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School and Conference on Analytical and Computational Astrophysics

14 - 25 November, 2011

Pulsar Models and Emission Mechanisms

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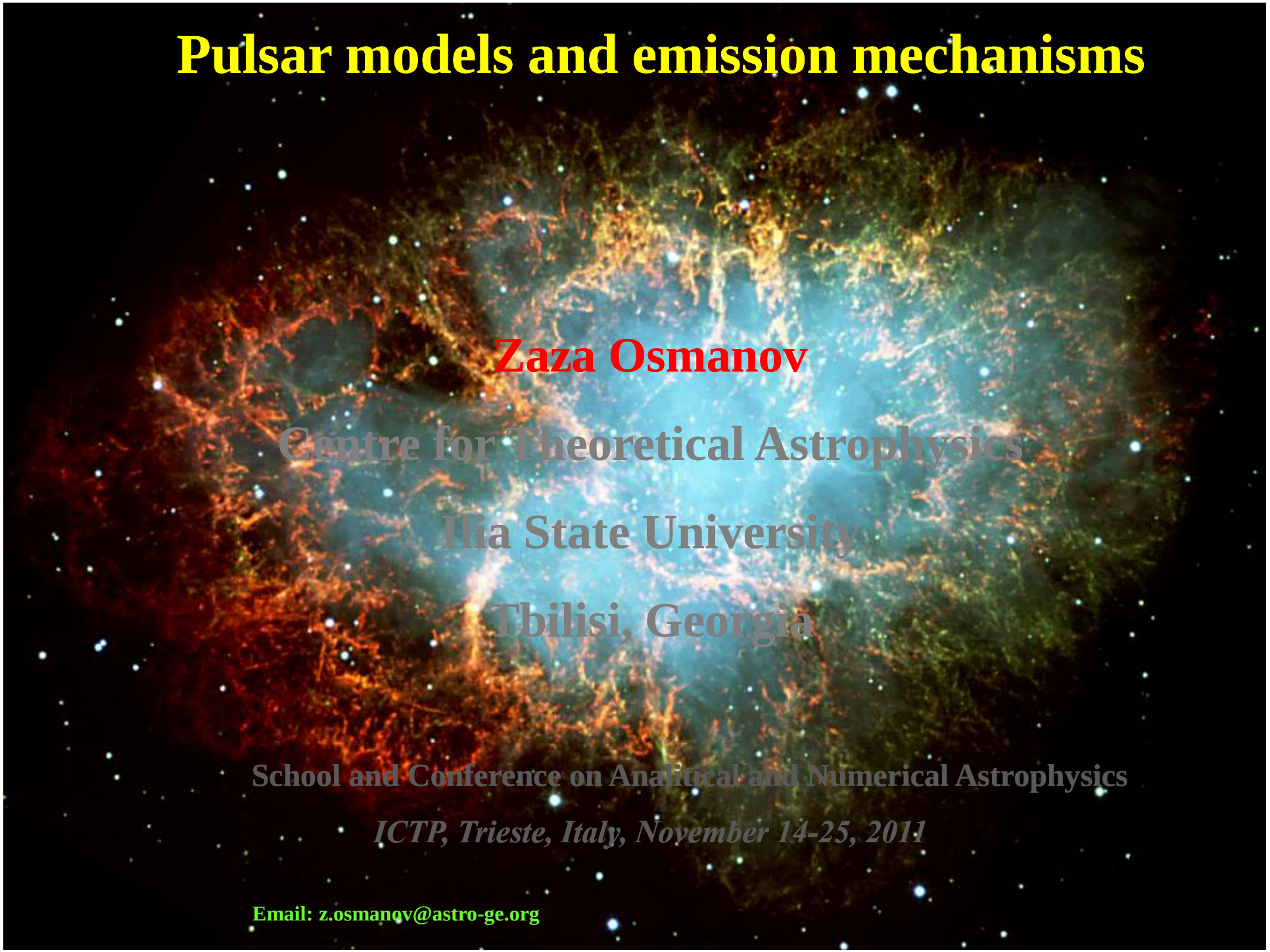
Pulsar models and emission mechanisms



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ICTP, Trieste, Italy, November 14-25, 2011

