Probing Galaxy Interactions via Spectropolarimetry

- Jamie Farnes

Dave Green (Cambridge, UK), Nimisha Kantharia (NCRA, India)

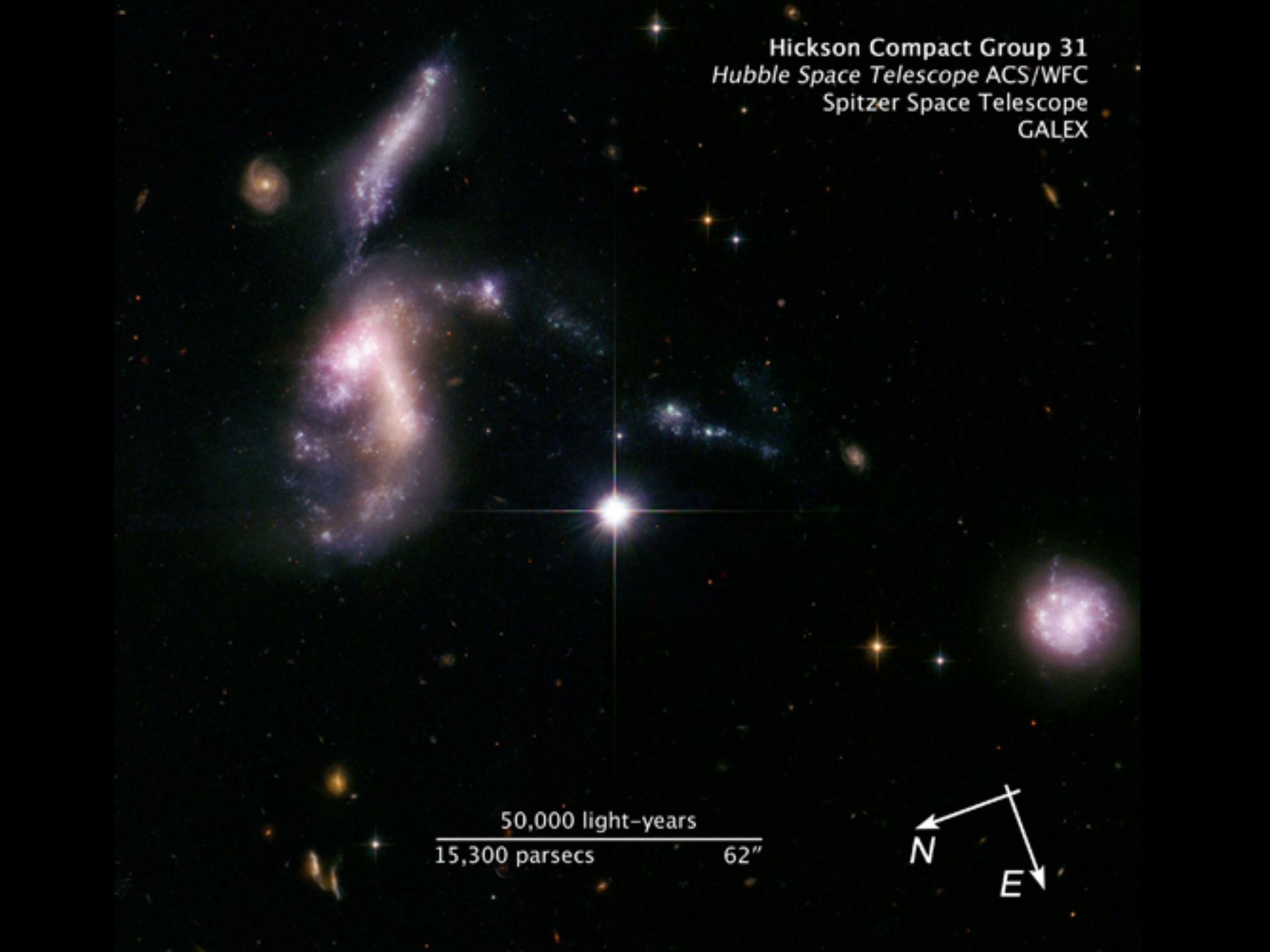
Jamie S. Farnes
jamie.farnes@sydney.edu.au

Magnetic Fields in the Universe IV – February 4th-8th 2013

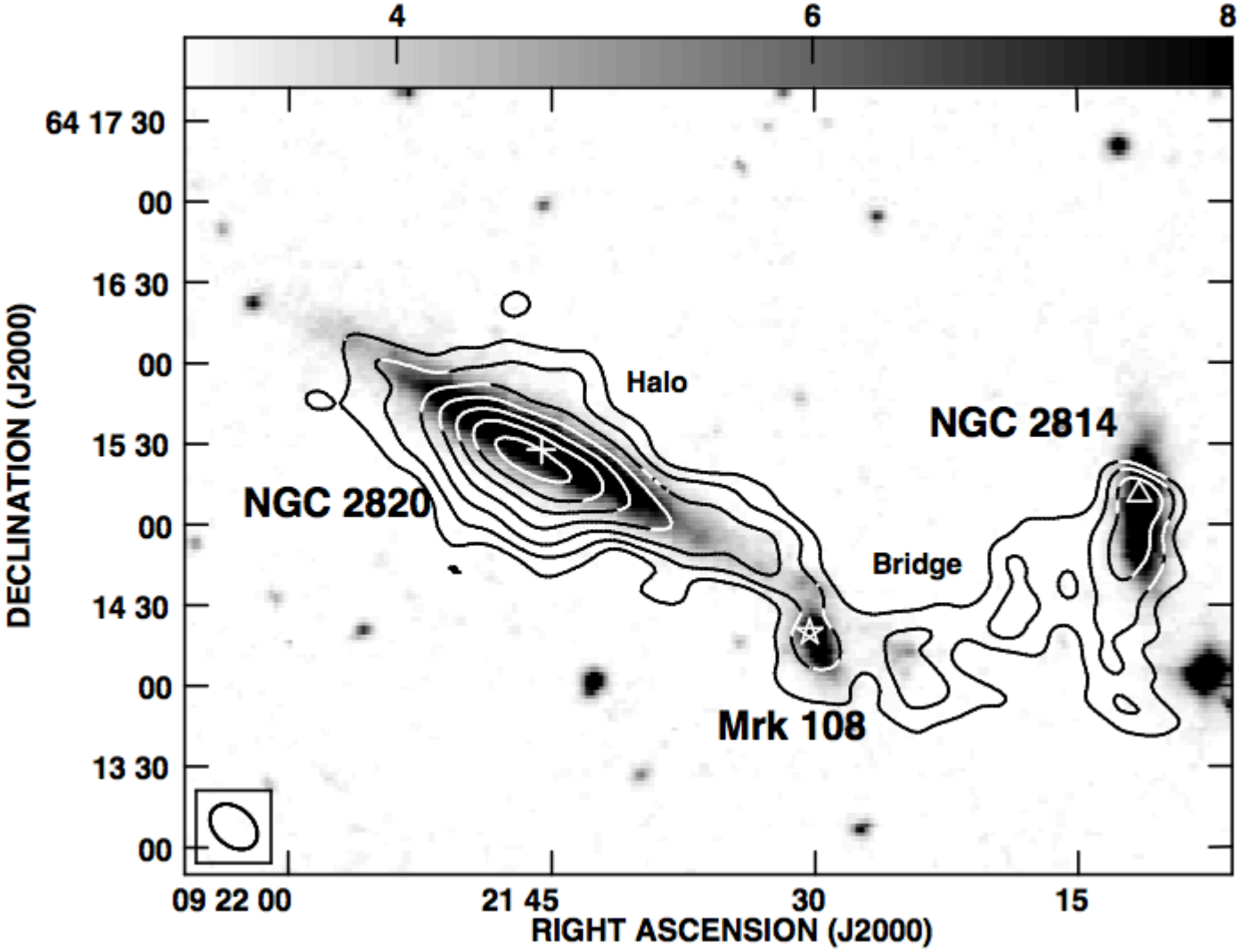
THE UNIVERSITY OF SYDNEY

Probing Galaxy Interactions via Spectropolarimetry

- Galaxy Groups
- Rotation Measure Synthesis/Spectropolarimetry
- The bigger issue: calibrating the Giant Metrewave Radio Telescope
- Some results
- Summary


Hickson Compact Group 31
Hubble Space Telescope ACS/WFC
Spitzer Space Telescope
GALEX
50,000 light-years
15,300 parsecs
62″
N
E

