

Polarization and RM-structure in the Galactic halo and the Perseus cluster

Ger de Bruyn

ASTRON, Dwingeloo

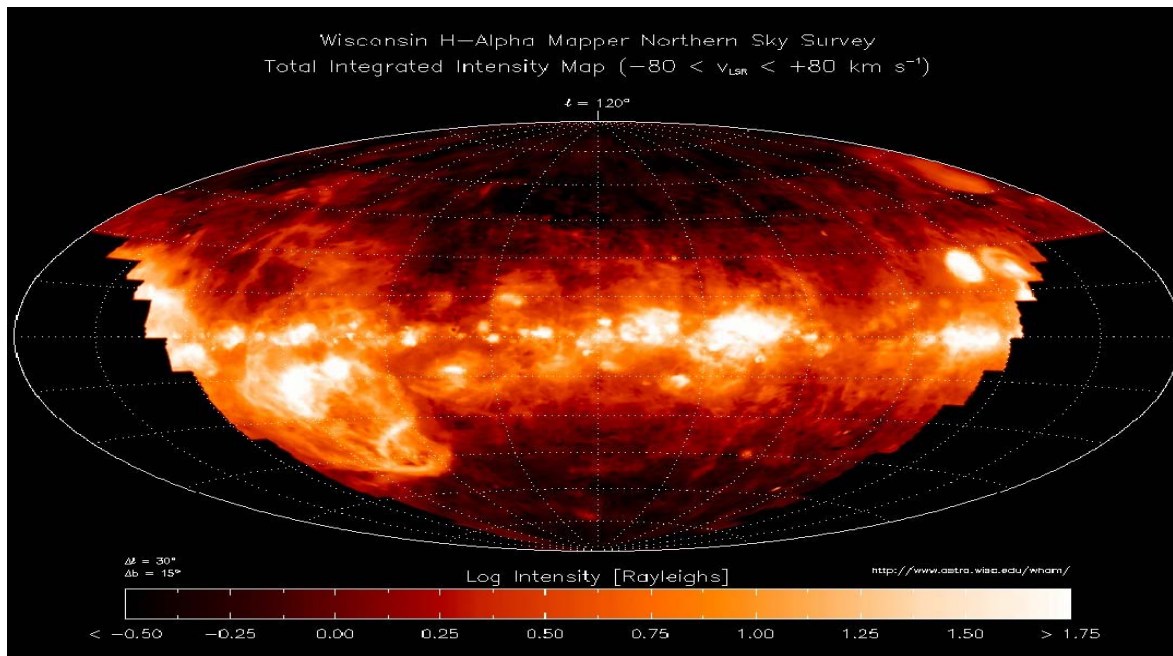
& Kapteyn Institute, Groningen

Collaborators:

*Peter Katgert, Marijke Haverkorn,
Dominic Schnitzeler & Michiel Brentjens*

Outline

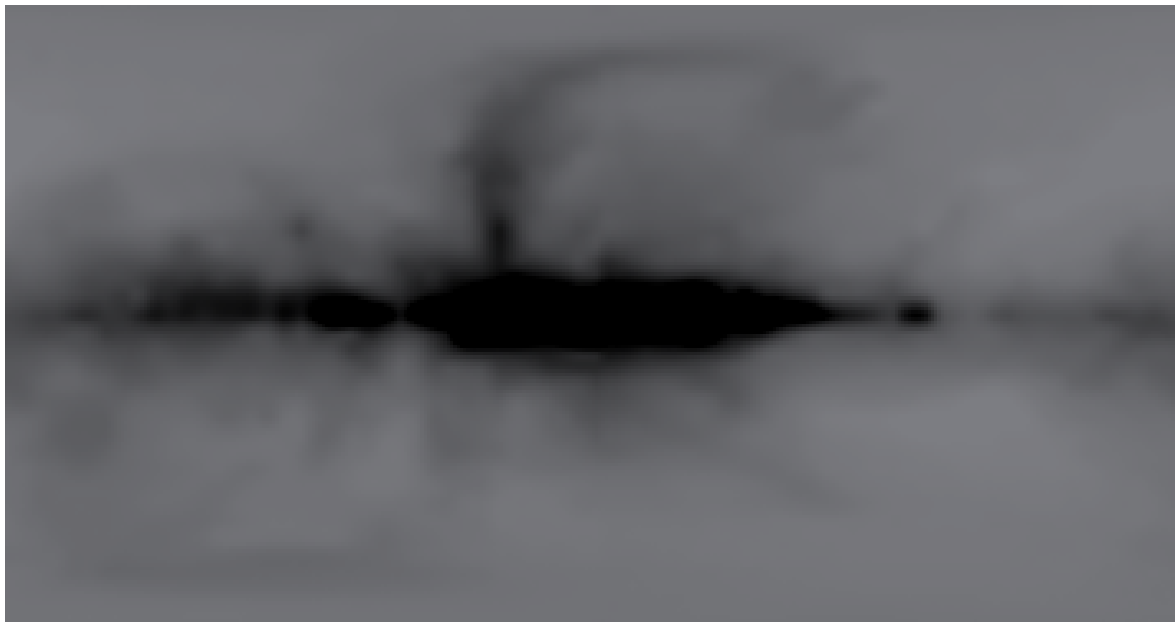
- Galactic synchrotron emission issues
- Low frequency polarimetry & RM synthesis
- High Galactic latitude polarization and RM structure
- LSS shocks, AGN relics and magnetic fields in clusters of galaxies
- Future: from 350 MHz (WSRT) → 150 - 60 MHz (LOFAR)



The Galaxy in H α

**WHAM survey,
Wisconsin**

**Haffner, Reynolds et al
2003**



**The Galaxy in 150 MHz
continuum**

**Landecker and
Wielebinski, 1970**

Observations of the Galactic magneto-ionic medium

Probes:

- **(Polarized) synchrotron emission**
- **Rotation Measures**
 - discrete sources: RG, QSR, PSR (> 1000 objects)
 - diffuse emission

Diffuse emission: Where to look ?

Disk ? → confusion due to l.o.s. superposition

High latitude? → faint → low frequencies (good T_b sensitivity)

The 'DOGLEG area' in Auriga

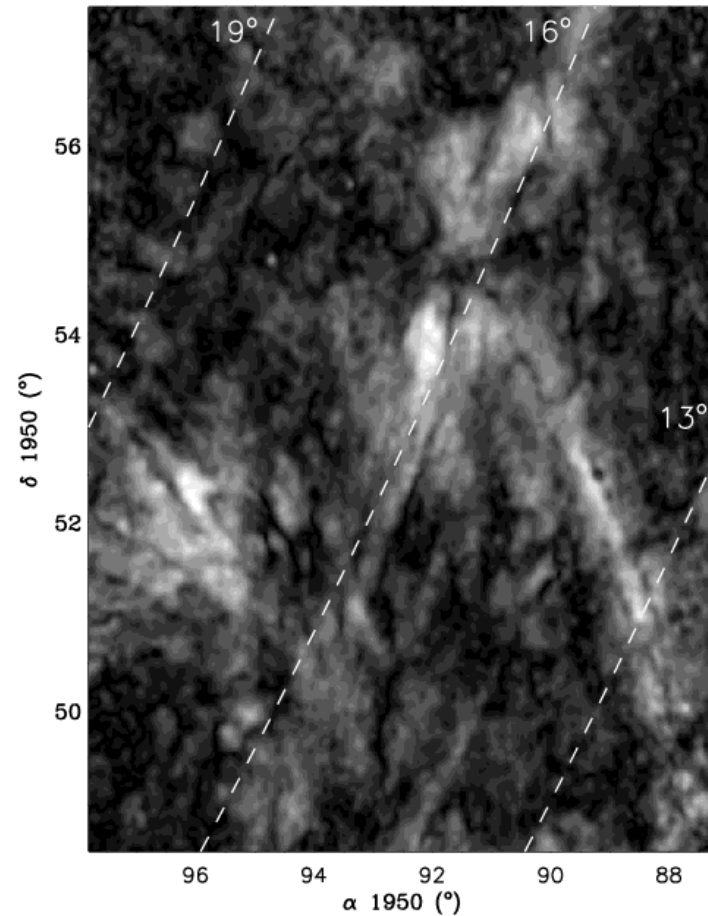
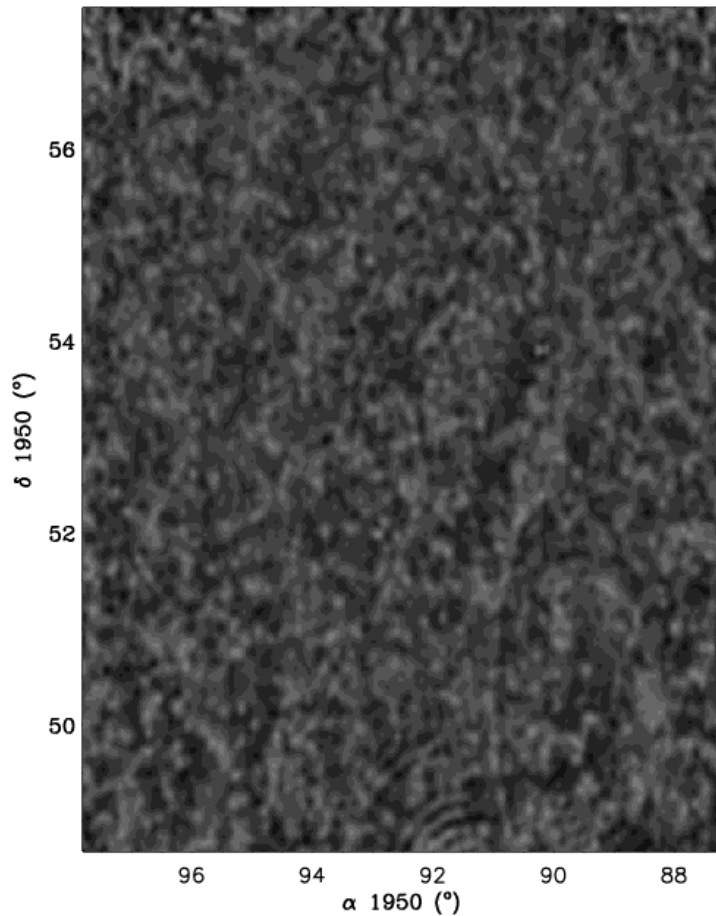
WSRT ~ 350 MHz

