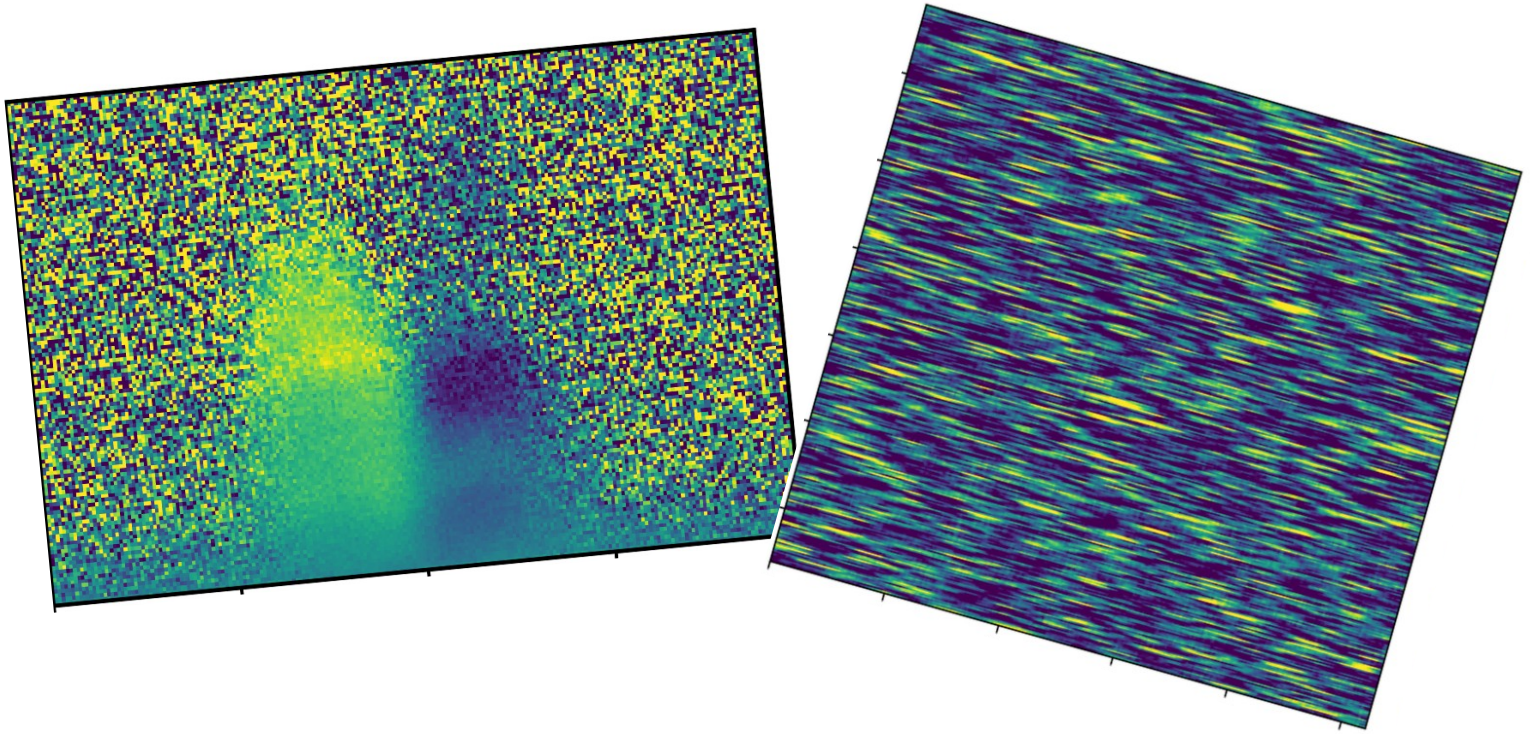


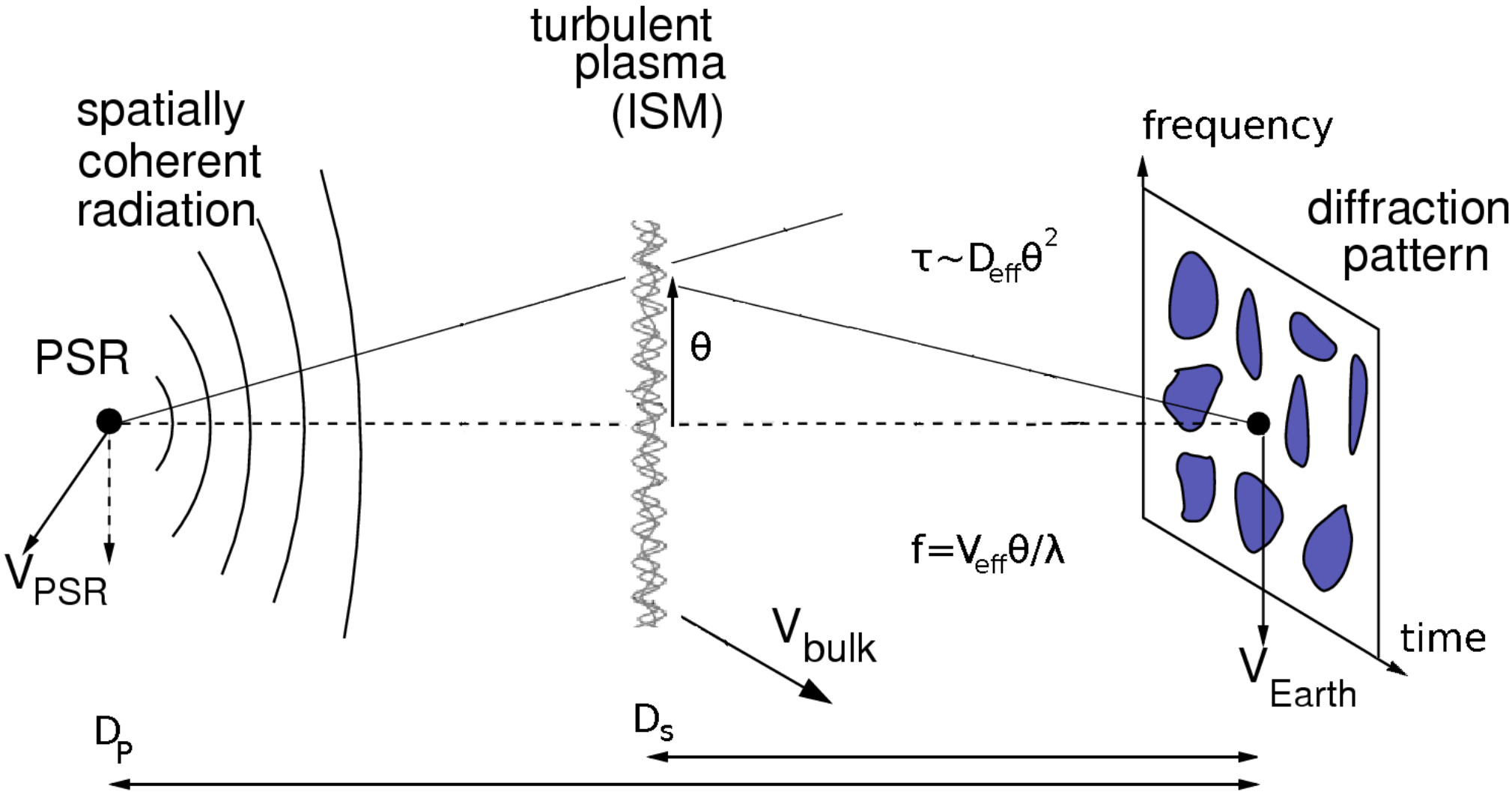
Pulsar scintillometry on the Vela pulsar with the LBA

Franz Kirsten
Chalmers University of Technology

With help from J.-P. Macquart, U.-L. Pen, D. Simard

EVN Symposium, Granada, Spain, 8-11 Oct 2018

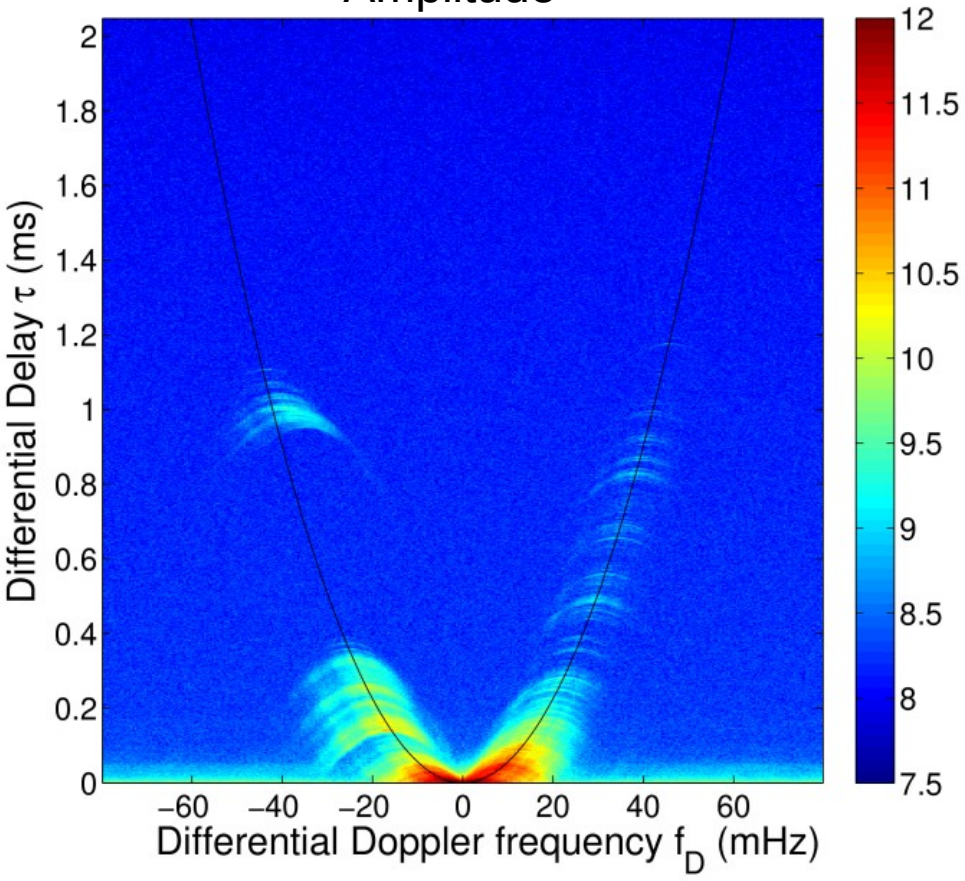
Pulsar Scintillation



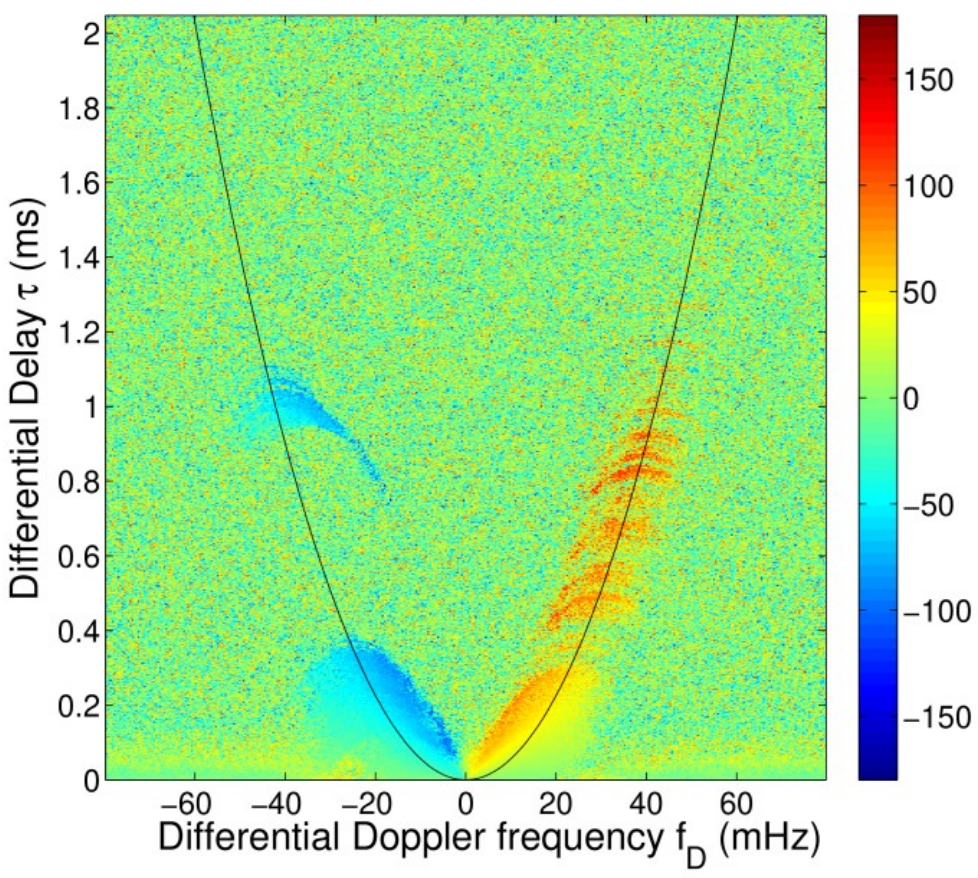
Pulsar Scintillation – Secondary Cross Spectra: PSR B0834+06

$$C(\tau,\ f,\ \vec{b}) = \tilde{V}(\tau,\ f,\ \vec{b})\ \tilde{V}(-\tau,\ -f,\ \vec{b})$$

