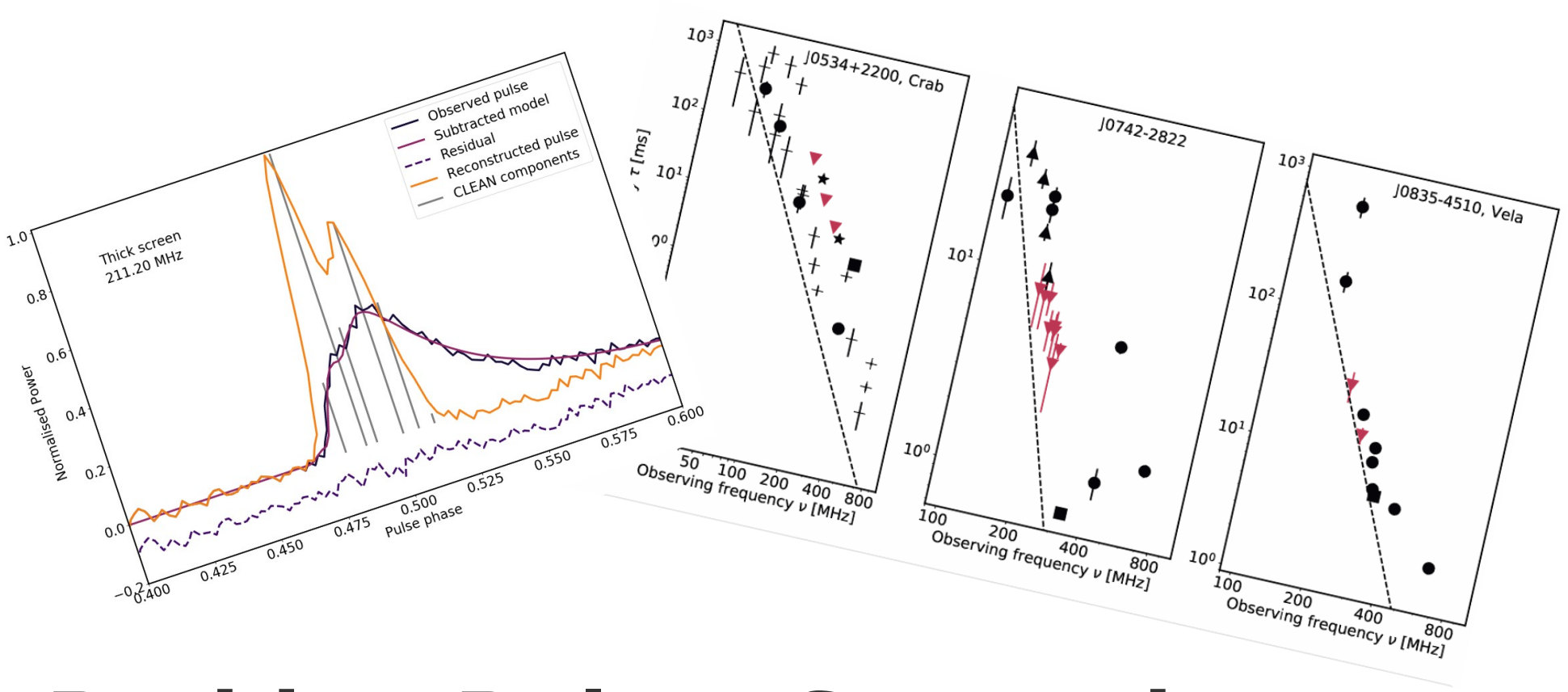
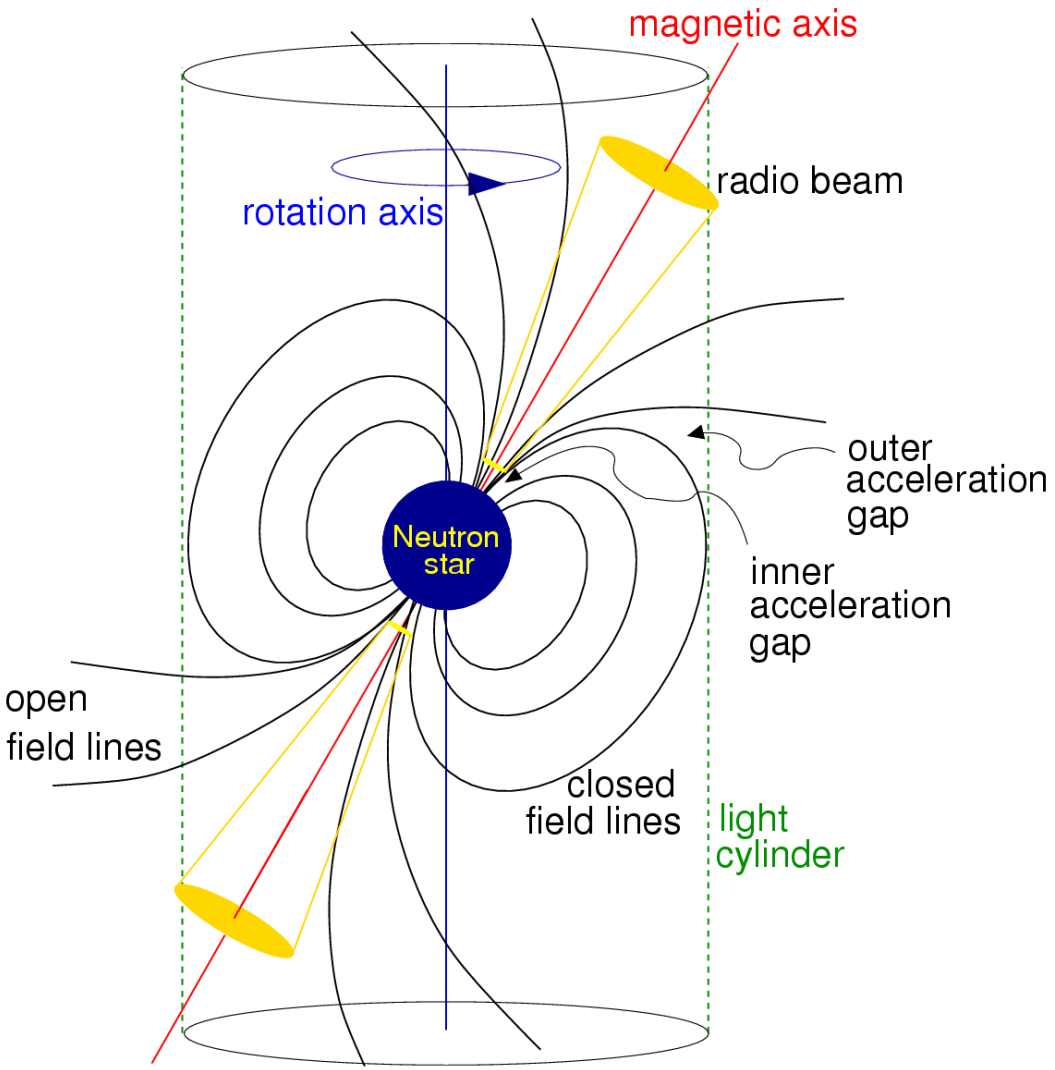


Probing Pulsar Scattering with the MWA

Franz Kirsten
Chalmers University of Technology
With help from: Ramesh Bhat, Bradley Meyers, Jean-Pierre Macquart, Steven Tremblay, Stephen Ord

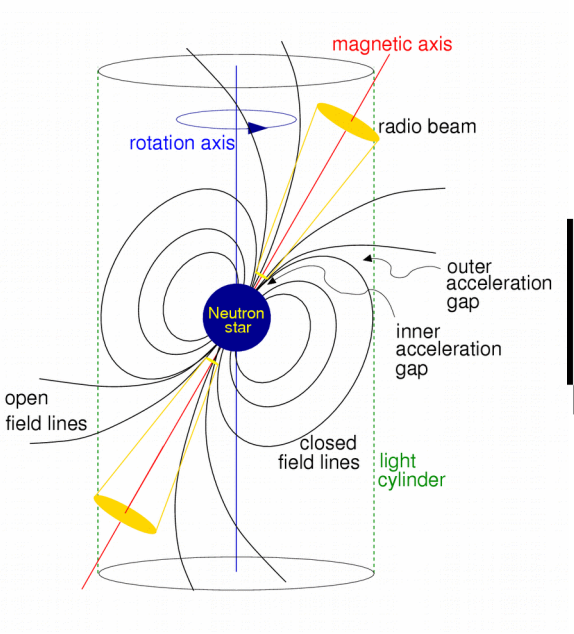
The Metre Wavelength Sky II, March 18-22 2019, Pune, India

