Positron generation in the magnetospheres of neutron stars

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Neutron stars

Radius -10km, $R/R_{sun} = 10^{-5}$, Mass - 1.4 M_{sun} , density in the center $\rho - 7\ 10^{14}$ g/cm^3 -(2-3)ρ_0

Gravitation energy – GM^2/R -5 10^{53} erg – $0.2Mc^2$

Fast rotation, P – 1.5 ms – 10s

Magnetic field, B – 10^12-10^13 Gauss

Magnetars – 10^14-10^15 Gauss

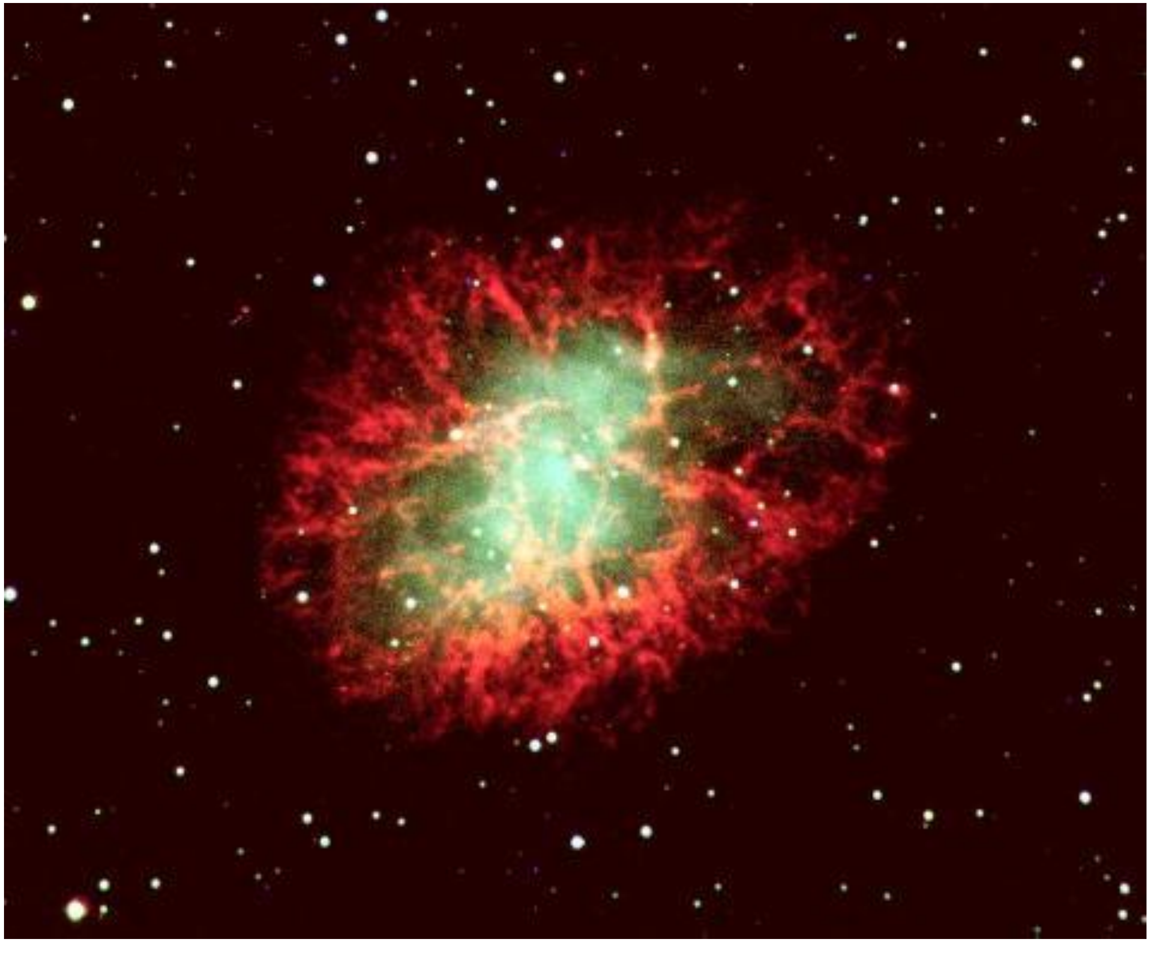
Neutron star faces

- Radio pulsars>1700, A.Hewish & J.Bell-1967.
- P - 1.5ms-8.5s, dP/dt -10^{-15} , $W=I\ \Omega\ d\Omega/dt$, W – 10^32 erg/s, Crab-10^{38} erg/s, W_r /W-10^{-5} -10^{-6}

  optics, x-rays, gamma-ray -10^{12} eV
- X-ray sources, x-ray pulsars.

