香 港 大 學
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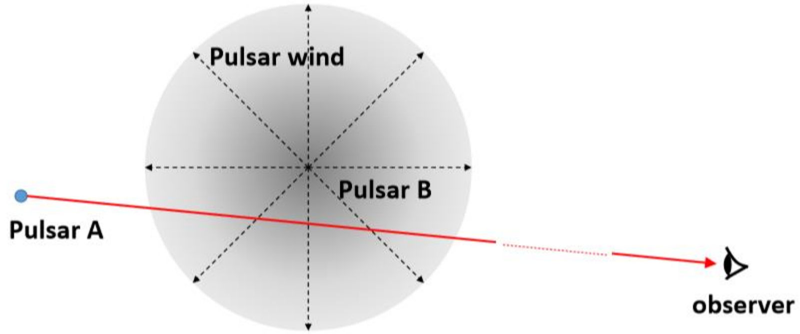
Dispersion in Pulsar Wind*



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2018年7月5日@FPS 7，广州

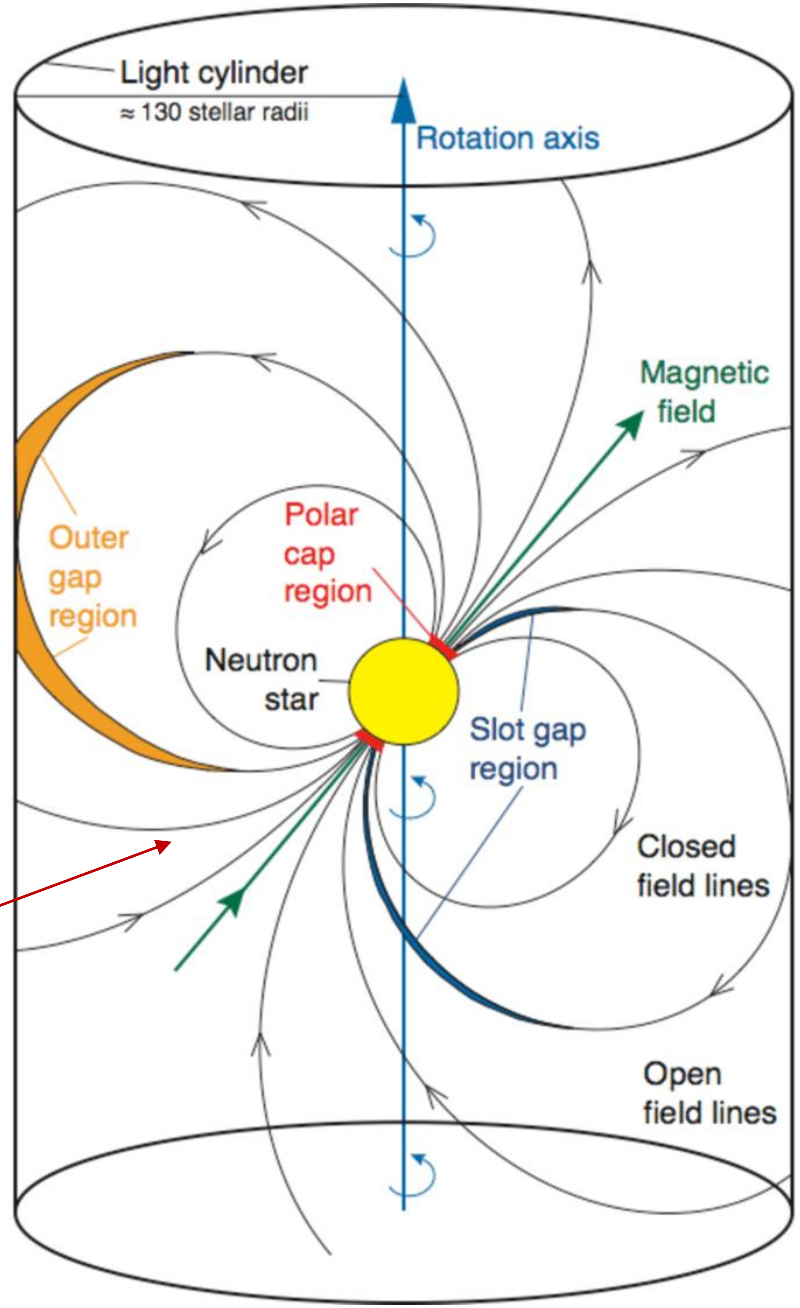
*Shu-Xu Yi, K. S. Cheng; Probing the properties of the pulsar wind via studying the dispersive effects in the pulses from the pulsar companion in a double neutron-star binary system, MNRAS,2017,472,4007.

