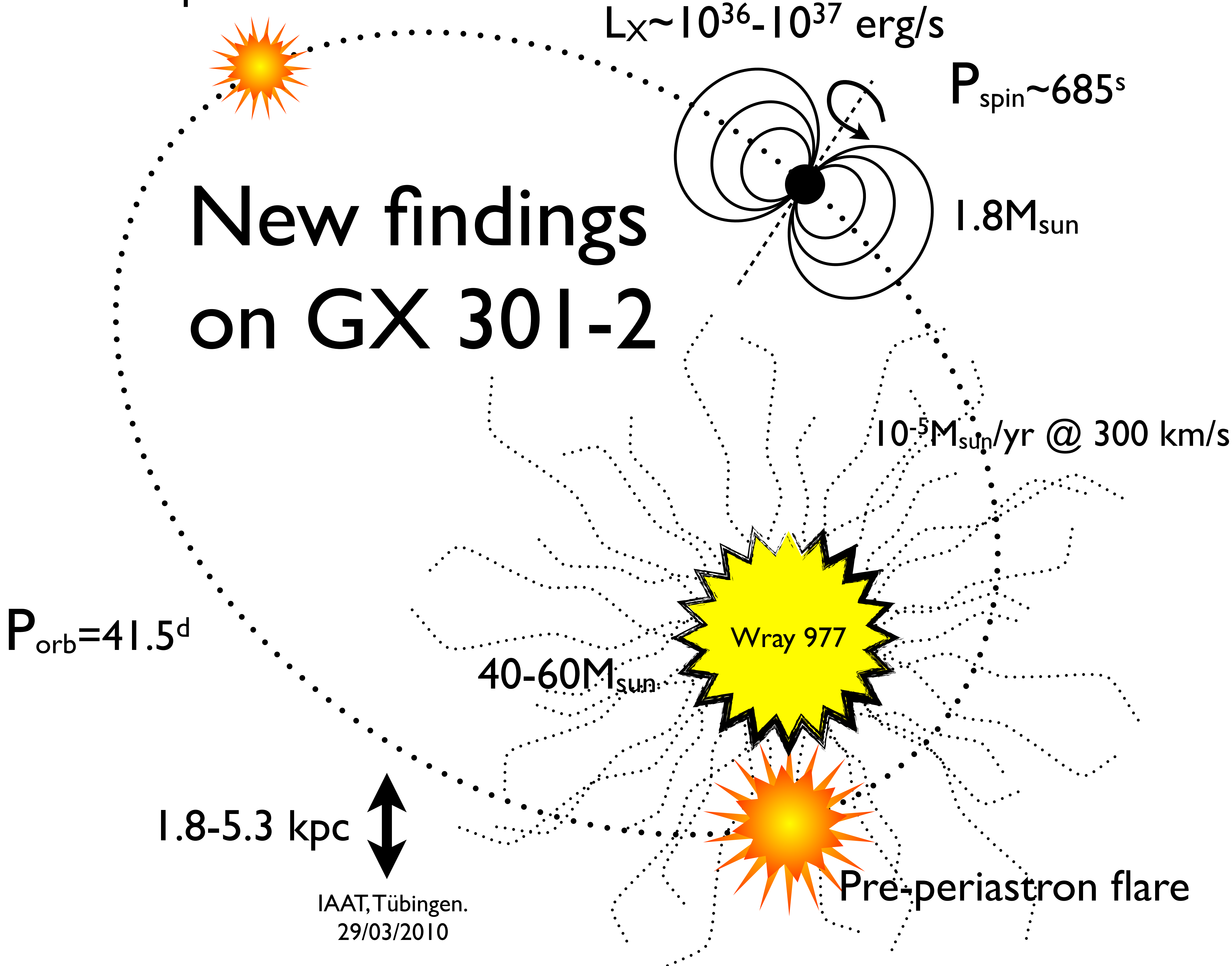
New findings on GX 301-2

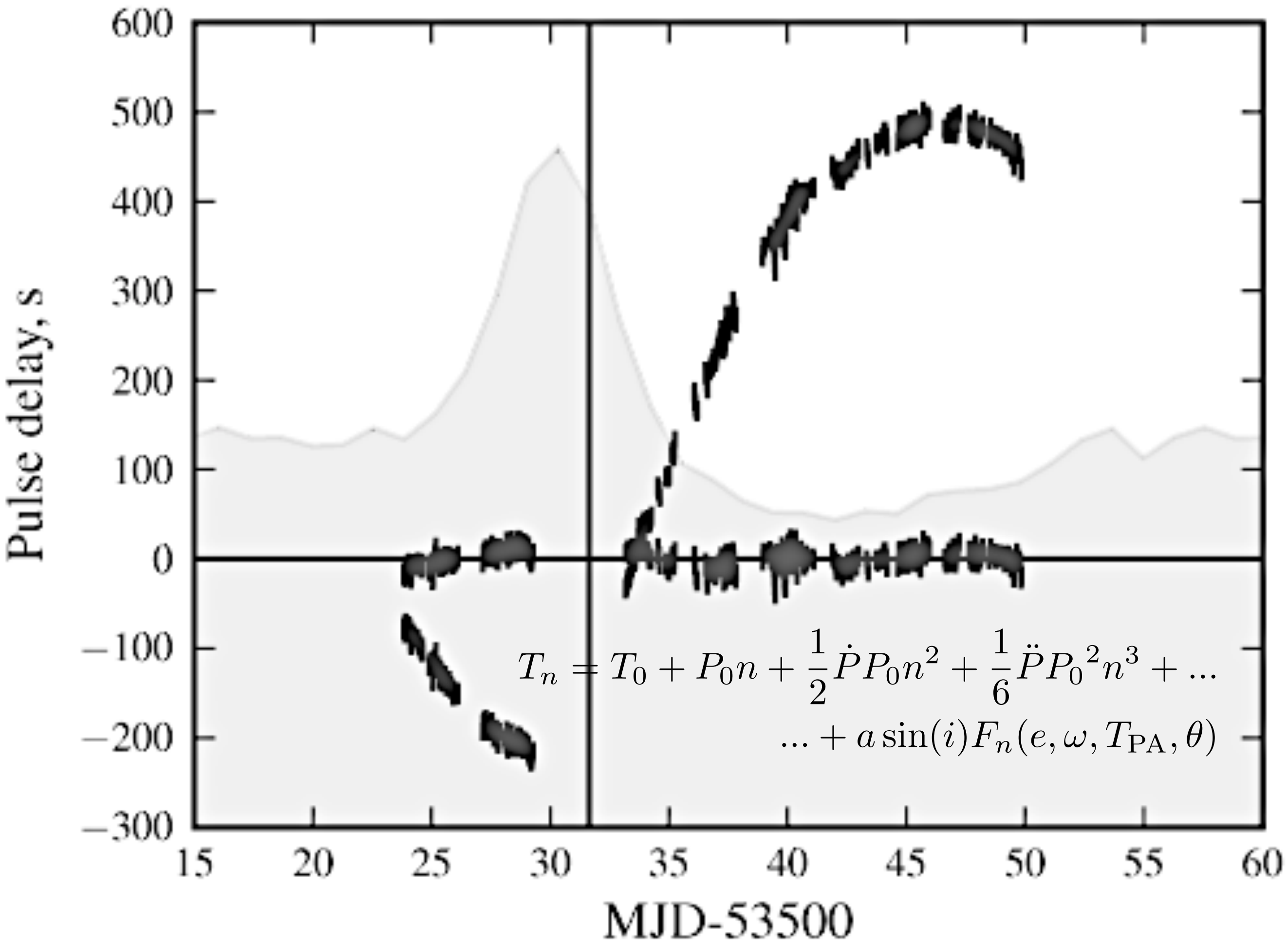


IAAT, Tübingen.
29/03/2010

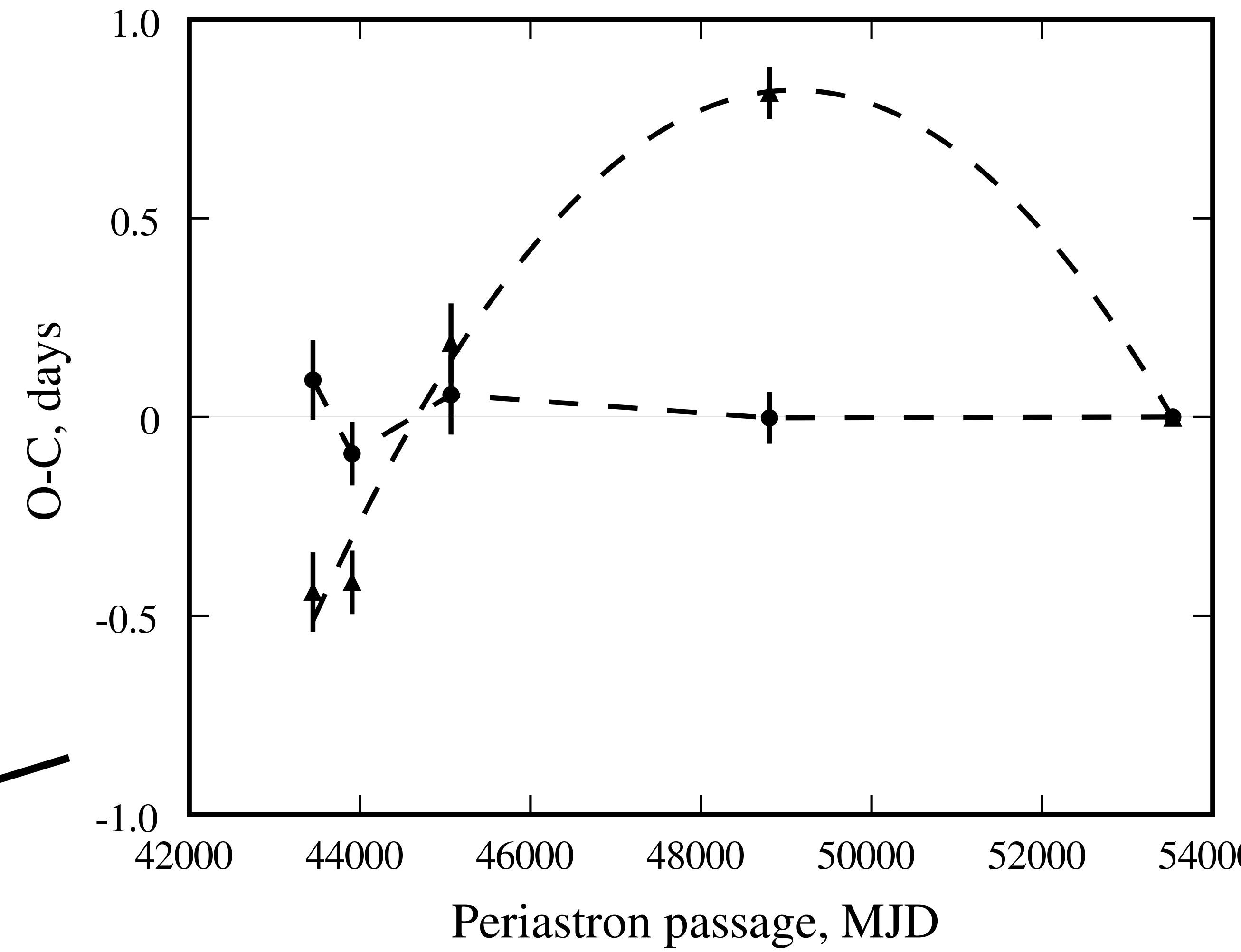
V. Doroshenko, A. Santangelo, V. Suleimanov, R. Staubert, I. Kreykenbohm, D. Klochkov

Measurement of the secular change of the orbital period.

Find periastron passage time via coherent pulse timing



Compare with historical values



P_{orb}=41.506 d,
$\dot{P}_{orb}$=-3.7∗10^{-6} d d^{-1}
@MJD 43906.06

Largest $\dot{P}$ so far, and measured for the first time in a system like GX 301-2, but may be in part due to apsidal motion

Old stuff with new details: pulse period and torques acting on the NS

$$I\frac{d\omega}{dt} = K_+(\dot{M}) + K_-(\omega, B, \dot{M})$$

$$K_- = -\dot{M}\frac{\omega^2 {R_H}^{7/2}}{4\sqrt{2GM}}$$

$$K_+ = \dot{M}k_w {R_A}^2\Omega_{\rm orb}$$

Davies et al, 1979

$$K_- = -\dot{M}k\frac{\xi}{2\pi}{R_H}^2\omega$$

Illarionov-Kompaneec, 1990

$$R_H = \left(\frac{B^2R^6}{2\dot{M}\sqrt{2GM}}\right)^{2/7}, R_A = \frac{2GM}{w^2}$$

Assuming torque equivalence:

$$B \approx 3\times10^{14}\,\mathrm{G}\left(\frac{k_w}{0.25}\right)^{1/2}\left(\frac{\dot{M}_{\rm eq}}{10^{17}\,\mathrm{g/s}}\right)^{3/2}\left(\frac{w}{400\,\mathrm{km/s}}\right)^{-2}$$

$$\times\left(\frac{P}{680\,\mathrm{s}}\right)^{1/2}\left(\frac{P_{\rm orb}}{41.5^{\rm d}}\right)^{-1/2}\left(\frac{M}{1.4M_\odot}\right)^{3/2}\left(\frac{R}{10^6\,\mathrm{cm}}\right)^{-3}$$

Davidson, Ostriker 1973

$$B \approx 2\times10^{14}\,\mathrm{G}\left(\frac{k_w}{0.25}\right)^{7/8}\left(\frac{k}{2/3}\right)^{-7/8}\left(\frac{\xi}{0.87}\right)^{-7/8}\left(\frac{\dot{M}_{\rm eq}}{10^{17}\,\mathrm{g/s}}\right)^{1/2}$$

$$\left(\frac{w}{400\,\mathrm{km/s}}\right)^{-7/2}\left(\frac{P}{680\,\mathrm{s}}\right)^{7/8}\left(\frac{P_{\rm orb}}{41.5^{\rm d}}\right)^{-7/8}\left(\frac{M}{1.4M_\odot}\right)^{2}\left(\frac{R}{10^6\,\mathrm{cm}}\right)^{-3}$$

Illarionov, Kompaneets, 1990

Disk accretion (Ghosh-Lamb, Lovelace) requires even stronger field.

Pulse period and torques acting on the NS

$$I\frac{d\omega}{dt} = K_+(\dot{M}) + K_-(\omega, B, \dot{M})$$

$$K_+ = \dot{M} k_w {R_A}^2 \Omega_{\rm orb}$$

$$K_- = -\dot{M}\frac{\omega^2 {R_H}^{7/2}}{4\sqrt{2GM}}$$

Davies et al, 1979

$$K_- = -\dot{M} k \frac{\xi}{2\pi} {R_H}^2 \omega$$

Illarionov-Kompaneec, 1990

$$R_H = \left(\frac{B^2 R^6}{2\dot{M}\sqrt{2GM}}\right)^{2/7}, R_A = \frac{2GM}{w^2}$$

GX 301-2 has a VERY long pulse period for given luminosity!!!
(so STRONG magnetic field is required)
Lets clarify the situation...