Pulsars and the Interstellar Medium

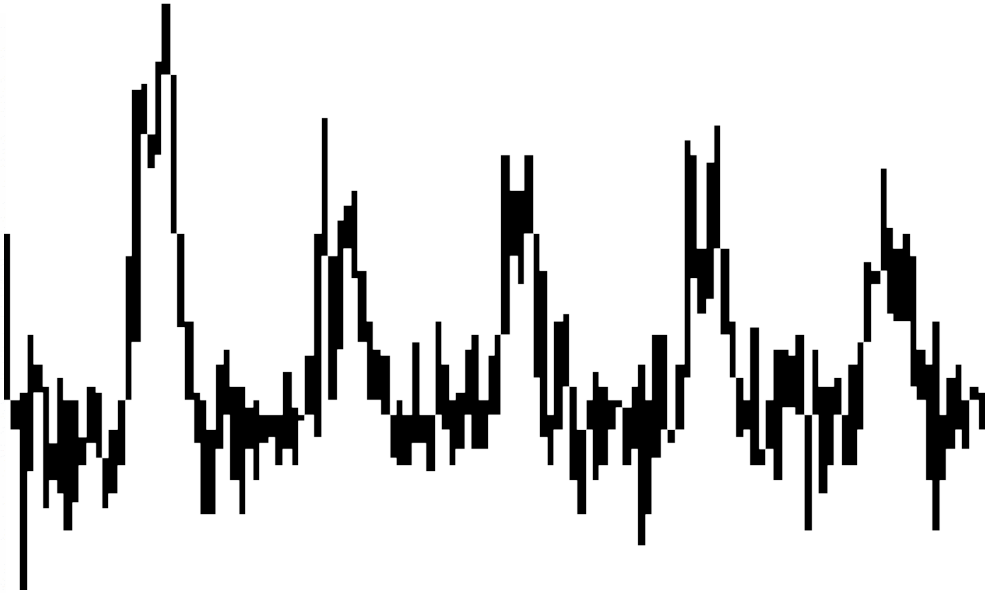


Pulsar

Pulsars and the Interstellar Medium

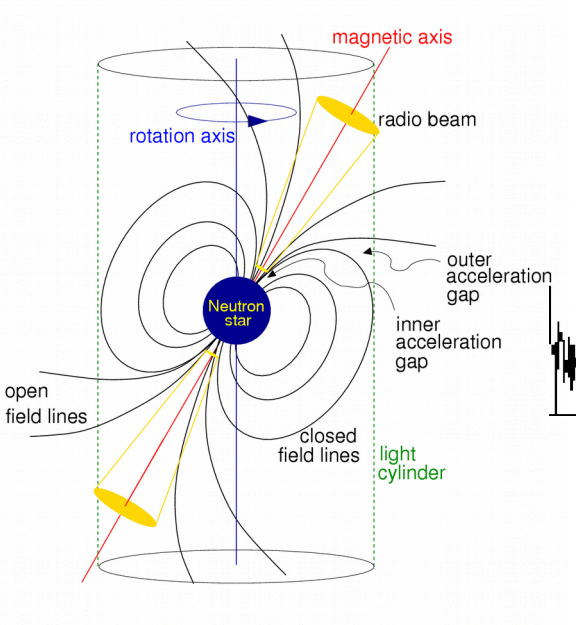


Pulsar

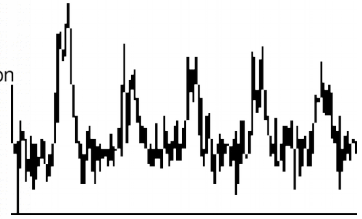


Regular pulses

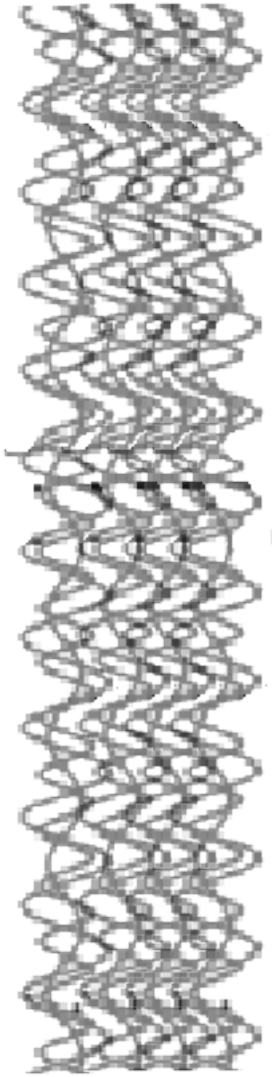
Pulsars and the Interstellar Medium



Pulsar

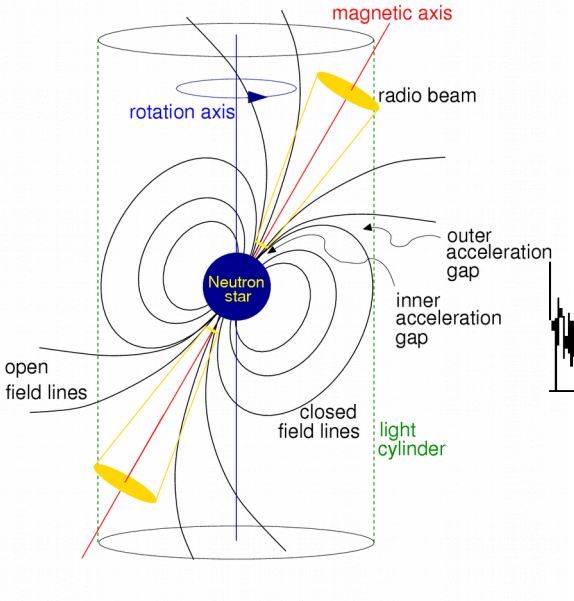


Regular pulses

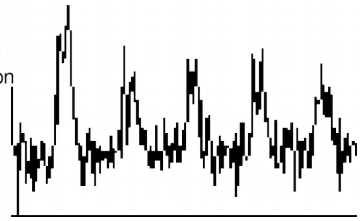


Density irregularities in Interstellar Medium
scattering pulsar radiation

Pulsars and the Interstellar Medium

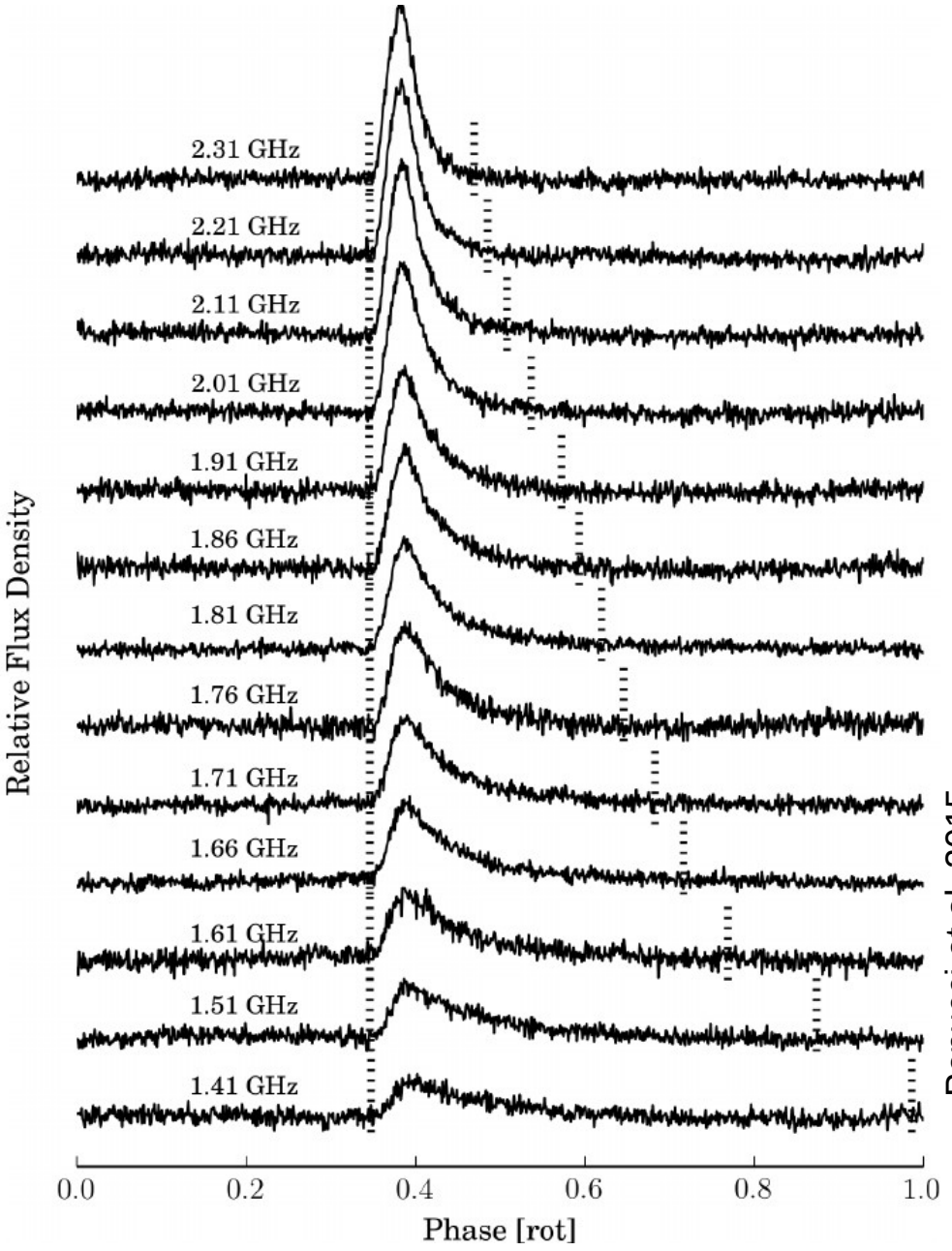


Pulsar



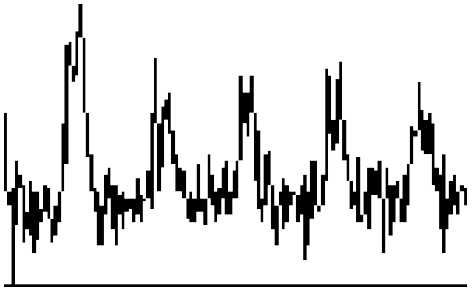
Regular pulses

ISM

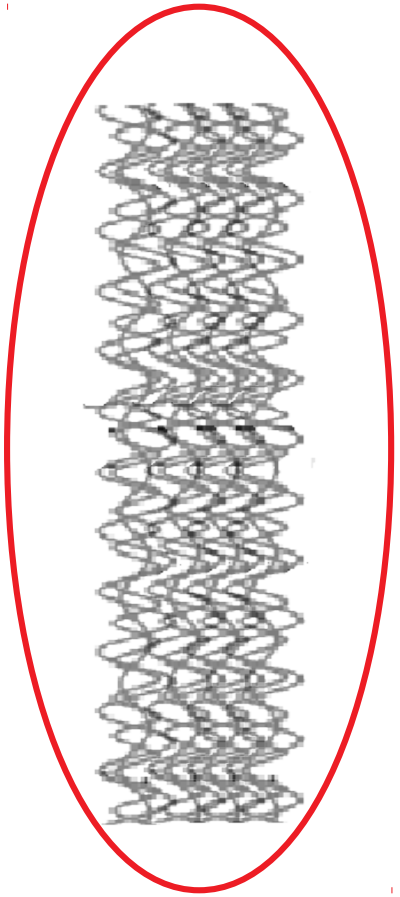


Penucci et al. 2015

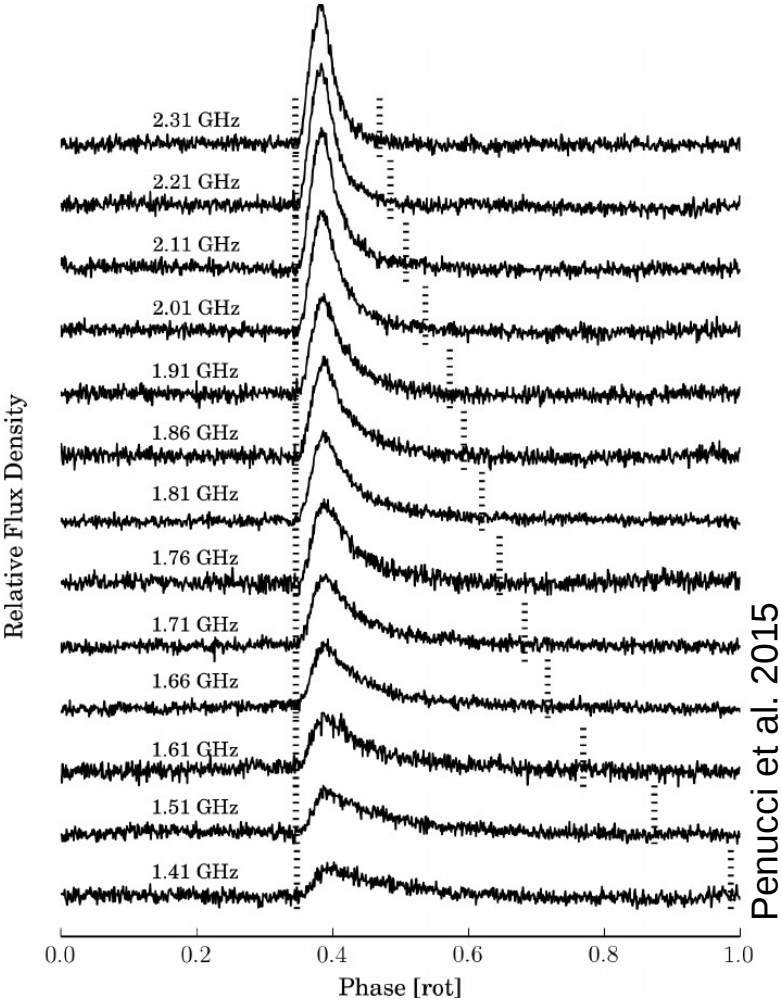
Pulsars and the Interstellar Medium



Regular pulses

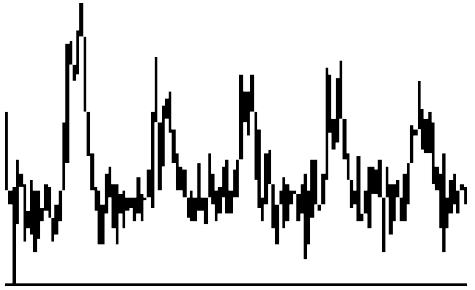


ISM



Penucci et al. 2015

Pulsars and the Interstellar Medium



Square law structure function?
Kolmogorov Turbulence?

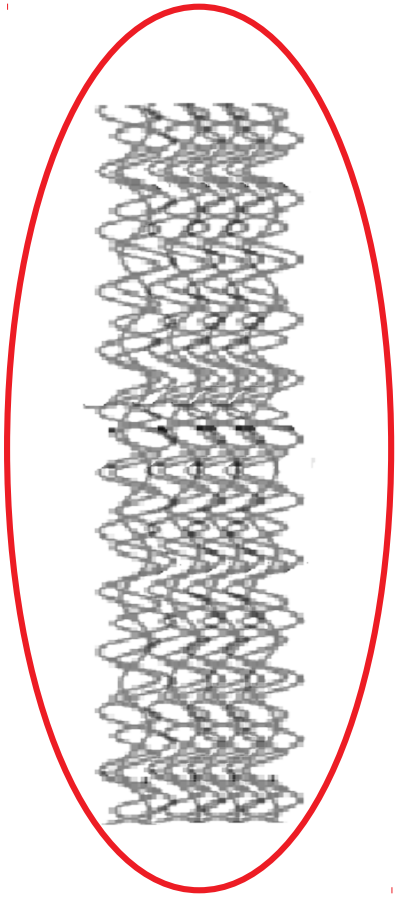
Anisottropic vs isotropic scattering?

Thin screen vs thick screen?

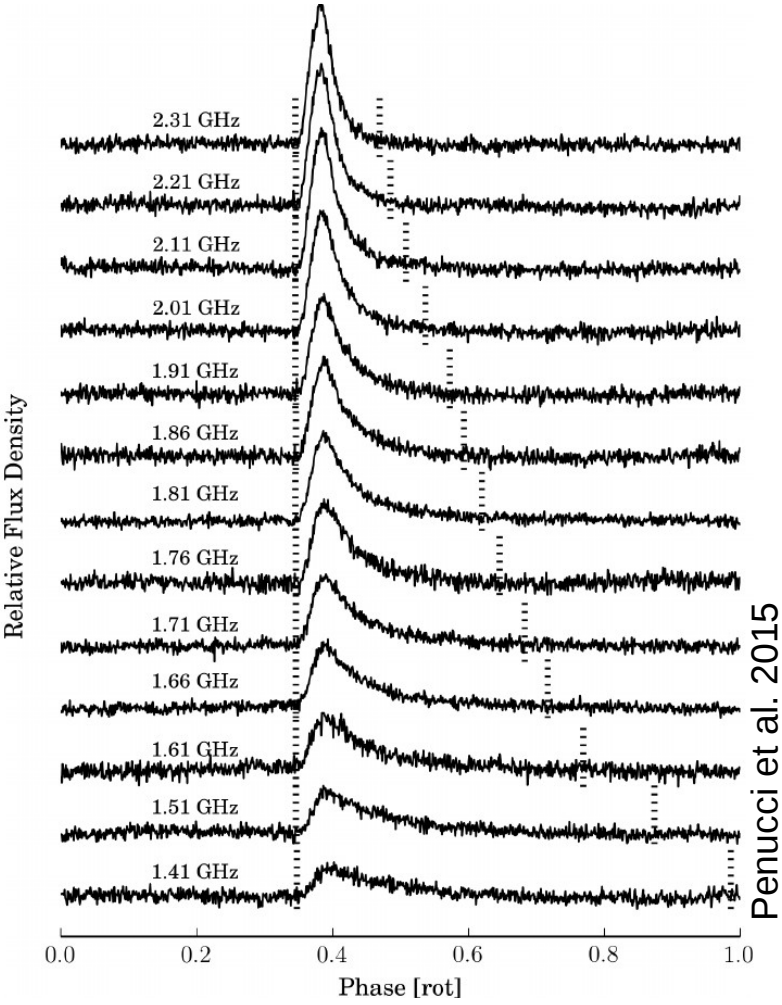
Filamentary geometry?

Temporal variability!

Intrinsic pulse structure?

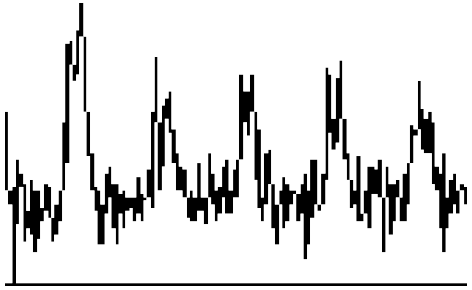


ISM



Penucci et al. 2015

Pulsars and the Interstellar Medium



Square law structure function?
Kolmogorov Turbulence?