Total intensity

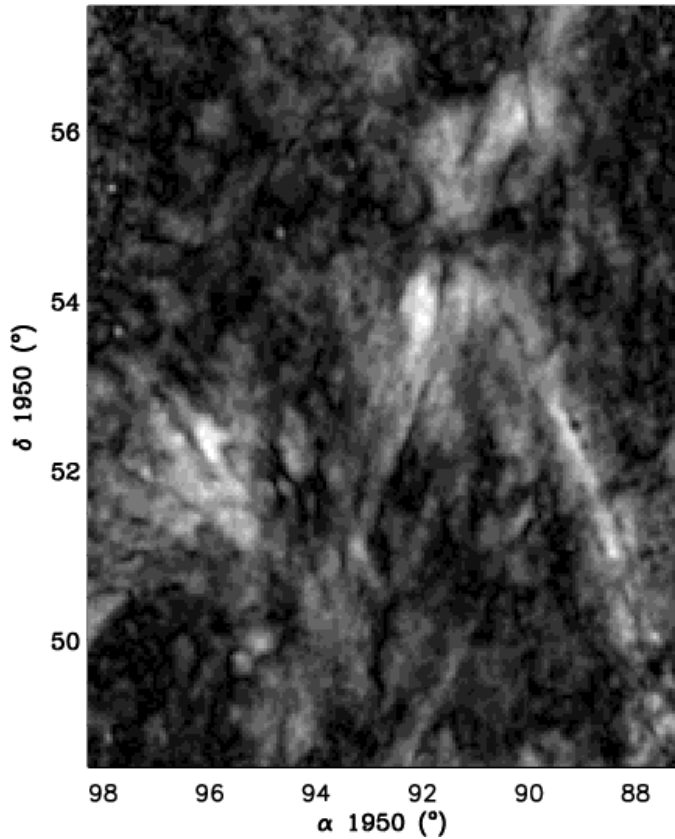
← same intensity scale !→

Polarised intensity

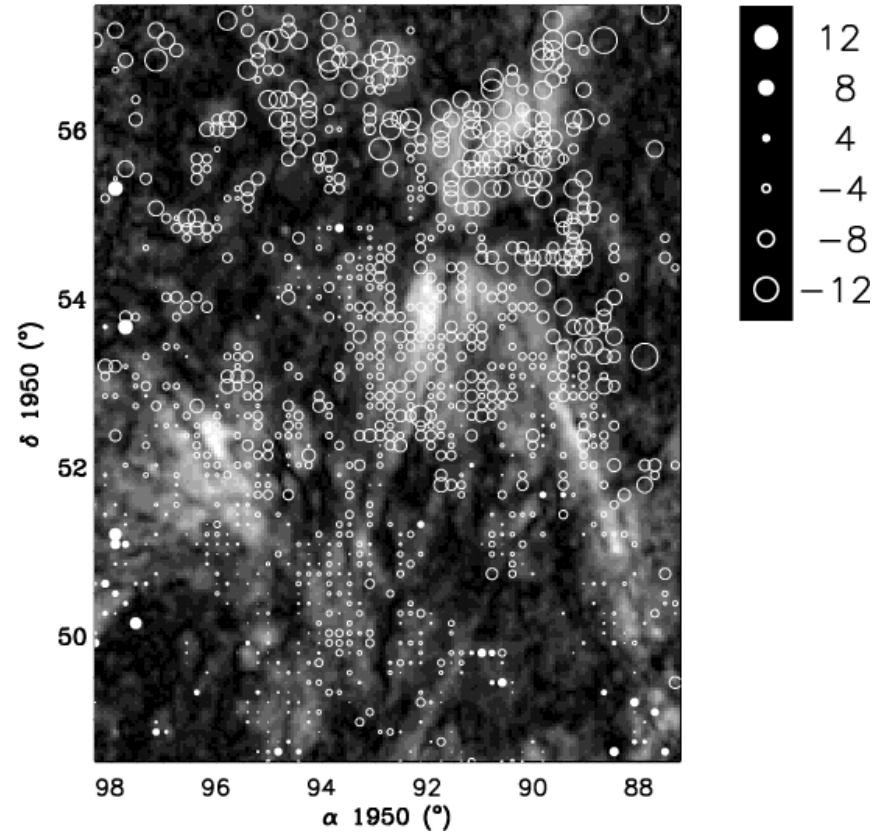
Discrete sources removed



Polarised intensity



RM distributions



Haverkorn et al (2003,2004)

RM-values using point-by-point fits to 5 frequency bands

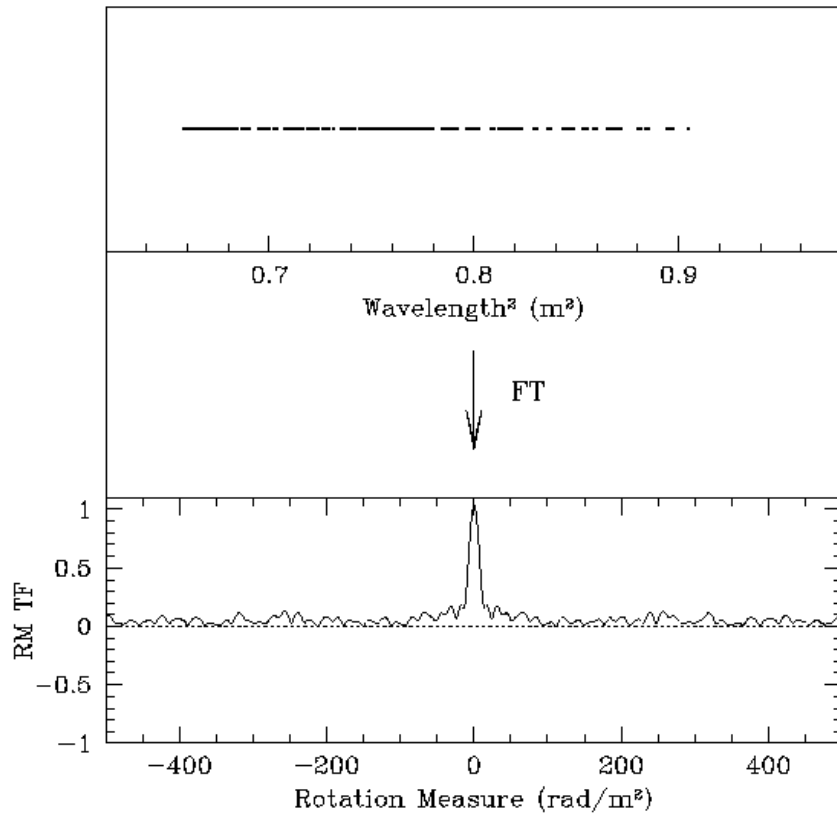
Low frequency polarimetry aspects:

(< 400 MHz, thusfar only WSRT)

- Spatial filtering of *smooth* Stokes I by an interferometer
(giving apparent polarization $\gg 100\%$)
- Propagation and instrumentation lead to various **depolarization** effects:
 - **beam** → use longer baselines (WSRT 3 km, LOFAR ~100 - 400 km)
 - **bandwidth** → use wide bands and RM-synthesis
 - **depth** → separate Faraday(-thick) layers in RM-space
- Powerful new tool: wide-field **RM synthesis**

