PSR B0329+54 – A pulsar with unique polarization properties

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Introduction to pulsars

Pulsars are rotating neutron stars born from core collapse of Type II supernova

Periods of pulsars range from 1.3 msec to 8.5 sec

Pulsars are seen to slow down at a steady rate

Pulsar Magnetic fields vary from 10^8 to 10^{13} Gauss

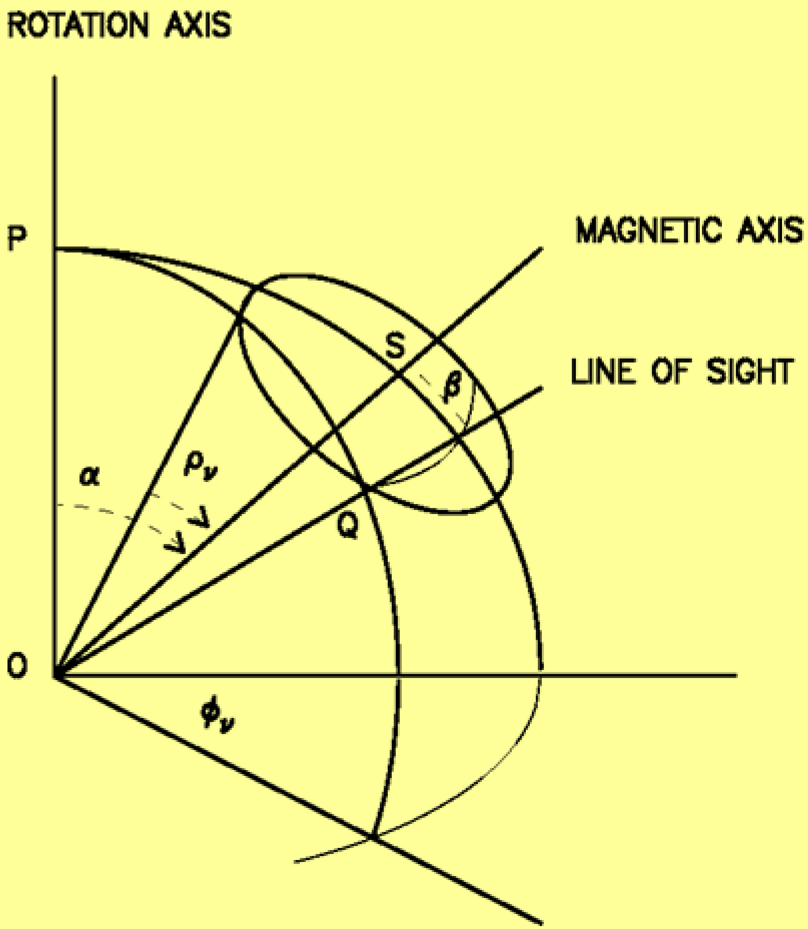
Pulsar emits pulsed radiation across the whole electromagnetic spectrum

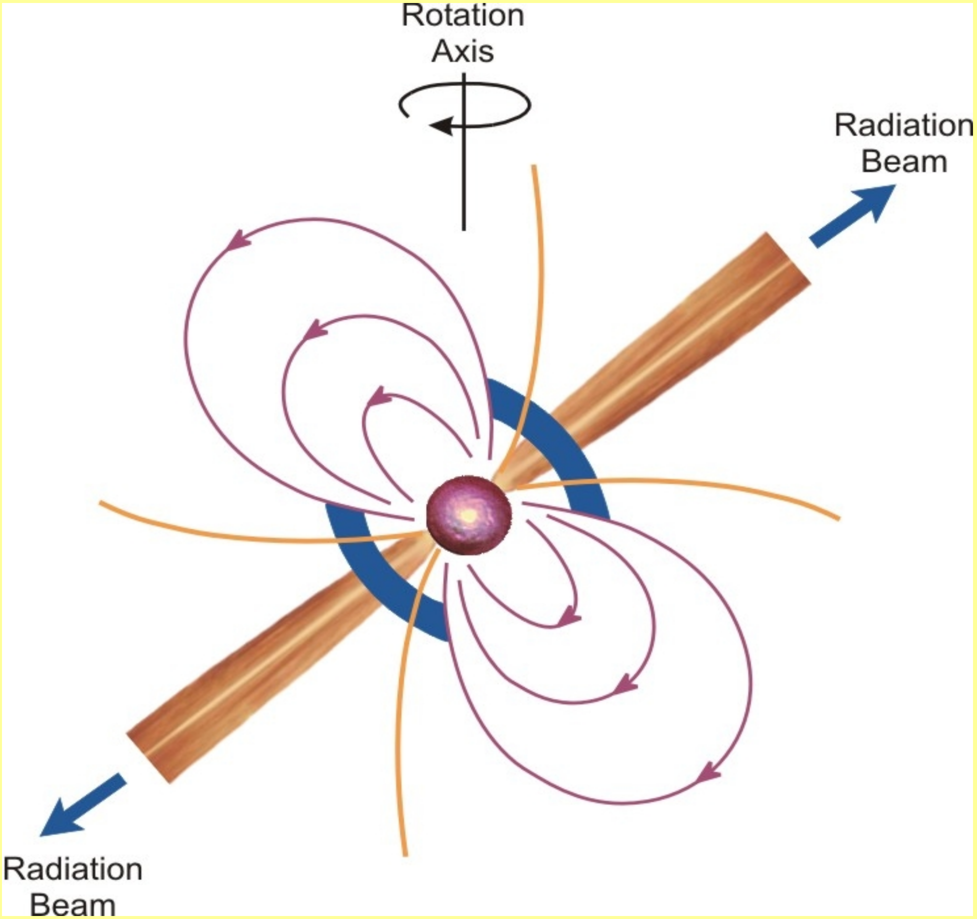
Radio Emission properties

- Radio emission from pulsars has high brightness temperature (10^{28} k) and is coherent and broadband in nature
- Radiation is highly polarized and hence has a non thermal origin
- Emission originates mostly from dipolar magnetic field line about hundreds of km above the surface of the NS.
- Emission is due to particles (or coherent bunch) moving along magnetic field with high lorentz factors (200)
- Emission is in the form of nested cones

What emission mechanism is set up in a pulsar to obey such emission properties is still unknown

