Summary

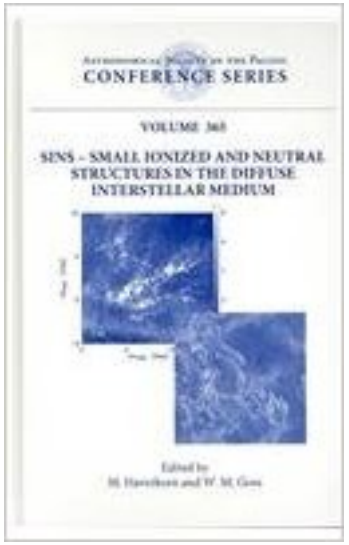
- Multi-path scattering in the ISM produces a wealth of info.
- Detecting gravitational waves with pulsars requires dealing with ISM scattering delays.
- Advanced signal processing techniques are yielding new insights.
- LOFAR is a powerful telescope for studying ISM effects in the 100 – 200 MHz range.

SINS - Small Ionized and Neutral Structures in the Diffuse Interstellar Medium

Proceedings

Marijke Haverkorn (Editor) ,
W. M. Goss (Editor)

Socorro, New Mexico May **2006**



Sins!

Macquart & Melrose, 2000

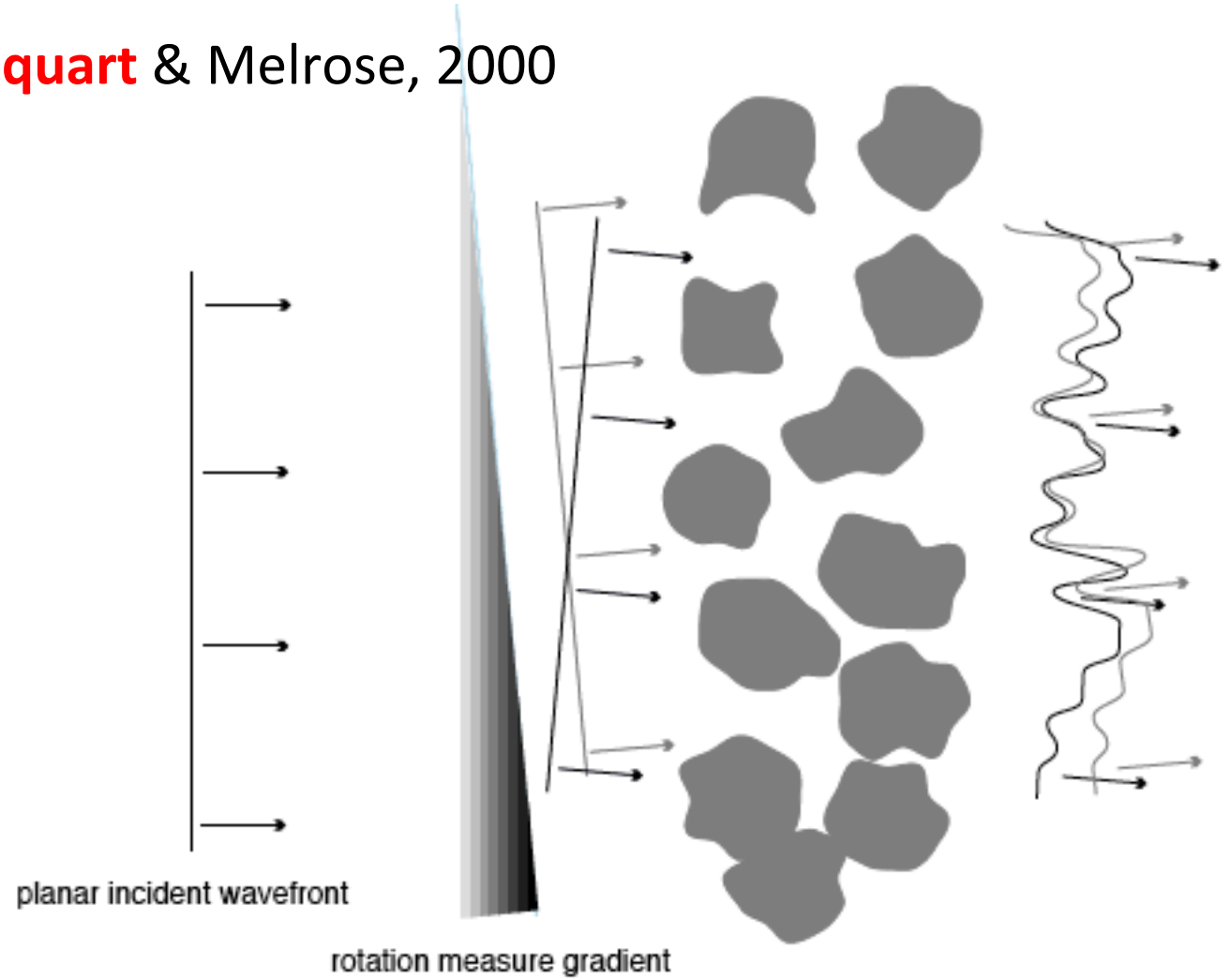
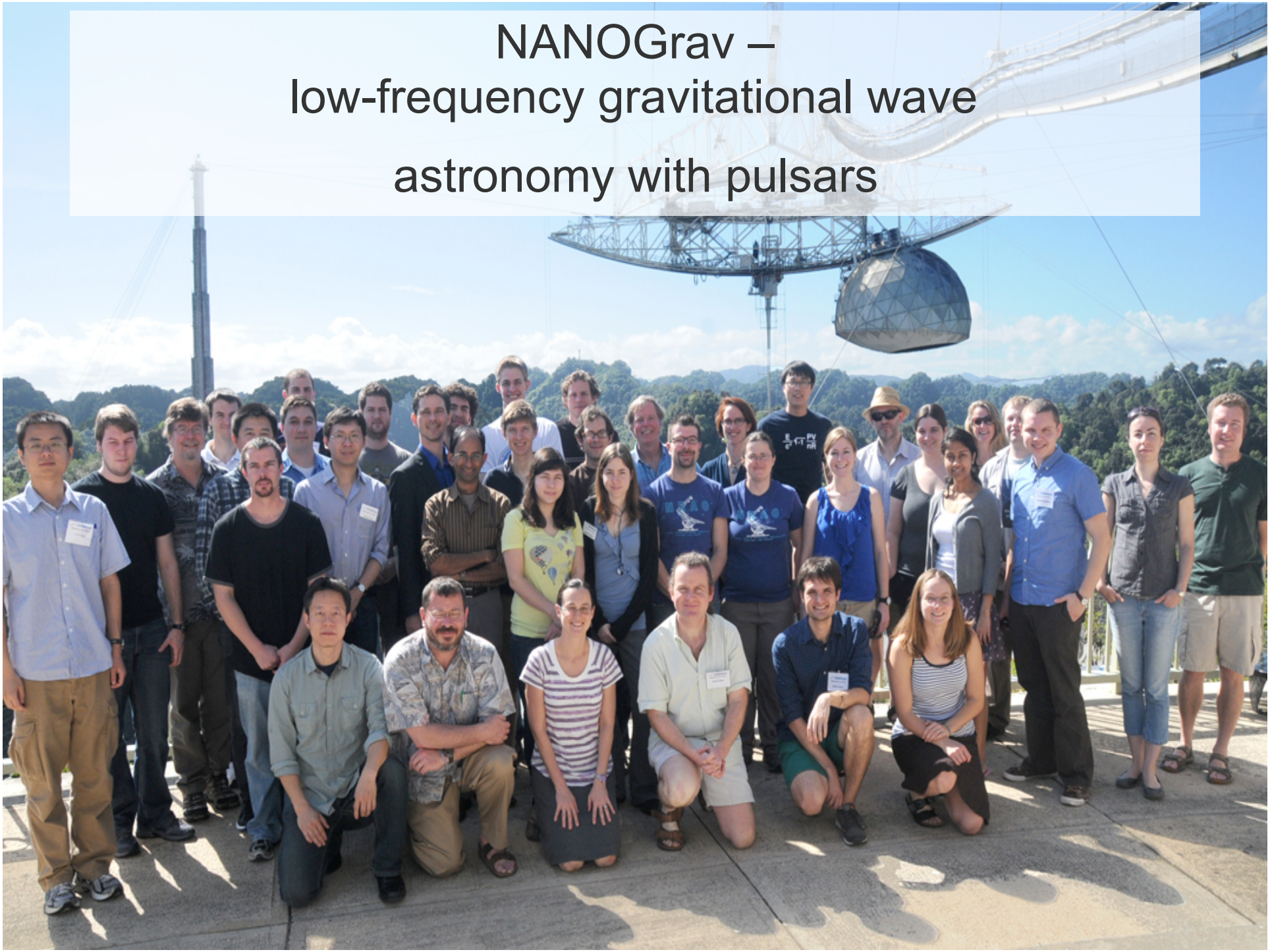


