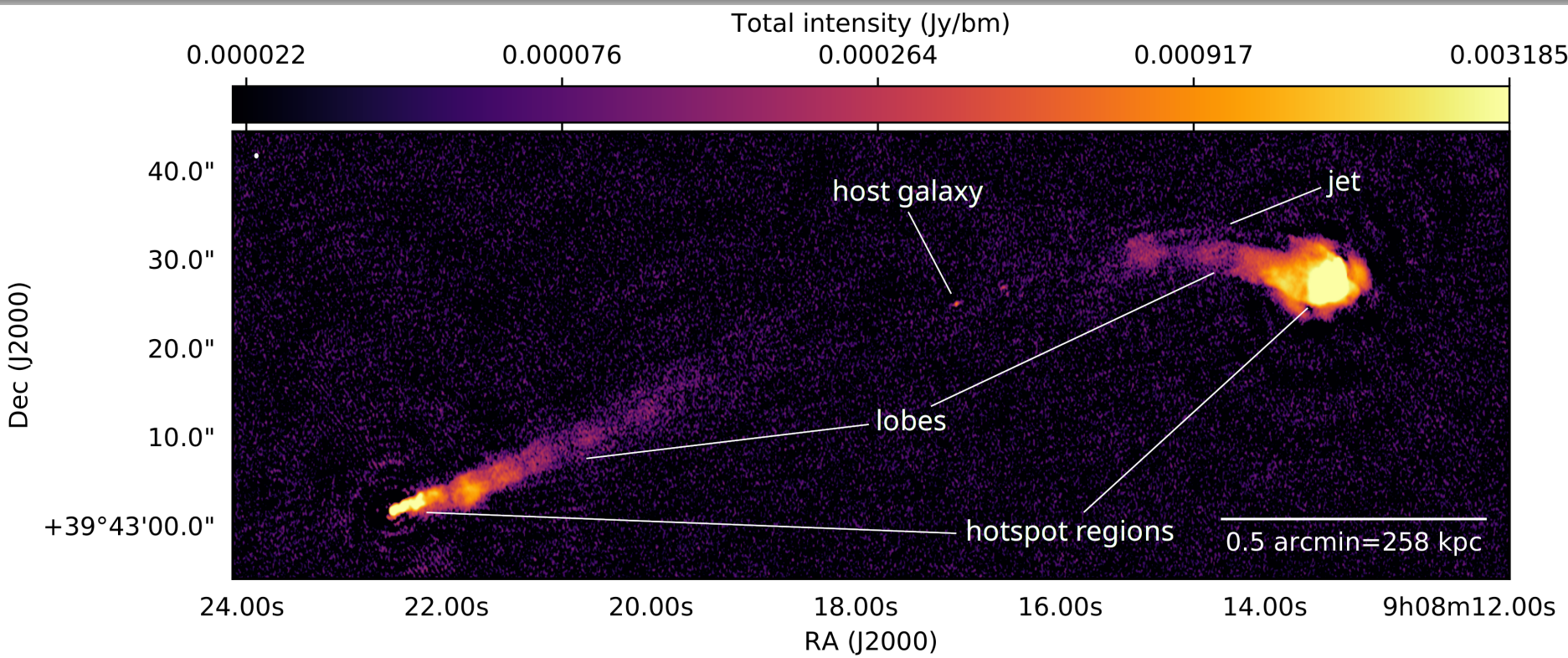


LOFAR 6 arcsecond image



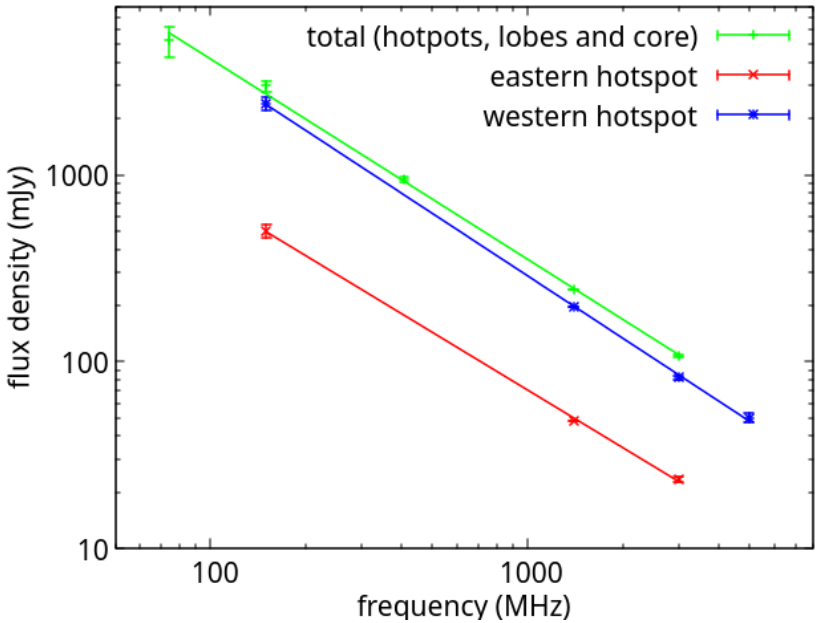
- very distant (z=1.88)
- rare in size (920 kpc)

