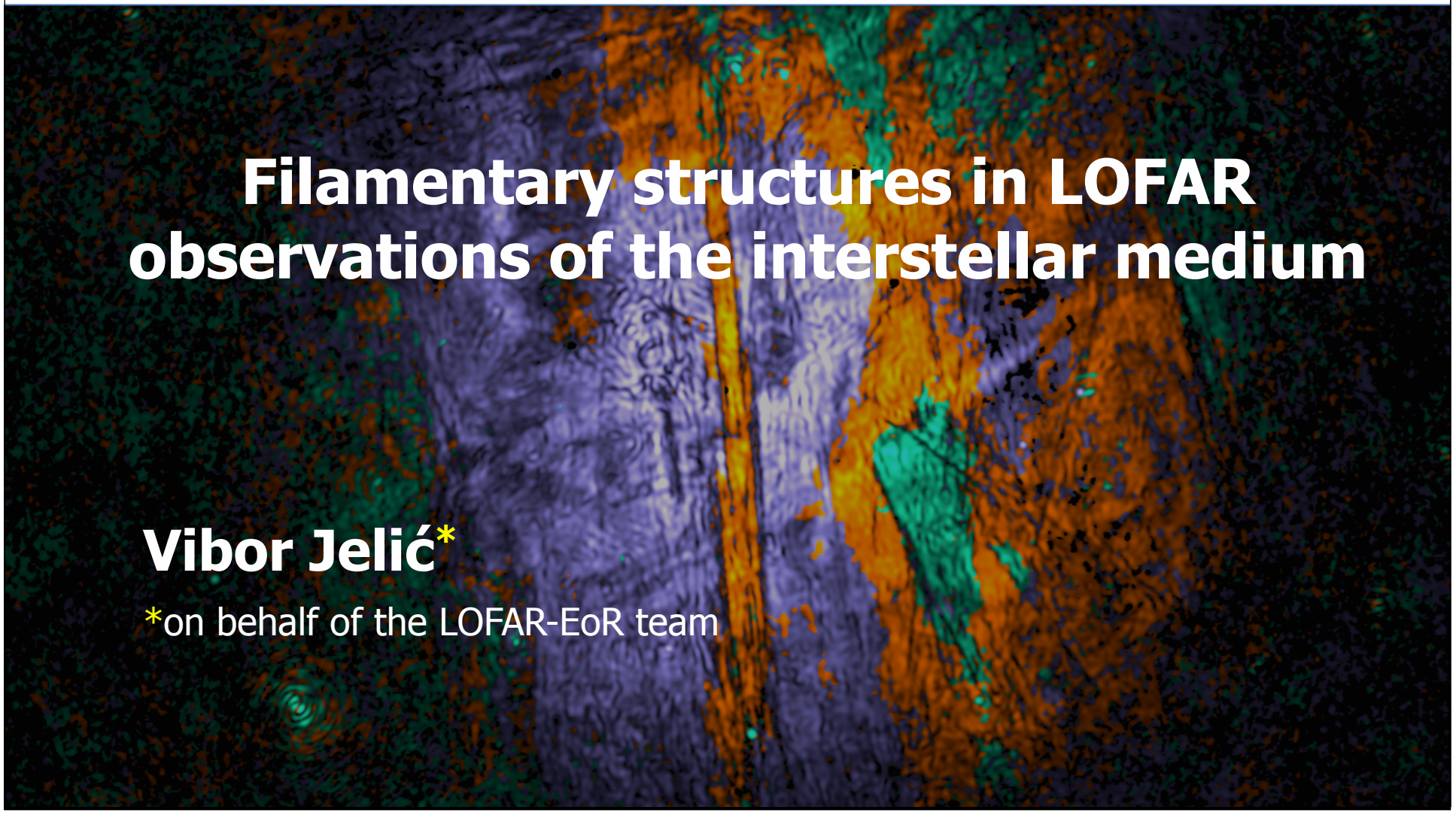
university of groningen / faculty of mathematics and natural sciences / kapteyn astronomical institute

LOFAR

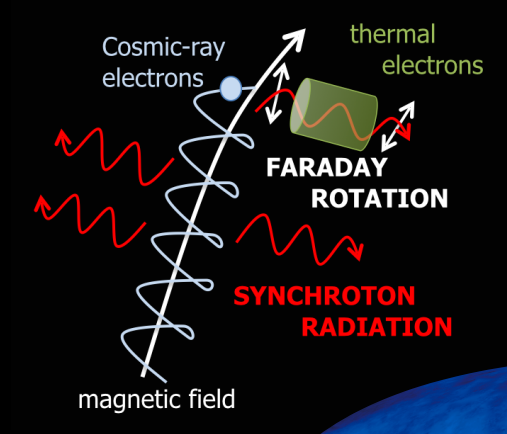
ASTRON
Netherlands Institute for Radio Astronomy

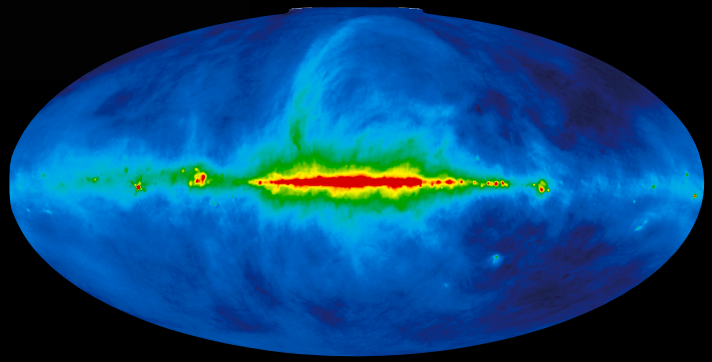


Filamentary structures in LOFAR observations of the interstellar medium

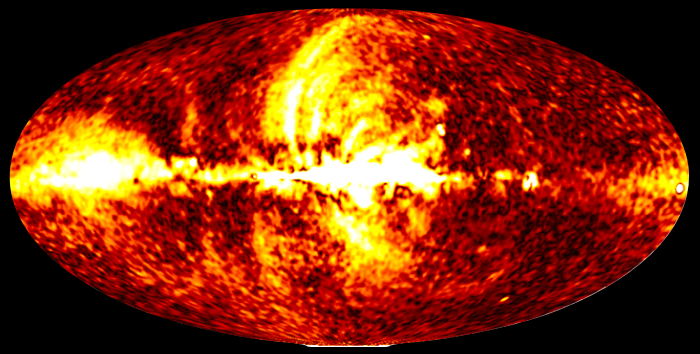
Vibor Jelić*

*on behalf of the LOFAR-EoR team

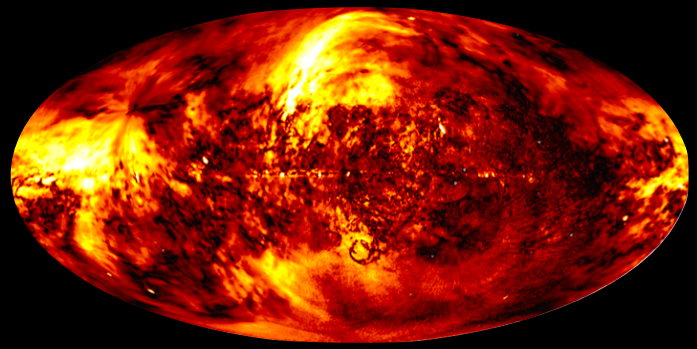




Total intensity @ 408 MHz



Polarized intensity @ 22.8 GHz

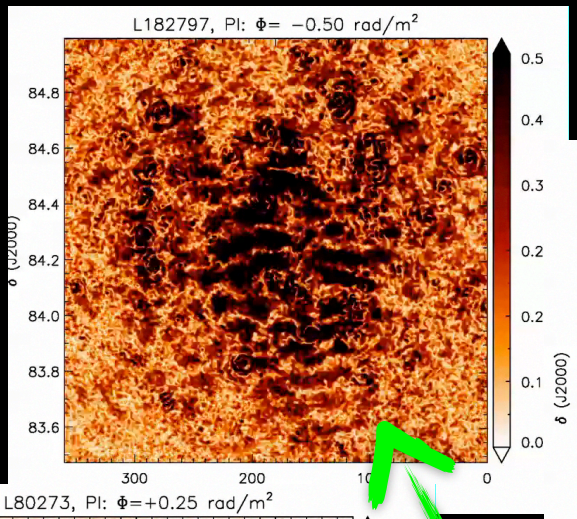


Polarized intensity @ 1.4 GHz

- at low radio frequencies, observed polarised emission has surprisingly high brightness temperature **(MWA:** Bernardi et al. 2013, Lenc et al. in prep; **LOFAR:** Iacobelli et al. 2013; Jelic et al. 2014,2015**)**

