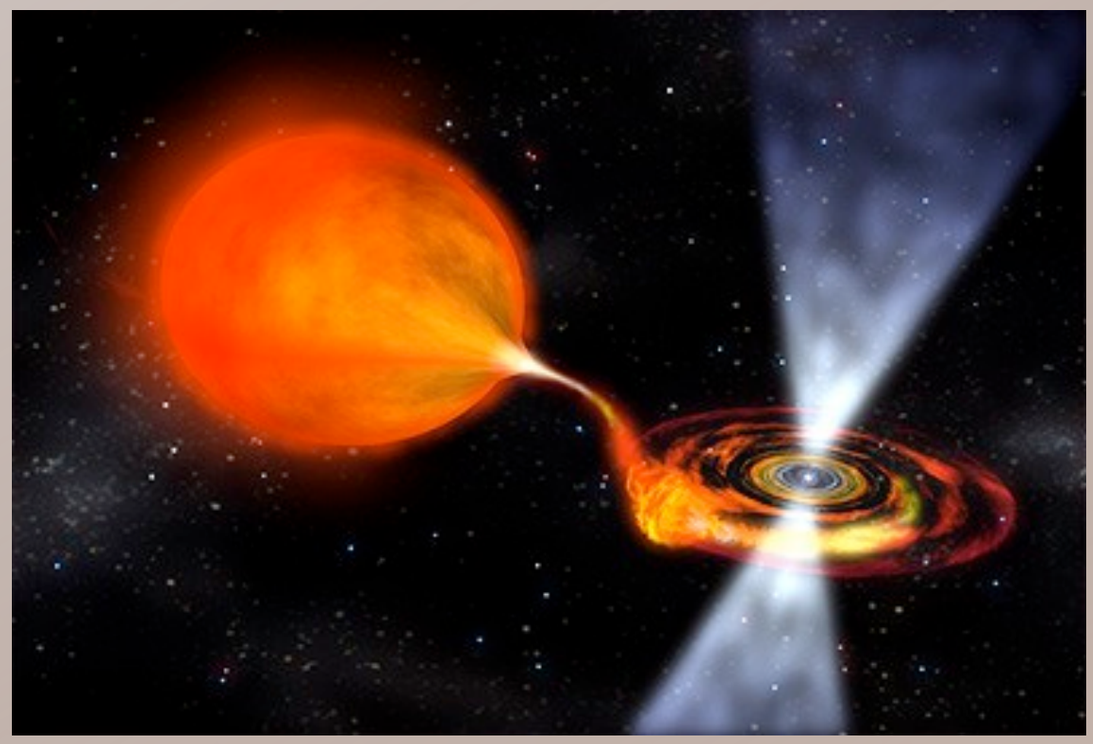
Simultaneous spectral and timing features in the UCXB 4U 0614+091



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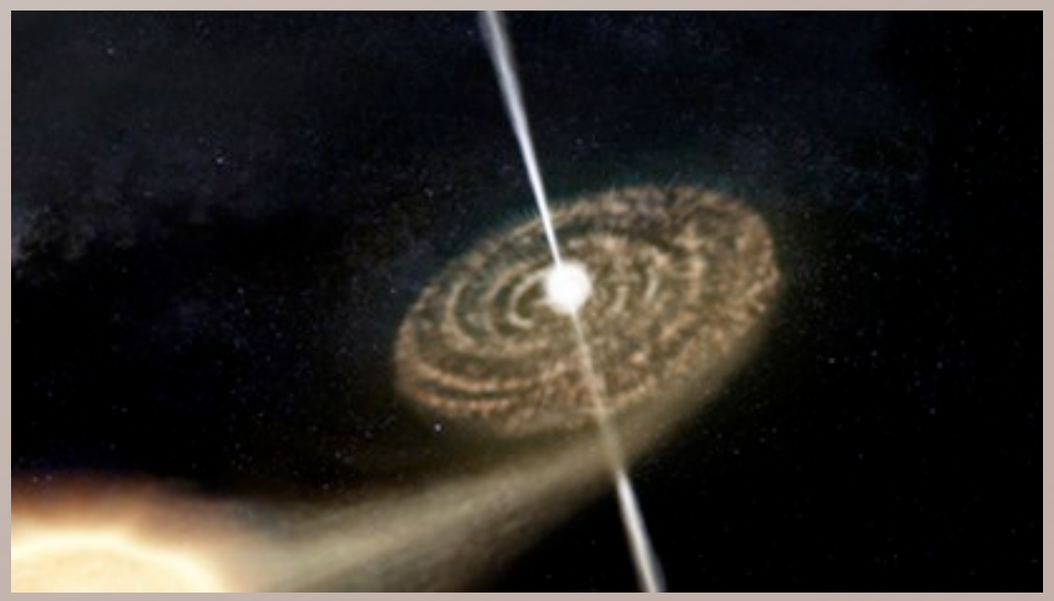
collaboration: Paul Groot, Randy Ross

SRON
Netherlands Institute for Space Research

Ultra-compact X-ray binaries

- subclass of Low Mass X-ray binaries
- orbital period: less than 80 minutes
- neutron star or black hole + white dwarf