Background & Motivation

Emissions in all EM frequency bands take only a small fraction of the spin down power.

Gamma-ray emission

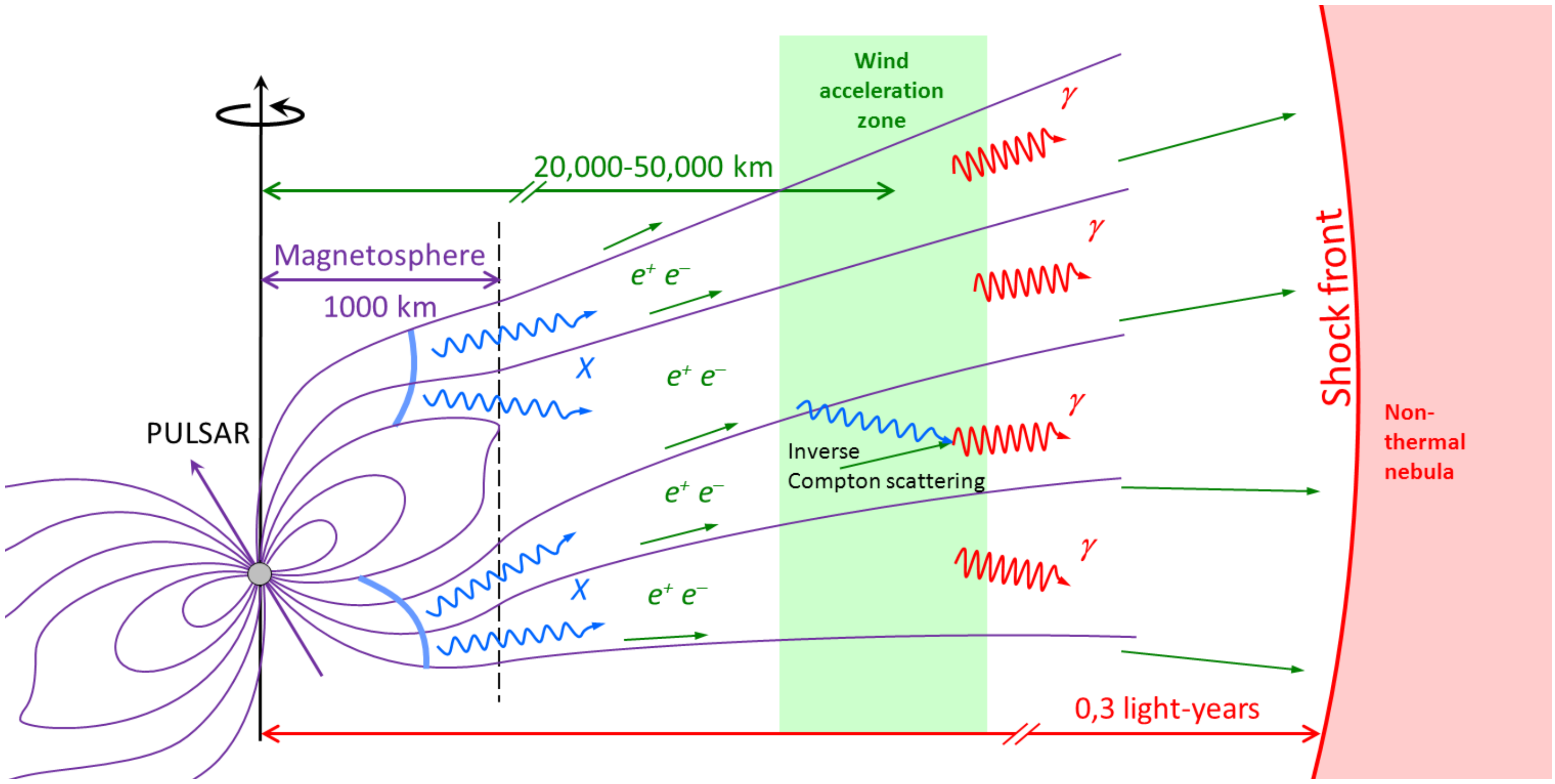
Radio, X-ray emission



Background & Motivation

Most of the spin down energy is in the pulsar wind!

