A unified polar cap/striped wind model for pulsed radio and gamma-ray emission in pulsars

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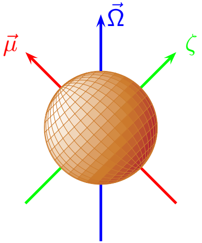
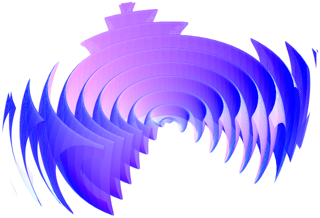
Summary

The structure of the striped wind

Near the star :
a magnetic dipole



At large distances :
striped wind (Bogovalov 1999)



- $\vec{\Omega}$: rotation axis
- χ : magnetic axis inclination with respect to $\vec{\Omega}$
- ζ : line of sight inclination with respect to $\vec{\Omega}$

- hot and magnetized plasma in the sheet
- relativistic beaming $\Gamma_{\rm vent} \gg 1$

=> pulsed emission

1. Objectives
   - high-energy pulsed emission (MeV/GeV)
   - spectral variability of several gamma-ray pulsars.
2. Processes
   - synchrotron radiation from hot and magnetized plasma in the stripe
   - inverse Compton with target photons
     - cosmic microwave background, CMB
     - synchrotron photons from the nebula, X-ray
     - thermal emission from the neutron star surface, black body with $T_{\rm bb} \approx 10^6$ K
     - photons from companion star
3. Applications
   - isolated pulsars => gamma ray pulsars
   - binary pulsars => PSR B1259-63
4. Link to other wavelengths ?
   - polar cap for radio emission : phenomenological
   - striped wind for optical up to gamma rays

$\Rightarrow$ geometry could be defined (χ and ζ).

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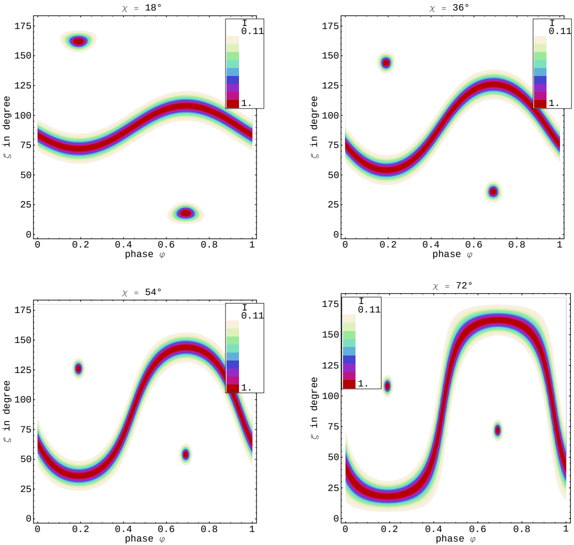
Relation between radio and gamma-ray pulses : phase-plot



(Pétri, MNRAS, 2011)

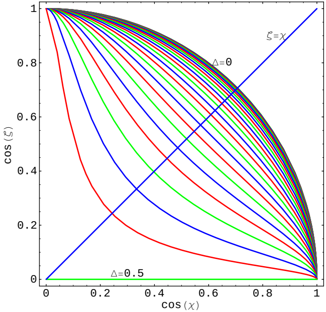
From pure geometric considerations

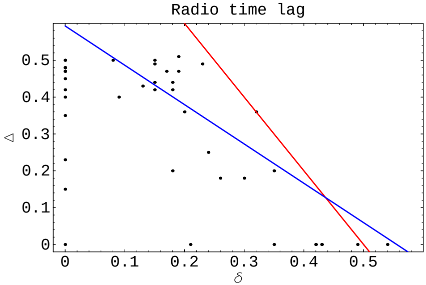
Gamma-ray peak separation Δ

$$\cos(\pi\,\Delta) = |\cot\zeta\;\cot\chi|$$

Radio time lag δ

$$\delta \approx \frac{1-\Delta}{2}$$





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Main results

- S-shape around $\zeta = 90^o$ reflects emission from current sheets
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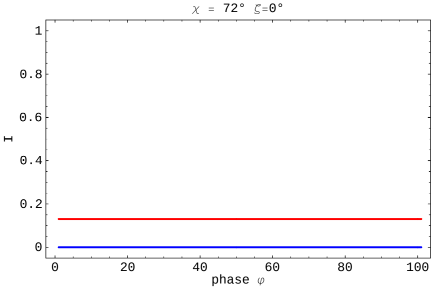