credit:ESA

4U 0614+091

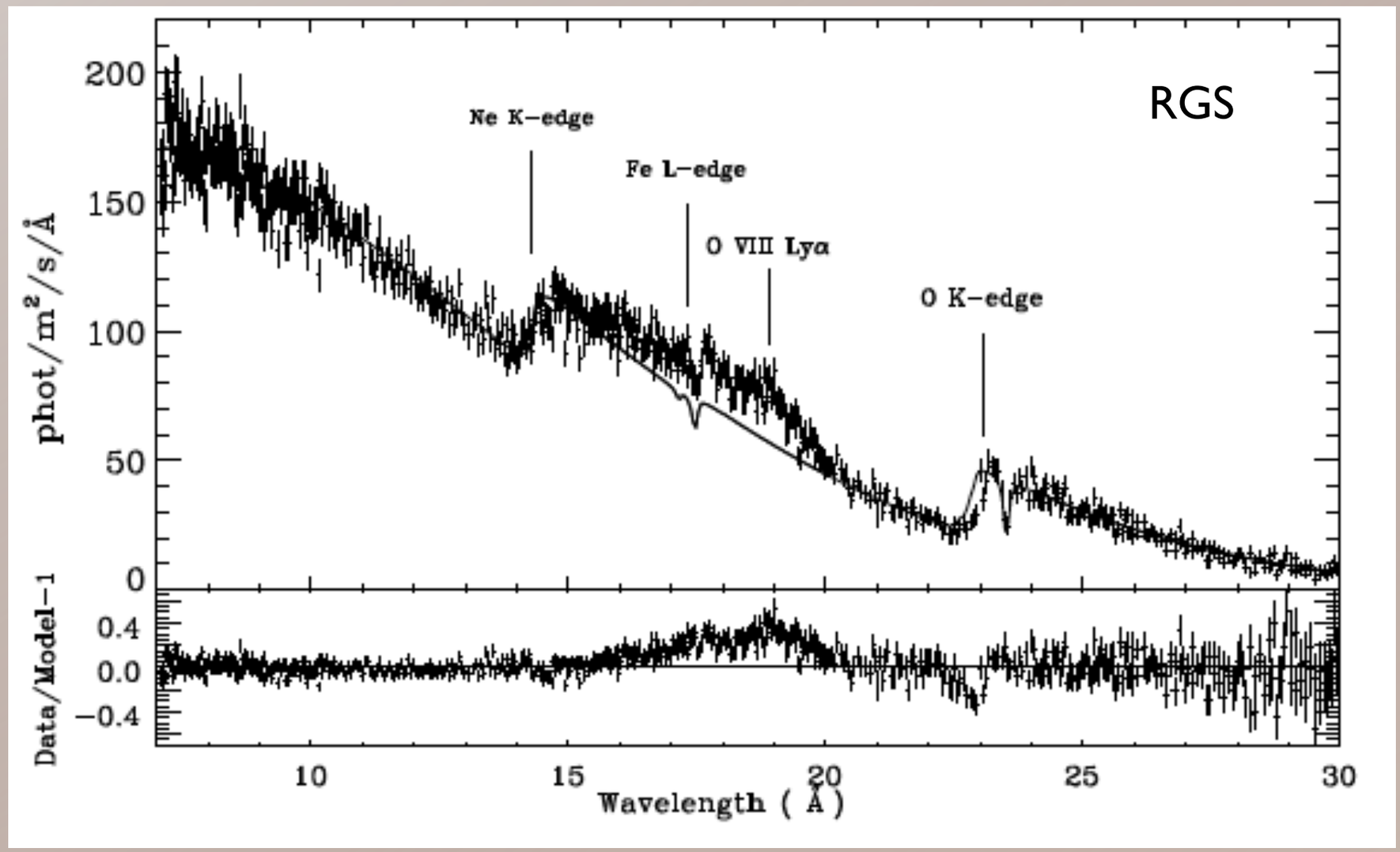
- orbital period: 51.3 min (Shahbaz et al. 2008)
- neutron star (type I X-ray bursts, Kuulkers et al. 2010)
- donor: CO or ONe white dwarf (Nelemans et al 2006)
- neutron star spin: 414.7 Hz (Strohmayer et al. 2008)
- **relativistically broadened O VIII Lyα line (Madej et al. 2010, in press)**
- **high frequency quasi-periodic oscillations (QPOs, Boutelier et al. 2009)**

constraining Mass and Radius of the neutron star

X-ray spectroscopy

- relativistically broadened O VIII Lyα line

R [GM/c^2]



Madej et al. 2010

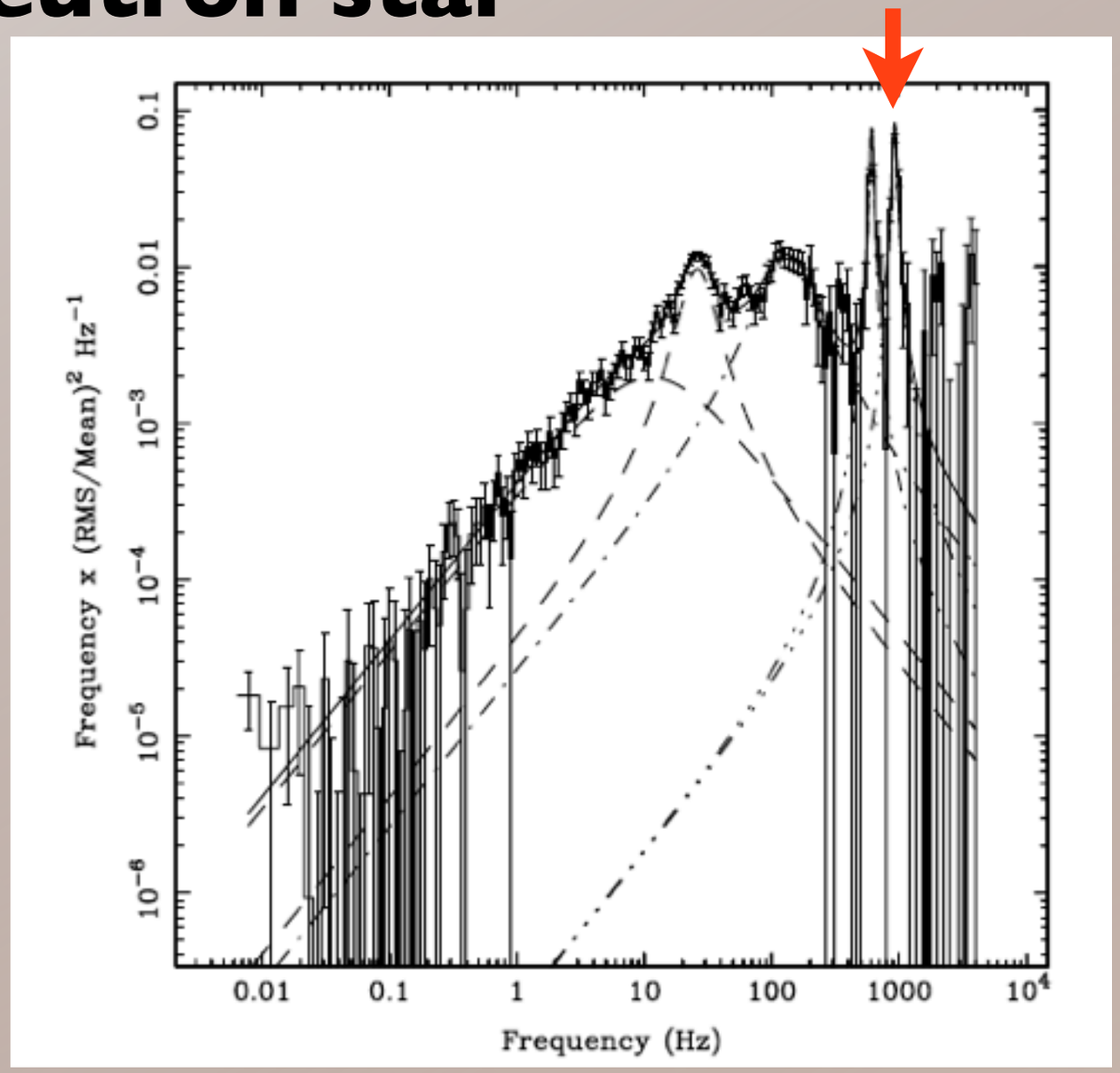
constraining Mass and Radius of the neutron star