$$I\frac{d\omega}{dt} = K_+(\dot{M}) + K_-(\omega, B, \dot{M})$$

$$K_- = -\dot{M}\frac{\omega^2 {R_H}^{7/2}}{4\sqrt{2GM}}$$

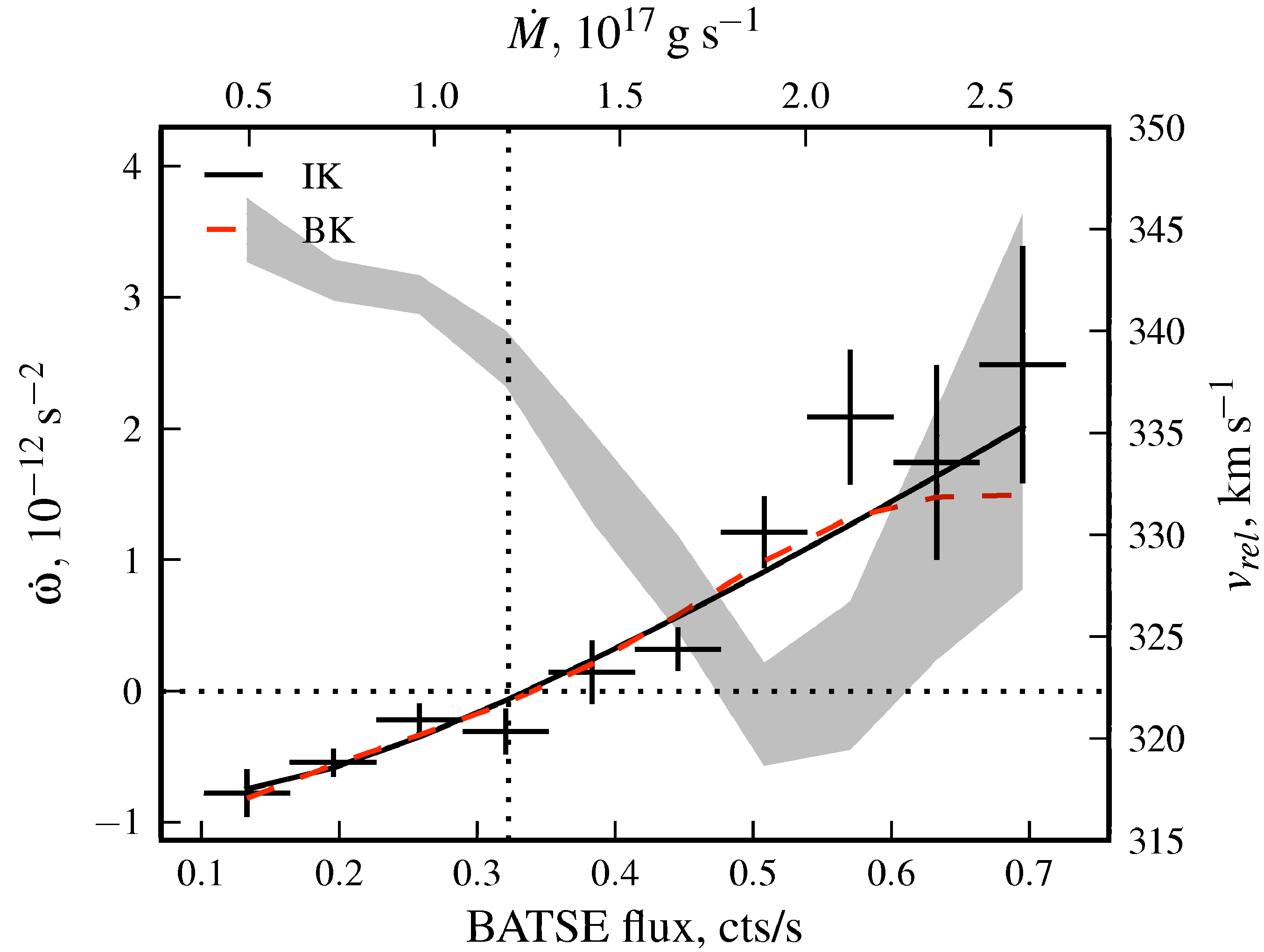
Davies et al, 1979

$$K_+ = \dot{M} k_w {R_A}^2 \Omega_{\rm orb}$$

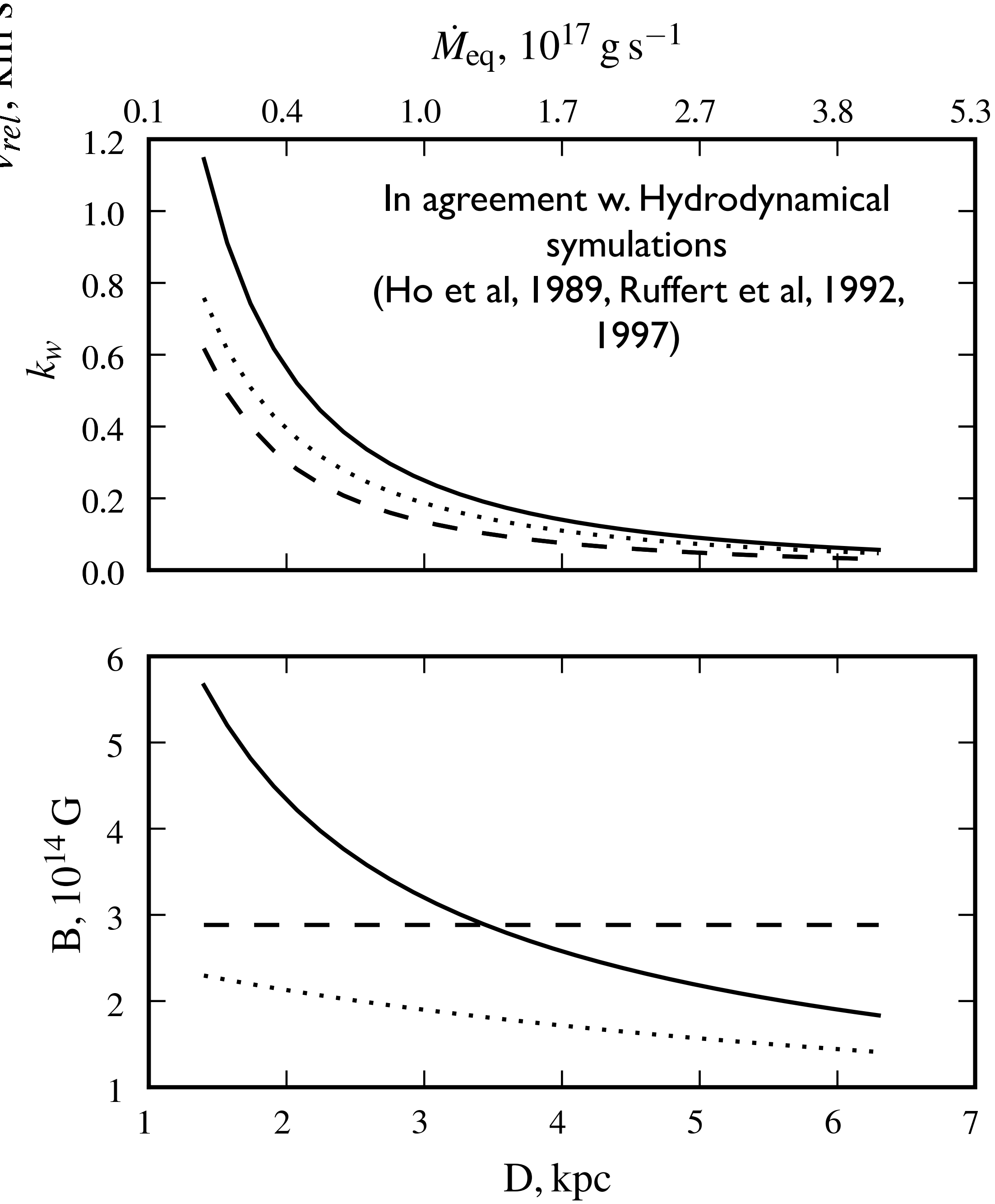
$$K_- = -\dot{M} k \frac{\xi}{2\pi} {R_H}^2 \omega$$

Illarionov-Kompaneec, 1990

$$R_H = \left(\frac{B^2 R^6}{2\dot{M}\sqrt{2GM}}\right)^{2/7}, R_A = \frac{2GM}{w^2}$$



CGRO BATSE-DISCLA data (Bildsten et al, Koh et al 1997)