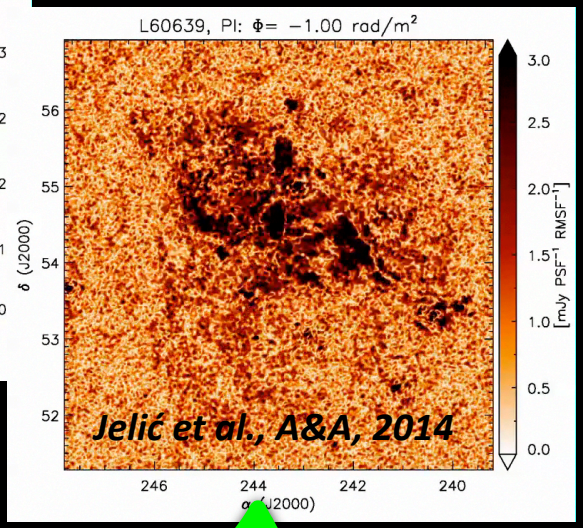
NCP field

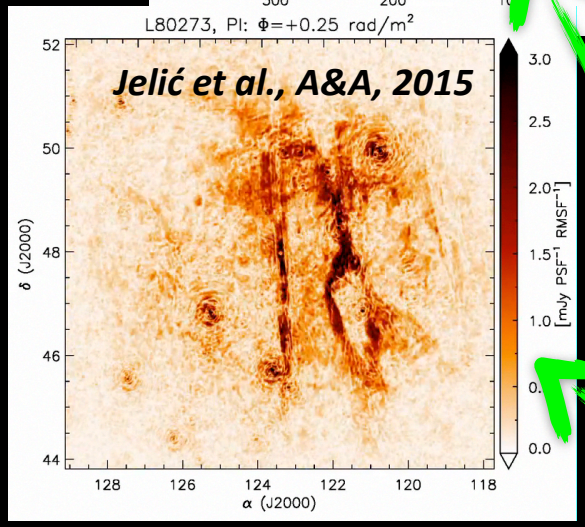
from -45 to +5 rad/m^2



ELAIS-N1 field

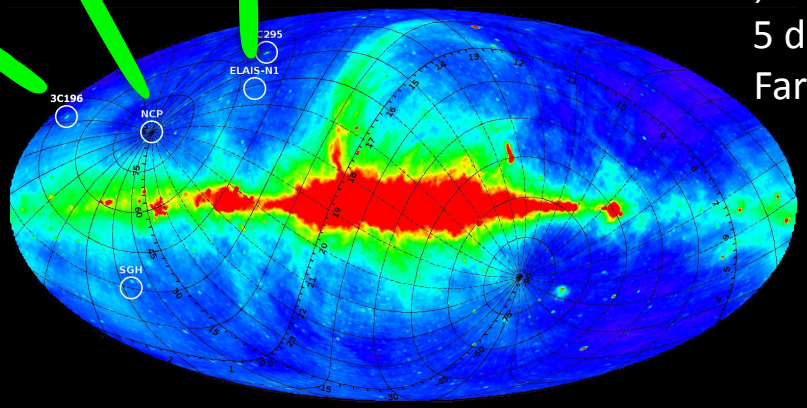
from -10 to +13 rad/m^2





3C196 field

from -3 to +8 rad/m^2



LOFAR-HBA (6h) observations

115-175 MHz, 0.2 MHz —> 1 rad/m^2

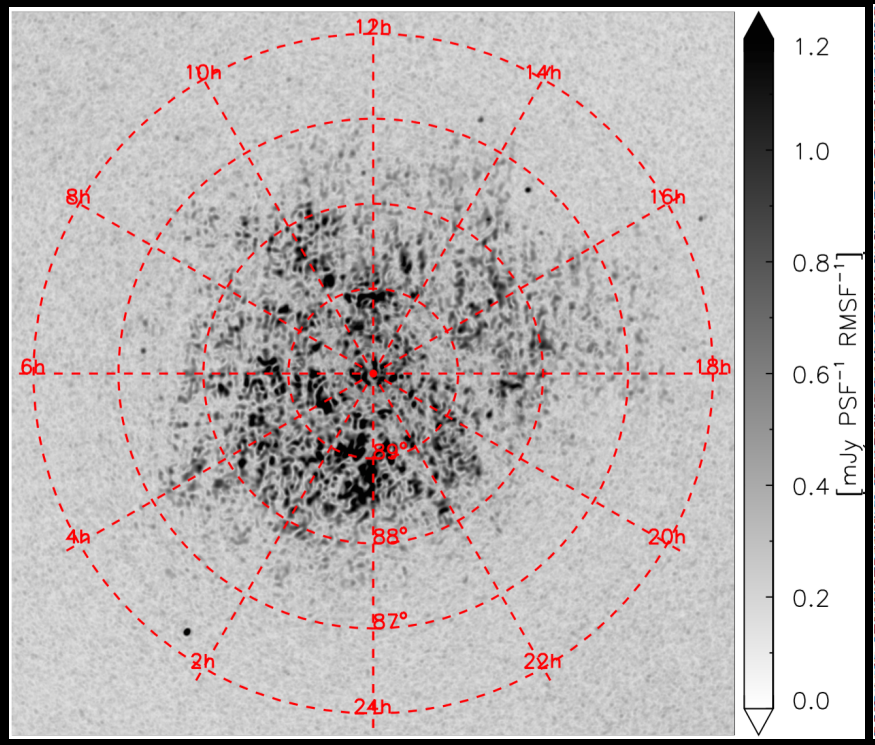
5 deg x 5 deg, 4 arcmin

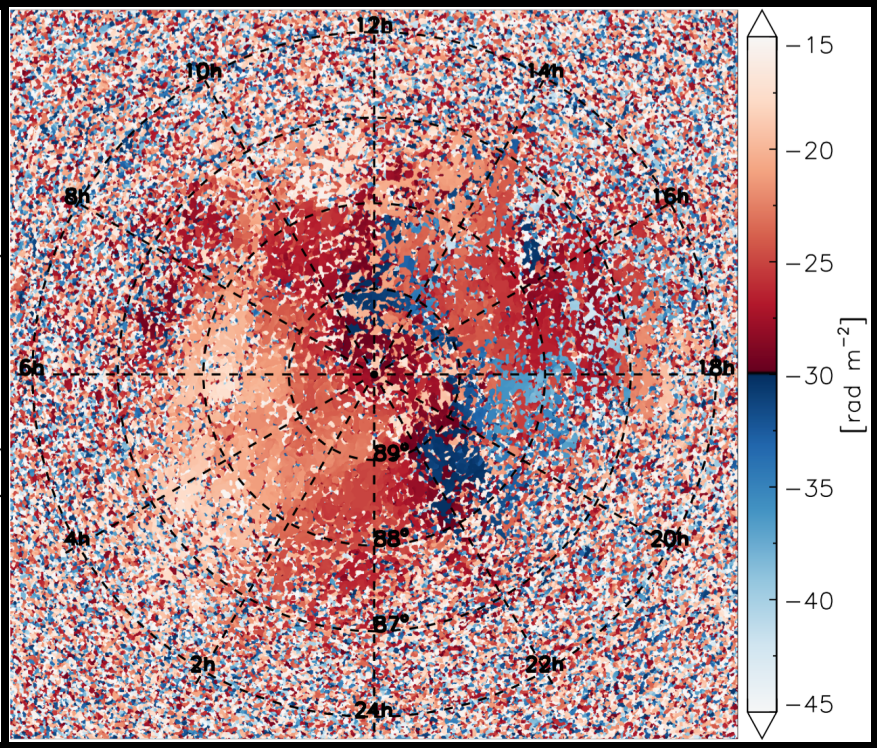
Faraday thin structures

NCP field

from -45 to +15 rad/m^2

brightness temperature: 100 mK



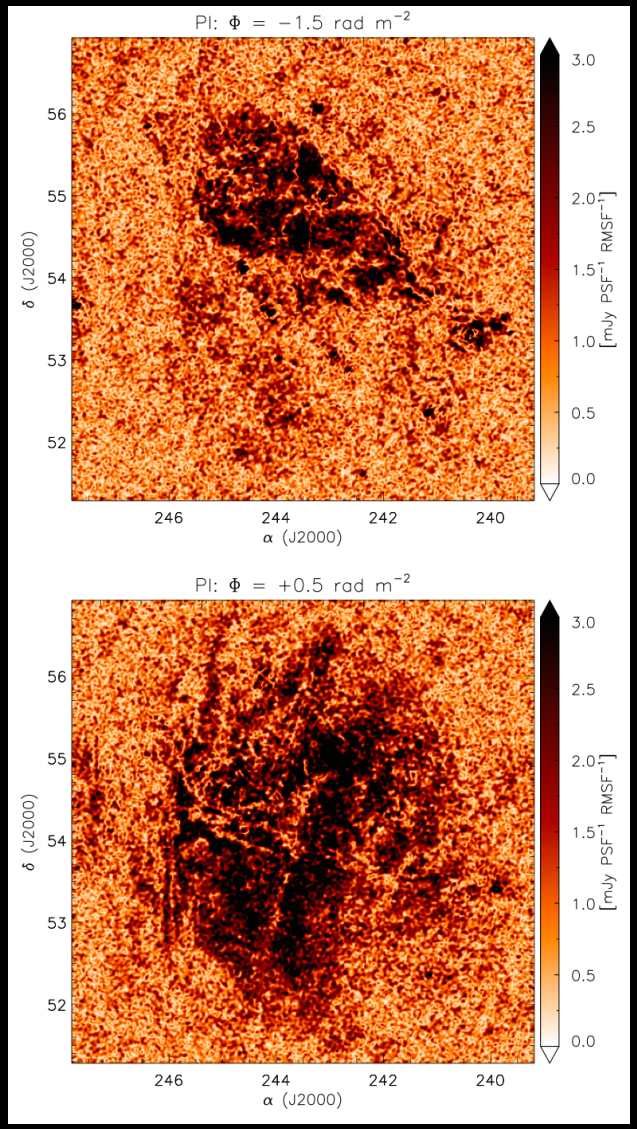


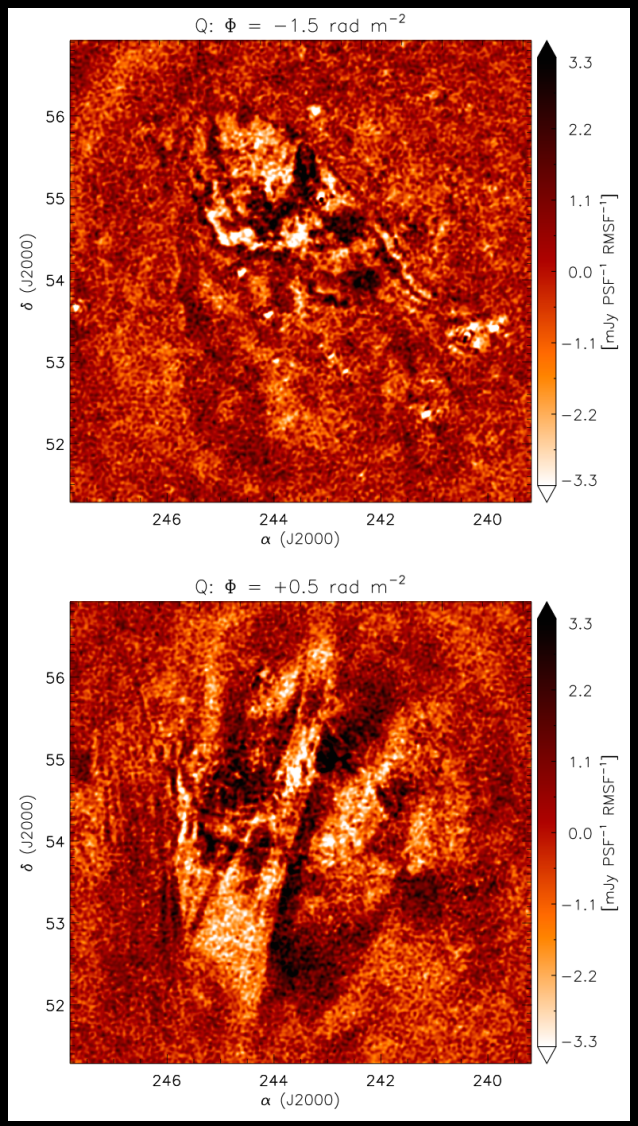
Jelic et al., in prep.

