

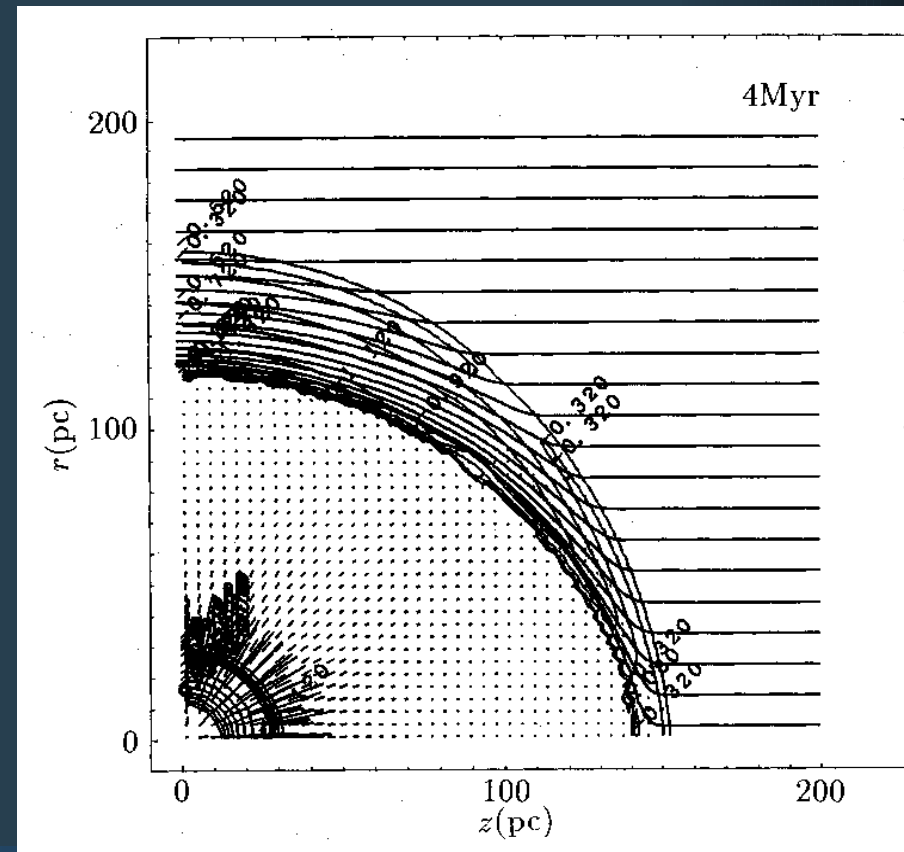
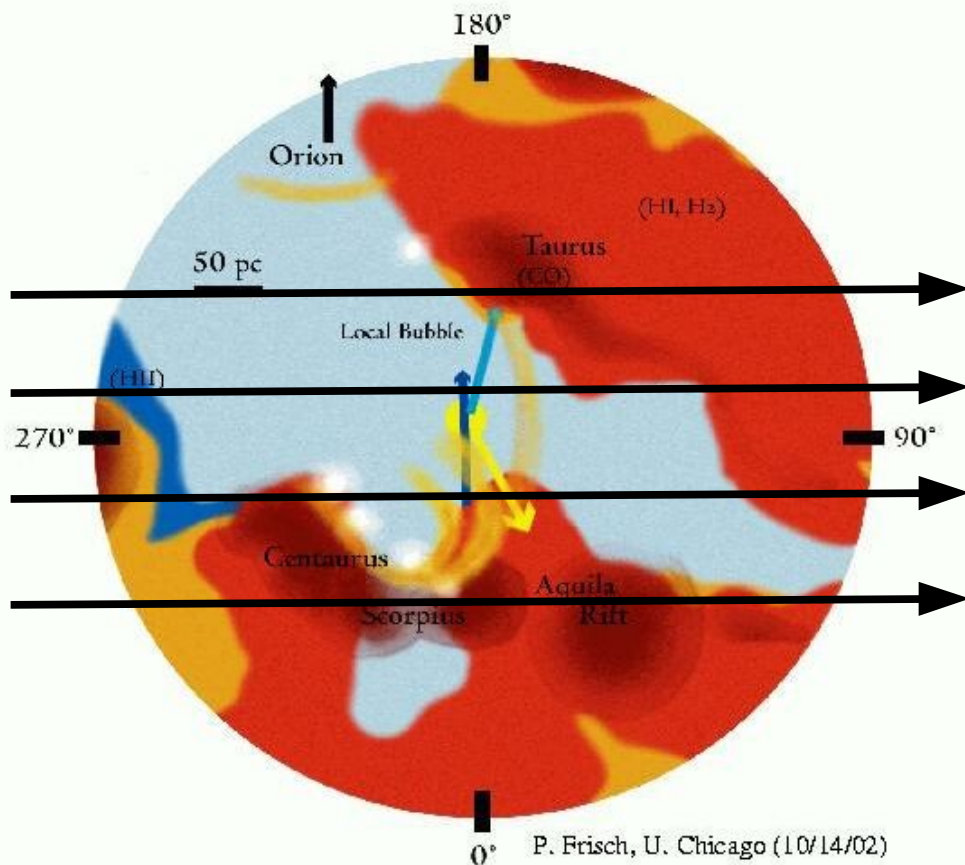