$$I\frac{d\omega}{dt} = K_+(\dot{M}) + K_-(\omega, B, \dot{M})$$

$$K_- = -\dot{M}\frac{\omega^2 {R_H}^{7/2}}{4\sqrt{2GM}}$$

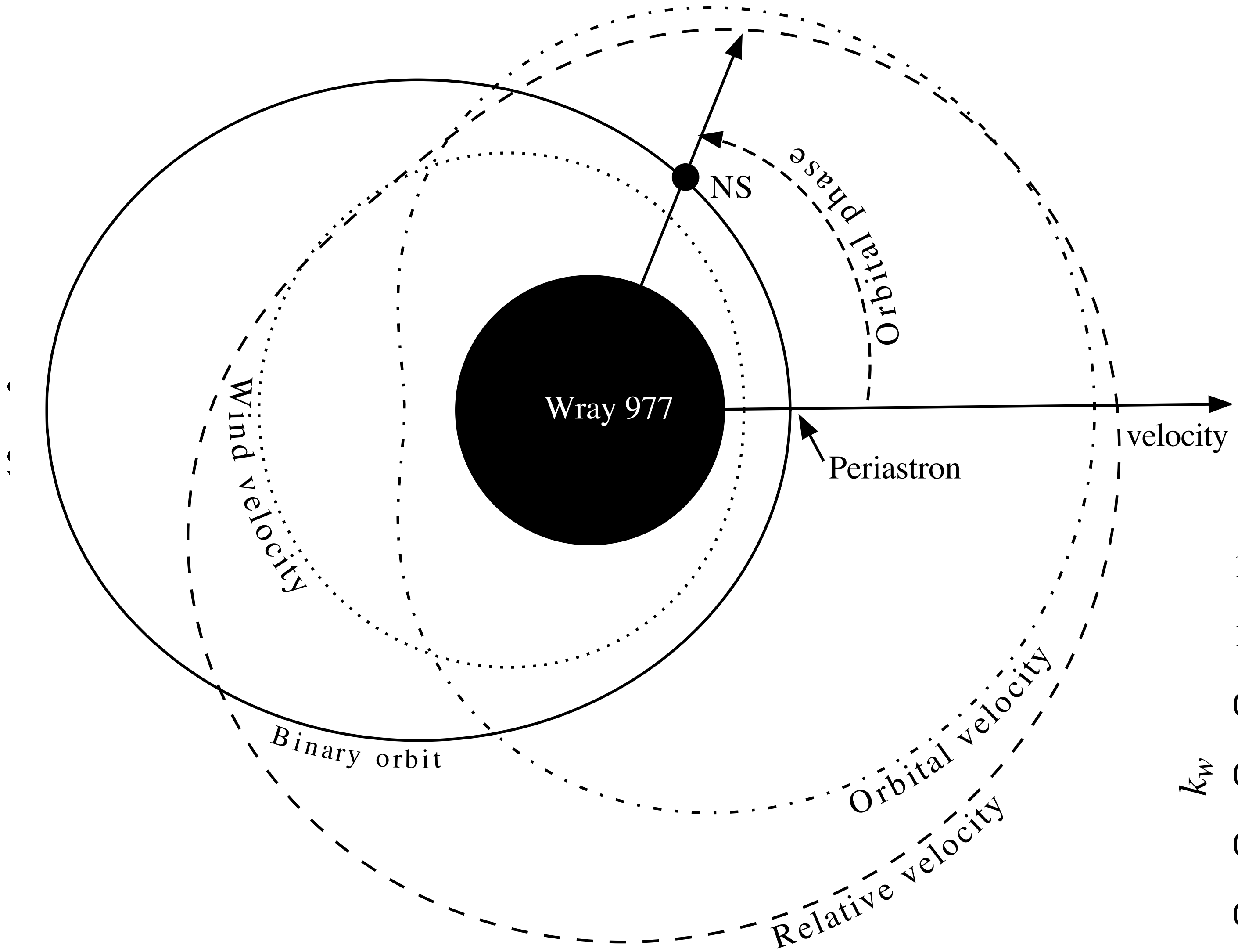
Davies et al, 1979

$$K_+ = \dot{M} k_w {R_A}^2 \Omega_{\rm orb}$$

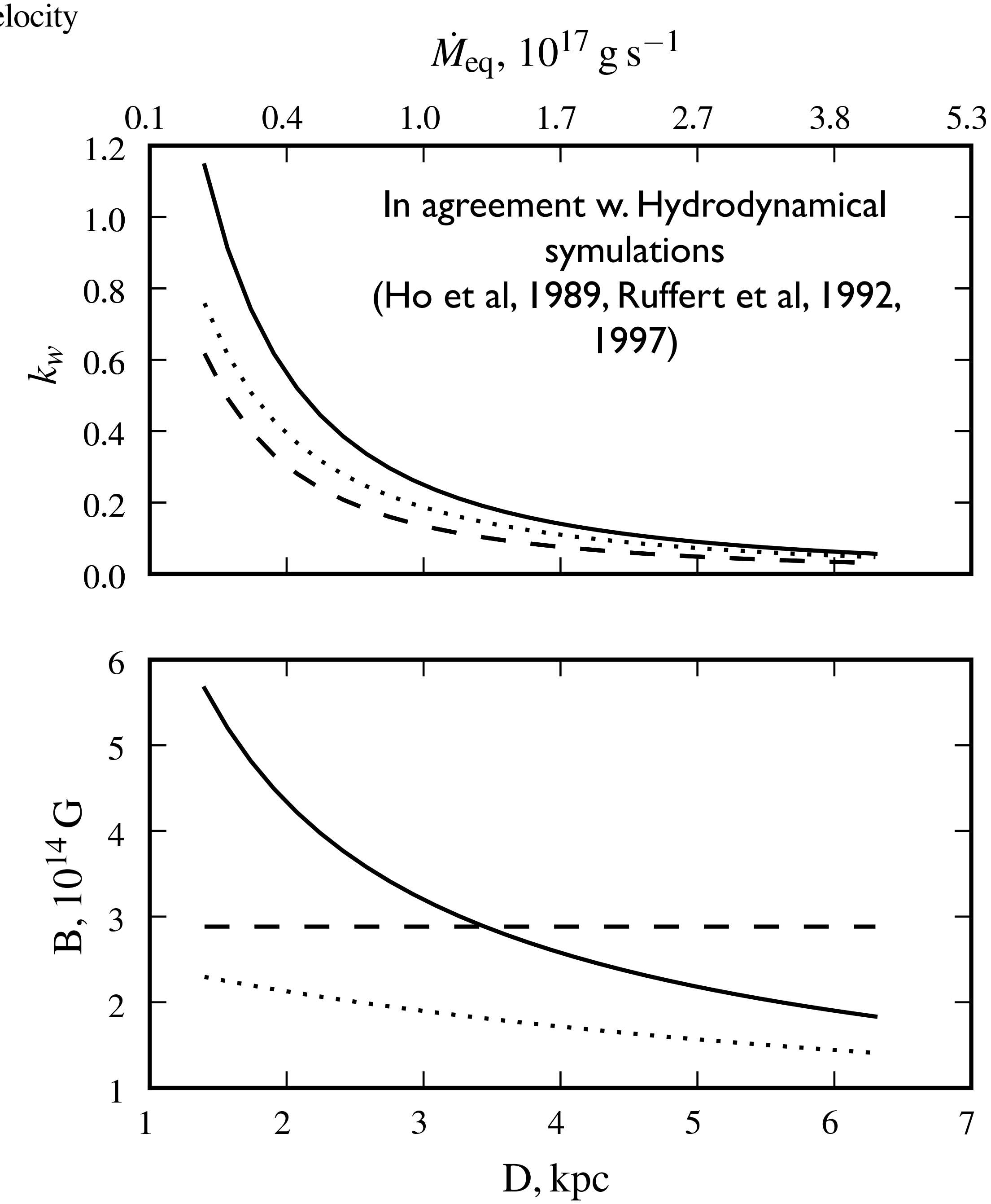
$$K_- = -\dot{M} k \frac{\xi}{2\pi} {R_H}^2 \omega$$

Illarionov-Kompaneec, 1990

$$R_H = \left(\frac{B^2 R^6}{2\dot{M}\sqrt{2GM}}\right)^{2/7}, R_A = \frac{2GM}{w^2}$$



