Pulsars at Low Frequencies: Some Ideas

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New Mexico Tech
SCIENCE · ENGINEERING · RESEARCH · UNIVERSITY

NRAO

Science objectives

- What can be learned about :
  - the Interstellar Medium and Solar Corona?
  - the pulsar magnetosphere and radio emission mechanism?
- What previously encountered enigmas can be solved by modern instrumentation?

Propagation through the ISM

- Cold plasma dispersion
  - Electron density × distance

$$\tau_d \propto \lambda^2$$

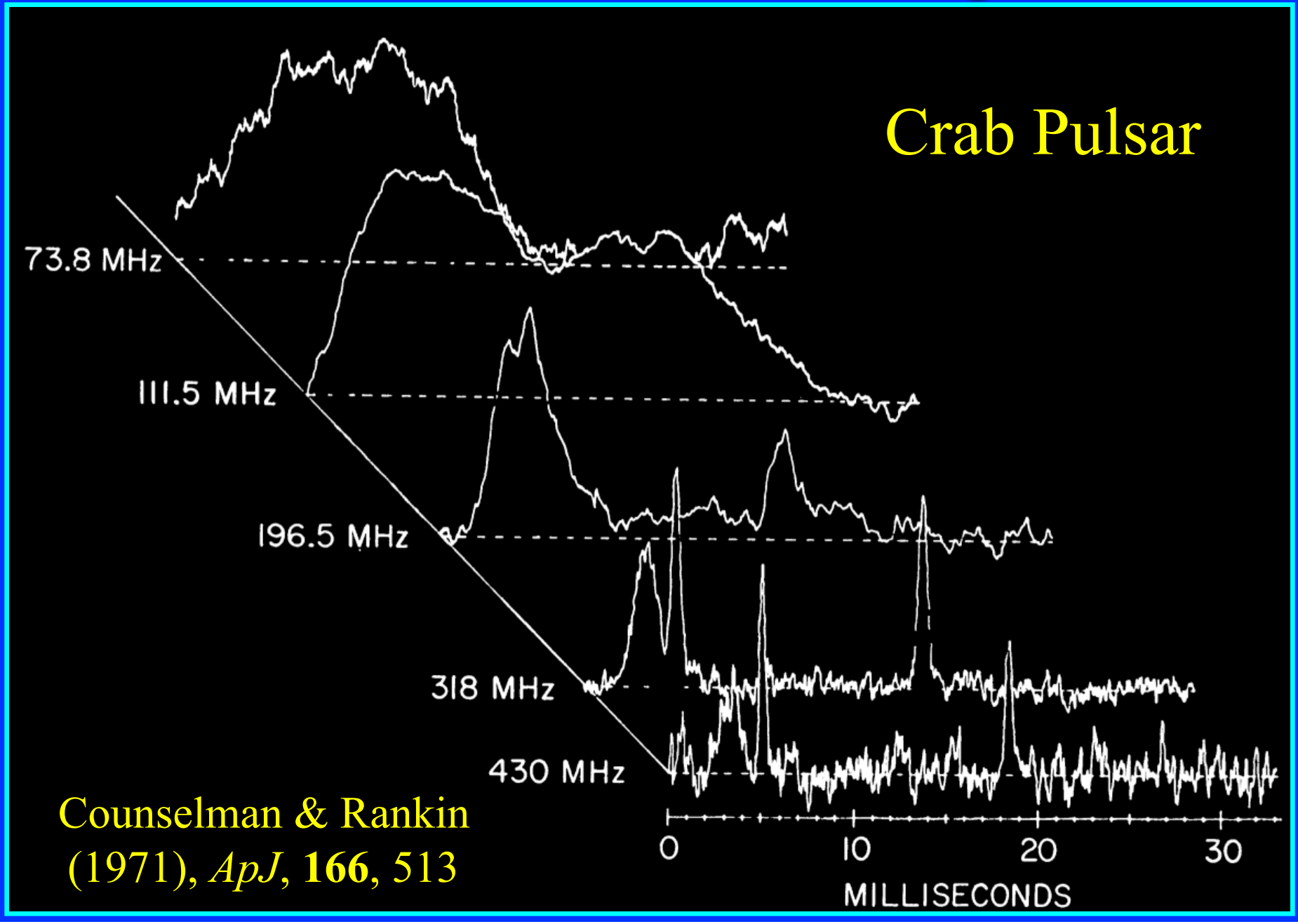
- Faraday rotation
  - $N_e B$ × distance