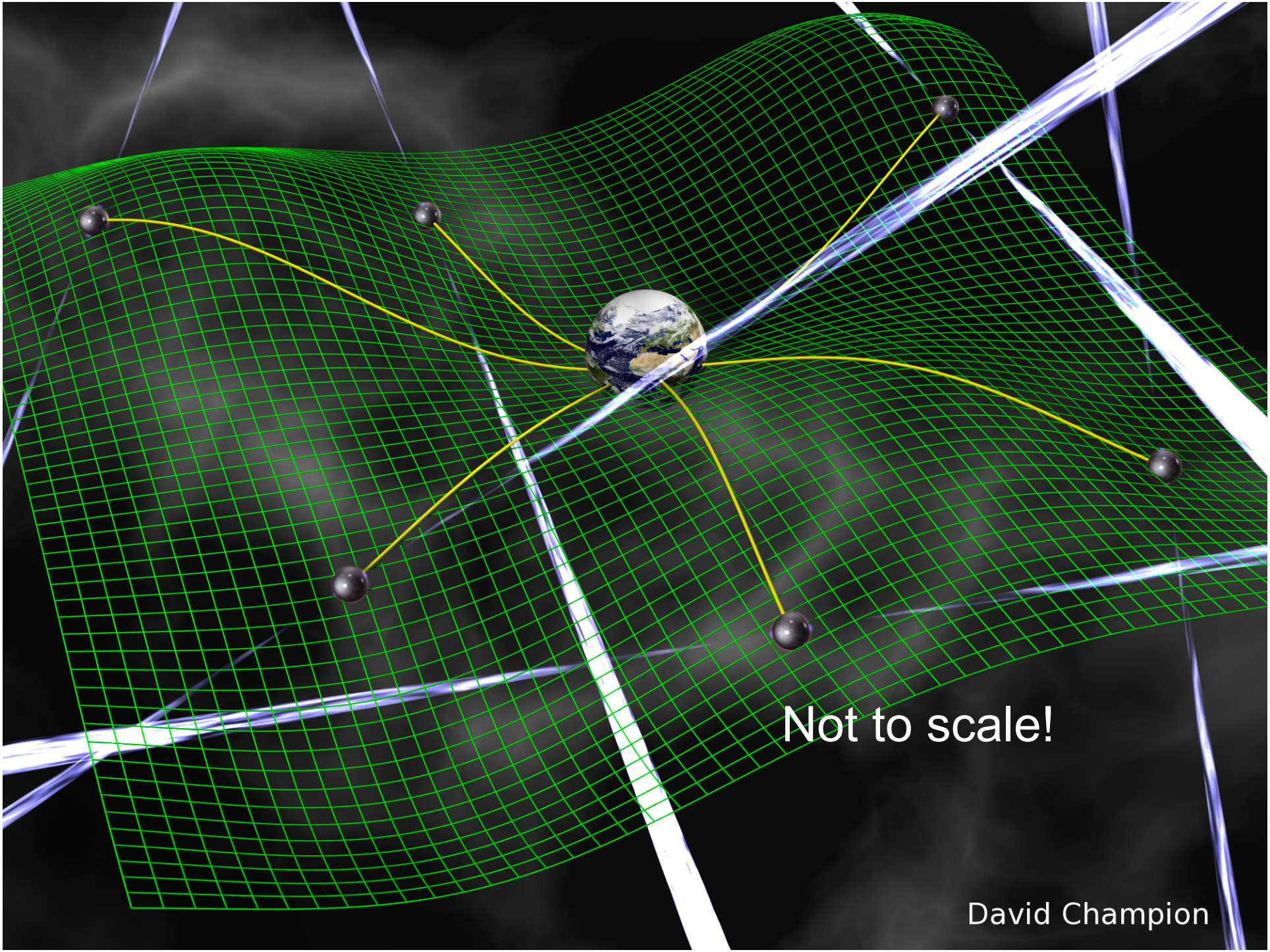
FIG. 3.—Schematic of the Faraday wedge from the viewpoint of physical optics. A RM gradient causes a difference in the ray paths of the left- and right-hand circularly polarized wave fronts. Upon arrival at the Earth, the scintillation pattern of one wave front is slightly displaced with respect to the other, leading to variability in the CP.

