Searching for Magnetic Fields at Low Frequencies: Early Observation with LOFAR on M51 & NGC4631

David Mulcahy

On behalf of the Magnetism KSP

MKSP galaxies & commissioning working groups

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- Krzysztof Chyzy - Jagiellonian University
- Robert Drzazga - Jagiellonian University
- René Giessübel –MPIfR
- George Heald - ASTRON
- Andreas Horneffer - MPIfR
- Wojciech Jurusik - Jagiellonian University
- David Mulcahy – MPIfR
- Blazej Nikiel-Wroczynski – Jagiellonian University
- Carlos Sotomayor - Ruhr-Universität Bochum

Challenges of Lofar

- Huge Field of View with very crowded fields that are brighter at low frequencies. This means more sources will have to be subtracted from the uv data.
- Beamshapes are less well defined and vary more in time & frequency than traditional parabolic reflectors.
- The sidelobe level of the beam is much higher than other parabolic reflectors.
- Rapid ionospheric changes will distort images.

Current Work

- Determining the best & most efficient method of calibration.
- Most ideal imaging parameters for extended emission is being investigated.
- Searching for optimal polarized calibrators:
  →Pulsars with a non-zero Rotation Measure
- Investigating the properties of the Ionosphere.

NGC4631

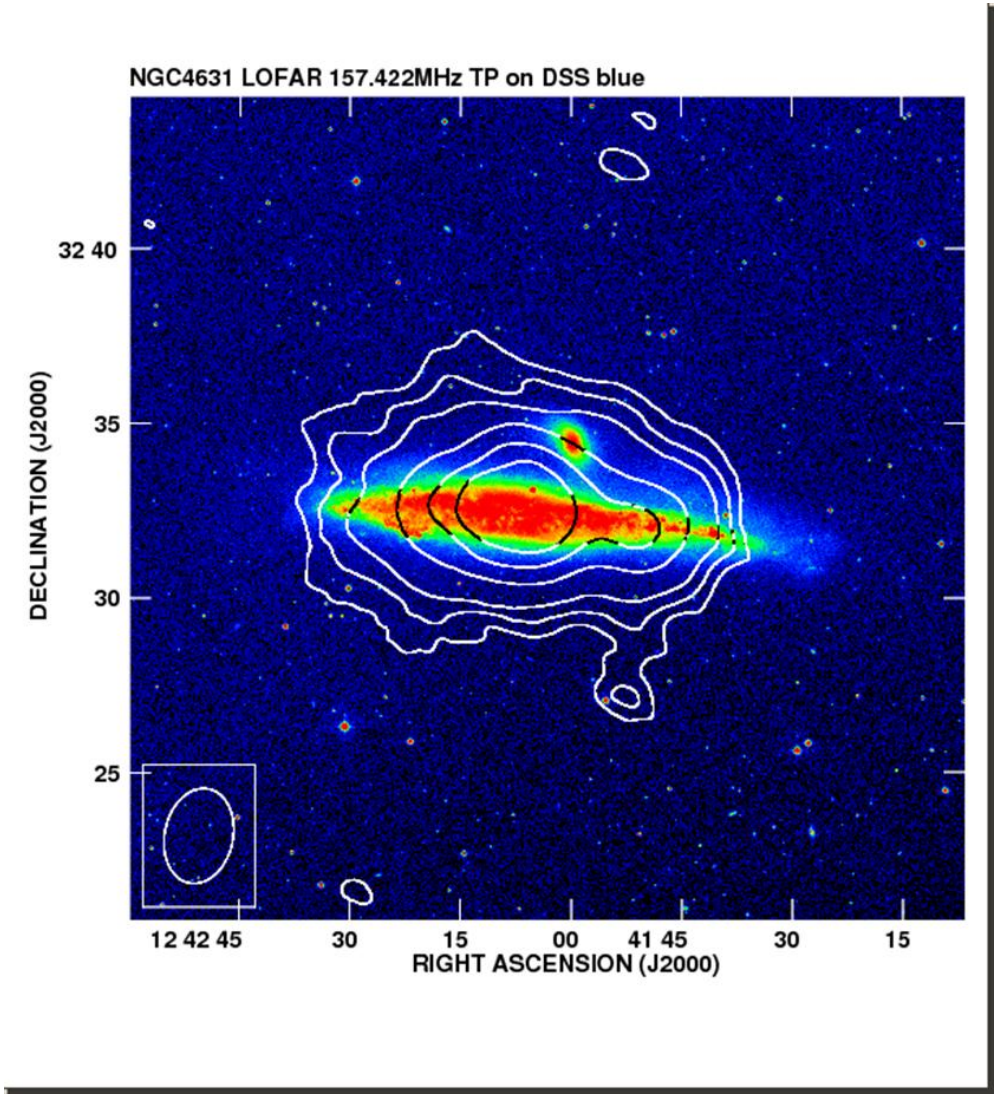
- Edge-on spiral galaxy at a distance of approx 6.7 Mpc.
- Has the largest Radio Halo observed thus far, with a scale height of approximately 2.5kpc.
- Assuming energy equipartition, the scale height of the total magnetic field is approx 10kpc.
- Radio Halo above the inner disk is composed of magnetic spurs connected to star-forming regions in the disk. The magnetic field is most likely dragged by a strong galactic wind.
- Ideal target for LOFAR observations

Marita Krause

NGC4631

LOFAR Observation

- Observed with LOFAR HBA (120-240MHz)
- Observed for 7 hours
- Dual-beam observation half of beamlets hence half of subbands.
- Observed calibrator 3C286 simultaneously
- Same frequency coverage on both source & calibrator
- 122 frequency channels of 210 KHz for source & calibrator.