Holmberg 124 - Kantharia et al., 2008



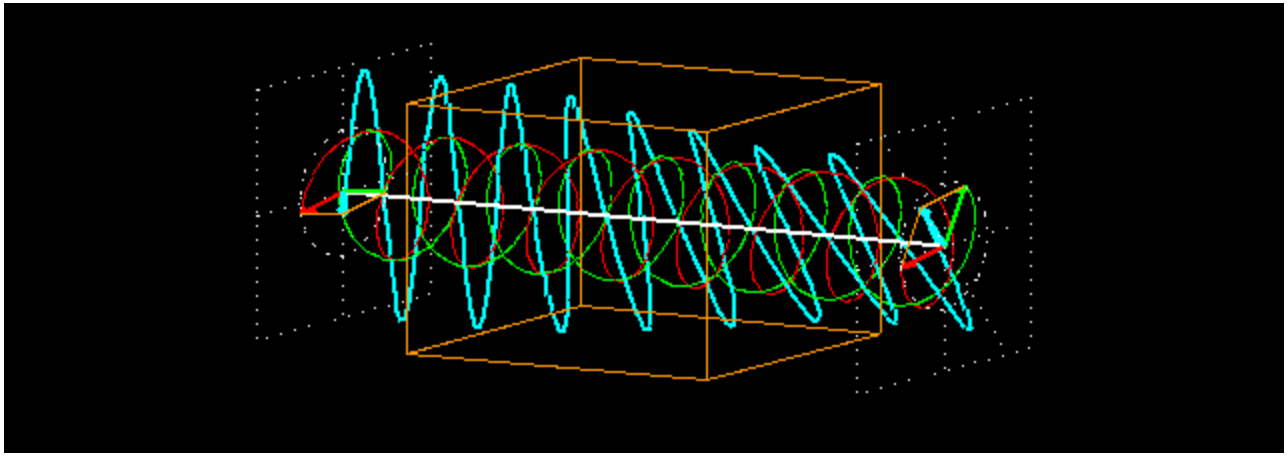
Galaxy Groups

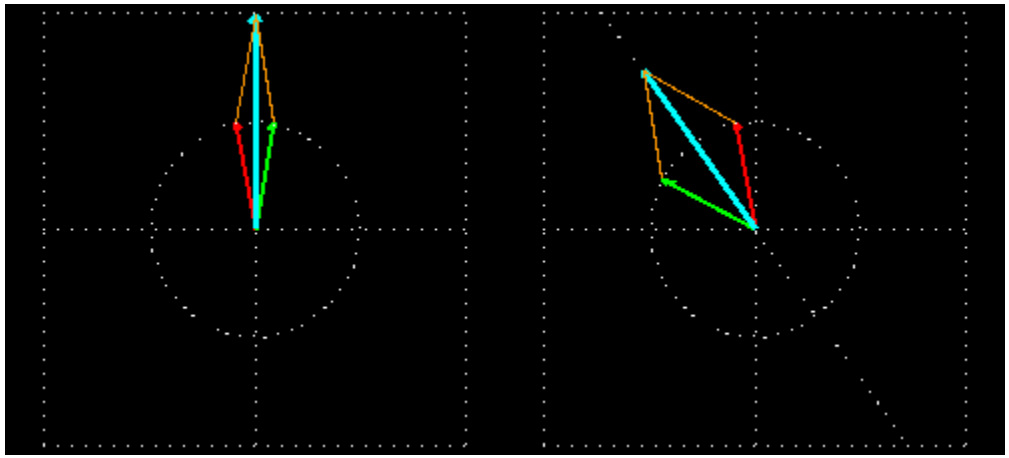
- Linear polarisation directly reveals regular magnetic fields. Such fields could be enhanced by tidal interactions or ram pressure from the intergalactic medium (IGM) compressing the *B* field of the galaxies. Can polarised ridges be detected in known interacting galaxies?

- Observed the Grus Quartet & USCG S063 - two galaxy groups from the Southern Compact Groups sample. Both groups have extended tidal tails, and a perturbed gas distribution - good candidates to look for interactions with the IGM.

- Observed with the GMRT to a sensitivity of 36μJy/beam in full-polarisation at 610 MHz.

- Want to use one of the best tools for detecting *B* fields: Spectropolarimetry!





$$\chi = \chi_0 + \phi\,\lambda^2,$$

$$\phi \propto \int_{\text{source}}^{\text{telescope}} n_e \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{l},$$

Spectropolarimetry/RM Synthesis

- Express the observed linear polarisation vector as an exponential:

$$P = Q + iU = p_0 \cos 2\chi + ip_0 \sin 2\chi = p_0 e^{2i\chi}$$

- By integrating over all Faraday Depths:

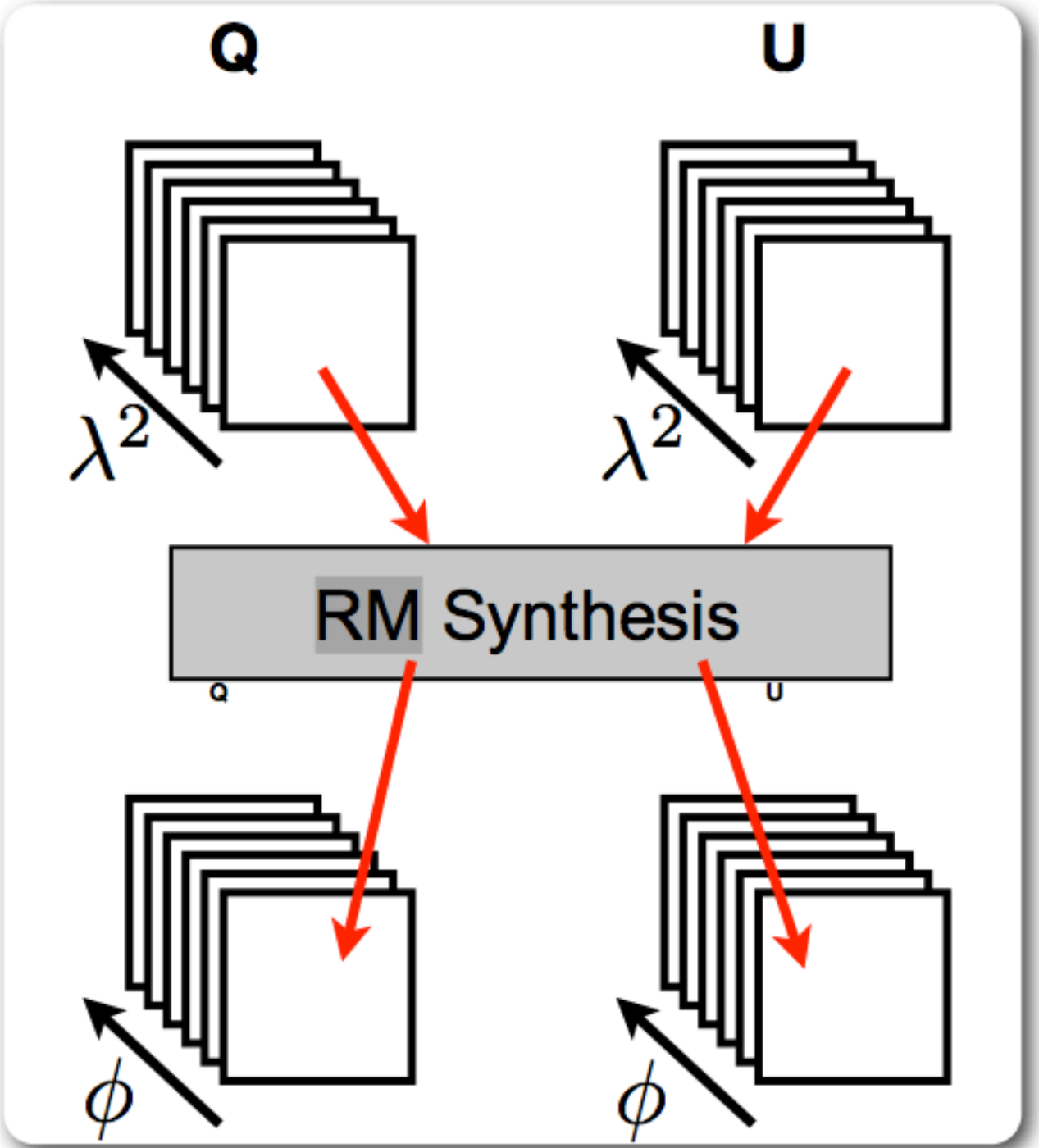
(Burn 1966)

$$P(\lambda^2) = \int_{-\infty}^{+\infty} F(\phi)\, \mathrm{e}^{2i\phi\lambda^2}\, \mathrm{d}\phi, \qquad F(\phi) = \int_{-\infty}^{+\infty} P(\lambda^2)\, \mathrm{e}^{-2i\phi\lambda^2}\, \mathrm{d}\lambda^2.$$

- Where $P(\lambda^2)$ is the complex observed polarisation, and $F(\phi)$ is the "Faraday Disperson Function" which describes the *intrinsic polarisation at each Faraday depth*.
- Everything on the RHS is observable! But is a sum including negative λ^2 !