NANOGrav –
low-frequency gravitational wave

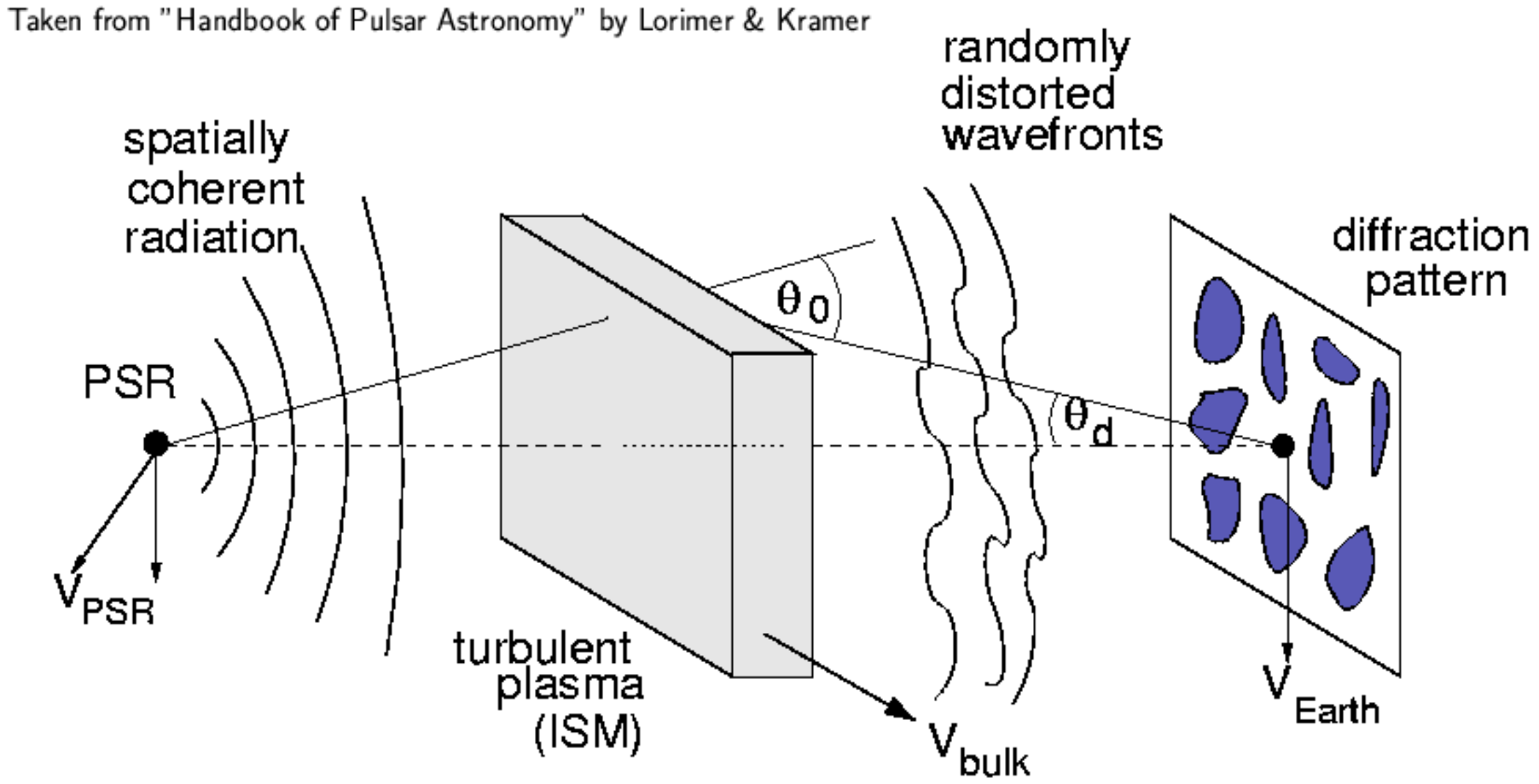
astronomy with pulsars



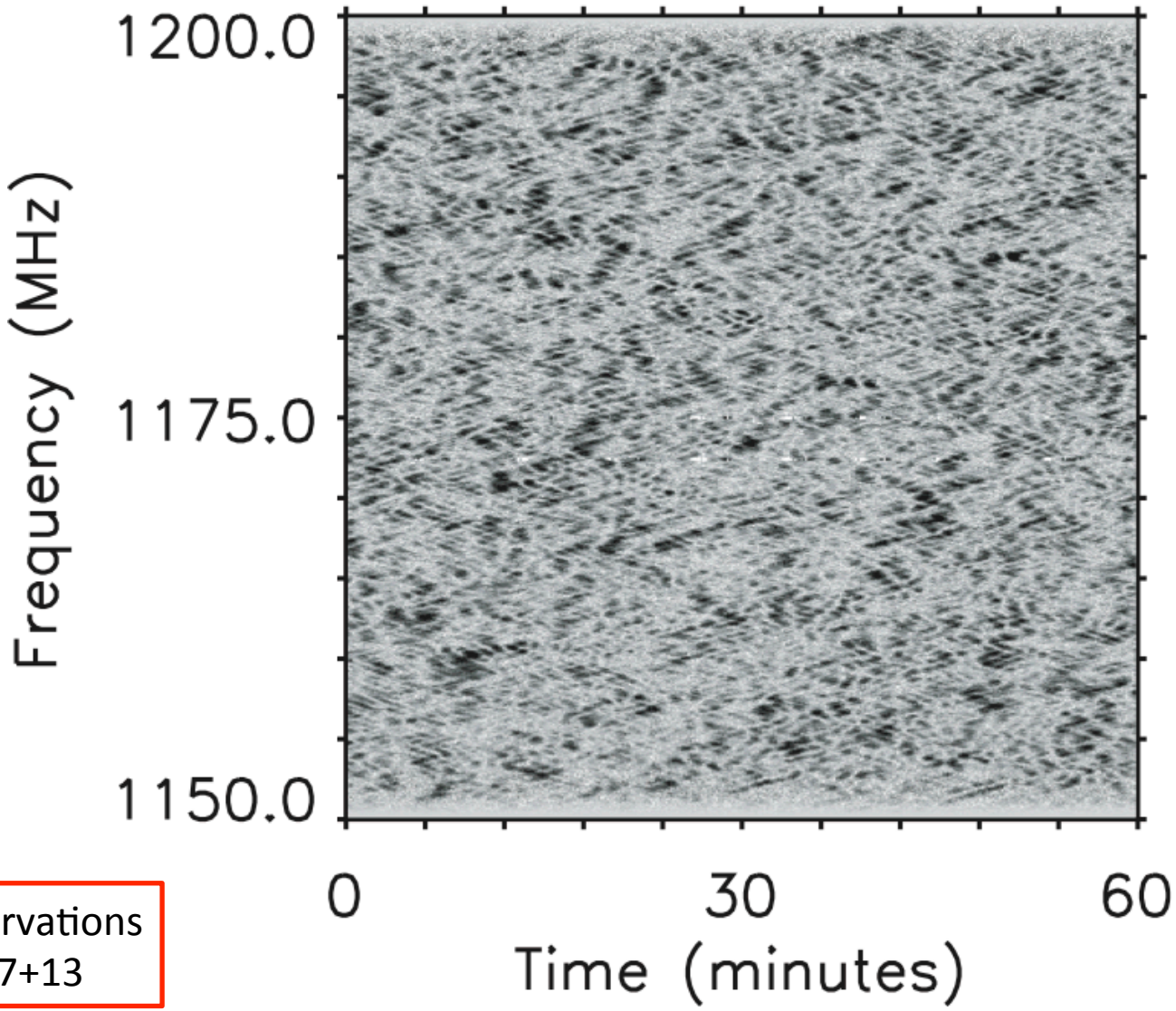
Our other vital telescope!


Not to scale!
David Champion

Multi-path scattering in the ISM



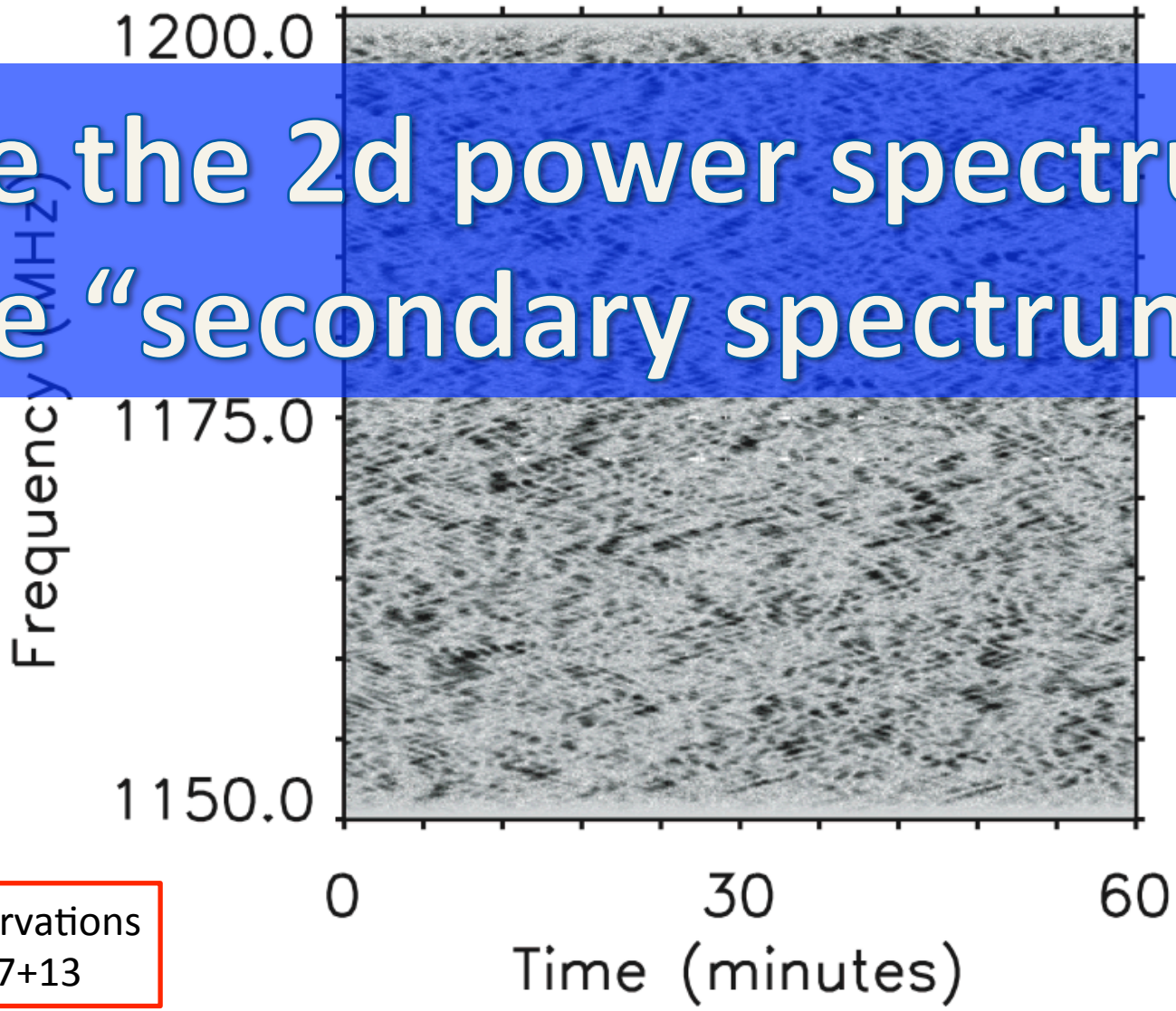
also, a frequency dependent angle of scattering (and net phase)



Arecibo observations
PSR B1737+13

Hemberger and Stinebring 2008, ApJ, 674, L37

Take the 2d power spectrum, the "secondary spectrum"



