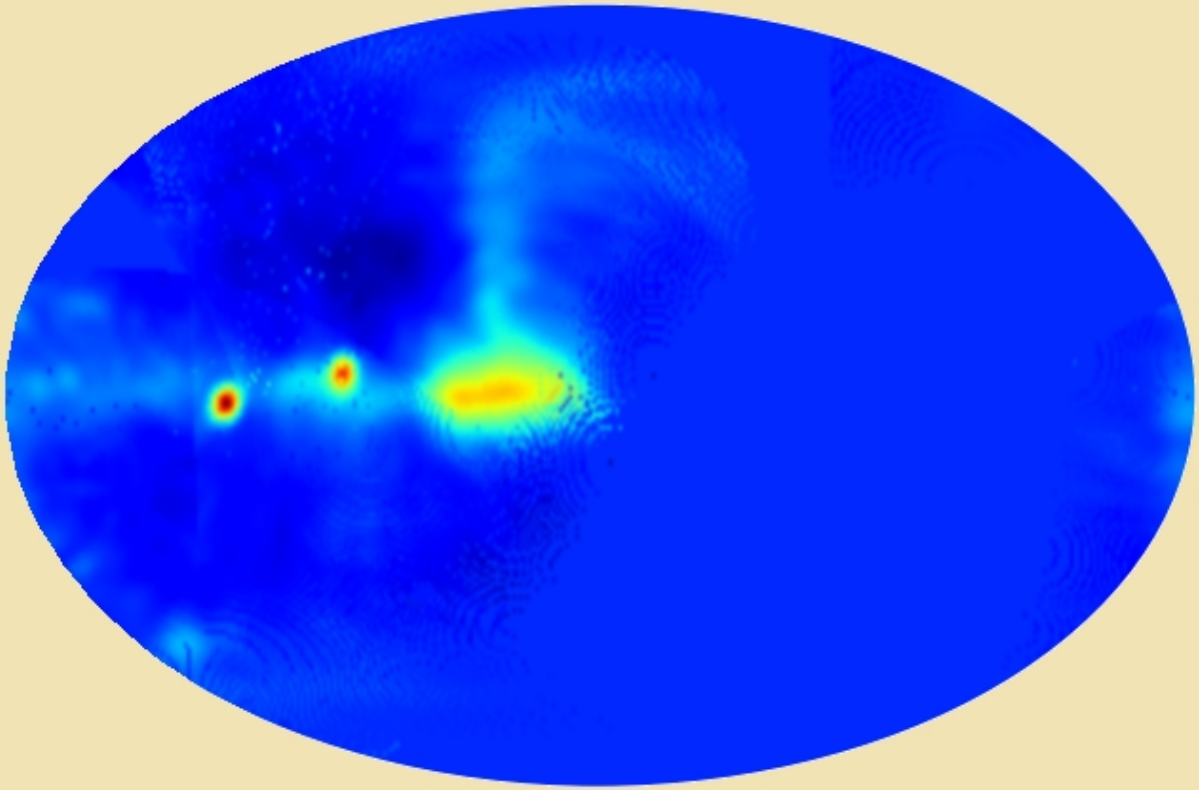
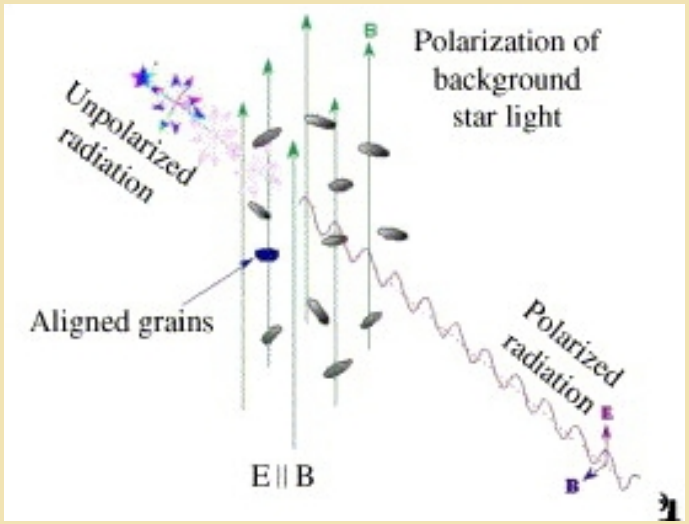
Study of Large-Scale Galactic Magnetic Fields at Low Frequencies

Jana Köhler
- MPIfR -



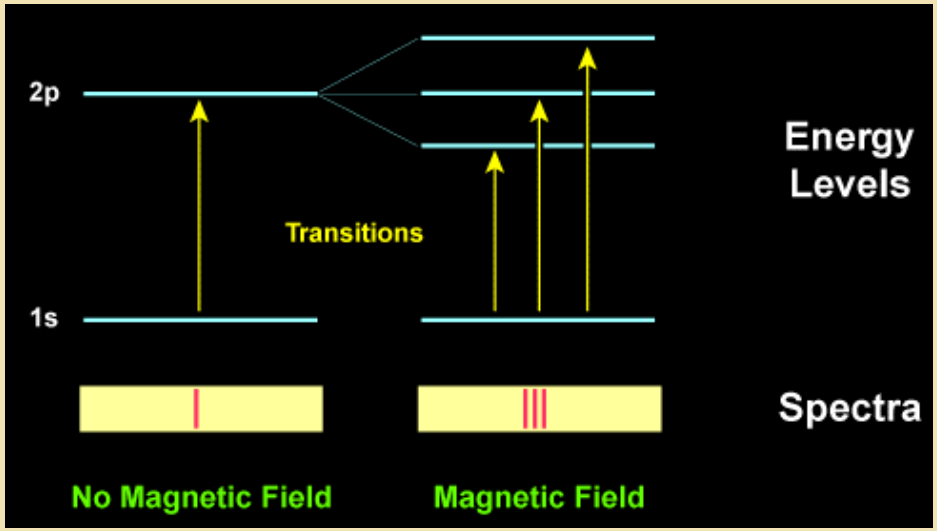
How to measure Magnetic Fields ???

How to measure Galactic Magnetic Field?



- Linear Polarization of Starlight
  - product by mostly coherent alignment of spinning dust grains
- Zeeman Splitting
  - 21 cm line get splitted into three levels by the influence of an external magnetic field

- Polarized synchrotron emission
  - product of acceleration of relativistic electrons in a magnetic field
  - WMAP (23 – 94 GHz)



How to Measure the Galactic Magnetic Field?

- Faraday Rotation

$$\chi = \chi_0 + RM \times \lambda^2 \quad \text{with} \quad RM = 0.81 \int n_e \, \mathbf{B} \bullet d\mathbf{l}$$

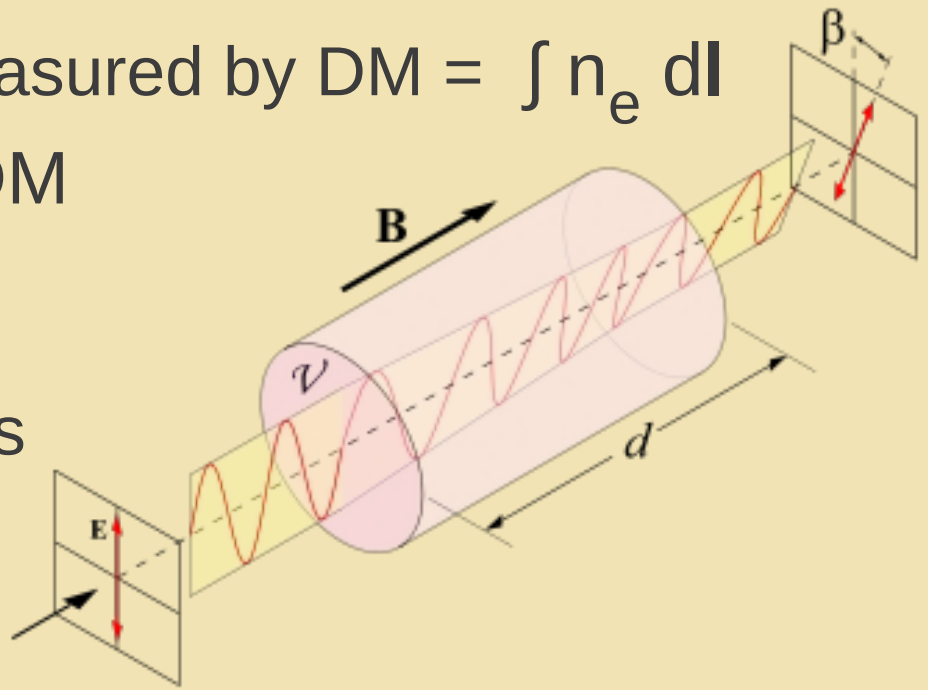
  - RM from extragalactic sources
  - Pulsar RMs