X-ray timing

- kHz quasi-periodic oscillations

(upper kHz QPO reflects motion in Keplerian orbit)

$M=(2\pi f)^2 G^{-1} R^3$

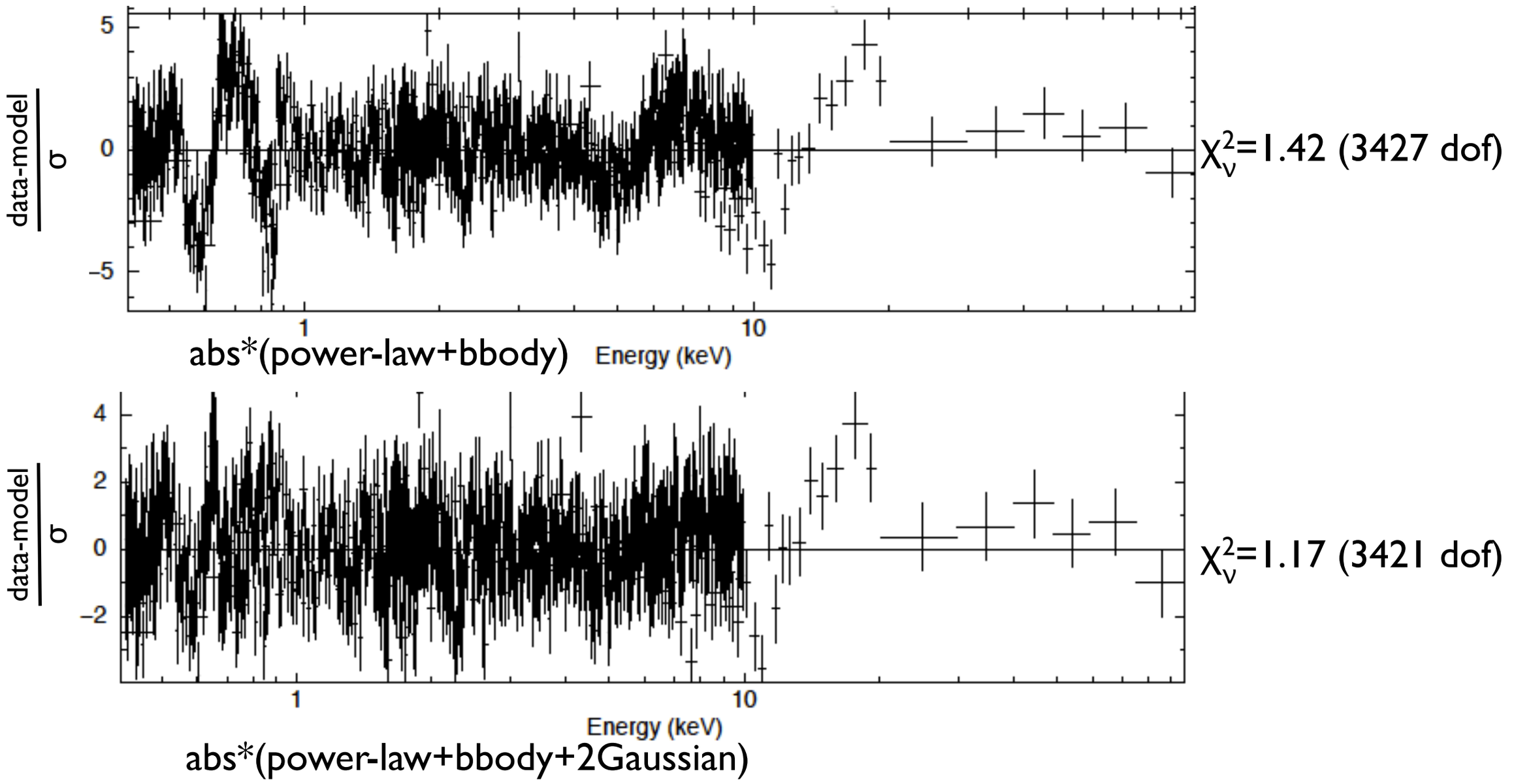


van Straaten et al. 2000

optical spectroscopy

- time resolved spectroscopy
- from mass function: M sin^3i