# Rotation Measure Synthesis of the Local Magnetized ISM: The B-field of a Nearby HI Bubble

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Covington Fellow, DRAO

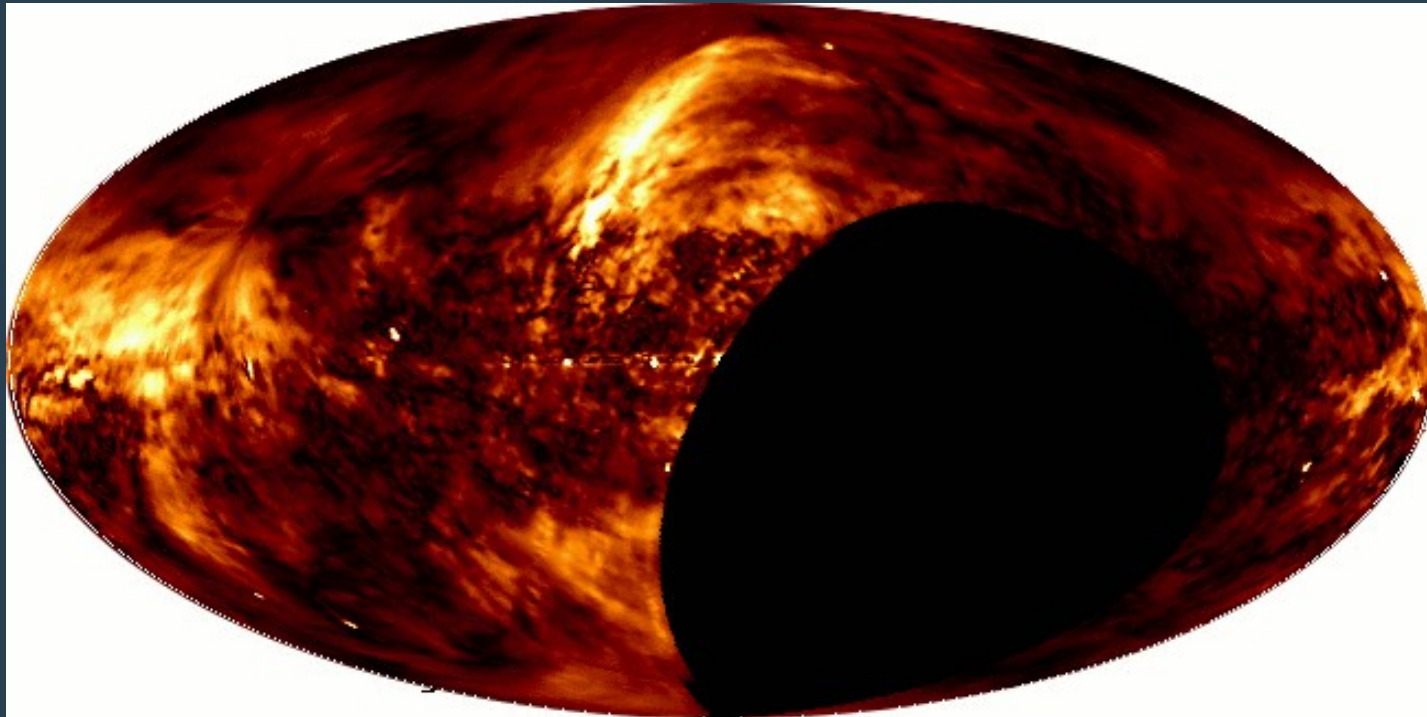
# The Local ISM

- Local Bubble, mean local B-field pointed towards  $l=90^\circ$
- Expanding shells sweep up and compress the ambient B-field
- Scorpius Centaurus association  $\sim 100\text{pc}$  away towards the Galactic centre



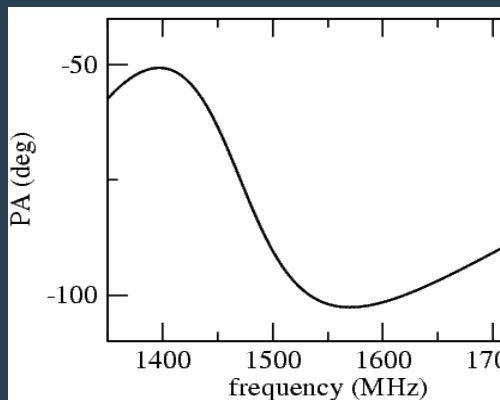
# Polarized Emission Surveys

- Polarized Intensity at 1.4 GHz
- Single frequency surveys (CGPS, EMLS, DRAO, Testori et al.)
- Data suffer from depolarization due to differential Faraday rotation and beam depolarization
- Polarized filament of the North-Polar Spur (local)
- Rotation measures unknown from these observations

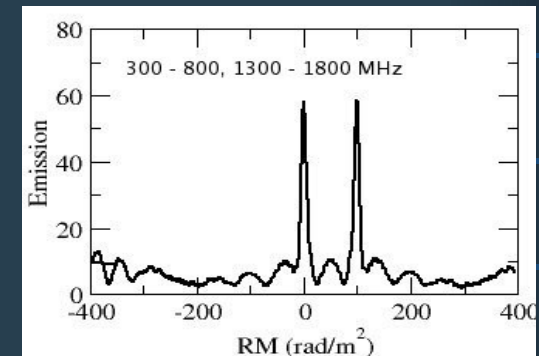
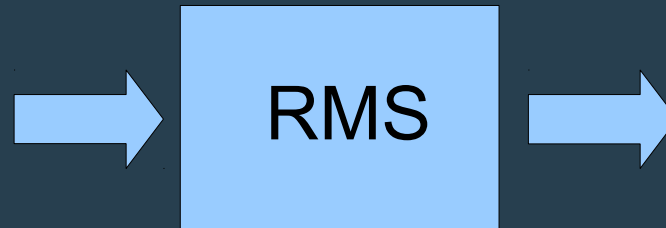


# Rotation Measure Synthesis

- Usually polarization angle does not depend linearly on  $\lambda^2$
- RM-Synthesis is a Fourier Transformation of Stokes U & Q
- Derotation of Faraday-rotated emission using a set of assumed RM values
- Resolution in RM-space (Faraday depth  $\phi$ ) depends on  $\lambda^2$  coverage

