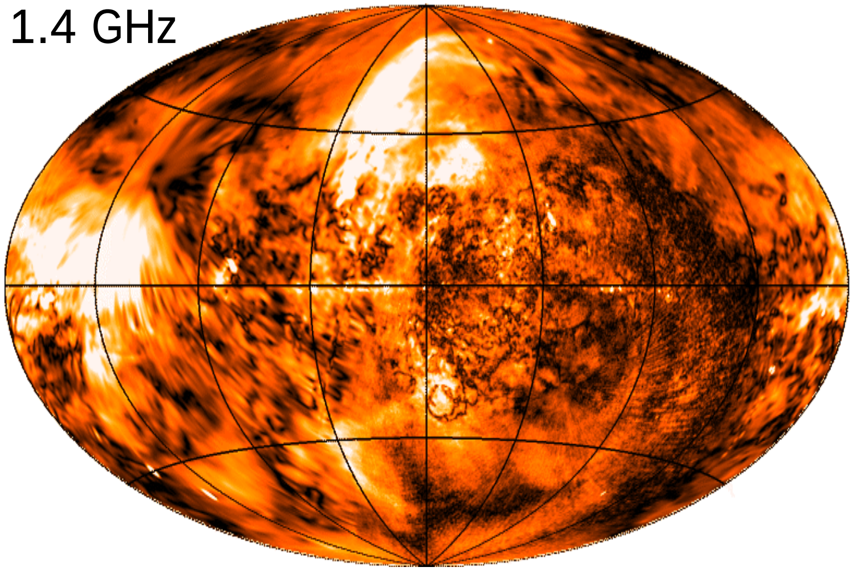
Sky Mapping:

Continuum and polarization surveys with single-dish telescopes

1.4 GHz



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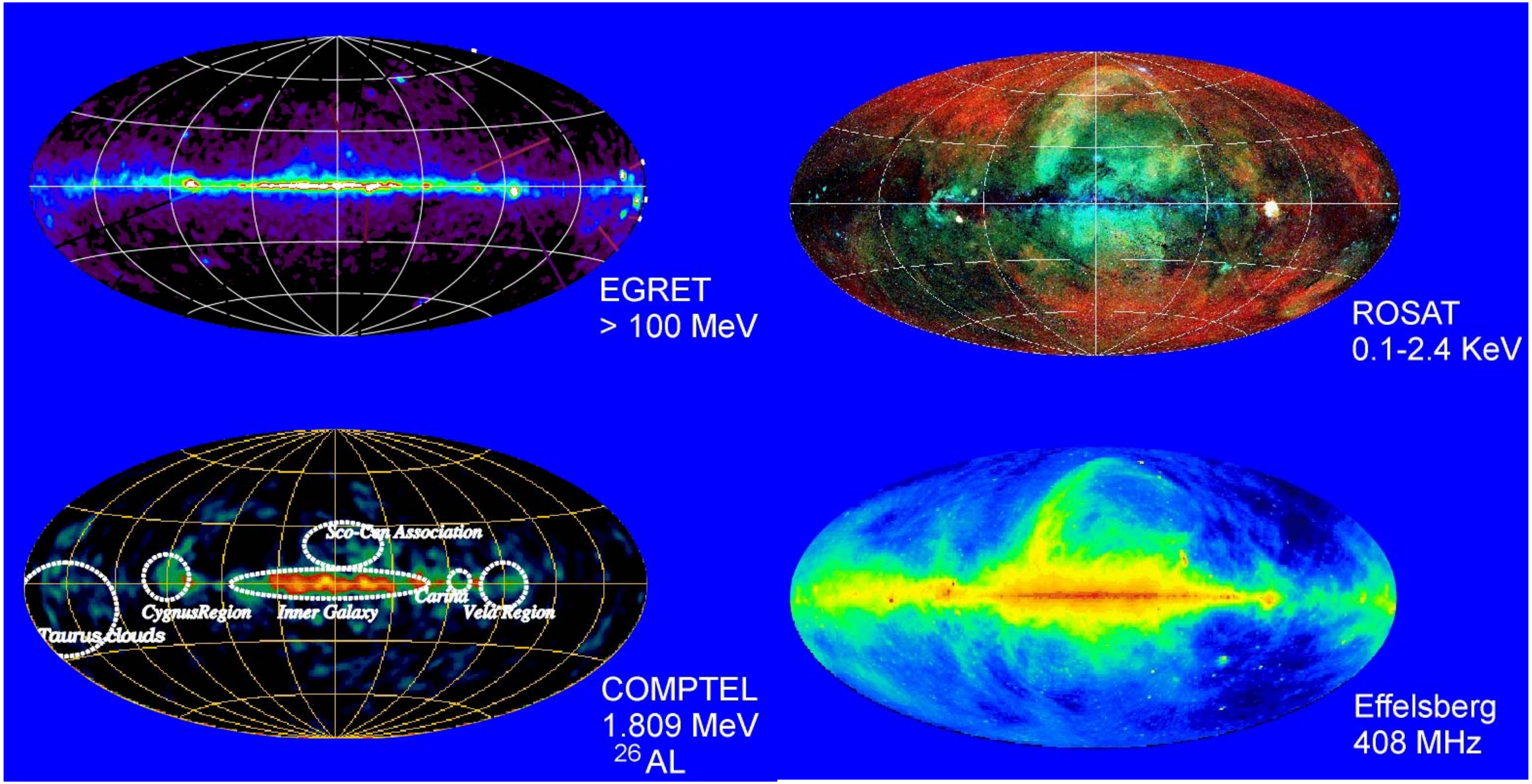
What is a ‘Survey’ ?

A <u>**Survey**</u> is an <u>*unbiased*</u> observation at a certain frequency of a specific area with uniform sensitivity and angular resolution to provide the distribution of sources and/or diffuse emission in that field.

Examples of All-Sky Surveys



Types of Sky Surveys

- **<u>Source surveys</u>**
- remove all extended emission from the data
- deep source surveys

- **<u>All-Sky surveys</u>**
- include extended emission and sources
- time consuming observations
- moderate angular resolution

- **<u>Galactic plane surveys</u>**
- need higher angular resolution to resolve sources/objects from diffuse emission

Why are Surveys needed ?

- **<u>Source surveys</u>**

- Source evolution
- Confusion term

- **<u>All-Sky surveys</u>**

- Thermal - non-thermal emission, spectral index distribution, Galactic 3D model, CMB foreground

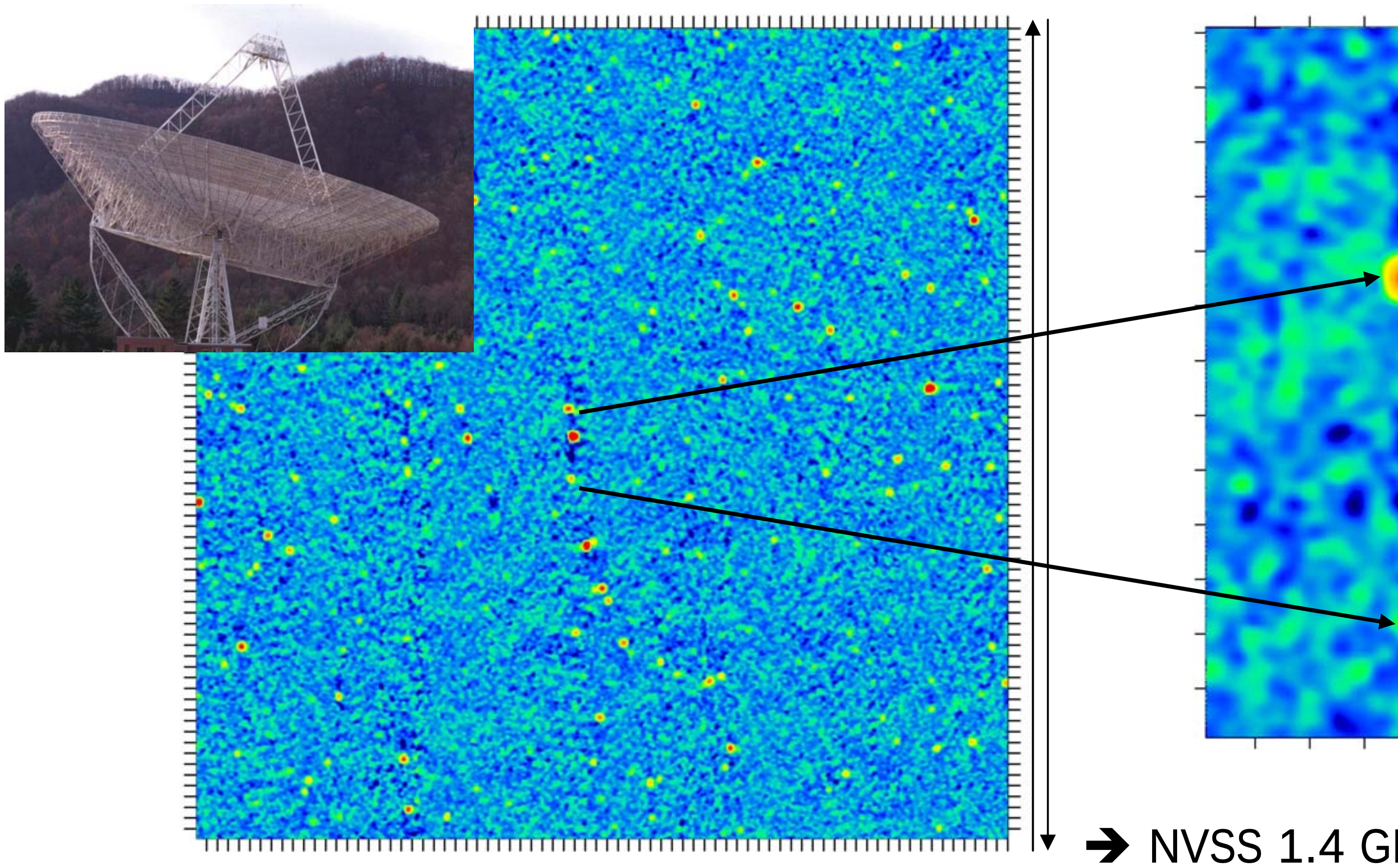
- **<u>Galactic plane surveys</u>**

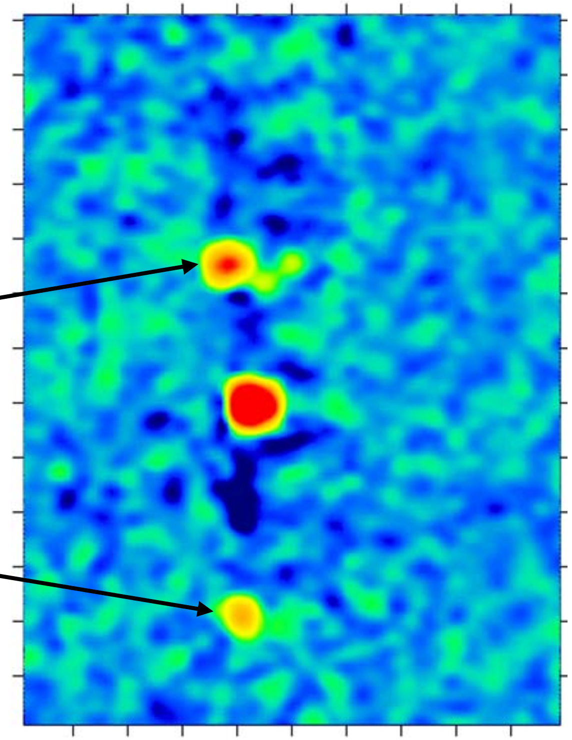
- Resolve sources and diffuse emission, identify SNRs and HII-regions

Source Surveys

Source survey made with the former 300-ft Green Bank transit dish

Field size 8.3° x 8.3°, λ = 6 cm, 7-beam RX, HPBW ~3.7‘
Condon et al., 1989, AJ, 97, 1064





➔ NVSS 1.4 GHz (much better)

