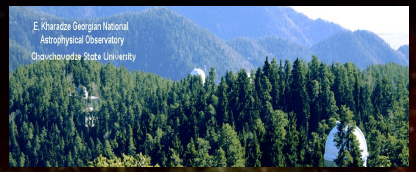

Georgian National Astrophysical Observatory

Pulsar winds: a possible mechanism of transition into the force-free regime

Zaza Osmanov

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G. Machabeli

The Modern Physics of Compact Stars, *Yerevan, Armenia, September 17-23, 2008*

Pulsars:

Crab

Thus the plasma co-rotates

Problem: how the plasma is transferred through the light cylinder (LC)

Pulsars:

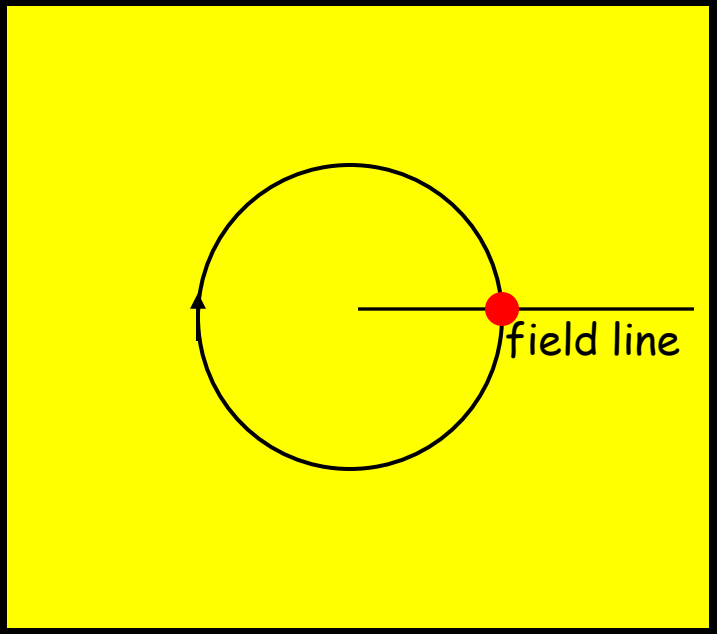
Crab

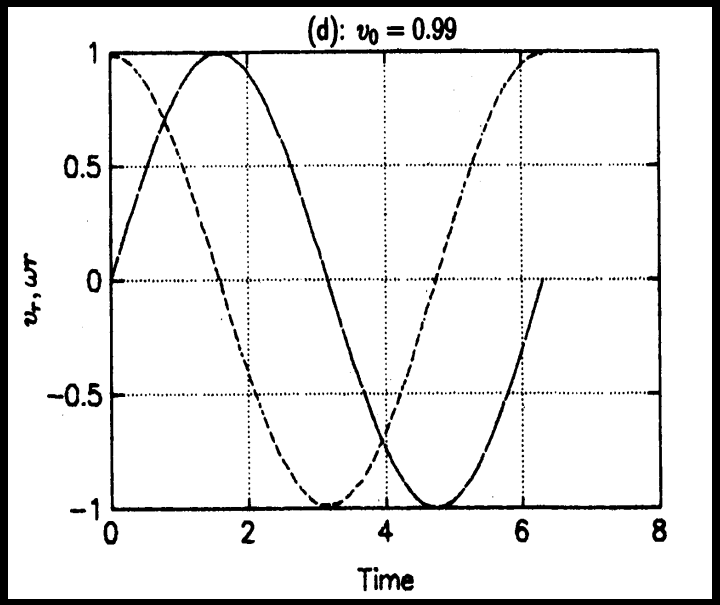
Mestel & Shibata 1994

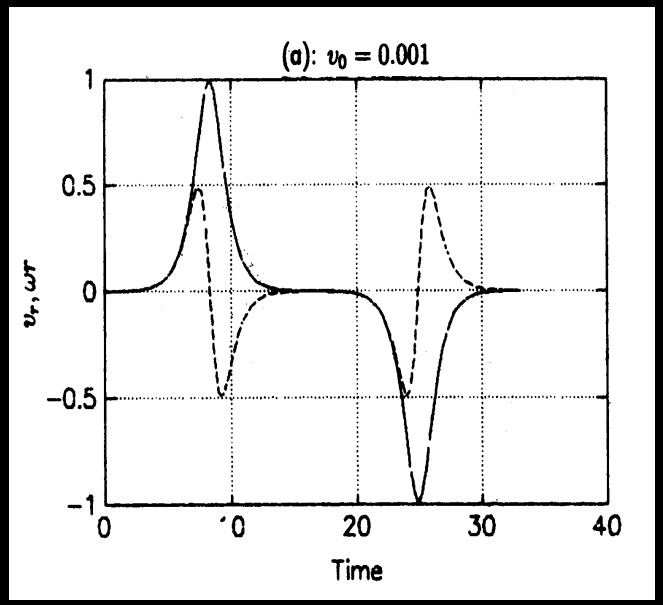
outside the LC there exists a domain with EBu0, providing high energy radiation