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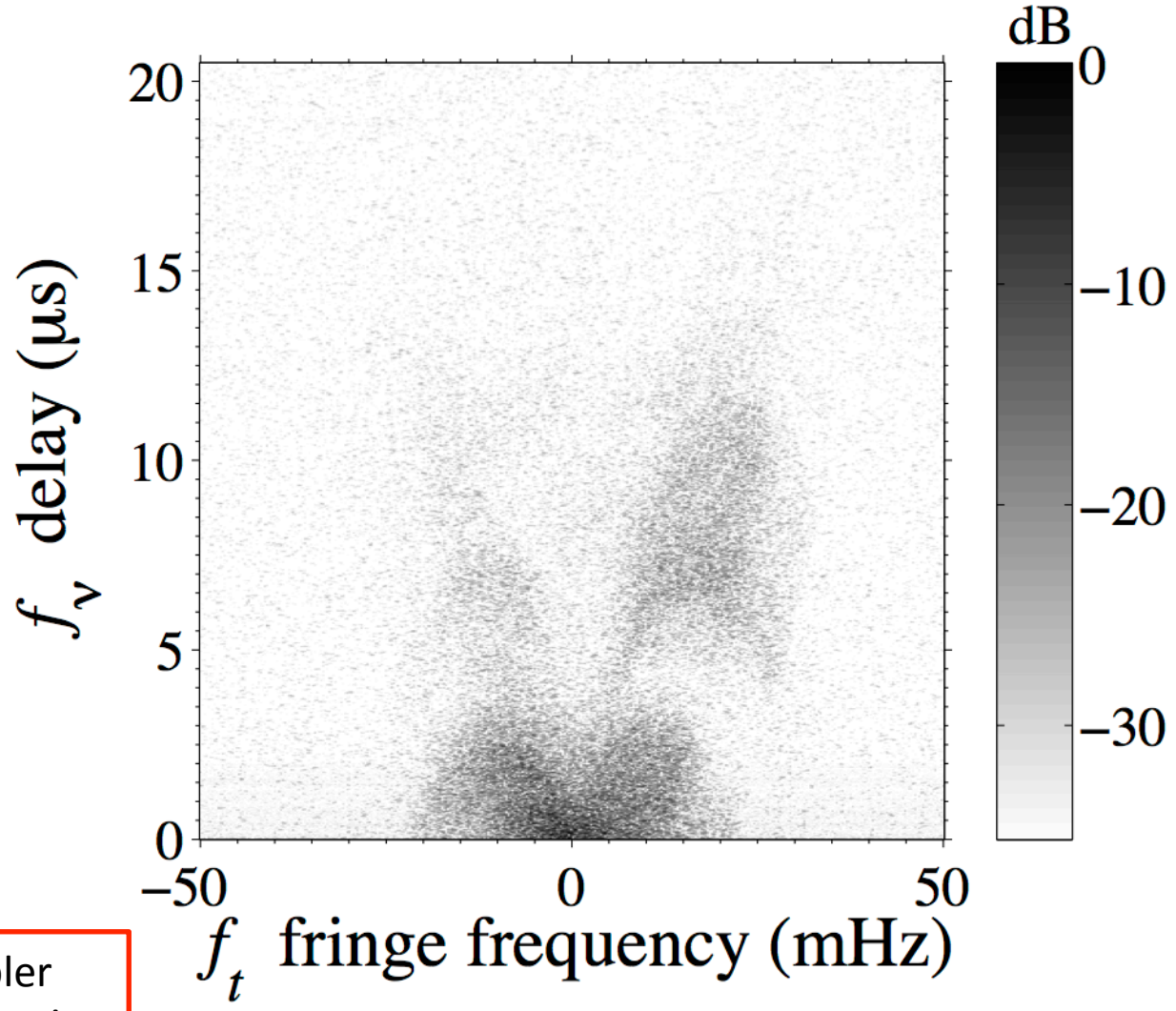
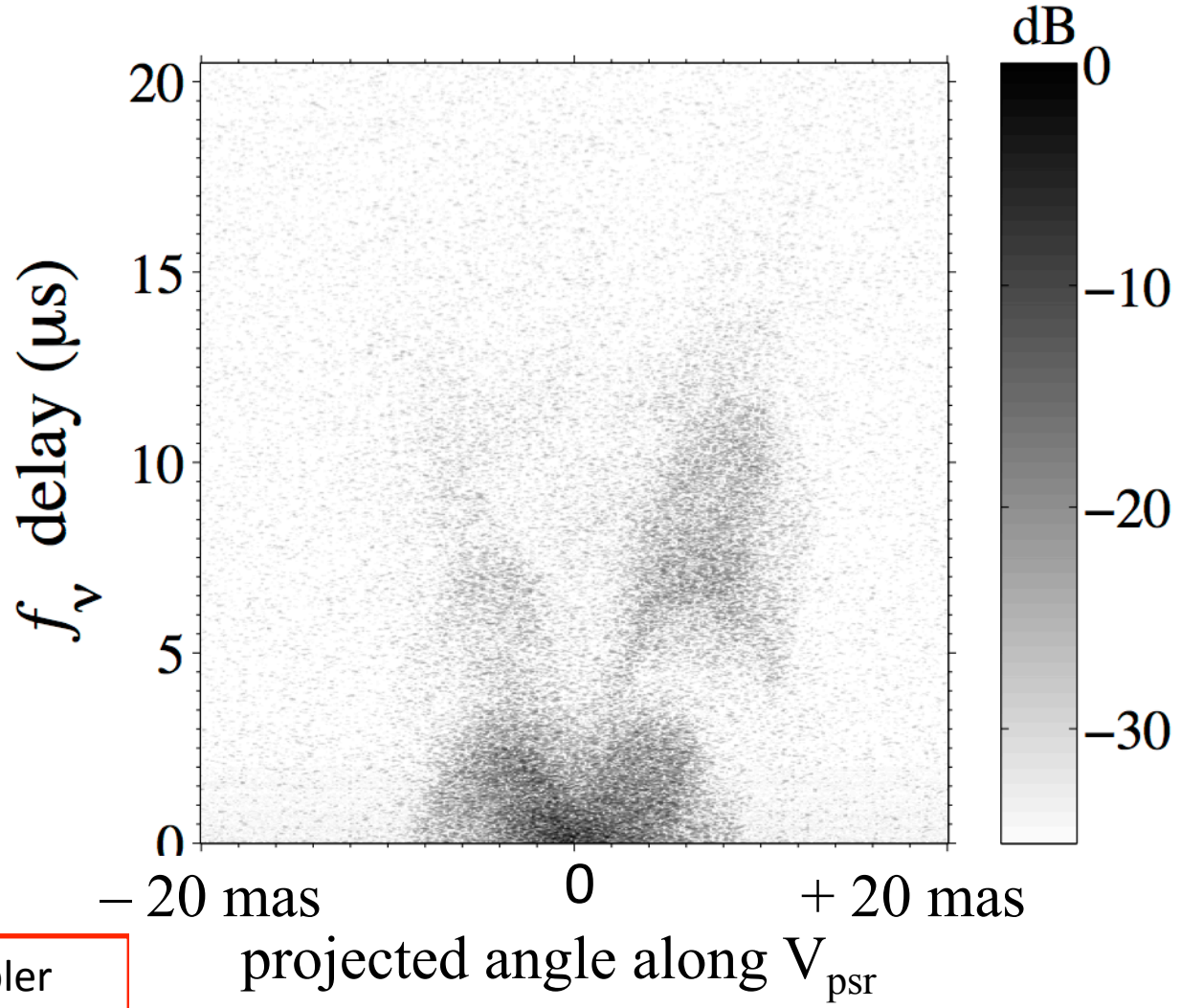


Delay-Doppler imaging information

Hemberger and Stinebring 2008, ApJ, 674, L37



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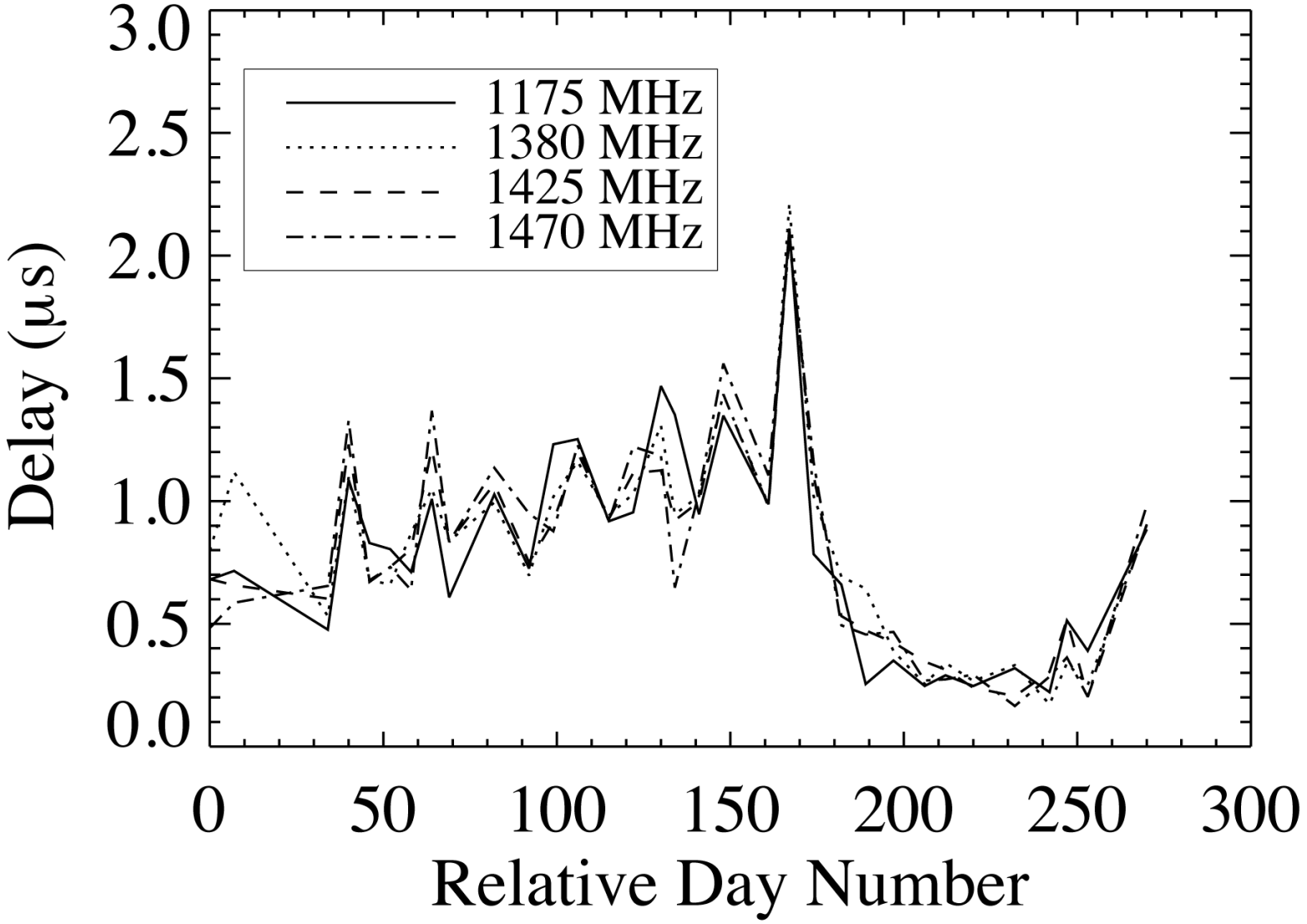
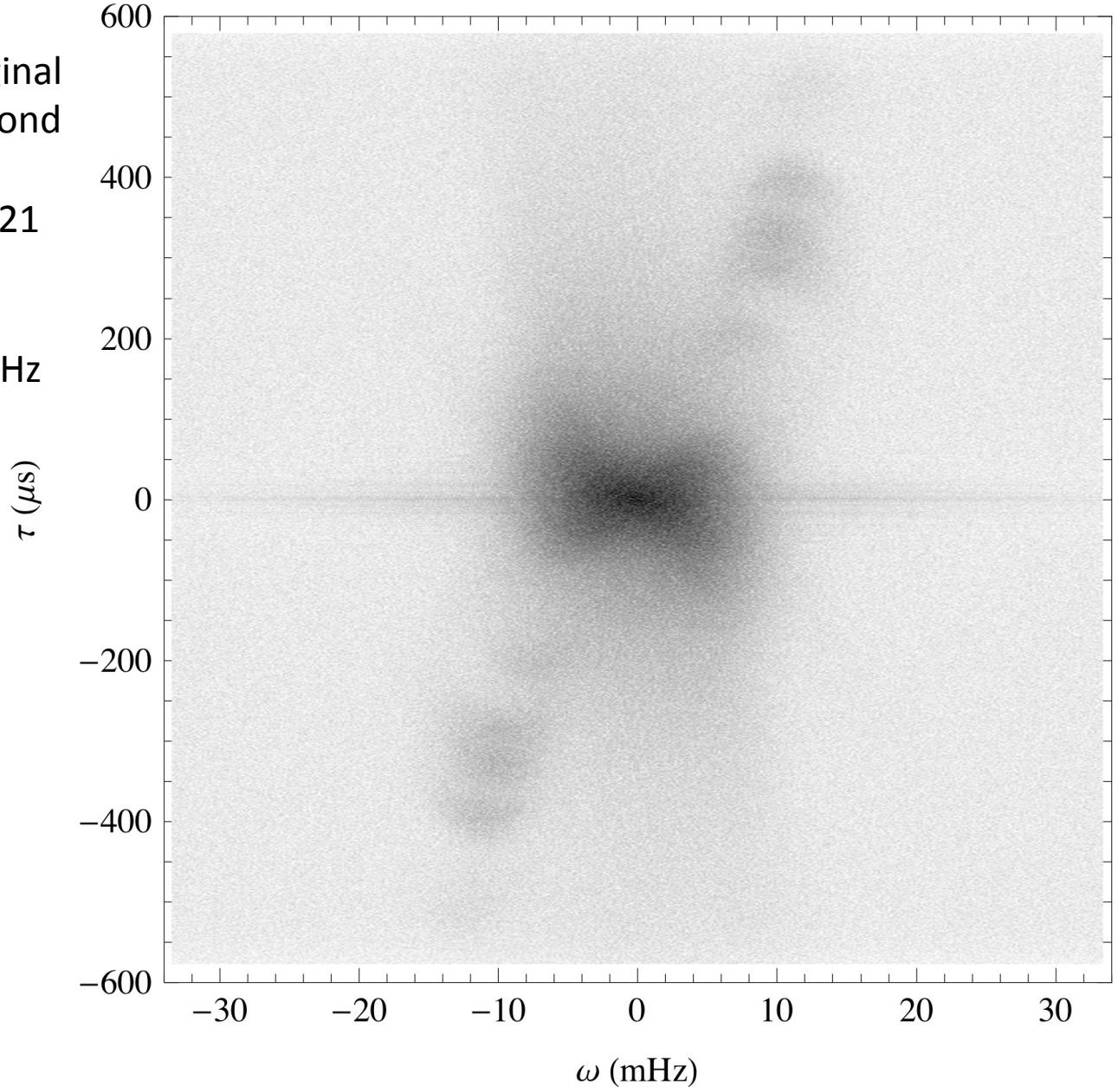


