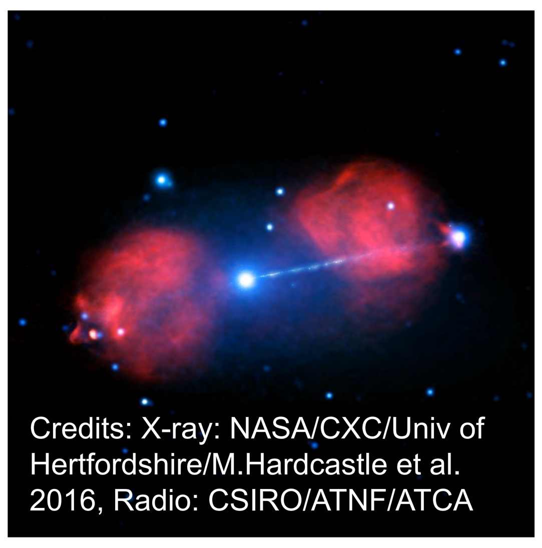

A multi-frequency polarimetric study of the Radio Galaxy "Pictor A"

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Abstract. Pictor A is one of the brightest and most extended radio sources of the Southern Hemisphere. Its distinctive FRII morphology is characterized by two hotspot complexes, each at the edge of a diffuse and roundish lobe: the Western one, i.e. the brightest, shows a more standard morphology, dominated by a compact feature preceded by a filamentary structure orthogonal to the jet direction, while the Eastern one displays a double-structure whose origin is still currently debated, despite this object has been extensively observed from 80 MHz up to 300 GeV (but few or none observations at radio/sub-mm frequency range above 10 GHz).

Both regions can be easily resolved by current facilities up to X-rays, hence offering a unique opportunity to characterize and understand the physics of hotspots. Moreover, the Western hotspot arose as one of the best candidates for calibrating and validating polarimetry of high frequency (> 10 GHz) CMB observations, a necessary step for pursuing precision cosmological studies.

We observed with the Australia Compact Array a 7 mm mosaic of the whole radio galaxy, providing high-fidelity polarimetric maps for hotspots and core regions (sampling spatial scales up to ~1 arcmin).

We complement our study with past ATCA 15 mm observations, and archival data from lower frequency observations of SKA precursors and pathfinders, such as ASKAP, MeerKAT, and GMRT. At the higher frequency, instead, we concentrate on the core, exploiting about a decade of ALMA (Bands 3,6 and 7) calibrator observations acquired on an almost regular (typically 3-7 days) basis.

Description of ATCA observations. In order to complement past ATCA observations and overcome their limitations, hence delivering a polarimetric characterization useful for both radio galaxy studies and to improve the calibration of current and future CMB experiments, the project C3085 (P.I.: Massardi) observed a 50 pointings (standard Nyquist) mosaic at 7 mm, namely two contiguous 2 GHz-wide bandwidths centered at 33 and 35 GHz (standard CABB spectral resolution, i.e. 1 MHz) at 7 epochs (between 2016 April 9 and 2016 September 7) with compact hybrid configurations (both N-S and E-W baselines) H75, H168 and H214. Thus, the total integration for each pointing resulted, on average, 18.7 min, corresponding to a theoretical sensitivity of ~55 μJy/beam (considering the total 4 GHz bandwidth at 7 mm).