$$\Delta\varphi \propto \lambda^2$$

- Scattering
  - Fluctuation of index of refraction

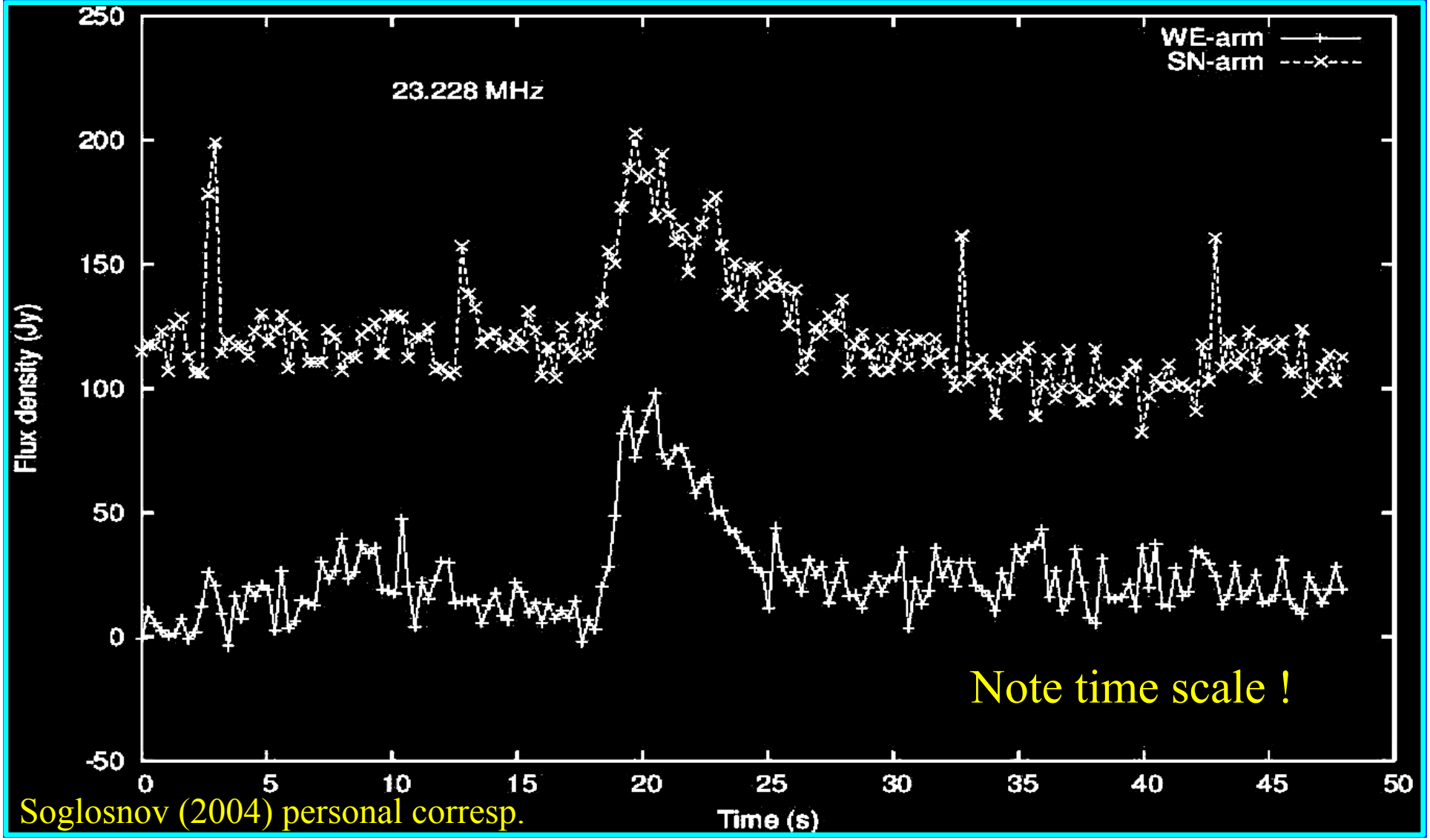
$$\tau_d \propto \lambda^4$$

Interstellar scattering



Counselman & Rankin (1971), *ApJ*, **166**, 513

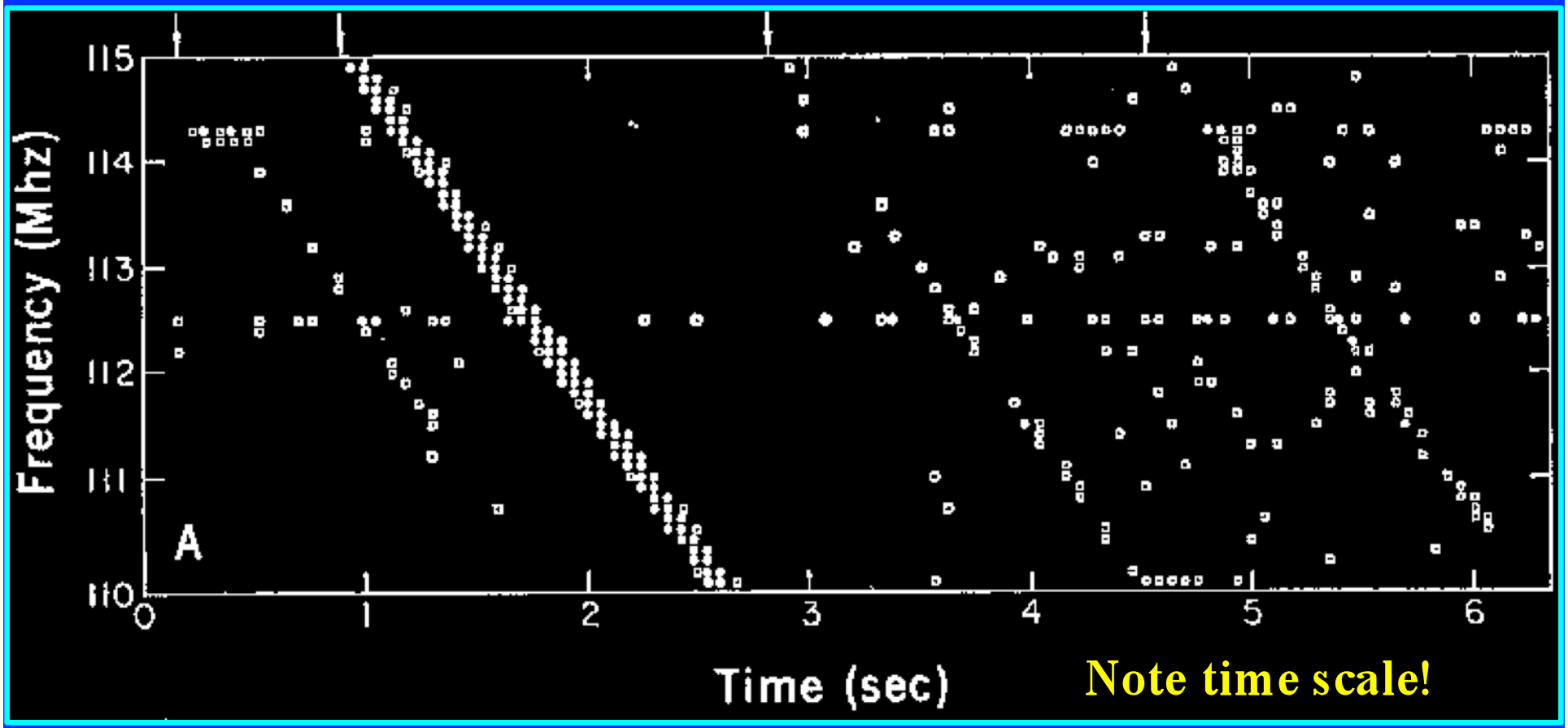
Crab Giant Pulse at 23 MHz



Soglosnov (2004) personal corresp.

Interstellar Dispersion

Crab pulsar discovered by dispersed "giant" pulses at 112 MHz

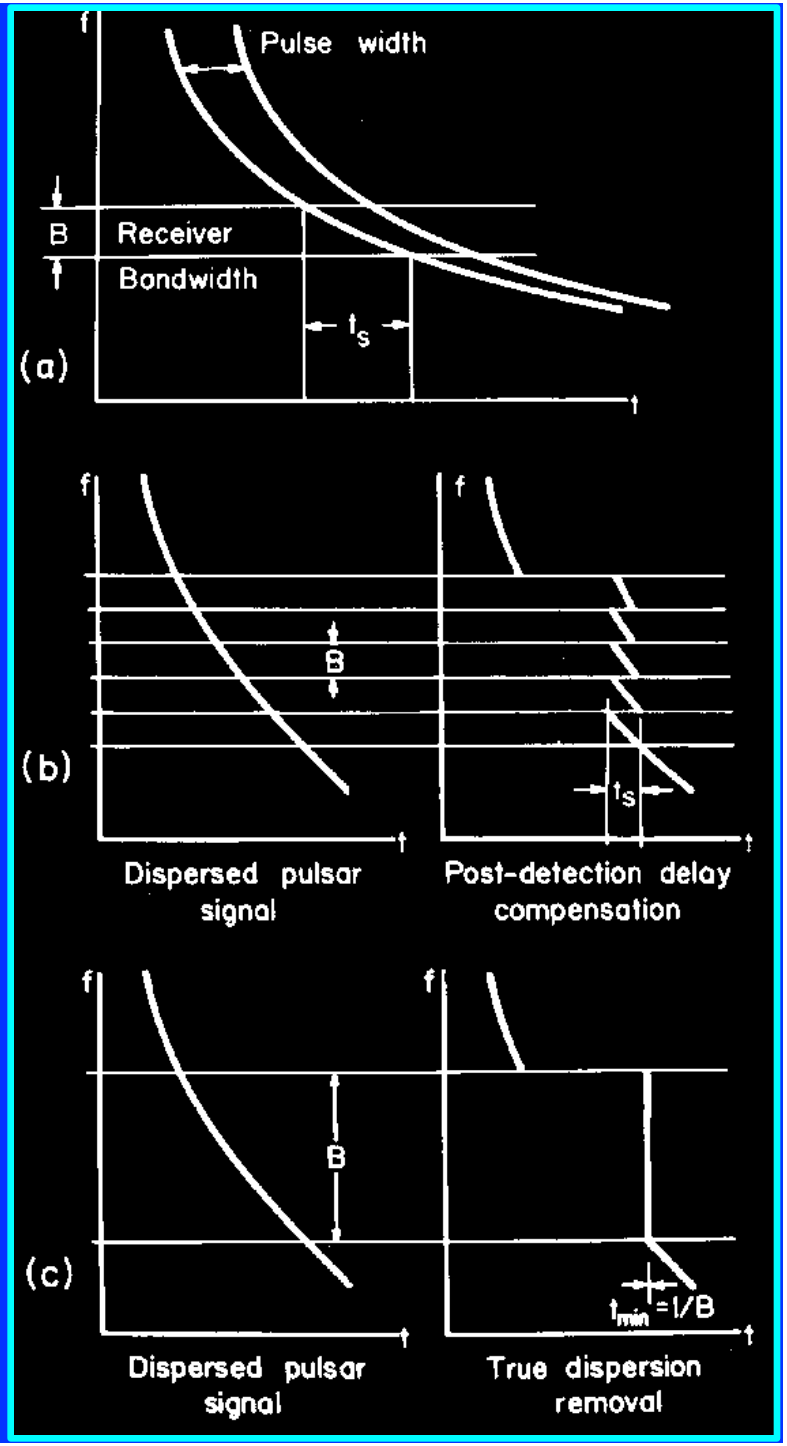


Staelin and Reifenstein, (1968) *Science*, 162, 148

Dedispersion principles

Incoherent dedispersion ➔
(detect, delay, add)
To optimize, choose $B=1/t_s$

Coherent dedispersion ➔
(Inverse filter, detect)



