Estimating mass and radius of neutron star in low-mass X-ray binary

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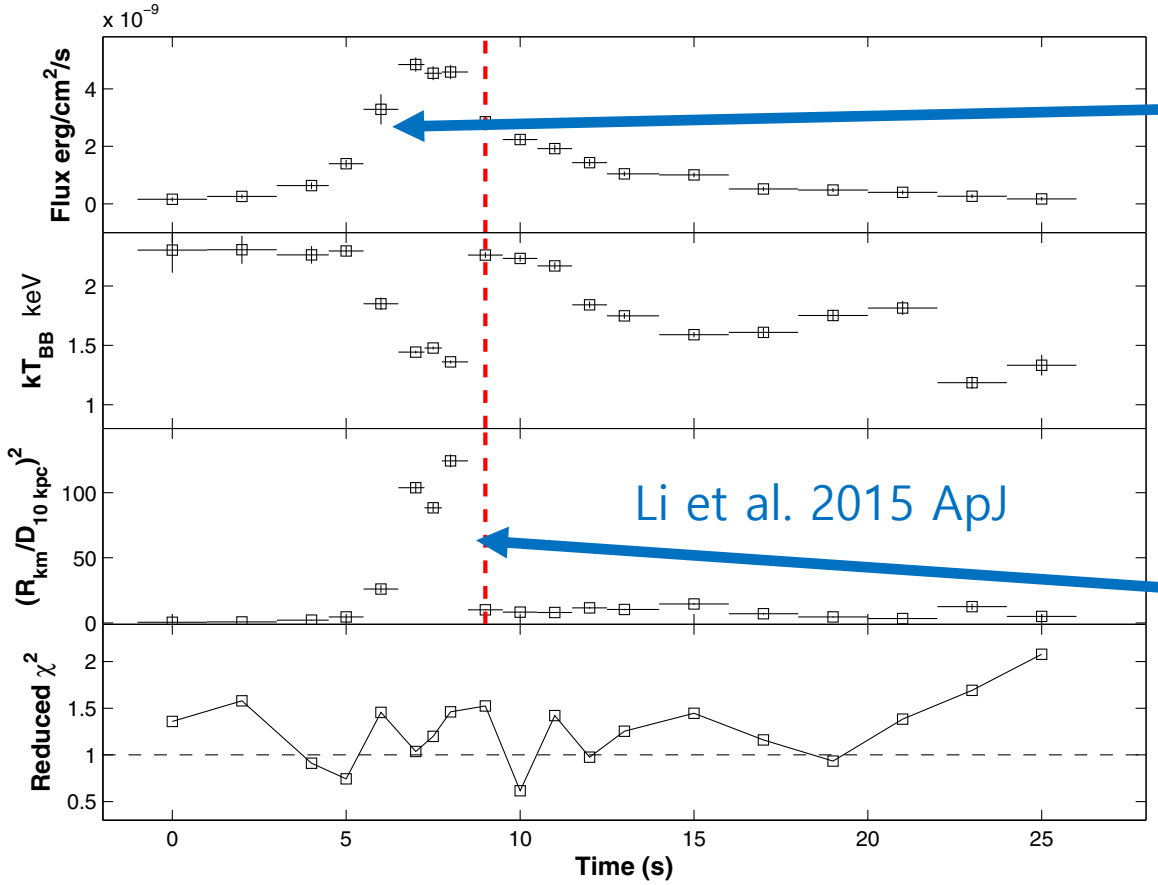
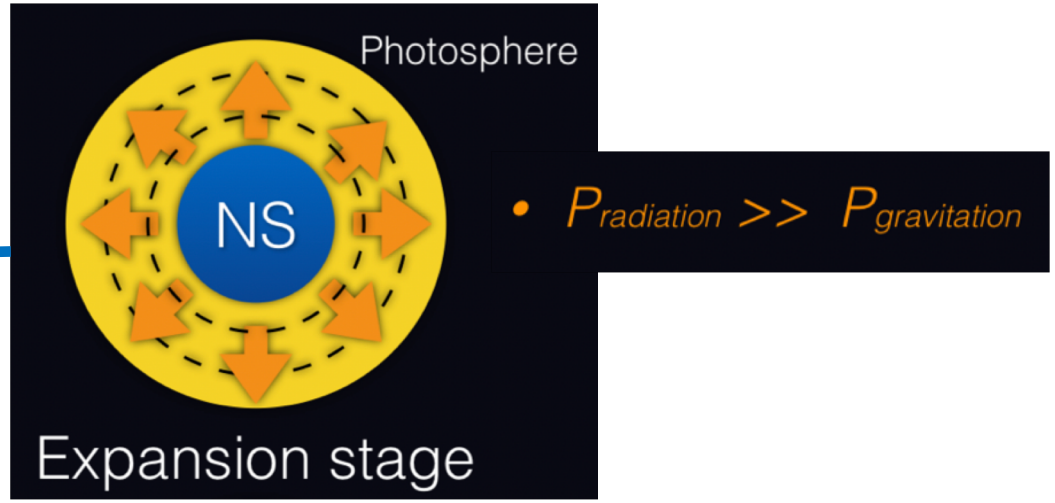
Photospheric Radius Expansion (PRE)

