Scattering Study of Pulsars below 100 MHz

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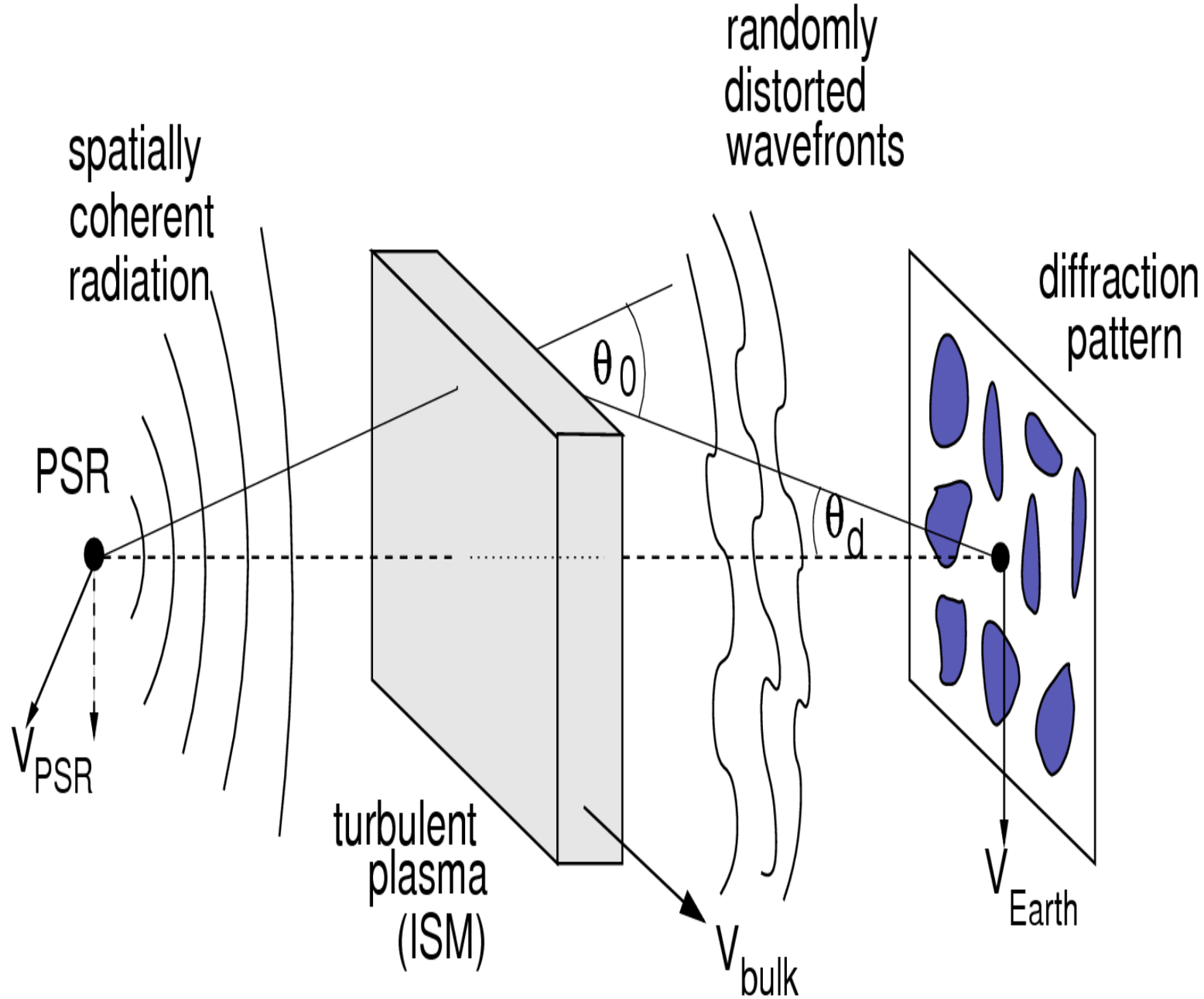
Interstellar medium

- Ionized plasma
- Magnetic field
- Inhomogeneous electron density

- Fluctuations in electron density
- Random irregularity of refractive index
- Multipath propagation of the pulsar signal