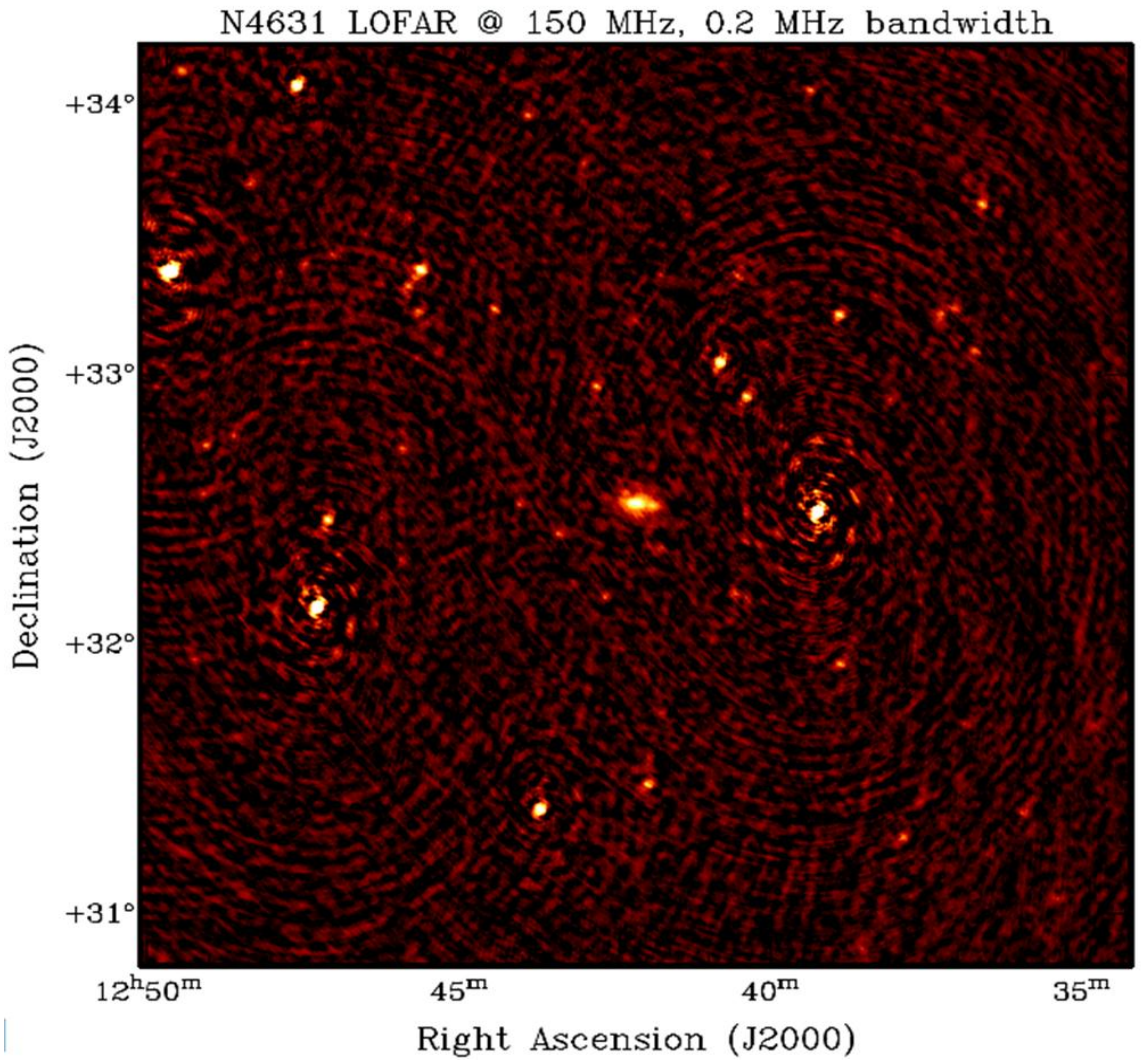


Robert Drzazga

NGC4631

LOFAR Observation – SelfCal Calibration

Calibration in BBS on a single source 4C+32.40 with a total flux density of 3.2 Jy at 157MHz (Single Subband), followed by two loops of self-calibration. Briggs weighting: robust = 1.0

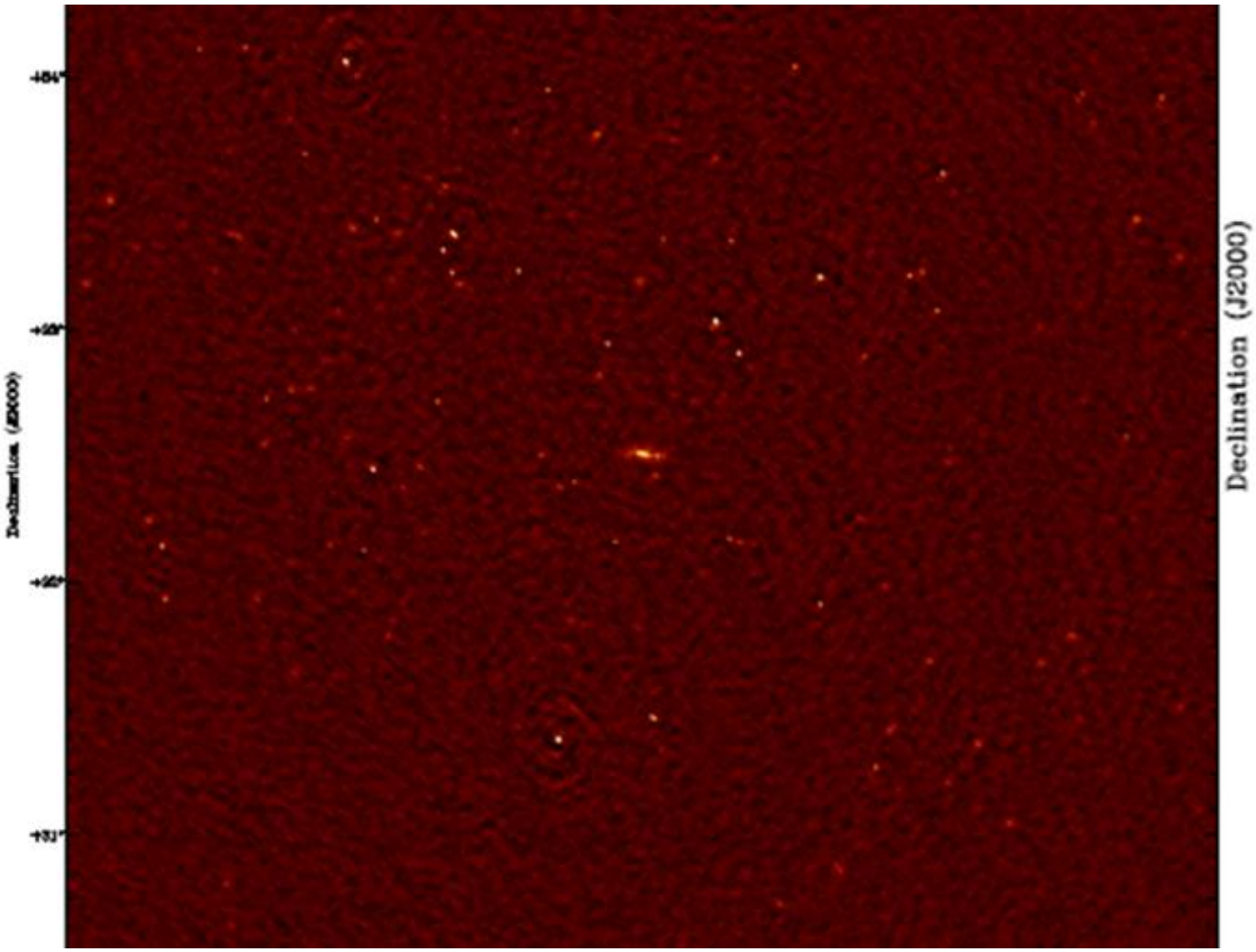


George Heald

NGC4631

LOFAR Observation – Transfer of Gain Solutions

Calibrated 3C286 first and then transferred the obtained Gain Solutions to NGC4631. Above image: robust = 0; 30’’ taper; no cleaning.