  → electron density can be measured by DM = $\int n_e \, d\mathbf{l}$

  → $< B_{||} > = 1.232 \, RM / DM$

- Diffuse Synchrotron Emission

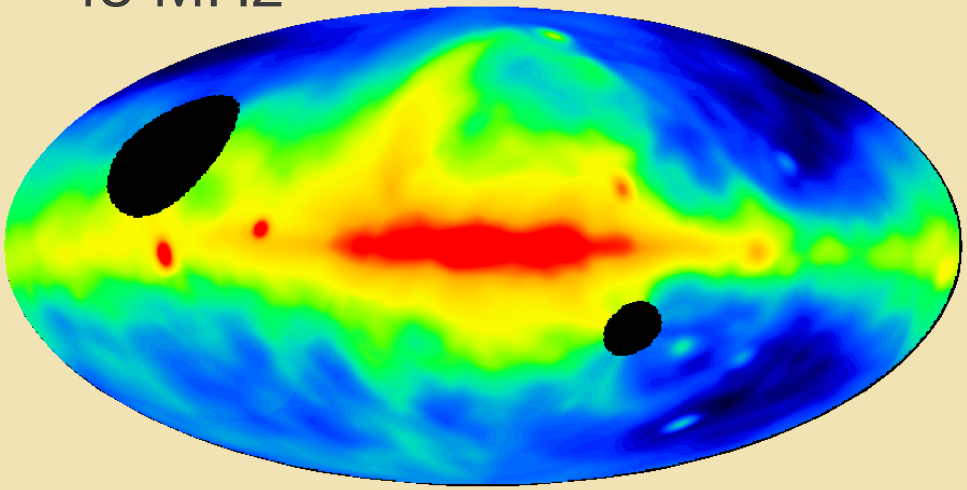
  → Rotation Measure Synthesis



What is known up to now ???