However, due to relativistic effects of the mass increment (Machabeli & Rogava 1994) **the value of the radial acceleration appears to be limited**

Some history

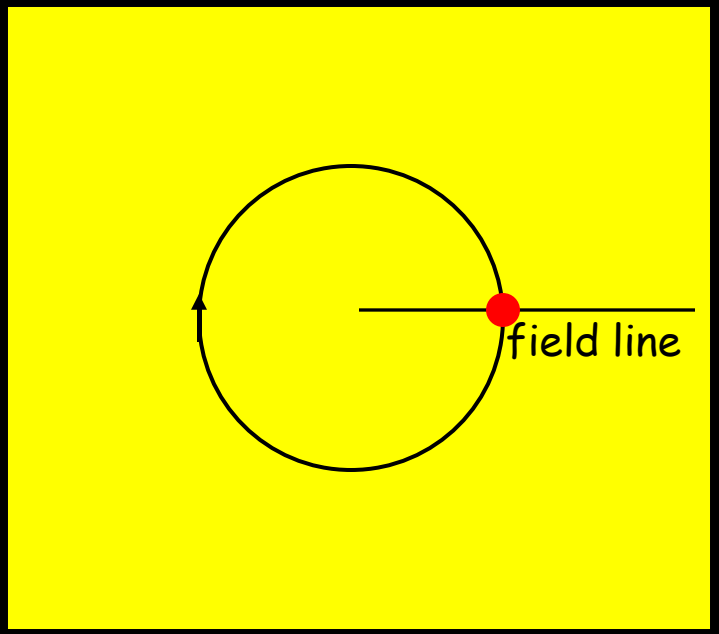






Problem one

Co-rotation of a plasma flow cannot be maintained nearby the LC, and therefore, the further exploration of this phenomenon is needed for studying twisting of field lines



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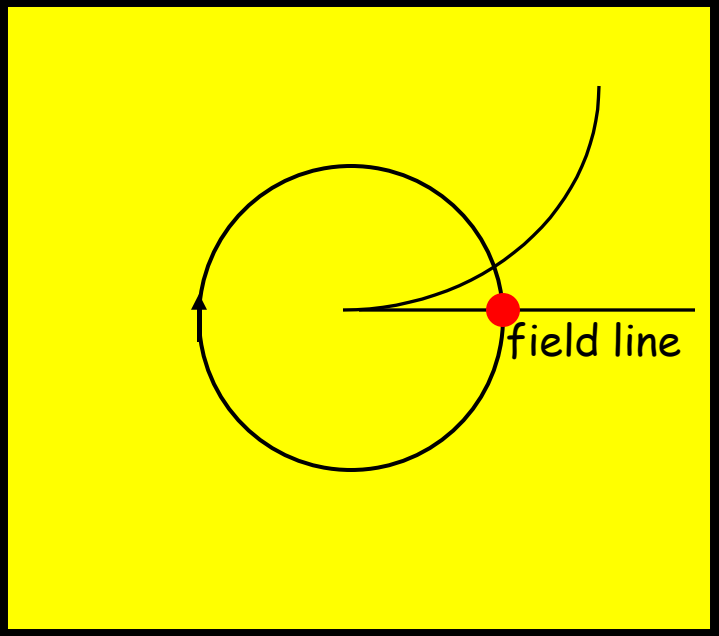