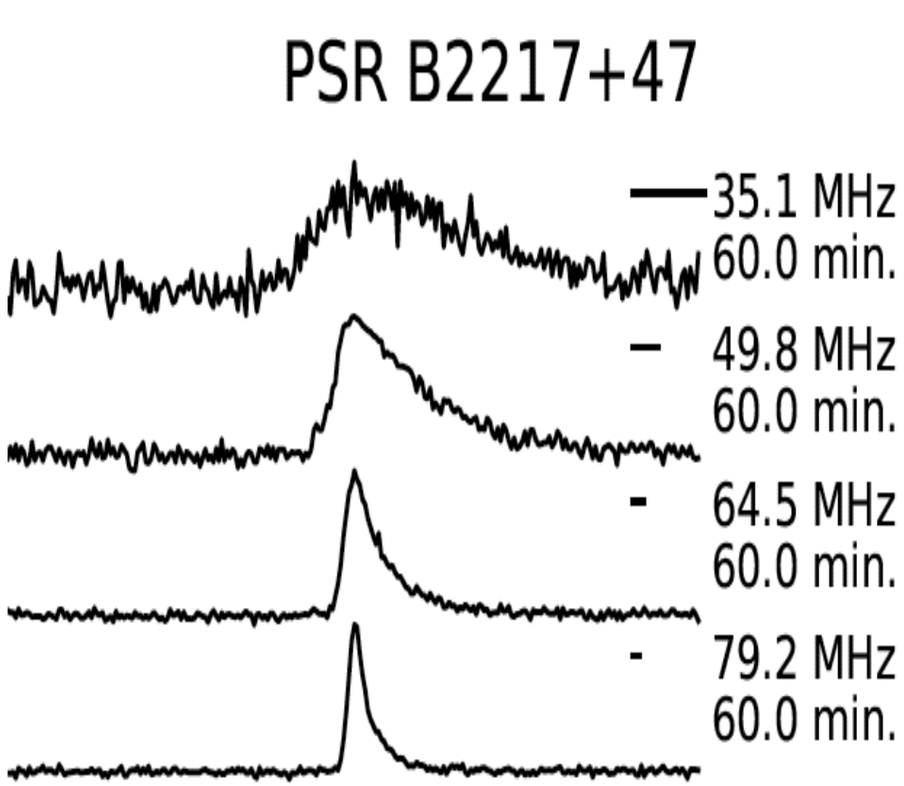


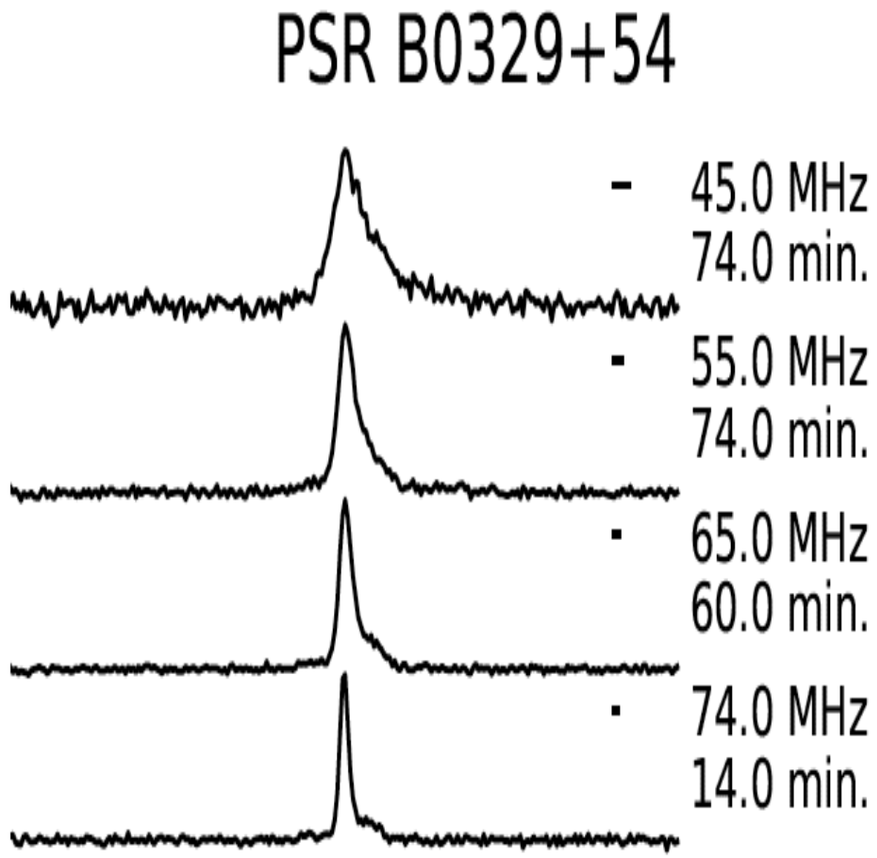
Credit: Cordes (2002)

Interstellar medium

- Ionized plasma
- Magnetic field
- Inhomogeneous electron density
- Effects: Dispersion, Angular Broadening, Temporal Broadening, & Scintillation

Scattering Observations





Stovall et al 2014

Motivation

- Understand the ISM
- Useful for Pulsar Timing Array

- Dispersion and scattering - strong at low frequencies
- Simultaneous multi-frequencies

Scattering model

Pulse Model

$$P(t) = P_i(t) * s(t) * D(t) * I(t)$$

Scattering function *Dispersion* *Instrumental*

Scattering Function

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

Theoretical Models

Gaussian Inhomogeneity:

$$\tau_{sc} \propto \nu^{-4} DM^2$$

Scattering Index

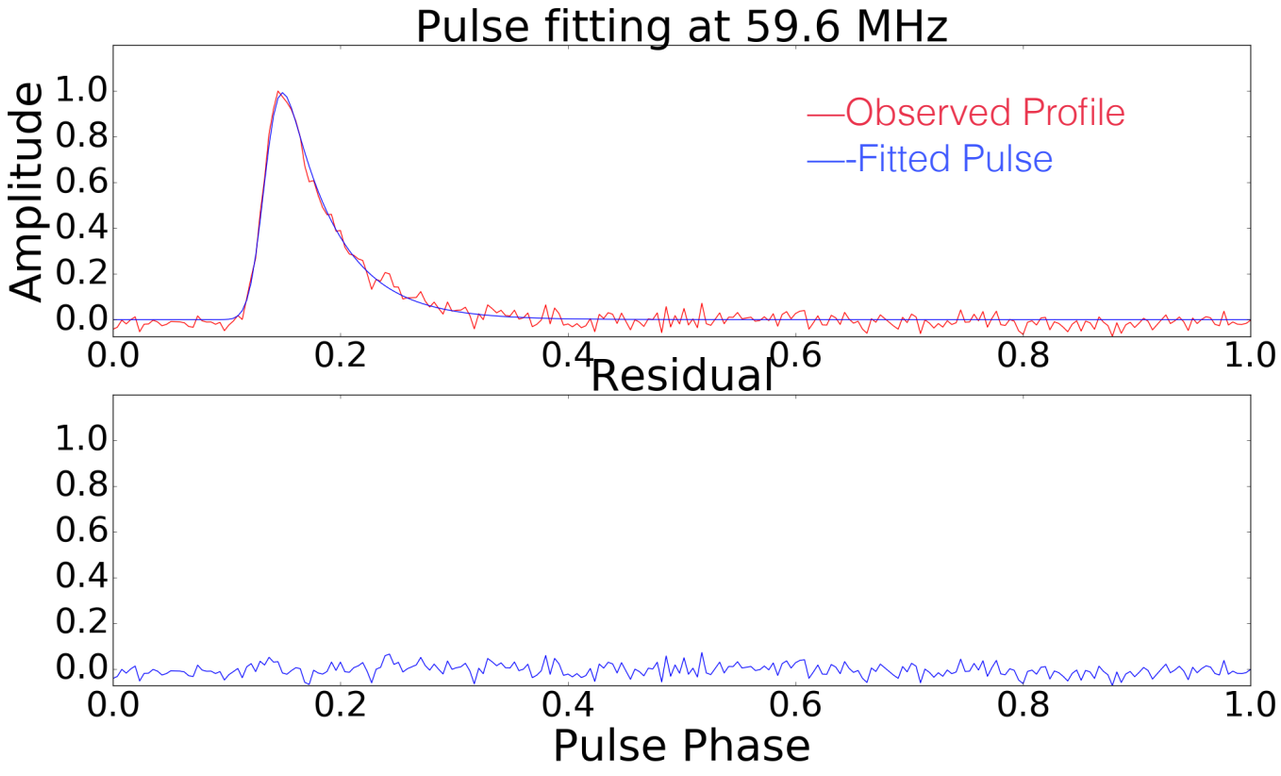
Kolmogorov Inhomogeneity Distribution:

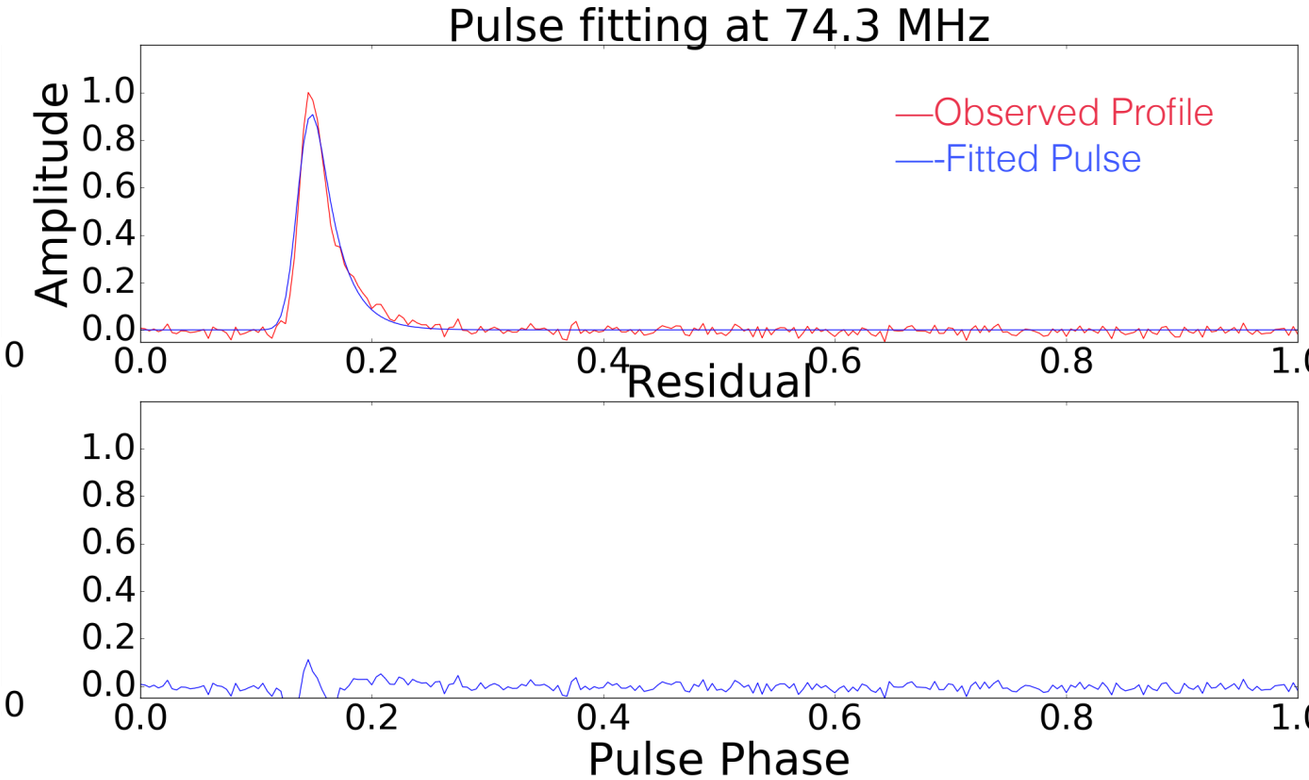
$$\tau_{sc} \propto \nu^{-4.4} DM^{2.2}$$

