GwsNS 2026 School – Flash talks

Modelisation of the multiwavelength emission properties of pulsars and their population

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Spin-orbit alignment hypothesis in millisecond pulsars

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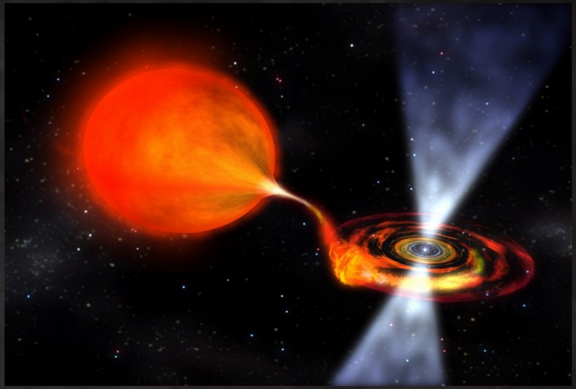
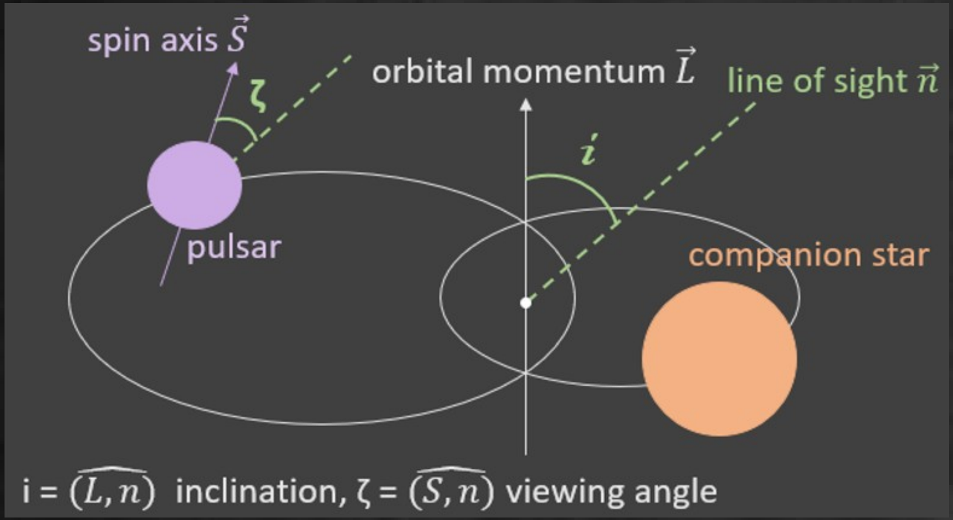
Formation and evolution of pulsar binaries

- Formation of a binary
- **Phase of accretion** possible ⟹ **millisecond** pulsar
- If accretion, **alignment** between $\vec{L}$ and $\vec{S}$ ⟺ $\zeta = i$



Artist view of an accretion phase (*D. Berry*).

duration of accretion phase : ~10^8 yr
typical alignment time : ~10^3 yr



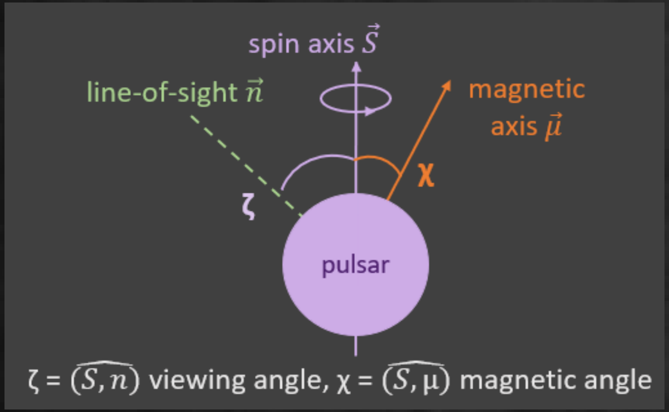
Scheme of a binary system.

