On the mean profiles of radio pulsars III:

New effects and reanalysis of individual pulsars

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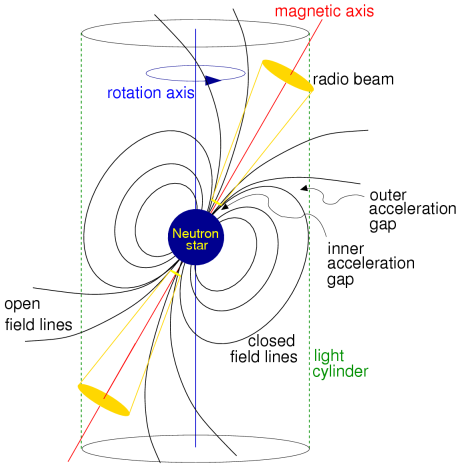
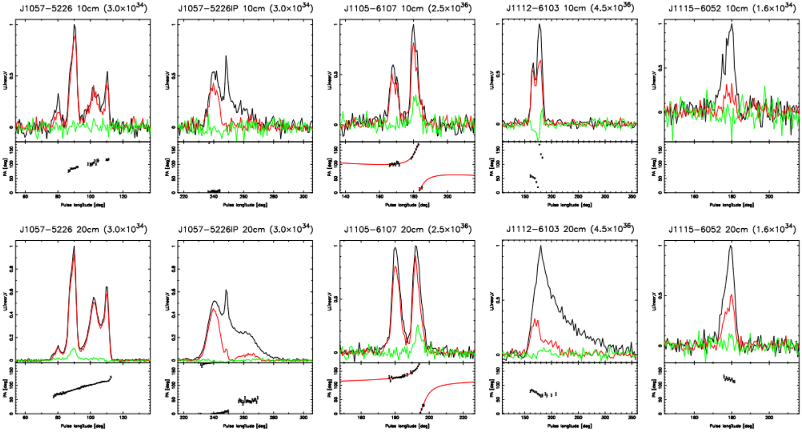
Profile formation
Emission



Profile formation
Mean Profile



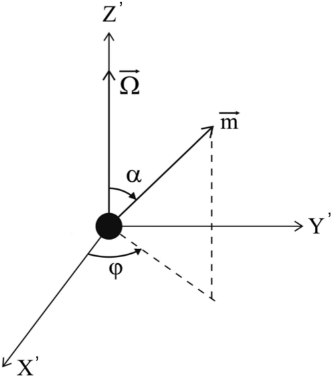
P. Weltevrede and S. Johnston (2008)

Hollow cone model:

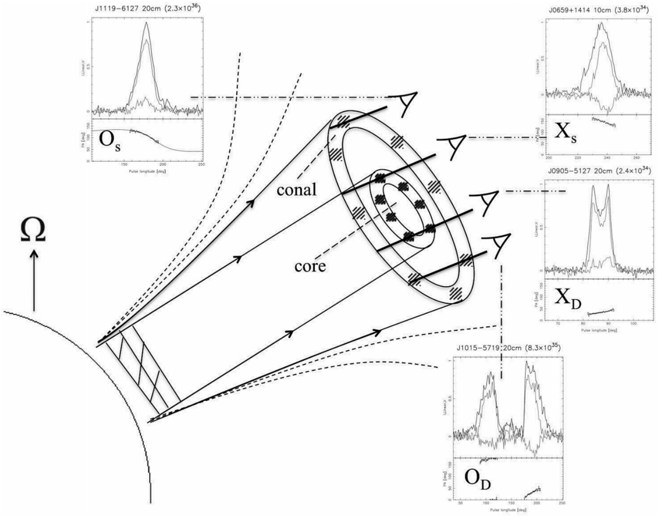
- the emission is formed near the surface;
- the magnetic field is dipole;
- no cyclotron absorption;
- the polarization is formed right away.

$$p.a. = arctan\left(\frac{\sin\alpha\sin\phi}{\sin\alpha\cos\zeta\cos\phi - \sin\zeta\cos\alpha}\right)$$

Radhakrishnan and Cocke (1969)



