Determining Critical Luminosity and Inclination Angle with *Polestar*

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Outline

- The Model (*Polestar*)
- The SMC Library
- Model Products
- Determination of Inclination Angle (*i*)
- Determination of Critical Luminosity

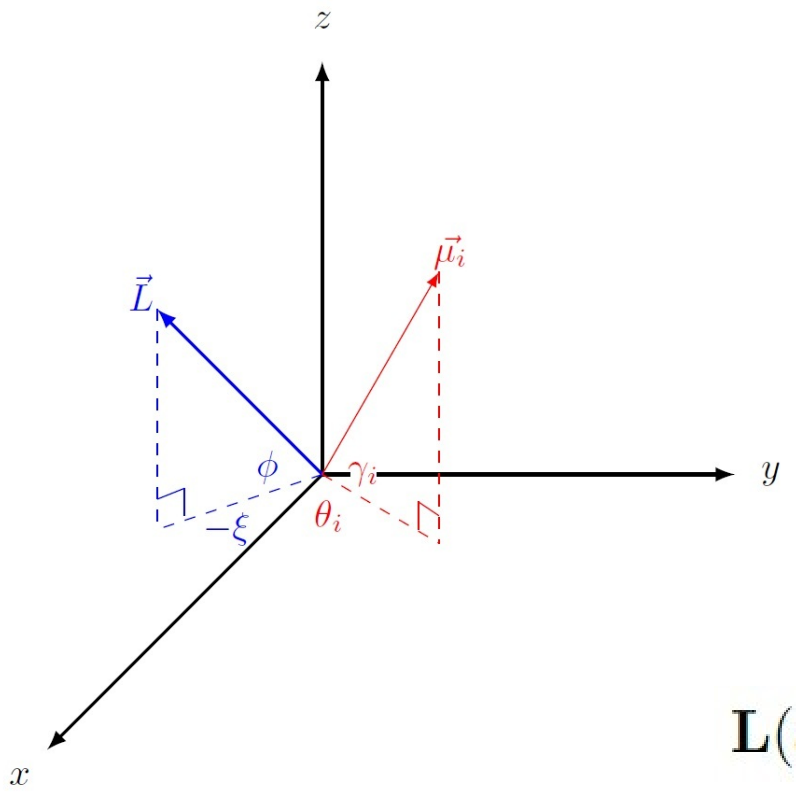
One fundamental tenant…

K IS S

One fundamental tenant…

Keep It Simple Stargazer

Polestar – a vector-based model



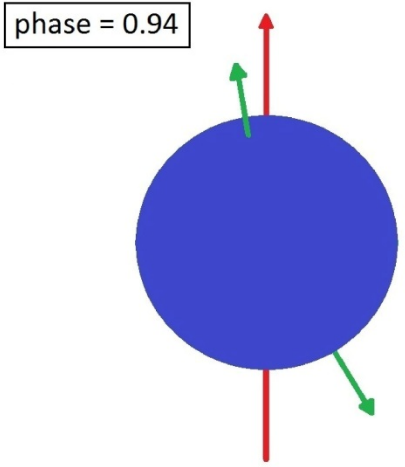
$$\mathbf{L} = \begin{pmatrix} \cos\xi\cos\phi \\ \sin\xi\cos\phi \\ \sin\phi \end{pmatrix}$$

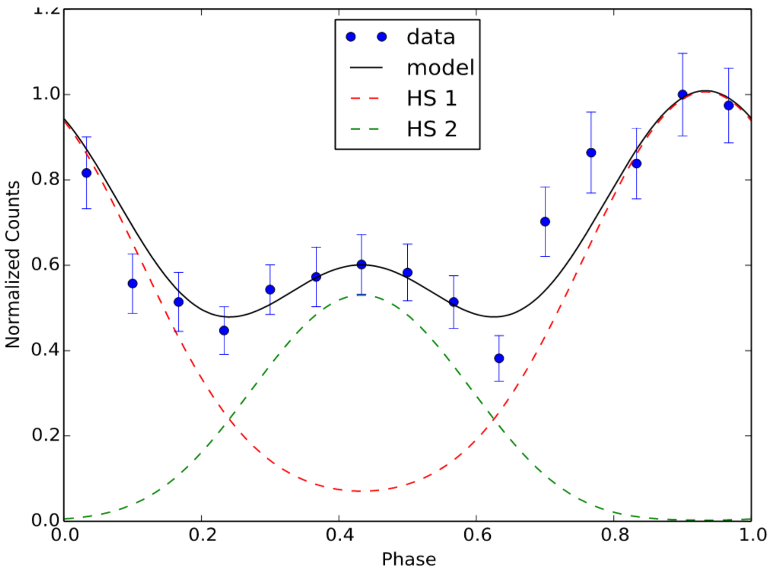
$$\boldsymbol{\mu_i} = \begin{pmatrix} \cos\theta_i\cos\gamma_i \\ \sin\theta_i\cos\gamma_i \\ \sin\gamma_i \end{pmatrix}$$

$$\mathbf{R} = \begin{pmatrix} \cos(\Delta\xi) & \sin(\Delta\xi) & 0 \\ -\sin(\Delta\xi) & \cos(\Delta\xi) & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$\mathbf{L}(\xi + \Delta\xi) = \mathbf{R}(\Delta\xi)\ \mathbf{L}(\xi)$$