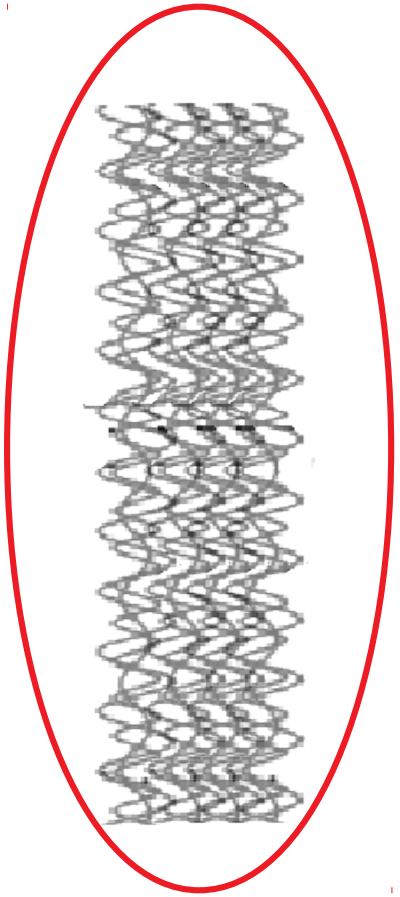
Anisottropic vs isotropic scattering?

Thin screen vs thick screen?

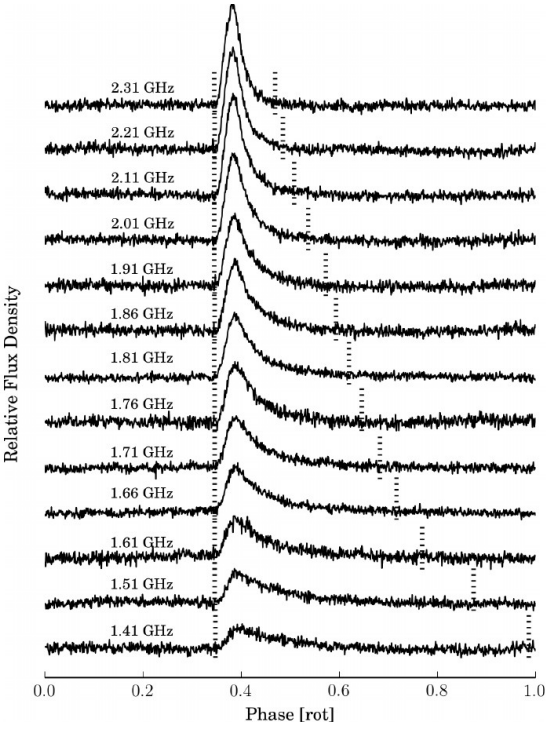
Filamentary geometry?

Temporal variability!

Intrinsic pulse structure?



ISM



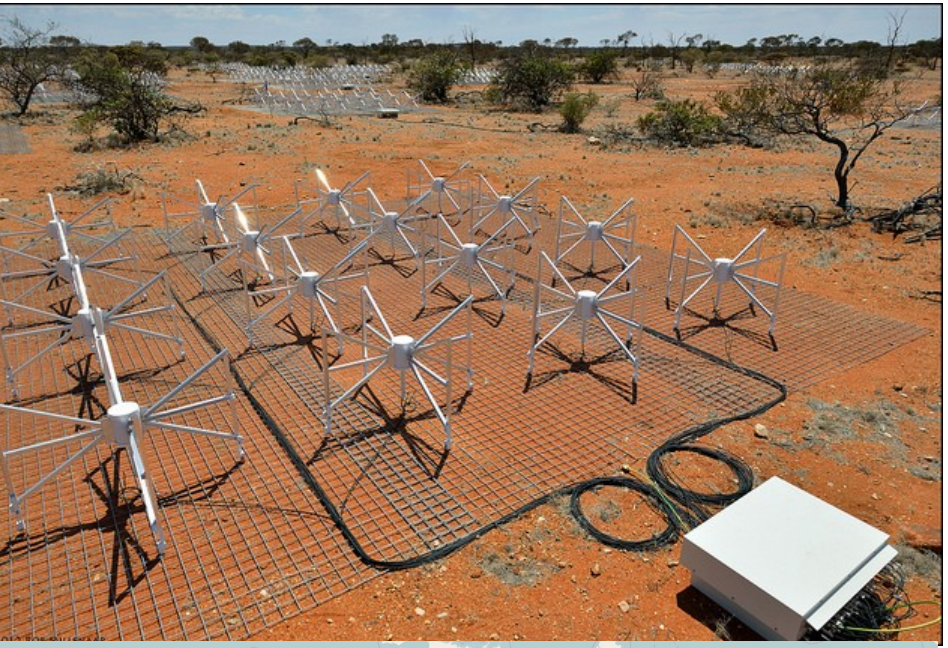
Shape of pulses: rise time,
Power in tail, i.e. decay time

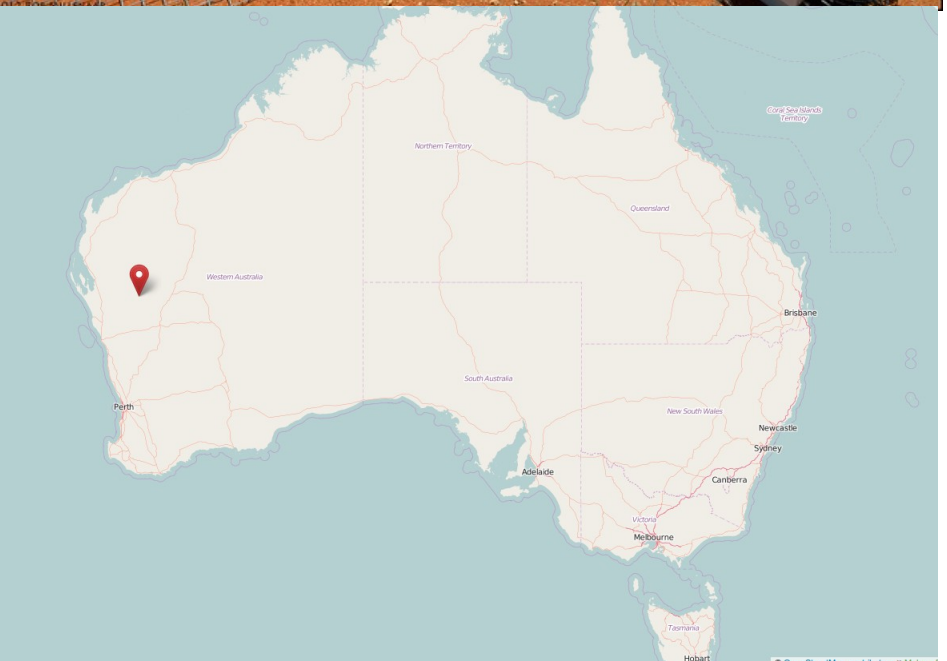
Frequency dependence:

$$\tau \propto \nu^{\alpha}$$

→ **need for simultaneous broadband observations**

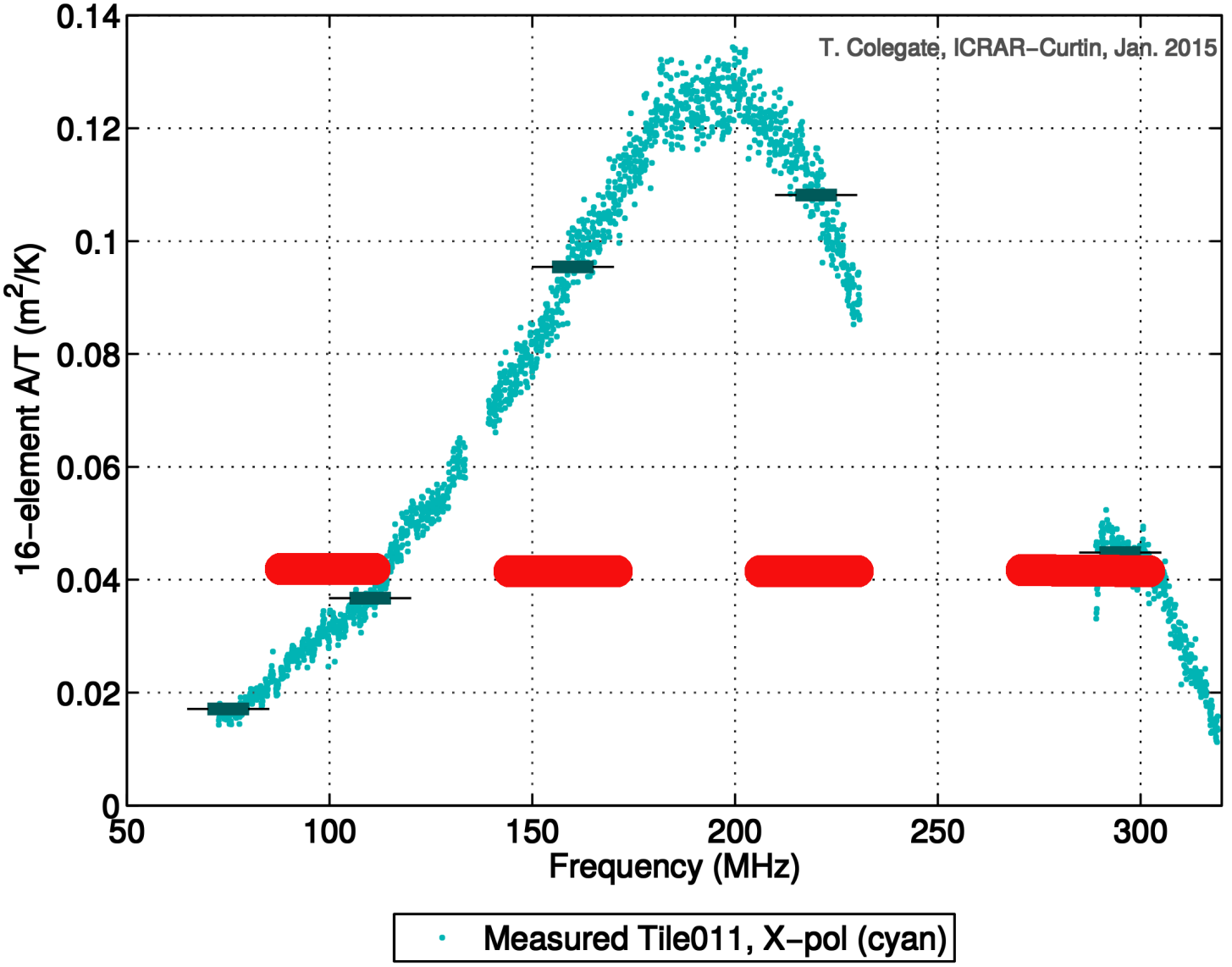
The Murchison Widefield Array



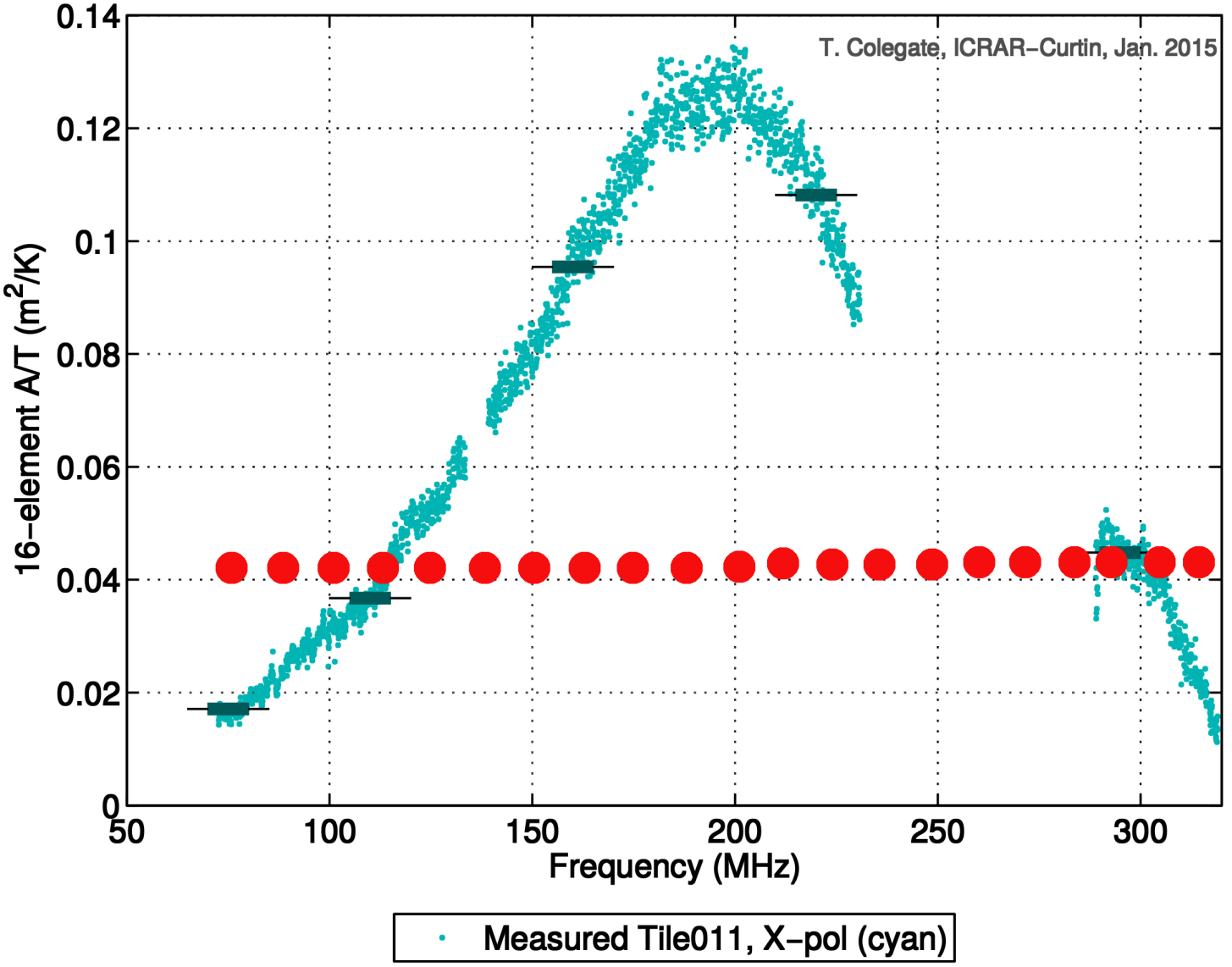


- SKA - low precursor, connected interferometer
- 128 (256) tiles, 4x4 dipoles per tile
- Different configurations: compact, extended
- 30 degree FOV
- max 6km baseline
- ~ 70 – 300 MHz
- 24 x 1.28 MHz = 30.72 MHz BW, picket fence
- 10 kHz, 100 us resolution (raw voltages, VCS)
- 28 TB / hour raw data
- regular pulsar observations → incoherent sum
- tied array capability (Ord et al., in prep)
- Output: 24 x 1.28 MHz PSRFITS or VDIF