Profile formation
Hollow cone model



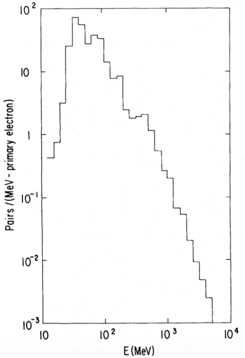
Manchester and Taylor (1977)

$\omega_B = \gamma \gamma_U \tilde{\omega}$ (limited magnetic field)

$$I_\infty = I_0 \exp\left(-\tau\right)$$

$$\tau = \frac{4\pi^2 e^2}{m_\mathrm{e} c} \int_0^\infty n_\mathrm{e}(l) \frac{1}{\omega} F\left(\frac{|\omega_B|\sqrt{1 - U^2/c^2}}{\tilde{\omega}}\right) \mathrm{d}l,$$

$$F(\gamma) = \frac{6\gamma_0}{2^{1/6}\pi} \frac{\gamma^4}{2\gamma^6 + \gamma_0^6}$$

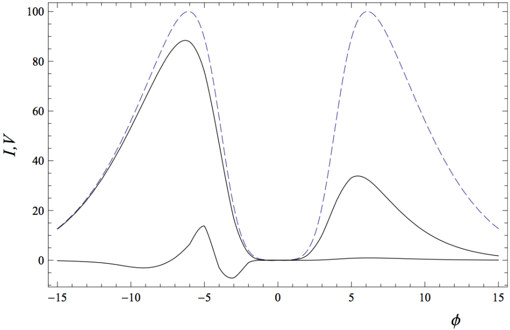


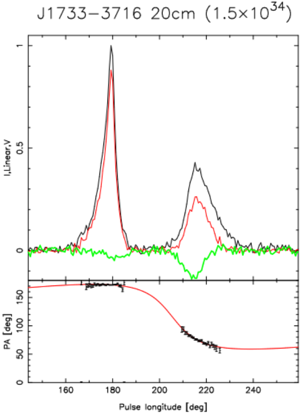
Daugherty & Harding (1982)

$$\frac{\mathrm{d}\Theta_1}{\mathrm{d}l} = -\frac{\omega}{2c}\left(\frac{\Lambda}{Q} + \Lambda\cos\left[2\Theta_1 - 2\beta_B(l) - 2\delta(l)\right]\sinh 2\Theta_2\right)$$
$$\frac{\mathrm{d}\Theta_2}{\mathrm{d}l} = \frac{\omega}{2c}\Lambda\sin\left[2\Theta_1 - 2\beta_B(l) - 2\delta(l)\right]\cosh 2\Theta_2$$

- Λ, δ and $Q \rightarrow plasma parameters \epsilon_{ij}$, and $\tan\beta_B = B_Y/B_X$;
- $p.a. = \Theta_1$ and $V = I\tanh 2\Theta_2$;

- Peak suppression (synchrotron absorption)





- Correlation between the signs of $\mathrm{d}p.a/\mathrm{d}\phi$ and V for X and O modes.

$$\frac{V}{I} \approx \frac{1}{|Q|} \frac{\mathrm{d}(\beta_B + \delta)/\mathrm{d}x}{A} \frac{1}{\cos\left[2\Theta_1 - 2\beta_b(l) - 2\delta(l)\right]}.$$

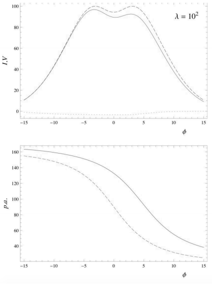
Andrianov and Beskin (2010)

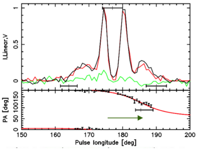
Signs of $\mathrm{d}(\beta_B + \delta)/\mathrm{d}x$ and $\mathrm{d}p.a/\mathrm{d}\phi$ are opposite, hence

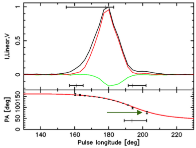
* X-mode: signs of V and $\mathrm{d}p.a/\mathrm{d}\phi$ are the same;
* O-mode: signs of V and $\mathrm{d}p.a/\mathrm{d}\phi$ are opposite;

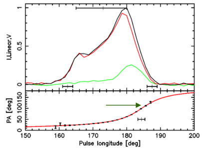
Results
Beskin and Philippov (2012)

- $(\mathrm{d}p.a./\mathrm{d}\phi)_{\max}$ shift from the center.

