Estimation of masses and radii of neutron stars introducing spin frequency in LMXBs

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X-ray binaries

- X-ray emit near the compact star (BH or NS)
- Matter falling to compact star make X-ray
- Companion star mass (HMXBs vs **LMXBs**)

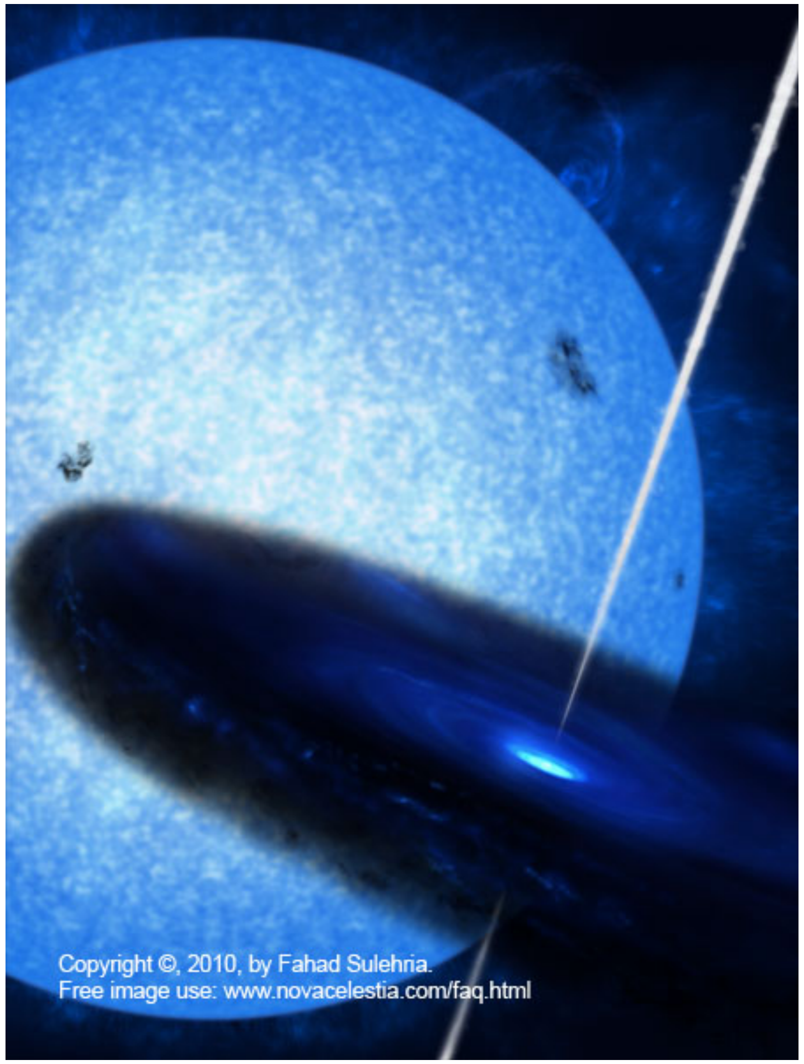


figure: www.novacelestia.com/faq.html

Mechanism of X-ray Burst

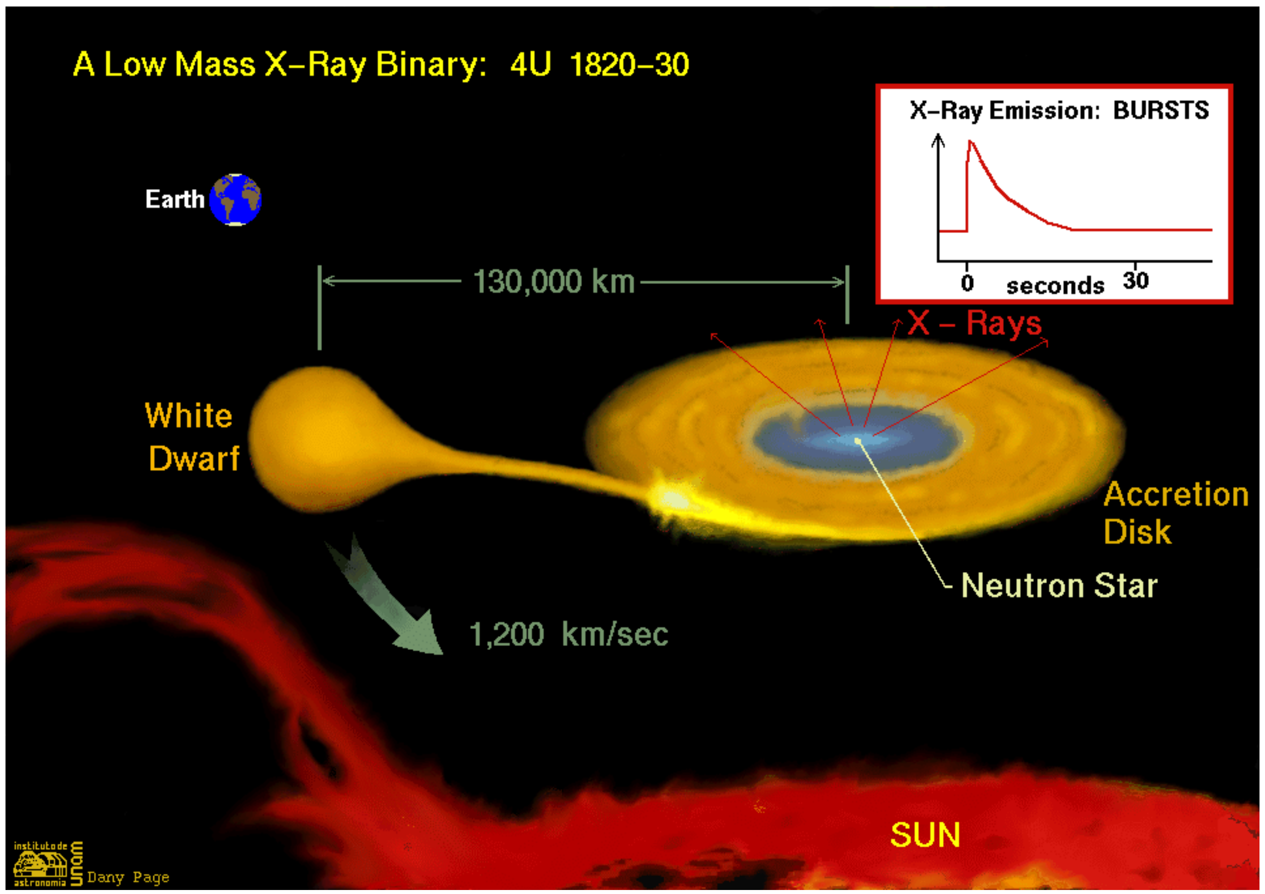
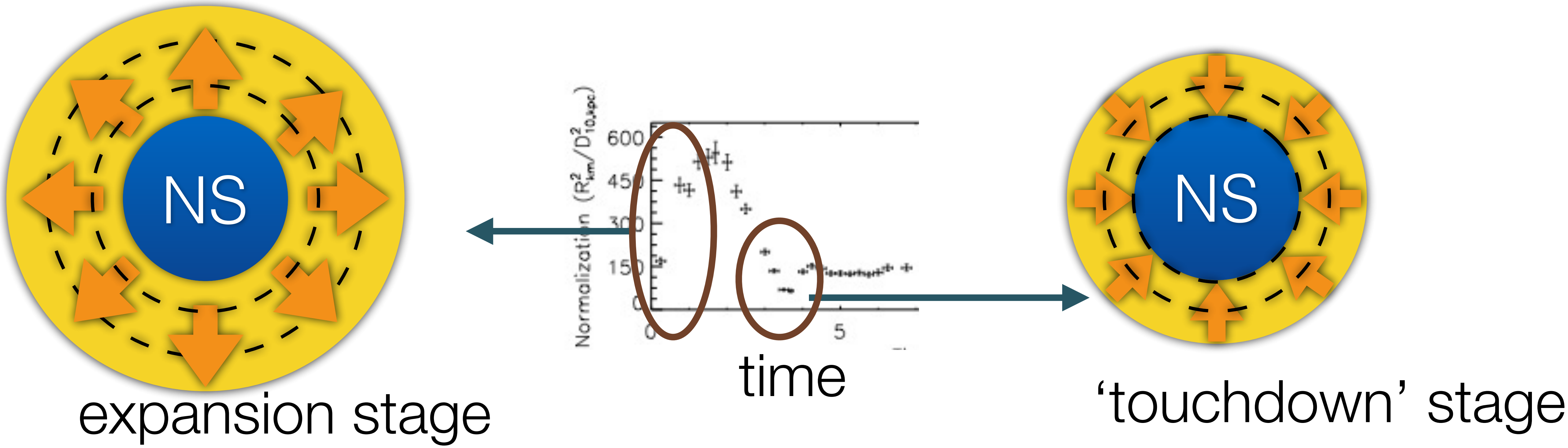