LOFAR long baseline image



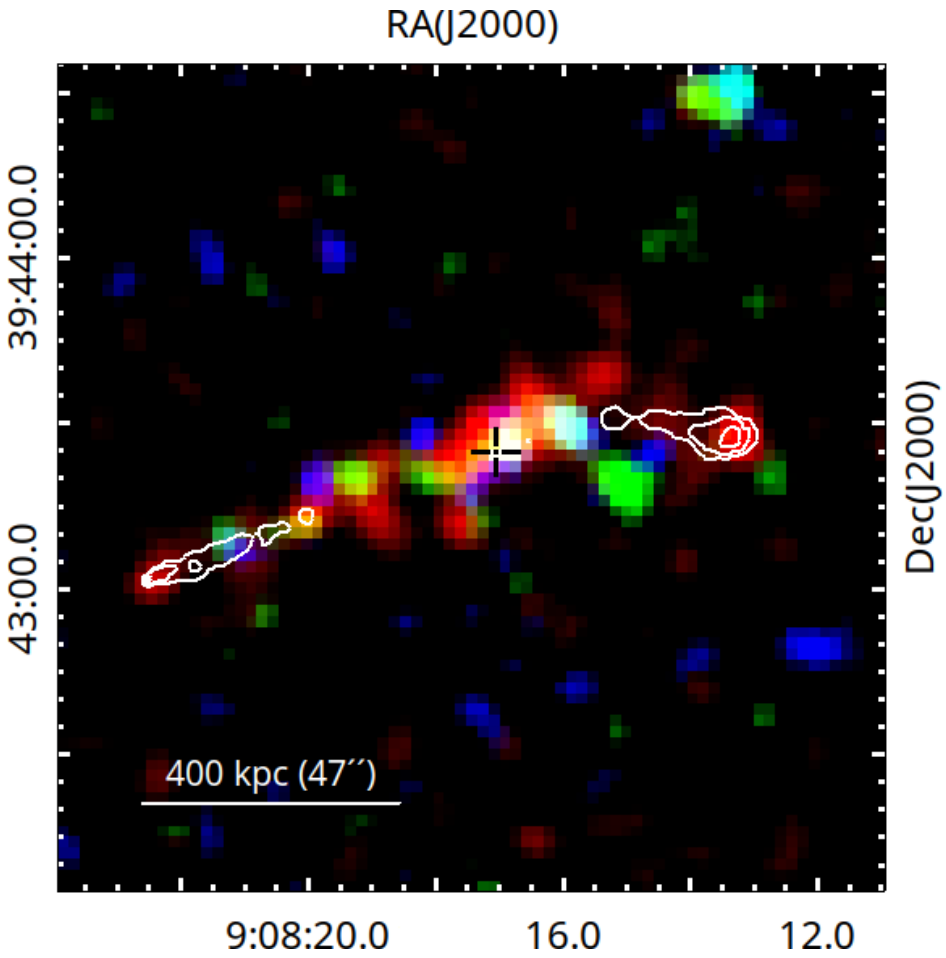
- asymmetry: narrow, well confined E lobe vs. smoothly bent W lobe & (1-sided) jet
- 144 MHz full array LoTSS image (0.33"x0.21", 41 μJy beam^{-1})
- data processed using standard pipelines for Dutch stations (24 core & 14 'remote' stations) and 13 international stations (van Weeren+2021, Morabito+2022)