Source counts from surveys

NVSS = Northern VLA Sky Survey
HPBW ~40“
Condon et al., 1998, AJ, 115, 1693

Effelsberg 1.4 GHz survey
HPBW = 9.3‘
Uyaniker et al., 1999, AAS, 138, 31

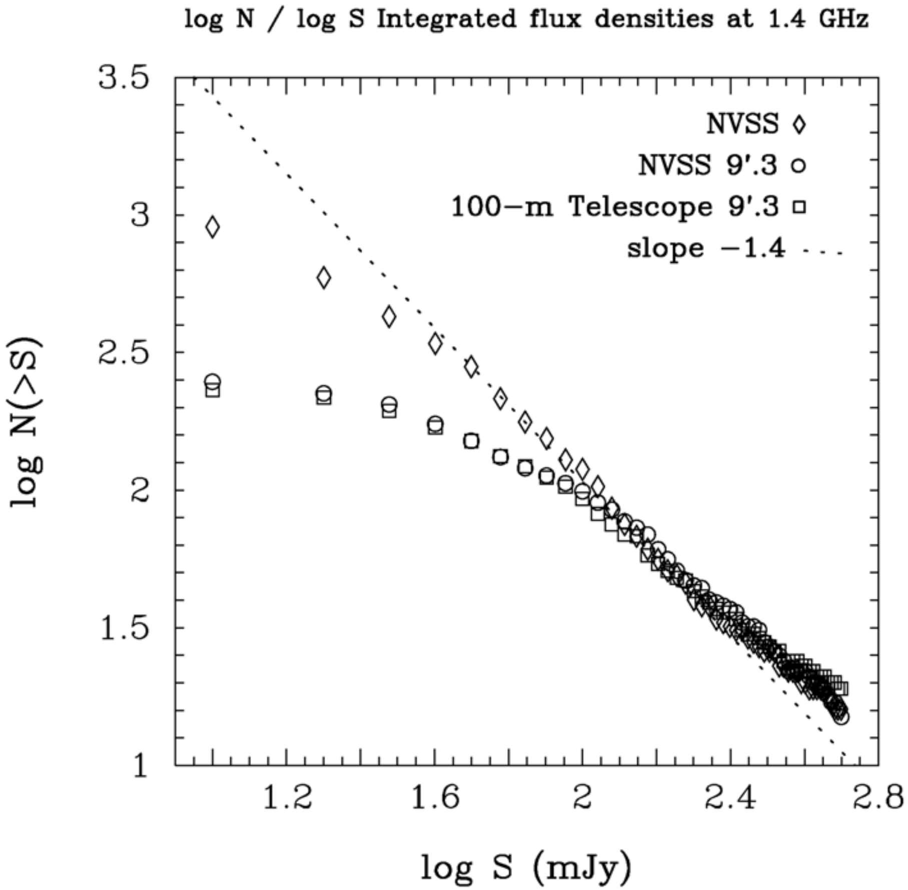
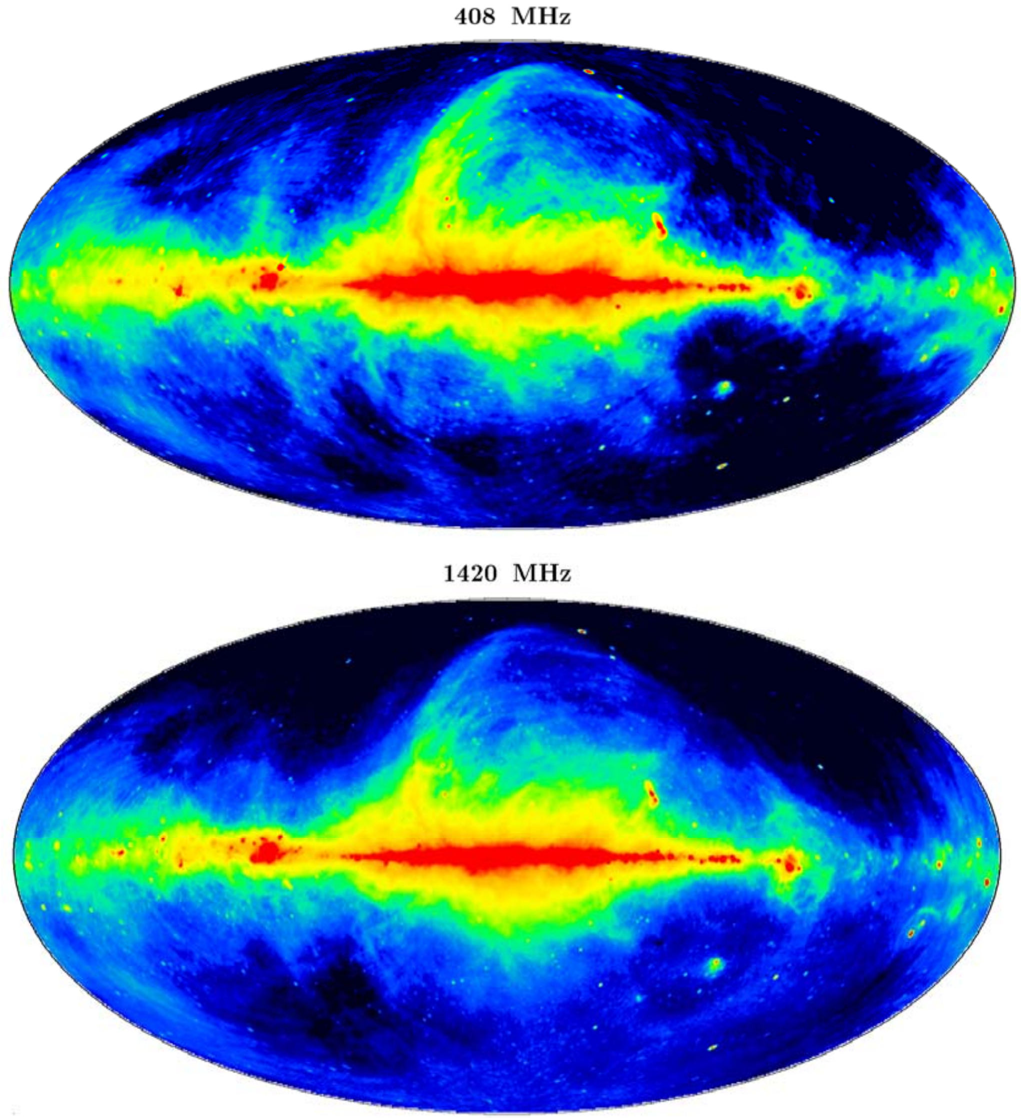


Fig. 1. Source counts from an area in the Galactic anticentre as described in Sect. 3

Total Intensity All-Sky Surveys

408 MHz
Haslam et al., 1982,
AAS, 47, 1
Jodrell Bank 76m,
Effelsberg 100m,
Parkes 64m
HPBW=51’, 2K (3σ)

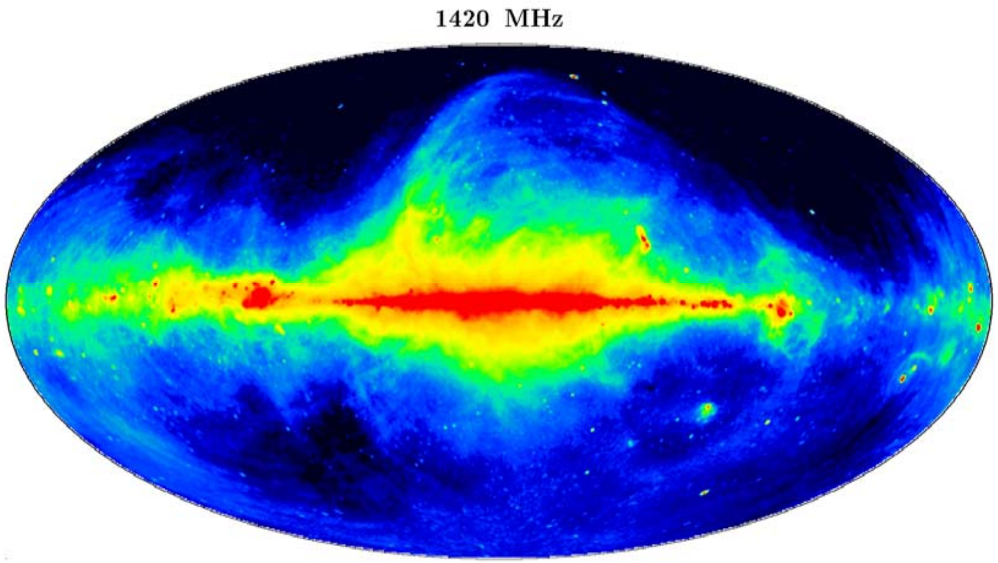
1420 MHz
Reich et al. 1982, 1986,
2001, AA
Stockert 25m,
Villa Elisa 30m
HPBW=36’, 50 mK (3σ)



Total Intensity All-Sky Surveys

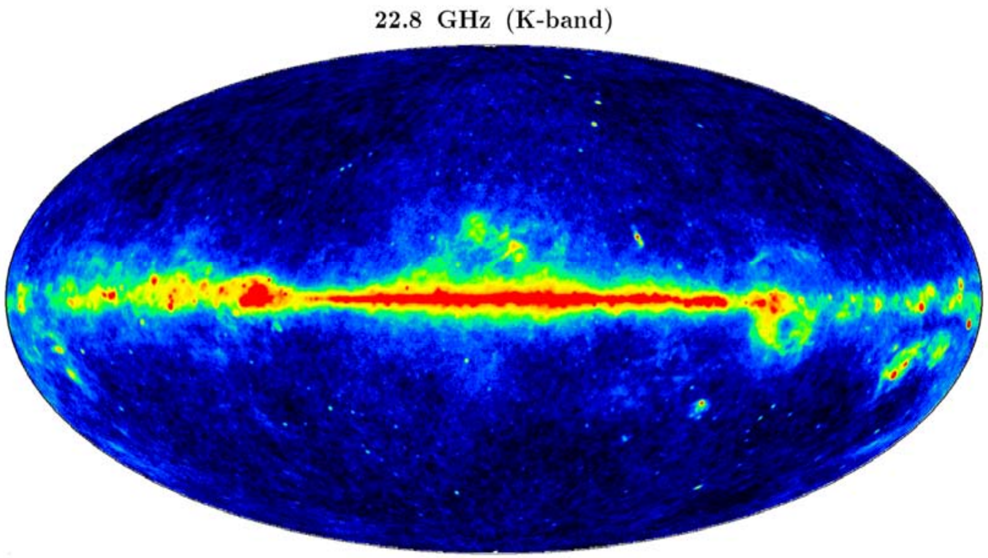
Groundbased all-sky surveys up to 1.4 GHz

HPBW = 36‘ (or less)