- PRE XRB in 4U 1746-37





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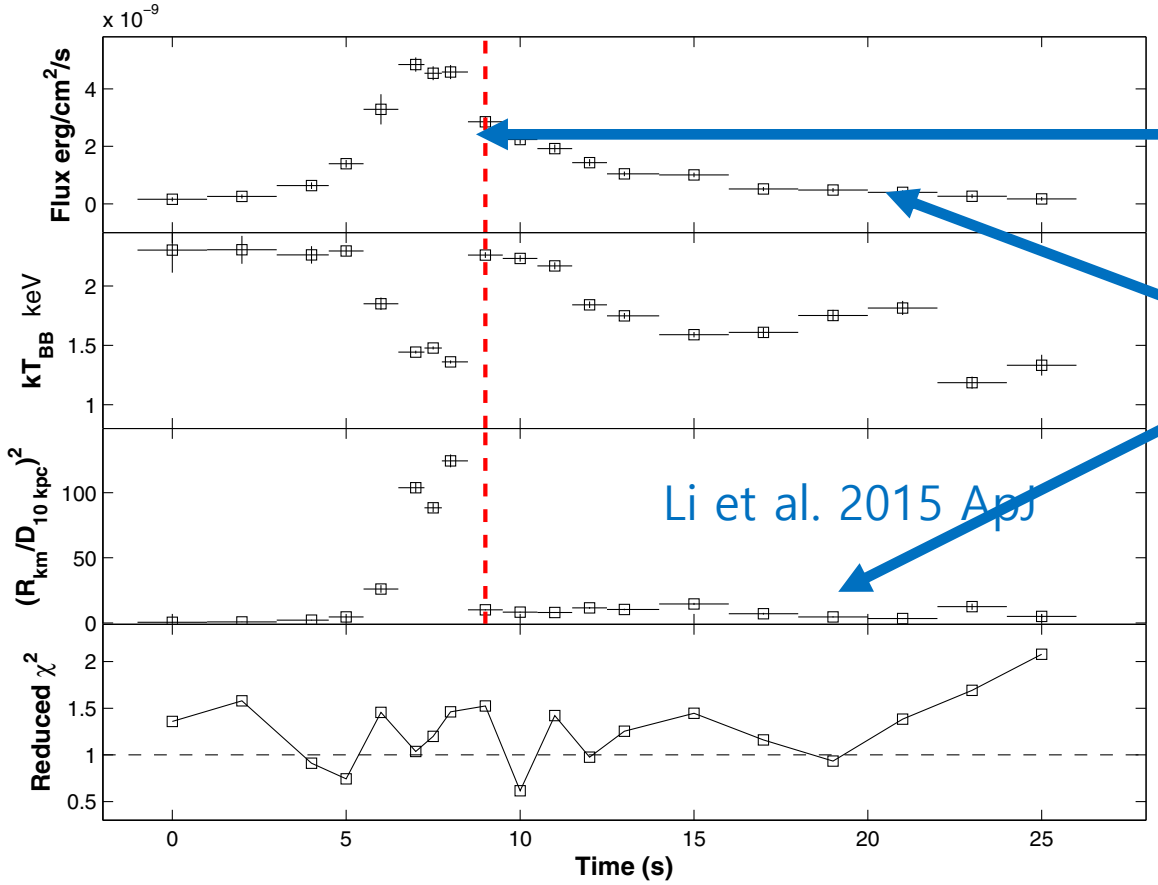