Coherent dedispersion

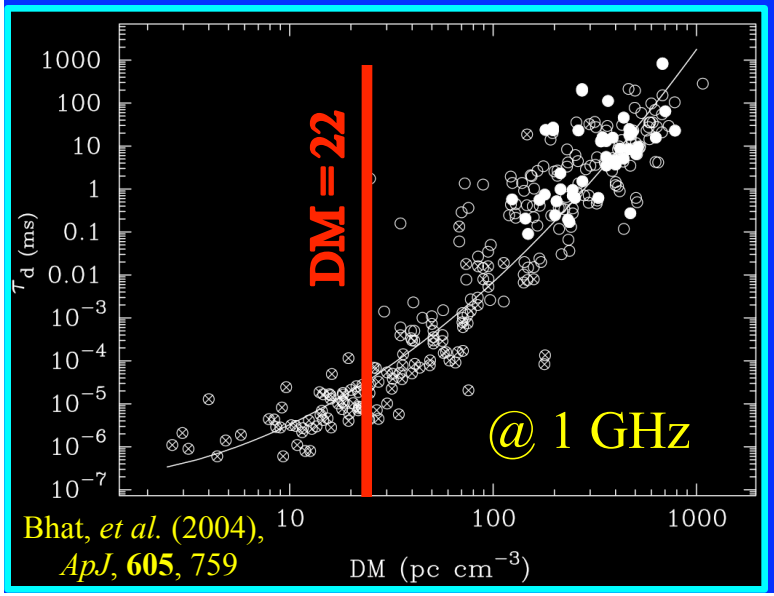
- **Emitted signal:** $s(t) \Leftrightarrow S(\omega)$
- **Dispersive ISM:** $H(\omega) = \exp[ik(\omega)z] \Leftrightarrow h(t)$
- **Received signal:** $s(t) * h(t) \Leftrightarrow S(\omega)\, H(\omega)$
- **Dedispersion processing:** $S(\omega)H(\omega) \cdot H(\omega)^{-1} \Leftrightarrow s(t)$
  - » and 10,000 lines of code