figure courtesy: Dany P. Page

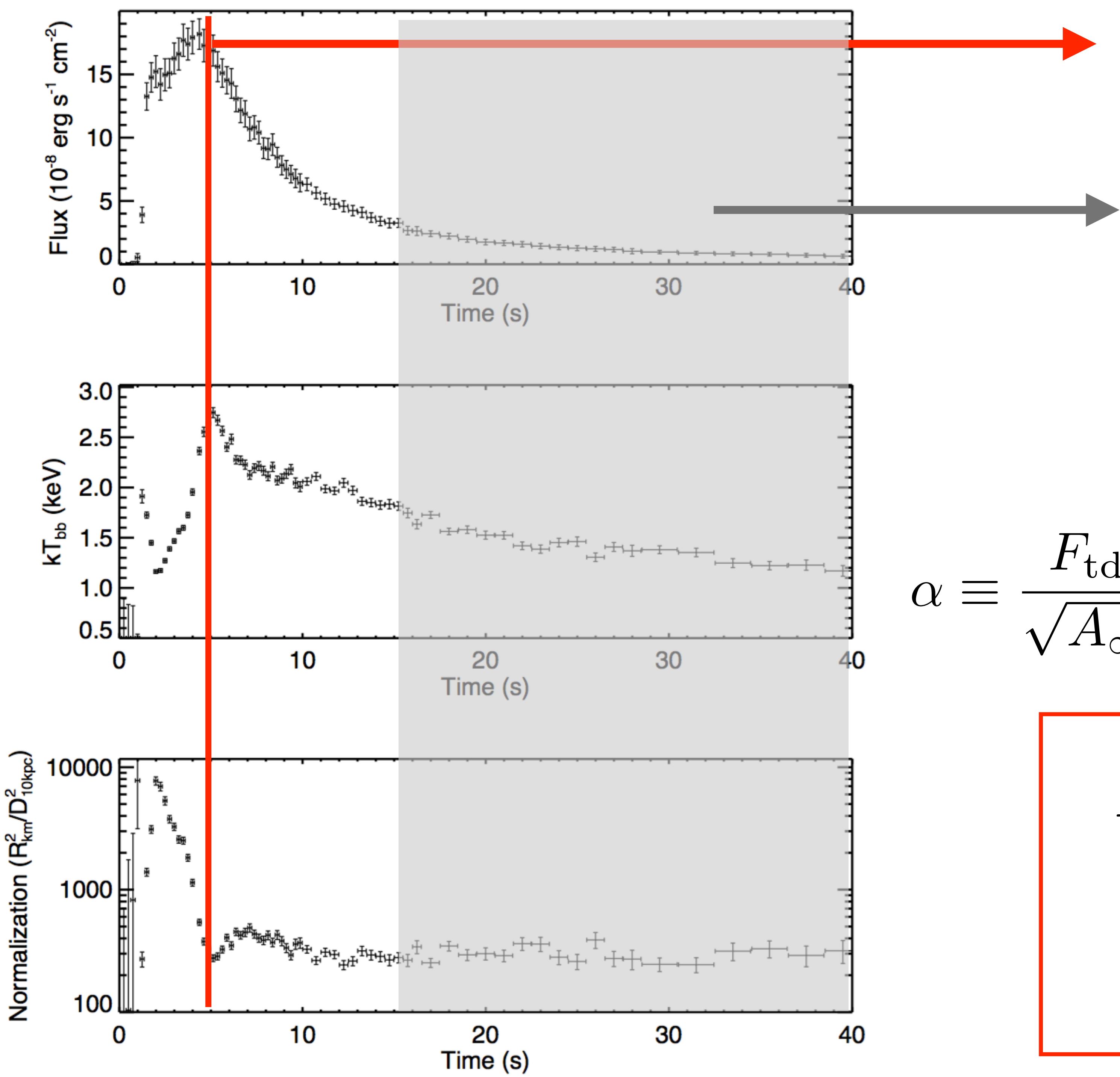
- In Low-Mass X-ray Binaries (LMXBs)
- Accretion of H and/or He (Roche lobe overflow)
- Thermonuclear explosion ($T_c \sim 10^7$ K)
- X-ray bursts (type-I)