ELAIS-N1 field

Φ = -1.5 rad/m²

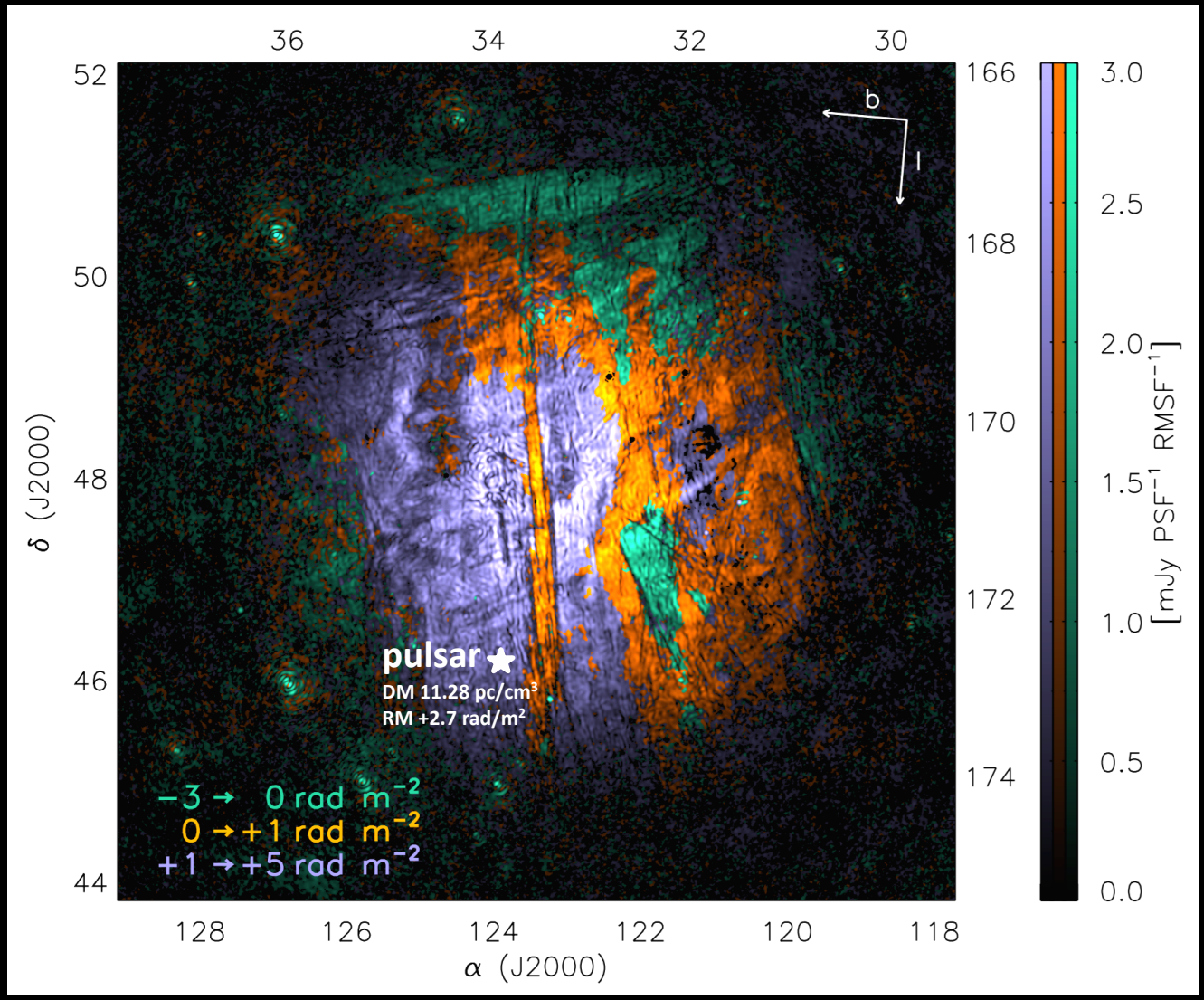
Φ = +0.5 rad/m²





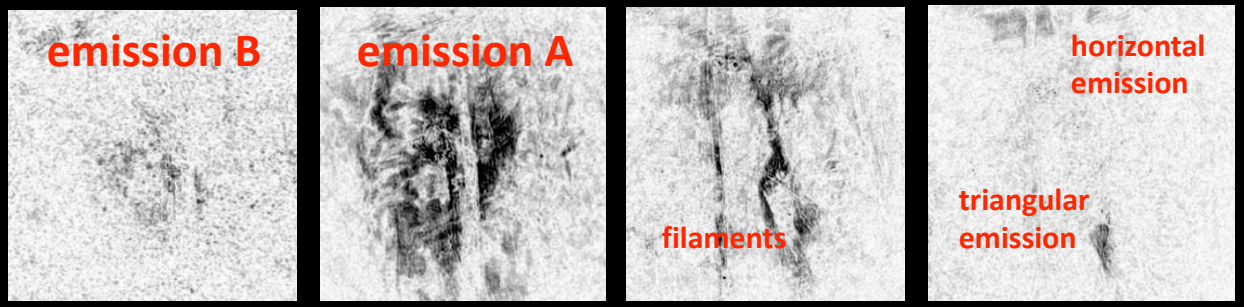
Jelic et al., 2014, A&A

3C196 field

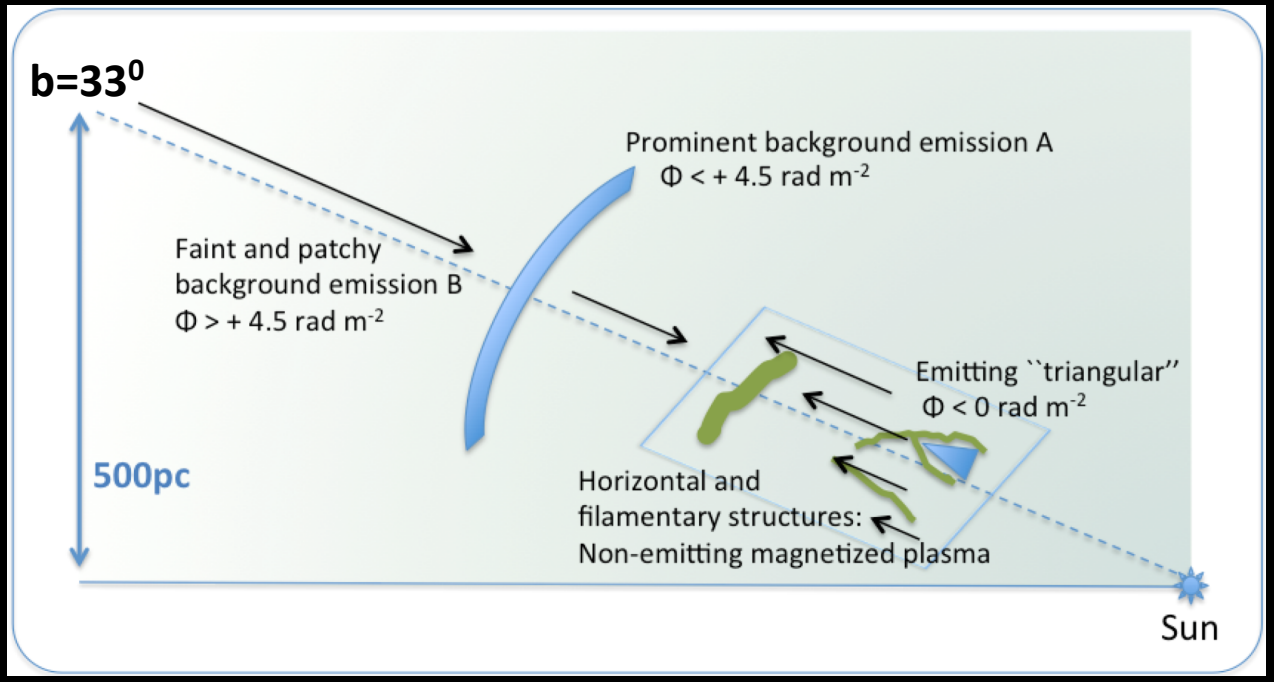


Jelic et al., 2015, A&A

3C196 field

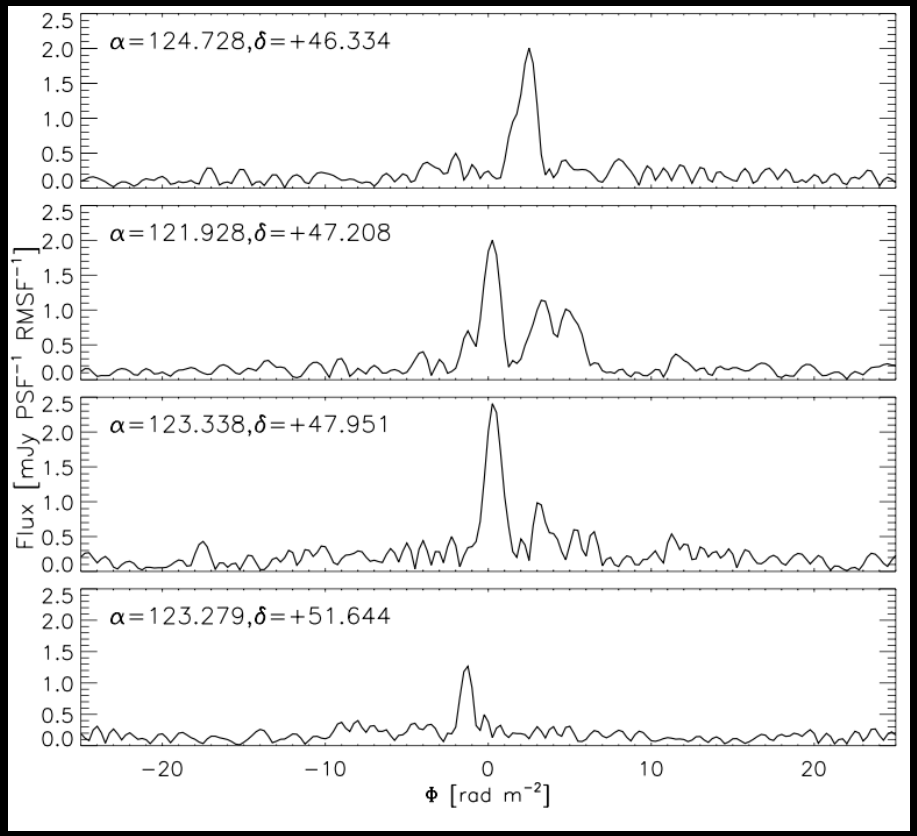


- magnetic field following spiral arms of our Galaxy is almost perpendicular to the line-of-sight
  $\langle B_{\parallel} \rangle$=0.3 (0.1) μG



Jelic et al., 2015, A&A

3C196 field

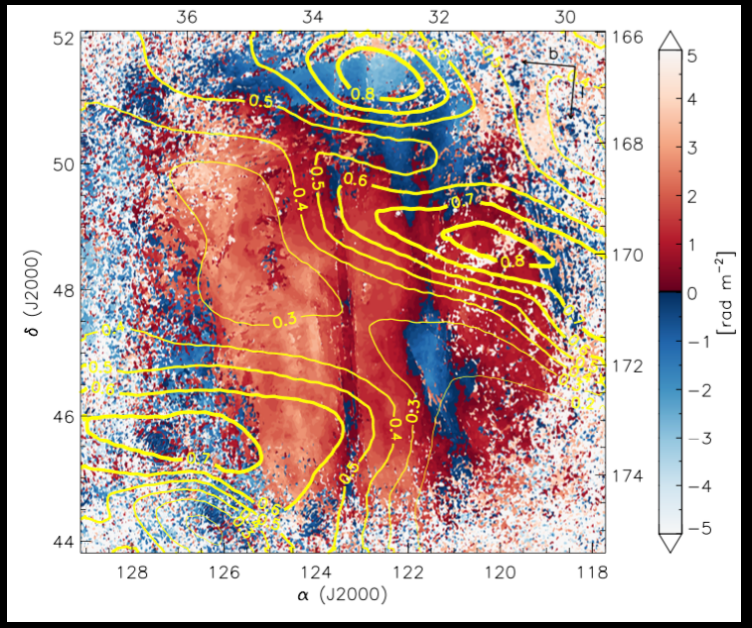


magnetic field reversal(s)