Radio spectrum



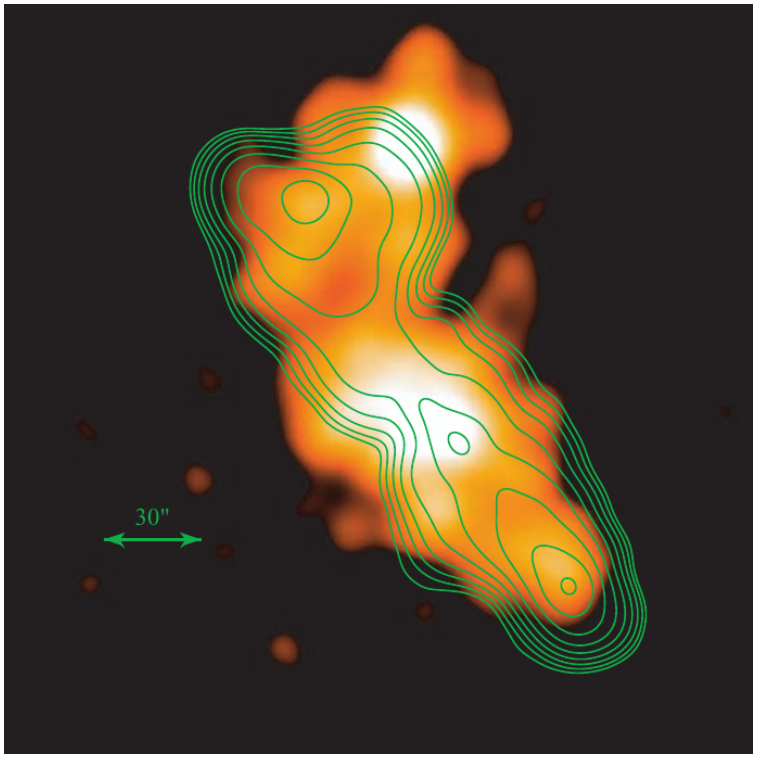
- spectral index similarity between eastern & western hotspot region ($\alpha \approx -1.07 \pm 0.03$), despite morphological dissimilarities
- radio luminosity $P_{150\ \mathrm{MHz}} = (8 \pm 1) \cdot 10^{36}\ \mathrm{erg\ s^{-1}\ Hz^{-1}}$
- suggests a power law energy distribution of the CRe with $p = -3.14 \pm 0.06$

Radio vs X-ray morphology



- 0.2..12 keV XMM-Newton (EPIC-pn) data shows 4C 39.24 very X-ray bright
- **most X-ray emission from lobe**, hotspot regions show faint X-ray
- magnetic field ~40 μG from radio to X-ray (IC with CMB photons) flux relation in hotspot regions

IC with core photons

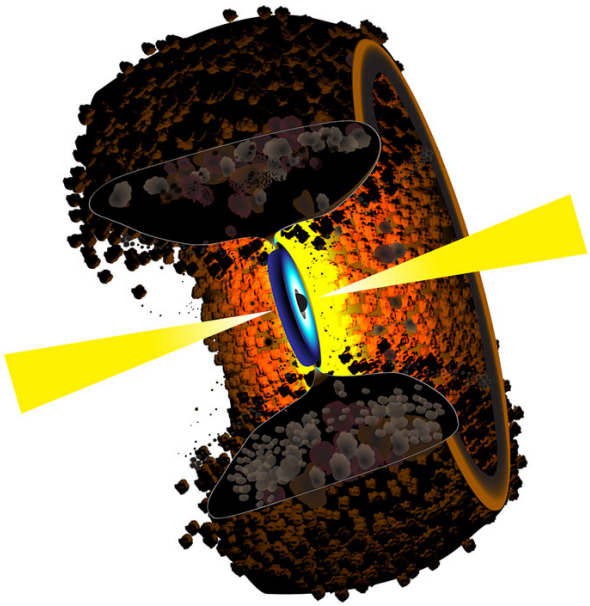


X-ray emission from lobes of 3C 219 (0.5..7 keV with substracted nuclear component) and 1.4 GHz radio-contours overlayed (Comastri+ 2003)