- Magnetars, B-10^{14}-10^{15} G, SGR, AXP
- CCO – central compact objects in supernova remnants
- RRAT – rotating radio transient
- Nearest radio-quiet isolated neutron stars
- Geminga – unusual x- and gamma-ray source

The pulsar in the Crab nebula



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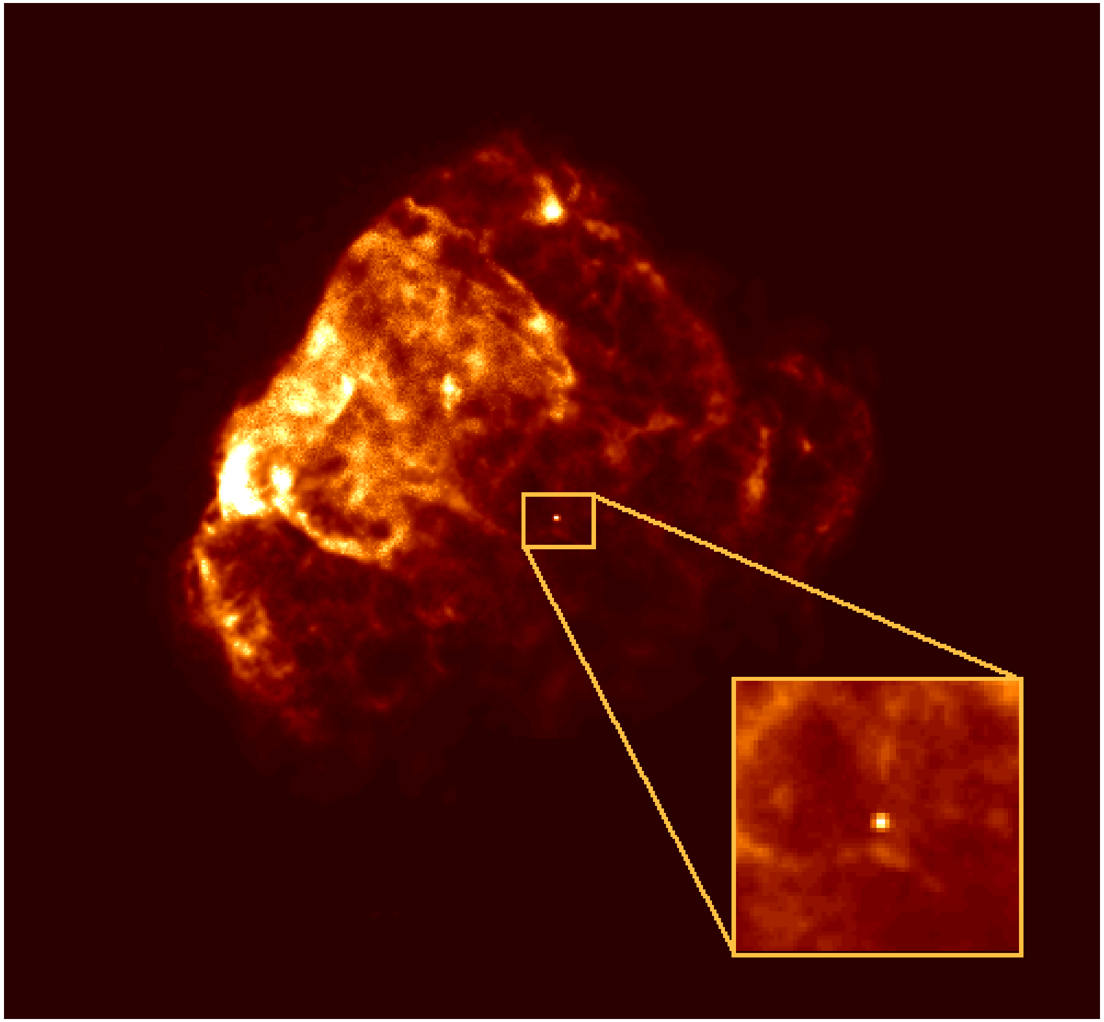


One of the most famous central compact X-ray sources in supernova remnants.

Age about 3700 years.

Probably the progenitor was a very massive star (mass about 30 solar).

