Partial Accretion in the Propeller Stage of Accreting Millisecond X-ray Pulsars

Can GÜNGÖR[1], K. Yavuz EKŞİ[1], Ersin Göğüş[2], & Tolga GÜVER[3]

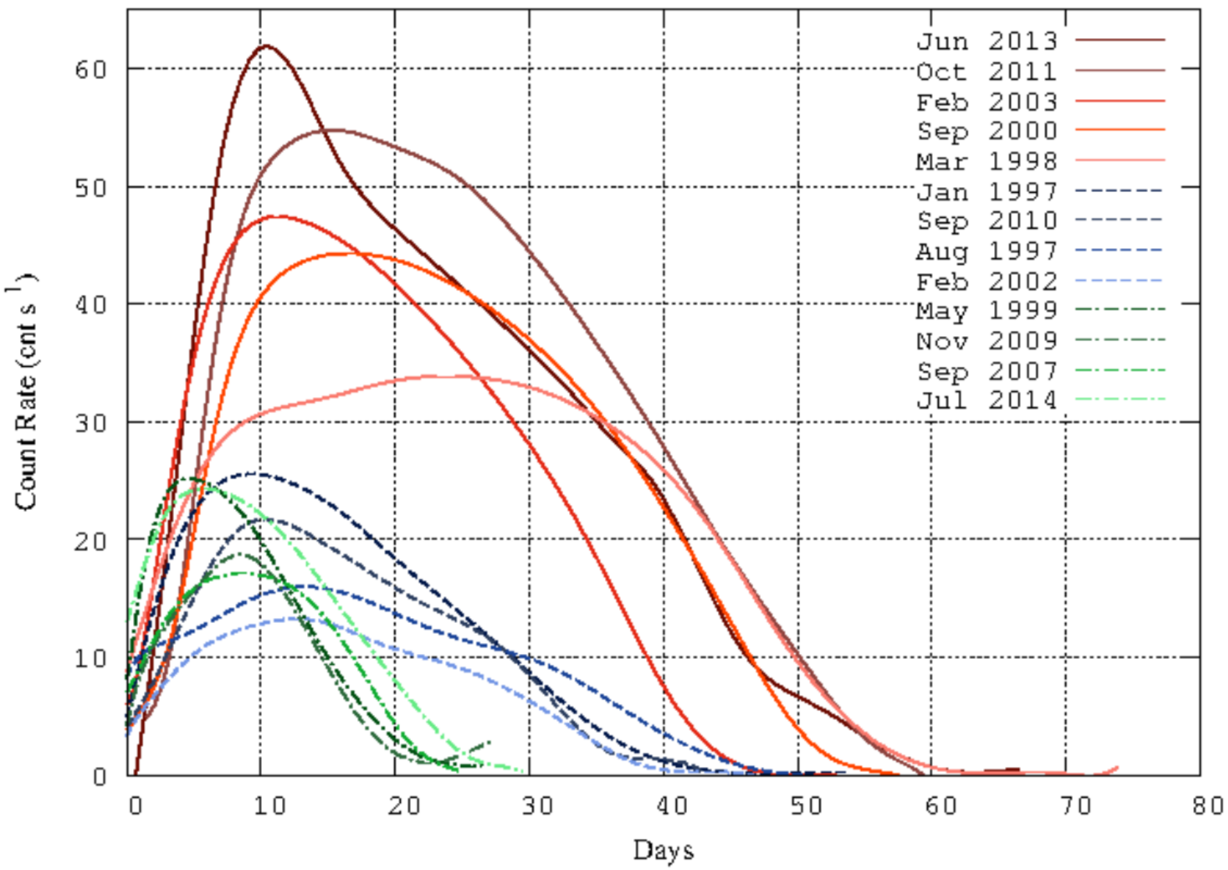
[1]Department of Physics Engineering, Istanbul Technical University

