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faculty of mathematics  
 and natural sciences

kapteyn astronomical  
 institute



**ASTRON**

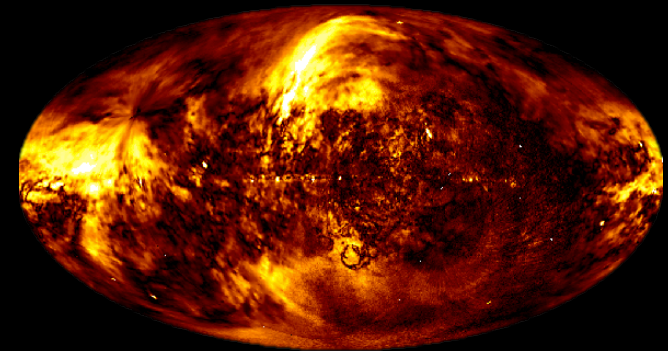
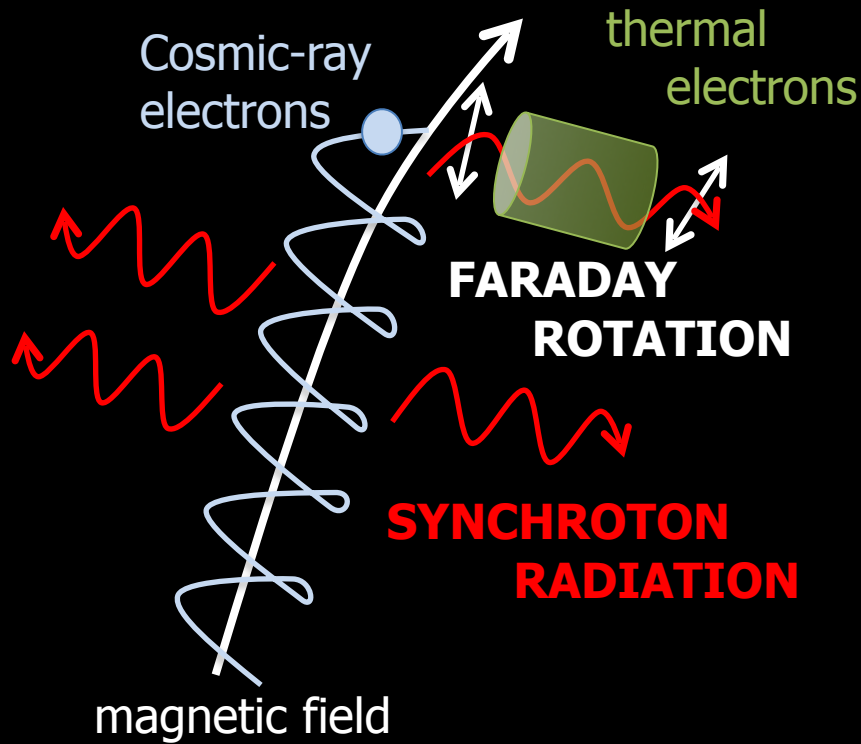
Netherlands Institute for Radio Astronomy

# Galactic polarized emission detected in the LOFAR-EoR observing windows

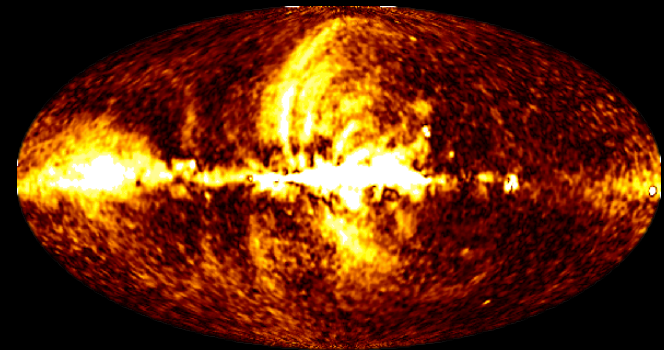
**Vibor Jelić\***

\*on behalf of the LOFAR-EoR team

# Galactic diffuse emission

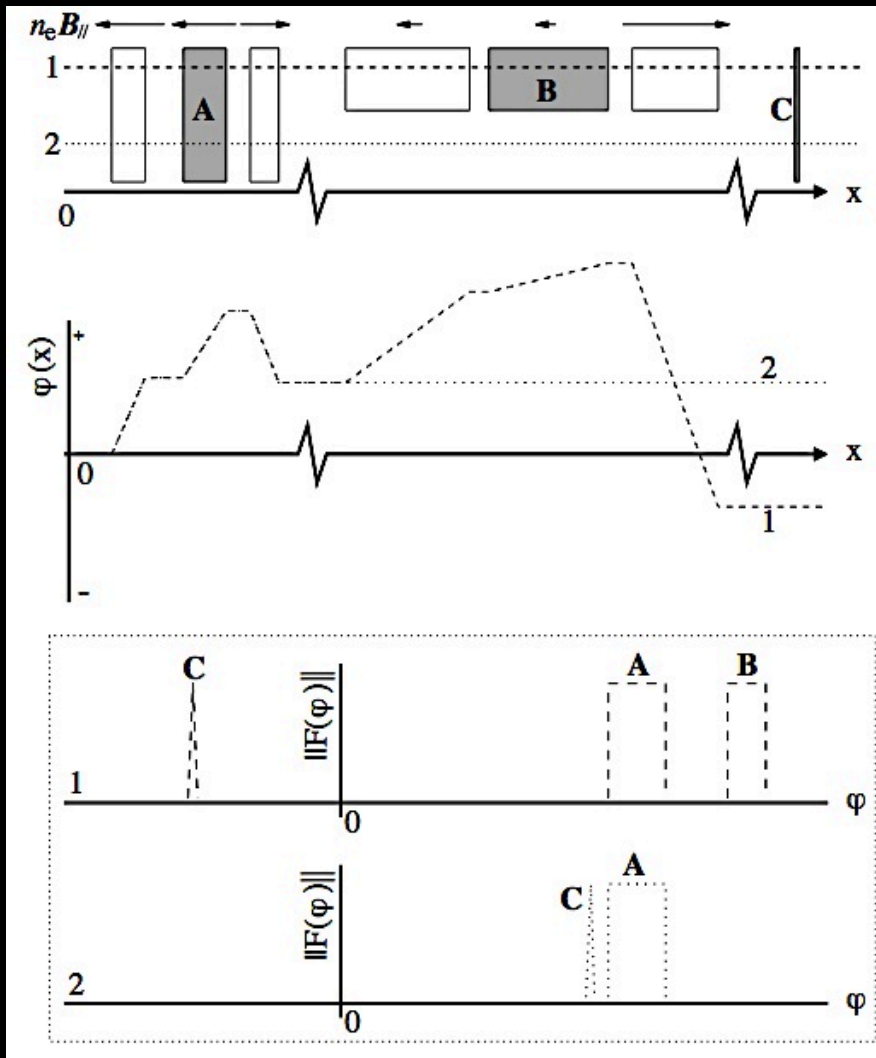


Polarized intensity WMAP @ 1.4GHz



Polarized intensity map @ 22GHz

# Rotation Measure synthesis



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

$$\Phi = \Phi_0 + \text{RM} \lambda^2$$

$$\text{RM} = \frac{e^3}{2\pi m^2 c^4} \int_0^d n_e(s) B_{\parallel}(s) ds,$$

*Brentjens & de Bruyn 2008*



13.7 Gyr  
( $z \sim 1100$ )

**COSMIC MICROWAVE  
BACKGROUND**

**DARK AGES**

13.2 Gyr  
( $z \sim 10$ )

**EPOCH OF  
REIONIZATION**

11.5 Gyr  
( $z \sim 3$ )

**EXTRAGALACTIC  
FOREGROUNDS**

1 kyr  
( $z \sim 0$ )

