V. Heesen (U Southampton), J. Croston (U Southampton), J. Harwood (U Hertfordshire), E. Orru (ASTRON), A. Shulewski (U Amsterdam), F. de Gasperin (U Hamburg), R. Morganti (ASTRON) on behalf of the nearby AGN group and the LOFAR surveys team

Cycle 0 observations of the nearby FRI radio galaxy 3C31

UNIVERSITY OF Southampton

Nearby AGN group

HBA + LBA observations for the entire sample

FRI

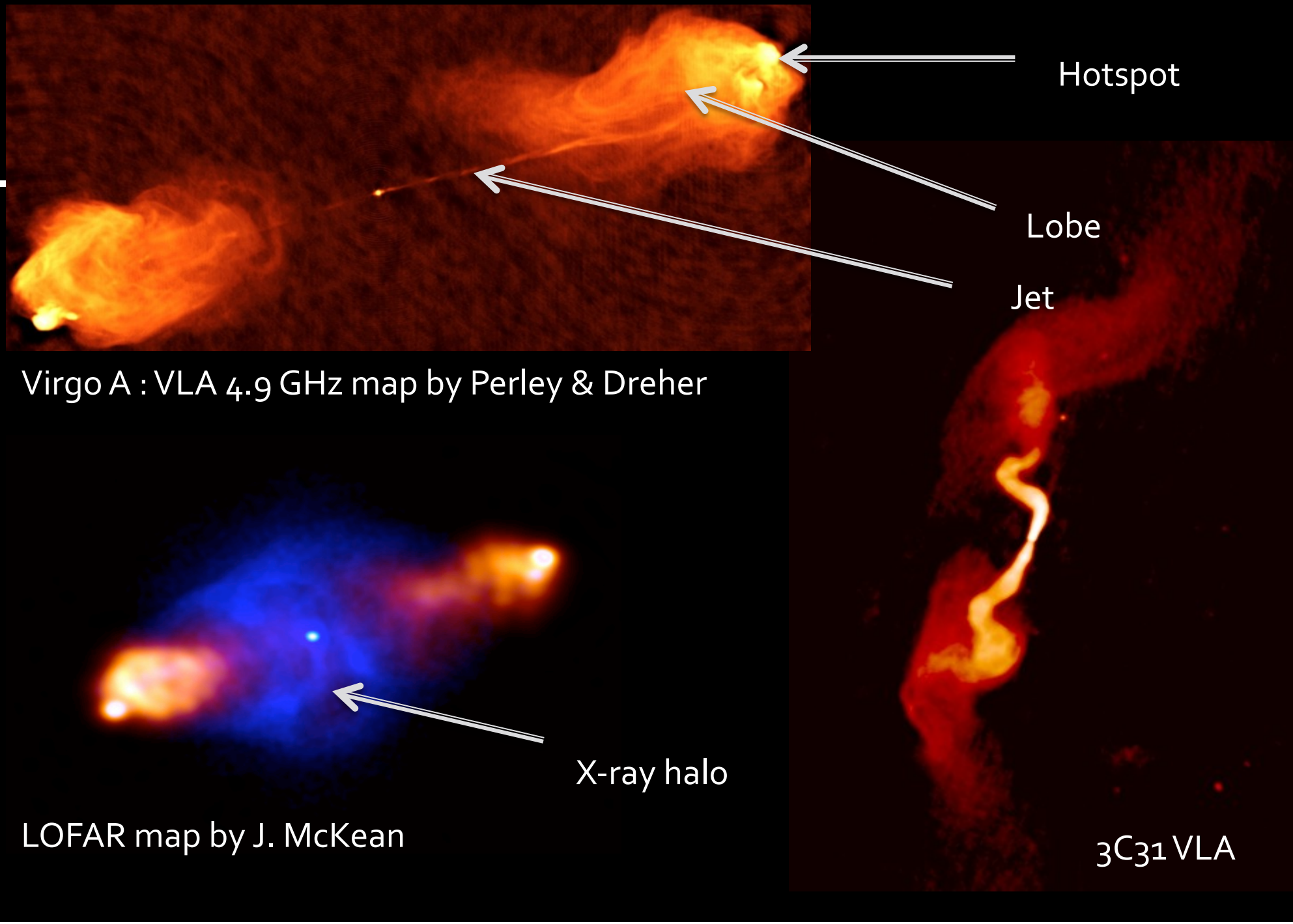
FRII

Targets for LC0_012 Cycle0 LOFAR

Using LOFAR for detailed studies of AGN, and AGN physics

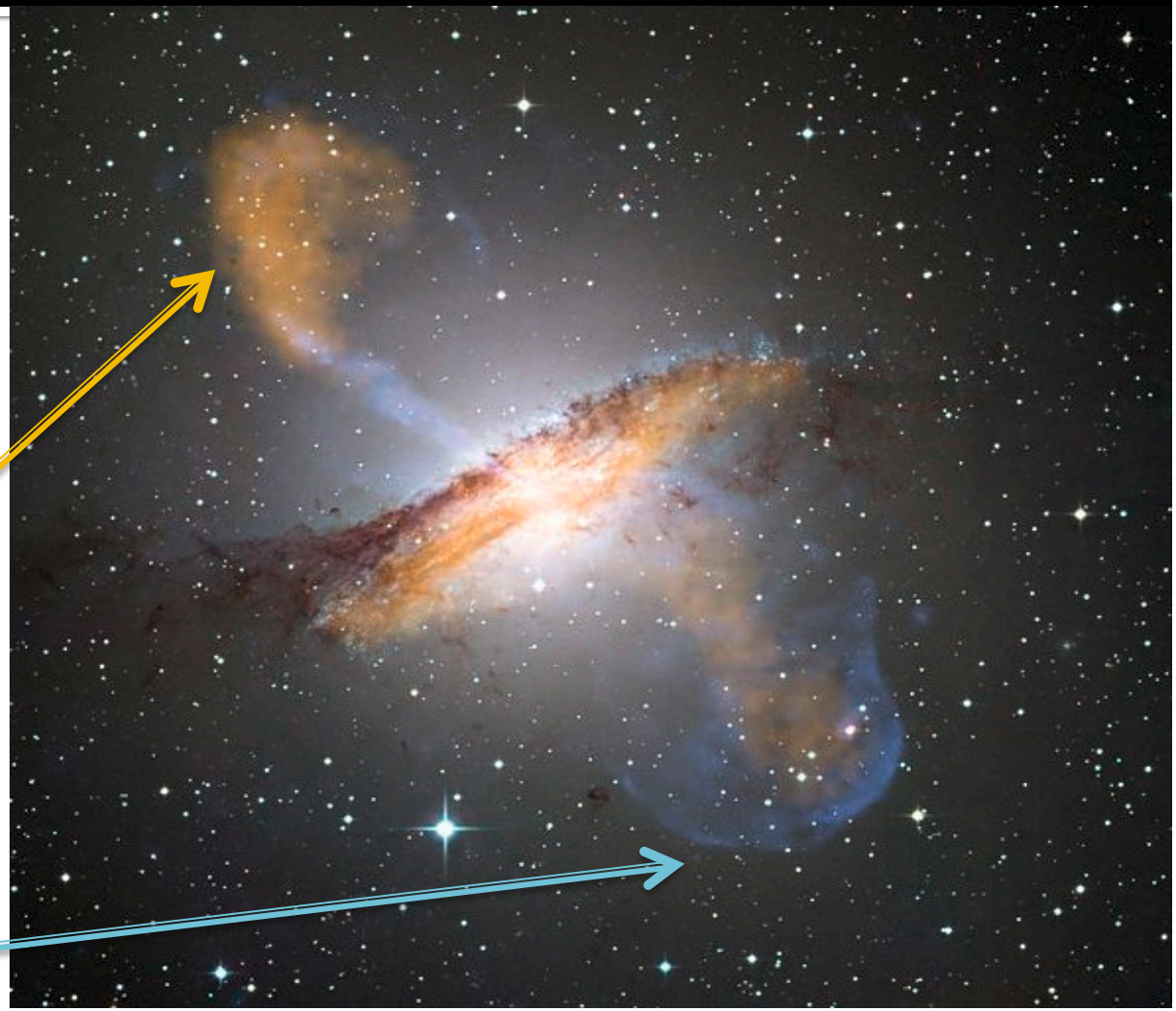
	HBA obs	HBA comp		LBA obs	LBA comp		Pre-processing	Leading
3C31	10	30		10	15		Southampton?	Nearby 3CR - Croston, Volker Heesen
3C223	10	30		10	15			Orru`+Croston
3C452	10	30		10	15			Croston+Jeremy Harwood
B1834	10	30		10	15		Nijmegen?	DDRG - Orru`+
3C35	10	30		10	15			Orru' (polariz.)+Shulevski
4C33.33	10	30		10	15			Giant RG Jamrozy+
3C237	10	30						LongBaselines group, Hardcastle et al.
3C41	10	30						LongBaselines group, Hardcastle et al.
M87	8	24		8	12			De Gasperin+
3C48				10	15		Amsterdam?	RRL group - Oonk+
Hydra A	6	18		6	9			Cavities - Rafferty, Wise+
Hercules A	6	18						Cavities: Birzan+
VLSS J1431.8+1331	8	24		8	30			Relics - Morganti, Shulevski, Kunert-Bajraszewska
Cygnus A	10	30						McKean+
Total	118	354		92	156			

Total observing	**210**	**Alloc**	**210**
Total computing	**510**		**373**


Hotspot
Lobe
Jet
Virgo A : VLA 4.9 GHz map by Perley & Dreher
X-ray halo
LOFAR map by J. McKean
3C31 VLA