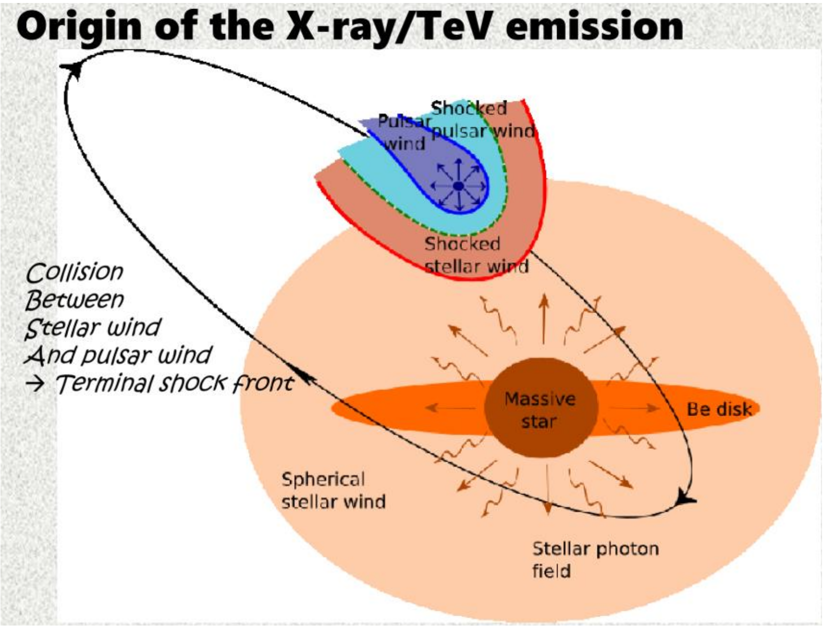
$W_{EM} / W_{part} = \sigma$

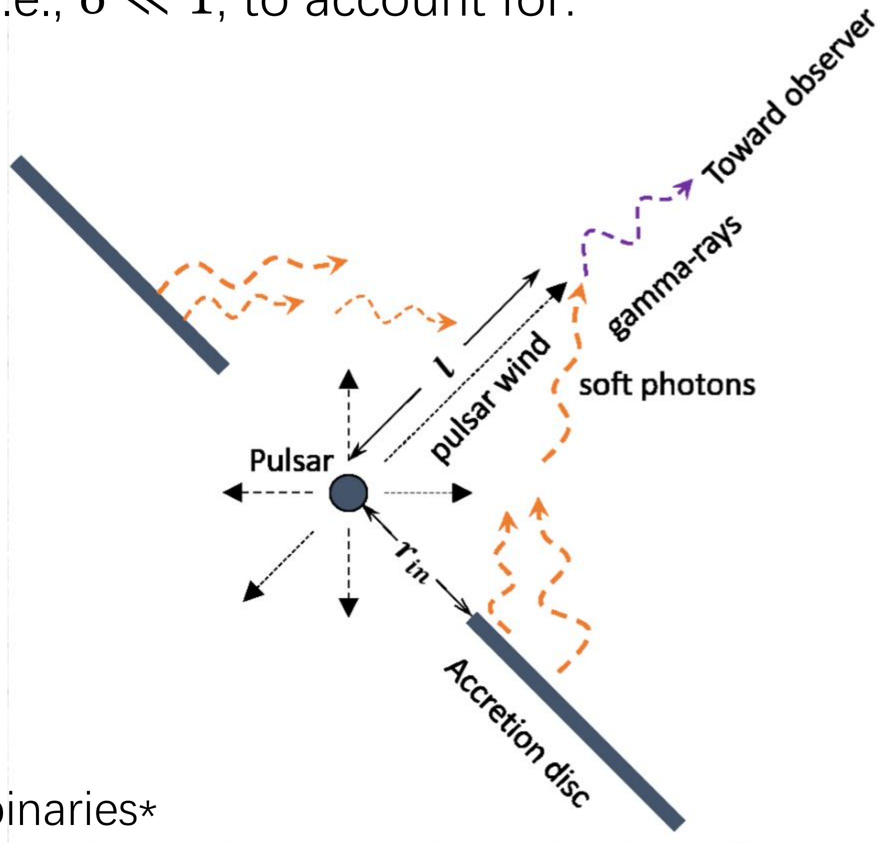


Background & Motivation

Energy should be transferred from EM wave to particles effectively, i.e., $\sigma \ll 1$, to account for:

Supernova remnant





Gamma-ray binaries*

*Shu-Xu Yi, K. S. Cheng; *A new approach to the GeV flare of PSR B1259-63/LS2883*, *ApJ*, Volumn 844, Issue 2, article id. 114, 8 pp, 2017

Background & Motivation

- However, many theoretical studies⋆ showed that the energy transfer from EM wave to particle kinetic energy is ineffective, i.e., $\sigma \gg 1$. “Sigma-Problem”.

$$\sigma = \sigma_{\mathrm{L}} \left(\frac{r}{r_{\mathrm{L}}} \right)^{-\alpha_{\sigma}} ,$$

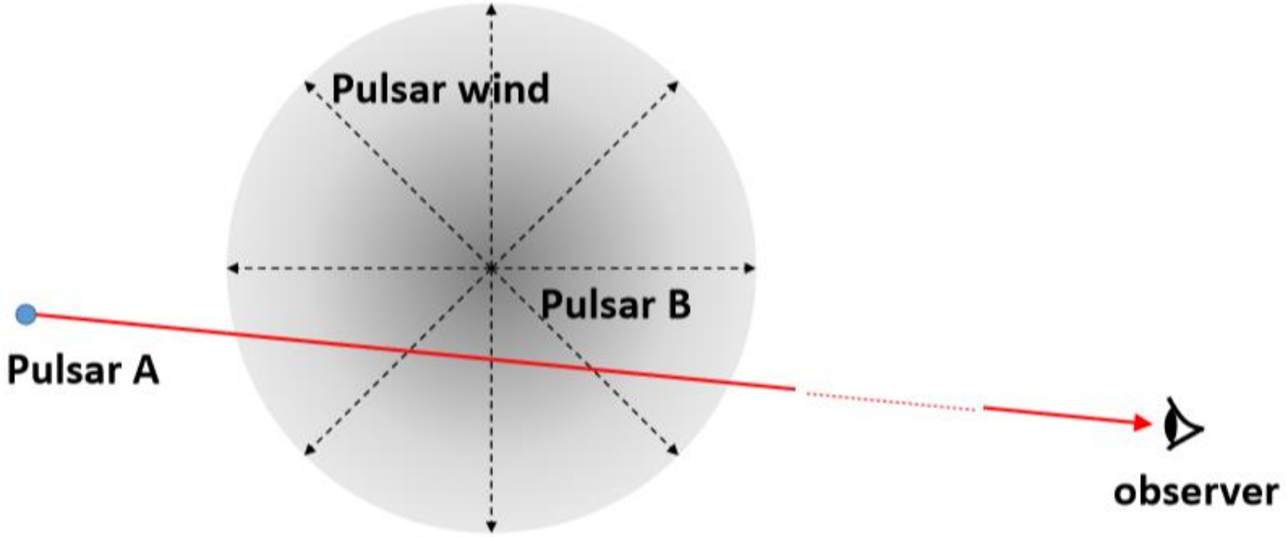
⋆Usov 1975; Melatos & Melrose 1996; Beskin et al. 1998; Chiueh et al. 1998; Bogovalov & Tsinganos 1999; Bogovalov 2001; Lyubarsky & Eichler 2001; Lyubarsky 2002

Idea

$$\delta \mathrm{DM} = \int_0^\infty \frac{1}{\sqrt{1 - r_\mathrm{s}/r}} \frac{n'_\mathrm{e}}{(1 - \beta\cos\theta)} dl.$$

$$n_\mathrm{e}(r) = \frac{L_\mathrm{sd}}{4\pi\beta c^3 r^2 m_\mathrm{e}(1+\sigma)\gamma},$$

$$W_{EM} \,/\, W_{part} = \sigma$$



Examples

- PSR J0737-3039A/B*, both are radio active pulsars.
- Orbital inclination angle: 88.69°
- Longitude of periastron: 87.0331°
- Eccentricity, $e = 0.087775$
- Projected semimajor axis, $x = (a/c)\sin i$: pulsar A: 1.415032s; pulsar B: 1.5161s
- Spin down luminosity of pulsar B, $L_{sd,B} = 1.7 \times 10^{30}$ erg/s.