Objectives of this work

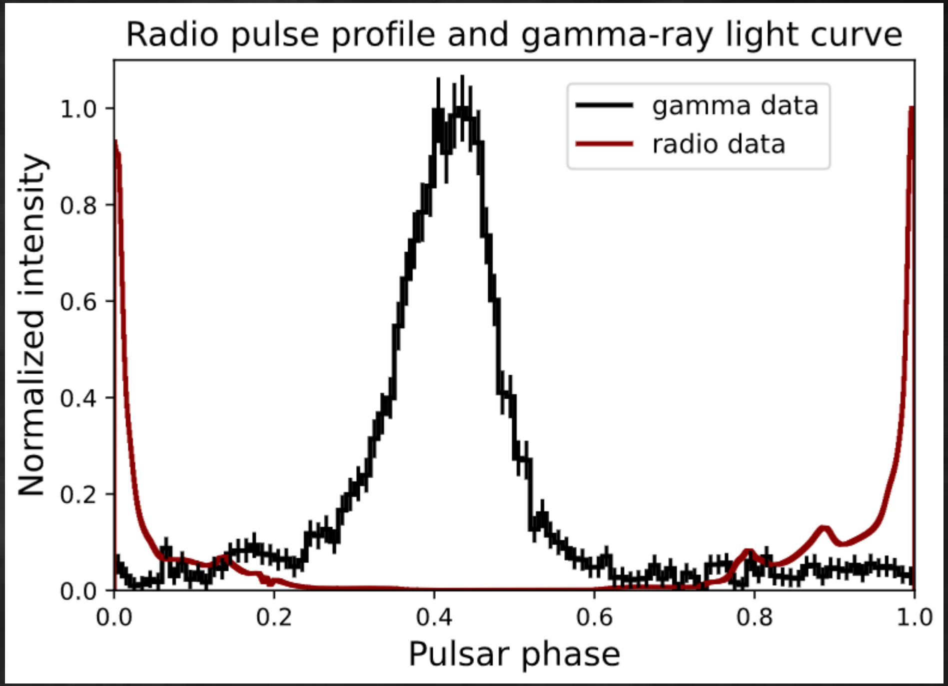
Main goal : verify the hypothesis of alignment between $\vec{L}$ and $\vec{S}$

Method : use of the multi-wavelength emission of pulsars

Tools : bayesian inference



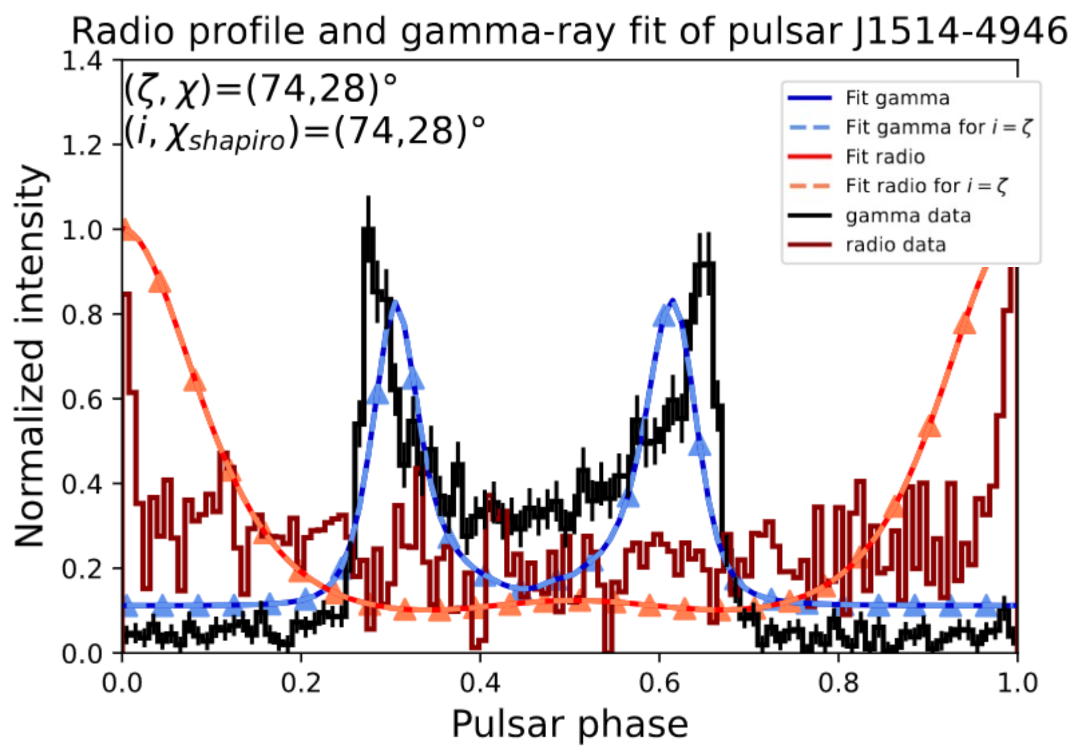
Scheme of the characteristic angles of a pulsar.



