MILLISECOND PULSAR EMISSION ALTITUDE FROM RELATIVISTIC PHASE SHIFT: PSR J0437- 4715

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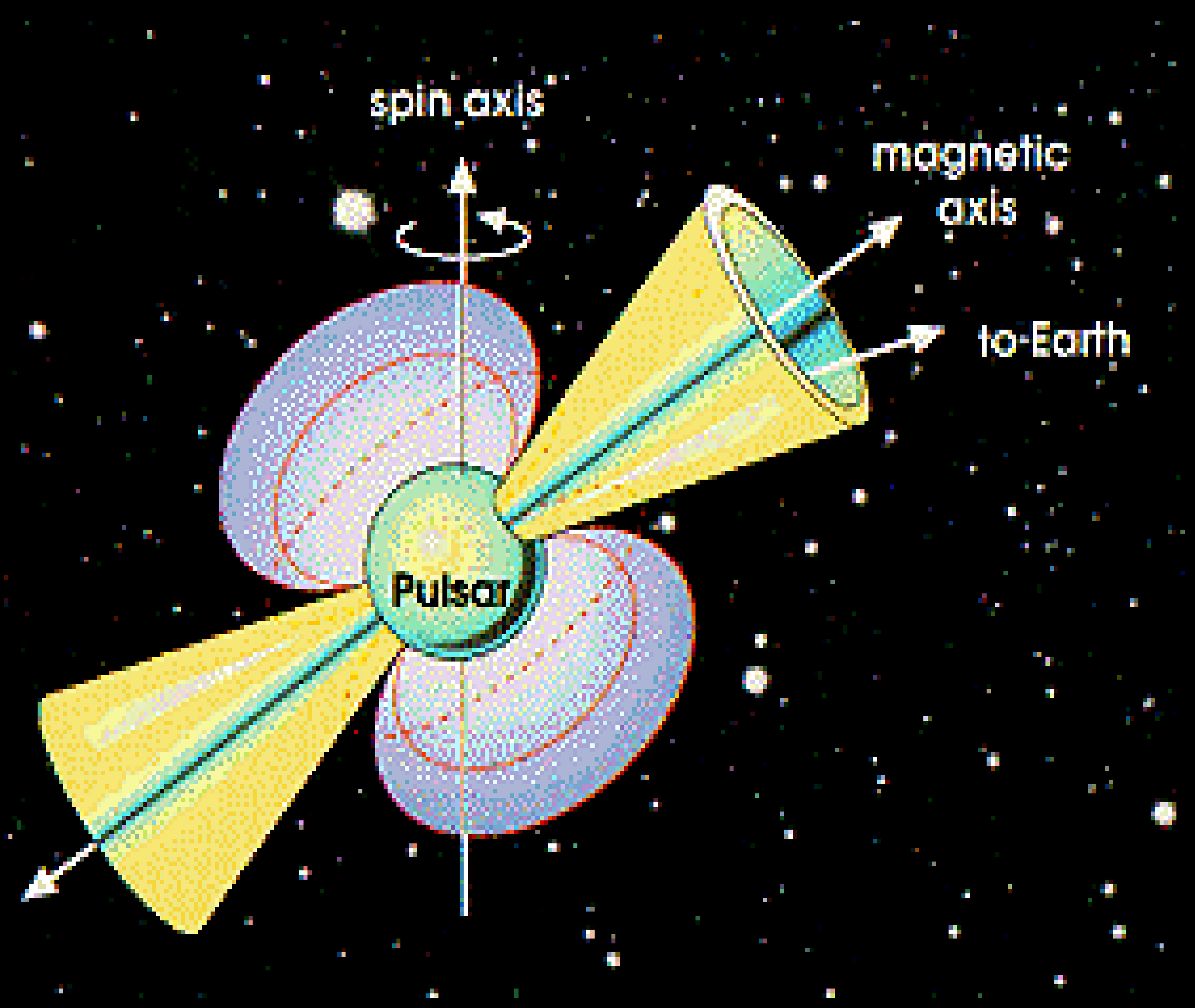
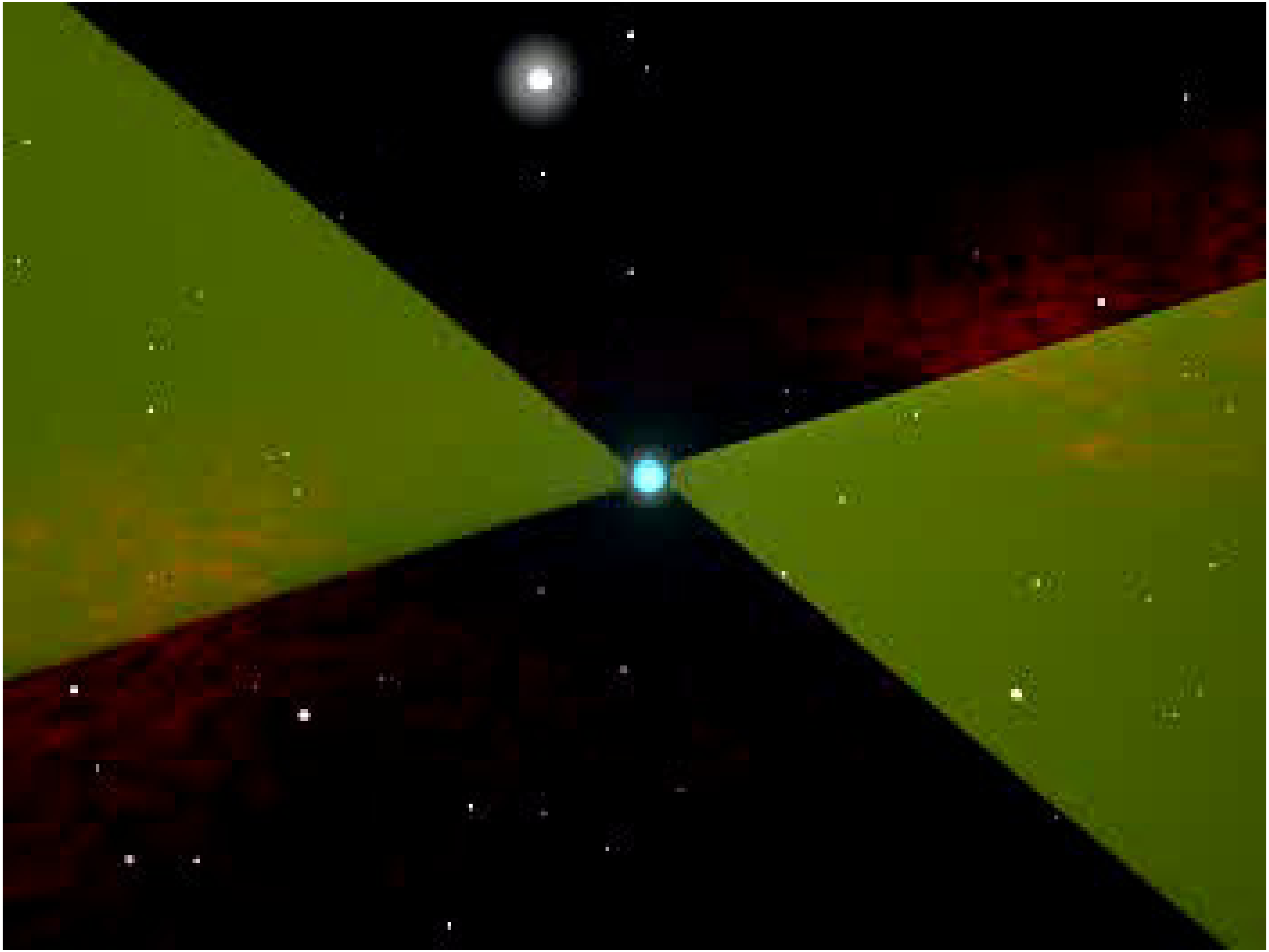
PLAN