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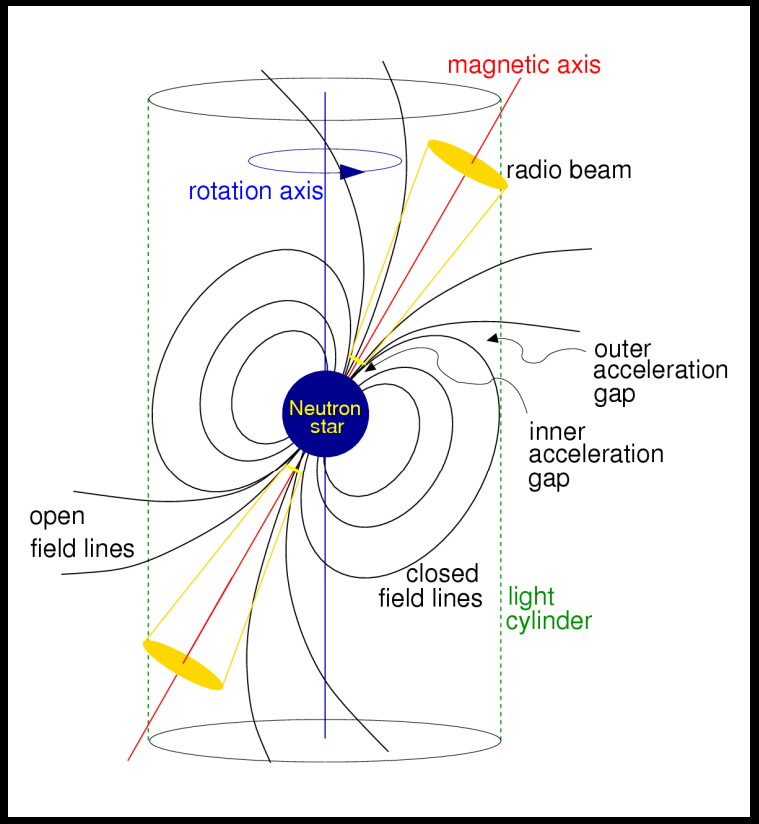
Pulsar model: vacuum dipole emisssion