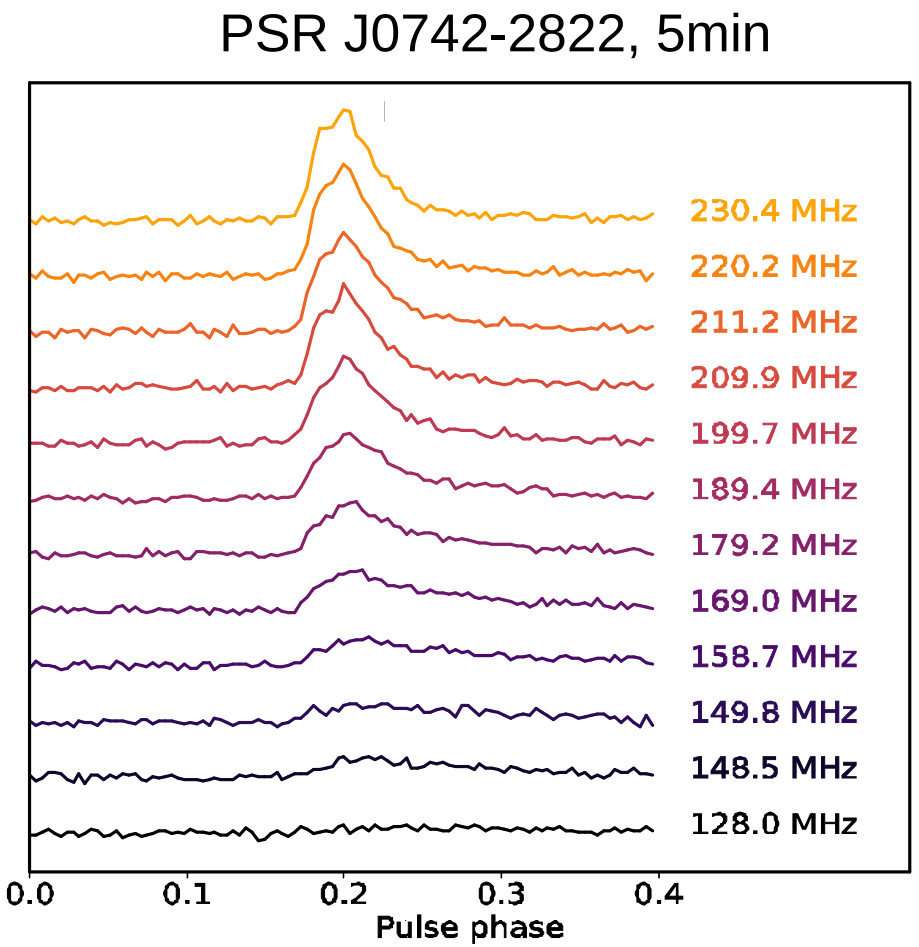
Picket Fence Observations

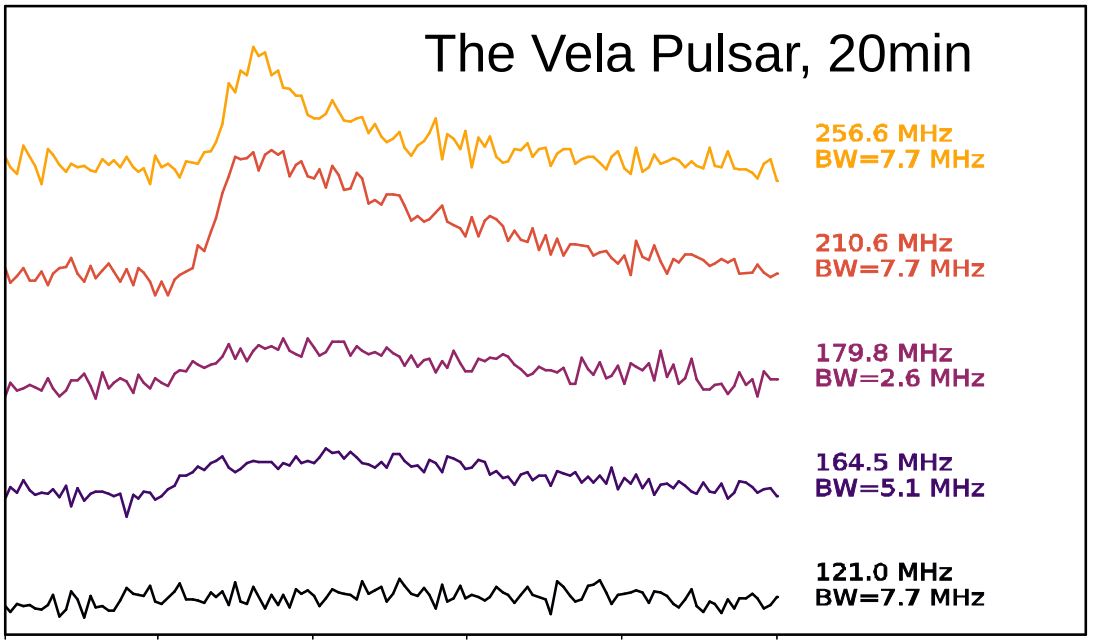


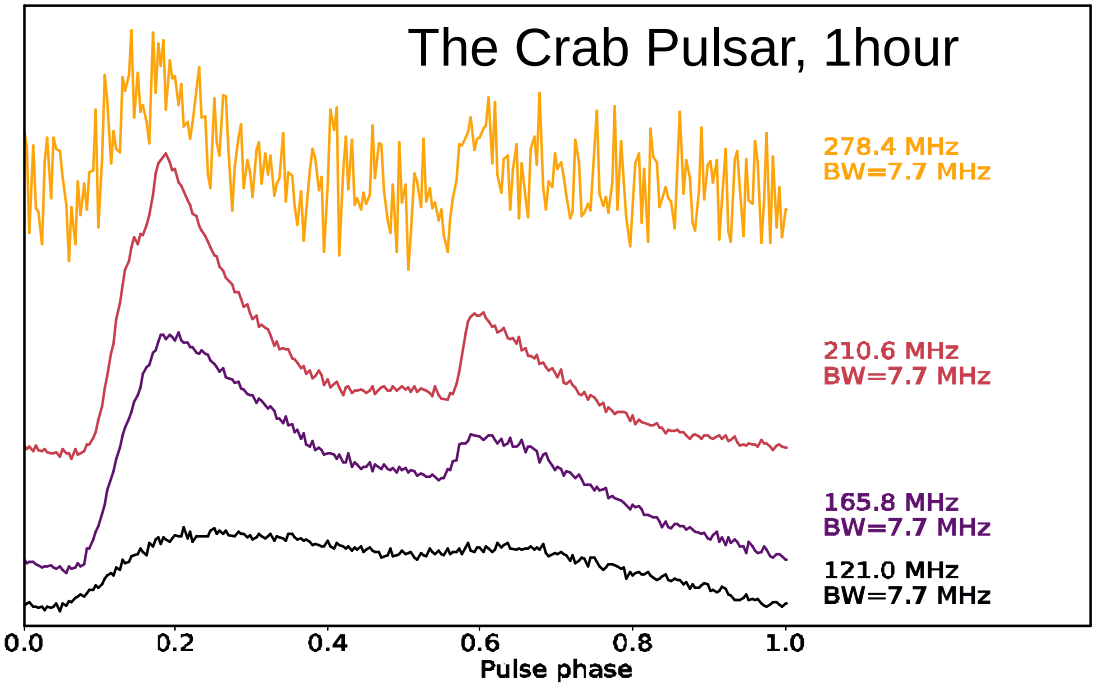
Picket Fence Observations



The targets: Vela, Crab, J0742-2822



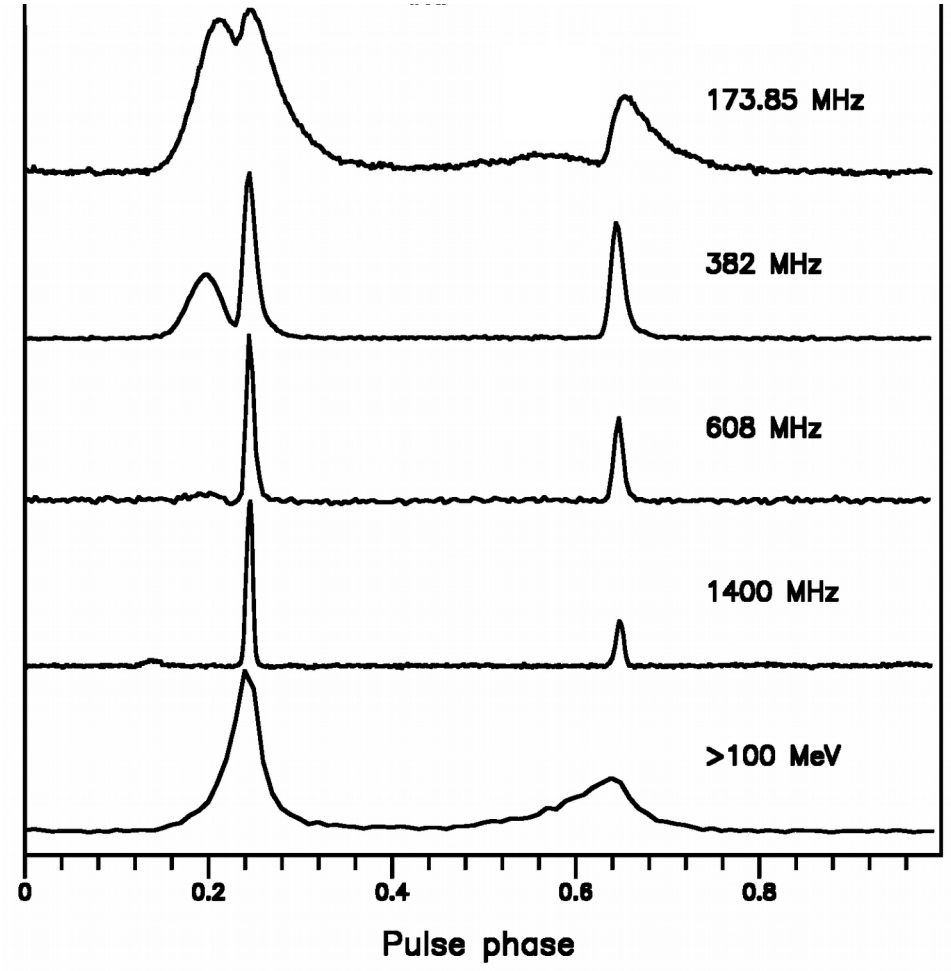




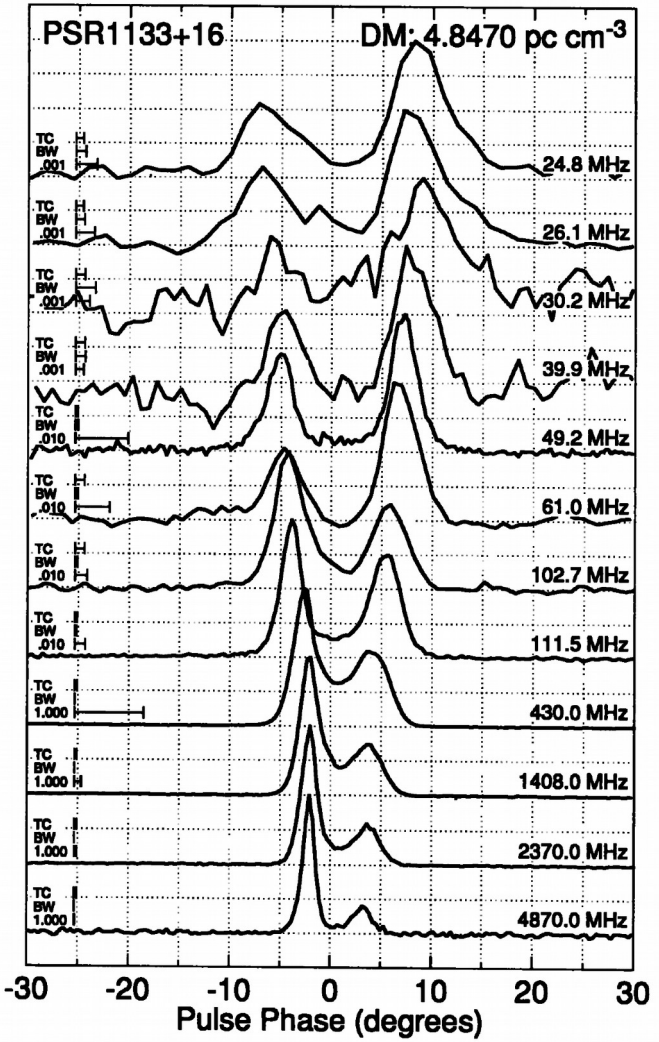
Kirsten et al., in press, ApJ

Pulse profile evolution

The Crab pulsar

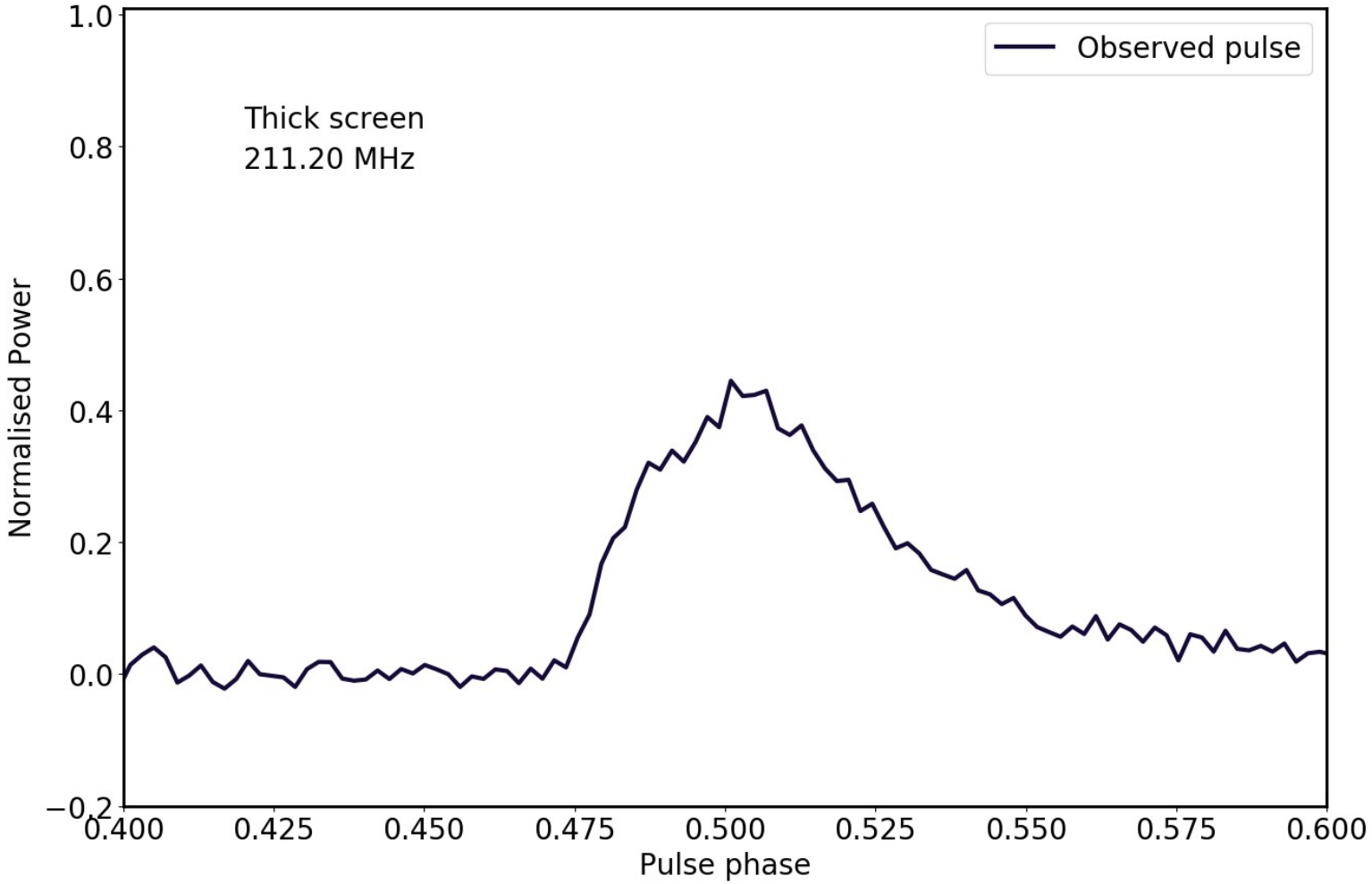


Karuppusamy et al. 2012



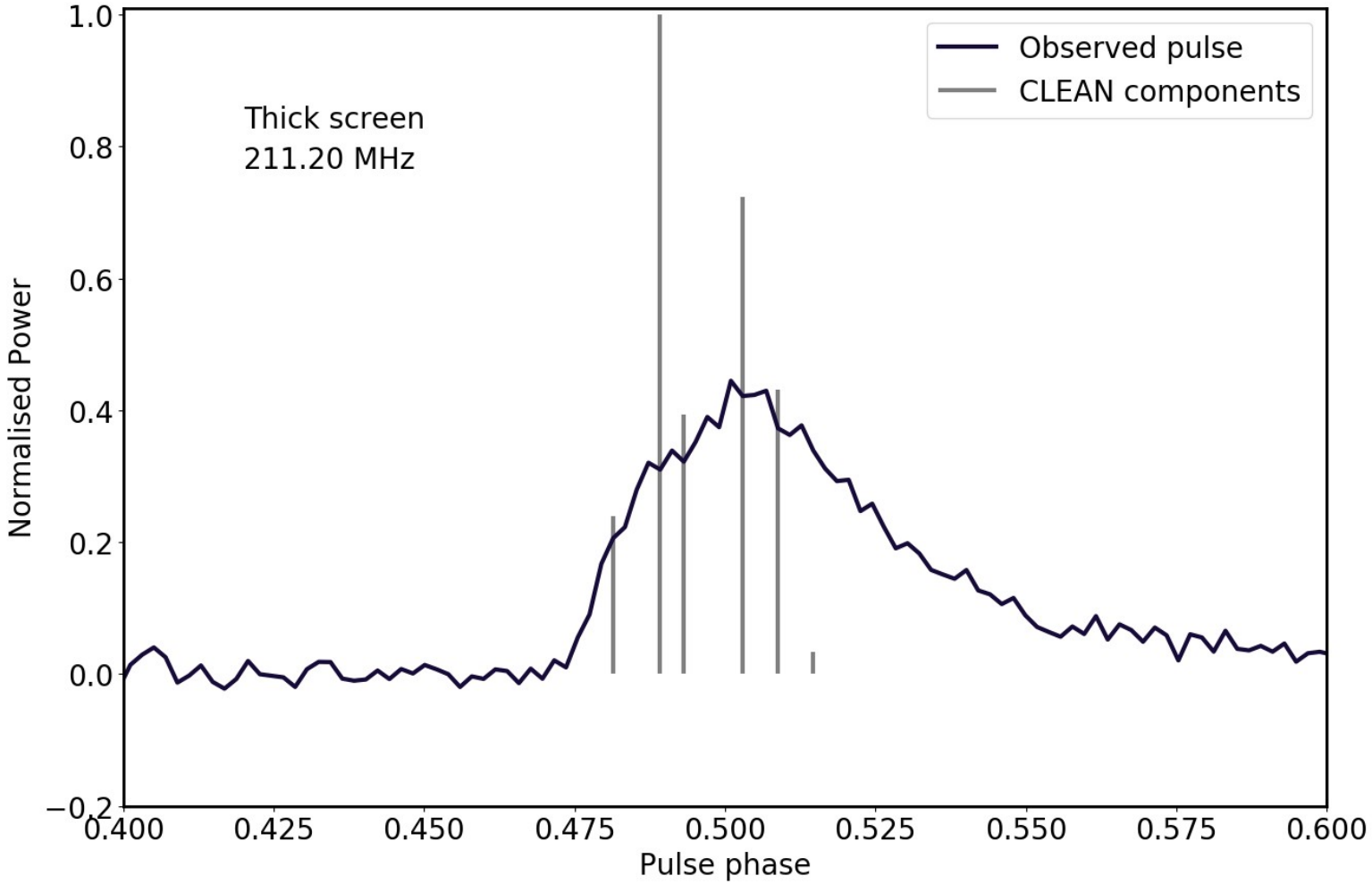
Hankins et al. 1991

The CLEAN method



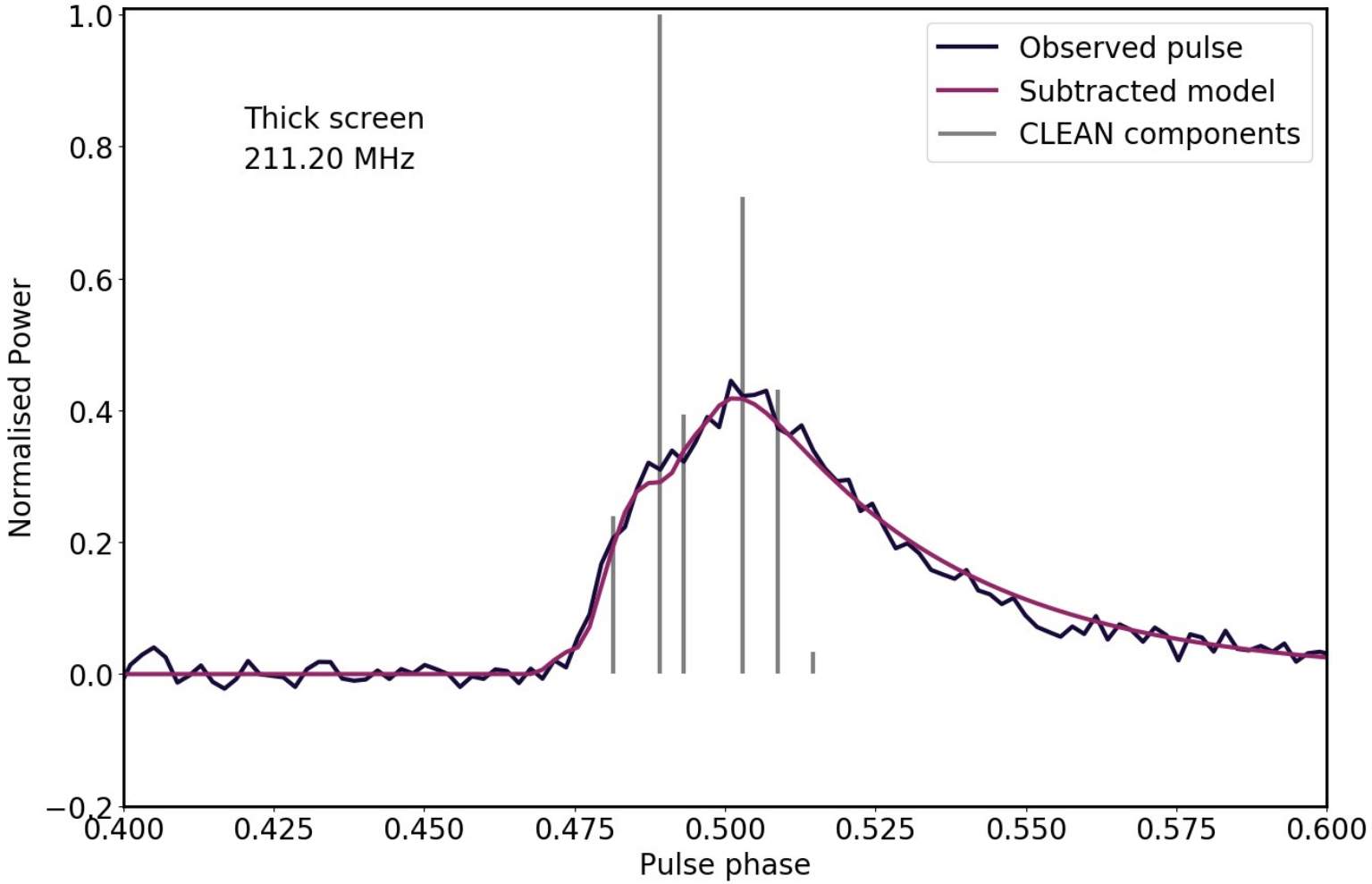
Code from Bhat et al. 2003

The CLEAN method



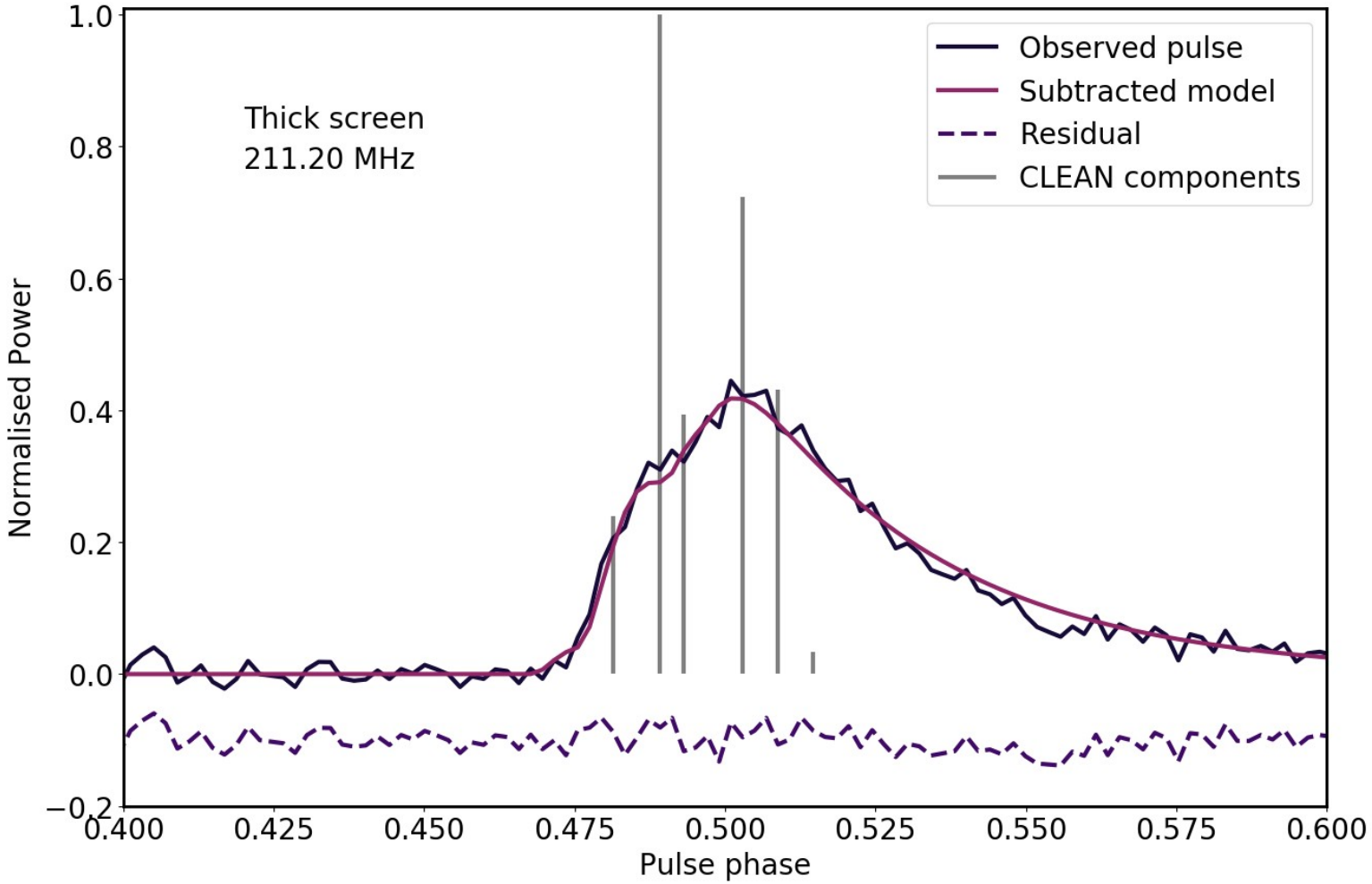