**GALACTIC  
FOREGROUNDS**

0.6 ms

**IONOSPHERE**

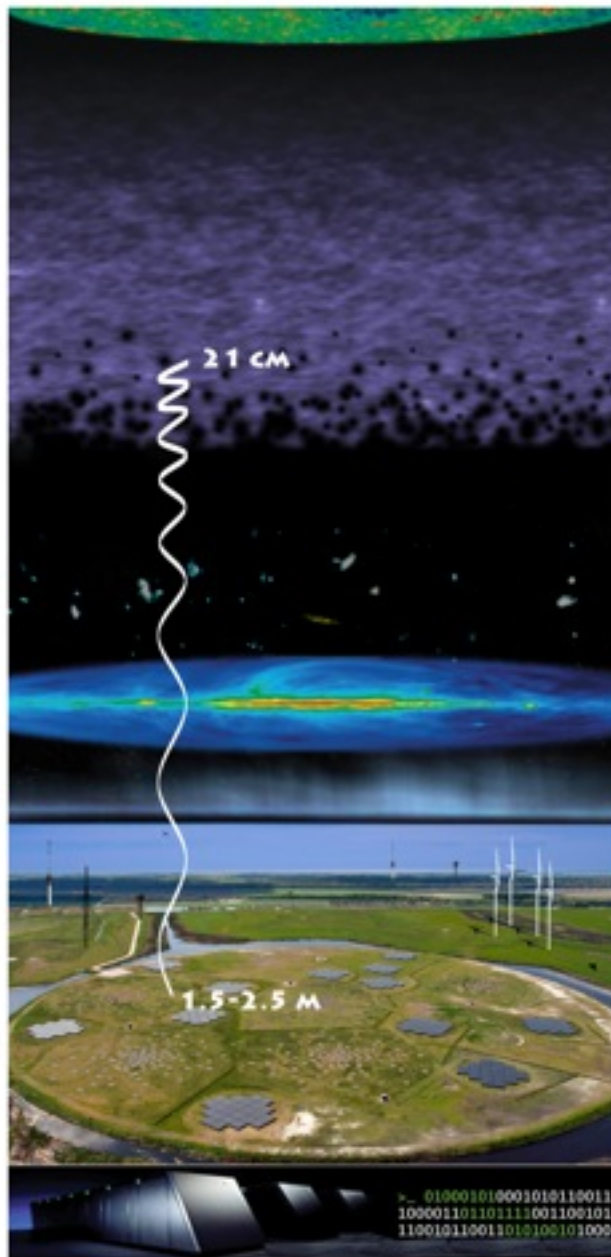
0.2 ms

**RADIO FREQUENCY  
INTERFERENCES**

**THE LOFAR TELESCOPE  
CORE STATIONS  
IN THE NETHERLANDS**

$t = 0$  s

**SUPERCOMPUTER  
BLUEGENE**



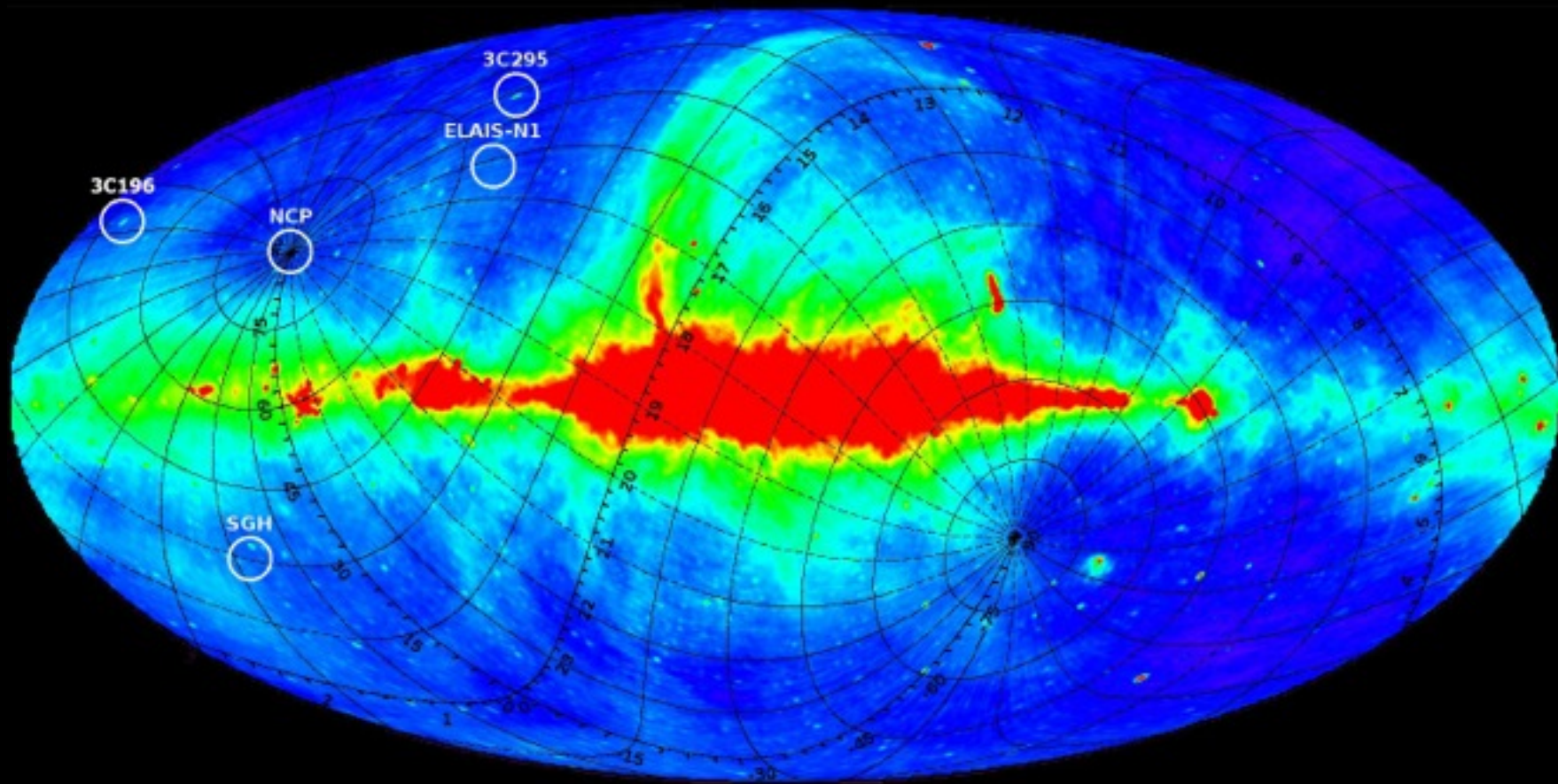
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>_ 010001010001010110011
100001101101111001100101
110010110011010100101000

```

# **LOFAR-EoR observations**

## 5 LOFAR-EoR observing windows



Haslam 408MHz map