W-E 0.8 deg/rad/m^2
N-S 0.3 deg/rad/m^2

$\sigma_{\langle B_{\parallel} \rangle} = 0.2\ \mu G$

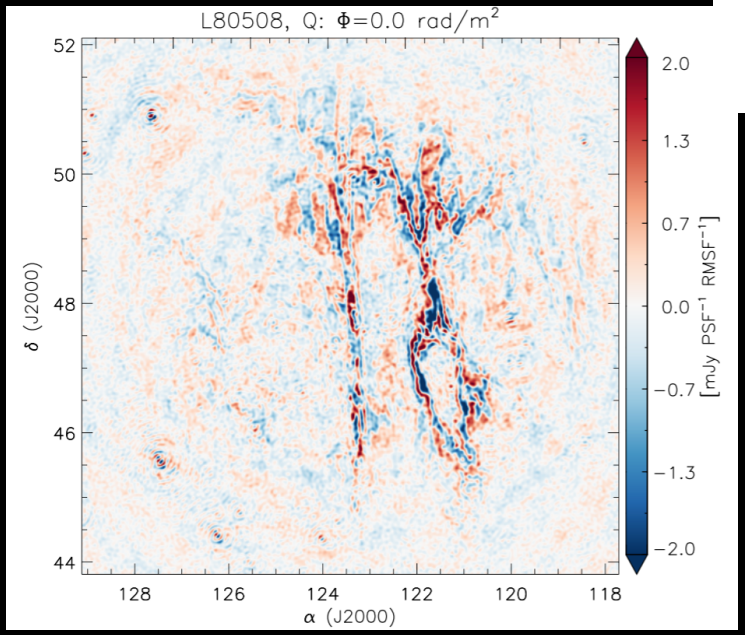
Hα map (*WHAM, Haffner et al. 2003*)

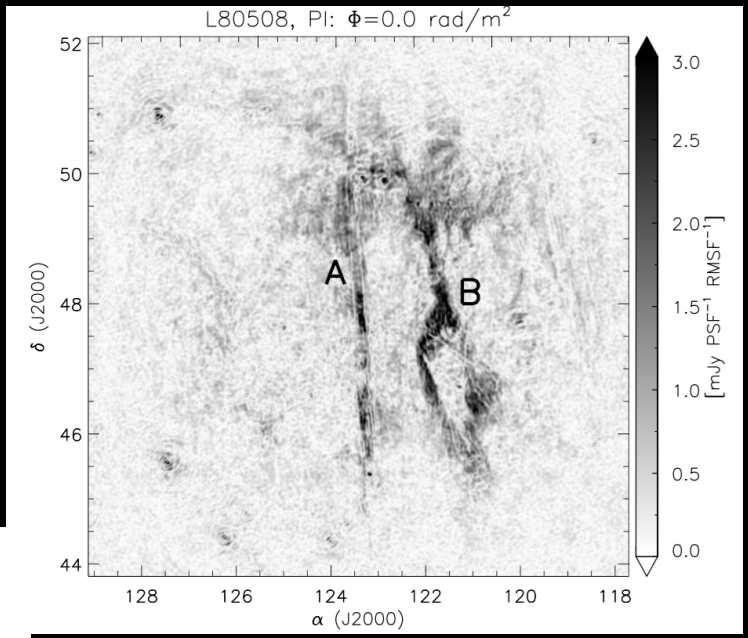


Jelic et al., 2015, A&A

3C196 field

- the lack of emission in total intensity, an upper limit to the thermal free-free emission, $T_{ff} < 0.2$ K
- $T_e = 8000$K and dl=1pc
  —> **$n_e < 1$ cm^{-3}**





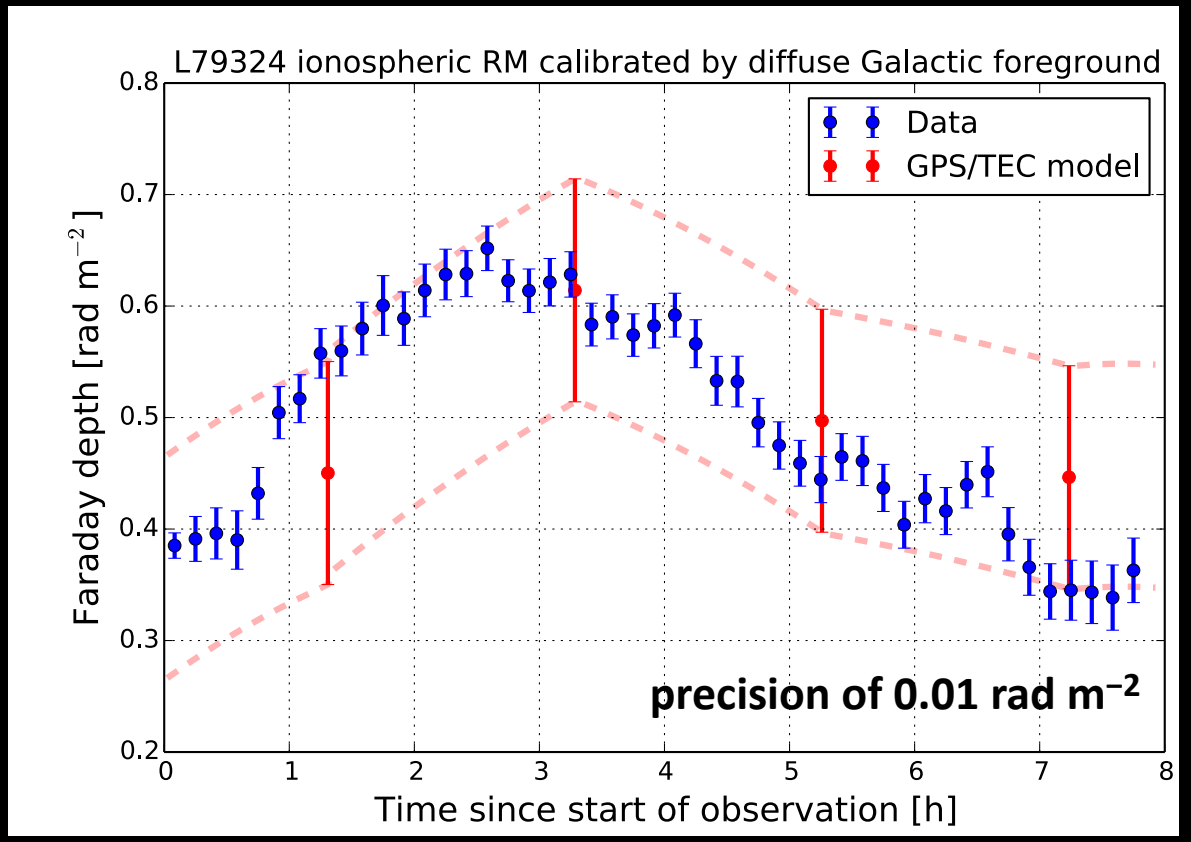
- thickness in Faraday depth of 1 rad/m^2
  $B_{||} > 1.2$ µG
- assuming equipartition between magnetic and thermal energy
  $B_{tot} < 6.5$ µG

Jelic et al., 2015, A&A

3C196 field

- aimed to measure a proper motion of the filament
- assuming 50 pc distance and a transverse velocity of 50 km/s
  —> 0.2′′ per year