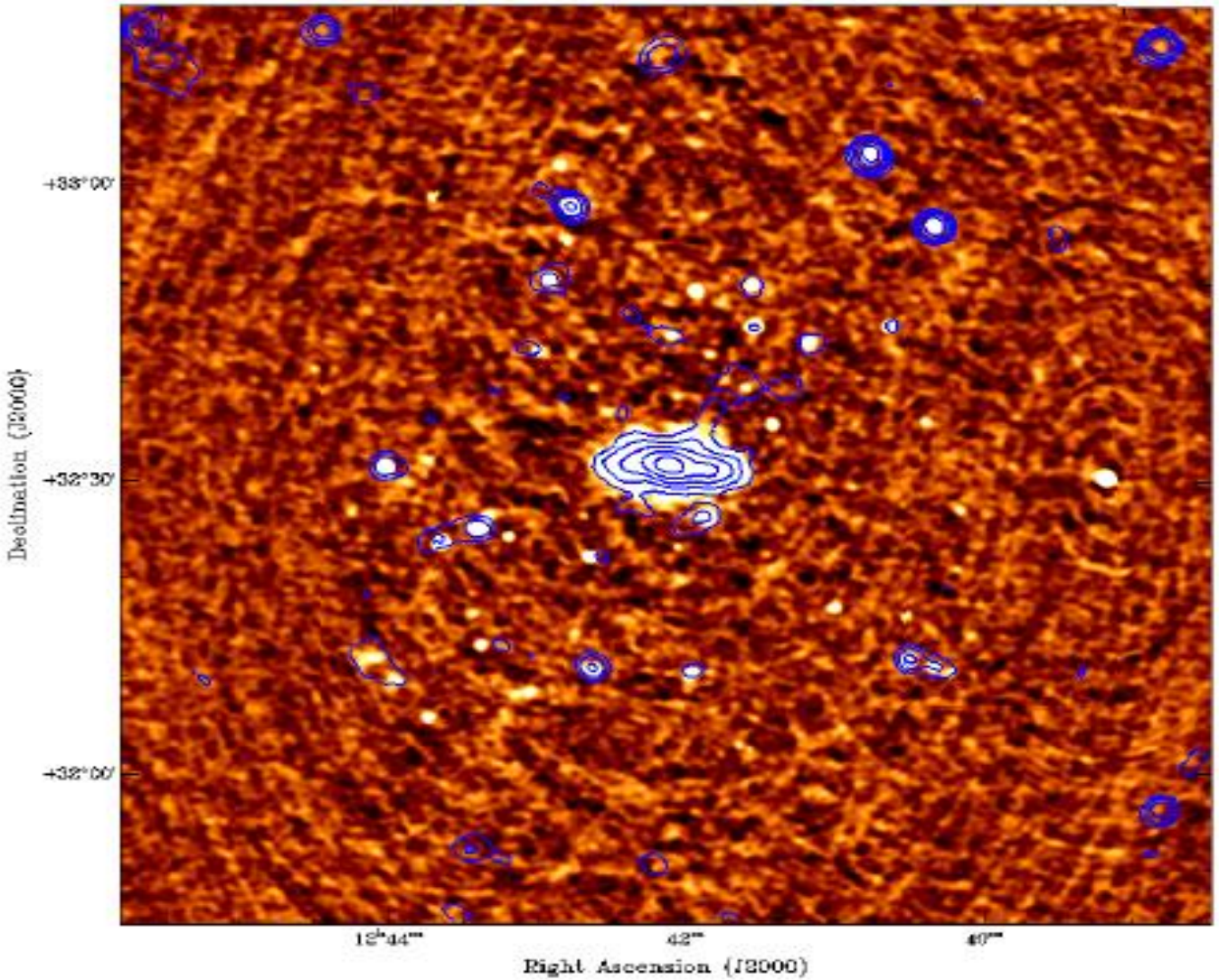
WIDEFIELD

George Heald

NGC4631

LOFAR Observation – Transfer of Gain Solutions

Images were produced after self cal and removing 3 brightest sources in the field using direction-dependent gains.



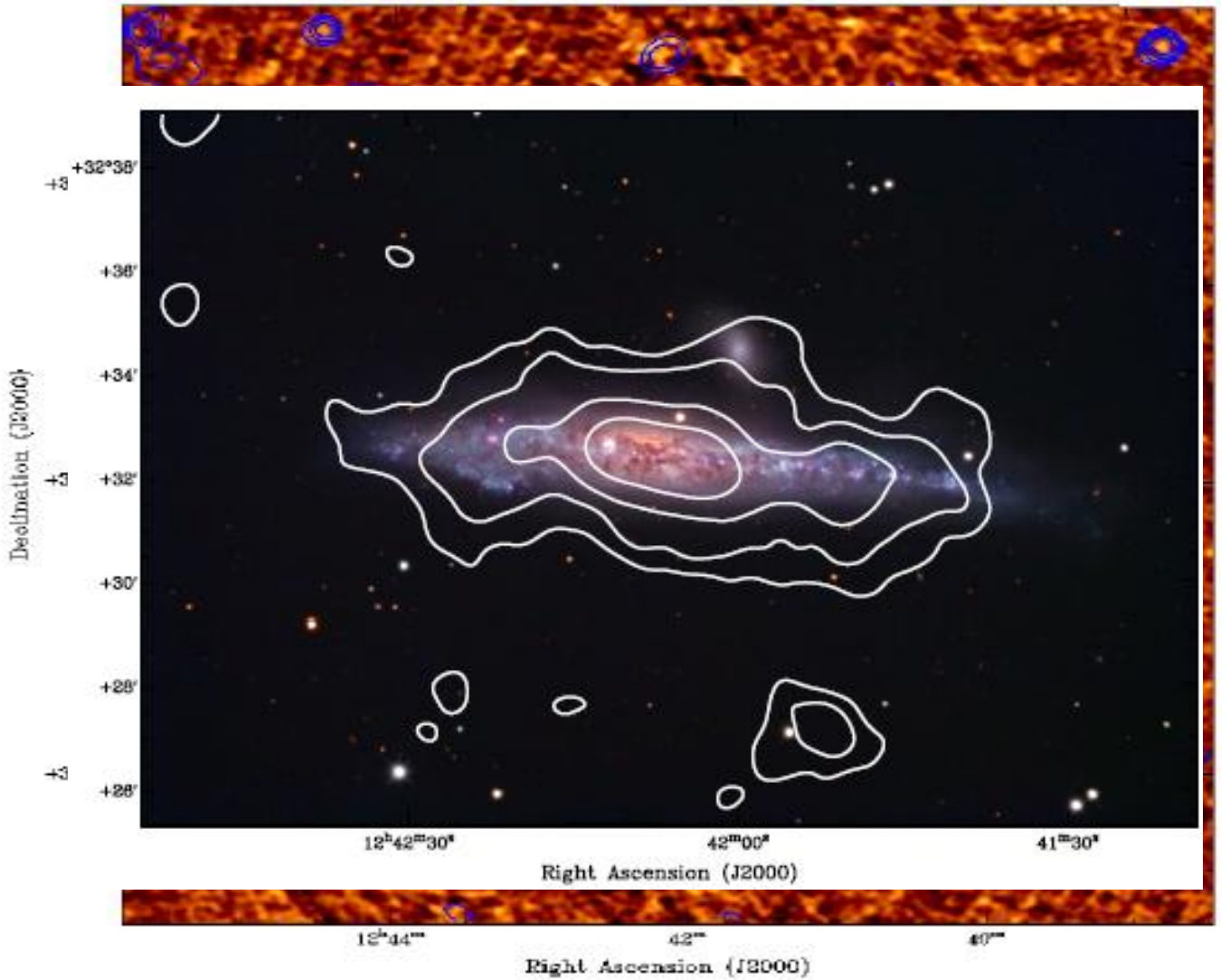
Overlaid onto HALOGAS Image

George Heald

LOFAR Observation – Transfer of Gain Solutions

Images were produced after self cal and removing 3 brightest sources in the field using direction-dependent gains.