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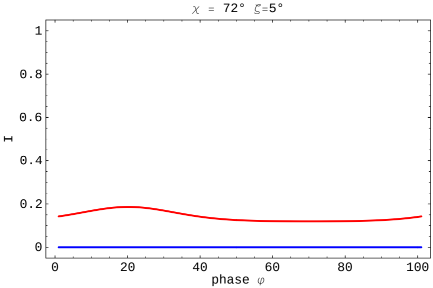

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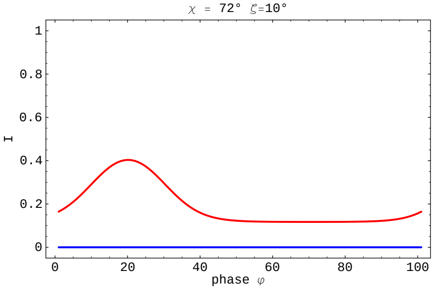

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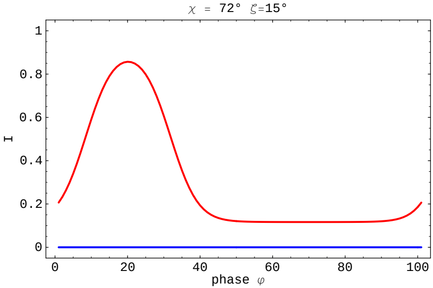

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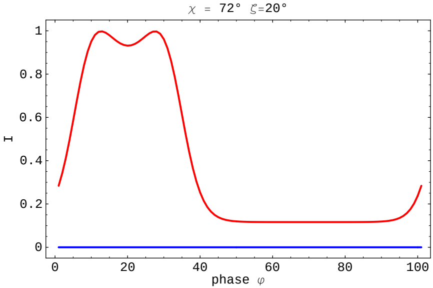

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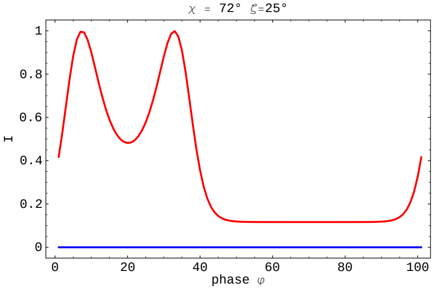

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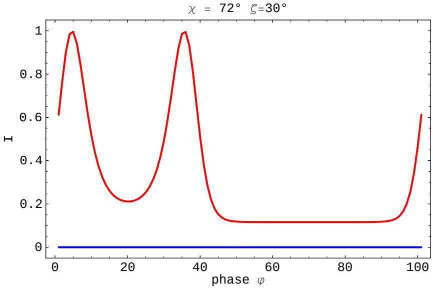

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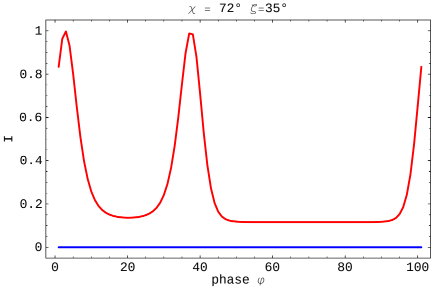

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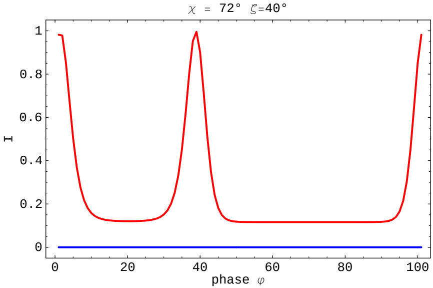

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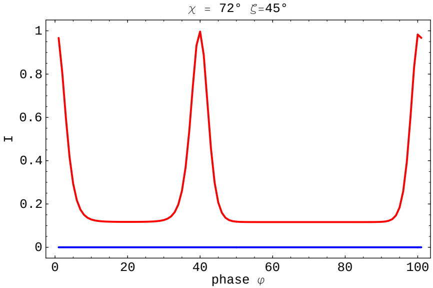

