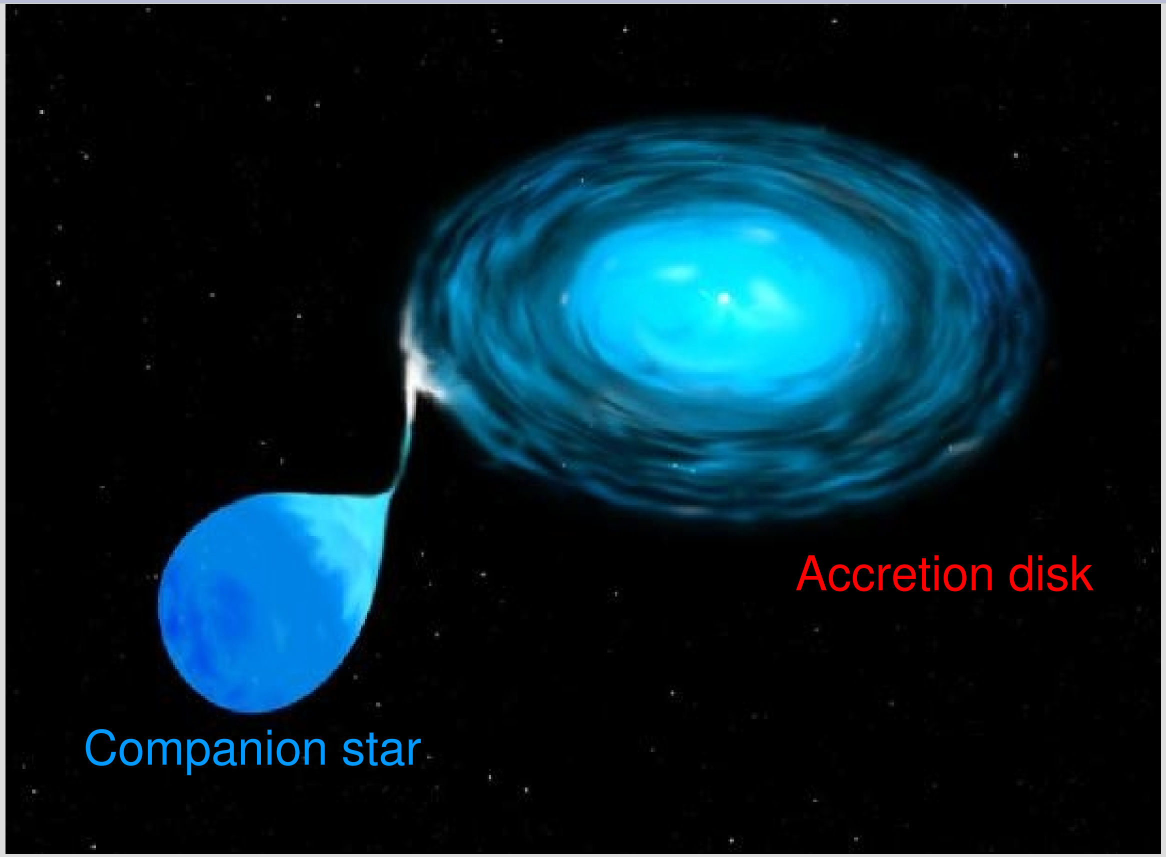
A. Meshcheryakov
M. Revnivtsev

Estimation of orbital parameters of LMXB from observations of their aperiodic optical variability.

ИКИ

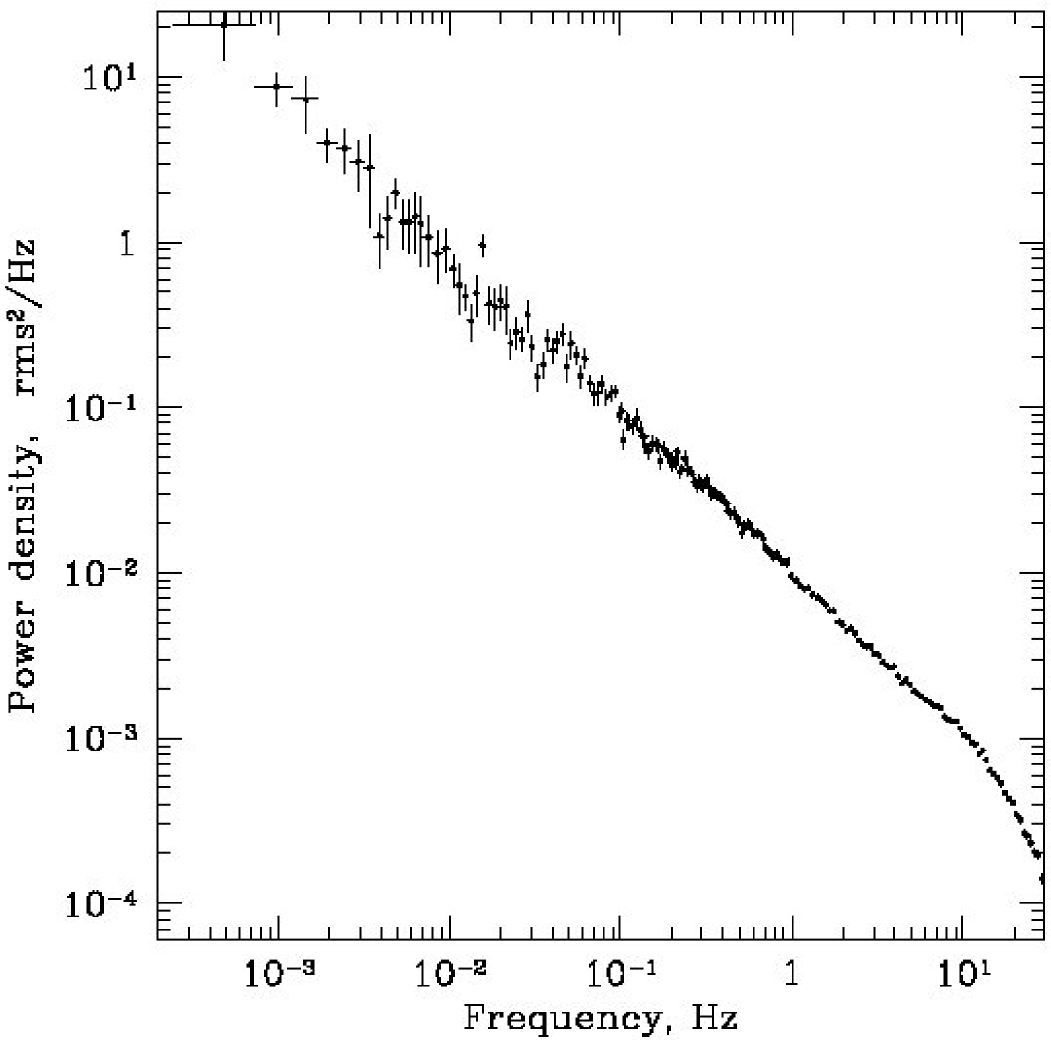
Low-mass X-ray binaries (LMXB).



- Close binary system.
- Optical star : M<~1Msun
- Compact object : neutron star or black hole
- Accretion disk emits radiation in broad range:

Optical radiation – from outer radii of the disk,
X-rays – from the central part.