Hemberger and Stinebring 2008, ApJ, 674, L37

the original millisecond pulsar B1937+21

Arecibo 1400 MHz



Walker, Demorest, and van Straten 2014, ApJ, accepted

Mark Walker kept wondering …

- 2004 Walker, Melrose, DS, Zhang 2004
- 2005 Walker, DS 2005
- 2008 Walker, DS, Koopmans, van Straten
- 2011 Demorest “Cyclic Spectroscopy”
- 2014 Walker, Demorest, van Straten

Cyclic Spectrum

- The standard spectrum of the source is

$$S_i(\nu) = < |\tilde{\epsilon}_i(\nu)|^2 >$$

$$\alpha_k = \frac{k}{P}$$

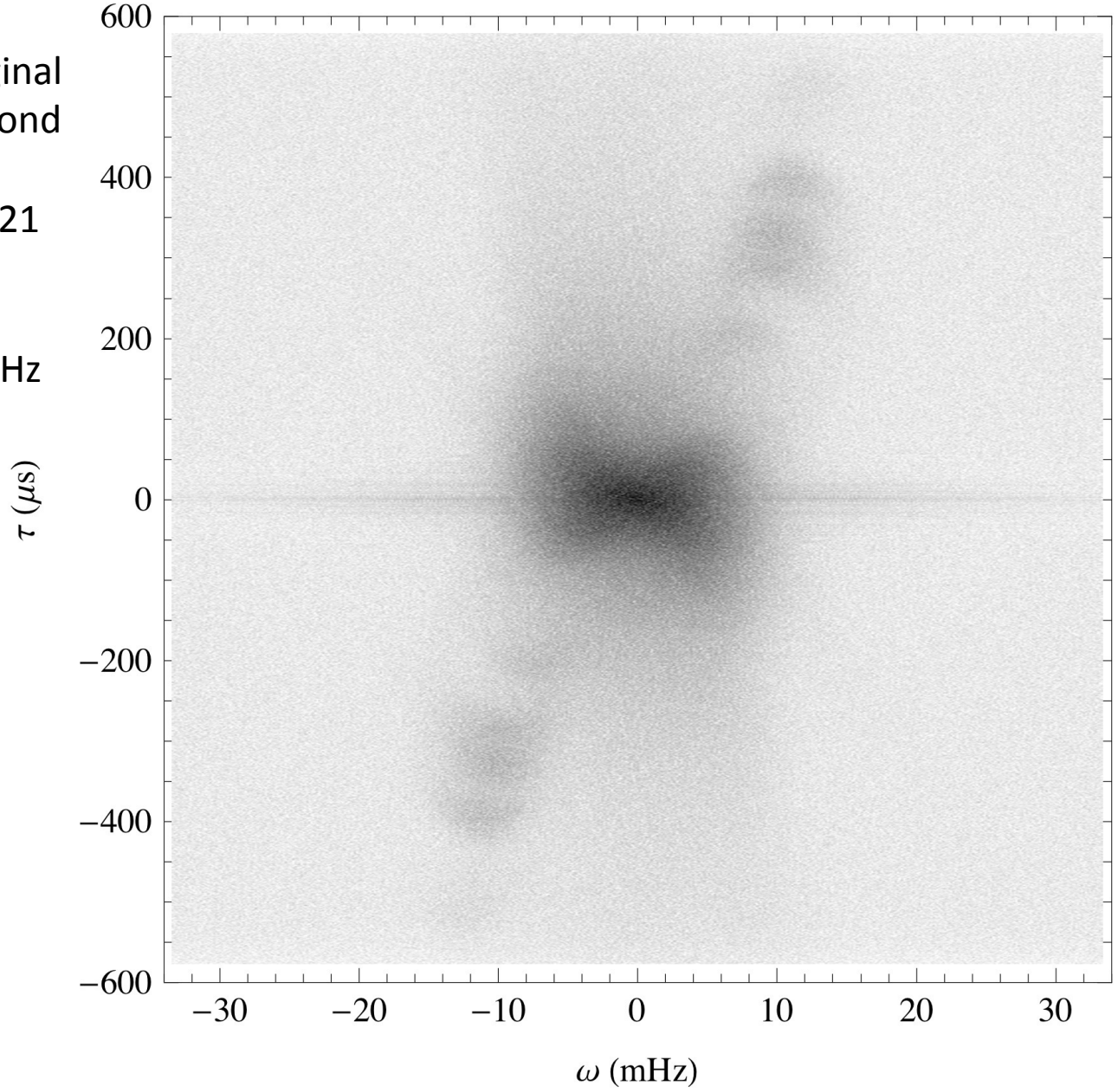
$$k = 0, 1, 2, \ldots$$

- But, the spectrum can be generalized for a periodic source (Demorest 2011)

$$S_i(\nu; \alpha_k) = < \tilde{\epsilon}_i(\nu + \alpha_k/2) \;\; \tilde{\epsilon}_i^*(\nu - \alpha_k/2) >$$