Influence on the environment

- AGN feedback
- Galaxy lum. fct.
- Shock heating
- Entrainment



Radio continuum synchrotron emission

X-ray synchrotron emission

Centaurus A

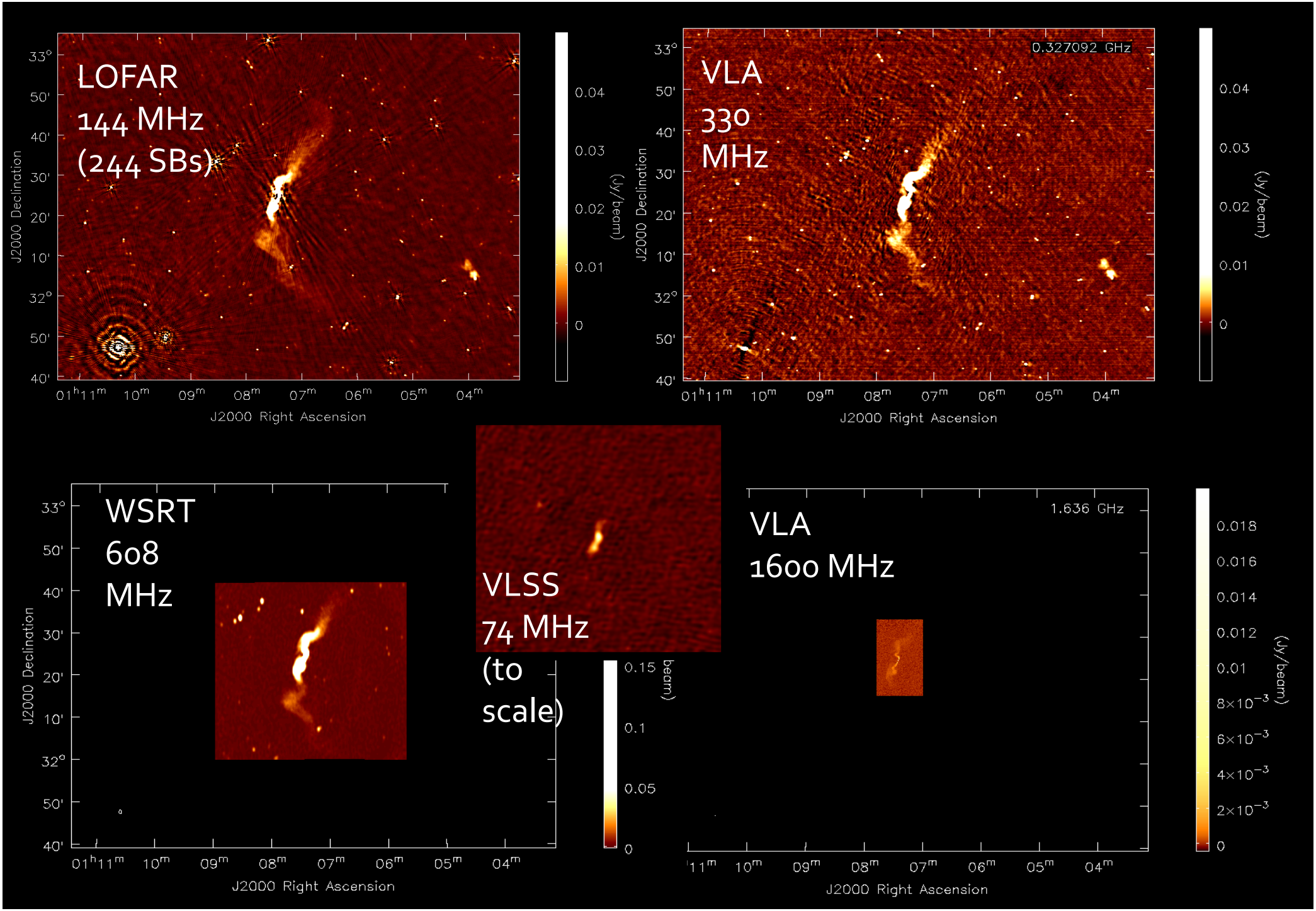
Particle content in FRI/FRII galaxies

- FRI are under-pressured
- FRII are close to pressure equilibrium
- Cosmic rays (CRs)
  - Upper limits from IC radiation
- Magnetic fields
  - Upper limits from Faraday rotation
- Hot gas
  - Upper limits from X-ray emission
- CR electron injection spectral index

3C31 LOFAR observations

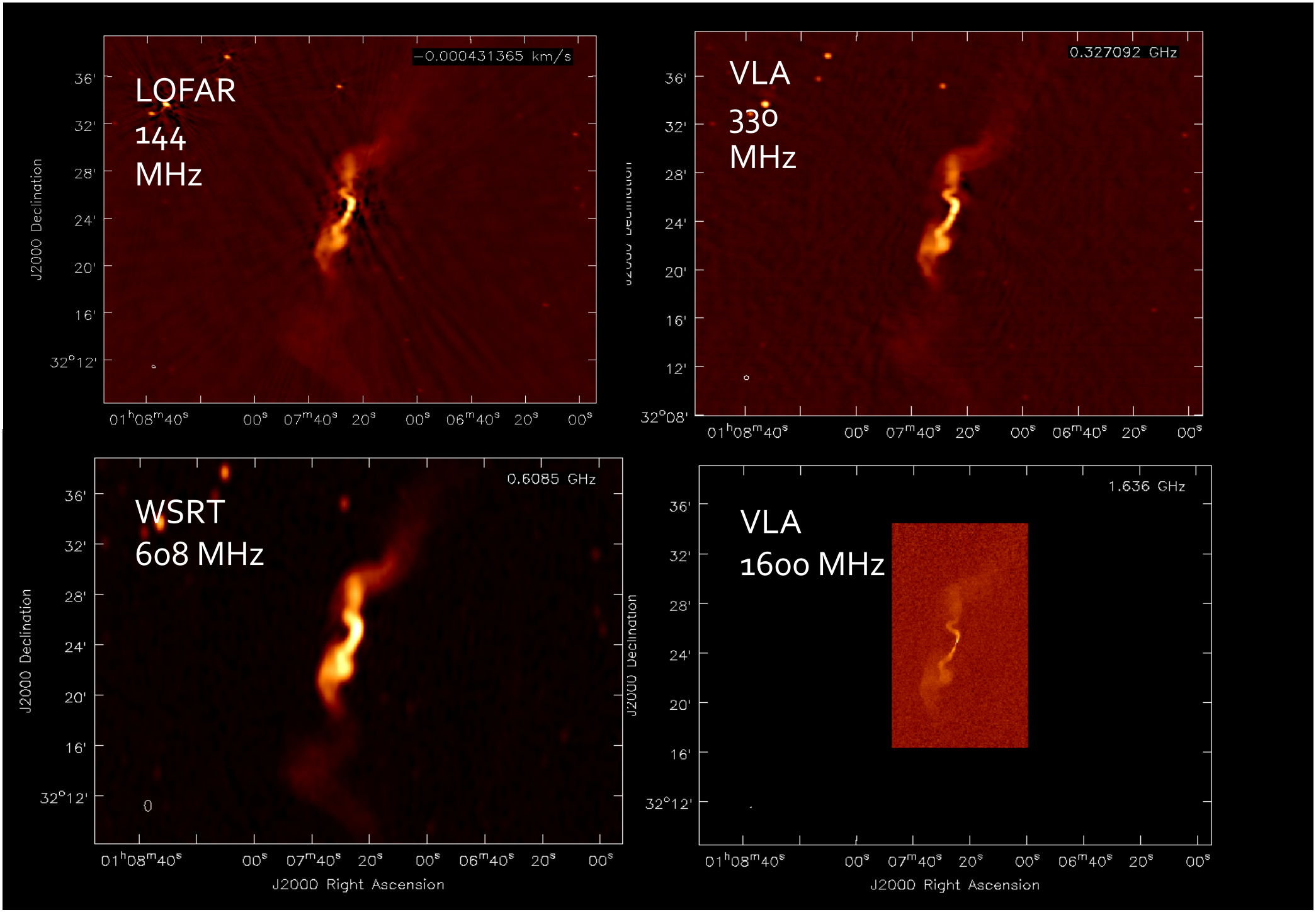
- 10 hrs observing time in HBA
- Interlaced 3C48 and 3C196 as calibrators
- HBA data pre-processed by ASTRON
- Initial NDPPP
- Calibrate calibrator and transfer solutions
- Combine sub-bands
- Phase-only calibration on each band
- Image with CASA or awimager

