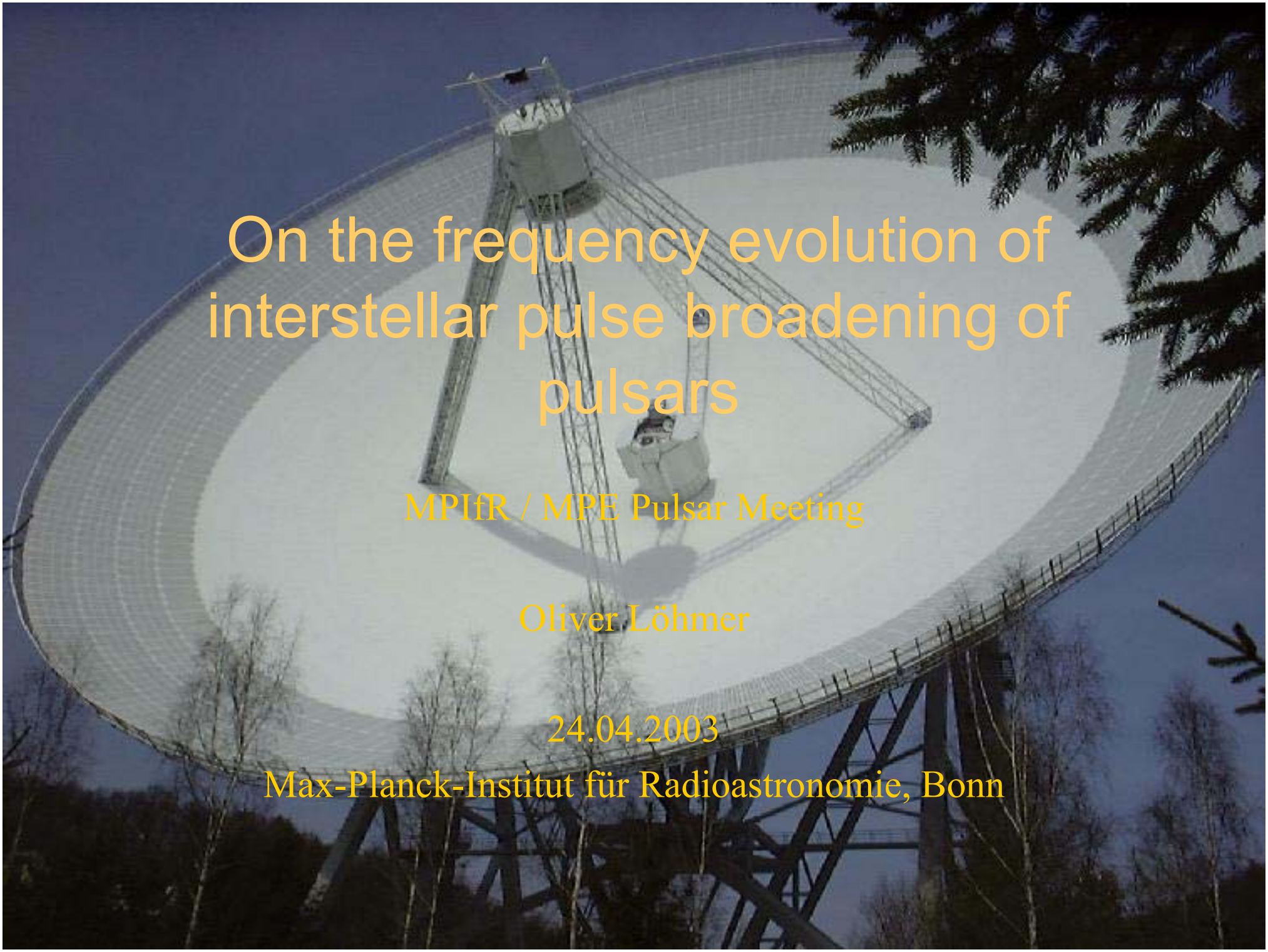


On the frequency evolution of interstellar pulse broadening of pulsars

MPIfR / MPE Pulsar Meeting

Oliver Löhmer

24.04.2003

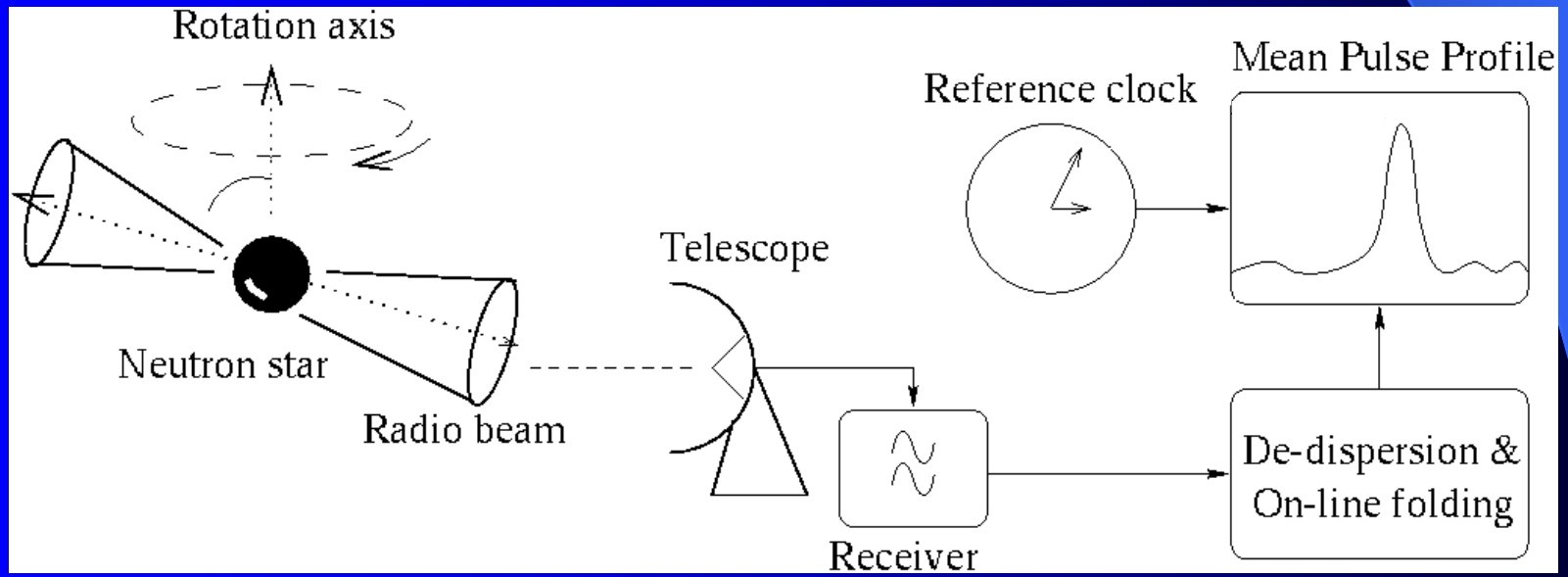
Max-Planck-Institut für Radioastronomie, Bonn

Pulsars as probes of the ISM

- Dispersion
  - electron column density along the line of sight
  - independent distance estimate: mean electron density, model of electron density distribution in the Galaxy
- Faraday Rotation
  - high linear polarization of pulsar radiation
  - combination of RM and DM: $B_{\parallel}$
- Interstellar scattering and scintillation
  - dynamical processes in the ISM (turbulence etc.)
  - spectrum of electron density fluctuations
  - scintillation speeds of pulsars

Observations and Data analysis

- Effelsberg: 0.86, 1.41, 2.7 and 4.85 GHz
- Jodrell Bank 0.4, 0.61, 0.93, 1.41 and 1.64 GHz