(Brentjens & de Bruyn 2005)

$$F(\phi) \approx K \sum_{i=1}^{N} W_i P_i \mathrm{e}^{-2i\phi(\lambda_i^2 - \lambda_0^2)},$$

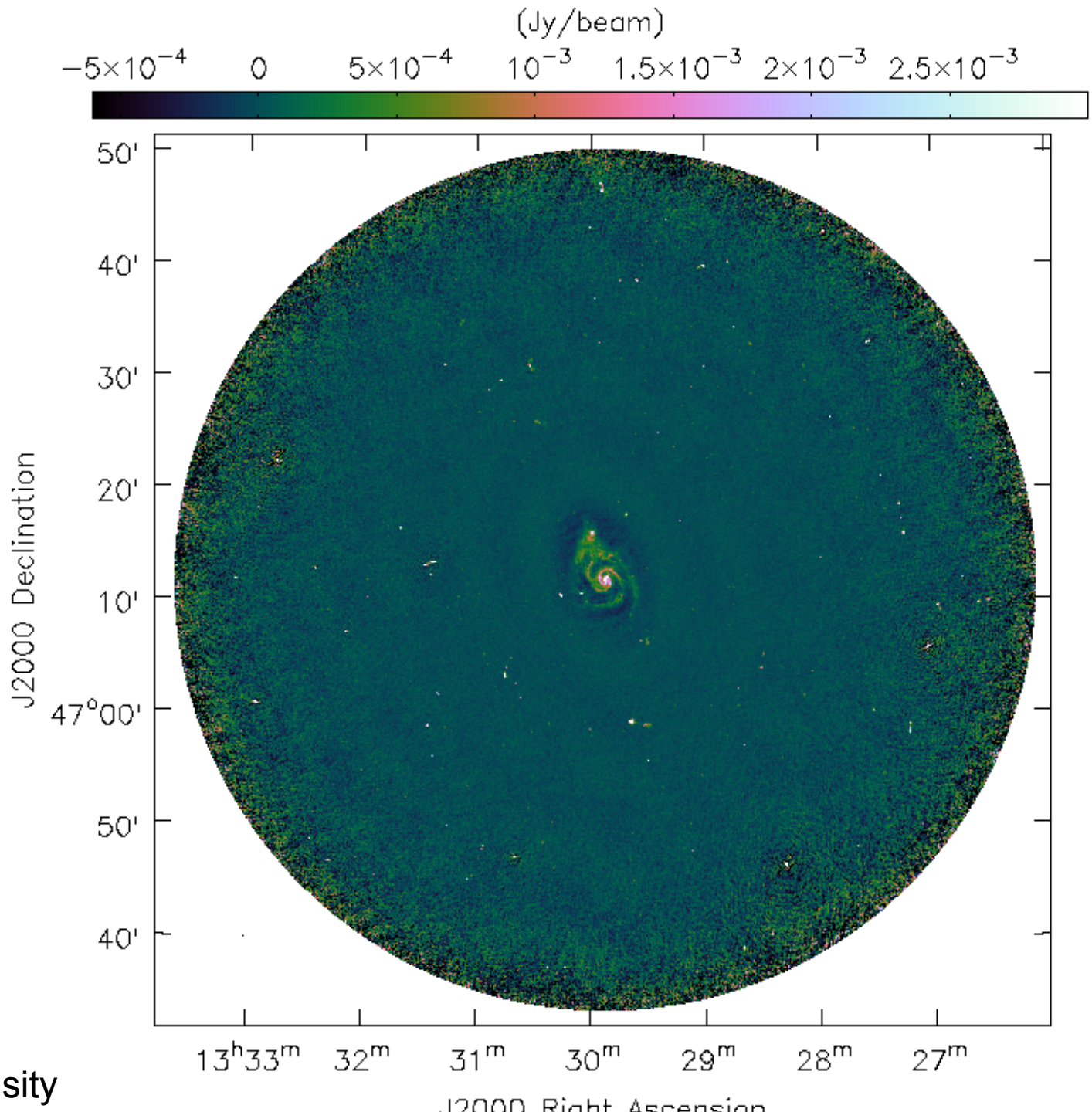


Spectropolarimetry is already, or will soon be, feasible at a number of radio facilities:

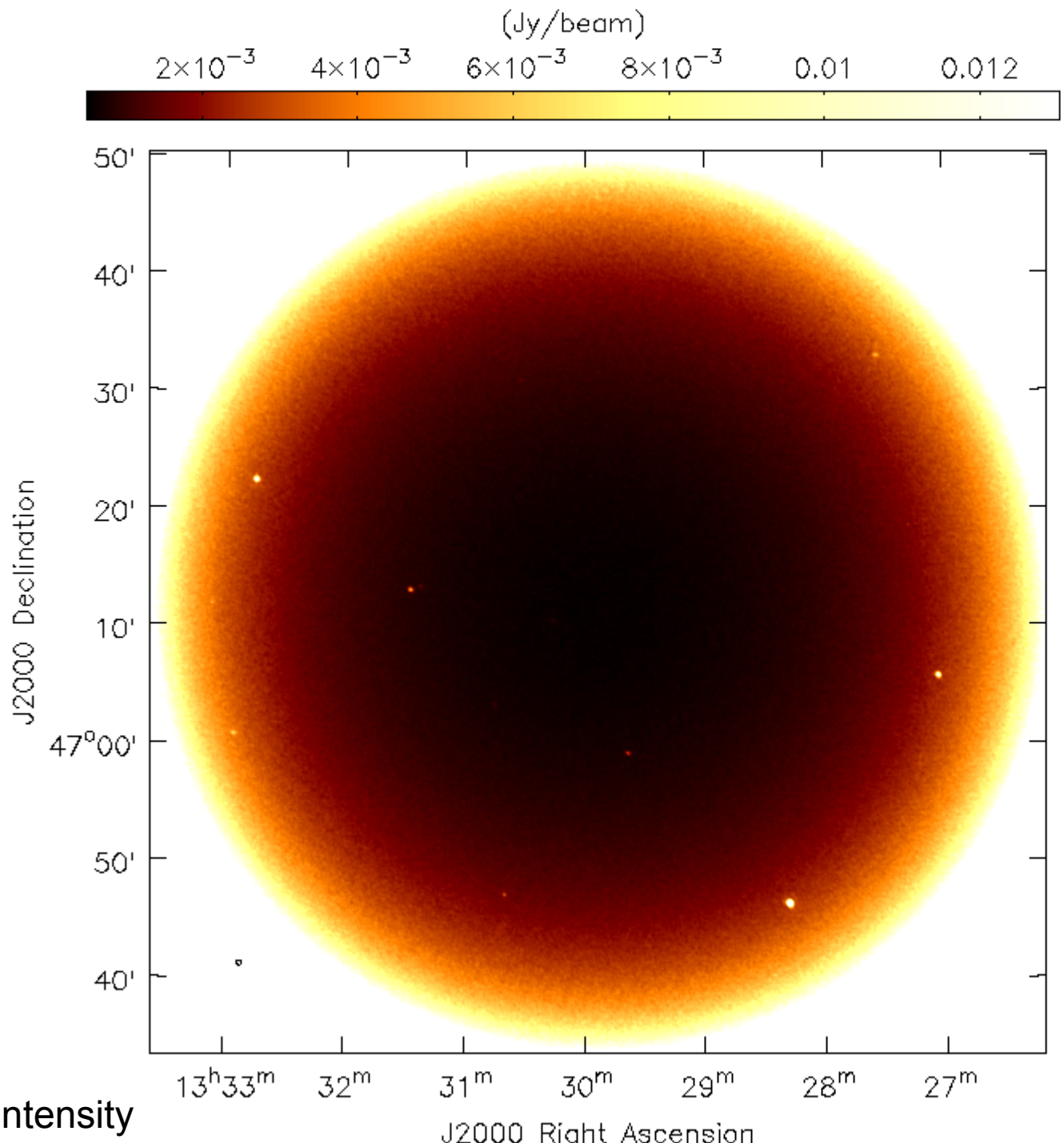
- JVLA
- LOFAR
- ASKAP
- Arecibo
- ATCA
- MWA
- Parkes
- **GMRT**