# LOFAR-EoR observations

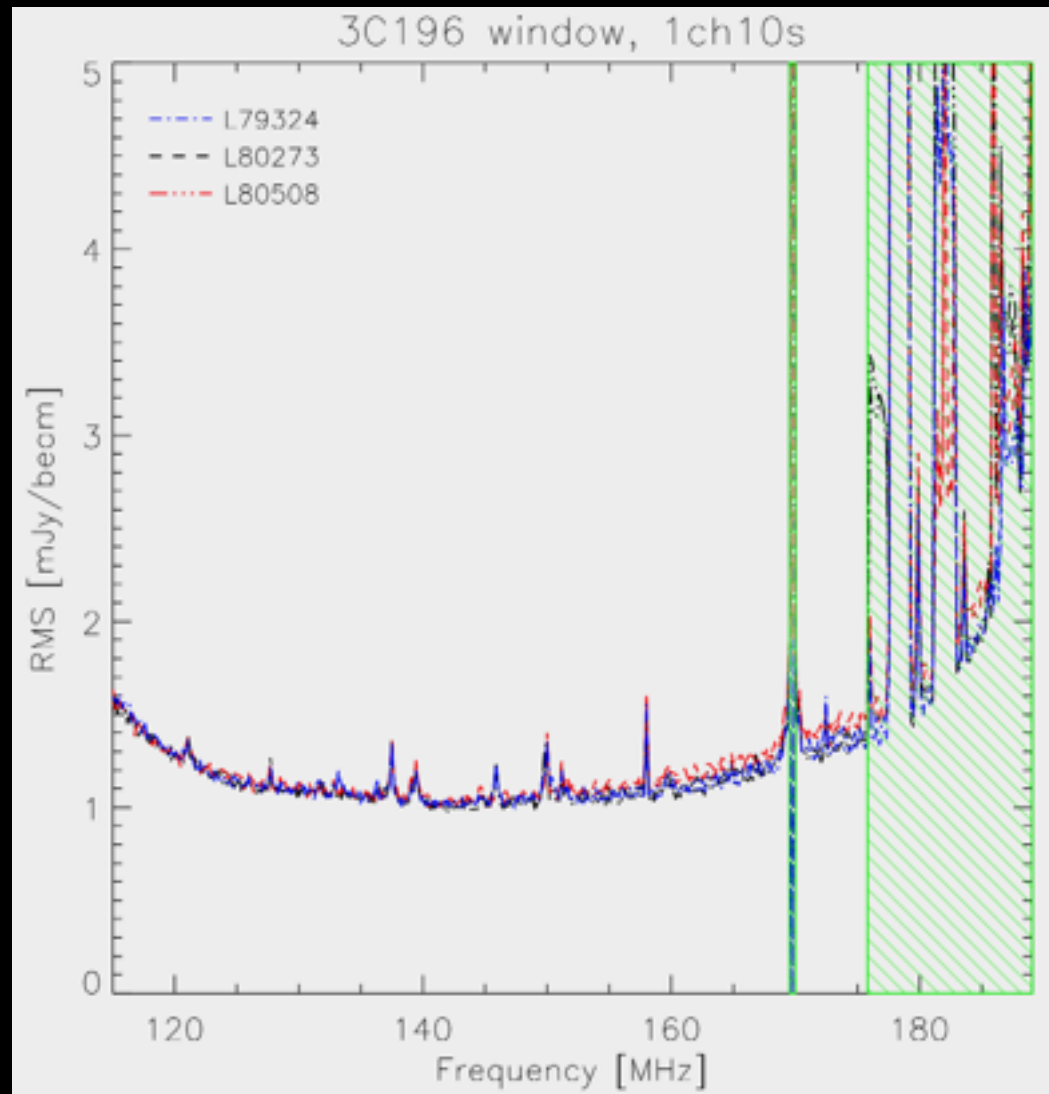
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- **North Celestial Pole** (*Yatwatta et al.*)
  - **3C196 field** (*Pandey et al.; Jelic et al.*)
  - **ELAIS-N1 field** (*Jelic et al., 2014*)
  - **3C295 field** (*Daiboo & Gosh et al.*)
    - direction independent calibration using BBS
    - direction **dependent calibration** using SageCal
    - **Ionospheric Faraday rotation** correction
    - correction for direction and time dependent LOFAR beam (**AWimager**)