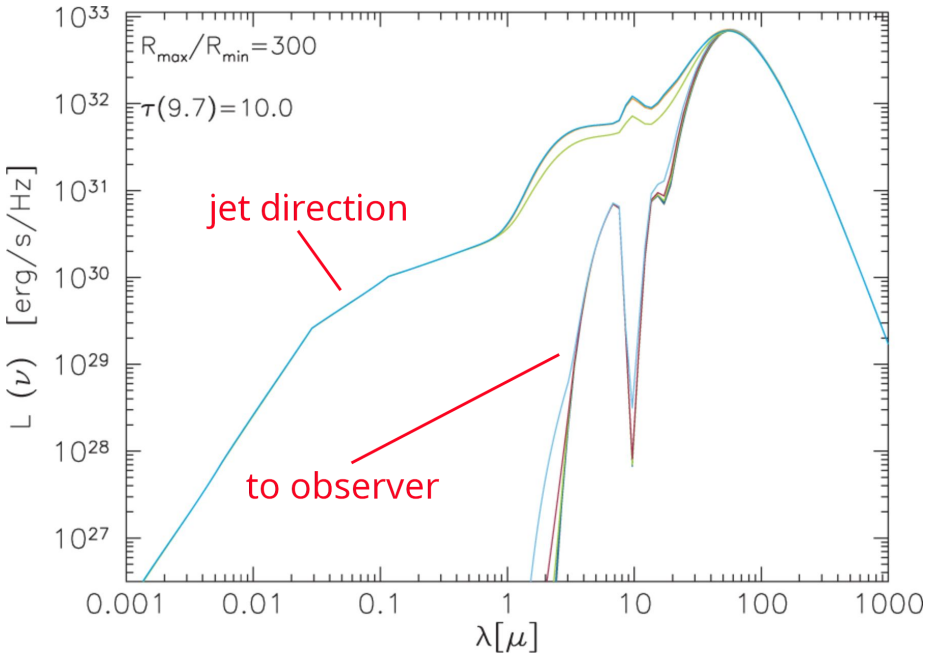
- inverse-Compton: photons gain energy from CRe
- which photons? CMB, starburst or AGN photons?
- associated with AGN or starburst photons discussed for ~a dozen radio galaxies & core distances of only some 10 kpc

Hypothesis

- IR bright, UV/opt faint → not sufficient to only use the measured L
- emission anisotropic: high photon flux in lobe direction since obscured to observer
- large-scale IC dominated by the up-scattering of photons from the AGN core, rather than the CMB