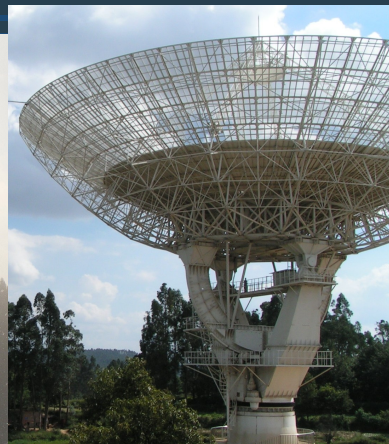
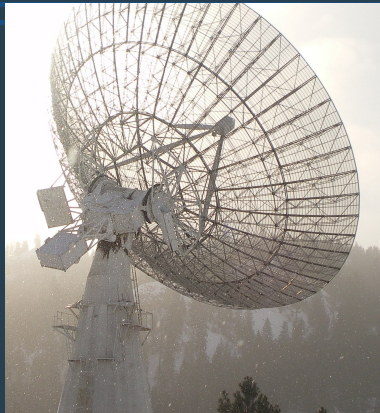


Polarization angle for a simulated line-of-sight



the RM-Spectrum for this line-of-sight

# GMIMS: The Global Magneto Ionic Medium Survey



ANTF, Australia  
 Univ. of Tasmania  
 Univ. of Newcastle, UK  
 Univ. of Sydney, Australia  
 CAS, China  
 ASTRON, Netherlands  
 DRAO, Canada  
 Univ. of Manchester, UK  
 CSIRO ATNF, Australia  
 CSIRO ATNF, Australia  
 MPIfR, Germany  
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E. Carretti  
 J. Dickey  
 A. Fletcher  
 B. Gaensler  
 J.L. Han  
 M. Haverkorn  
 T. Landecker  
 P. Leahy  
 N. McClure-Griffith  
 D. McConnell  
 W. Reich  
 R. Taylor  
 M. Wolleben (PI)

300 -800 MHz Effelsberg 100-m

800 -1300 MHz Kunming 40-m

1300-1800 MHz DRAO 26-m

Rx under constr.

feas. study

55% complete

300 -900 MHz Parkes 64-m

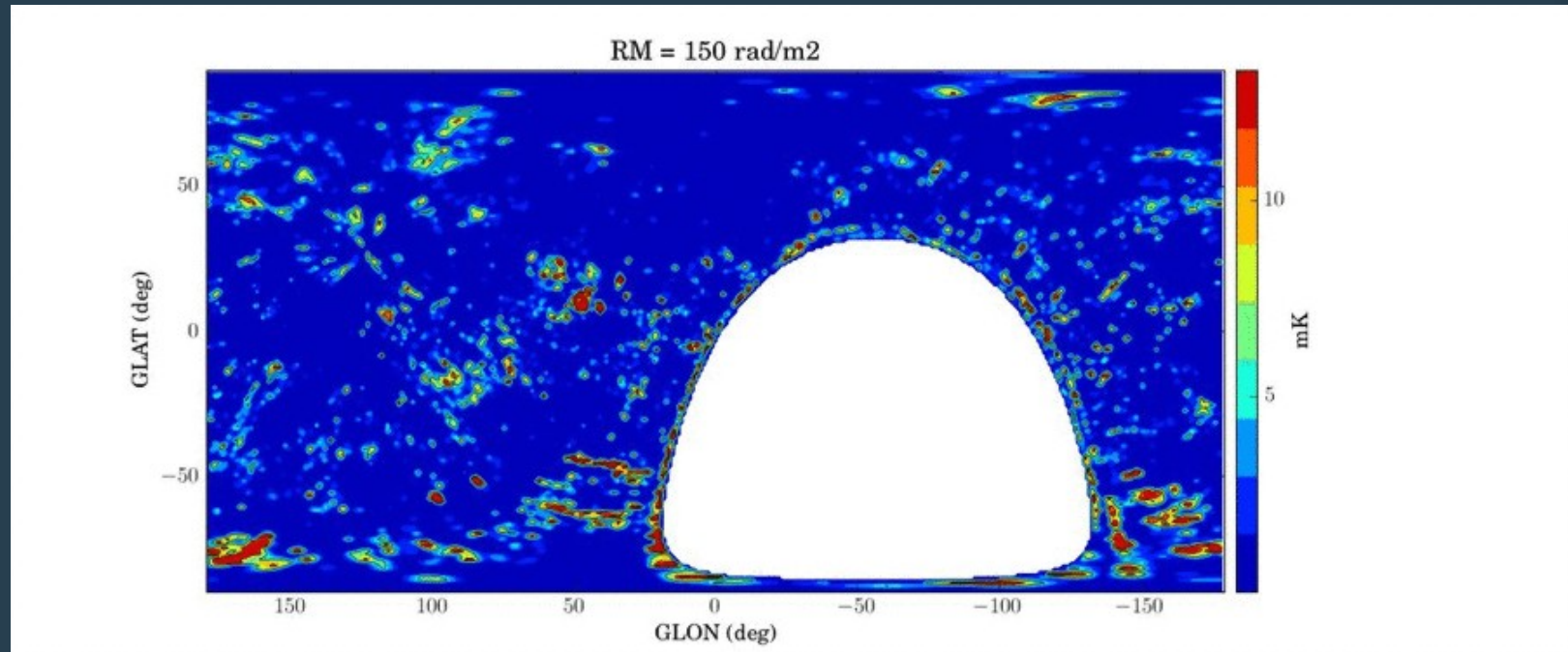
30% complete

800 -1300 MHz ?