Polestar

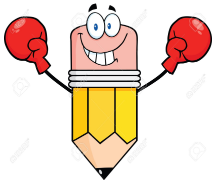




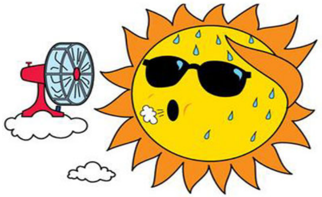
Built from a simple vector model with parameters which can be fit or fixed to add various complexities.

Model Fitting Parameters

- position of line of sight *(i)*
- position of hot spots (θ)
- ratio of pencil to fan behaviour
- ratio of HS intensities
- exponent (or form) of the beam generating function
- compactness parameter
- pulsed fraction
- height of accretion column

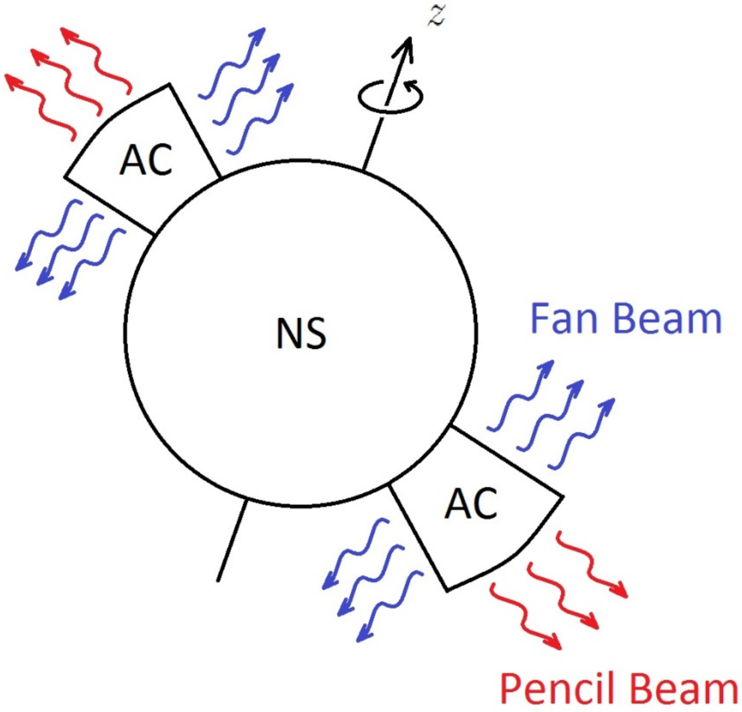


Pencil vs. Fan

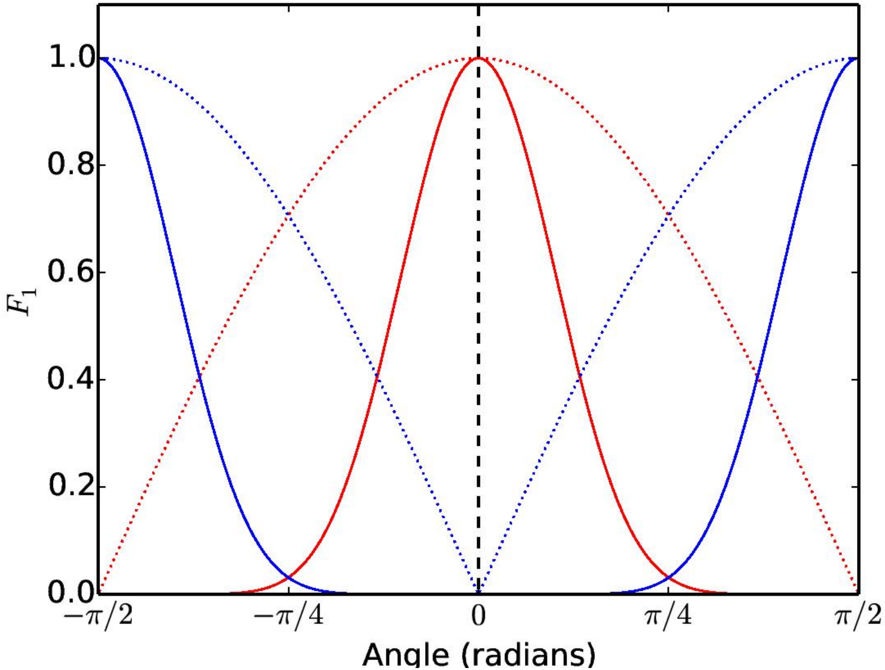


In lower luminosity states the accreting matter is slowed by Coulomb scattering and a pencil beam is produced radiating along the magnetic axis.

Above the critical luminosity the plasma is decelerated by radiation pressure and forms a shock, below which an accretion column forms.