$\Leftrightarrow$: Fourier Transform

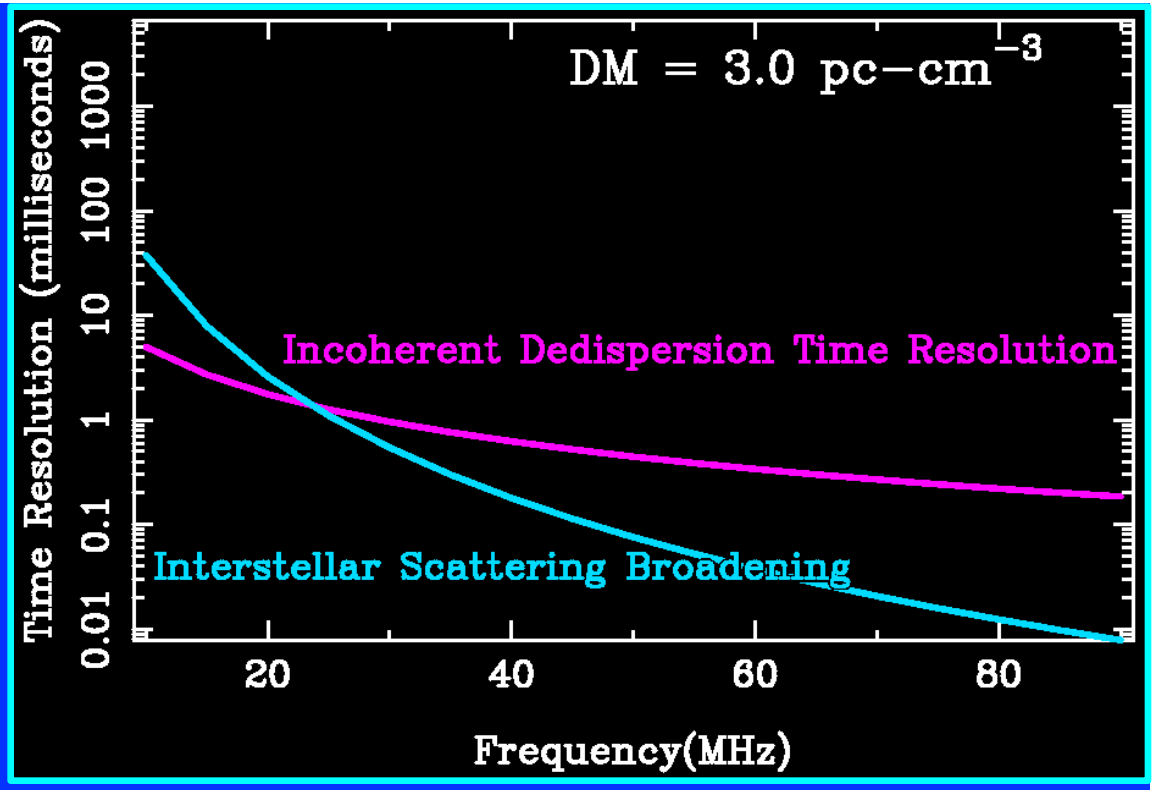
$*$: Convolution

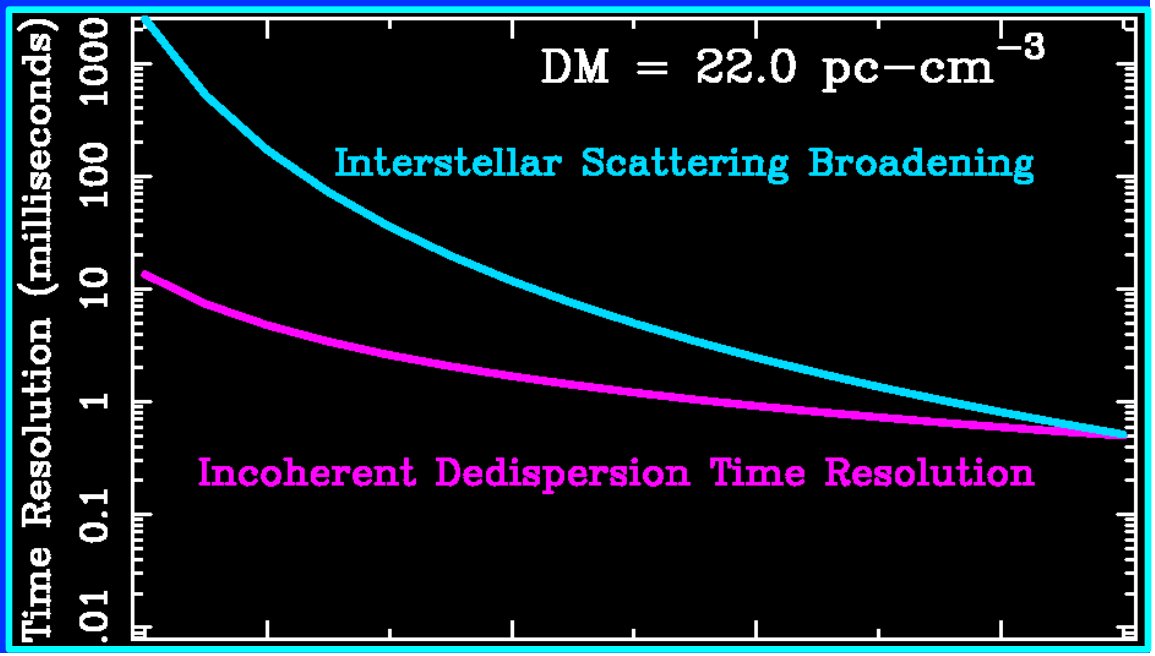
$\cdot$: Multiplication

Time Resolution Limits: Incoherent Dedispersion and ISS Broadening



Bhat, *et al.* (2004), *ApJ*, **605**, 759





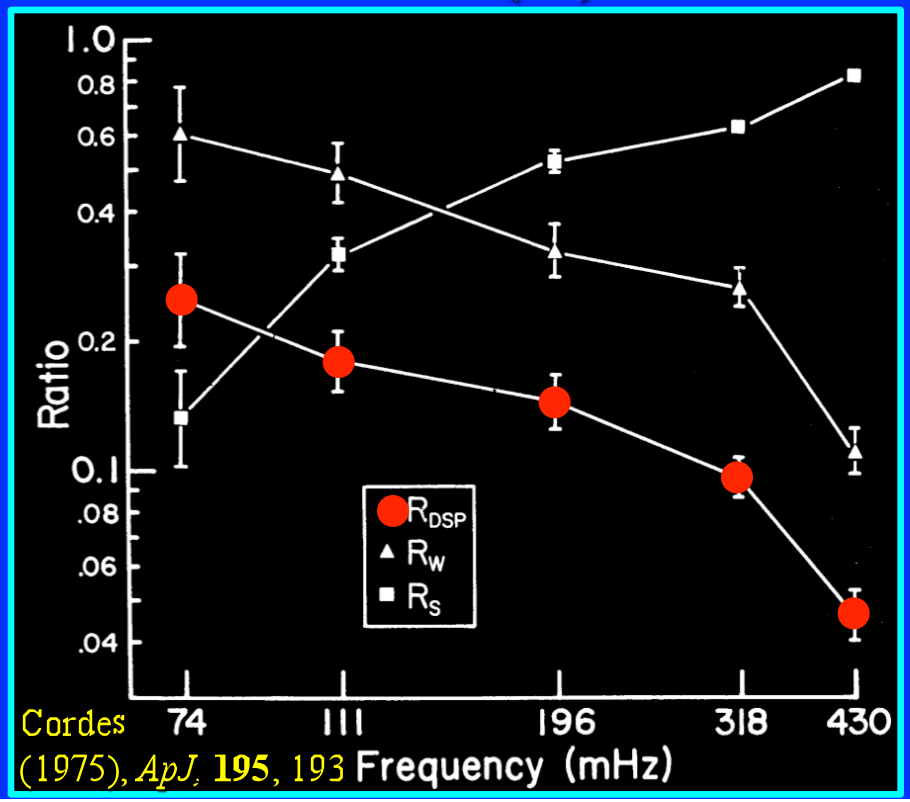
Pulsar Science

- Drifting subpulses
- Polarization
- Magnetospheric structure

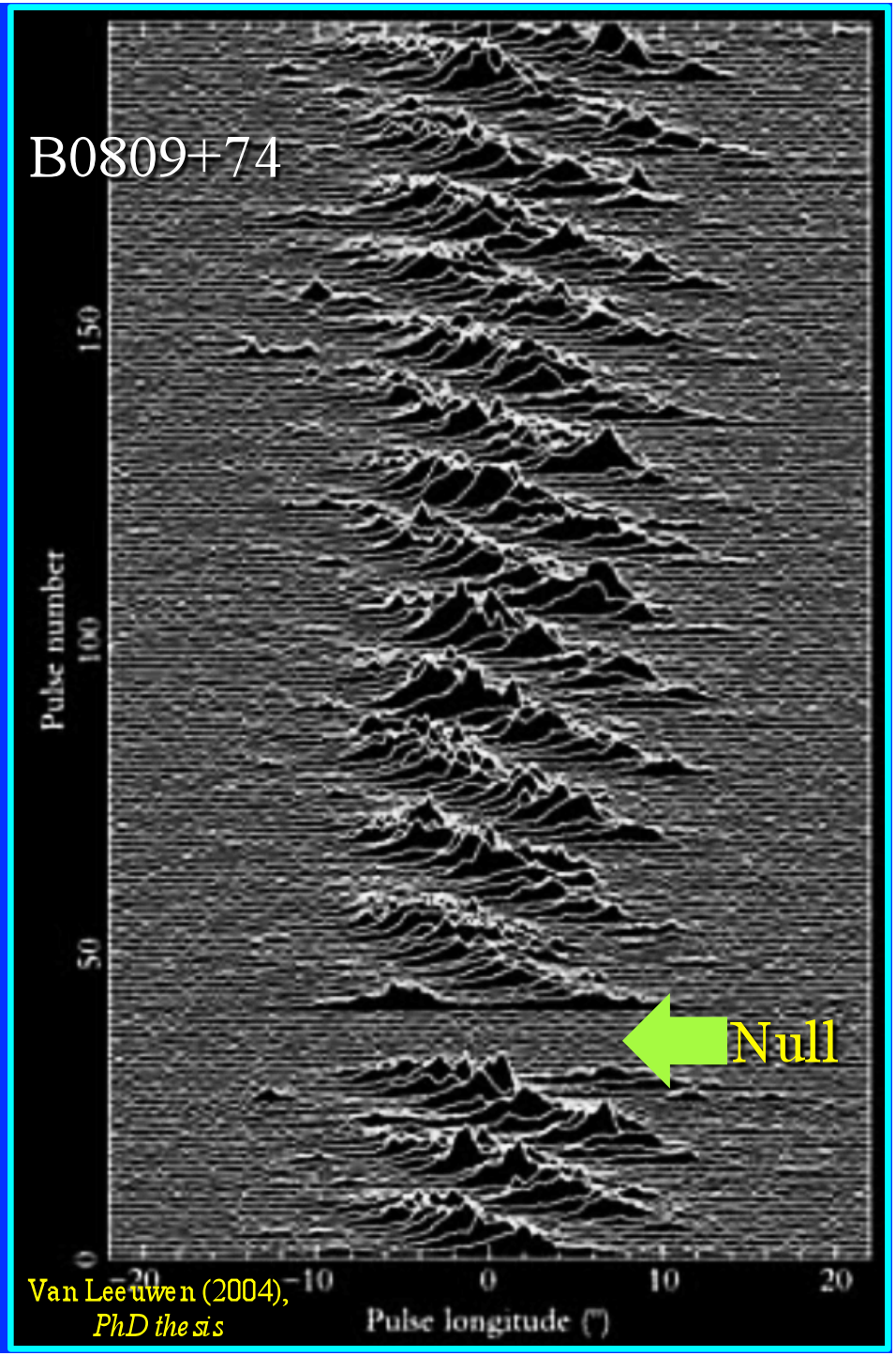
Drifting subpulses

Pulse fluctuation power components:

- Steady (S)
- Drifting subpulse (DSP)
- White noise (W)