Photospheric Radius Expansion (PRE)



- *$P_{radiation}$ >> $P_{gravitation}$*
  Photospheric layers are lifted off
- During PRE, the constant luminosity (L_{Edd})
- 20% shows the evidence of PRE (Galloway et at. 2008)

Mass and Radius distribution from observation 1



Ozel et al. 2015

Touchdown Flux : F_{td}

apparent radius : A_∞

Distance : D + f_c and κ

$$\alpha \equiv \frac{F_{\rm td}}{\sqrt{A_\infty}} \frac{\kappa D}{c^3 f_c^2} \qquad \gamma \equiv \frac{A_\infty c^3 f_c^4}{F_{\rm td}\kappa} \qquad \beta = \frac{GM}{Rc^2}$$

$$R = \alpha\gamma\sqrt{(1 - 2\beta_{1,2})}$$

$$M = \frac{\beta R c^2}{G}$$

Mass and Radius distribution from observation 2

Source	App. Angular Size $(\mathrm{km}/10\ \mathrm{kpc})^2$	Touchdown Flux[a] $(10^{-8}\ \mathrm{erg\ s^{-1}\ cm^{-2}})$	Spin Freq.[b] (Hz)	Distance[b] (kpc)	Radius[c] (km)
4U 1820−30	89.9±15.9	5.98±0.66	...	7.6 ± 0.4[4] or 8.4 ± 0.6[5,6]	11.1 ± 1.8
SAX J1748.9−2021	89.7±9.6	4.03±0.54	410[1]	8.2 ± 0.6[4,5,7]	11.7 ± 1.7
EXO 1745−248	117.8±19.9	6.69±0.74	...	6.3; $\Delta D = 0.63$[8,9]	10.5 ± 1.6
KS 1731−260	96.0±7.9	4.71±0.52	524[2]	$\sim 7 - 9$[10]	10.0 ± 2.2
4U 1724−207	113.8±15.4	5.29±0.58	...	7.4±0.5	12.2 ± 1.4
4U 1608−52	314±44.3	18.5±2.0	620[3]	see Appendix	9.8 ± 1.8