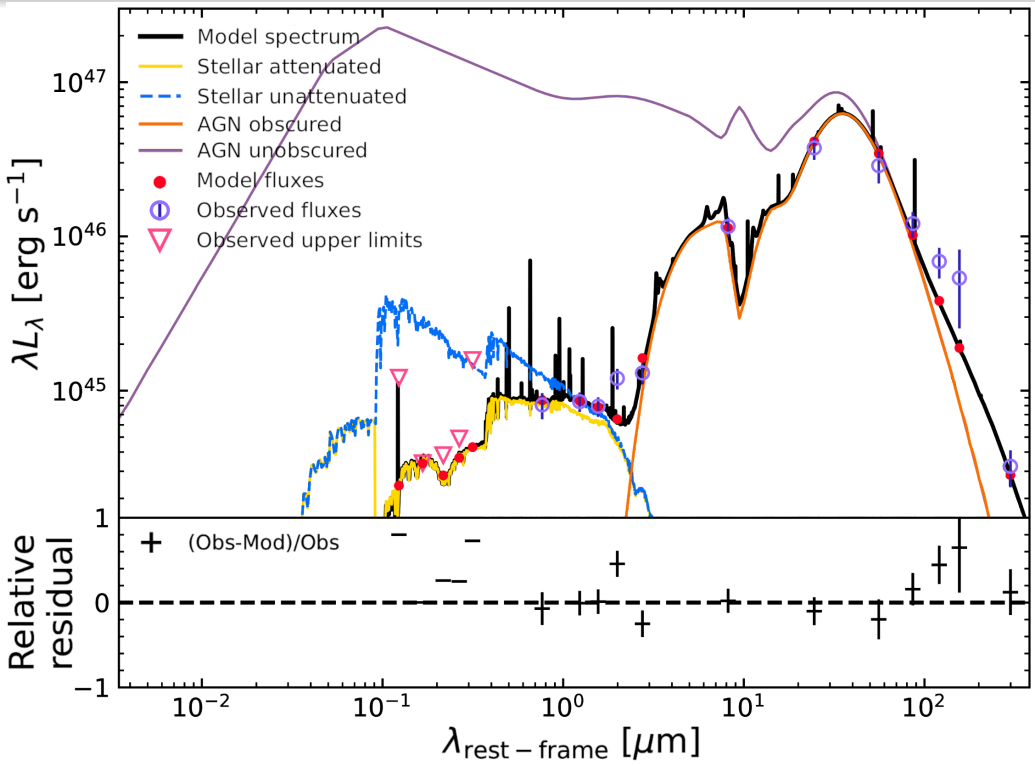


Bill Saxton/NRAO/AUI/NSF



Fritz+2006

SED

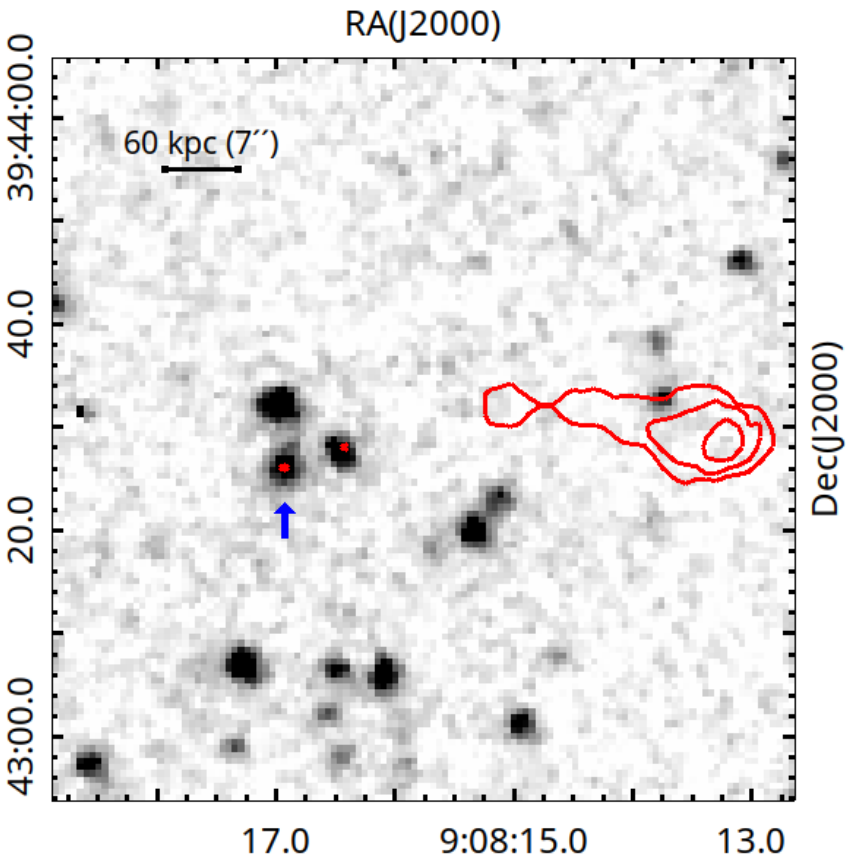


AGN fraction of IR luminosity	0.95
Opening angle	100°
Viewing angle	10°
Optical depth τ	10
$R_{\mathrm{max}}/R_{\mathrm{min}}$-ratio	150
AGN IR luminosity	$8 \cdot 10^{46}$ erg s^{-1}
AGN total luminosity	$6 \cdot 10^{47}$ erg s^{-1}

- strong peak in far-IR → heavily obscured AGN
- SED in jet direction: spectral fitting allows to estimate obscuration, and therefore allow to give the unobscured SED
- AGN total luminosity → hyper-luminous quasar