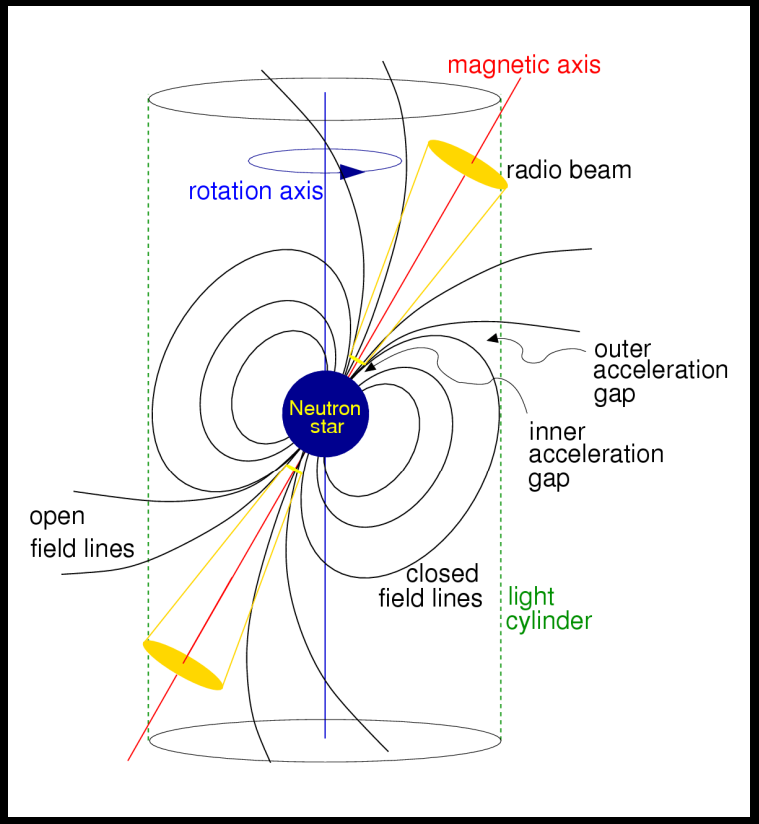
Magnetic dipole moment of the pulsar

$$|m| = \frac{B_0 R^3}{2}$$

A time-varying dipole moment leads to radiation with the following luminosity

$$W = -\frac{2}{3c^3}\left|\ddot{m}\right|^2$$

Pulsar model: vacuum dipole emisssion



$$\dot{W} = -\frac{B_0^2 R^6 \Omega^4 \sin^2 \alpha}{6c^3}$$

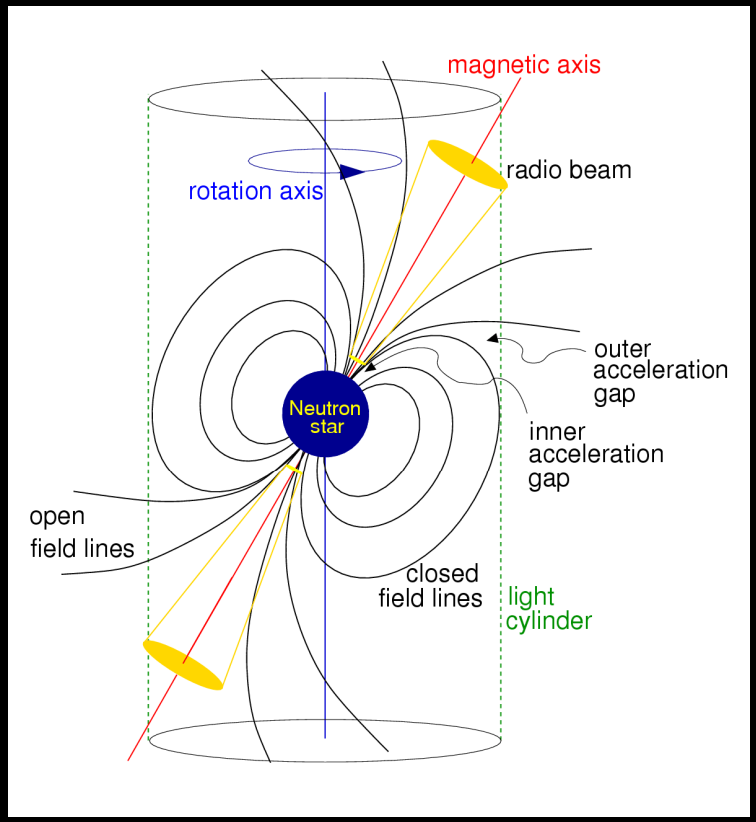
$$\dot{W} = I\Omega\dot{\Omega}$$

For the Crab pulsar

$$M = 1.4 M_s; R = 12 km$$

$$\dot{P} \approx 4.21 \times 10^{-13} s\, s^{-1}; \quad \alpha = \frac{\pi}{2}$$

Pulsar model: vacuum dipole emisssion

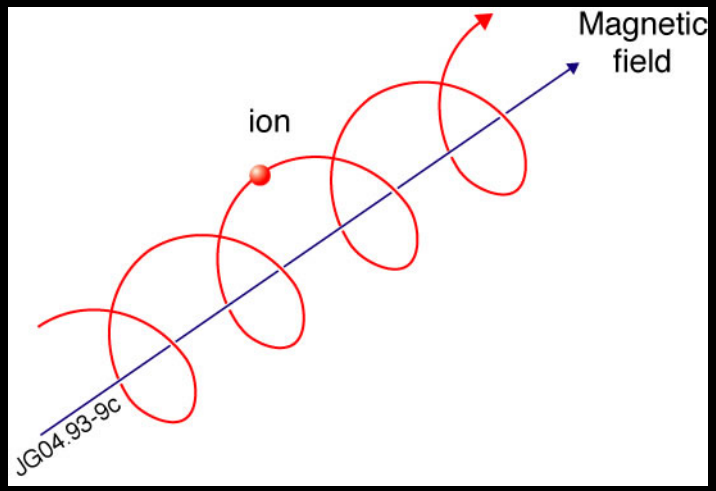


$$B_0 \approx 1.4\times10^{12}\left(P\frac{\dot{P}}{10^{-15}\,ss^{-1}}\right)^{1/2} G$$