CGRO BATSE-DISCLA data (Bildsten et al, Koh et al 1997)



$$I\frac{d\omega}{dt} = K_+(\dot{M}) + K_-(\omega, B, \dot{M})$$

$$K_- = -\dot{M}\frac{\omega^2 {R_H}^{7/2}}{4\sqrt{2GM}}$$

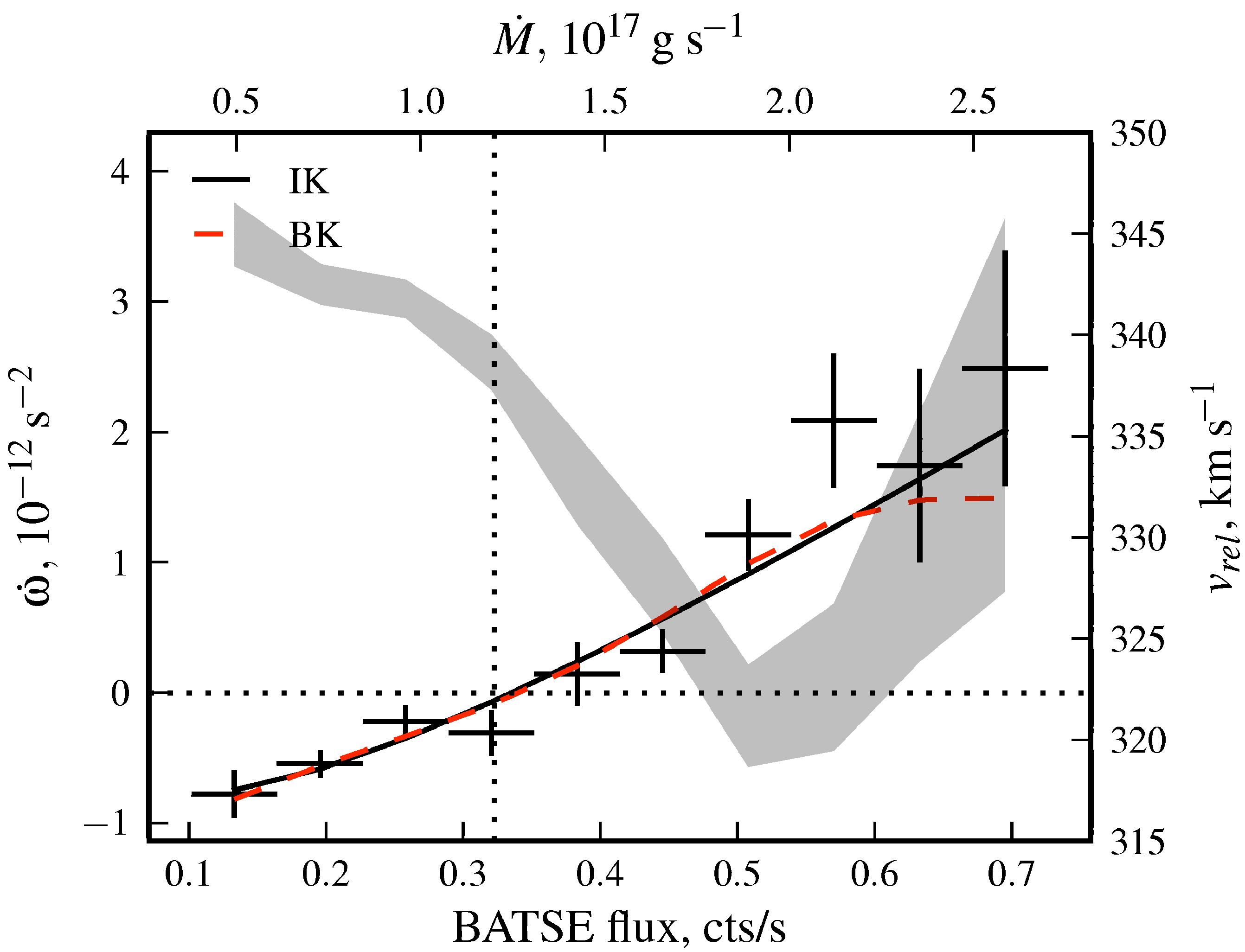
$$K_+ = \dot{M} k_w {R_A}^2 \Omega_{orb}$$

Davies et al, 1979

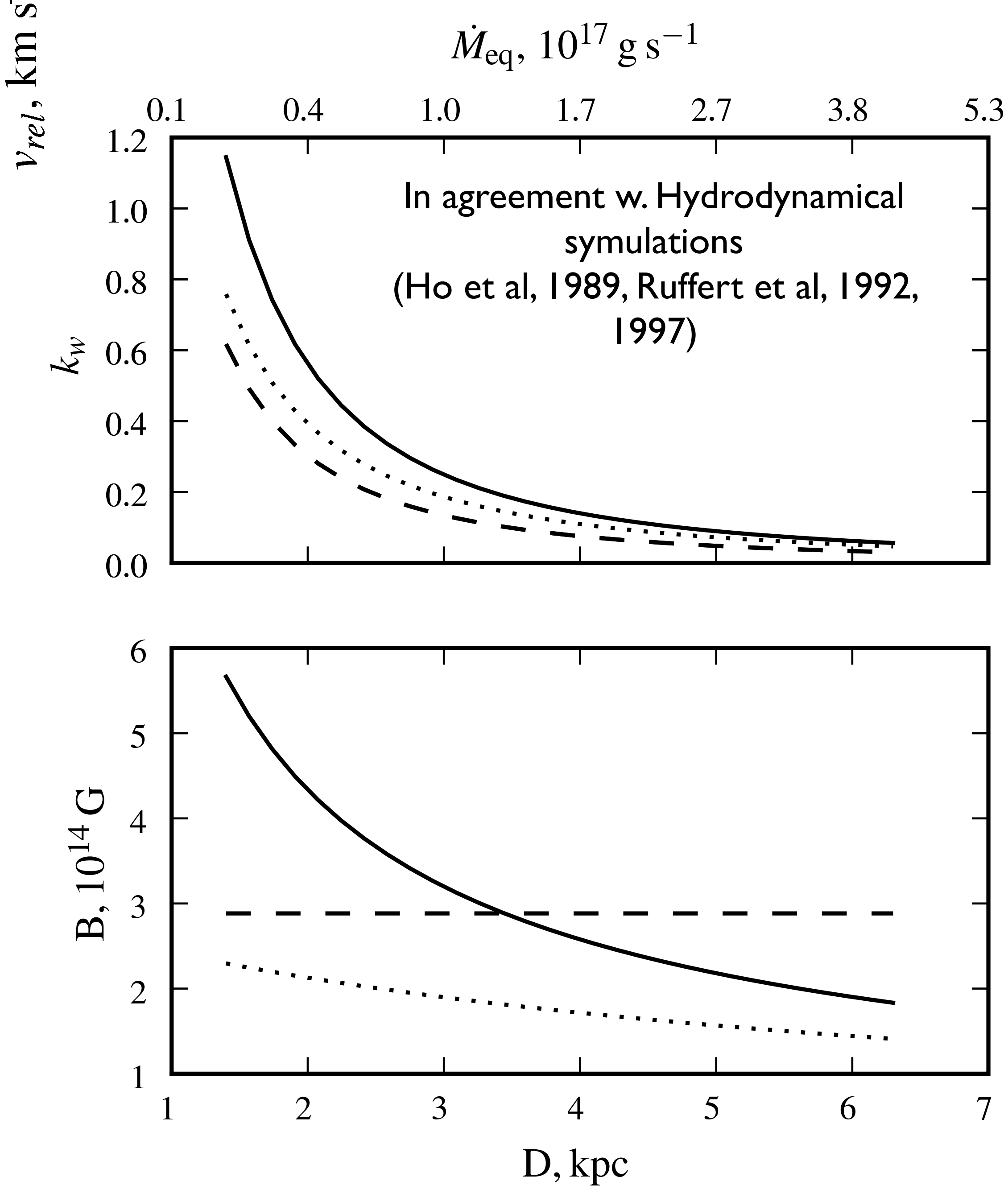
$$K_- = -\dot{M} k \frac{\xi}{2\pi} {R_H}^2 \omega$$