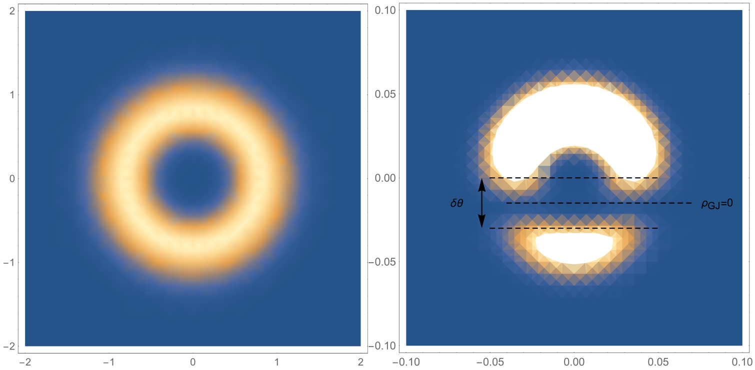






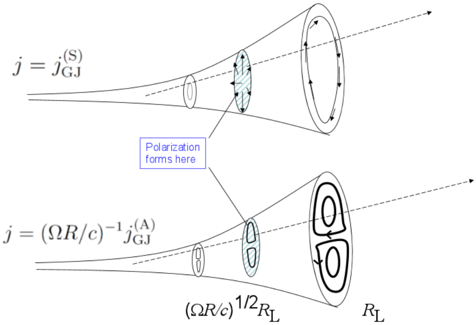


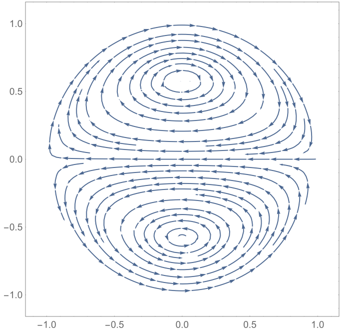
New phase
Density function modification



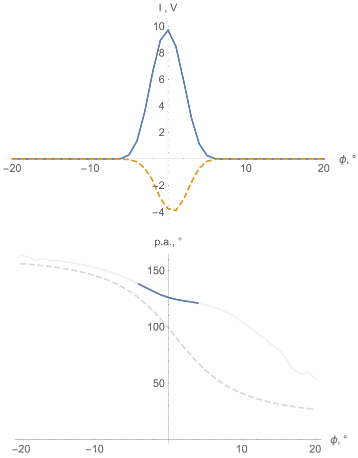
Philippov, Tchekhovskoy and Li (2014).

$$i_{\mathrm{A}} > (\Omega R/c)^{-1}$$

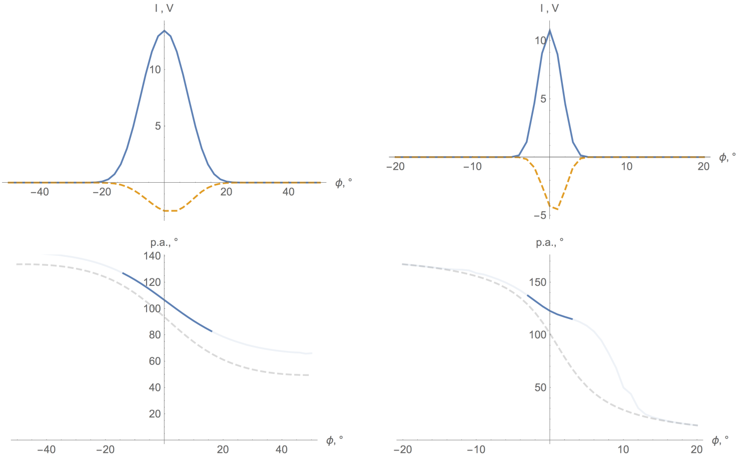




Profiles for 45° (edge and central transition).



Profiles for 10° and 90°.