Code from Bhat et al. 2003

The CLEAN method



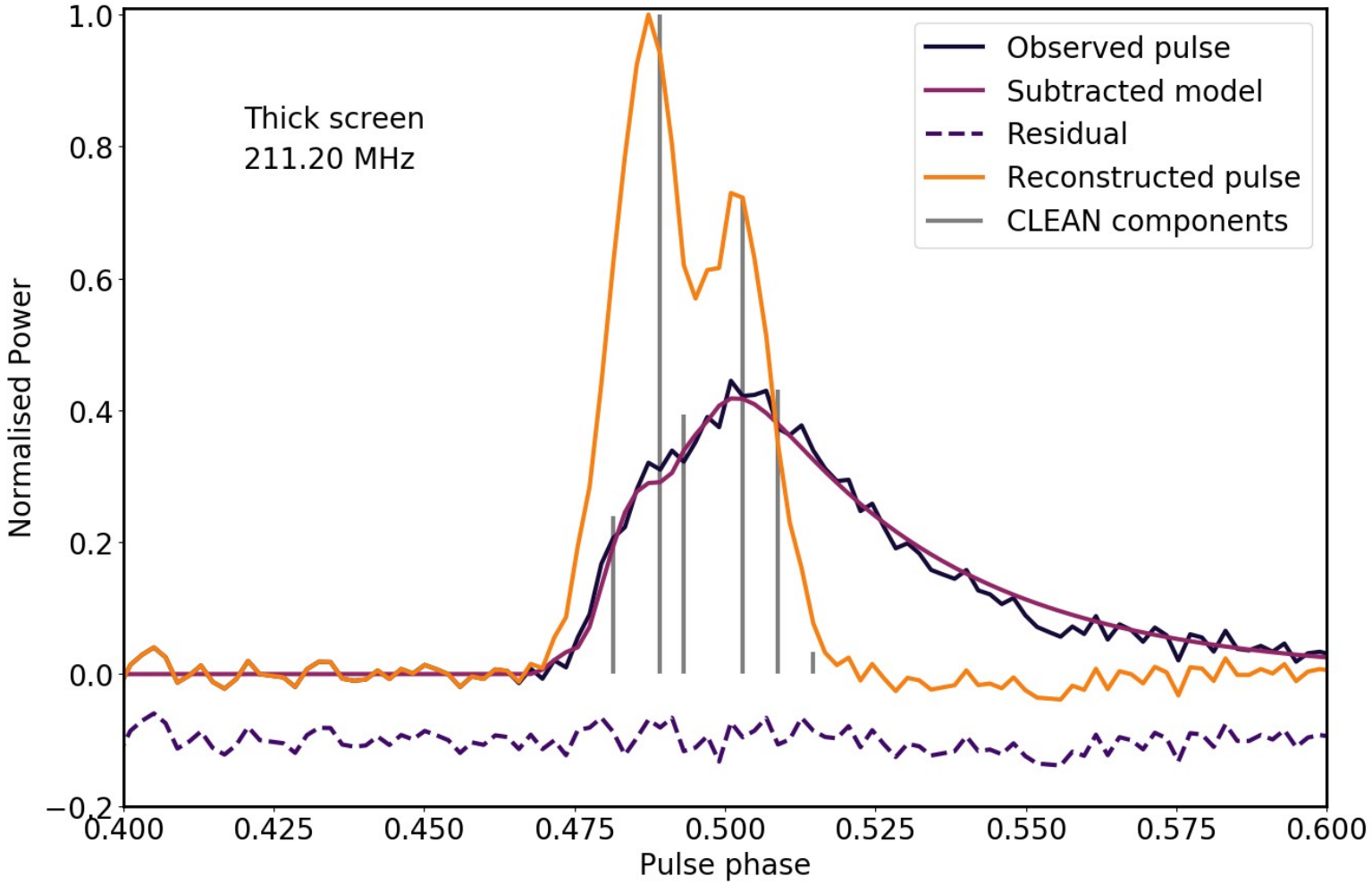
Code from Bhat et al. 2003

The CLEAN method



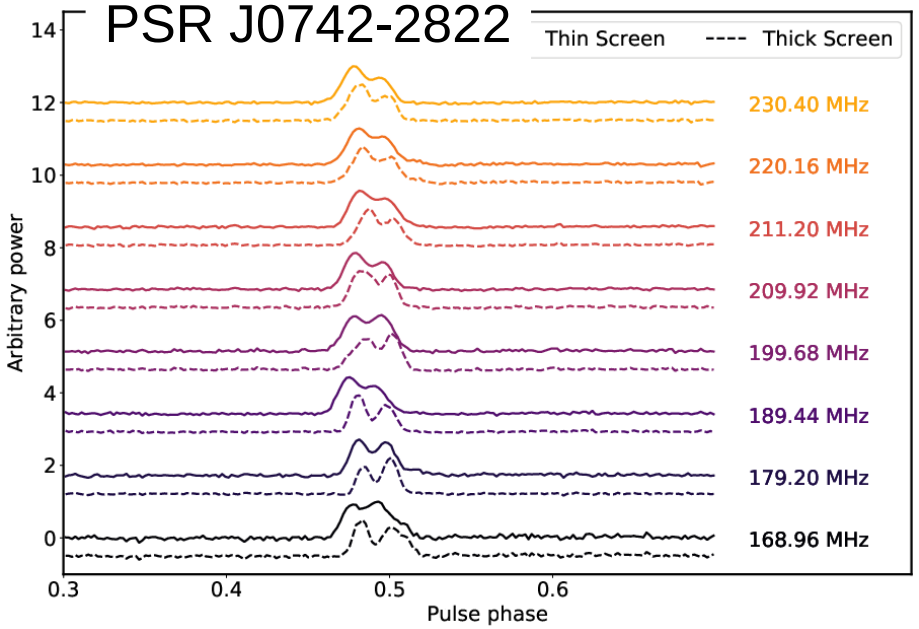
Code from Bhat et al. 2003

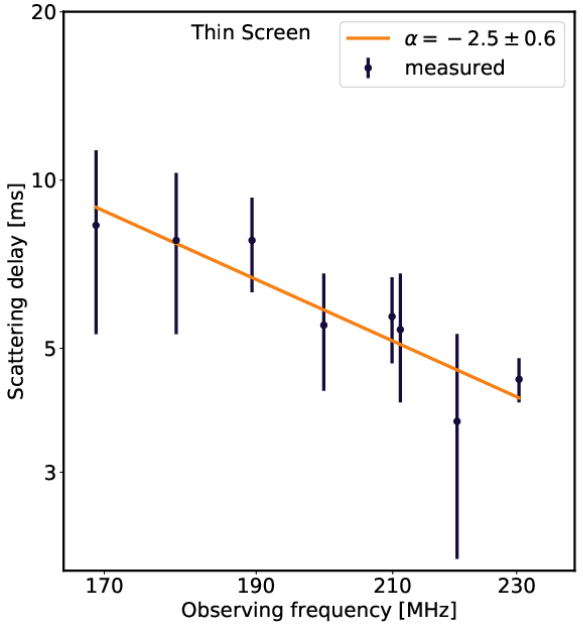
The CLEAN method

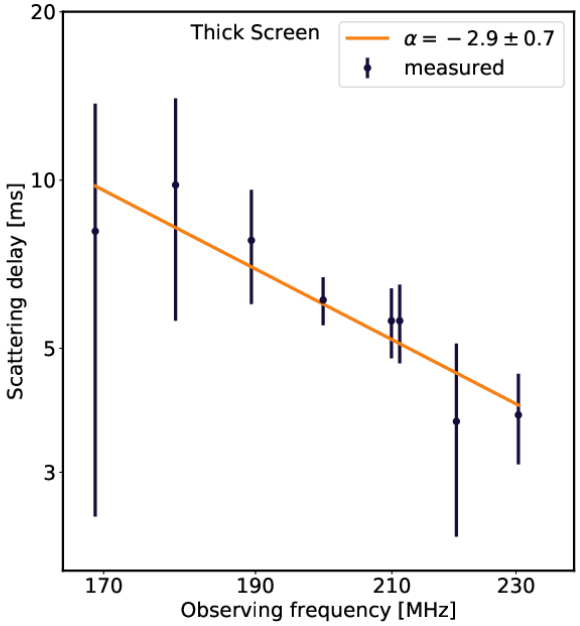


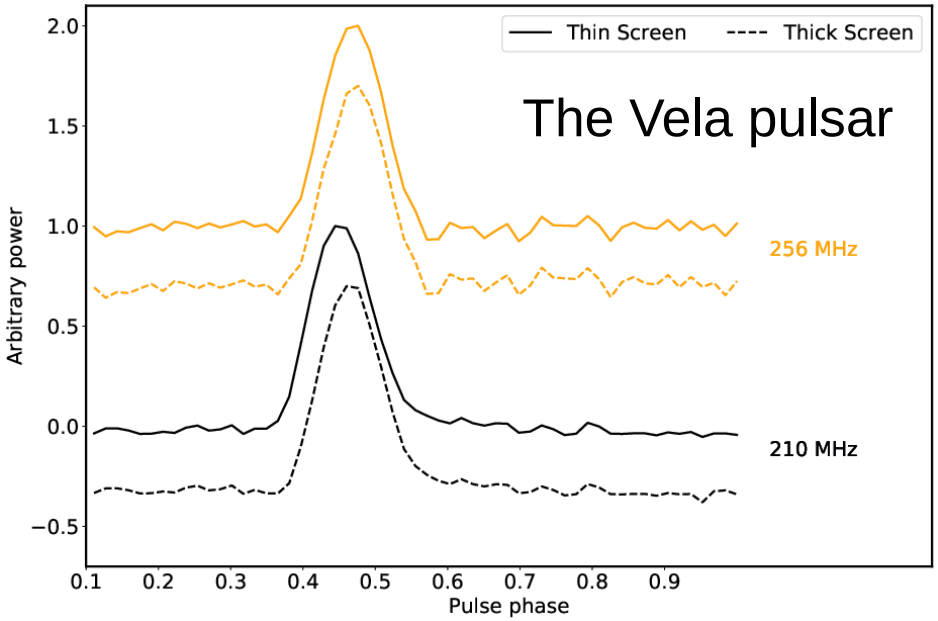
Code from Bhat et al. 2003

Results: Vela, J0742-2822









PSR J0742-2822

Thin Screen: $\alpha = -2.5 \pm 0.6$

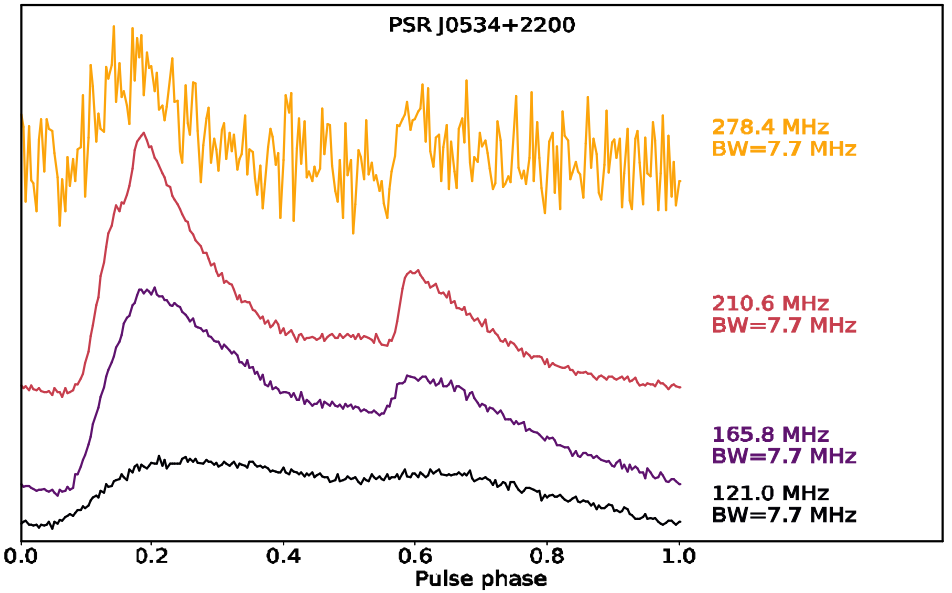
Thick Screen: $\alpha = -2.9 \pm 0.7$

The Vela pulsar

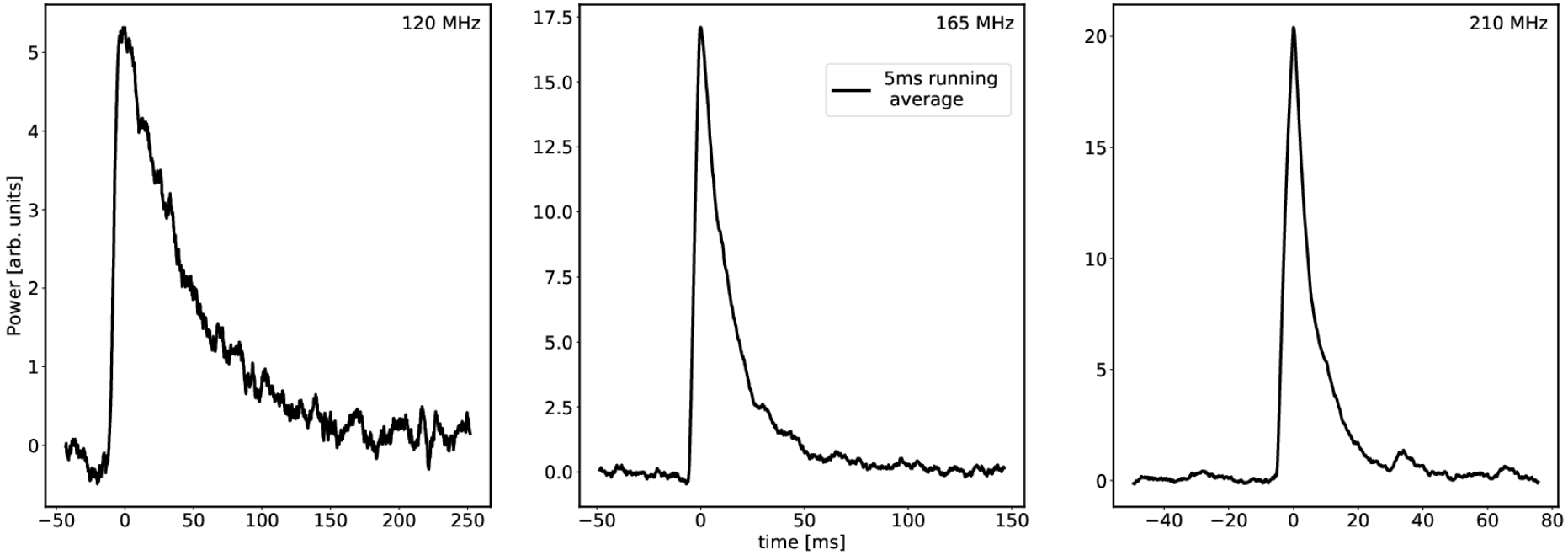
Thin Screen: $\alpha = -4.0 \pm 1.5$