Beam generating function



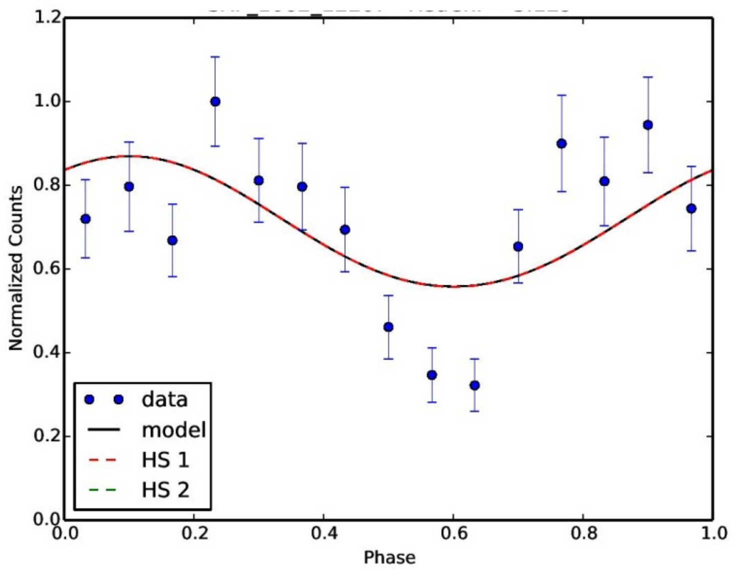
Red is pencil beam (cos), blue is fan (sin)
The dashed lines are an exponent of one,
solid an exponent of 10

$$F_{1,pencil}(\alpha_1) = I_1 \cos \alpha_1$$

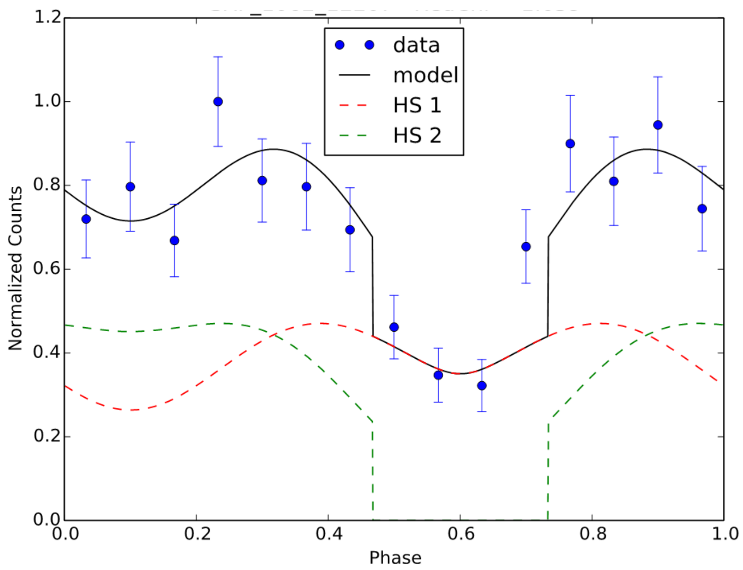
$$F_{1,fan}(\alpha_1) = I_1 \sin \alpha_1$$

$$F_{1,total}(\alpha_1) = I_1 \left(C_p \cos \alpha_1 + C_f \sin \alpha_1 \right)$$

Additional Parameters = Better Fits

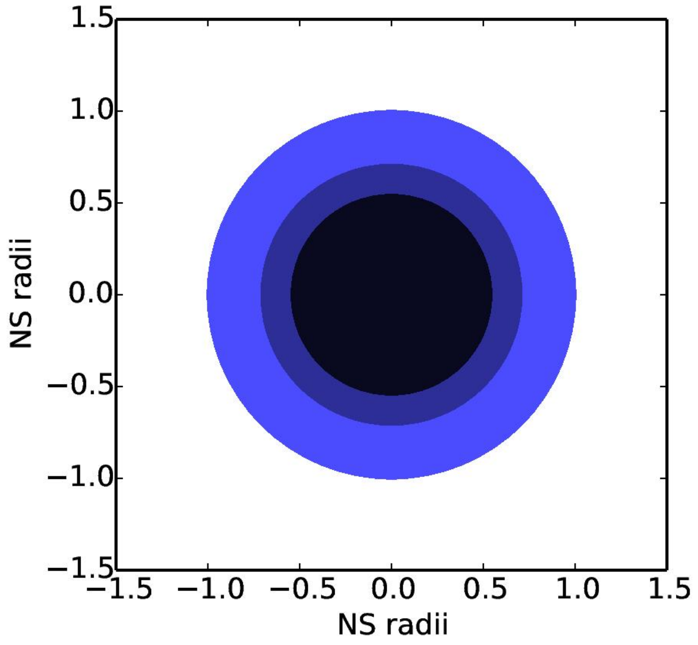


Fit with only pencil (cos)