HALOGAS- HI survey with WSRT



Closeup:
Overlaid onto
Optical Image

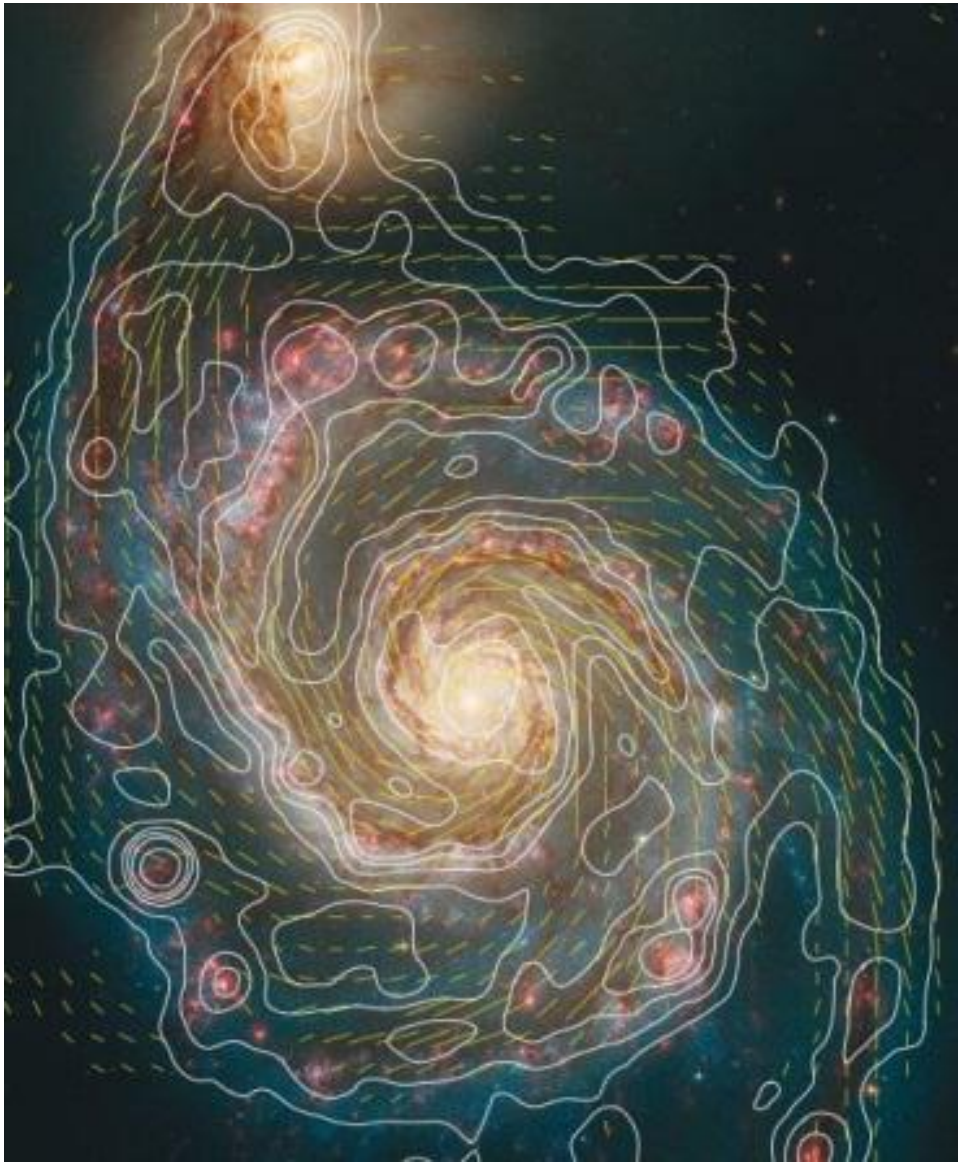
George
Heald

LOFAR Observation – Transfer of Gain Solutions

Images were produced after self cal and removing 3 brightest sources in the field using direction-dependent gains.

M51

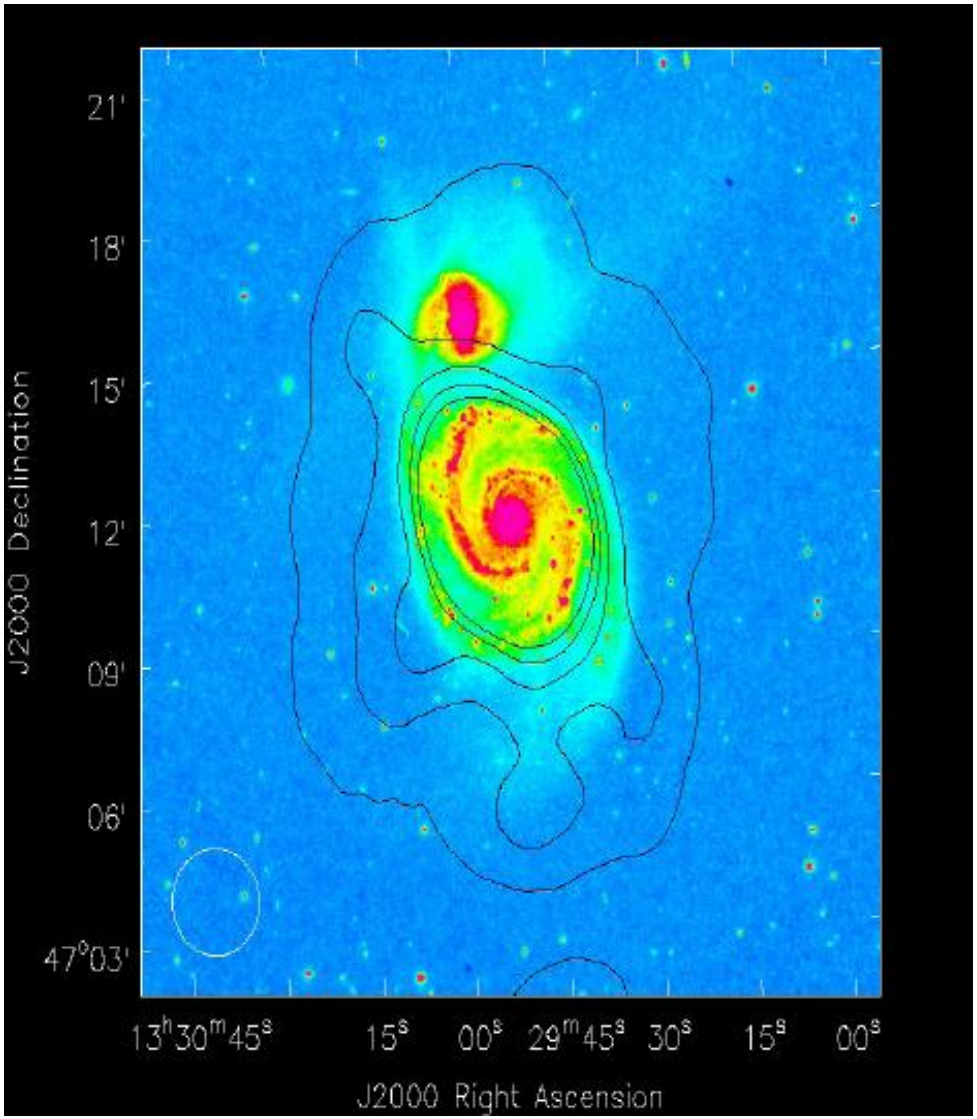
- M51 is a grand-design spiral galaxy with two very prominent spiral arms.
- Perturbed by its close companion NGC5195 which may have resulted in two systems of density waves.
- Orientation of the magnetic field lines follow very closely the spiral arms. (Berkhuijsen et al. 1996, Patrickeyev et al 2006)



Fletcher, Beck et al

M51 LOFAR Observation – Self calibration

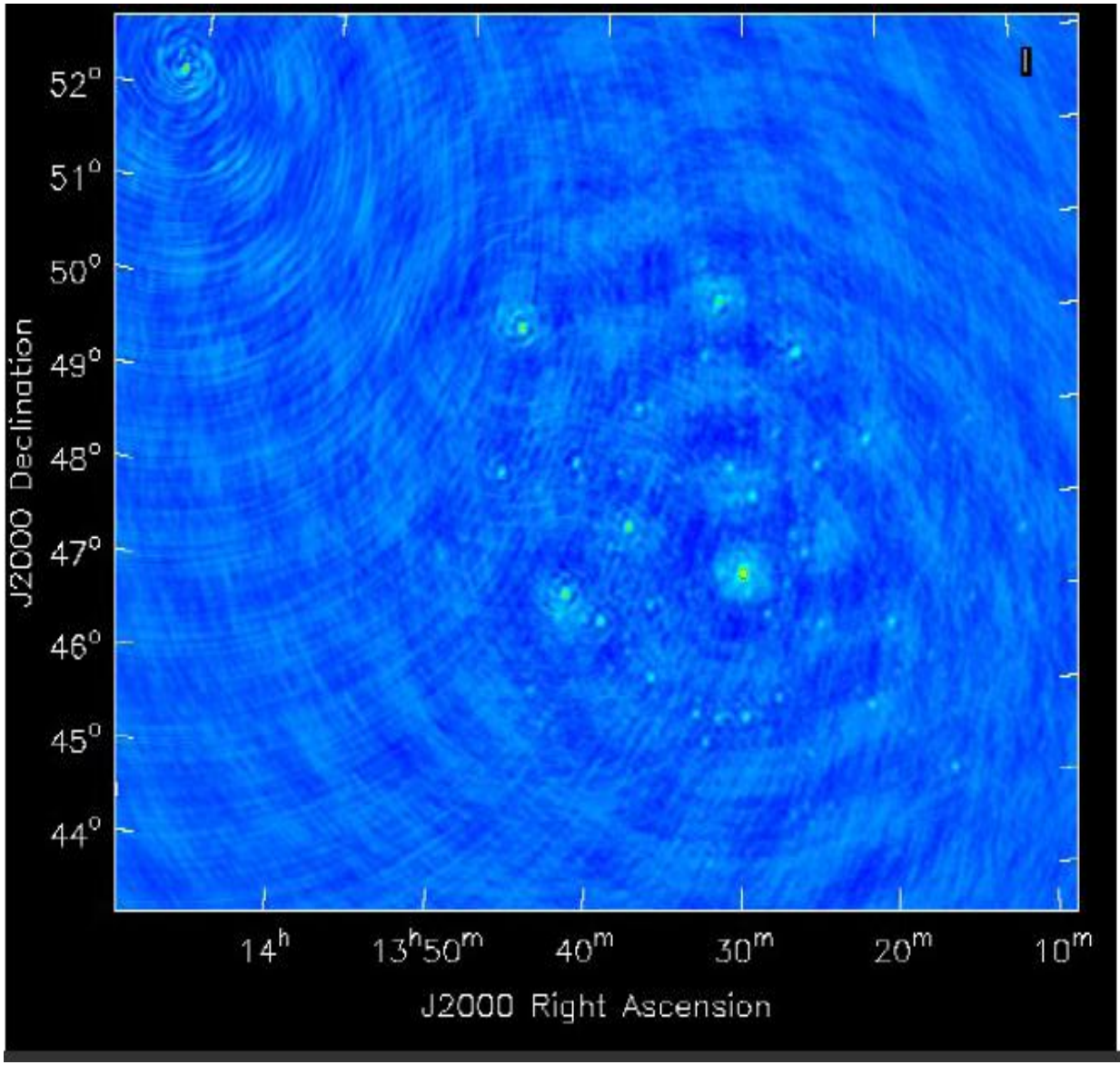
- Observed with LOFAR HBA (120-240MHz).
- Observed for 6 hours.
- Observed calibrator 3C295 simultaneously.
- Same frequency coverage on both source & calibrator.
- 121 frequency channels of 210 kHz for source & calibrator.
- Image of M51 using simple WENSS skymodel overlaid on NVSS at 139MHz