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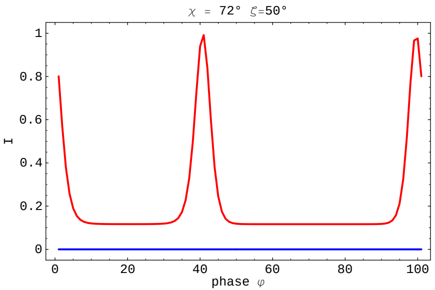

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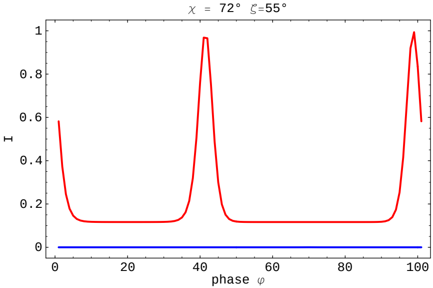

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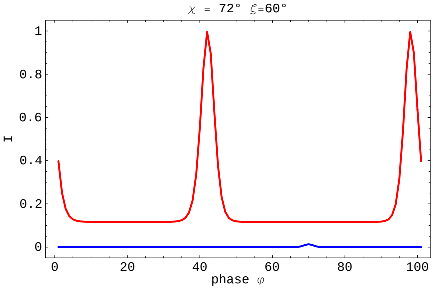

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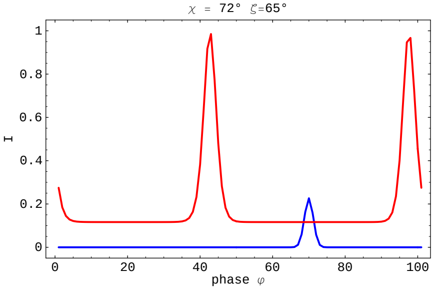

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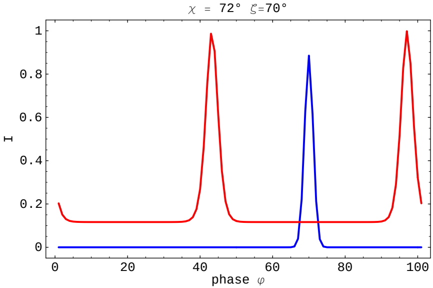

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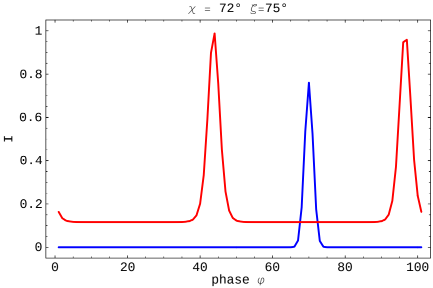

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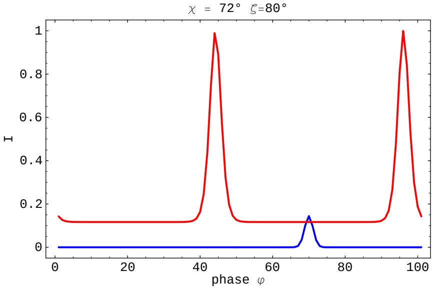

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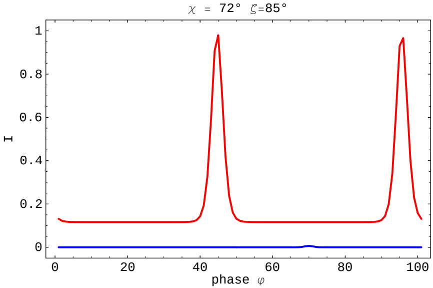

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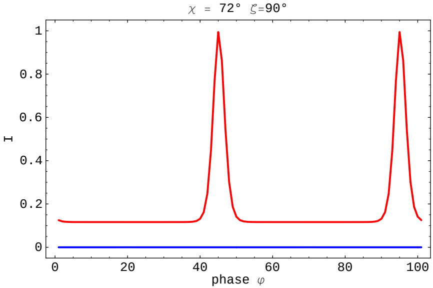