[2]Department of Physics, Sabanci University

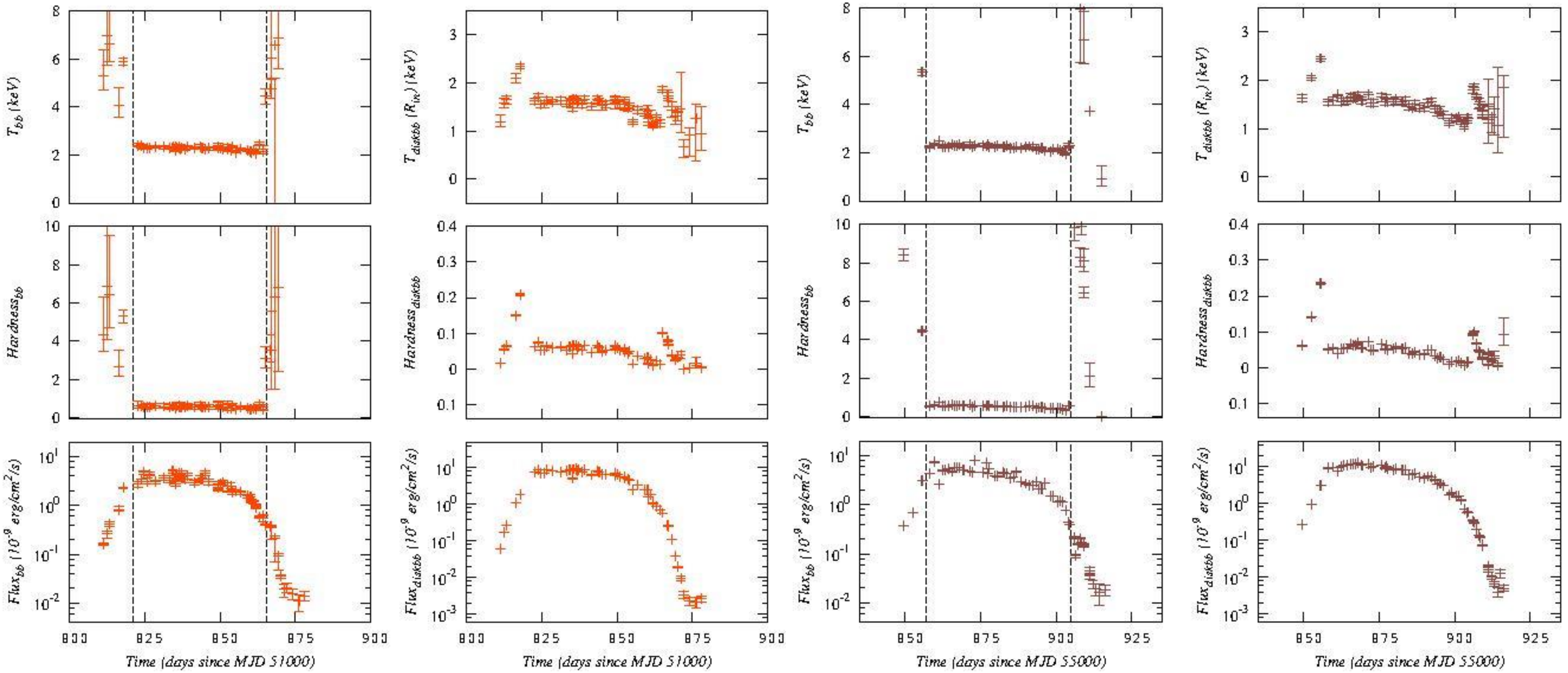
[3]Department of Astronomy and Space Sciences, Istanbul University

Classification of Outbursts Aql X-1

- Long – High Outbursts: 50-60 days, 37-61 cnt/s
- Medium – Low Outbursts: 40-50 days, 13-25 cnt/s
- Short – Low Outbursts: 20 days, 17-25 cnt/s