Illarionov-Kompaneec, 1990

$$R_H = \left(\frac{B^2 R^6}{2\dot{M}\sqrt{2GM}}\right)^{2/7}, R_A = \frac{2GM}{w^2}$$



CGRO BATSE-DISCLA data (Bildsten et al, Koh et al 1997)



$$I\frac{d\omega}{dt} = K_+(\dot{M}) + K_-(\omega, B, \dot{M})$$

$$K_- = -\dot{M}\frac{\omega^2 {R_H}^{7/2}}{4\sqrt{2GM}}$$

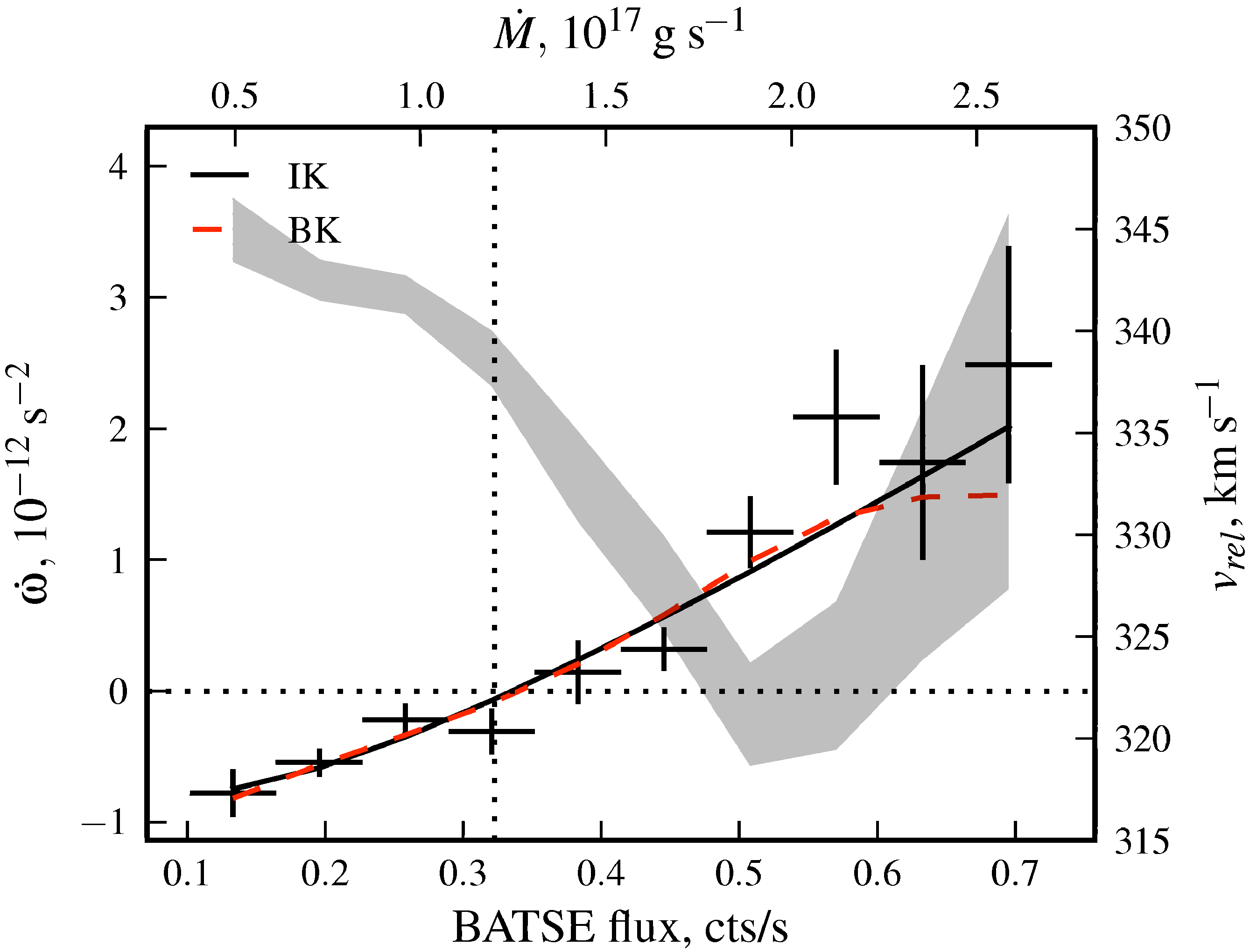
Davies et al, 1979

$$K_+ = \dot{M} k_w {R_A}^2 \Omega_{\rm orb}$$

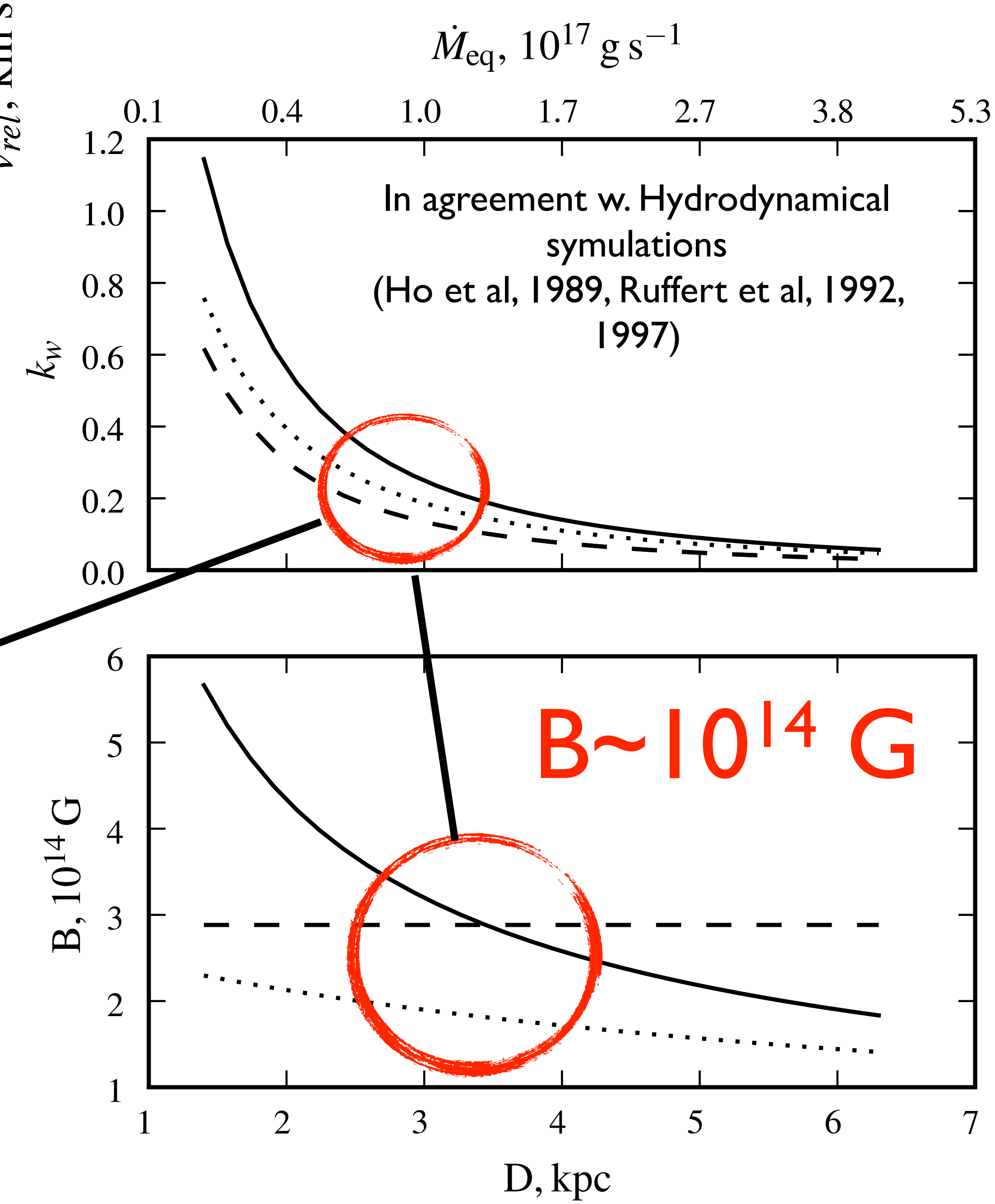
$$K_- = -\dot{M} k \frac{\xi}{2\pi} {R_H}^2 \omega$$

