Pulsed emission from a rotating off-centred magnetic dipole in vacuum

Anu Kundu[1]
PhD Student (II yr)
Supervisor : Jérôme Pétri

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UNIVERSITÉ DE STRASBOURG

Observatoire astronomique de Strasbourg

[1] E-mail: anu.kundu@astro.unistra.fr

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  - Light curves, spectra, polarization features don't fit well with present models
  - Possible for stars and planets [Stift(1974)], [Komesaroff(1976)]
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- Exact analytic solutions for an offset rotating dipole electromagnetic field in vacuum [Pétri(2016)]
- We study the consequences of this field topology (first order correction) on radiation properties [Kundu(2017)]

Outline

Off-centred geometry

- Magnetic moment: $\vec{\mu} = m(\sin\alpha\cos\beta, \sin\alpha\sin\beta, \cos\alpha)$
- Located at $\vec{d} = D(\sin\delta, 0, \cos\delta)$
- Condition : $\epsilon = D/R \ll 1$
- α, β, δ shuffled to change orientations
- 2 ms period pulsar
- $\epsilon = 0.2$ for off-centred calculations

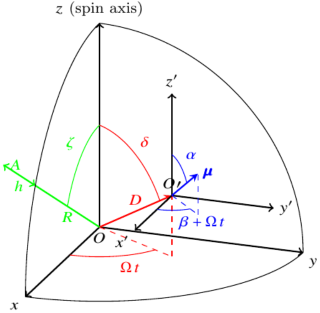


Figure : Geometry of an off-centred pulsar ([Pétri(2017)])

PC : Why and How?

- PC - locus of the feet of the last closed field lines
- Central to the pulsed emission
- Radio emission : polar cap model [Sturrock(1971)]
- High energy emission : slot gap model [Arons(1983)]
- θ calculated corresponding to field lines grazing the light cylinder

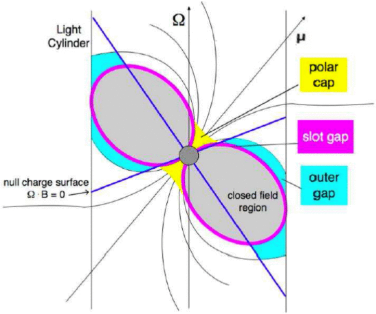
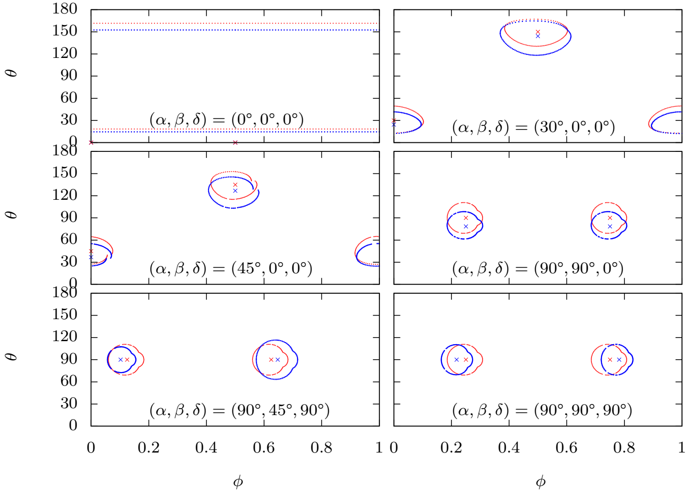


Figure : A schematic representation of the different geometric pulsar models ([Harding (2004)])

PC geometry



Centred case ($\epsilon = 0$) and Off-centred case ($\epsilon = 0.2$)

Emission : Why and How?

- Light curves give insight into magnetic topology
- Two-pole caustic model explained by [Dyks & Rudak(2003)], revised by [Bai & Spitkovsky(2010)].
  - Aberration formula to transform photon propagation direction from the corotating frame $\boldsymbol{\beta_c}$ to the lab frame $\boldsymbol{\beta_0}$