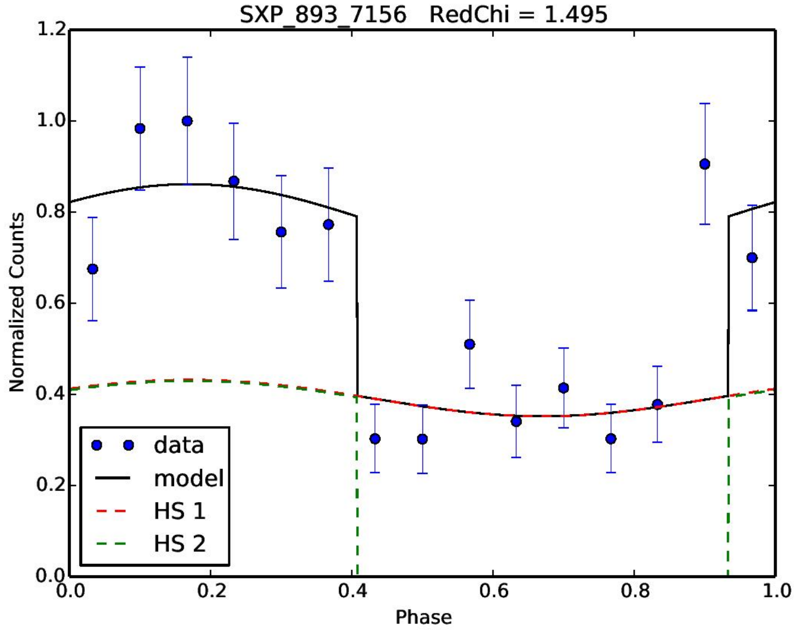


Fit with pencil and fan (sin)

Fan Beams Crossing the Terminator

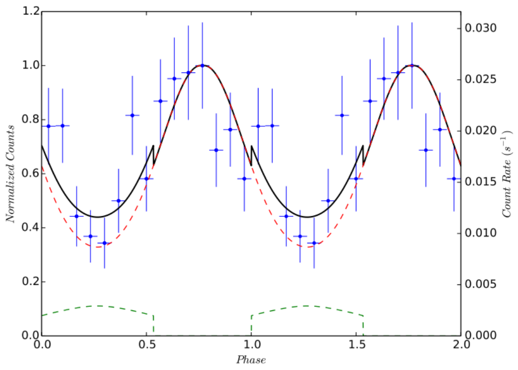


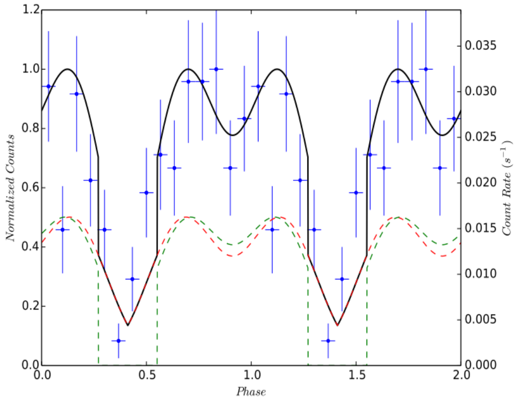
The visible portion of the far side of a NS. The black denotes the terminator for a canonical NS.



An example of a profile with a sharp cutoff fit with a fan beaming function.