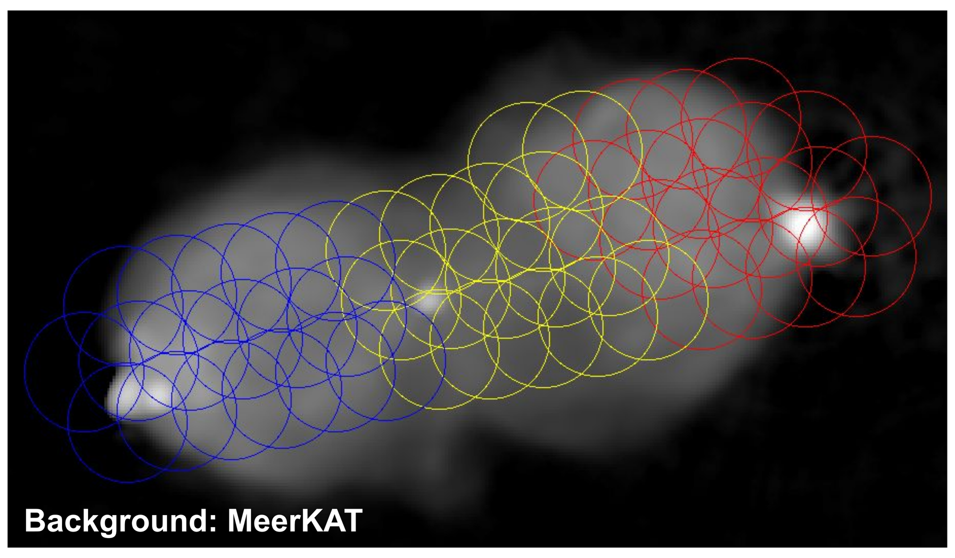
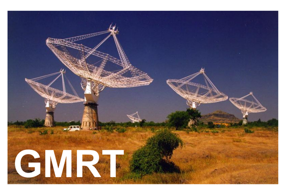
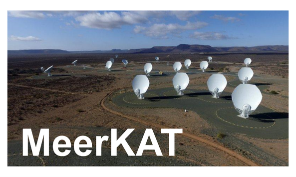


Fig. 1: The 50 pointing mosaic (Nyquist-sampled at 35 GHz) observed with ATCA at 7 mm for the project C3085 (PI: Massardi) in 2016. The three colors are for the western region (in red), the core region (in yellow) and the eastern region (in blue); the area enclosed by each circle corresponds to the ATCA primary beam at 34 GHz, as we combined observations at contiguous band tuned at 33 and 35 GHz.

Archival radio/(sub)-mm data

Telescope	Proposal/ Programme ID	P.I.	Frequency [GHz]	Spatial res. [arcsec]	LAS [arcsec]	Sensitivity [mJy/beam]
 GMRT	28_083	J. Riding	0.150	~ 30	~ 600 (*)	20
	20_012	S. Pal	0.235	~ 15	~ 240 (*)	40
 ASKAP	AS110–RACS (LOW-DR1)	E. Lenc A. Hotan D. McConnell	0.887	25	~ 2250	0.4
 MeerKAT	SCI-20190418-LS-01	L. Sebokolodi	1.280	7.5	600	0.050
 ALMA (*Pictor A core only*)	2015.1.01522.S	V. Galluzzi	97.5	0.4	6.8	0.042
	ALMA Calibrators Monitoring *(more than 1500 obs. in about 10 years of ALMA operations, with a 3-7 days cadence)*	JAO	91.5 (Band 3) 103.5	0.042 ÷ 3.4	0.5 ÷ 28.5	0.01 ÷ 0.1
			233.0 (Band 6)	0.018 ÷ 1.5	0.22 ÷ 12.4	
			343.5 (Band 7)	0.012 ÷ 1.0	0.14 ÷ 8.2	

(*) Significantly limited due to RFI affecting shortest baselines.