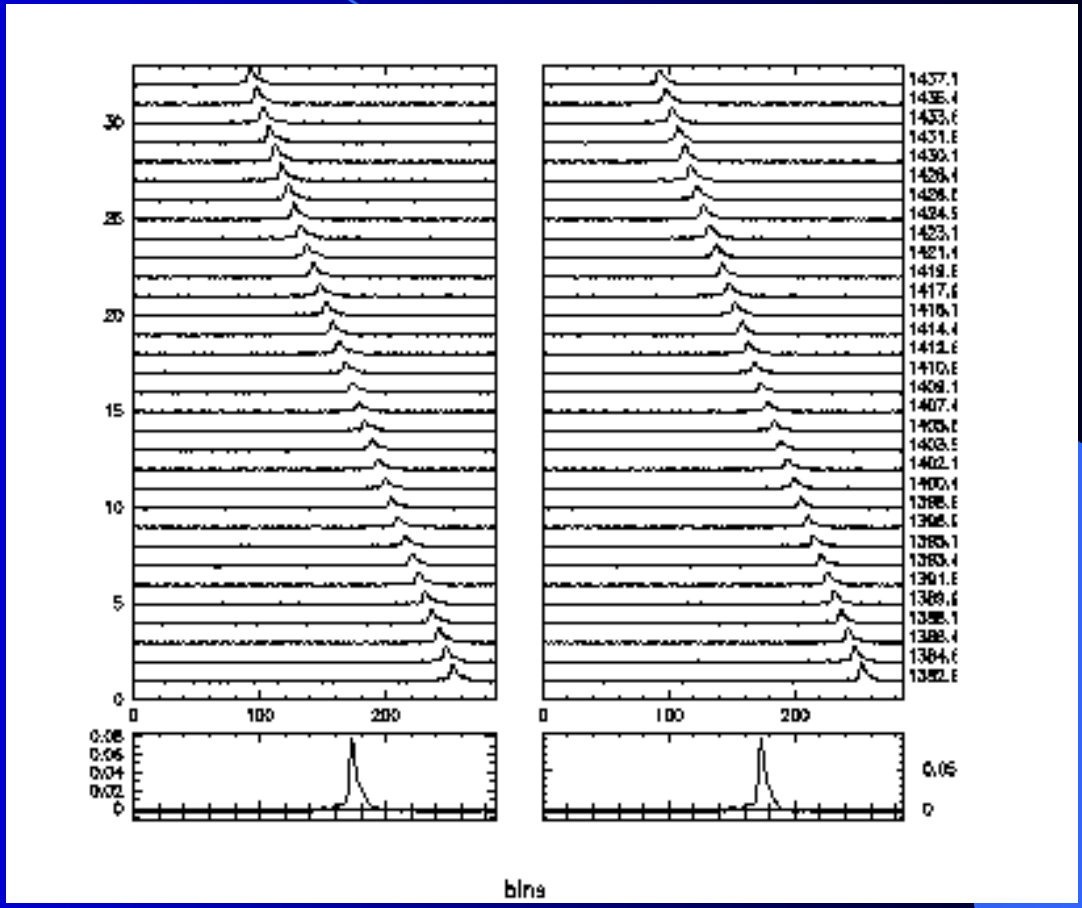


Interstellar dispersion

- frequency-dependent delay of pulse arrival times

$$\Delta t_{\mathrm{DM}} \approx 4.1494 \cdot \mathrm{DM} \cdot \left(\frac{1}{\nu_1^{\,2}} - \frac{1}{\nu_2^{\,2}} \right) \mathrm{ms}$$

$$\mathrm{DM} = \int_0^d n_e(s)\,ds$$



Interstellar Scattering

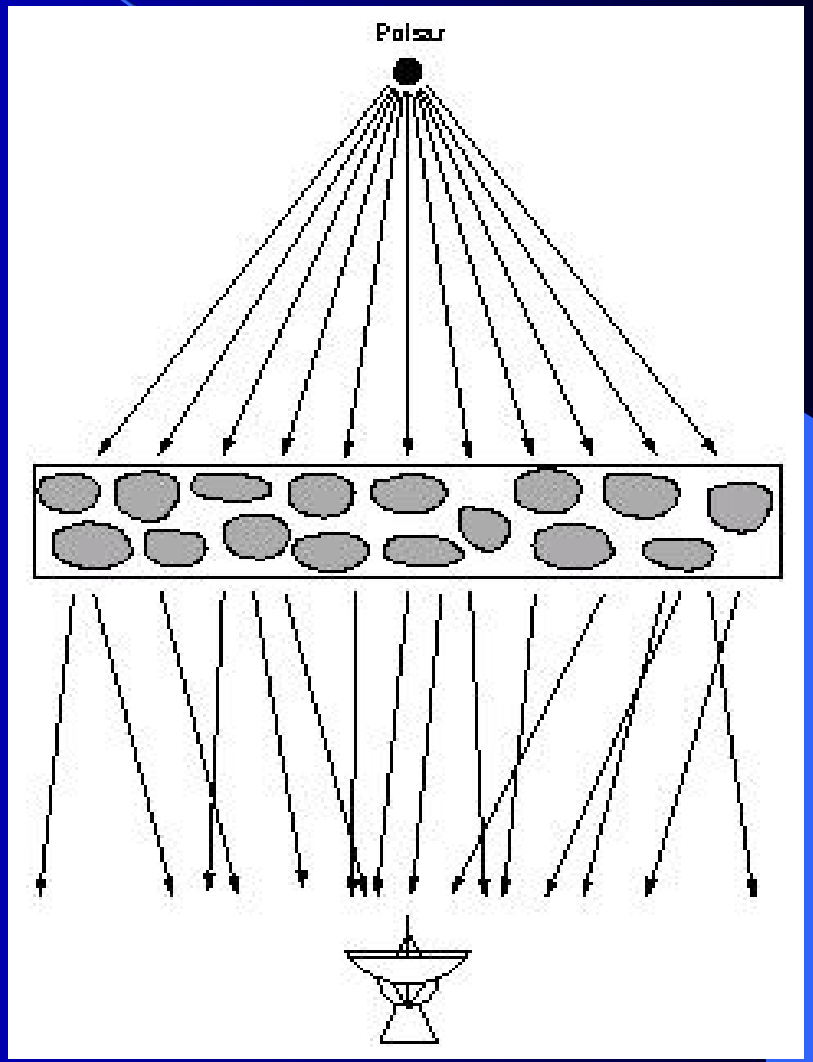
- Fluctuations in the Galactic electron density distribution
- multi-path propagation of radio waves due to diffraction at the irregularities
- Fluctuation spectrum:

$$P_{n_e}(q) = C_{n_e}^2 \, q^{-\beta}$$

- Turbulent medium:

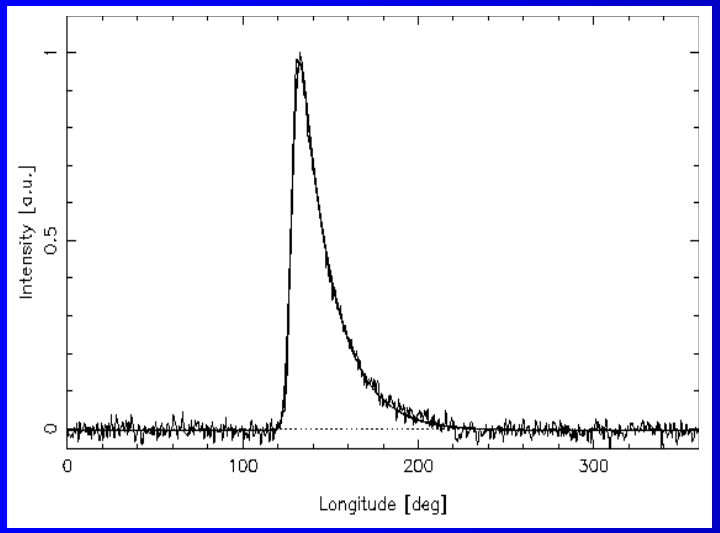
$$\beta_K = \frac{11}{3}$$ Kolmogorov index

Thin screen model



Scattering and Scintillation of pulsars

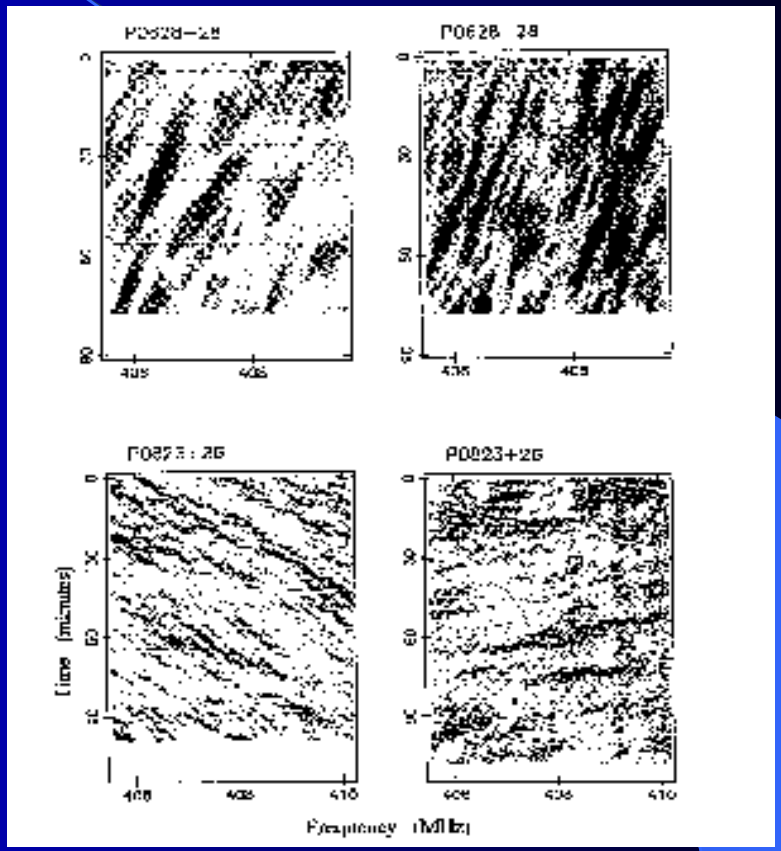
Pulse broadening



scatter broadening time τ_{sc}

$$2\pi\tau_{sc}\Delta\nu_d = C$$

Scintillation spectra



decorrelation bandwidth

$\Delta\nu_d$

How to measure the scatter broadening

- Observed profile:

$$P^{obs}(t) = P^{intr}(t) * s(t) * d(t) * i(t)$$

$s(t)$	Scatter broadening function
$d(t)$	Dispersion smearing
$i(t)$	Instrumental response