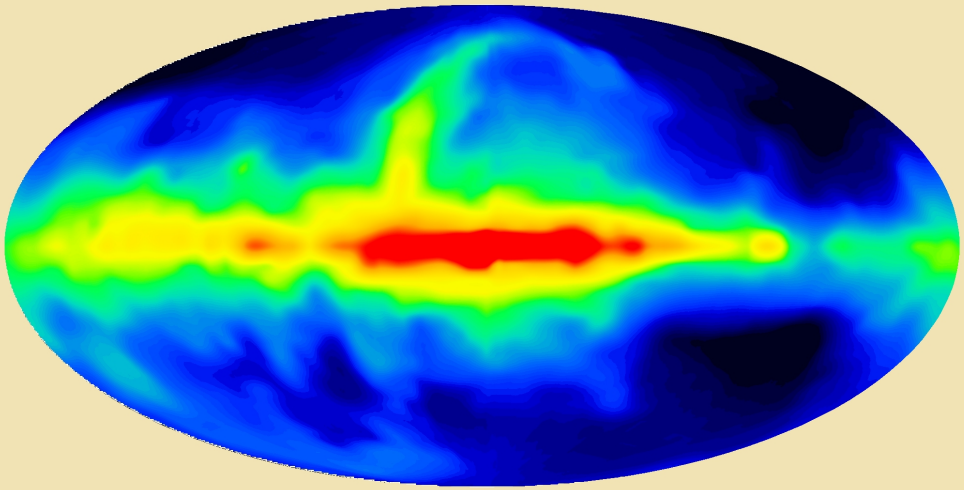
All-Sky Surveys at Low Frequencies

45 MHz



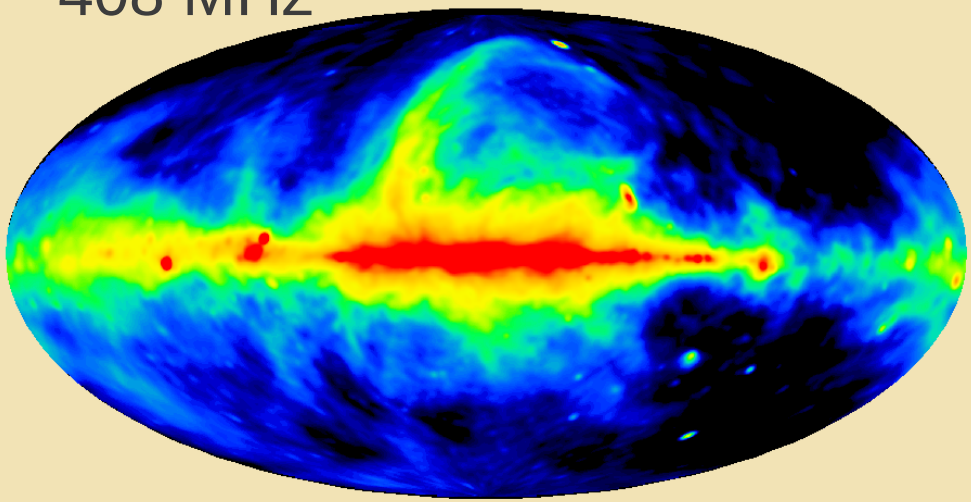
MU Radar & Maipu Array

150 MHz



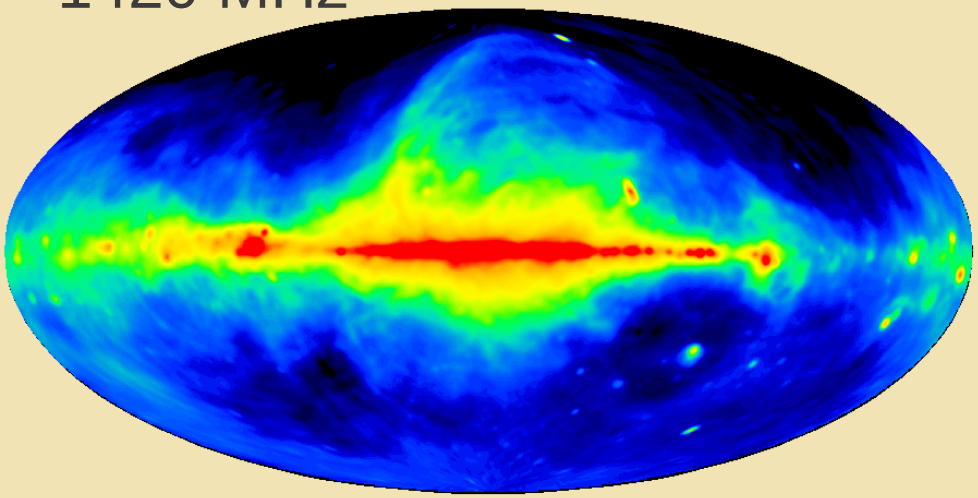
Parkes

408 MHz



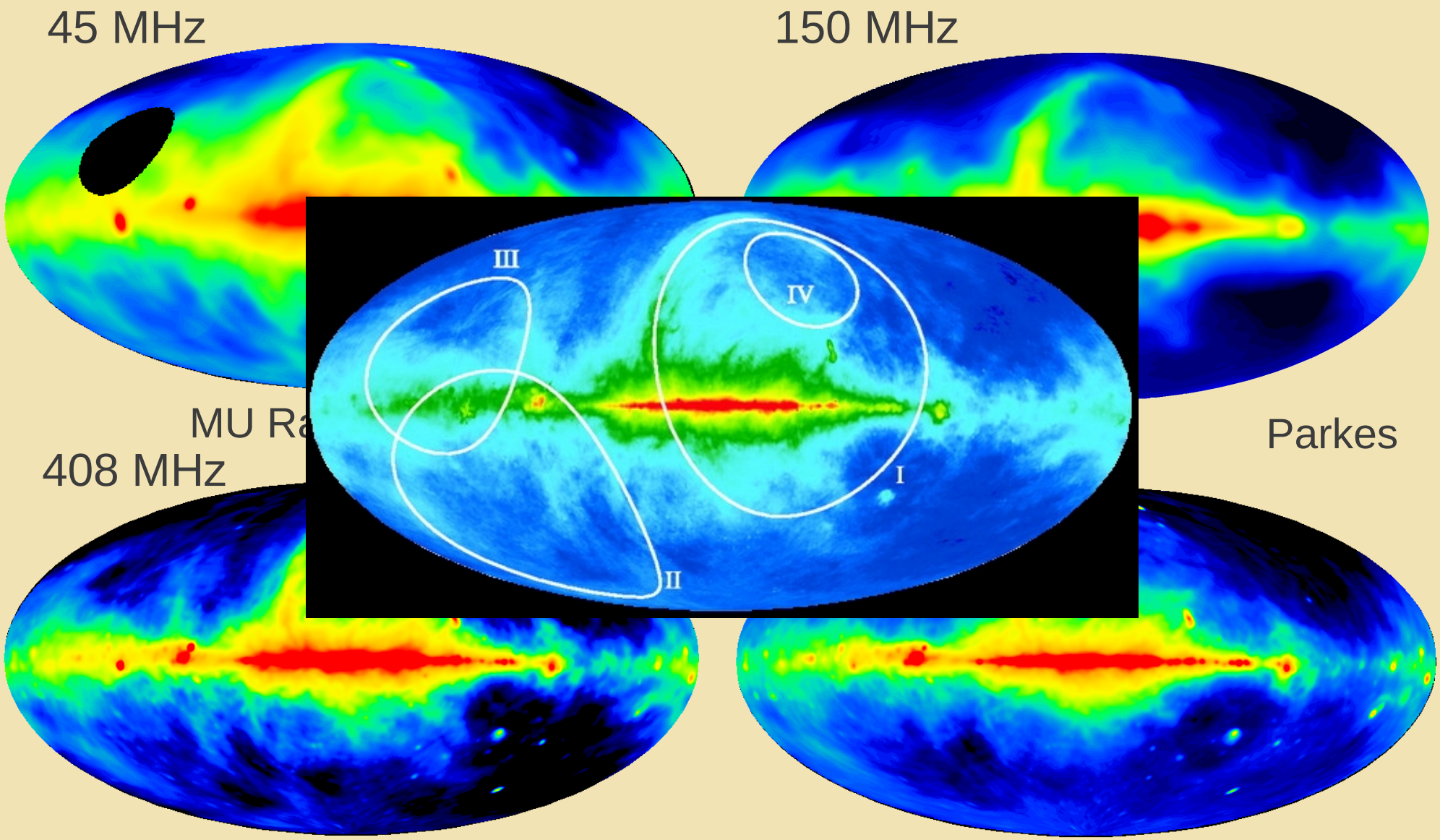
Jodrell Bank & Effelsberg & Parkes

1420 MHz

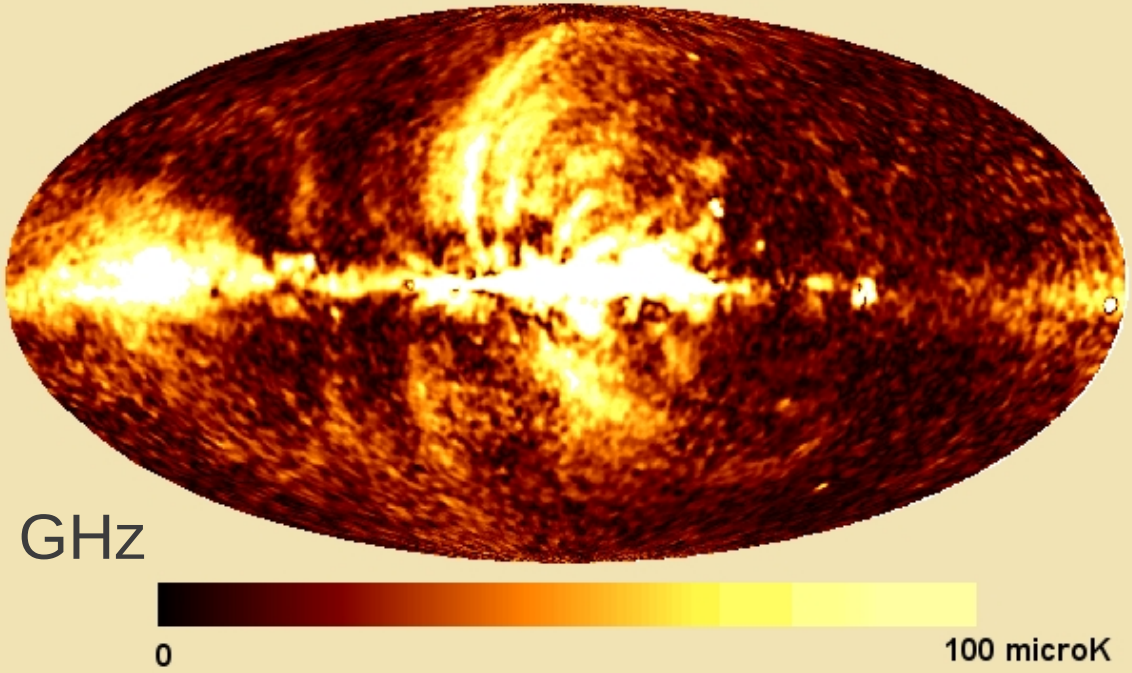


Stockert & Villa Elisa