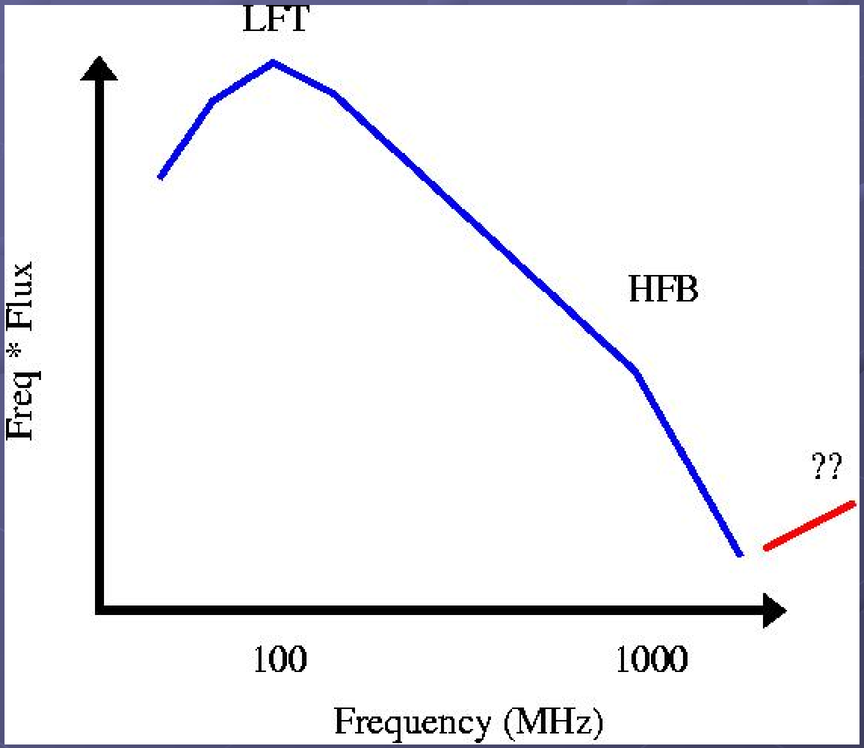
THE GEOMETRICAL PREMISE





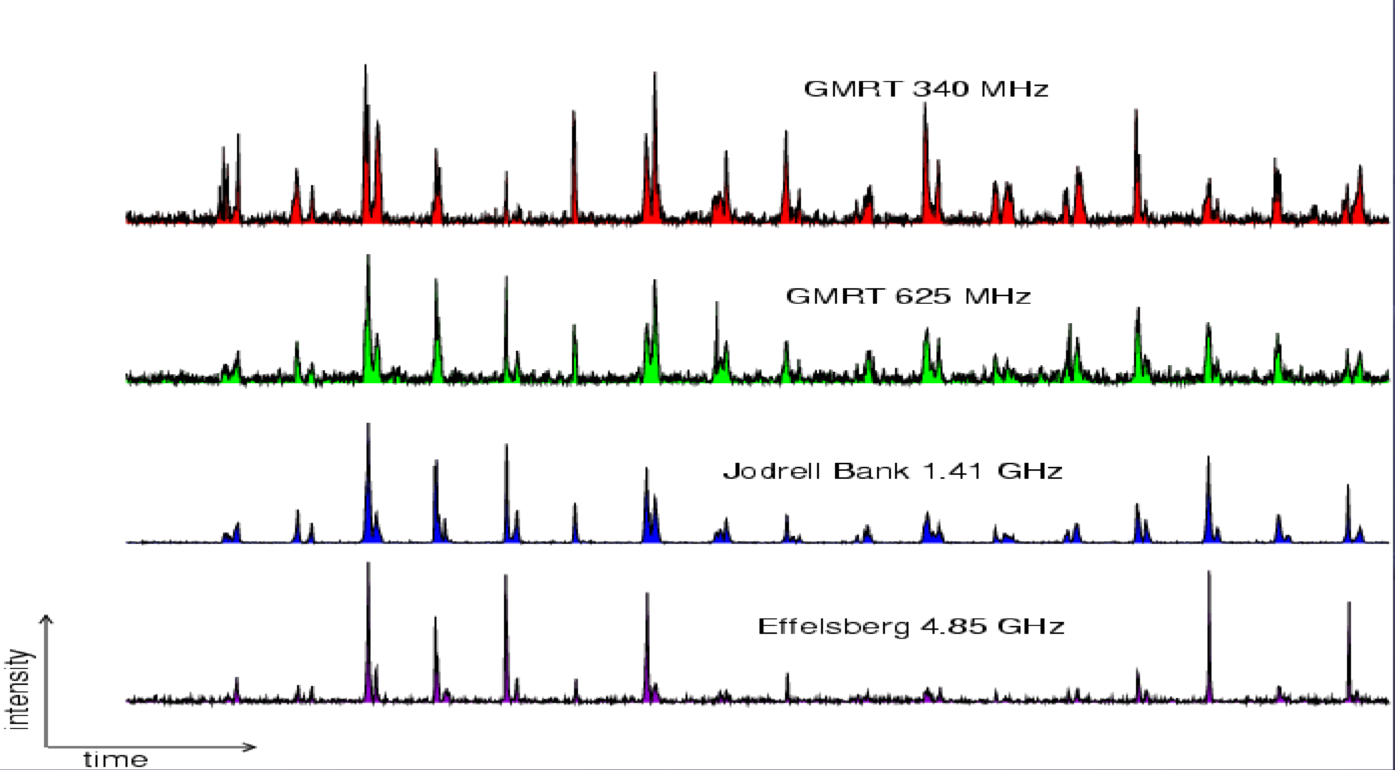
More radio emission properties

PULSARS ARE BROAD-BAND EMITTERS



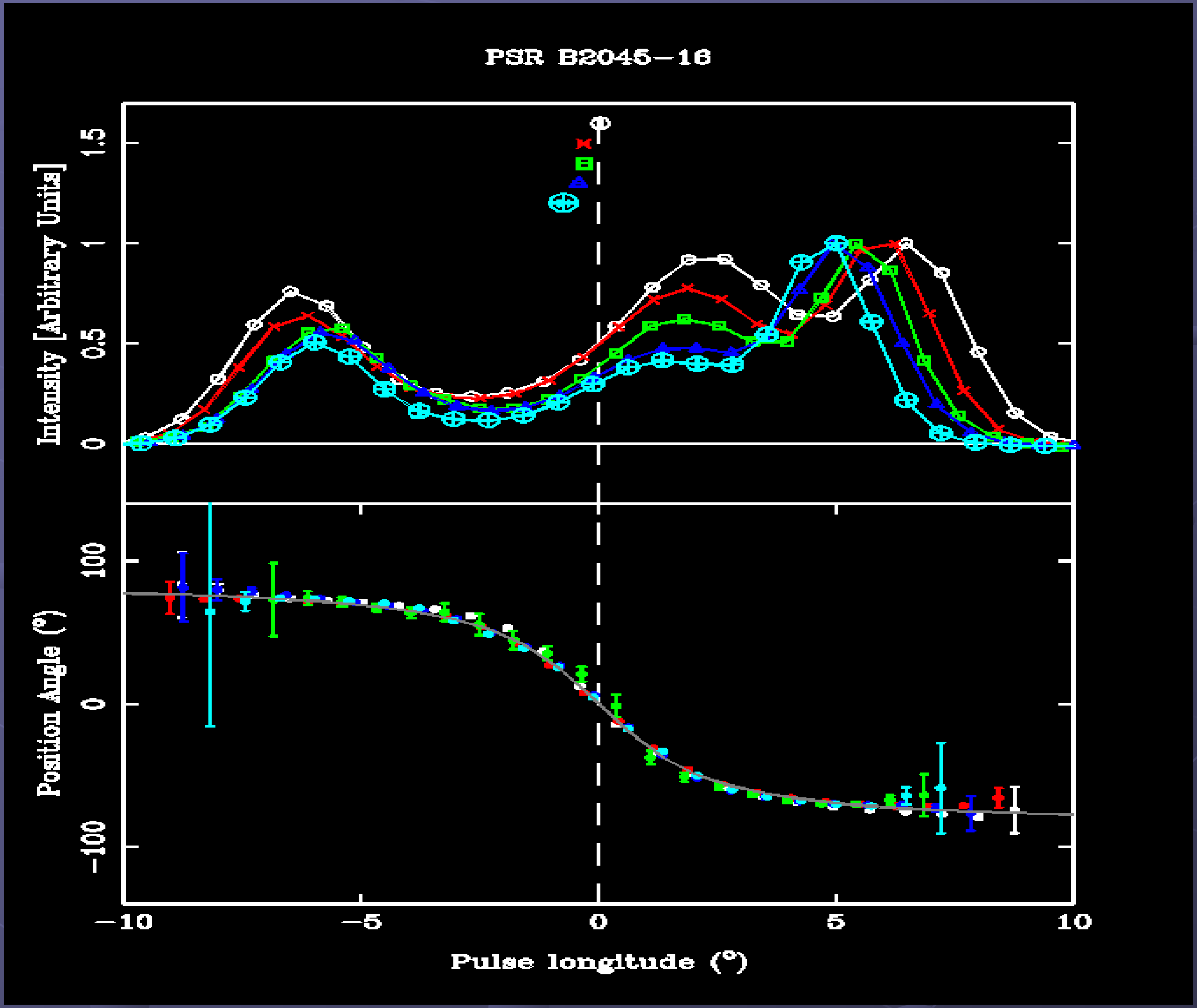
The coherent radio emission from pulsars has a steep spectral index (-1.7) !