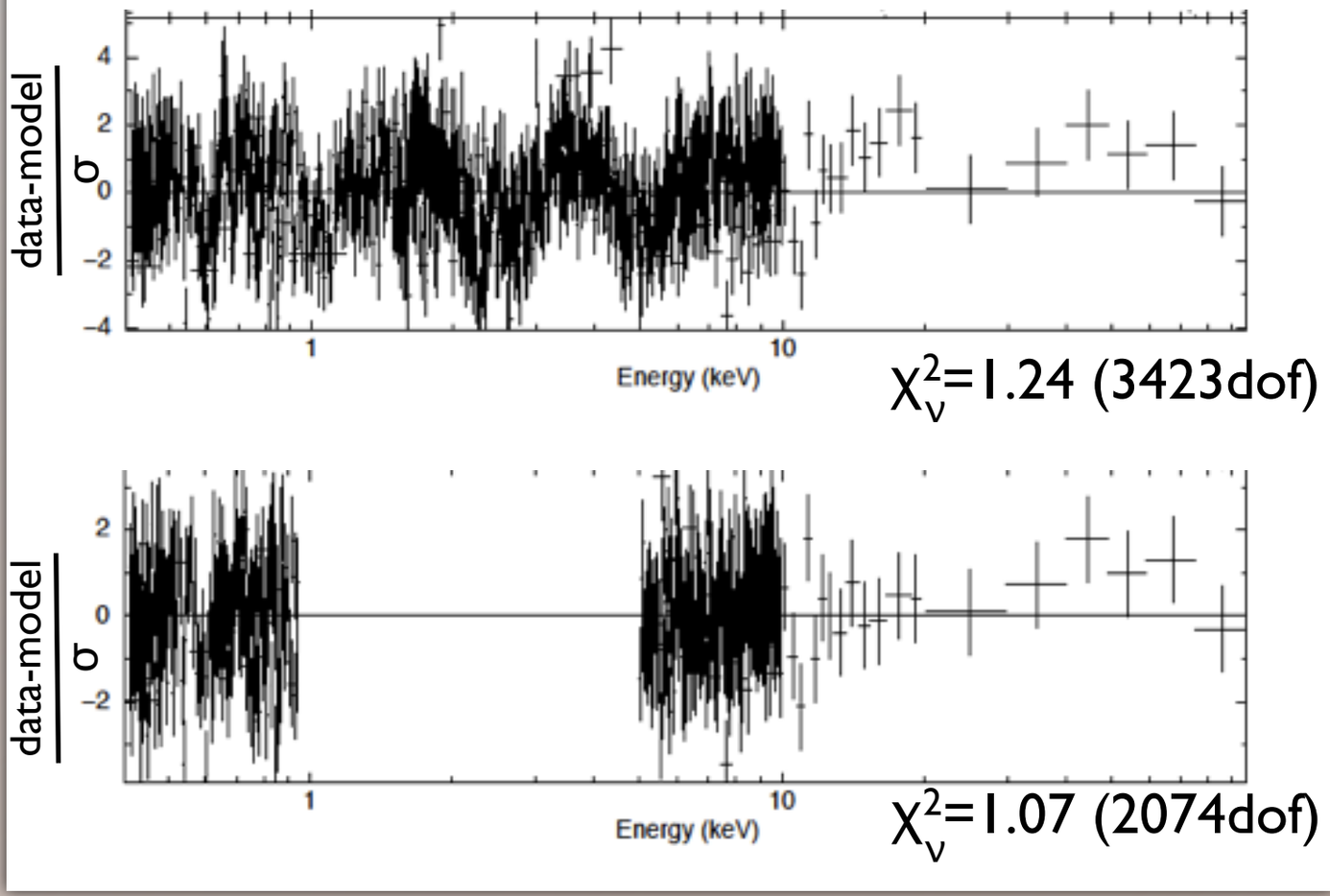
Broad band spectrum: XMM-Newton + RXTE



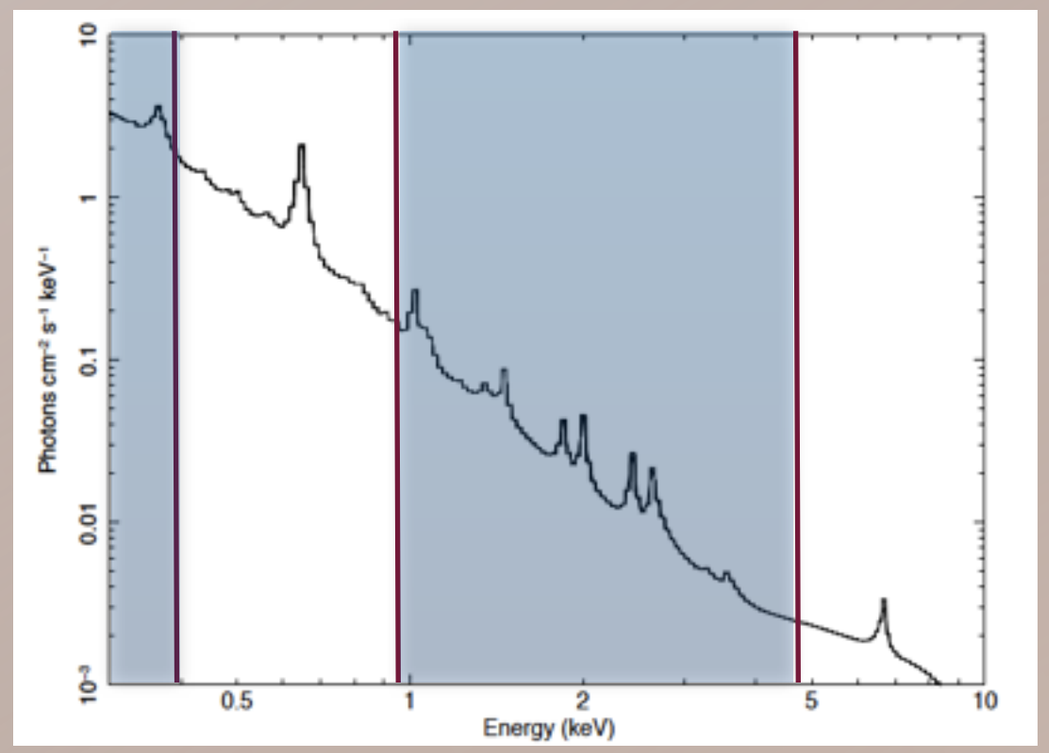
- broad features at ~0.7 keV (O VIII Lyα)
  ~6.4 (Fe Kα ?)

Broad band spectrum: XMM-Newton + RXTE

abs*(power-law+bbody+reflionx)