All-sky surveys from satellites: WMAP at 22.8 GHz or higher

HPBW 51‘ or higher



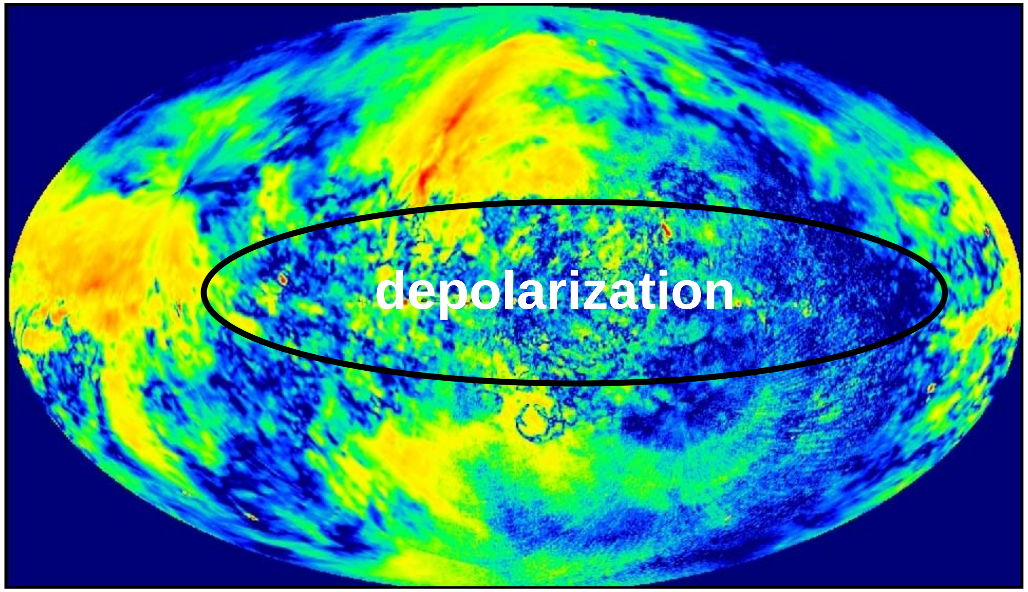
All-Sky Surveys of polarized emission

Groundbased all-sky survey at 1.4 GHz

Wolleben et al. 2006, AA , 448, 441

Testori et al. 2008, AA, 484, 733

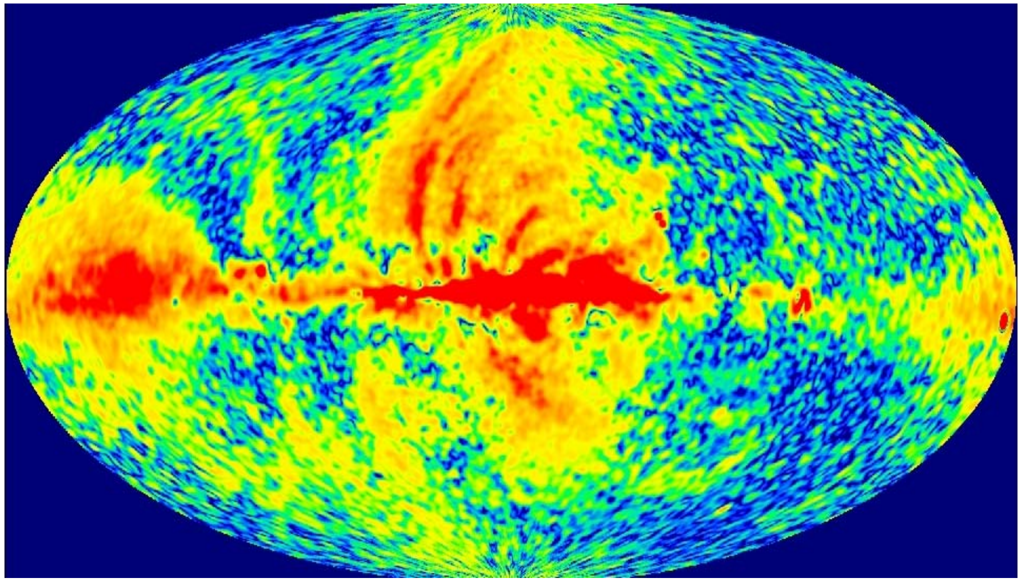
HPBW = 36‘



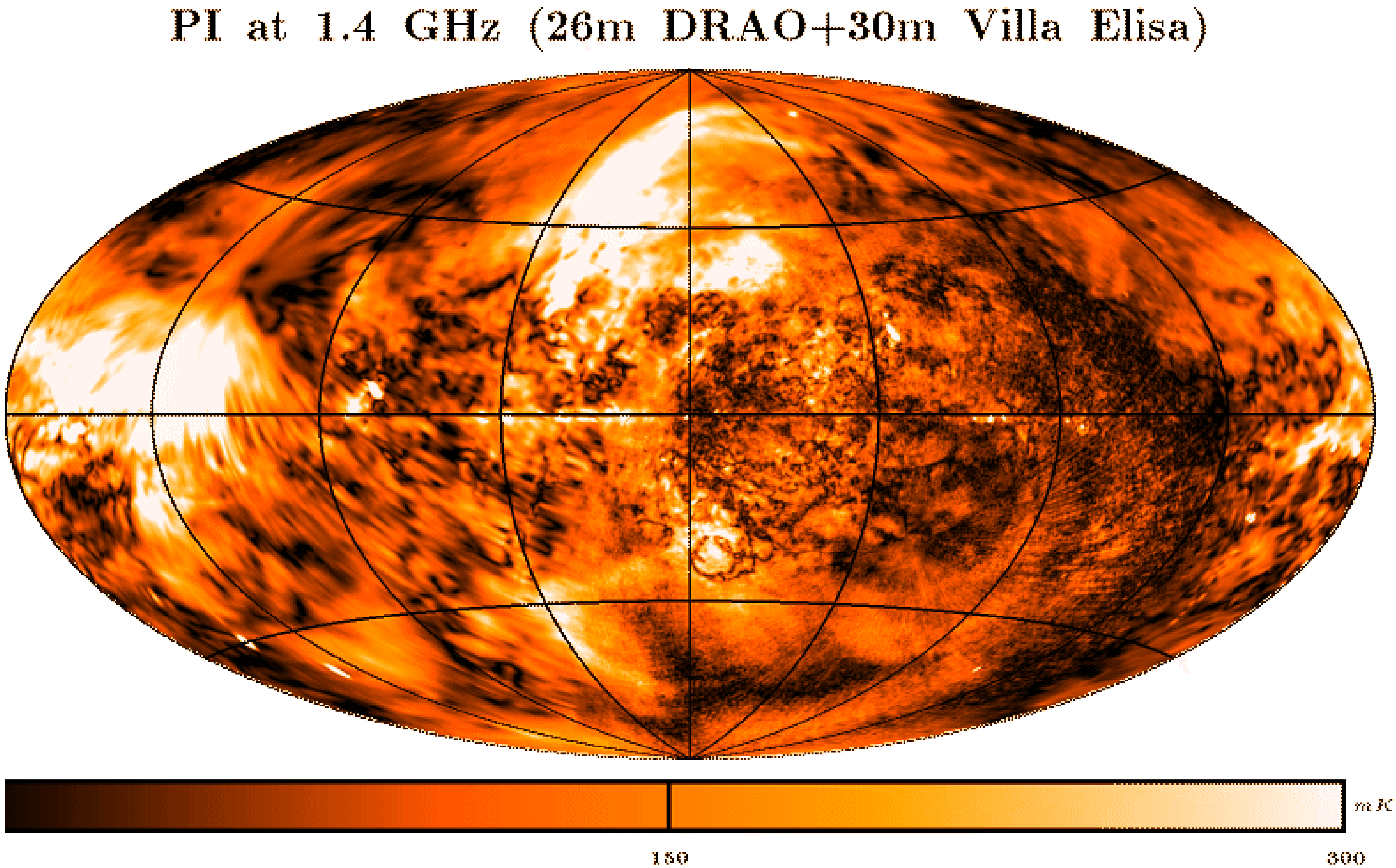
WMAP at 22.8 GHz and higher

Page et al. 2007, ApJS, 170, 335

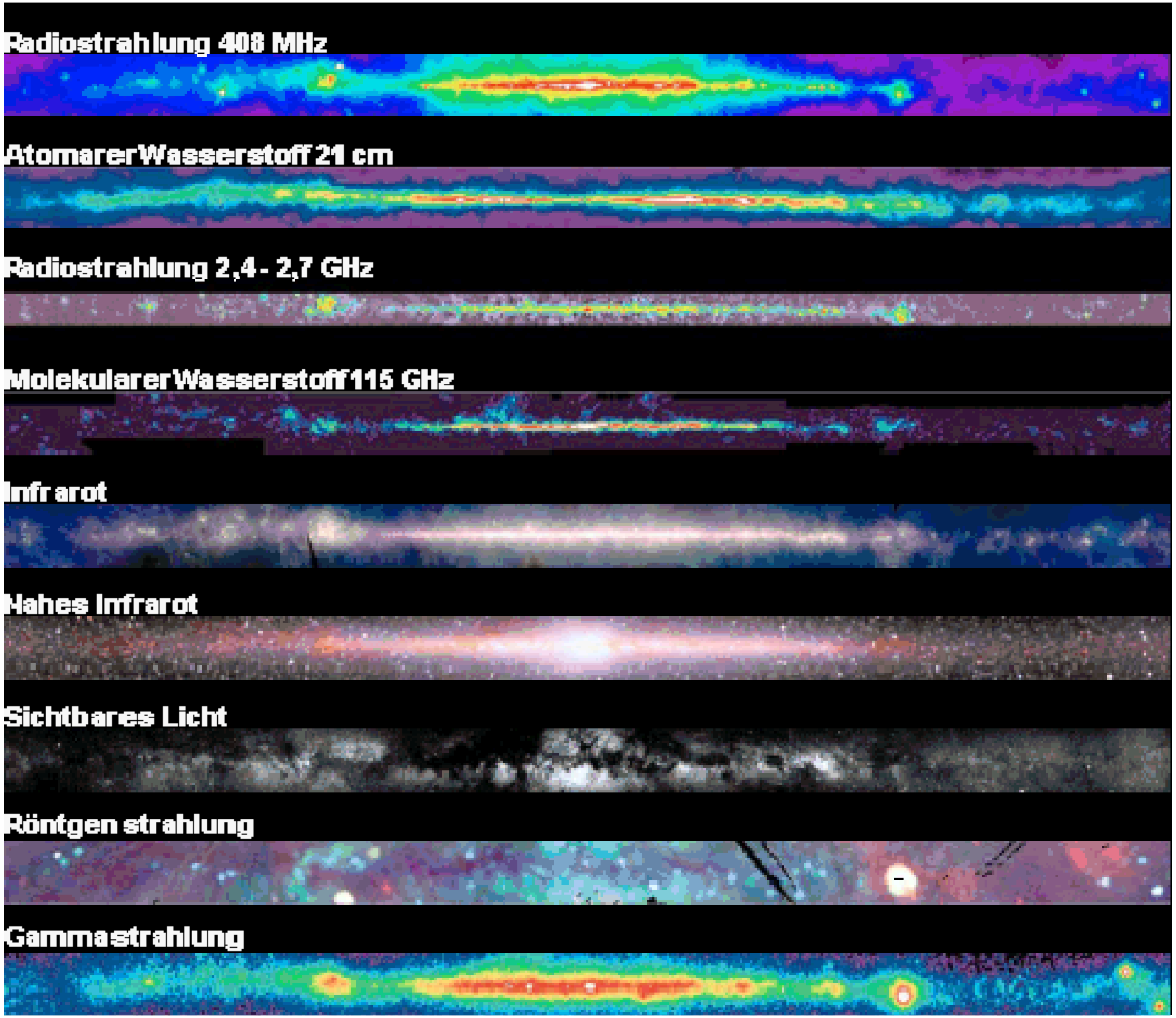
HPBW 51‘ or higher



Total intensity versus polarization

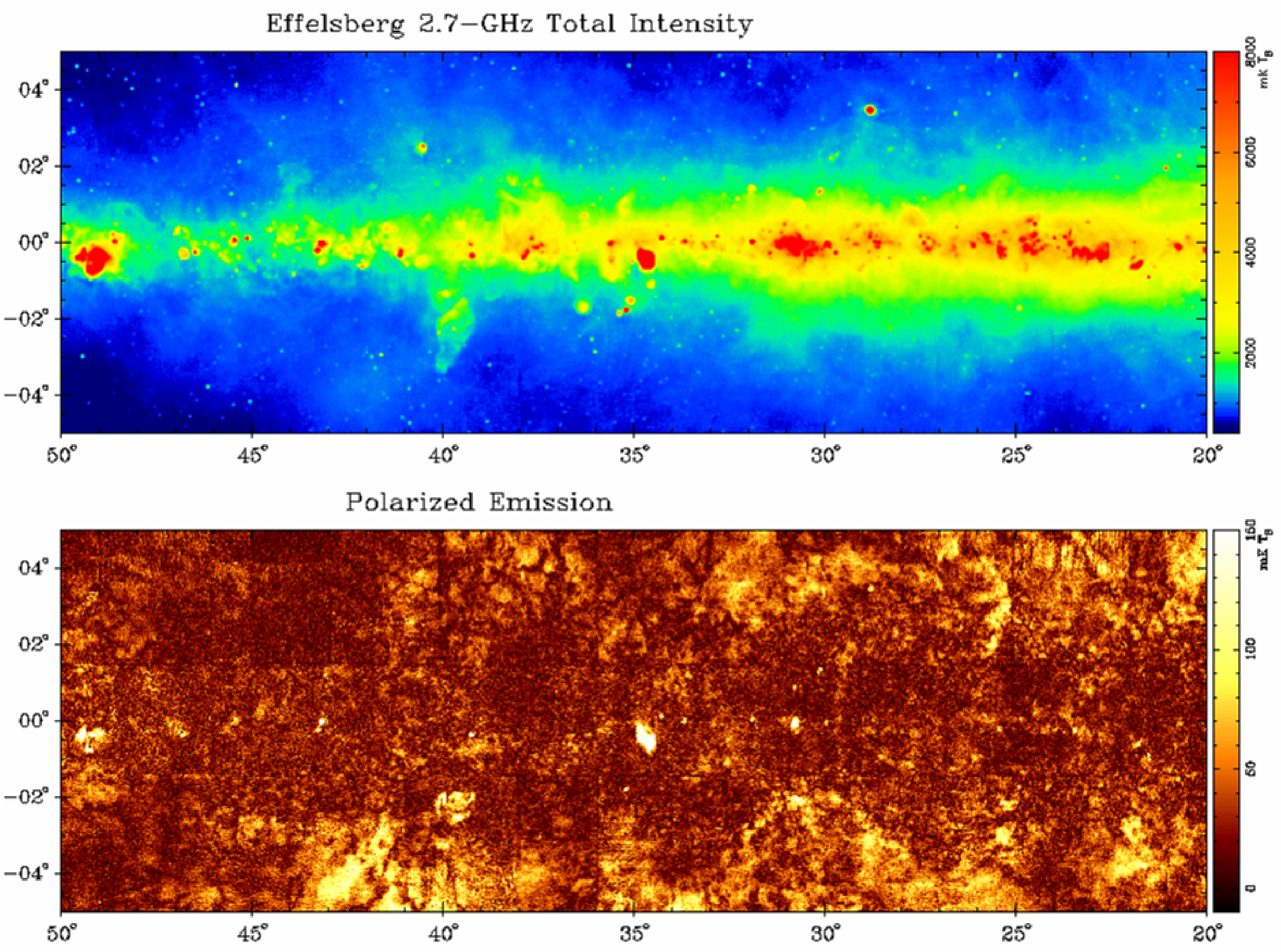


Galactic Plane Surveys



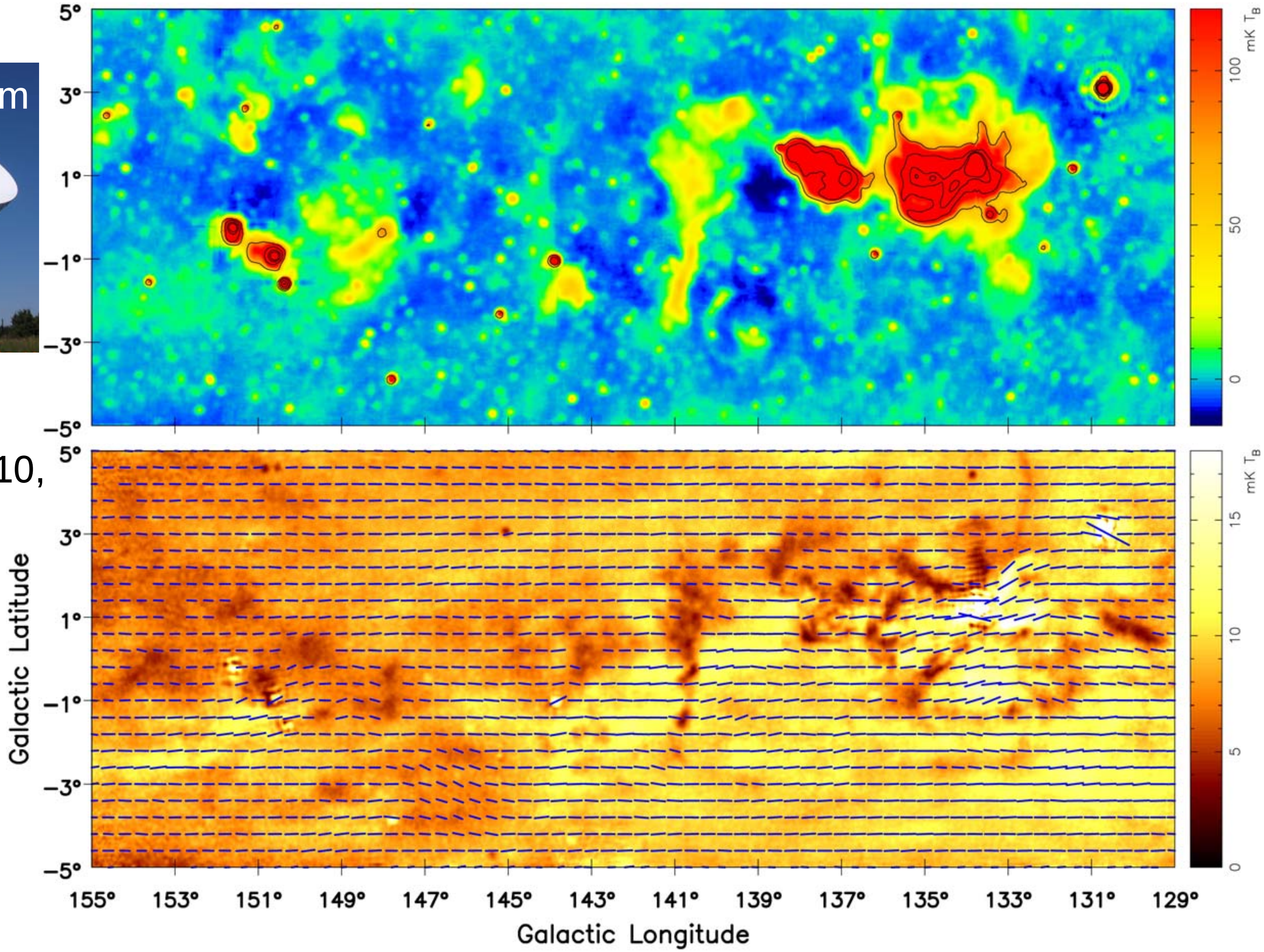
Effelsberg 2.7 GHz Galactic Plane Survey