The SMC Library

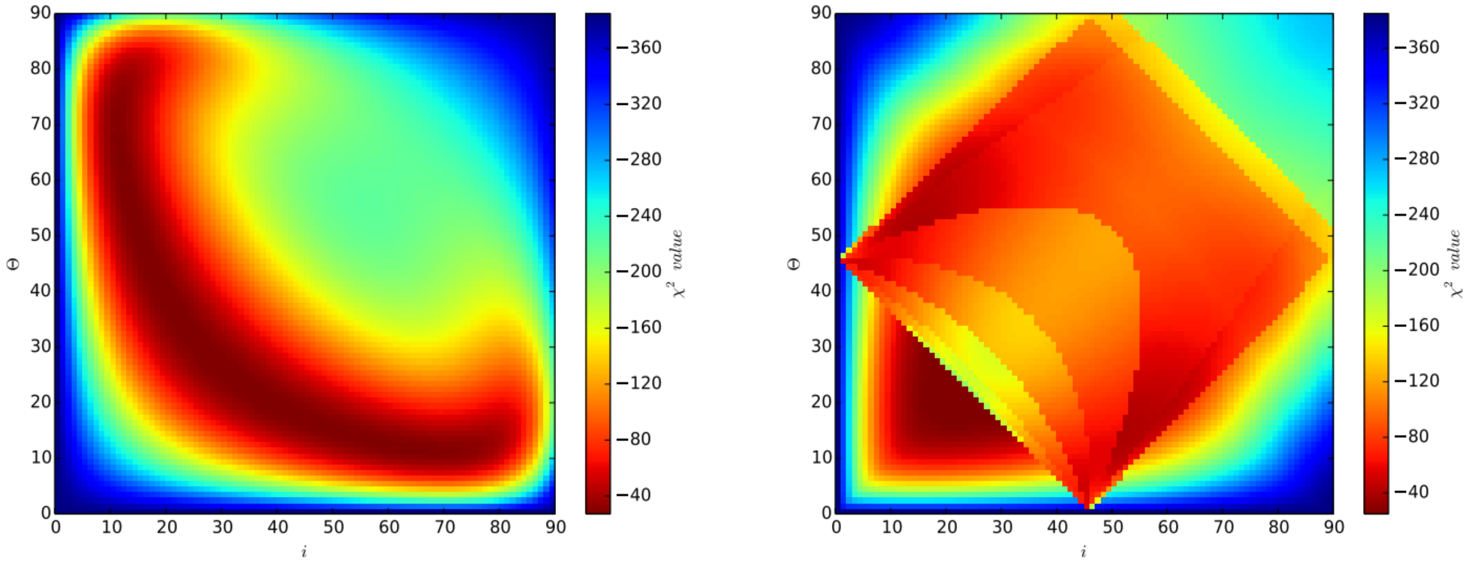




Obtain pulse-profiles from the same pulsar on many different occasions, at different luminosities and states in order to break model degeneracies.

Initial release available at www.xraypulsars.space and includes 116 XMM, 952 RXTE, and 496 (!) Chandra observations of the SMC over 20 years.

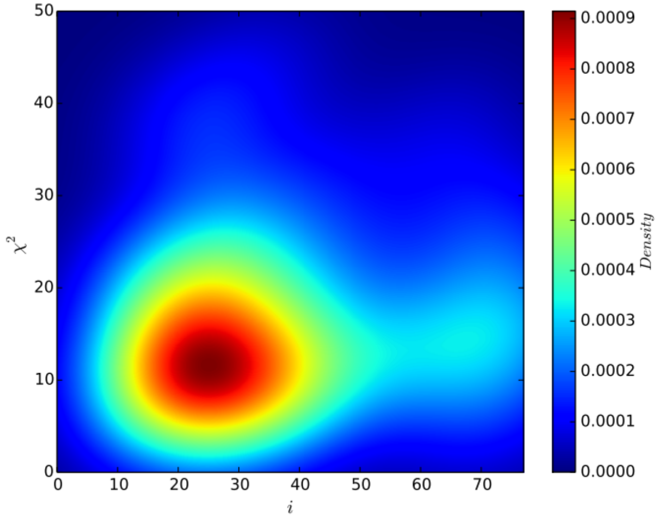
Heat Maps of the Parameter Space

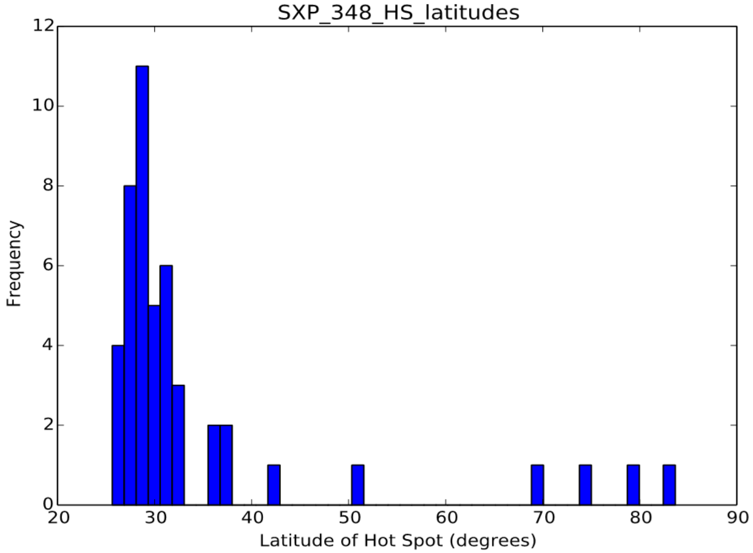


Two fits of an identical pulse profile. The left one only allows pencil beam, the right allows both pencil and fan beams.

Determination of Inclination Angle (i)