Ionospheric self-calibration using Galactic polarized emission

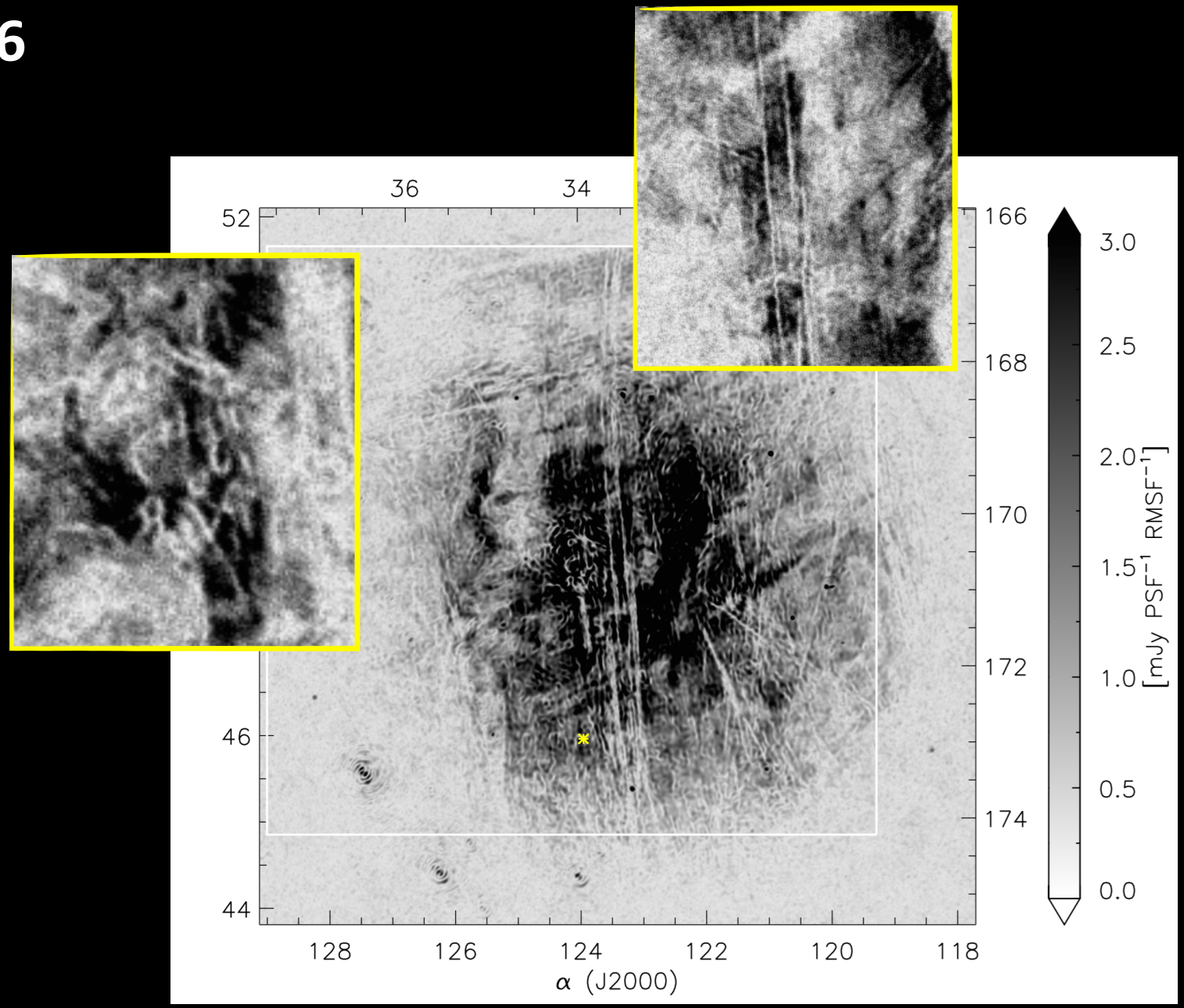


Brentjens et al., in prep.

3C196 field

depolarization canals

Haverkorn et al.,2000,2004

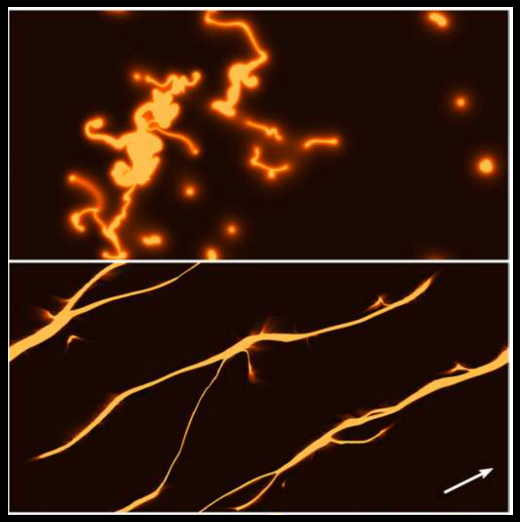


Jelic et al., 2015, A&A

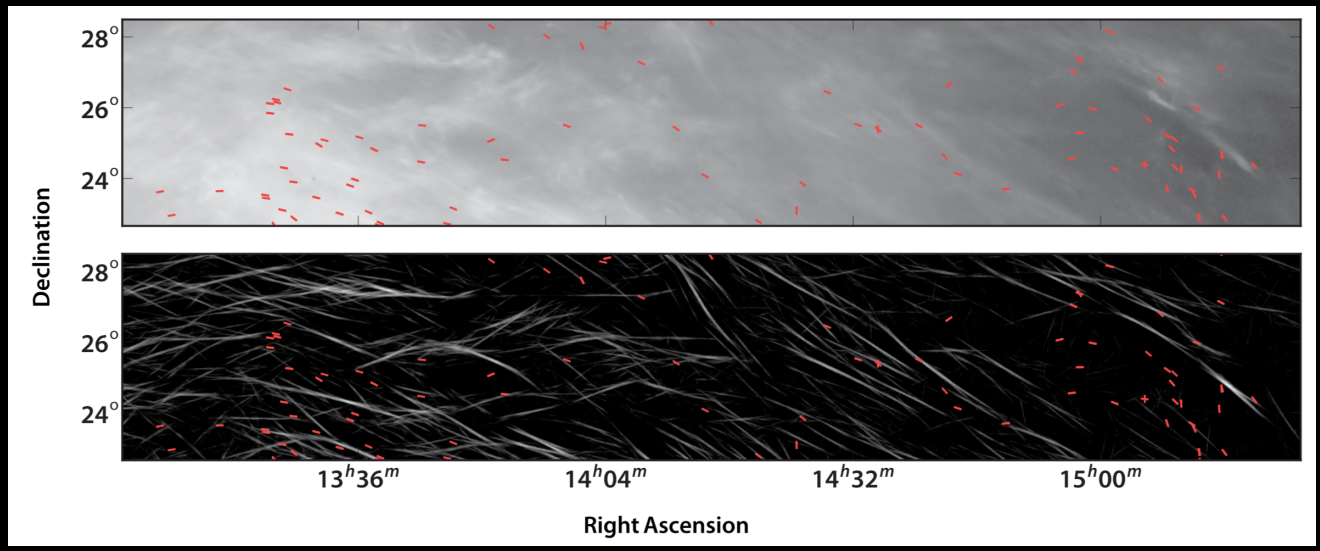
Origin and straightness of the observed structures ?!

Are they a projection effect of complicated morphology in the magnetic field and/or in the ionized gas distribution ?

Are they associated with fast-moving close-by stars interacting with the ISM?