- **LOFAR – HBA observation @ 115 – 175 MHz, 0.2 MHz**  
robust weighting, 40 - 1000 $\lambda$ , 3 arcmin  
**RM synthesis:  $\Delta\Phi \approx 1 \text{ rad/m}^2$**

# LOFAR-EoR observations

Frequency (Q,U)  
1.2 mJy/PSF

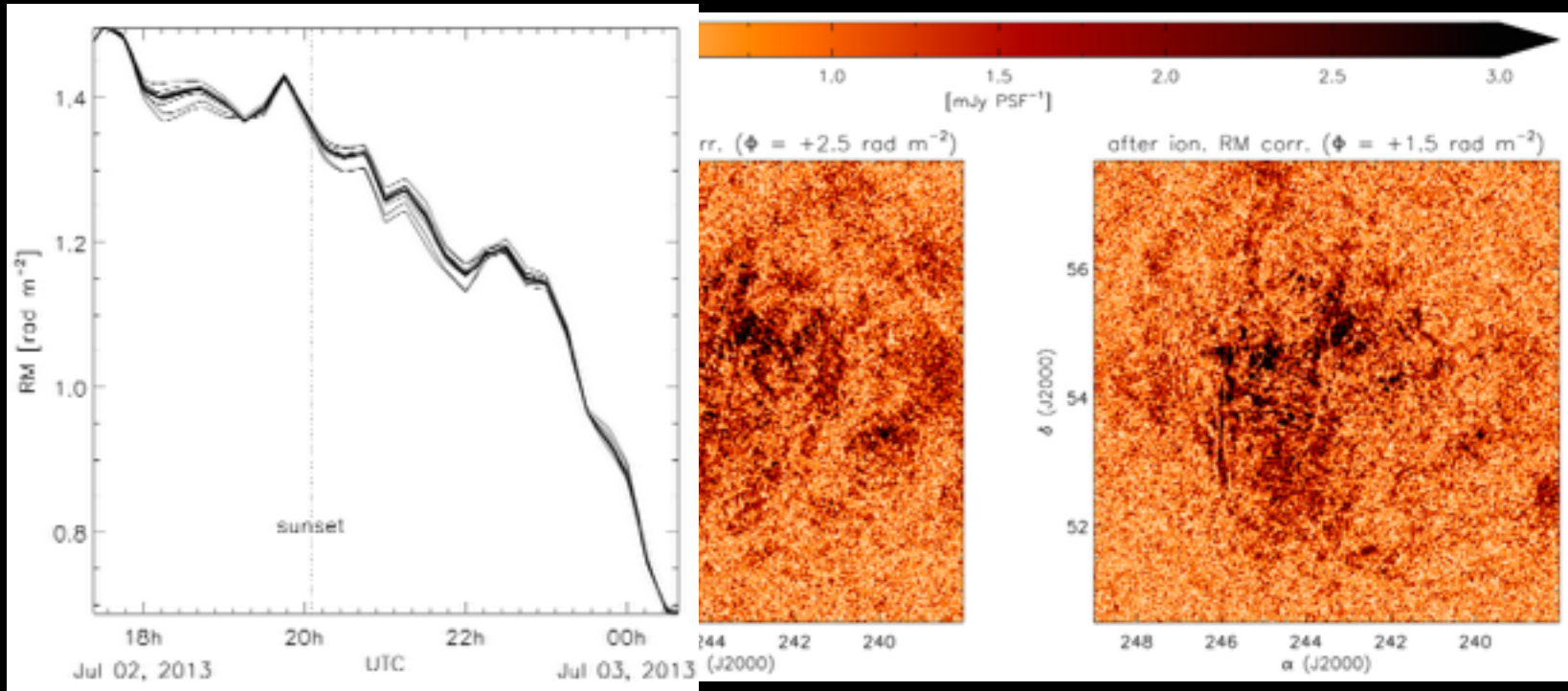
Faraday space (Q,U)  
0.75 mJy/PSF/RMSF



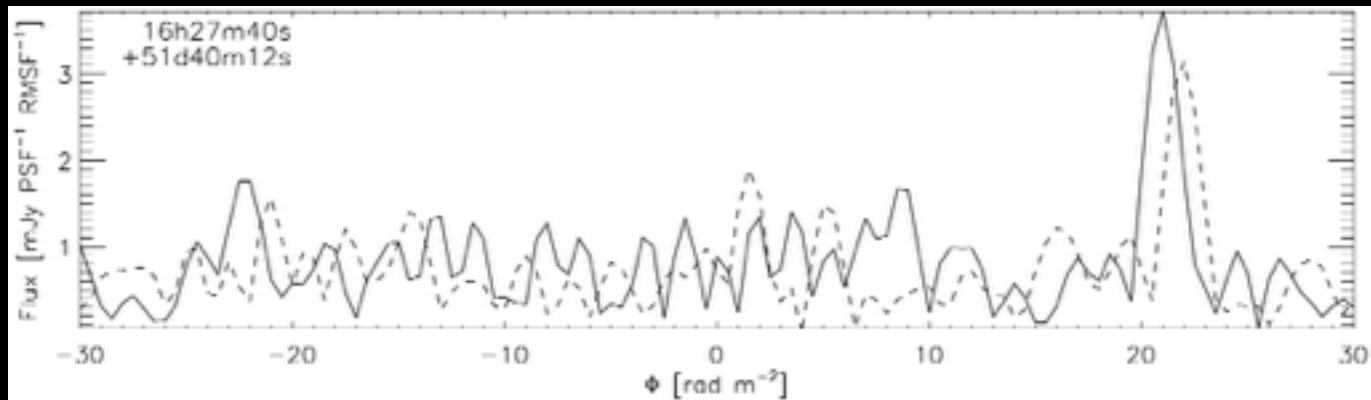


# **Faraday rotation in the Earth's ionosphere**

# Ionosphere: Faraday rotation

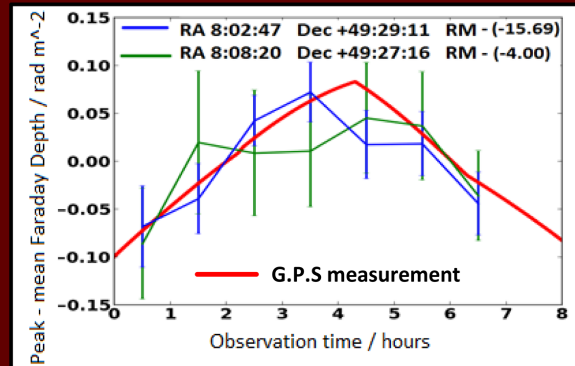
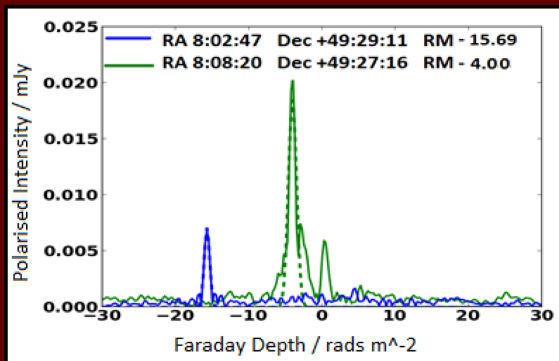
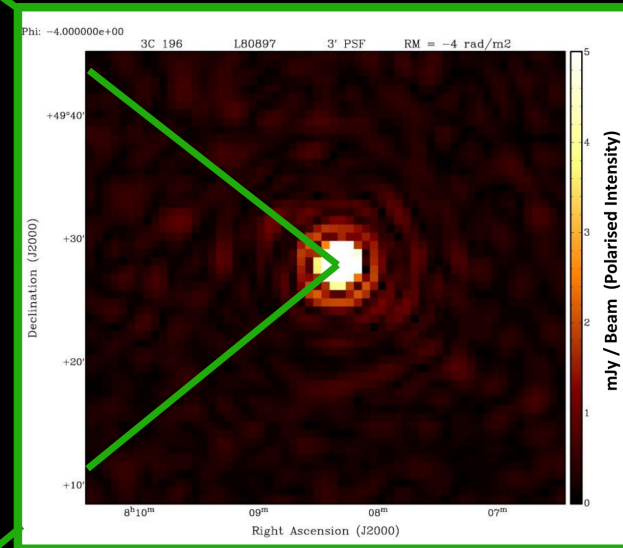