All-Sky Surveys at Low Frequencies



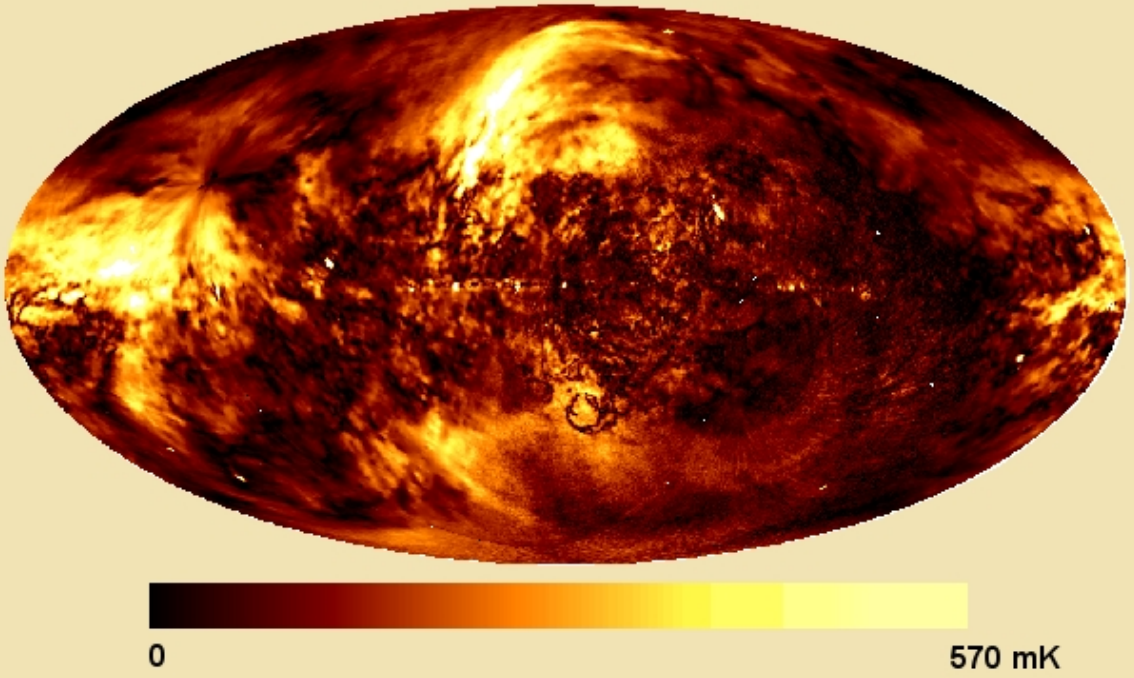
Polarized Intensity



22 GHz

- more depolarisation at lower frequencies

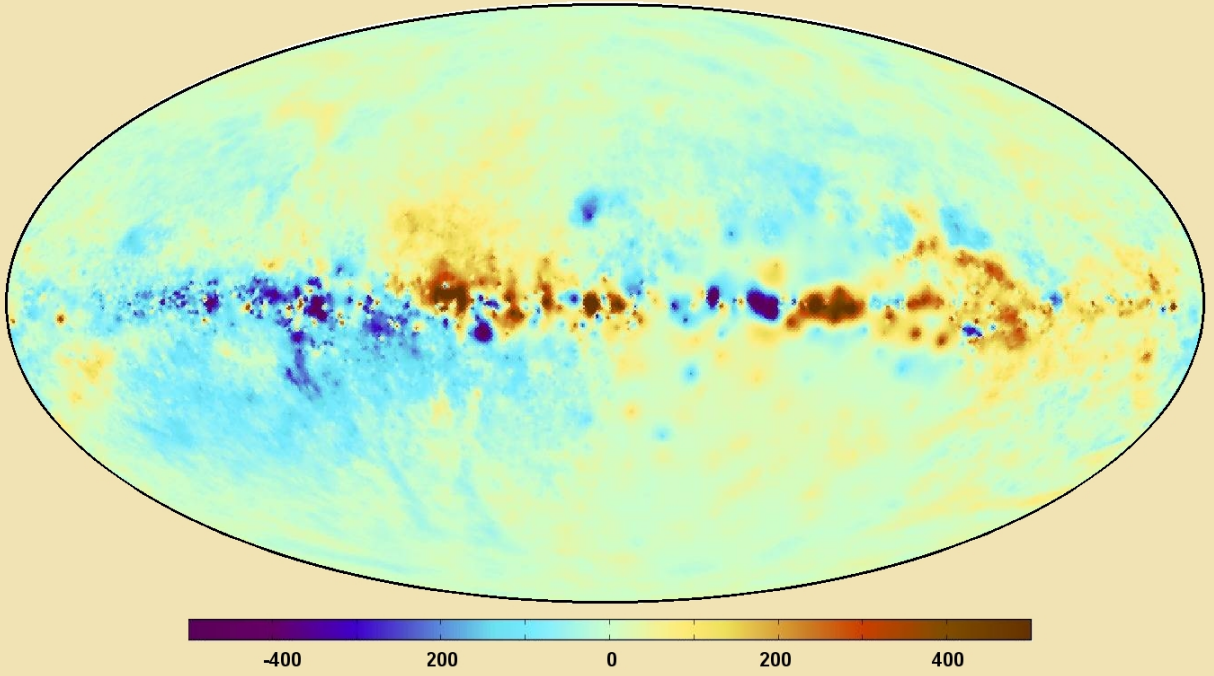
1.4 GHz



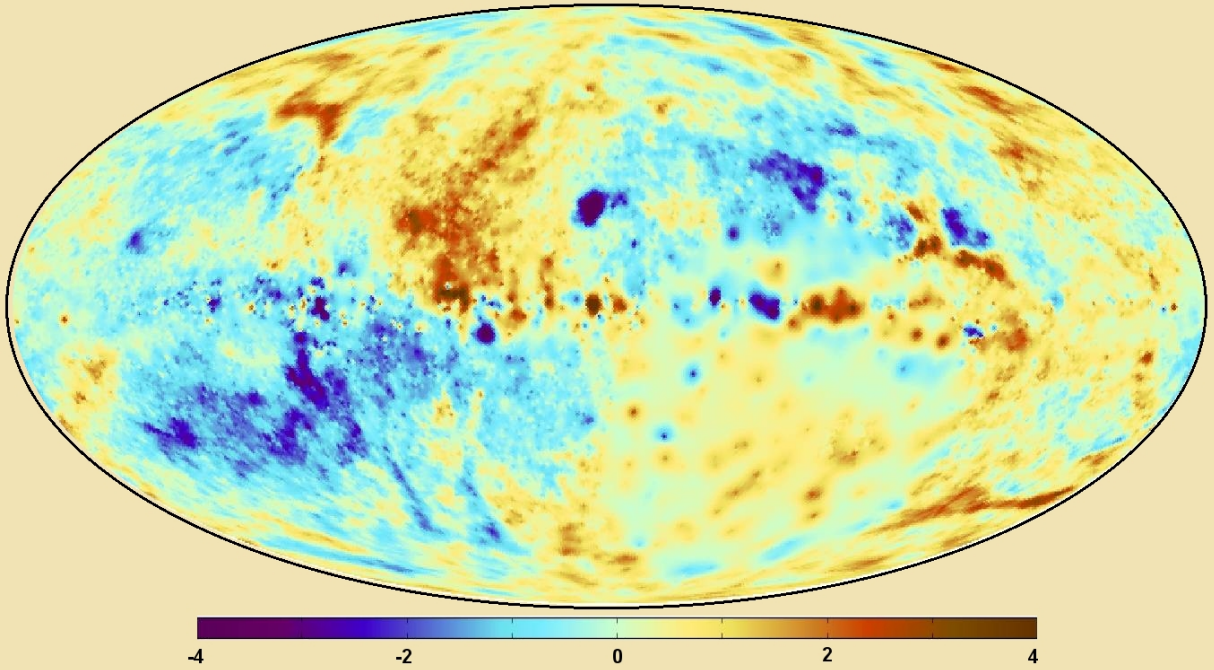
- at low frequencies strongest polarisation at Fan region and Northern Spur
- at lower frequencies patchy structure in the Galactic plane