Simultaneous observations



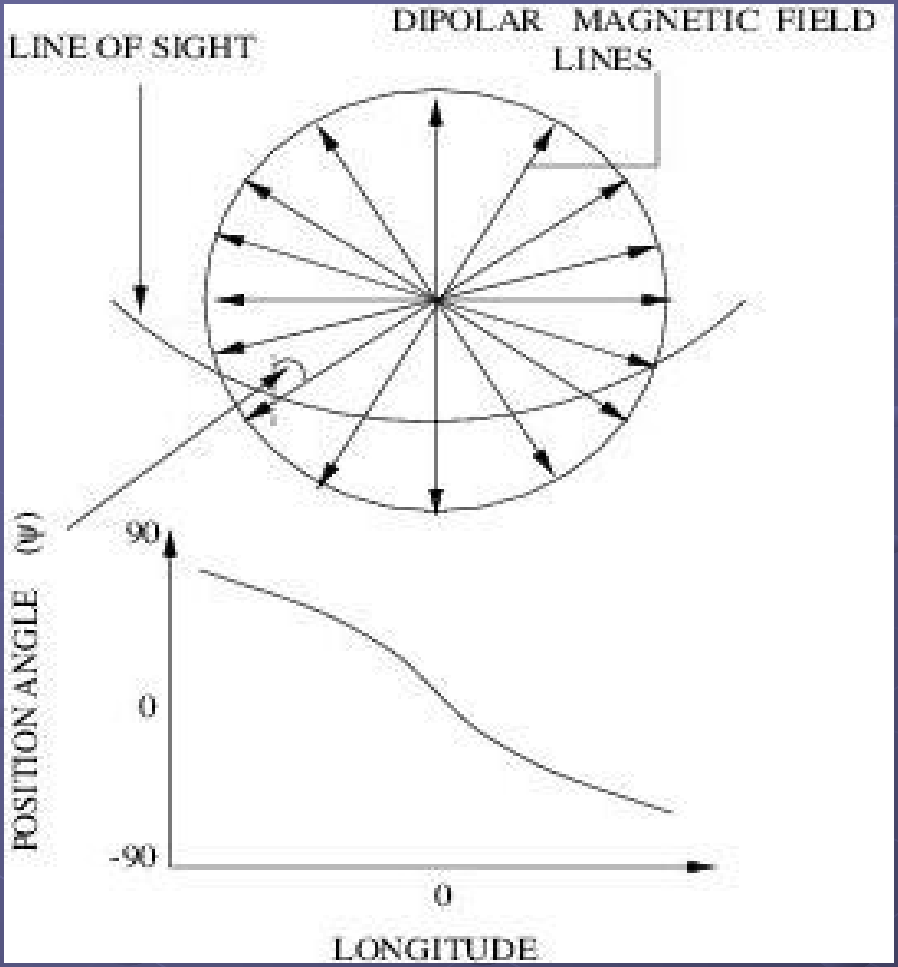
(Karastergiou et al 2003)

RVM seen in PSR B2045-16



(Mitra and Li 2004)

The Rotating vector Model

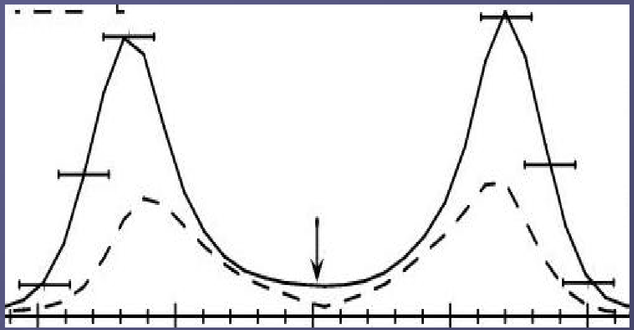


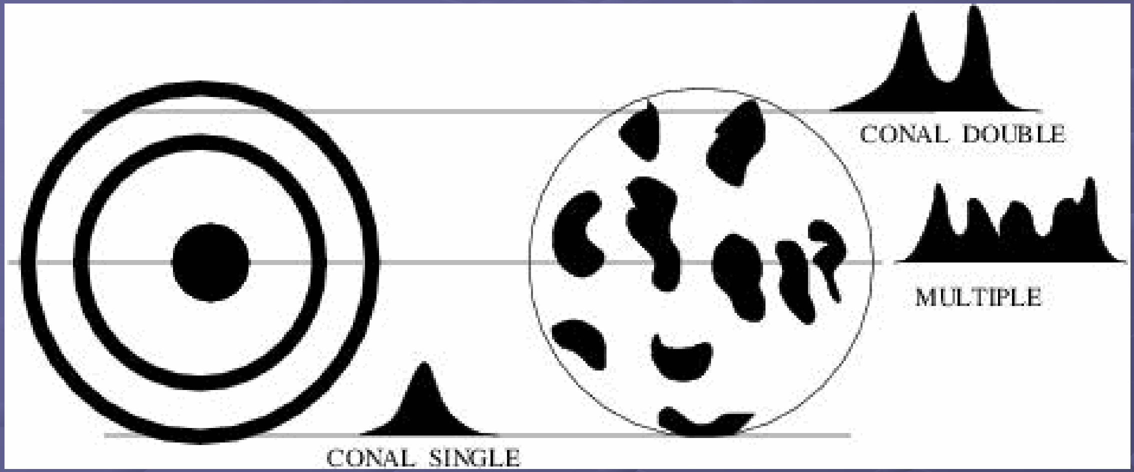
This model is extensievely used to find the viewing geometry

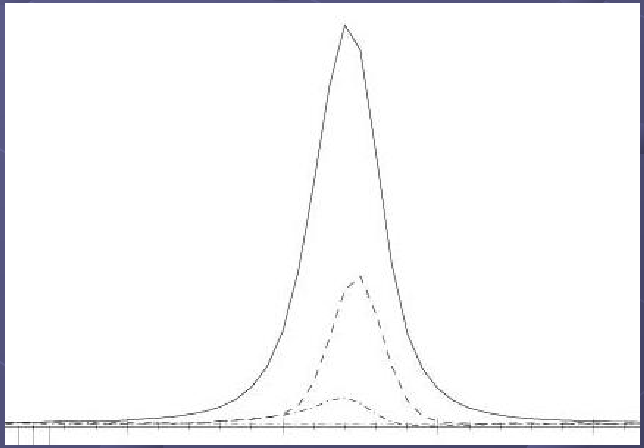
α , the angle between the rotation axis and the magnetic axis!

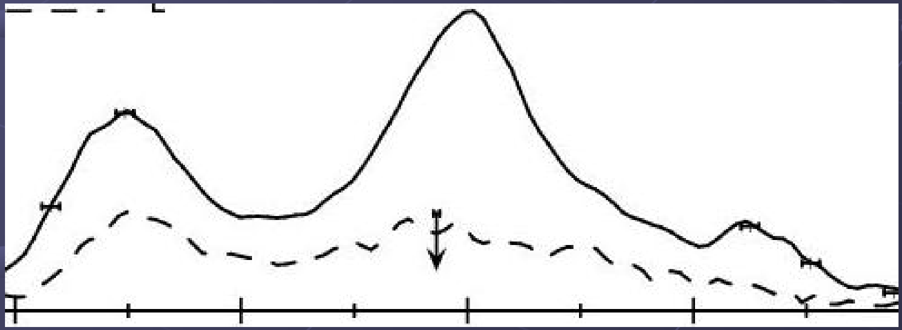
β, the angle between the magnetic axis and the observers line of sight