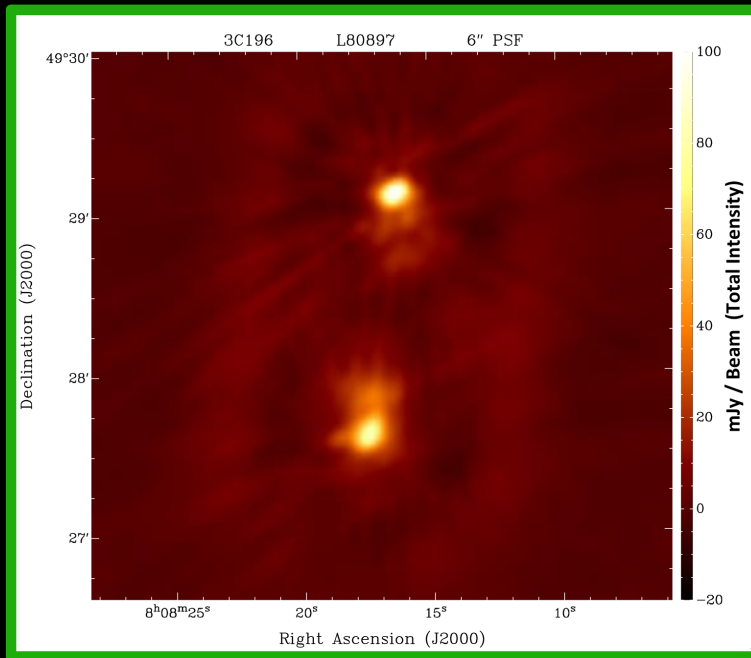


Jelic et al. 2014

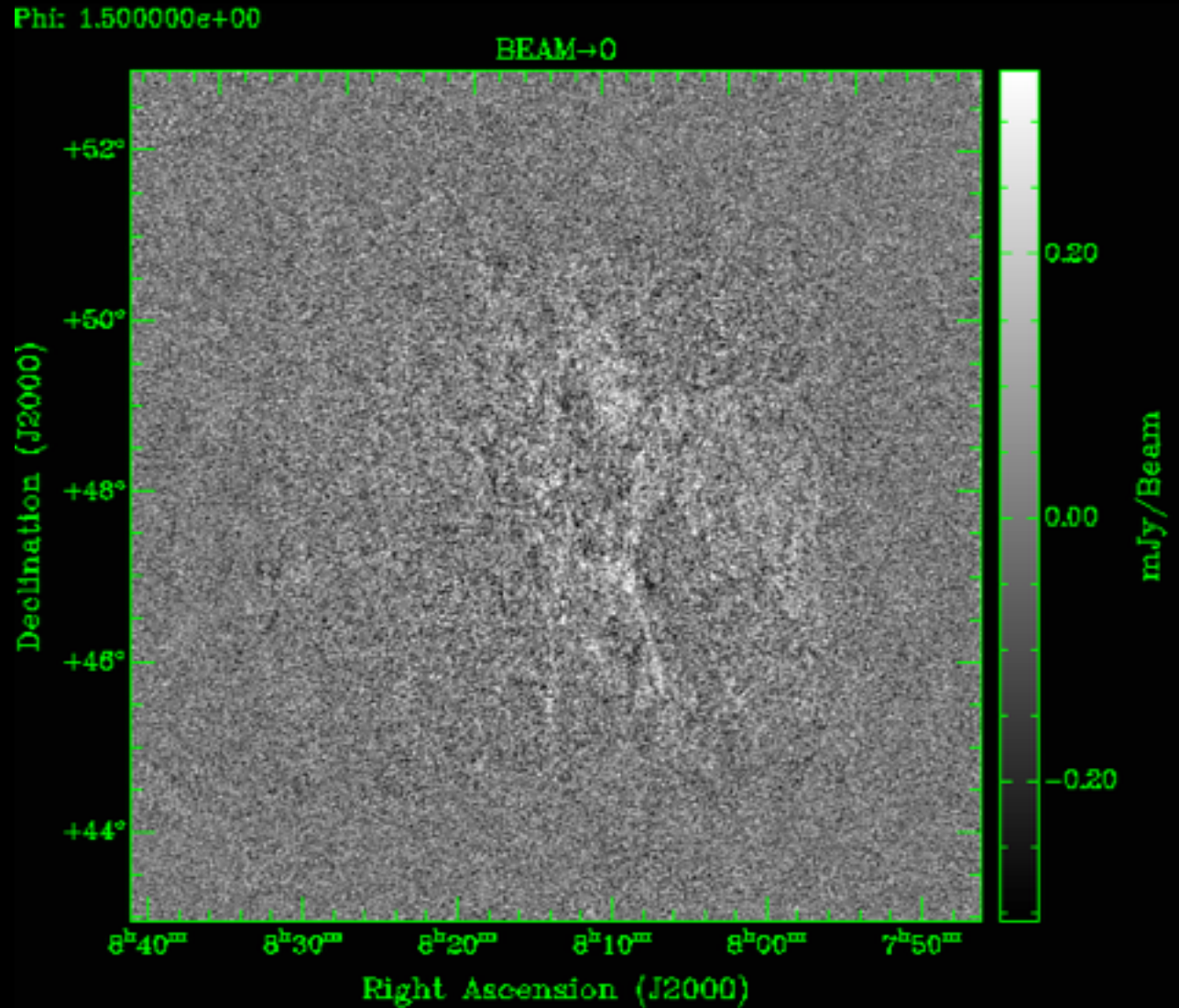


# Ionosphere: Faraday rotation

D. Starkey



# Ionosphere: Faraday rotation



diffuse emission  
2.5 mJy/PSF

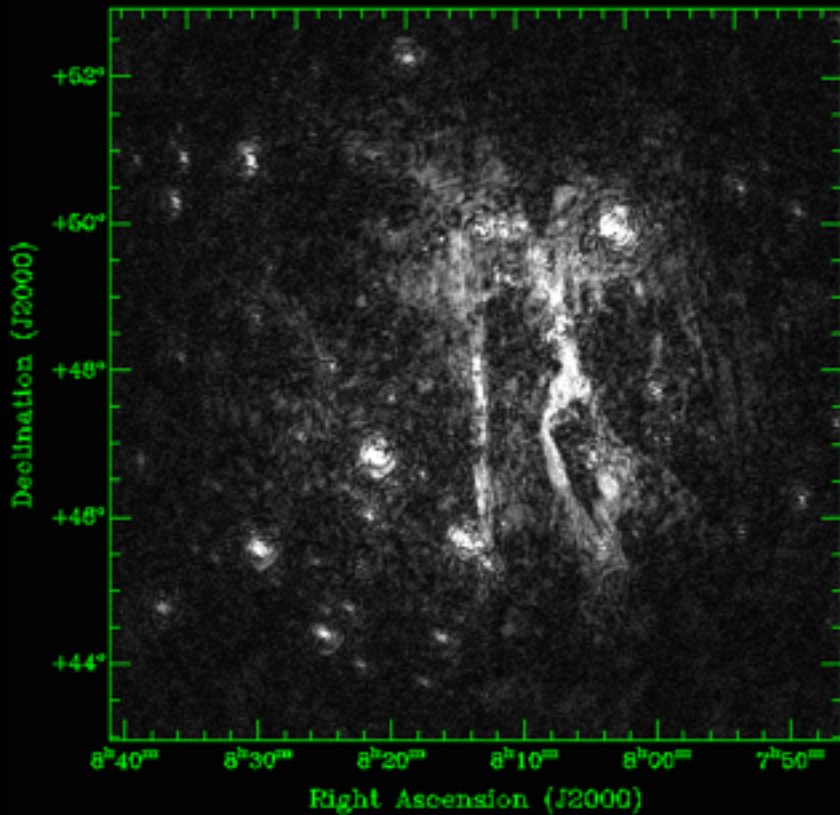
residual emission  
0.1 mJy/PSF, 1-4%

**3C196 field**

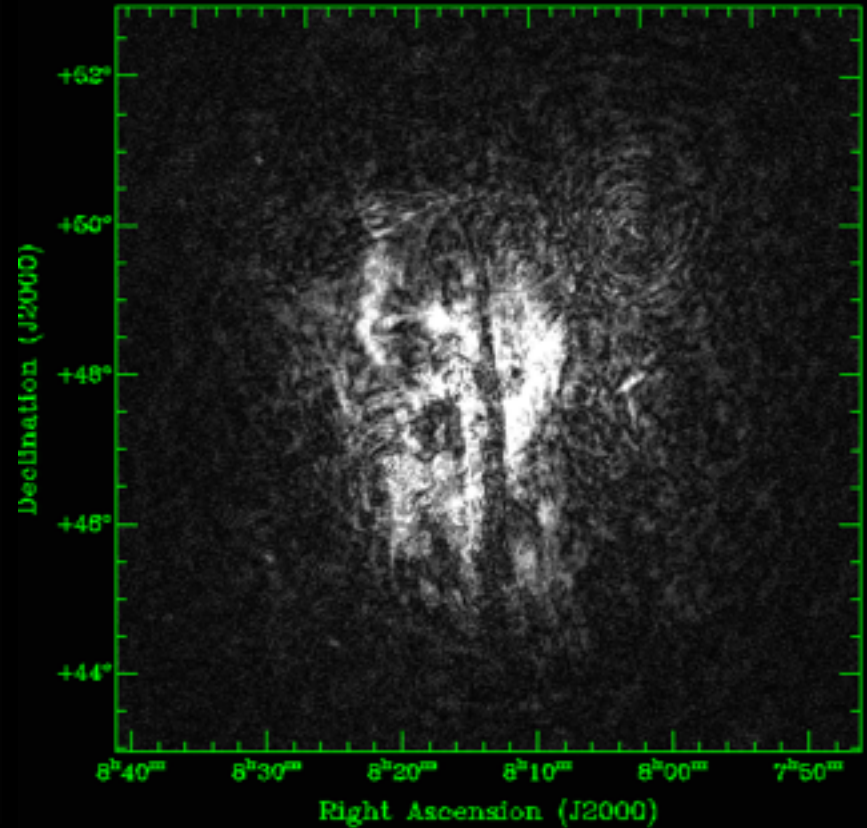


# 3C196 field

+0.75 rad/m<sup>2</sup>



+2.5 rad/m<sup>2</sup>



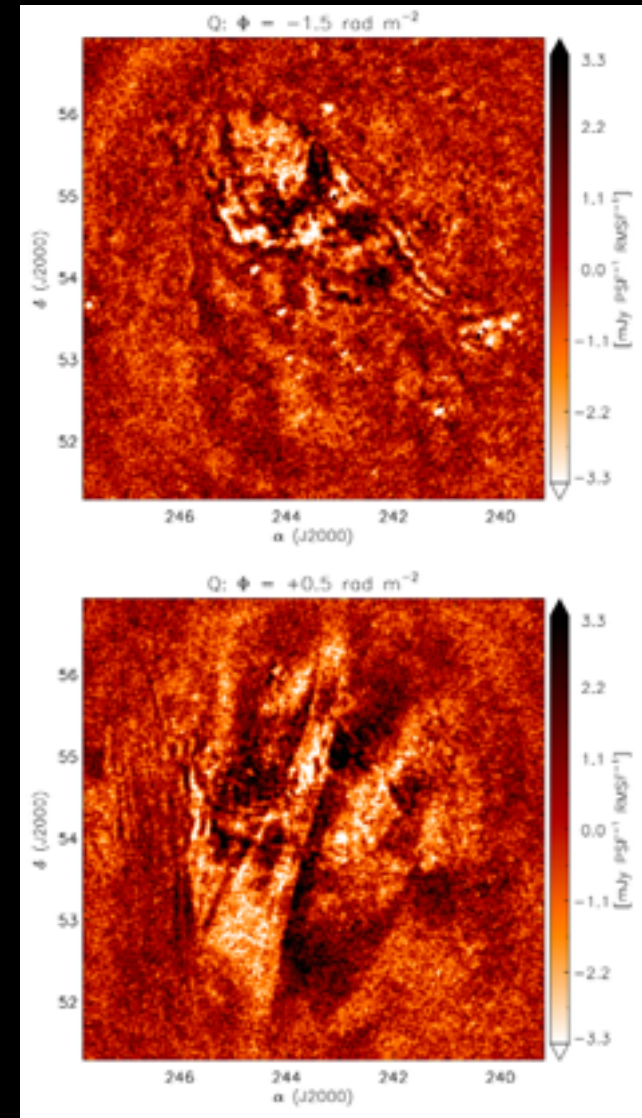
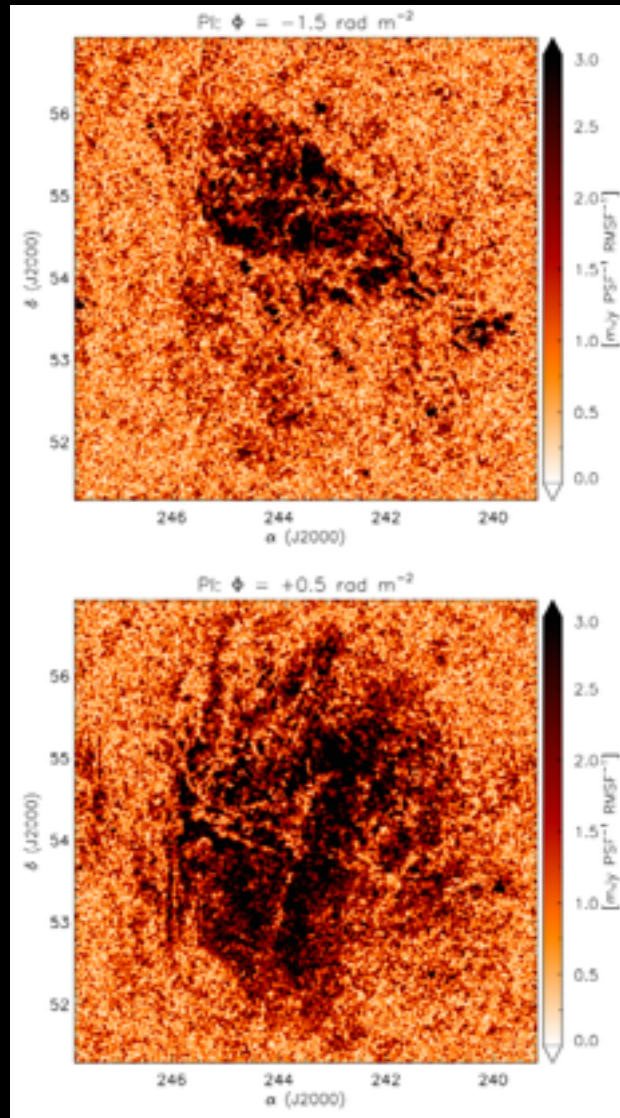