Amplitude



Phase

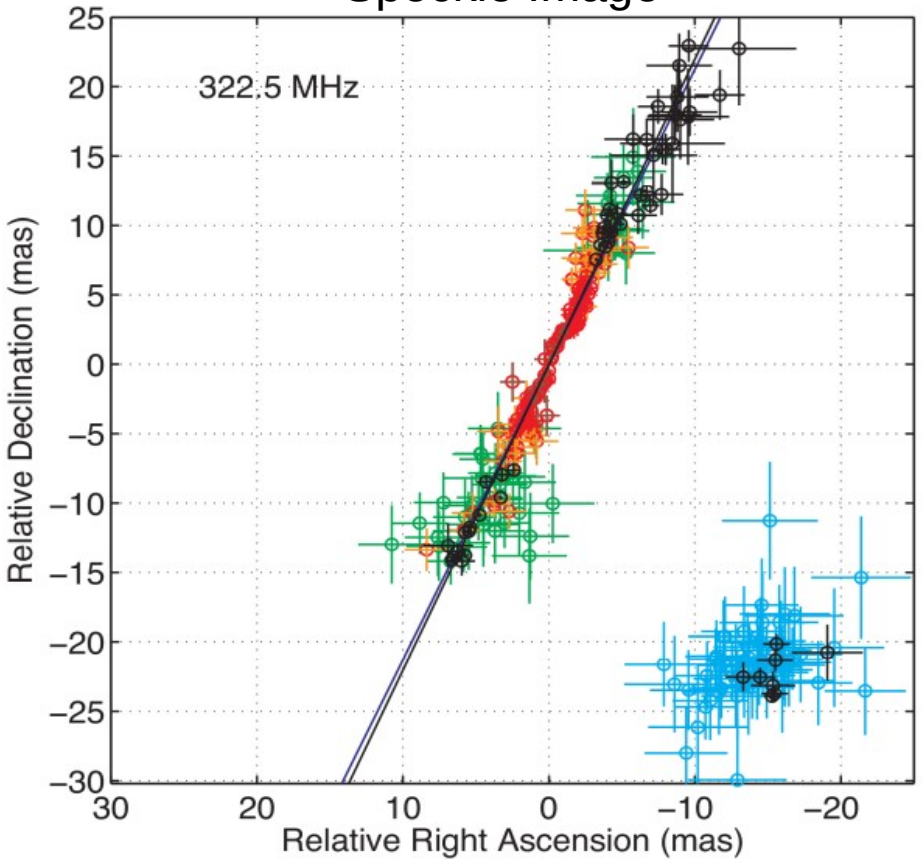


Brisken et al. 2010

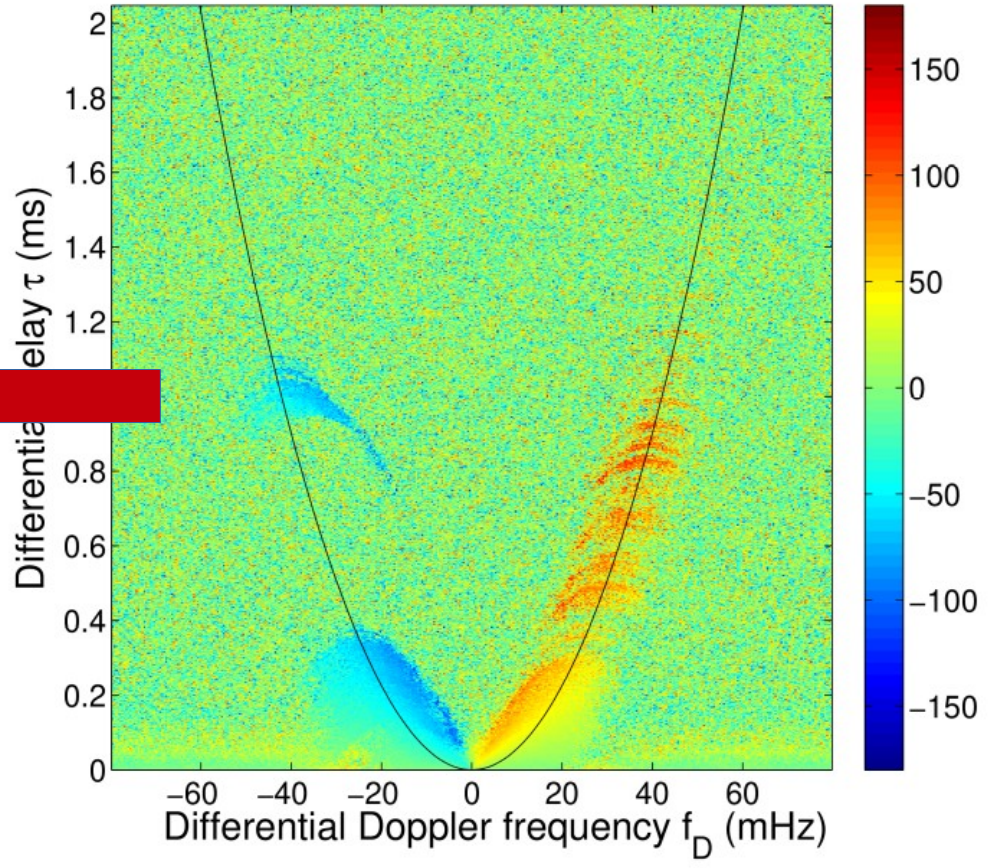
Pulsar Scintillation – The first ever speckle image: PSR B0834+06

$$C(\tau,\ f,\ \vec{b}) = \tilde{V}(\tau,\ f,\ \vec{b})\ \tilde{V}(-\tau,\ -f,\ \vec{b})$$