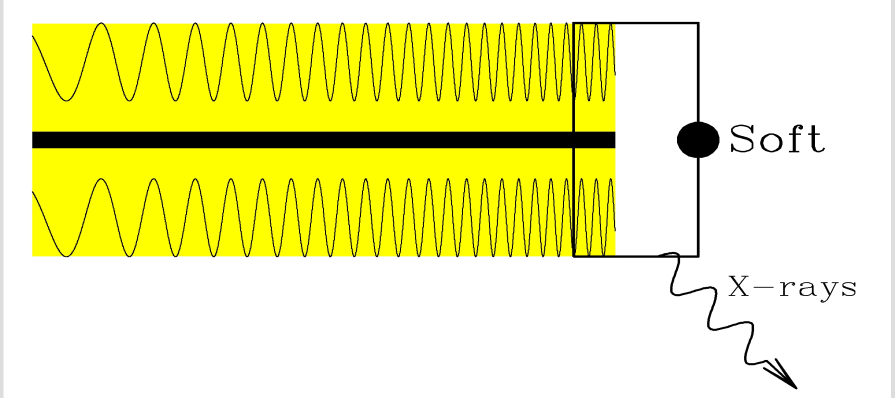
Characteristic aperiodic variability in Xray binaries .



X-ray fluctation power density spectrum of Cyg X-1 (soft state):

“flicker noise” $P \propto \nu^{-1}$

$10^{-4} .. 10\, Hz$



propagation flow model (Lyubarsky, 1997)

Fig. from Churazov et al.,2001

Light curve
(evenly sampled)

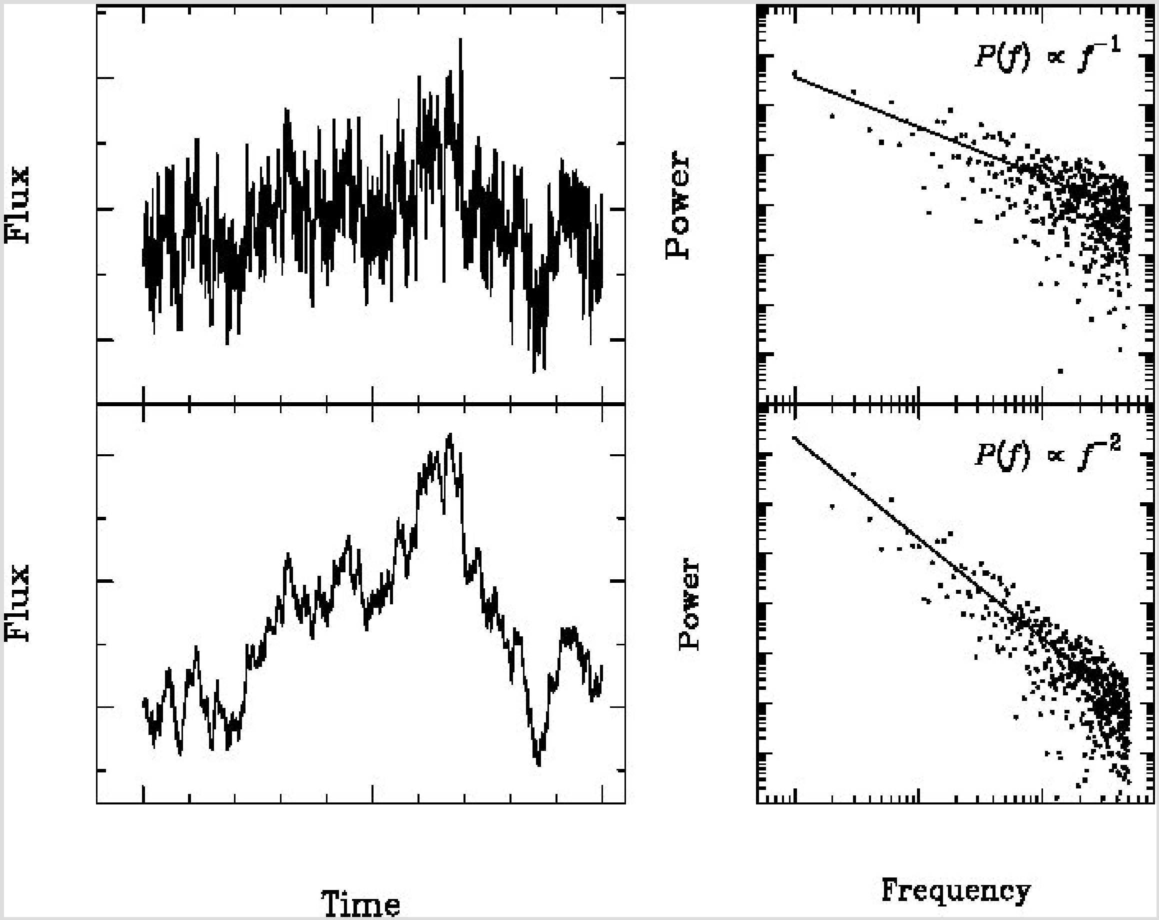
Fluxes $\{x_i\}$ measured at discrete times $t_i(i=1,2,\ldots N)$

Power density spectrum

$$P(f_j) = A|DFT(f_j)|^2 = \frac{2\Delta T}{\bar{x}^2 N}|DFT(f_j)|^2$$

Frequencies: $f_j = j/N/\Delta T\,(j=1,2,..\frac{N}{2})$

$$|DFT(f_j)|^2 = \left|\sum_{i=1}^{N} x_i\, e^{2\pi i f_j t_i}\right|^2 = \left\{\sum_{i=1}^{N} x_i\, \cos(2\pi f_j t_i)\right\}^2 + \left\{\sum_{i=1}^{N} x_i\, \sin(2\pi f_j t_i)\right\}^2$$



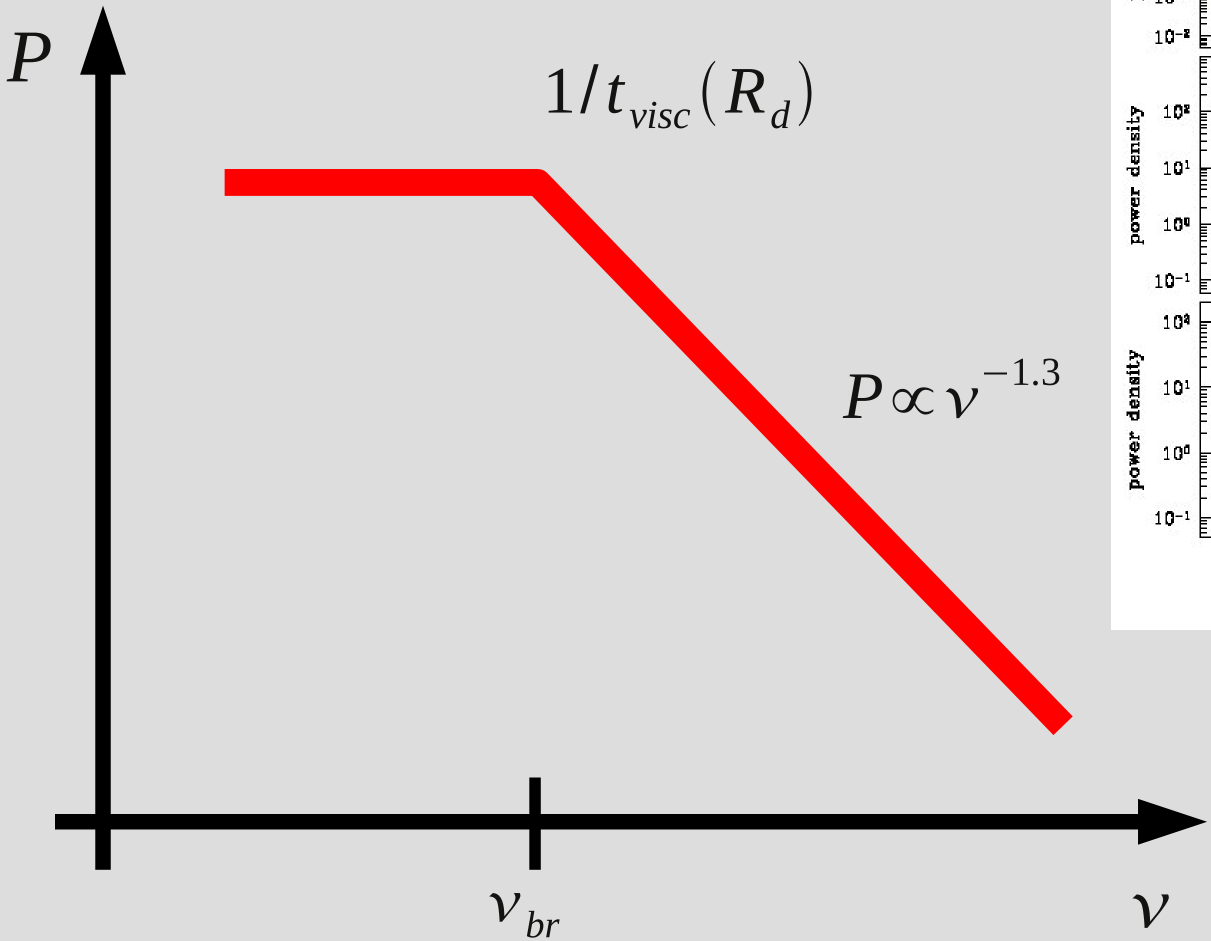
PDS range: $\frac{1}{T}\cdots\frac{1}{2\Delta T}=f_{Nyq}$