Shape of the pulsar beam



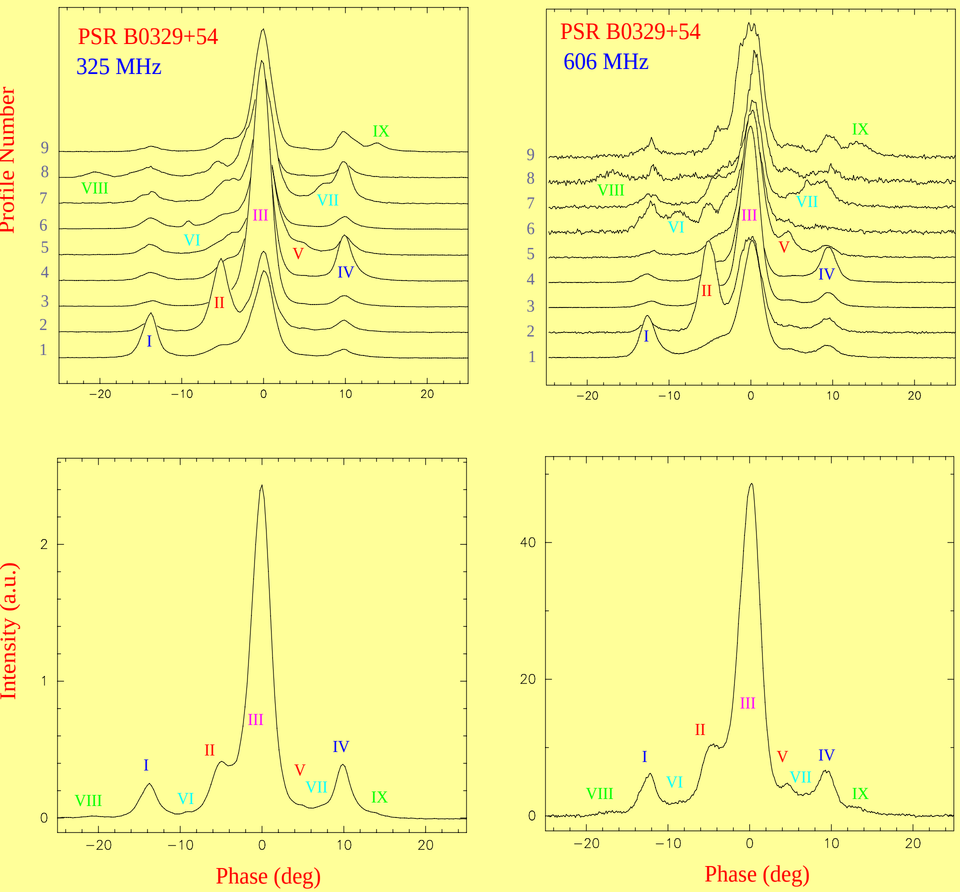


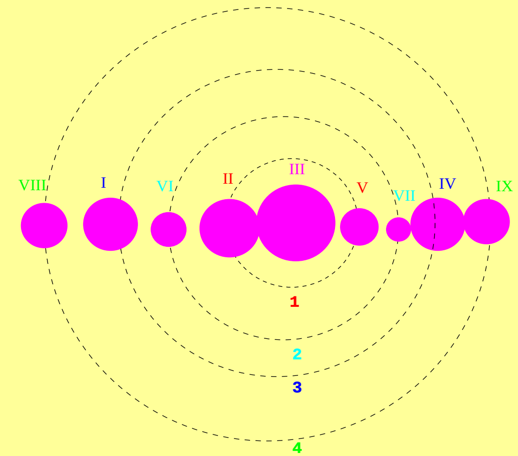


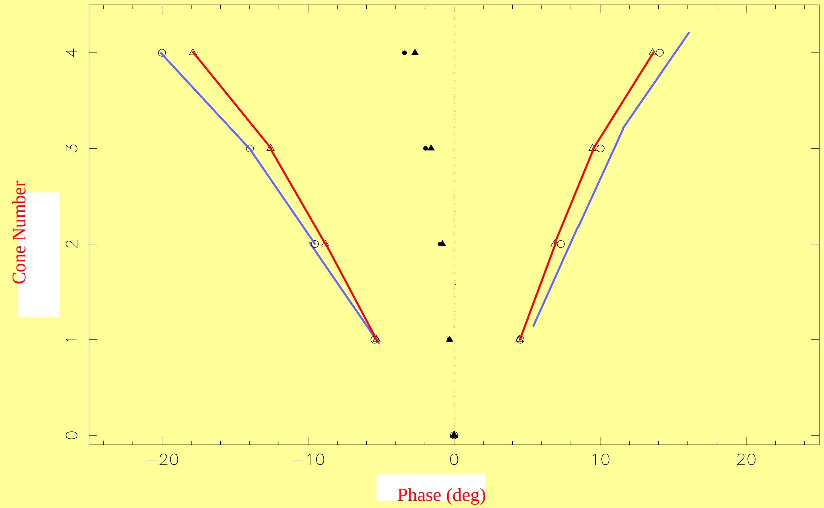


Example of nested cone emission in PSR B0329+54

Location of 9 emission components







606 MHz   325 MHz

(Gangadhara and Gupta 2003)

Average pulse profiles

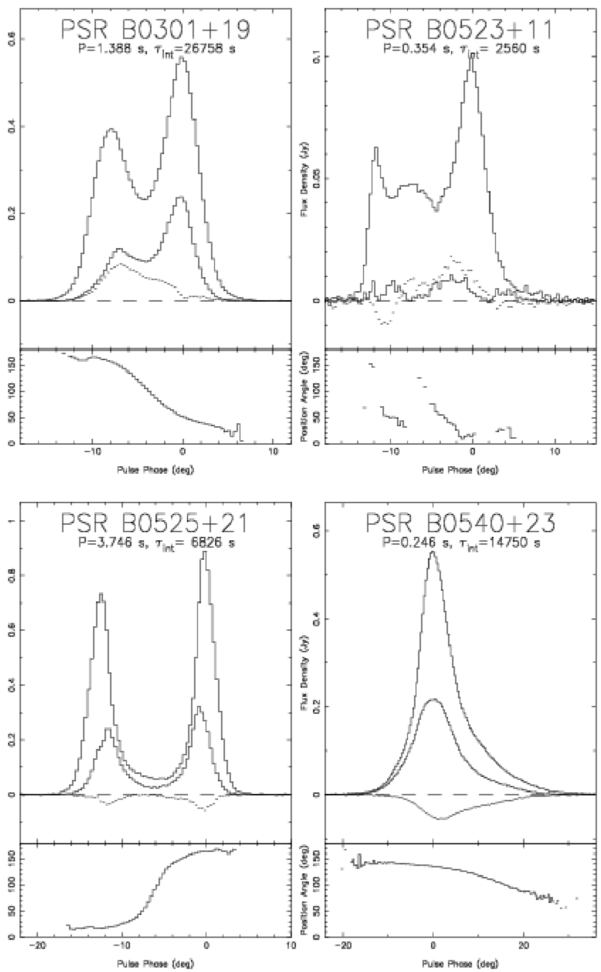


FIG. 1.—Polarized profiles for four pulsars. For each pulsar, the upper panel displays total (I), linearly polarized (L), and circularly polarized ($V = S_{left} - S_{right}$) flux densities. Total flux density is always the highest curve. Circularly polarized flux density is dashed, with each dash having a duration of 1/1024 pulsar period or 0°35 of longitude. The lower panel displays the position angle of linear polarization. Unless otherwise indicated on the plot itself, the position angle is plotted only at longitudes where $L \geq 3\ \sigma_L$. In the case of some particularly weak pulsars, L, V, and/or the position angle are not plotted because of insufficient sensitivity.

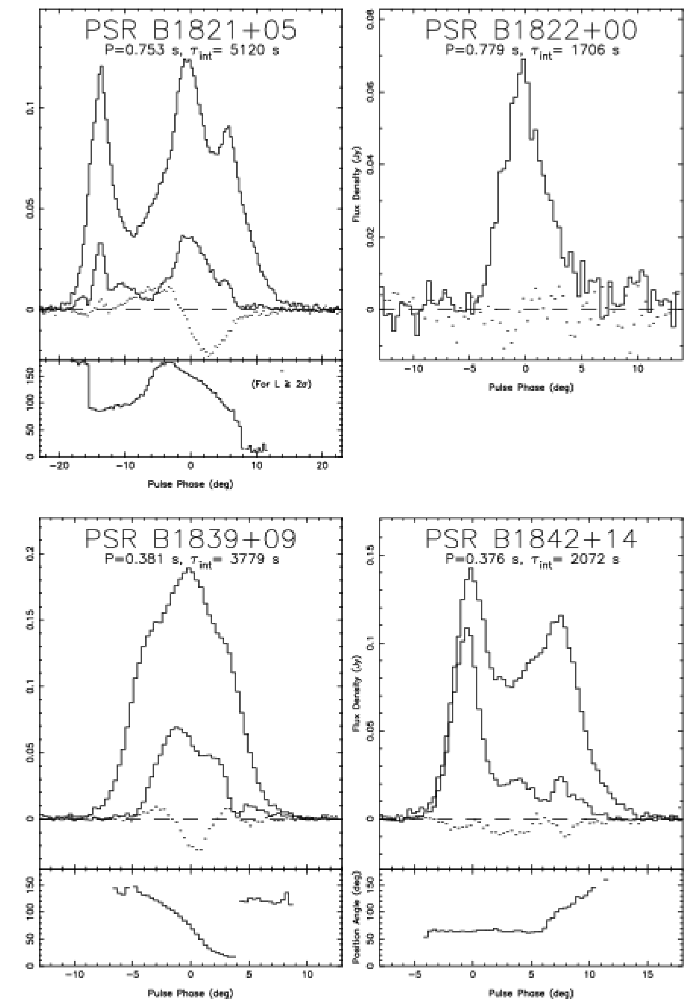
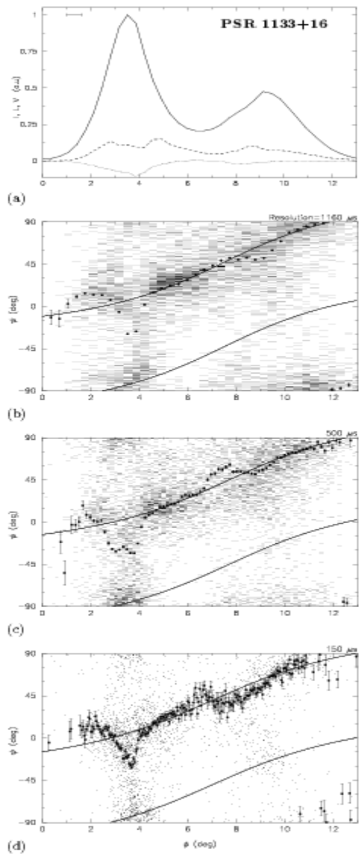


FIG. 3.—Polarized profiles for four pulsars. See Fig. 1 for details.