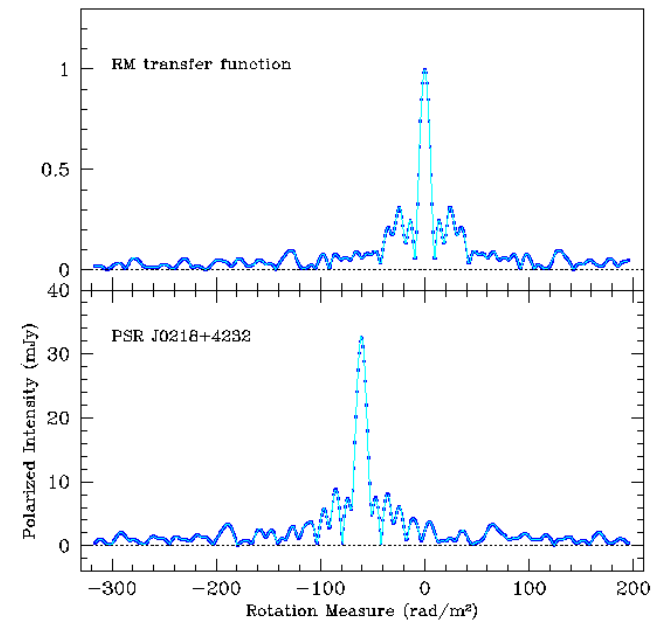
Wide-field low-frequency polarimetry through coherent addition of polarization (Q,U) images → RM synthesis

Brentjens & de Bruyn (astro-ph-0507349)



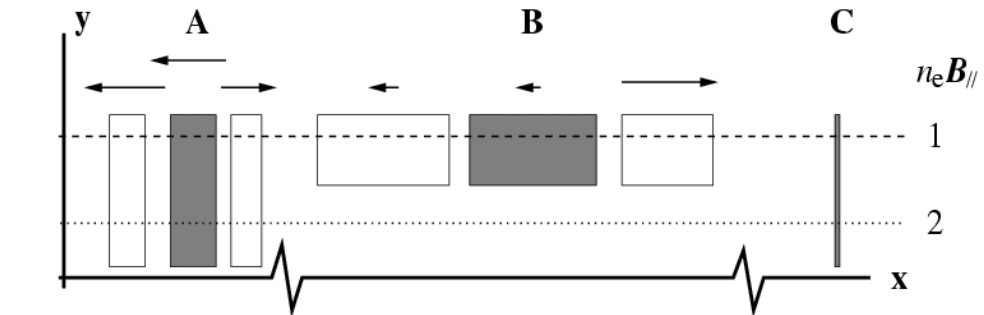
Rotation Measure Transfer Function
halfwidth $\sim 12 \text{ rad/m}^2$

RM and λ^2 form a Fourier pair in Faraday rotation (Burn, 1966)

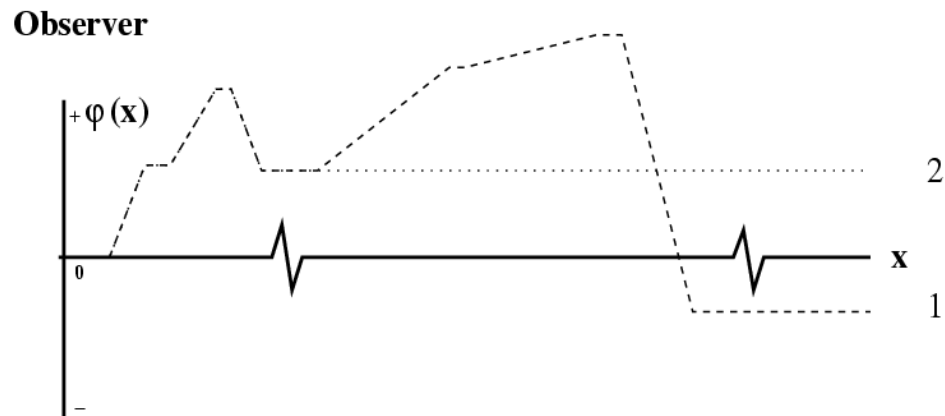


Multiple 'Faraday' layers along the line of sight

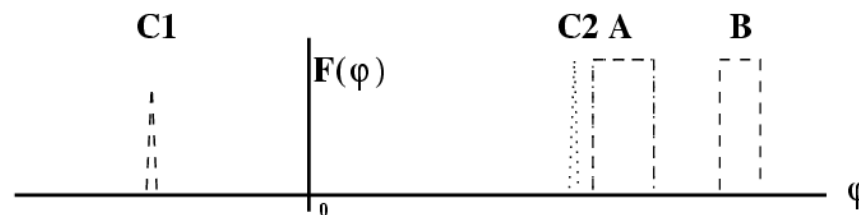
Physical sketch
(emission and/or rotation along l.o.s.)



Faraday depth (x)
along l.o.s



Polarised flux as
function of Faraday depth.



WSRT observations of a North Galactic Pole area (13h, +47; latitude = + 70)

I^2 range

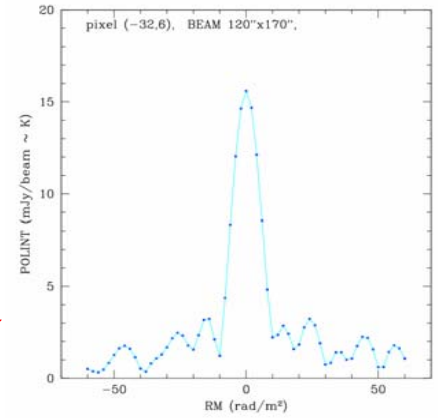
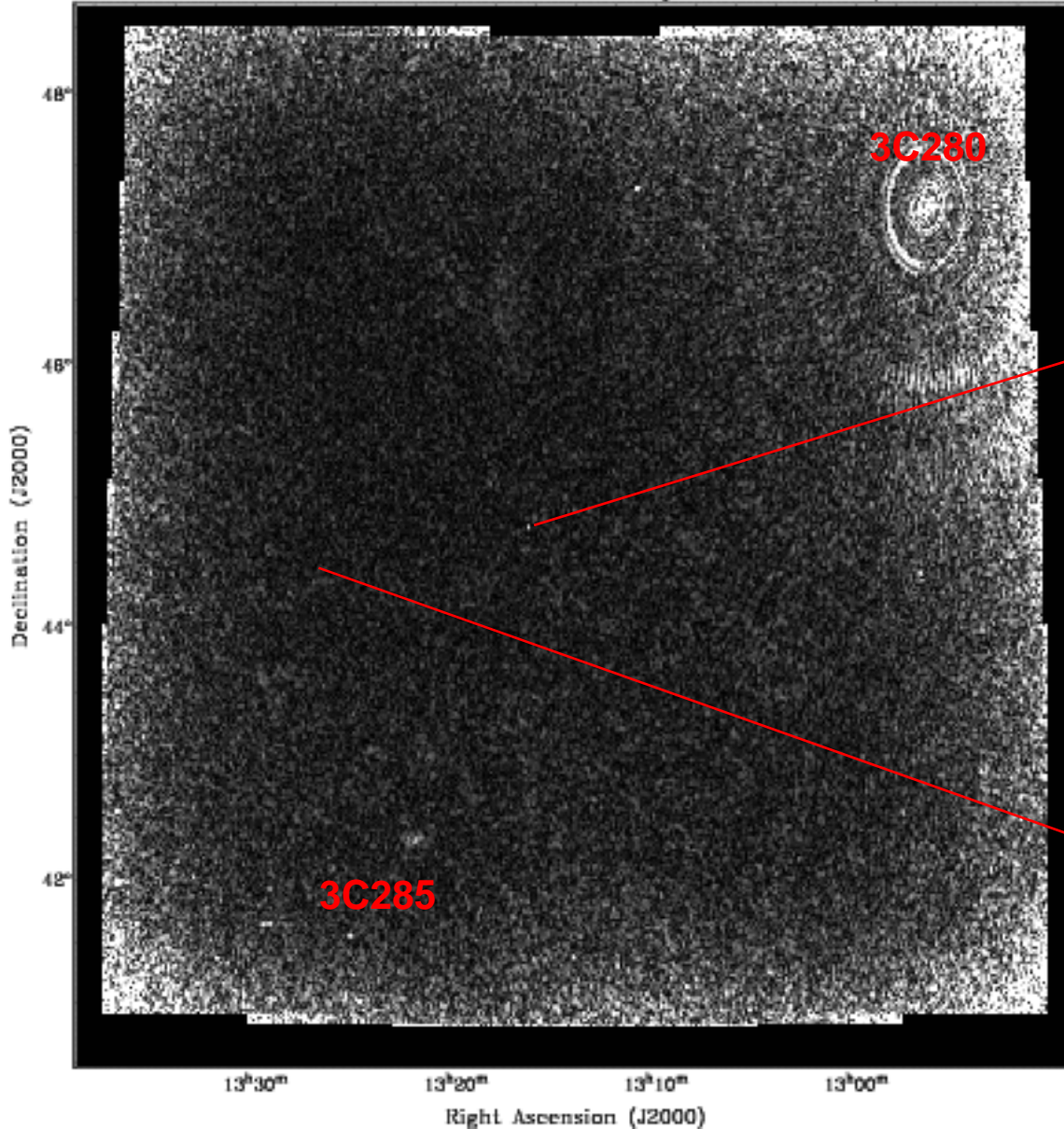
6x12h 315 - 388 MHz (512 ch) '1 meter band' 0.60 - 0.90 m^2

