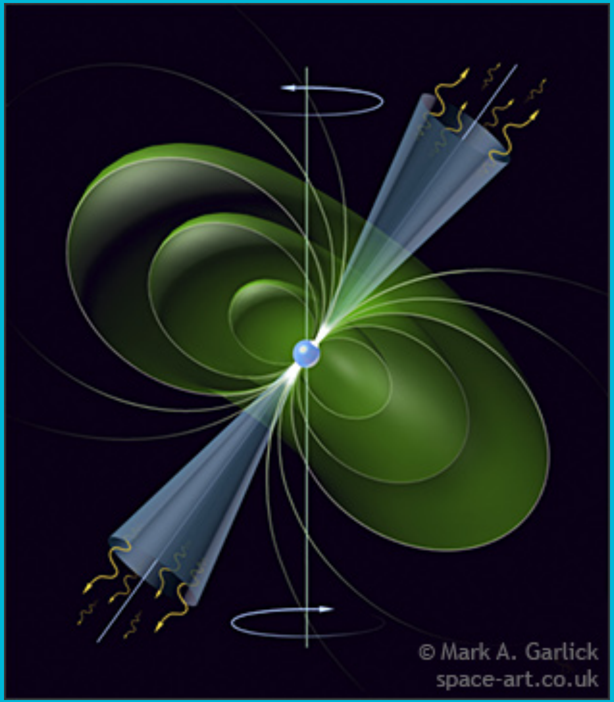

Geometry of γ-ray loud pulsars from radio observations

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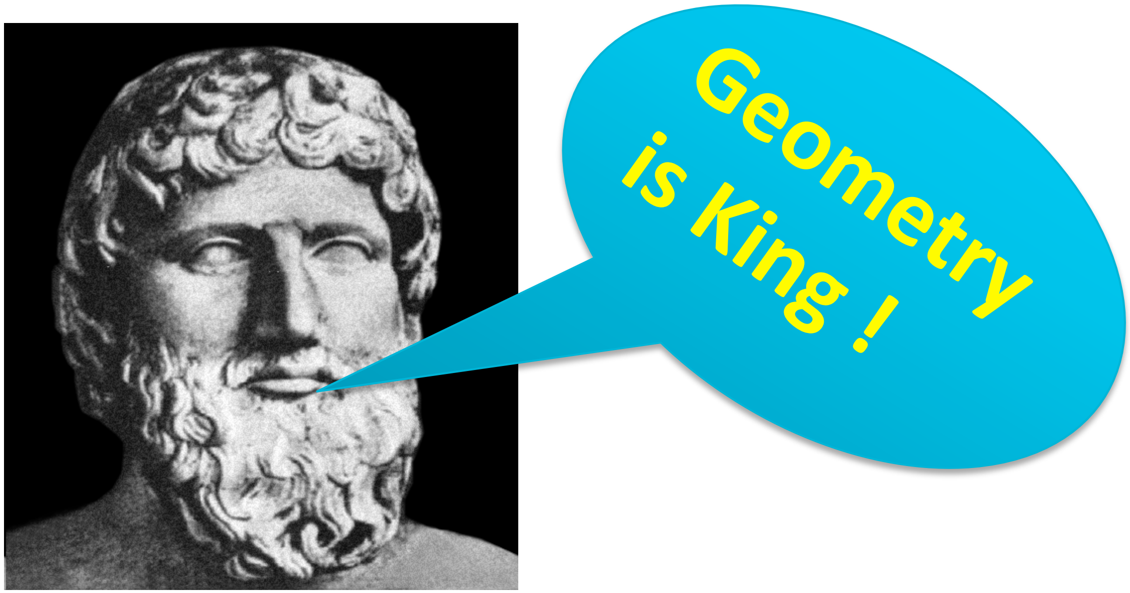
Motivation

Pulsars are fantastic objects but we don't know how they work

- Where does the gamma-ray emission come from?
- Where does the radio emission come from?
- How are the two linked?

→Geometry is the key to unlock these secrets!