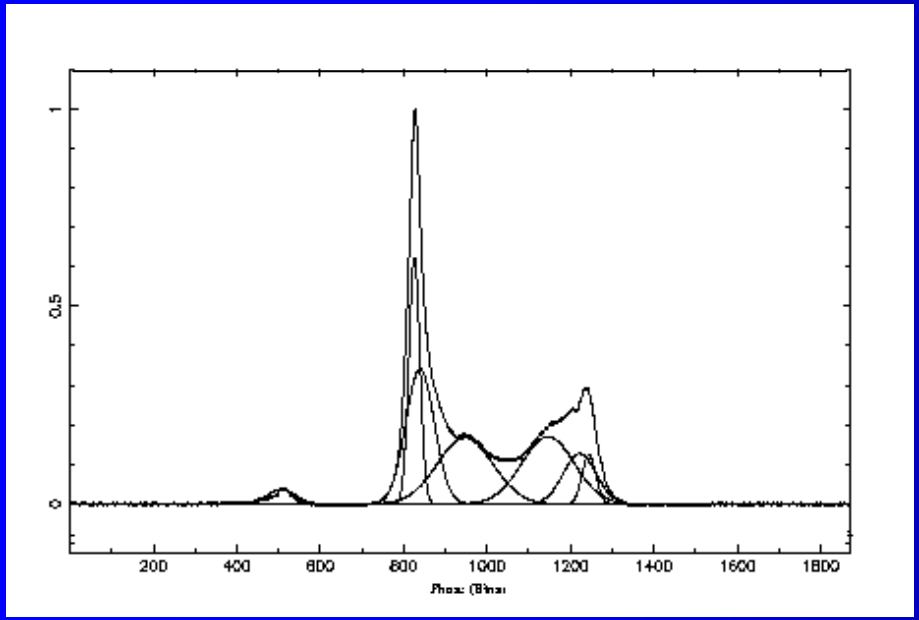
- Template-fitting method

  Model profile:

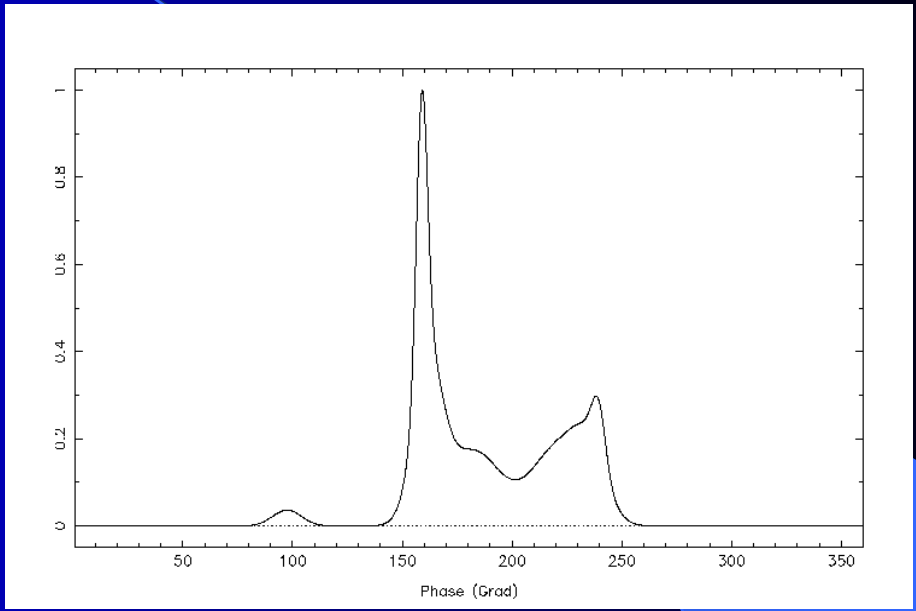
$$P^{M}(t) = P^{T}(t) * s(t) * d(t) * i(t)$$

How to create a model pulse profile

Pulse profile



Template



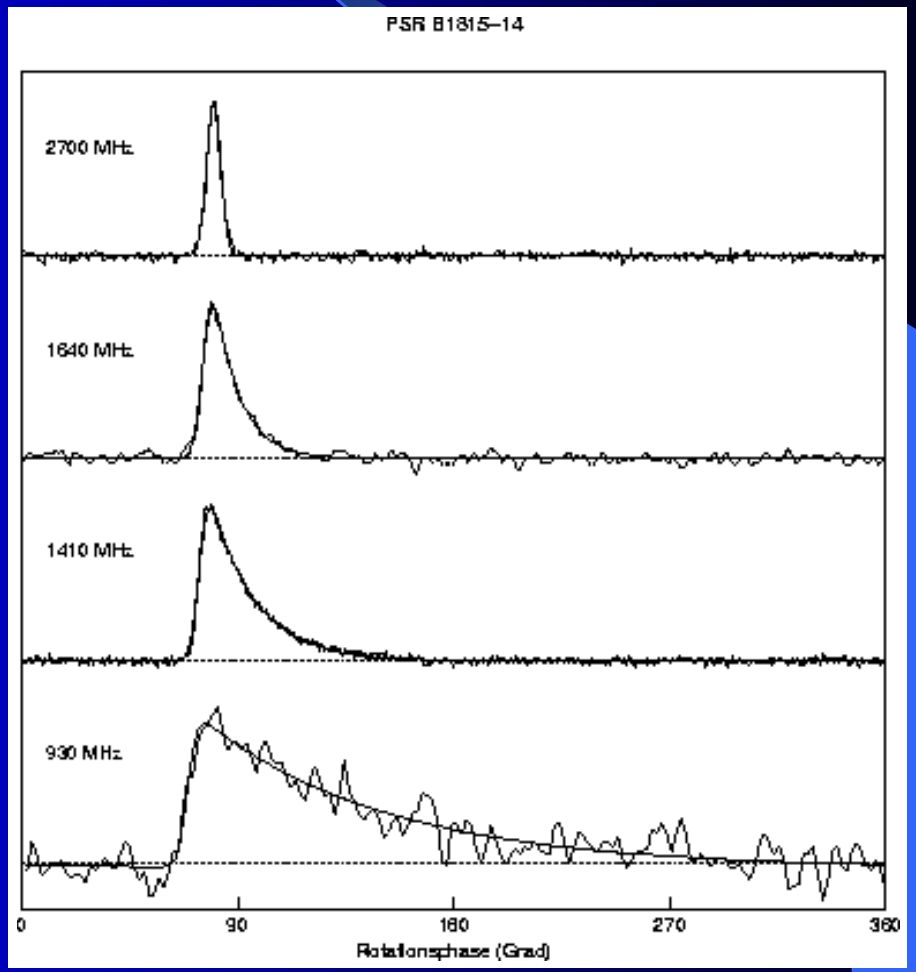
- decomposition of the profile in Gaussians (PSR J2145-0750)