the original millisecond pulsar B1937+21

Arecibo 1400 MHz



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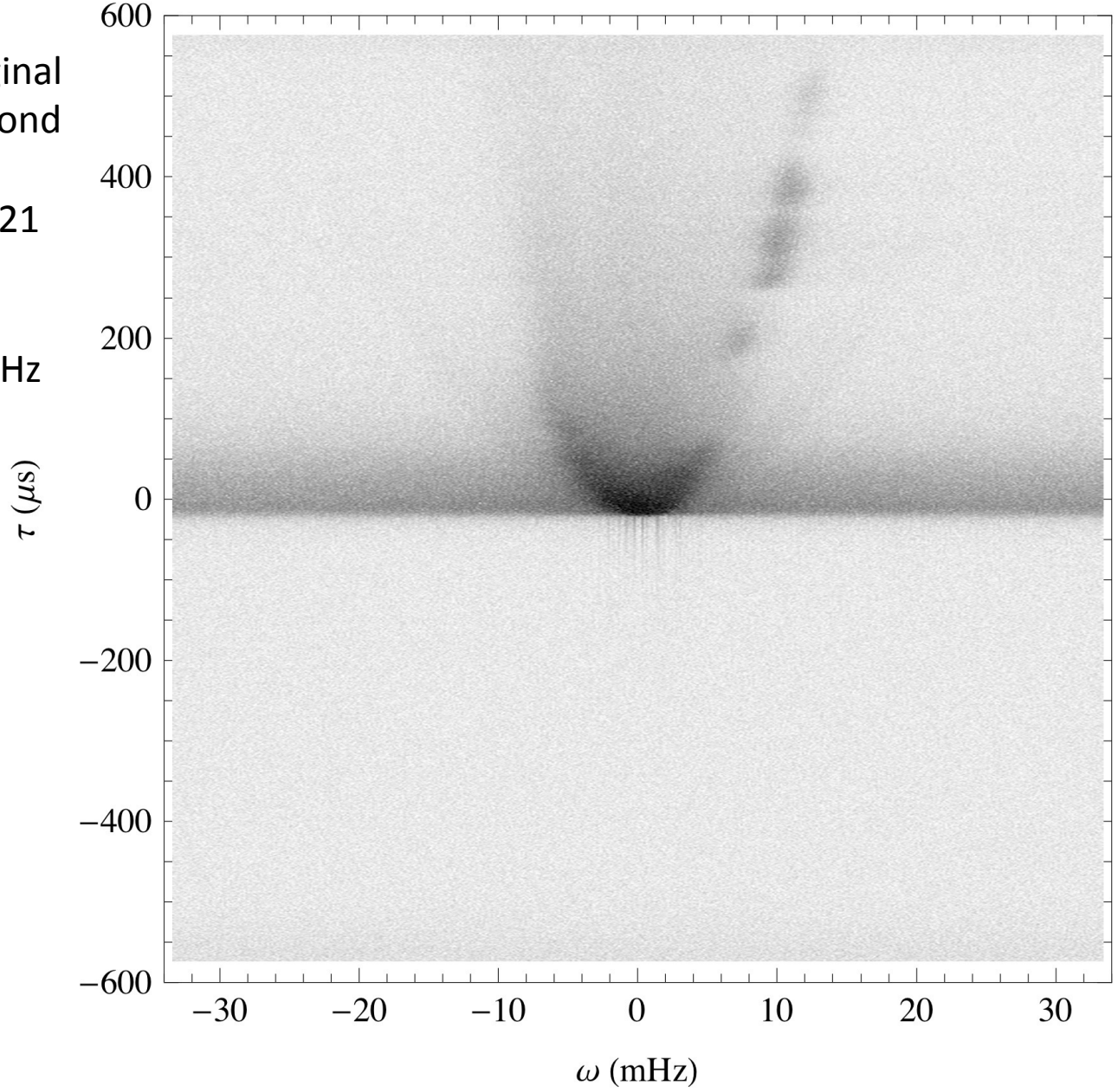
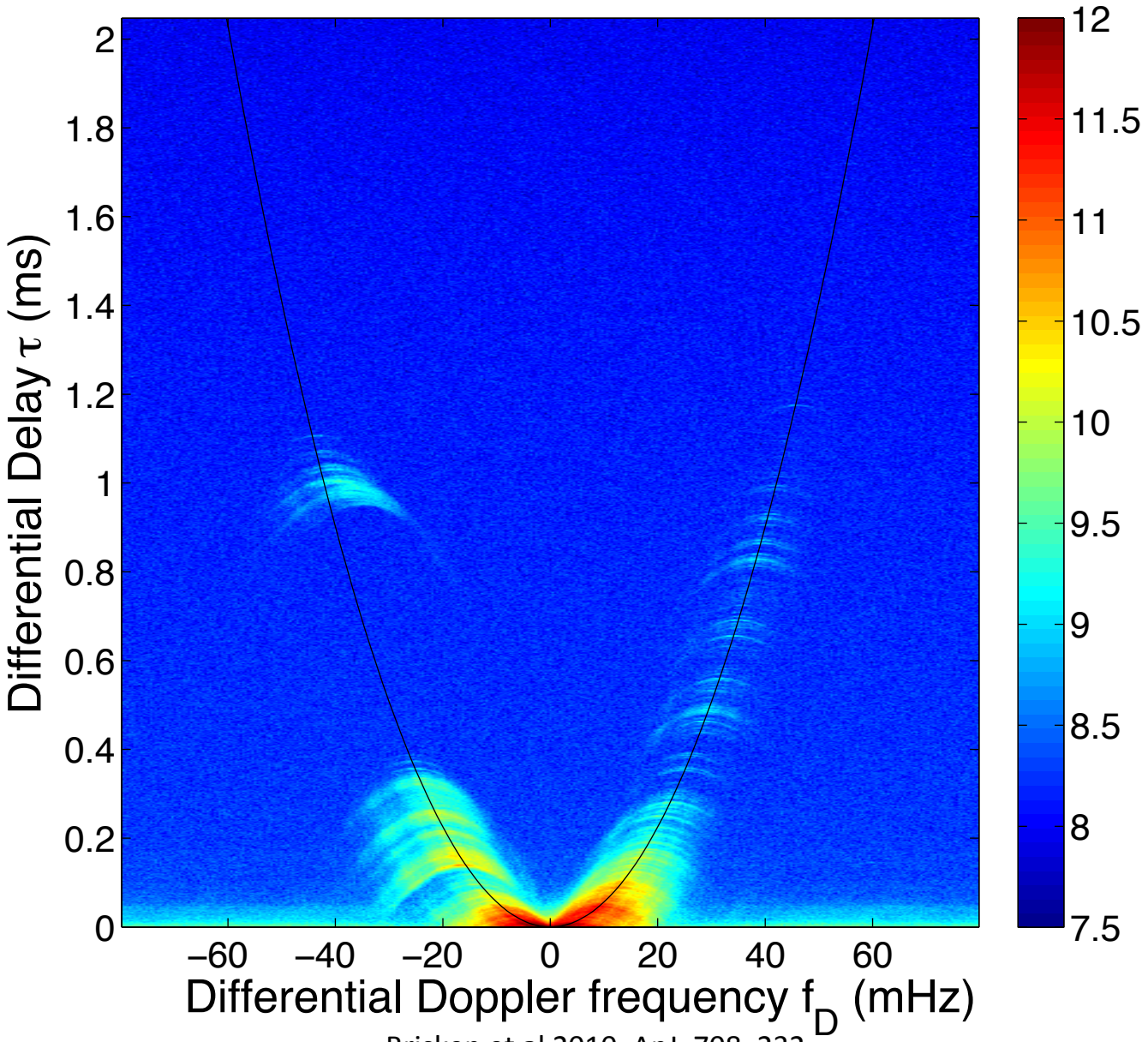


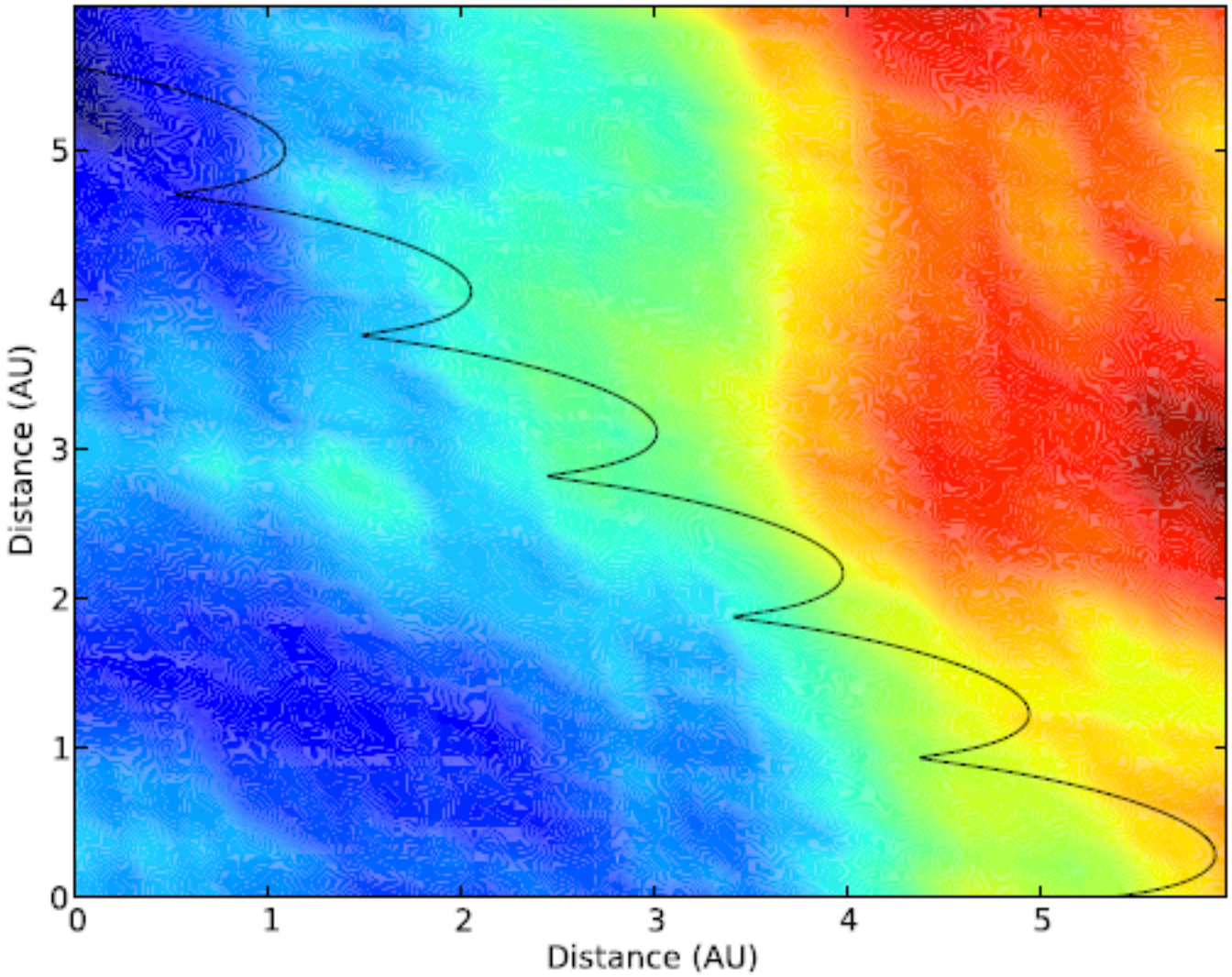
Walker, Demorest, and van Straten 2014, ApJ, accepted