Reich et al.
1990, AAS,
85, 633
HPBW 4.3‘

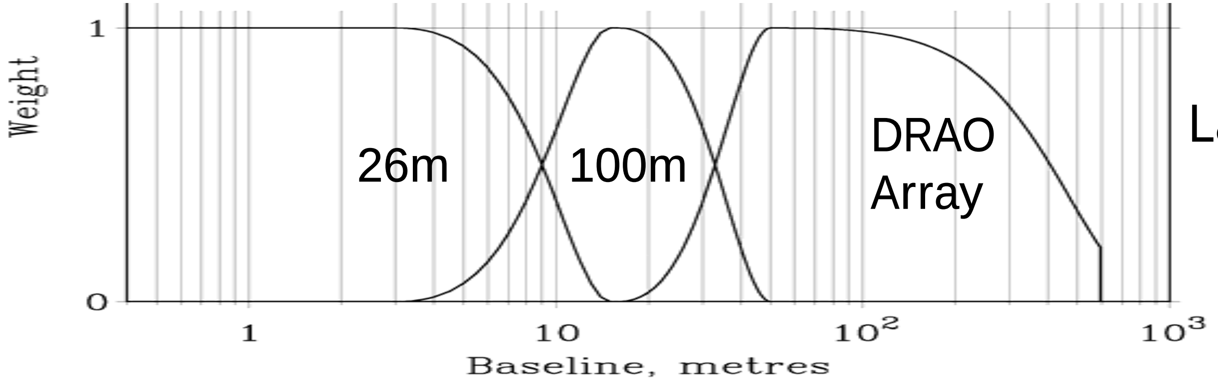


Sino - German (Urumqi)
4.8 GHz Galactic Plane Survey

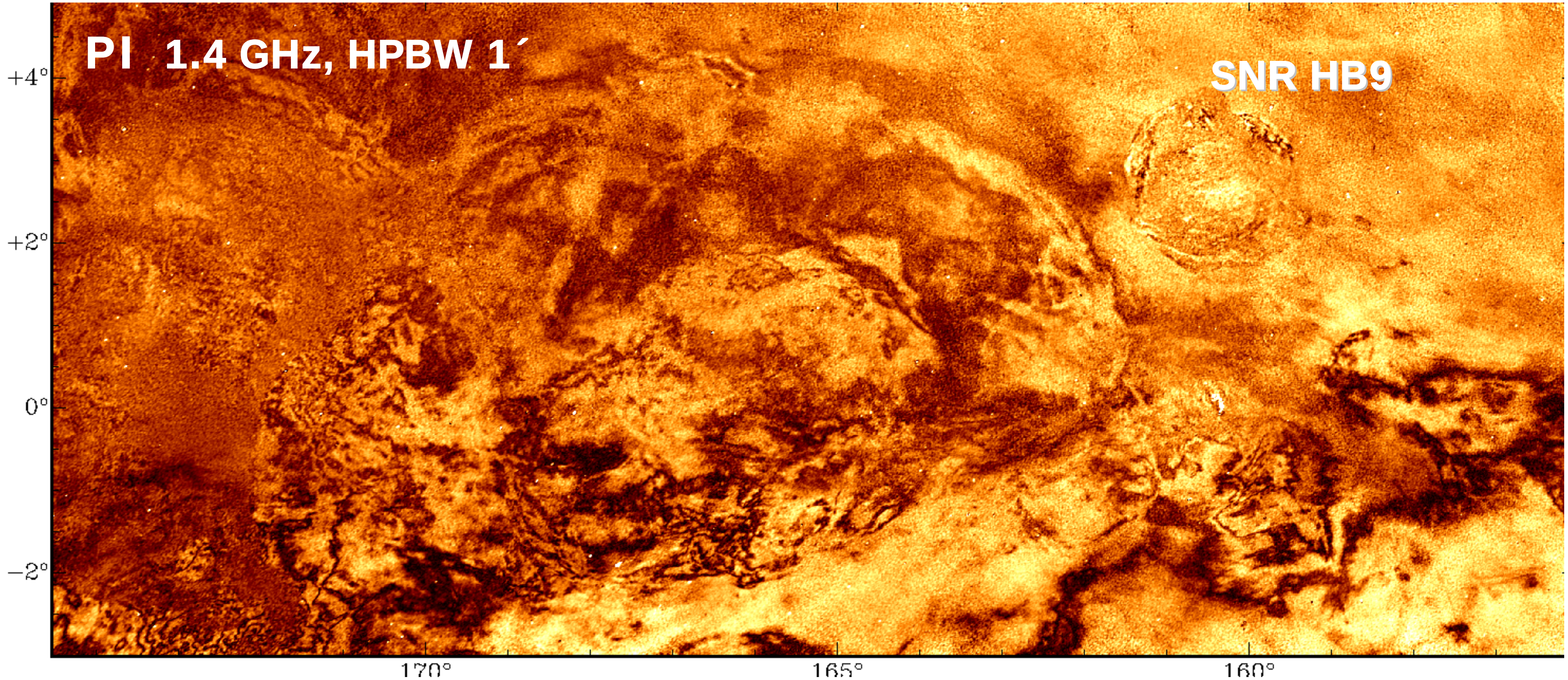
Gao et al. 2010,
AA, 515, A64
HPBW 9.5‘



DRAO 26m + Effelsberg 100m + CGPS Polarization Survey

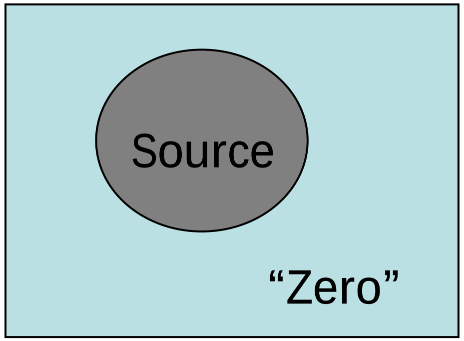


Landecker et al. 2010

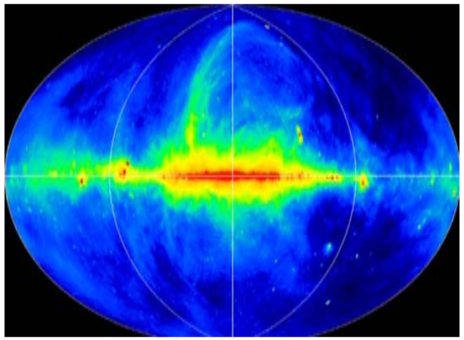


‘Standard Mapping’ versus ‘Surveys’

Singe-dish surveys require *non-standard* observing, data reduction and calibration techniques to preserve large scale emission with highest possible accuracy



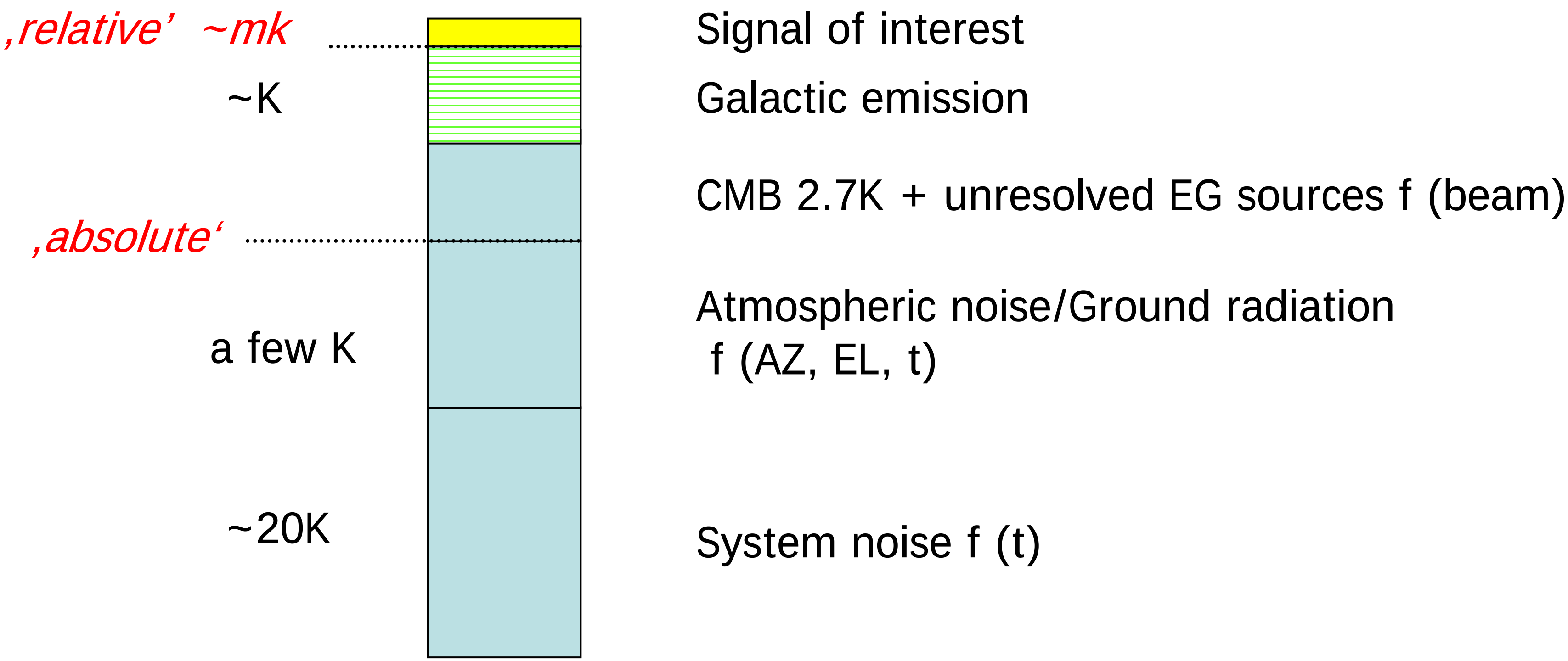
Standard mapping - local zero-level



All-Sky Survey – absolute zero-level

Observed components

Centimetre wavelengths :



System gain f (t)

Are you big enough for the telescope ?

What is observed ?

- **Sky emission**:

- Galactic diffuse emission + discrete sources
- resolved and unresolved extragalactic sources
- CMB (almost) isotropic background 2.71 K

- **Antenna pattern dependent components**:

- atmospheric emission f(EL, t)
- ground radiation f(AZ, EL, sidelobes)

- **Receiver dependent components**:

- receiver noise level stability f(t)
- gain stability f(t)

Survey strageties

All-sky surveys:

- long scans – fixed AZ, or EL
- fast scanning
- baseline adjustment (e.g. ‘Nodding Scans’)

Galactic plane surveys:

- long latitude scans (inner Galactic plane)
- latitude + longitude scans elsewhere
- survey area split into many sections (no strong source complexes at map boundaries)

What is observed ?

➔ The observed temperature T_{obs} at a certain frequency consists of :

$$\mathbf{T_{obs} = T_{gal} + T_{cmb} + T_{ex} + T_{off}}$$

with: T_{gal} = Galactic brightness temperature

T_{cmb} = 2.71 K Cosmic Mircowave Background

T_{ex} = unresolved extragalactic sources

$\approx$ 15 mK $(\nu/1.4\ \mathrm{GHz})^{-2.9}$ (‚confusion')

➔ T_{off} = deviation from true zero-level <u>f (AZ,El,t)</u>

➔ <u>*survey strategy important*</u>

Survey reduction

In general:

editing of each scan for RFI and other distortions
- as for standard mapping

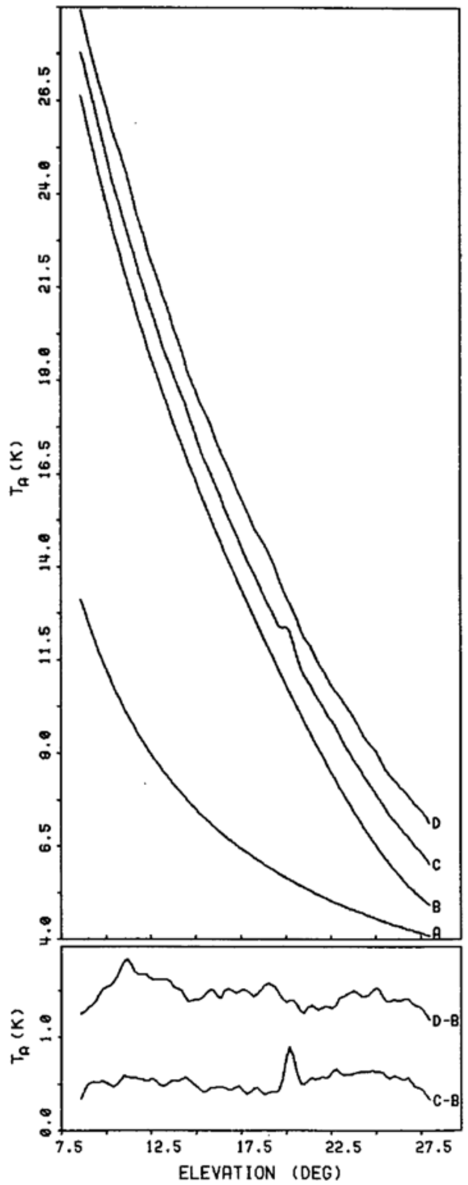
<u>All-sky surveys:</u>

- iterative baseline adjustment in case of ‘Nodding Scan’ observations
- ‘groundradiation profile’ subtraction

<u>Galactic plane surveys:</u>

- many sections, processing similar to standard mapping + edge adjustments of adjacent maps

Survey reduction



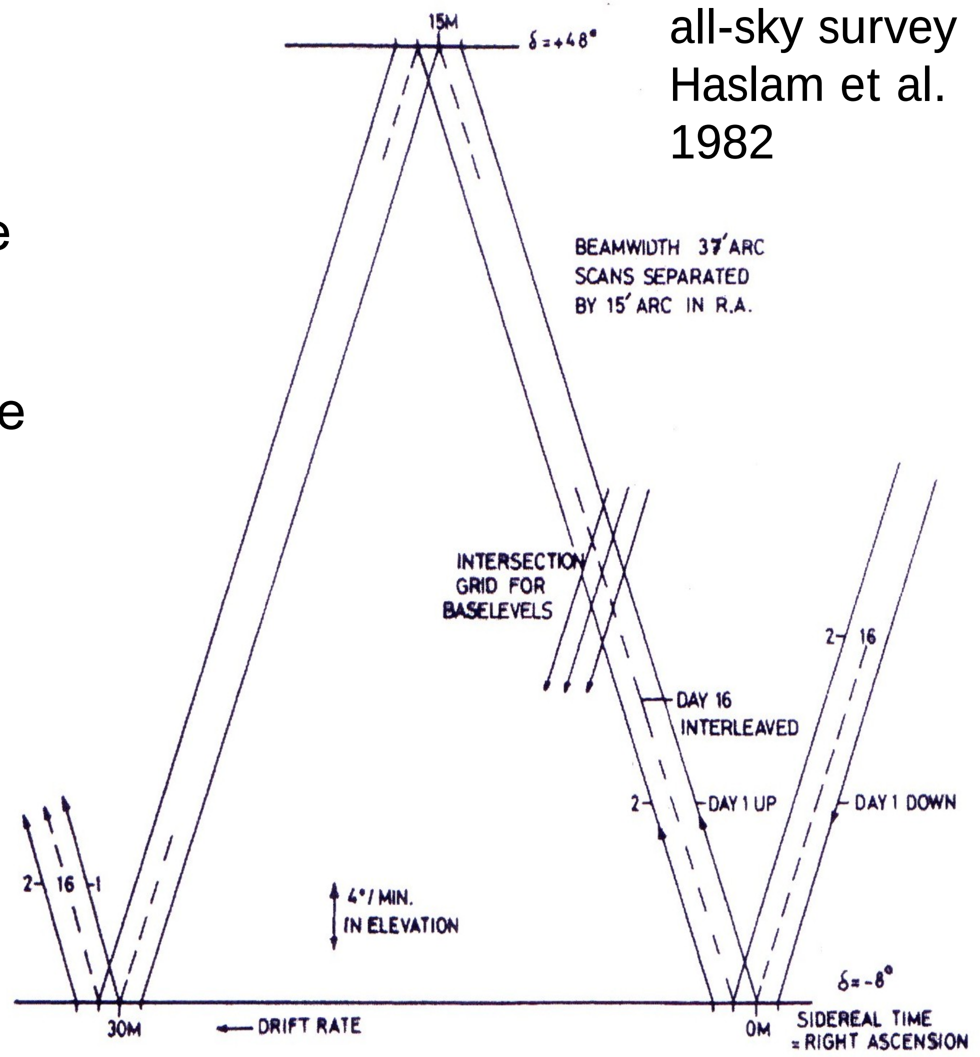
Theoretical and observed antenna temperature as a function of elevation. A: theoretical atmospheric contribution as described in Sect. 3. B: "mean" scan as the average of all observed scans. C,D: examples of original scans (Their positions are indicated in Fig. 3). Scans B,C and D are shown with a positive offset of 1 K, 2 K and 3 K respectively. The difference scans D-B and C-B are shown below. The temperature scale is relative.