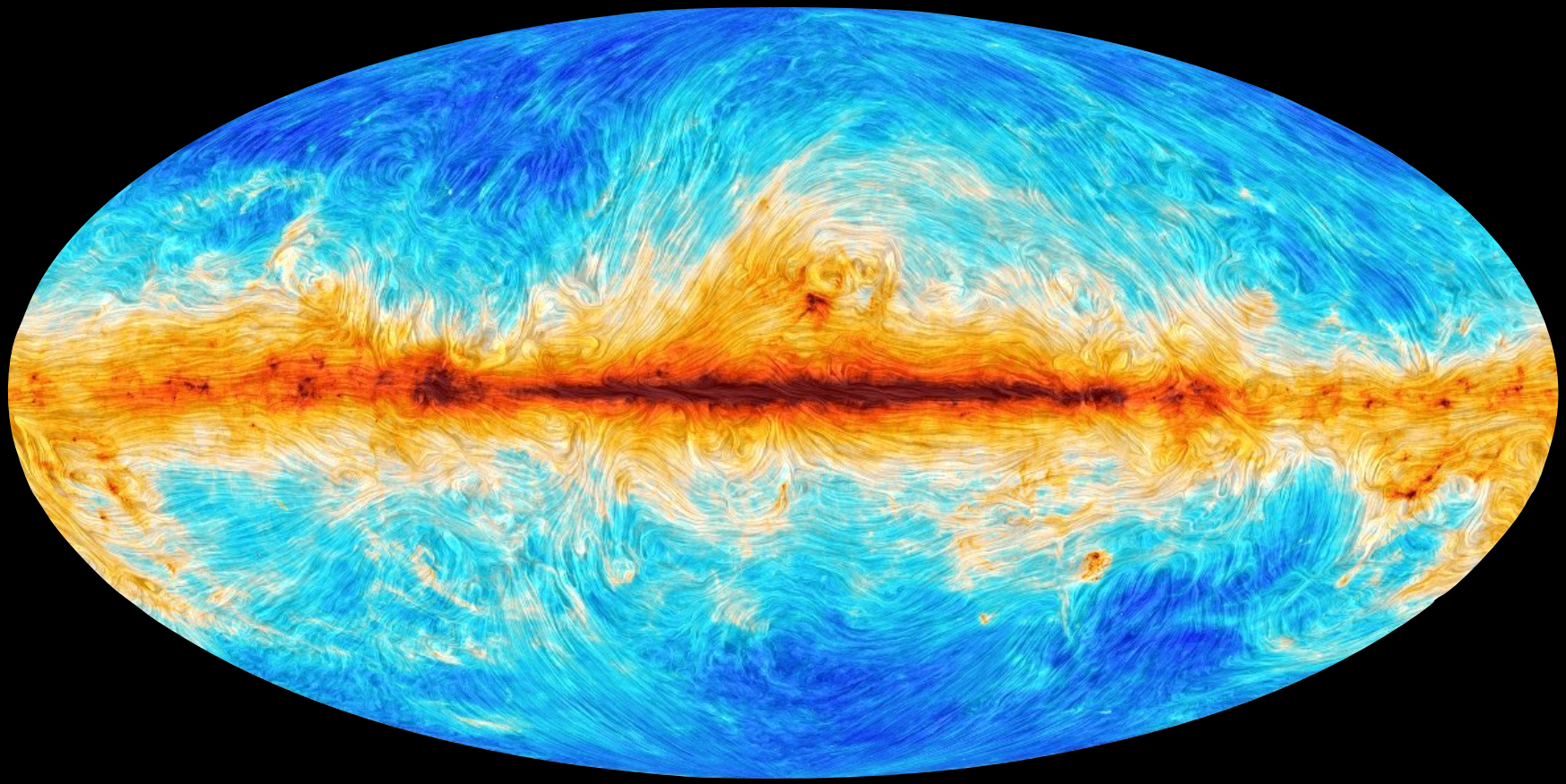
MHD simulations of ISM:
in the presence of weak ordered magnetic fields, sub-Alfvenic anisotropic turbulence produce fibers/ filaments aligned along the magnetic field lines
(e.g. Henebelle 2013, Choi & Stone 2013)



GALFA-HI and GASS Surveys
magnetically aligned fibres
(Clark et al. 2014)

=> edge-on seen shocks in which the field is parallel to the sheet
(Heiles & Crutcher 2005)