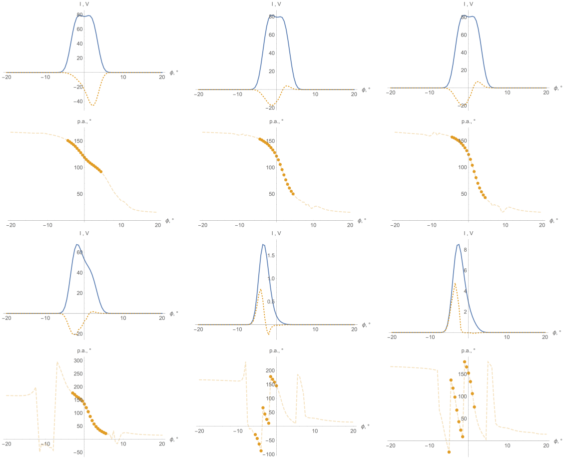
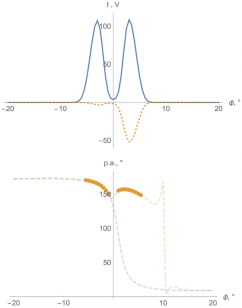
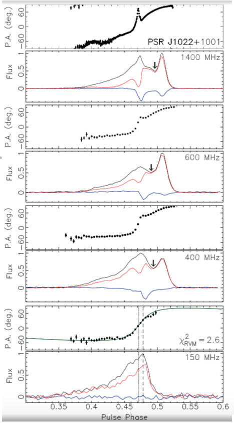
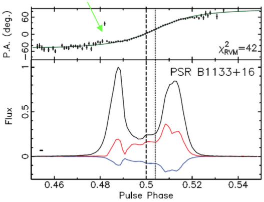


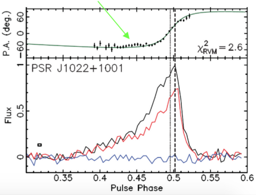
Figure: Toroidal field multiplication parameter $\{0 \to 1\}$.

Discussion
Central hump

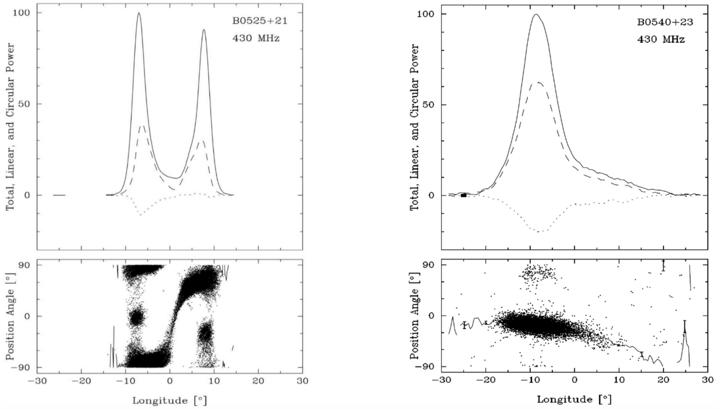








Discussion
P.A. curve width



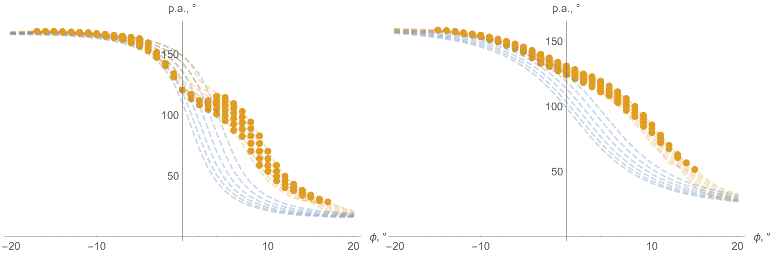


Figure: $r_{\rm em} = \{10R \to 60R\}$.

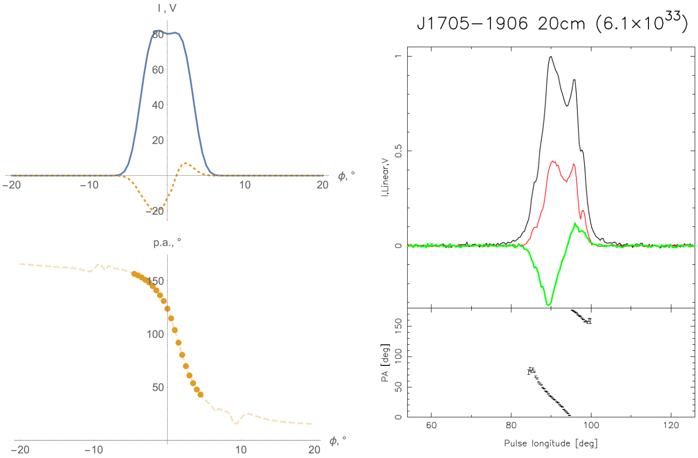


Figure: Toroidal field is ON ($\times 0.02$)