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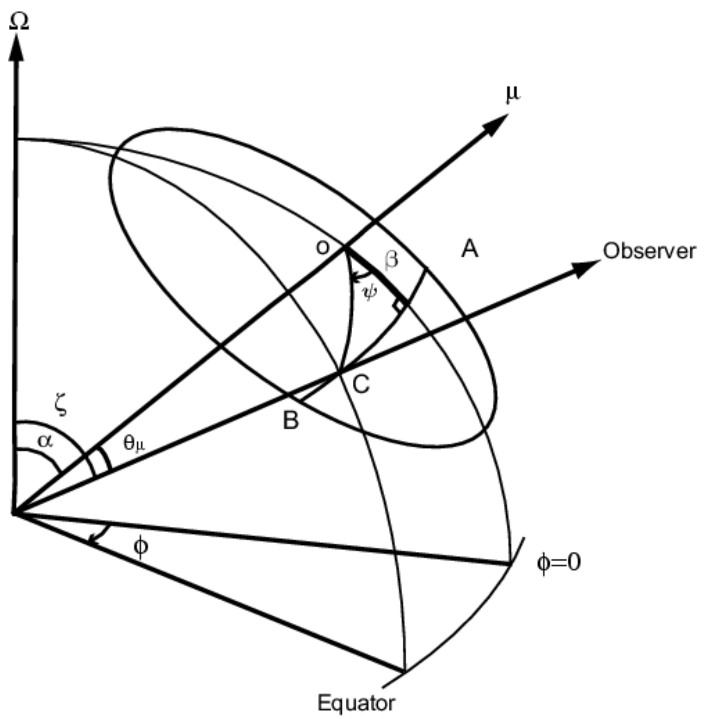

Important angles are:

α – angle between the rotation and magnetic axis

β – closest approach of line of sight to magnetic axis

ρ – cone opening angle

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Expectations

- γ-ray: High α expected for γ-ray loud (young) pulsars.
- Radio: Random distribution of α at birth → sinusoidal distribution as observed. Beaming fraction higher for high α. β is small in radio pulsars.
- γ-ray+radio: Expect strong bias to high α in the sample.

The Parkes Fermi timing programme

- Started in February 2007 [pre-launch]
- Patrick Weltevrede, Ryan Shannon, Matthew Kerr postdocs
- 165 pulsars, vast majority with Edot > 10^34 erg/s
- Observe every month for 20 hours at 1400 MHz
  - And every 6 months at 700 and 3100 MHz
- Timing solutions sent to Fermi collaboration
- Wealth of science from radio data alone
  - Full polarization profiles → pulsar geometry
  - Dispersion measure versus time
  - Profile variability versus time
  - Timing noise and glitches
- **This dataset: 27 γ-ray loud, radio loud young pulsars (not MSPs)**