RM Map

- larger RM values near the Galactic disc
- antisymmetric structure

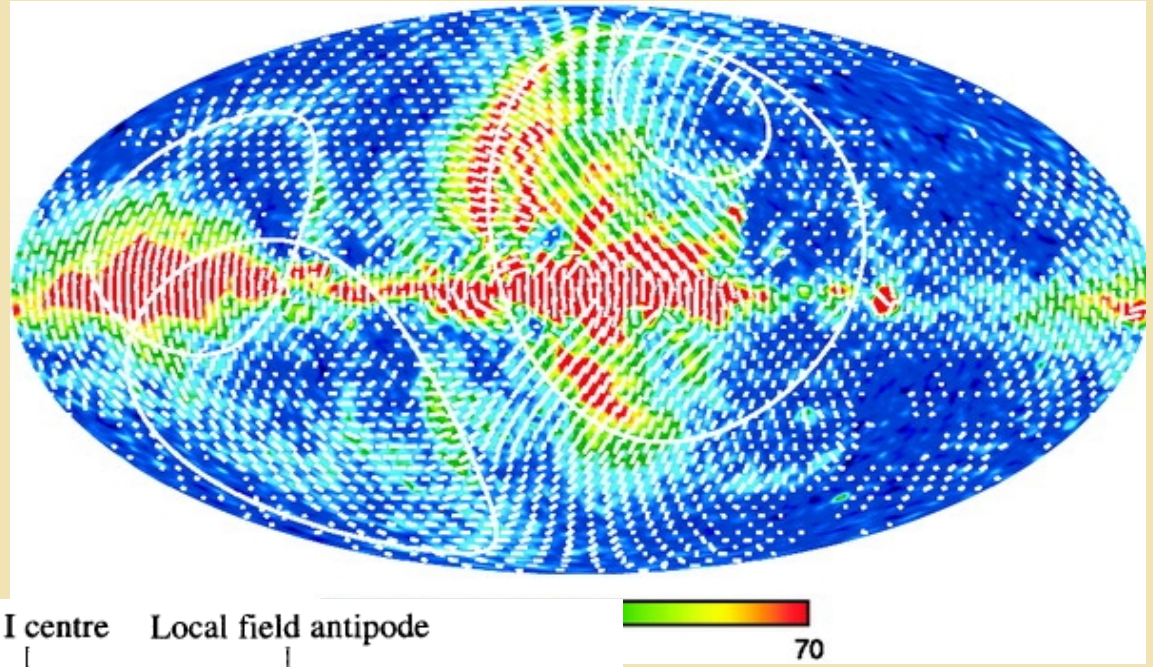


Oppermann et al., 2012

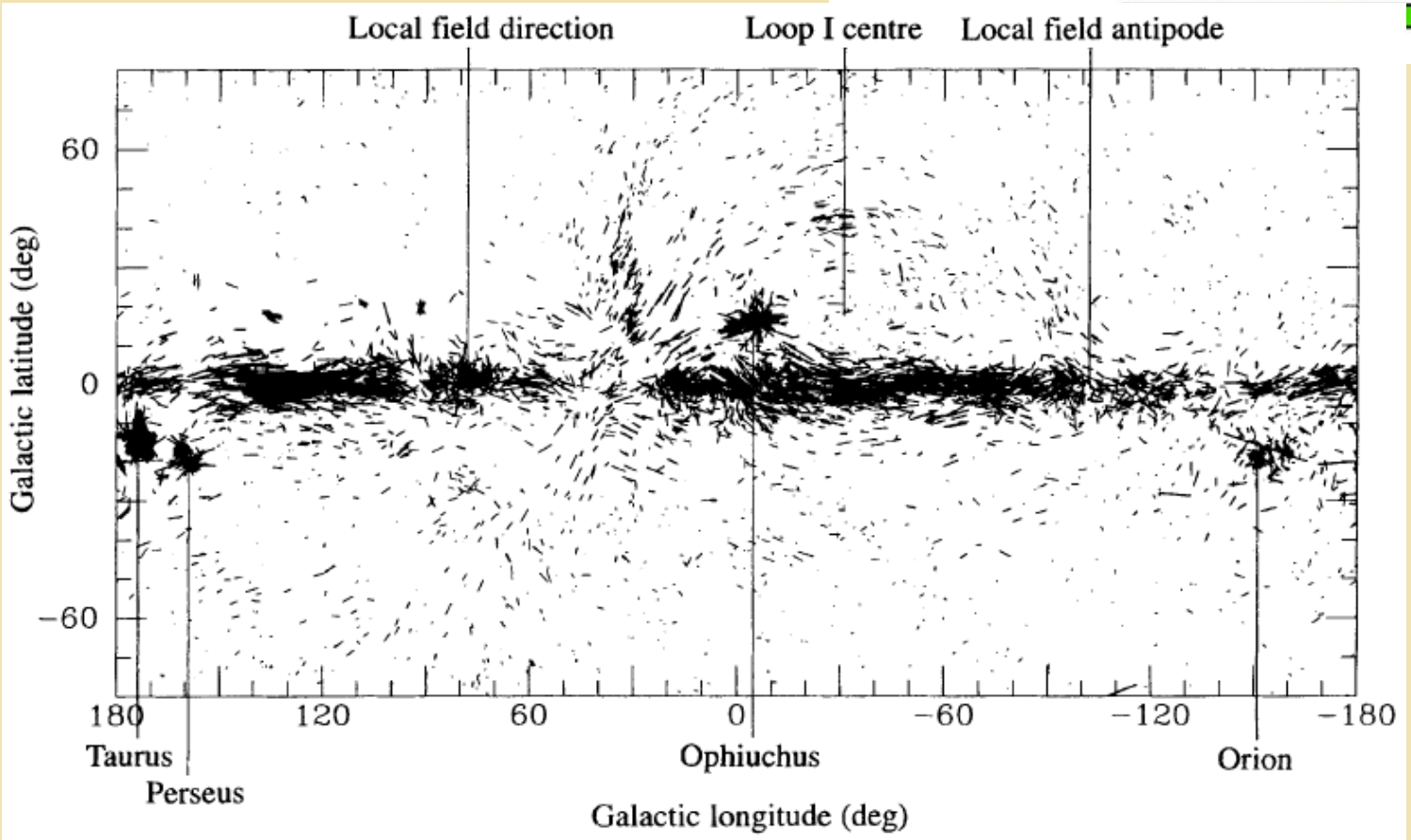


- RM > 0: magn. field pointing towards the observer
- RM < 0: magn. field pointing away from observer

Magnetic Fields

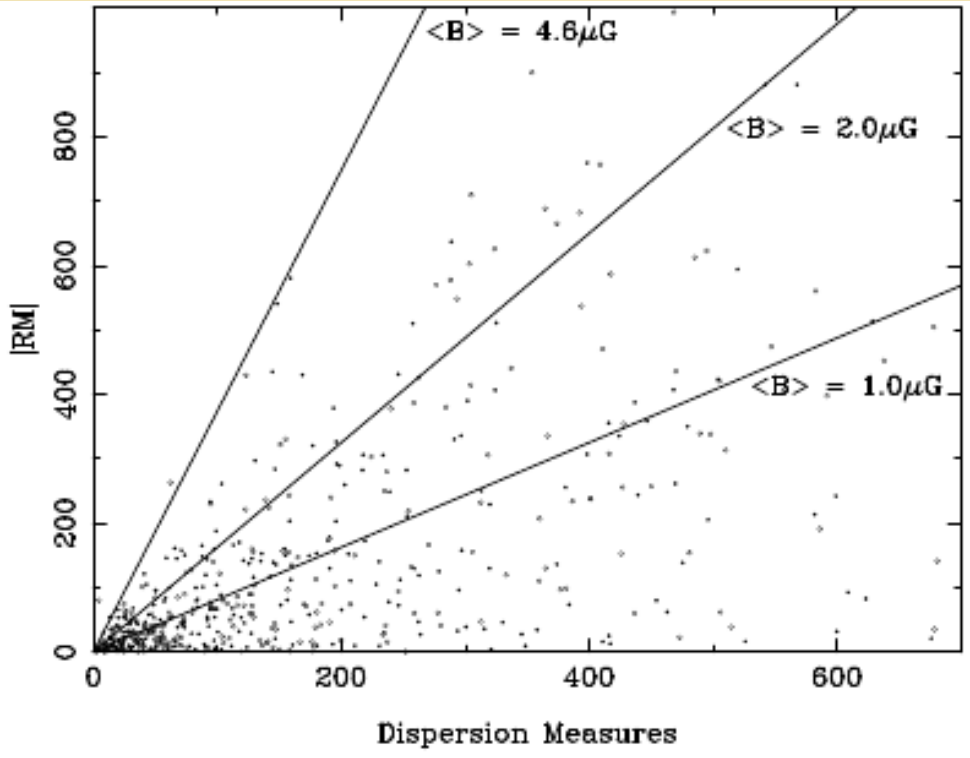


WMAP



Zweibel & Heiles, 1997

Magnetic Field Strength



Han, 2001

- Magnetic Field in the vicinity of the Sun is about 5 μG
- total field is stronger in the arm regions (mainly random fields)
- regular fields are stronger in interarm regions; mostly in a range of 1~2 μG
- field strength probably increases towards the Galactic center

Magnetic Field Studies at Low Frequencies

- low frequencies for measuring low RM
  → necessary for studying weak magnetic fields
  → ideal to study fields in the galactic outer disc and halo and in the intergalactic medium

- RM in Galactic Disk: ~ few 100 rad/m^2
- RM in Galactic Halo: ~ few 10 rad/m^2

What I want to do ...