David Mulcahy

M51
LOFAR Observation – Transfer of Gain Solutions

- Calibrator 3C295 was calibrated and the Gain solutions were transferred to M51.
- Shown Right is Subband 60 at 139.06MHz; widefield view
- Natural weighting used

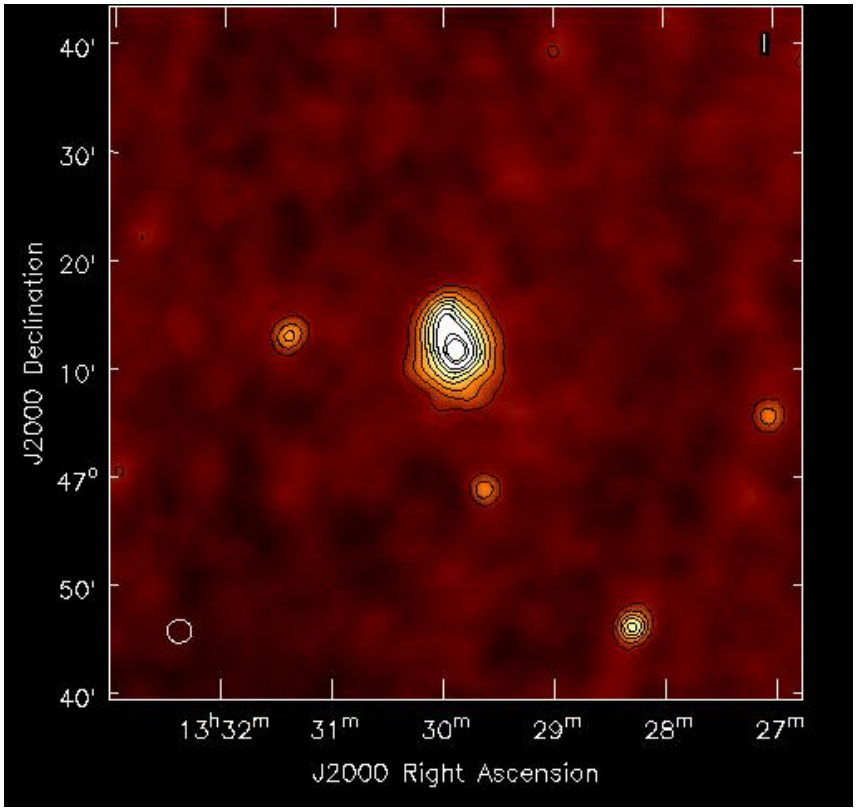


David Mulcahy

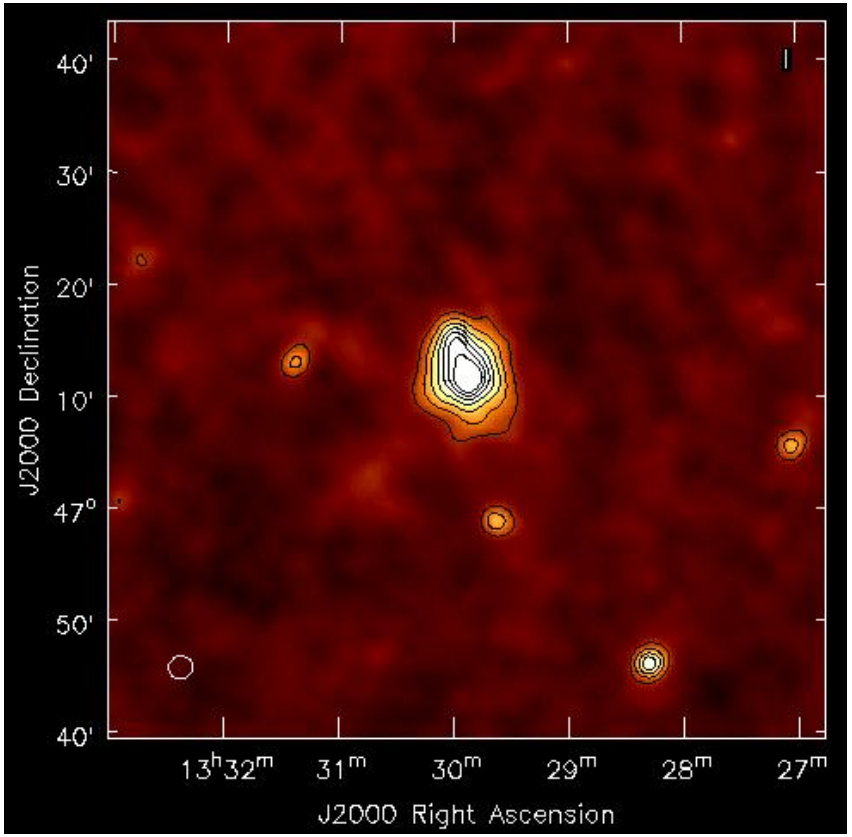
M51 LOFAR Observation

Transfer of Gain Solutions

Subband 79 (145.12MHz)