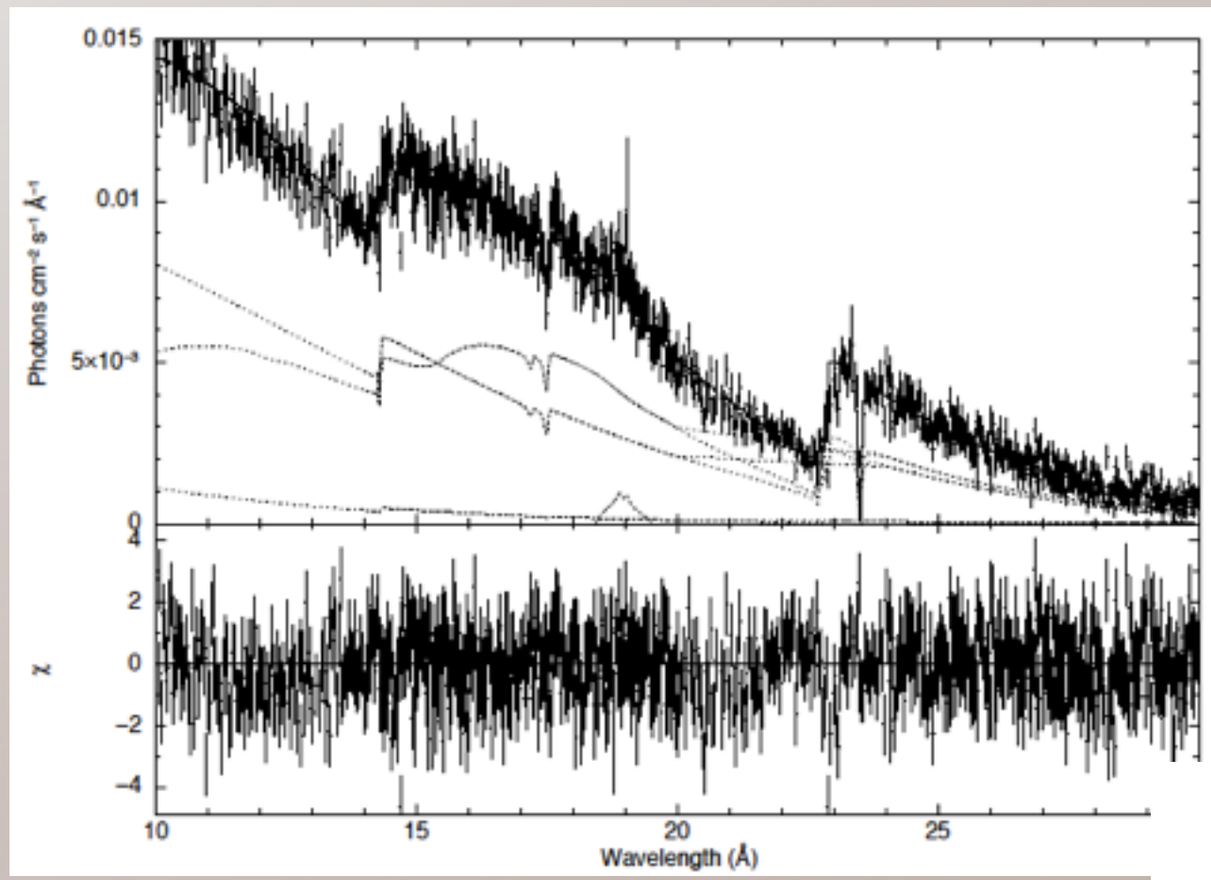


reflionx (Ross & Fabian 2005)
takes into account Compton scattering



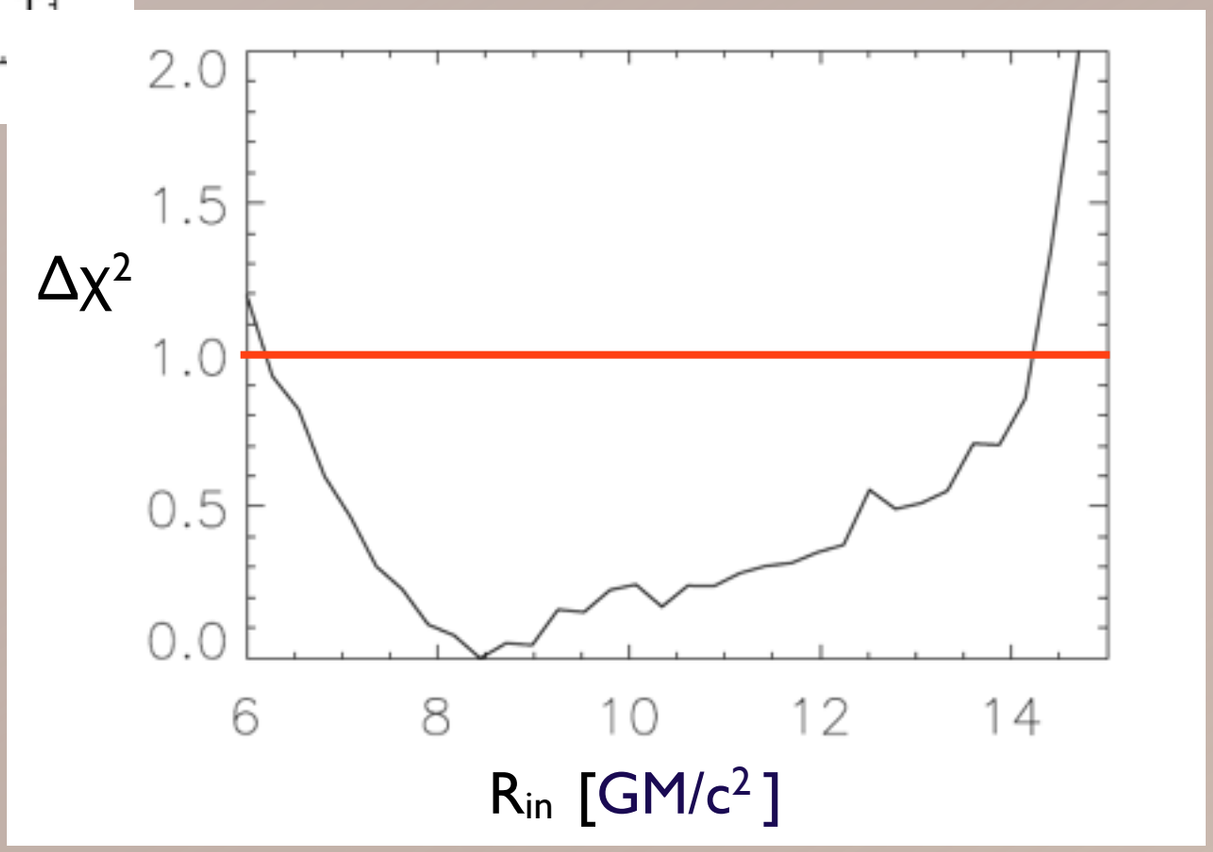
disk overabundant with oxygen
but
abundance of oxygen in the model
solar (Lodders 2003)