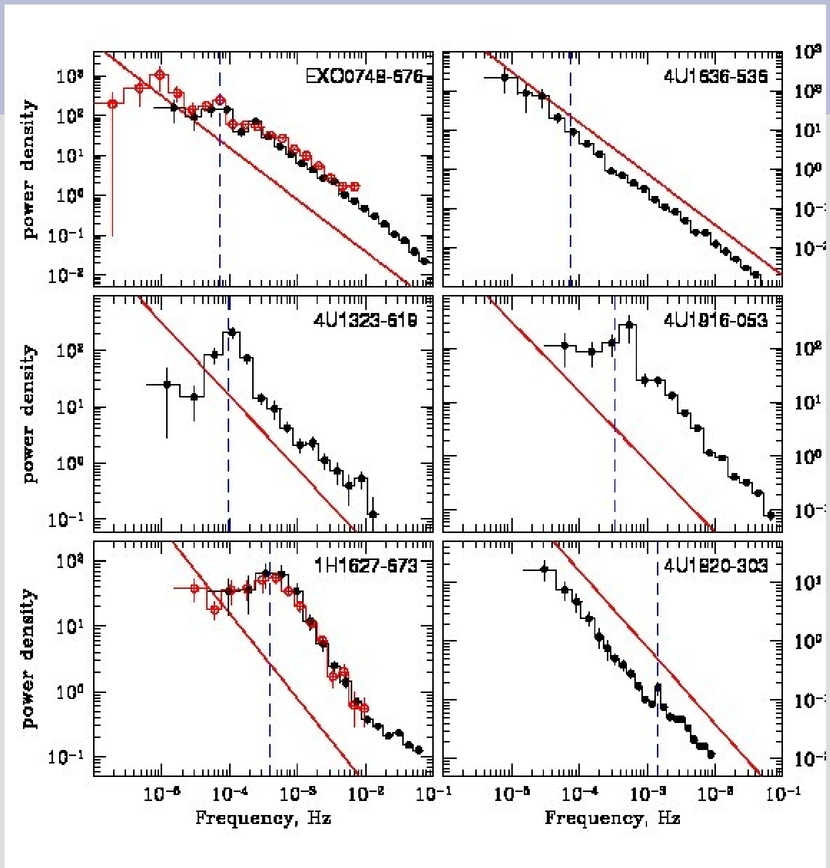
Specific forms of PDS:

"white noise" : $P(f)=const$

"red noise" : $P(f)\propto f^{-\alpha}, \alpha>1$

Low-frequency break in X-ray fluctation power density spectra of LMXB.





Gilfanov, Arefyev (2005)

Expectations from theory:

Standard accretion disk model (Shakura&Syunyaev, 1973)

3rd Kepler law

$$t_{visc} = \frac{2}{3\alpha}\left(\frac{H_d}{R_d}\right)^{-2}\frac{1}{\omega_k(R_d)}$$

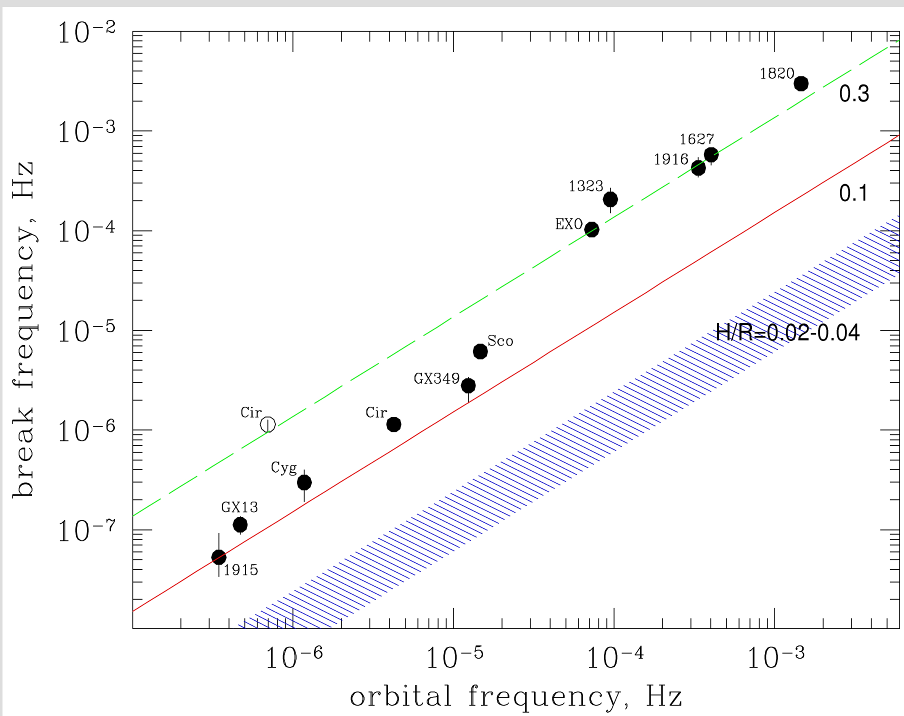
$$P_{orb} = \frac{2\pi a^{3/2}}{\sqrt{G(M_1+M_2)}}$$

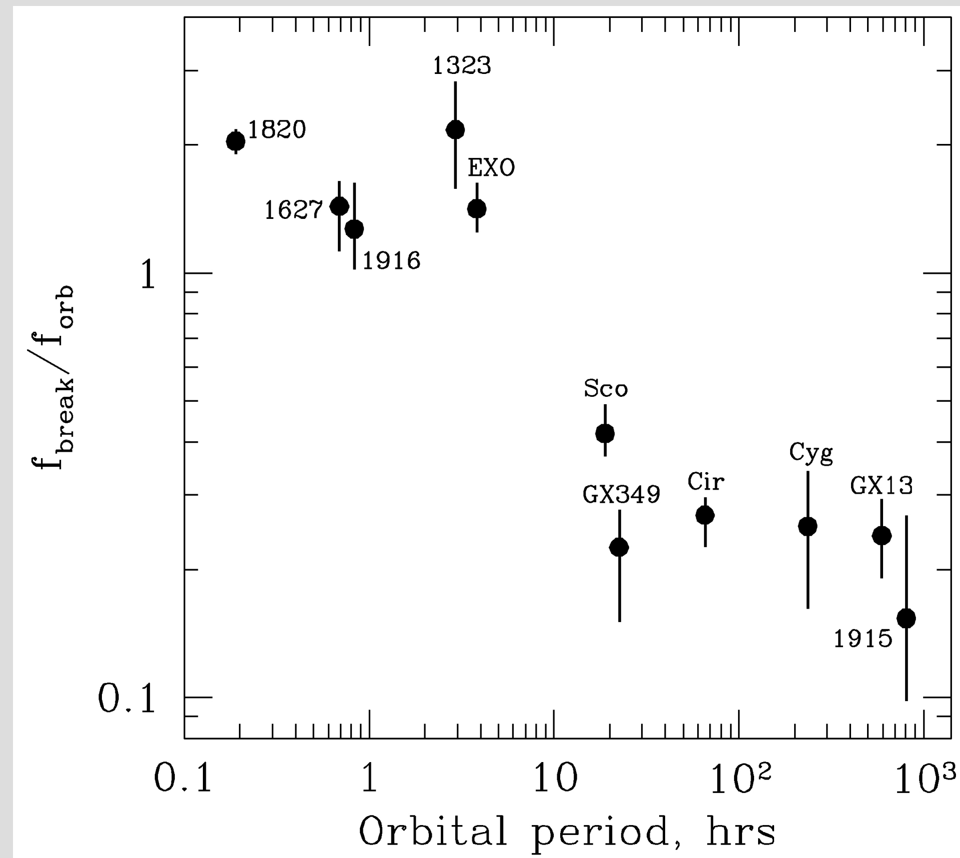
$$\nu_{break} = \beta\frac{1}{t_{visc}}$$