6x12h 115 - 165 MHz (1024 ch) '2 meter band' 3.3 - 6.8 m^2

(April 05, still being processed)

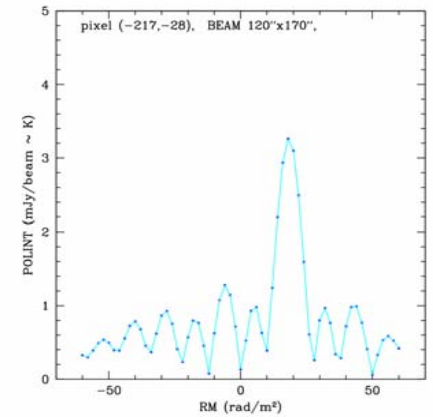
6x12h, 5 x 5 mozaic, 6° x 6° field

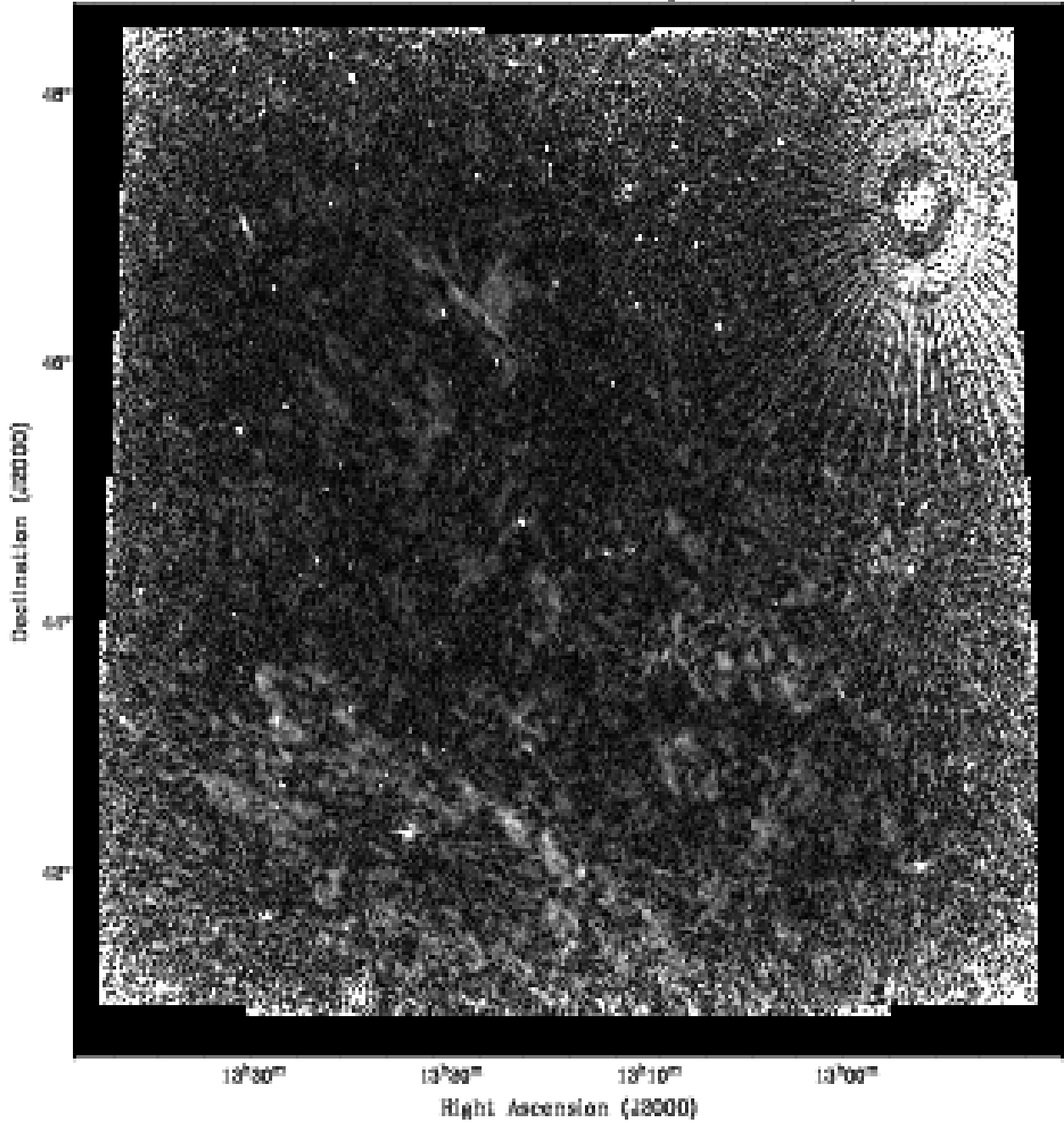
WSRT 315-388 MHz Polarised intensity RM=-20 rad/m²