Complexities in pulsar polarization properties



Presence of orthogonal polarization mode

(Gangadhara et al 1997)

PSR B0329+54

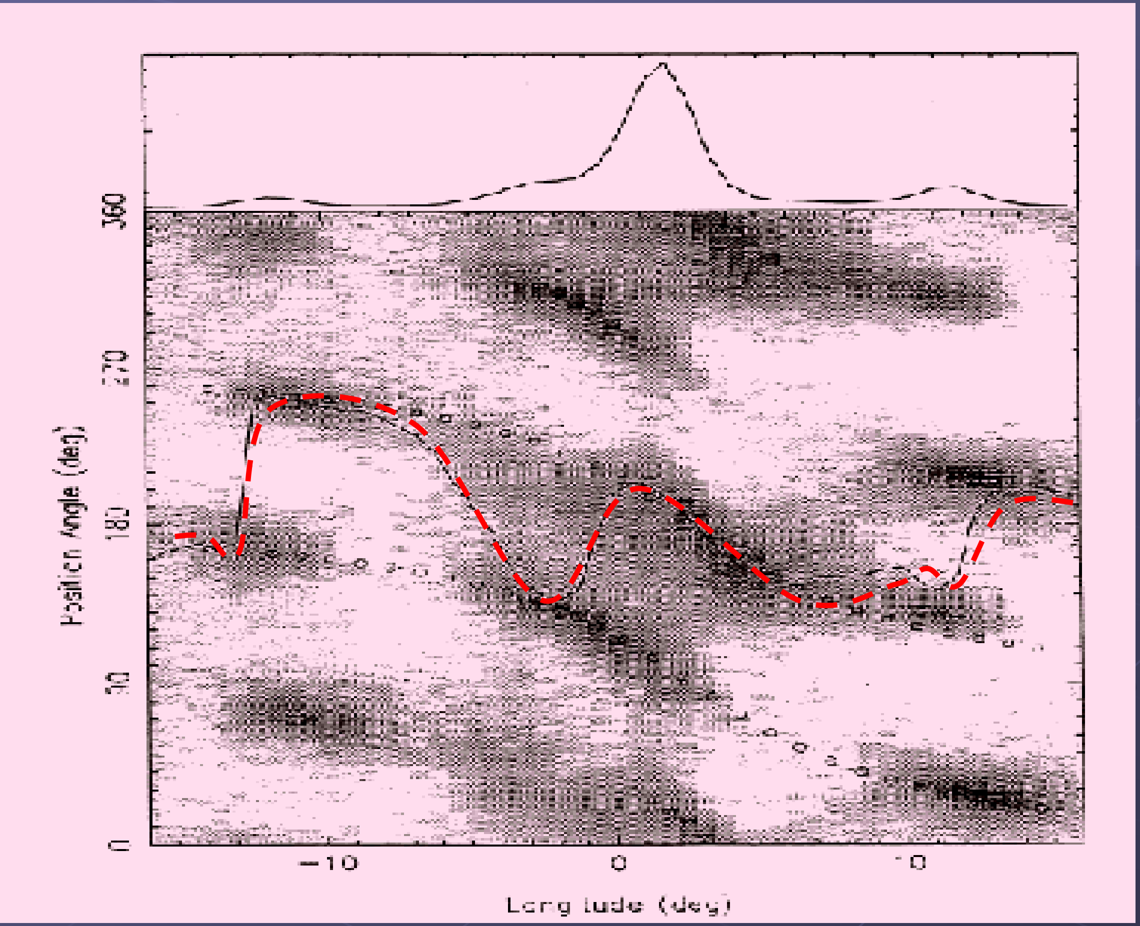
A bright pulsar about a kpc away

Period ~ 714 msec, B ~ 10^{12} Gauss,

Age~ 5.5 myr

Has three nested cones of emission and a central core emission

Presence of orthogonal polarization mode in B0329+54



(Gil & Lyne 1994)

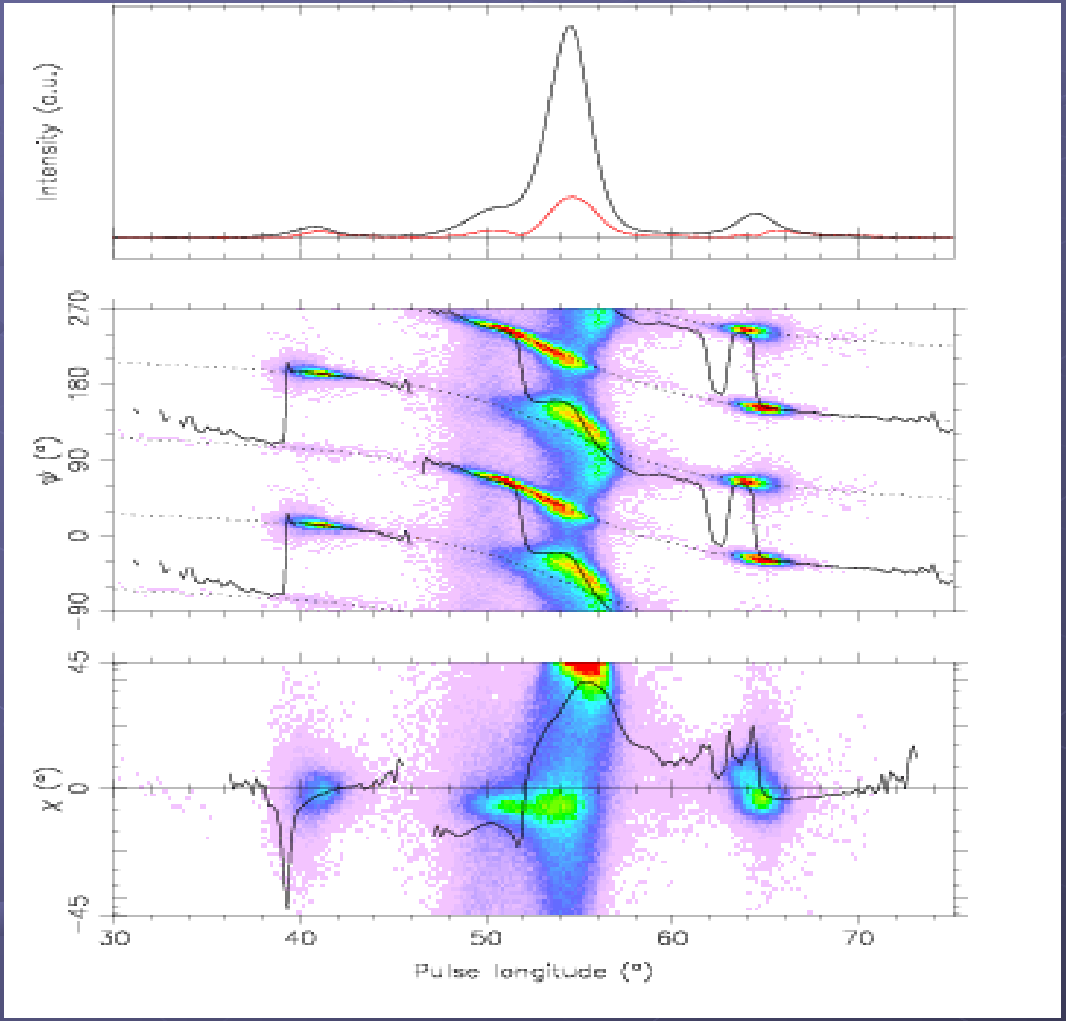
How are OPM’s produced?

One possible explanation proposed is that the magnetospheric plasma is birefringent and causes the linear polarization to split into ordinary and extraordinary mode

The ordinary mode travels along the magnetic field lines and the extraordinary mode is perpendicular to it. The O mode is prone to further refraction while the X mode travels unaffected.