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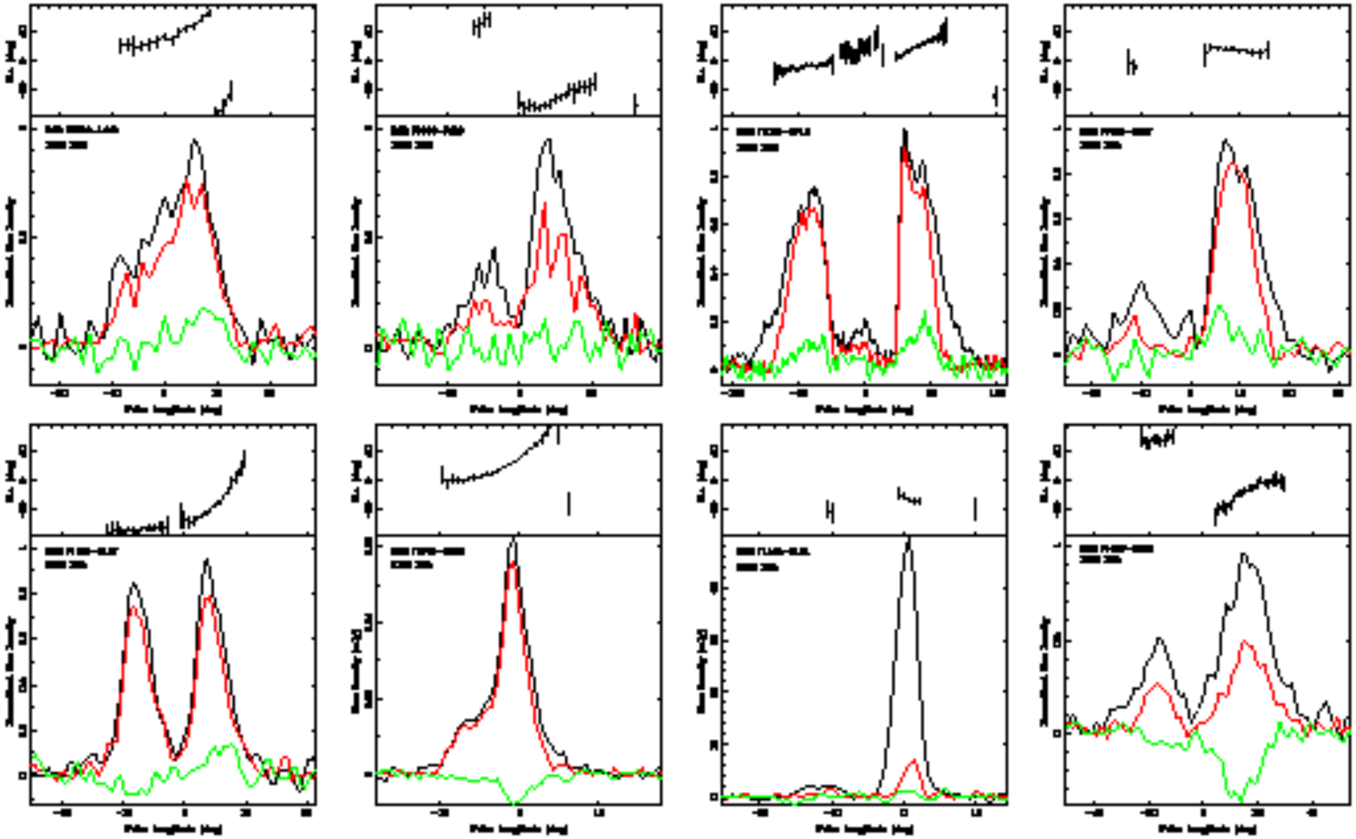
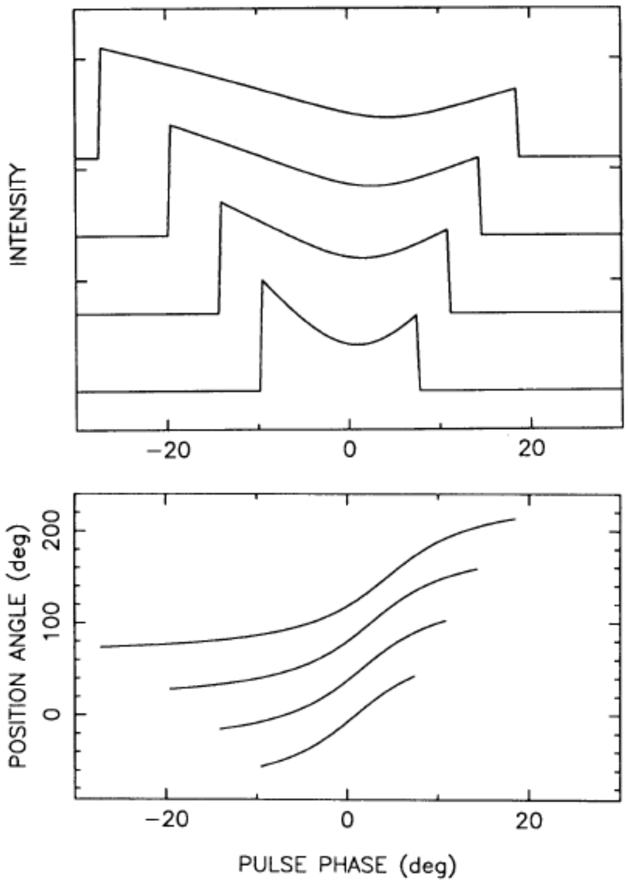
High Edot (young) pulsars

Johnston & Weisberg 2006



High Edot pulsars tend to be highly polarized (good S/N), symmetric and obey the RVM law in the swing of position angle



Blaskiewicz, Cordes Wasserman (1991). Relativistic modification to the Rotating Vector Model.
See also Dyks (2008).

Location of the inflexion point relative to the profile midpoint allows a determination of the emission height.