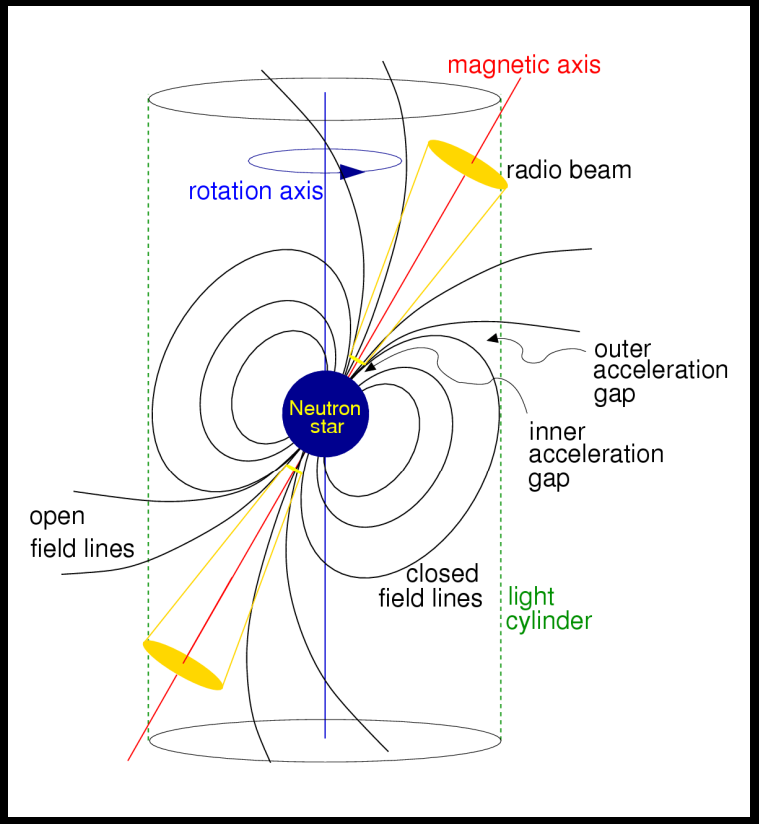
$$B_0 \approx 5.2\times10^{12} G$$

Relativistic particles in magnetic fields

$$r_g = \frac{\gamma mc}{eB_0} \approx 10^{-14}\times\frac{\gamma}{10^6}\ cm$$



Pulsar model: vacuum dipole emisssion

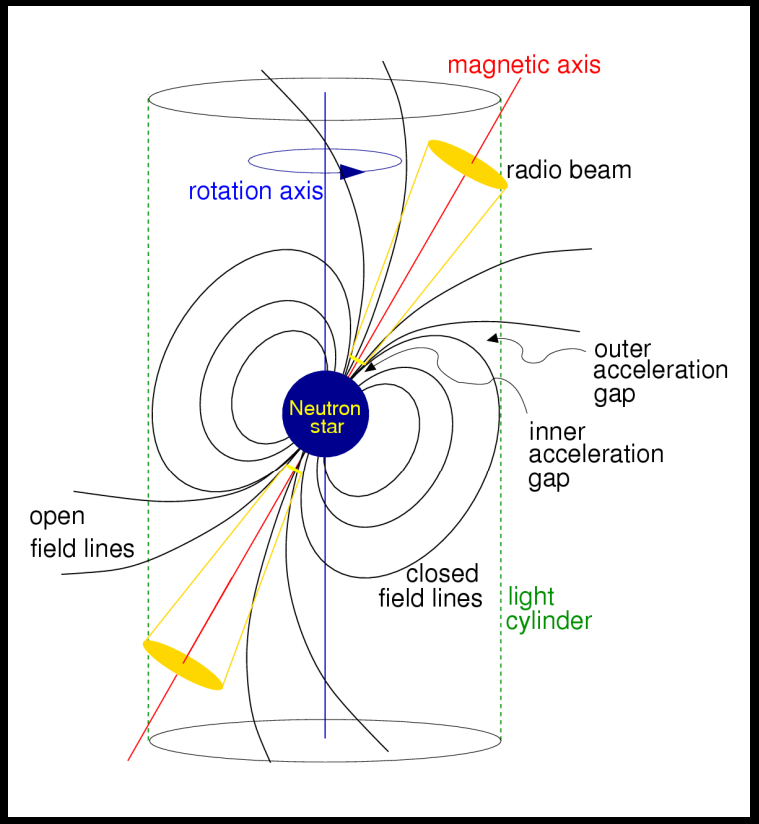


$$B \approx B_0 \times \frac{R^3}{r^3}$$

$$r = R_{lc} = \frac{c}{\Omega} \Rightarrow B \approx 1.3 \times 10^6 G$$

$$r_g = 5 \times 10^{-8} \times \frac{\gamma}{10^6}\ cm$$