Conclusions

- Strong asymmetric current can affect the sign of the circular polarization.
- The emission region for a given frequency can be wide $100R$.
- It is possible to do speculate about the geometry of the pulsar according to simulations of polarization characteristics.

Appendix 1
Density function

$$g(f) = \frac{f^{2.5} \exp\left(-f^2\right)}{f^{2.5} + f_0^{2.5}} \quad \to \quad g(f) = e^{-f^2} \tanh\left(\left(f/f_0\right)^6\right)$$

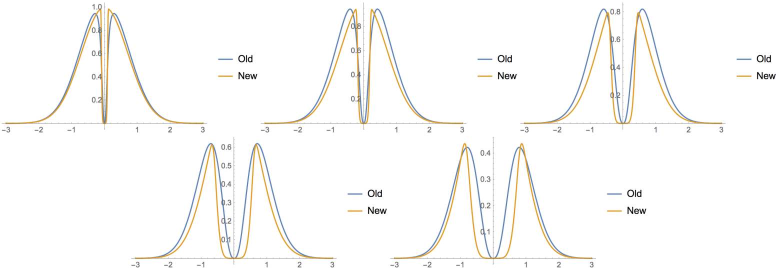


Figure: $f_0 = \{0.1,\ 0.2,\ 0.4,\ 0.6,\ 0.8\}$

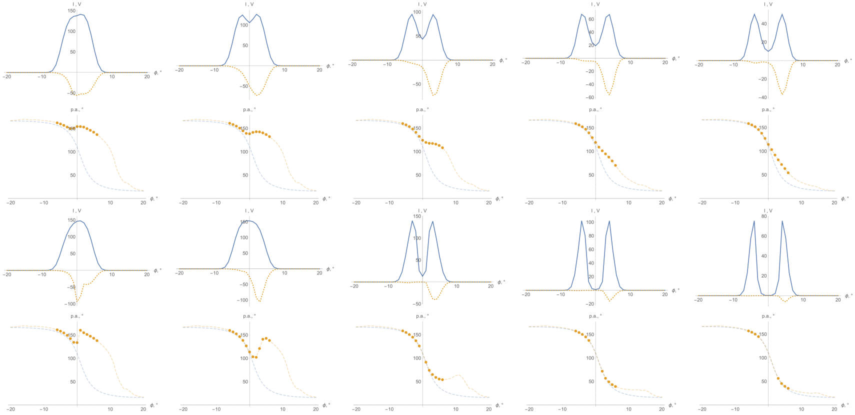
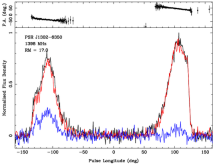
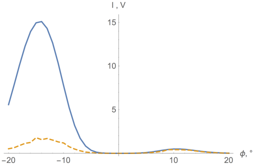


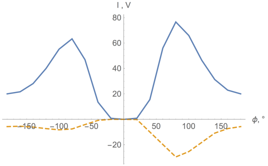
Figure: Profiles comparison for $f_0 = \{0.1,\ 0.2,\ 0.4,\ 0.6,\ 0.8\}$. The upper plots are for an "old" function, the lower plots are for the "new" one.

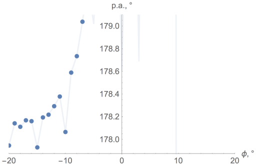
Appendix 2
Pulsars with interpulses

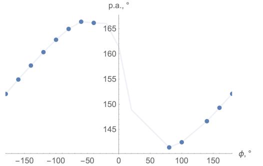
PSR J1302-6350: $P = 0.047$ sec, $B_0 = 3 \times 10^{11}$ G, $\omega = 1.4$ GHz.











PSR B0943+10: $P = 1.1$ sec, $B_0 \approx 10^{12}$ G, $\omega = 0.33$ GHz.