$$F_{\rm TD} = \frac{GMc}{k_{\rm es} D^2};$$

$$F_{\rm TD} = \frac{GMc}{k_{\rm es} D^2}\left(1 - \frac{2GM}{Rc^2}\right)^{1/2} \quad (6)$$

$$A = \frac{R^2}{D^2 f_{\rm c}^4}\left(1 - \frac{2GM}{Rc^2}\right)^{-1}, \quad (7)$$

$$A_1 = \frac{F_{\infty,1}}{\sigma T_{bb,\infty,1}^4}$$

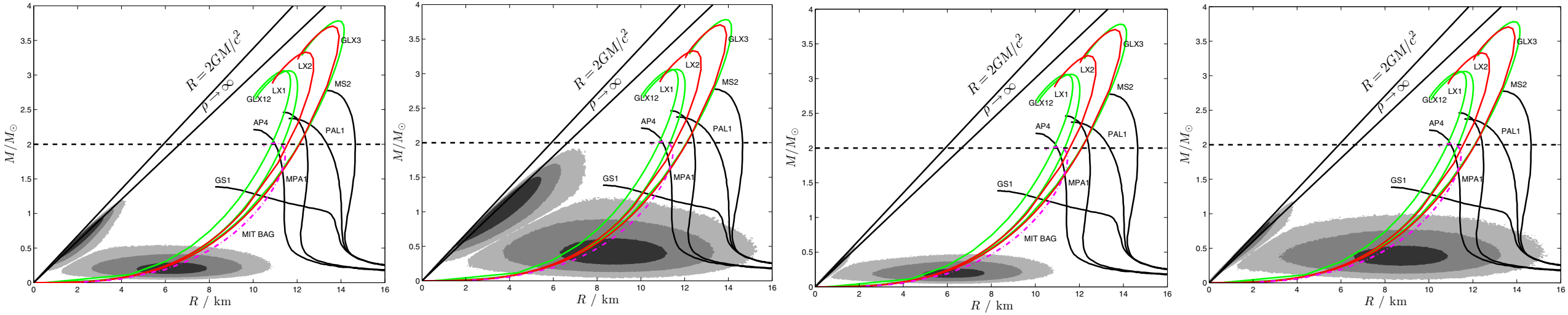
$$k_{\rm es} = 0.2(1 + X)\,{\rm cm}^2\ {\rm g}^{-1}$$

Results for 4U 1746-37

Too Small/Light for Known Neutron Star (1.4 Msun, 10 km)

Table 1
PRE Bursts in 4U 1746-37

Obs_ID	Touchdown Flux (10^{-9} erg s^{-1} cm^{-2})	Peak Flux (10^{-9} erg s^{-1} cm^{-2})	DCOR[a]	PCU on[b]	*M–R*
30701-11-03-000	2.86 ± 0.16	4.84 ± 0.25	1.028-1.035	All	$0.21 \pm 0.06\, M_\odot$, 6.26 ± 0.99 km[c]
30701-11-04-00	2.21 ± 0.14	5.23 ± 0.26	1.023-1.030	All	$0.41 \pm 0.14\, M_\odot$, 8.73 ± 1.54 km[d]
60044-02-01-03	3.01 ± 0.13	5.84 ± 0.23	1.015-1.026	0,2,4	