Pulsar model: vacuum dipole emisssion

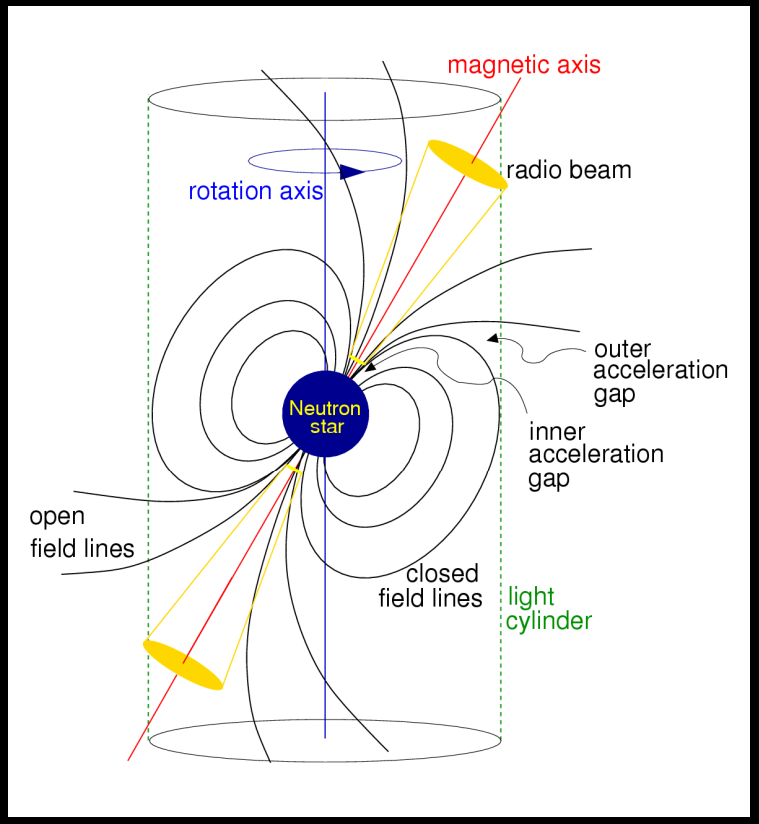


$$I\Omega\dot{\Omega} = -\frac{B_0^2 R^6 \Omega^4 \sin^2\alpha}{6c^3}$$

$$t \approx \frac{3Ic^3}{B_0^2 R^6 \Omega^2 \sin^2\alpha} = \frac{1}{2}\frac{\Omega}{\dot{\Omega}}$$

$$t \approx \frac{1}{2}\frac{P}{\dot{P}}$$

Pulsar model: Goldreich-Julian M



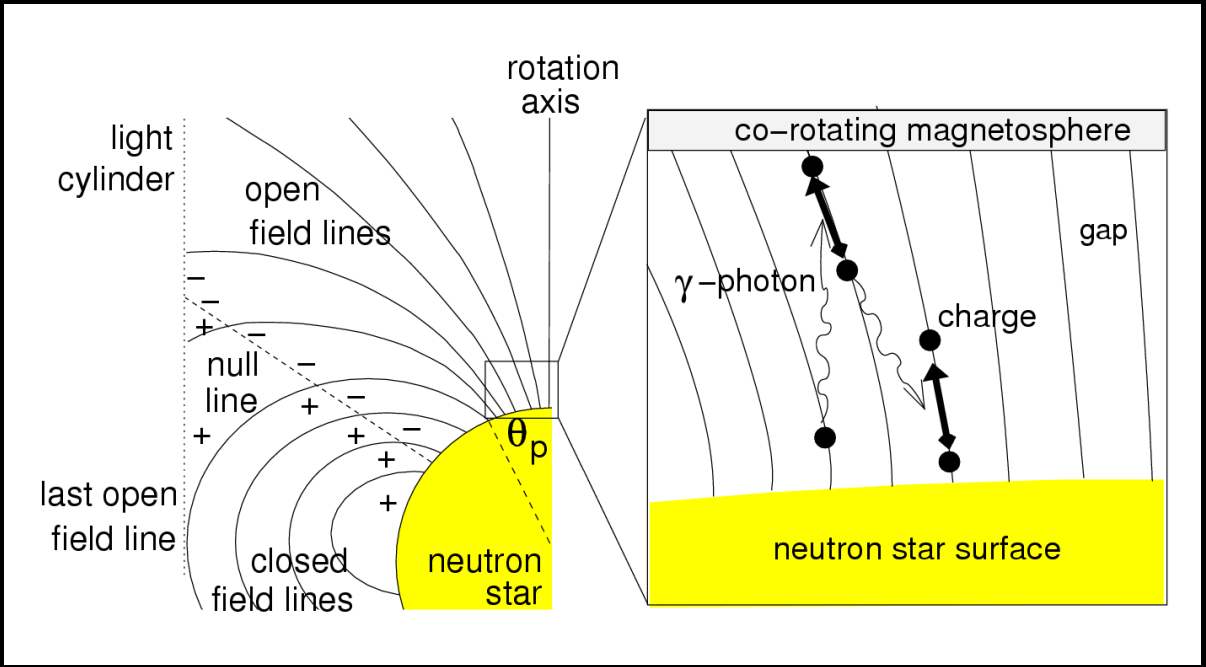
$$E^{in} + \frac{\Omega \times r}{c} \times B^{in} = 0$$