    $$\boldsymbol{\beta_0} = f\mathbf{B} + \boldsymbol{\beta_c}$$

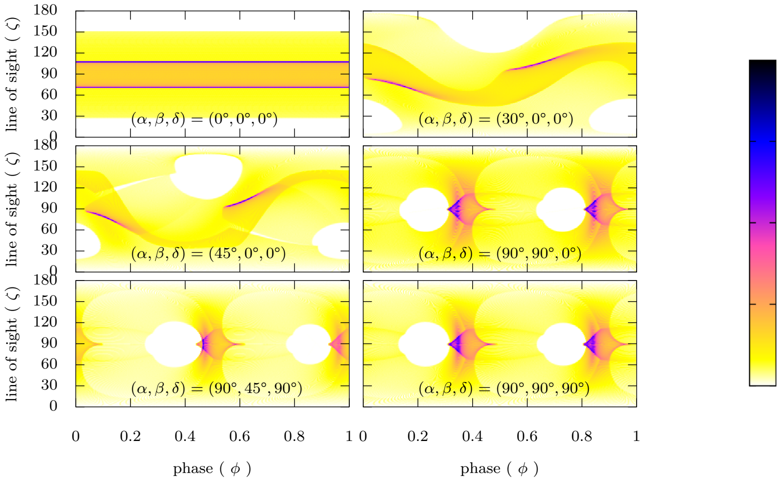
    where f is a coefficient determined by $|\boldsymbol{\beta_0}| \to 1$.
  - Considering photon travel delays, phase ϕ is

    $$\phi = -\phi_{em} - \mathbf{r} \cdot \boldsymbol{\beta_0}/R_L$$

    where ϕ_{em} is the azimuth for the direction $\boldsymbol{\beta_0}$ and R_L is the radius of the light cylinder.

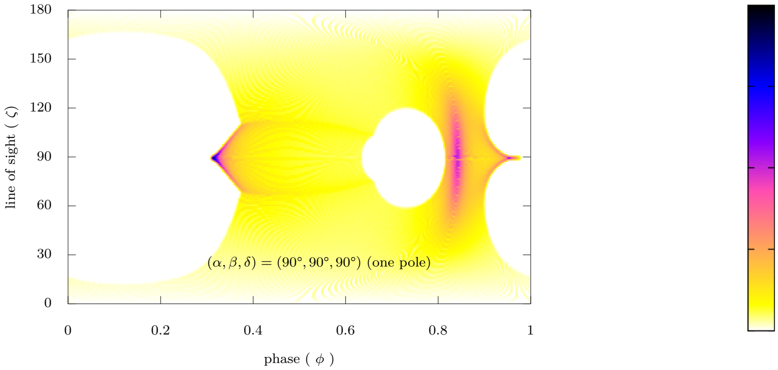
High energy emission

High energy emission for off-centred cases with $\epsilon = 0.2$



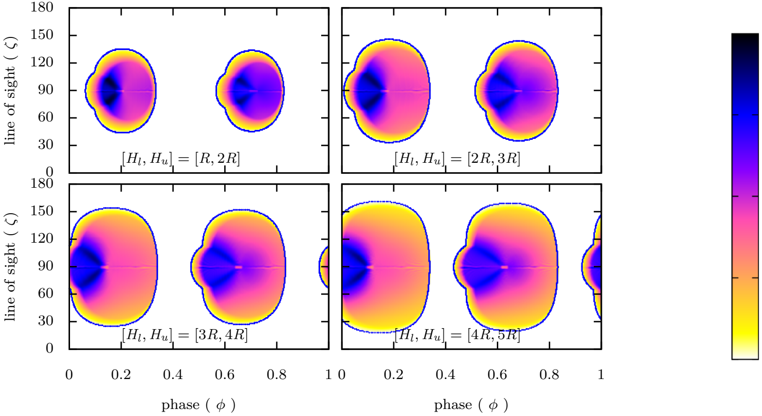
High energy emission

High energy emission for an off-centred ($\epsilon = 0.2$) case of $(\alpha, \beta, \delta) = (90°, 90°, 90°)$ for one pole.