*Kramer & Stairs 2008

PSR J0737-3039A/B

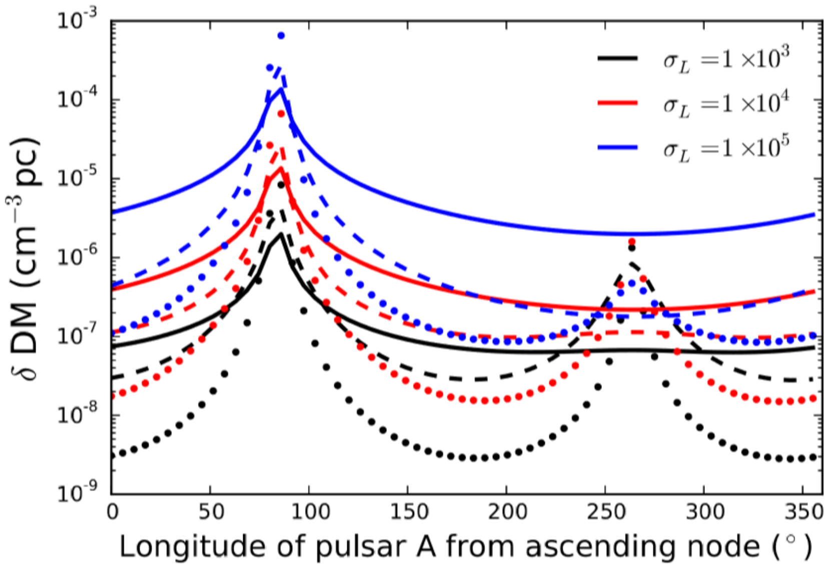


Figure 3. The additional DM in PSR J0737-3039A, under the assumptions of different σ_L and α_σ. The black, red and blue line colors correspond to $\sigma_L = 1\times10^3$, 1×10^4 and 1×10^5 respectively; The solid, dashed and dotted line styles correspond to $\alpha_\sigma = 0$, 1, 2. For all curves, $\gamma_\infty = 10^3$ is adopted.

