Introduction to Radio Pulsars

Nikita Prokopenko

MIPT

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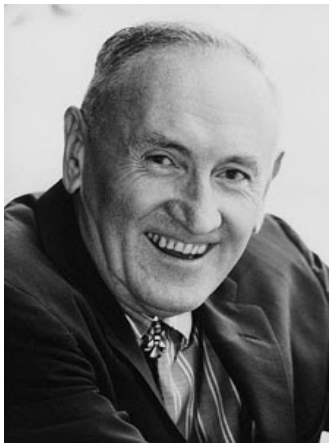
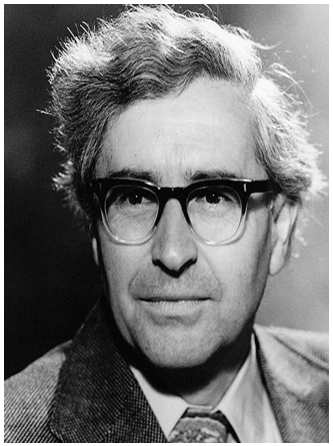
Presentation Plan

- A brief history of the discovery
- Vacuum model
- The zeroth-order model

A brief history

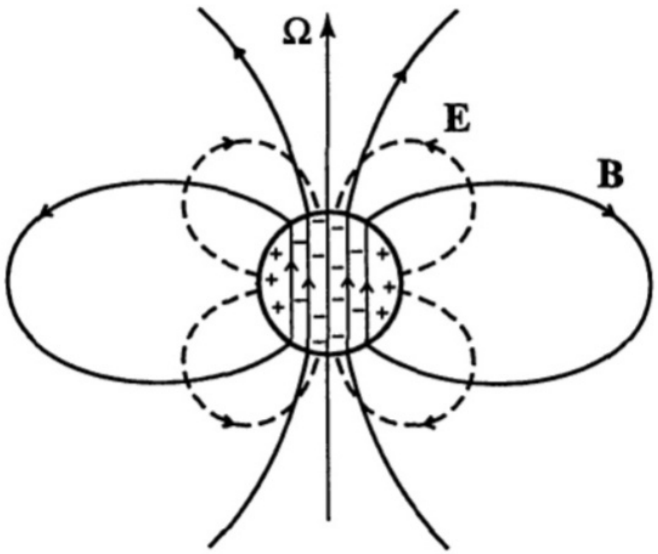




- Prediction - [Baade, Zwicky, 1934; Landau 1932]
- Discovery - [Hewish et al., 1968]

Basic parameters:

- $M \approx 2 \cdot 10^{33}$g
- $R = 10 \div 15 km$
- $P = 1.5 ms$
- $B_0 \sim 10^{12} Gs$

Vacuum model



Inside a well-conducting sphere:

$$\mathbf{E}_{in} + \frac{\mathbf{\Omega} \times \mathbf{r}}{c} \times \mathbf{B}_{in} = 0$$

Let the axis of rotation is parallel to the axis of magnetization, so:

$\Phi_e(r < R, \theta) = \frac{1}{2}\frac{\Omega}{c} r^2 \sin^2\theta$

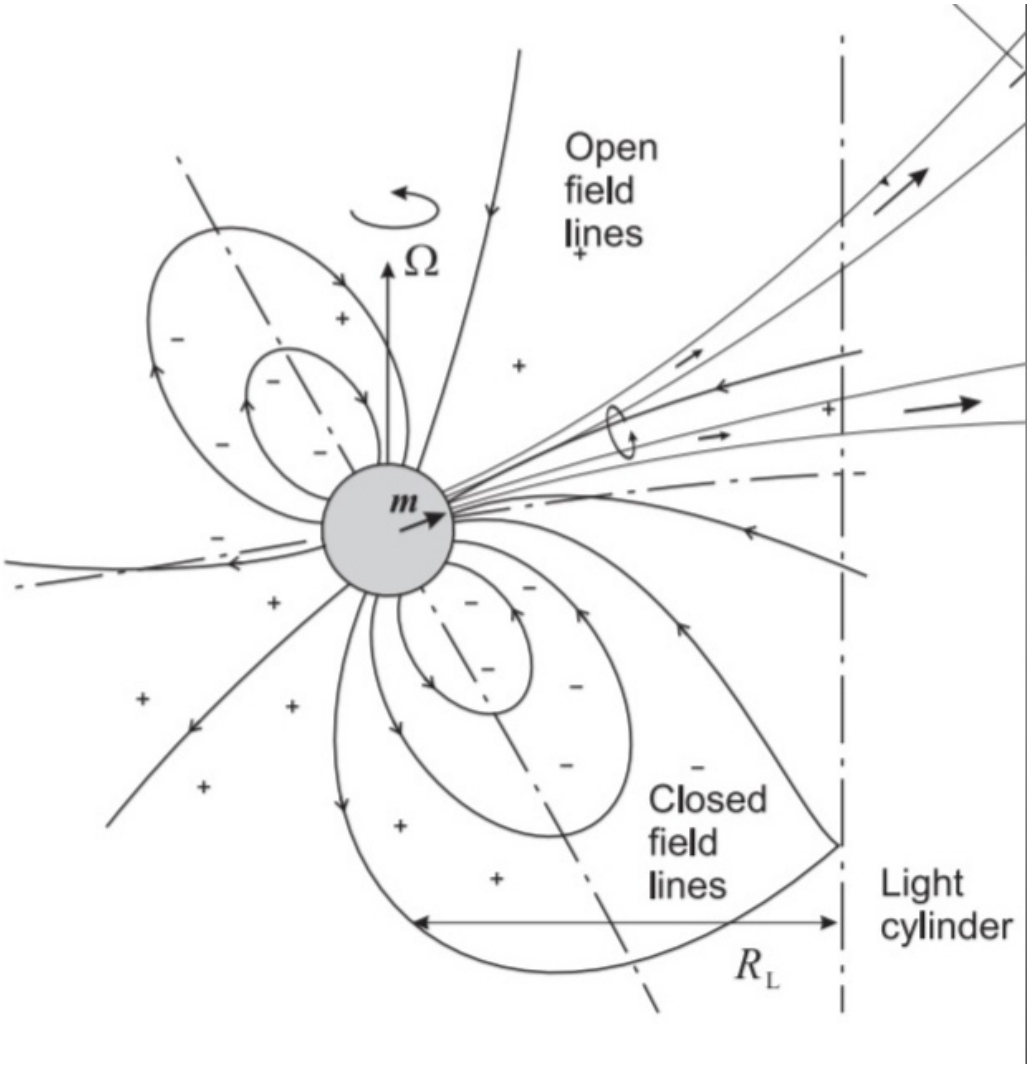
$\Phi_e(r > R, \theta) = -\frac{1}{3}\frac{\Omega B_0}{c}\frac{R^5}{r^3} P_2(\cos\theta)$

The zeroth-order model

Curvature of the force lines of the dipole magnetic field $\Longrightarrow$ radiation of hard gamma quanta
$\gamma + B \to e^+ + e^- + B$ [Sturrock, 1971]
A chain of processes:

- acceleration of primary particles
- radiation of bending photons birth of secondary electron-positron pairs
- acceleration of secondary particles, radiation of bending photons by them
- screening of the longitudinal electric field

Structure of the magnetosphere



A magnetosphere completely filled with plasma, so:

- $E_{\parallel} = 0$

Corotation:

- $\mathbf{E} + \frac{\mathbf{\Omega} \times \mathbf{r}}{c} \times \mathbf{B} = 0$

Drift speed:

- $\mathbf{U_{dr}} = \mathbf{c}\frac{\mathbf{E} \times \mathbf{B}}{\mathbf{B^2}} = \mathbf{\Omega} \times \mathbf{r} + \mathbf{j}_{\parallel}\mathbf{B}$

Light cylinder:

- $R_L = \frac{c}{\Omega}$

Summary

- One of the most important discoveries in astrophysics of the 20th century
- The zeroth-order model is not a vacuum, but a model of a magnetosphere completely filled with plasma
- Existence of Open and Closed field lines

Conclusion

References:

- V.S.Beskin, **Radio pulsars: already fifty years!**
- V.S.Beskin,
  MHD Flows in Compact Astrophysical Objects

Thank you for attention!