Thick Screen: $\alpha = -5.0 \pm 1.5$

Results: The Crab pulsar

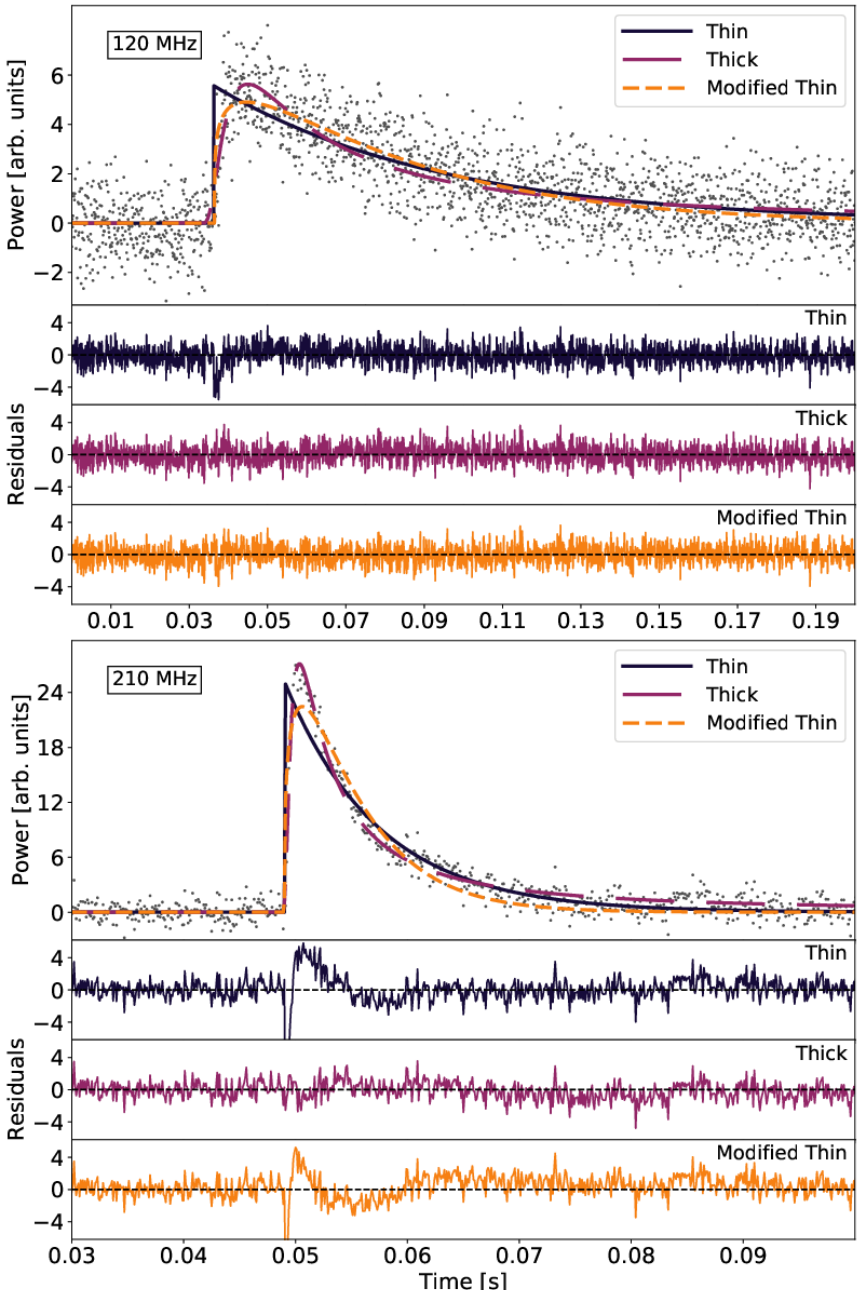


Giant Pulse

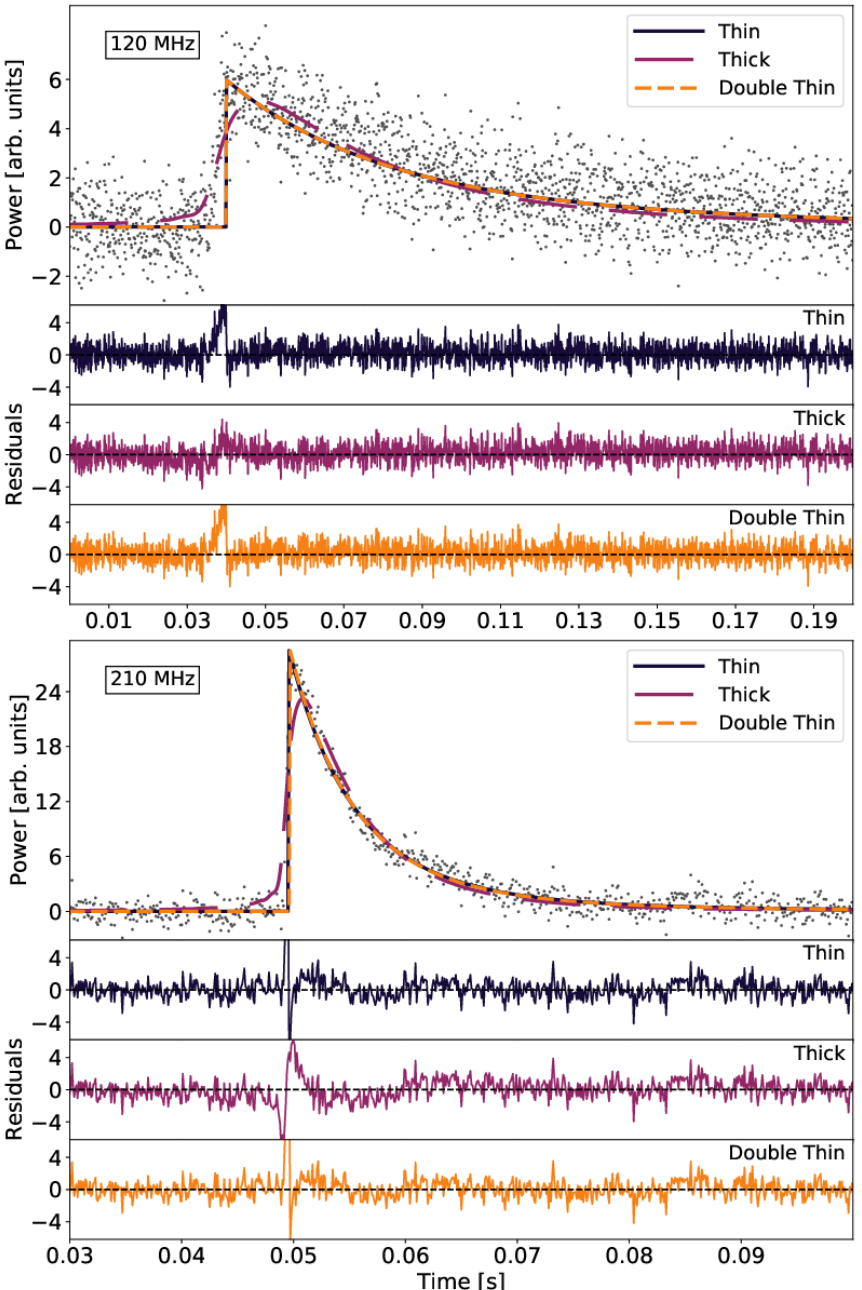


Results: The Crab pulsar

Square law structure function

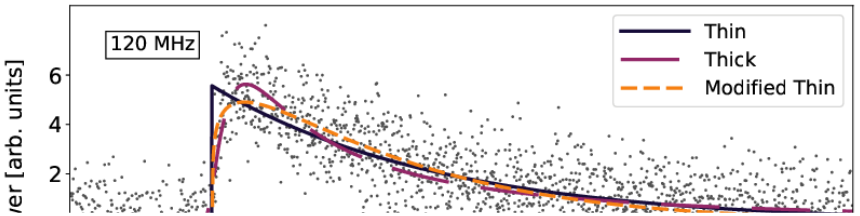


Fully diffractive Kolmogorov turbulence



Results: The Crab pulsar

Square law structure function



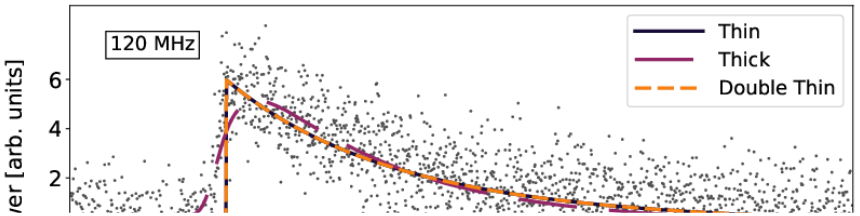
Square law structure function

Thin Screen: $\alpha = -3.5 \pm 0.1$

Thick Screen: $\alpha = -3.8 \pm 0.2$

Modfied Thin: $\alpha = -3.9 \pm 0.1$

Fully diffractive Kolmogorov turbulence

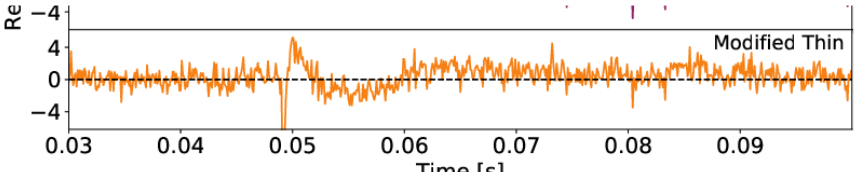