The average PA curve will get distorted depending on which mode dominates and by what fraction

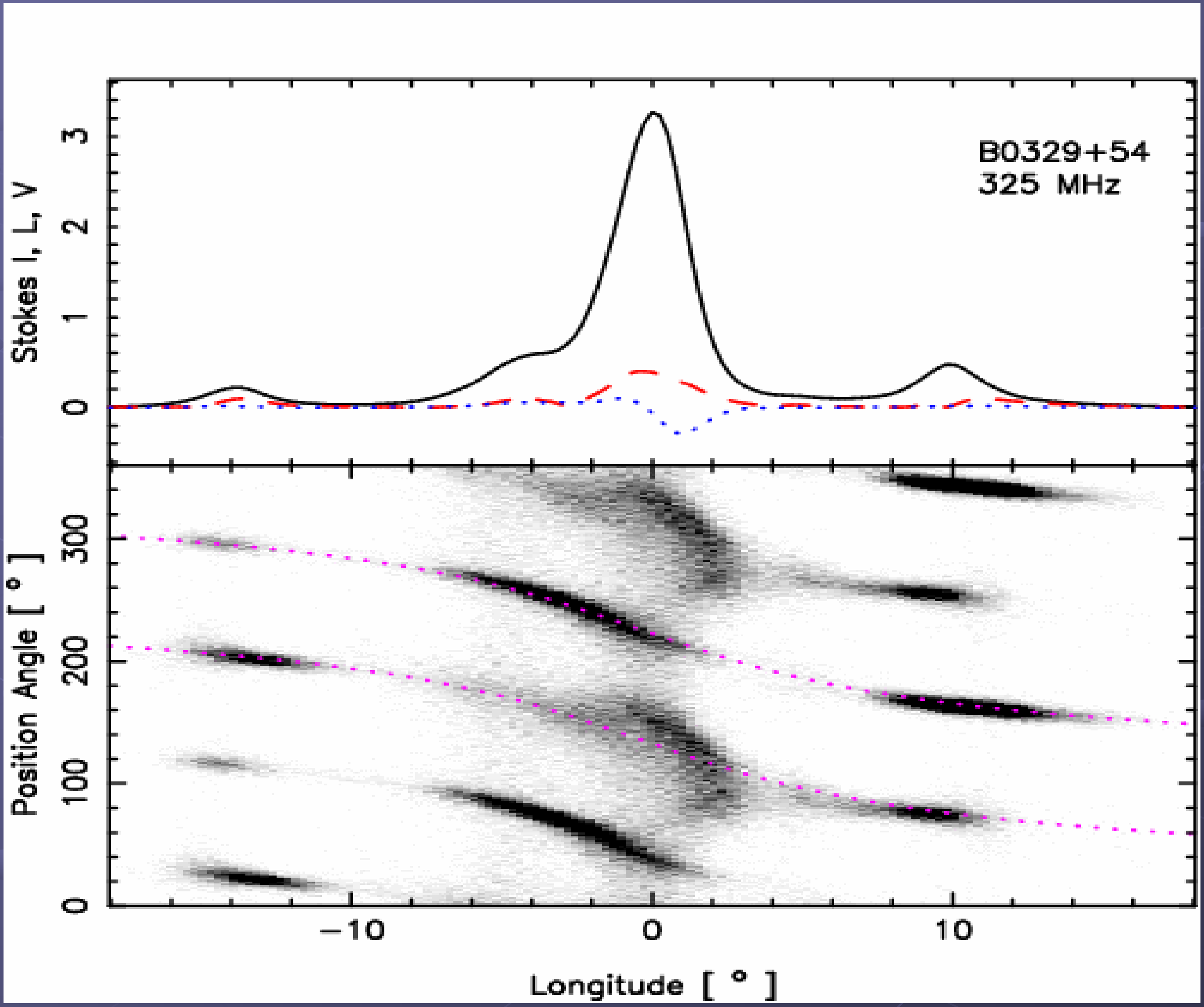
PSR B0329+54



The central distortion can be a result of refraction of the ordinary mode

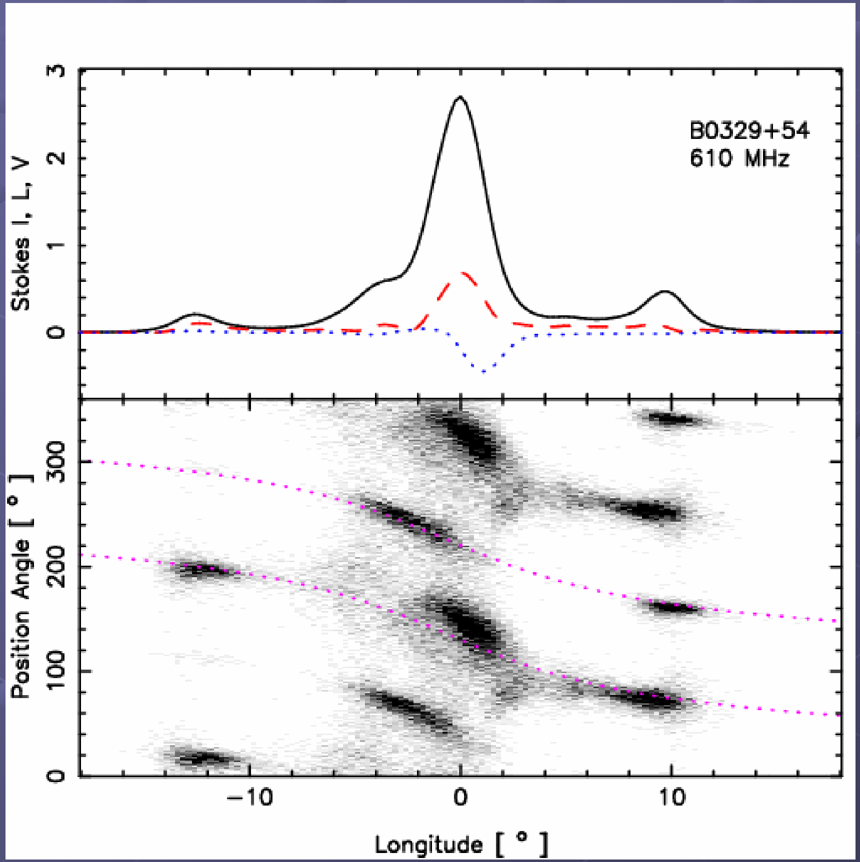
(Edwards & Stappers 2004)