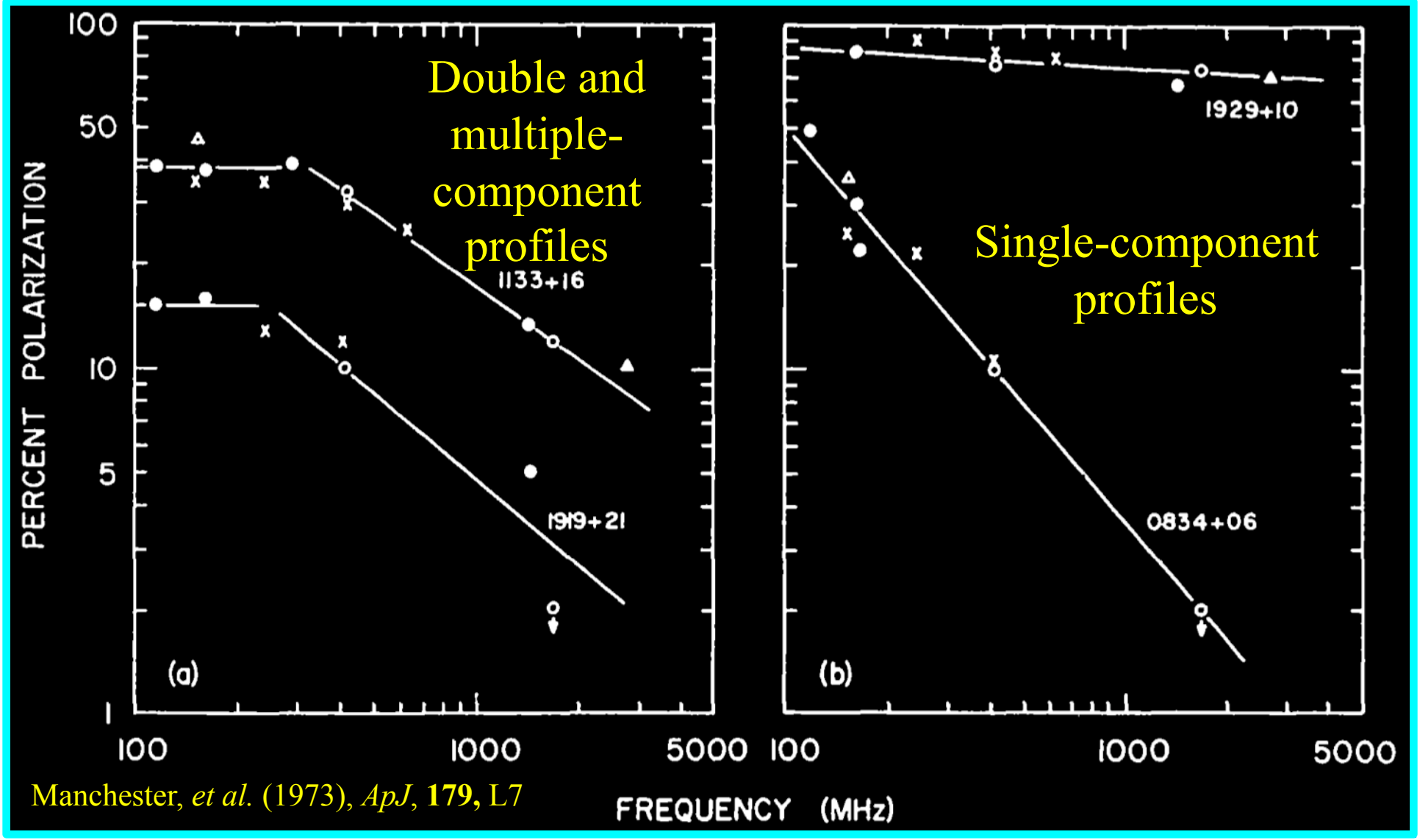


Cordes (1975), *ApJ*, **195**, 193



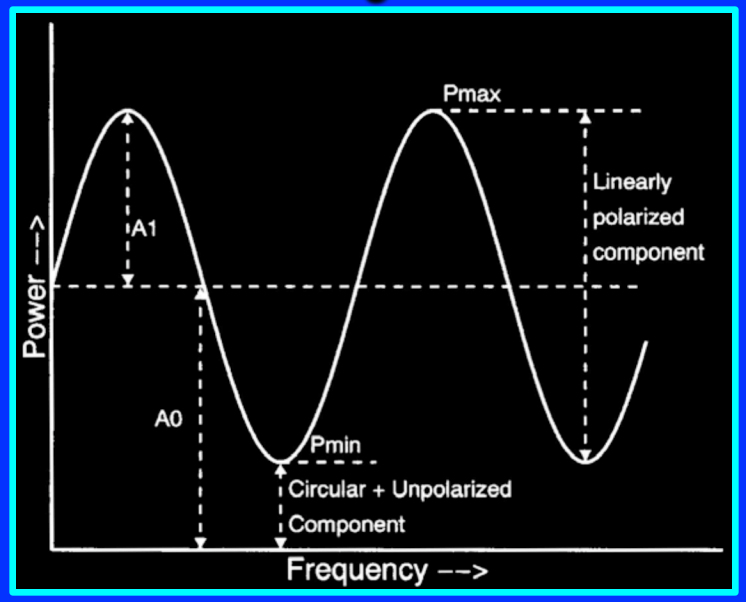
Van Leeuwen (2004), *PhD thesis*

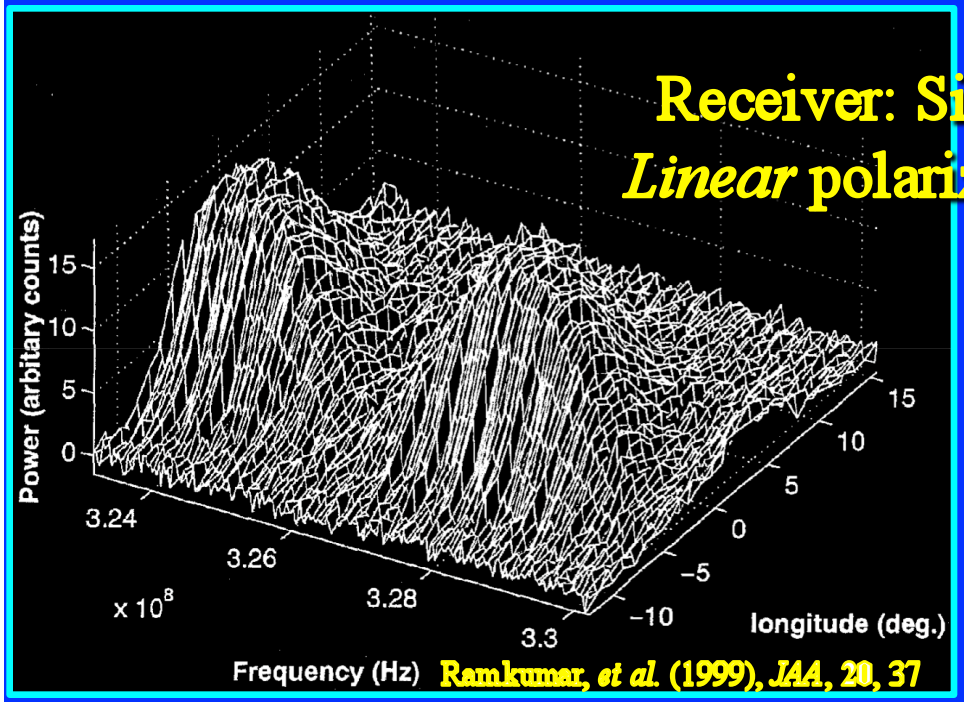
Pulsar polarization: 100% at $f \leq 100$ MHz?