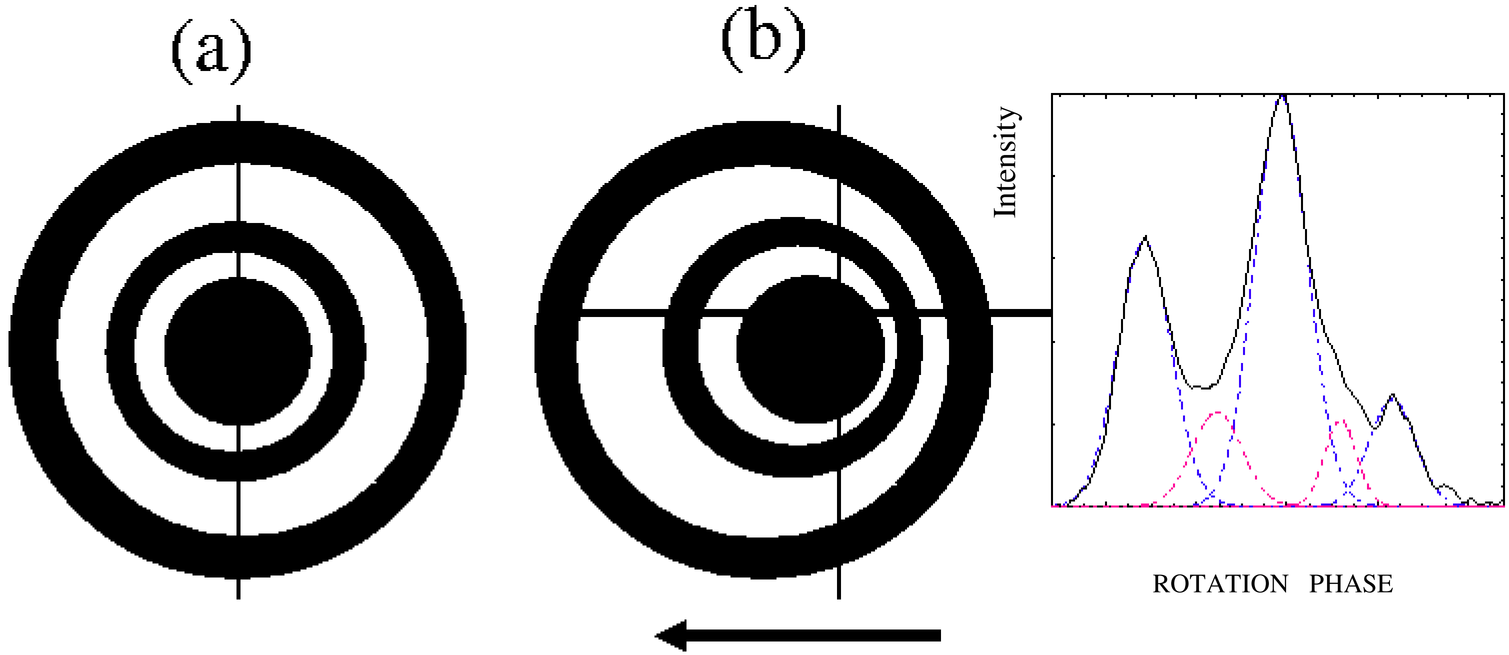
- Asymmetric pulse profiles
- Detection of components
- Phase shift

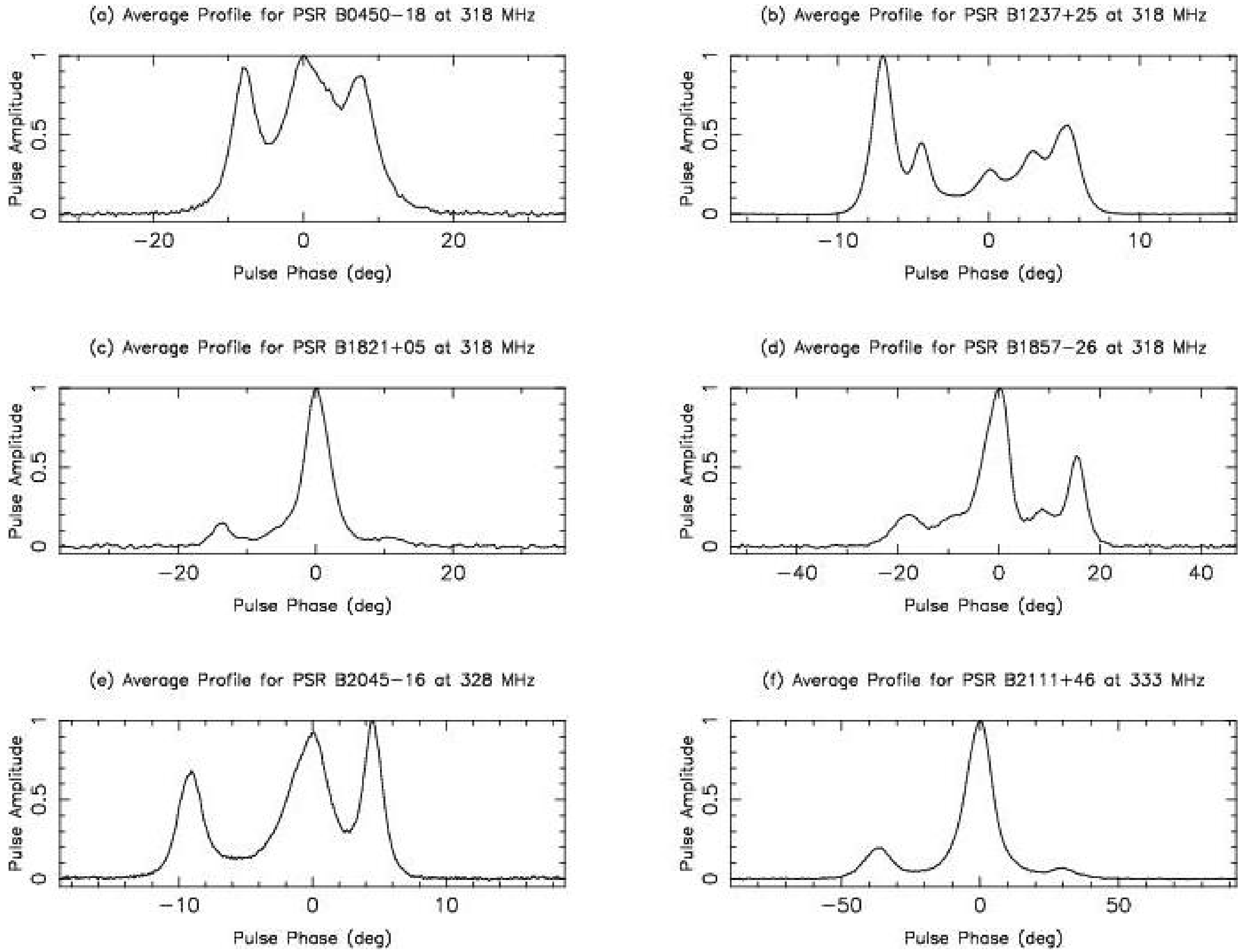
- Aberration, Retardation and Polar cap current phase shift
- Polarization angle swing (RVM)
- Estimation of emission height

