Synchrotron Radiation of a Pulsar Wind

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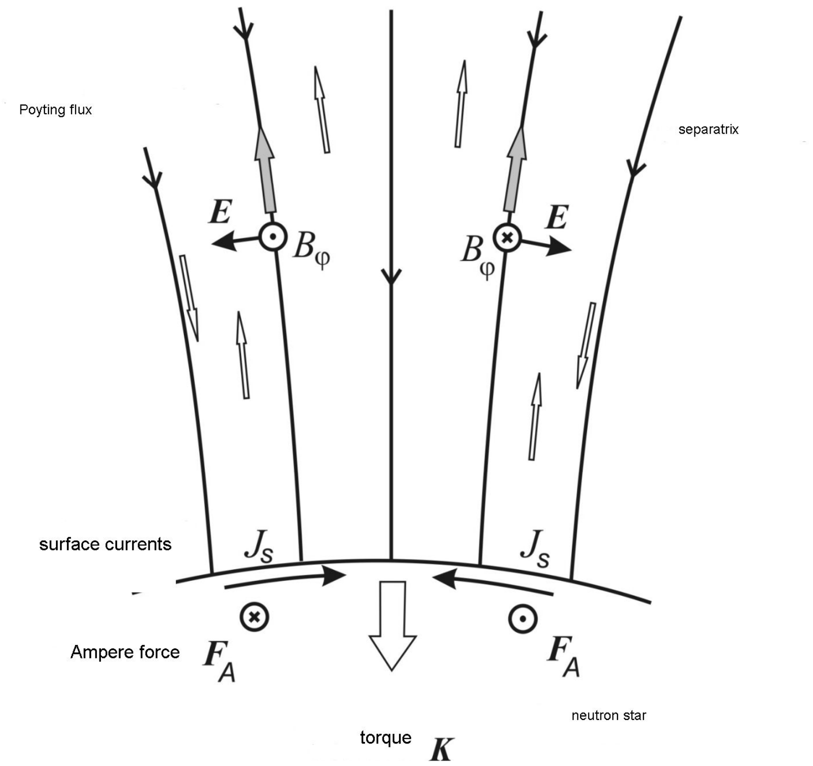
- What is the reason of a neutron star spin down?
- 1) Magnetodipole radiation – radiation of electromagnetic wave of Ω frequency and $2\pi c/\Omega$ wave length. The energy loss is
- $W = B_0^2 R^6 \Omega^4 \sin^2\chi / 6c^3$

- 2) Pulsar wind – relativistic electron-positron plasma flux. Energy loss is
- $W = f_*^2 B_0^2 R^6 \Omega^4 i_0 \cos^2\chi / 4c^3$, $f_*(\chi) = 1.59\text{-}1.96$