Manchester, *et al.* (1973), *ApJ*, **179,** L7

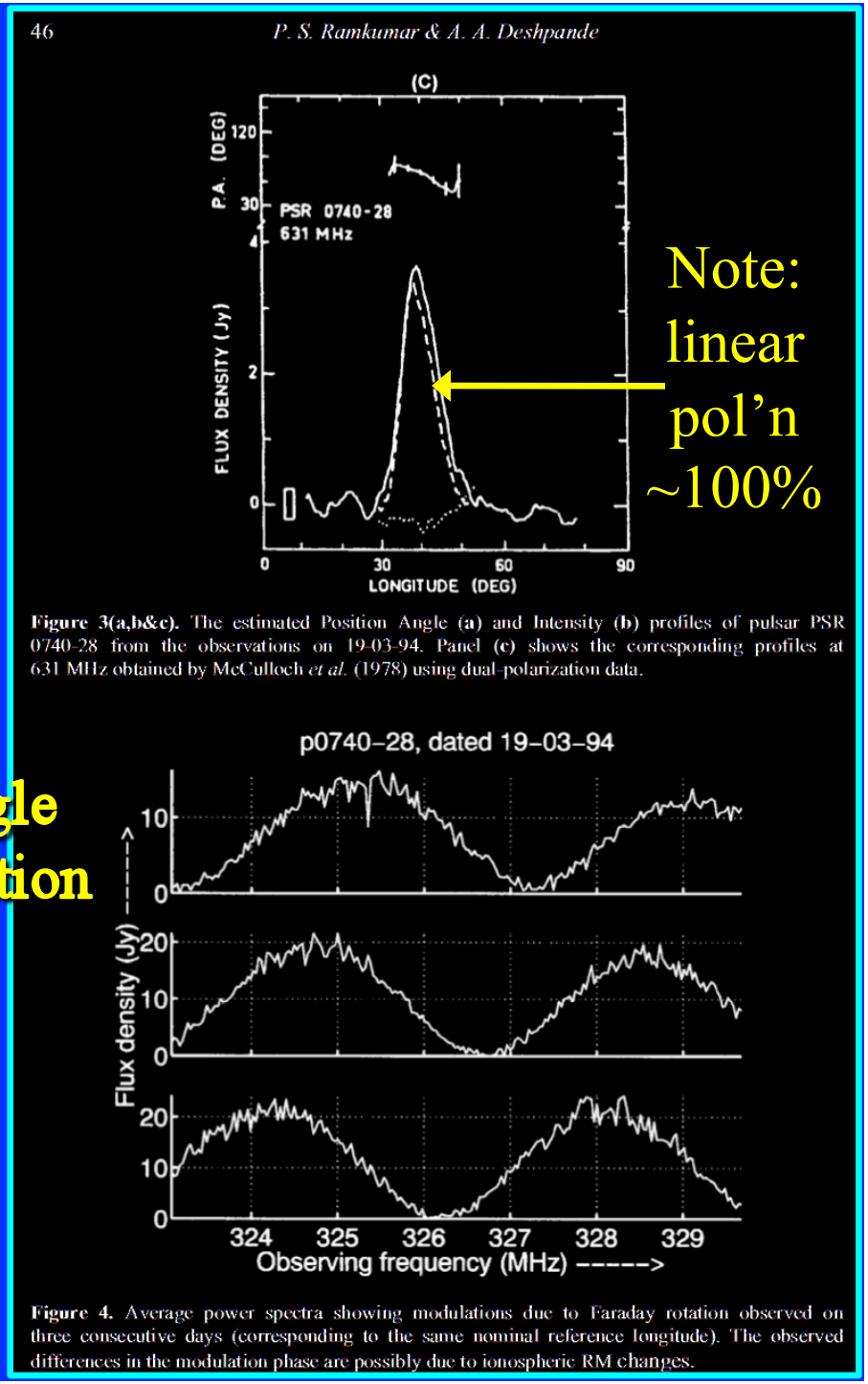
Faraday Rotation





Receiver: Single
Linear polarization

Ramkumar, *et al.* (1999), *JAA*, 20, 37

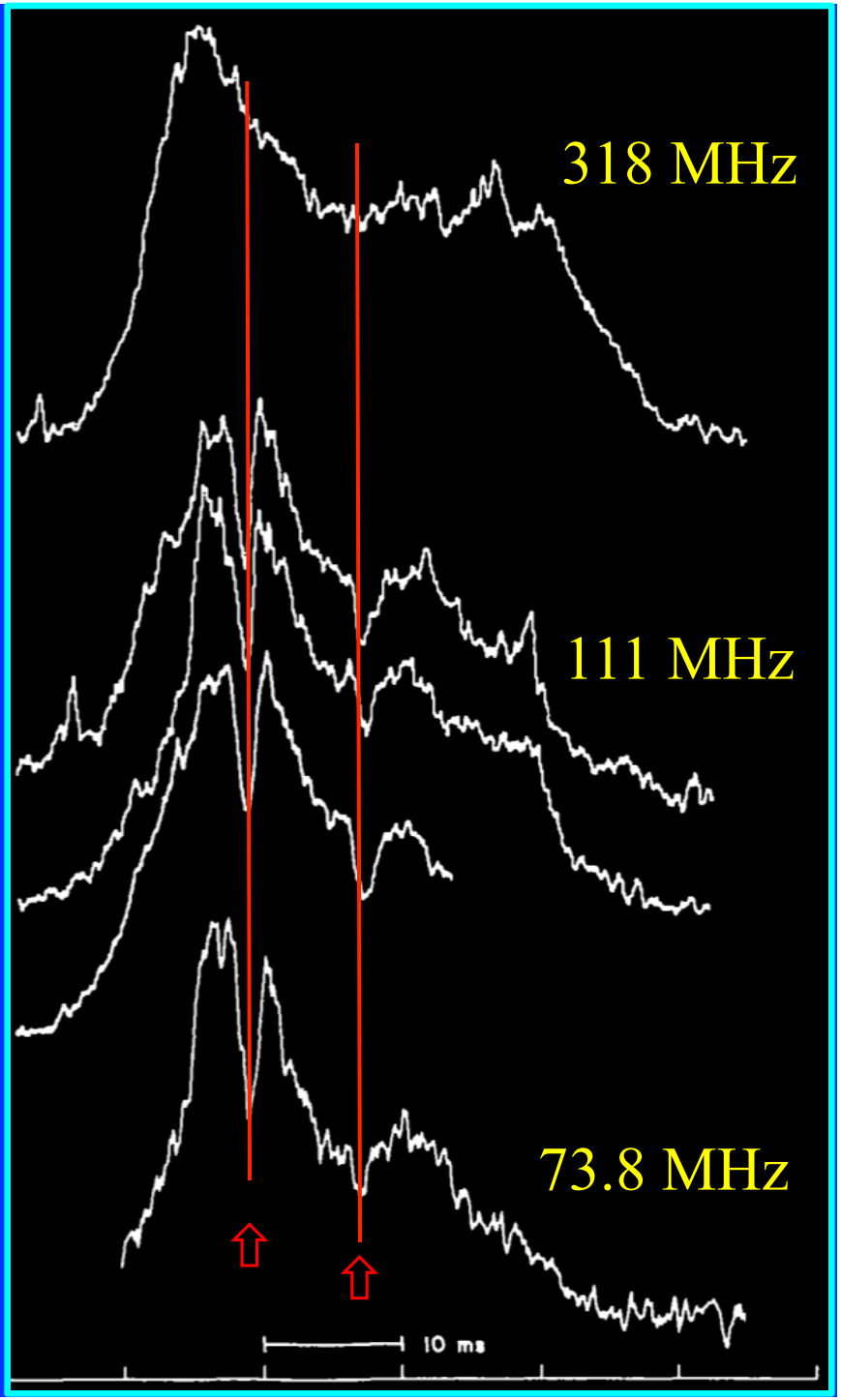


Notches in the Average Profile of B1919+21

Requires coherent dedispersion to resolve notches.

Polarization artifact?

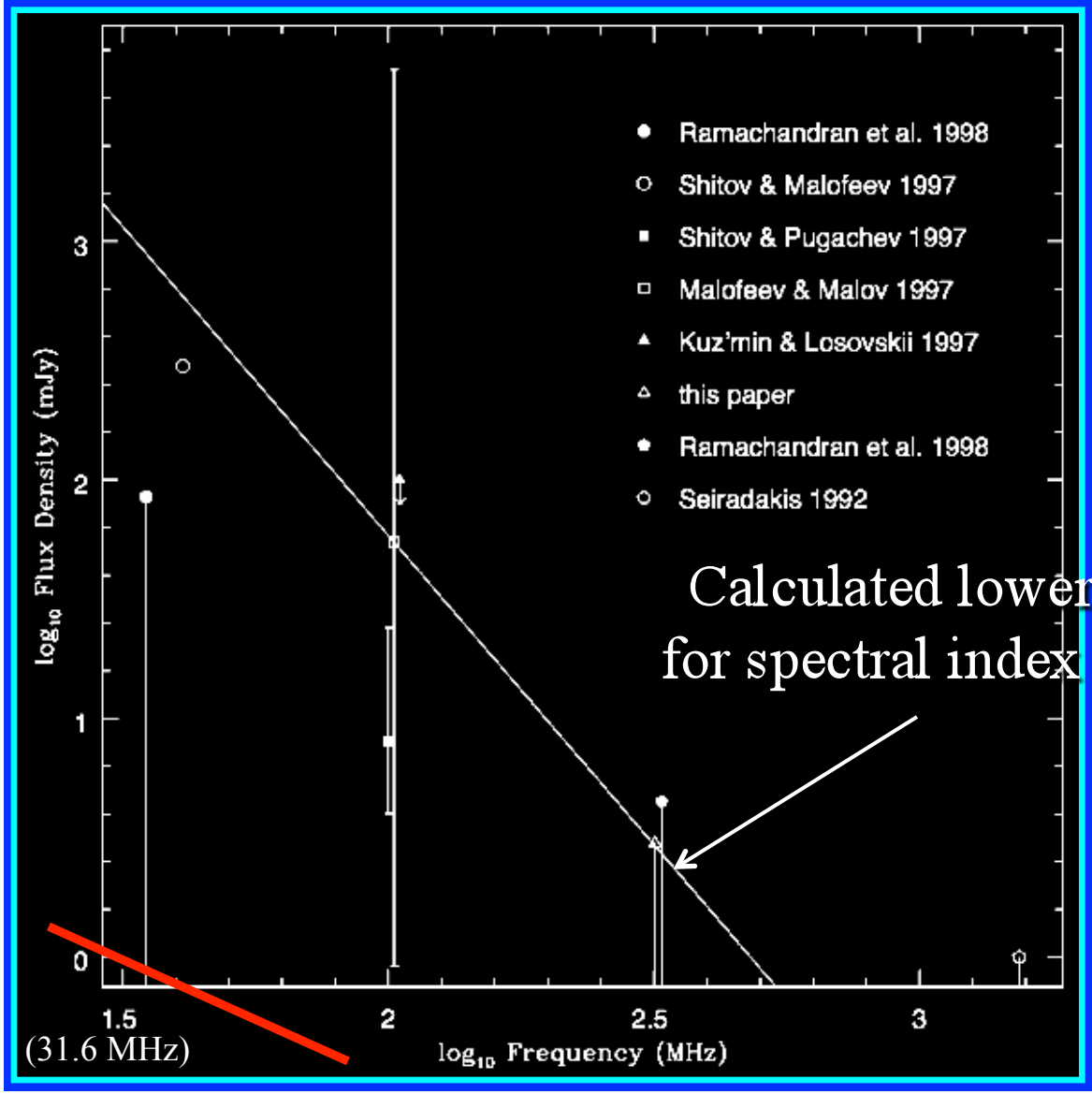
Hankins, (1973), *ApJ*, **181**, L49



Why is the Geminga radio pulsar only seen in Russia?

- Gamma-ray pulsar, P=0.237 sec
- Beaming issue?
- Scintillation issue?
- RRAT? (Rotating RAdio Transient)
- Not there?