1300-1800 MHz STAPS, Parkes 64-m 100% complete, PI: M. Haverkorn

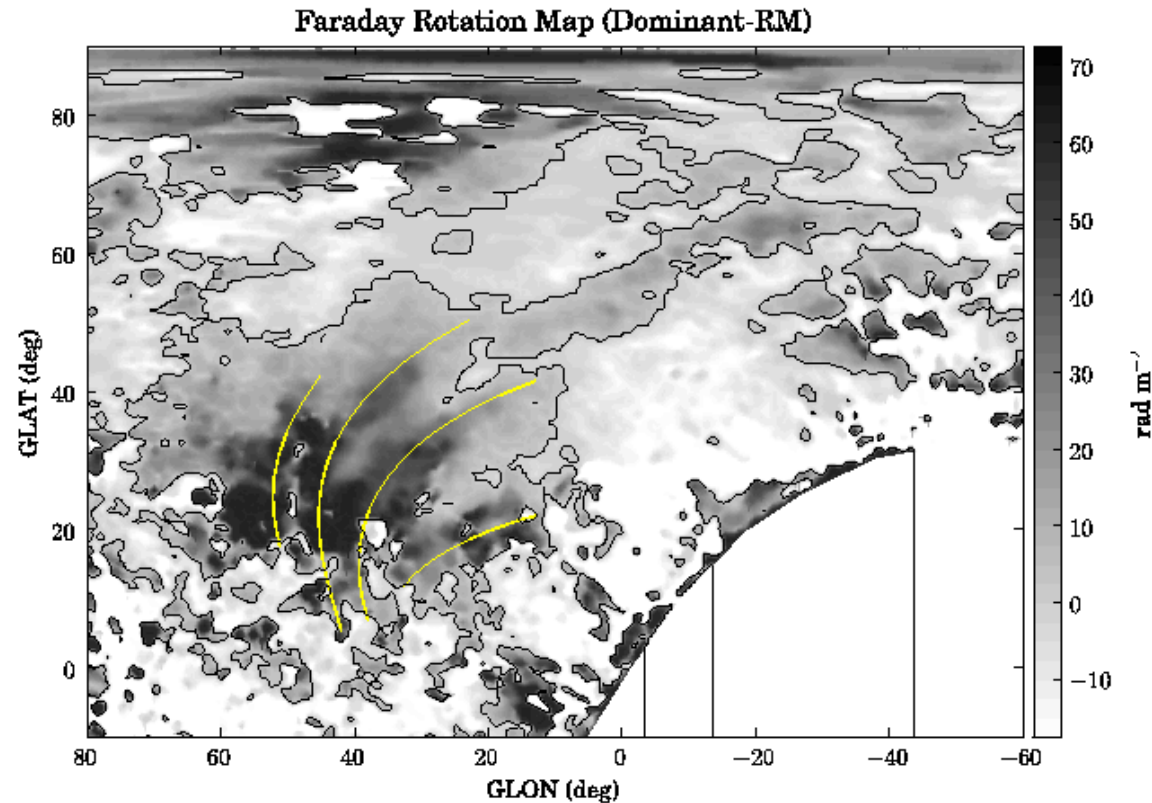


# GMIMS: The Global Magneto Ionic Medium Survey



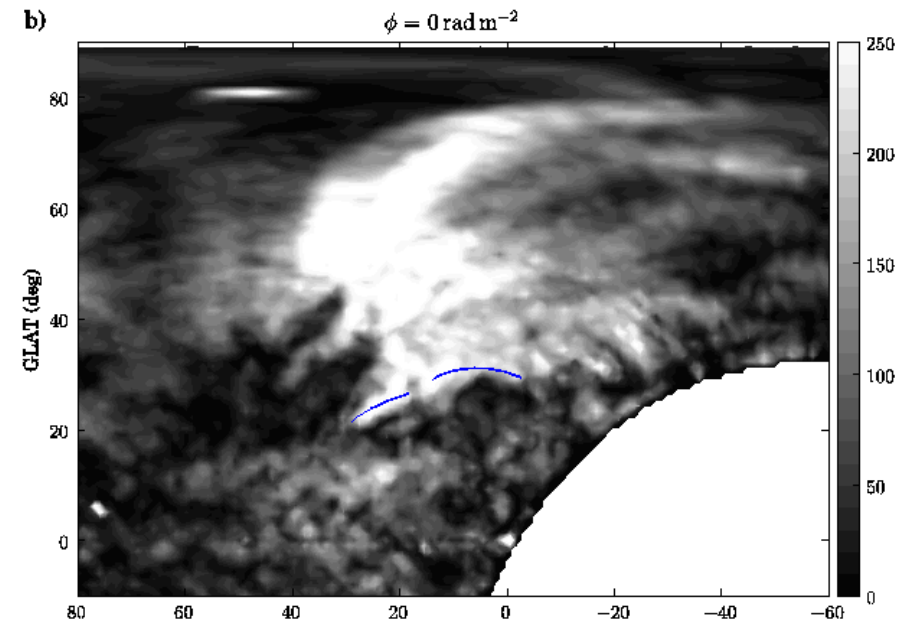
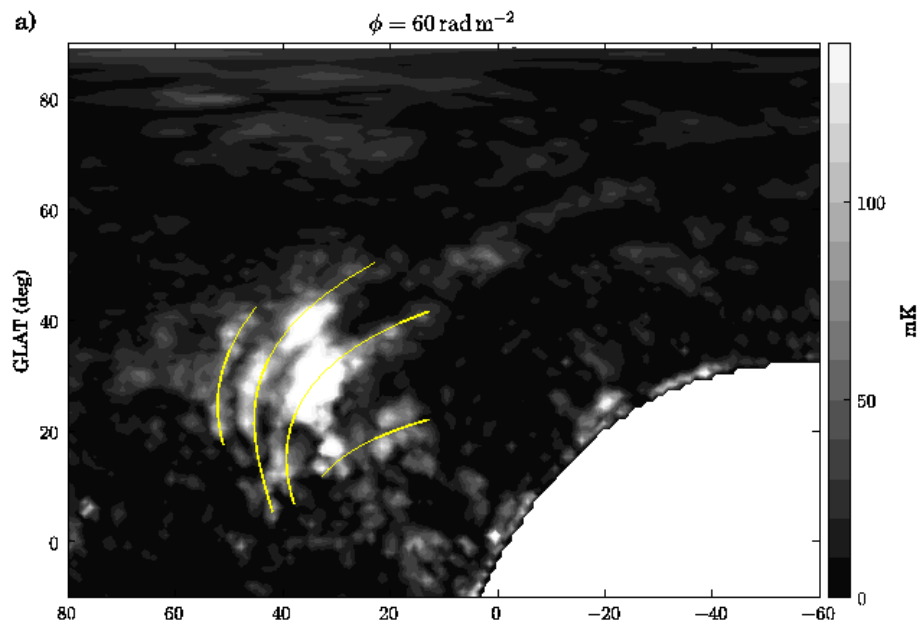
- RM-Synthesis Cube, Galactic coordinates, third dimension: Faraday depth  $\phi$
- First data from GMIMS North (1.3 – 1.8 GHz), 2048 frequency channels
- rms noise: 25 mK in a single channel, 1 mK in an RM-Synthesis frame
- RM cleaning performed
- Resolution in Faraday depth: 132 rad/m<sup>2</sup>
- Largest scale in Faraday depth: 106 rad/m<sup>2</sup>