Pipeline in Soton by Adam Stewart

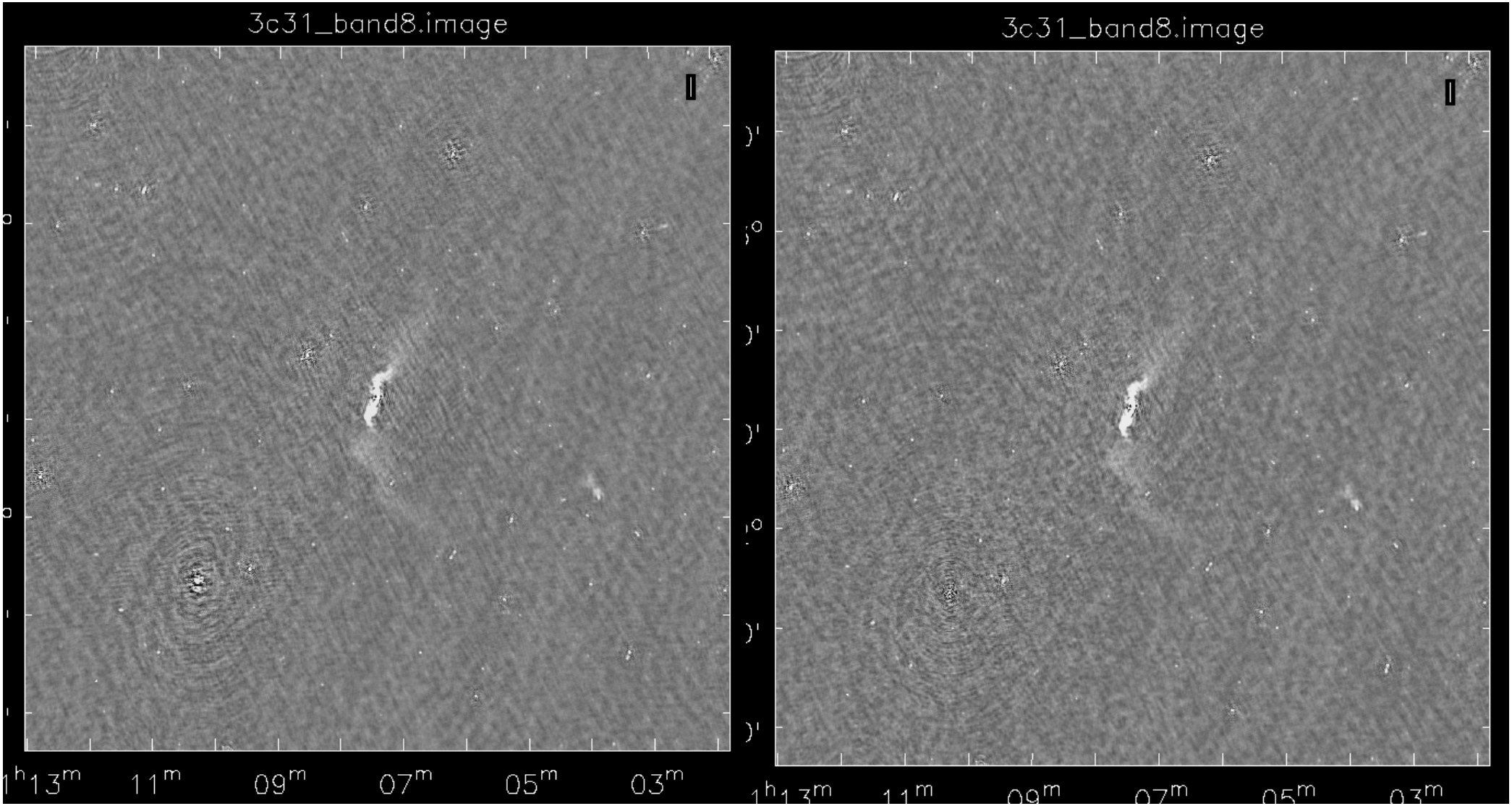

LOFAR
144 MHz
(244 SBs)
VLA
330
MHz
0.327092 GHz
WSRT
608
MHz
VLSS
74 MHz
(to
scale)
VLA
1600 MHz
1.636 GHz
J2000 Declination
J2000 Right Ascension
(Jy/beam)

HBA imaging

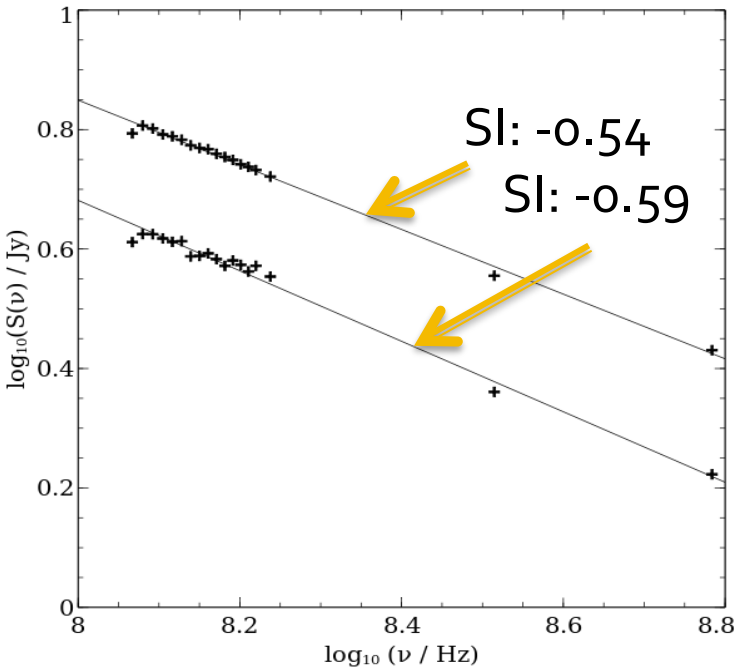
- Imaged with CASA clean (multi-scale)
- Peak flux density: 5.2 Jy, rms = 0.7 mJy/beam
- Resolution: 17x12 arcsec, S/N = 7400
- First skymodel: VLSS
- Self-calibration in phase, no change!
- Directional dependent gains for 3C34


LOFAR
144
MHz
−0.000431365 km/s
VLA
330
MHz
0.327092 GHz
WSRT
608 MHz
0.6085 GHz
VLA
1600 MHz
1.636 GHz
J2000 Declination
J2000 Right Ascension