Geminga spectrum limits

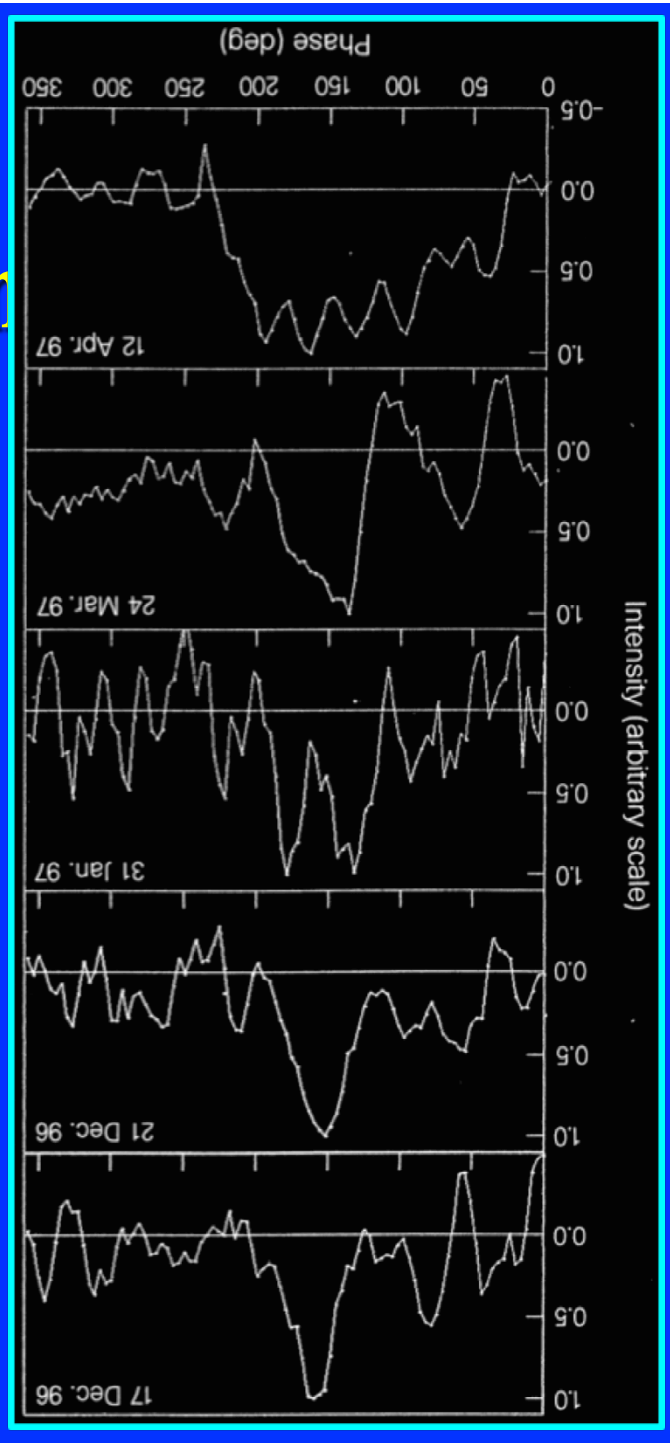


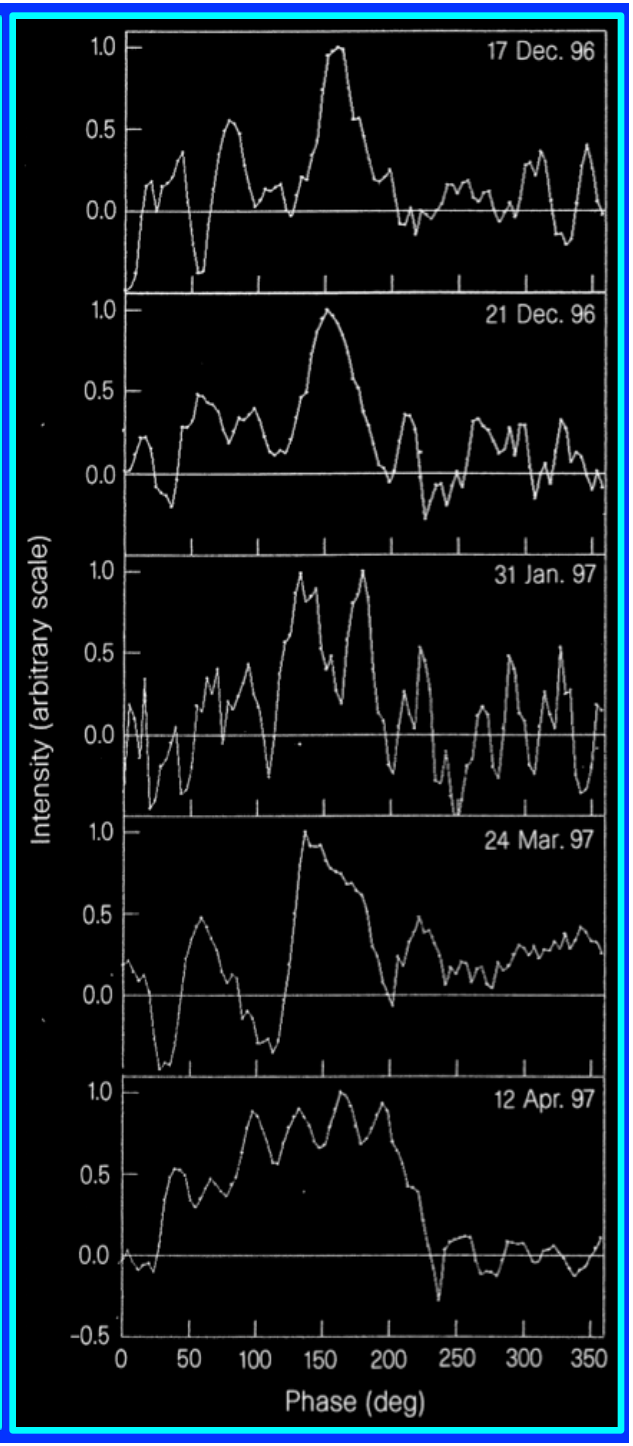
Calculated lower limit
for spectral index = 2.65

LWA sensitivity
50 stations
2 pol'n, 1 hr, 4MHz

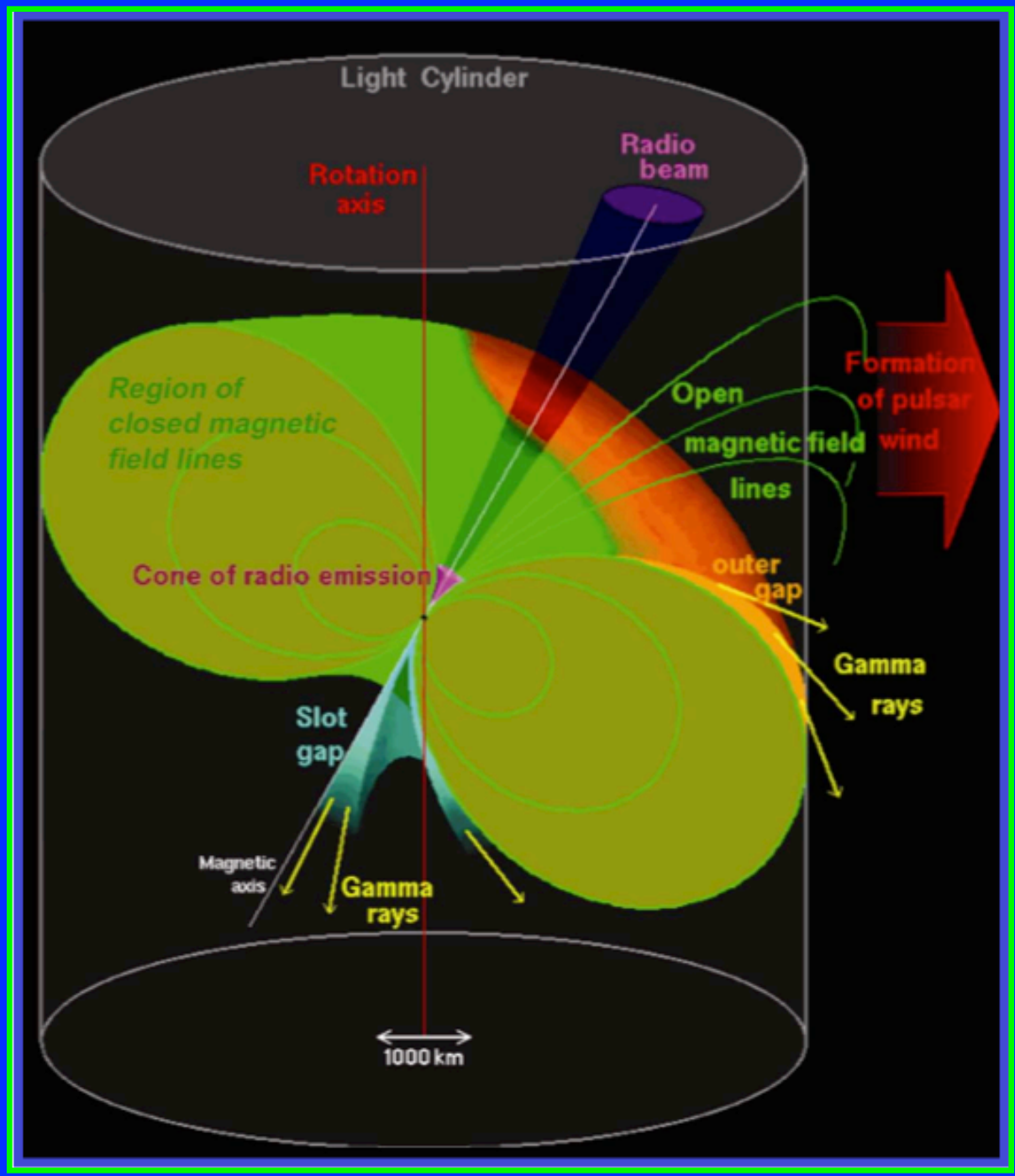
McLaughlin, et al.
(2000), *ApJ*, **512**, 929