# Faraday Rotation Map

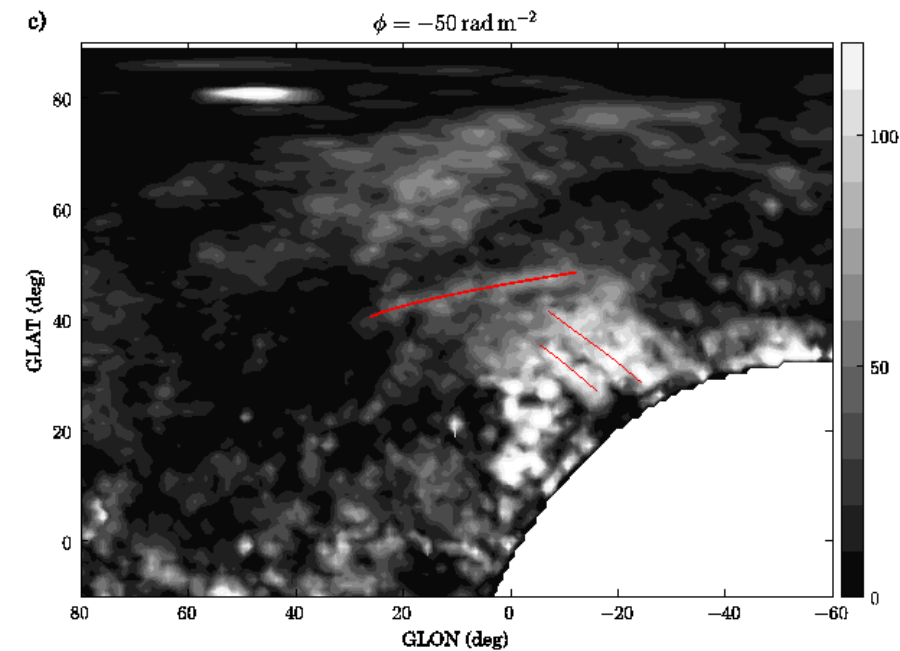


- Map shows  $\phi$  of the dominant emission in each pixel
- (the position of the peak in the RM-Synthesis spectrum for each pixel)
- Grey scales chosen to make structures with positive  $\phi$  more visible
- Contour line corresponds to  $\phi = 0 \text{ rad/m}^2$
- Four yellow lines, fitted by eye, indicate location of four filaments identified in the Faraday rotation map

# RM-Synthesis Frames



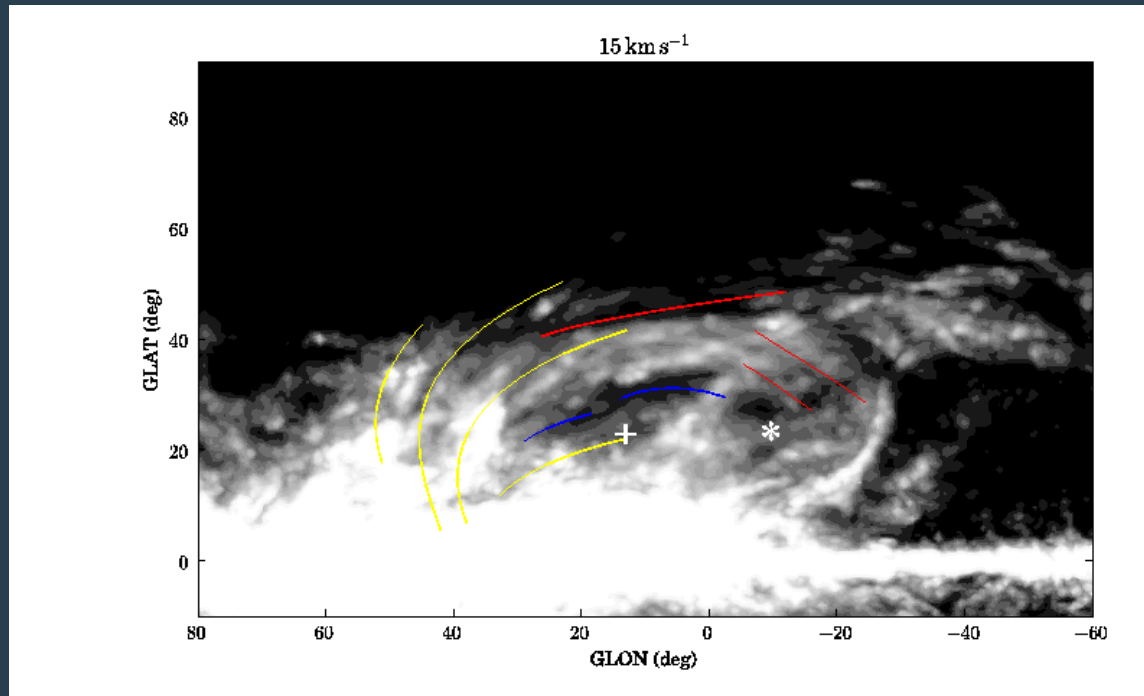
- RM-Synthesis frames showing polarized intensity at various Faraday depths
- Four yellow lines are repeated at  $60 \text{ rad/m}^2$
- Blue and red lines indicate polarized filaments identified in the RM-Synthesis cube