Stockert 25m telescope at 1420 MHz
Reich & Steffen 1981, AA, 93, 27

Survey Observing Method

- Example of the ***'nodding scan***' technique:
- The telescope is moved along the local meridian, 'Up' and 'Down'
- sky rotation provides RA coverage
- high antenna velocity   >10°/min
- Full sampling
- Ground radiation = f (dec,t)

408 MHz
all-sky survey
Haslam et al.
1982



Survey reduction

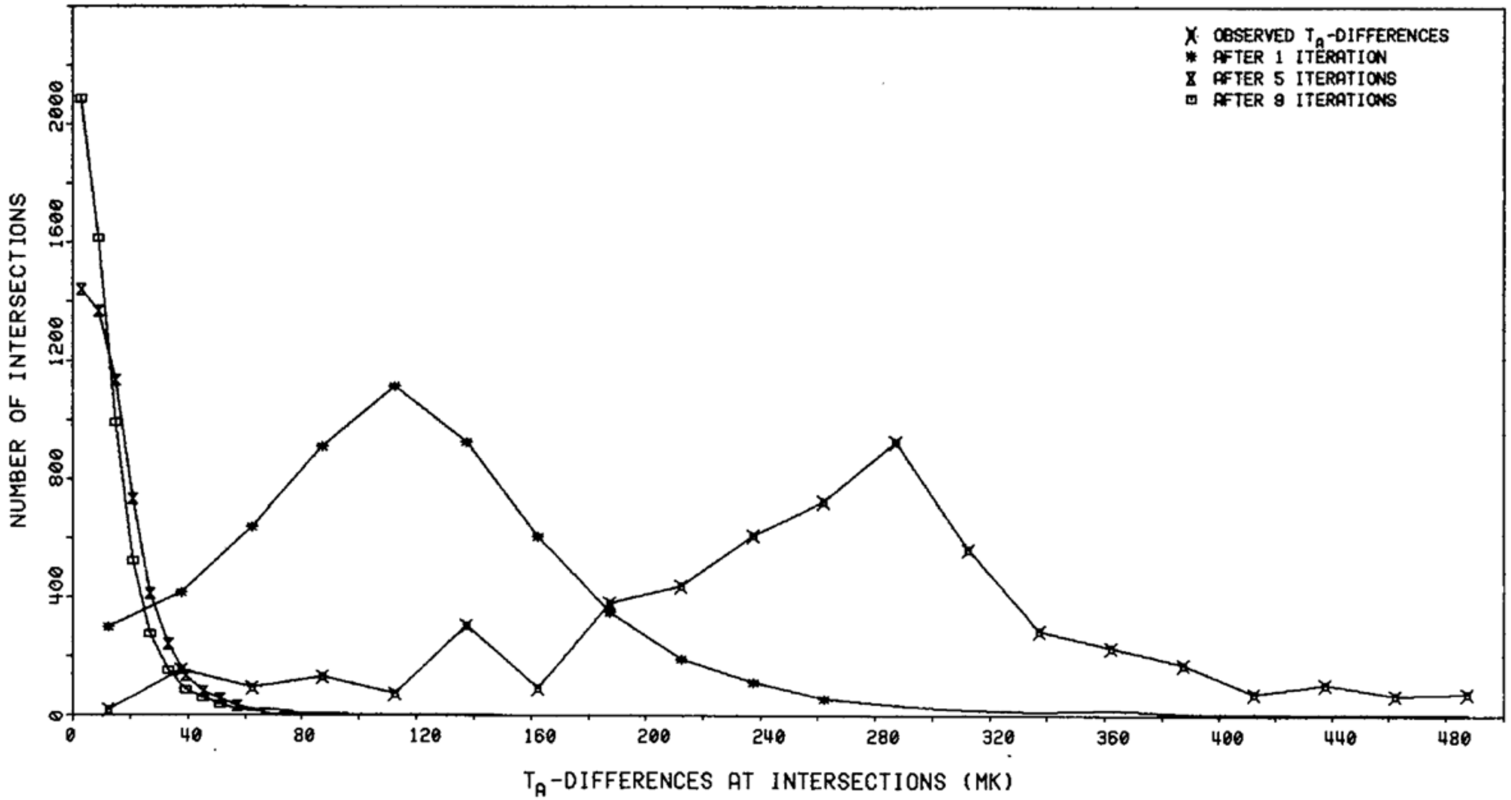


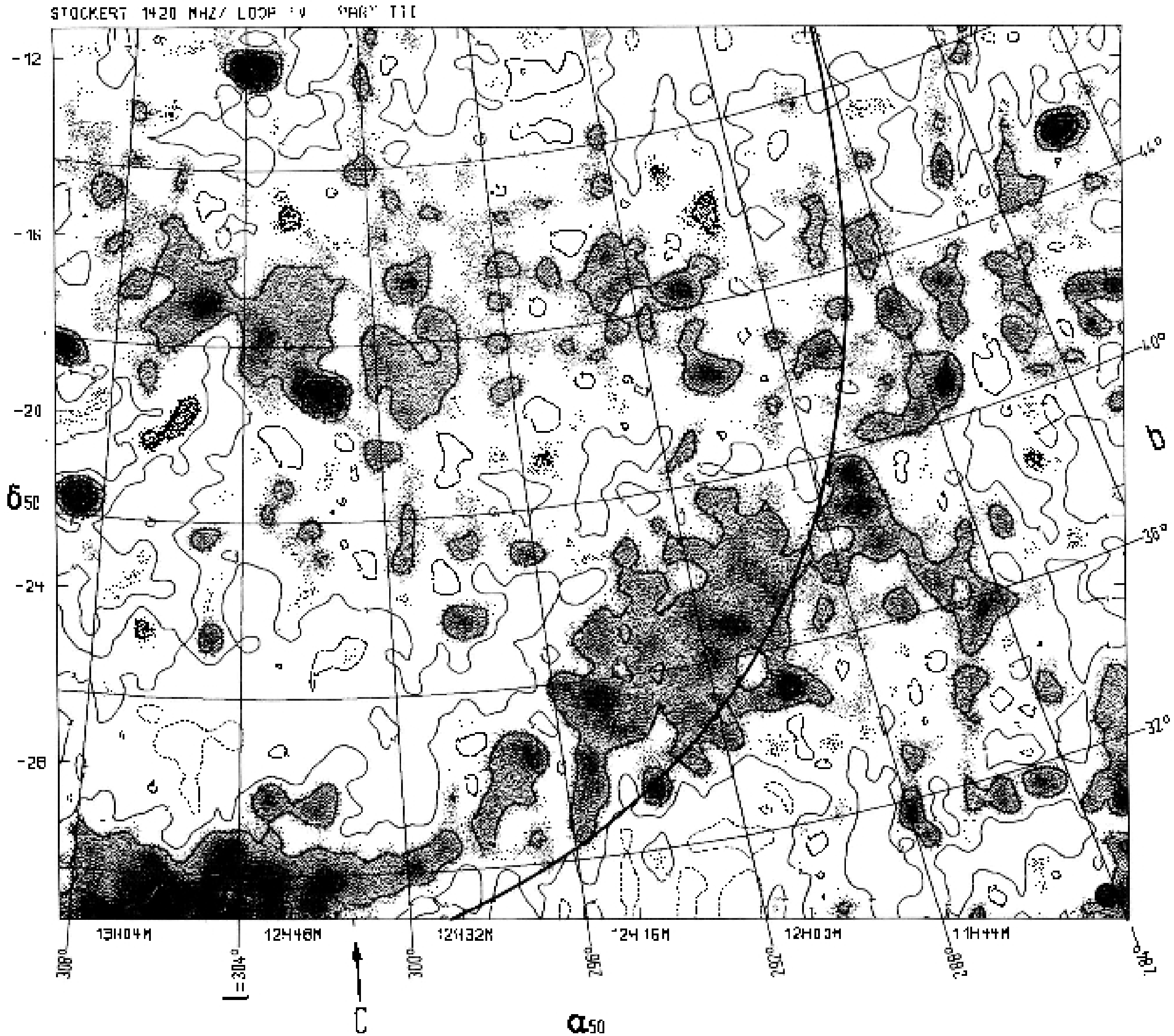
Figure 2:
Frequency distribution of temperature differences at intersections of up and down scans. The shifting of the maxima and the decreasing standard deviation with iteration number shows the convergence of the procedure applied.

Reich & Steffen 1981, AA, 93, 27

Survey reduction

Survey of Loop IV at 1420 MHz

Reich & Steffen 1981, AA, 93, 27



Absolute zero-level adjustment (total intensity)

<u>All-sky surveys:</u>

- additional low resolution sky horn data needed
- convolution of all-sky survey to sky horn beam
- check temperature differences and correct all-sky survey

<u>Galactic plane surveys:</u>

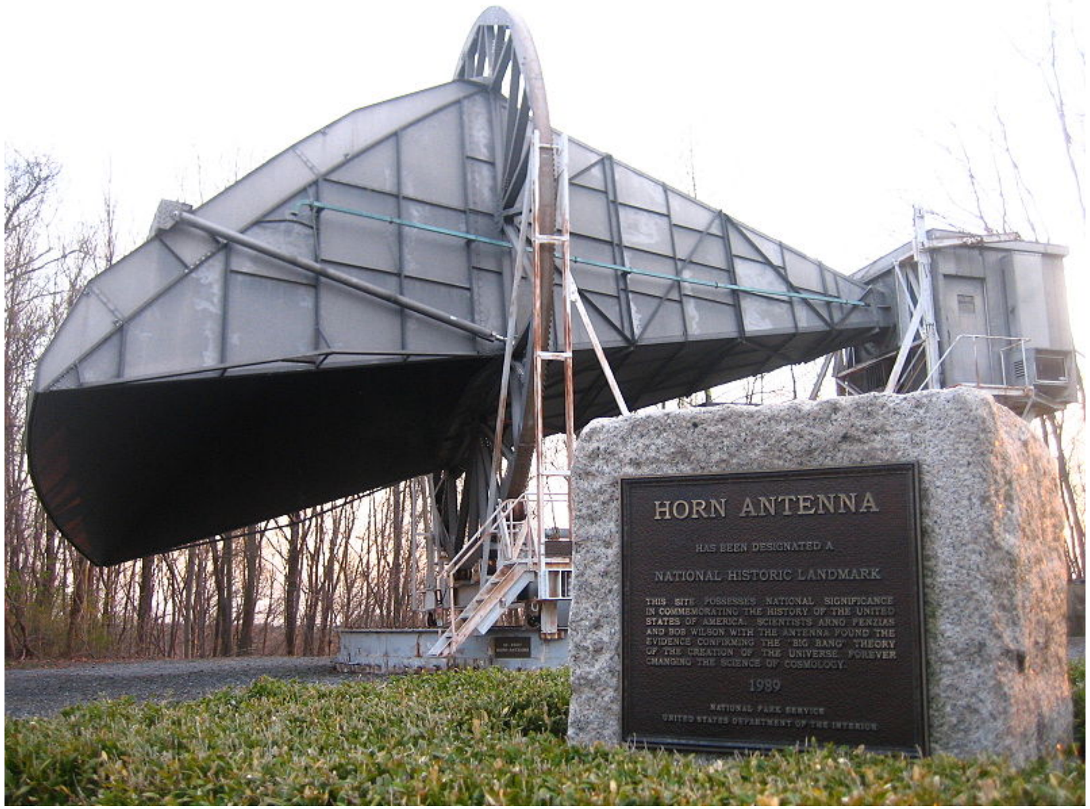
- use all-sky surveys to find absolute zero-level
- e.g. Effelsberg 100-m 1.4/2.7 GHz surveys were calibrated with Stockert 25-m surveys

Sky horns to measure T_{sky}

$$T_{obs} = \underbrace{T_{gal} + T_{cmb} + T_{ex}}_{} + T_{off} = T_{sky} + T_{off}$$

➔ Convolve a survey to the low resolution of a sky horn and find $\mathbf{T_{off}}$

Bell Lab satellite antenna

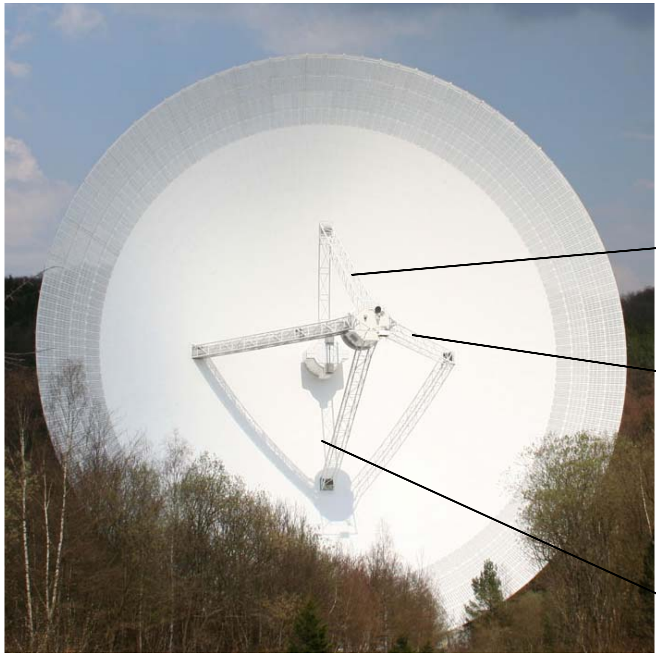


Detection of 3K CMB radiation in 1963
Nobel Prize 1978 - Penzias & Wilson

Antenna pattern

- **HPBW** = k λ /D
  λ = wavelength, D = diameter of antenna
  k = illumination dependent (Effelsberg: 58 to 70)
- **Near sidelobes** (level is illumination dependent)
  diffraction: dish → rings
  subreflector support legs → radial response
- **Far sidelobes**:
  very low levels, but integration over a large area