Puschino Observation (102 MHz)

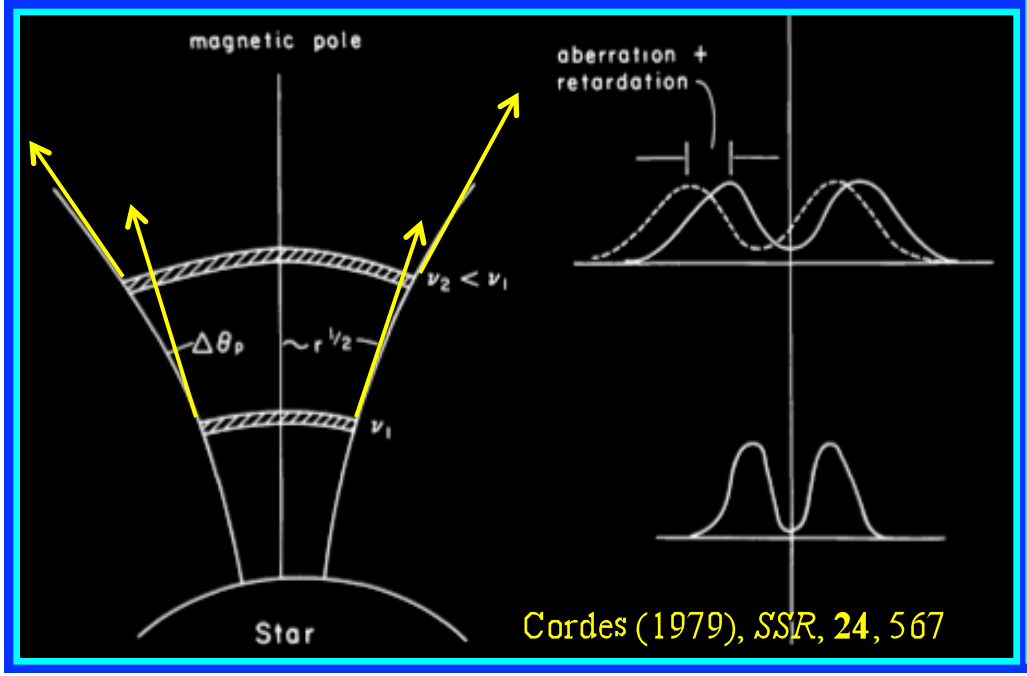




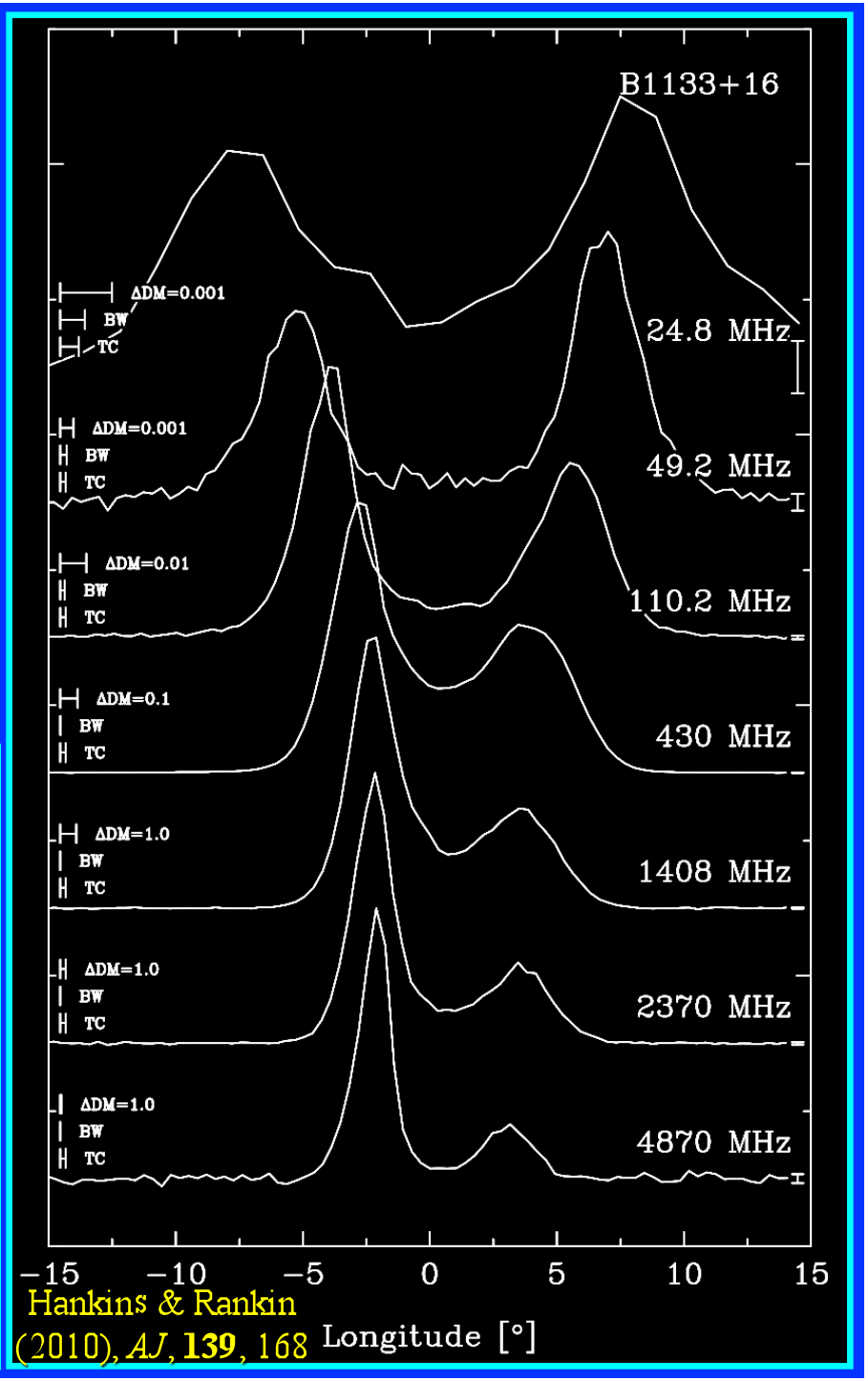
Standard pulsar model → Radius to Frequency Mapping



Radius to Frequency Mapping



Cordes (1979), *SSR*, **24**, 567



Hankins & Rankin (2010), *AJ*, **139**, 168

Conclusion

Lots of pulsar stuff to do at low frequencies.

- Searches: Steep spectrum objects
- Precise timing could do some things.
  - Ionosphere, average profiles, Faraday rotation
- Single pulse studies: neglected for decades!
  - Drifting, nulling, polarization
- ISM "weather"