Speckle Image



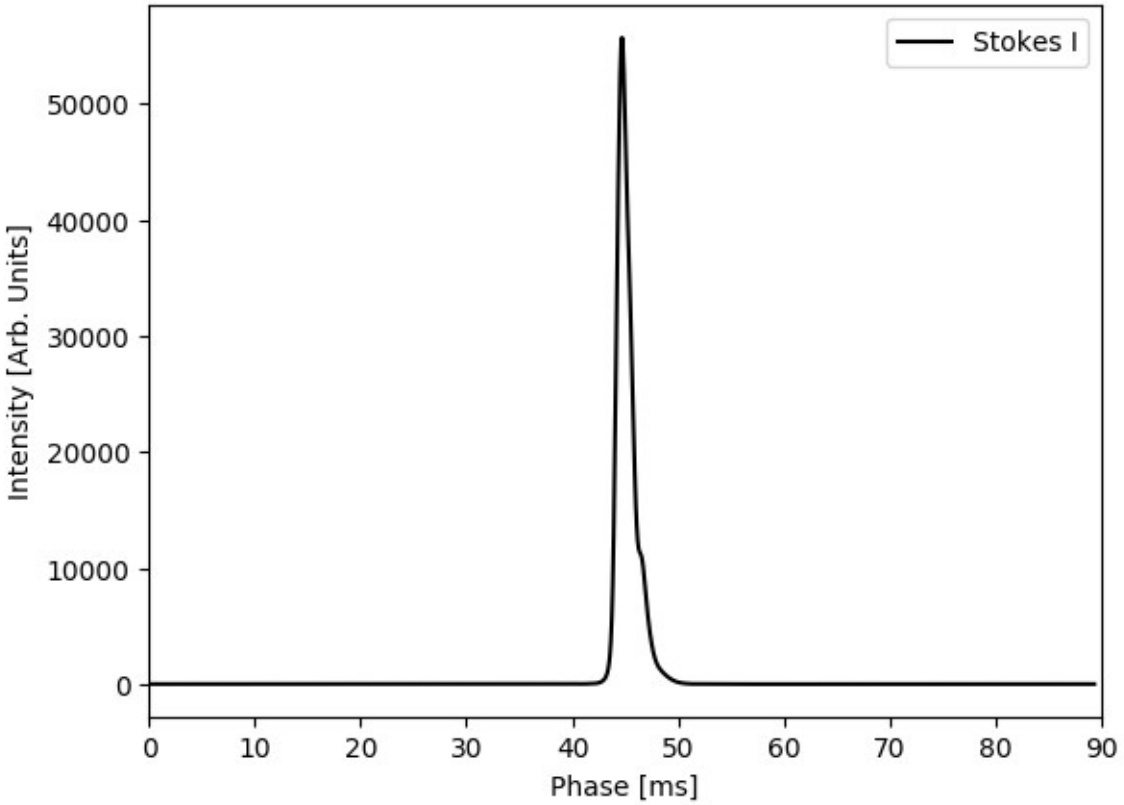
Phase

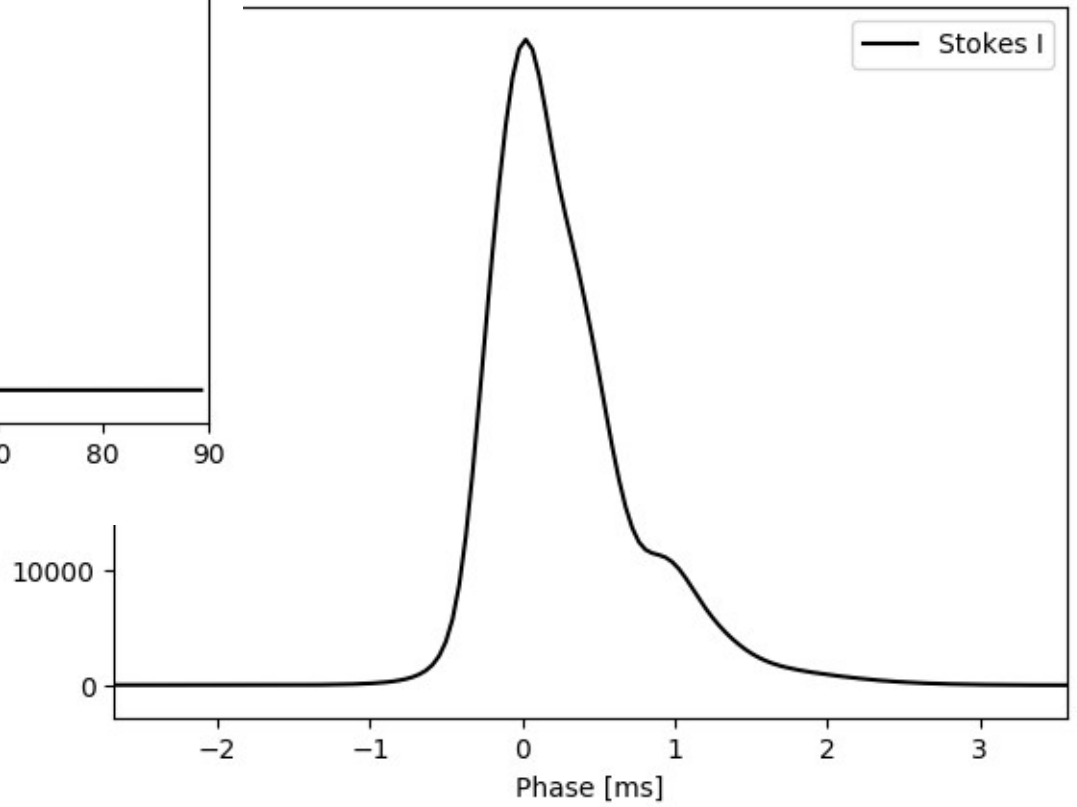


Brisken et al. 2010

The Vela Pulsar

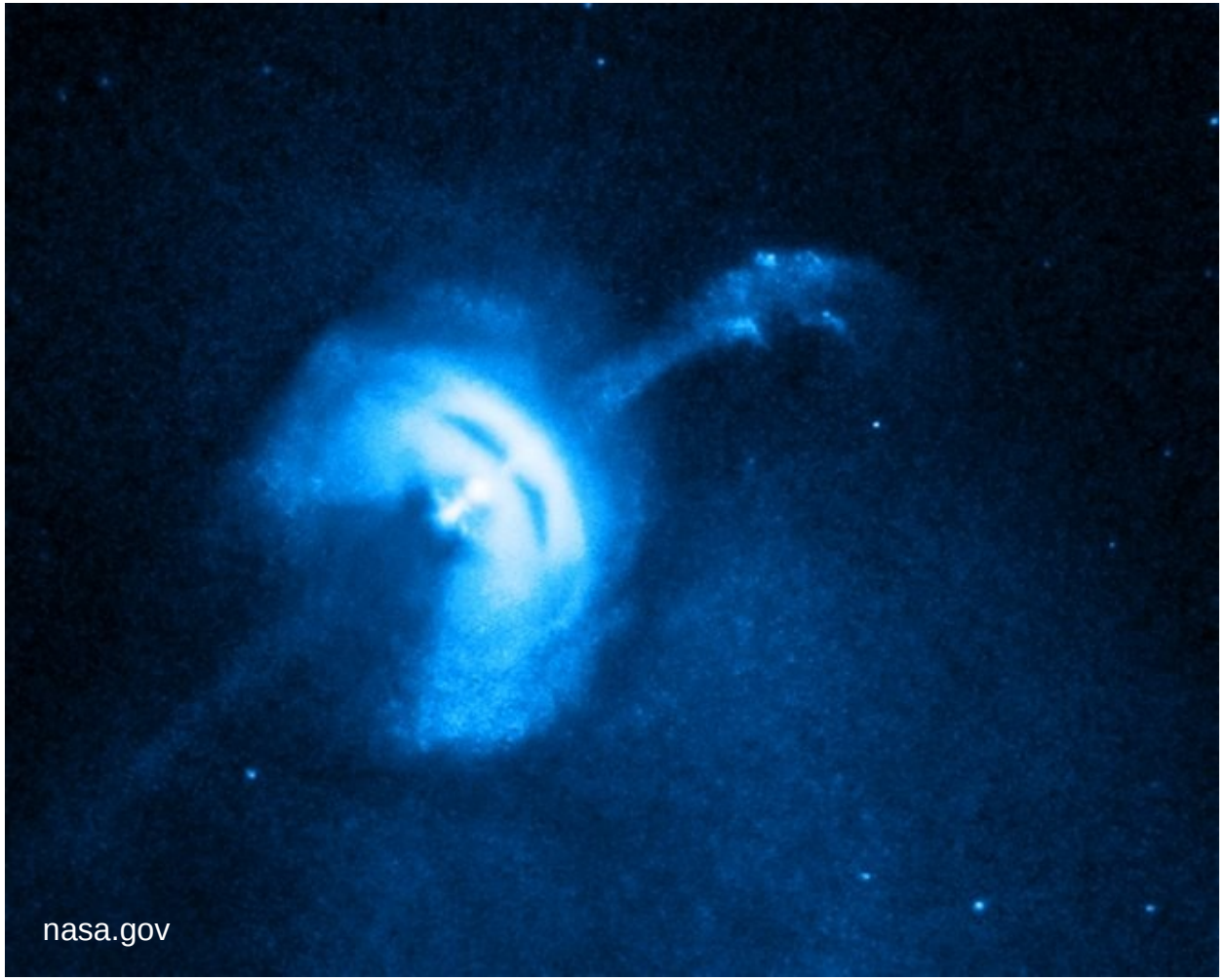
Period = 89.3 ms
Scatter broadening τ_s ~ 10 μs
Distance ~ 290 pc