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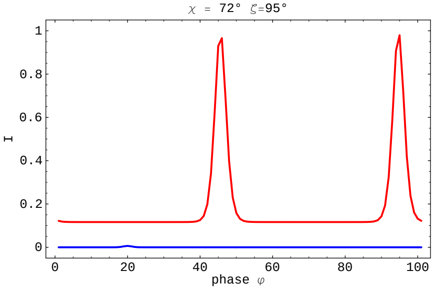

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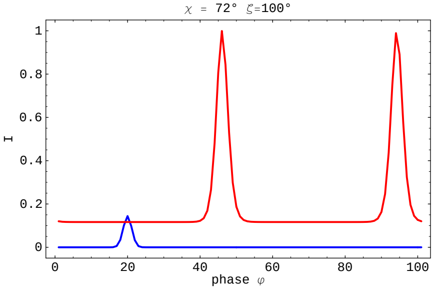

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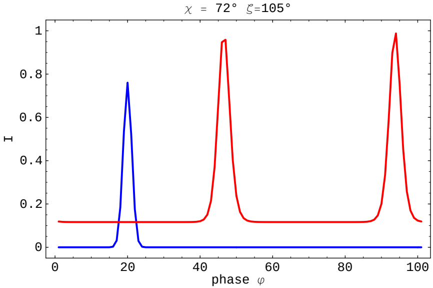

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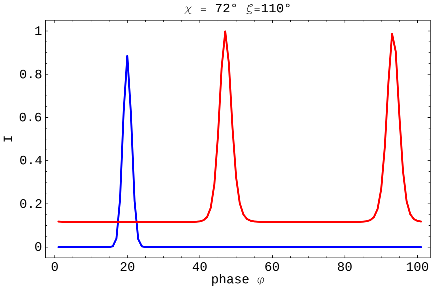

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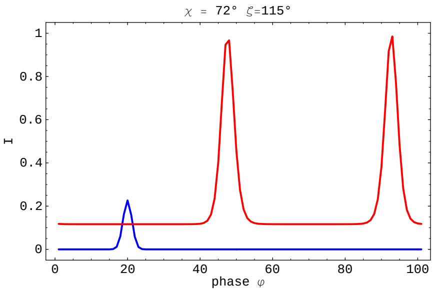

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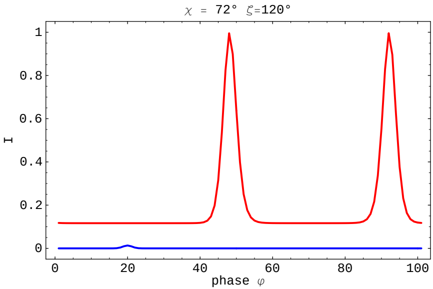

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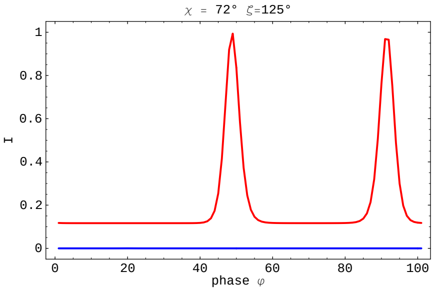

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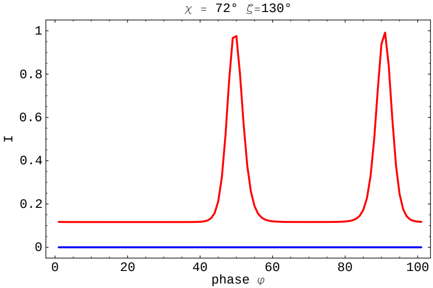

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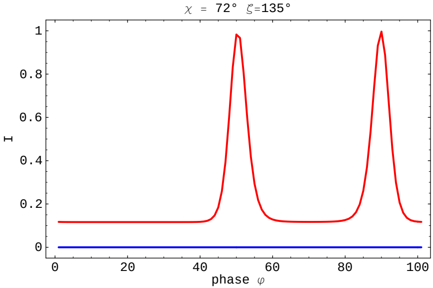

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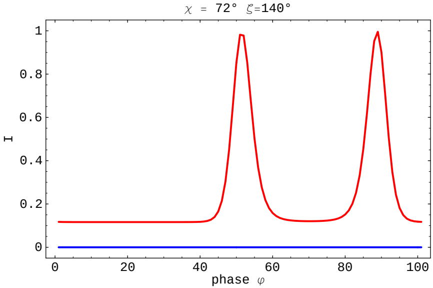