Directional dependent gains



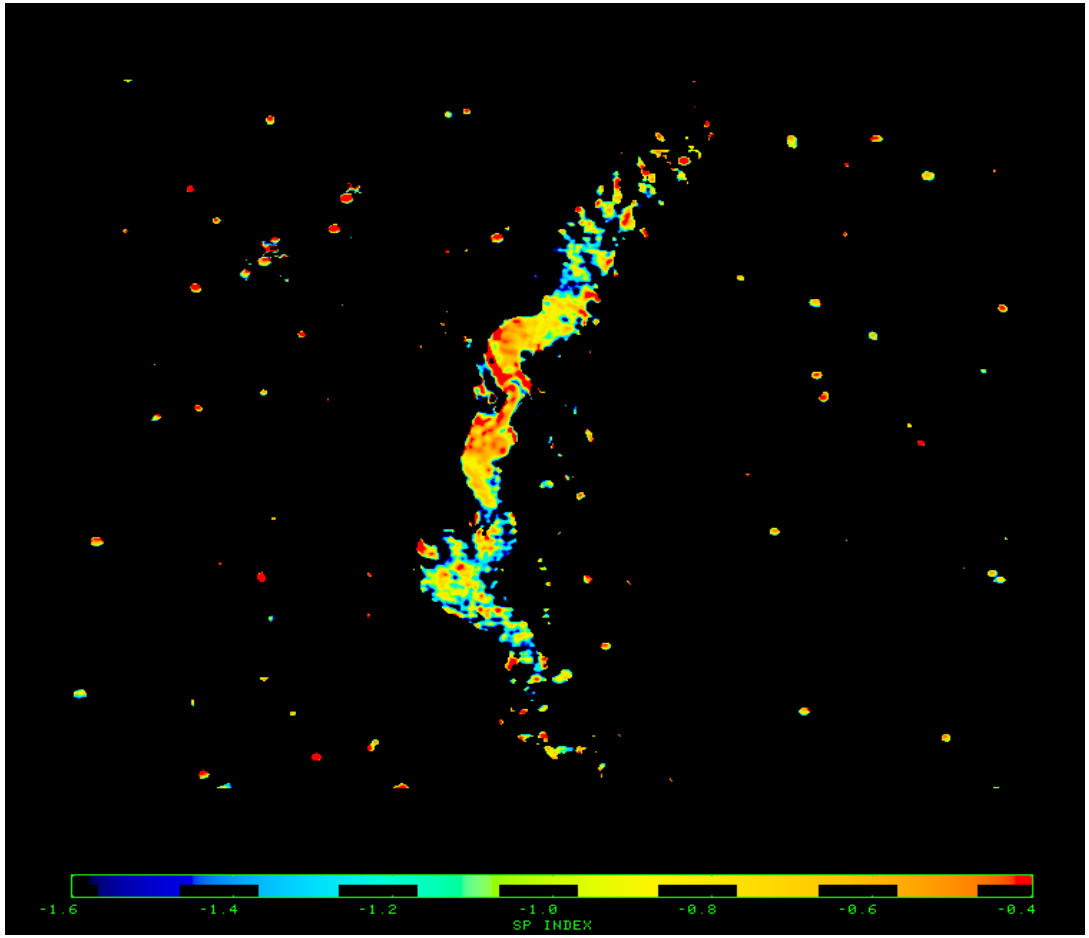
Radio spectral index (SI)



Expected from shock acceleration: -0.5

HBA in-band spectral index
Consistent

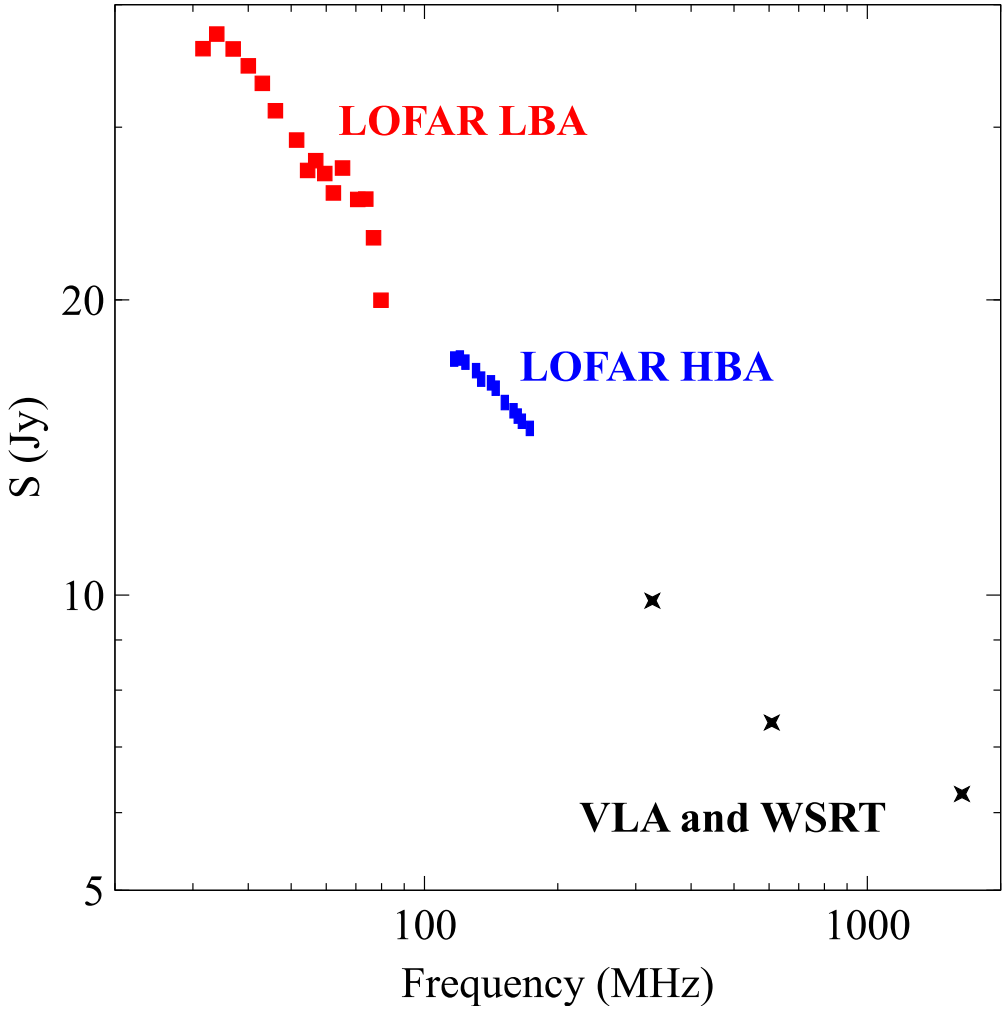
144 / 330 MHz spectral index



-1.6

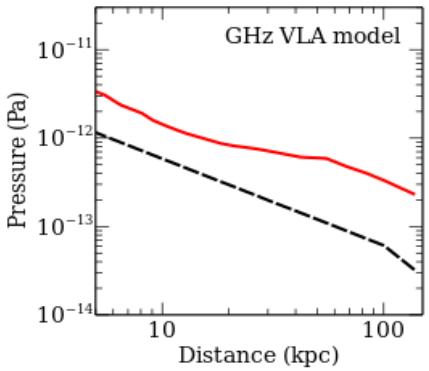
-0.4

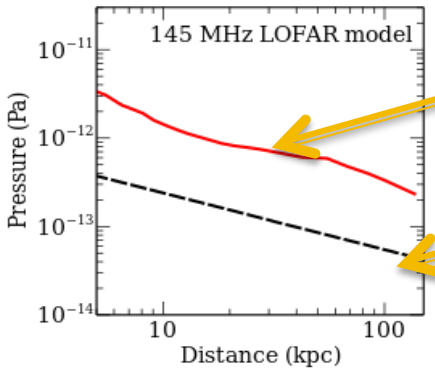
30 MHz – 1.6 GHz spectrum



- Spectrum of the inner, bright part only
- Spectral index about expected ~ -0.7
- In-band spectral index consistent