$$\frac{\nu_{break}}{\nu_{orb}} = \frac{3\pi\alpha\beta}{\sqrt{1+M_2/M_1}}\left(\frac{H_d}{R_d}\right)^2\left(\frac{R_d}{a}\right)^{-3/2}$$

Orbital period of LMXB can be estimated from their aperiodic variability (by measuring low-frequency break in PDS) !!!

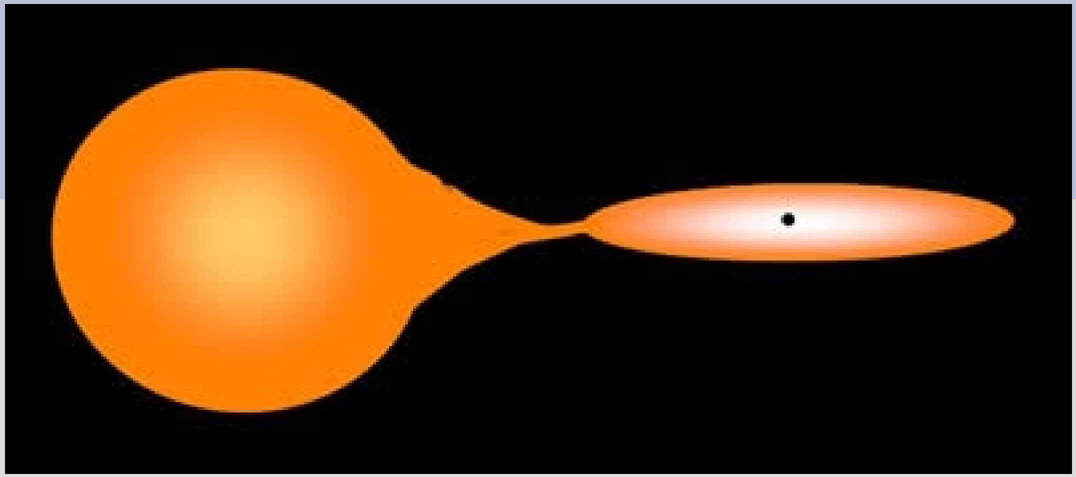
Short-period LMXB: $\frac{\nu_{br}}{\nu_{orb}} \approx 1.4$





Gilfanov, Arefyev (2005)

GS1826-238



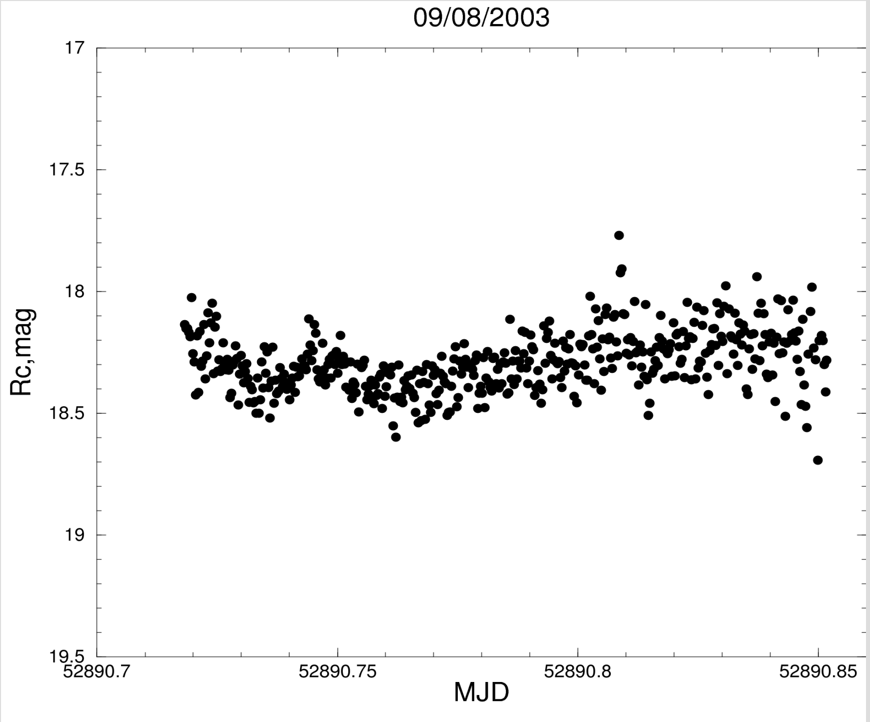
- I type X-ray burster (stable bursts every 4-6 hours)
- Distance : *7.5 kpc*
- Optical flux (R≈*18.2 mag Sep2003)* comes from irradiated accretion disk
- Disk size Rd≈*8.4e10 cm* (from burst delay between X-ray and optical band)
- Expected Porb : *2 – 7 h.*

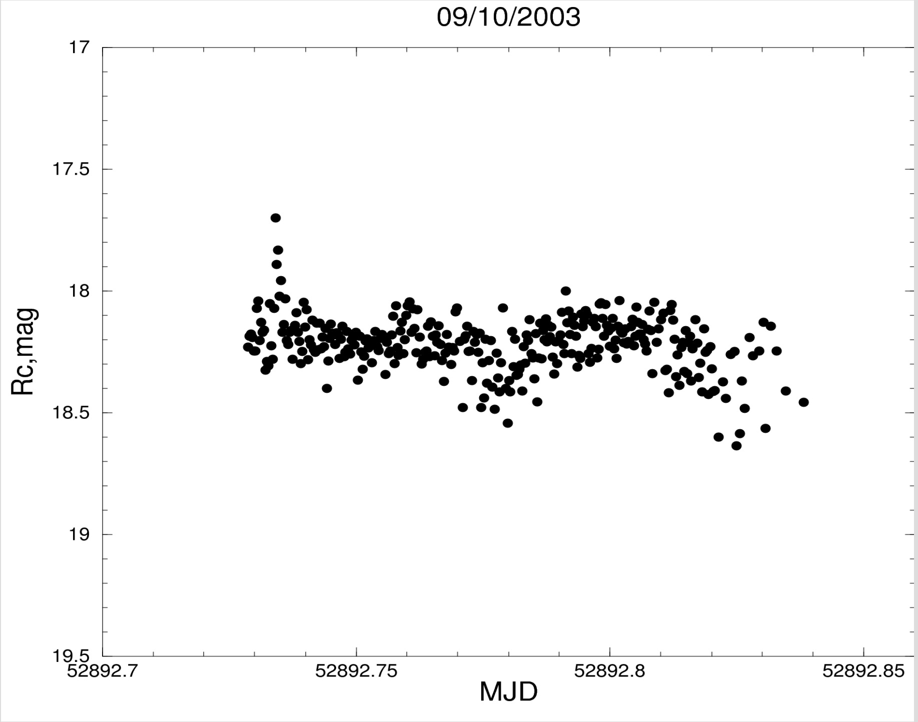
Optical light curves of GS1826-238
/ 1.5-m Russian-Turkish Telescope RTT150 /