MODEL OF PULSAR






(a)
(b)
Intensity
ROTATION PHASE

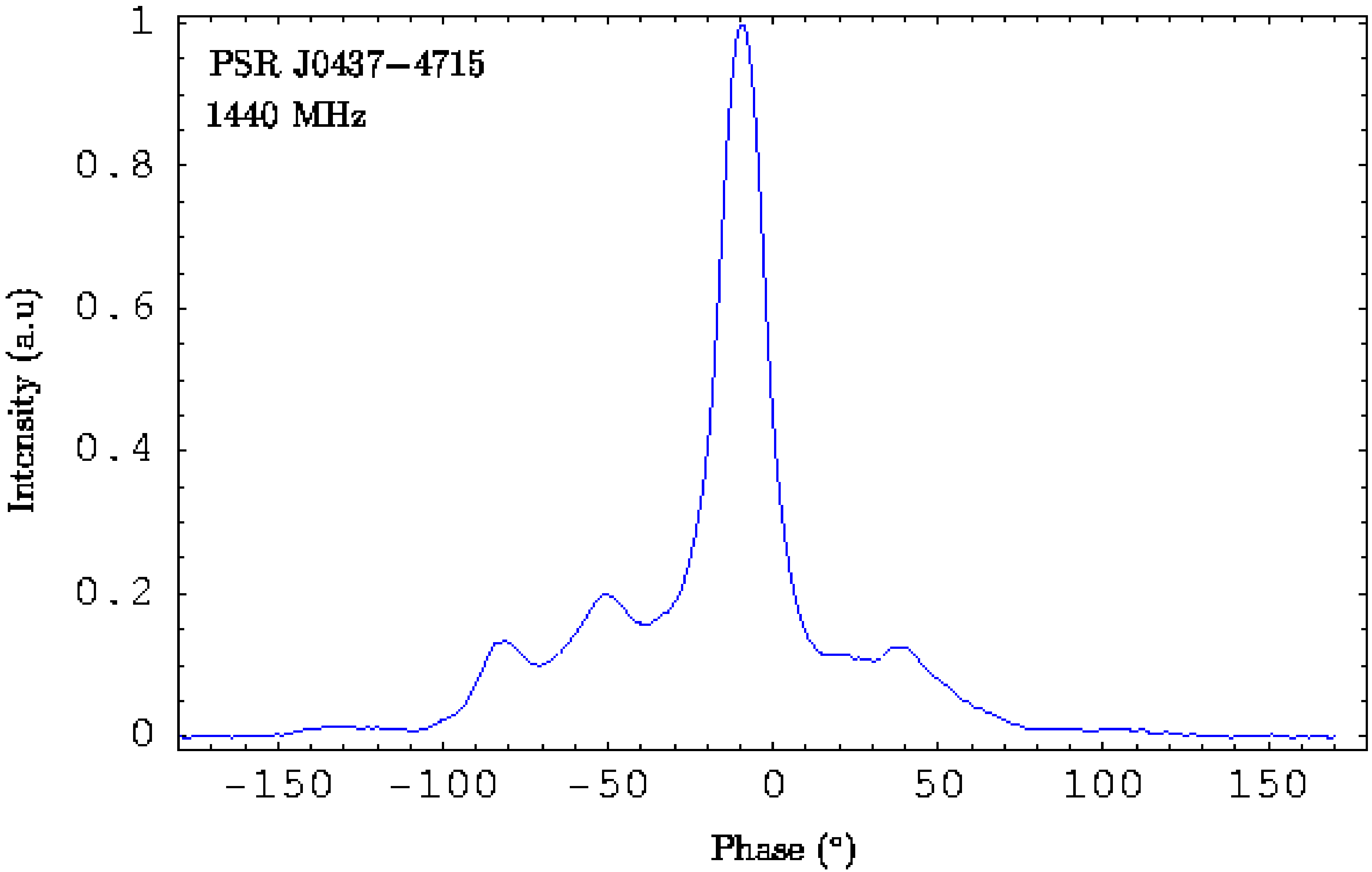


Gangadhara, R. T. , & Gupta, Y., 2001, ApJ, 555, 31
Gupta, Y. & Gangadhara, R. T. , 2003, ApJ, 584, 418

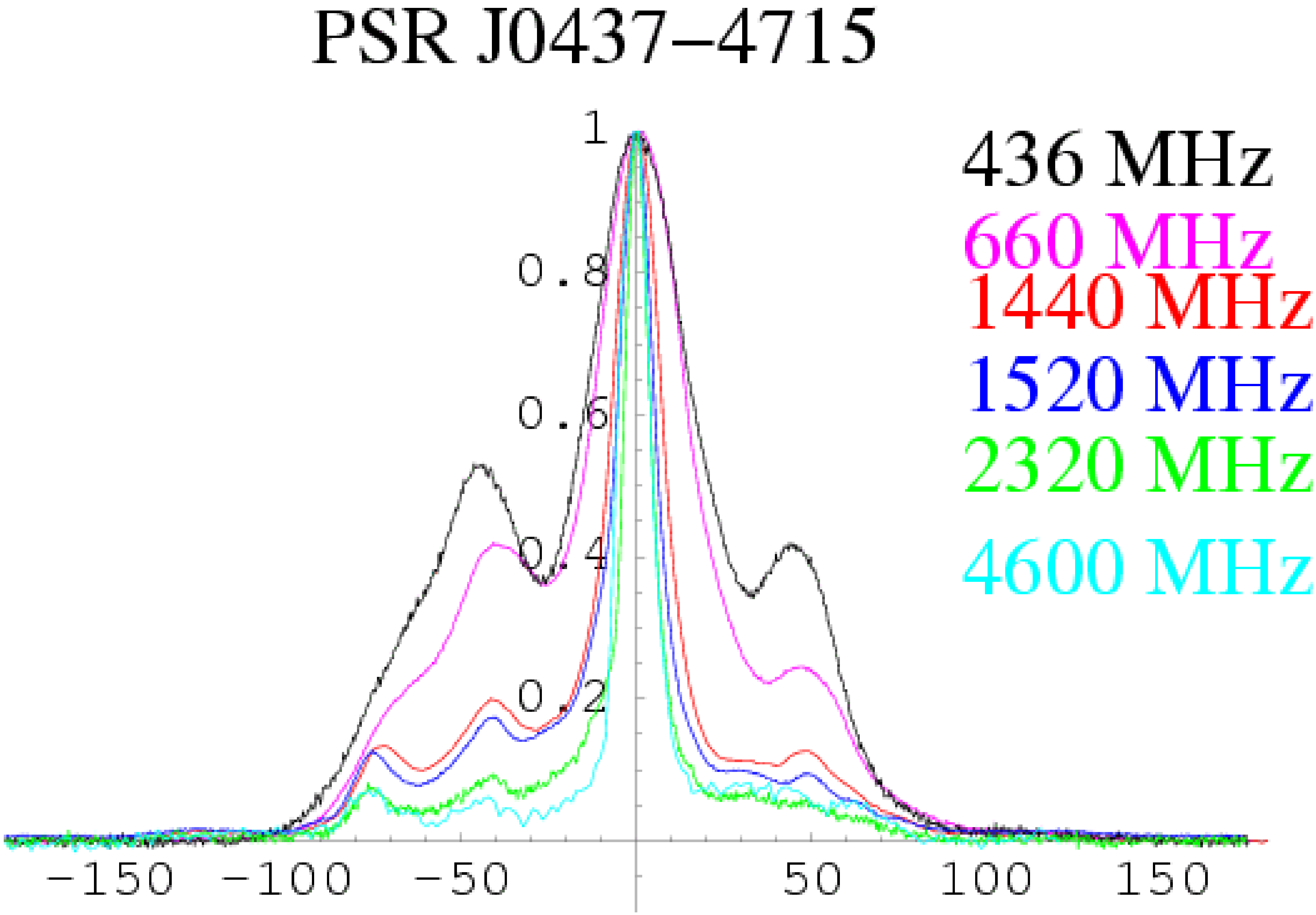
MILLISECOND PULSAR: PSR J0437-4715

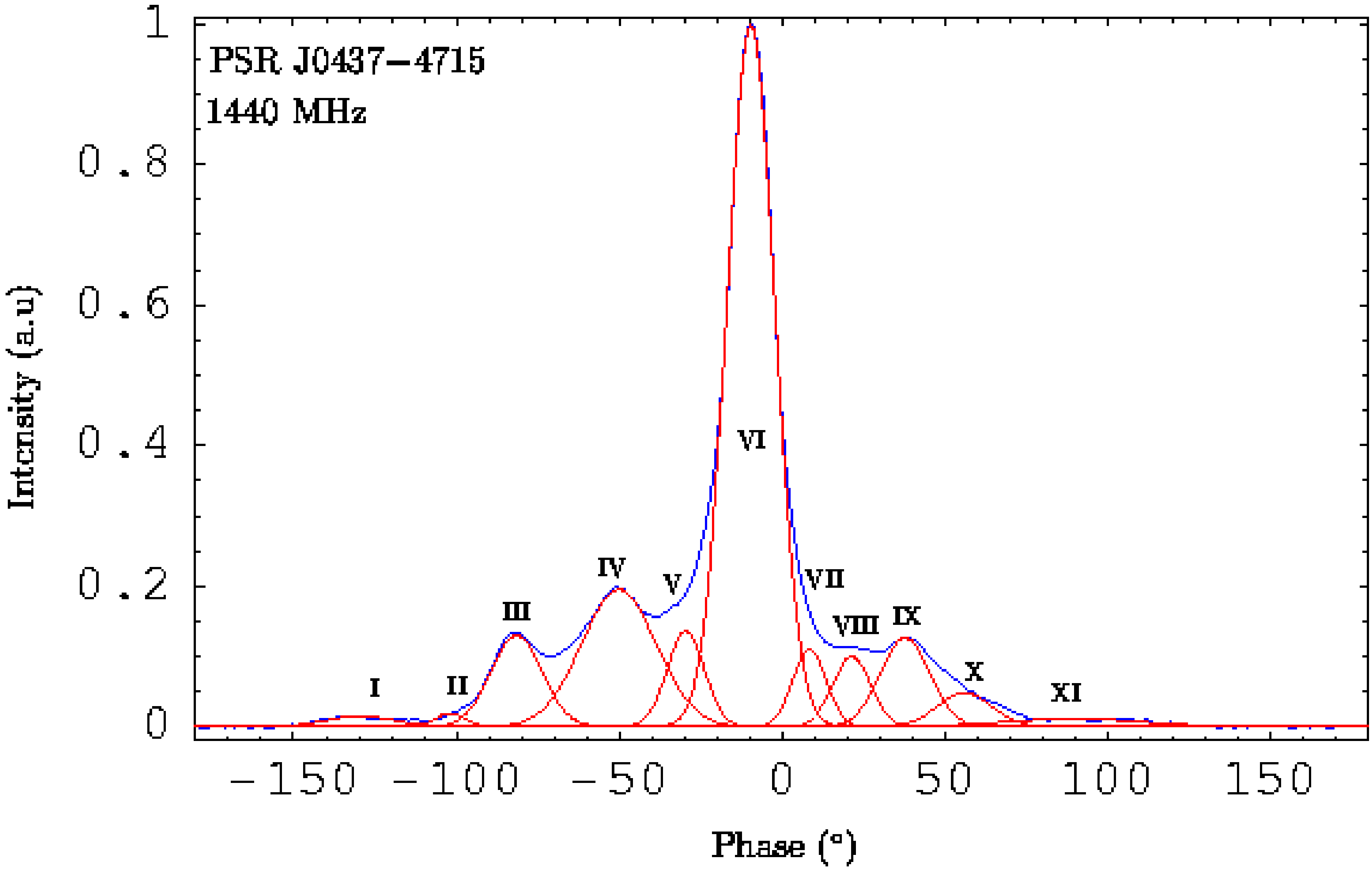
Discovered in Parks by Johnston et al. (1993).