$$B^{in} = B_0 \left(e_r \cos\theta + \frac{\sin\theta}{2} e_\theta \right)$$

$$E_\theta^{in} = E_\theta^{out}$$

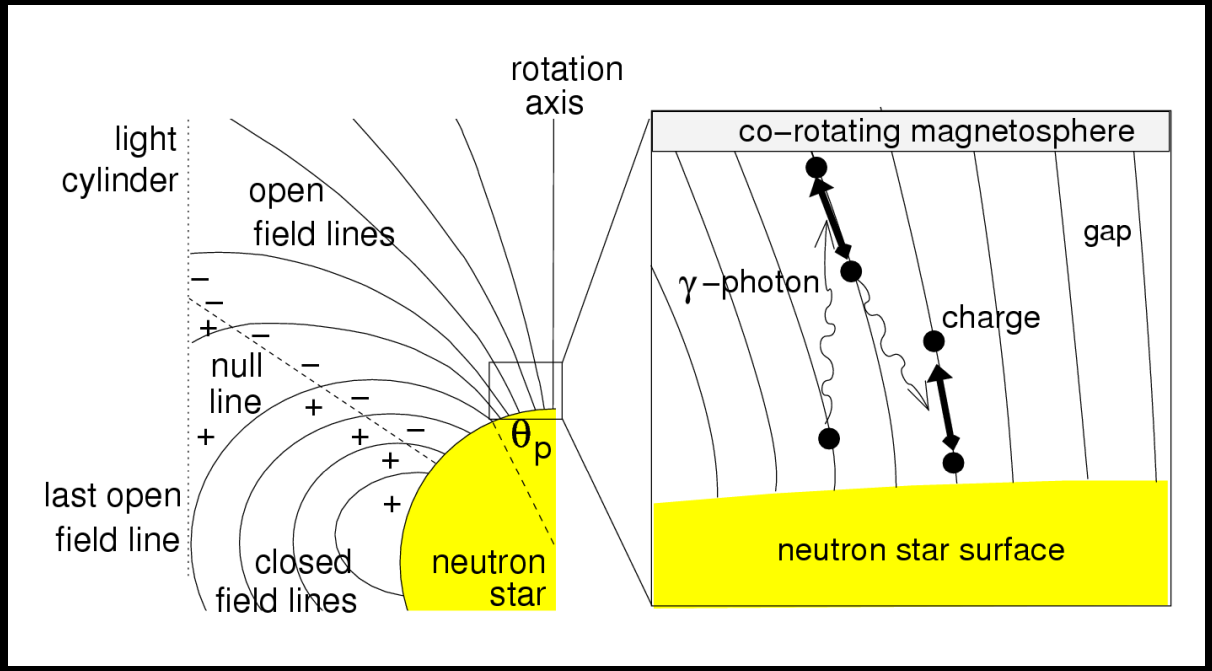
$$E^{out} = -\nabla\Phi \Rightarrow \Phi = -\frac{B_0 \Omega}{3c} \frac{R^5}{r^3} P_2(\cos\theta)$$

Pulsar model: Goldreich-Julian M



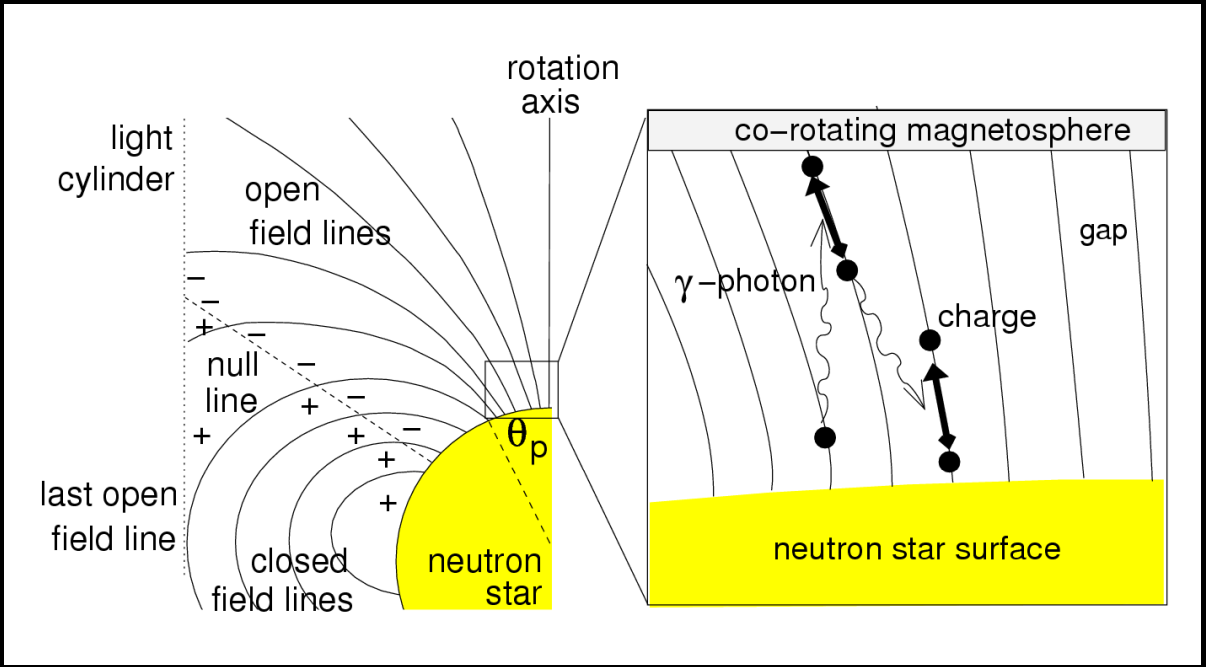
$$n_{GJ} = \frac{\Omega \cdot B}{2\pi e c}$$