Brisken et al 2010, ApJ, 708, 232

How we like to model the ISM:

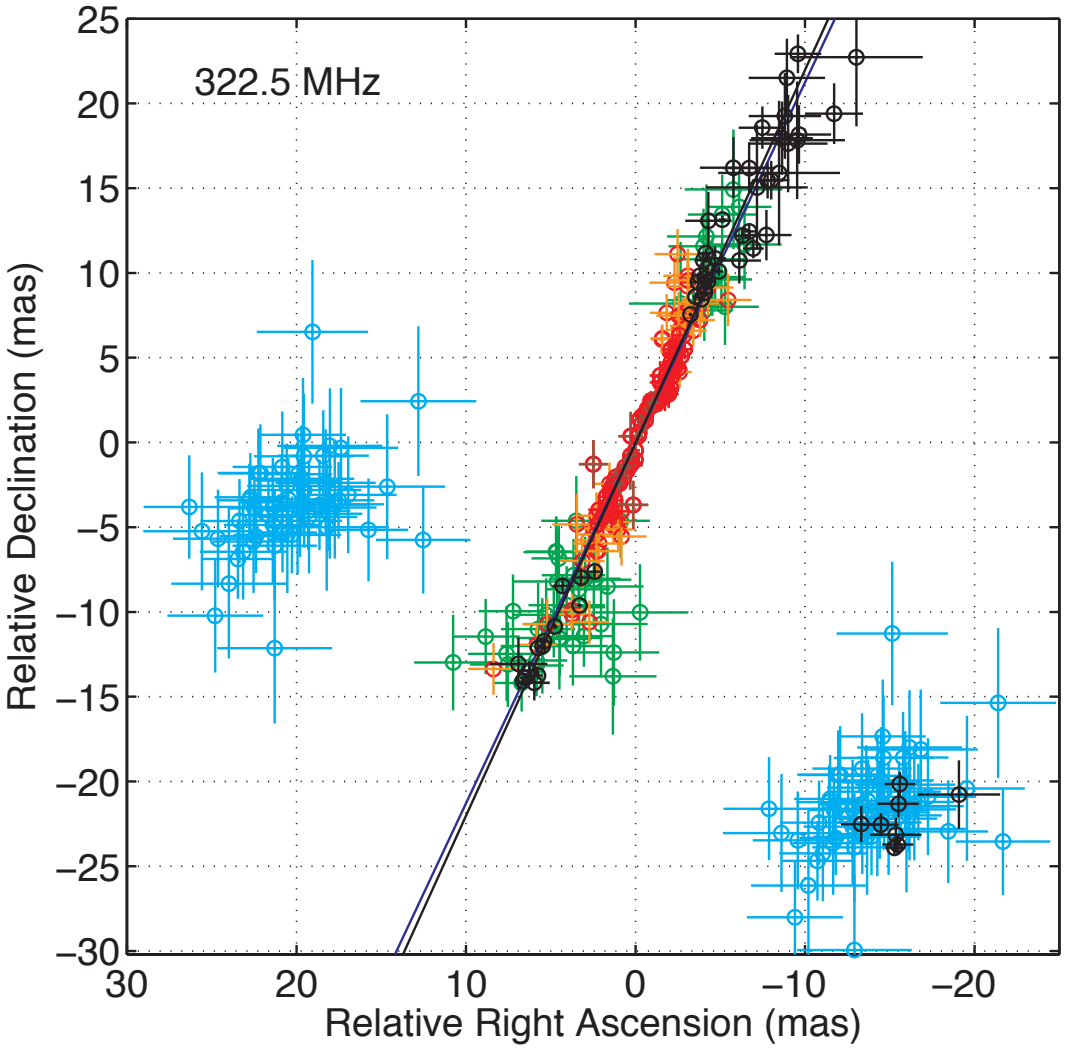
Kolmogorov, isotropic, homogeneous



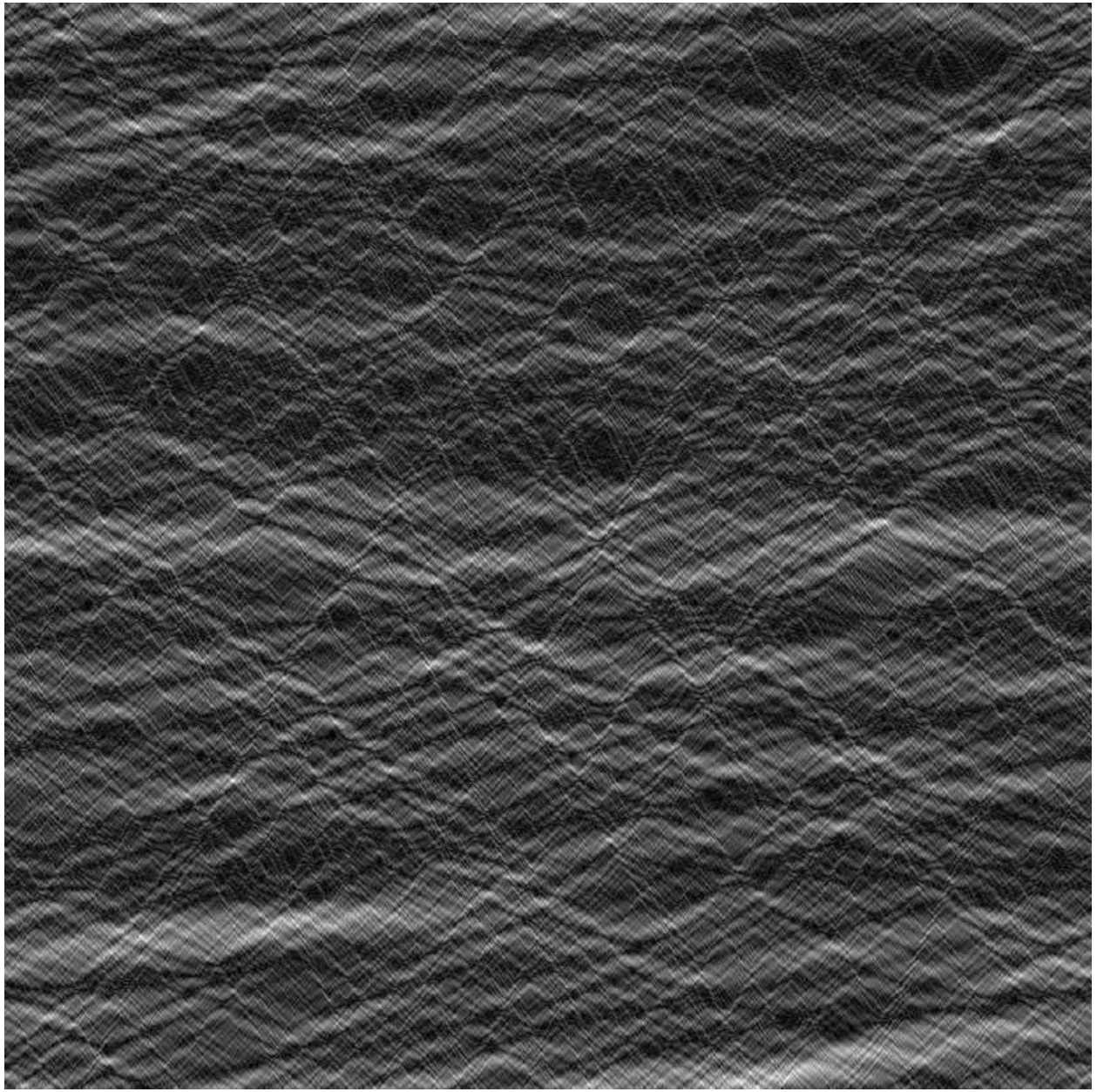
Keith et al 2012 arXiv: 1211.5887

The reality:

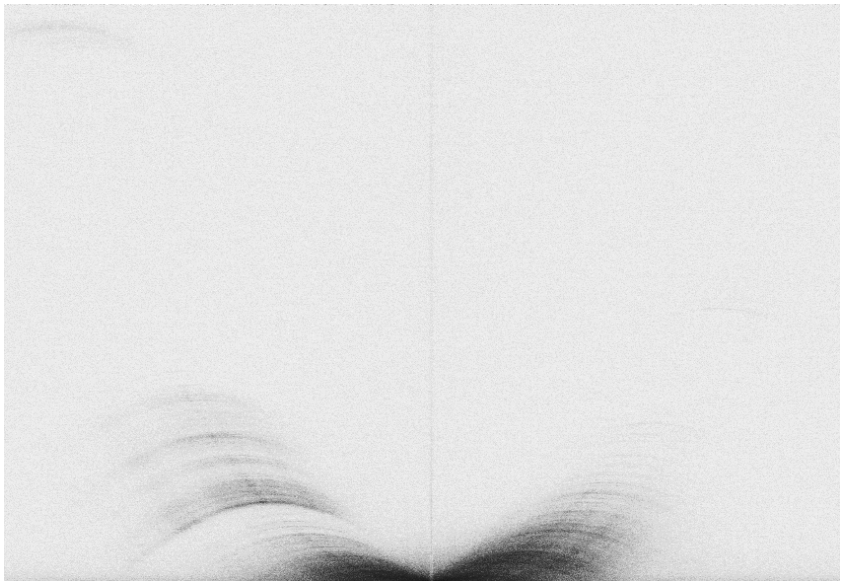
(non-Kolmogorov), anisotropic, intermittent