Antenna diagram



Effelsberg 100-m four subreflector support legs

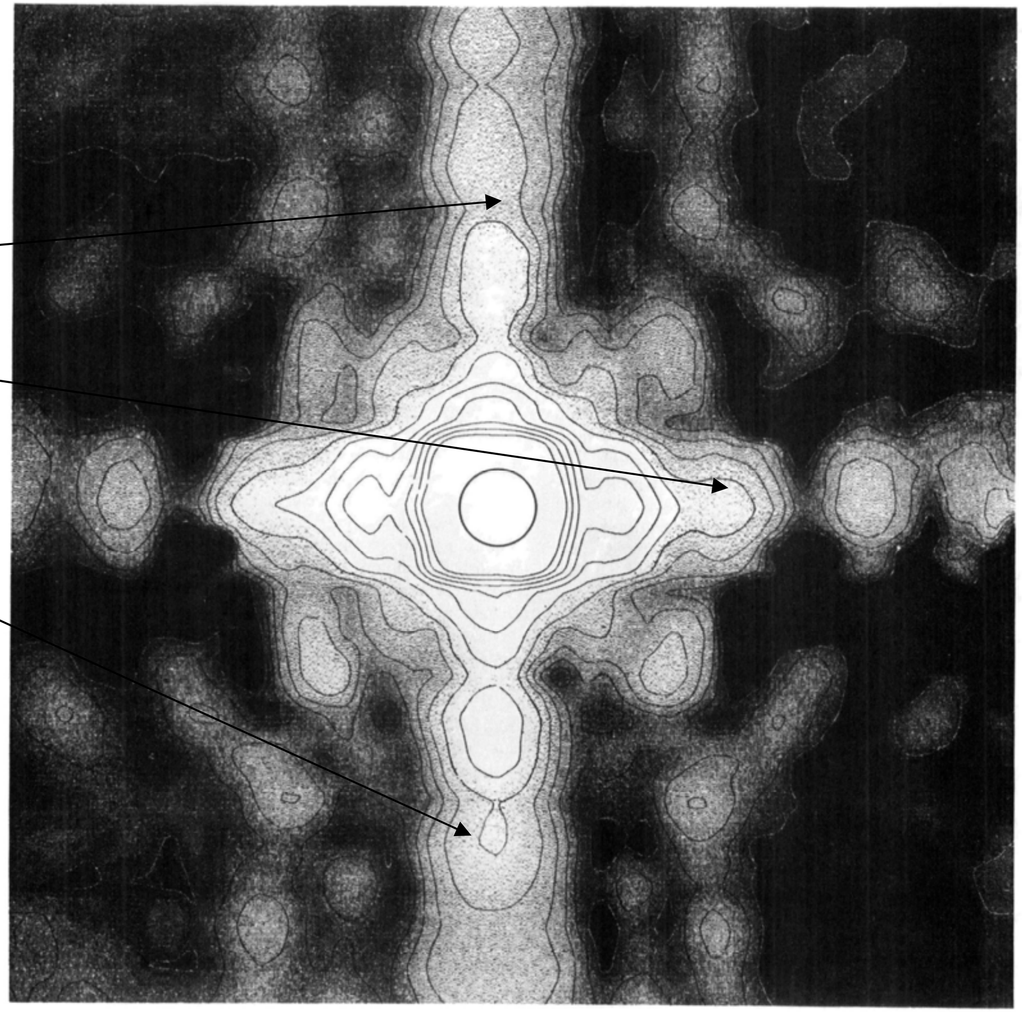


Fig. 1. Antenna pattern of the 100 m telescope at $\lambda = 21$ cm. The field size is $2° \times 2°$, north is at the top, west at the left. The -3 dB level for the main beam is indicated by a circle. The levels from -12.5 dB to -40 dB are shown by isophotes separated by 2.5 dB. Sidelobe levels between -25 dB and -47 dB are indicated by the gray scale

Brightness temperature

- **Antenna solid angle** : $\Omega_0 = \int_{4\pi} P(\Phi,\Psi)\, d\Omega$
  with $\Omega_0 = \lambda^2 / A_{eff}$

- **Main beam**: $\Omega_{MB} = \int_{MB} P(\Phi,\Psi)\, d\Omega$
  $T_{MB} = T_A\, \Omega_0 / \Omega_{MB}$
  main beam averaged sky temperature

- **Full beam**: $\Omega_{FB} = \int_{FB} P(\Phi,\Psi)\, d\Omega$
  $T_{FB} = T_A\, \Omega_0 / \Omega_{FB}$
  Full beam includes sidelobes up to a certain distance (not well defined)

Main (Full) beam efficiency ~70% (90%) (typical values)

➔ all-sky surveys often have lower efficiencies !

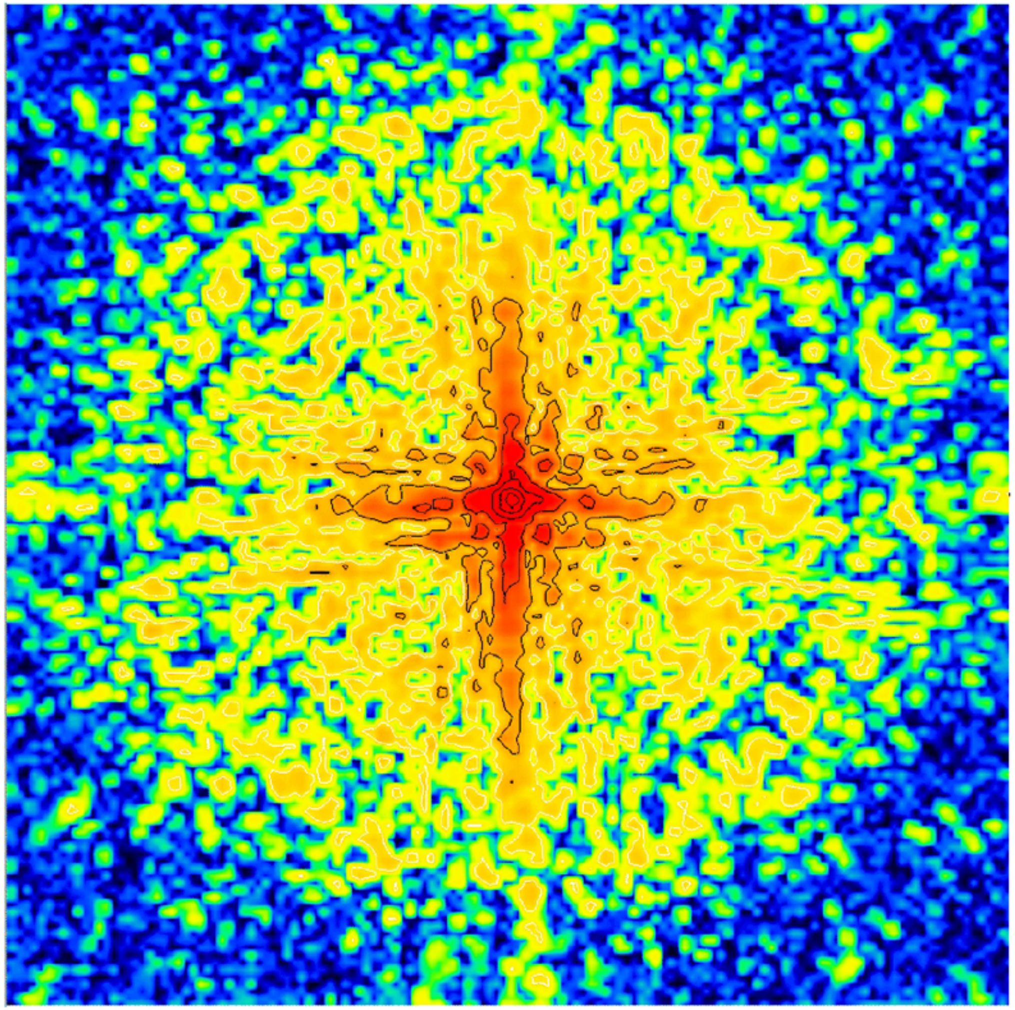
Antenna diagram

ITALSAT at 11.7 GHz

Reich & Fürst, 2000

HPBW ~ 67“
sensitivity ~ -63 dB

contours at -3, -10, -20, -30, -40 dB of peak



Field size 81‘ x 81‘

Antenna diagram – far sidelobes

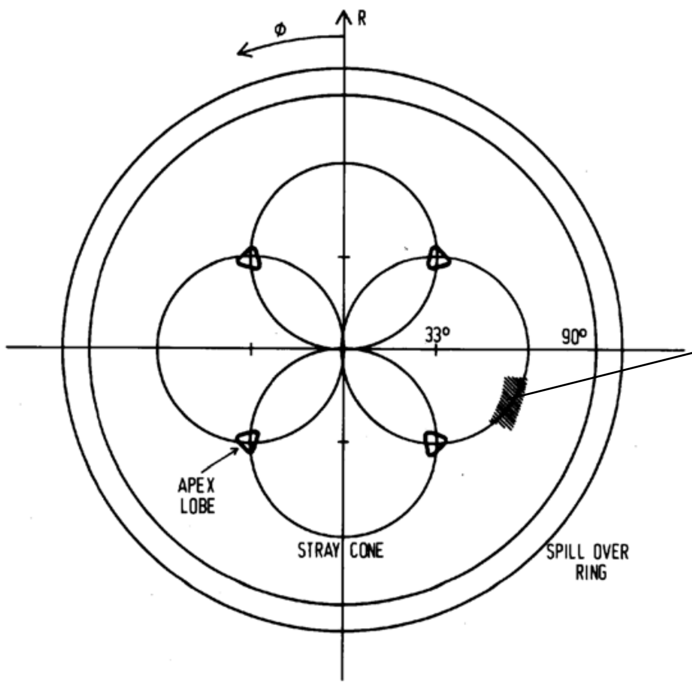


Fig. 3 Model for the far sidelobes of the 100 m telescope. Indicated are 4 stray cones centered in N, E, S, and W direction 33° from the main beam, 4 triangular shaped sidelobe regions caused by the roof of the apex cabin and a spill over ring for $90° \leq R \leq 100°$. The shaded area indicates the section of the stray cone which is plotted in Fig. 4

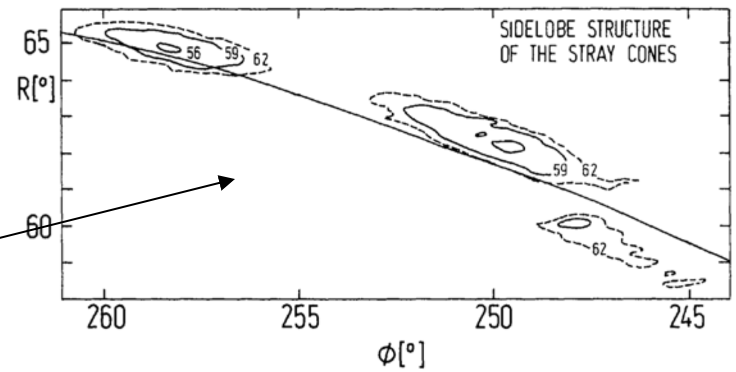


Fig. 4. Sidelobes which were found in the shaded area in Fig. 3. The solid line is the corresponding section of the stray cone circle. The isophotes are at the −56 dB, −59 dB, and −62 dB levels

Kalberla, Mebold & Reich, 1980, AA, 82, 275

Absolute zero-level adjustment for polarized intensities

Problems:

- no sky horn data available, but ‘special’ experiments
- missing large scale polarization adds as a <u>vector</u> !
  (total intensity as a scalar)

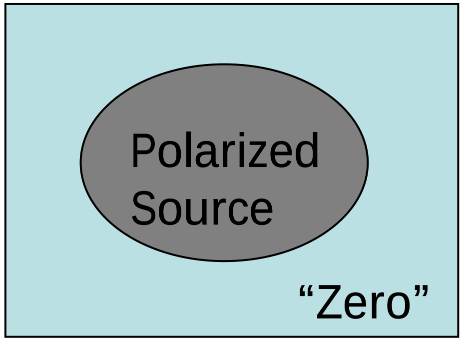
<u>All-sky polarization surveys:</u>

- 1.4 GHz all-sky polarization survey – complex procedure
- WMAP surveys <u>*are*</u> on an absolute zero-level

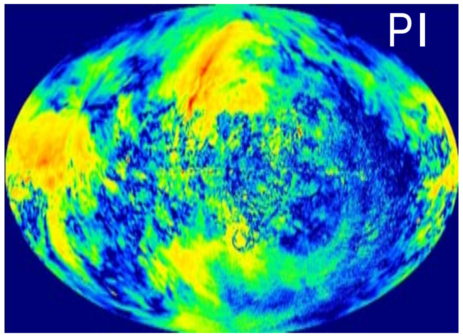
<u>Galactic plane surveys:</u>

- 1.4 GHz plane survey calibrated by all-sky survey
- 5 GHz plane survey calibrated by WMAP 22.8 GHz survey

Absolute zero-level adjustment for polarized intensities



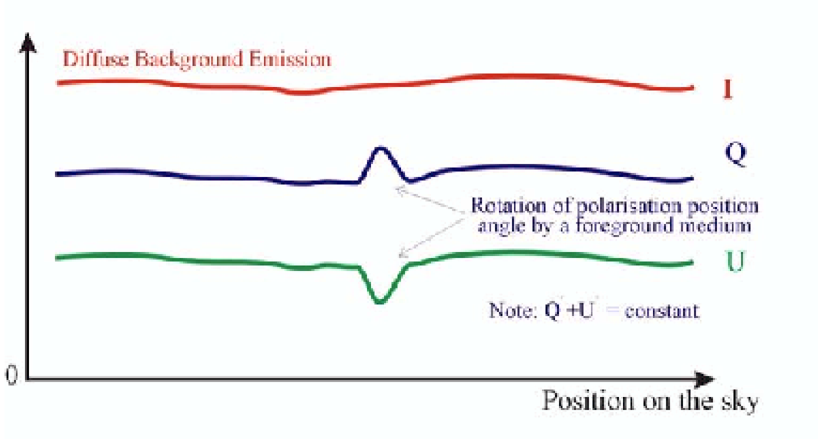
Stokes U/Q are measured
“relative” as Stokes I



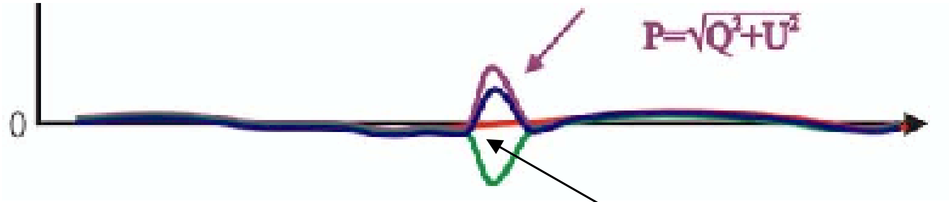
All-Sky PI maps require an **“absolute”** temperature level

most PI results from Faraday rotation

Absolute zero-level adjustment for polarized intensities



Large scale emission subtracted (relative measurement) :