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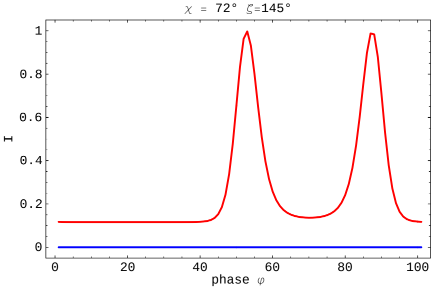

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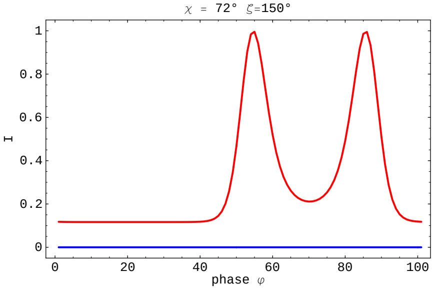

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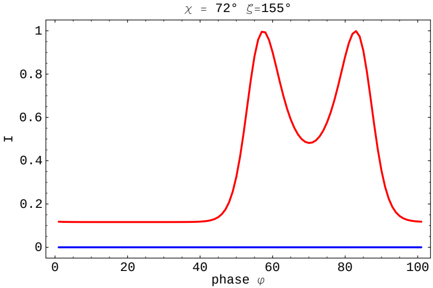

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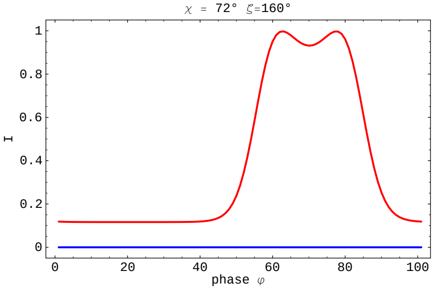

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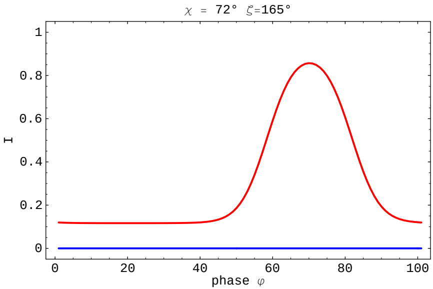

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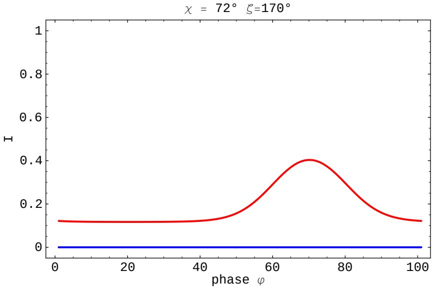

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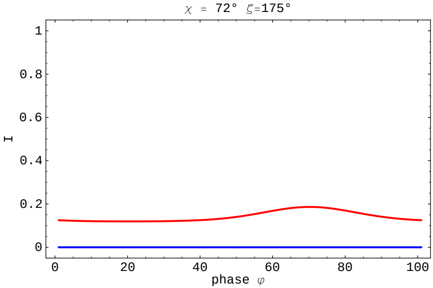

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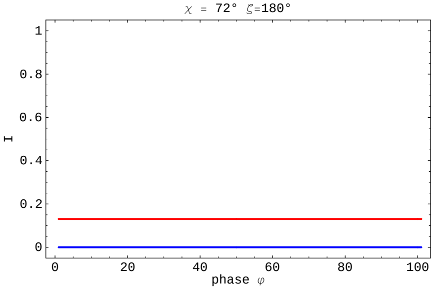