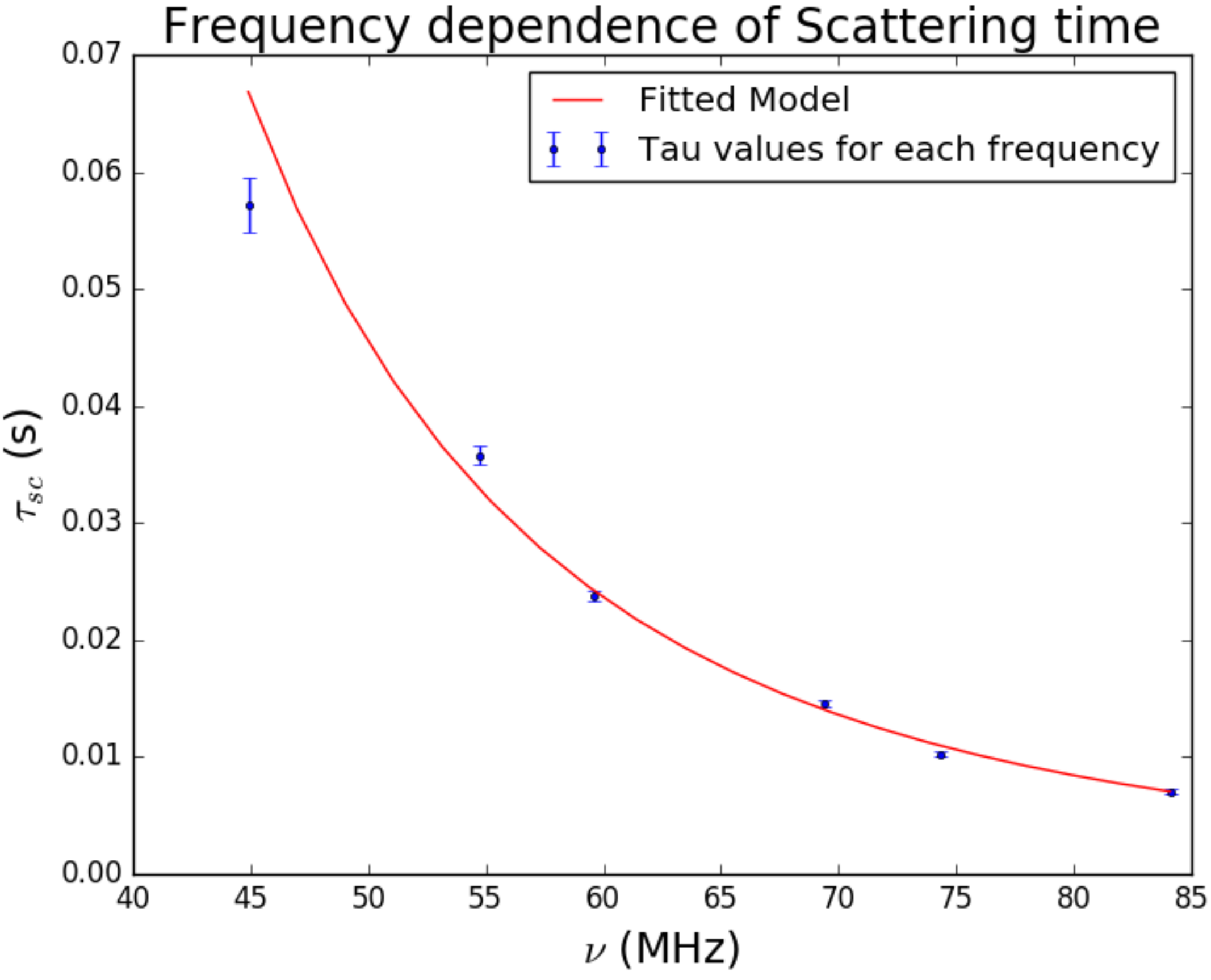
Dispersion Measure

$$DM = \int n_e dl$$

Fitting for PSR B2217+47





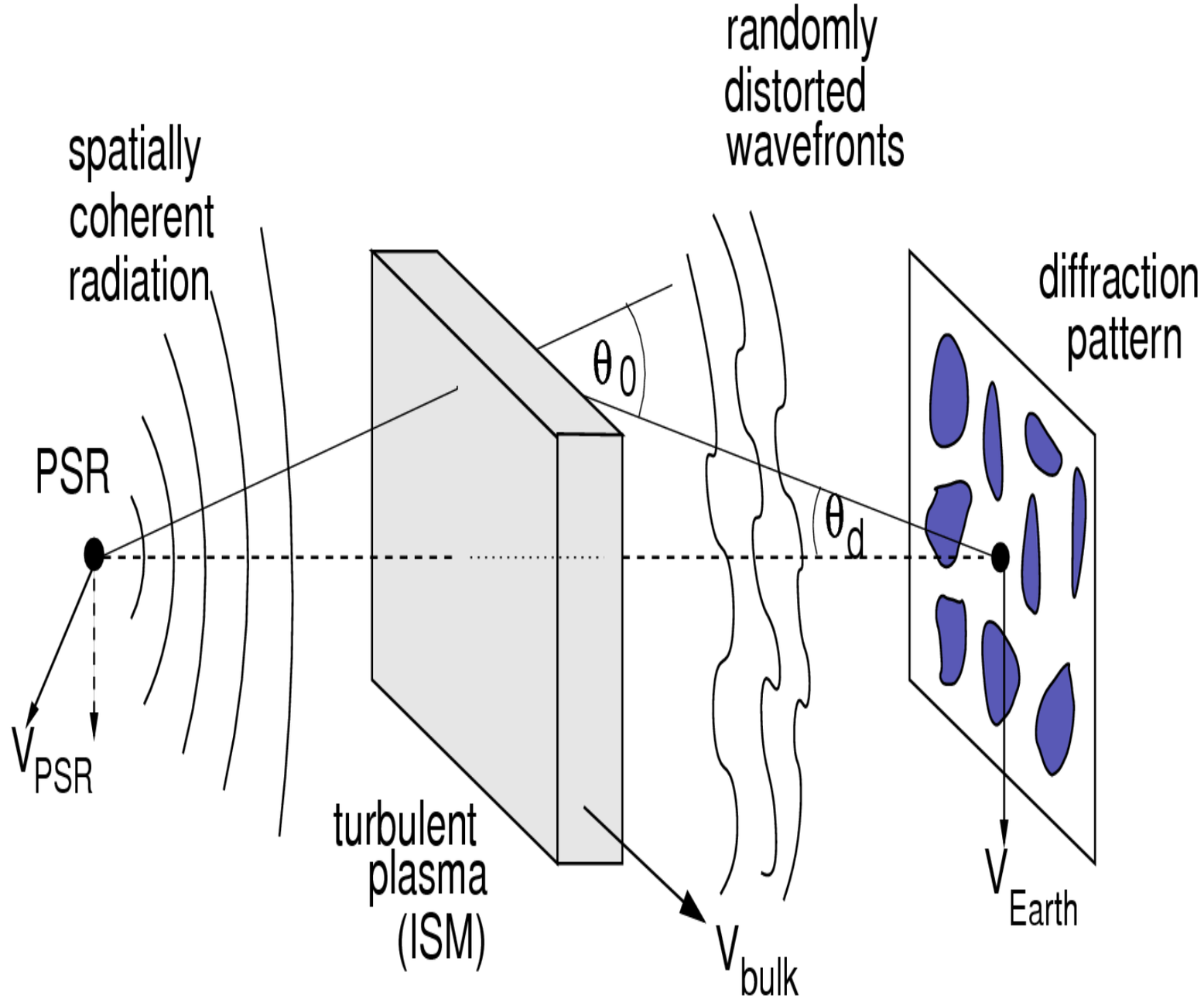

Frequency dependence of Scattering time
Fitted Model
Tau values for each frequency
τ_{sc} (s)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
40
45
50
55
60
65
70
75
80
85
ν (MHz)

PSR B2217+47

Results

Pulsar	α (Average)
B0329+54	4.05 ± 0.14
B0823+26	1.55 ± 0.09
B0919+06	2.83 ± 0.18
B1822−09	4.18 ± 0.13
B1839+56	2.70 ± 0.16
B1842+14	3.24 ± 0.11
B2217+47	3.58 ± 0.10

- Fluctuations in electron density
- Random irregularity of refractive index
- Multipath propagation of the pulsar signal