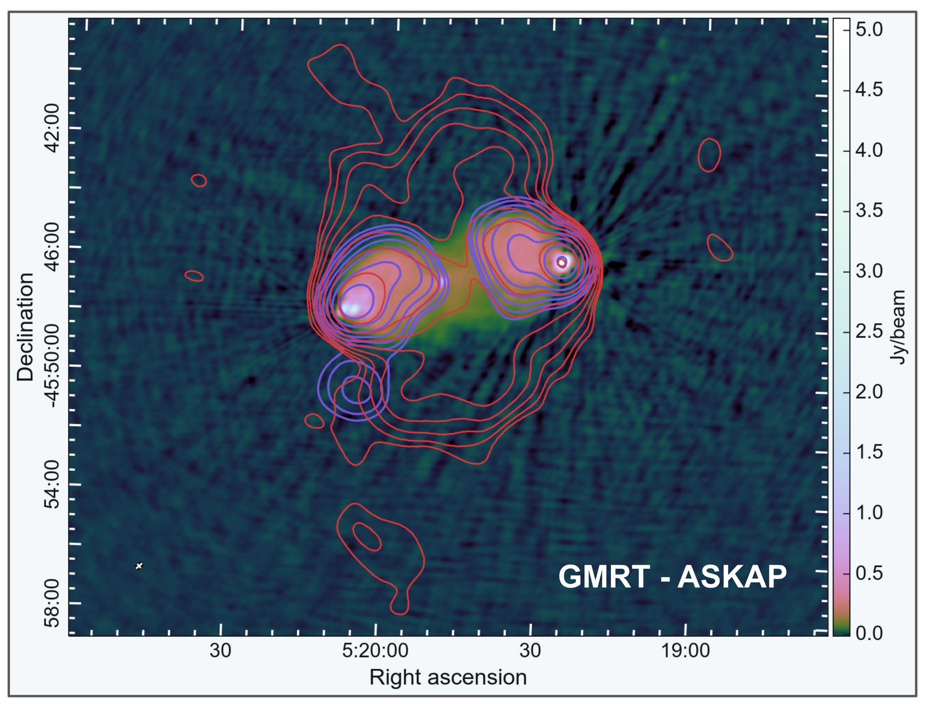
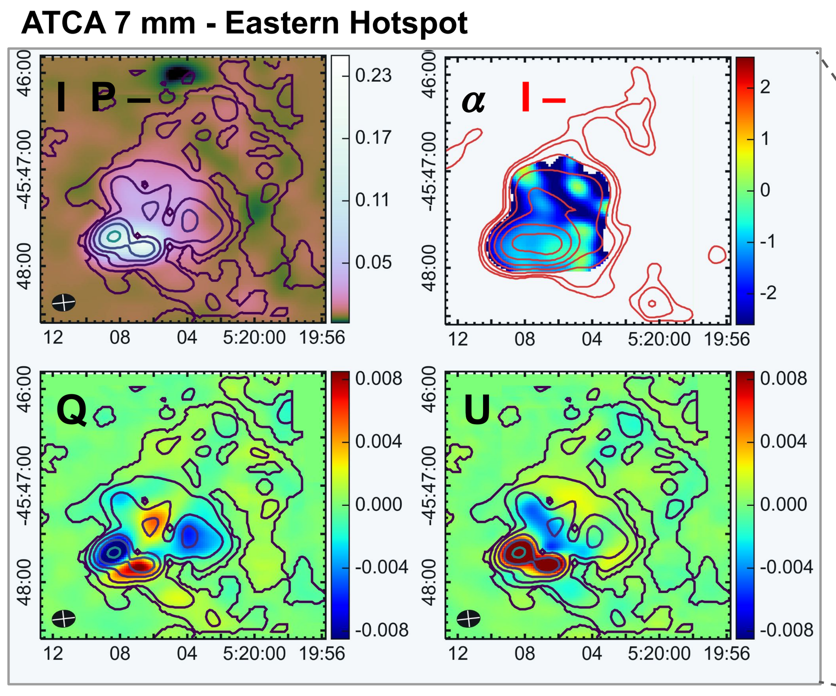