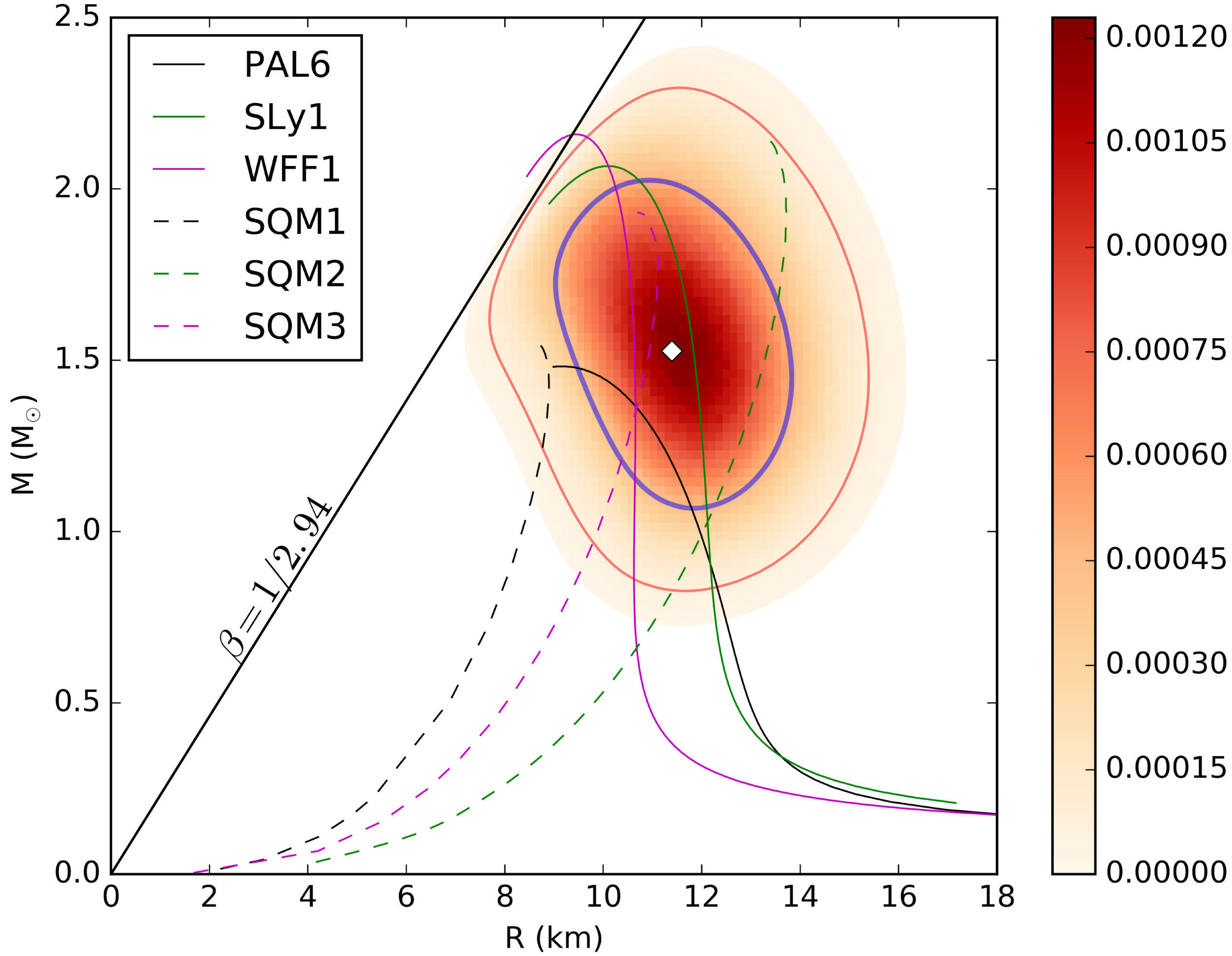
Ozel et al. 2015

- Previous - Gaussian distribution for F_{td}, A_∞, and D
  uniform distribution for f_c and X