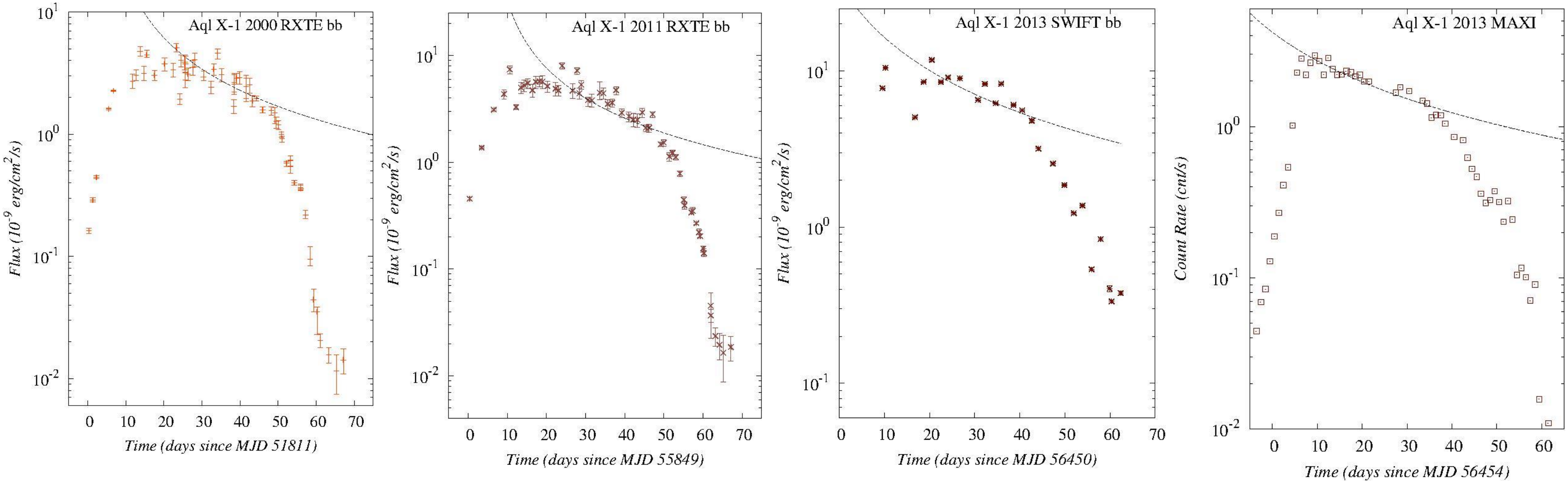
Observation and Data Analysis



Result of sprectral analyses of RXTE/PCA observations of the 2000 and the 2011 outbursts of Aql X-1.

The light curve for the blackbody component (bottom left), the light curve for the disk blackbody component (bottom right), the time evolution of the ratio of the flux in the range of 3-10 keV to to the flux 10-30 keV only for blackbody component (middle left), the time evolution the ratio of the flux in the range of 3-10 keV to to the flux 10-30 keV only for disk blackbody component (middle right), the time evolution of the temperature of the blackbody in keV (top left), the time evolution of the Inner disk temperature of disk blackbody component (top right).

$\dot{M}_*/\dot{M}$ vs Fastness Parameter; Aql X–1



The Slow decay phase represent the accretion stage. We fit the slow decay phase with a simple power low.

$$L(t) = L_0\left[1+\left(\frac{t-t_0}{\tau}\right)\right]^{-\propto}, t_0 < t < t_{knee}, L < L_0$$

Assumption; $\dot{M}(t)$ follows the same trend in the propeller stage.

Since $L_X = \frac{GM\dot{M}_*}{r_*}$, **then** $f \equiv \frac{\dot{M}_*}{\dot{M}} = \frac{L_X}{L(t)} = f(t)$

$\dot{M}_*/\dot{M}$ vs Fastness Parameter; Aql X–1

$$\omega_* = \frac{\Omega_*}{\Omega_K(R_{in})} = \left(\frac{R_{in}}{R_{co}}\right)^{3/2} \longleftarrow \quad R_{co} = \left(\frac{GM}{\Omega^2}\right)^{1/3} \quad R_{in} = \left(\frac{GM}{\Omega^2(R_{in})}\right)^{1/3}$$

- When $R_{in} = R_{co}$, we can define the critical mass accretion $(\dot{M}_{co})$ rate as following;

$$\dot{M}_{co} = \frac{\zeta^{7/2}\mu^2{\Omega_*}^{7/3}}{\sqrt{2}(G\dot{M}_*)^{5/3}} \longleftarrow \quad R_A = \left(\frac{\mu^4}{2GM\dot{M}^2}\right)^{1/7} \quad R_{in} = \zeta\, R_A$$

$$\omega_* = \left(\frac{\dot{M}}{\dot{M}_{co}}\right)^{-3/7} = \left(\frac{L(t)}{L_c}\right)^{-3/7} = \left(\frac{L_0\left[1+\left(\frac{t-t_0}{\tau}\right)\right]^{-\propto}}{L_c}\right)^{-3/7} = \omega_*(t)$$

$\dot{M}_*/\dot{M}$ vs Fastness Parameter; Aql X–1

As a result, we obtain two parameters, both depends on time

$$\omega_*(t) = \left(\frac{L_0\left[1+\left(\frac{t-t_0}{\tau}\right)\right]^{-\propto}}{L_c}\right)^{-3/7}$$