Example of radio pulse profile and gamma-ray light curve for the millisecond pulsar J0437-4715.

Results for the second sample

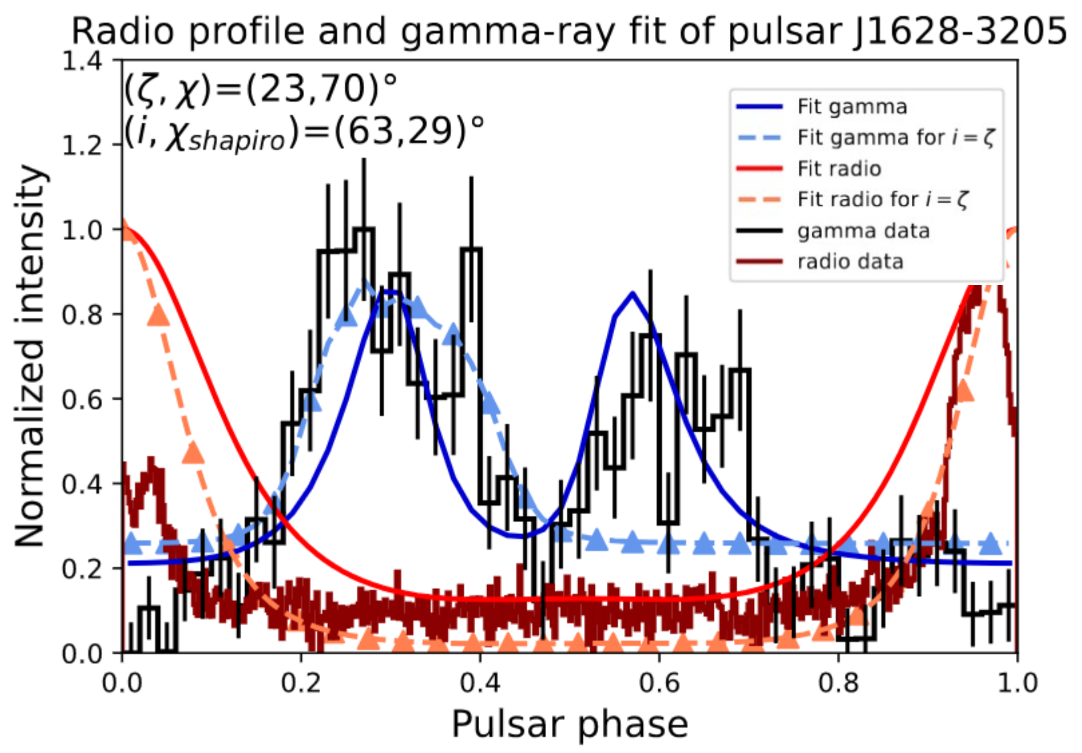
- Fitting of the light curves from a sample of 15 millisecond pulsars.



→ hypothesis of alignment verified for this pulsar

Results for the second sample

- Fitting of the light curves from a sample of 15 millisecond pulsars.