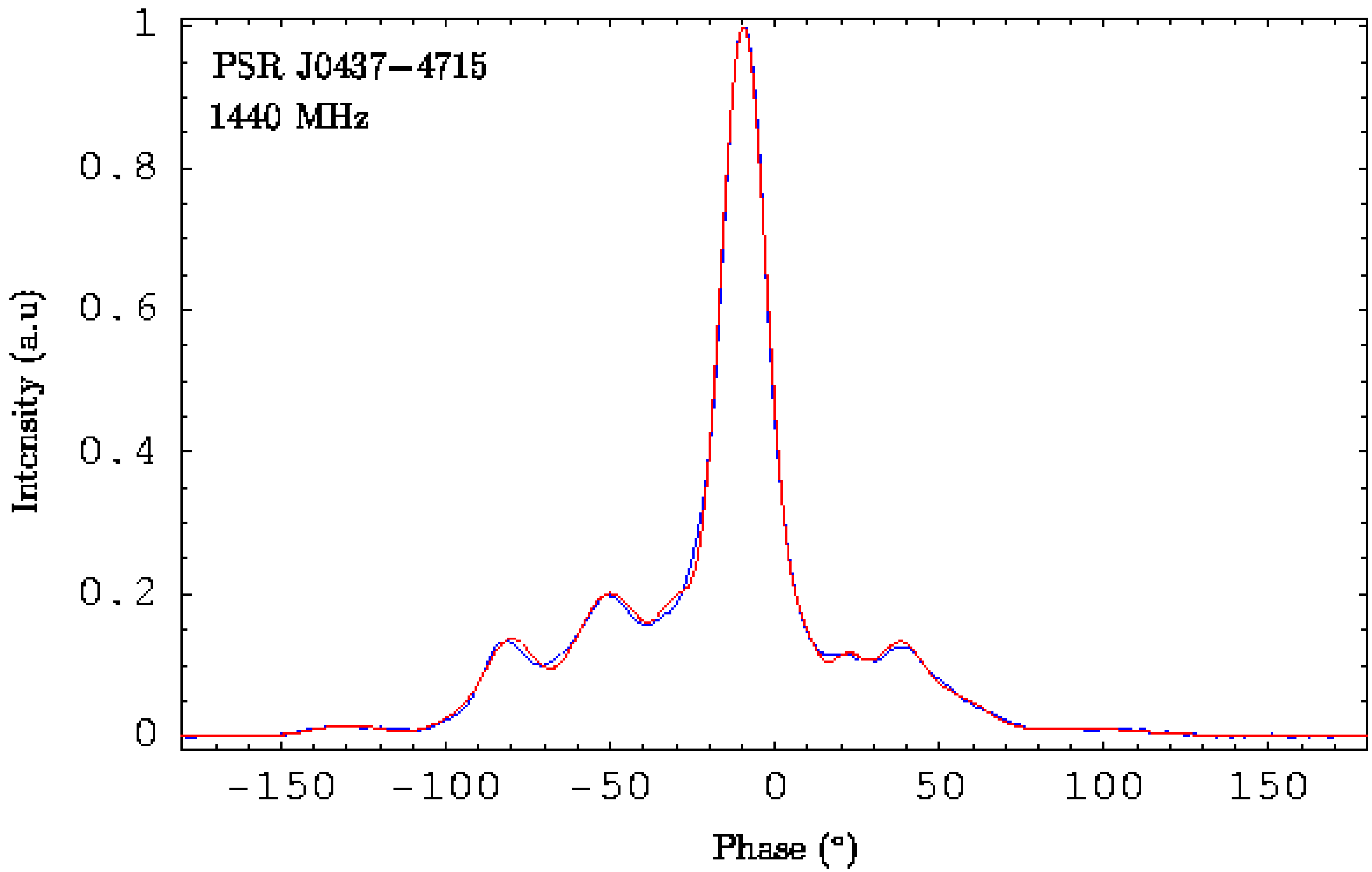
- Nearest and bright millisecond pulsar (~180 pc)
- Spin period 5.75 ms
- Has a low mass white dwarf in binary with orbital period 5.74 days

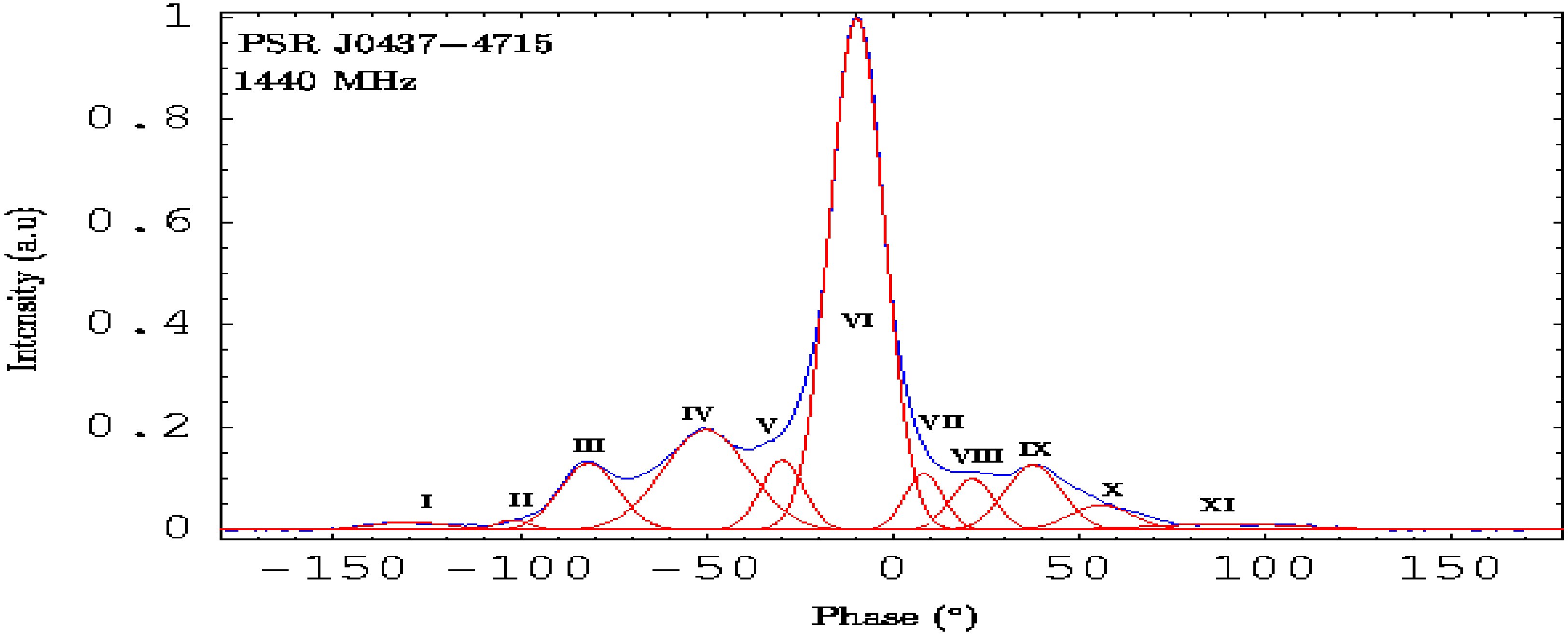


Data by Johnston and Manchester (2005) from Parks.