SXP348

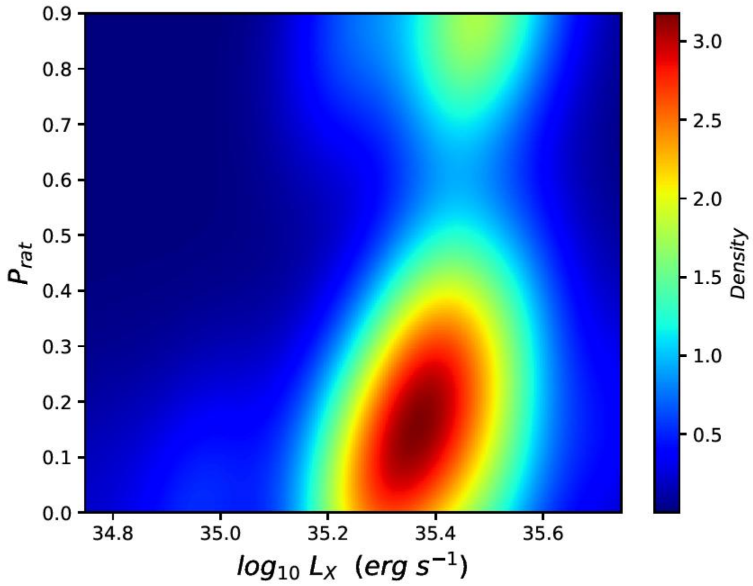




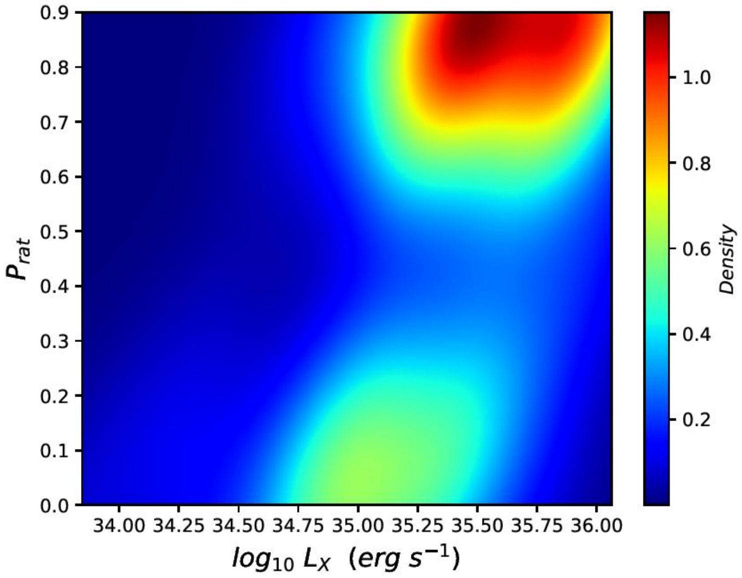
Fitting with a few parameters while holding others constant produces histograms of likely values for a given source.