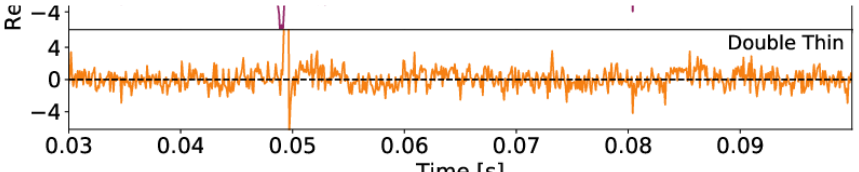
Fully diffractive Kolmogorov turbulence

Thin Screen: $\alpha = -3.7 \pm 0.2$

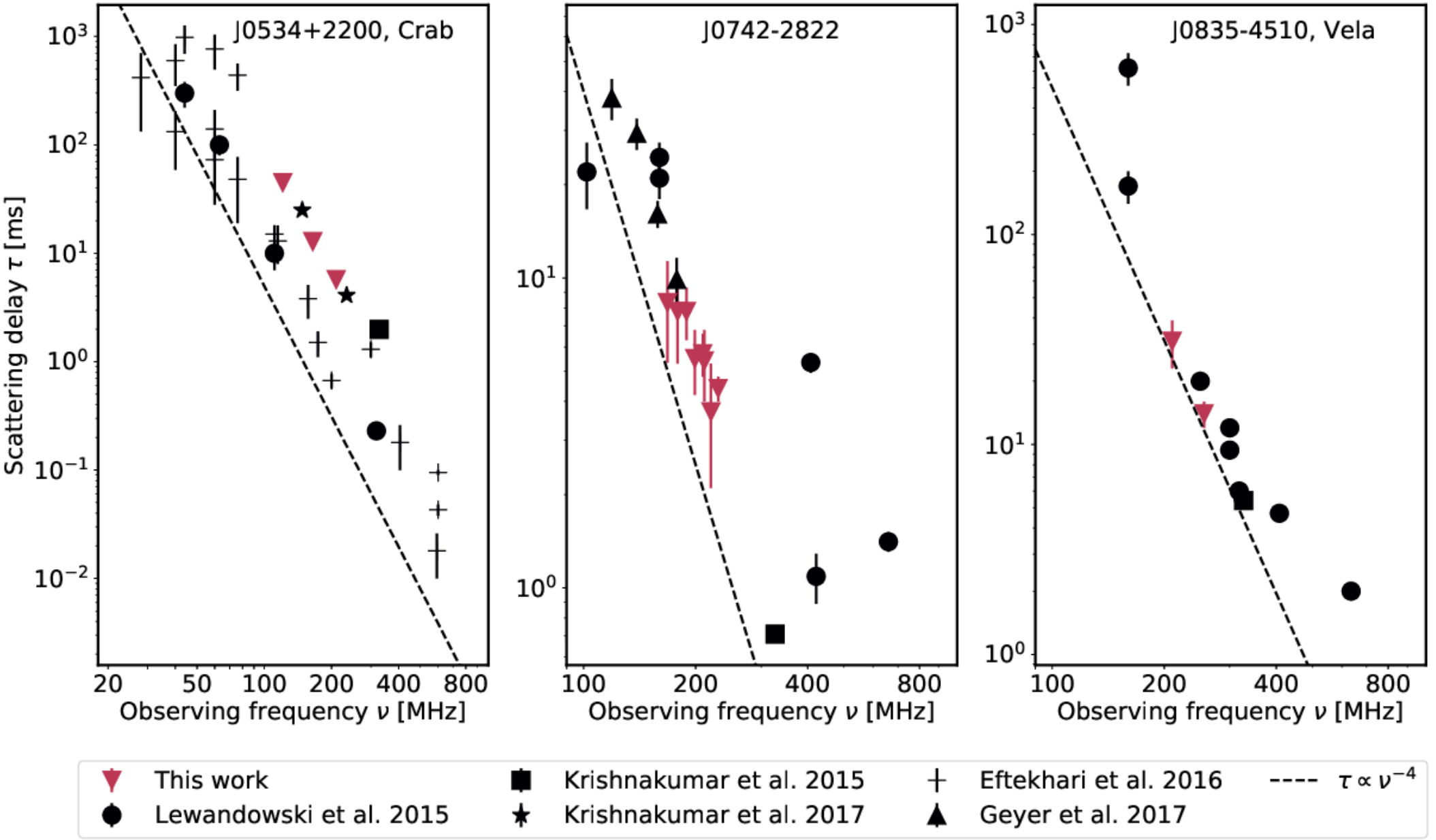
Thick Screen: $\alpha = -3.6 \pm 0.3$

Double Thin: $\alpha = -3.7 \pm 0.2$





Comparison with previous work



Summary

→ High sensitivity and large flexibility of MWA allowed us to measure the scattering spectral index in as short as 5 minute observations

→ Simultaneous broadband observations essential to exclude bias in measurement due to temporal variability of scattering

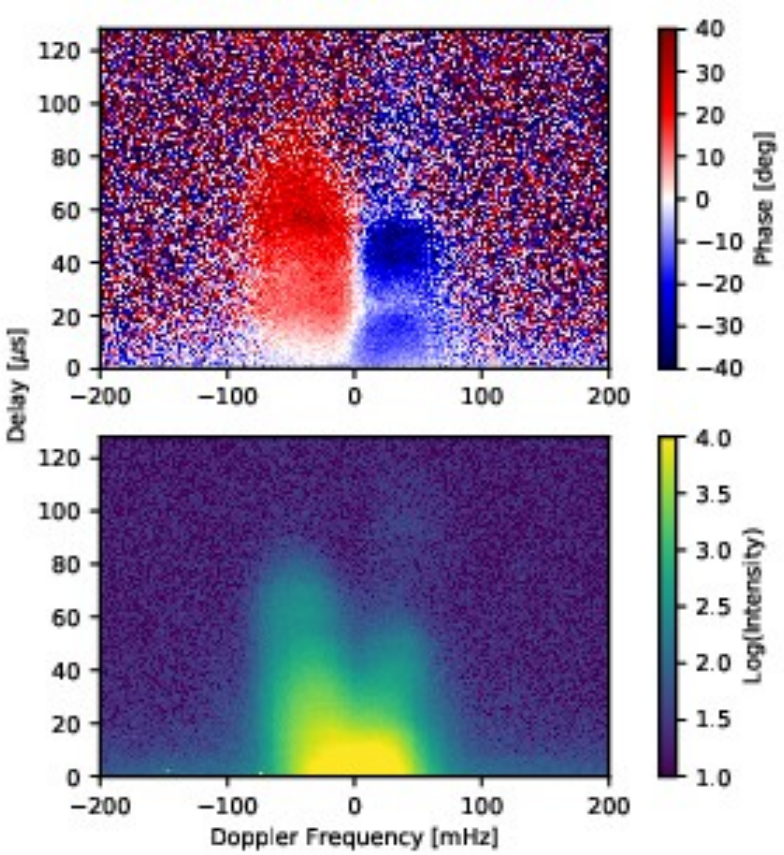