V_{kick}=1500 km/s
Winkler, Petre 2006 (astro-ph/0608205)

Critical magnetic field

- $B_c = m^2c^3/eh = 4.414\ 10^{13}$G

Particle energy

$E_n = 1 + p^2 + 2nB$, B=B/B

One-photon e+e- pair creation,

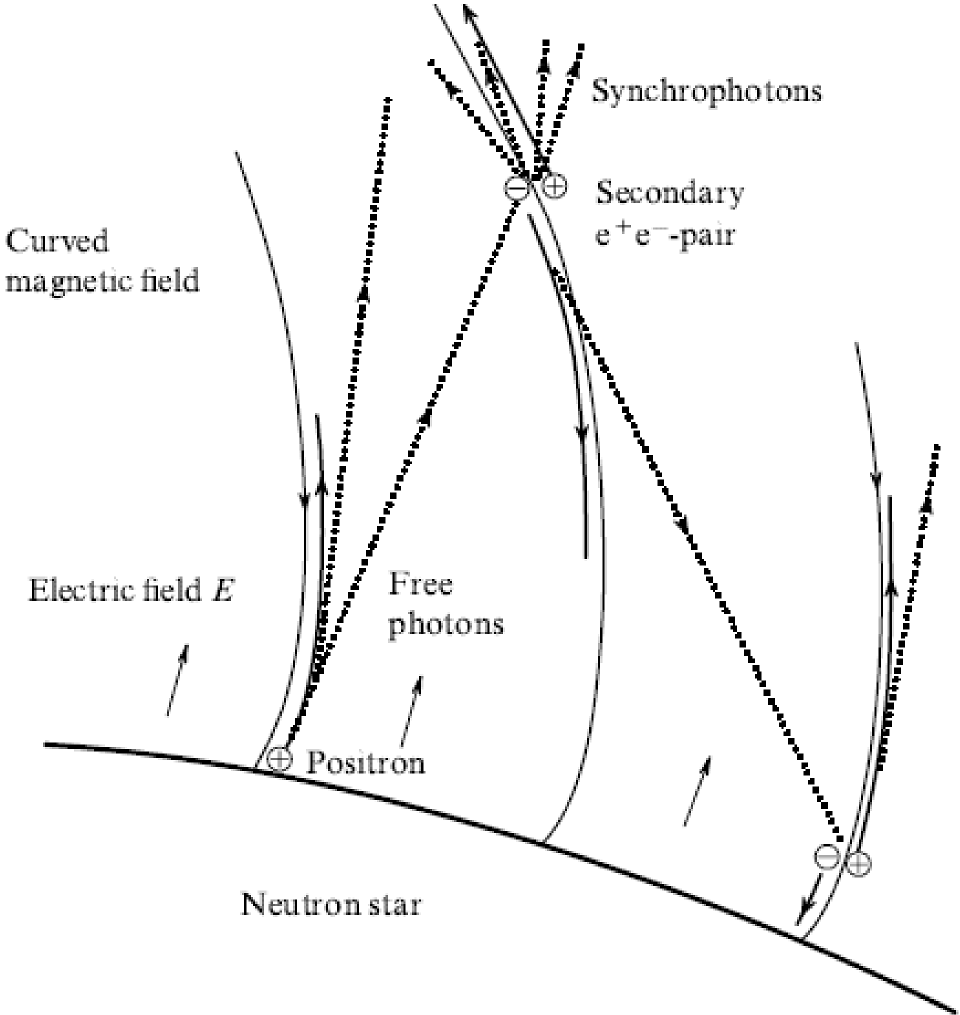
$w = b\alpha B\sin\beta\ \exp(-8/3B\ k\ \sin\beta)$, B<1