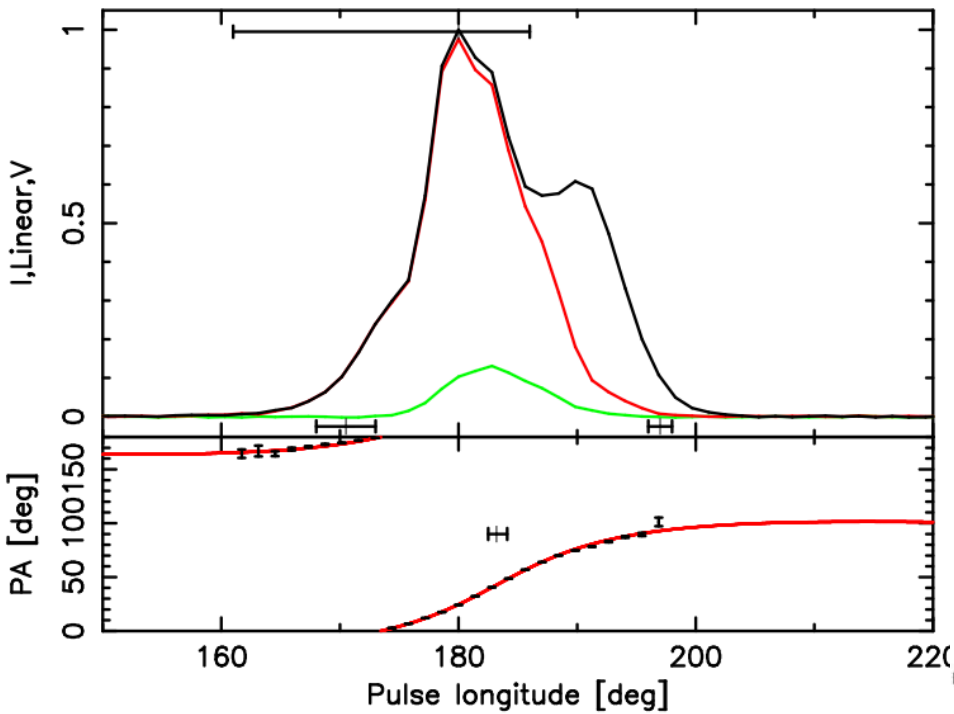
$$h_{\mathrm{P.A.}} = \frac{P\,c}{8\pi}\Delta\phi = \frac{1}{4}R_{\mathrm{LC}}\Delta\phi,$$

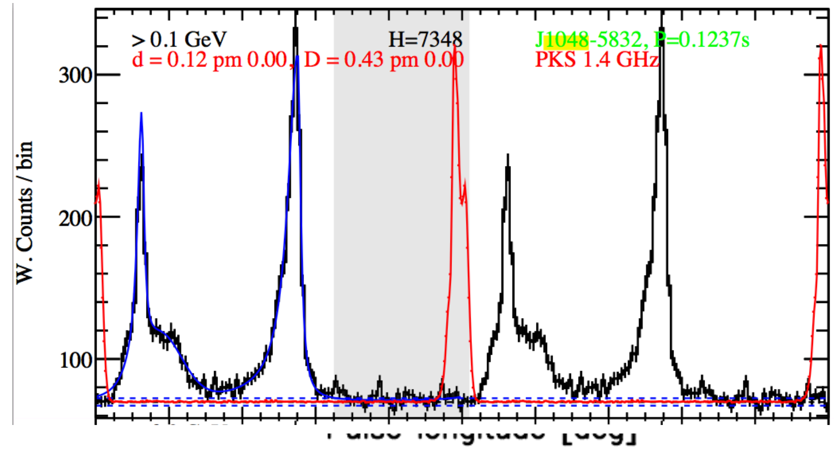
$$\rho = \sqrt{\frac{9\pi h_{\mathrm{em}}}{2Pc}},$$

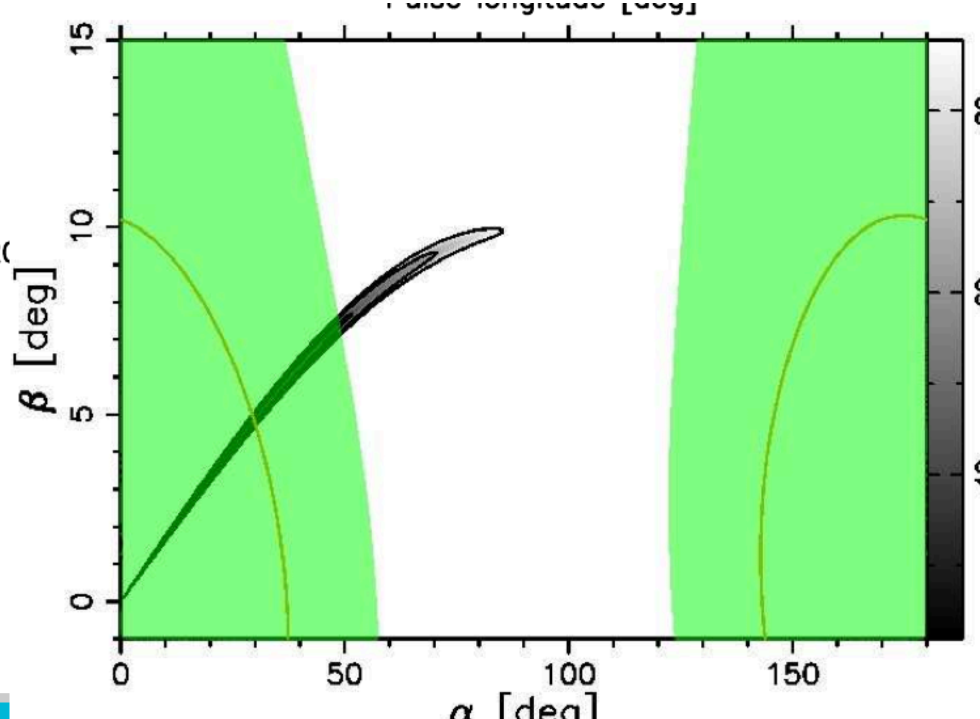
In turn, emission height yields ρ and from ρ and W get further angle constraints