RM-movie

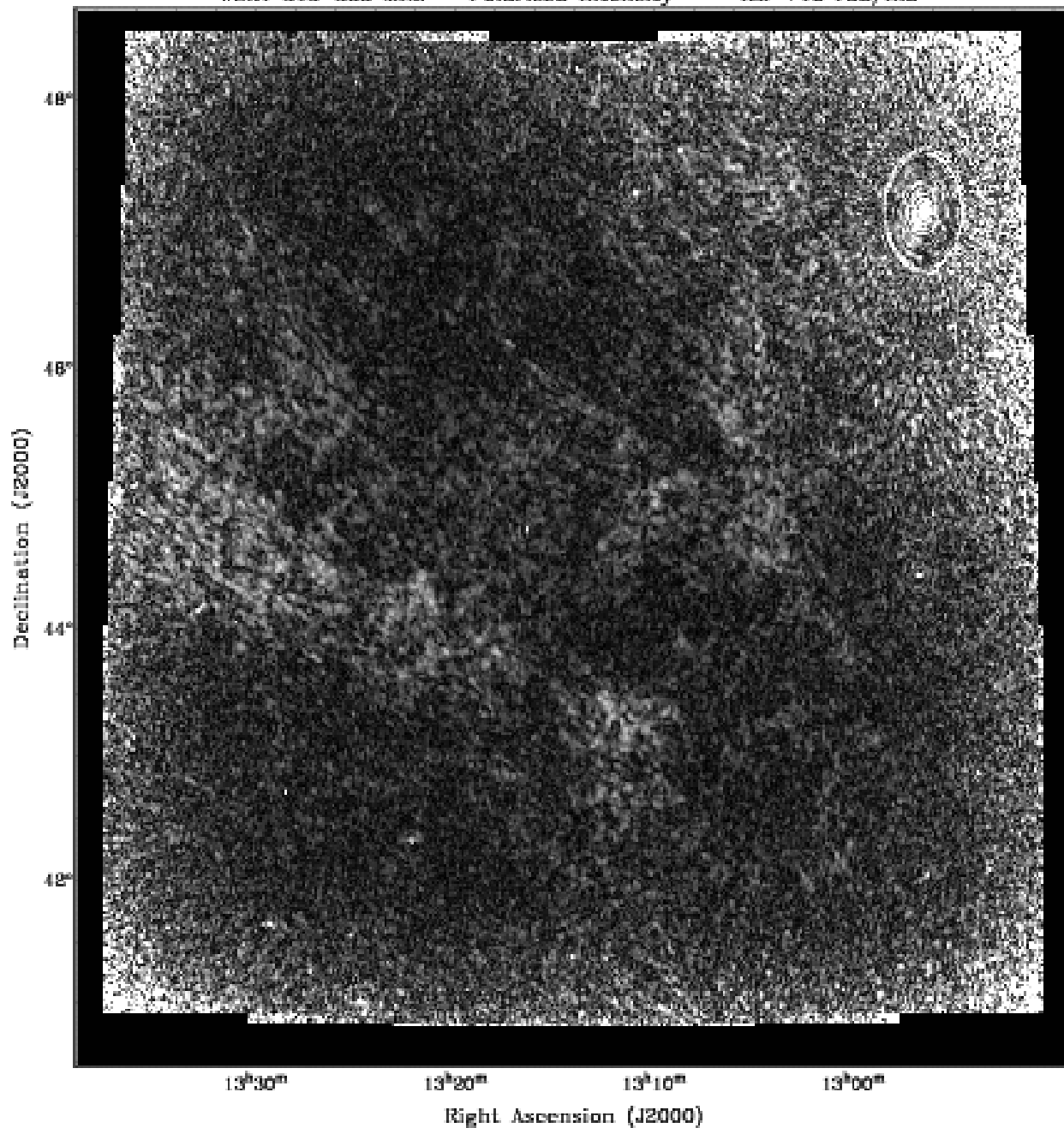
RM= -20 (4) +28 rad/m²





RM = 0 rad/m² frame

**noise in 2' beam
~ 0.4 mJy = 0.4 K**



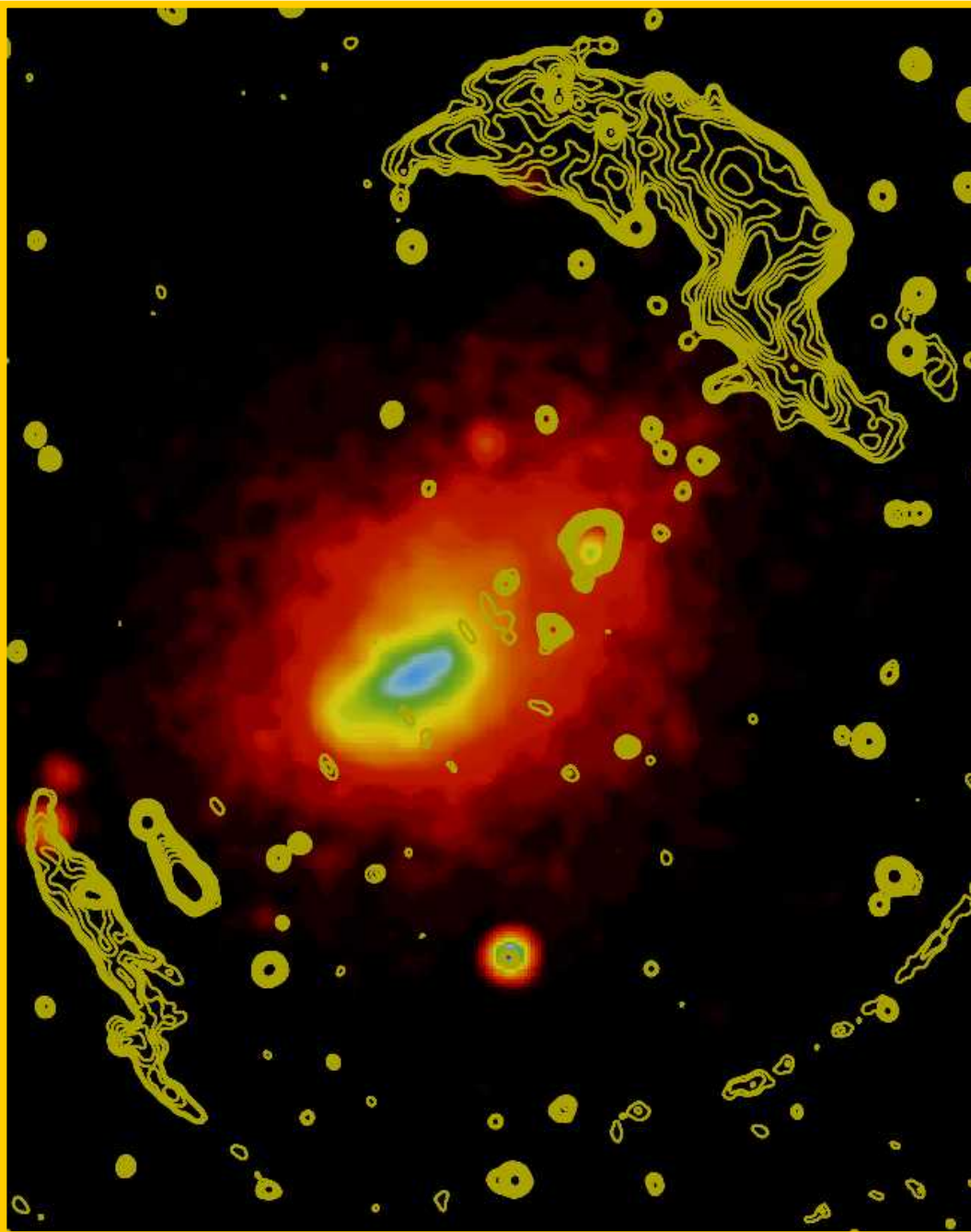
RM = +16 rad/m² frame

Conclusions (I)

- ❑ Large scale Galactic diffuse polarization in 1 meter band , $T_b \sim 5$ K
→ *extended probe* (as compared to RG, PSR)
- ❑ Complex spatial RM structure (-15 to +25 rad/m²) but,
- ❑ RM structure mostly **unresolved by the RMTF** in '1 meter band'
- ❑ Synchrotron emission & magneto-ionic distribution functions must be different

Some (radio-)astrophysical questions in clusters

- **Very rich radio phenomenology !**
- **halos (or mini-halos), relics, shocks, bubbles**
- **Radio galaxy duty cycle → relics, bubbles,...**
- **Origin and (significant) strength of magnetic fields**
- **Feedback of AGN on cluster evolution ('cooling catastrophe')**
- **Source of UHECR in LSS shocks ?**



Diffuse Mpc-scale
radio emission in A3667

Merger/infall shocks ?

Yellow contours show the
1.4 GHz ATCA data:

Pseudo-colour is the ROSAT
PSPC data

Rottgering et al, 1997

Johnston-Hollitt et al, 2003

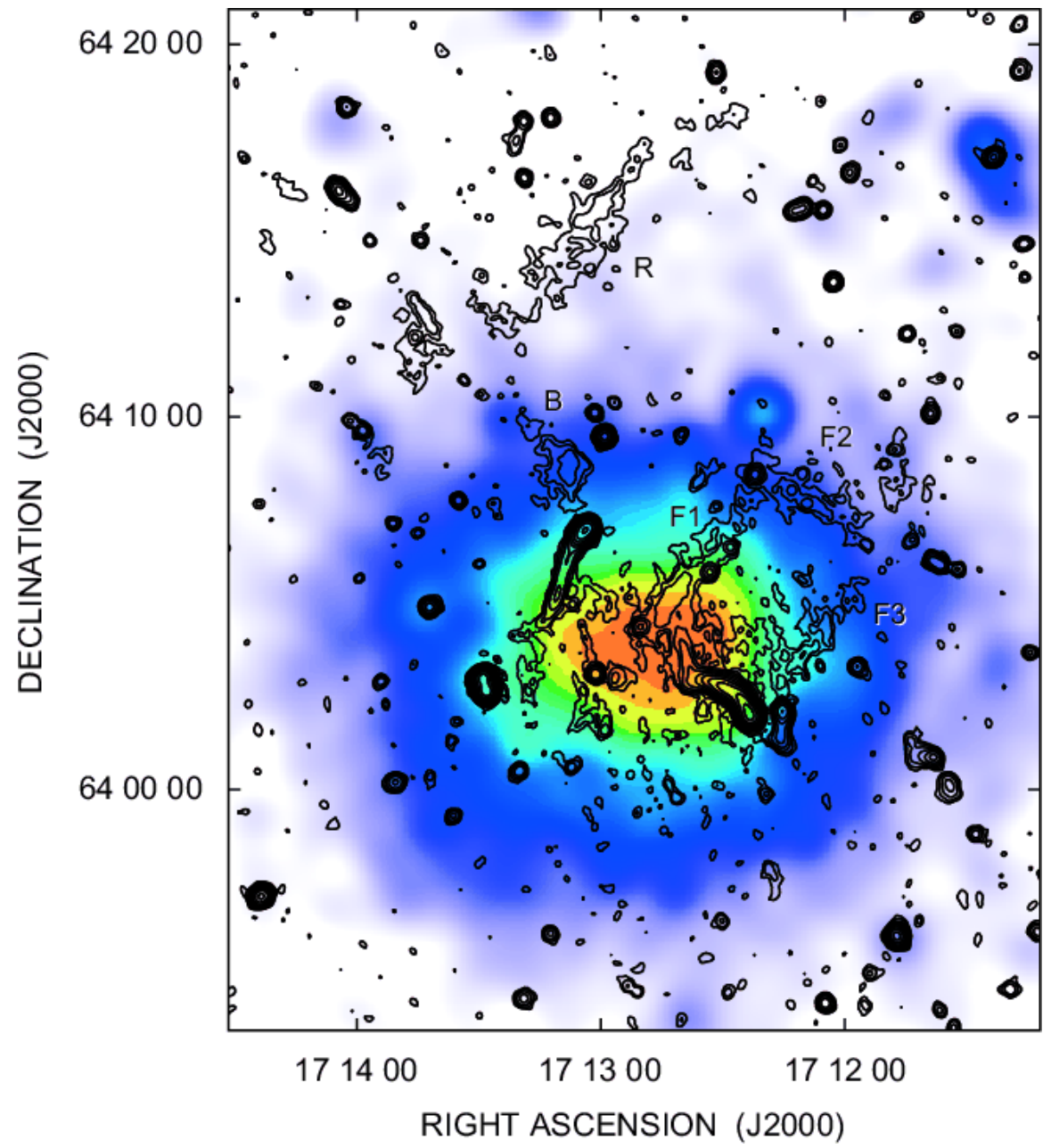
Abell2255 ($z=0.08$)

Govoni et al (2005)