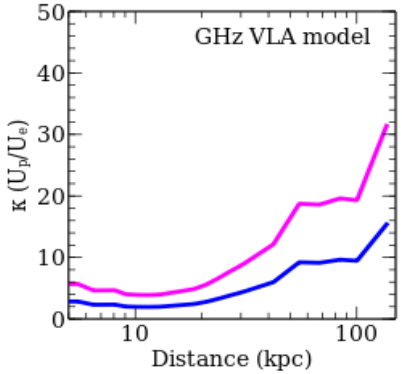
Particle models of 3C31 jet

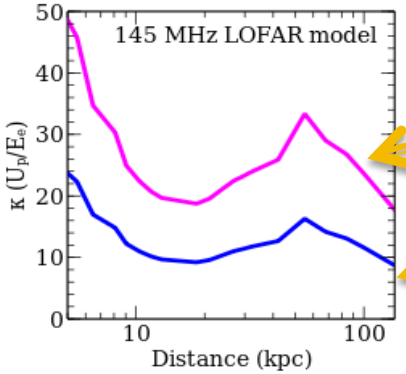




External pressure

Internal pressure





Relativistic protons

Thermal protons

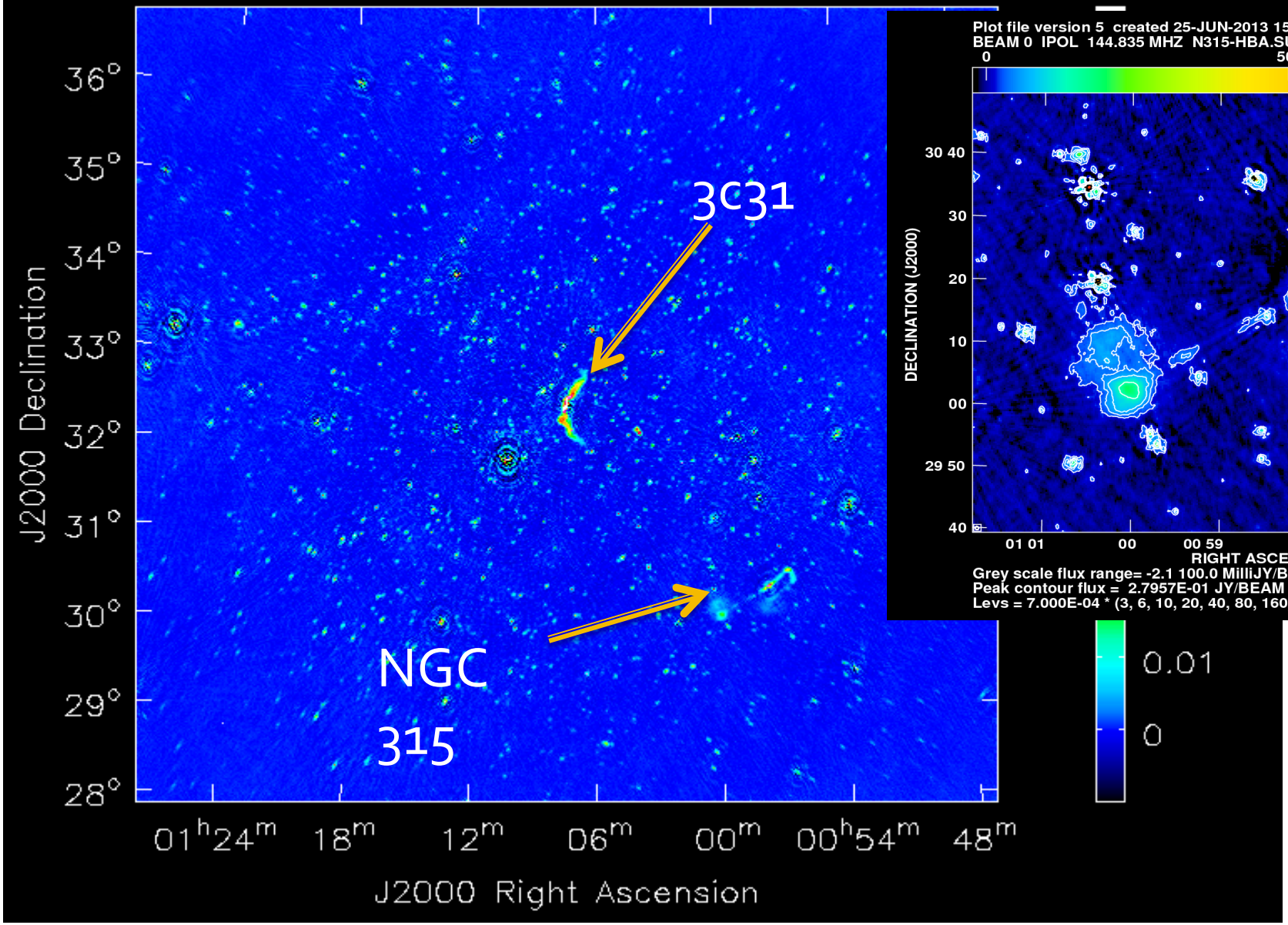
Model with constant SI

Model with SI from LOFAR

VLA model: entrainment along jet
LOFAR model: less entrainment
=> Needs more investigation

Wide field of view!

Still need to primary beam correct …



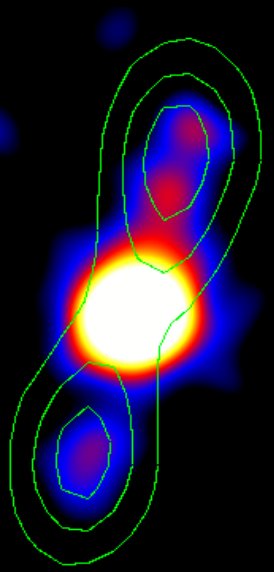
HBA
20 km
baseline
244 SBs

Summary

- First promising results
  - Angular extent 15% larger than at 330 MHz
- Flux scale is broadly consistent
  - Spectral indices agree with expected values
- Noise level 5-10x thermal level
  - Worse near bright sources
- Bright sidelobe structure near our target
  - Directional dependent gains on dominating source does not remove them