The GMRT

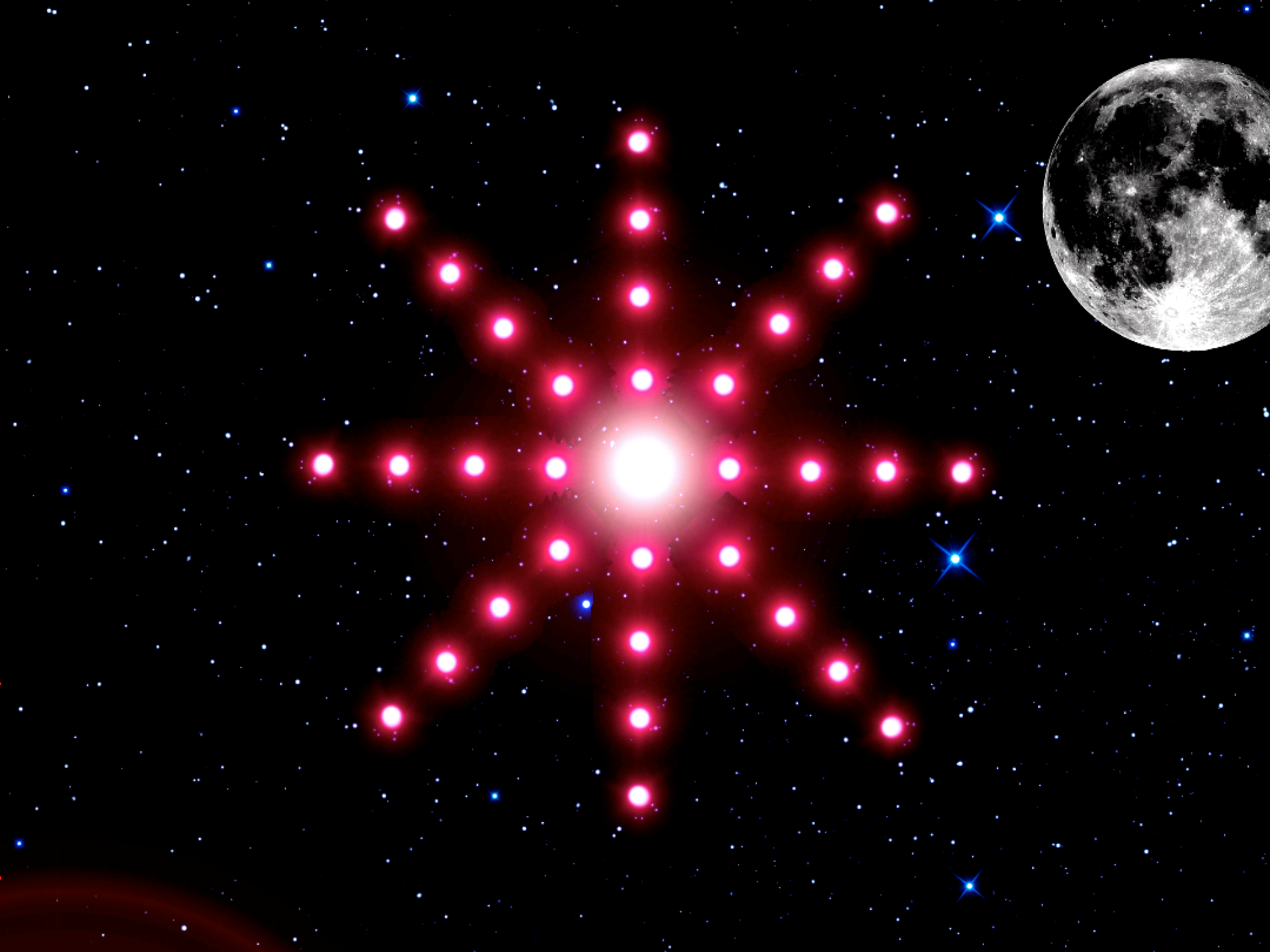
- 5 observing bands at 150 MHz, 235 MHz, 325 MHz, 610 MHz and 1.4 GHz
- 30x 45m dishes – collecting area of ~50,000 m^2 with Tsys ~ 102K @ 610 MHz = 2.5% SKA
- Observe in spectral line mode with software correlator (512 channels across 32 MHz) - helps with the RFI environment
- Maximum baseline of 27 km = resolution ~5” at 610 MHz
- Full-polar observations (RR, LL, RL, LR) online since late 2008 - initially on an experimental basis - had to commission, calibrate, and test in order to create a pipeline for polarimetric data. Many systematics…
  - **Calculating instrumental polarisation**, *time-variability of the instrumental polarisation*, **applying corrections to the *uv*-data**, *ionospheric Faraday rotation*, **electric vector polarisation angle corrections across the observing bandwidth.**
- Relatively wide field of view, FWHM = 0.75° at 610 MHz (wide-field polarimetry).