Template Fitting including scatter broadening

- Scatter broadening function for a thin screen:

$$s(t) = \exp(-\frac{t}{\tau_{sc}})$$

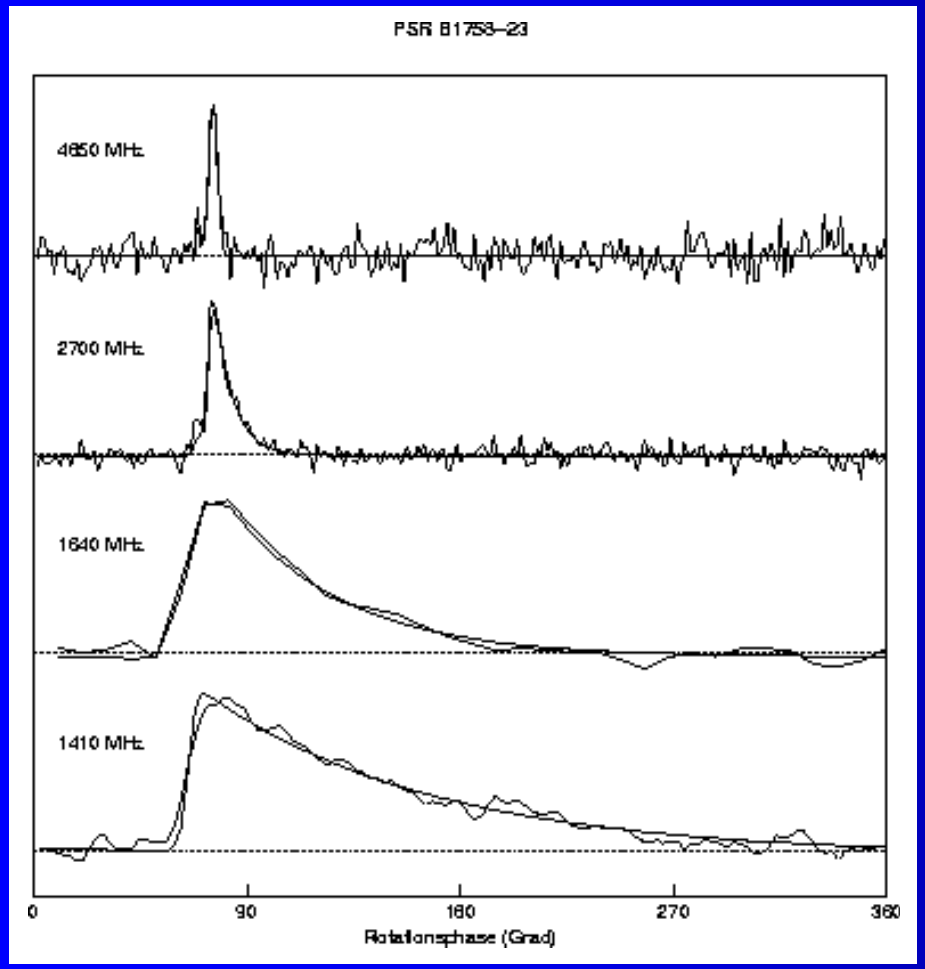
- 4-parameter fit:
  - baseline
  - amplitude
  - offset
  - scatter broadening time τ_{sc}

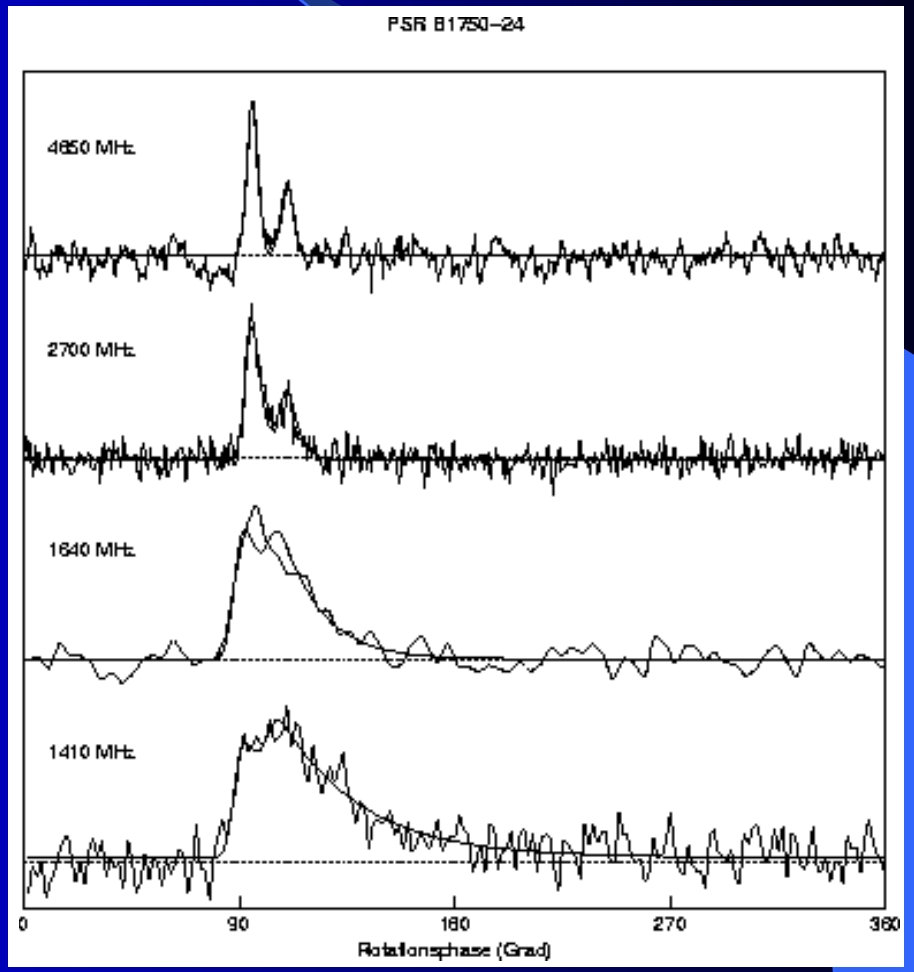


Scattering of highly dispersed pulsars

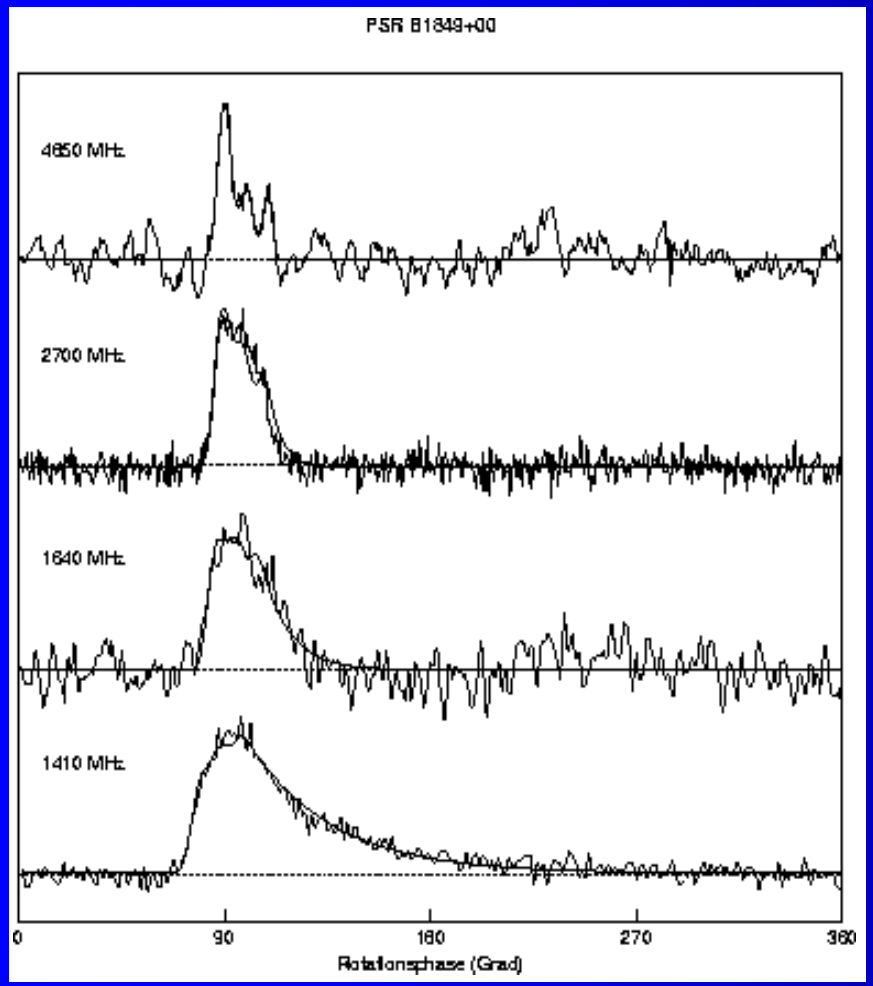
- Pulsars with DM = 428 – 1074 pc cm^{-3}
- Central region of the Galaxy $-0.4^o < b < 0.9^o$