$$\cos\rho = \cos\alpha\cos\zeta + \sin\alpha\sin\zeta\cos(W/2),$$

Putting it together: PSR 1048-5832

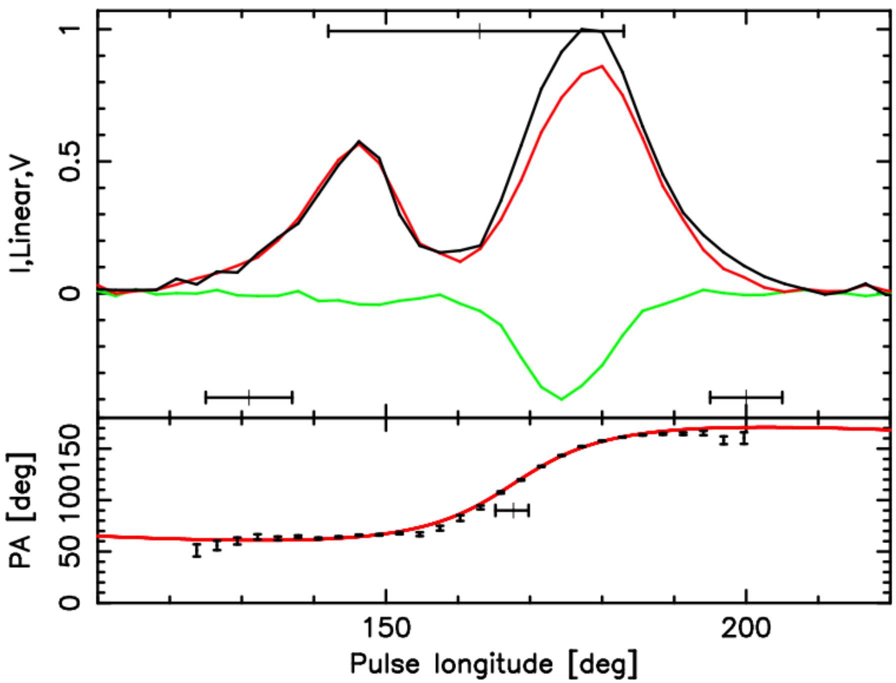


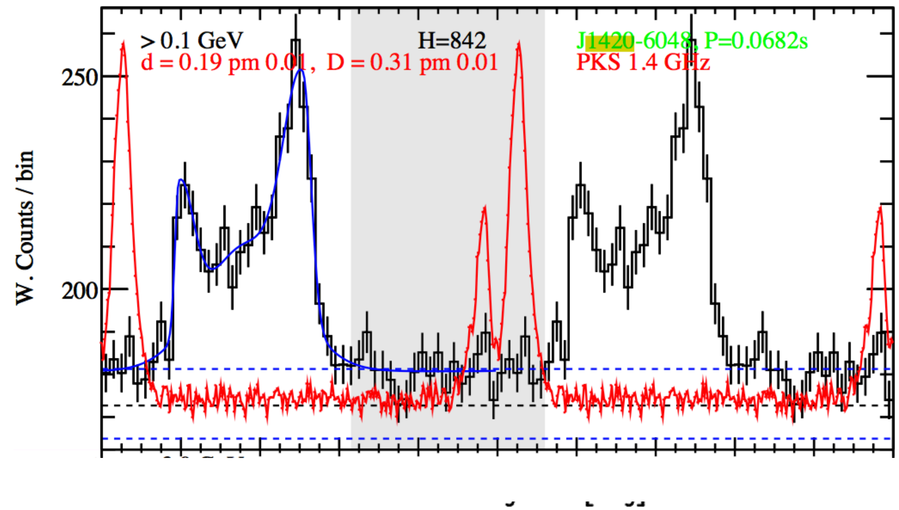


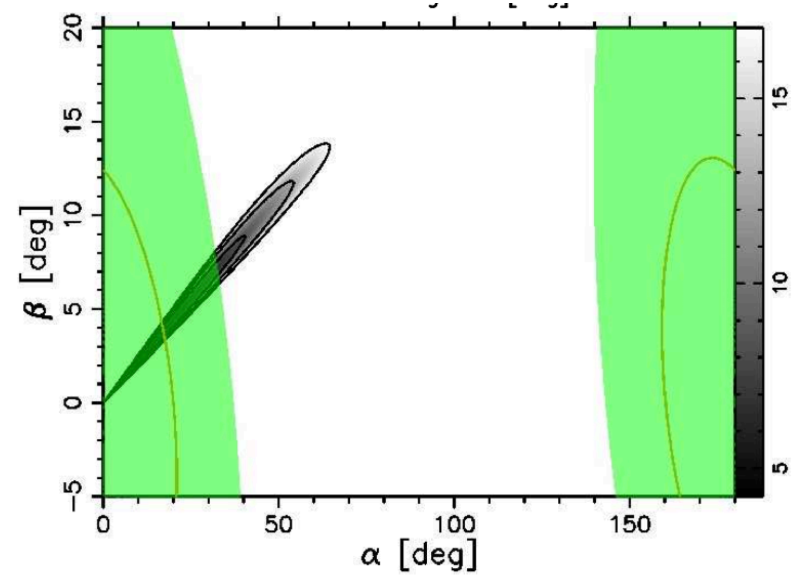