HBA observation, 115-175 MHz, 0.05 mJy/PSF/RMSF  
0 — +10 rad/m<sup>2</sup>  
a few K

**ELIAS-N1 field**

# ELIAS-N1 field

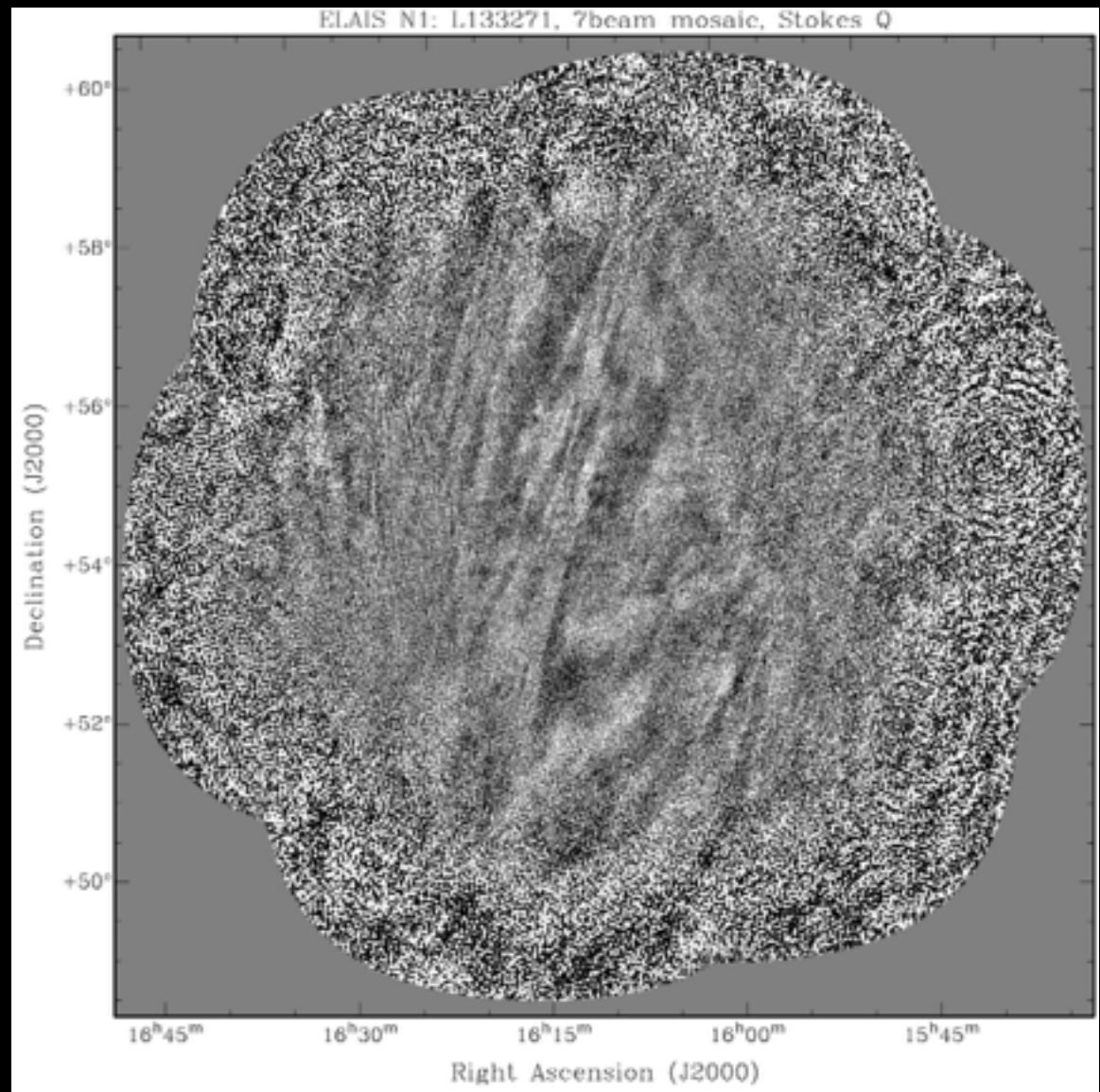
HBA observation  
138 - 185 MHz  
0.3 mJy/PSF/RMSF  
0.5 mJy/PSF/RMSF  
-10 — +10 rad/m<sup>2</sup>

*Jelic et al. 2014*



# ELIAS-N1 field

7 beam HBA  
60 SB per beam  
0.2 mJy/PSF/RMSF

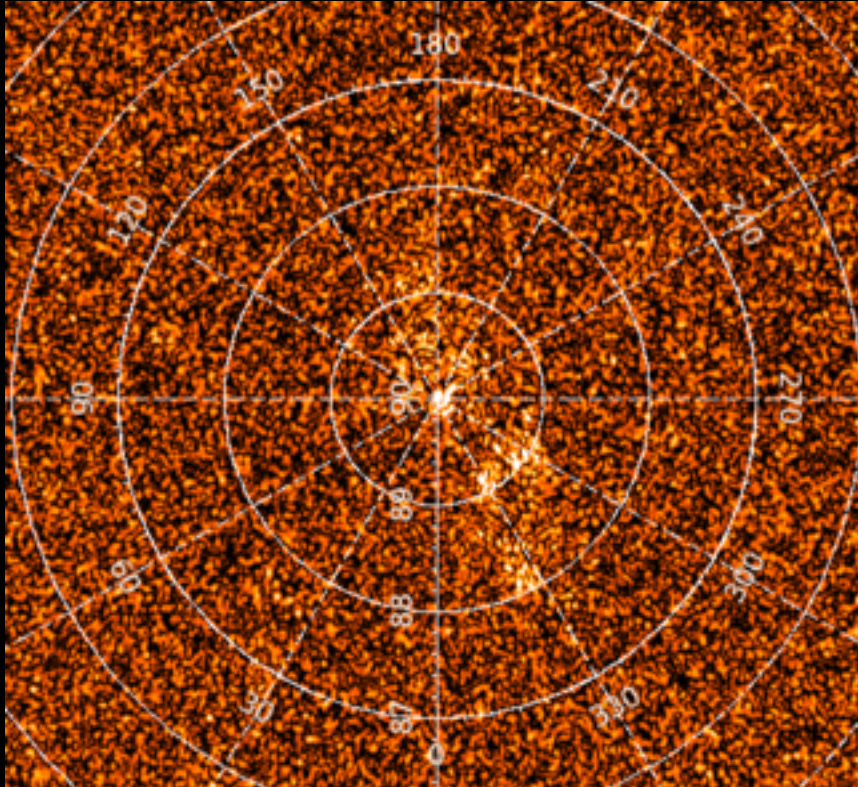


**NCP field**

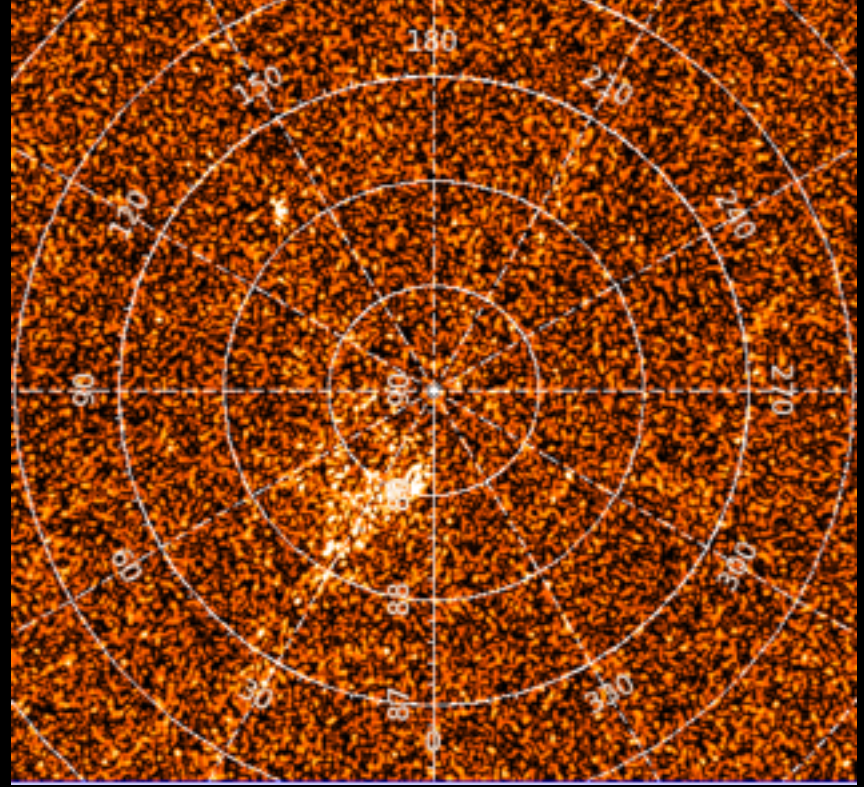


# NCP field

-30 rad/m<sup>2</sup>



-23 rad/m<sup>2</sup>