➡ hypothesis of alignment not verified for this pulsar

Results for the second sample

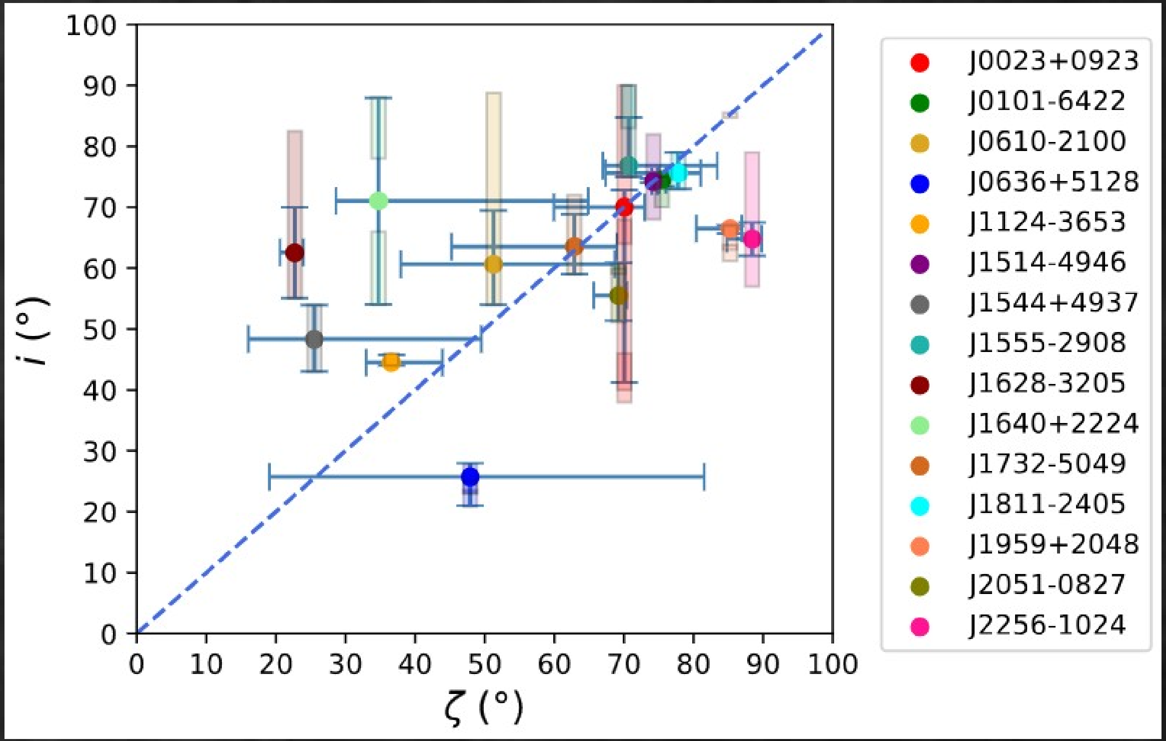
- Comparison between i and ζ angles for the whole sample.

➡ **80%** of pulsars aligned

⟺ 12/15 pulsars

alignment timescale larger than expected ?

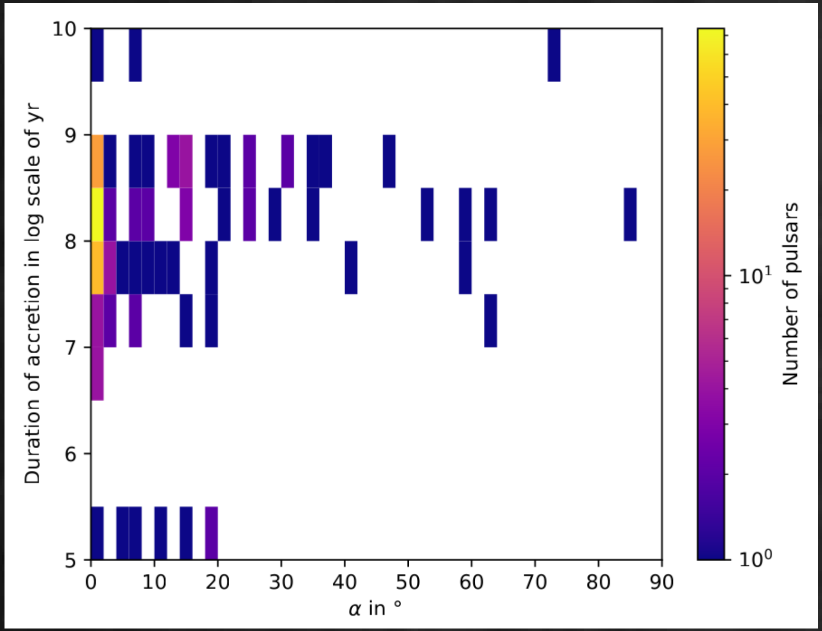
➡ result confirmed by *pulsar population synthesis*



Discussion about possible misalignment

- Alignment timescale :

$$\tau_{\mathrm{align}} = 3.8 \times 10^{6}\mathrm{yr} \left(\frac{\mathrm{P}_0}{1\mathrm{ms}}\right)^{-1} \left(\frac{\mathrm{R}}{10\mathrm{km}}\right)^{8/7} \left(\frac{\mathrm{M}_0}{1.4\mathrm{M}_\odot}\right)^{4/7} \left(\frac{\dot{\mathrm{m}}}{\dot{\mathrm{M}}_{\mathrm{Edd}}}\right)^{-6/7} \left(\frac{\mathrm{B}}{10^{6}\mathrm{T}}\right)^{-2/7}$$



Spin-orbit inclination angle α of a simulated population of millisecond pulsars.