Best fit: α~30, β~5

Putting it together: PSR 1420-6048







Best fit: α~20, β~3

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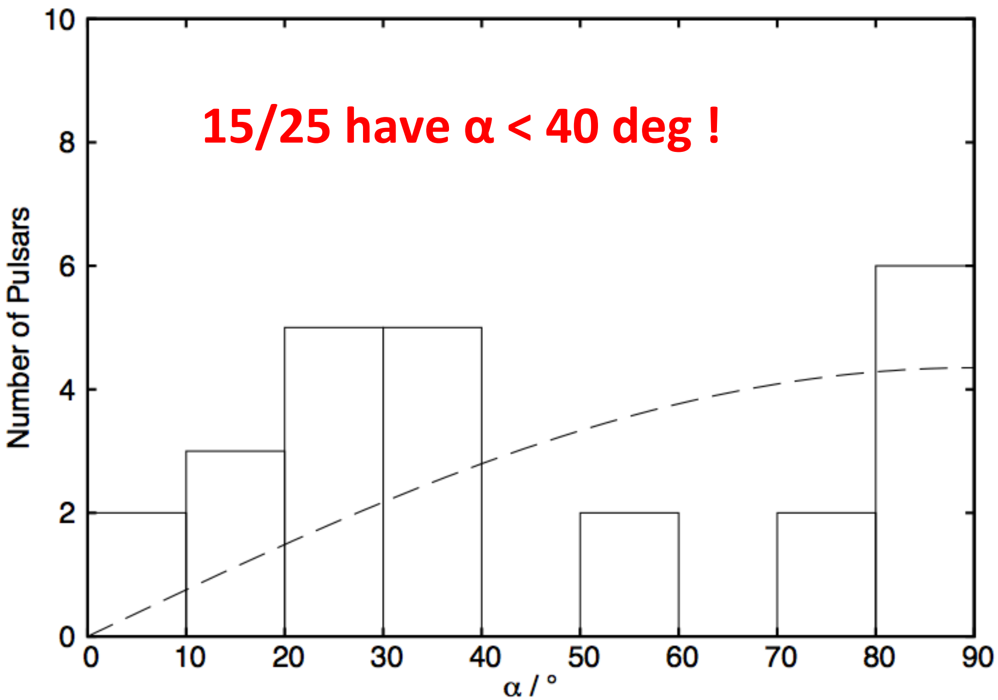
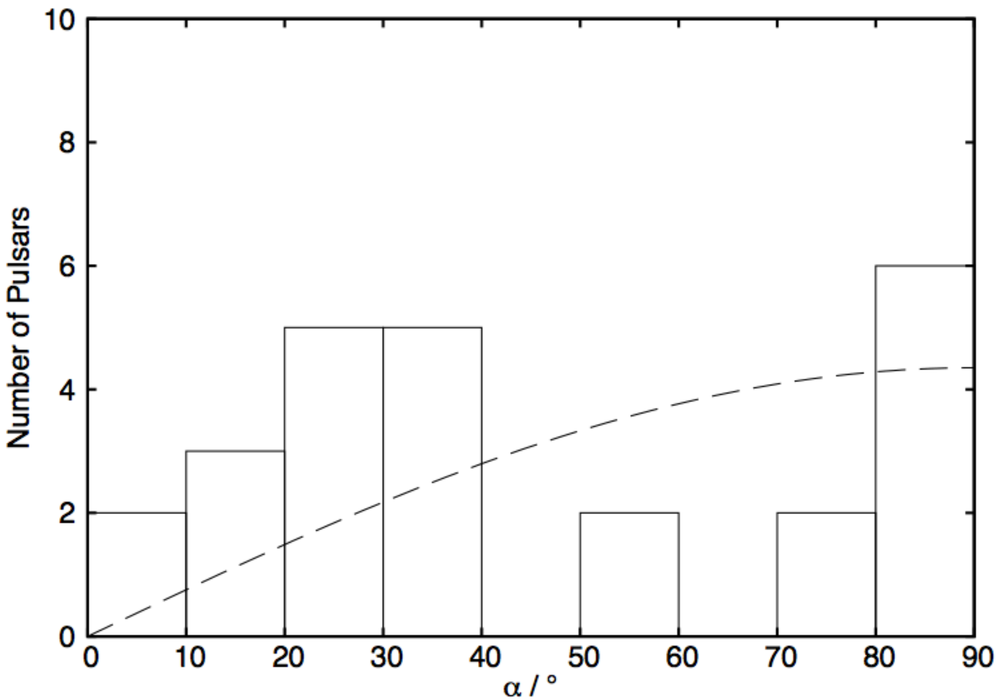
Results