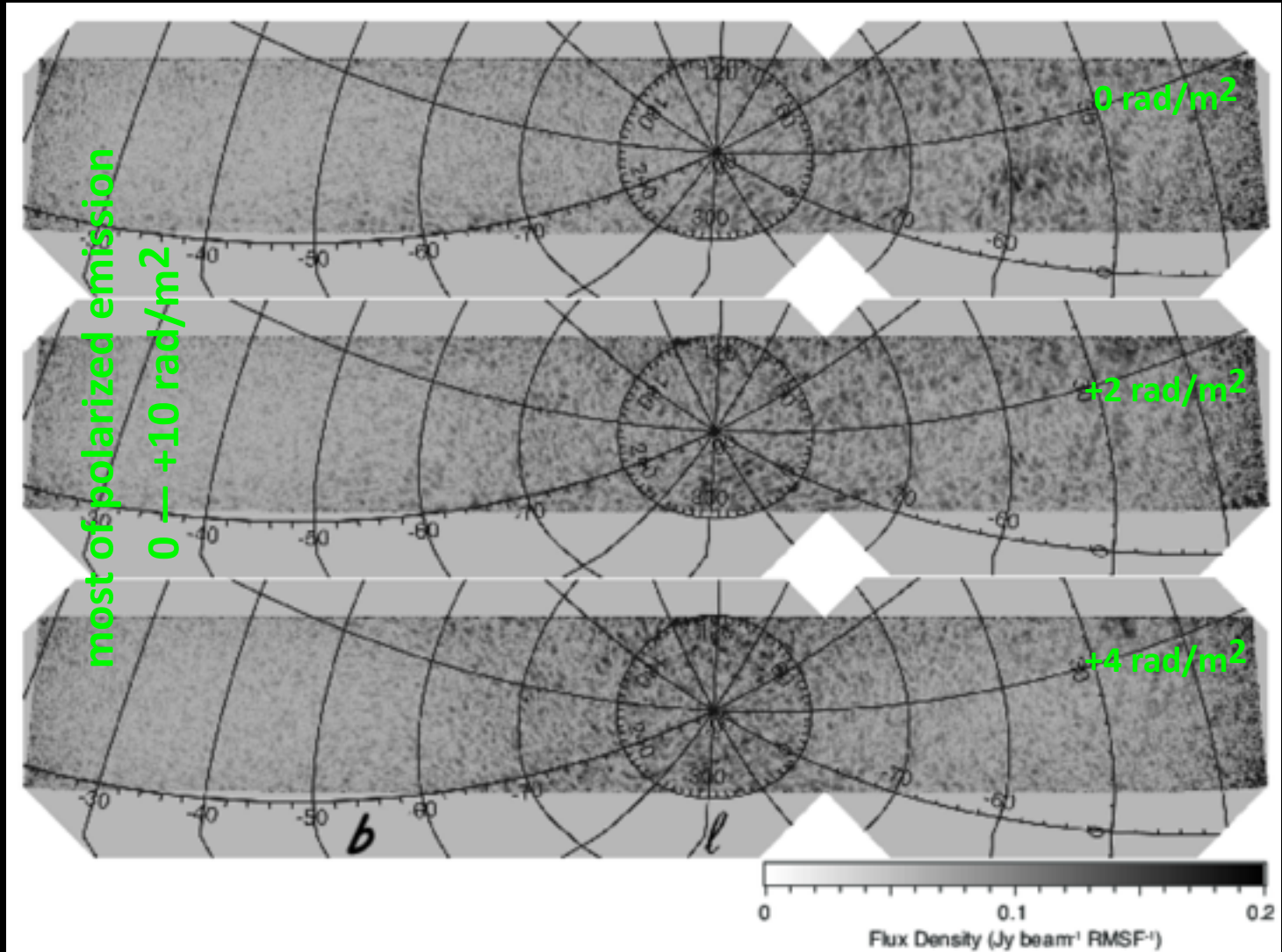


HBA observation, 115-175 MHz, 0.05 mJy/PSF/RMSF  
-30 — -10 rad/m<sup>2</sup>  
diffuse emission of 0.1 K

# **Comparison with some other observations**

# MWA: polarization survey

@ 189 MHz  
2400 sq deg  
15.6 arcmin  
15 mJy/beam  
4.3 rad/m<sup>2</sup>

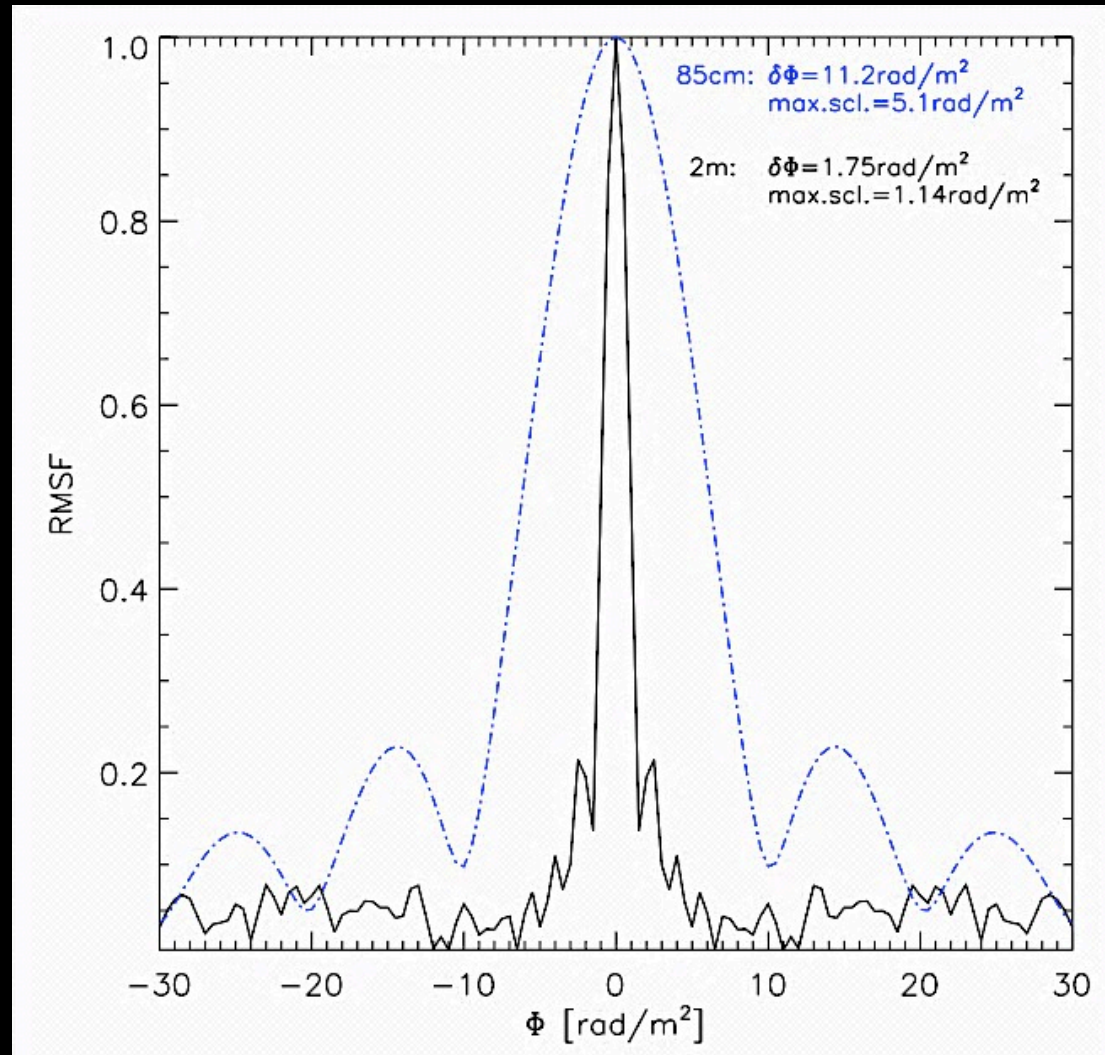


*Bernardi et al. 2013*



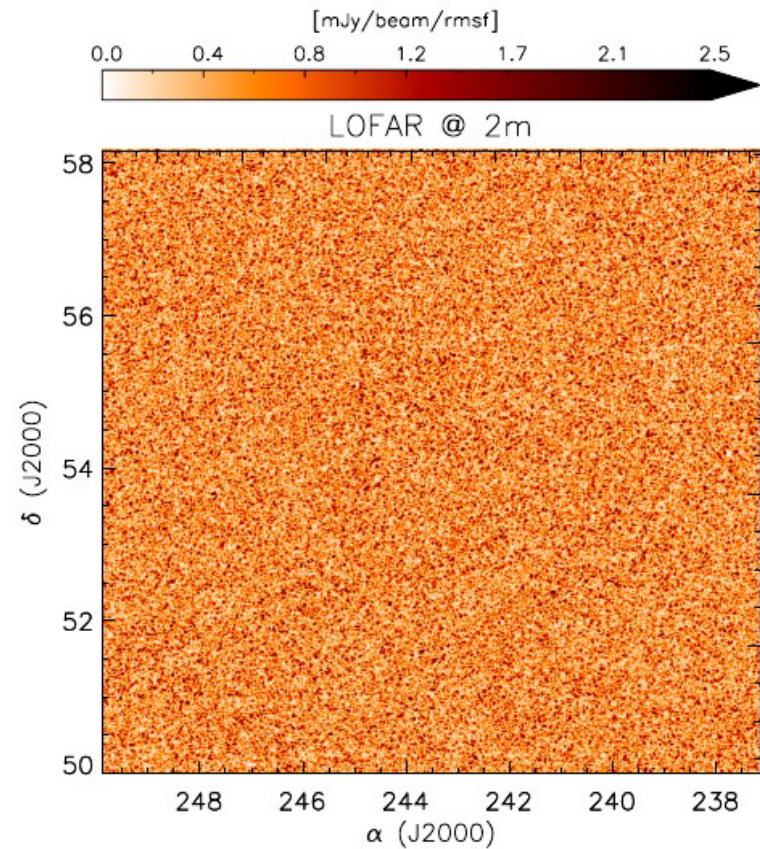
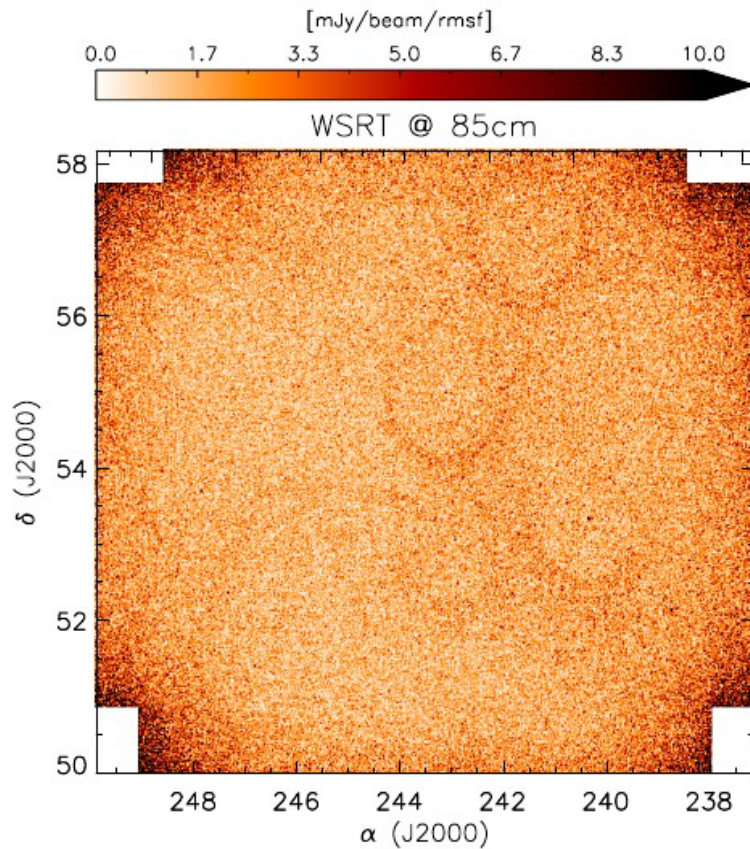
# WSRT 350 MHz: ELIAS-N1 field

315-385 MHz  
Follow Up