Profile: Johnston, S. & Kerr, M., 2017

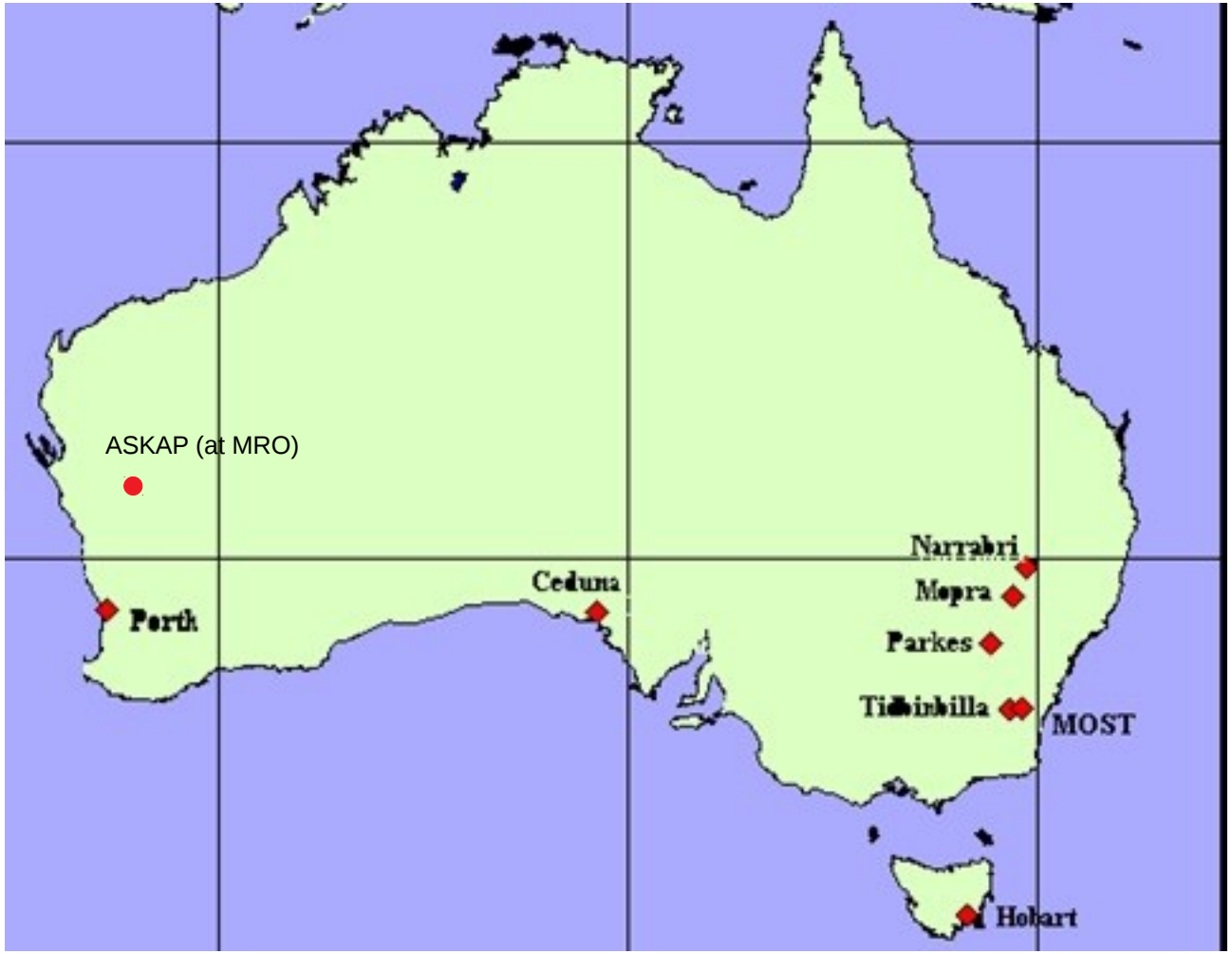
The Vela Pulsar



Period = 89.3 ms
Scatter broadening τ_s ~ 10 μs
Distance ~ 290 pc

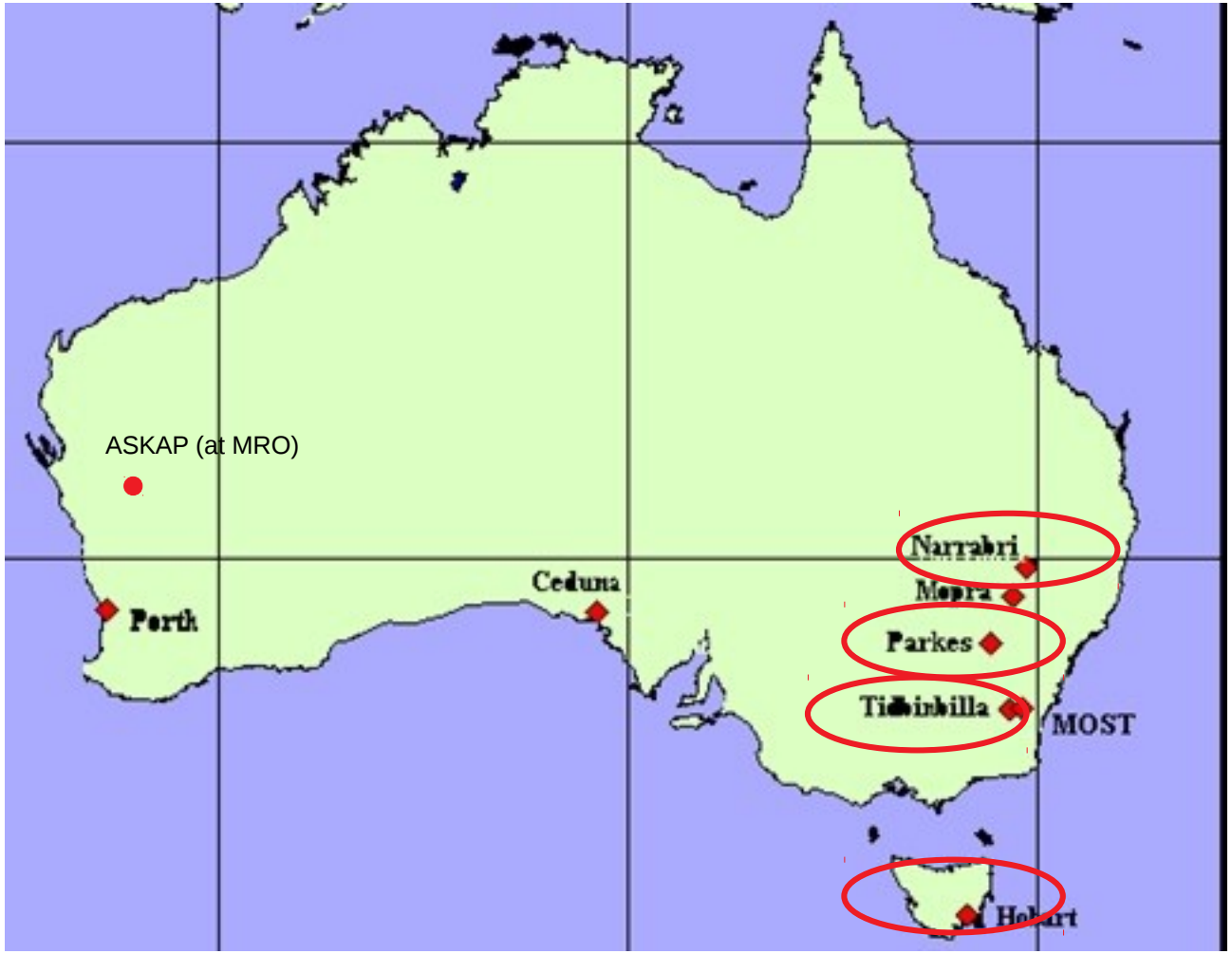
Embedded in a supernova remnant

The Long Baseline Array



Baselines
~300 – 3300 km

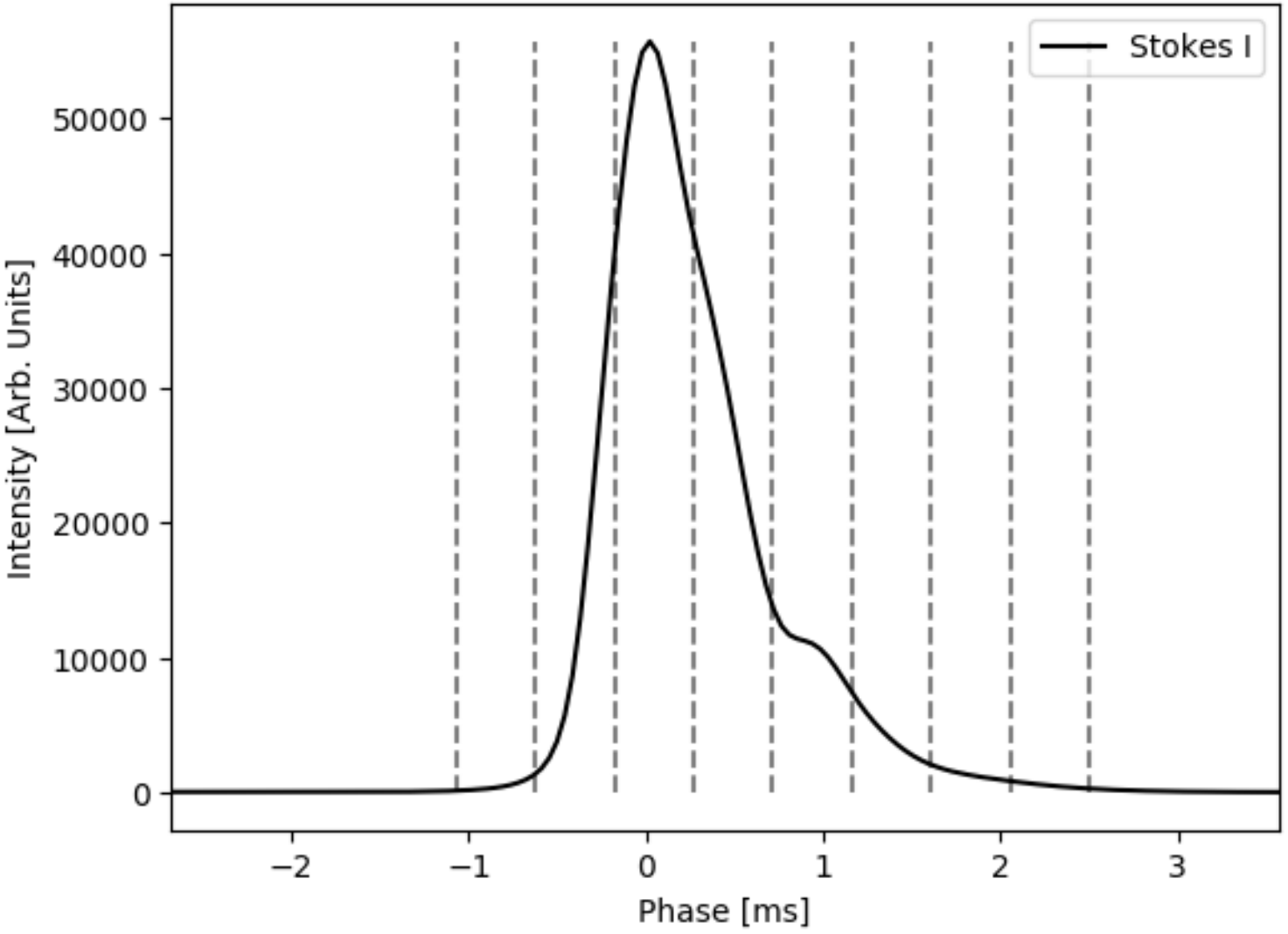
The Long Baseline Array



Baselines
~300 – 1700 km

→ Beamsize at L-band
20 – 120 mas

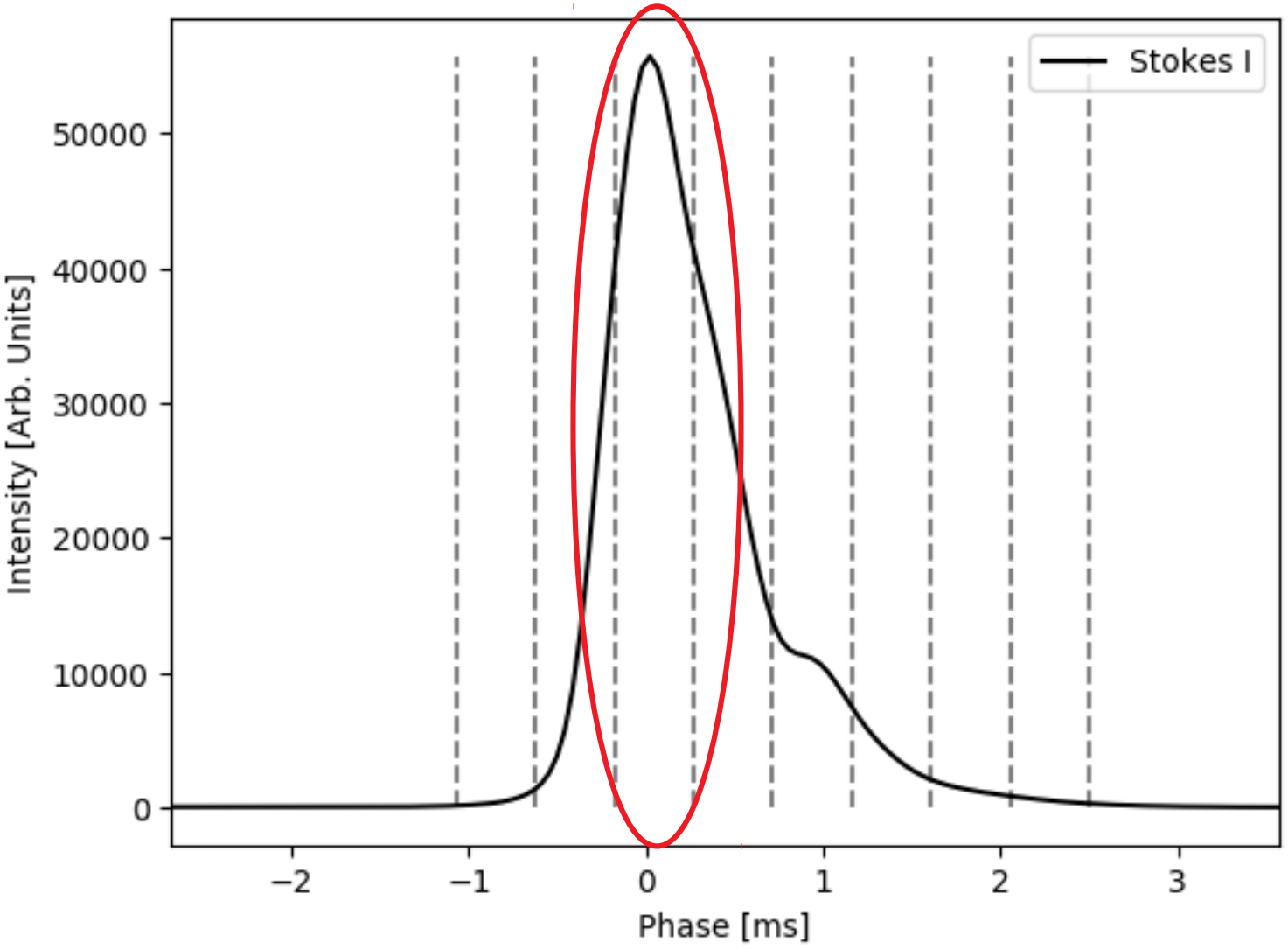
Pulsar binning



Gain ~ 10 =