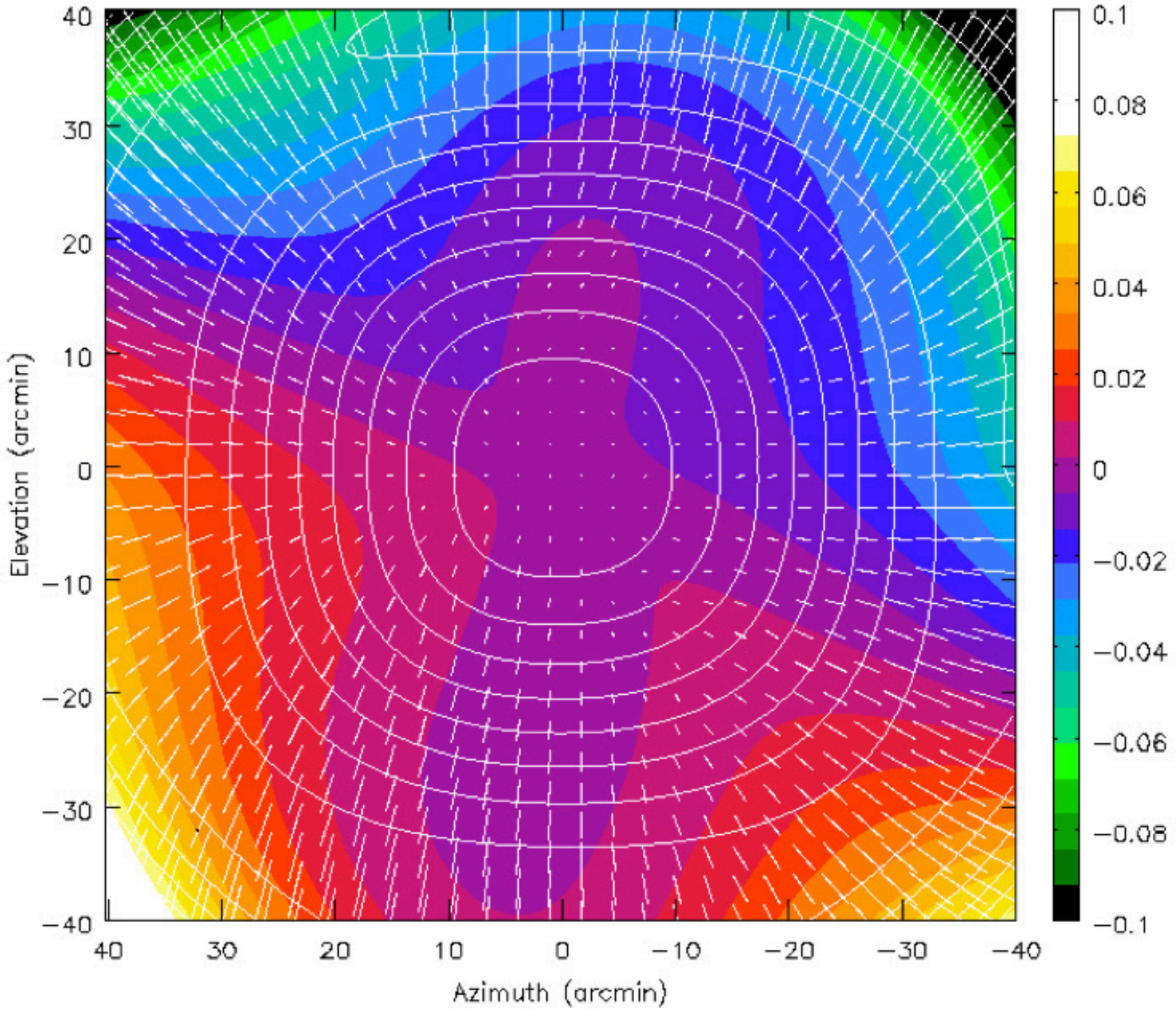


Total Intensity

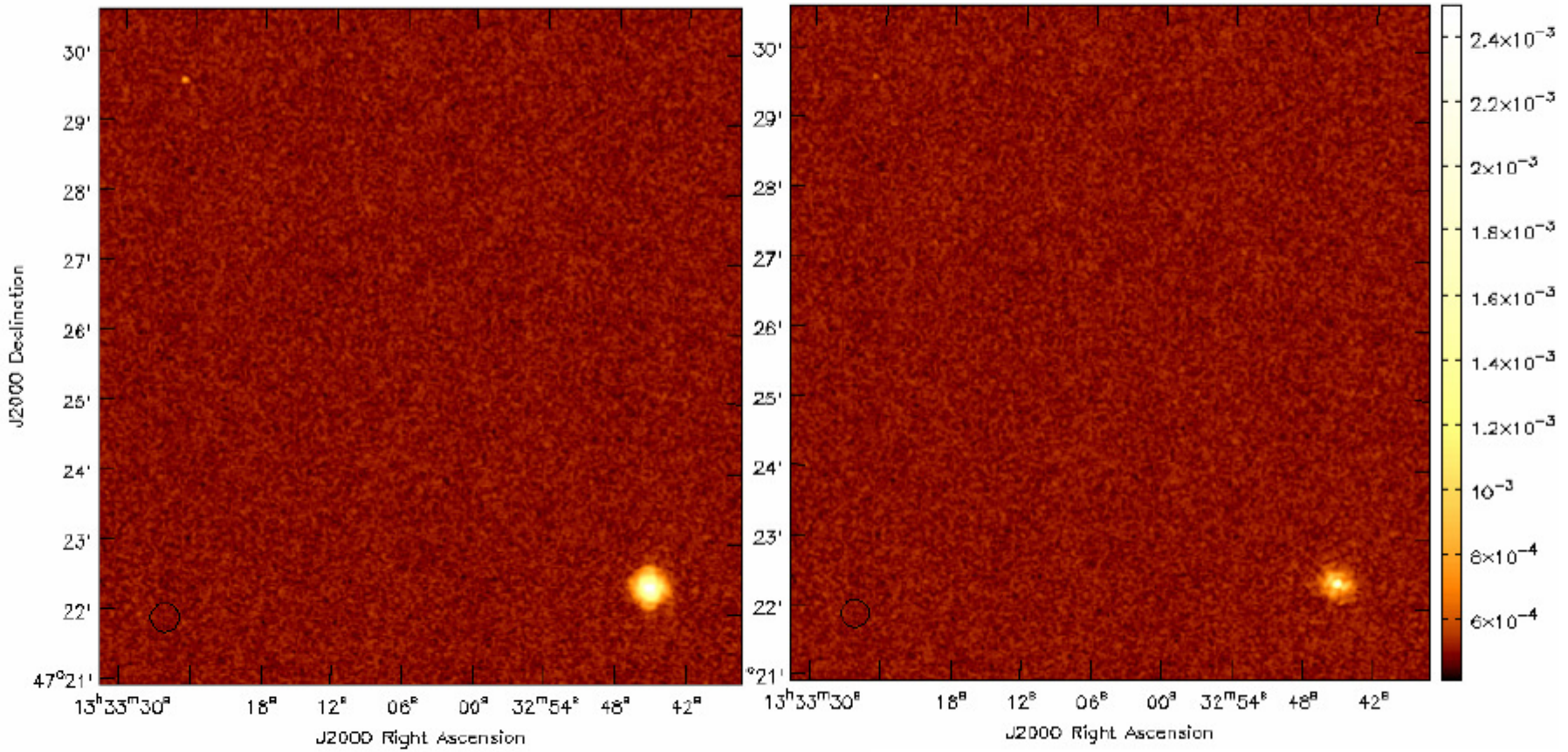


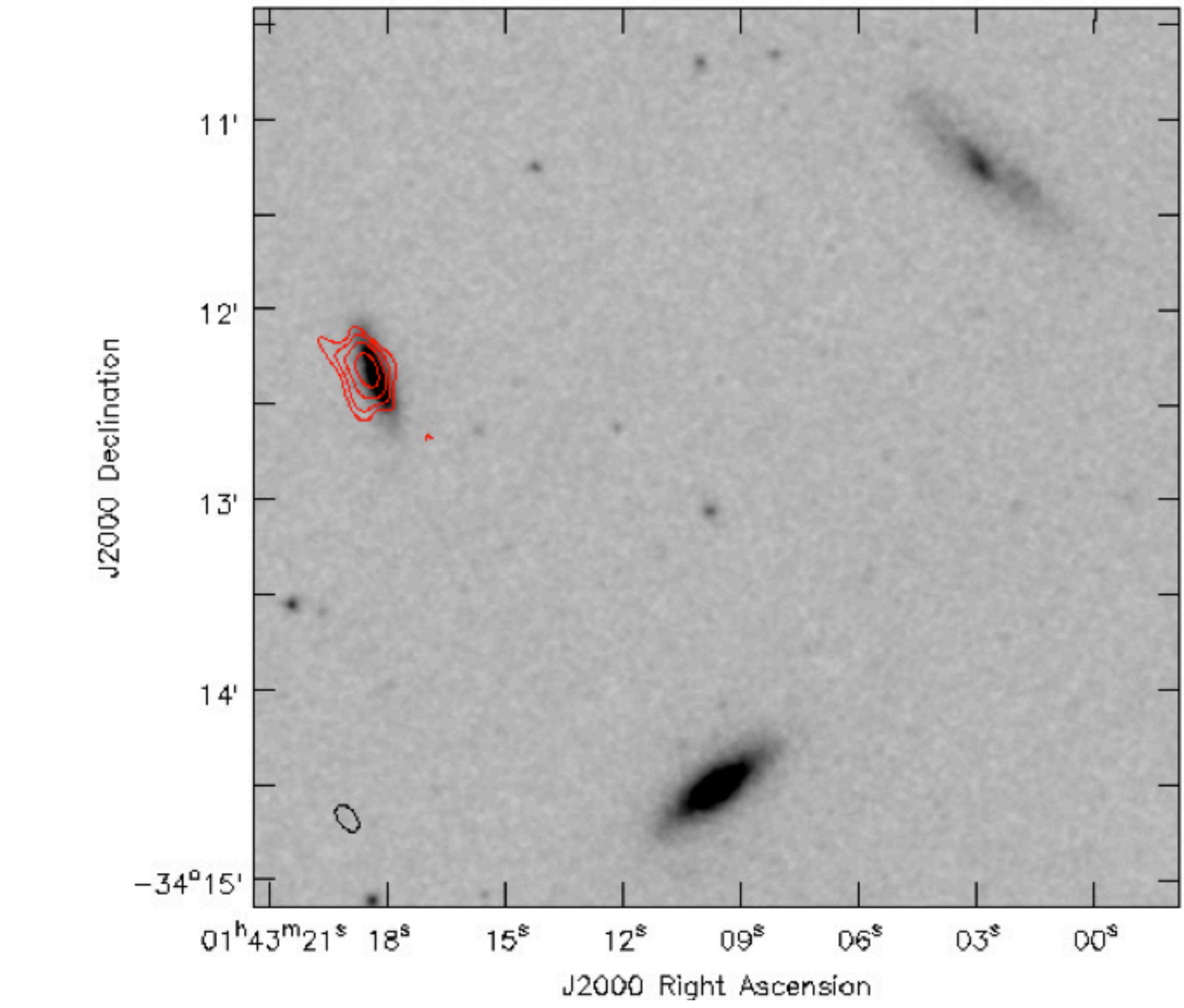
Polarised Intensity

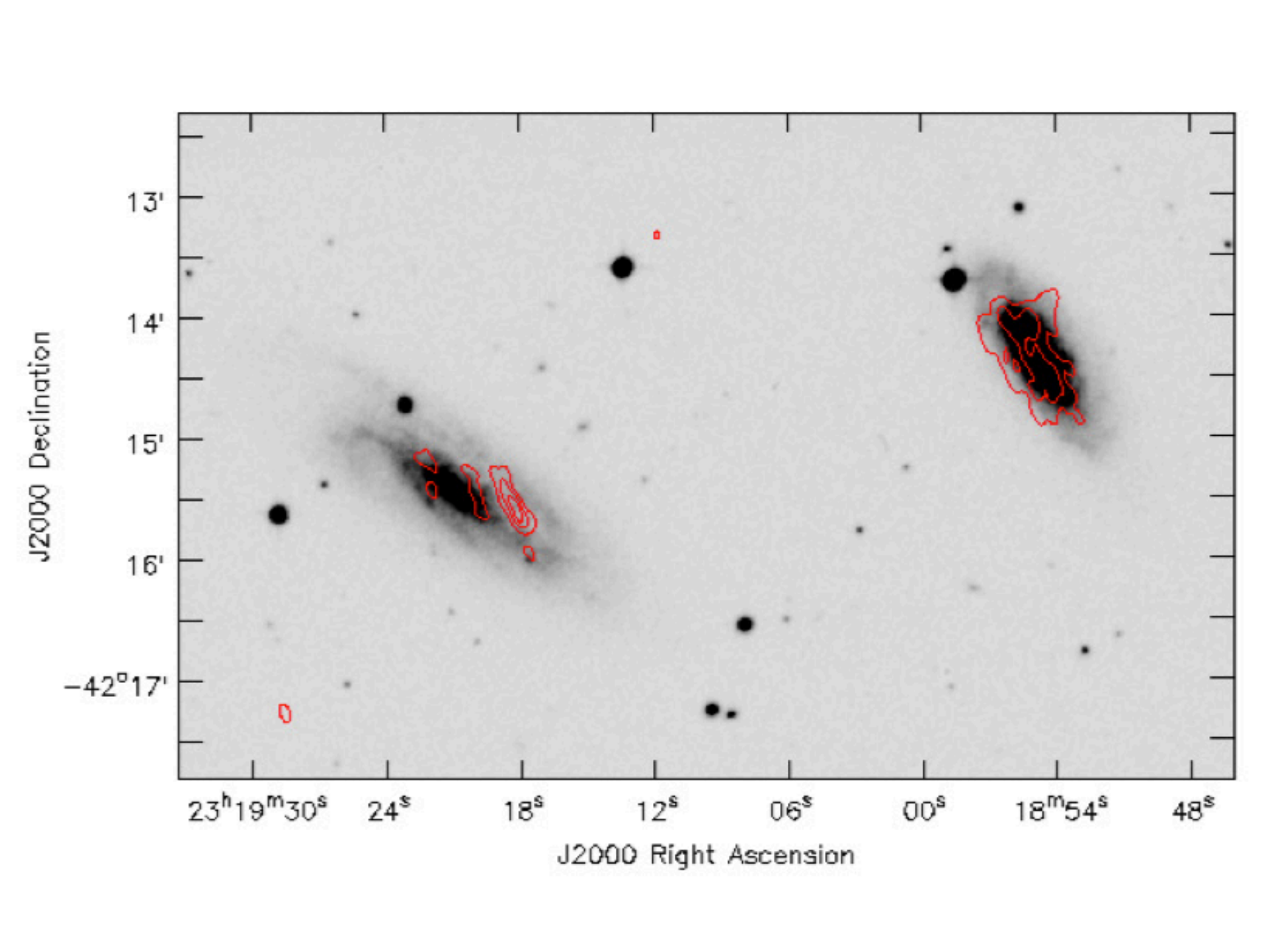


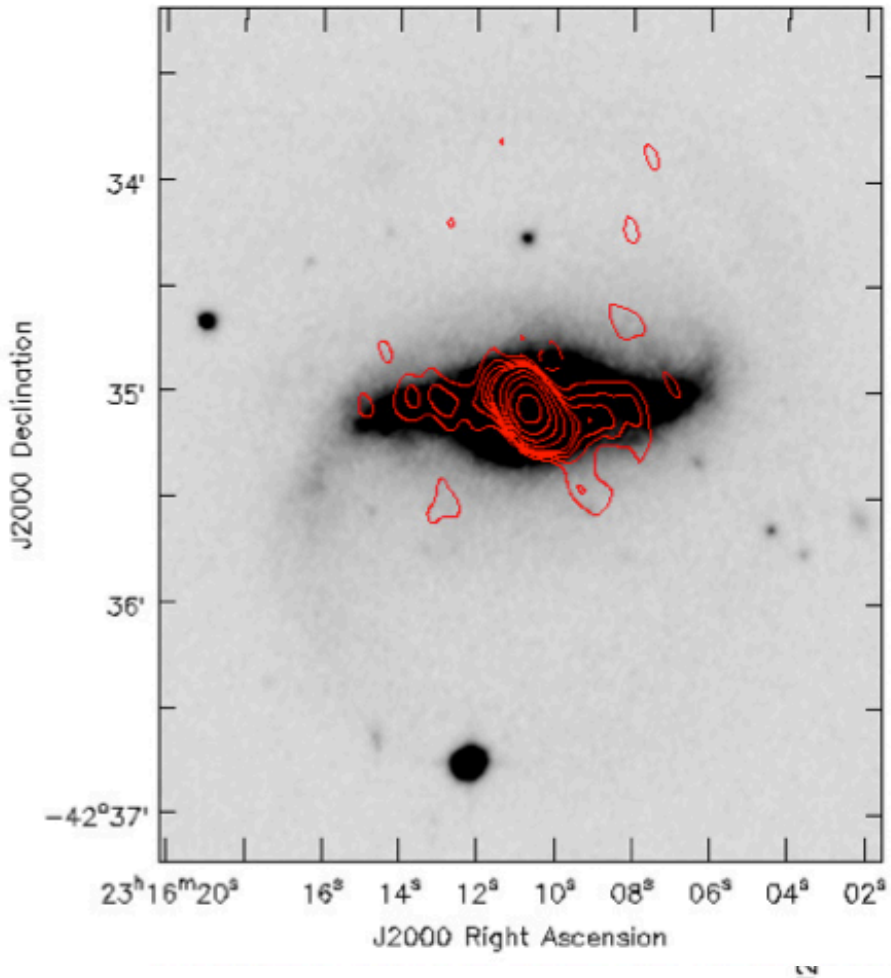

Elevation (arcmin)
40
30
20
10
0
−10
−20
−30
−40
Azimuth (arcmin)
40
30
20
10
0
−10
−20
−30