Determining Critical Luminosity

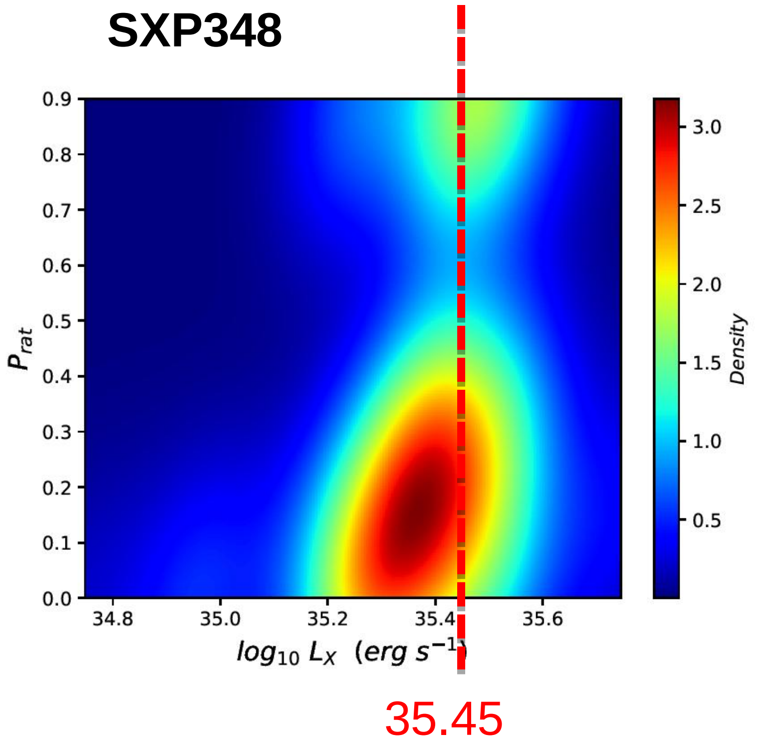
SXP348

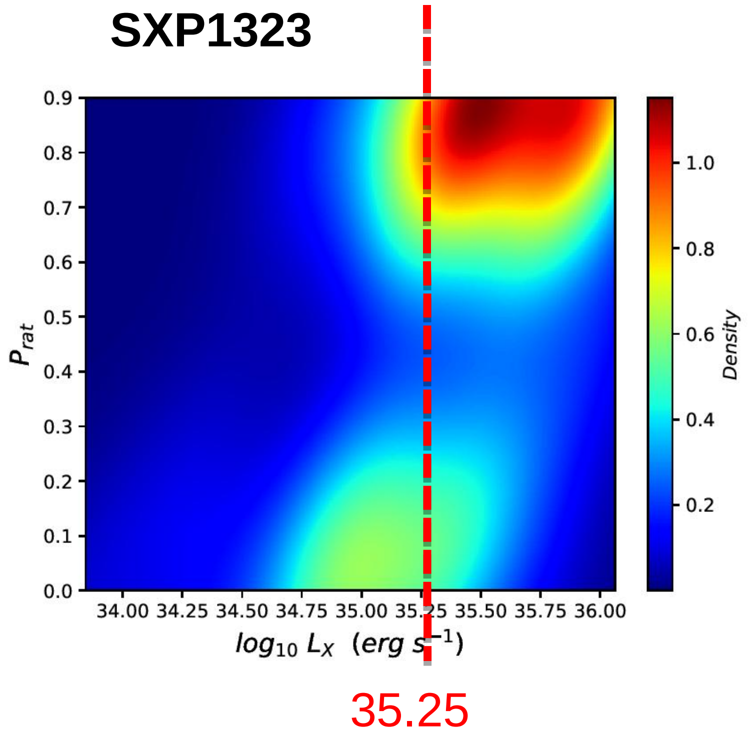


SXP1323



Determining Critical Luminosity





Conclusions and Future Work

- *Polestar* represents a simple, accessible framework for future additions and adaptations.

- Fit XRB populations beyond the SMC.

- Can be used as an initial test for interesting behaviour, thus tweezing out interesting sources for more sophisticated (and computationally expensive) models to probe.

- Provides the possibility of a unique way of determining various parameters of a given system.

- Can be used as tool to probe statistical trends of large XRB pulse profile samples.

Acknowledgements

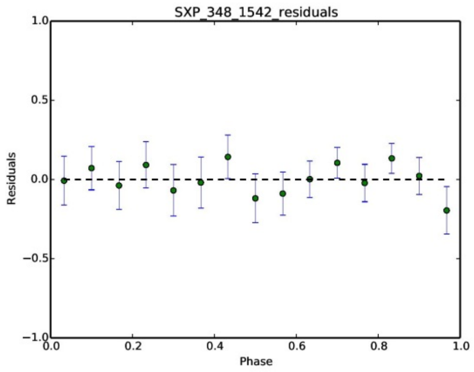
We would like to thank:

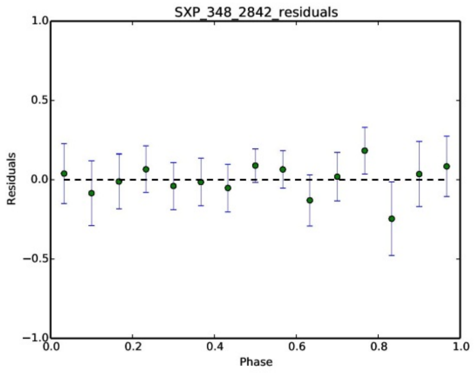
Malcolm Coe, Wynn Ho, Andreas Zezas, and Helen Klus for their continuing support and collaboration

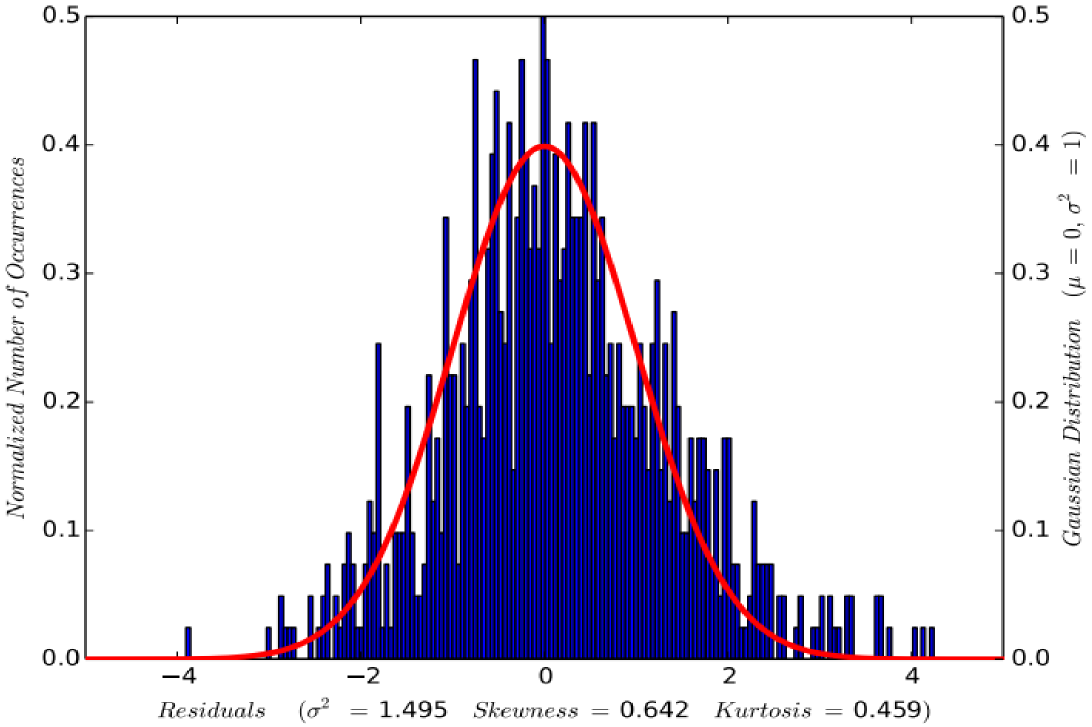
LoCSST (Lowell Center for Space Science and Technology)