$$\sqrt{\text{Period} \ / \ \text{Pulse Width}}$$

Pulsar binning

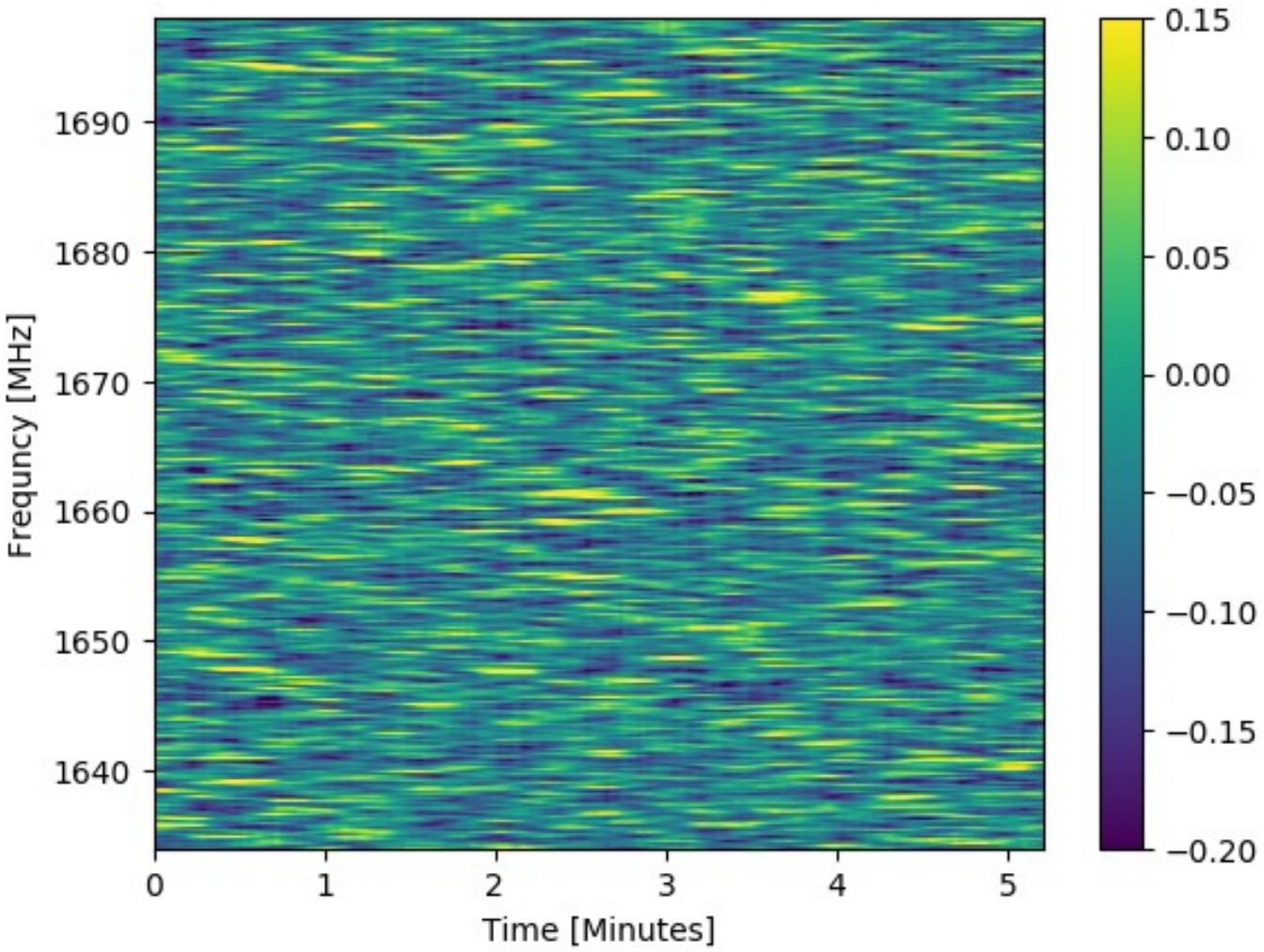


Gain ~ 10 =

$$\sqrt{\text{Period} \ / \ \text{Pulse Width}}$$

Vela – Dynamic spectra

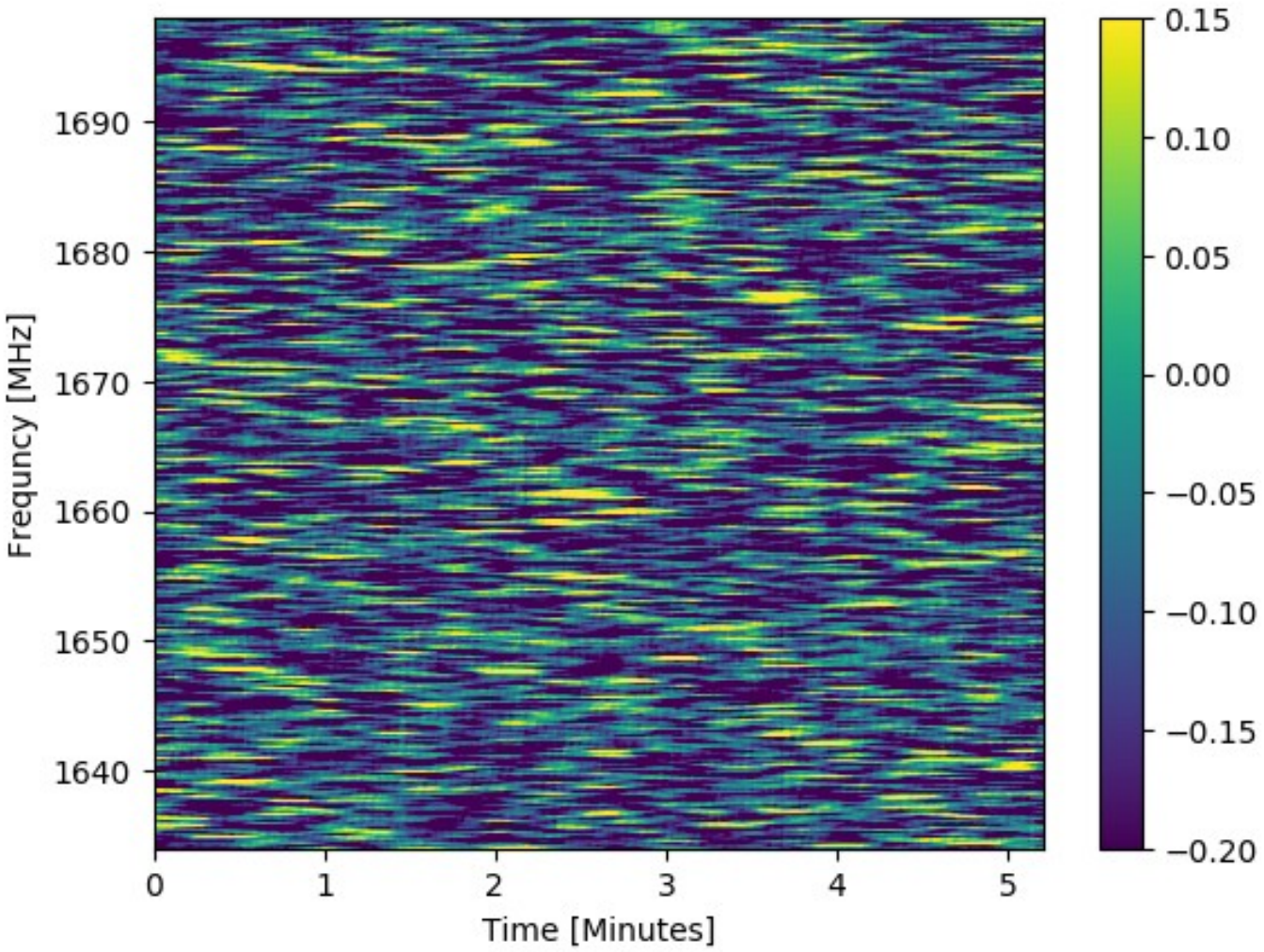
Parkes Auto-correlations



Kirsten et al., in prep

Vela – Dynamic spectra

ATCA-Parkes Cross-correlation amplitudes



Decorrelation Bandwidth
$\Delta\nu \sim 20$ kHz

Decorrelation Timescale
$\Delta\tau \sim 20$ s

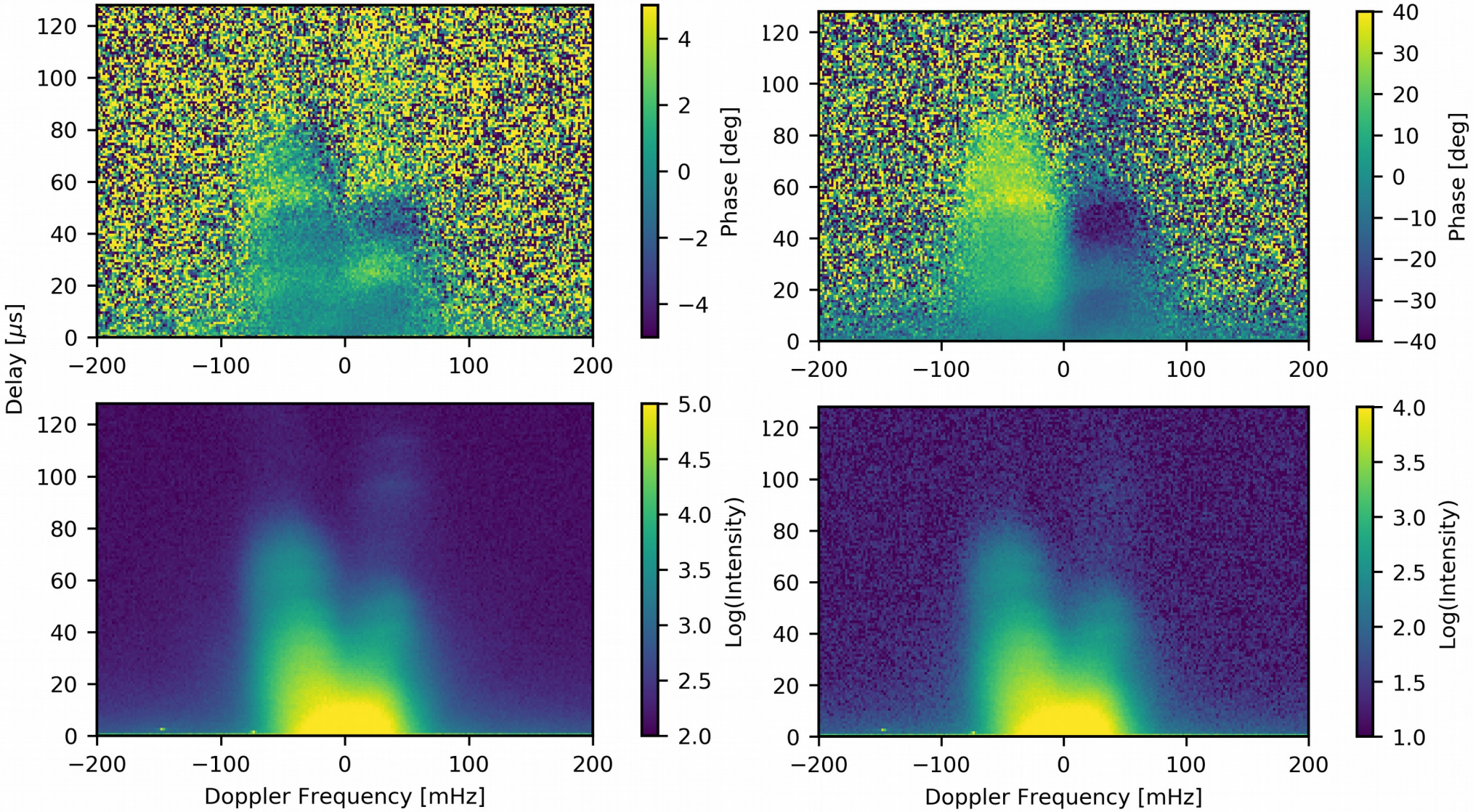
Kirsten et al., in prep