−40
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
−0.08
−0.1

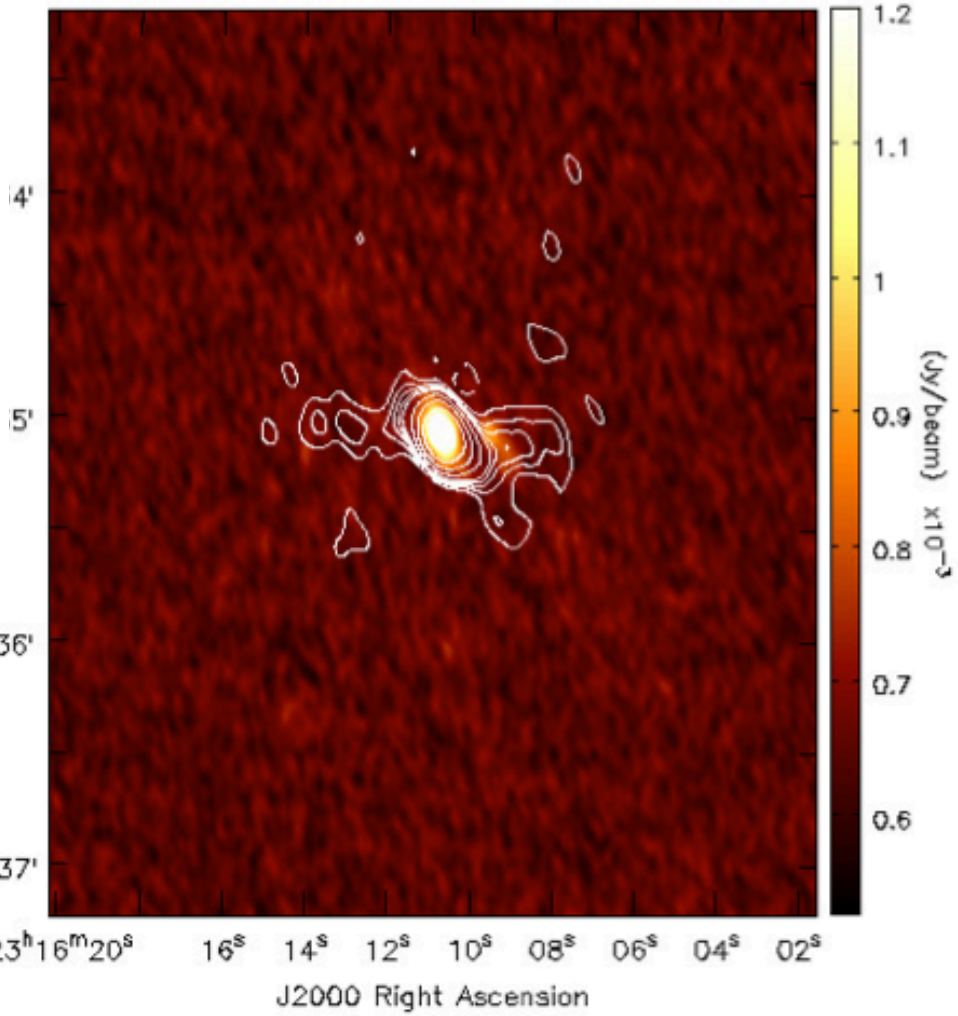
$$R = \sum_{i=1}^{k} I_i(x,y)\left\{Q(x',y') + iU(x',y')\right\} e^{2i\chi} \ni \begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\chi & \sin\chi \\ -\sin\chi & \cos\chi \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