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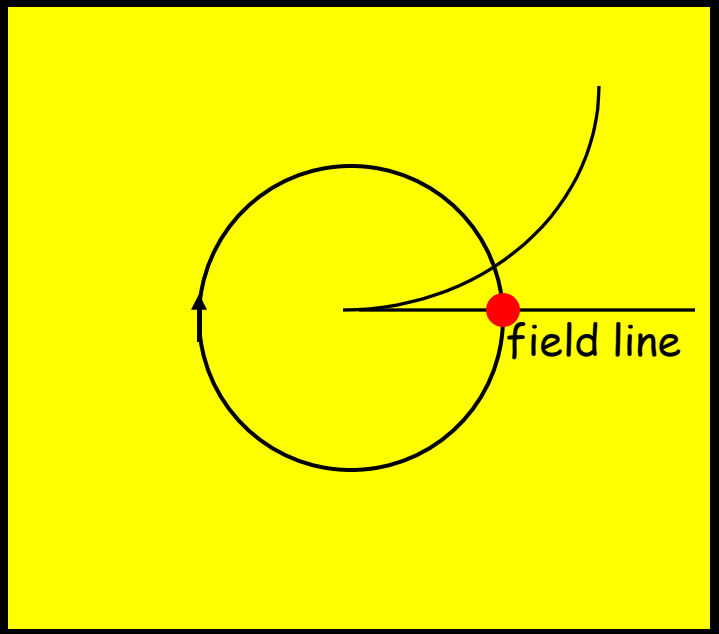
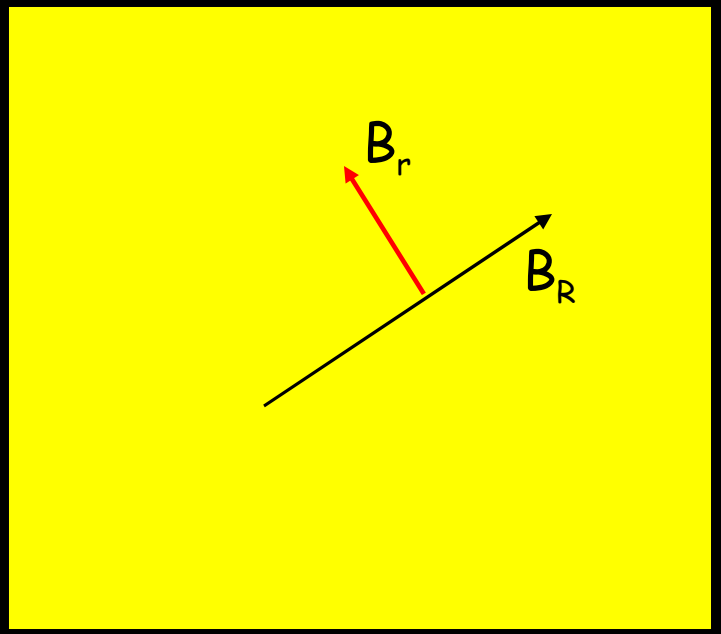




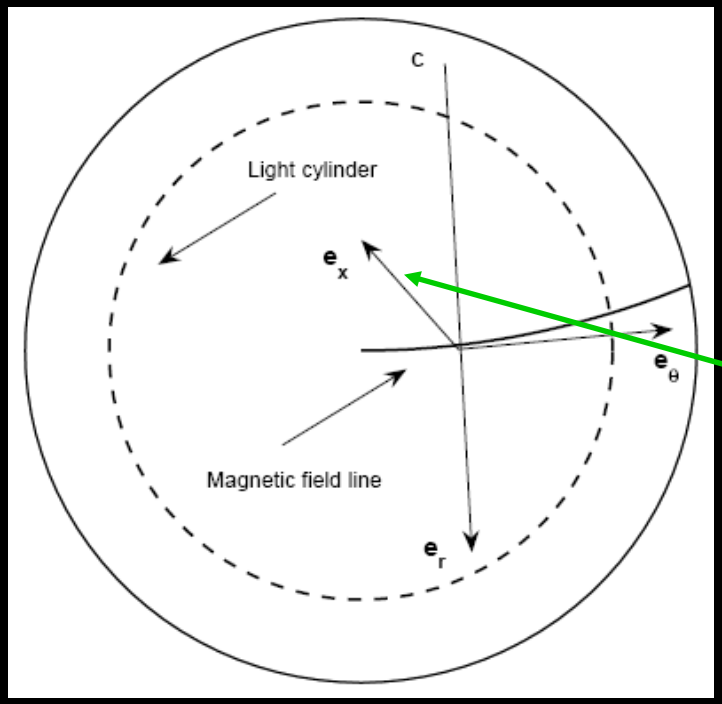
Problem one

Near the LC zone, the value of the electric drift current provides the toroidal component of the magnetic field of the order of 10^2G