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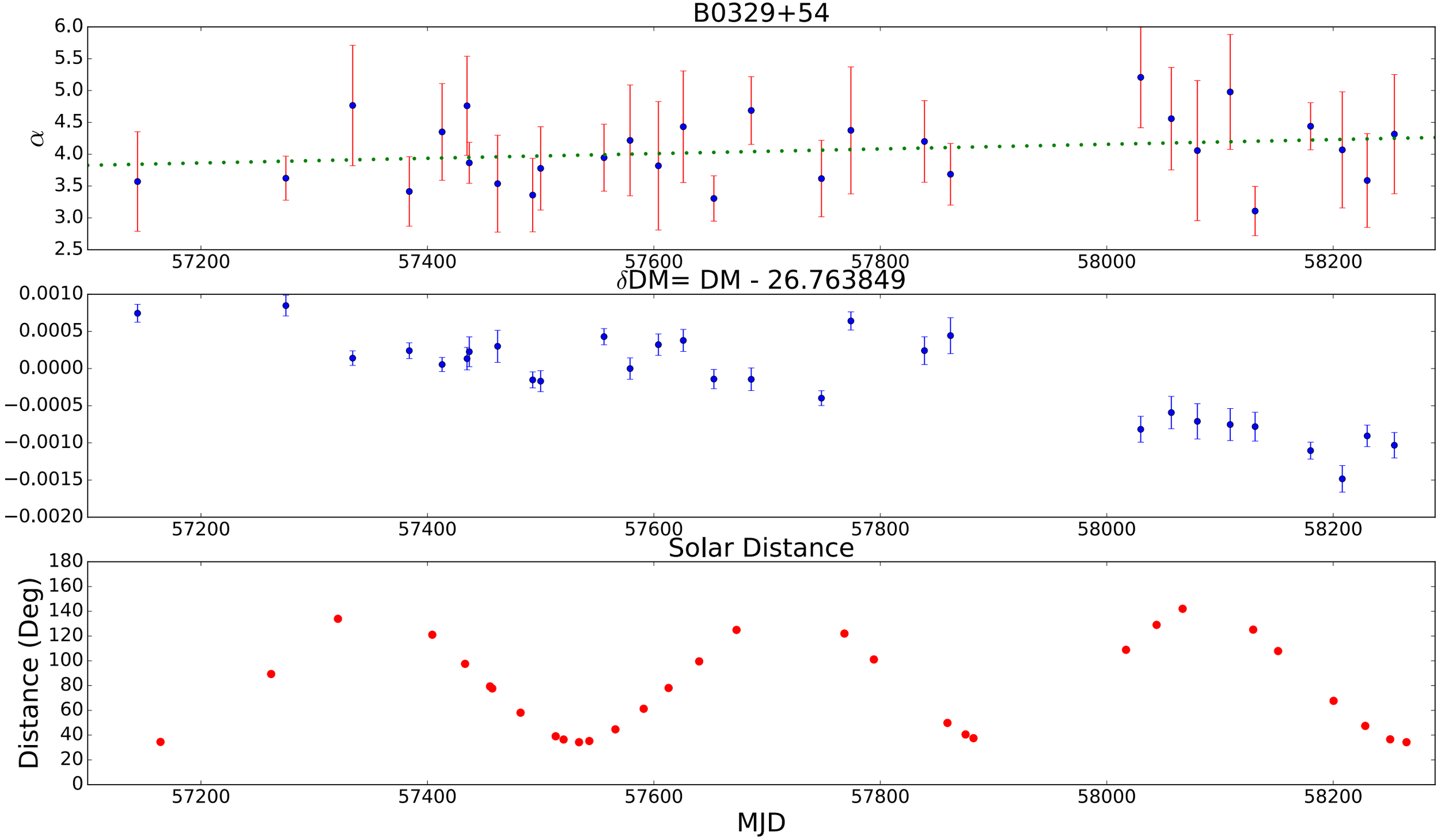
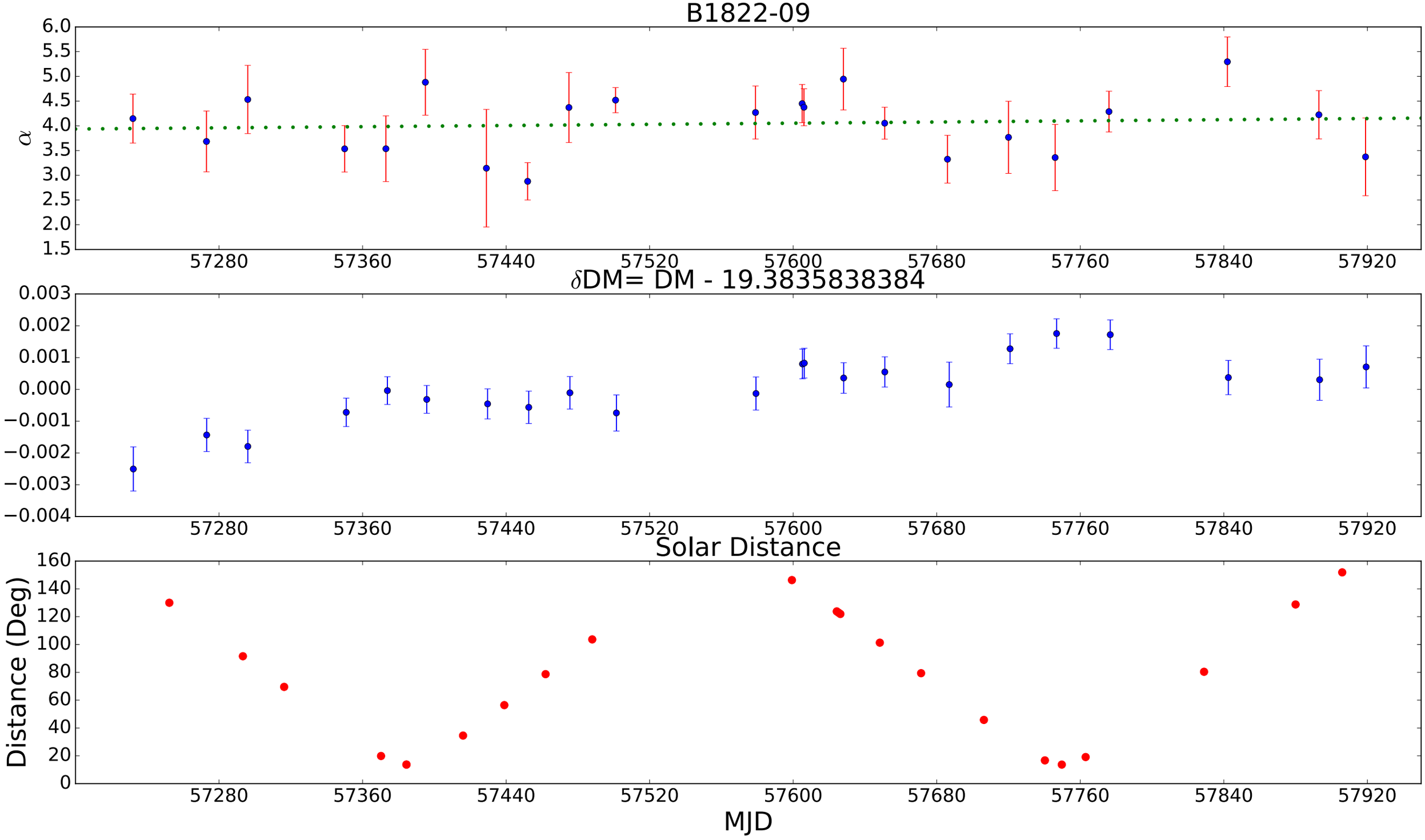