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- Map of the large scale total and polarized intensity of the entire Northern Sky at low frequencies
- using RM Synthesis for measuring the polarized emission
- having a closer look at the polarization properties of the Milky Way

→ especially polarization properties of the cosmic rays in the disk and halo

→ studying the structure of the ISM of the Milky Way and turbulences

- properties of special targets like CasA, CygA, TauA

… and how to get there

- using LOFAR for studies for low frequencies (< 250 MHz)
  → large scale structures only visible in Single Station mode
- using RM synthesis for measuring the polarized emission
  → good frequency resolution needed for not running into bandwidth depolarisation
  → therefor using raw uncorrelated TBB data
- at these low frequencies good calibration of the ionosphere is needed
- Dipole Beam correction is needed
- simultaneous pulsare observations for polarization calibration
- (for a lot of the Single Stations locale RFI is a big problem for the calibration)

Using TBB Data
(Transient Buffer Boards)

PRO

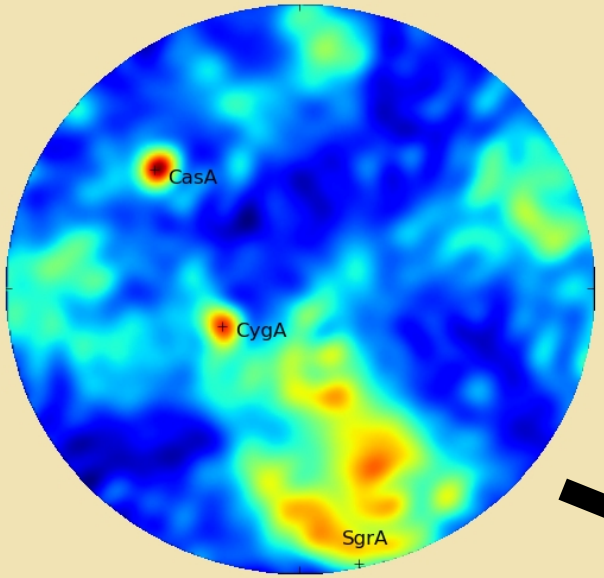
- good frequency resolution
- all sky within one measurement
- simultaneous pulsar observations possible

CON

- small integration time for one measurement (1.3 sec)
- big datasets (100GB raw data)
- long writing time (10 ~15 min)

Self written correlator, where frequency resolution can be chosen freely

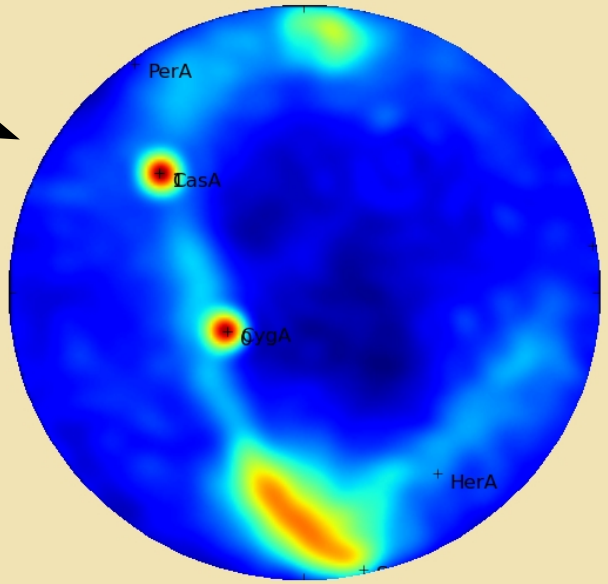
Calibration



- Correlation of TBB dataset
- Phase calibration with CasA and CygA
  → for subbands with strong RFI also use the RFI as Calibrator source

- Self Amplitude-Phase Calibration
  → search for sources in the field (also RFI) and use them for the calibration

- use gains for calculating delays
  → maybe creating own CalTables



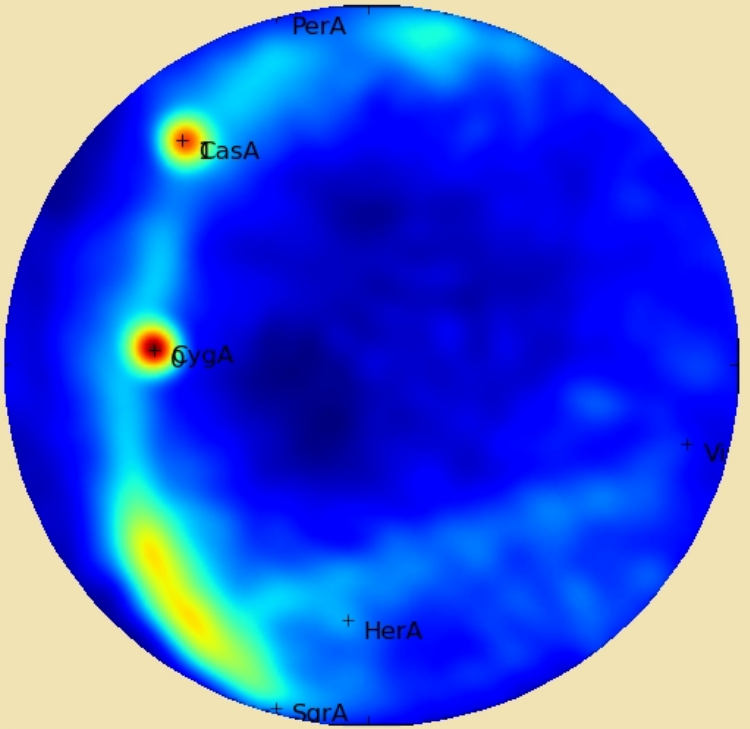
Measuring the Entire Northern Sky

- 2 x 24 h observations (with different stations)
- gap of half a year in between
  → combine to measure to hole (northern) sky
  → better sensitivity
  → RFI and Sun will get averaged out

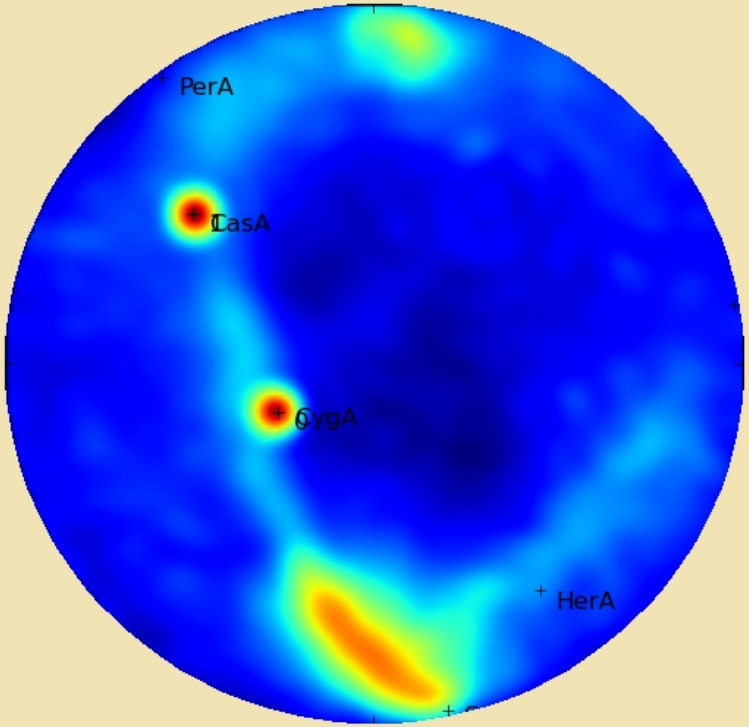
- also useful/helpful to study:
  - behaviour of the ionosphere
  - beam model