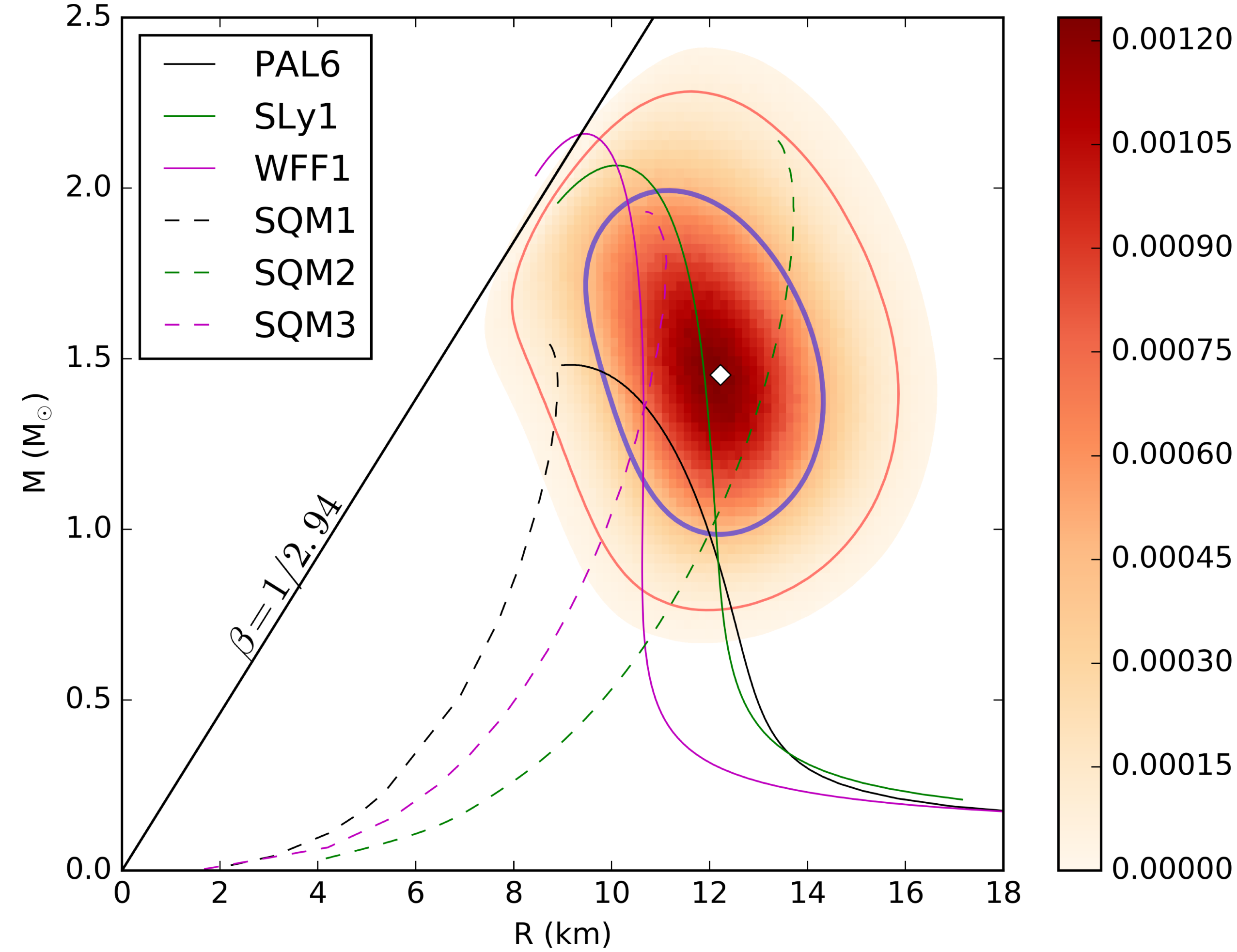
- *X dependence with spin frequency information*
  (hydrogen rich, hydrogen poor and intermediate case)