PSR J0437−4715
436 MHz
660 MHz
1440 MHz
1520 MHz
2320 MHz
4600 MHz
1
0.8
0.6
0.4
0.2
−150
−100
−50
50
100
150

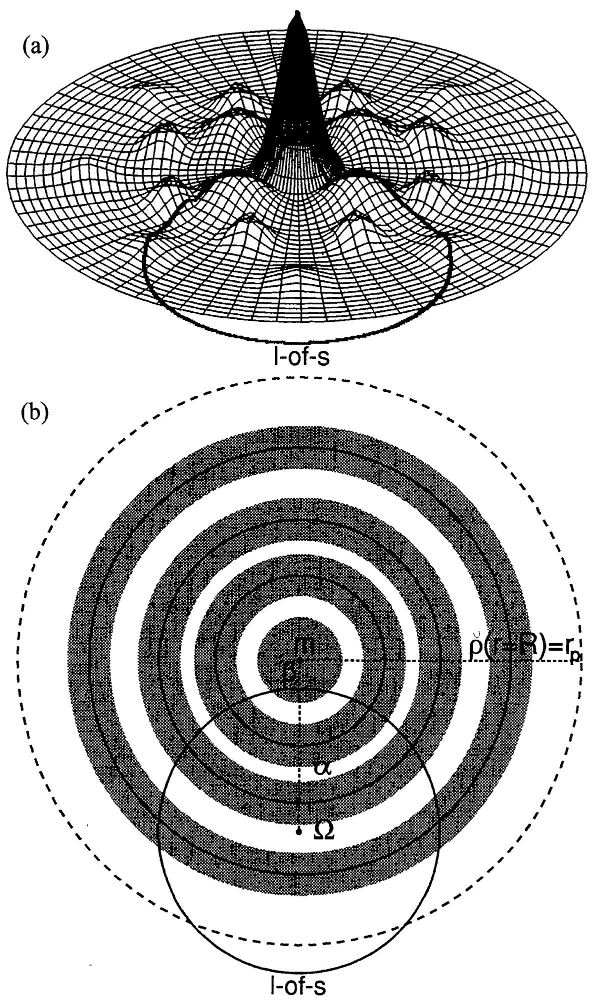

PSR J0437−4715
1440 MHz
Intensity (a.u)
Phase (°)
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
0
0.2
0.4
0.6
0.8
1
−150
−100
−50
0
50
100
150

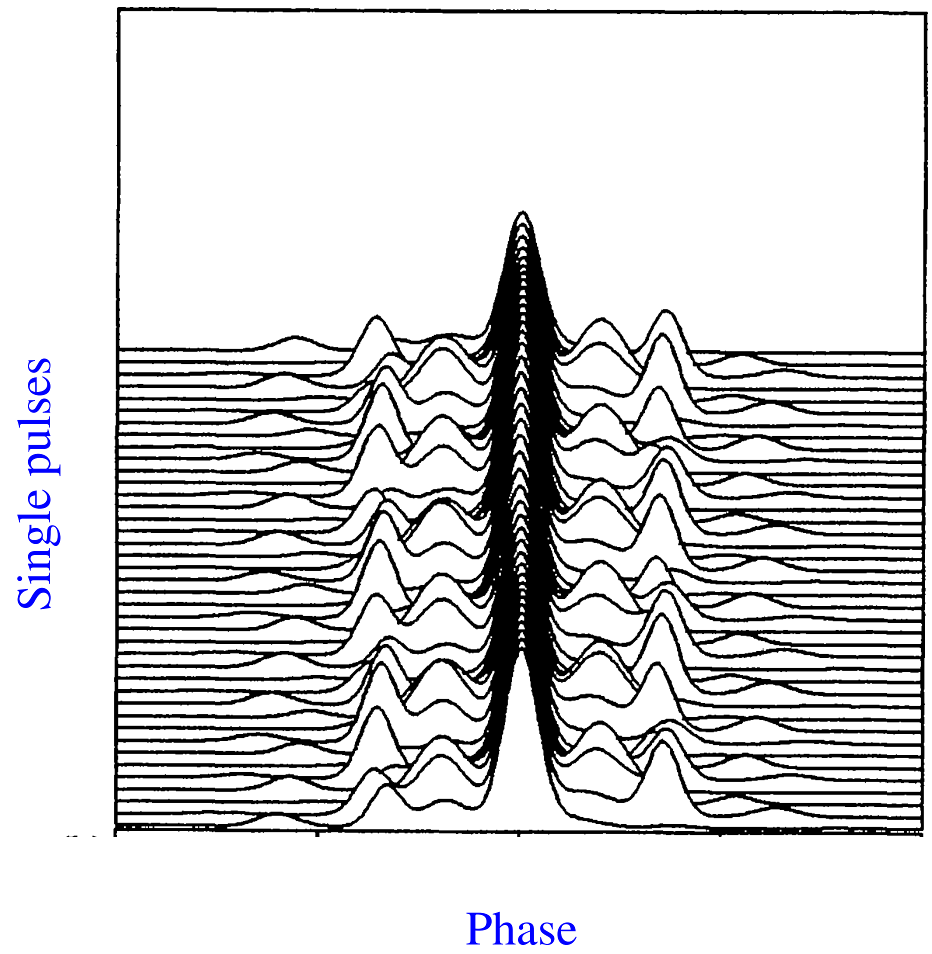

PSR J0437−4715
1440 MHz
Intensity (a.u)
Phase (°)
1
0.8
0.6
0.4
0.2
0
-150
-100
-50
0
50
100
150



Cone No. (1)	ϕ'_l (°) (2)	ϕ'_t (°) (3)	$\delta\phi'$ (°) (4)	Γ (°) (5)
0	—	—	−9.50±0.26	4.00±0.00
1	−29.50±0.24	8.50±0.46	−10.50±0.26	7.06±0.06
2	−50.00±0.50	21.50±0.54	−14.25±0.37	11.50±0.10
3	−81.50±0.15	37.94±0.08	−21.78±0.08	18.00±0.02
4	−102.01±0.36	56.14±0.29	−22.90±0.23	22.93±0.05
5	−129.50±1.01	89.54±4.15	−19.98±2.10	29.30±0.40

(Gil & Krawczyk 1997)



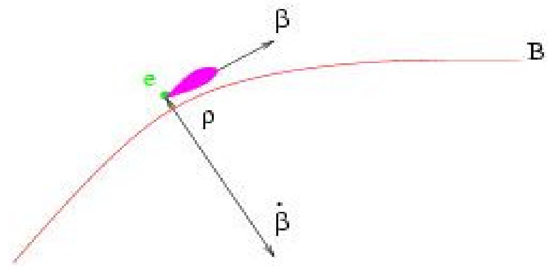


Pulsar Radio Emission

Curvature Radiation

Relatvistic charged particles (e^+, e^-) moving along the curved magnetic field lines experience curvature acceleration, and hence radiate the electromagnetic waves.

♌ ■ / c



The frequency of radiation:

$$\nu_c = \frac{3}{4\pi}\gamma^3\frac{c}{\rho}$$

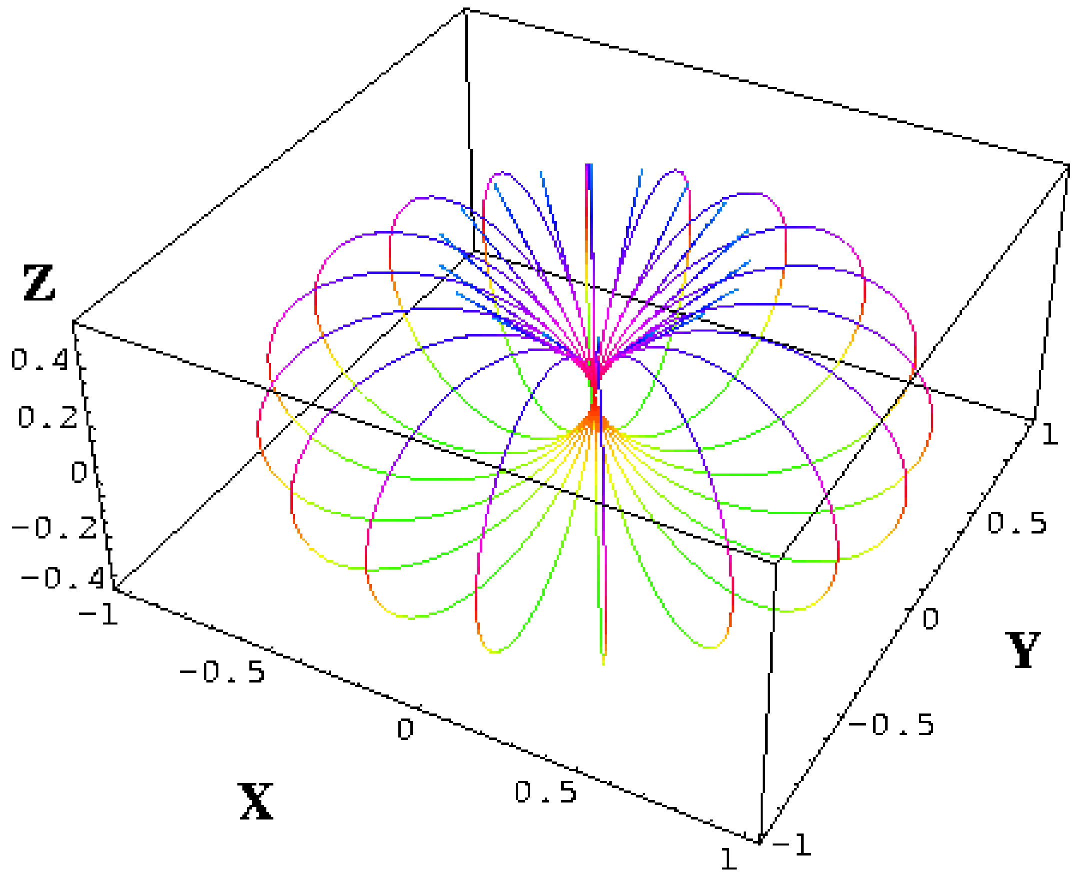
The power radiated by particles:

$$P = \frac{2}{3}\frac{q^2}{c}\gamma^4\left(\frac{c}{\rho}\right)^2$$

$\rho =$ Radius of curvature of filed lines,
$\gamma = 1/\sqrt{1-\beta^2}$ Lorentz factor.

(Sturrock 1971; Ruderman & Sutherland 1975)

Magnetic field lines in 3D space



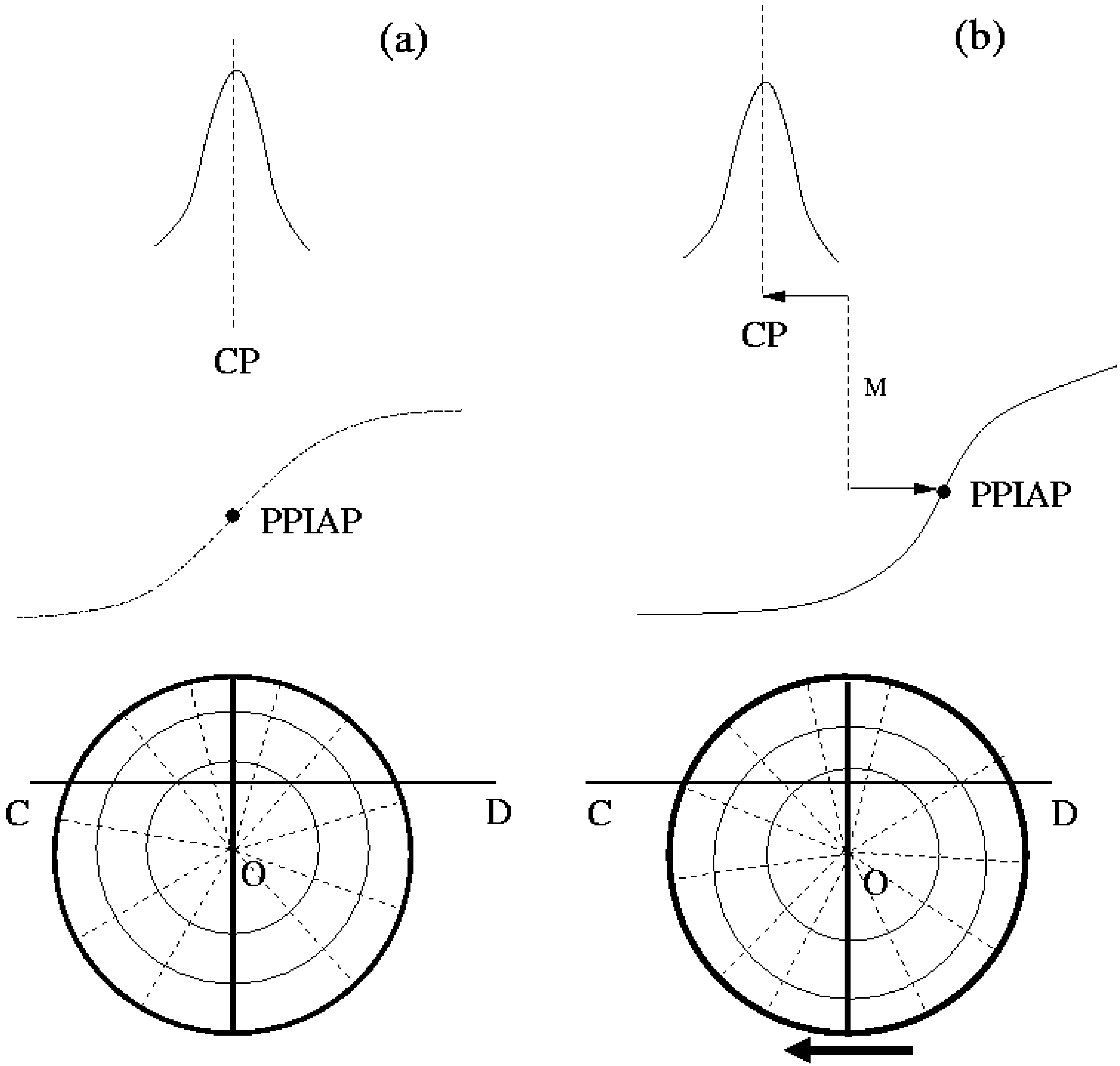
Gangadhara, R. T., 2004, ApJ, 609, 335

EMISSION ALTITUDE FROM PHASE SHIFT

- Aberration
- Retardation
- Polar cap current

$$r \approx \frac{r_{\rm LC}}{2}\delta\phi'$$

Gangadhara, R. T., 2005, ApJ, 628, 923



(a)
CP
PPIAP
C
D
O
(b)
CP
M
PPIAP
C
D
O

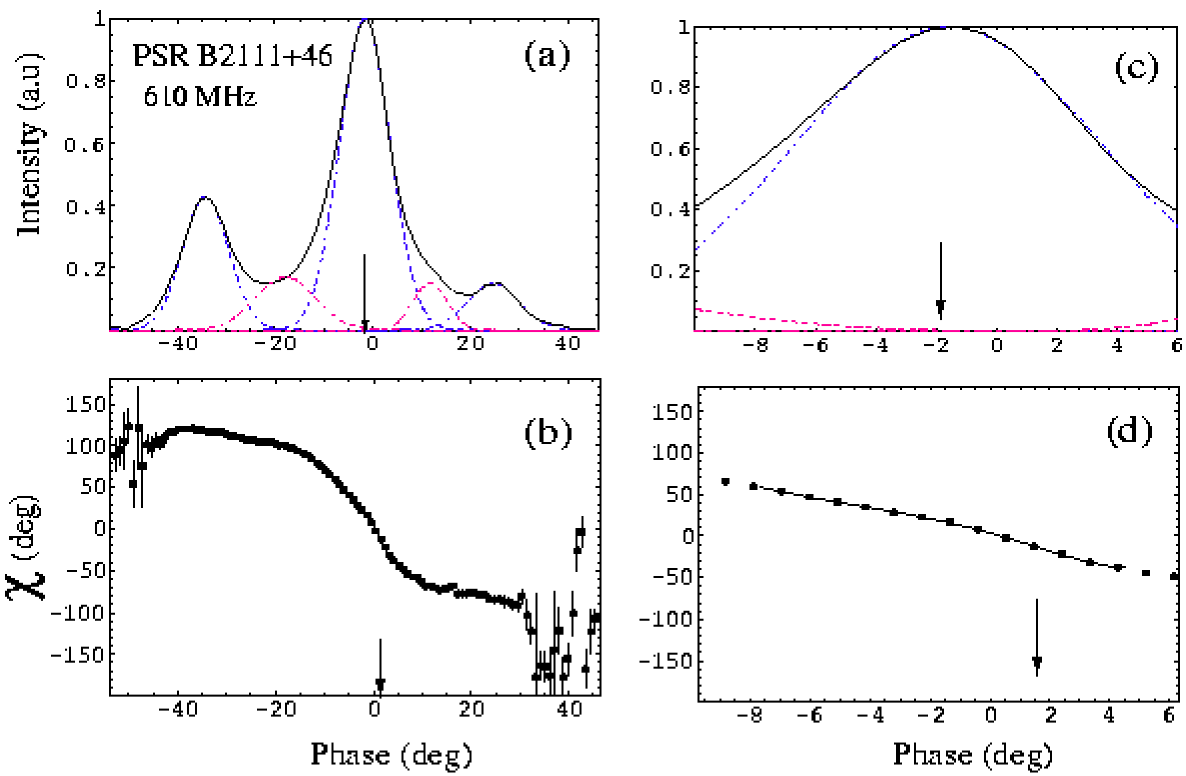
POLARIZATION ANGLE

Radhakrishnan and Cooke (1969) proposed "Pulsar radiation is polarized in the direction of curvature of mag. field lines."