Combination of Skymaps

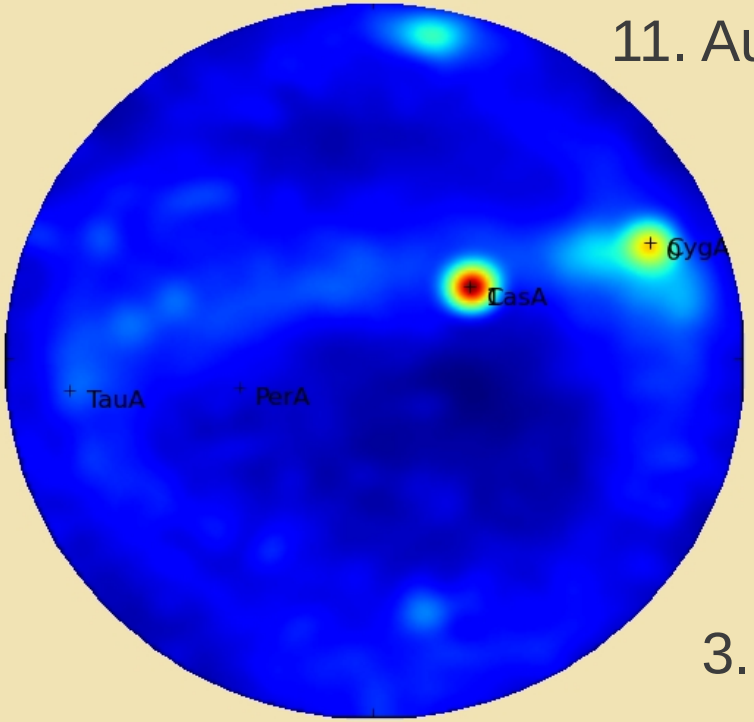
49 MHz – total intensity
1.3 sec integration time
200 kHz bandwidth