Даты наблюдений	фильтр	t_{exp} [сек] †	номер серии
2003/09/6–12	R	4	1
2003/10/16,18,19,22	R	4	2
2004/06/29	V	10	3
2004/06/30 , 07/2-5	R	10	3
2004/07/31 , 08/1,4	R	20	4
2004/08/29–09/02	r	20	5

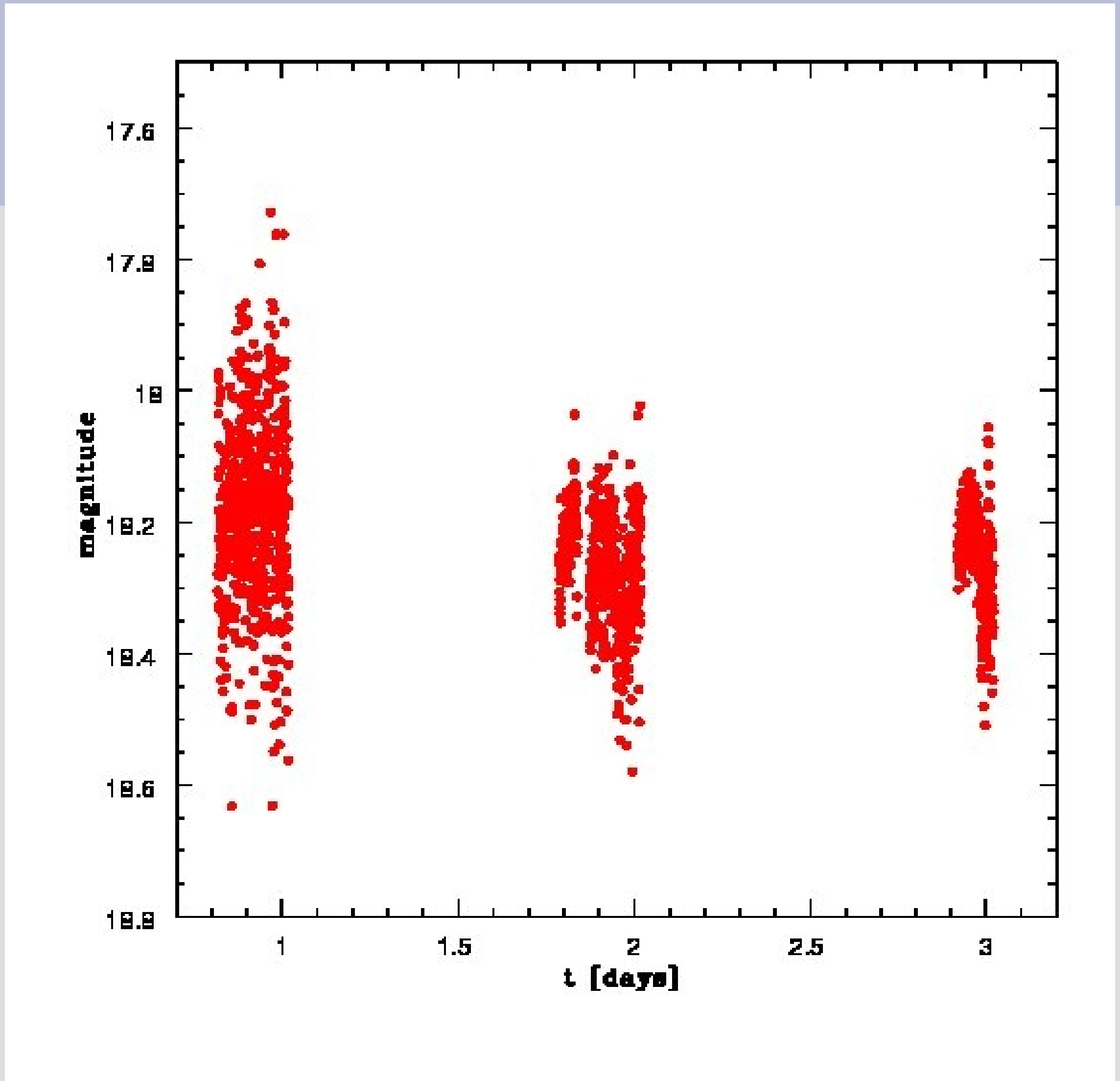
† t_{exp} – время экспозиции одной картинки в серии.

- Object was observed 25 nights during a year: 09/2003 – 09/2004, 1.5-4 hours every night
- The total light curve can be divided into 5 time intervals, duration ~5-7 nights each
- Bursts were removed from optical light curves





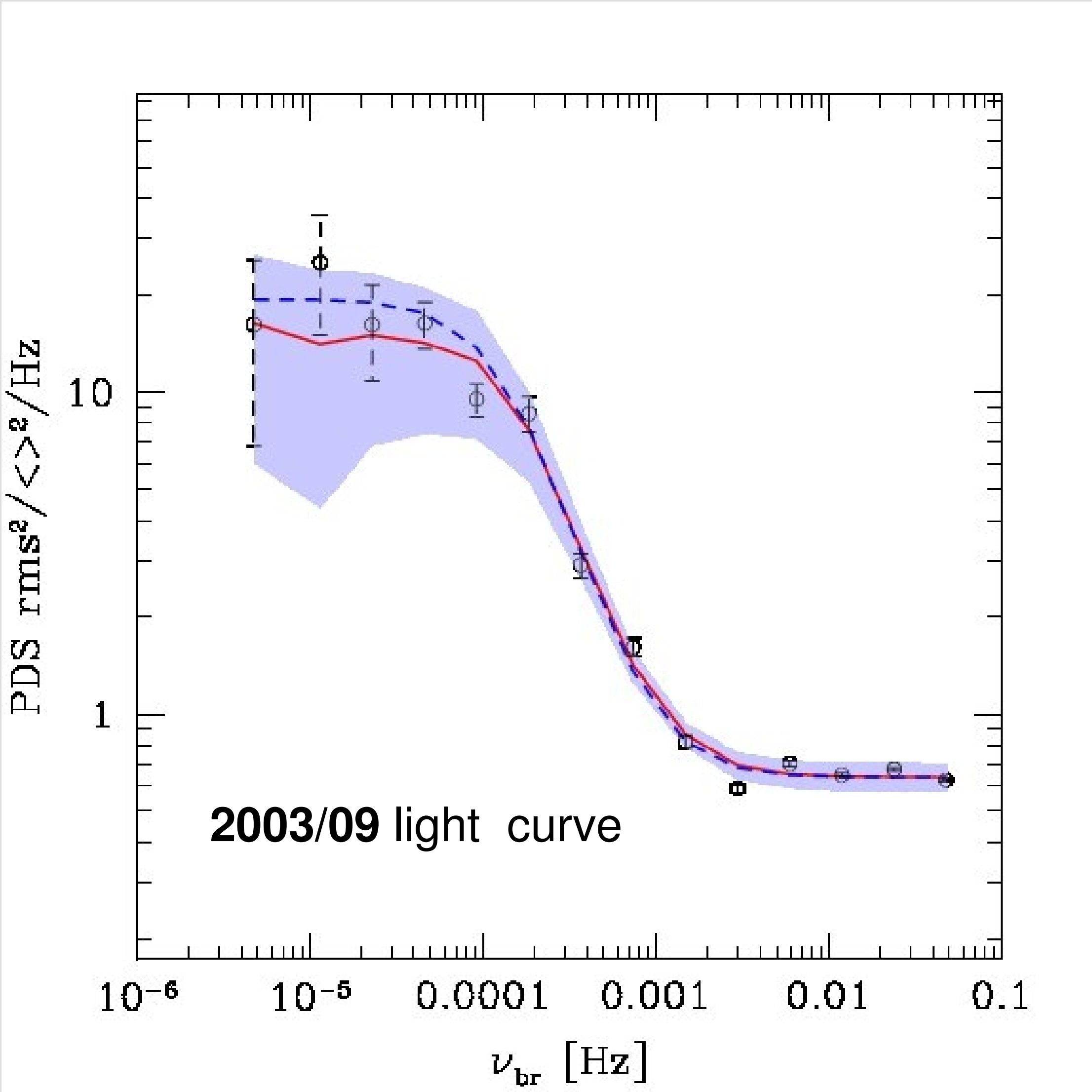
Gaps in optical lightcurve of GS1826-236.