Minimum Solar Elongation ~ 34.2°

Bansal et al., (under review)

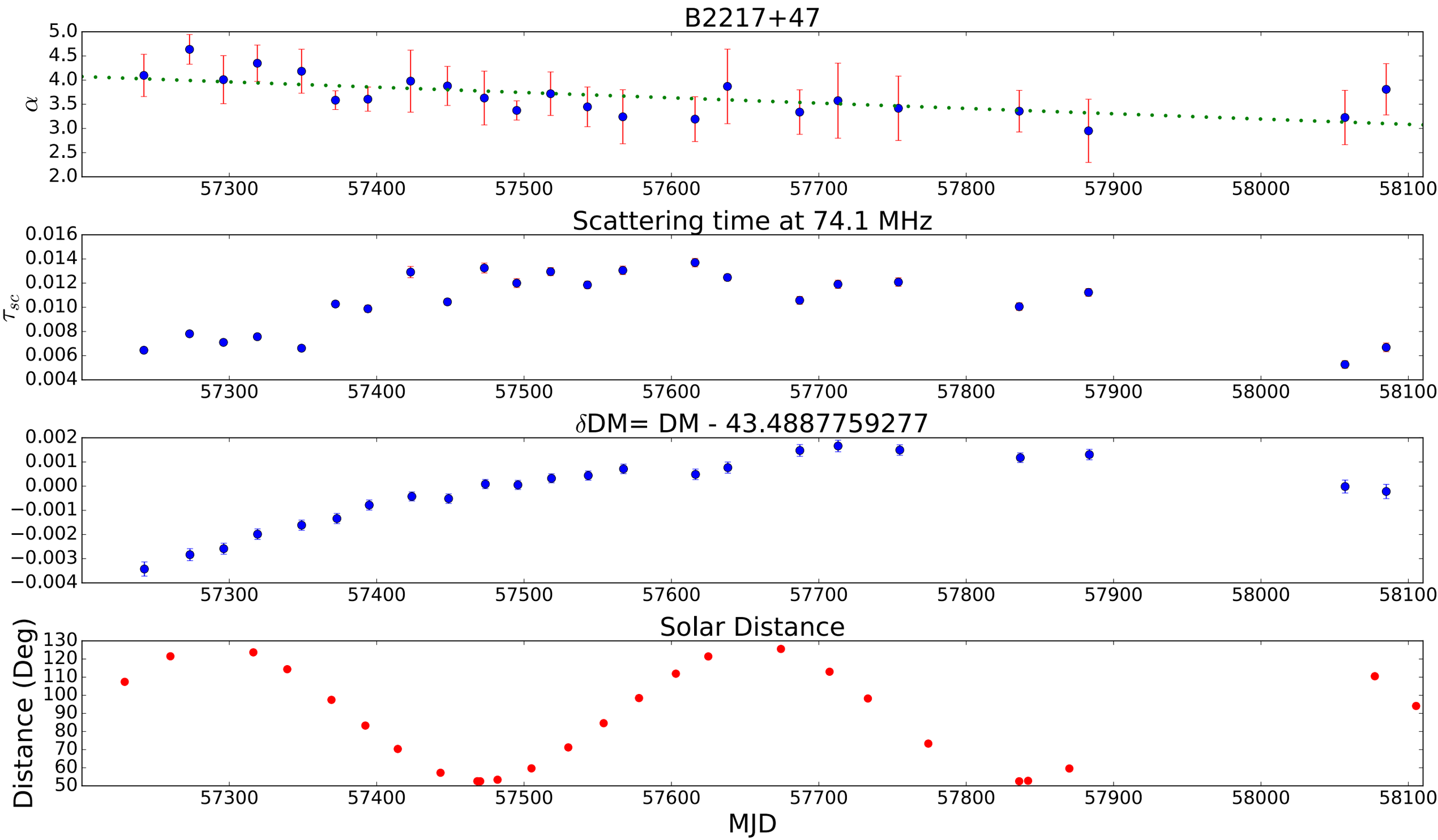
Slope of α plot: - 1.3 ± 1.1 * 10^{-1} $year^{-1}$