# HI Bubble

(LAB HI Survey, Kalberla 2005)

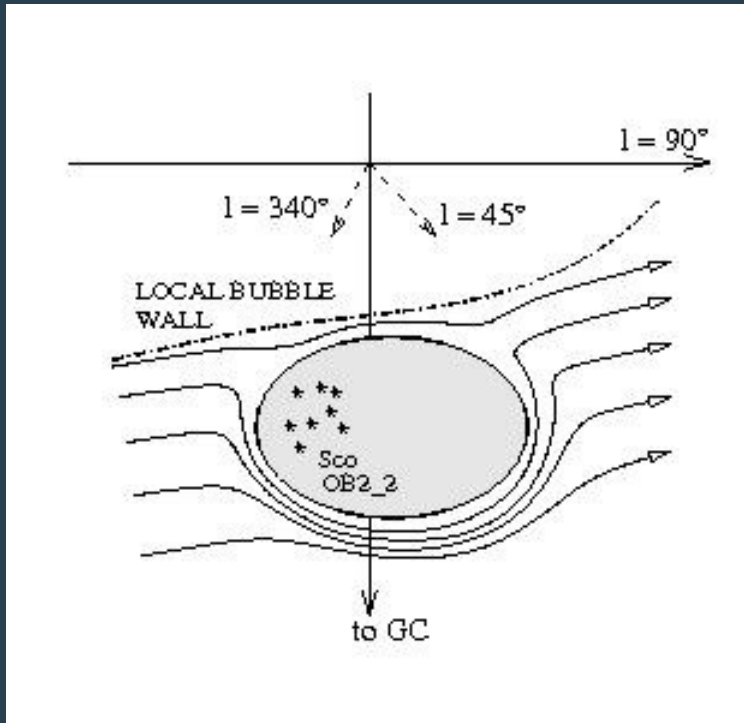


- Map of HI temperature at  $15 \text{ km s}^{-1}$
- Polarized filaments associated with HI bubble
- correlations and anti-correlations between polarized intensity and HI
- Position of the Upper-Scorpius OB association today and 5 Myr ago

# Distance and Origin

- Expanding HI shells associated with stellar winds and supernovae explosions originating in the stars of the Scorpius-Centaurus OB association
- Upper Scorpius sub-group is the furthest away (145 pc), in the centre of the western side of the HI shells.
- Linear size of bubble of the order of 200pc x 100pc
- Nearside is 95pc away, far side 195pc away
- Wall of Local Bubble about 80pc away in this direction
- The shells act as a Faraday-rotating screen to the strong background emission and also as a weaker mixed emitting and rotating slab
- These structures are not associated with the North Polar Spur as they do not resemble the shape of the spur

# Magnetic Field

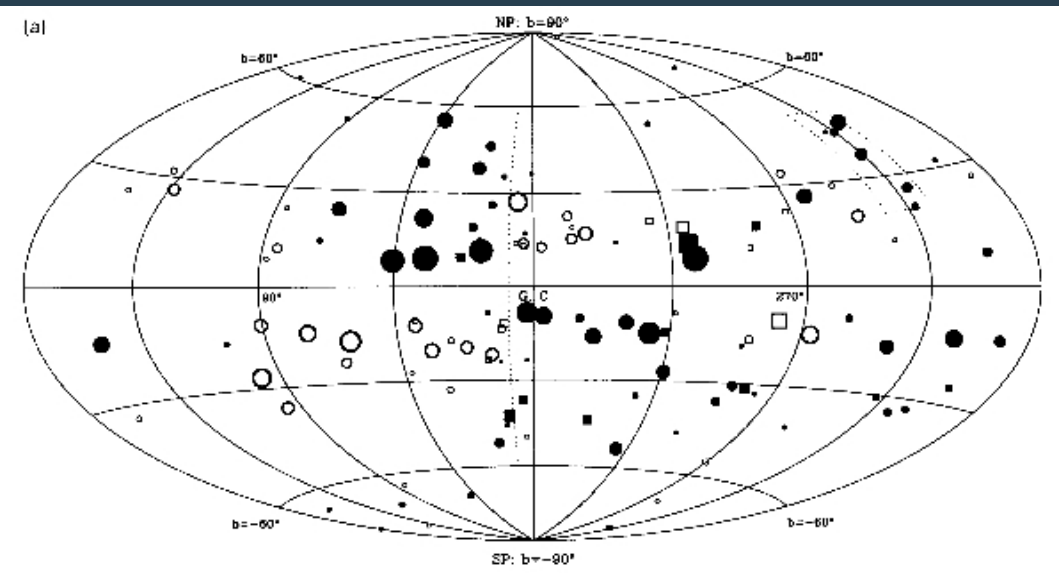


- Positive  $\phi$  in the east changes to negative  $\phi$  in the west, suggesting that the B-field is wrapped around the bubble
- Polarized emission at  $\phi=0$  rad/m<sup>2</sup> along the centre of the bubble links these two regions
- Shape and implied B-field configuration of this HI bubble suggest that it has expanded asymmetrically
- Expansion constrained to only one direction along the line-of-sight