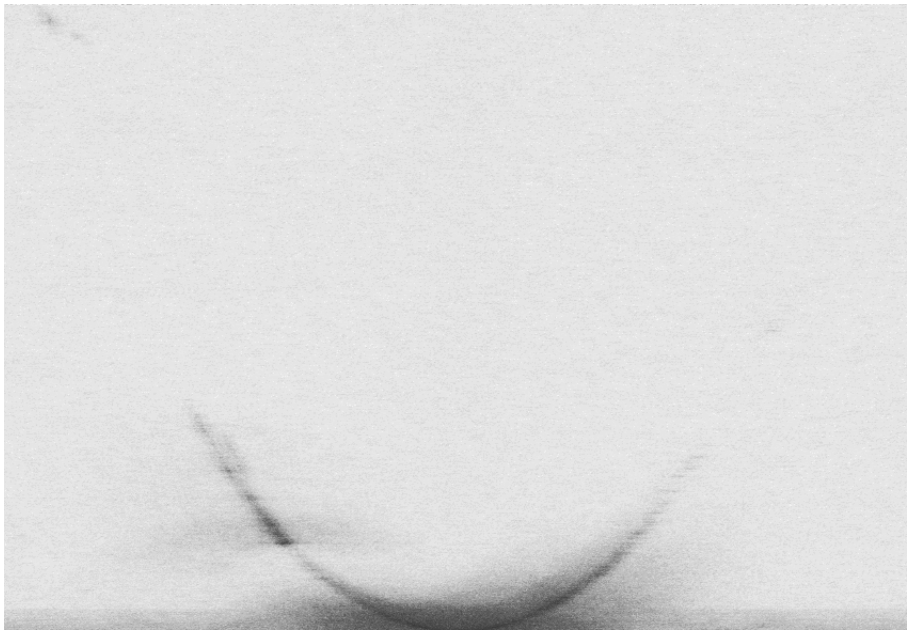
Brisken et al. 2010



Pen and Levin 2013

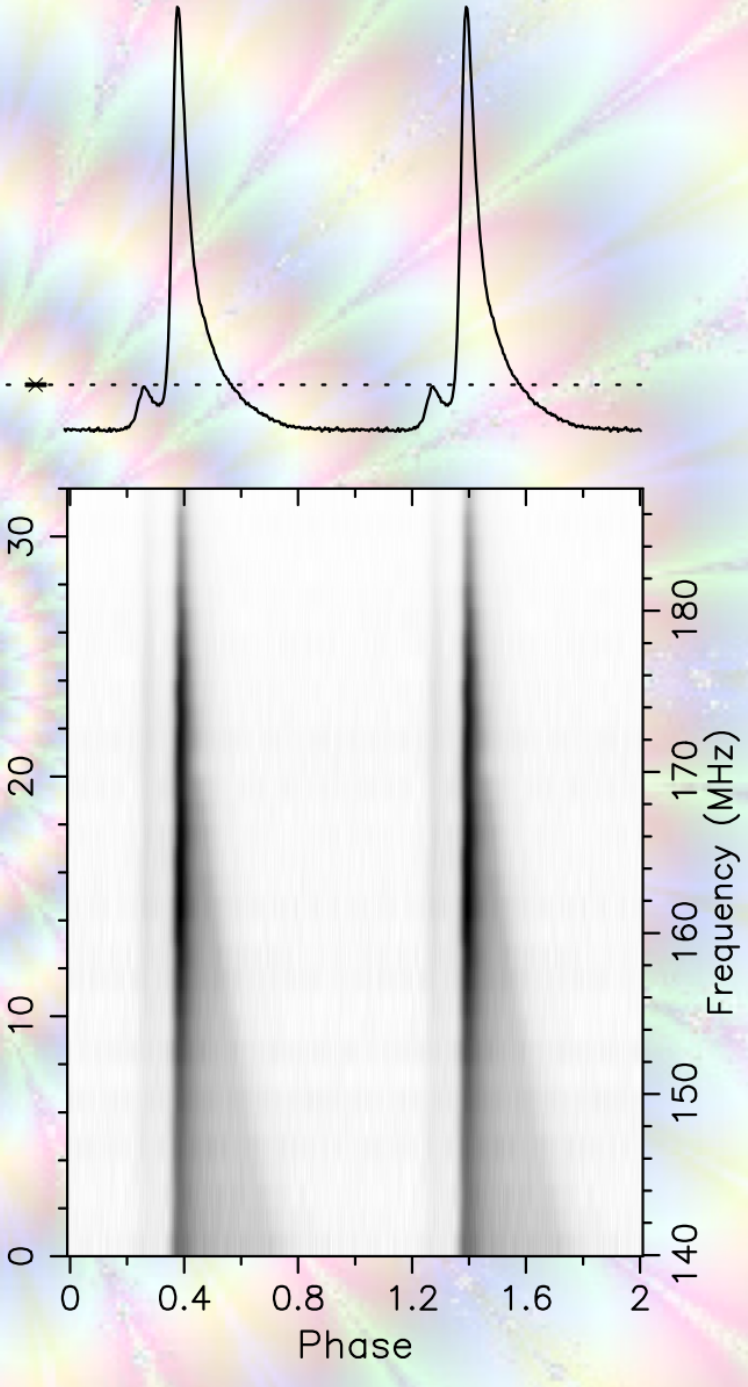


Pen, Macquart, Deller, and Brisken 2013



cycling near
ASTRON

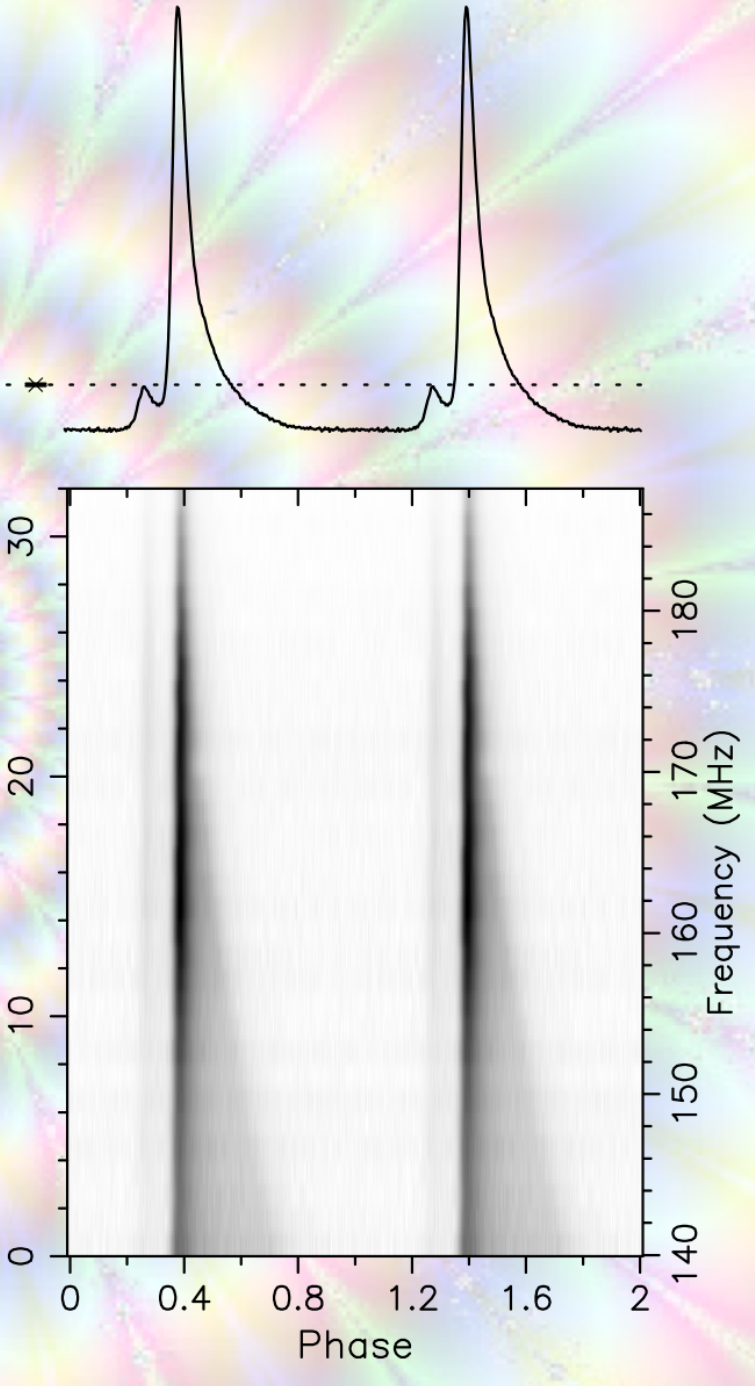
PSR B2111+46's Groovy Pulse Profile



ASTRON daily image 2012-07-31, Jason Hessels

PSR B2111+46's Groovy Pulse Profile

LOFAR observation (1/4 of the core and half the frequency range – the upper half)



ASTRON daily image 2012-07-31, Jason Hessels

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