Power density spectrum for non-evenly spaced light curve :

Lomb-Scargle periodogramm method (see Scargle, 1982) used.

GS1826-238 : observed power spectrum of optical variability.



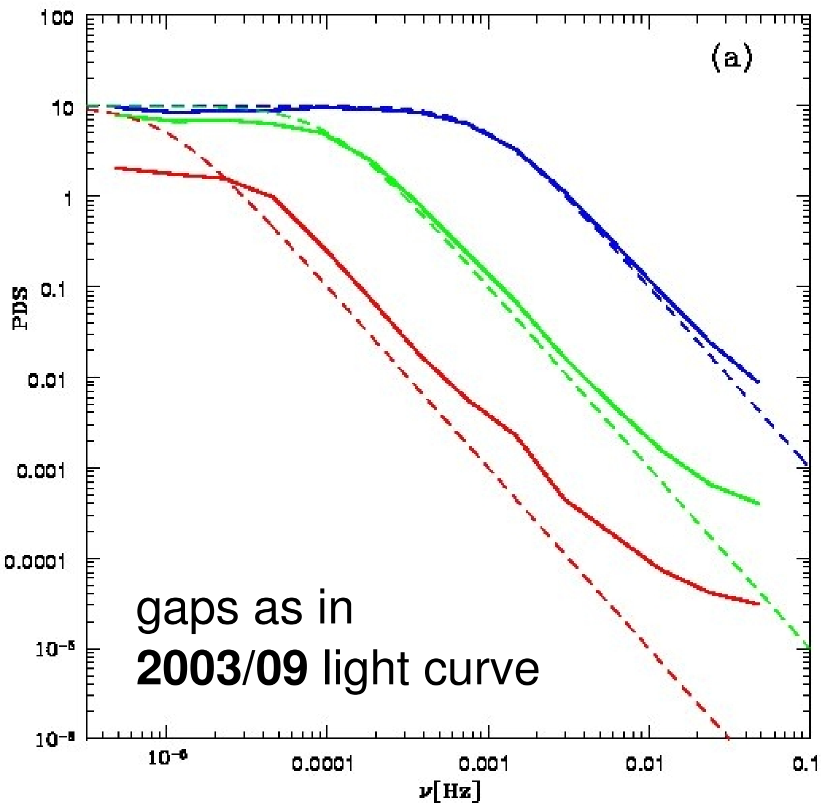
PDS model:

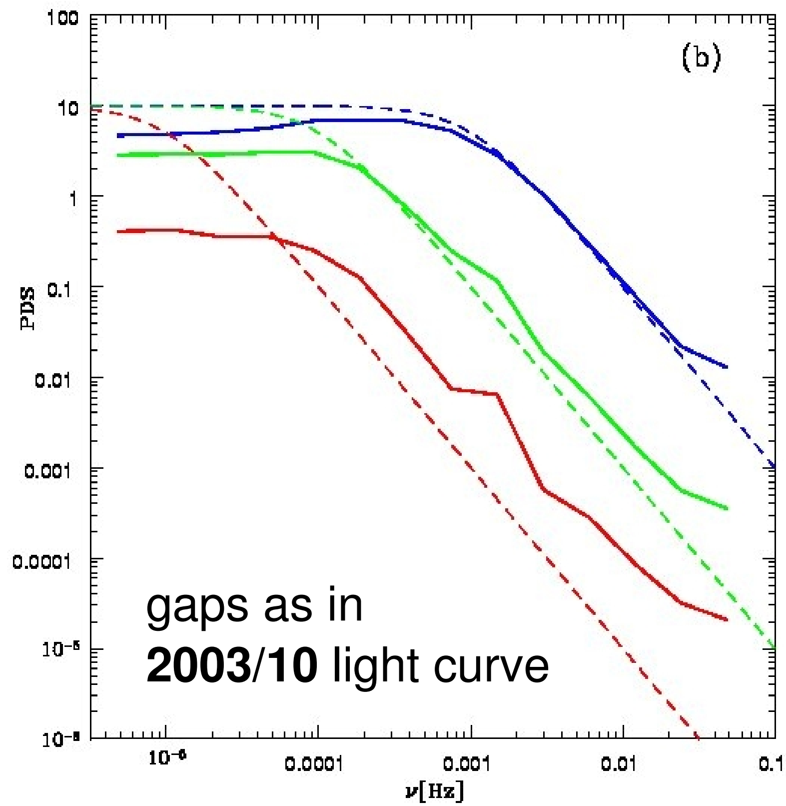
$$P(\nu) = \frac{A}{\left[1 + \left(\frac{\nu}{\nu_{br}}\right)^2\right]^{\alpha/2}} + C$$

Monte Carlo simulations:

How gaps in light curve distort the measurement of PDS.