□ $\varepsilon_p = (E_L^2 + B_L^2)/8\pi$, $E_L = B_L = B_0 (R\Omega/c)^3$,

- $W = c\varepsilon_p 2\pi (c/\Omega)^2$

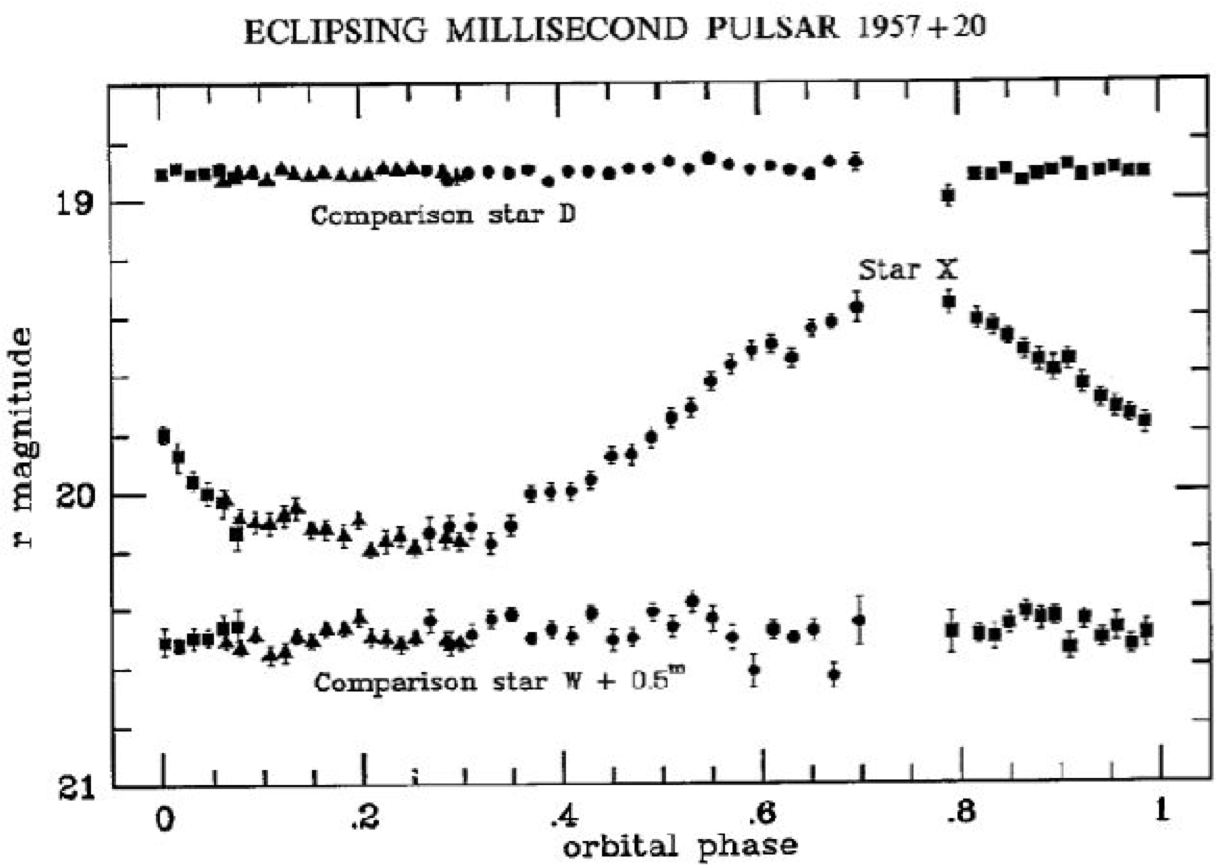
Spin-down by the current



Arguments for the current loss

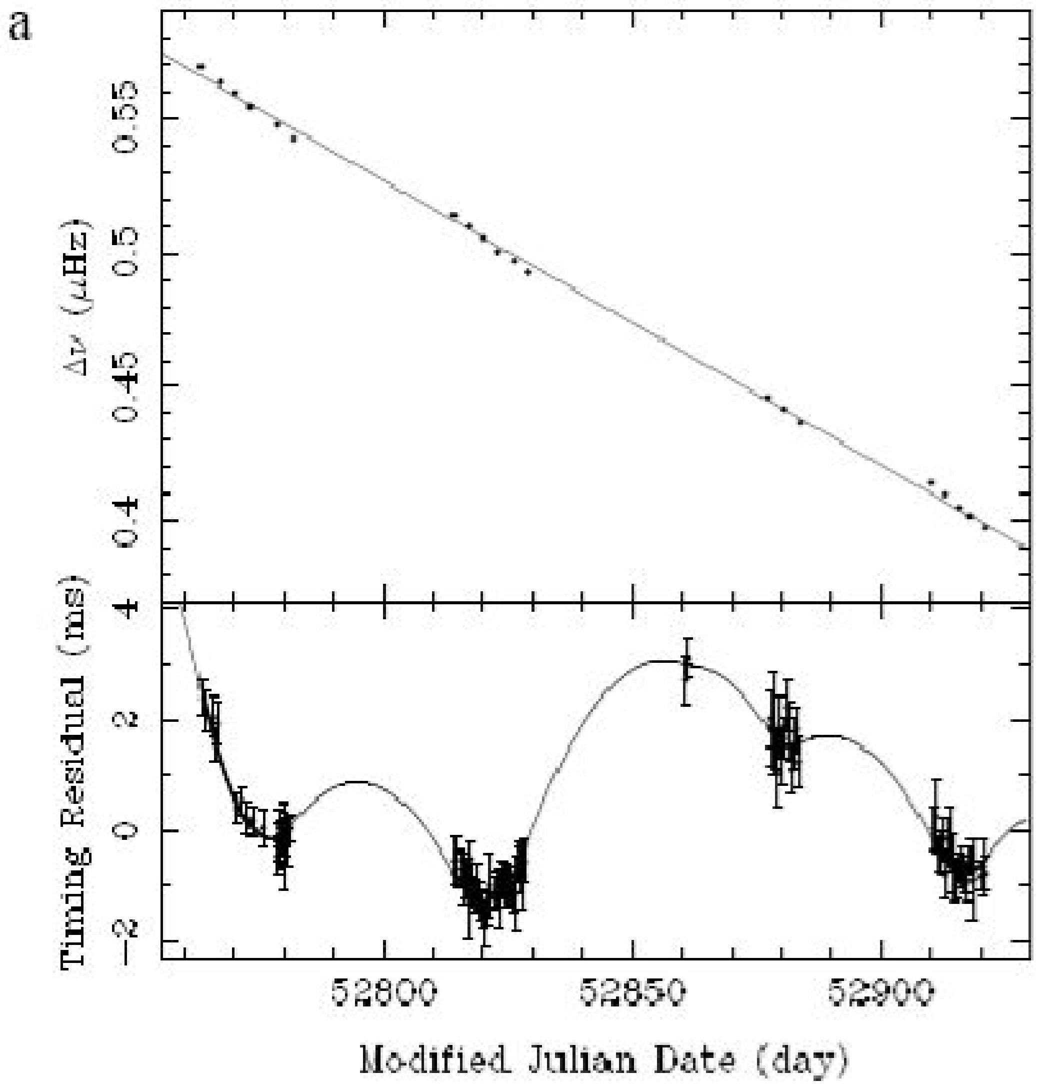
- Rotation frequency is much less than plasma frequency (Lipunov, A&A, **127**, L1, 1983)
- Interaction with the companion star in binary systems (Djorgovski & Evans, ApJ, **335**, L61, 1988)
- Blow up of the pulsar magnetosphere in binary pulsars PSR J0737–3039 A, B