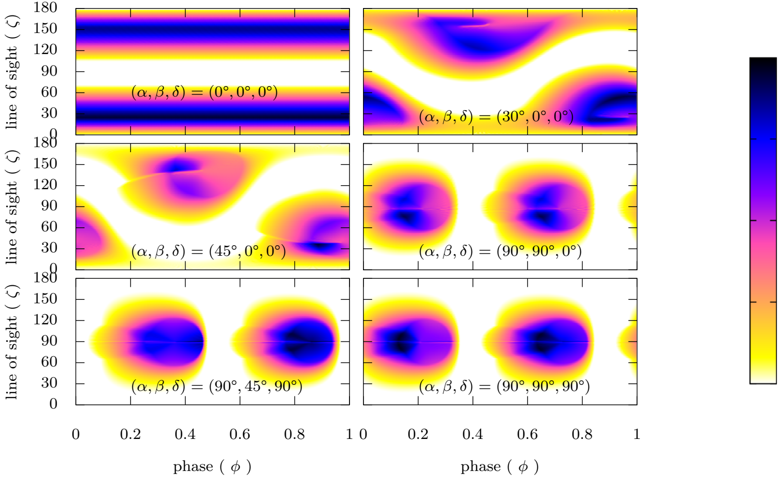
Radio emission

Radio emission for sections of heights from surface within range $[H_l, H_u] = [R, 5R]$ for $(\alpha, \beta, \delta) = (90°, 90°, 90°)$ for off-centred case ($\epsilon = 0.2$). Blue boundary depicts the outer rim of the emission region.



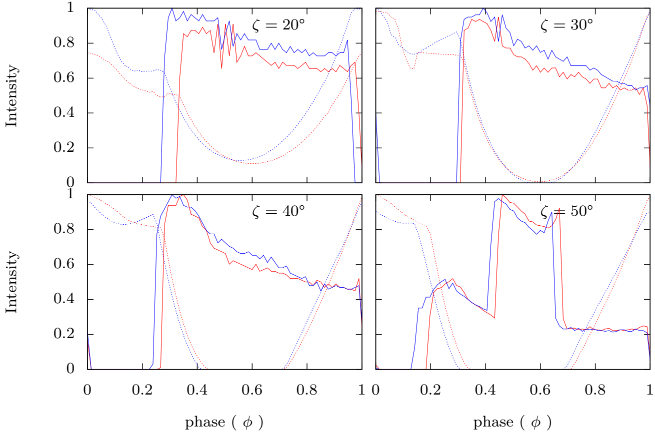
Radio emission

Radio emission for off-centred cases with $\epsilon = 0.2$



Light curves for $\alpha = 30°$

Phase zero light curves for $(\alpha, \beta, \delta) = (30°, 0°, 0°)$ for $\zeta = 20°, 30°, 40°, 50°$
Centred case ($\epsilon = 0$) and Off-centred case ($\epsilon = 0.2$)
High energy emission : Solid; Radio emission : Dashed

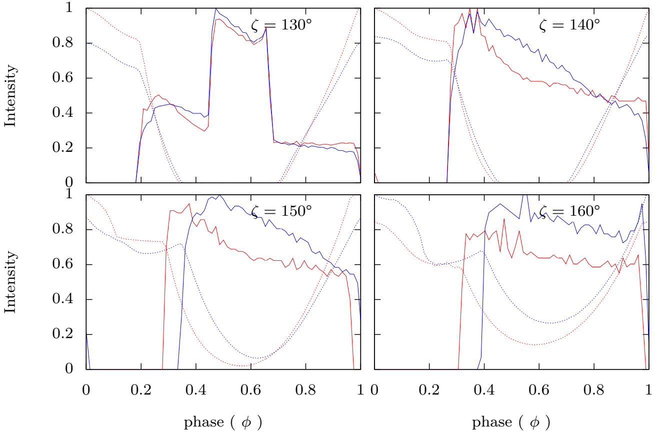


Light curves for $\alpha = 30°$

Phase zero light curves for $(\alpha, \beta, \delta) = (30°, 0°, 0°)$ for $\zeta = 130°\ , 140°\ , 150°\ , 160°]$

Centred case $(\epsilon = 0)$ and Off-centred case $(\epsilon = 0.2)$

High energy emission : Solid; Radio emission : Dashed



Conclusions

- The off-centred topology is a reliable approach trying to better explain the polar caps and fit the light curves.
- Polar cap comparison shows shift highlighting difference in size and phase difference, could justify the pulse widths away from the power law fit.
- Phase diagrams gives insight into site of production of pulsed radiation for better understanding of the emission mechanism.
- Comparison of the emission light curves shows phase contrasts between the radio and high-energy profiles, could explain observational signatures of time lags between the two.
- **Future works:**
  Work in progress to create the broadband spectrum of pulsar radiation.
  All this work will then be extended to pulsar force-free magnetospheres.

Thank You!

```
#include <iostream>
using namespace std;

int main()
{
 bool YouAreStillAwake = true;
 YouAreStillAwake : cout << "Thank you for your attention!" << endl;
}
```

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