1) Changes in average PDS : “red noise” leakage

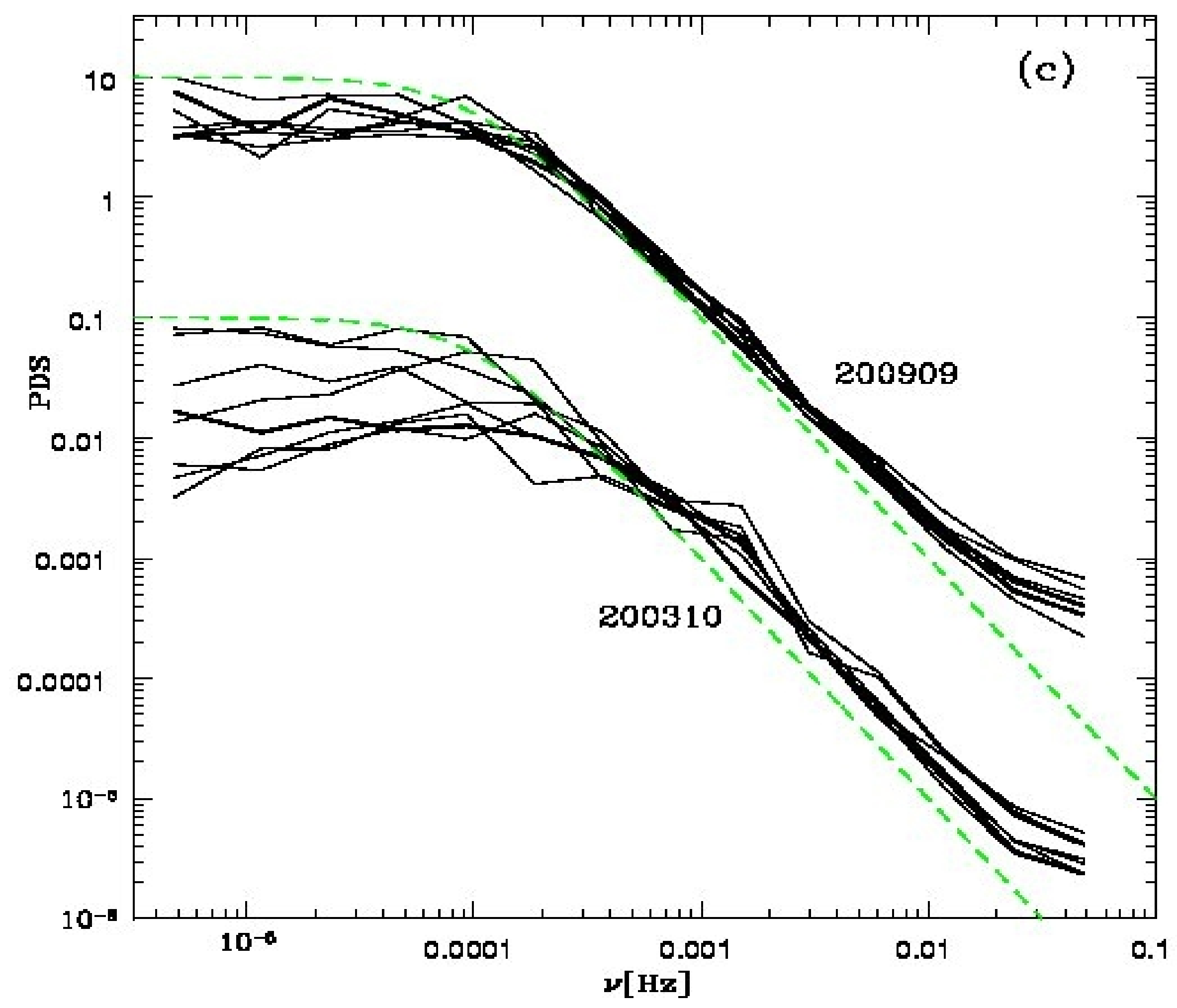




Monte Carlo simulations:

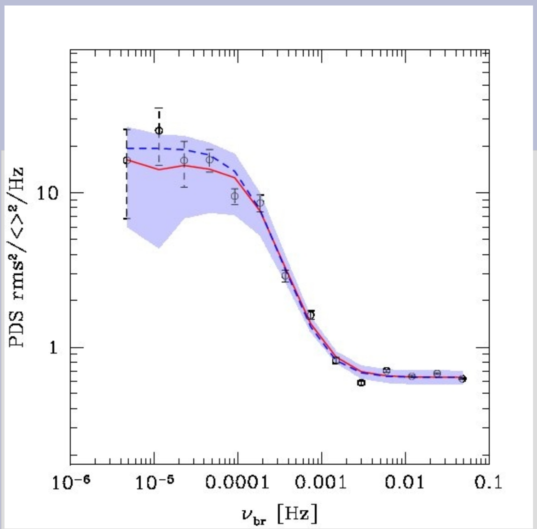
How gaps in light curve distort the measurement of PDS.

2) Larger variations in individual PDS

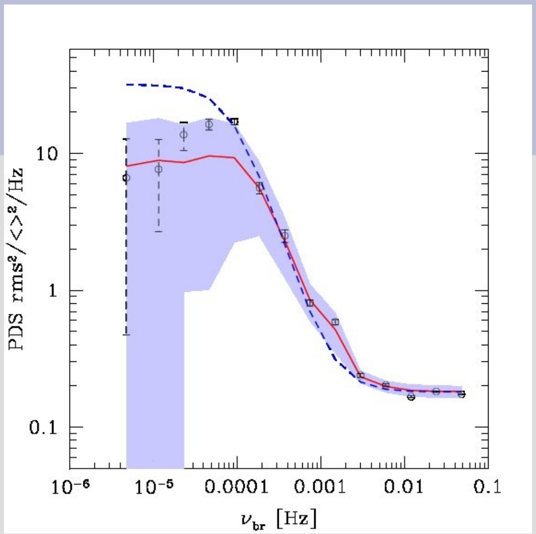


GS1826-238 : data vs model.