SURPRISE!! We find low values of α with more than ½ the pulsars showing α < 40 contrary to expectations.

Results



Problem in a nutshell:
The radio profiles are too wide for the pulsars to be close to orthogonal rotators.

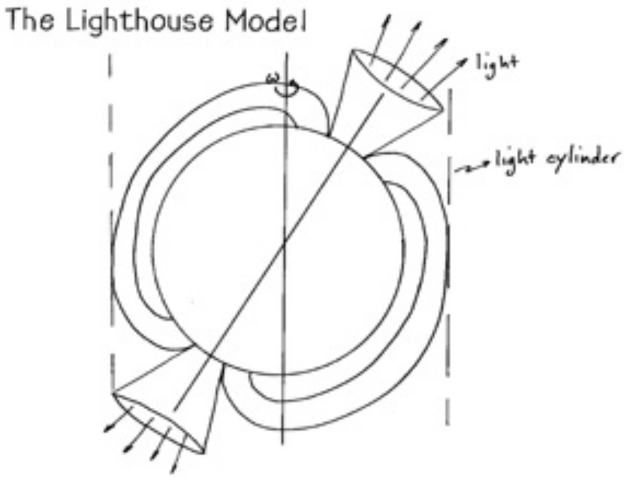
SURPRISE!! We find low values of α with more than ½ the pulsars showing α < 40 contrary to expectations.

How to fix the alpha problem?

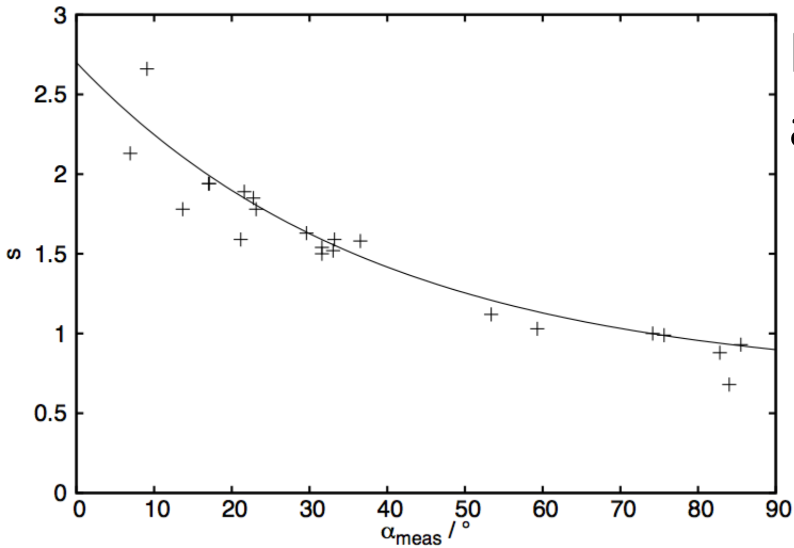
- Move the inflexion point later?
- Move the fiducial plane earlier?
- Make a height gradient between inner / core regions
- Emission from outside the polar cap

For various technical reasons the first three options make things better but cannot solve the problem fully.