Initial magnetic field is of order 10^6G (Crab pulsar)

Therefore, a new mechanism is needed

Problem one: curvature drift

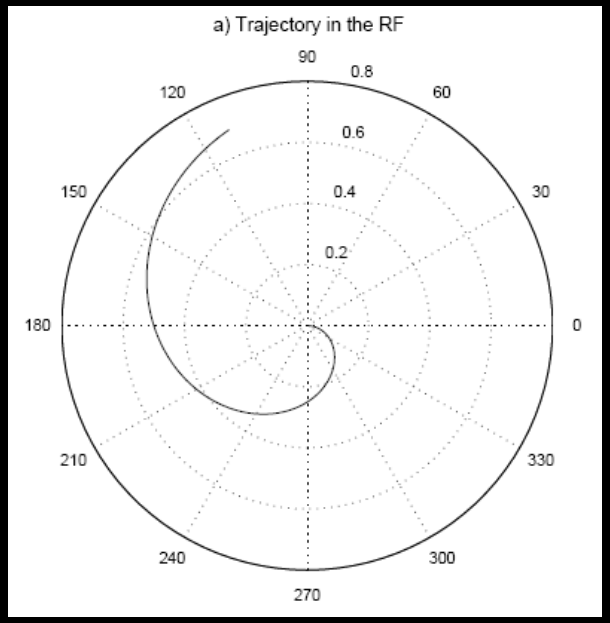


Curvature drift current (CDC)

CDC will create the toroidal magnetic field

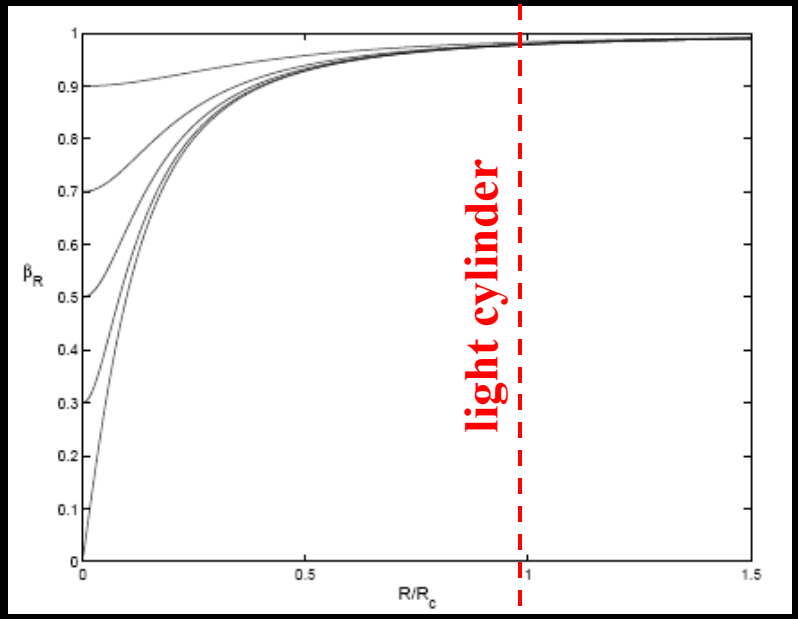
Current will inevitably twist the magnetic field line

Problem two: force-free



Rogava et al. 2003

For a given spiral there exists a characteristic velocity characterizing a force-free regime



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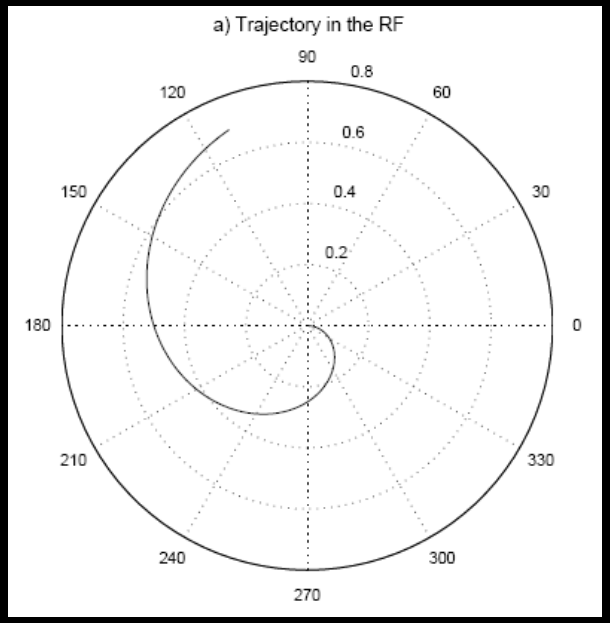