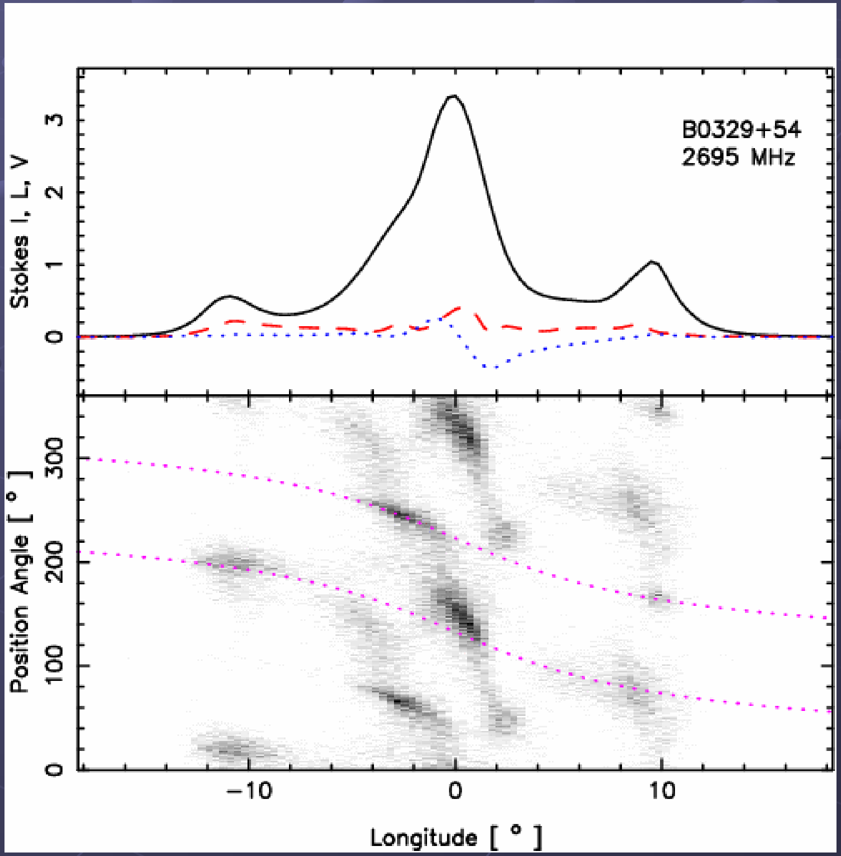
Our observation of PSR B0329+54



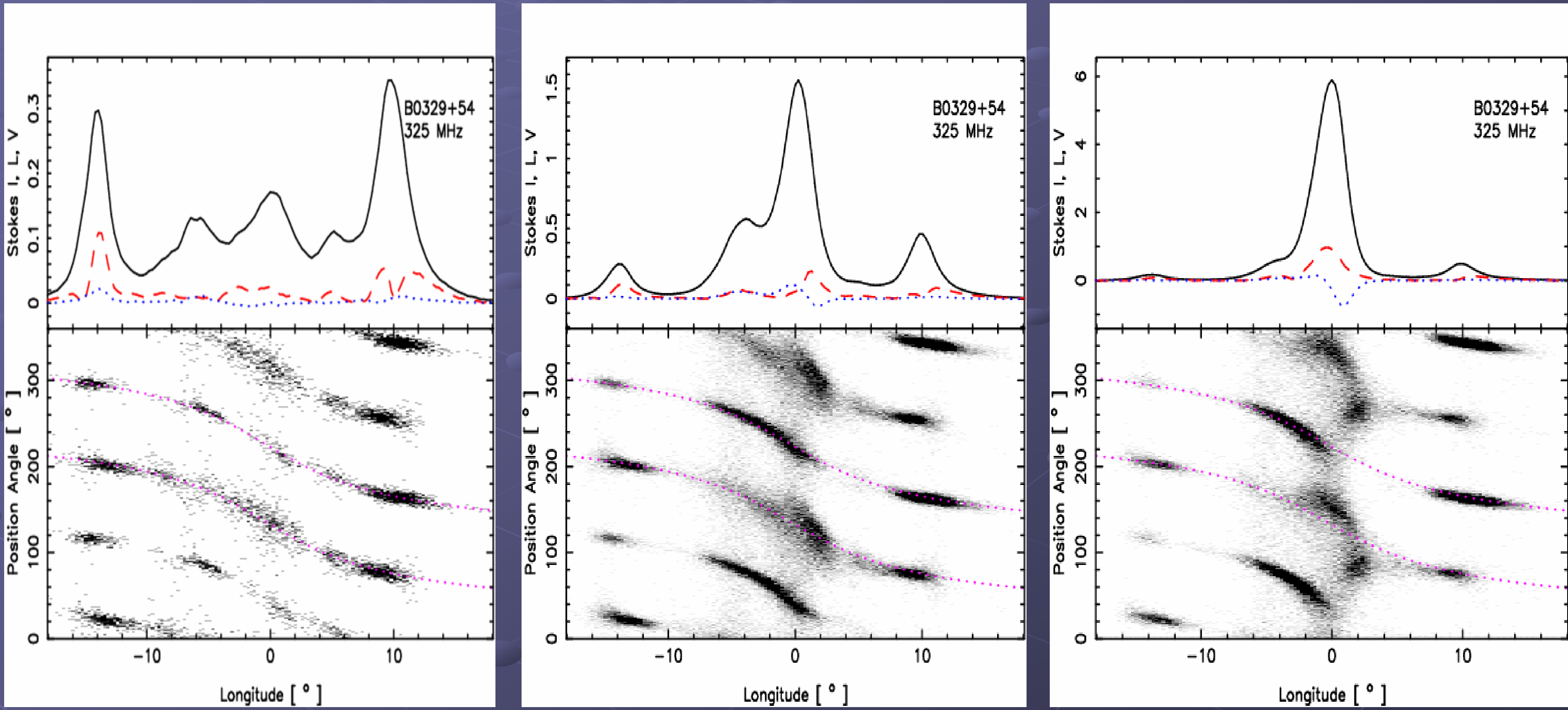
325 MHz
GMRT

610 MHz (GMRT)   2.6 GHz (Effelsberg)

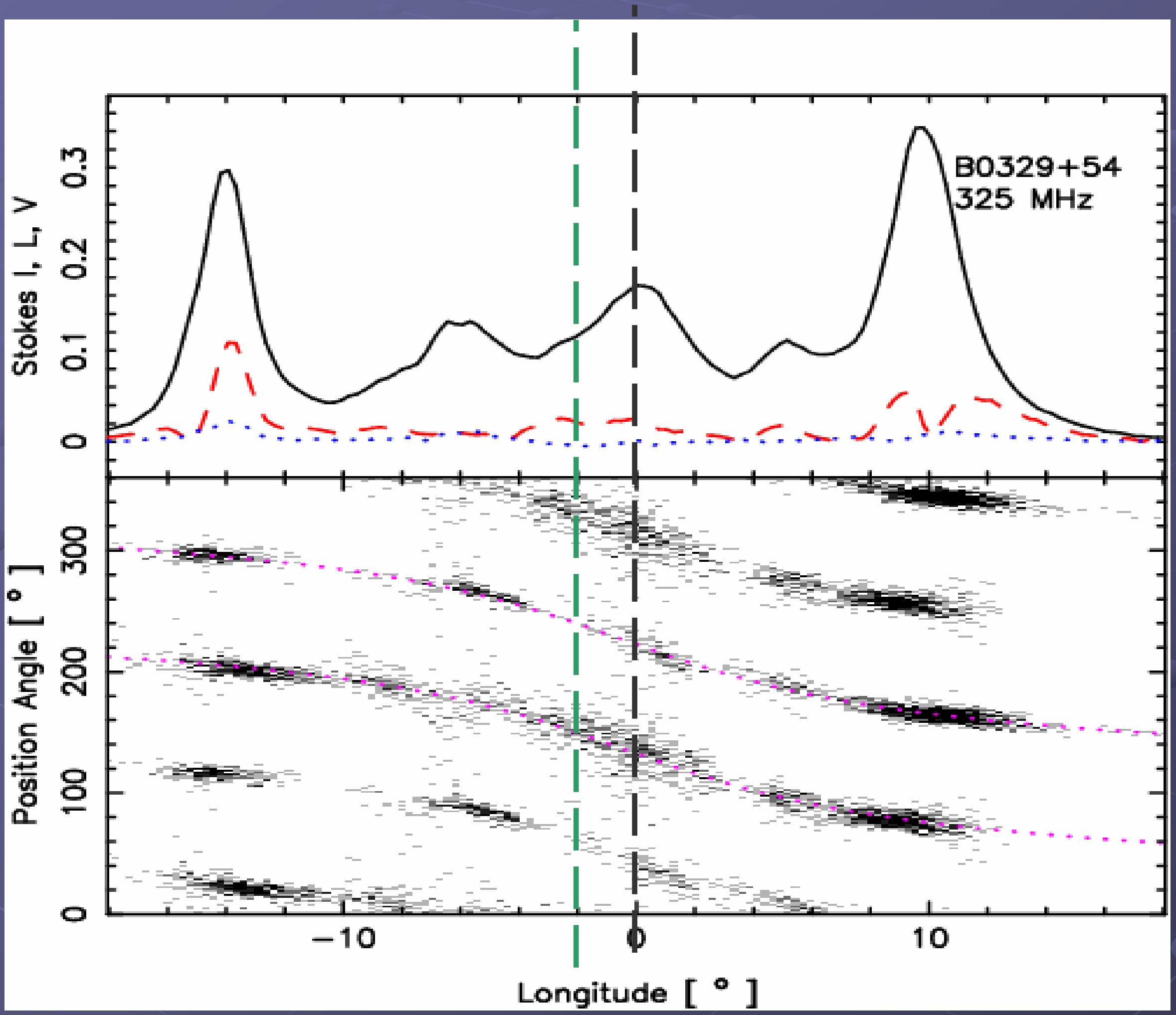




Intensity dependent PA



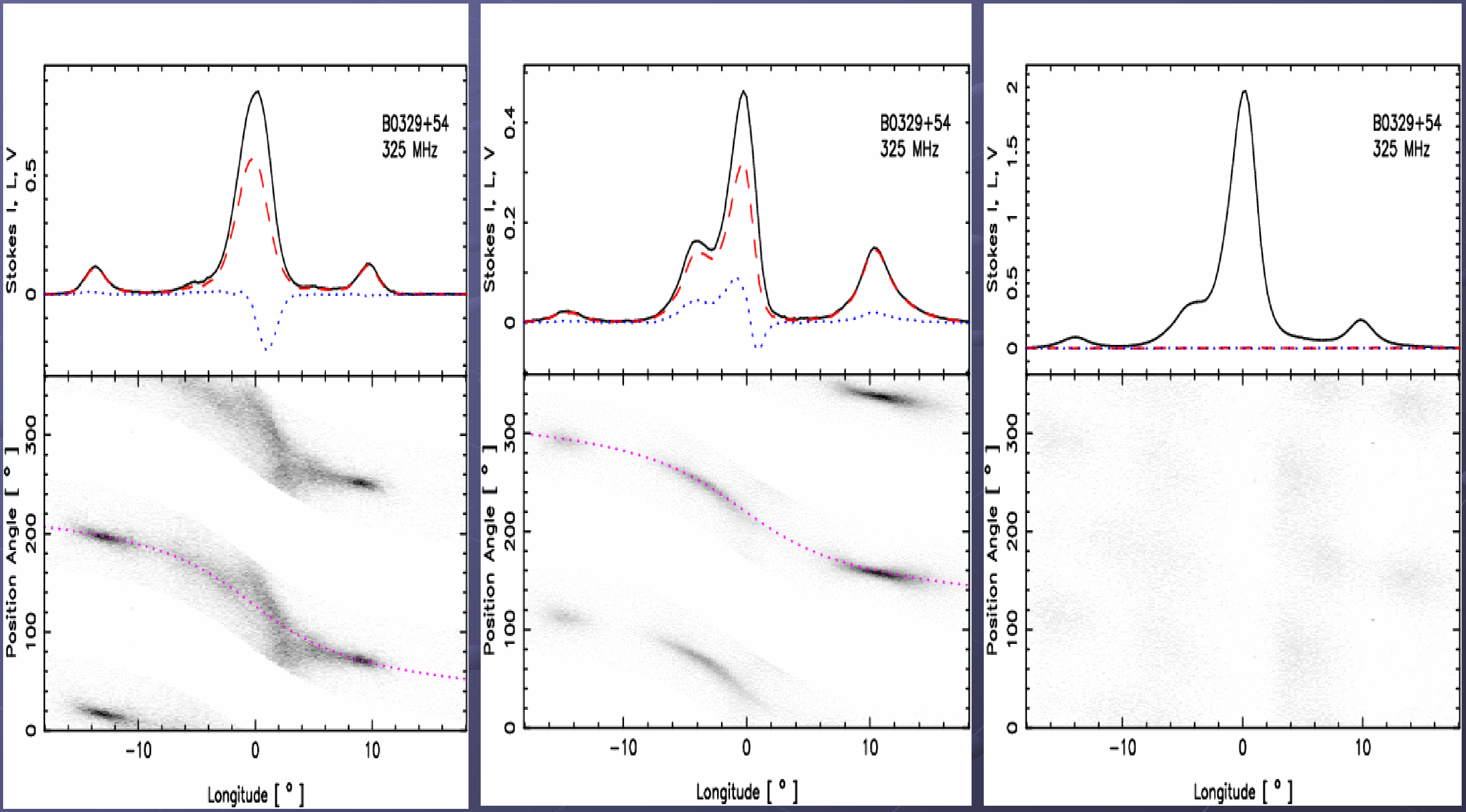
Emission height of the O and X mode



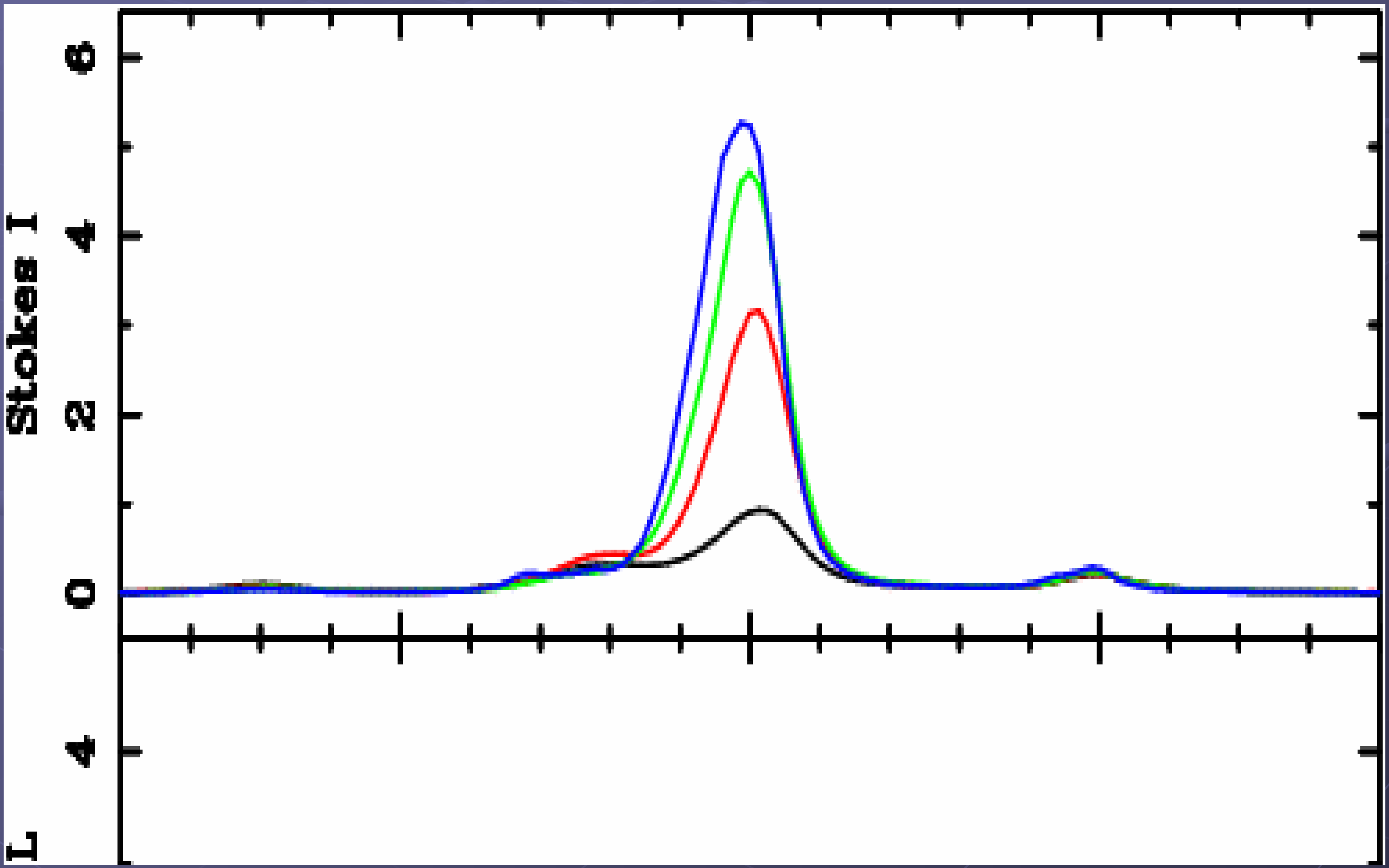
For emission arising at a given height Abberation causes the steepest gradient to lag w.r.t the center of the pulse profile.

The shifts are seen to be the same for X and O mode, and hence the emission heights are same for both the modes

Mode separated profiles



The core component appears earlier with intensity