X-ray spectra



reflection spectrum
+
diskline profile

R_{out} =1000 GM/c^2
i~60 deg



- low S/N
- need for better reflection model

Quasi-periodic oscillations in 4U 0614+091

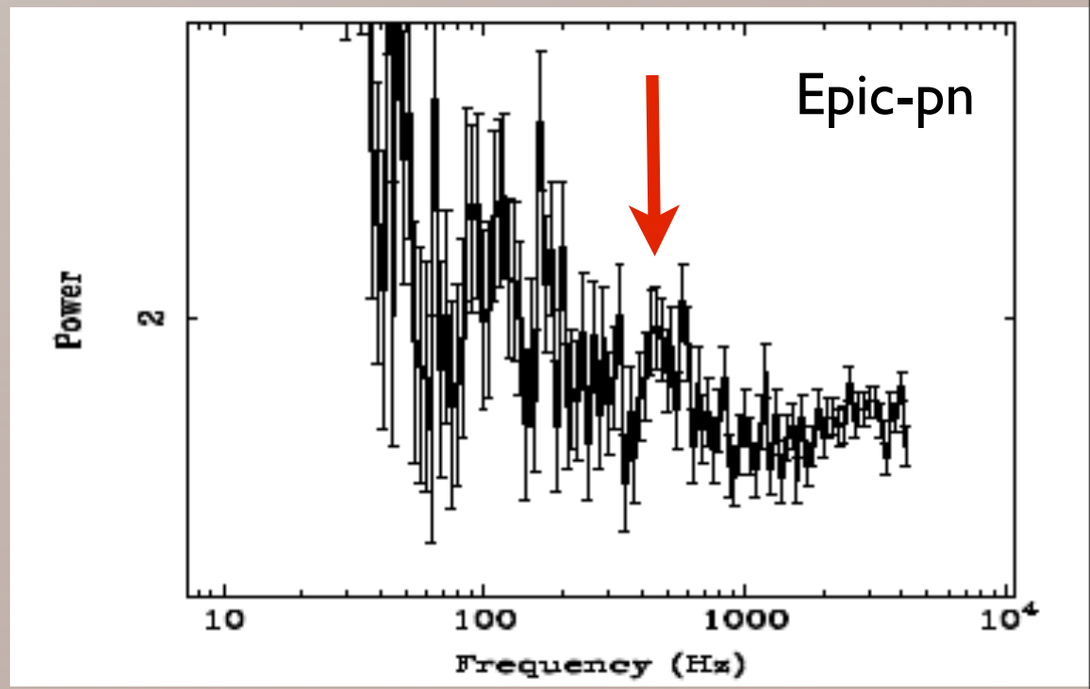
- Max kHz QPO observed: f=1224 Hz

⇓ at ISCO=$6GM/c^2$

- upper limit on the mass M < $1.8M_{sun}$
- Δf=320 Hz (Boutelier et al. 2009)