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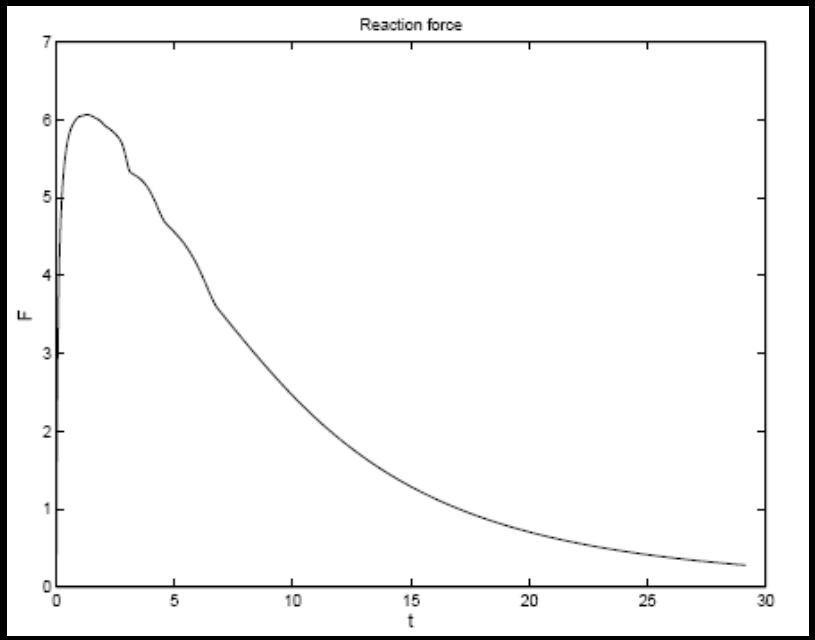

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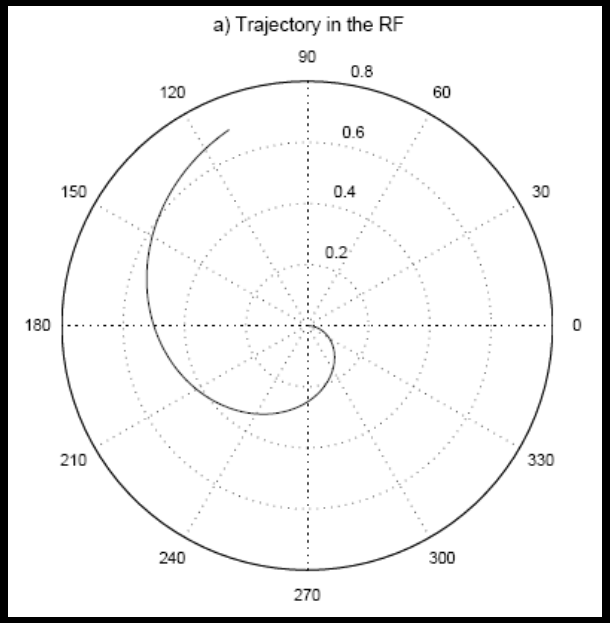

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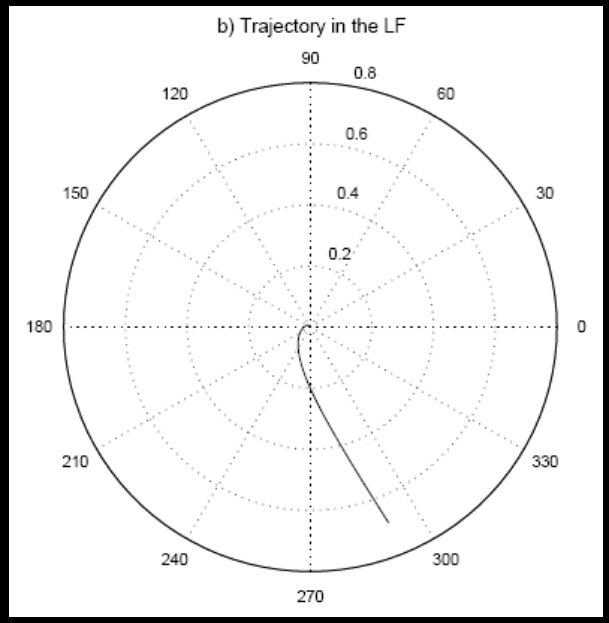