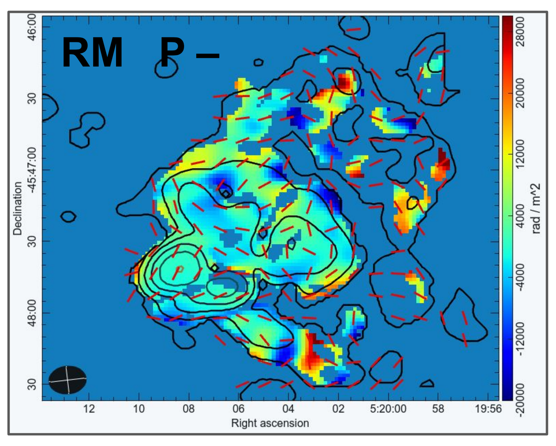
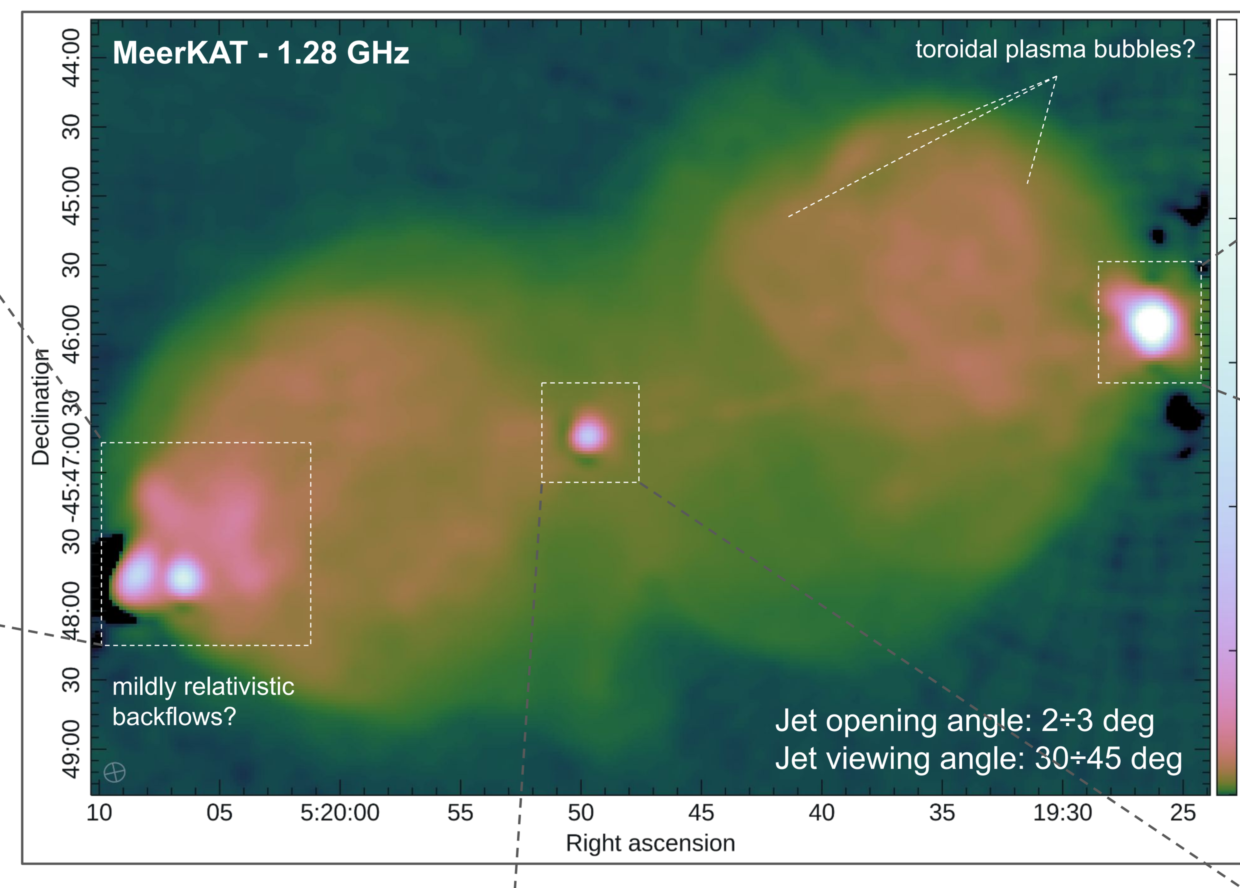