# WSRT 350 MHz: ELIAS-N1 field

ELIAS-N1 FIELD AT FARADAY DEPTH OF  
 $\Phi = -30.0 \text{ rad/m}^2$



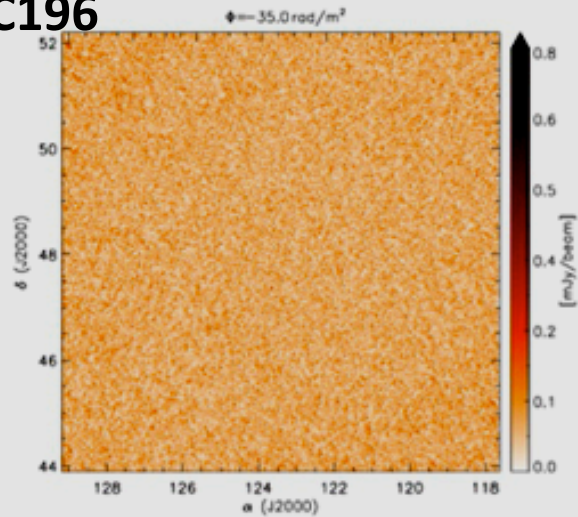
*Jelic et al. 2014*



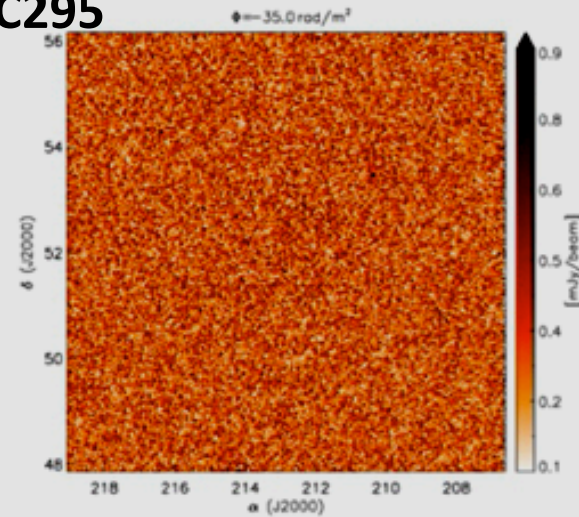
# Summary & Conclusion

PC

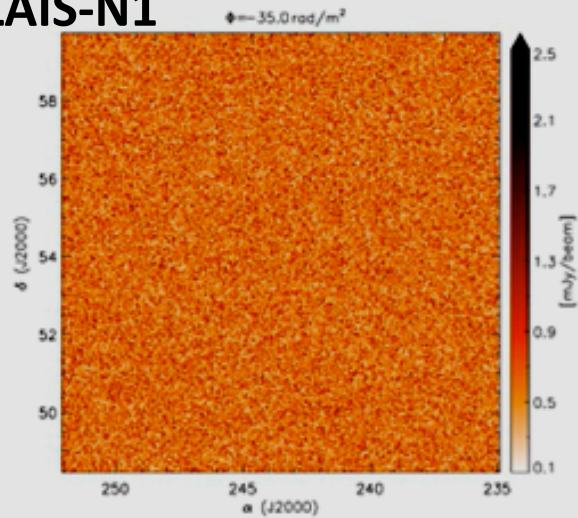
3C196



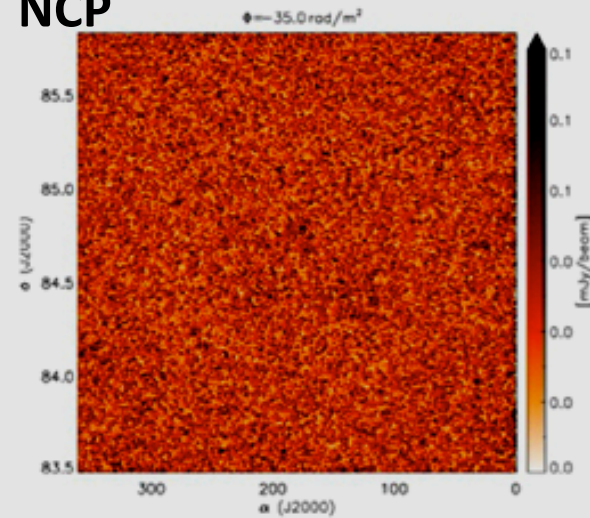
3C295



ELAIS-N1



NCP



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**THANK YOU  
 FOR YOUR ATTENTION !**

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[www.astro.rug.nl/eor](http://www.astro.rug.nl/eor)