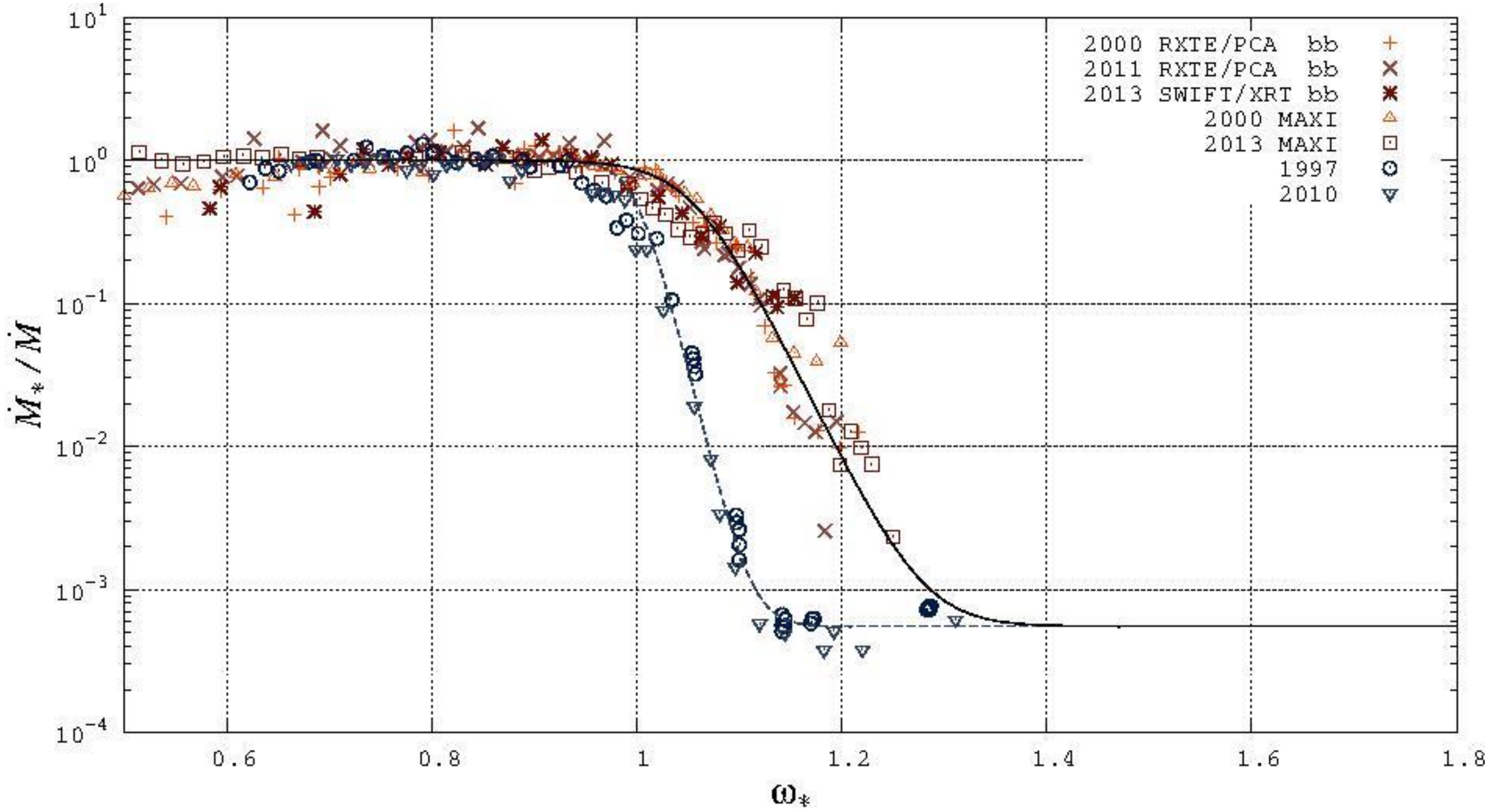
$$f(t) = \frac{L_X}{L_0\left[1+\left(\frac{t-t_0}{\tau}\right)\right]^{-\propto}}$$

We can make a parametric plot of f vs ω_*
As expected f function shows a step function: All of the material falls onto the neutro star in accretion stage, a portion of the material falls onto the neutron star in the propeller stage and no falling material in the radio pulsar stage.

$$f(\omega) = \begin{cases} 1, & \omega < 1 \\ 0, & \omega \geq 1 \end{cases}$$

$$f(\omega) = \frac{1}{2}\left[(1+f_{min}) + (1-f_{min}) \times tanh\left(\frac{\omega_c-\omega}{\delta}\right)\right]$$

Result:



$$f(\omega) = \begin{cases} 1, & \omega < 1 \\ 0, & \omega \geq 1 \end{cases}$$

$$f(\omega) = \frac{1}{2}\left[(1 + f_{min}) + (1 - f_{min}) \times tanh\left(\frac{\omega_c - \omega}{\delta}\right)\right]$$

Thanks for listening

Can GÜNGÖR
Ress. Assist.
Istanbul Technical University