Illarionov-Kompaneec, 1990

$$R_H = \left(\frac{B^2 R^6}{2\dot{M}\sqrt{2GM}}\right)^{2/7}, R_A = \frac{2GM}{w^2}$$



CGRO BATSE-DISCLA data (Bildsten et al, Koh et al 1997)



$$I\frac{d\omega}{dt} = K_+(\dot M) + K_-(\omega, B, \dot M)$$

$$K_- = -\dot M \frac{\omega^2 {R_H}^{7/2}}{4\sqrt{2GM}}$$

Davies et al, 1979

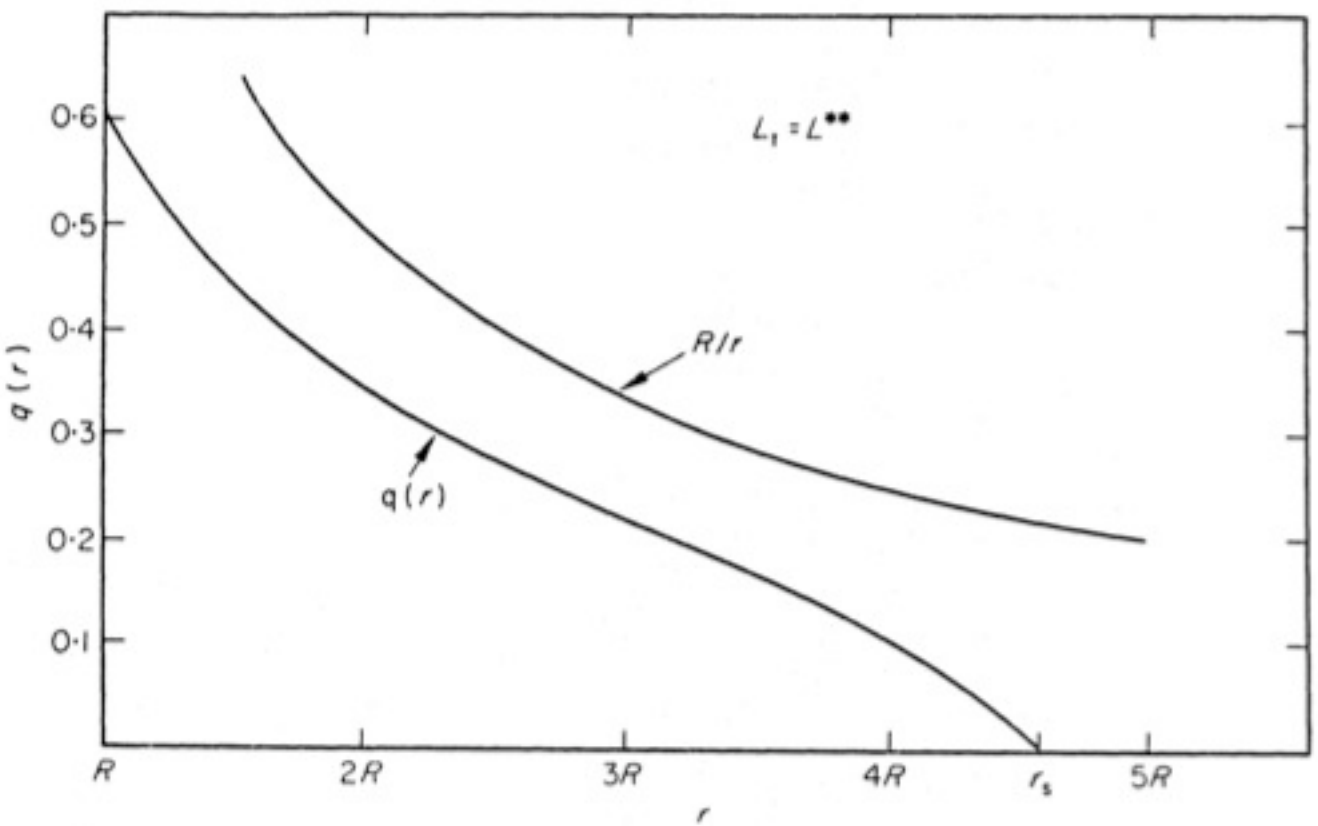
$$K_+ = \dot M k_w {R_A}^2 \Omega_{\rm orb}$$

$$K_- = -\dot M k \frac{\xi}{2\pi} {R_H}^2 \omega$$

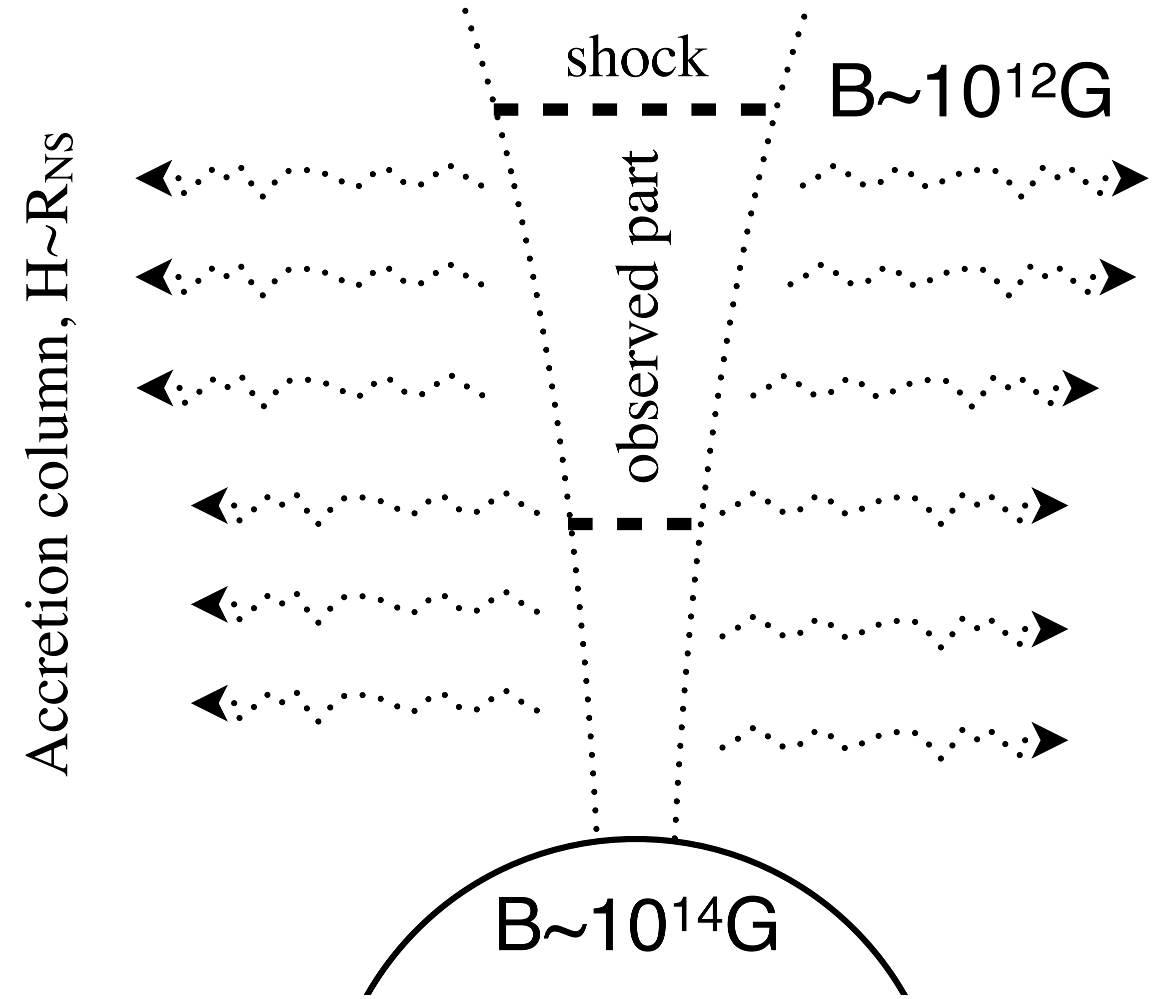
Illarionov-Kompaneec, 1990

$$R_H = \left(\frac{B^2 R^6}{2\dot M\sqrt{2GM}}\right)^{2/7}, R_A = \frac{2GM}{w^2}$$

What's about the CRSF?