$k\ \sin\beta > 2$ – threshold

$w = b\alpha B\ \exp(-k^2\ \sin^2\beta/2B)$, B>1

$E = \Omega RB/c$ – 10^10 V/cm

Pairs creation



Positron flux from radio pulsars

$\gamma=10^{(2-3)}$, $S=10^{36}$ p/s, for Crab – 10^{42} p/s

$n=10^{(17-18)}$ $cm^{(-3)}$, $n/n_0 = 10^{(5-6)}$

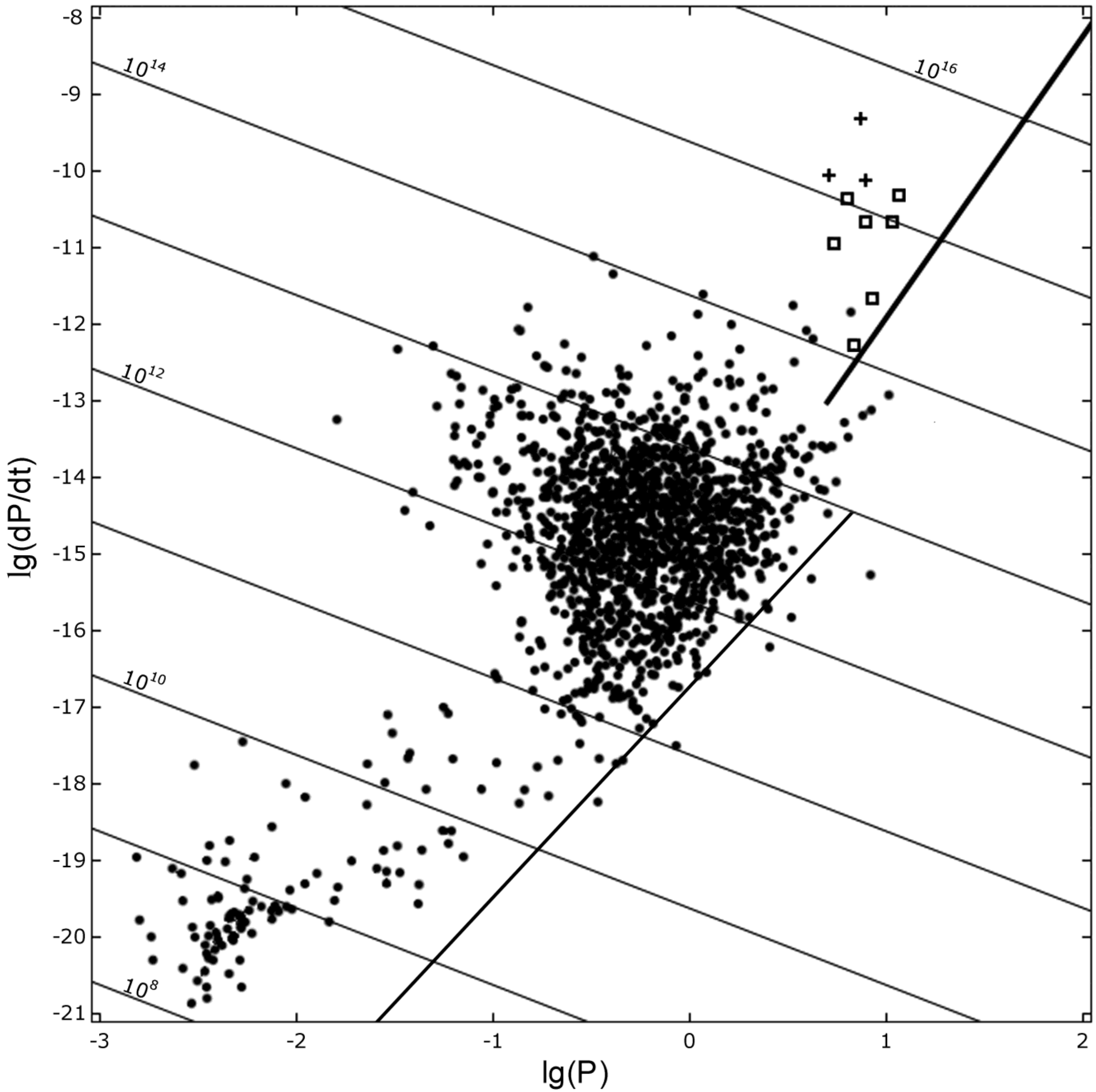
If in Galaxy 10^5 pulsars, $S=10^{41}$ p/s

Splitting of photons in a strong magnetic field

$\perp$ polarization photon decays into two || photons

$$\perp \Rightarrow \parallel , \parallel$$

This leads to 100% polarization of gamma photons



10^14
10^16
10^12
10^10
10^8
-8
-9
-10
-11
-12
-13
-14
-15
-16
-17
-18
-19
-20
-21
lg(dP/dt)
-3
-2
-1
0
1
2
lg(P)

- Neutron stars with vacuum magnetosphere
- Photon flux – 10^(-5)ph/cm^2 s, E>1MeV
- Cross section for photon absorption
- σ – (10^2 R)^2 = 10^16 cm^2
- A=10^11 a/s, 1photon produces 10^28 pairs, S=10^39 p/s

- RRATs – cosmic gamma-ray background produces ‘lightnings’ in the neutron star magnetosphere, it is the tube of the dense electron-positron plasma moving toward the surface with the speed of the light.

- Conclusions
- 1. Pulsar – 10^{36} p/s
- 2. Vacuum n.s. – 10^{39} p/s
- 3. In Galaxy 10^{5} n.s. – 10^{44} p/s

- Poster ‘How to find positrons in
- space’ - $\langle E(\omega)^2 E(2\omega) \rangle$