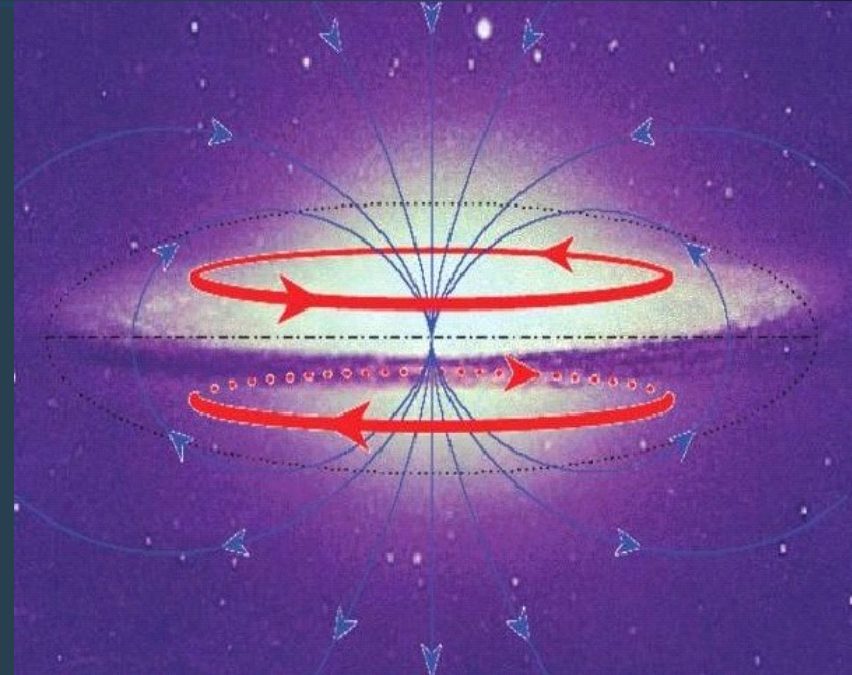
# Magnetic Field

- No H $\alpha$  emission found (VTSS/WHAM)
- RM must be due to enhanced B-field
- average  $n_e$  approx  $0.02 \text{ cm}^{-3}$
- shell thickness  $\sim 13\text{pc}$ , path length  $\sim 100\text{pc}$
- $50\text{-}60 \text{ rad/m}^2$  corresponds to  $B_{\parallel}$  approx  $20\text{-}34 \mu\text{G}$

# Antisymmetries in the FR Sky



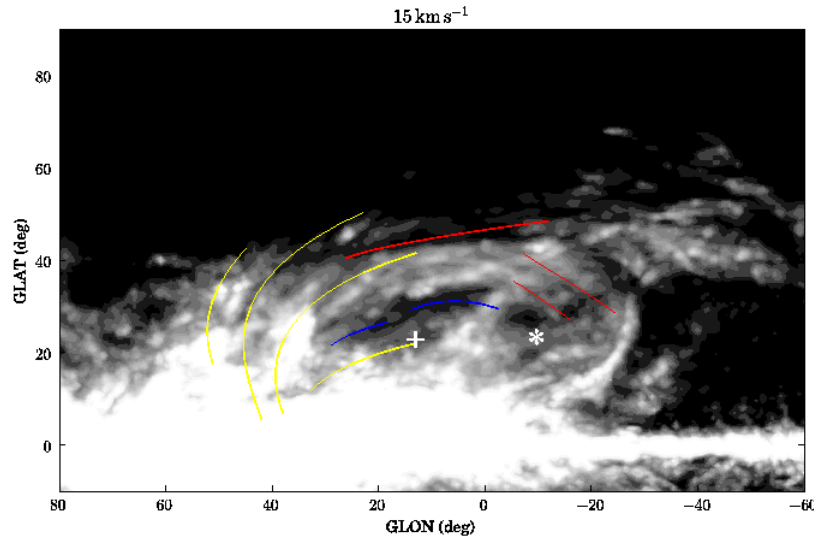
(Han et al, 1999)



- Observed antisymmetry of RMs in the inner Galaxy.
- Indicates azimuthal B-field with reversed field directions.
- This seems to suggest an A0 dynamo acting in the halo.