Basko, Sunyaev, 1976

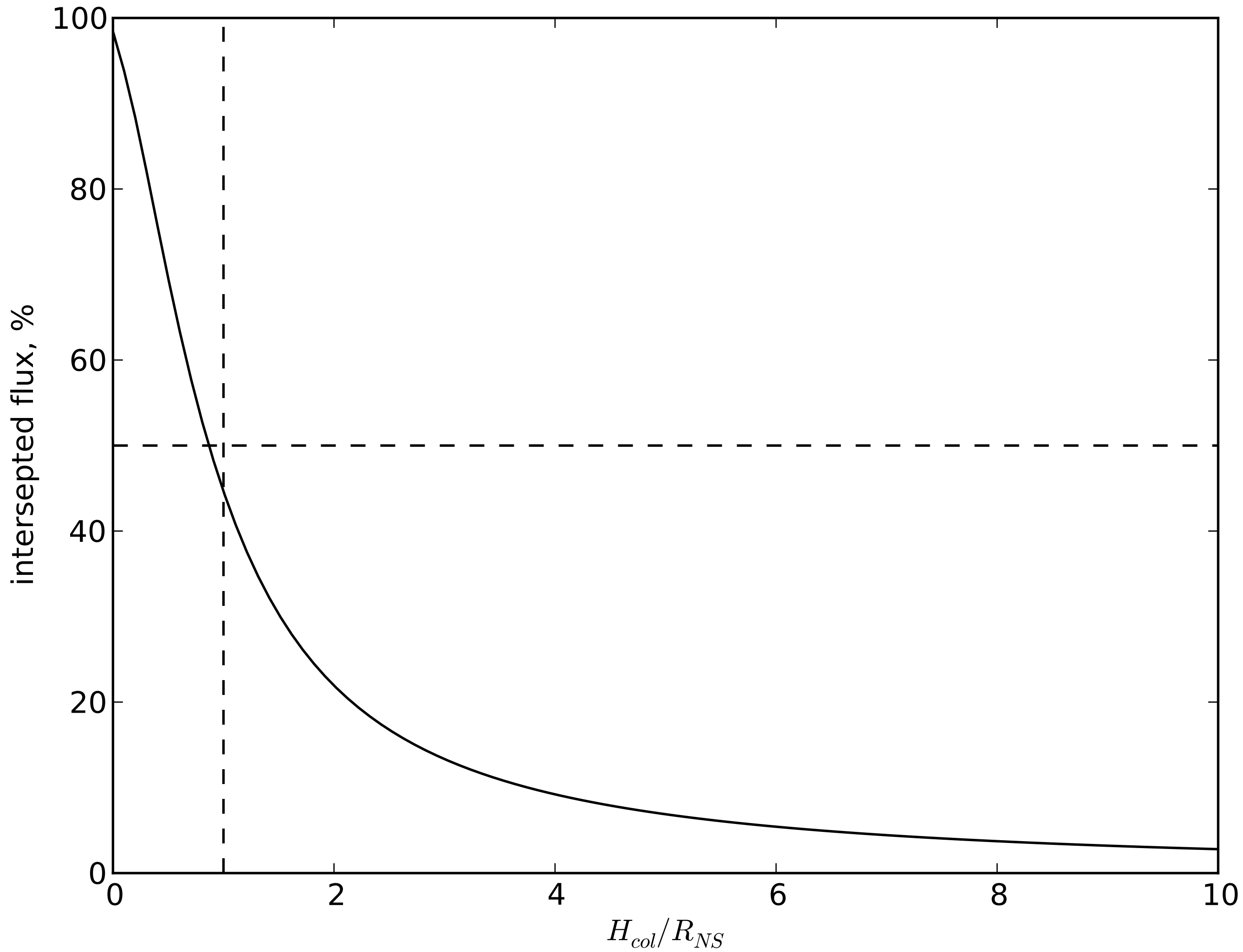


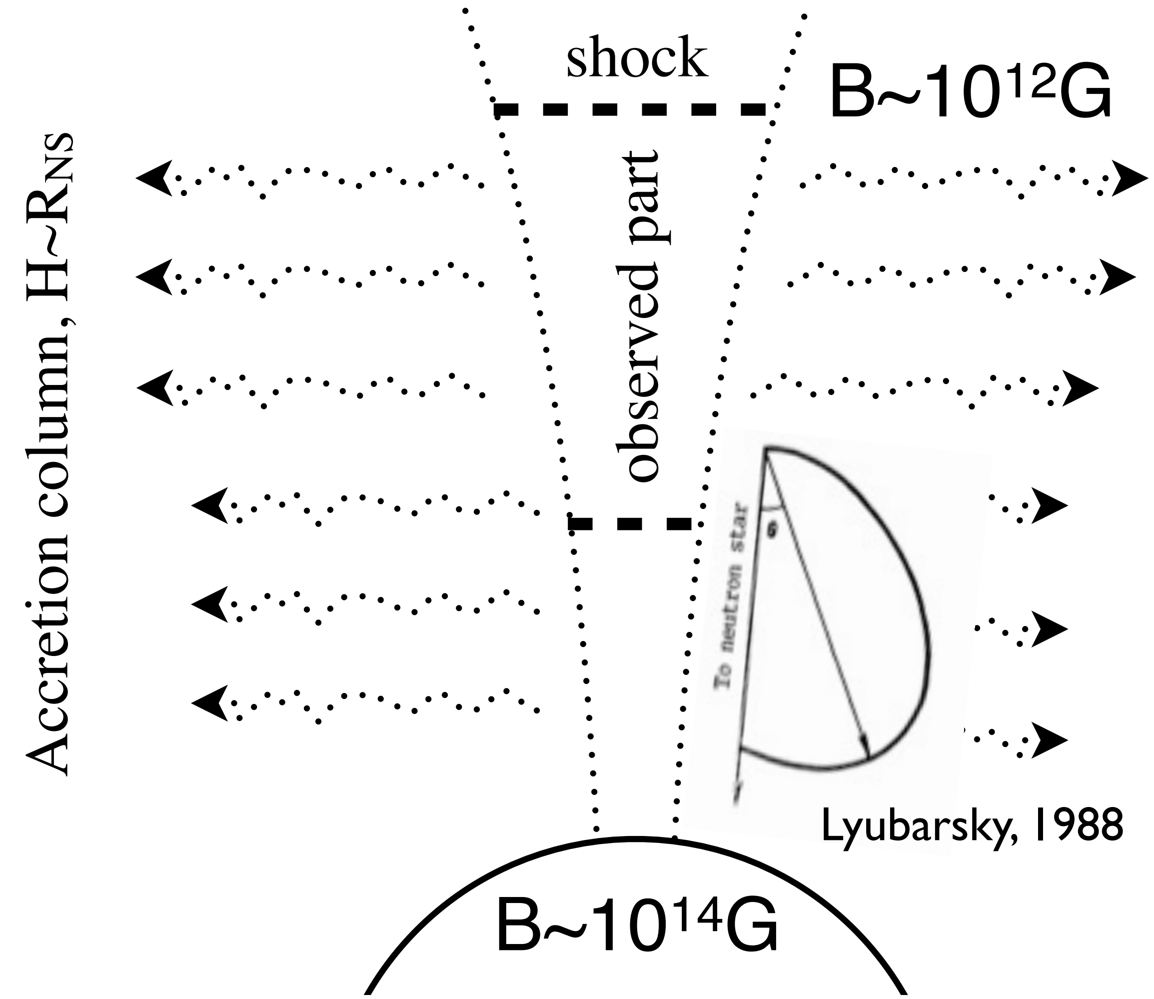
$$R \sin\theta \approx R(R/R_{\rm H})^{1/2} \approx 100 - 200 \text{ m}$$

$$L \approx 2\ \sigma_{\rm SB} T^4_{\rm Edd}\ 2\pi R \sin\theta\ H \Rightarrow H \sim 10 - 30\,{\rm km}$$

$$(R/R_*)^3 \sim (0.25 - 0.5)^3 \sim B/B* \Rightarrow B \approx 3 - 25 \times 10^{12}\,{\rm G}$$

What's about the CRSF?