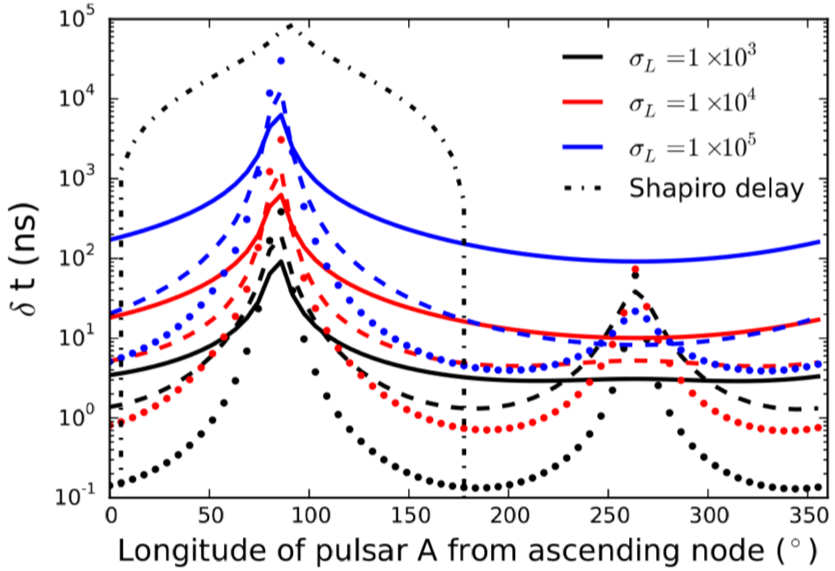
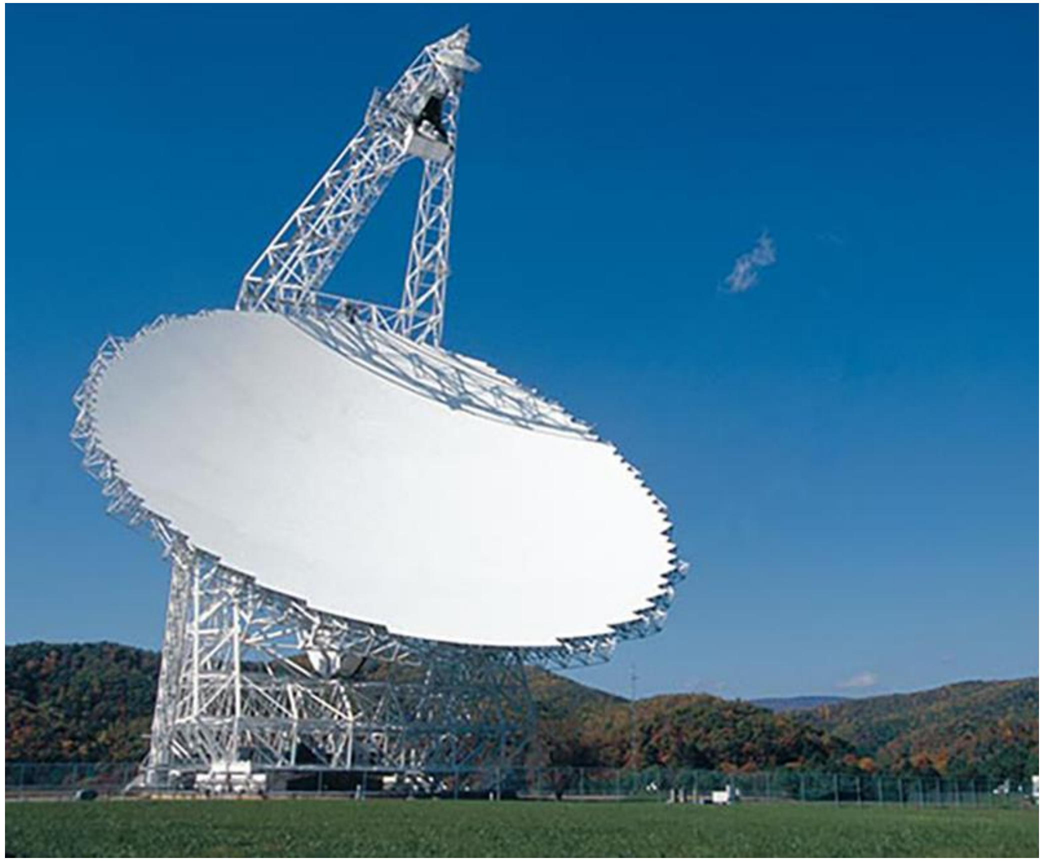


Figure 4. Time delay due to the additional DM in PSR J0737-3039A/B in the observing frequency of 300 MHz, compared with Shapiro delay (dash-dotted curve). The black, red and blue line colors correspond to $\sigma_L = 1\times10^3$, 1×10^4 and 1×10^5 respectively; The solid, dashed and dotted line styles correspond to $\alpha_\sigma = 0$, 1 and 2 respectively. For all curves, $\gamma_\infty = 10^3$ is adopted.

PSR J0737-3039A/B

- Best timing precision:
- 18 micro second, integral 30s,
- @800 MHz, GBT



PSR J1915+1606 (B1913+16)

- Hulse-Taylor binary*
- Only one of the neutron star is detected as radio pulsar.
- Orbital inclination angle: 42.84°
- Longitude of periastron: 292.54450°
- Eccentricity, e = 0.6171340
- Projected semimajor axis, x = (a/c)sini = 2.341776s
- Mass ratio between the pulsar and the companion neutron star: 1.0345

*(Weisberg & Huang 2016):

PSR J1915+1606 (B1913+16)