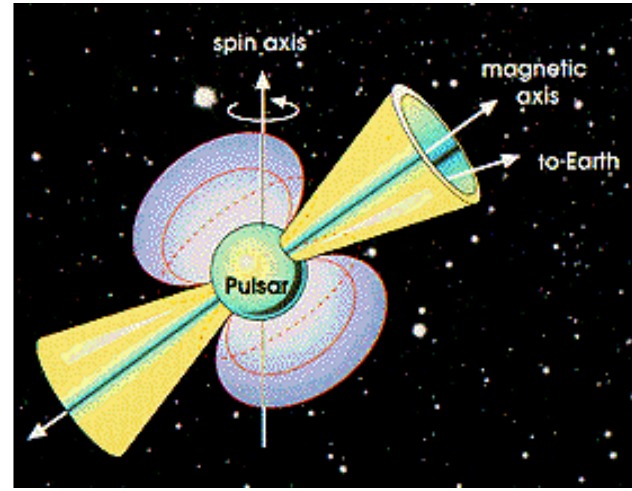
Make the polar cap extend beyond its nominal radius



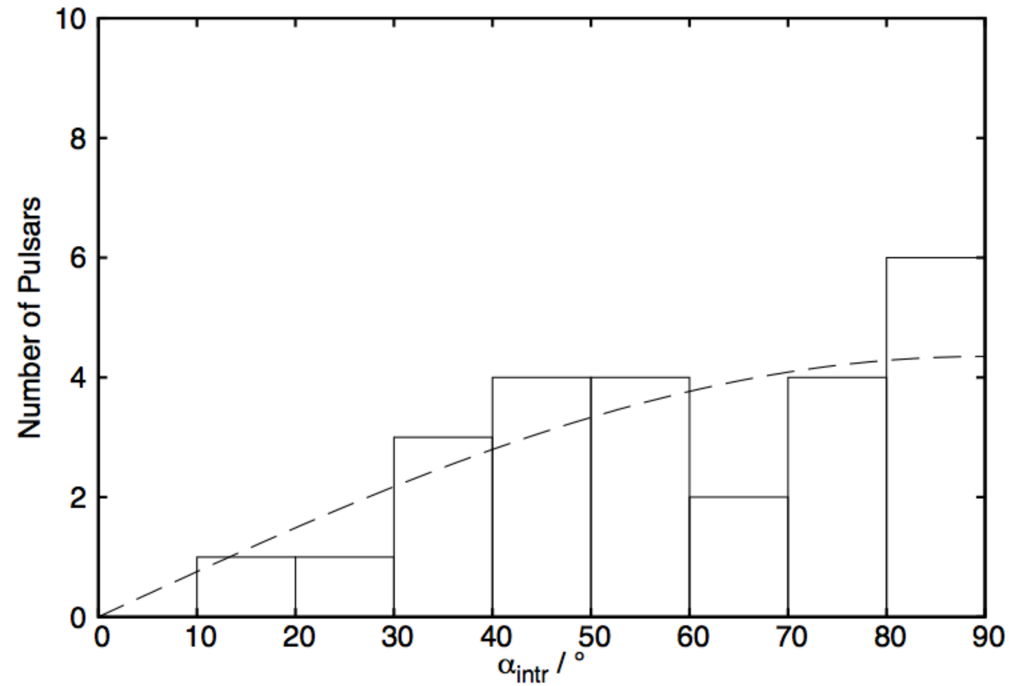
Extra-cap emission solution



Polar cap size is a function of α.



α now consistent with a random (sinusoidal) distribution at birth.



Summary

- Geometry is critical to understanding the emission we see from pulsars (cf Andrey's talk).
- We have developed a method for deriving robust values of α and β.
- Values of α are smaller than expected.
- Either
  - α really is small → gamma-ray models have problems
  - Radio polarization info is misleading → radio models have problems
  - Fix by postulating emission from outside the conventional polar cap region. Implications for joint radio/gamma-ray modeling.

Read the papers!

Rookyard et al. astro-ph 1410.3294 (data paper)

Rookyard et al. astro-ph 1410.3310 (interpretation paper)

CASS Radio Telescopes in Australia

ASKAP: Wide field of view. Fastest survey radio telescope until SKA.

ATCA: Interferometer from 1-100 GHz with 4 GHz BW

Please talk to me for more information!

Parkes: 64-m Single Dish

Thank you

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