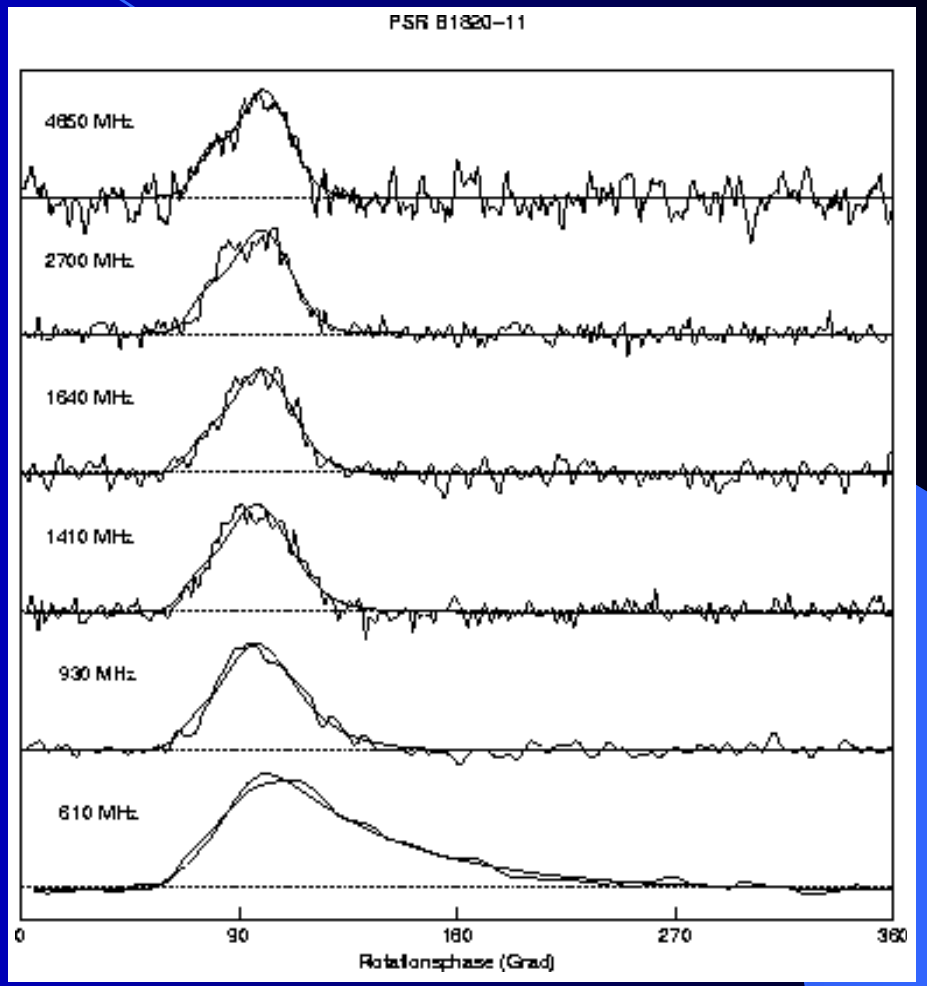
$4.3^o < l < 33.5^o$





Intrinsic profile evolution





Electron density fluctuations in the ISM

- fluctuation spectrum of the electron density

$$P_{n_e}(k) = C_{n_e}^2 \; k^{-\beta}$$

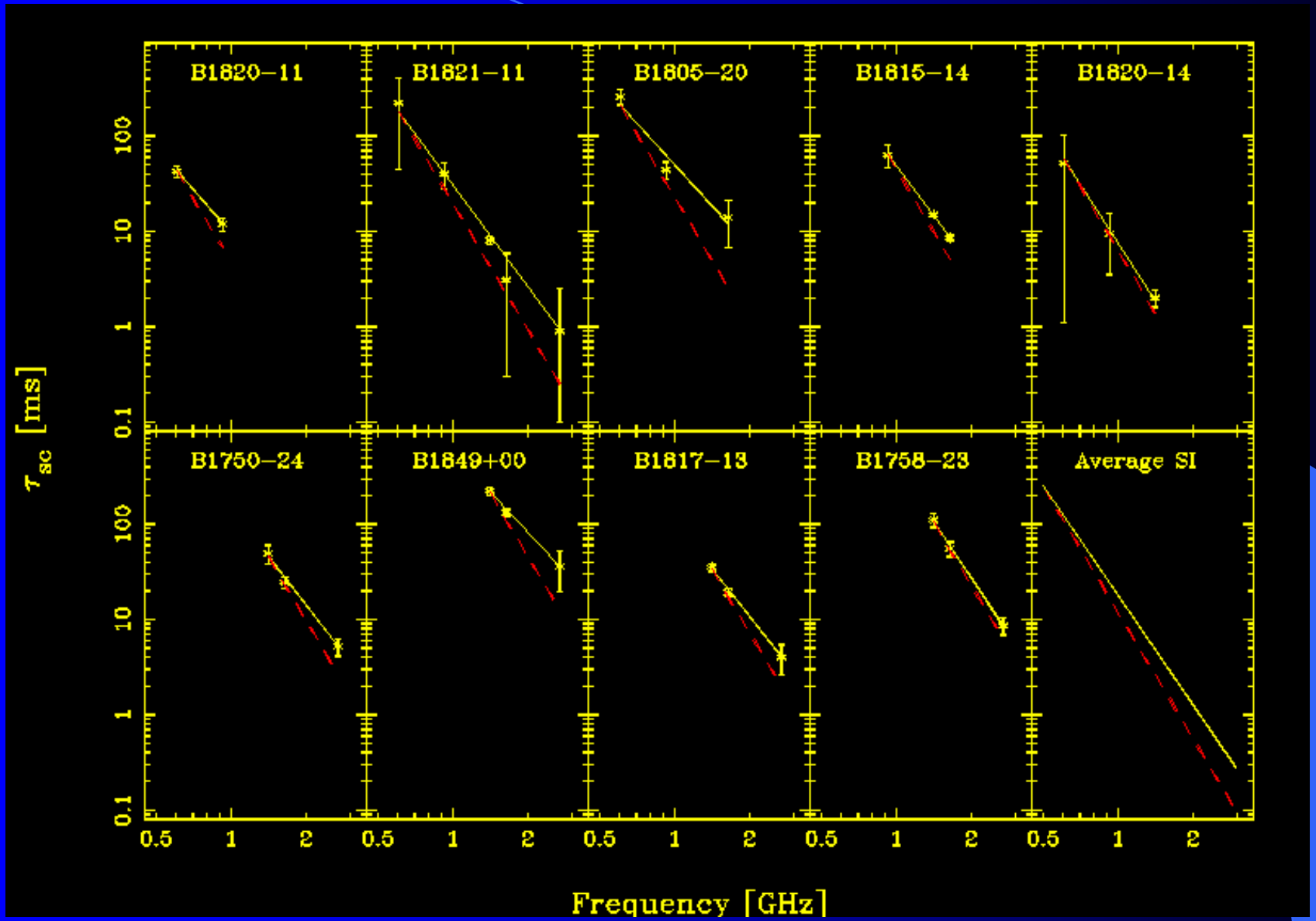
- Multifrequency observations:
  - spectral index of scatter broadening α

$$\tau_{sc} \propto \nu^{-\alpha} \qquad \alpha = \frac{2\beta}{\beta - 2}$$

- Kolmogorov spectrum:

$$\beta_K = \frac{11}{3} \qquad \alpha_K = 4.4$$

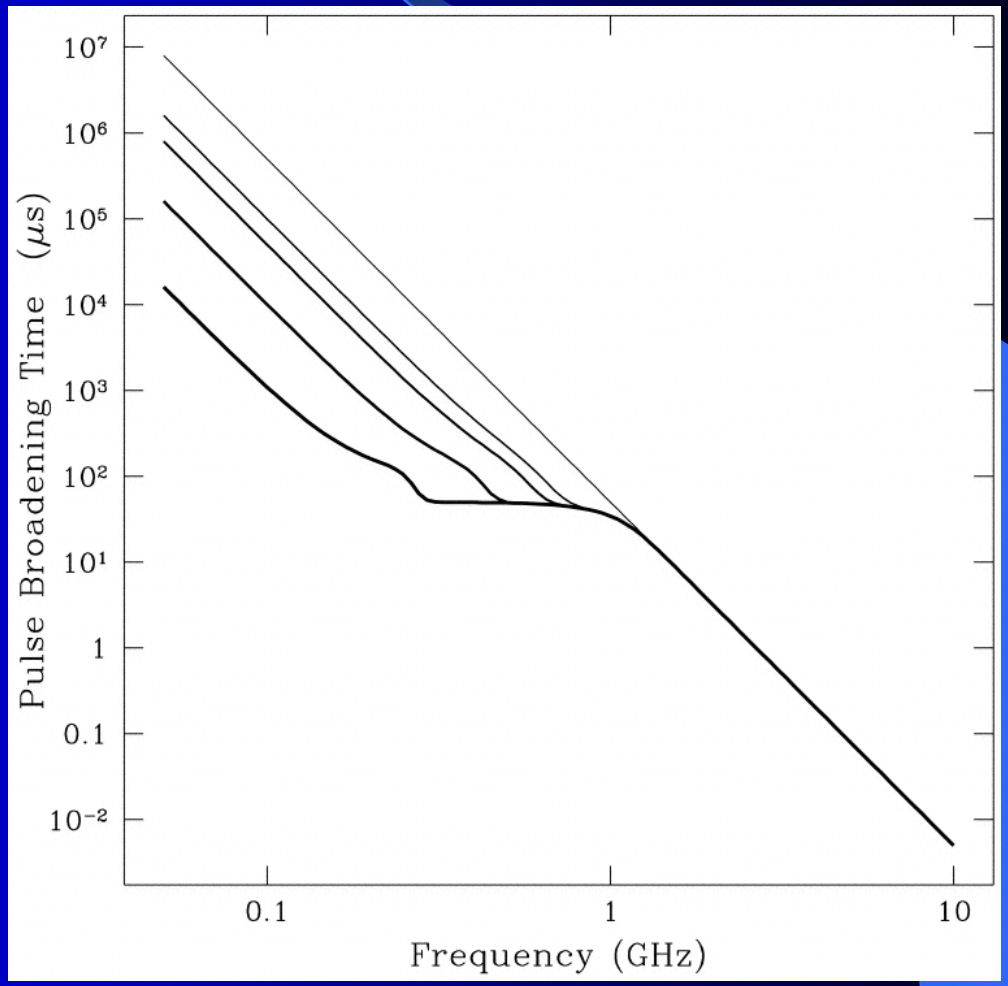
Highly dispersed pulsars: Results



$$\alpha = 3.44 \pm 0.13$$

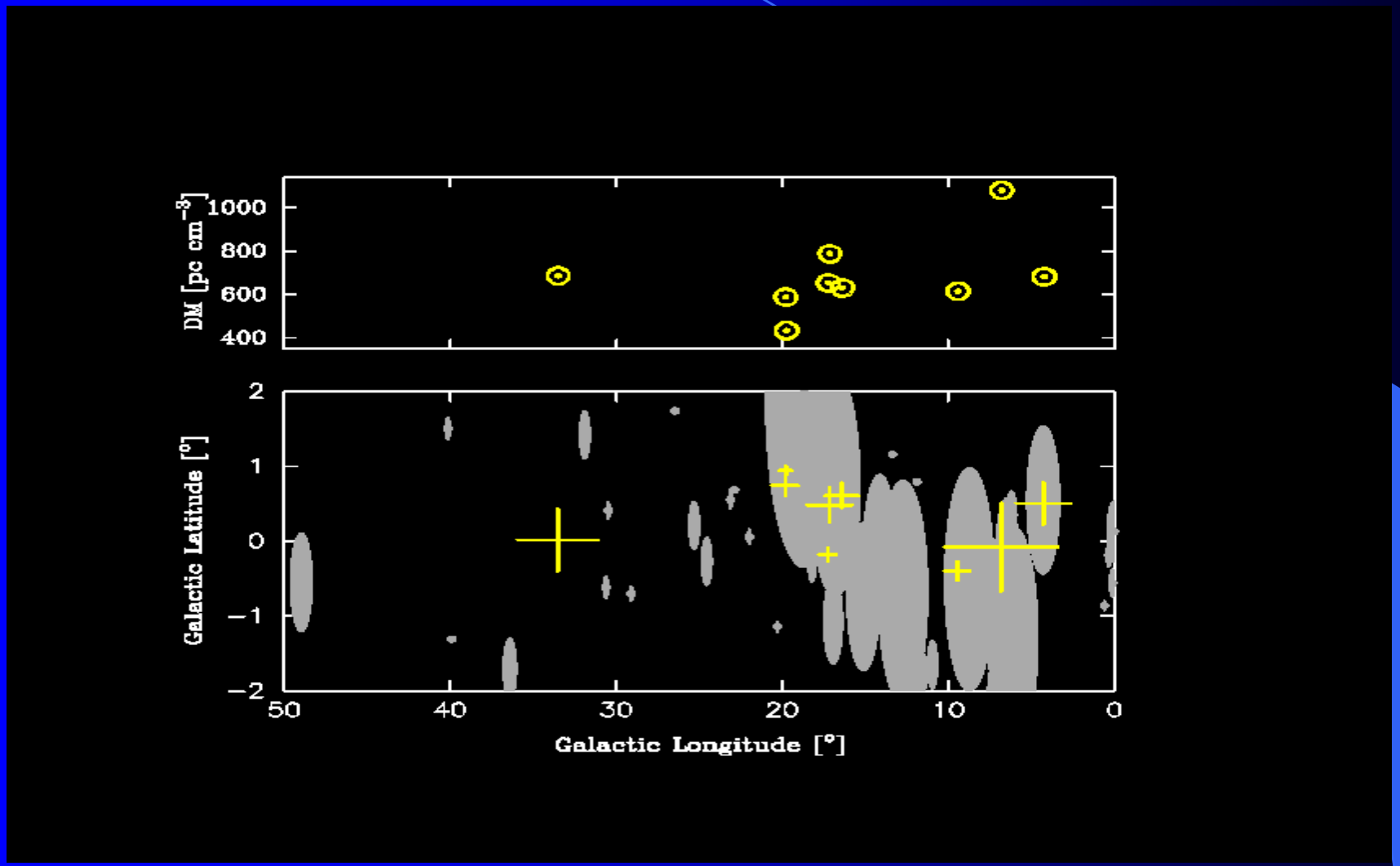
Anomalous scattering

- geometrical interpretation: scattering screen with finite transverse extension => flattening of the spectrum at lower frequencies
- scattering at multiple screens with different fluctuation scale lenghts => plateau



Cordes & Lazio (2001)