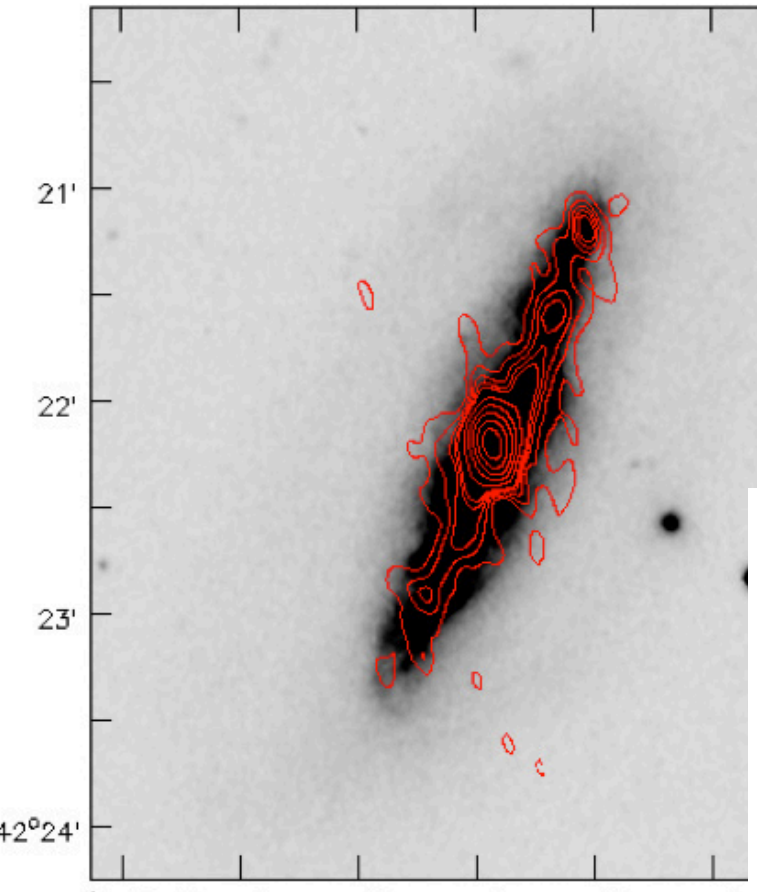


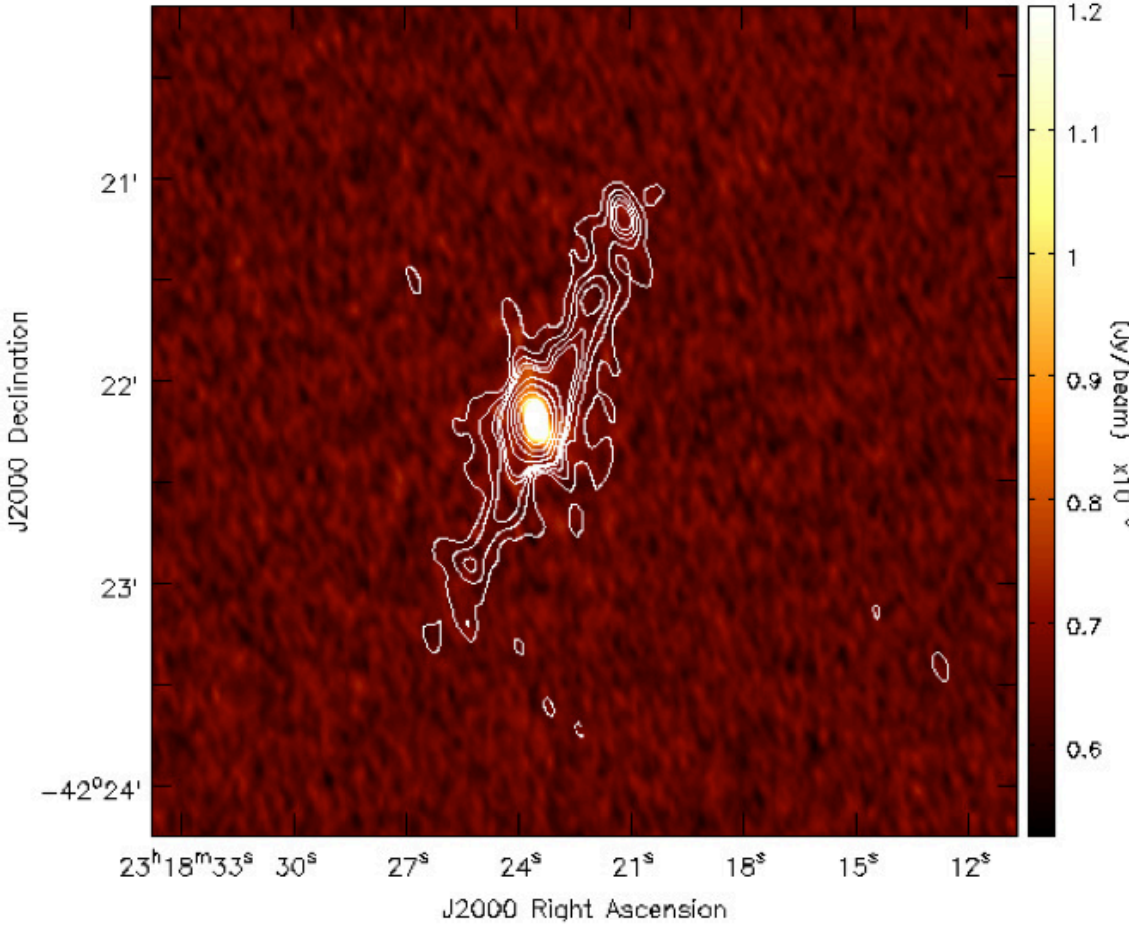

11'
12'
13'
14'
−34°15'
J2000 Declination
01h43m21s
18s
15s
12s
09s
06s
03s
00s
J2000 Right Ascension