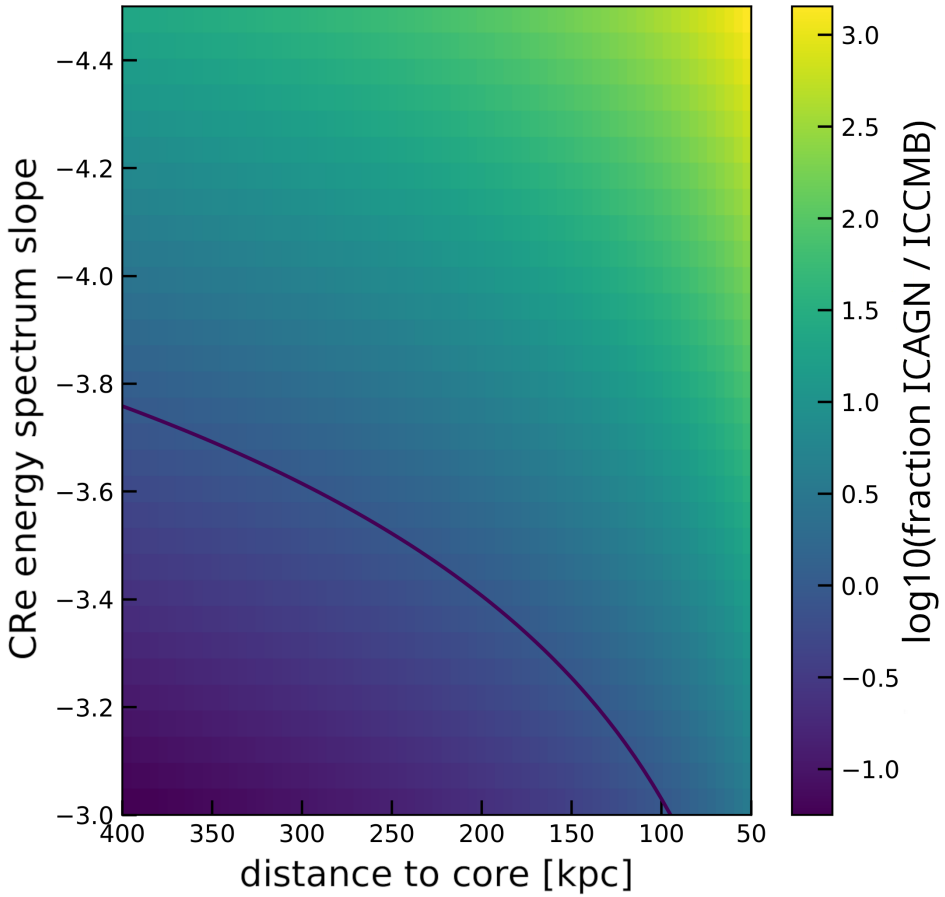
Most luminous AGN

- compare 4C 39.24 results with $L_{\rm bol}$ of type-1 AGN from literature
- e.g. $\sim 10^5$ quasars from the catalogue of quasar properties from SDSS DR7 (Shen+ 2011)
- realistic assumption for a max $L_{\rm bol} = 2 \cdot 10^{48} {\rm ergs}^{-1}$
- total luminosity of 4C 39.24 close to maximum but still plausible



Sum of Spitzer bands, blue arrow: host galaxy, red contours: LoTSS

IC with AGN photons (ICAGN)



ageing →

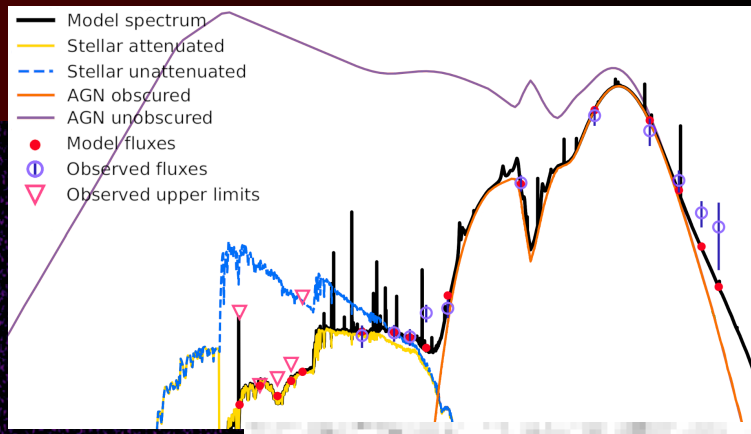
← decreasing photon flux

- for ICAGN relevant CRe γ ~100
- what dominates: IC with CMB photons (unavoidable) or IC with AGN photons?
- answer to this question depends on
  - CRe energy spectrum
  - unobscured AGN photon density
- because CRe density is unknown, we computed the ratio of AGN-induced IC & CMB-induced IC
- AGN dominates large-scale IC X-ray

How common are these sources?

- compare with other large RG from compilation containing over 20k objects
- only 40 with similar z & linear size
- 4C 39.24 most luminous object at 150 MHz ($P_{150\ \mathrm{MHz}} = (8 \pm 1) \cdot 10^{36}\ \mathrm{erg\ s^{-1}\ Hz^{-1}}$, median $3 \cdot 10^{34}$)
- only 4 sources show similar steep radio spectrum
- only 5 sources show higher bending angle (4C 39.24 has 13°, median 7°, highest 28°)
- 4C 39.24 is a rare object

Summary



- 0.3" image @144MHz showing well confined and narrow E lobe structure, E multiple spot structure, smoothly bent W jet and lobe
- power law CRe energy spectrum with $p = -3.14 \pm 0.06$
- SED of host galaxy & unobscured AGN with luminosity $\sim 6 \cdot 10^{47}\,\mathrm{ergs}^{-1}$ $\rightarrow$ hyper-luminous quasar
- we suggest that for 4C 39.24 the large scale X-ray emission is dominated by AGN-induced IC