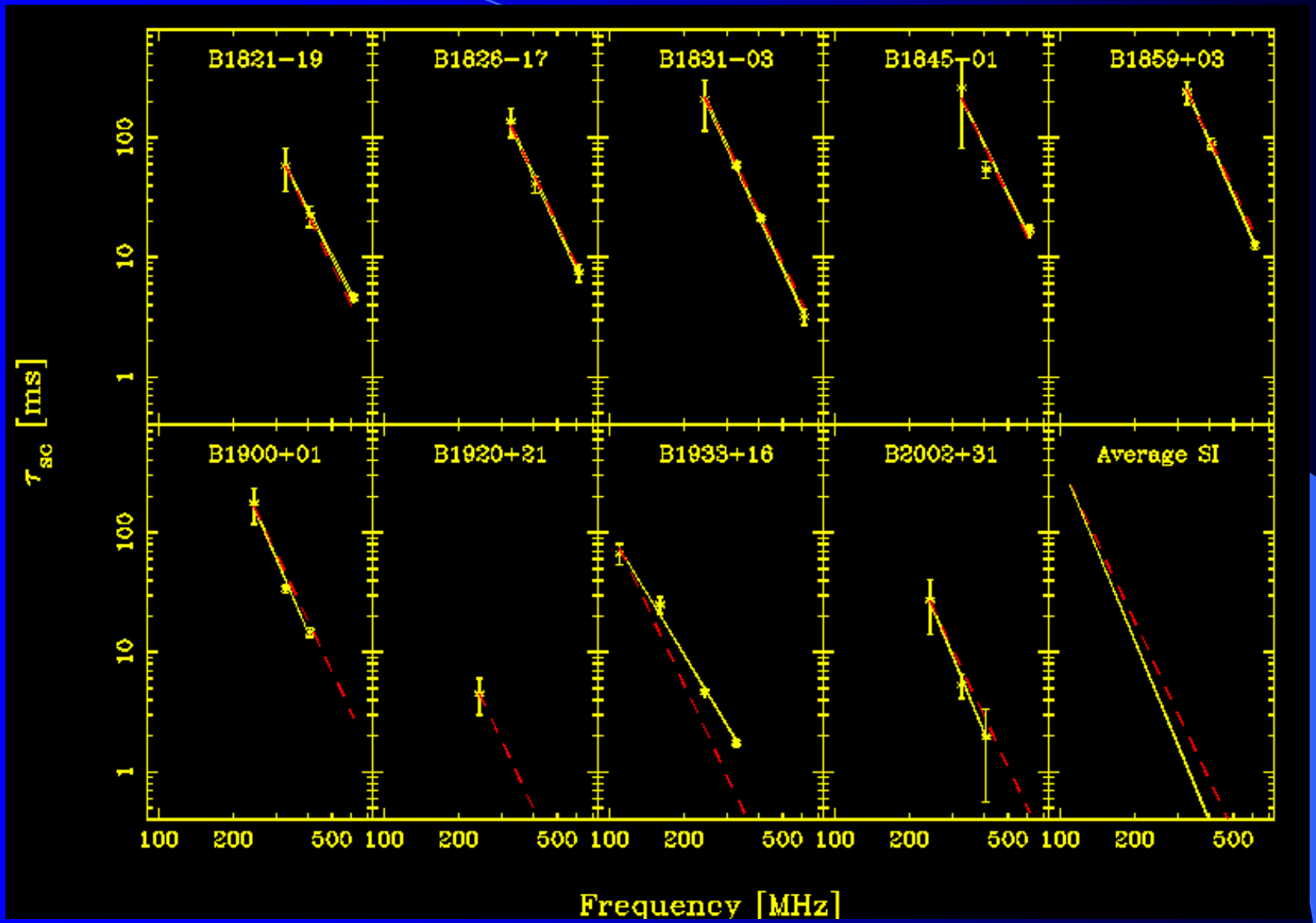
HII-Regions and interstellar scattering



GMRT observations

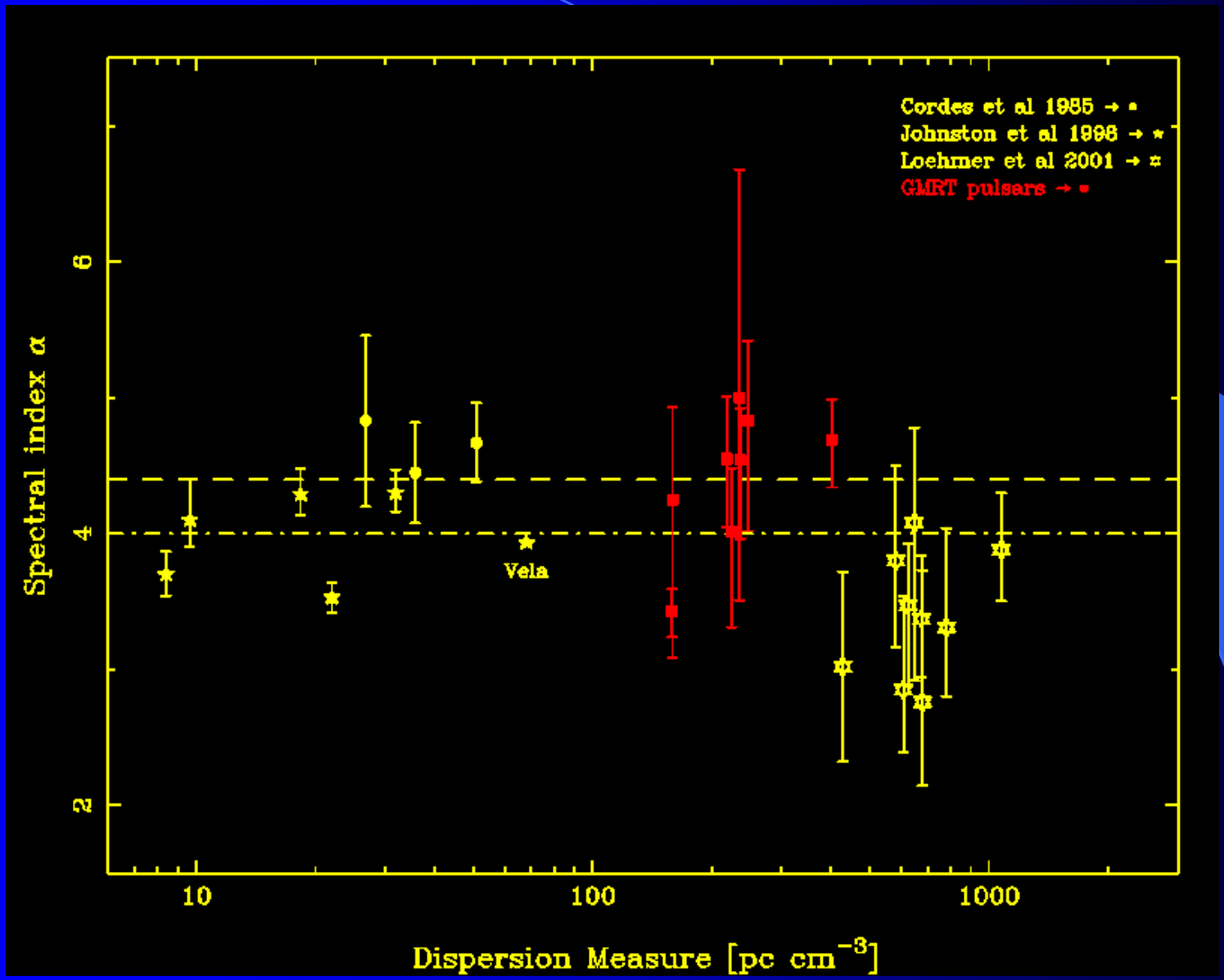
- GMRT: 243, 325 and 610 MHz
- Jodrell Bank 410, 610 and 1410 MHz