Djorgovski & Evans, ApJ, **335**, L61, 1988

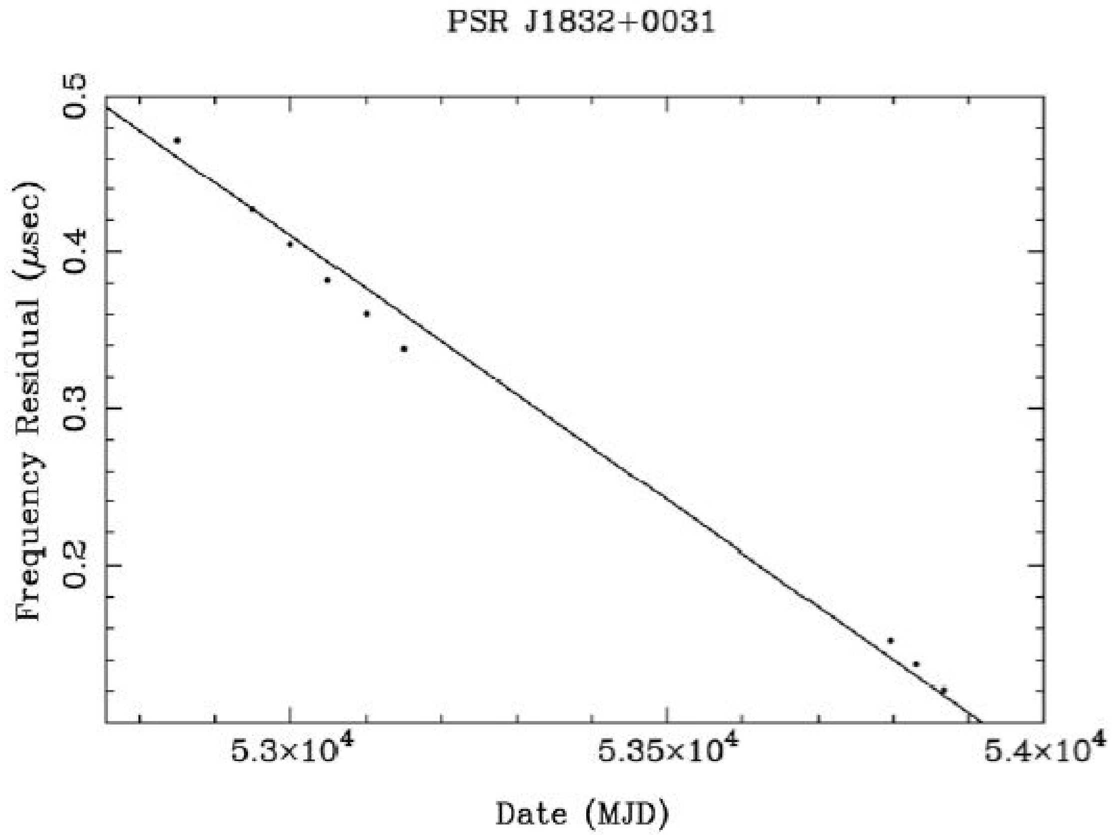


Switch off pulsar – PSR B1931+24

Right ascension (J2000)	$19^h33^m37^s.832(14)$
Declination (J2000)	$+24°36'39''.6(4)$
Epoch of frequency (MJD)	50629.0
Rotational frequency ν (Hz)	1.2289688061(1)
Rotational frequency derivative $\dot{\nu}$ (Hz s^{-1})	$-12.2488(10) \times 10^{-15}$
Rotational frequency derivative on $\dot{\nu}_{on}$ (Hz s^{-1})	$-16.3(4) \times 10^{-15}$
Rotational frequency derivative off $\dot{\nu}_{off}$ (Hz^{-1})	$-10.8(2) \times 10^{-15}$
Dispersion measure DM ($cm^{-3}pc$)	106.03(6)
Flux density during on phases at 1390 MHz (μJy)	1000(300)
Flux density during off phases at 1390 MHz (μJy)	≤ 2
Flux density during on phases at 430 MHz (μJy)	7500(1500)
Flux density during off phases at 430 MHz (μJy)	≤ 40
Active duty cycle (%)	19(5)
Characteristic age τ (Myr)	1.6
Surface magnetic field strength B (Tesla)	2.6×10^8
Spin-down luminosity $\dot{E}$ (W)	5.9×10^{25}
Distance (kpc)	~ 4.6



Switch off pulsar – PSR J1832+0031



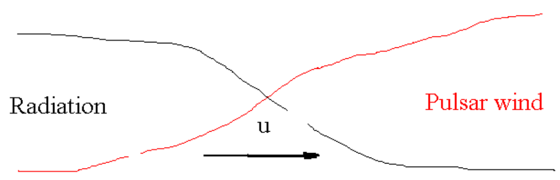
'on' state >300 days

'off' state ~700 days

Conclusions(A.V. Gurevich, Ya.N. Istomin: MNRAS, v. 377, pp. 1663-1667, 2007)

1. First observation of the magnetodipole loss by pulsars B1931+24, J1832+0031
2. The current loss does exist
3. The plasma source is located in a open part of the magnetosphere

- Switching is very short, less than 10sec.
- At the moment of switch off we can observe the interaction of the magnetodipole radiation with the pulsar wind. Radiation propagates with the speed of the light, $u_R=c$, but the pulsar wind moves with the slightly less velocity, $u_w=c[1-\gamma_{min}^{-2}(\beta-1)/(\beta+1)]^{1/2}$.



- The scale of interaction is of the radiation wave length

- W_{wind}=1.5W_R for PSR B1931+24
- $N'=1-8\gamma_{min}\omega_p{}^2/\Omega^2<<0$, $u_R<c$, $\Gamma=(1-u_R{}^2/c^2)^{-1/2}$
- $E'=0$, $B'=B/\Gamma$
- $B'^2/8\pi+P'$=const,

□ $\Gamma=2\gamma_{min}[\beta W_R/(\beta-2)W_{wind}]^{1/2}$

- Synchrotron radiation

□ $\nu_0 < \nu < \nu_1$, $\nu_0 = 140(B_L/50G)(1+\Omega t)^{-1}$MHz,

□ $\nu_1 = \nu_0(\gamma_{max}/\gamma_{min})^2$

- $dS/d\nu = 5\ 10^{16}(B_L/50G)(n_L/10^6 cm^{-3})(P/1s)^3$
- $(\nu/\nu_0)^{-(\beta-1)/2}(1+\Omega t)^{-1}$erg/s Hz
- PSR B1931+24, d=4.6kpc, I=2μJy
- PSR J1832+0031, d=1.45kpc, I=20μJy

- Nulling pulsars
- J0659+14, d=0.29kpc, I=78mJy, ν=2.3GHz
- J1932+10, d=0.36kpc, I=2mJy, ν=1.3GHz
- Coherency: if N is number of particles in bunch then I is N times larger.

- Conclusions: we can measure
- 1) magnetic field on the light surface cylinder B_L and then B_0
- 2) wind parameters – density on the light cylinder n_L, energy and spectrum of wind particles