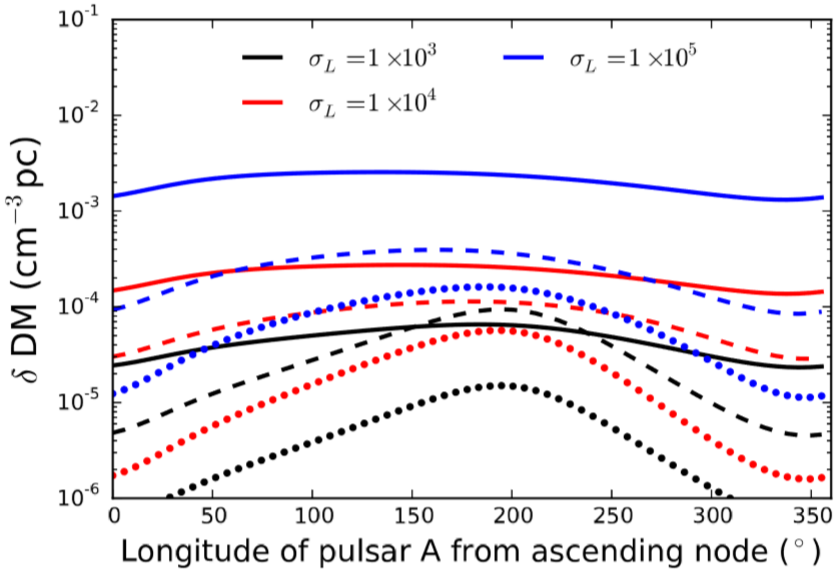


Figure 5. The additional DM of PSR J1915+1606, under the assumptions of different σ_L and α_σ. The black, red and blue line colors correspond to $\sigma_L = 1\times10^3$, 1×10^4 and 1×10^5 respectively; The solid, dashed and dotted line styles correspond to $\alpha_\sigma = 0$, 1, 2. For all curves, $\gamma_\infty = 10^3$ is adopted.

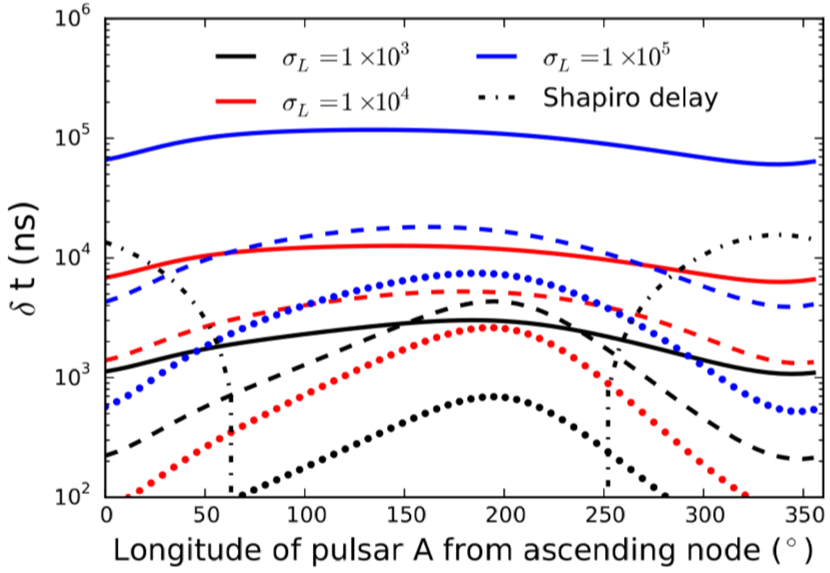


Figure 6. Time delay due to the additional DM in PSR J1915+1606 in the observing frequency of 300 MHz, compared with Shapiro delay (dash-dotted curve). The black, red and blue line colors correspond to $\sigma_L = 1 \times 10^3$, 1×10^4 and 1×10^5 respectively; The solid, dashed and dotted line styles correspond to $\alpha_\sigma = 0$, 1 and 2 respectively. For all curves, $\gamma_\infty = 10^3$ is adopted.

PSR J1915+1606 (B1913+16)

- Best timing precision
- 5 micro second,
- @Arecibo 1.4 GHz, integral 5-min

Summary

- Study the properties of pulsar wind with its dispersive effects (How electrons/positrons accelerate in pulsar wind)
- PSR J0737-3039 A/B, larger telescope, longer observation can see
- PSR J1915+1606, may find it in archival data, or set upper-limit to spin down power of the invisible neutron star.