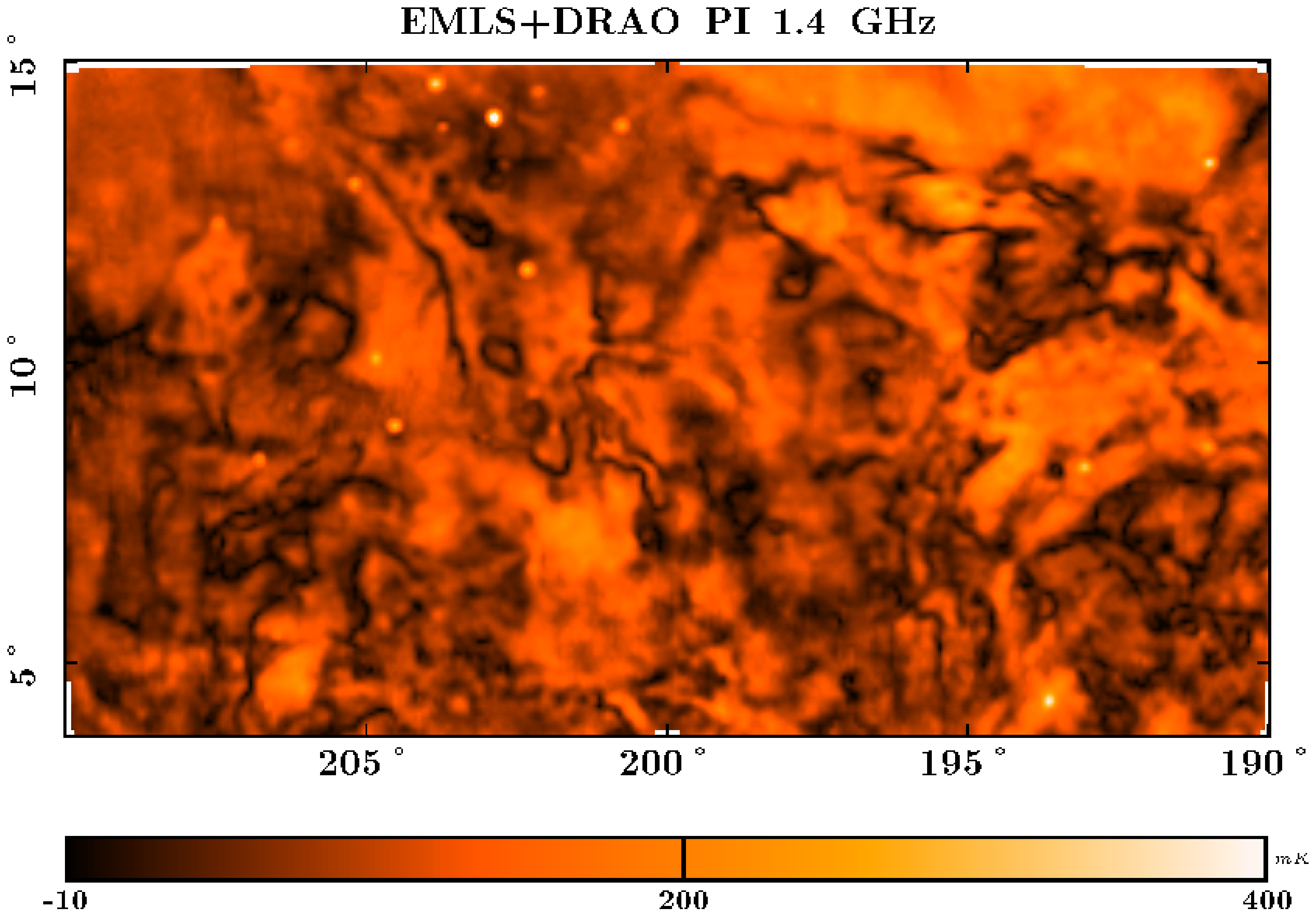
Percentage Polarization may exceed 100% !!

Vector addition !!

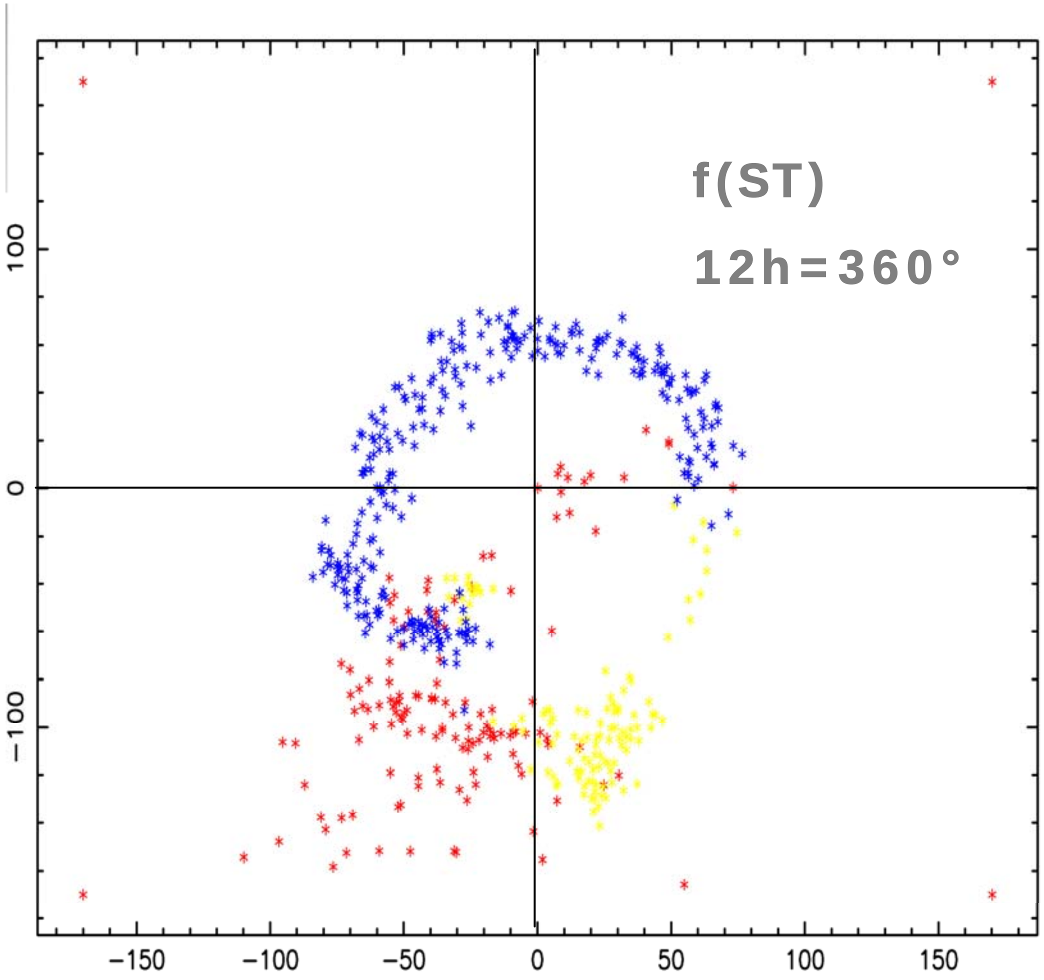
$PI_{abs}^2 = (U+U_{off})^2 + (Q+Q_{off})^2 \Rightarrow PI_{abs} \neq PI + P_{off}$

$\varphi_{abs} = 0.5 \text{ atan } ((U+U_{off})/ (Q+Q_{off})) \Rightarrow \varphi_{abs} \neq \varphi + \varphi_{off}$

Absolute zero-level adjustment for polarized intensities



DRAO 26m NCP Calibration



UQ-Diagram
NCP

M. Wolleben (PhD 2005)

blue: night-time

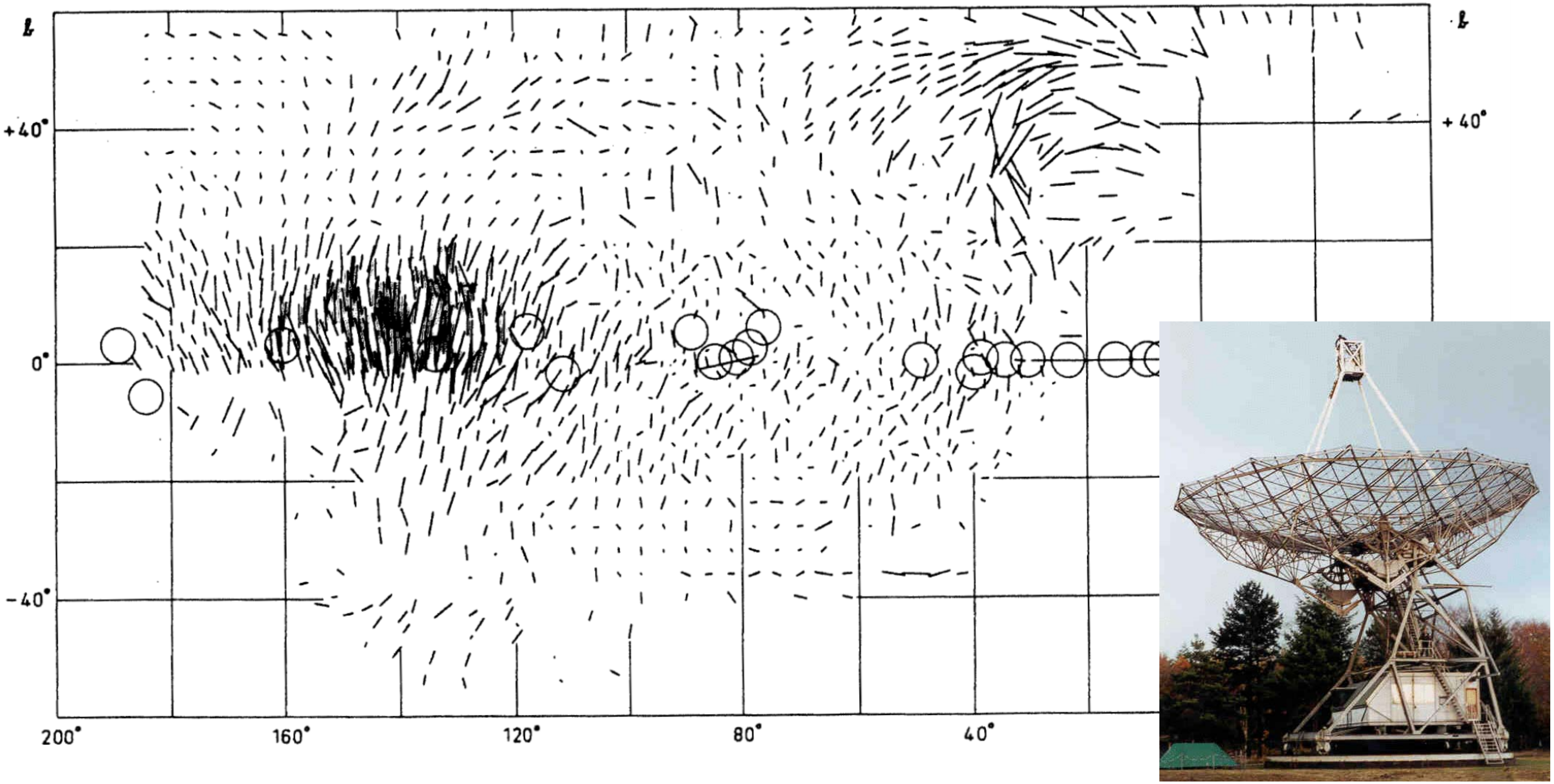
yellow: sun-rise

red: daytime

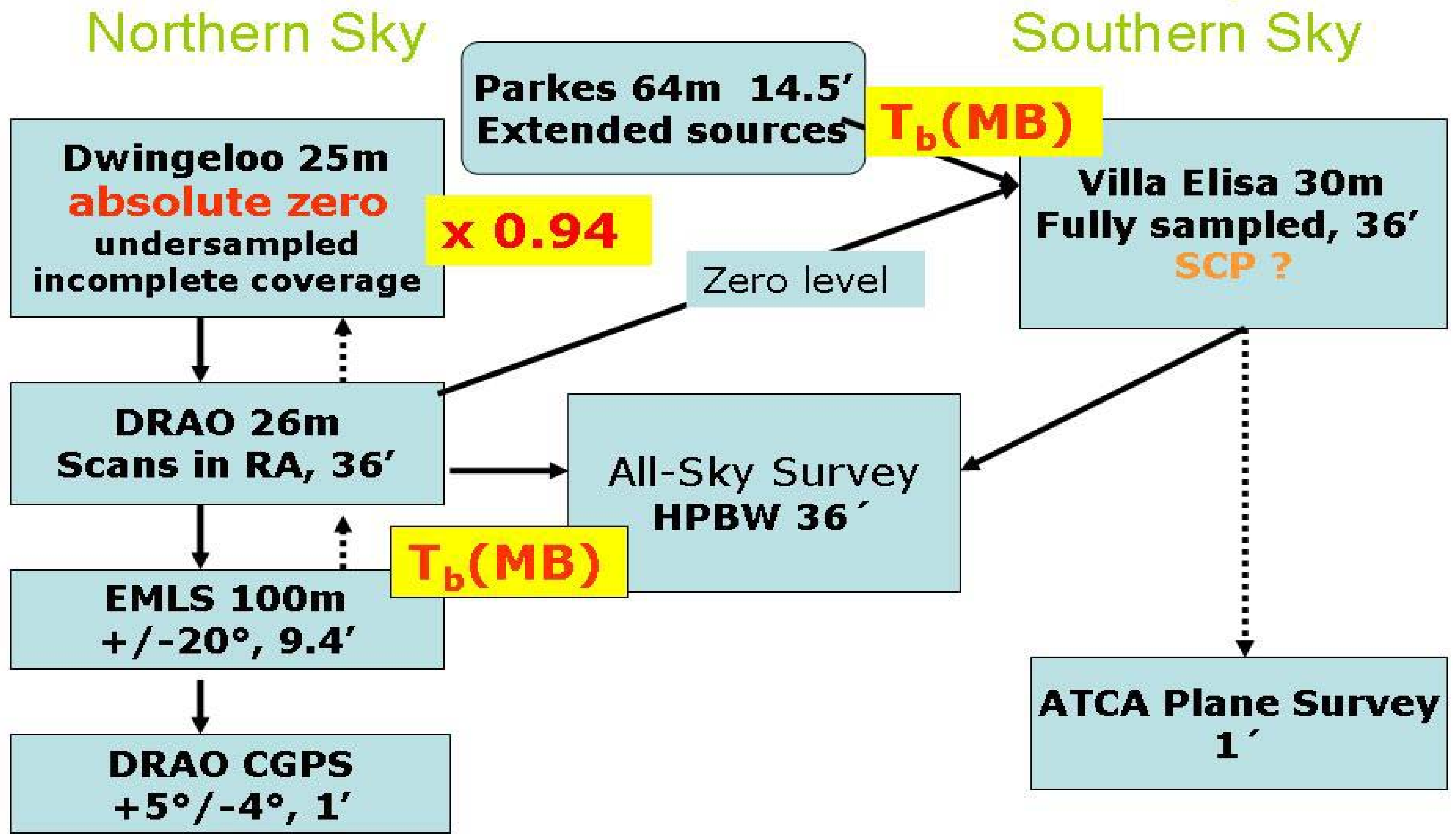
1.4 GHz Dwingeloo polarization survey

Brouw & Spoelstra, 1976, AAS, 26, 129

absolute zero-level – rotating dipoles in focus



Calibration steps of the 1.4 GHz polarization all-sky survey



Why are Surveys needed ?