M-R distribution for SAX J1748.9-2021

w/o spin frequency



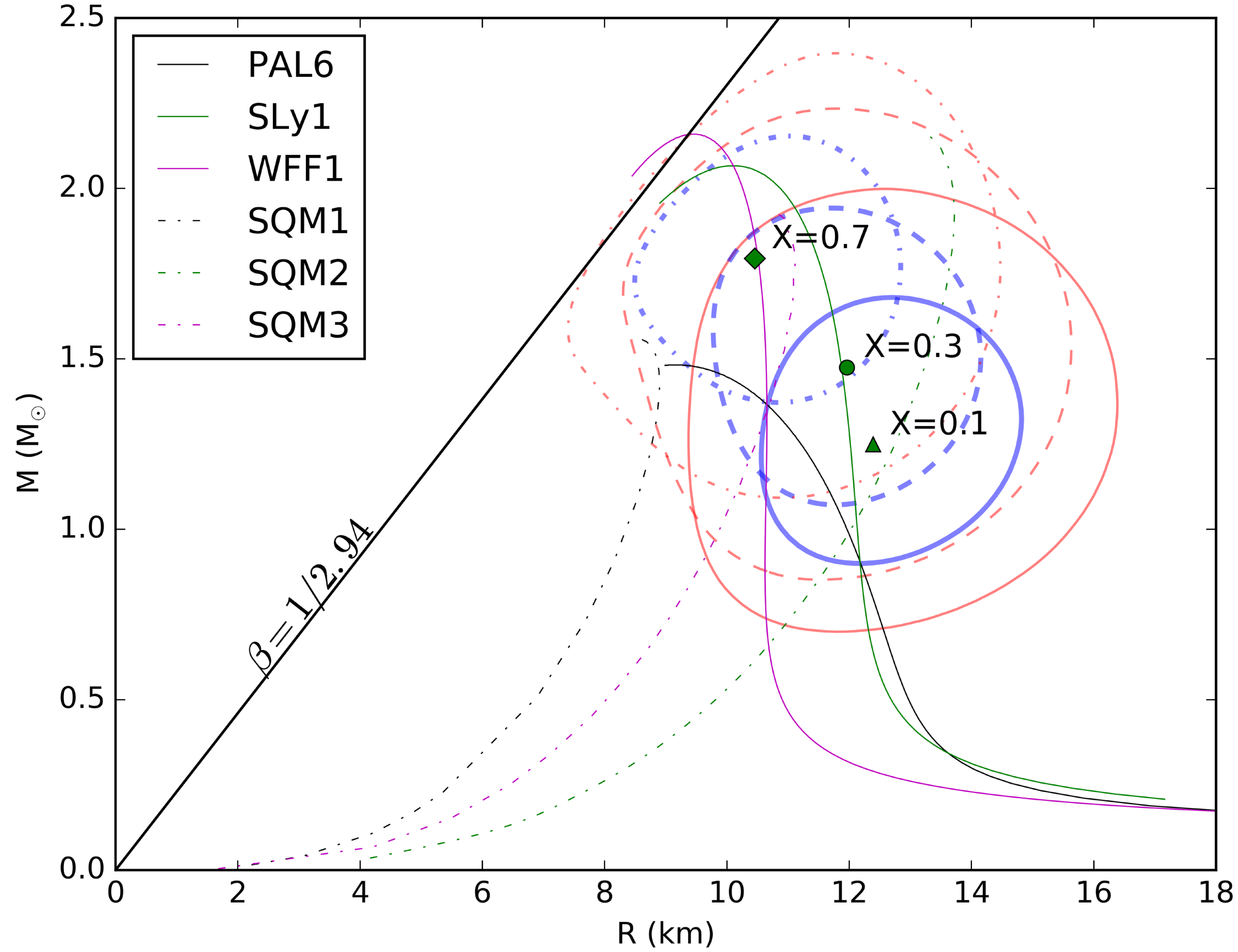
w/ spin frequency



- Mass - 1.51 (56%)
- Radius - 11.23

- 1.42 (71%)
- 12.13 km

M-R distribution for fixed hydrogen mass fraction



hydrogen poor rich

- Mass - 1.24 (98%) ~ 1.79 (28%)
- Radius - 12.39 ~ 10.45 km

Summary

- X-ray burst showing PRE is main idea to estimate mass and radius of neutron star simultaneously
- From the mass and radius distribution, Monte-Carlo statistics prefer the case of spin frequency
- Mass and radius distribution *depends on hydrogen mass fraction*
- Expect to suggest specific information of matter in the **neutron star atmosphere** or **accreted materials** from companion stars

Thank you