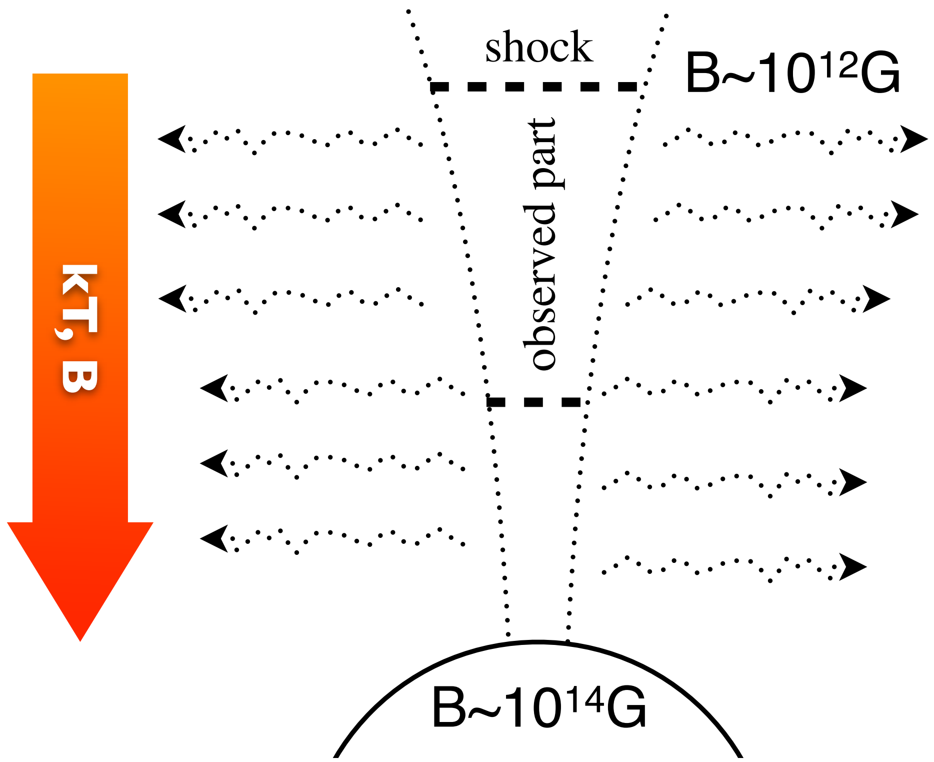


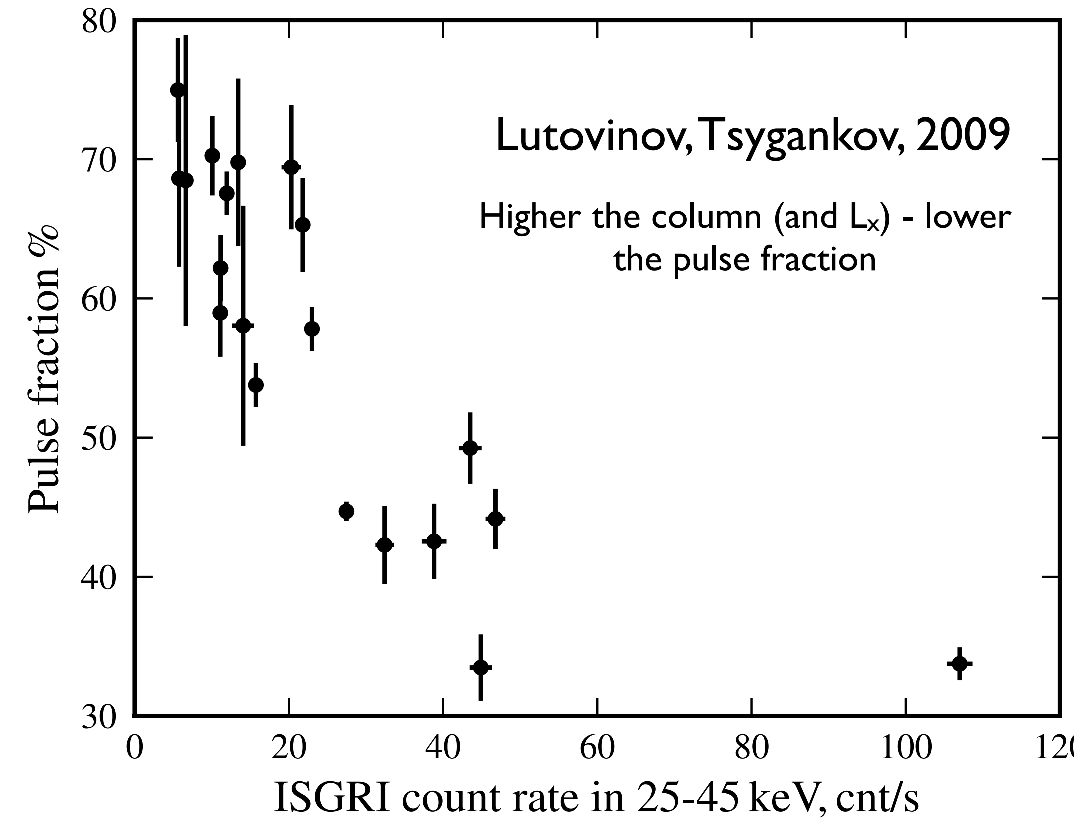
$$R\sin\theta \approx R(R/R_{\rm H})^{1/2} \approx 100 - 200 \text{ m}$$

$$L \approx 2\ \sigma_{\rm SB} T_{\rm Edd}^4\ 2\pi R \sin\theta\ H \Rightarrow H \sim 10-30\,{\rm km}$$

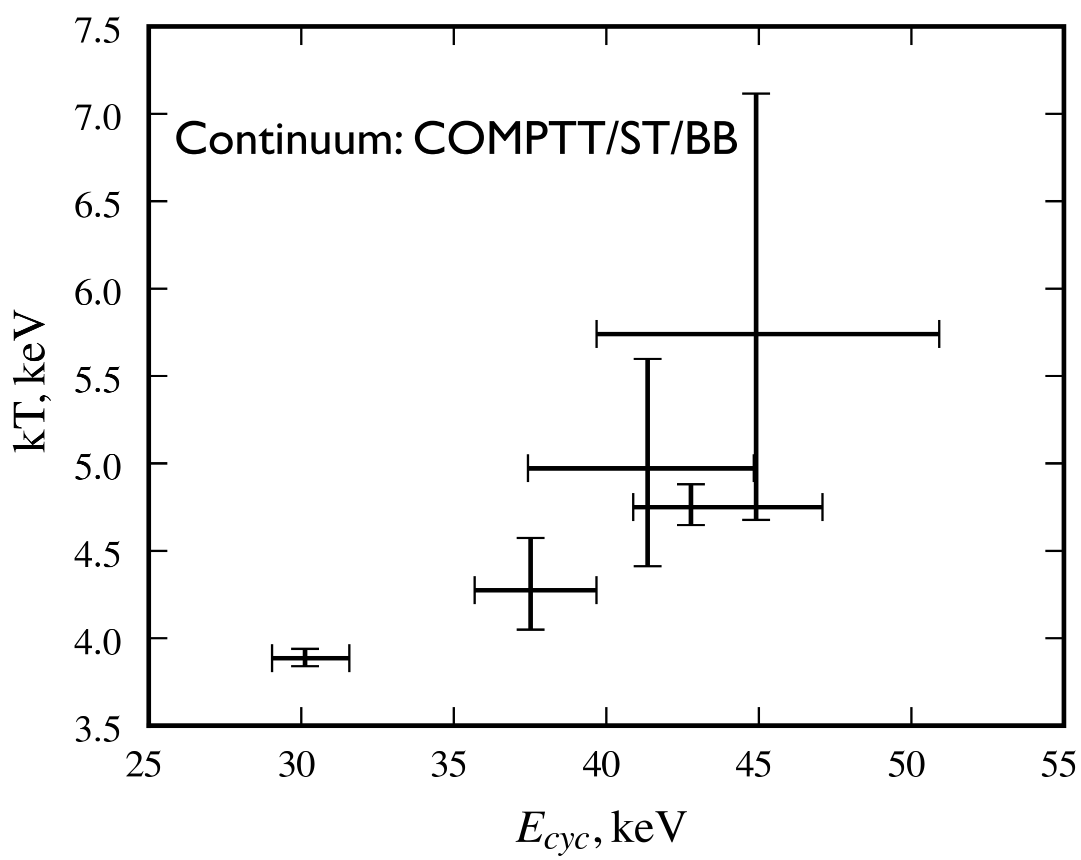
$$(R/R_*)^3 \sim (0.25-0.5)^3 \sim B/B* \Rightarrow B \approx 3-25\times 10^{12}\,{\rm G}$$

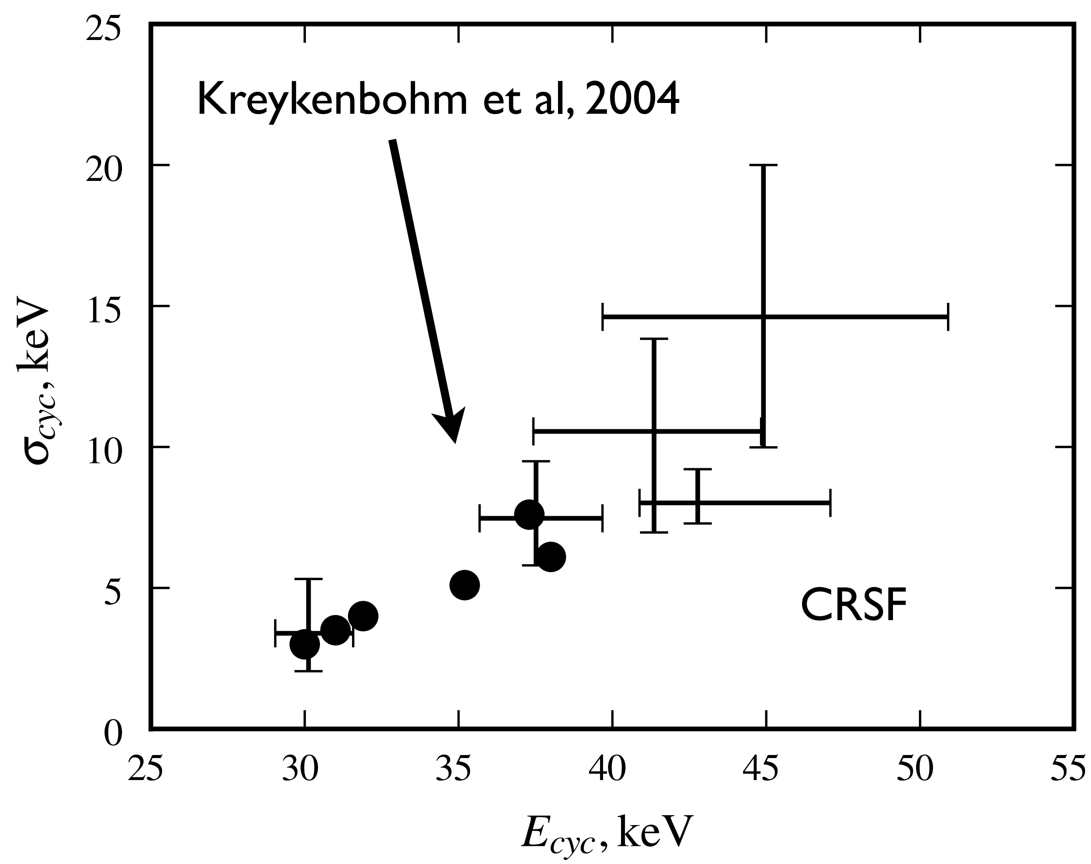
Is it possible at all? Don't know...





Phase dependence of the spectrum?





Safe to say (conclusions)

- It is more difficult (if possible) to explain the observed timing properties of GX 301-2 if the field Is weaker than B~10^{14}G.

- It is more difficult (if possible) to explain the observed L_x and pulse profile energy dependence of GX 301-2 (and many other pulsars) if there is no tall accretion column.

- If the column exists, we can not ignore contribution of the upper parts of the accretion column to the observed CRSF (geometry + beaming + we can't see contribution of lower parts to the CRSF at all due to instrumentation/spectral limitations).

- We do not really know, how the <u>observed</u> CRSF is formed in the accreting pulsars with an accretion columns (and halo), what implications does the geometry, advection- and gravitation-beaming have for the line formation process.

- The implications may be dominant, so this complex problem must be solved as a whole: "low-level" physics + geometry + relativistic effects (and this applies not only to GX 301-2, but for majority of pulsars with CRSF).