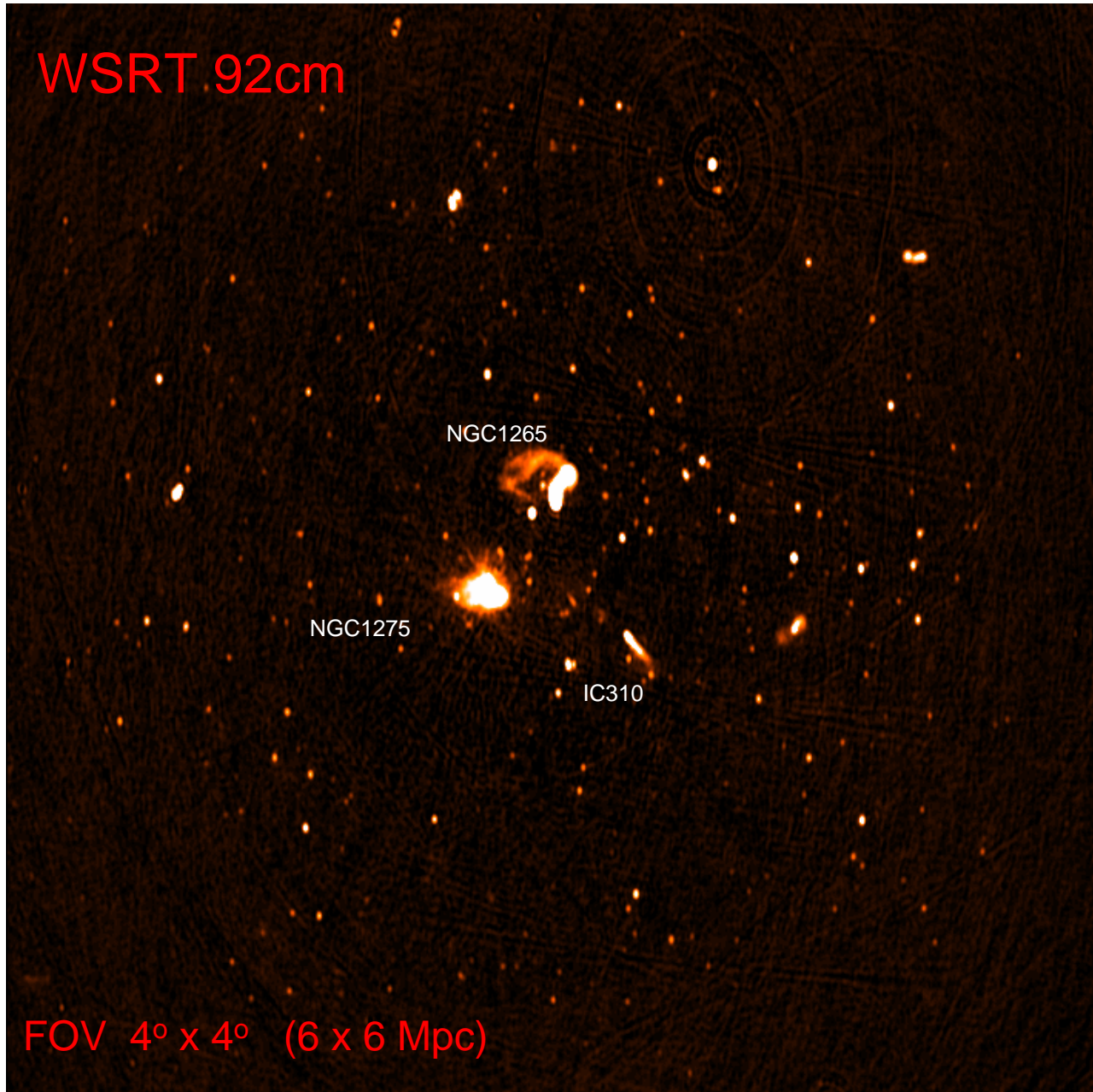
Contours: VLA 21cm

Colours: Chandra X-ray

Halo + relics + shocks ?



WSRT 92cm



Perseus (Abell 426)

$z=0.018$

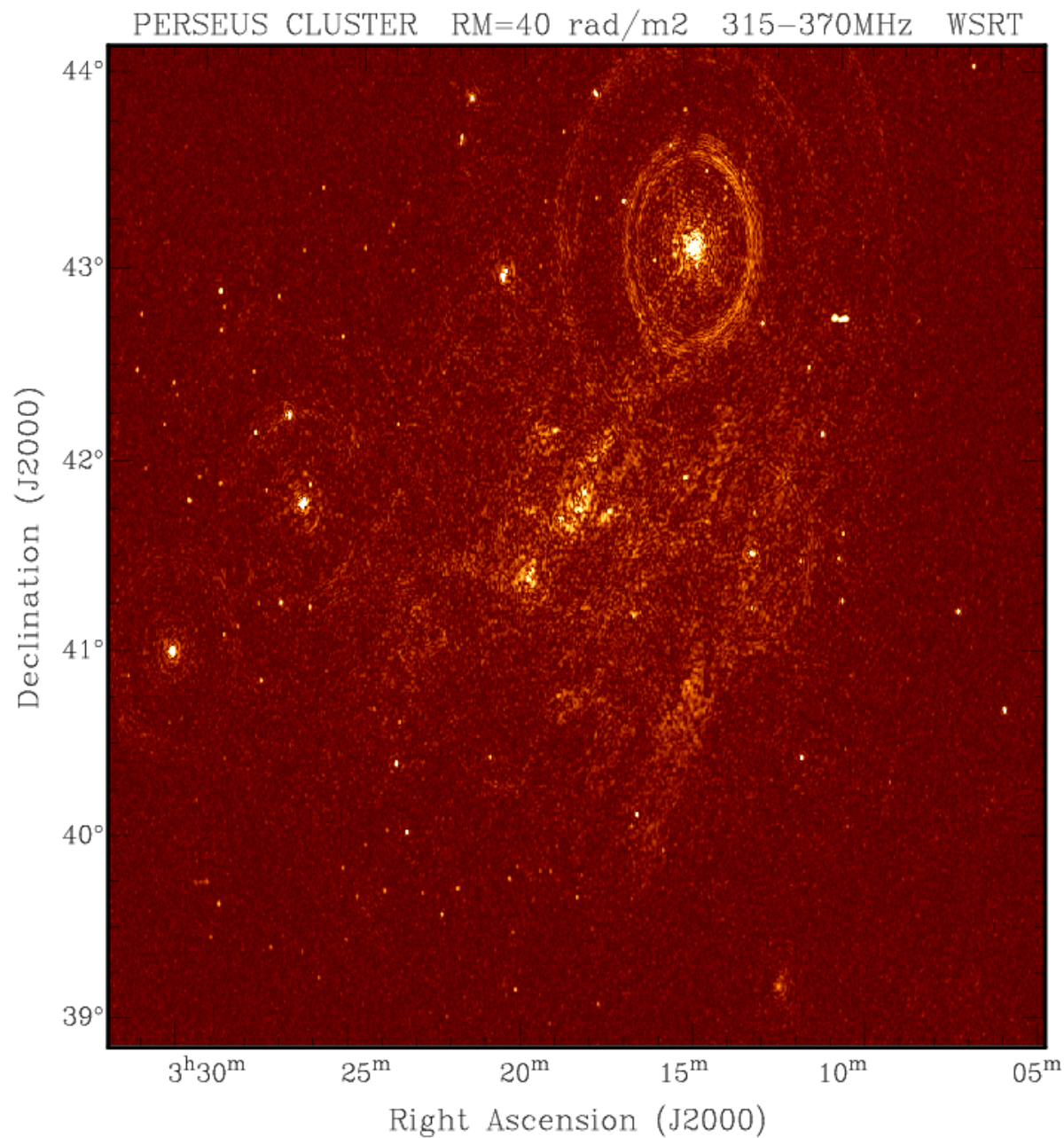
$D=80$ Mpc, $1' = 23$ kpc

FOV $4^\circ \times 4^\circ$ (6 x 6 Mpc)