Intermediate DM pulsars: Results

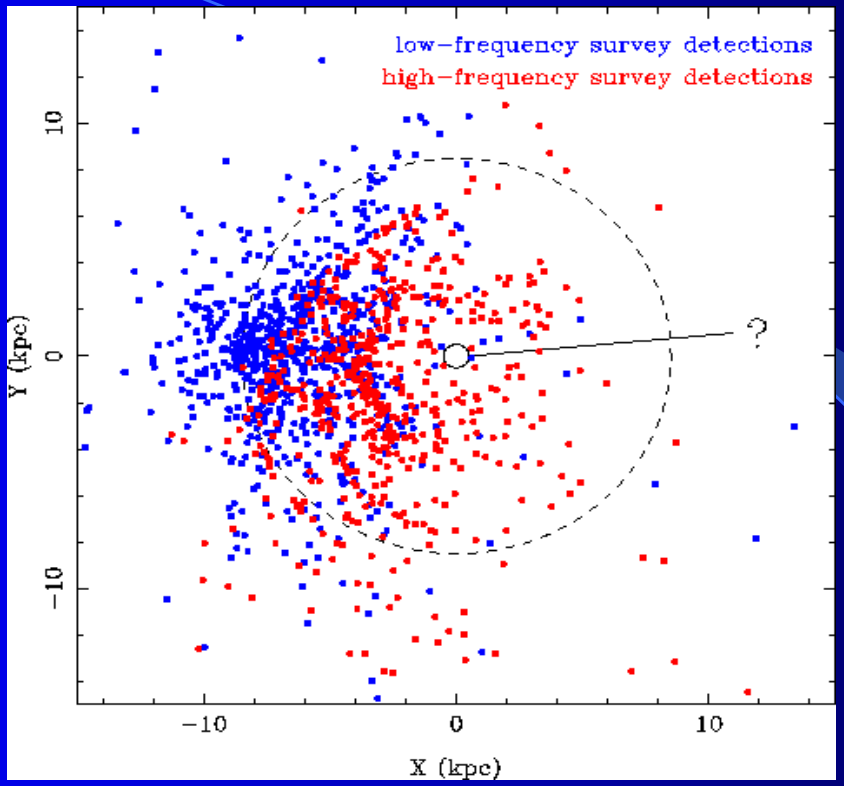


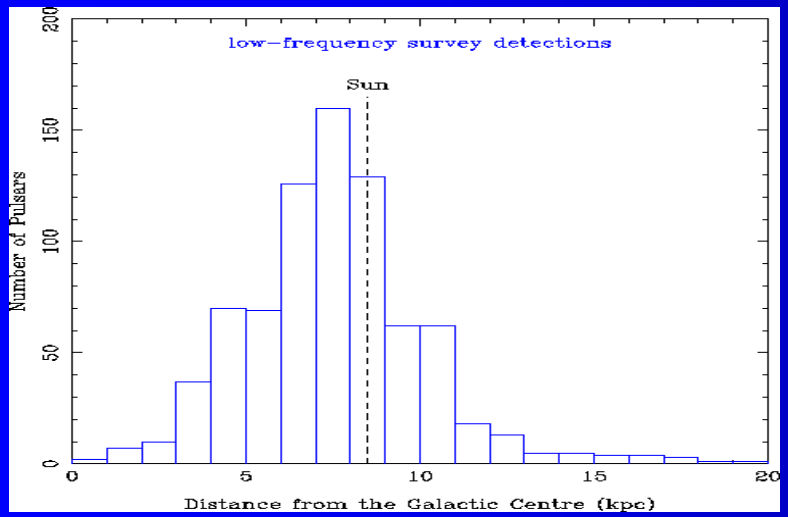
$$\alpha = 4.56 \pm 0.10$$

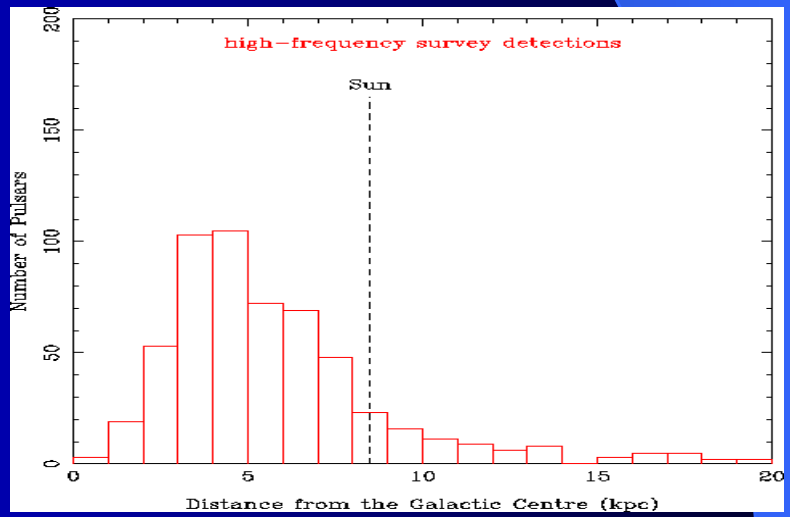
Spectral index of scatter broadening



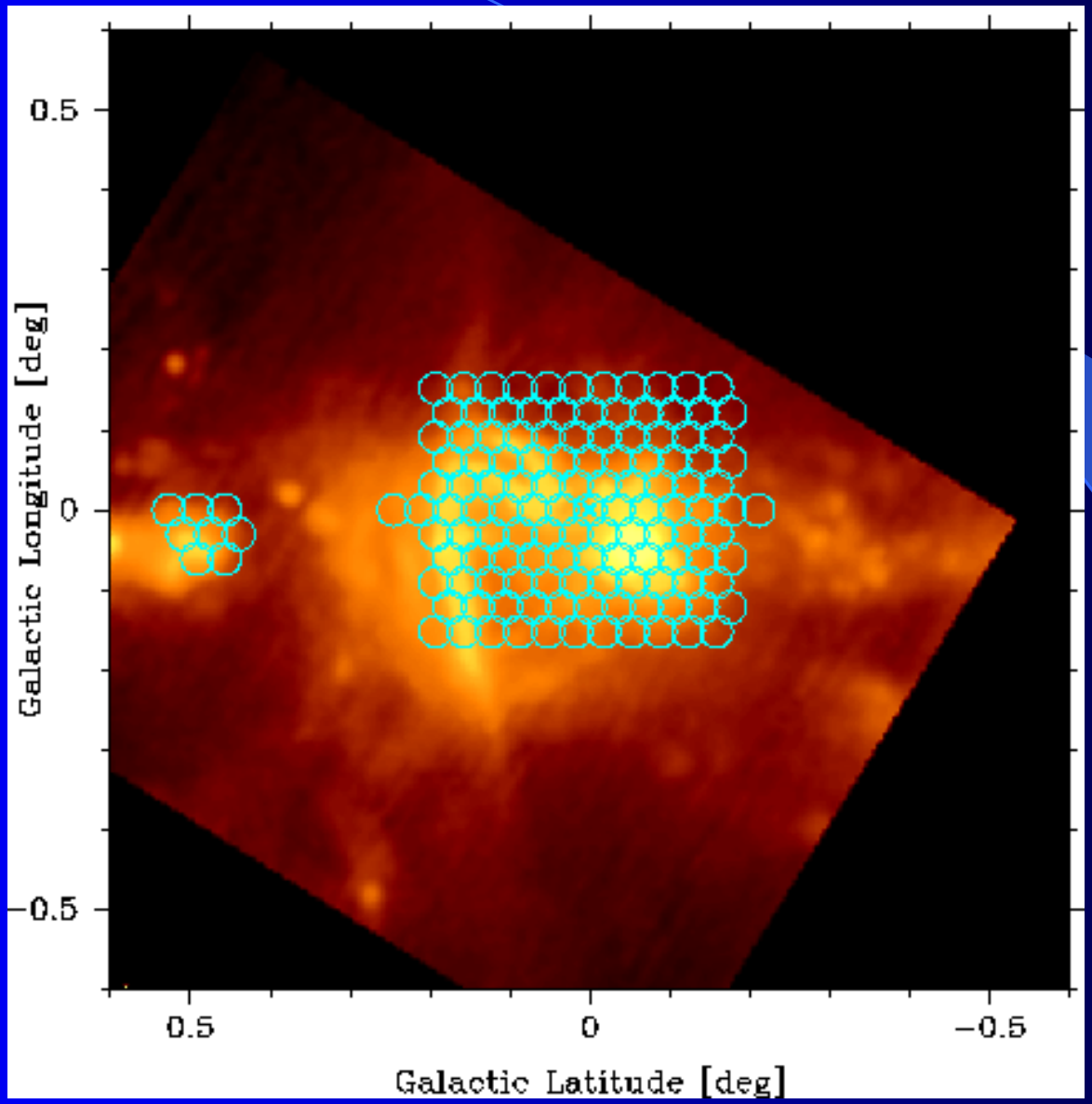
Pulsar search in the Galactic centre



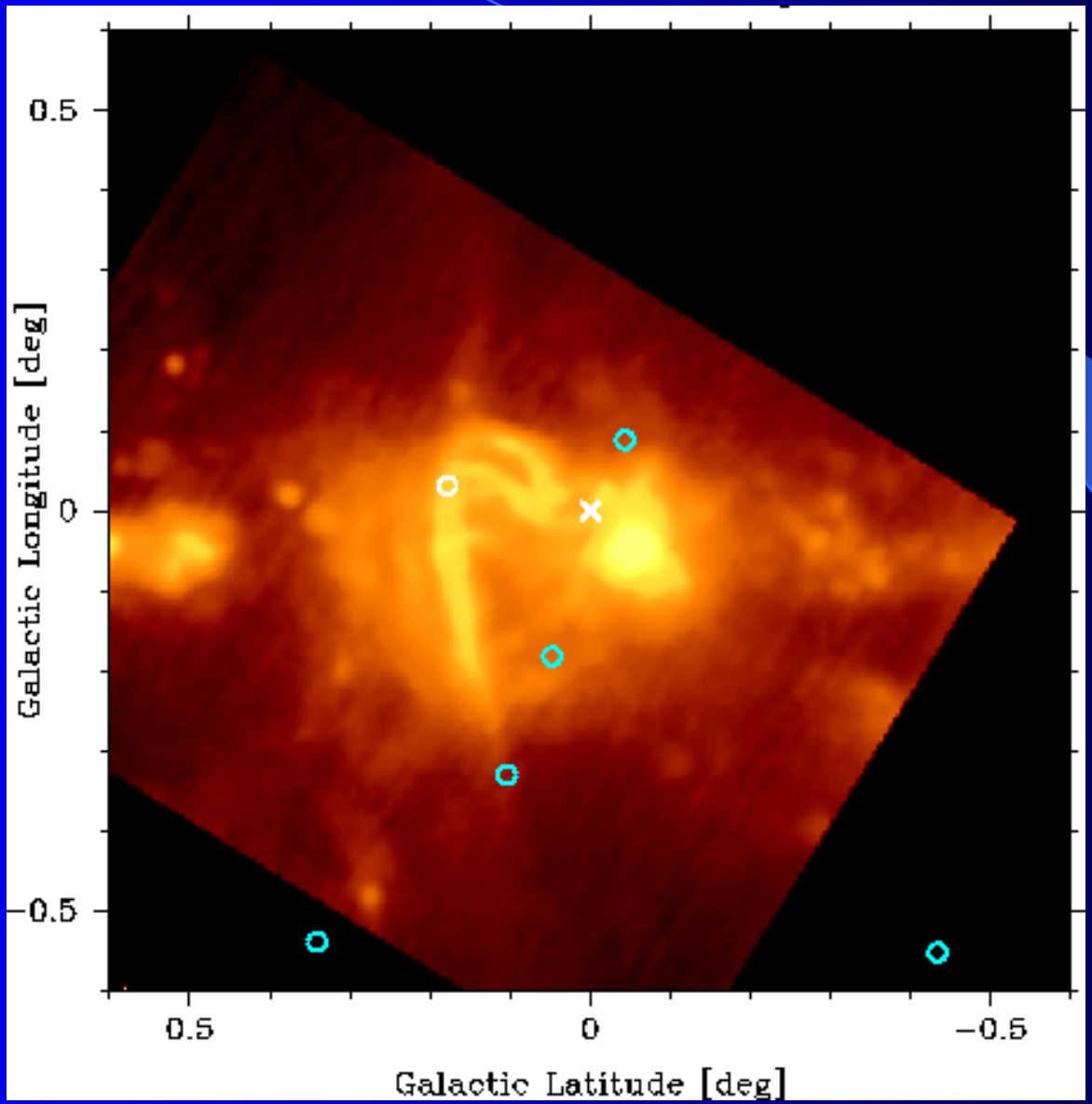




Galactic centre survey at 4.85 GHz



Target search at 8.35 GHz



Scattering Estimates in the GC