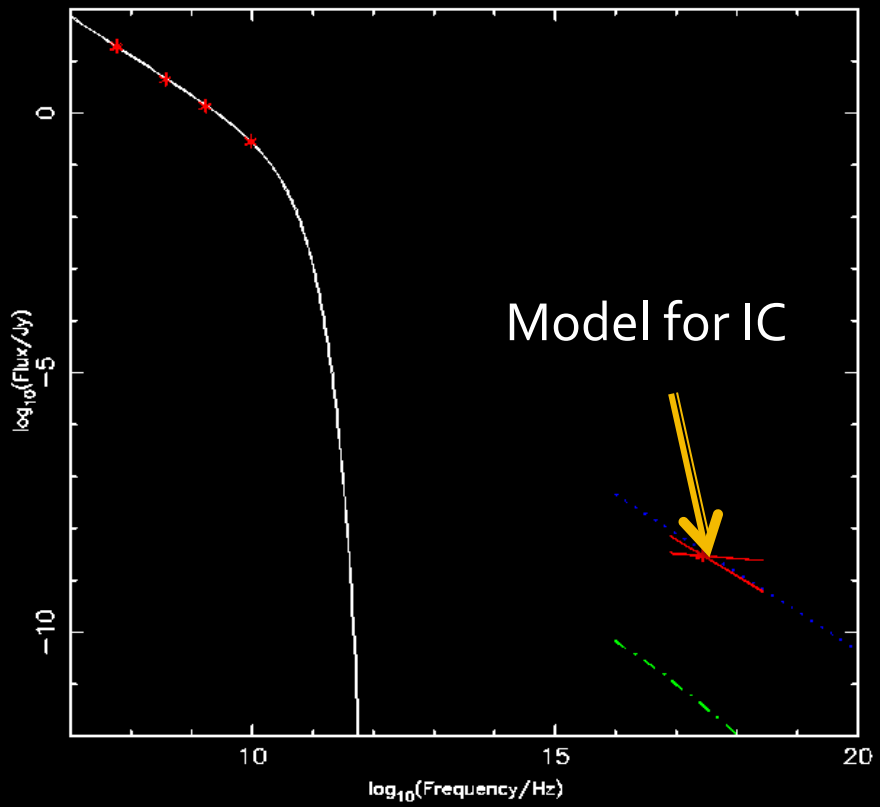
3C223

(J. Harwood in prep.)