11. August 2011; 19:00

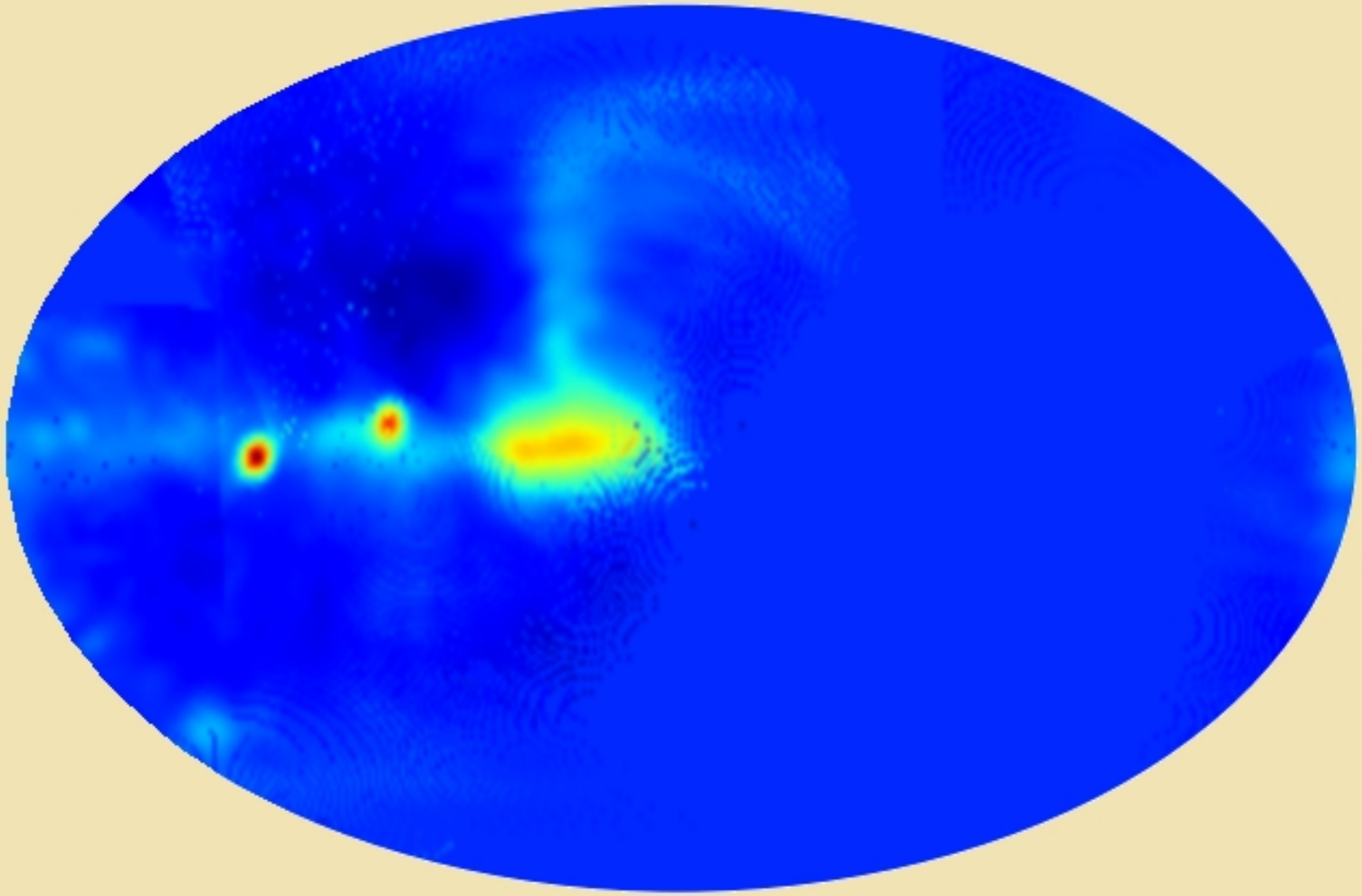


22. August 2011, 20:00

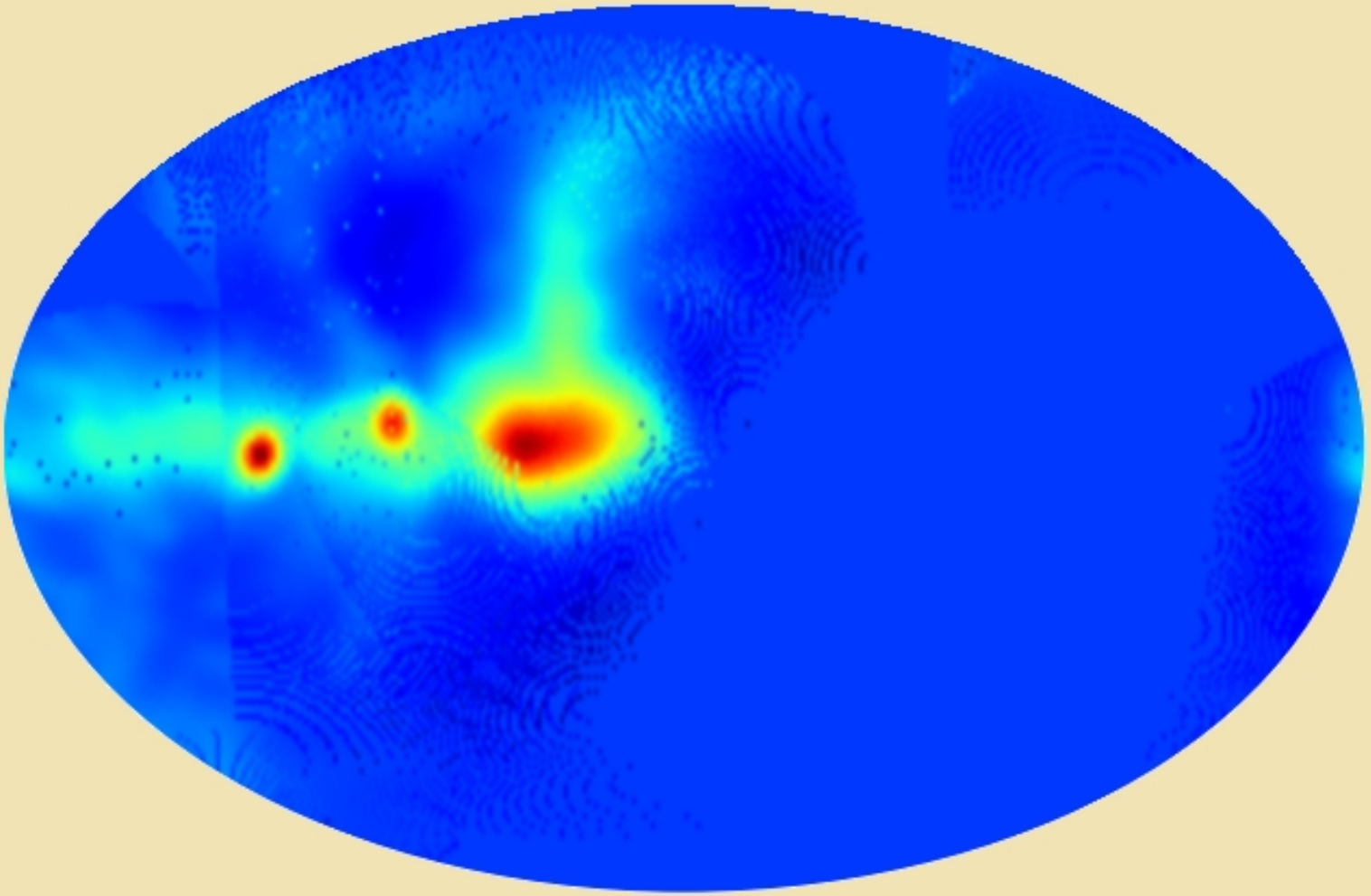


3. April 2012; 12:00

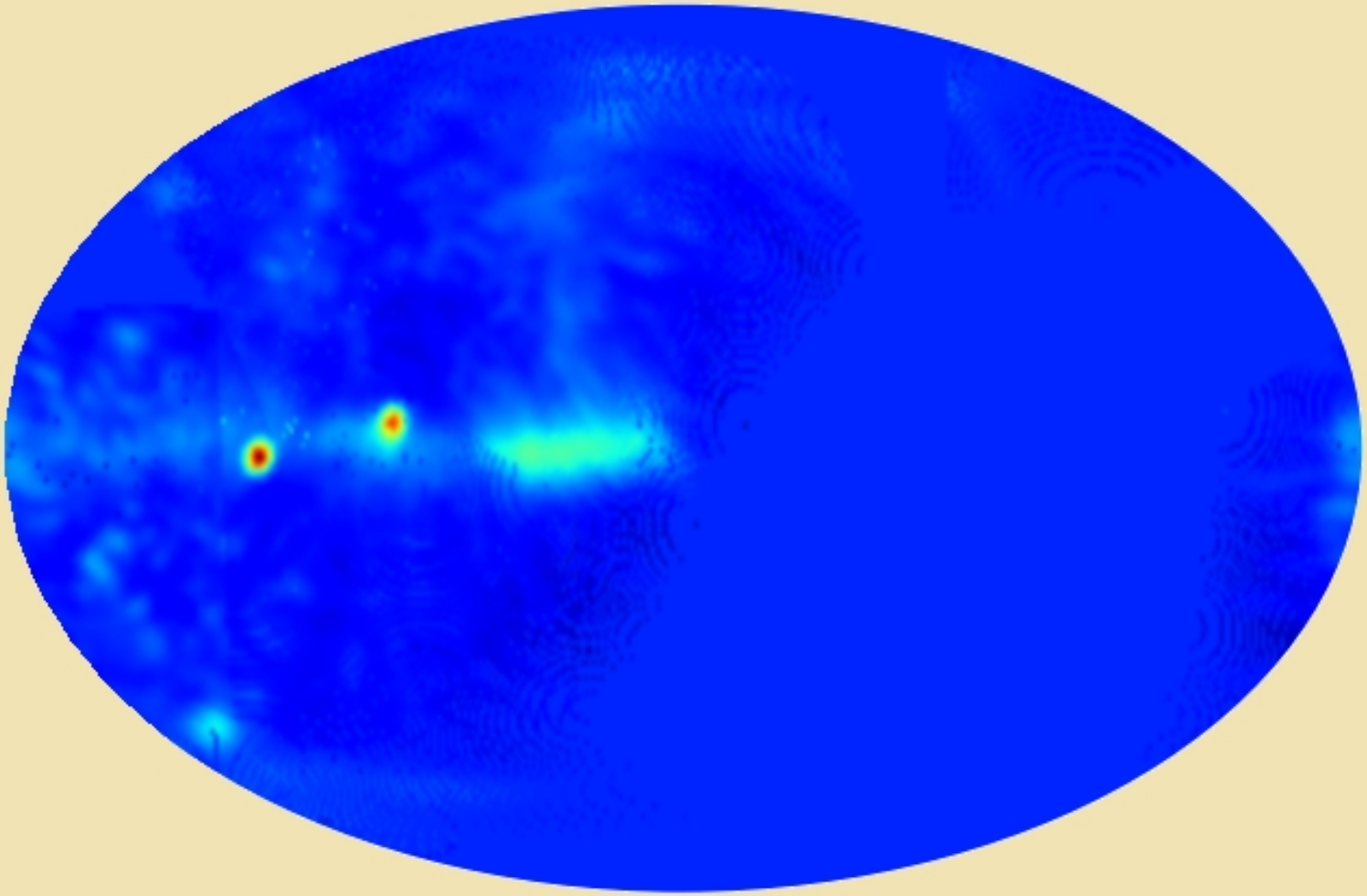
Galactic Coordinates – 49 MHz

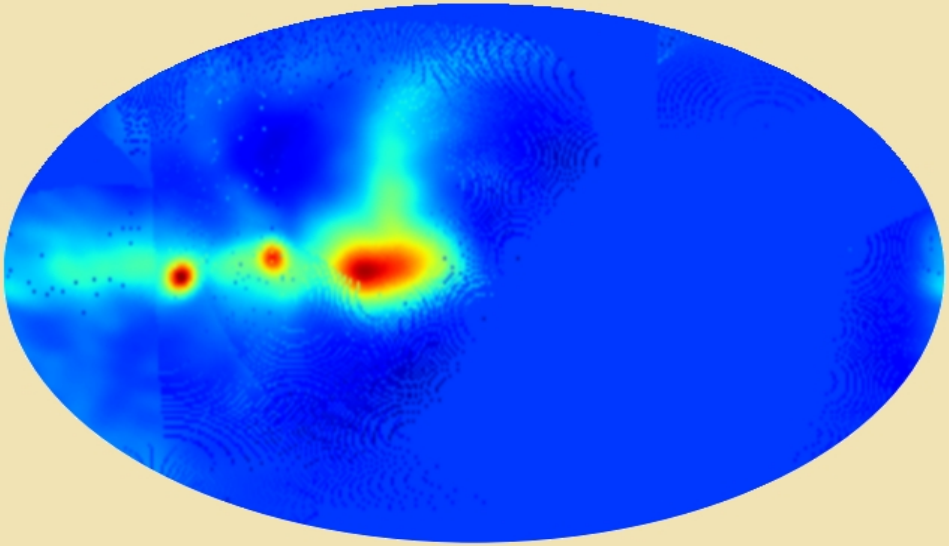


Galactic Coordinates – 36 MHz



Galactic Coordinates – 62 MHz





Thank you