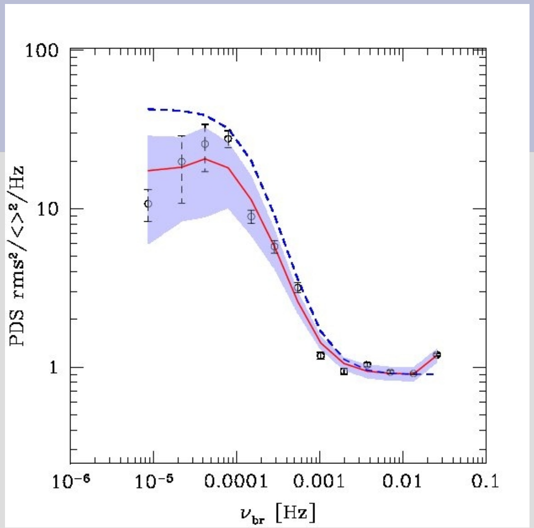
2003/09

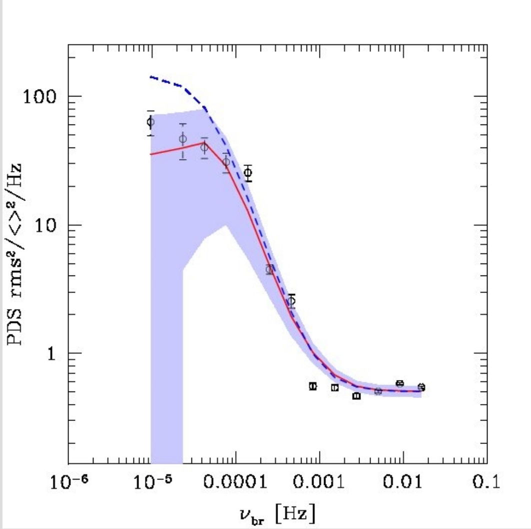


2003/10

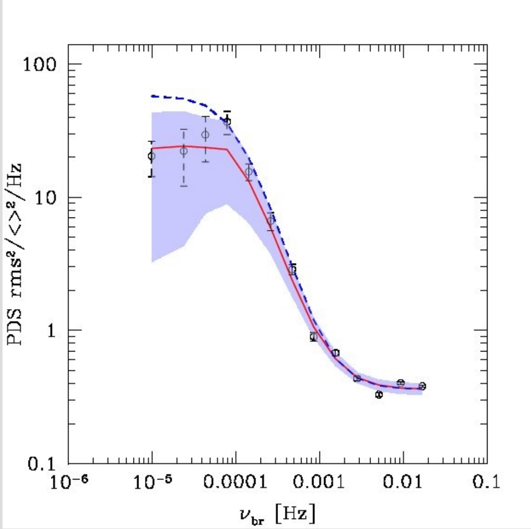


2004/06





2004/07

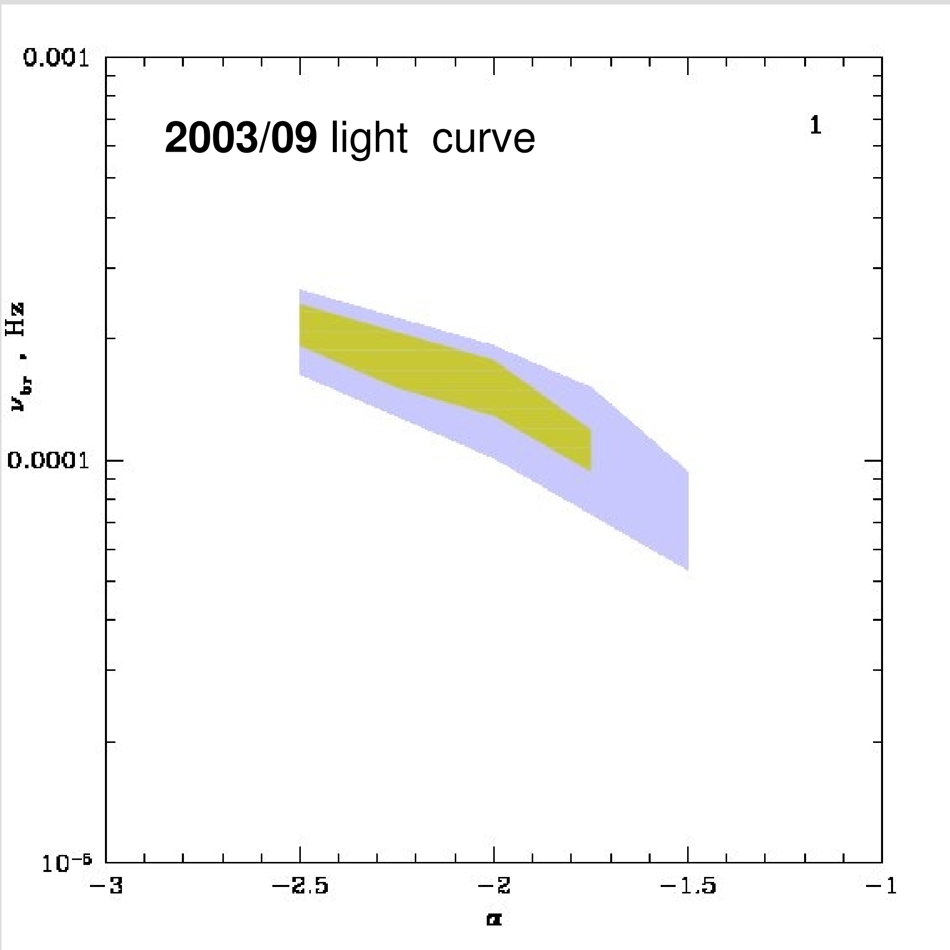


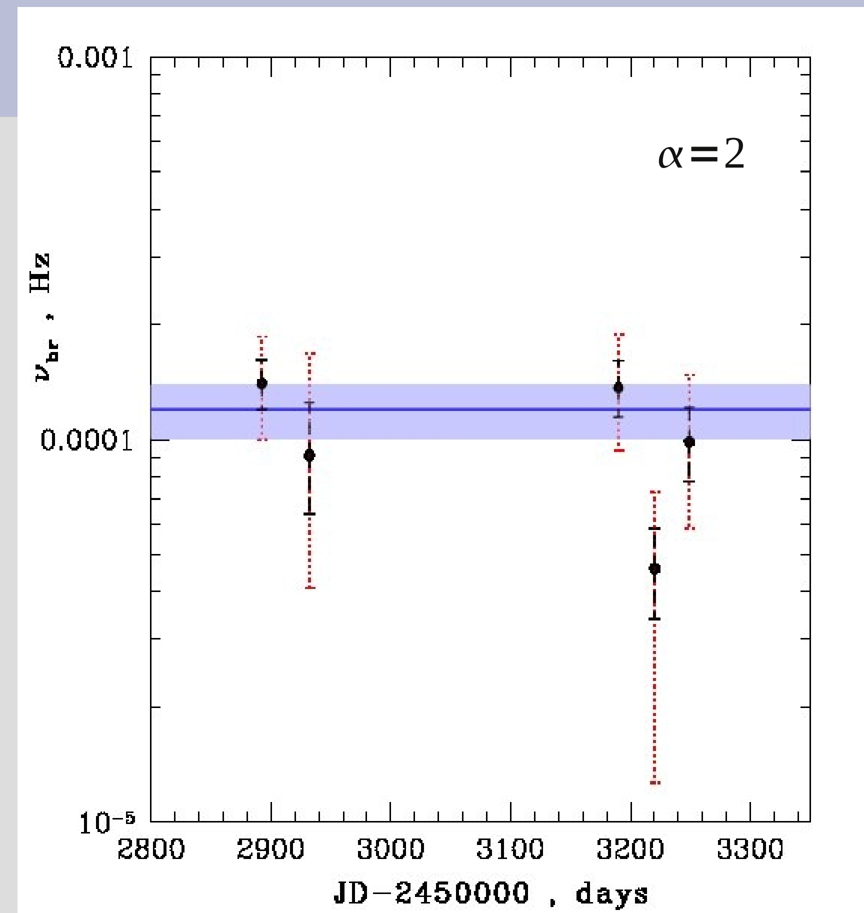
2003/08

PDS power law index fixed:

$\alpha = 2$

GS1826-238 : PDS break frequency & power law index





$$\nu_{br} = (1.199 \pm 0.192) \times 10^{-4}\, Hz$$

Conclusions.

Using observations from 1.5-m Russian-Turkish telescope, we studied the optical variability in low-mass X-ray binary GS1826-238 at the frequency range: $f = 10^{-5} \dots 10^{-1}\, Hz$

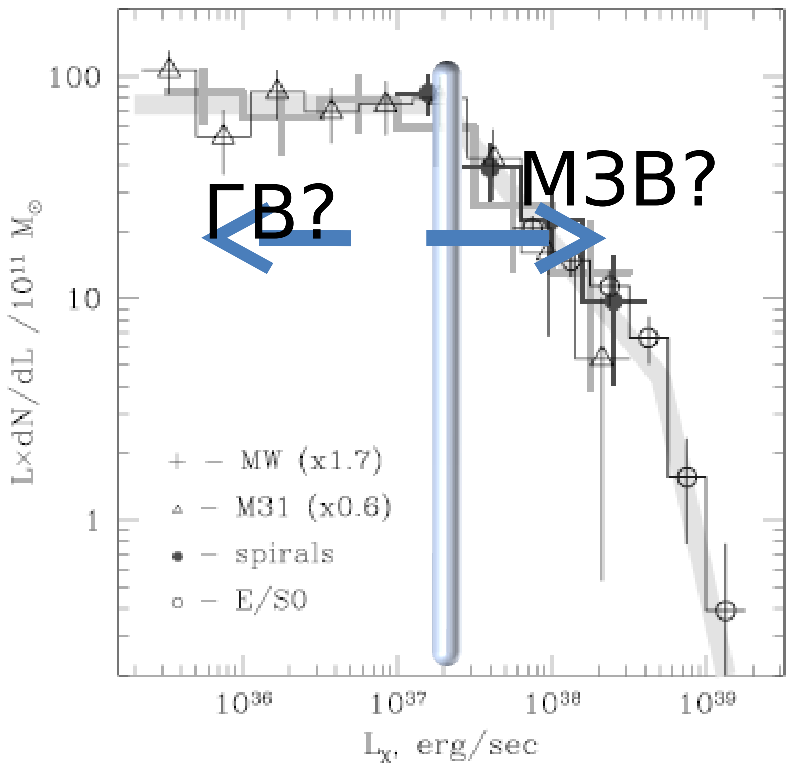
The optical light curve of the object shows aperiodic variability, power density spectrum have a form of “red noise” $P(f) \propto f^{\alpha} (\alpha \approx -2)$, PDS flattens below break frequency: $f_{br} = (1.20 \pm 0.19) \times 10^{-4}\, Hz.$

Using our measurement of break frequency, we estimated the orbital period of the binary system GS1826-238 : $P_{orb} \sim \frac{1}{f_{br}} \approx 2.3\, h$

- Thank you !

Luminosity function of low-mass X-ray binaries

Observations:



Gilfanov rt al., 2004

Theory:

Magnetic stellar wind?

$$\frac{dN}{d\ln L_0} \sim L_0^{-1.6...-1.13}, \quad \Gamma_{\rm msw} \sim 1.6\ldots1.13.$$

Gravitational radiation?

$$\frac{dN}{d\ln L_0} \sim L_0^{-0.16...0.3}, \quad \Gamma_{\rm gr} \sim 0.16\ldots0.3.$$

Postnov, Kuranov 2005

Talk plan.

- Characteristic aperiodic variability in X-ray binaries.
- Measuring orbital parameters from aperiodic variability of LXMB
- Periodogram & power density spectrum (PDS) of “red noise”.
- Case study: GS 1826-328
- Summary.