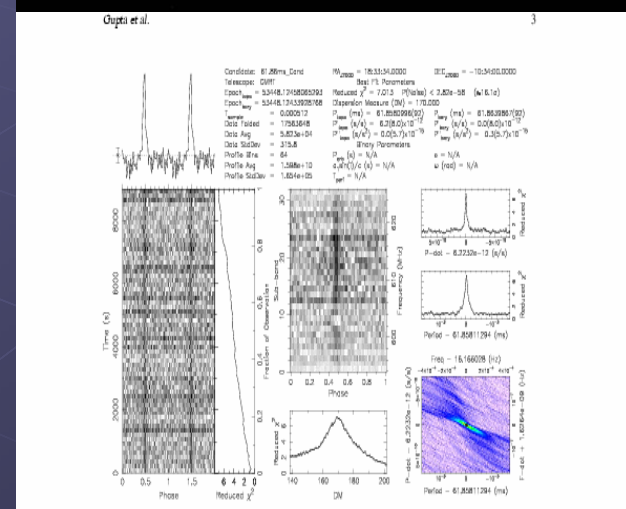
(also seen by Mckinnon and Hankins 1993)

Summary

- For the first time we have seen the phenomenon of intensity dependent PA
- The phenomenon is invariant across wide frequency range and we can rule out the effect of refraction
- Intensity variation can happen due to sudden increase of charged particles flowing along the magnetic field lines
- Increased particles can cause distortions in the magnetic field and produce the PA variations observed. Further theoretical modelling is needed to understand this effect.

Pulsar and TypeII supernova

Crab nebula and its pulsar
(Chandra observations)



Pulsar found in G21.5-0.9
using GMRT (Gupta, Mitra, Green, Acharya)

back