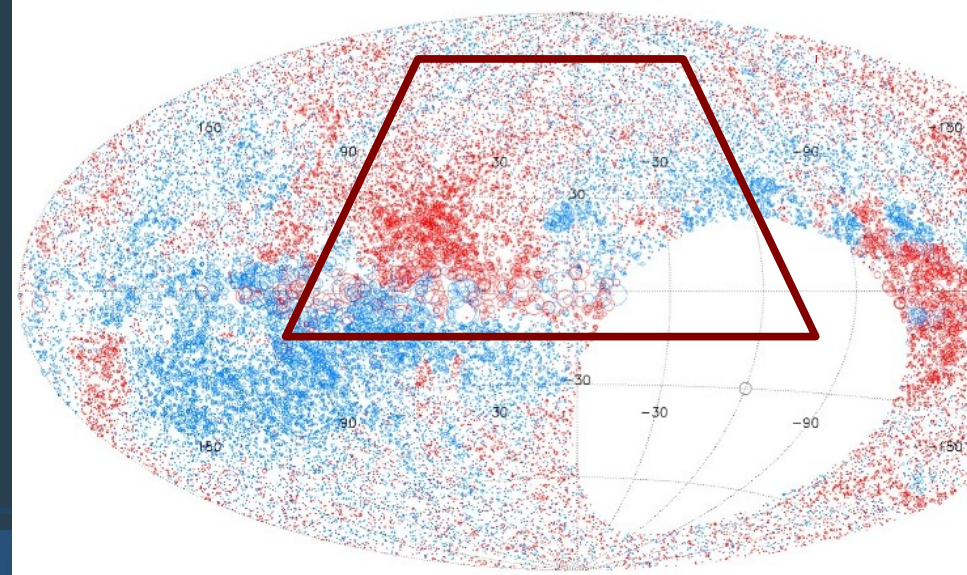
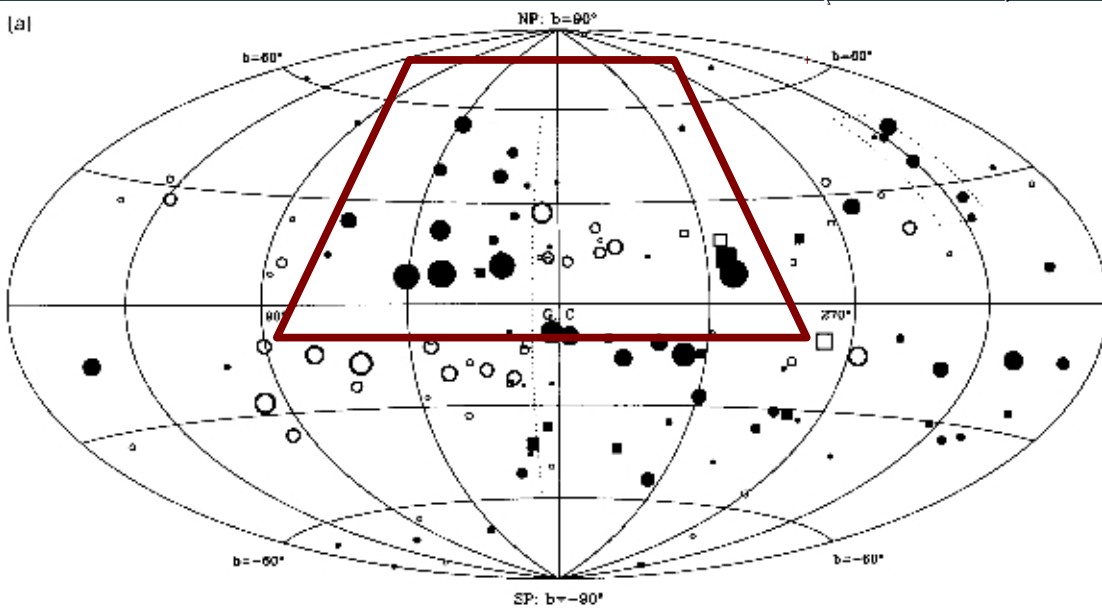
# Antisymmetries in the FR Sky



- Several authors have pointed out that the antisymmetry may be due to Loop I
- Our data show that another local object (not the NPS) mimics the antisymmetric pattern of a large scale B-field
- Detection made possible by high angular resolution RM-maps of the diffuse Galactic emission


Pulsars (Han et al, 1999)

EG sources (Taylor et al, 2009)



# Summary


- GMIMS is a wide-band, spectro-polarimetric survey from 300 MHz to 1.8 GHz, using single-dish telescopes
- First RM-Synthesis of the Galactic diffuse emission with a single-dish telescope over the whole Northern sky
- High angular resolution Faraday-rotation map reveals filamentary structures associated with a local HI bubble (not the North Polar Spur)
- These structures can be explained by a B-field wrapped around this bubble
- The resulting signature in the Faraday rotation sky mimics that of a large-scale Galactic B-field
- (Wolleben et al, 2010, in prep.)



The Global Magneto-Ionic Medium Survey

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#### Parkes 64-m Telescope

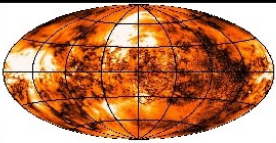


The Parkes 64-m Telescope in Australia is used for two GMIMS surveys: Low-Band South (300-900 MHz) and STAPS (1.2-1.8 GHz).


#### Introduction

GMIMS is a survey of the polarized emission over the entire sky, covering the wavelength range from 16 cm up to 1 metre (300 MHz to 1.8 GHz). 10 institutions around the world are participating to study the magneto-ionic medium of our Galaxy - the medium composed of magnetic fields and electrons.

The prime tracers of magnetic fields are polarized radio waves: synchrotron emission bears the imprint of the field direction at origin, and Faraday rotation along the propagation path permits quantitative measurement of the line-of-sight field. Current data (e.g. picture on the right shows polarized intensity at 1.4 GHz in Galactic coordinates) suggest that the appearance of the polarized sky is dominated by Faraday rotation but are inadequate for deriving physical quantities except for a few objects. Recent advances in digital signal processing have made wide-band spectro-polarimetric back-ends available for astronomy, and a powerful new signal processing technique, RM-Synthesis, has been developed (Brentjens & de Bruyn, 2005). GMIMS brings these two techniques together. This will allow important physical parameters to be measured that are otherwise hard to quantify.



#### DRAO 26-m Telescope



Of particular importance are some questions that can be studied in the Milky Way. Are the magnetic fields in the disk and halo related, and if so, on what scales? What are

<https://www.astrosci.ca/users/drao/gmims>