Vela – Secondary Cross Spectra

ν = 1658 MHz, BW = 16 MHz

ATCA – Parkes

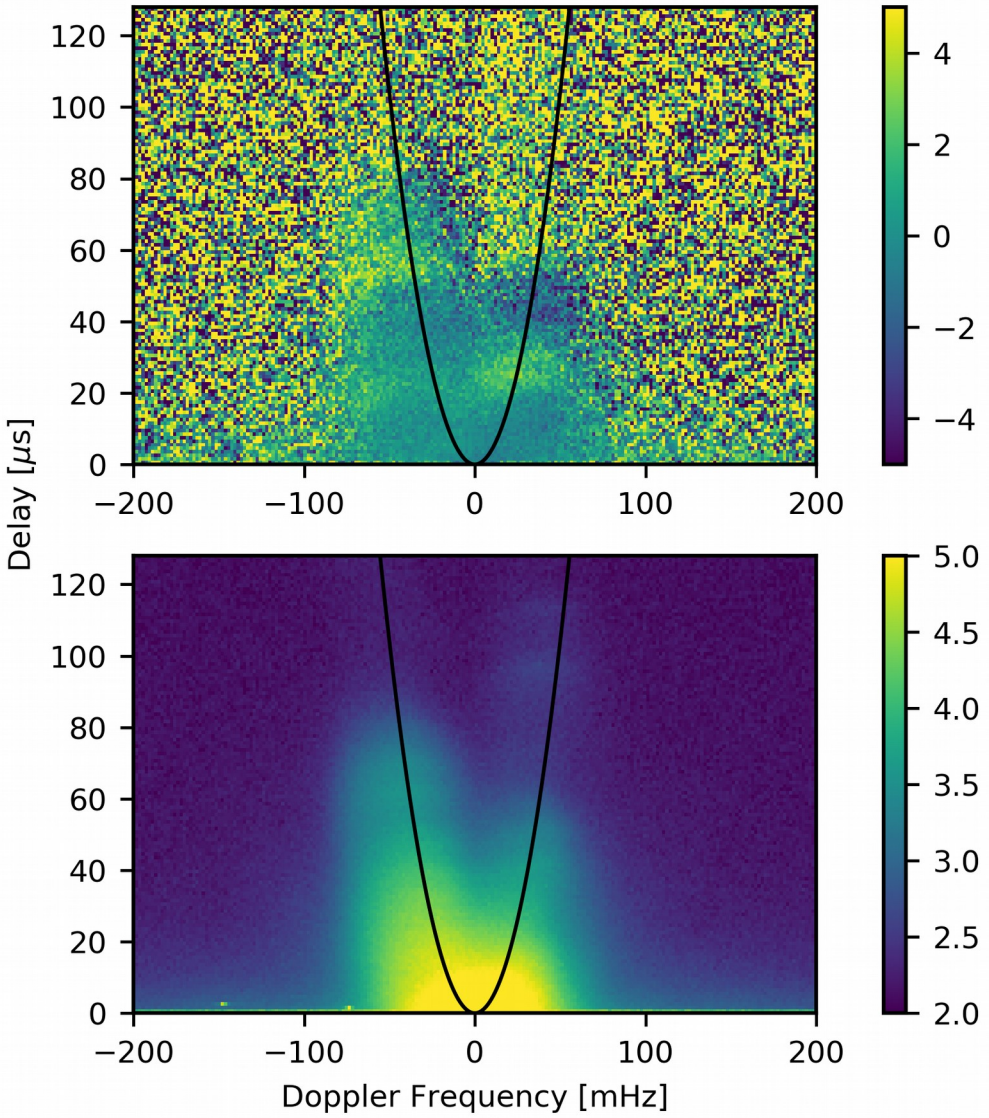
ATCA – Hobart



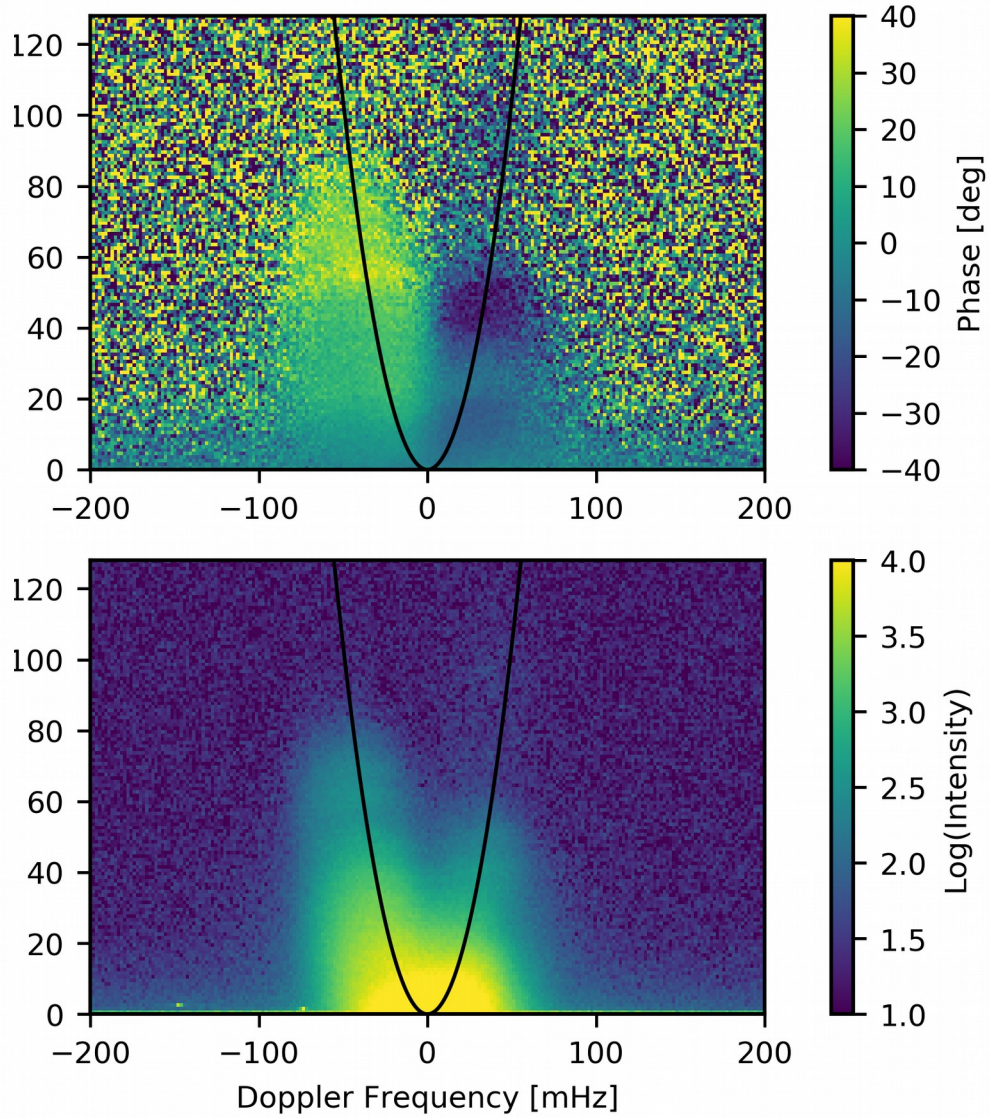
Vela – Secondary Cross Spectra

ν = 1658 MHz, BW = 16 MHz

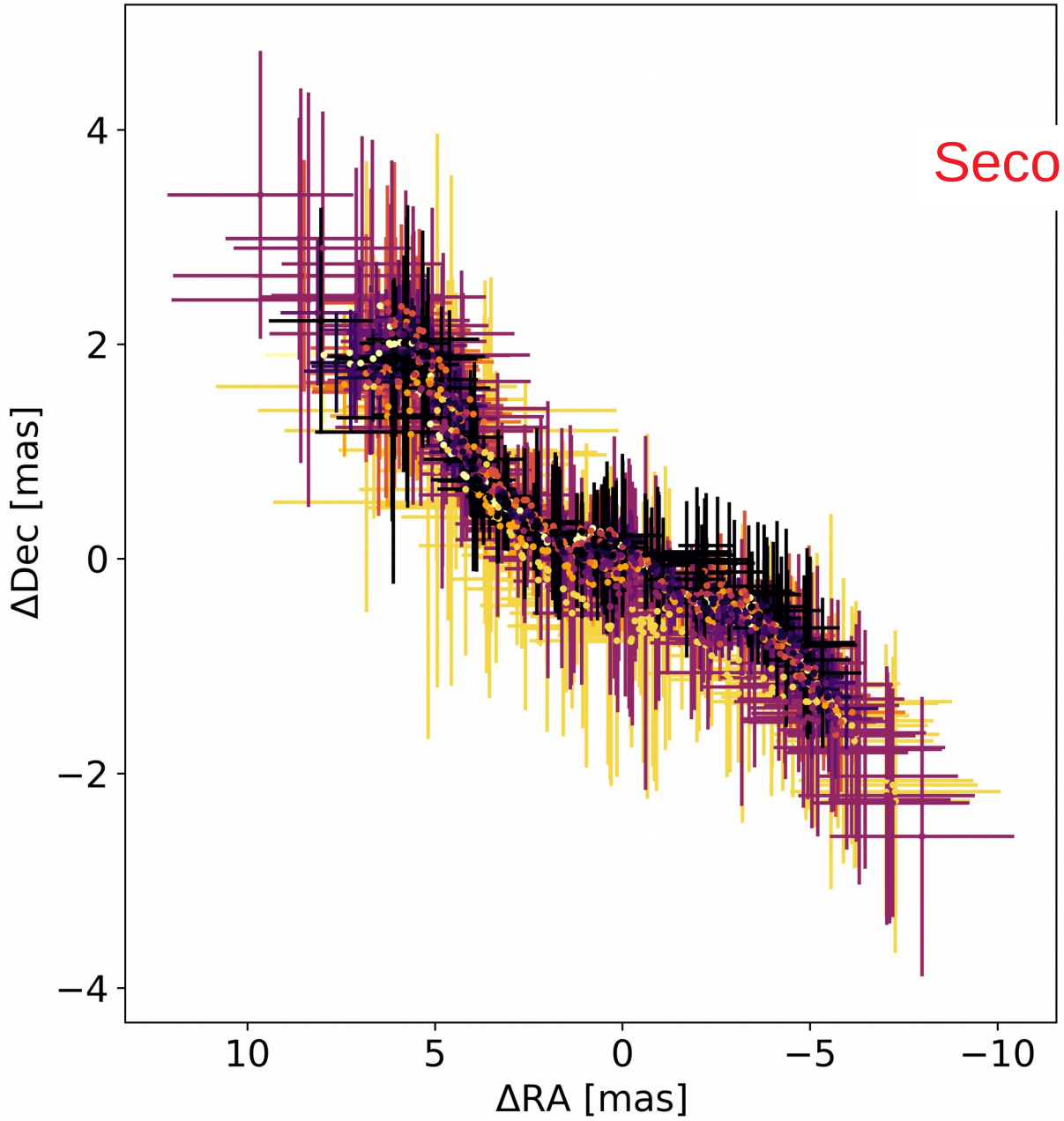
ATCA – Parkes



ATCA – Hobart



VELA – The speckle image



Second EVER speckle image!

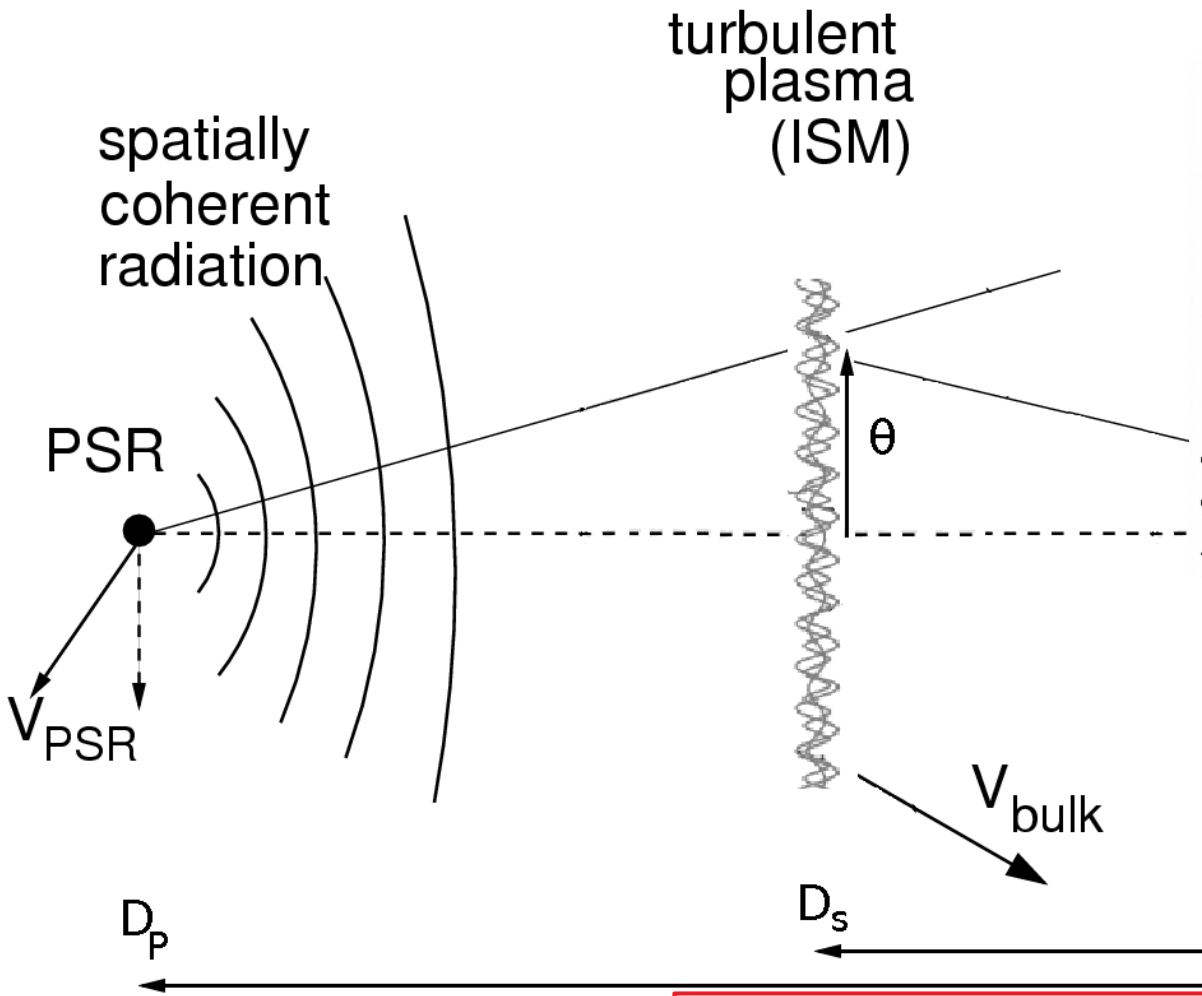
Reminder: Beamsize > 20 mas

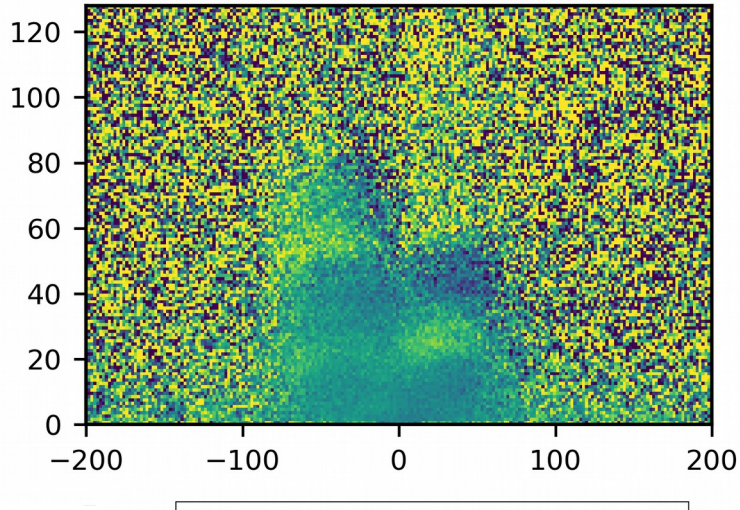
Seems speckle images do not lie on a line