- **<u>All-Sky surveys</u>**

- Thermal - non-thermal emission, spectral index distribution, Galactic 3D model, CMB foreground

- **<u>Galactic plane surveys</u>**

- Resolve sources and diffuse emission, finding SNRs and HII-regions

<u>Survey access sites</u>:

http:/www.mpifr-bonn.mpg.de/survey.html

http://skyview.gsfc.nasa.gov

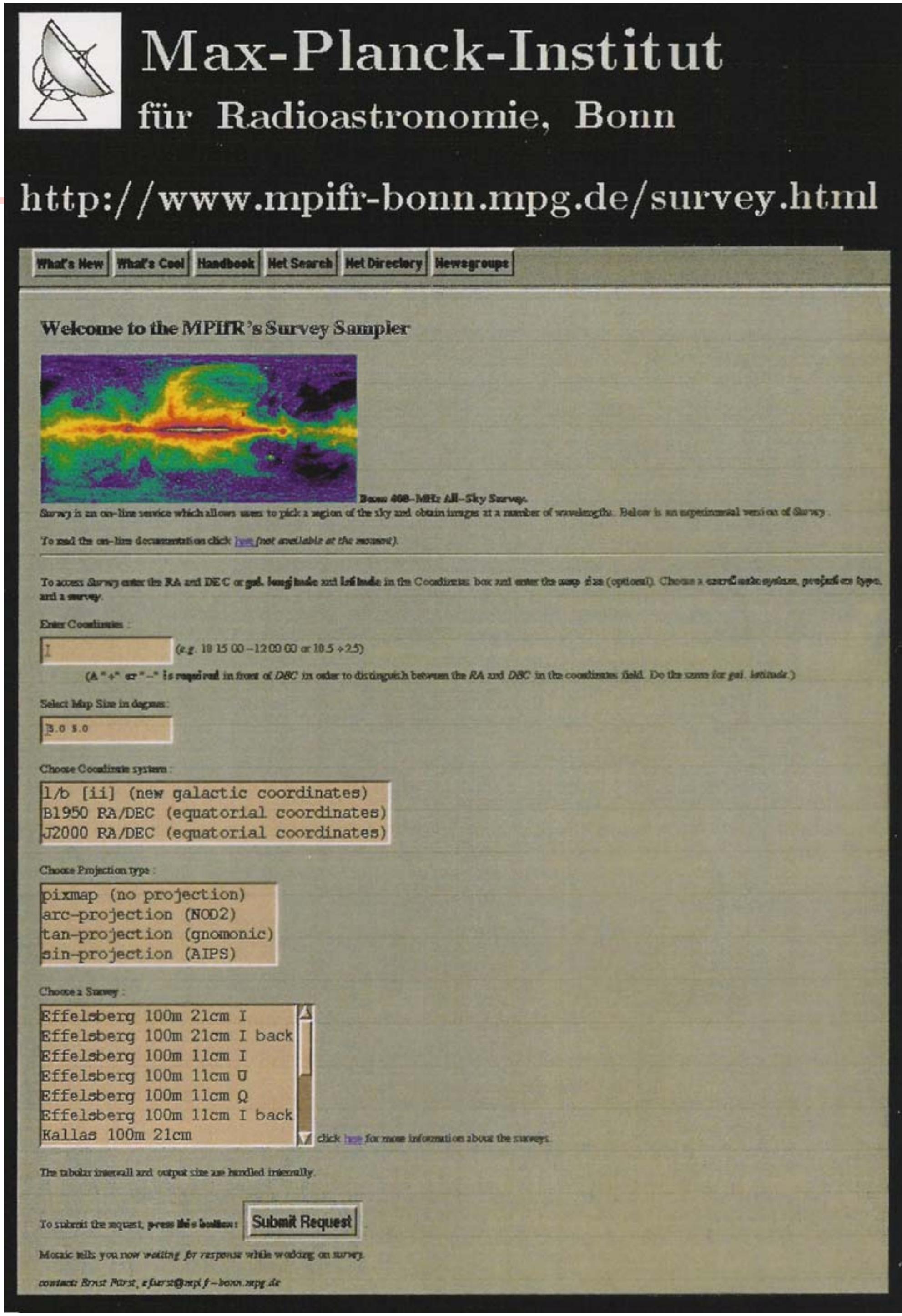
(http://cdsweb.u-strafbg.fr)

Using sky surveys for your purpose

a) Download data from MPIfR survey sampler:
- Specify your field: sampling and coordinate system
- Select the survey or several surveys (READ the documentation)
- coordinate transformations are provided (also for polarization)
- Maps are provided in Fits format (also GIF, NOD2)

b) More processing needed ?
- smoothing, high-/low-pass filter, relative zero-level, etc.

c) Analyse the maps or overlay with your data



Max-Planck-Institut
für Radioastronomie, Bonn

http://www.mpifr-bonn.mpg.de/survey.html

What's New | What's Cool | Handbook | Net Search | Net Directory | Newsgroups

Welcome to the MPIfR's Survey Sampler

Bonn 408-MHz All-Sky Survey.

Survey is an on-line service which allows users to pick a region of the sky and obtain images at a number of wavelengths. Below is an experimental version of *Survey*.

To read the on-line documentation click here *(not available at the moment)*.

To access *Survey* enter the RA and DEC or **gal. longitude** and **latitude** in the Coordinates box and enter the **map size** (optional). Choose a **coordinate system**, **projection type**, and a **survey**.

Enter Coordinates :

(*e.g.* 18 15 00 −12 00 00 or 18.5 +2.5)

(A "+" or "−" **is required** in front of *DEC* in order to distinguish between the *RA* and *DEC* in the coordinates field. Do the same for *gal. latitude*.)

Select Map Size in degrees:

3.0 3.0

Choose Coordinate system :

l/b [ii] (new galactic coordinates)
B1950 RA/DEC (equatorial coordinates)
J2000 RA/DEC (equatorial coordinates)

Choose Projection type :

pixmap (no projection)
arc-projection (NOD2)
tan-projection (gnomonic)
sin-projection (AIPS)

Choose a Survey :

Effelsberg 100m 21cm I
Effelsberg 100m 21cm I back
Effelsberg 100m 11cm I
Effelsberg 100m 11cm U
Effelsberg 100m 11cm Q
Effelsberg 100m 11cm I back
Kallas 100m 21cm

click here for more information about the surveys.

The tabular intervall and output size are handled internally.

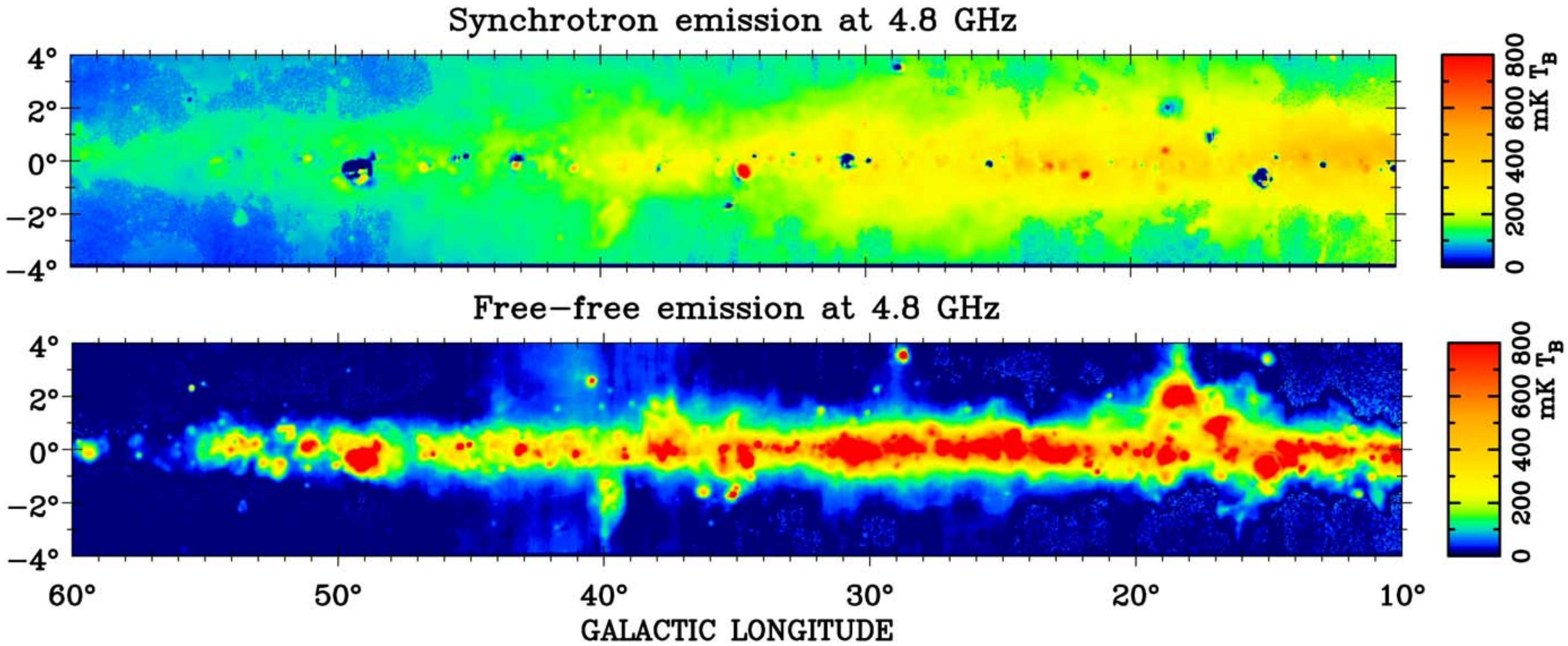
To submit the request, **press this button**: Submit Request

Mosaic tells you now *waiting for response* while working on survey.

contact: Ernst Fürst, efuerst@mpifr-bonn.mpg.de

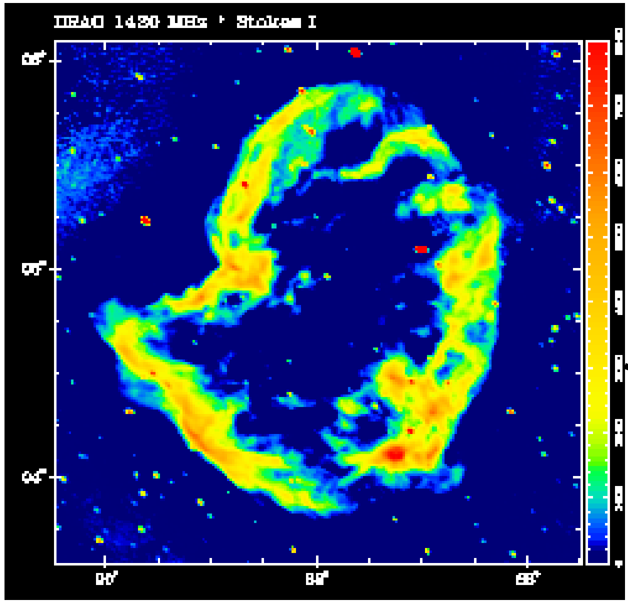
Maintained by
Patricia Reich

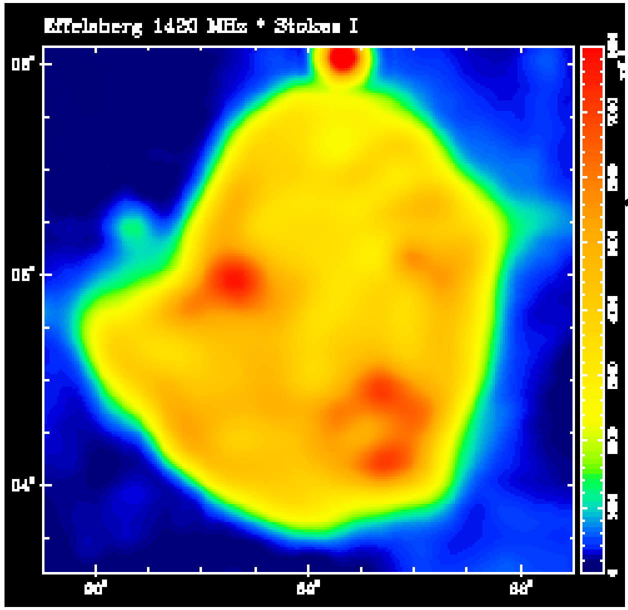
Thermal/non-thermal separation using several surveys



Based on Effelsberg 1.4 GHz, 2.7 GHz and Urumqi 4.8 GHz Galactic plane surveys (Sun et al., 2010, AA submitted)

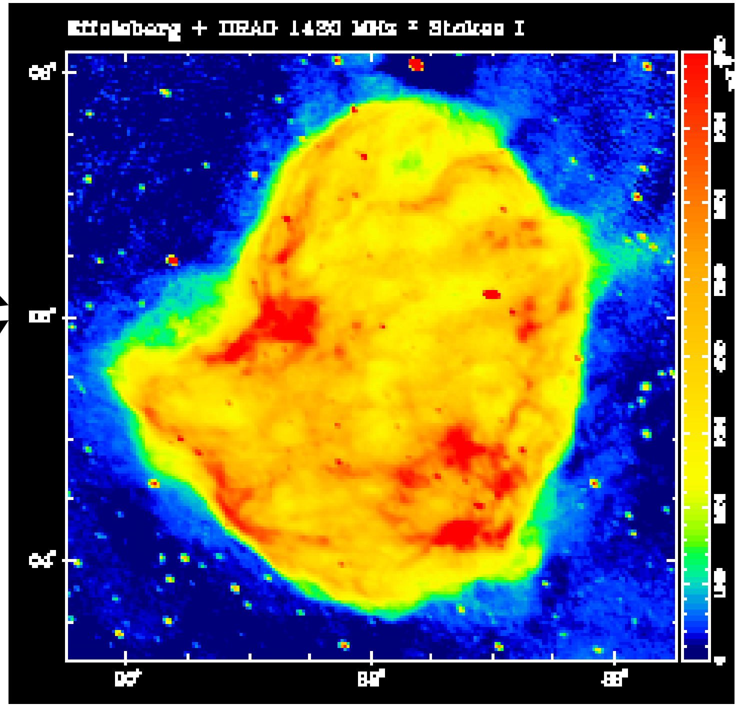
Zero-spacings from single-dish surveys





Interferometer observation of SNR HB21 (1‘)

single-dish survey (9.4‘)



Combined 1.4 GHz image of HB21

Thank you !