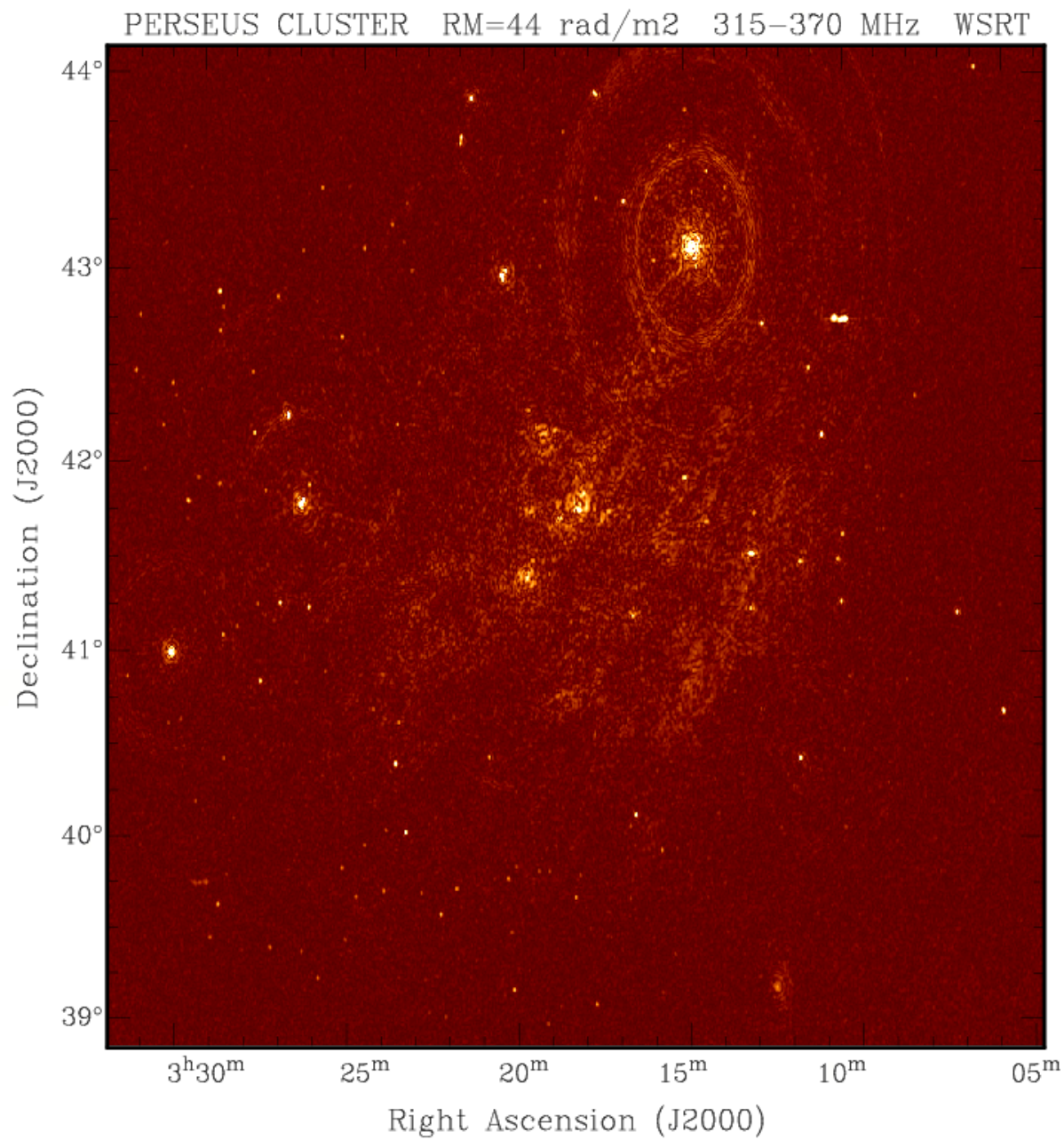
RM = +40 rad /m²

'cleaned' and at
full angular
resolution (1')

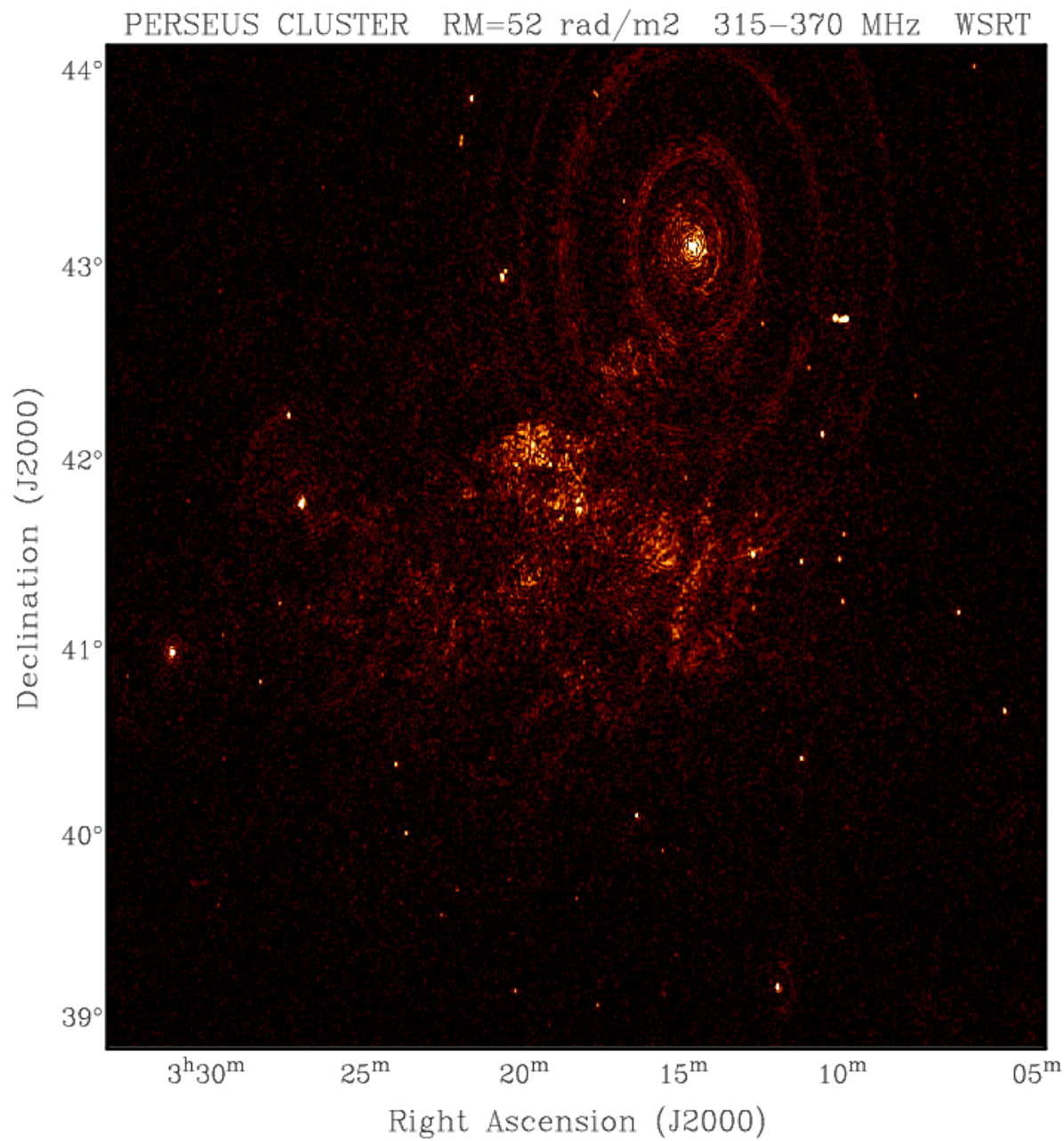
De Bruyn & Brentjens, 2005
(*astro-ph 0507351*)