Minimum Solar Elongation ~ 13°

Slope of α plot: 1.1 ± 2.5 * 10^{-1} $year^{-1}$

Bansal et al., (under review)



Minimum Solar Elongation ~ 50°

Slope of α plot: -4.3 ± 1.0 * 10^{-1} $year^{-1}$

Bansal et al., (under review)

Summary/Conclusions

- Scattering study for 7 pulsars
- 5 out of 7 pulsars show deviation from the theoretical models
- Time variation for only one source - B2217+47
- B0823+26 - scattering index - 1.55 - lowest ever

Plausible explanations

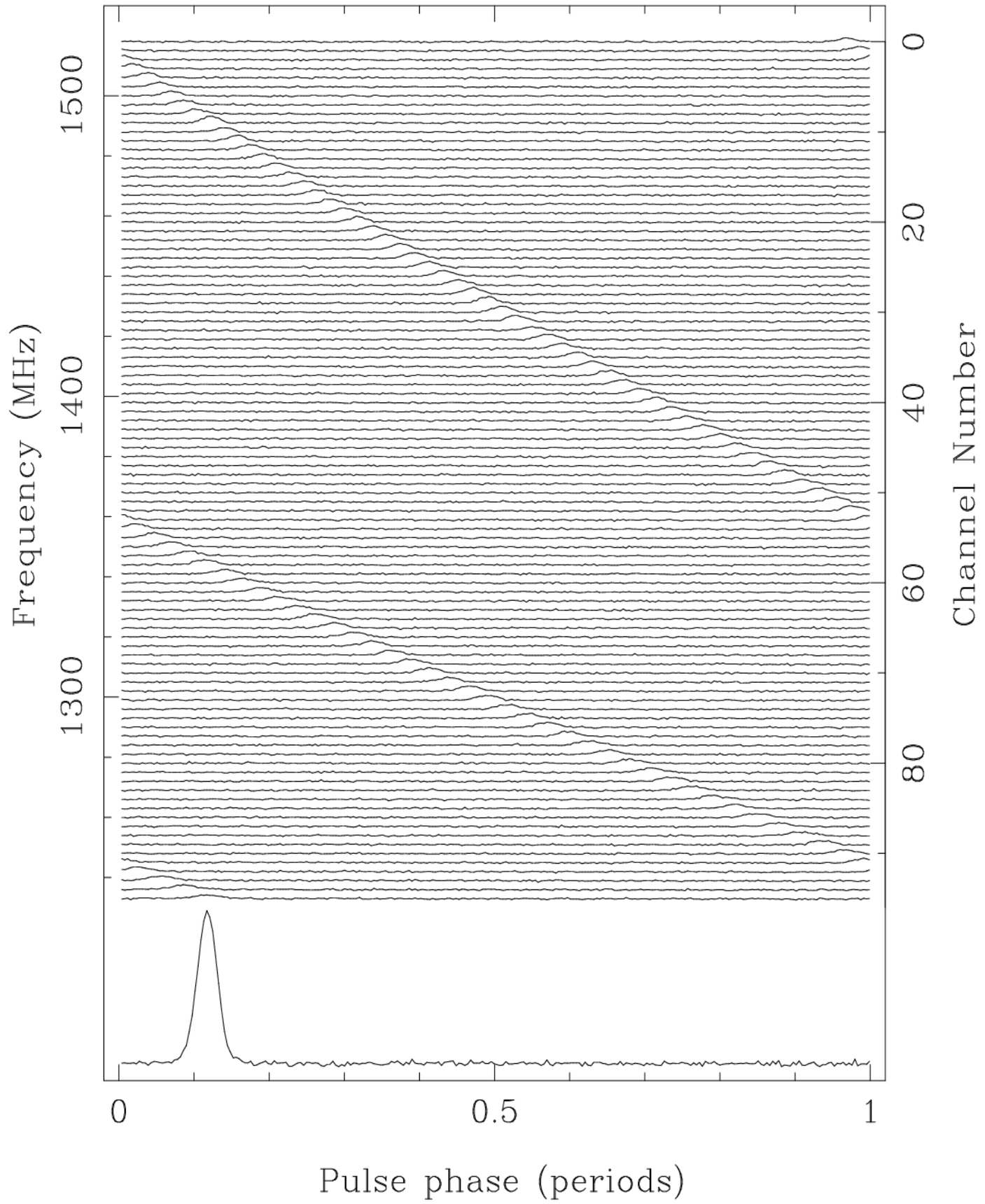
- Most of the previous studies at higher frequencies
- Multiple screens
- Limited screen size
- Anisotropic scattering

Dispersion Time Delay

$$t \propto DM\nu^{-2}$$

Dispersion measure

$$DM = \int_0^D n_e dl$$



Credit: Handbook of Pulsar Astronomy by Lorimer and Cramer