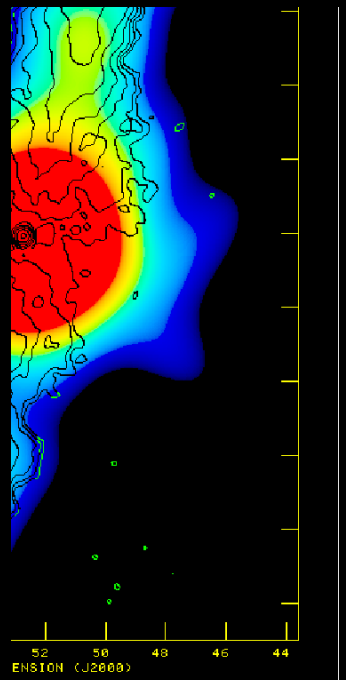


LOFAR LBA
+
X-ray

Spectrum does not flatten
-> total energy doubles in northern lobe

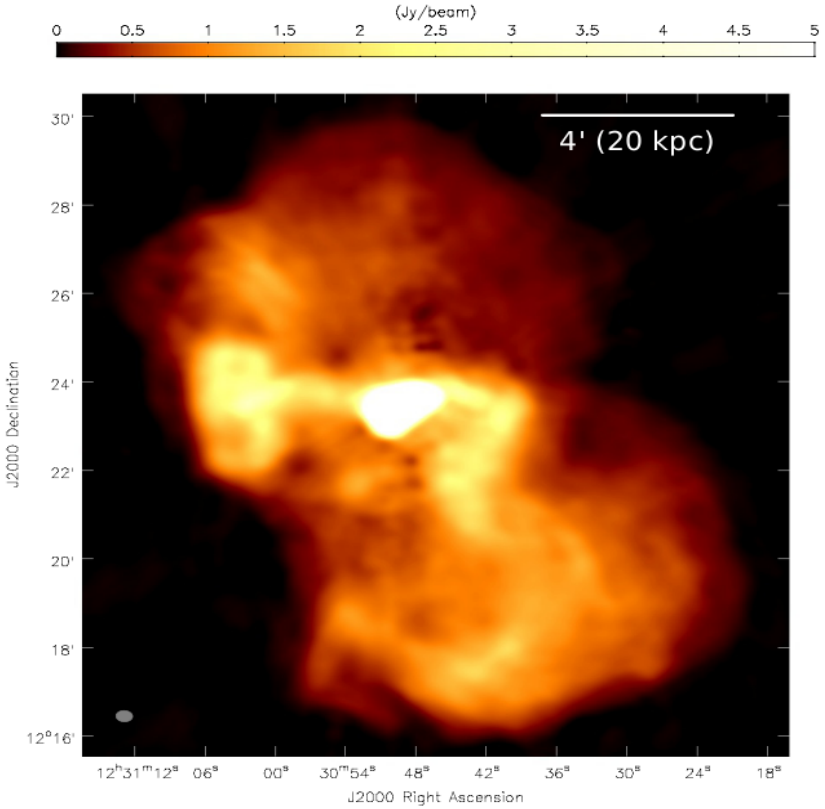


Model for IC