RM = +44 rad /m²



RM = +52 rad /m²



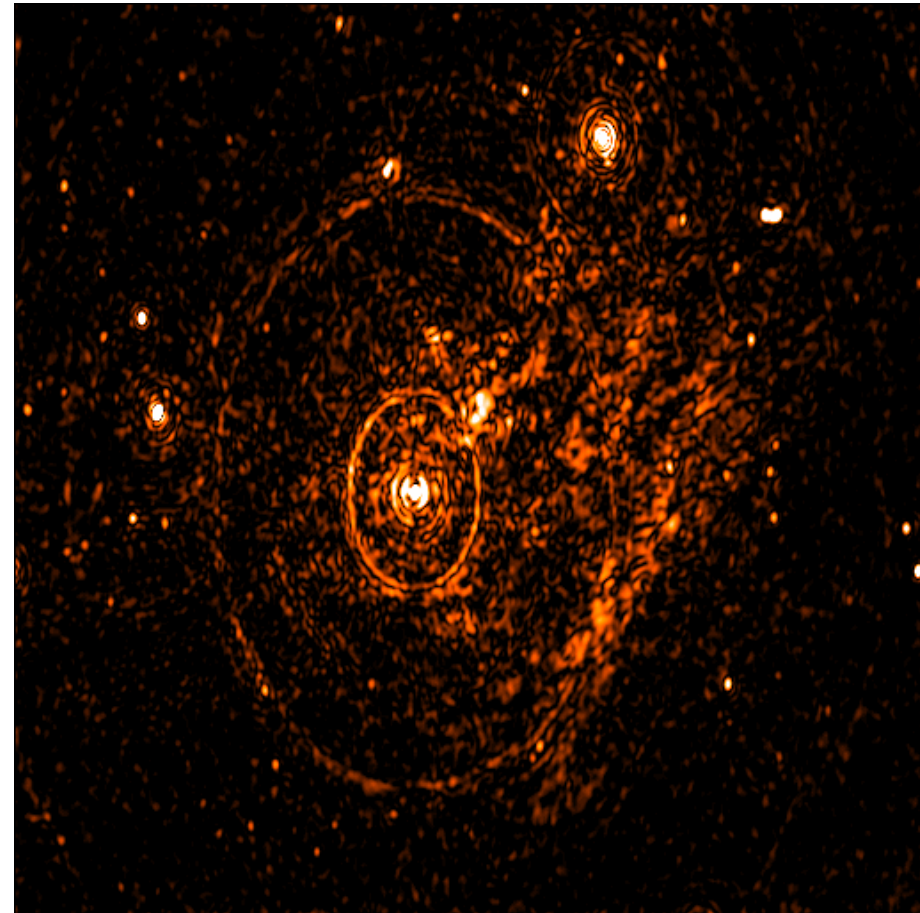
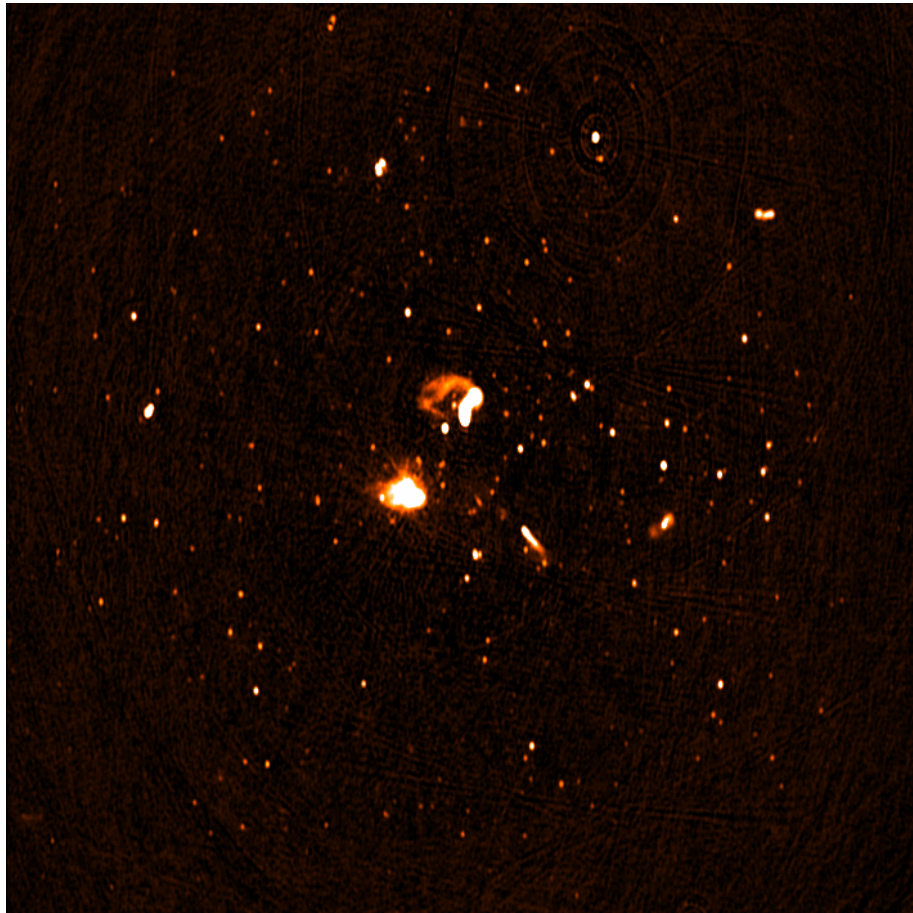
Total intensity

PERSEUS

Polarized intensity

20 Jy peak ~ 1-2 mJy noise

RM=+42 rad/m² ~ 70 - 100 mJy noise



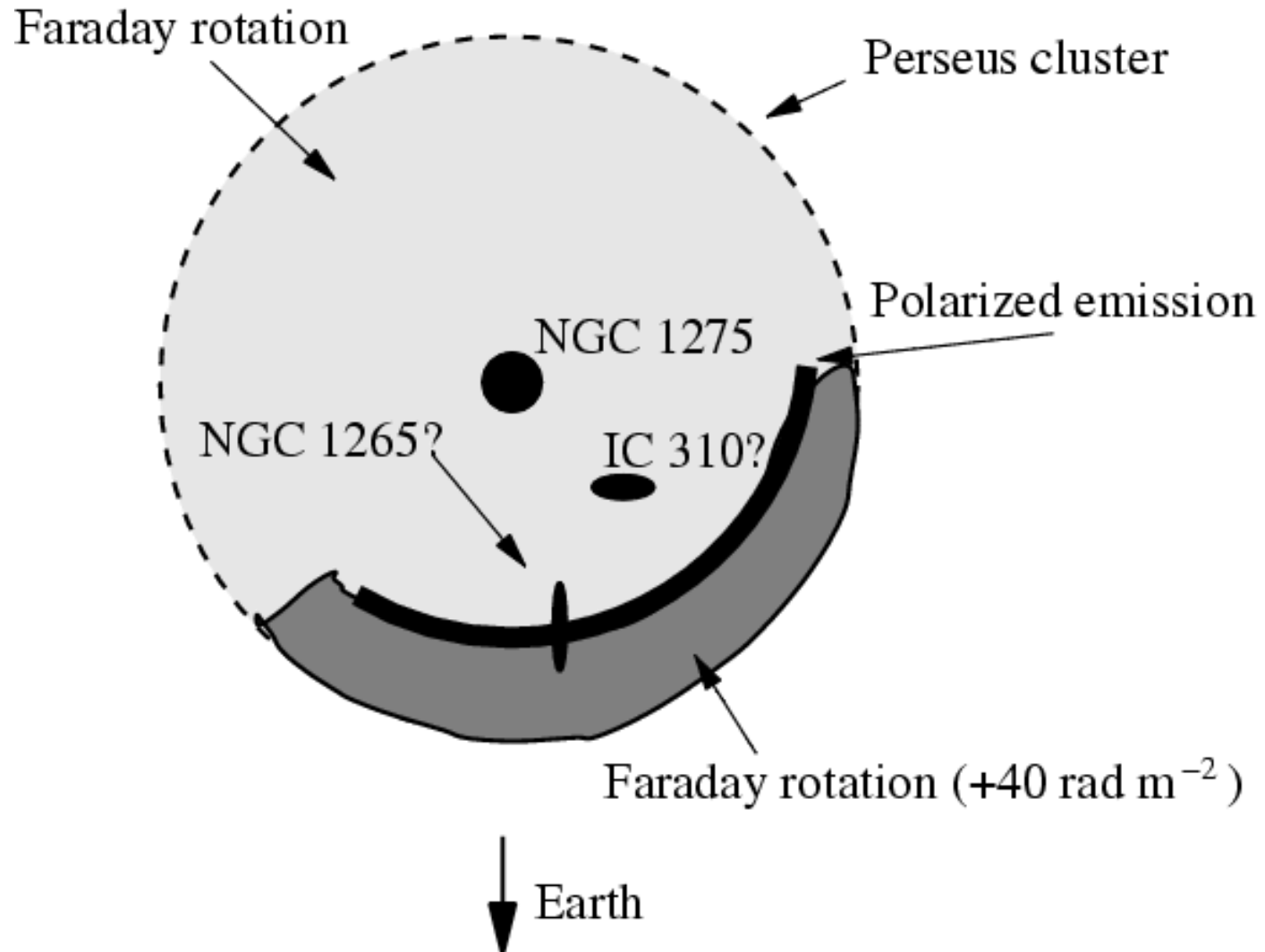
Possible origins of polarized emission

- Galactic foreground synchrotron emission
- Within Perseus cluster:
 - Thomson scattering (Sunyaev, 1982)
 - Shocked emission (synchrotron)
(e.g. A3667 Rottgering et al 97; Ensslin et al 1998/2003)

Probable locations of Faraday rotating 'screens'

- Galactic foreground $RM = -10$ to $+10$ rad/m²
- Within Perseus cluster $RM = +30$ to $+90$ rad/m²

A cartoon of a possible 3-D geometric model



CONCLUSIONS (II)

Presence of large scale polarized emission in ICM in / around Perseus:

- ❑ clusterwide shocks (+ TS in inner part ?)
- ❑ compression / alignment ICM magnetic fields
- ❑ If $RM=+40 \text{ radm}^{-2}$ at the periphery \rightarrow coherent B field of order 1 mGauss
- ❑ Probe of continuous 'merger' (Perseus-Pisces) or infall of gas
- ❑ Origin particles ? AGN-relics / buoyant bubbles or LSS shock acceleration.

Bright future for study of diffuse emission in / around clusters !

Will there be Galactic or Cluster polarization left at 120-180 MHz or even 20-80 MHz ?

1) **Depth-depolarization:** only effective IF emission and Faraday rotation are mixed →

‘Upper halo’ , or very local, polarized emission **may only rotate, and not depolarize!**

2) **Beam depolarization:** important → LOFAR resolution needed

e.g.: a RM-gradient of $6 \text{ rad/m}^2 / \text{degree}$ at 150 MHz

or $1 \text{ rad/m}^2 / \text{degree}$ at 60 MHz

→ 38° rotation / 2' beam

Some future developments in low frequency polarization and RM studies

- ❑ WSRT 115 - 170 MHz
- ❑ LOFAR 20 - 80 / 115 - 240 MHz
- ❑ RM 'resolution' of $\sim 1 \text{ rad/m}^2$
- ❑ Create a polarized Global Sky Model to Calibrate ionospheric Faraday rotation
- ❑ Solar system weather (turbulence, n_e , B-field)
- ❑ Preparing for LOFAR Epoch of Reionization (Galactic foreground is a MAJOR challenge)

Declination (J2000)