➡ 20 % of the simulated pulsars are more than 10° away from alignment

Discussion about possible misalignment

- Evolution of the angular momentum of the pulsar :

$$\frac{dL}{dt} = I\,\dot{\Omega} + I\,\frac{\dot{m}}{M}\Omega = \dot{m}\,\sqrt{G\,M\,r_{\mathrm{acc}}}$$

- Variation of the angular momentum for which the pulsar reach alignment :

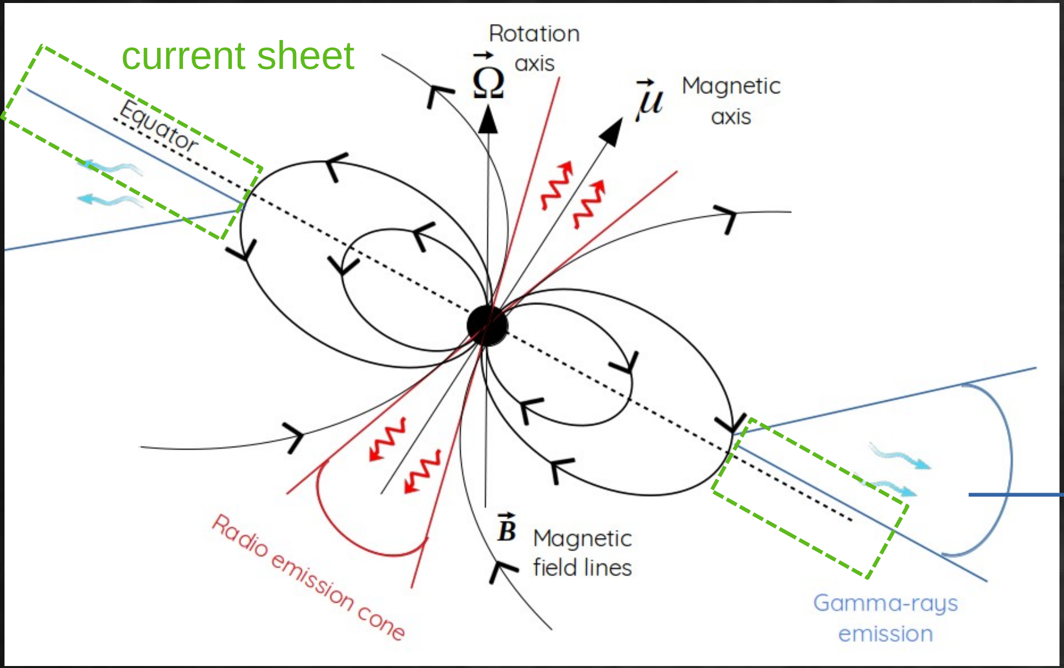
$$\frac{\Delta L}{L_0} = \frac{5\,P_0\,\dot{m}}{4\,\pi\,R^2}\,\tau_{\mathrm{align}}\,\sqrt{\frac{G\,r_{\mathrm{acc}}}{M_0}\left(1+\frac{\dot{m}}{M_0}\,\tau_{\mathrm{align}}\right)} \approx 1$$

- Alignment timescale :

$$\tau_{\mathrm{align}} = 3.8\times10^6\mathrm{yr}\left(\frac{\mathrm{P}_0}{1\mathrm{ms}}\right)^{-1}\left(\frac{\mathrm{R}}{10\mathrm{km}}\right)^{8/7}\left(\frac{\mathrm{M}_0}{1.4\mathrm{M}_\odot}\right)^{4/7}\left(\frac{\dot{\mathrm{m}}}{\dot{\mathrm{M}}_{\mathrm{Edd}}}\right)^{-6/7}\left(\frac{\mathrm{B}}{10^6\mathrm{T}}\right)^{-2/7}$$

Gamma-ray emission model

- **Force free** model of the magnetosphere (*Pétri 2024*).
- Emission region of gamma-rays : **current sheet.**



Scheme of the emission regions in radio and in gamma-ray of a pulsar (*M. Sautron*).

3D view of the current sheet.