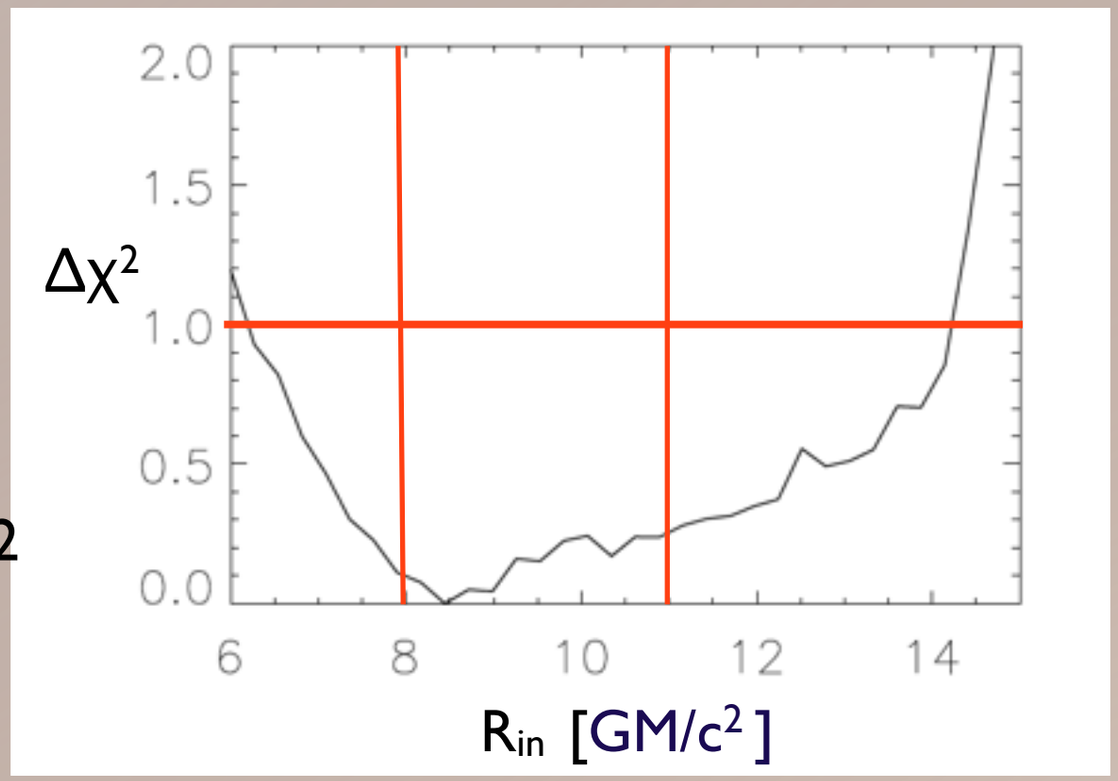
f= 493±29 Hz

Boutelier et al. 2009

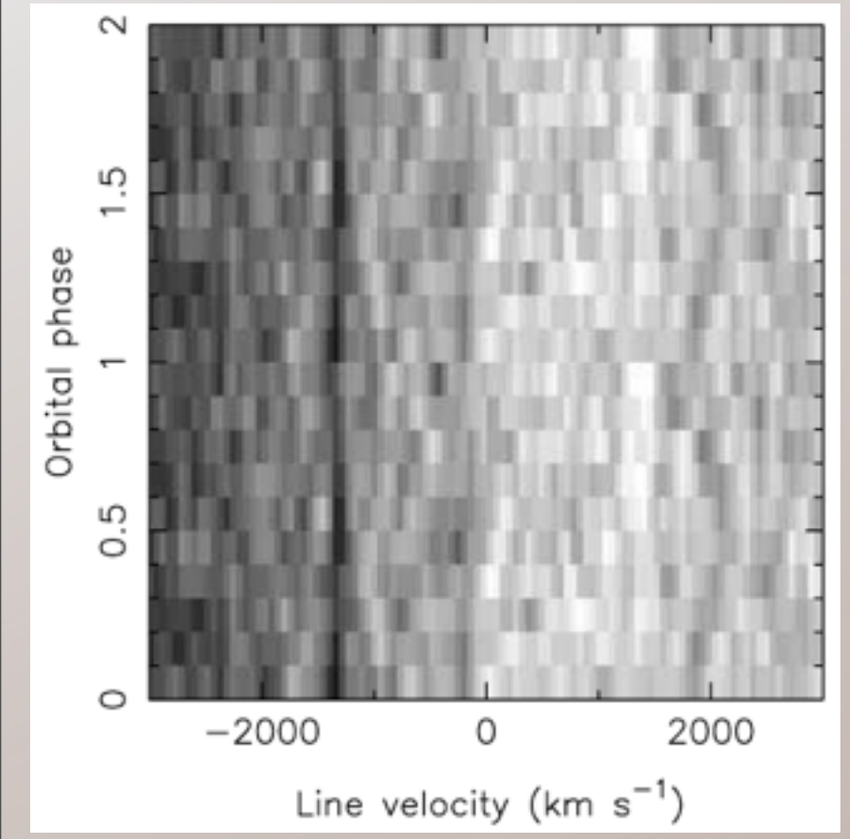


- If observed QPO <u>upper one</u>
  500 Hz & $1.8M_{sun}$ ⇨ 11 GM/c^2

- If observed QPO lower one
  500+320 Hz & $1.8M_{sun}$ ⇨8 GM/c^2

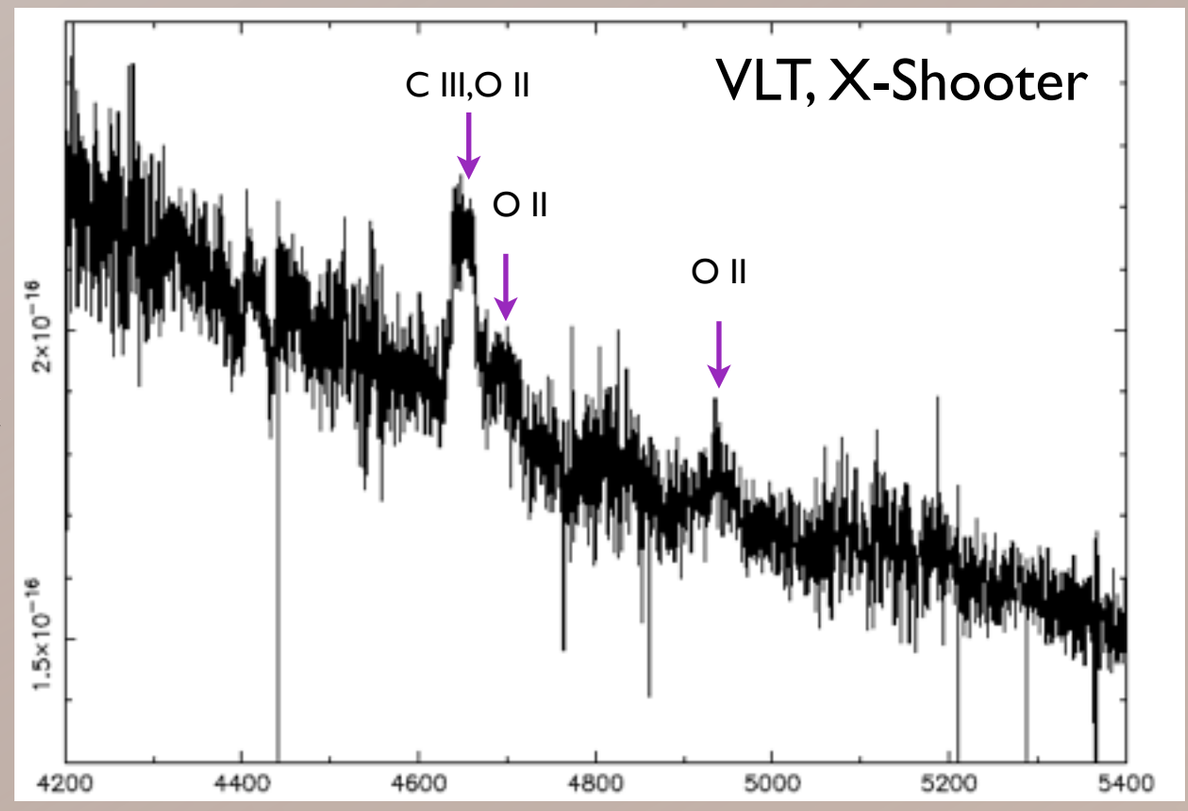


Optical spectra



Nelemans et al. 2006

- M sin^3i
- M_{ns} = 1.8 M_{sun} ⇨ i ~ 14 deg



Madej et al., in prep

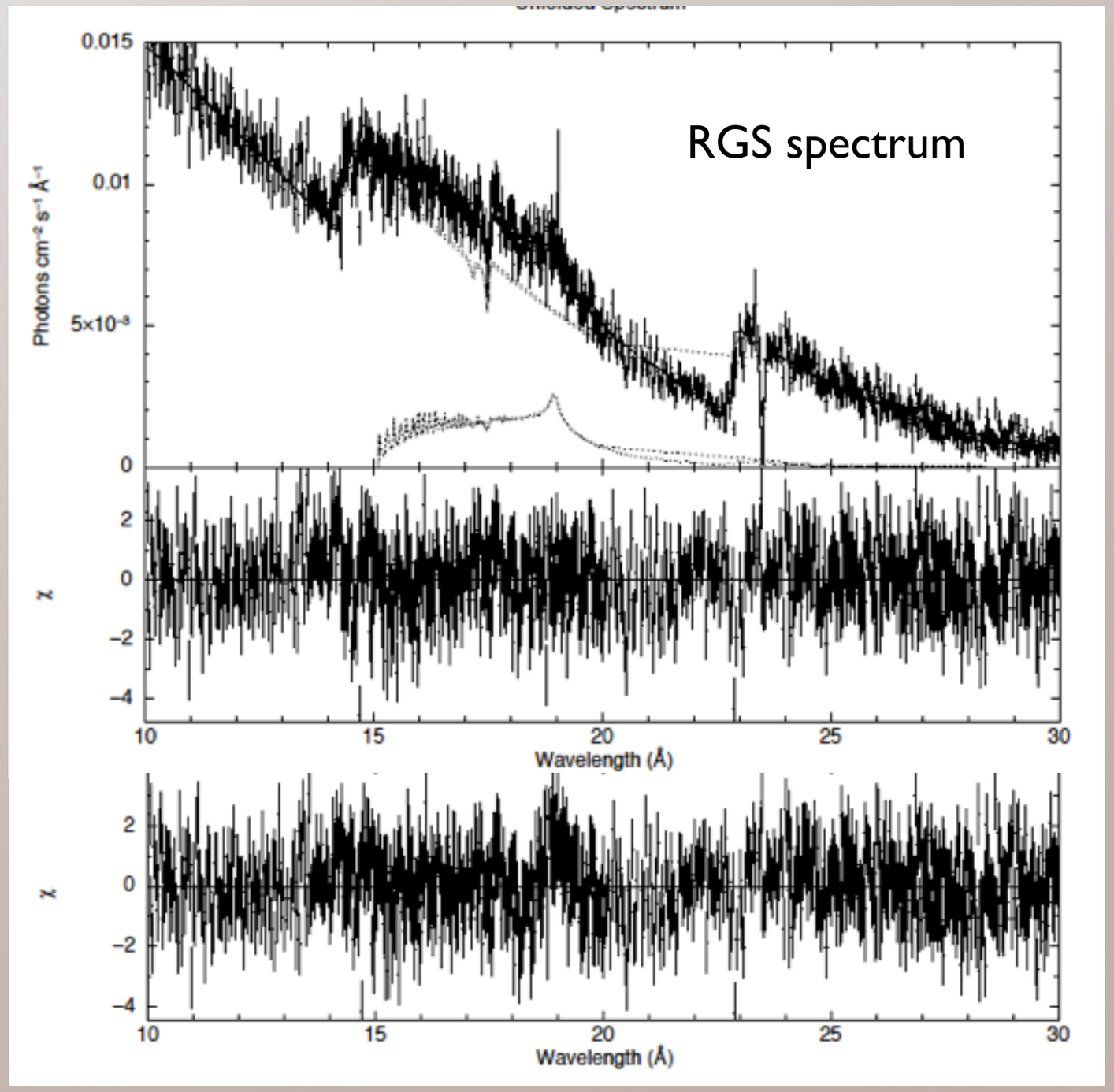
Conclusions

- For the first time we can apply the method to constrain the neutron star mass and radius using kHz QPOs a 'new tool' - relativistically broadened O VIII Lyα line

- The data were not of sufficient quality yet to draw secure conclusions about the mass and the radius of the neutron star