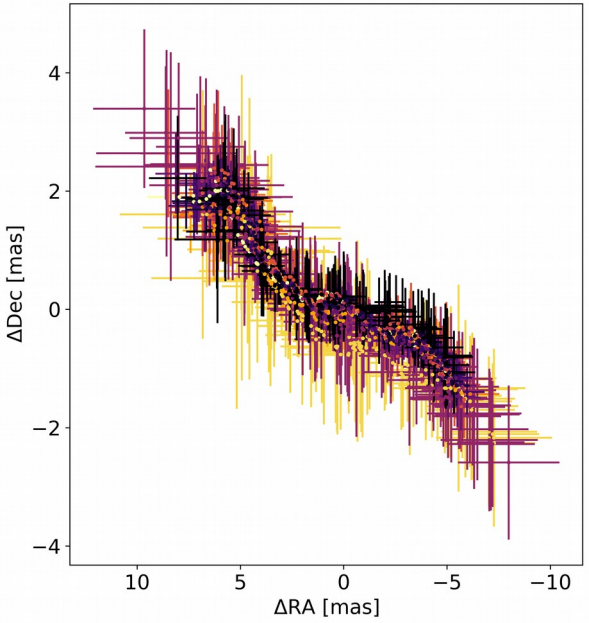
Kirsten et al., in prep

So what do we have?

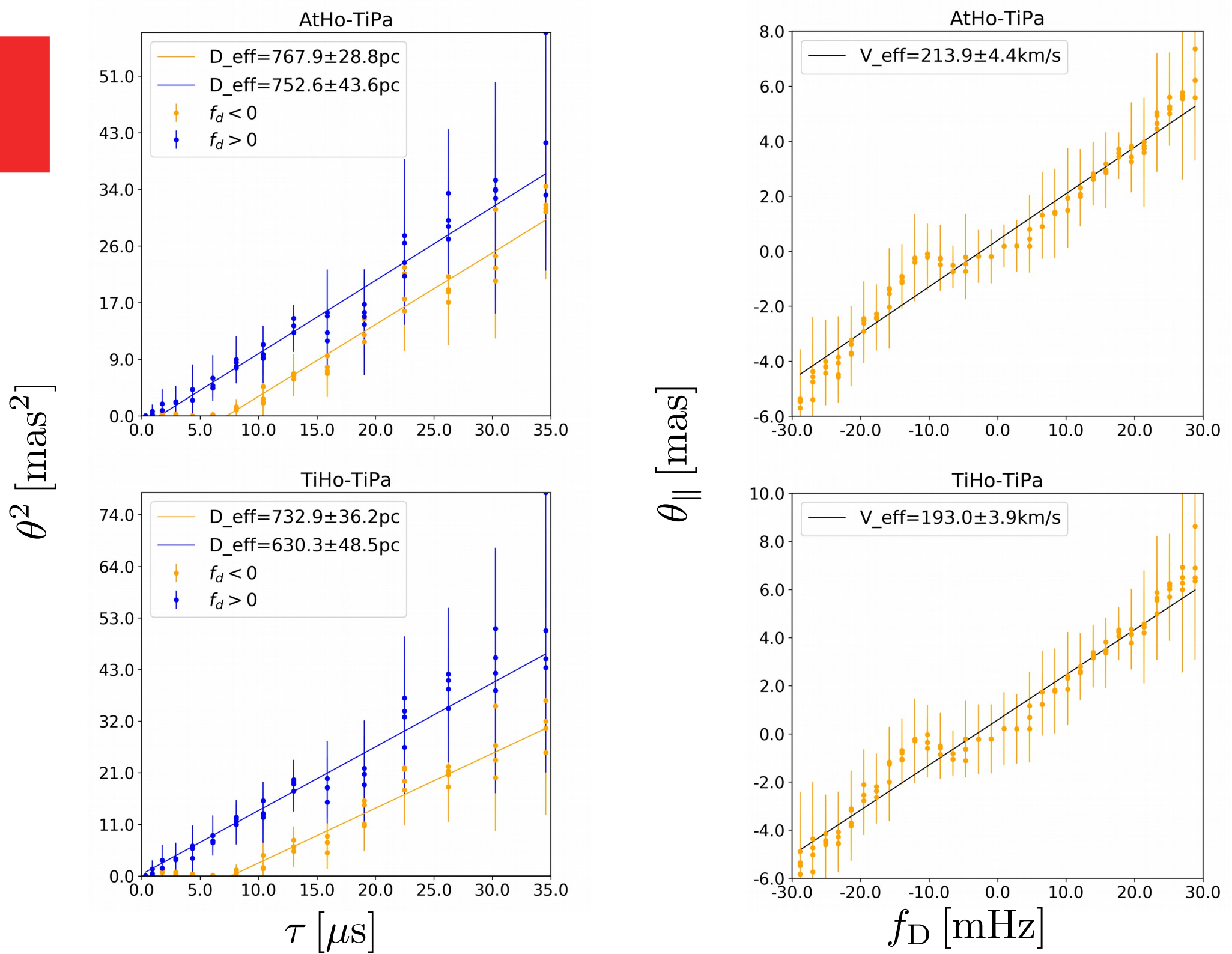
$$\tau = D_{\rm eff}\theta^2/2c$$







$$f_D = V_{\rm eff||}\theta_{||}/\lambda$$


AtHo-TiPa
D_eff=767.9±28.8pc
D_eff=752.6±43.6pc
$f_d < 0$
$f_d > 0$
TiHo-TiPa
D_eff=732.9±36.2pc
D_eff=630.3±48.5pc
$f_d < 0$
$f_d > 0$
θ^2 [mas^2]
τ [μs]
AtHo-TiPa
V_eff=213.9±4.4km/s
TiHo-TiPa
V_eff=193.0±3.9km/s
$\theta_{||}$ [mas]
f_D [mHz]

Distance to the scattering screen

$$D_{\rm eff} = D_{\rm pulsar}\frac{1-\beta}{\beta}$$

$$V_{\rm eff} \approx V_{\rm pulsar}\frac{1-\beta}{\beta}$$

$$\beta = 1 - \frac{D_{\rm screen}}{D_{\rm pulsar}}$$

$$D_{\rm pulsar} = 287^{+19}_{-17}\,{\rm pc}$$

$$V_{\rm pulsar} = 61 \pm 2\,{\rm km/s}$$

$$D_{\rm eff} = 700 \pm 100\,{\rm pc}$$

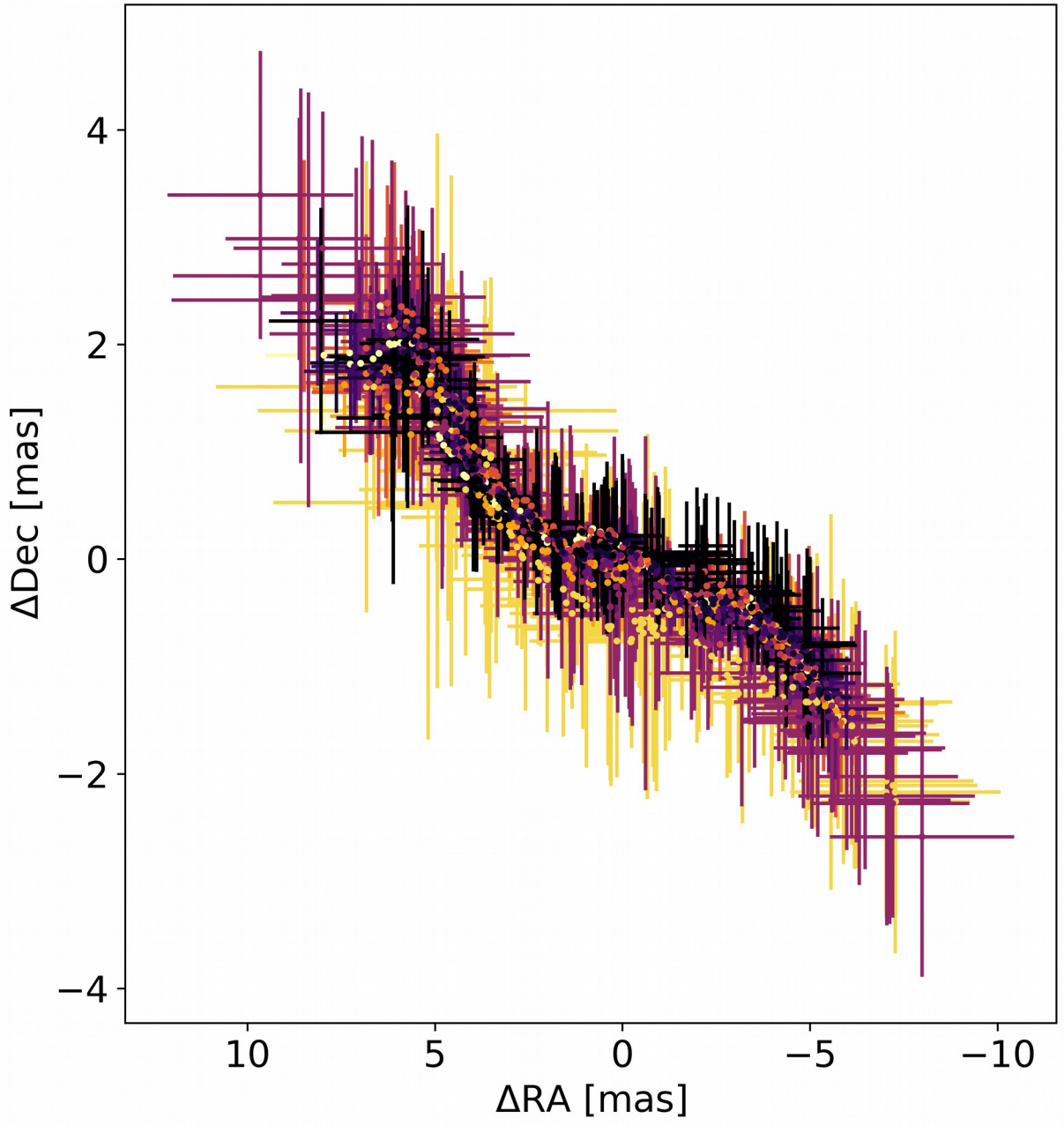
$$V_{\rm eff} = 205 \pm 15\,{\rm km/s}$$