Initial conditions

Field lines are almost straight with very small curvature

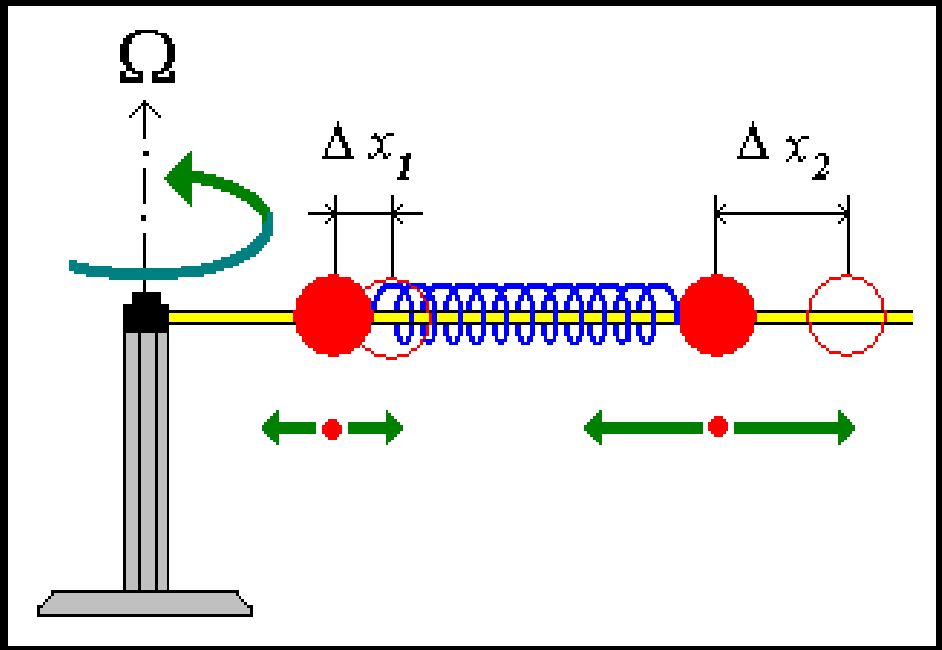
Plasma flow is composed of two components:

- **Electron-positrons**
- **Beam component**

Equations

Parametric instability

Machabeli et al. 2005; Osmanov et al. 2008

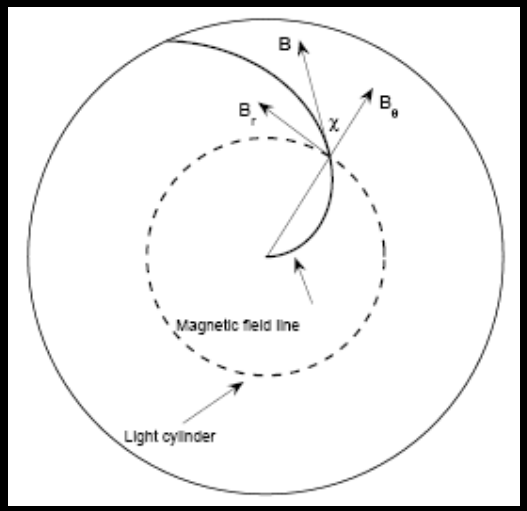


Linear analysis

Saturation: force-free regime

Due to the curvature drift instability the toroidal component will grow and the shape of the field lines will gradually transform to that of the Archiemde's spiral with $v_c=c$

The corresponding timescale is given by:



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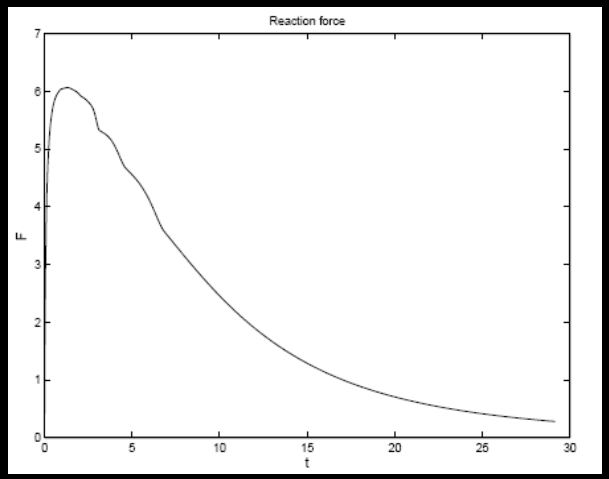
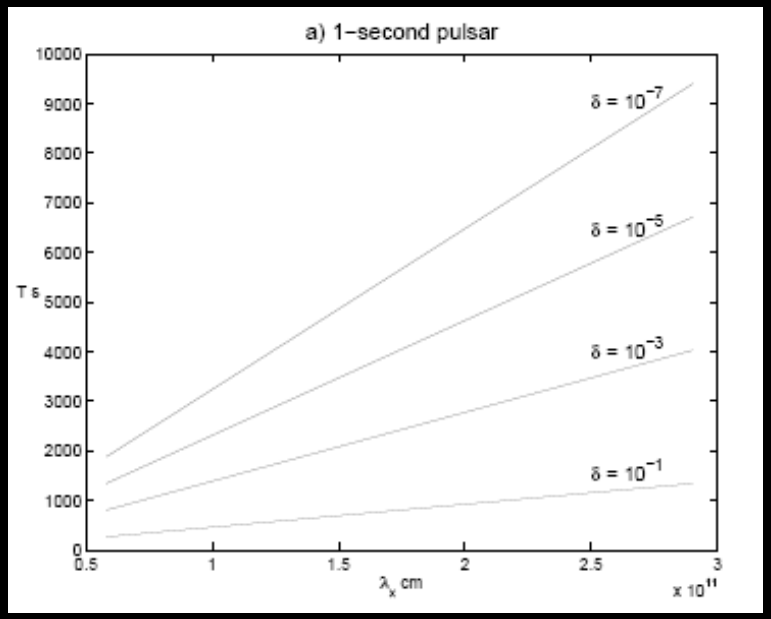
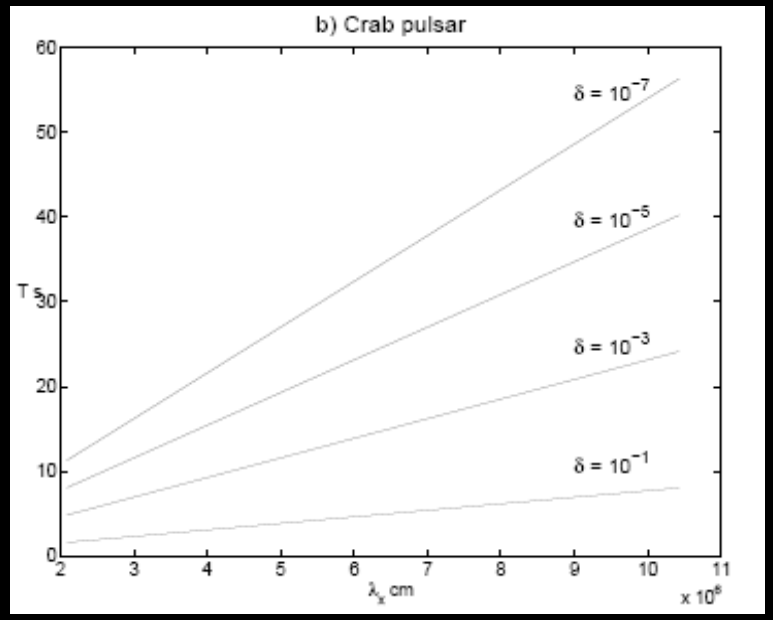


Efficiency of the twisting process





P/P$^{(1)}$ ranges from 10^{11}s (PSR 0531) to 10^{18}s (PSR 1952+29)

This effect is extremely efficient

Energy budget

Twisting requires a certain amount of energy, therefore it is essential to estimate pulsar's slowdown luminosity L_P comparing it to the "magnetic luminosity“ $L_m \doteq E_m/T$

Energy budget

Crab pulsar

Therefore, the twisting process is feasible

Results

Examining the pulsar magnetospheric relativistic plasma, we have studied the role of the parametrically excited CDI in the process of sweepback of magnetic field lines and the saturation process of the instability

Transition into the force-free regime has been studied for typical 1-second and Crab type pulsars. For the both cases it was found that the corresponding timescales are less than pulsar's spin down rates by many orders of magnitude indicating high efficiency of the present process

Studying the problem of energy budget, we showed that energy required for twisting the magnetic field lines is less than energy provided by pulsar's slowing down by many orders of magnitude.

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