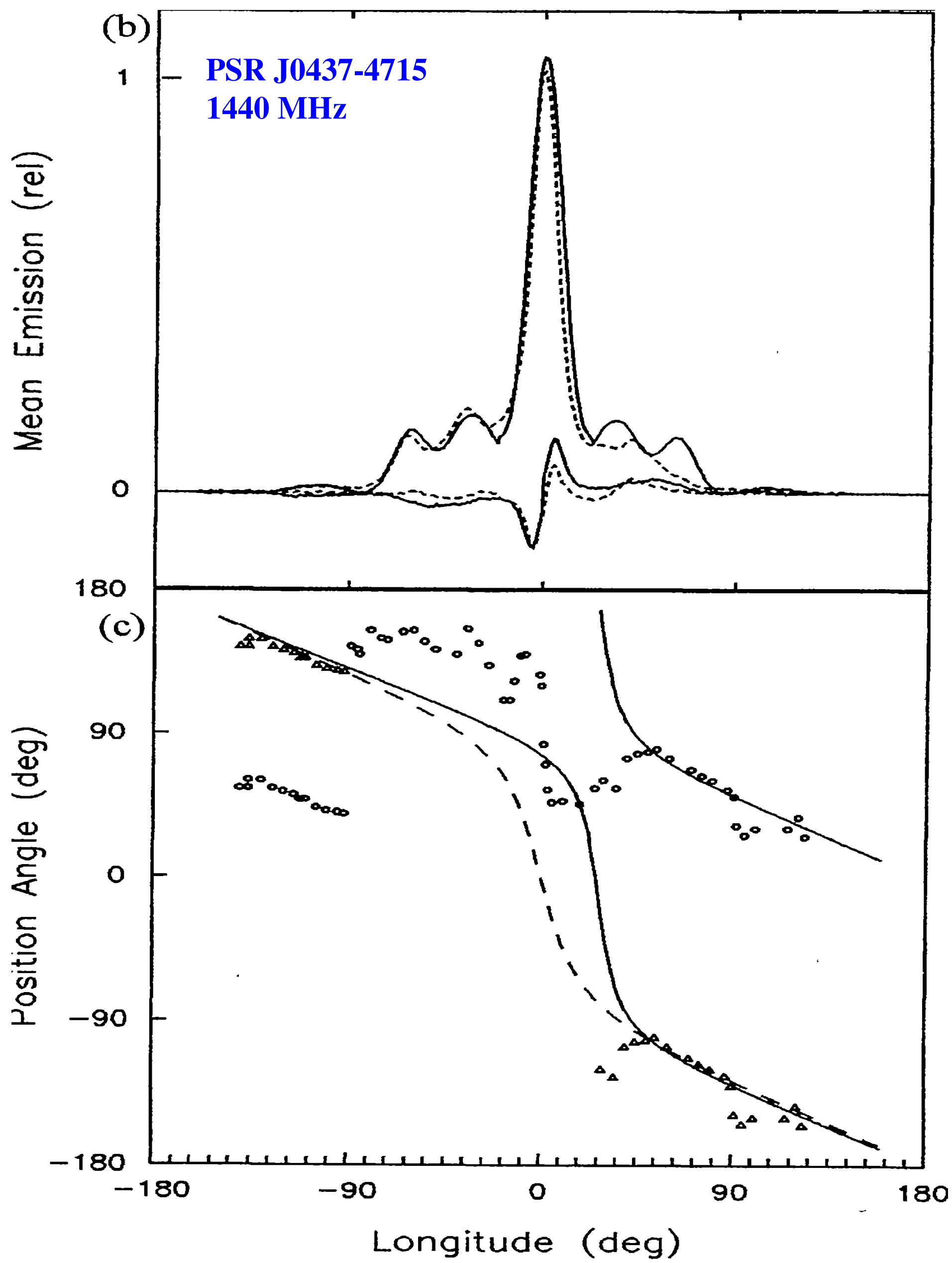
Blaskiewicz, Cordes and Wasserman (1991) derived the expression for PA by taking into account of aberration at constant emission height.

$$\psi = \arctan\left[\frac{\sin\alpha\sin\phi' - 3(r/r_{\rm LC})\sin\zeta}{\sin\beta + \sin\alpha\cos\zeta(1-\cos\phi')}\right]$$

Dyks, Rudak and Harding (2004) have proposed "Intensity profile Advances and PA inflection point delays by equal amount when we include retardation.



PSR B2111+46
610 MHz
(a)
(b)
(c)
(d)
Intensity (a.u)
χ (deg)
Phase (deg)
Phase (deg)

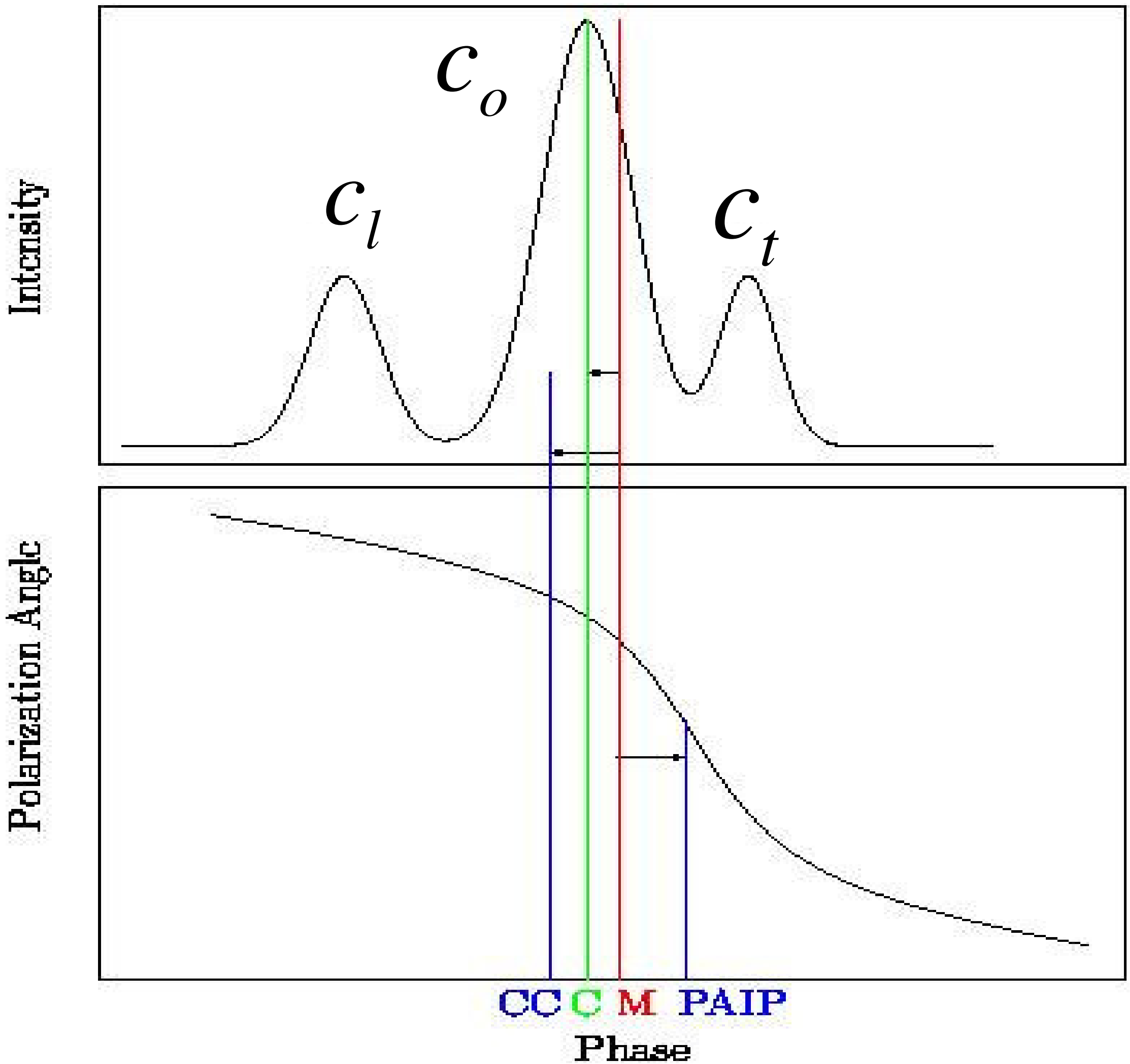


(Gil & Krawczyk 1997)