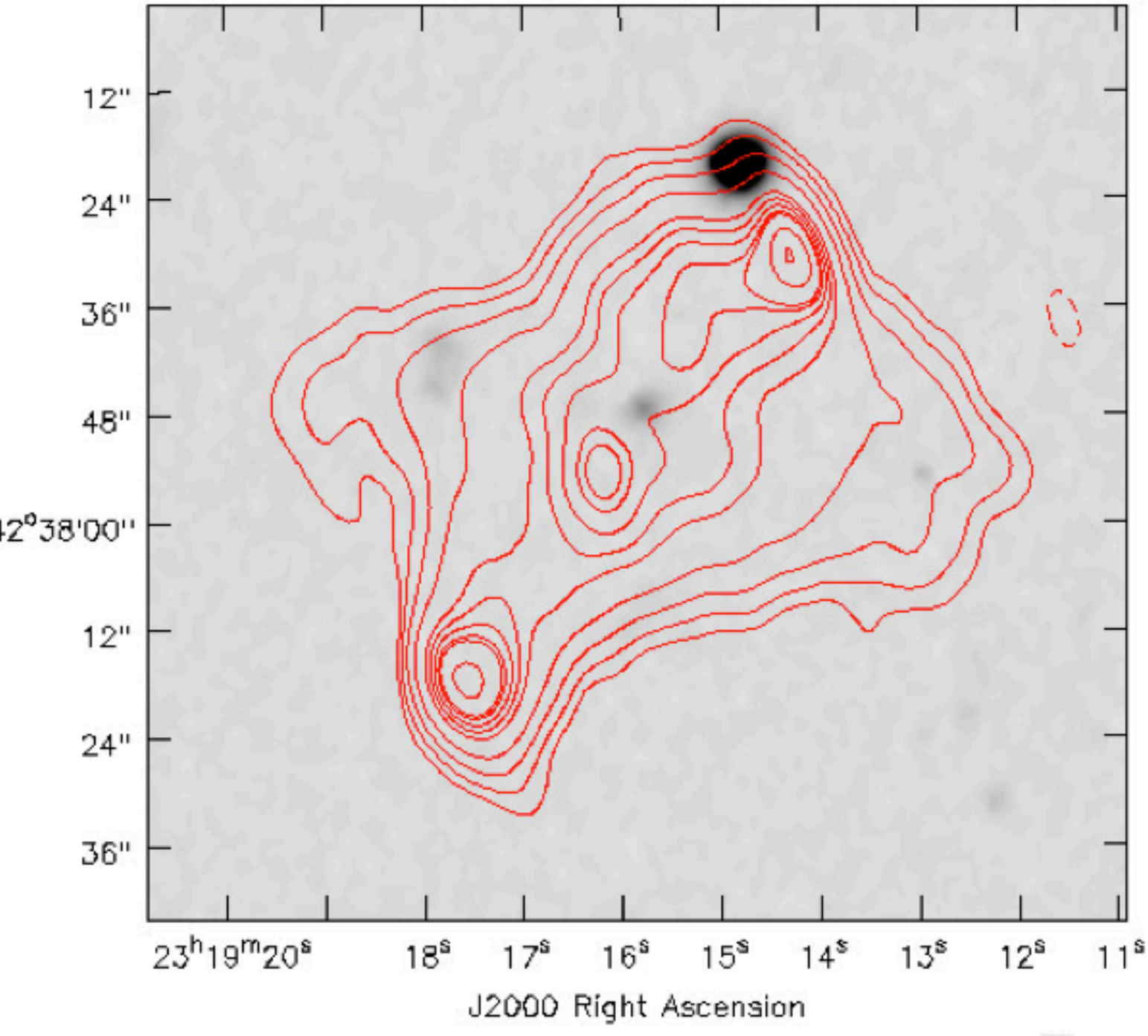

13'
14'
15'
16'
−42°17'
J2000 Declination
23h19m30s
24s
18s
12s
06s
00s
18m54s
48s
J2000 Right Ascension


34'
35'
36'
−42°37'
J2000 Declination
23h16m20s
16s
14s
12s
10s
08s
06s
04s
02s
J2000 Right Ascension


4'
5'
36'
−42°37'
23h16m20s
16s
14s
12s
10s
08s
06s
04s
02s
J2000 Right Ascension
1.2
1.1
1
0.9
0.8
0.7
0.6
(Jy/beam) x10−3


21'
22'
23'
42°24'
23h18m33s 30s 27s 24s 21s 18s
J2000 Right Ascension


21'
22'
23'
−42°24'
J2000 Declination
23h18m33s 30s 27s 24s 21s 18s 15s 12s
J2000 Right Ascension
1.2
1.1
1
0.9
0.8
0.7
0.6
(Jy/beam) x10

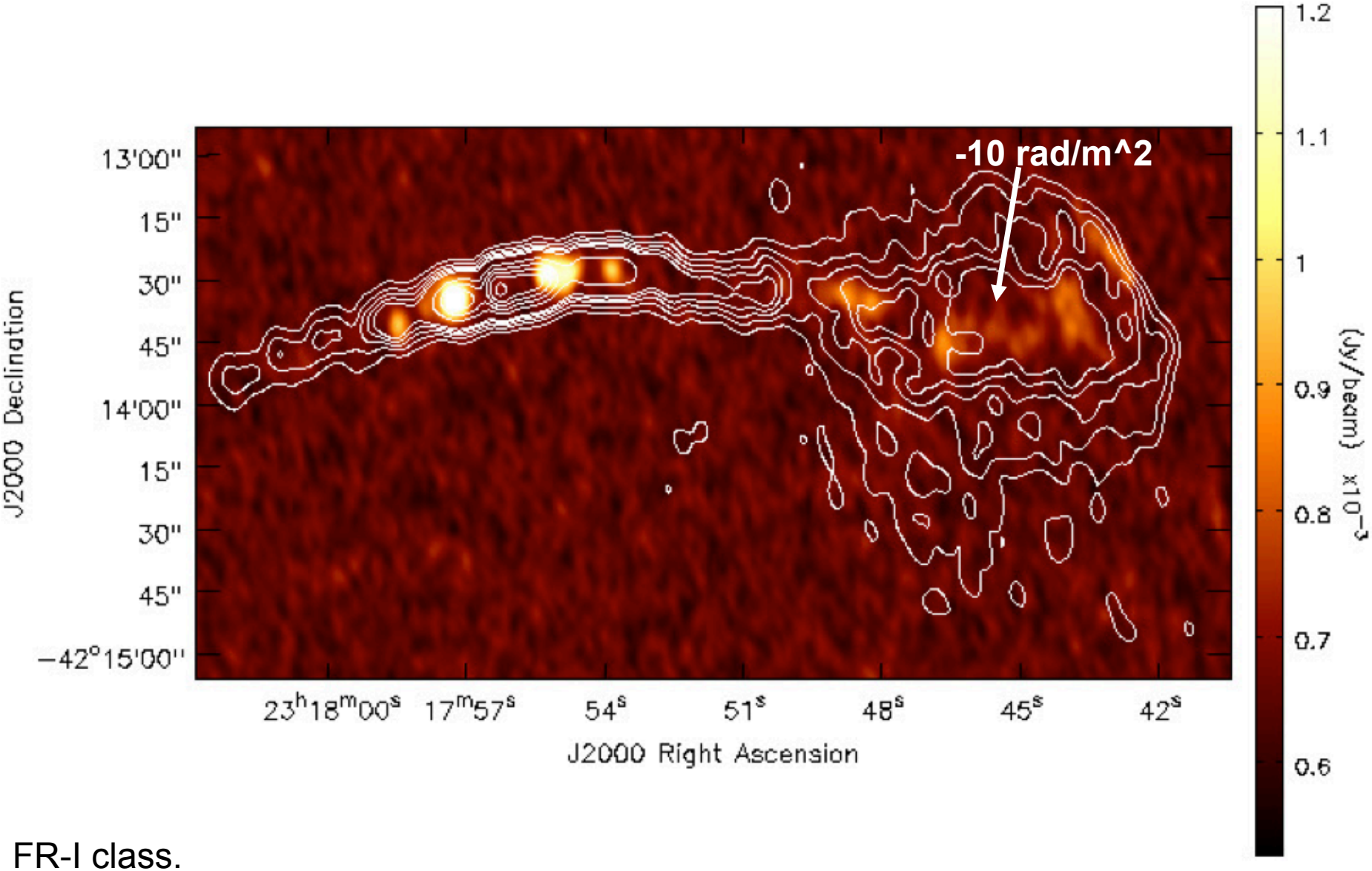


α = 0.57±0.13

X-shaped radio source

P (%)	5.2±0.4	4.0±0.3	2.2±0.2	3.2±0.3
FD (rad/m^2)	+15.9±1.3	+12.7±0.5	+22.1±0.6	+27.4±1.1

AGN



FR-I class.

Large-scale change of sign of the magnetic field in the jet relative to the nucleus.

Summary (1)

- Setting up an instrument for wide-field spectropolarimetry at low radio frequencies requires many systematics to be dealt with, but crucial for understanding cosmic magnetism.

- Some initial probes of galaxy interactions with the GMRT find a number of interesting sources, and make useful measurements of the group members' spectral index, polarisation fraction, and Faraday dispersion function.

- BUT we find no evidence for interaction with the IGM in either group:
  - Either tidal interactions or ram pressure from the IGM does not significantly compress the magnetic field of these group galaxies,
  - Or a substantial improvement in sensitivity is still required to probe galaxy interactions via polarimetry at low frequencies (Faraday depolarisation likely significant for our limited sample).

Summary (2)

- The GMRT can now be used for μJy level full-polarisation radio surveys at low frequencies with a large field of view – a new tool to probe magnetic fields.

- Multiple new facilities about to observe the magnetic Universe at a range of frequencies:
  - LOFAR @ <230 MHz
  - JVLA @ > 1.2 GHz
  - ASKAP @ 700 MHz – 1.8 GHz
  - GALFACTS (Arecibo) @ 1.2 GHz – 1.5 GHz

- A GMRT upgrade is underway – likely to provide nearly seamless frequency coverage from 50 MHz – 1.5 GHz with instantaneous bandwidths of 400 MHz. Centred within an important observational void of the SKA pathfinders...

Thanks for listening!