Pulsar model: Goldreich-Julian M



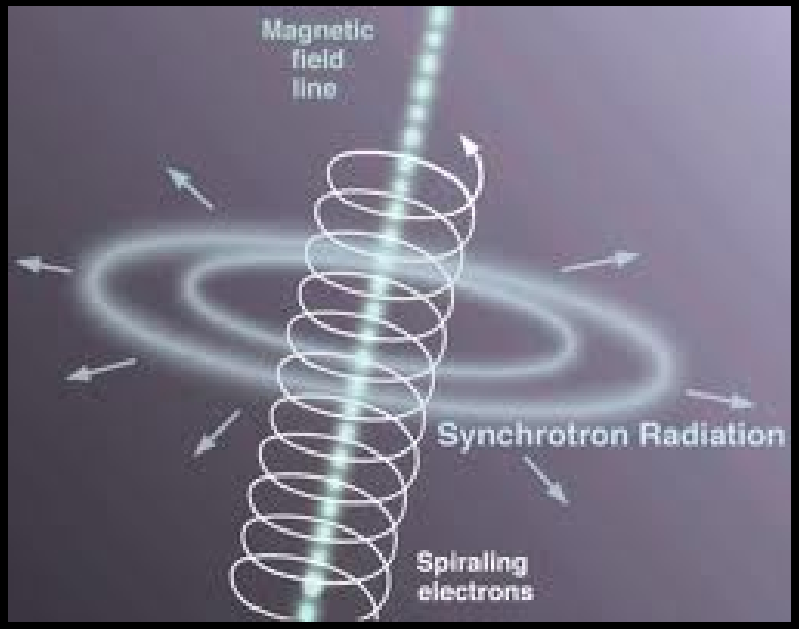
$$n_{Crab} \approx 10^{13} cm^{-3}$$

Pulsar model: Corotation



$$E_B = \frac{B_0^2}{8\pi}; E_p = \gamma m c^2 n$$

Pulsar model: synchrotron emission



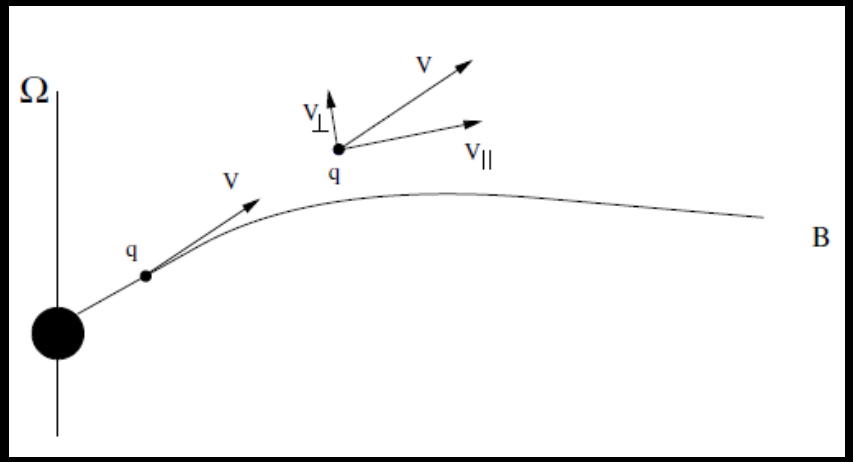
$$\mathcal{W}_{syn} \approx \frac{2e^4\gamma^2 B^2}{3m^2c^3}$$

$$t_{syn}^{st} \approx \frac{\gamma mc^2}{\mathcal{W}_{syn}} \approx 2\times10^{-23}\,s$$

$$t_{syn}^{st} \approx 3\times10^{-10}\,s$$

$$t_{kin} \approx \frac{R_{lc}}{c} \approx 0.005s \qquad t_{kin} >> t_{syn}$$

Pulsar model: curvature emission

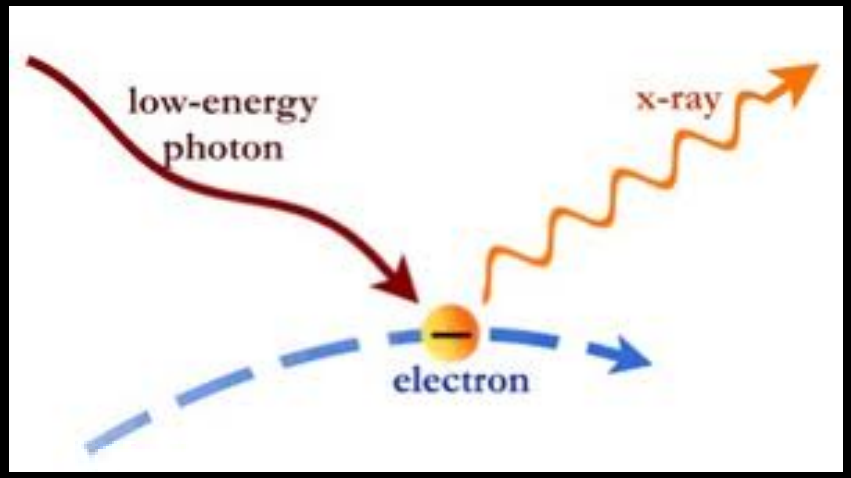


$$\mathcal{W} \approx \frac{2}{3}\frac{e^2}{c}\gamma^4\left(\frac{c}{\rho}\right)^2$$