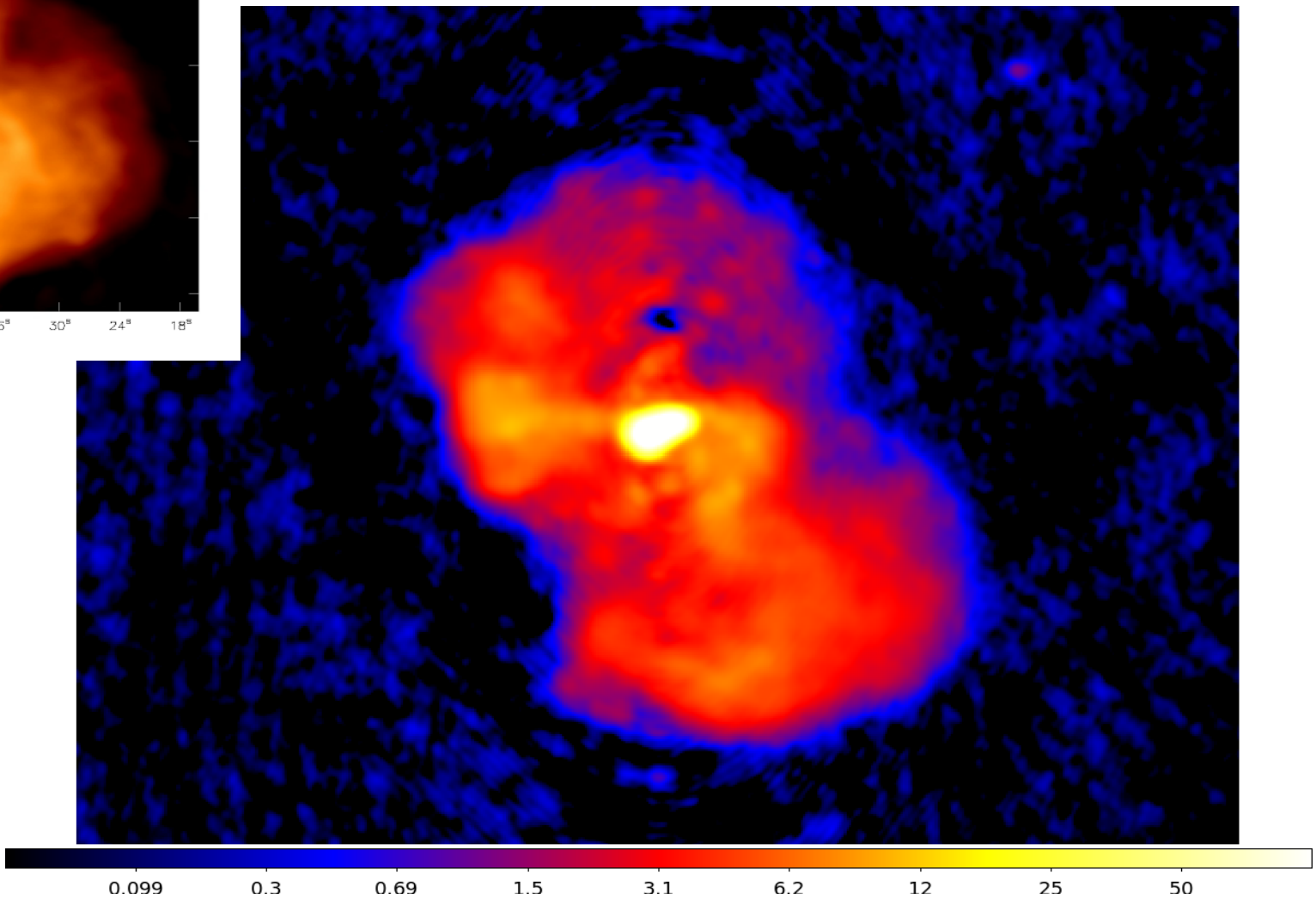


VLA contours + X-ray

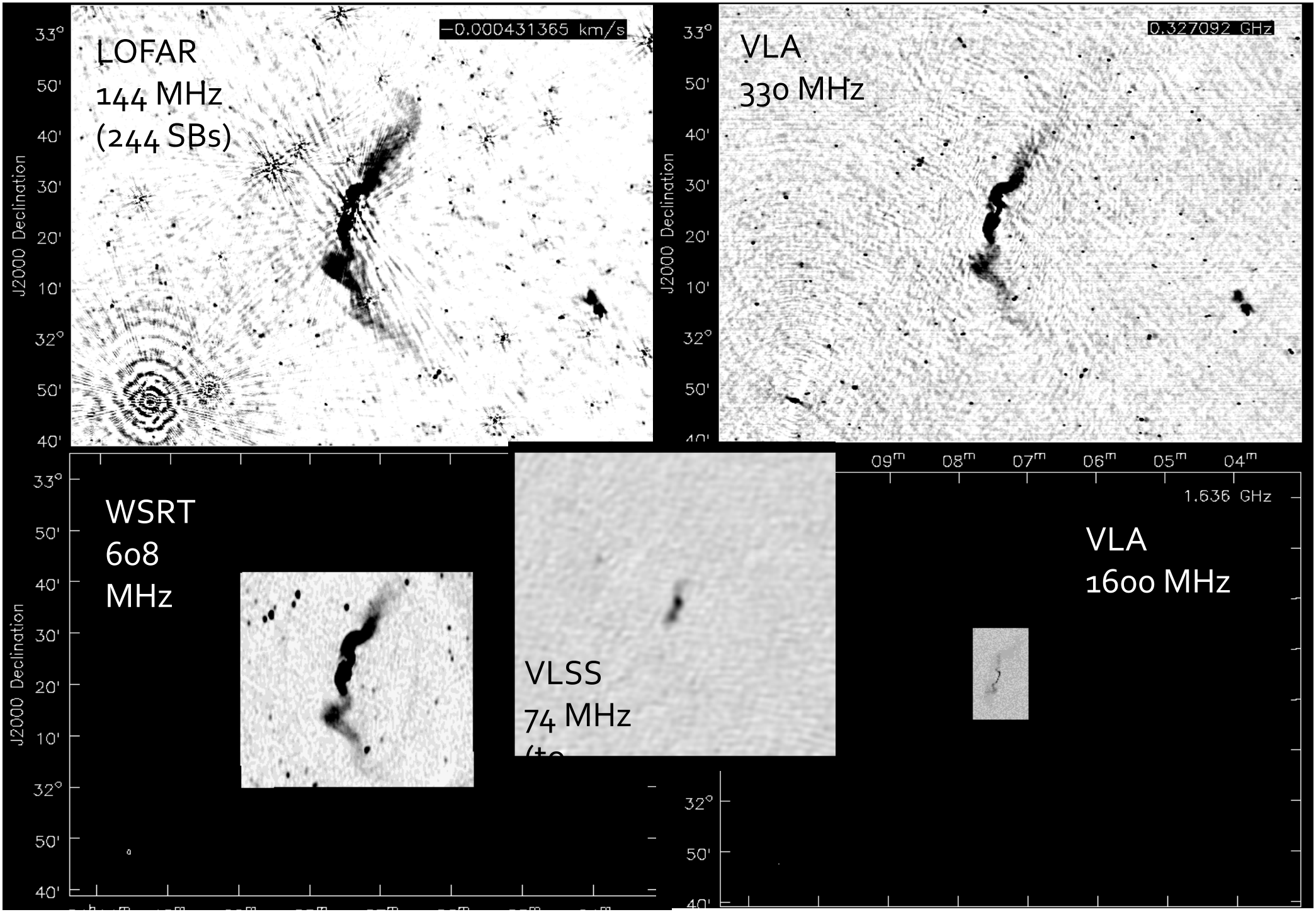
Virgo A, M87



HBA,
published in A&A



LBA,de Gasperin, in prep.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