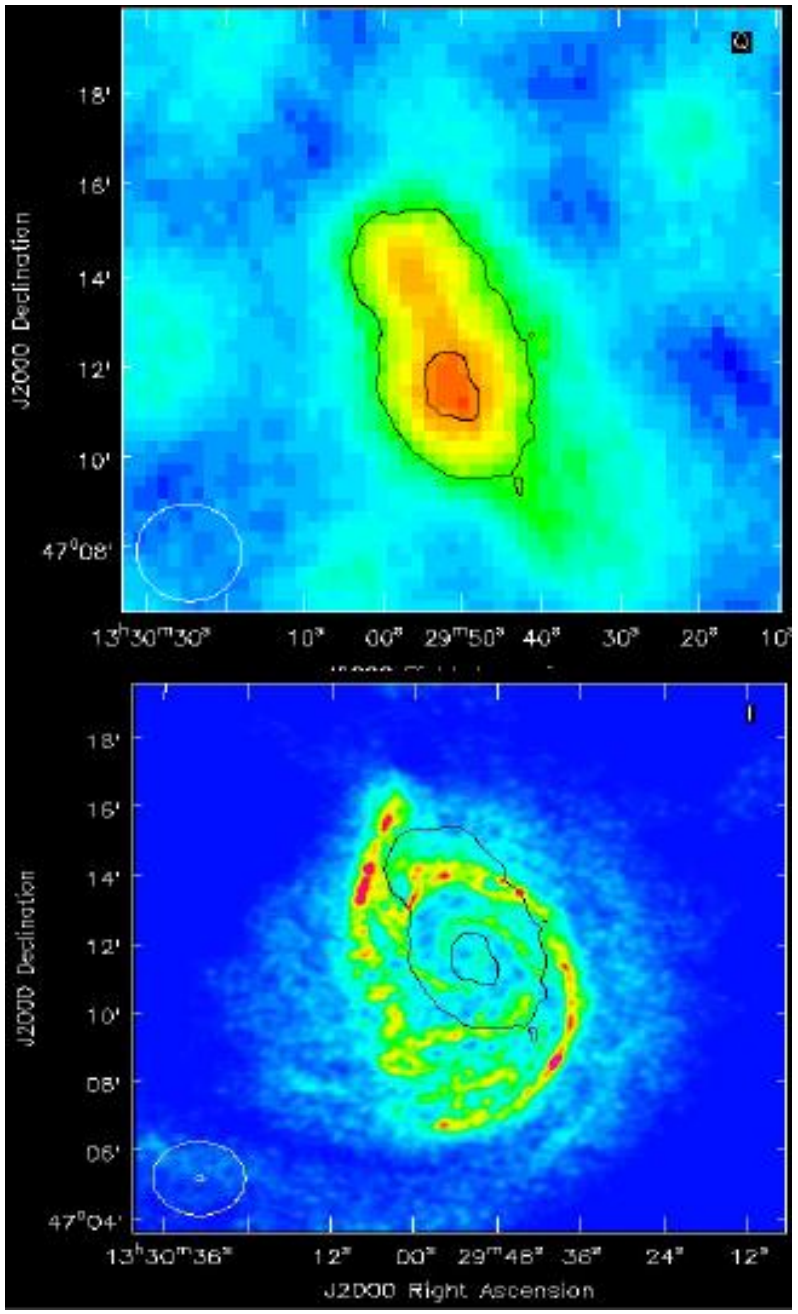
Subband 121 (162.89MHz)



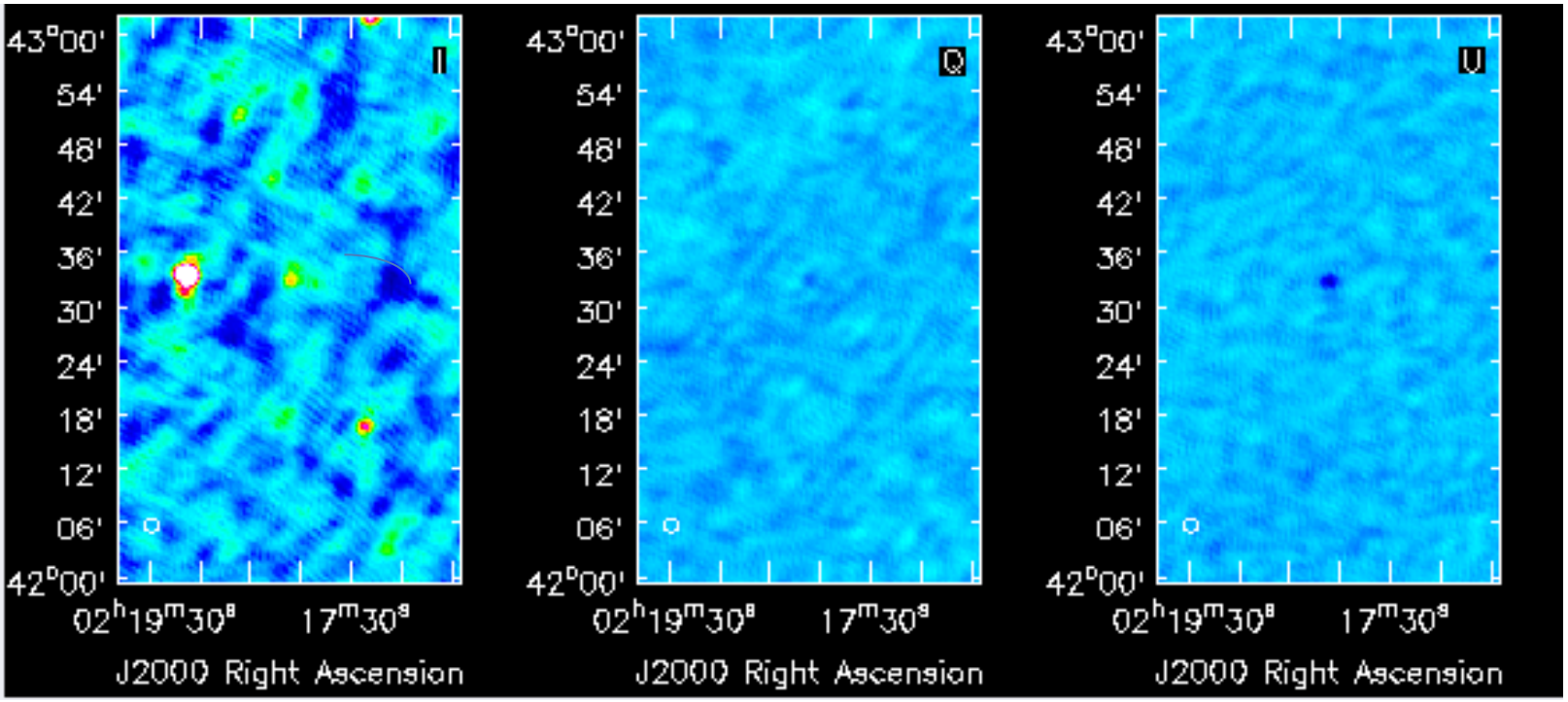
David Mulcahy

M51 LOFAR Observation – Instrumental Polarization

- Subband 60 (139MHz) shows polarization at the location of M51.
- Unlikely to see real polarization in a single subband due to bandwidth depolarization as we are dealing with long wavelengths . Instrumental polarization is too strong, signal to noise is too weak.
- Therefore, RM Synthesis is needed to separate instrumental and real polarization.
- Observations of PSR 0218 with LOFAR show this.



David Mulcahy



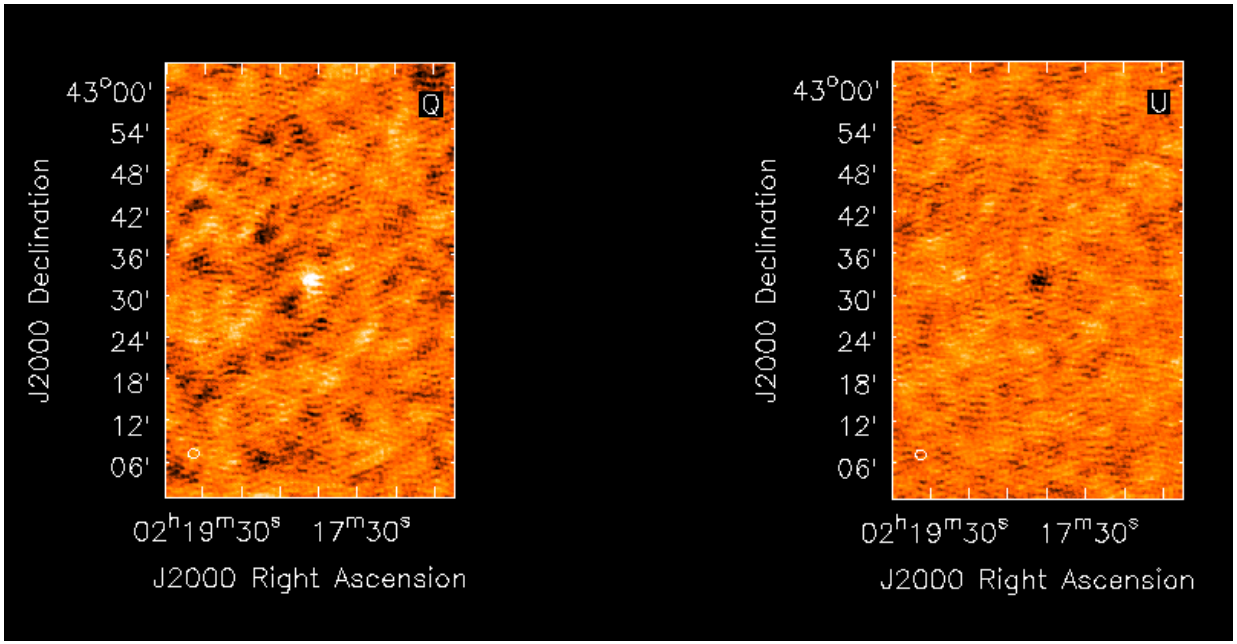
Andreas Horneffer

PSRJ0218

- Pulsar can be seen in Stokes I & U clearly
- Subband 110 3rd channel – 146.898MHz
- First detection of polarization with LOFAR in imaging data

PSR 0218

- Pulsar visible in subband 81 (138MHz).
- Shown here are channels 1-4
- Pulsar is clearly seen & the polarized emission can be seen to rotates fast through Q & U.