- The target: 4U 0614+091 is a very good candidate to apply the described method and provide valuable information about structure of the neutron stars

X-ray spectra



Laor profile

R_{in}= 3±0.2 GM/c^2

spin correction of 1%

Diskline profile

R_{in} pegs at 6 GM/c^2

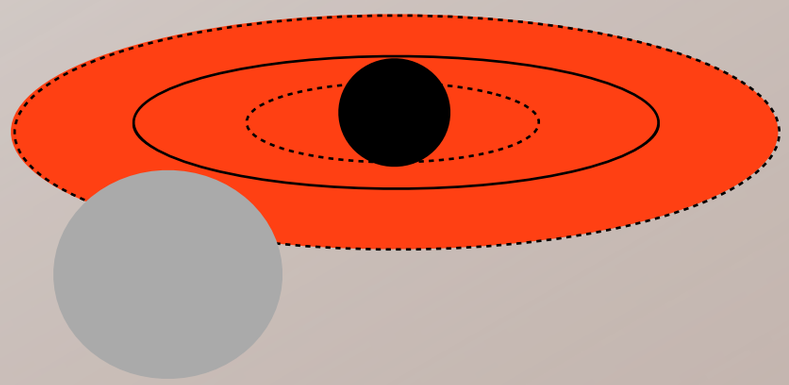
i=(70,90) deg

R_{out}~1e5 GM/c^2

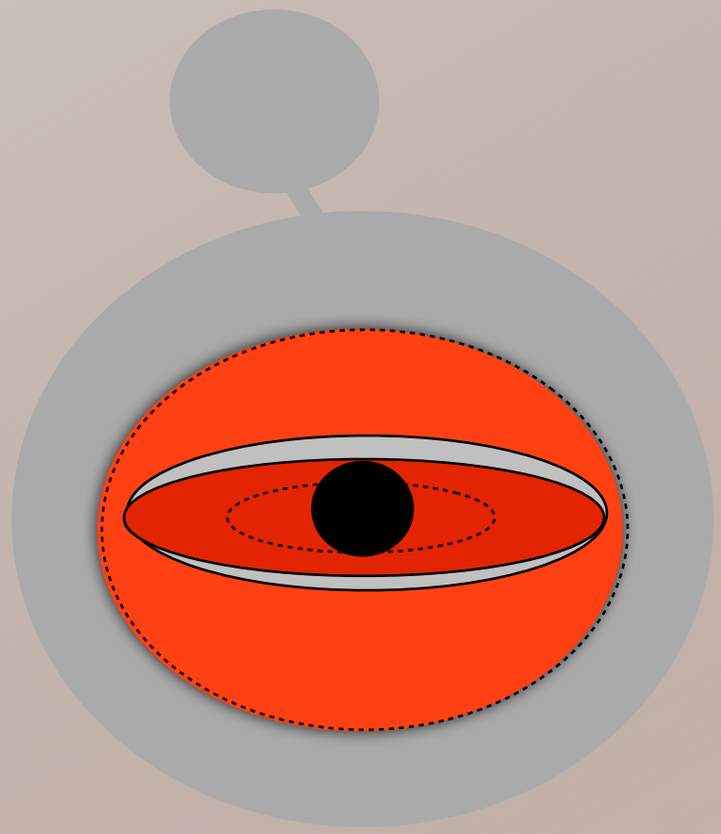
R_{out} =1000 GM/c^2

- at Rout=1000 GM/c^2 GR effects weak but Doppler effect still strong

geometry



no eclipses visible in
the light curve...



twisting, warping of the disc:
1.precession in the system
(Petterson 1977)
2. Irradiation by neutron star