This work was made possible in part by the NASA Astrophysics Data Analysis Program (ADAP), award NNX14AF77G

Determining Goodness of Fit

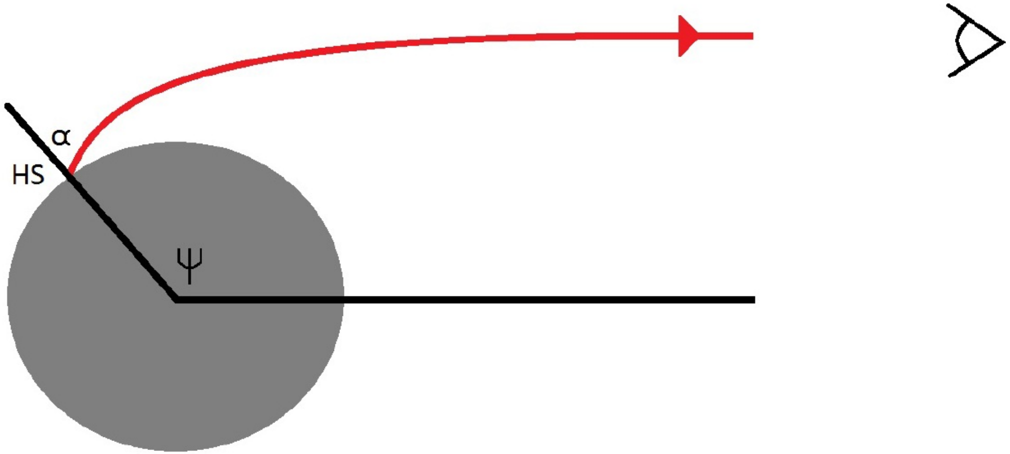






Beloborodov’s Approximation (2002)

$$1 - \cos\alpha = (1 - \cos\psi)\left(1 - \frac{r_g}{R}\right)$$



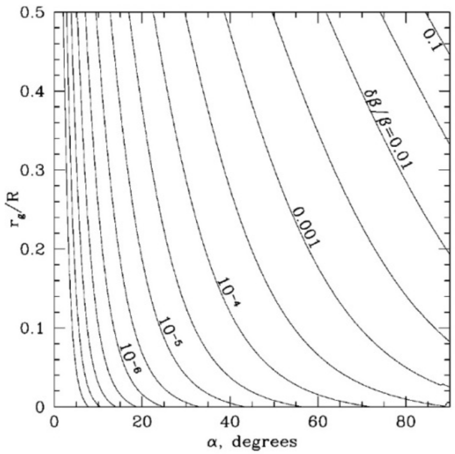
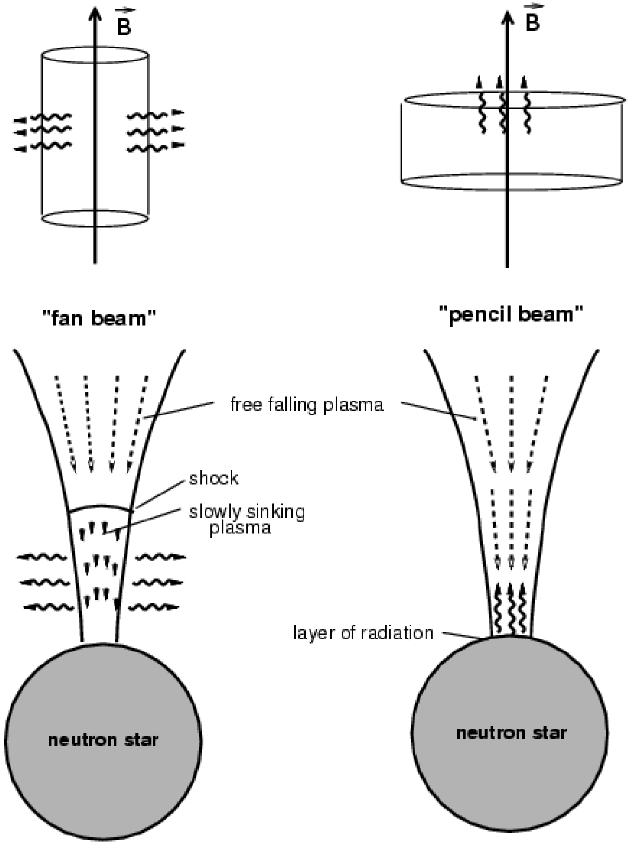


FIG. 2.—Accuracy of the cosine relation (eq. [1]). This relation gives the nding angle $\beta = \psi - \alpha$, with an error $e = \delta\beta/\beta$, which depends on the aission radius R/r_g and the emission angle α. Here the contours of e = nst (with logarithmic step 0.5) are plotted on the r_g/R-α plane.



B
B
"fan beam"
"pencil beam"
free falling plasma
shock
slowly sinking plasma
layer of radiation
neutron star
neutron star