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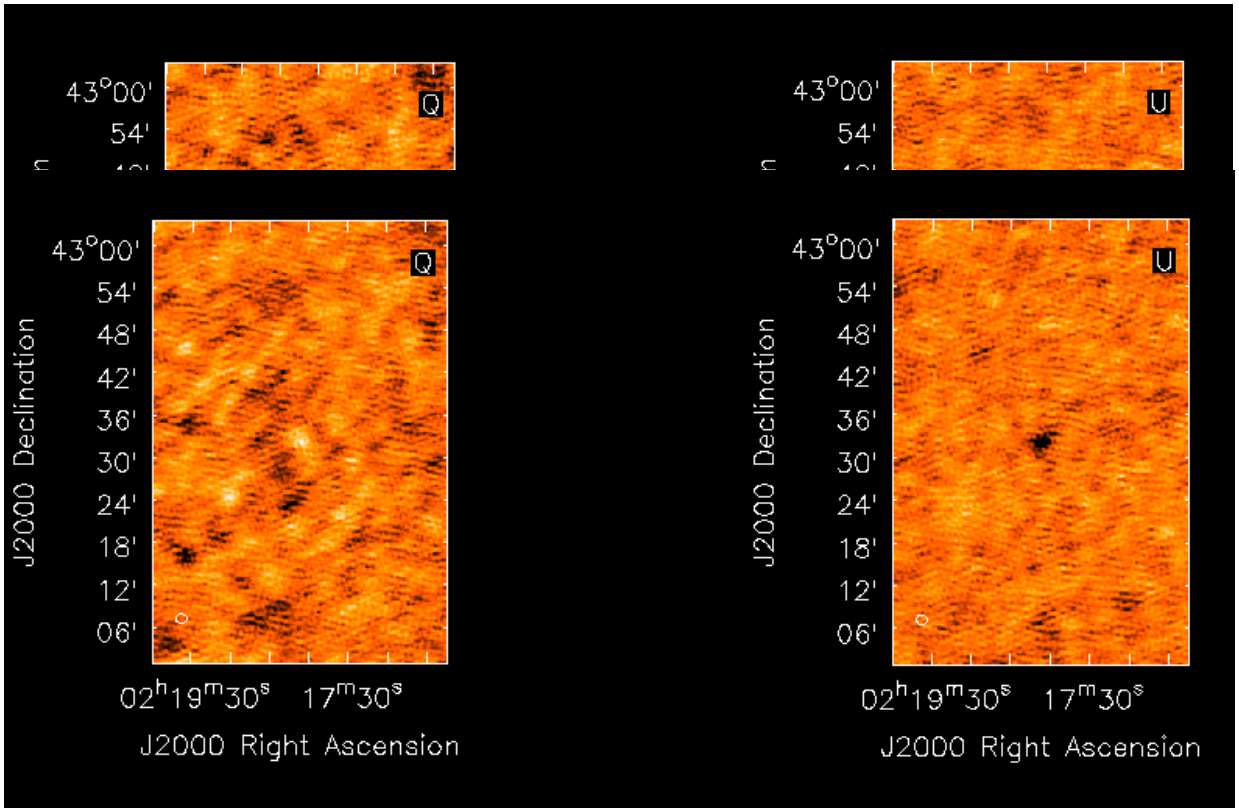

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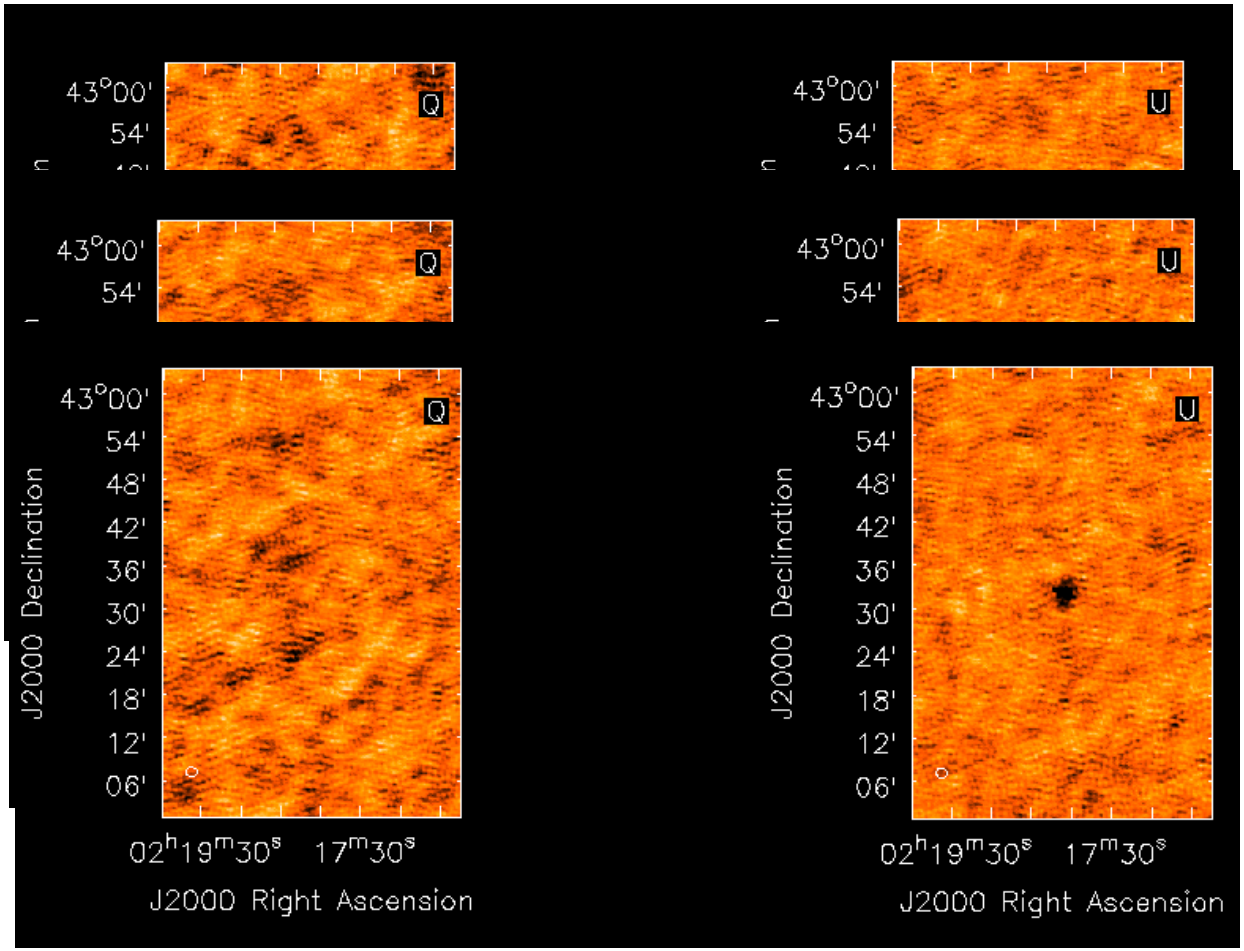