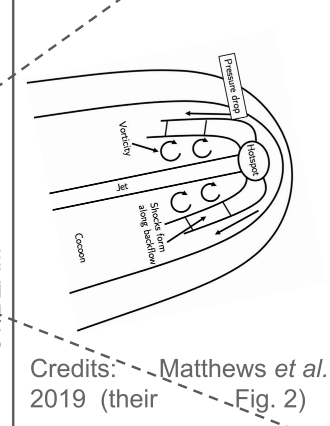
Fig. 2: RACS-LOW (887 MHz) map in colour with contours provided by archival GMRT observations: 150 MHz in red and 235 MHz in violet (convolved to a common resolution of 55 arcsec). Contours levels are at: 0.15, 0.30, 0.60, 1.2, 2.4, 4.8, 9.6, and 19.2 Jy/beam.

ATCA 7 mm - Eastern Hotspot

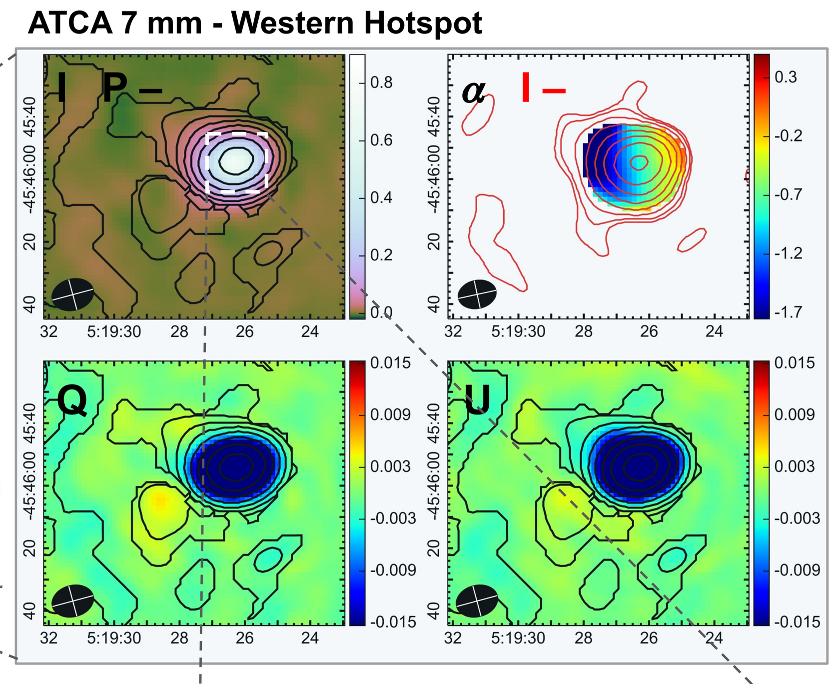




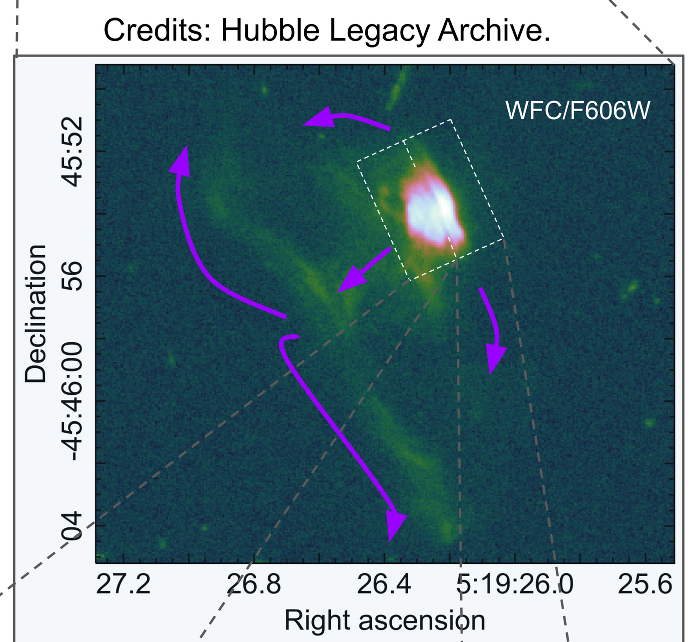




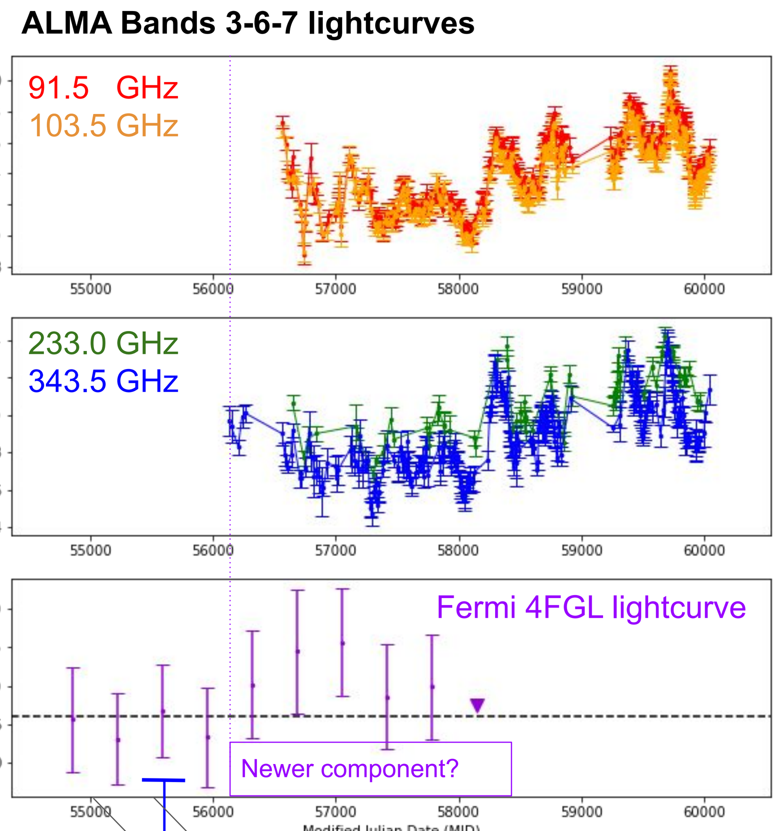
ATCA 7 mm - Western Hotspot

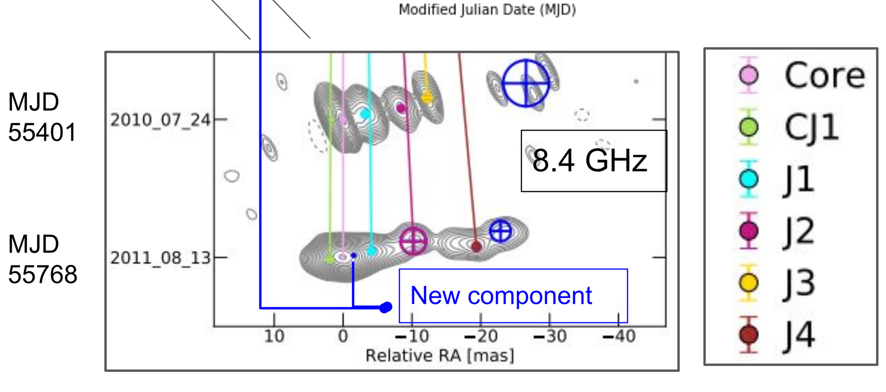


Credits: Hubble Legacy Archive.