Dodson et al. 2003

$$D_{\rm screen}(D_{\rm eff}) = 202 \pm 43\,{\rm pc}$$

$$D_{\rm screen}(V_{\rm eff}) = 220 \pm 23\,{\rm pc}$$

Implications



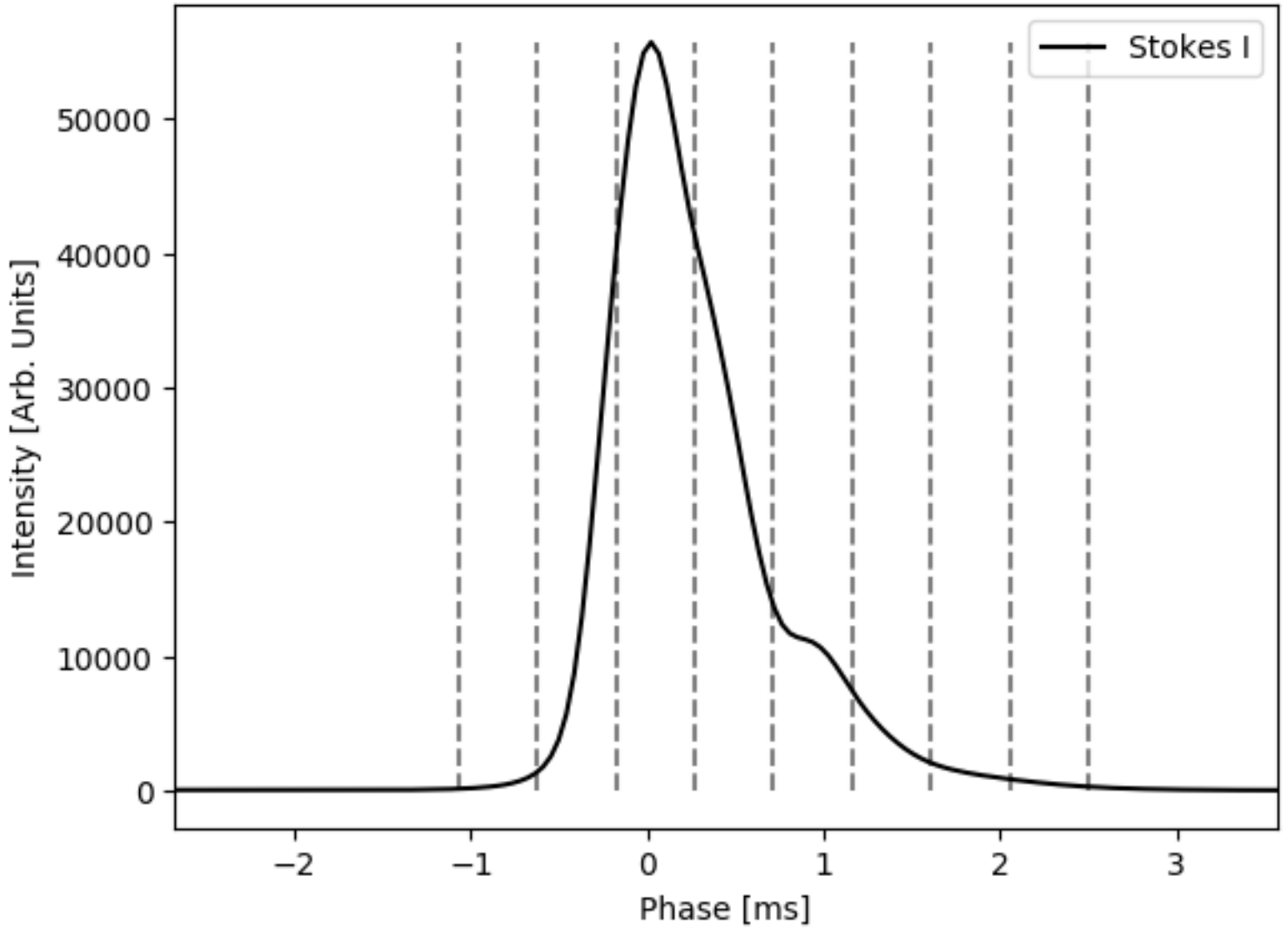
At ~210 pc, 5mas correspond
Correspond to ~ 1 AU

‘beamsize’ of this interstellar interferometer:
~ 250 nanoarcseconds

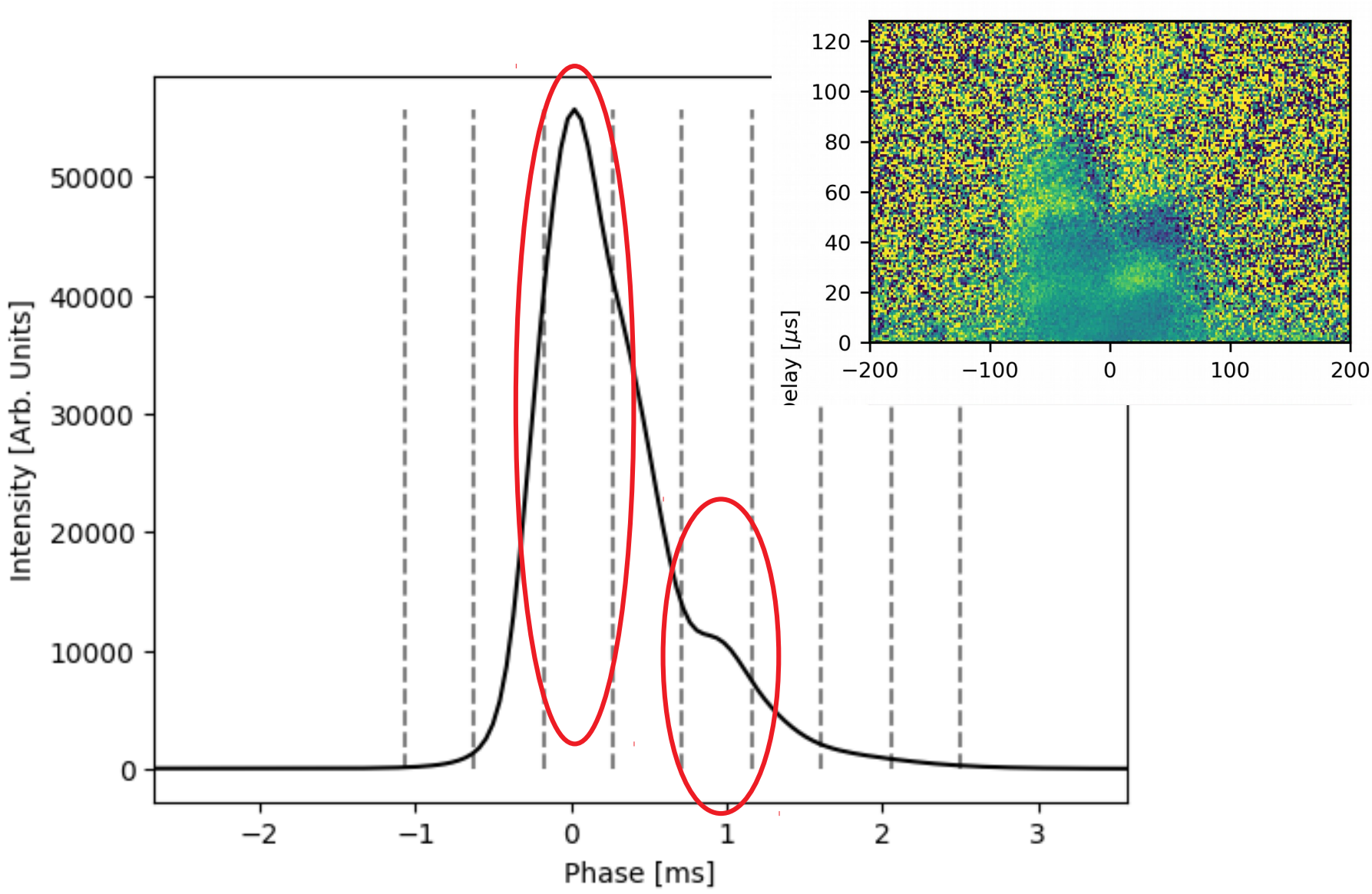
Nominal resolution at Vela:
~ 3000km

Corresponds to ~70 nas resolution from Earth

Application

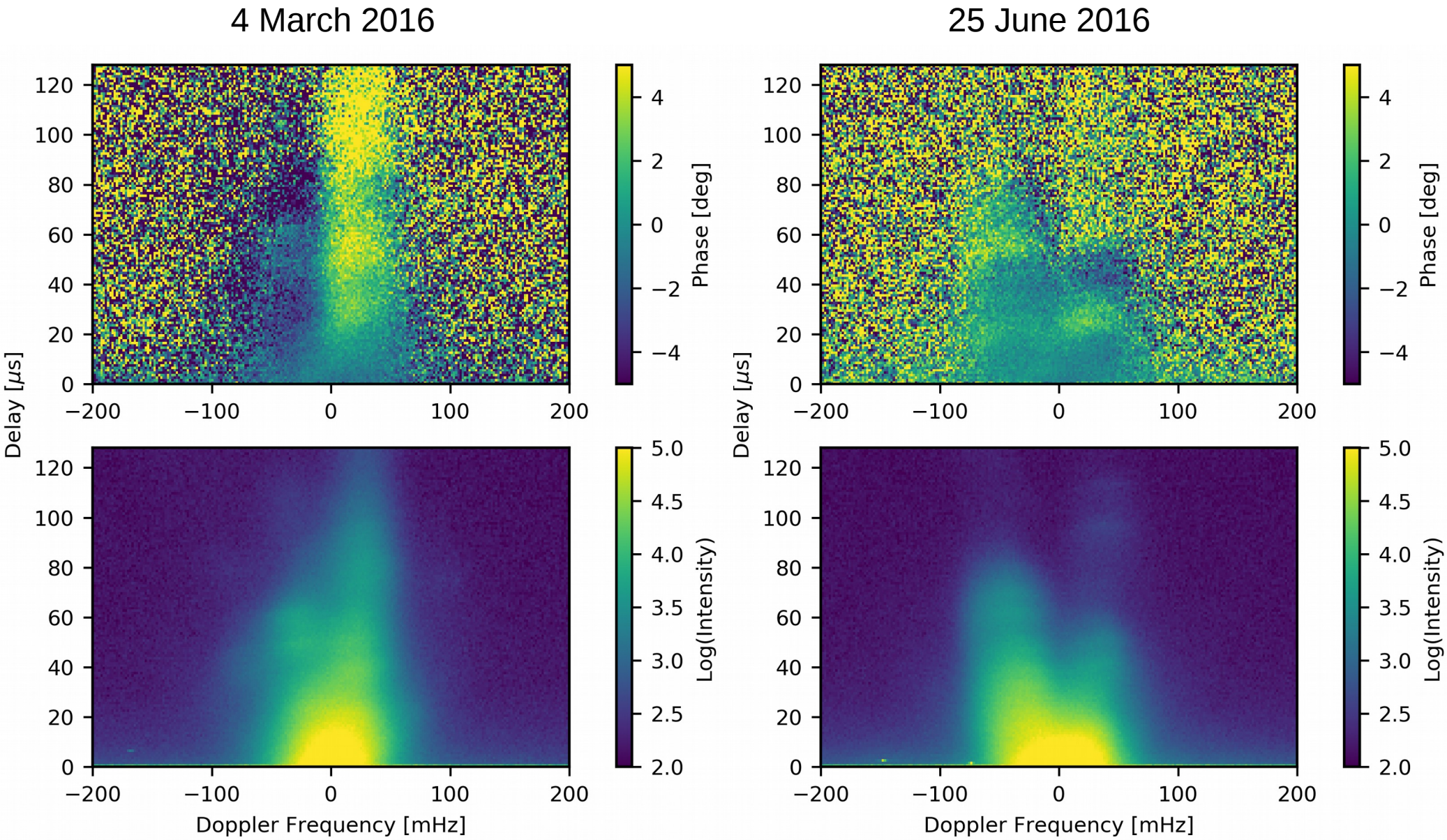


Application



Vela: Interstellar Weather

ATCA – Parkes



Thank you!