→ For the Vela Pulsar and also PSR J0742-2822 thin screen model provides a better fit to the data – most likely scattering is dominated by Gum Nebula

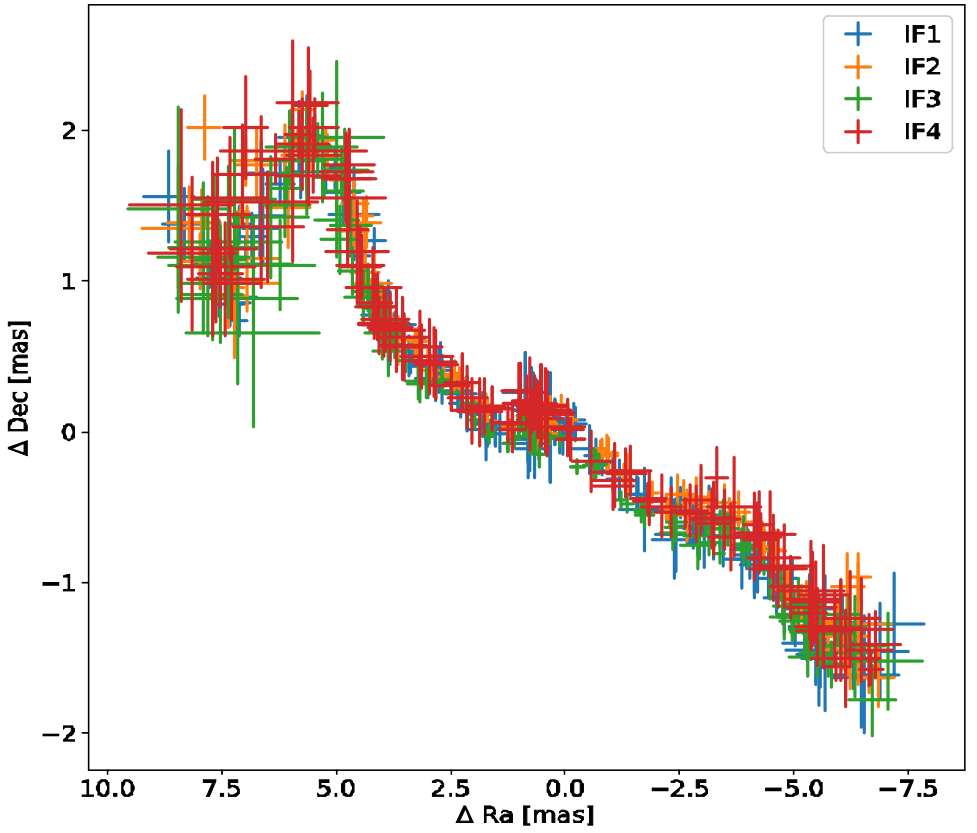
→ The giant pulse of the Crab Pulsar is best described by a thick screen model

→ All α we measure are less than 4.4, even less than 4 → existence of an inner scale of turbulence?

→ will apply same idea to more pulsars, invest more observing time, try variety of models

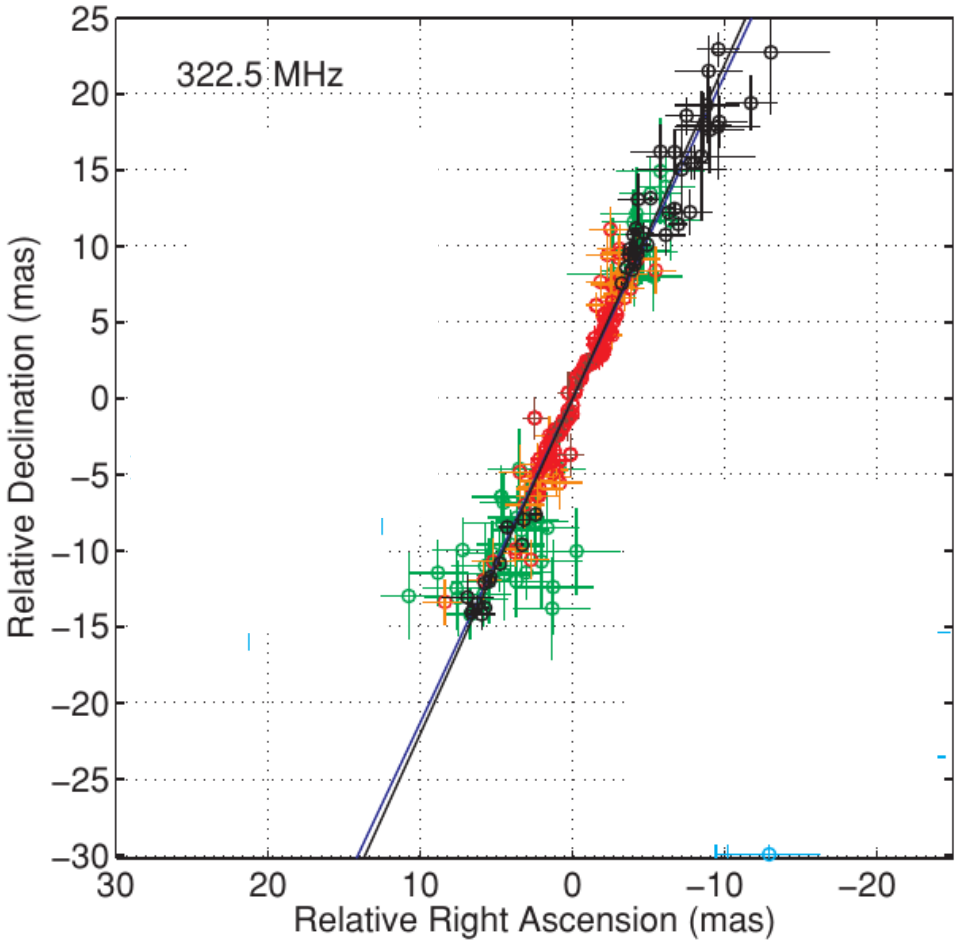
LBA Vela Scintillation



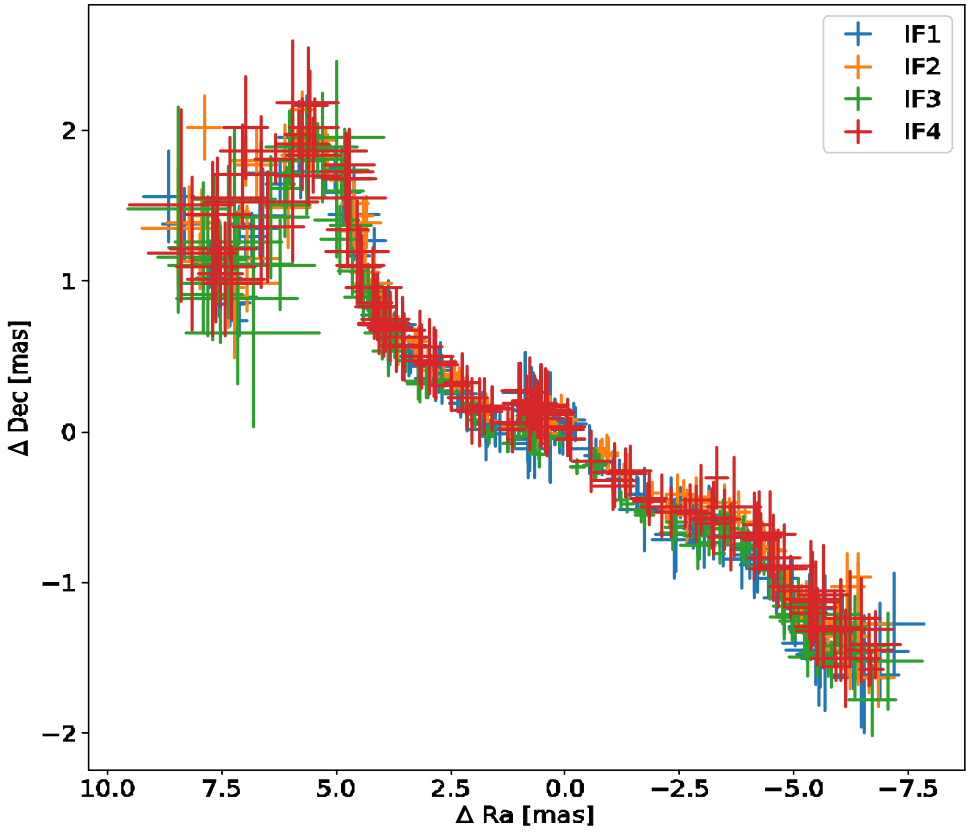


Kirsten et al., in prep

LBA Vela Scintillation



B0834+06, Brisken et al., 2010



Kirsten et al., in prep

Thank you

Extras – Figures of Merit