$$t_{cur} \approx 1.5s >> t_{kin}$$

$$\nu_{cur} = \frac{3}{4\pi}\gamma^3\frac{c}{\rho} \approx 4.5\times10^{25}\gamma_6^3\ Hz$$

Pulsar model: IC emission



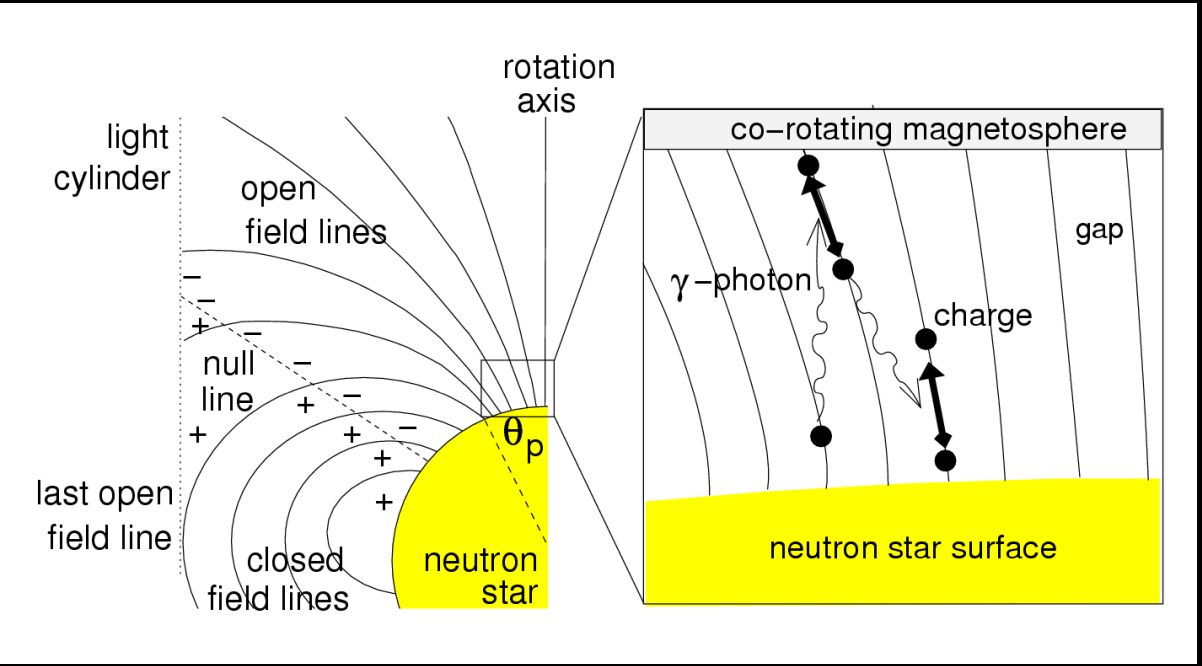
$$t_{IC} \approx 3\times10^{7}\,\frac{1}{\gamma U_{ph}}\,s$$

$$t_{cur} >> t_{kin}$$

$$\varepsilon_{ph} \approx \gamma^{2}\varepsilon_{ph0}$$

Emission: acceleration problem

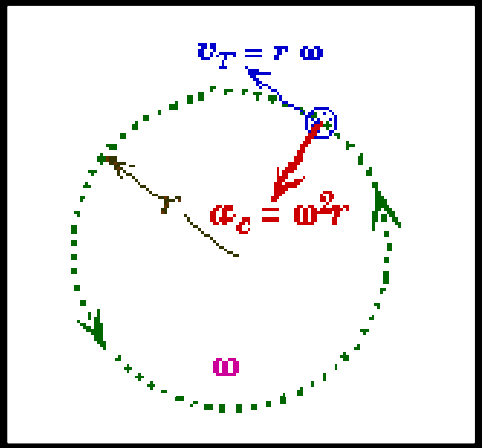
Gap model



$$U \approx 10^6 V \Rightarrow \varepsilon \approx 10^6 eV$$

Emission: acceleration problem

Centrifugal acceleration



Gold, 1968,1969; Machabeli & Rogava, 1994; Gangadhara 1996; Blandford & Payne 1982

$$\varepsilon \approx 1 TeV$$

Thank you