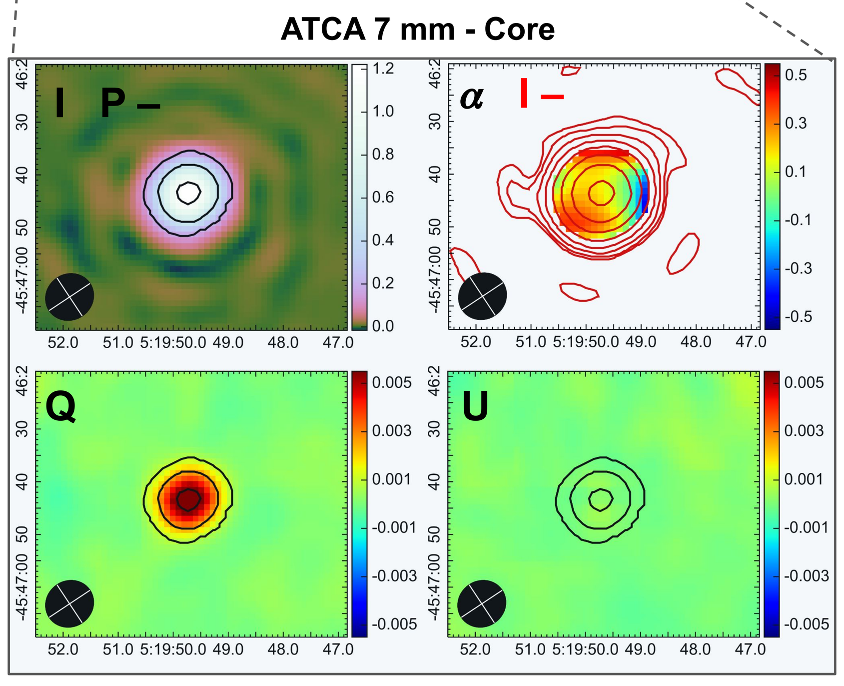
ALMA Bands 3-6-7 lightcurves

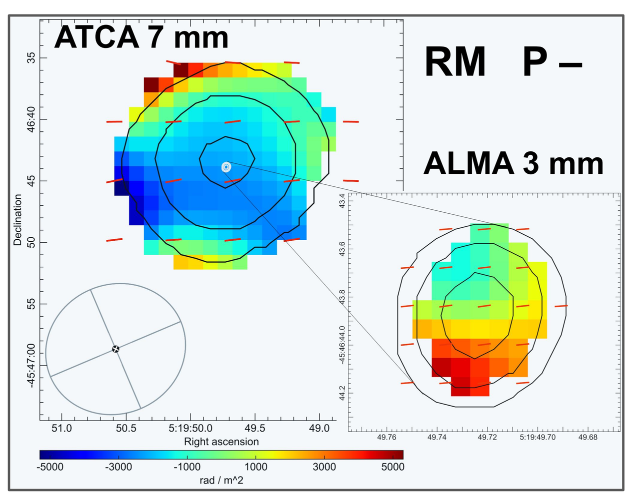




Credits: Angioni et al. 2019 (TANAMI programme, *cf.* their Fig. B.1).

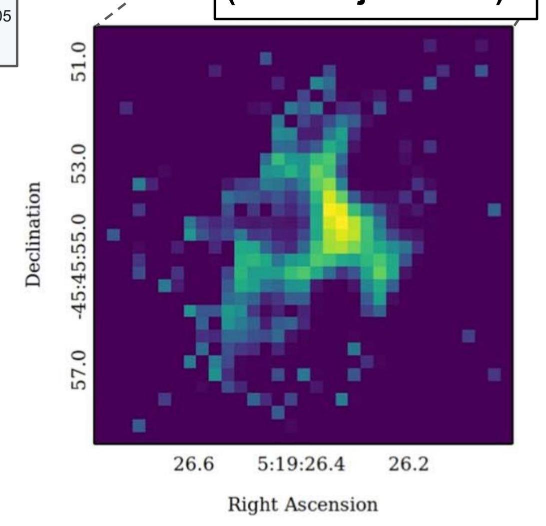
ATCA 7 mm - Core





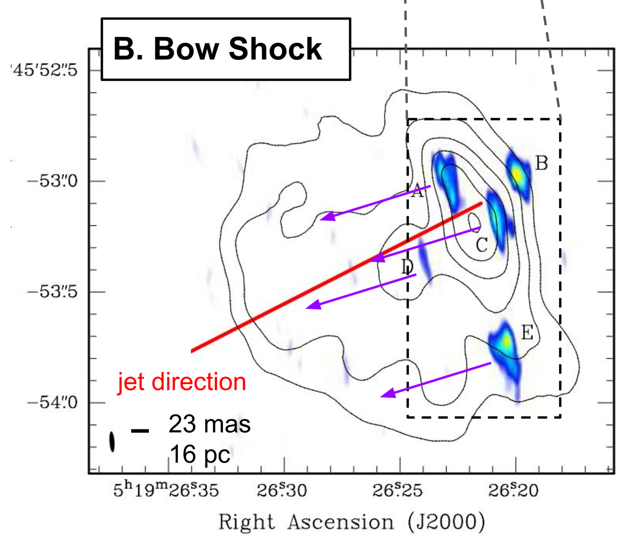
Backflow flux tubes (*cf.* VLBA components A, C, D, E)

R. Reverse Shock (internal jet shock)



Credits: Thimmappa *et al.* 2022 (*cf.* their Fig. 4). X-ray Chandra (0.5-2.5 keV) soft band image of Western hotspot.

B. Bow Shock



Credits: Tingay *et al.* 2008 (*cf.* their Fig. 3). 18 cm VLBA image, overlaid on the highest resolution VLA map (15 GHz) from Perley *et al.* 1997.

References

• V. Galluzzi, *et al.*, in prep. • R. A. Perley, H. J. Röser, and K. Meisenheimer, 1997, A&A, 328, 12-32 • J. H. Matthews, *et al.*, 2019, EPJ Web of Conferences, 210, 04002 • S. J. Tingay, E. Lenc, G. Brunetti, and M. Bondi, 2008, The Astronomical Journal, 136, 2473-2482 • M. J. Hardcastle, *et al.*, 2016, MNRAS, 455, 3526-3545 • R. Angioni, *et al.*, 2019, A&A, 627, A148 • R. Thimmappa, *et al.*, 2022, ApJ, 941, 204.