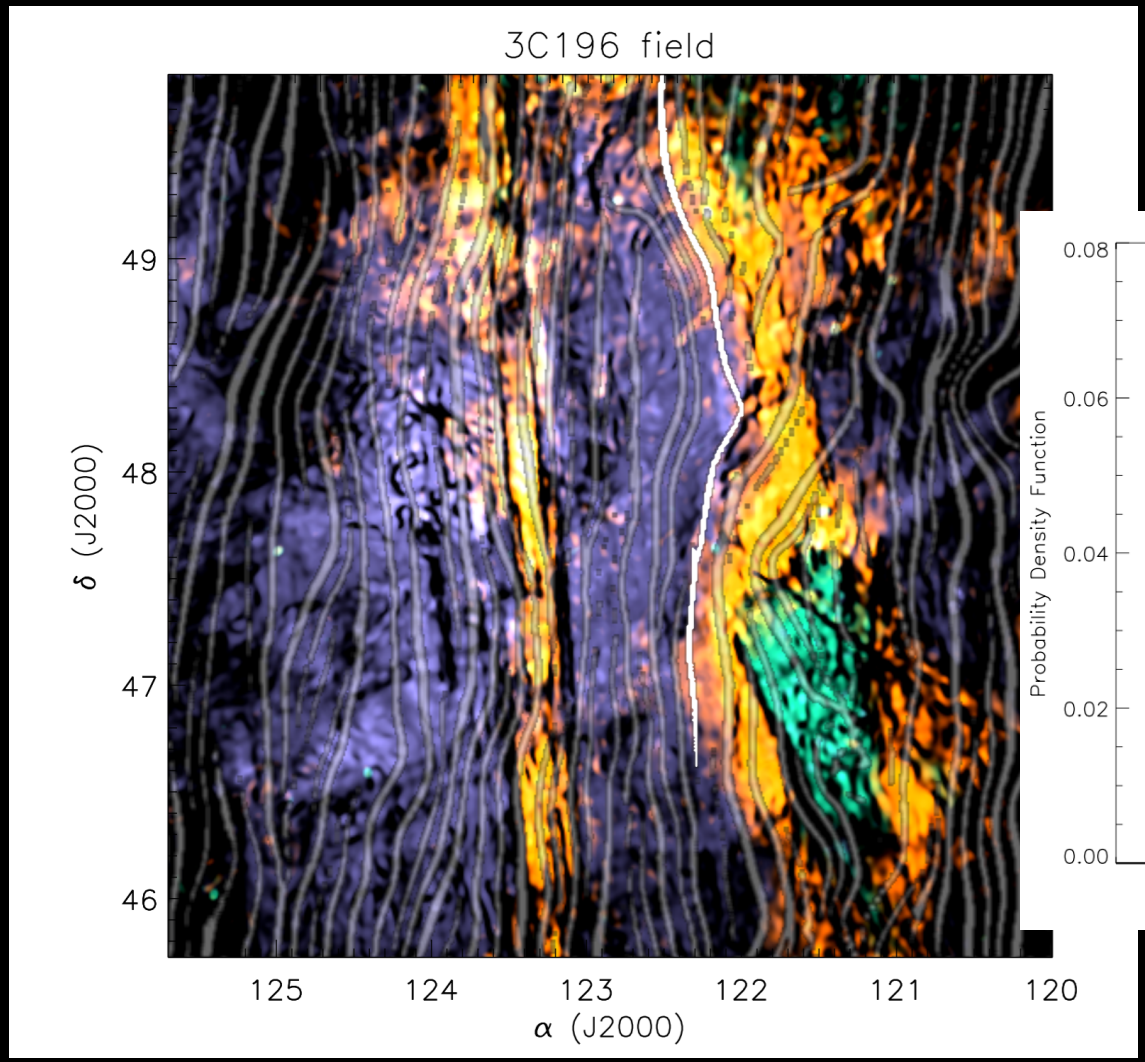
3C196 field
Planck and LOFAR

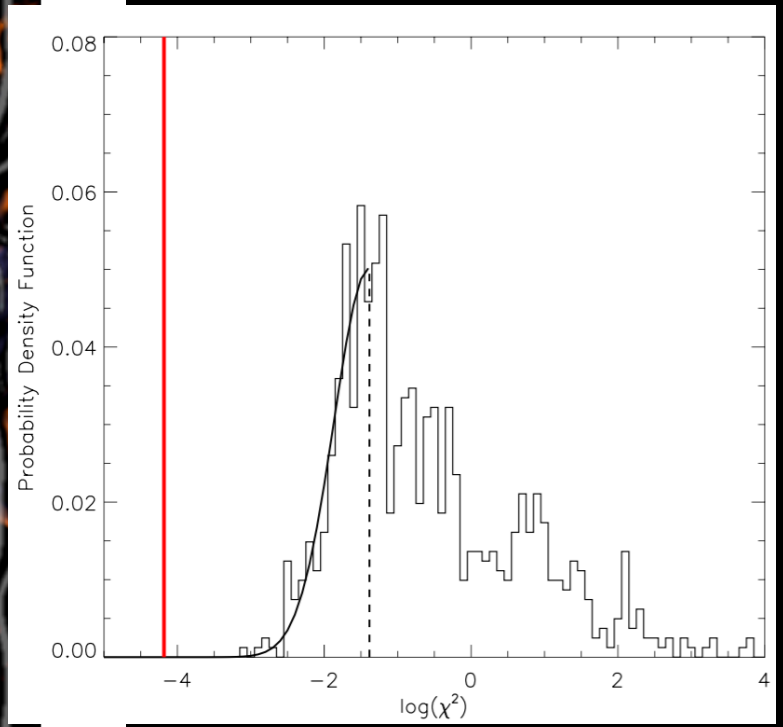


Planck map @ 343 GHz

Planck Collaboration I and XIX 2015

3C196 field
Planck and LOFAR

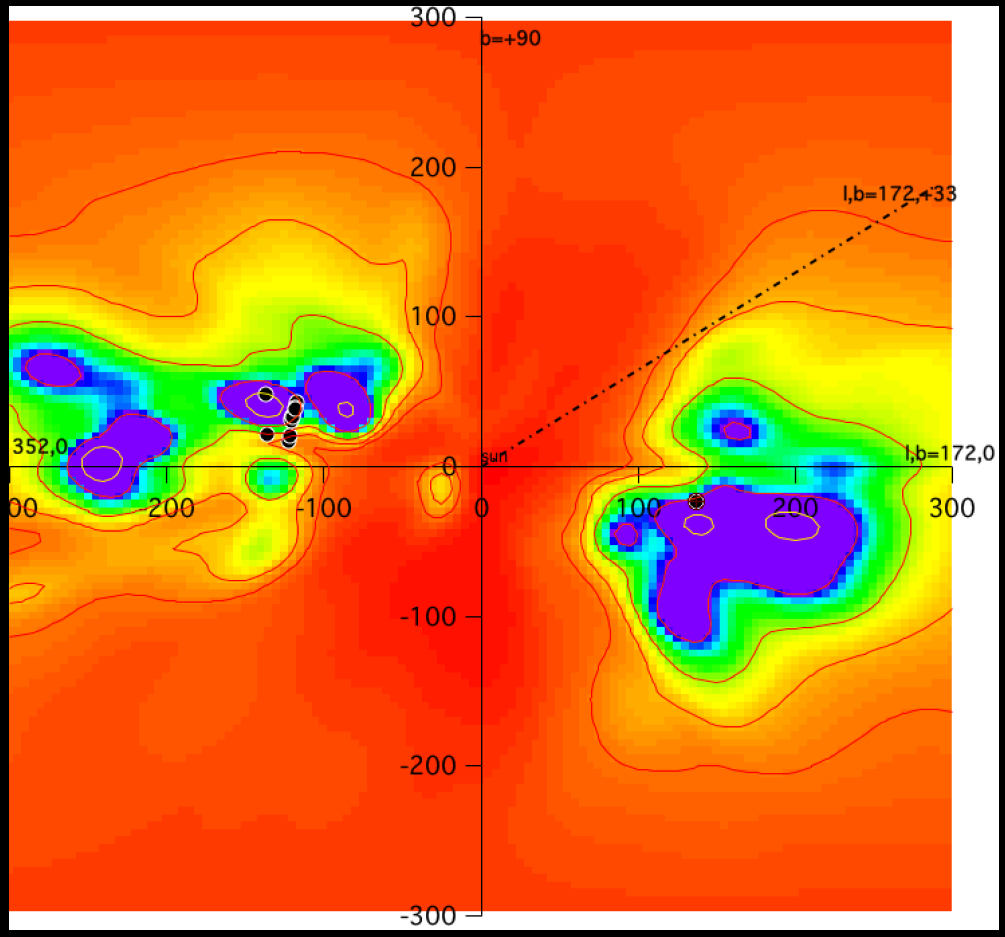




Zaroubi et al., 2015, MNRAS Letters

3C196 field
3D local interstellar dust distribution

- based on colour excess data and parallax/photometric distance for 23 000 stars within 2.5 kpc from the Sun



Lallement et al., 2014, A&A and private communication

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LOFAR

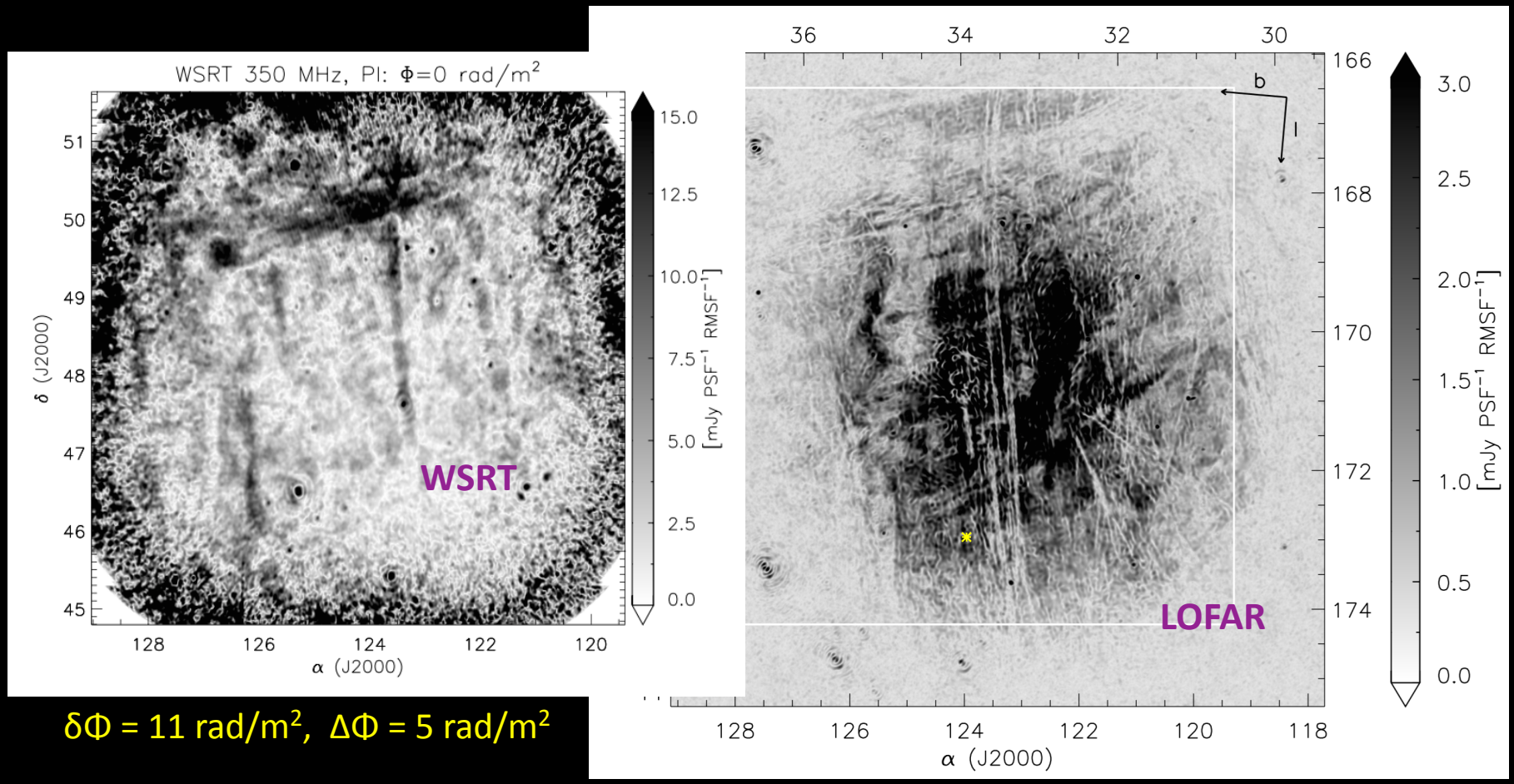
ASTRON
Netherlands Institute for Radio Astronomy

- rich morphology of polarized emission detected with LOFAR (115 - 175 MHZ), with the brightness temperature of a few K
- probed ISM mostly close by (<200 pc), within the Local Bubble
- discovery of many filamentary structures and linear depolarization canals (sub-Alfvenic anisotropic turbulence in the presence of magnetic field)
- the filamentary structure also shows a signature is Planck dust polarization maps, a common underlying physical structure
- surveying a larger area of the sky and observations at other frequencies
- LOFAR an excellent instrument to study ISM and constrain its physical properties, at an exquisite resolution in Faraday depth (1 rad/m^2) and at angular resolution hardly affected by the beam depolarization

THANK YOU !

3C196 field
WSRT 350 MHz and LOFAR

$\delta\Phi = 1$ rad/m^2, $\Delta\Phi = 1$ rad/m^2



$\delta\Phi = 11$ rad/m^2, $\Delta\Phi = 5$ rad/m^2

Jelic et al., 2015, A&A