$$\alpha = 20^{\mathrm{o}}$$

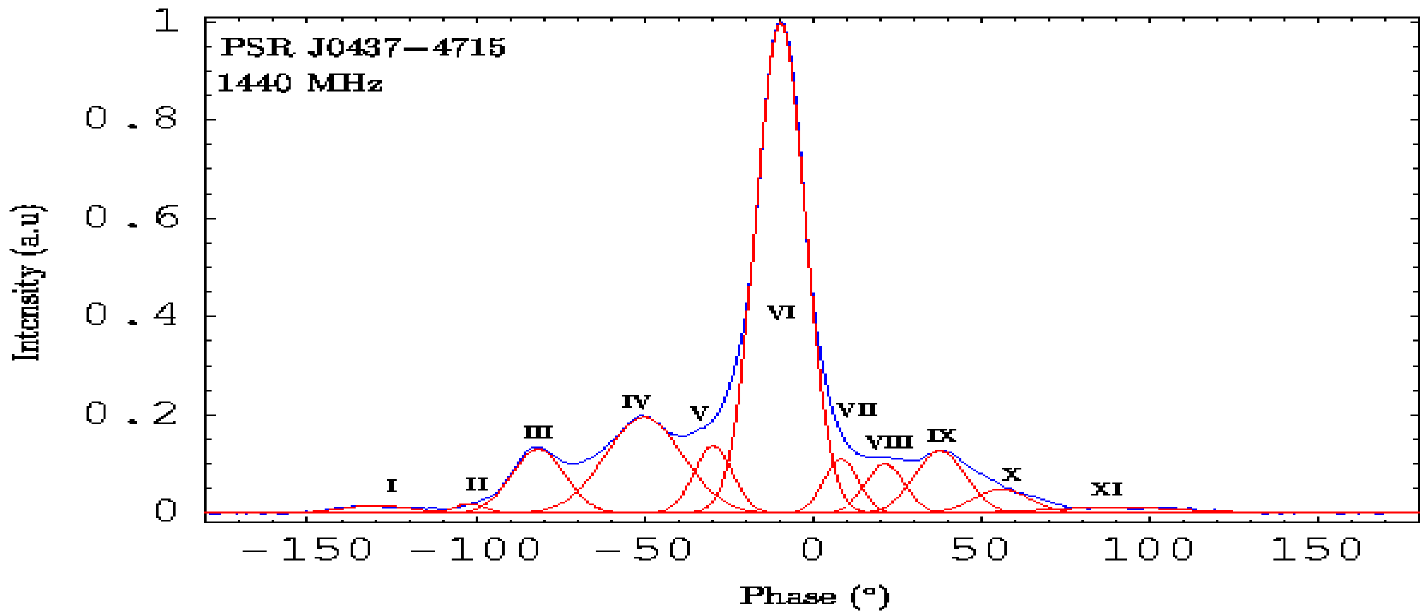
$$\beta = -4^{\mathrm{o}}$$

$$r \approx 48 \text{ Km}$$



$$\delta\phi' \approx -2r/r_{LC}$$

$$\delta\phi' \approx 2r/r_{LC}$$



Cone No.		h_{em}		Δ	$s/s_{\rm lof}$
	(Km)	(Km)	(% $r_{\rm LC}$)	(%)	
(1)	(6)	(7)	(8)	(9)	(10)
0	22.8	20.3±0.6	7.4	12.0	0.17±0.00
1	25.2	23.3±0.5	8.5	8.2	0.28±0.01
2	34.2	34.3±0.9	12.5	0.4	0.38±0.01
3	52.2	64.3±0.3	23.4	18.8	0.43±0.00
4	55.0	84.9±0.9	30.9	35.2	0.47±0.00
5	48.0	91.8±6.2	33.4	47.8	0.57±0.02

DRH04 **G05**

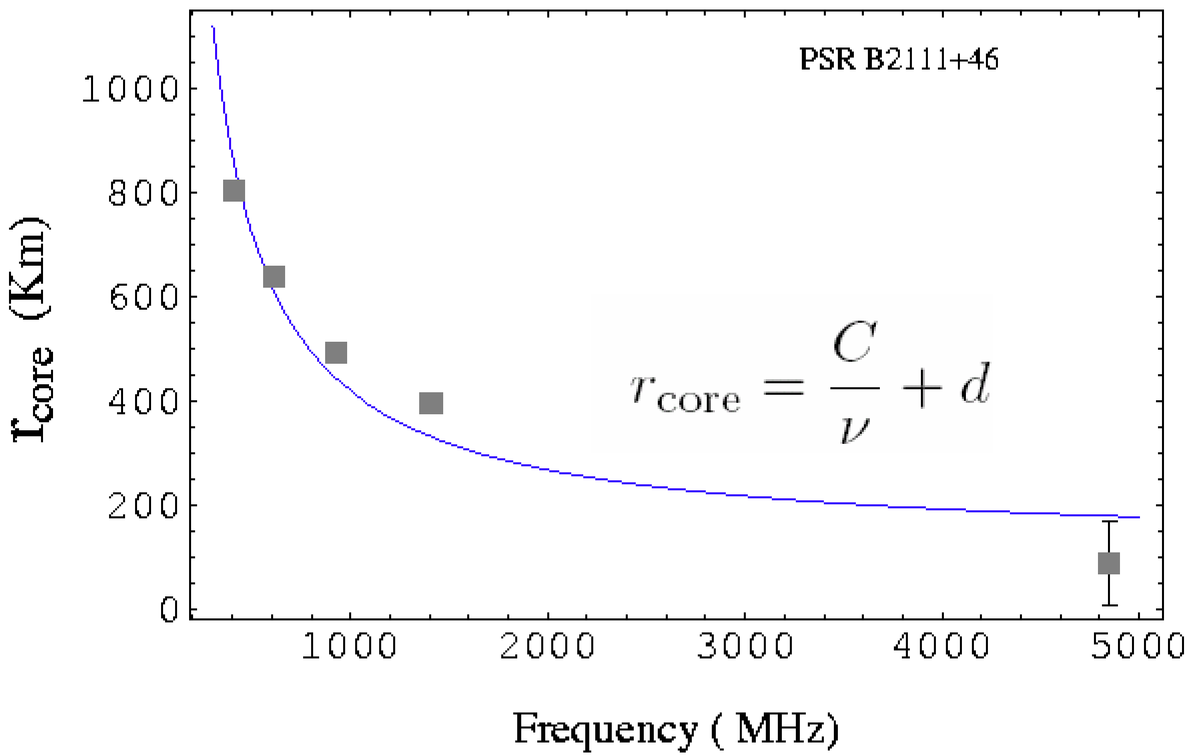
Light Cylinder Radius ~ 275 km

Table 1. The parameters related to the core emission in PSR B2111+46

ν	$\delta\phi'_{\rm core}$	$\delta\phi'_{\rm PAIP}$	$d\psi/d\phi'$	$r_{\rm core}$		$r_{\rm LC}(\%)$	$\rho/r_{\rm LC}$	$s/s_{\rm lof}$
(MHz)	($^\circ$)	($^\circ$)		(Km)[a]	(Km)[b]			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
4850	−0.23±0.15	0.23±0.17	-5.73±7	97	91±24	0.19	0.14	0.43±0.06
1408	−0.99±0.04	0.99±0.05	-7.00±6	418	393±8	0.81	0.58	0.21±0.02
925	−1.24±0.07	1.24±0.17	-7.66±7	524	493±16	1.02	0.73	0.18±0.03
610	−1.60±0.05	1.60±0.05	-11.25±2	676	636±9	1.31	0.94	0.16±0.01
408	−2.02±0.11	2.02±0.20	-12.00±5	853	803±23	1.66	1.19	0.15±0.02
333	−2.46±0.10	2.46±0.22	-12.20±4	1040	978±25	2.02	1.45	0.13±0.01

[a]Emission heights computed from the approximate formula (DRH04), and [b]those using the more exact formula (G05).

EMISSION HEIGHT OF CORE



$$C = 3 \times 10^5 \text{ Km MHz}$$

$$d = 115 \text{ Km}$$

CONCLUSION

- Developed a method for estimating the absolute emission heights of core as well as conal components.

In millisecond pulsar: J0437-4715

(i) A/R phase shift is quite high (~20 deg).

(ii) Core component is emitted from an altitude close to NS surface (~20 Km).

(iii) Emission altitude of cones increases from core to outer most cone (~90 Km).

In normal pulsars: PSR B2111+46

(i) Core emission also shows RFM

(ii) High freq. emission comes lower altitude (~100 Km) than the low freq. (~1000 Km).