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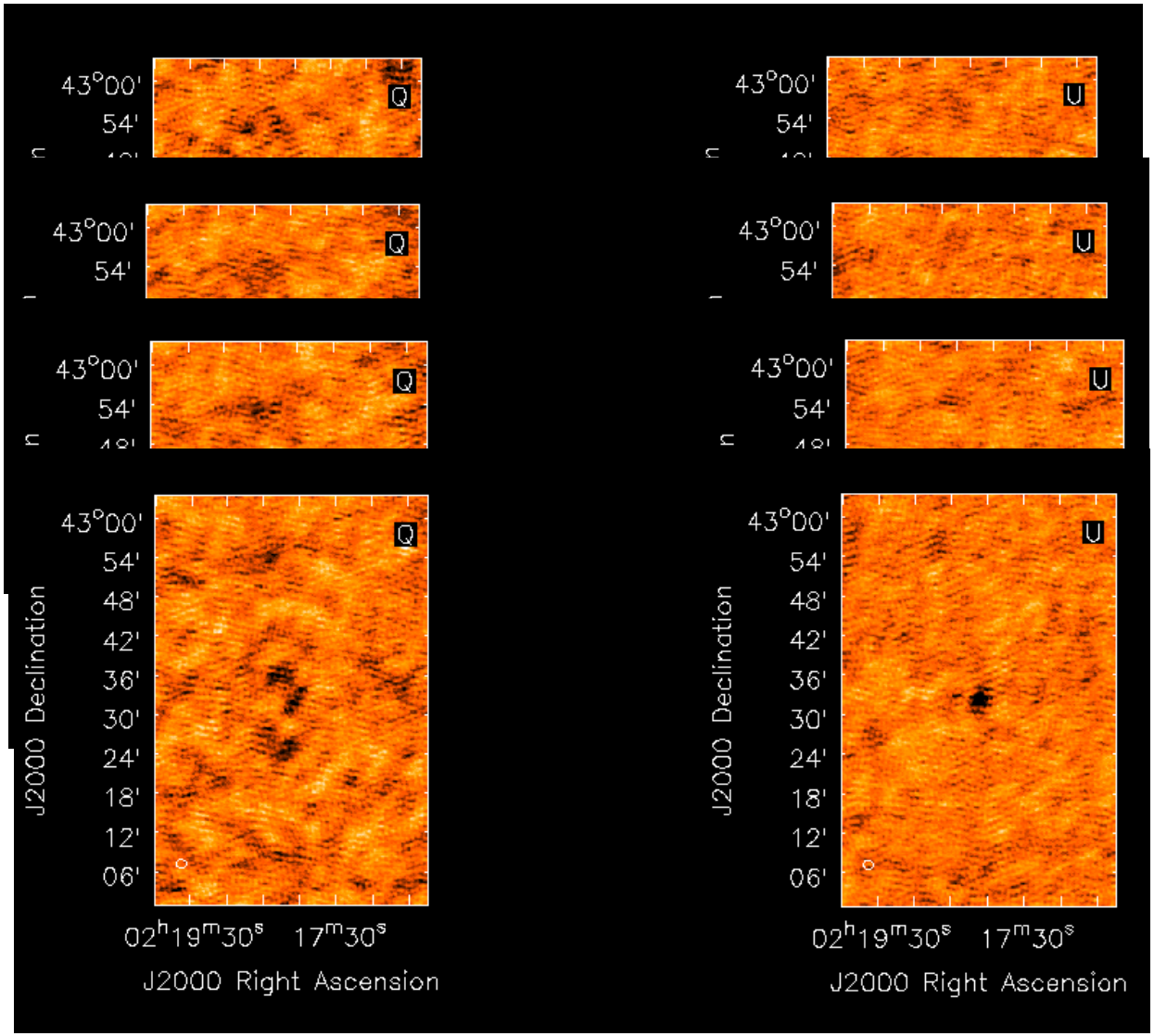
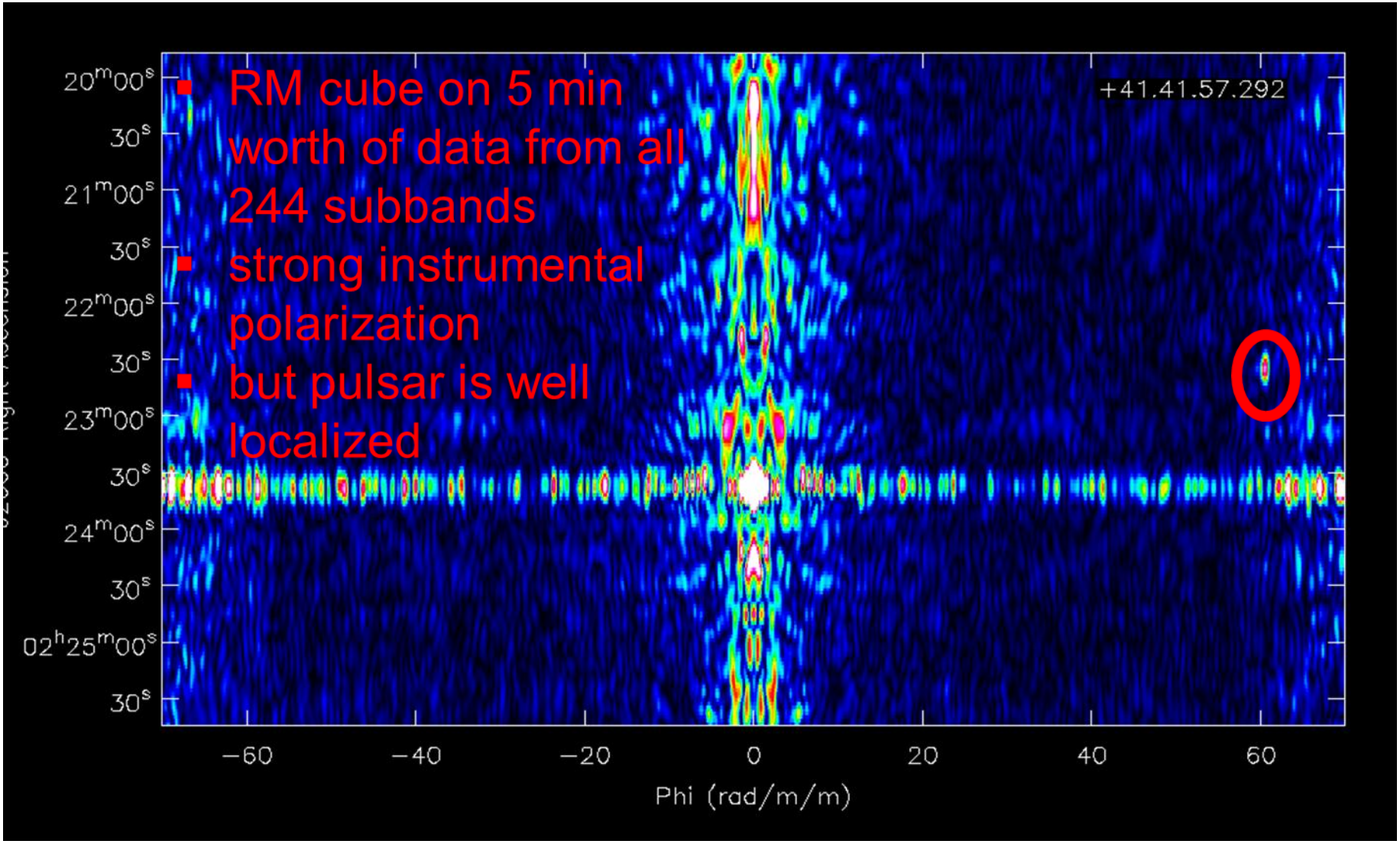


Mike Bell

PSR 0218 – RM Synthesis

Faraday depth spectrum vs right ascension at constant declination



Mike Bell & Andreas Horneffer

Conclusions

- NGC4631 & M51 are clearly visible at LOFAR frequencies
- Polarization of pulsars can be detected by LOFAR.
- Much progress has been made in recent months with respect to commissioning.
- However, much more work is needed especially with respect to calibration and detection of diffuse polarized emission.