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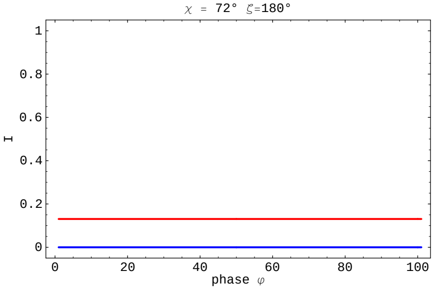
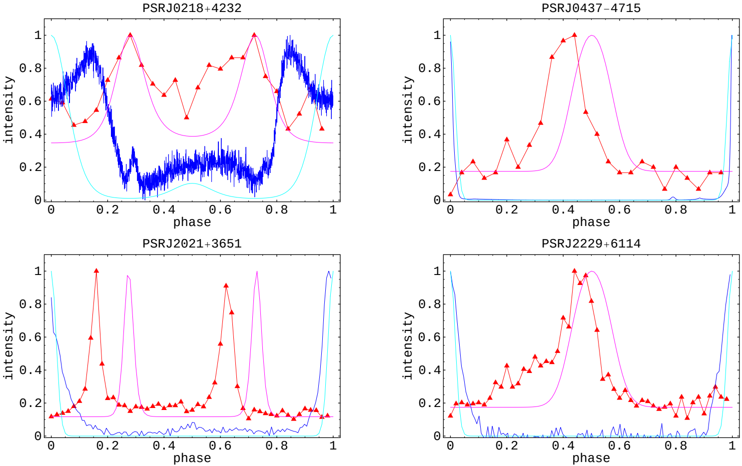
- several light-curve combinations possible depending on geometry χ, ζ

1. no radio/gamma pulse !
2. only radio
3. only gamma
4. one radio + one/two gamma-ray pulse(s)
5. two radio pulse
   => perpendicular rotator, $\zeta \approx \chi \approx 90^o$

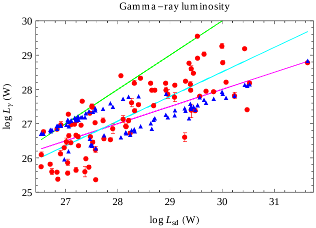


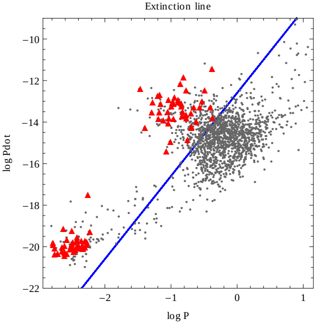
(Pétri, MNRAS, 2011)

Radio and gamma-ray light-curve fitting



What about luminosities ?





Assumptions

- synchrotron emission in the stripe
- radiative cooling compensated by reheating due to magnetic reconnection

Main results

- the predicted luminosity function

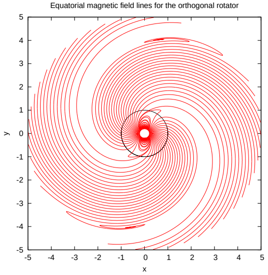
$$L_\gamma \approx 2\times10^{26}\ \mathrm{W} \left(\frac{L_{sd}}{10^{28}\ \mathrm{W}}\right)^{1/2} \left(\frac{P}{1\ \mathrm{s}}\right)^{-1/2}$$

- condition for pulsed emission

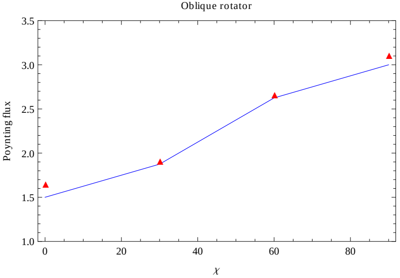
$$\frac{L_{sd}}{P} \geq 10^{27}\ \mathrm{W/s}$$

(Pétri, MNRAS, 2012b)

Perpendicular rotator



Spin-down luminosity



$$L_{\rm sp} \approx \frac{3}{2} L_{\rm dip}^{\perp} (1 + \sin^2 \chi) \tag{1}$$

=> more realistic formula than the magnetodipole in vacuum.

=> $B_\perp$ AND $B_{||}$ constrained.

(Pétri, MNRAS, 2012a)

Conclusions & perspectives

Pulsed emission

- high-energy pulsed emission emanating from regions well outside the light cylinder, $r \approx (\mathrm{few} - 100)\, r_{\mathrm{L}}$.
- gamma-ray luminosities from Fermi/LAT second source explained by synchrotron emission in the stripe.

Further investigations

- link between asymptotic toroidal magnetic field and magnetosphere
  $\Rightarrow$ location where most of the high-energy pulsed emission is expected.
- phase-resolved polarisation properties in X-ray (Crab ?)
- possible explanation for gamma-ray binaries ?
- deeper multi-wavelength study
  (anticorrelation in radio and X-rays flux, Hermsen et al., Science, 2013)