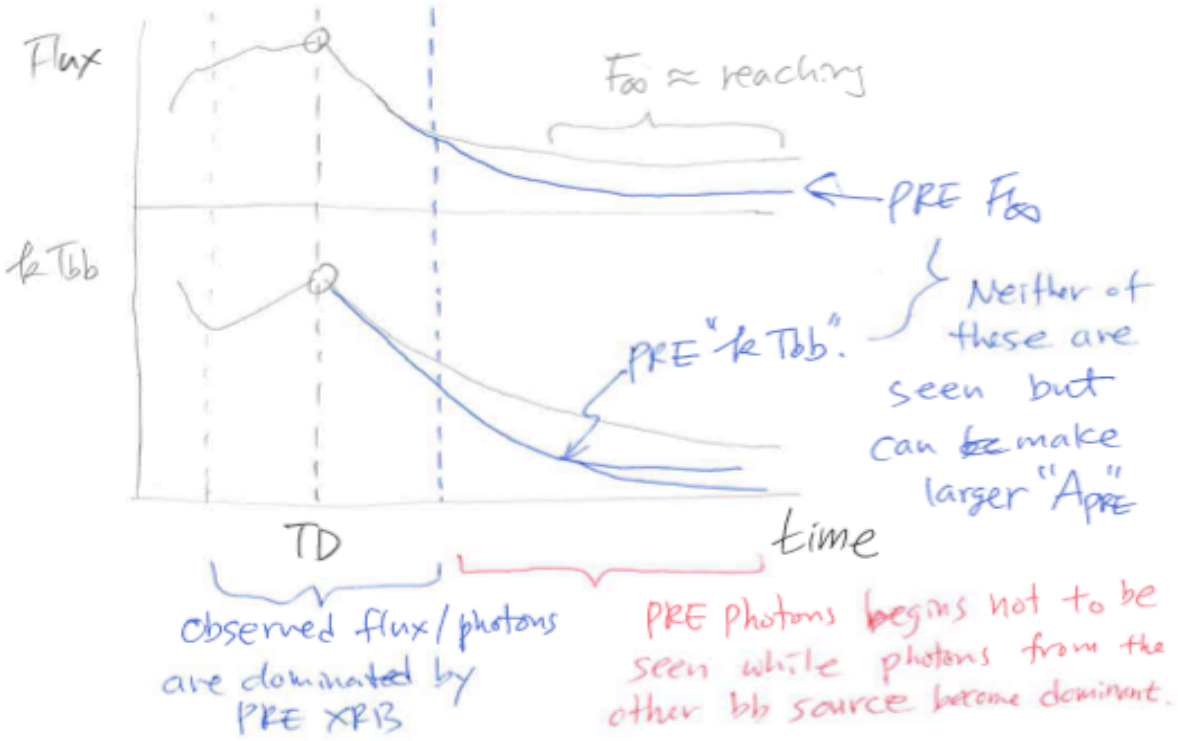


Issues for 4U 1746-37

- X-ray dipping source
  - Shows a regular period (~5.2 hrs) in the X-ray light curve
  - May be caused by the accretion disk
  - Could affect the light curve of PRE XRB
    - Disk scatters (case 1) or blocks (case 2) the emitted light:
    - Case 1: A = A_obs F_TD = F_TD_obs
    - Case 2: $A_{\rm mod} = fA_{\rm obs}$ $F_{\rm TD,\infty,mod} = fF_{\rm TD,\infty,obs}$ $f = F_{\rm peak}/F_{\rm TD} = 2.1 \pm 0.9$
- Belongs to globular cluster (GC) NGC 6441 that is far (~ 11 kpc) and very crowded, having the 2nd highest stellar encounter rate among all the Galactic GCs
  - Galloway+ 2008 suggested two bursting sources co-exist within NGC 6441 based on two different (regular bright and out-of-phase faint) bursts observed simultaneously

Question: Can two XRBs detected at the same time change the estimated mass and radius?

- One shows PRE XRB
- The other shows quiescent emission only



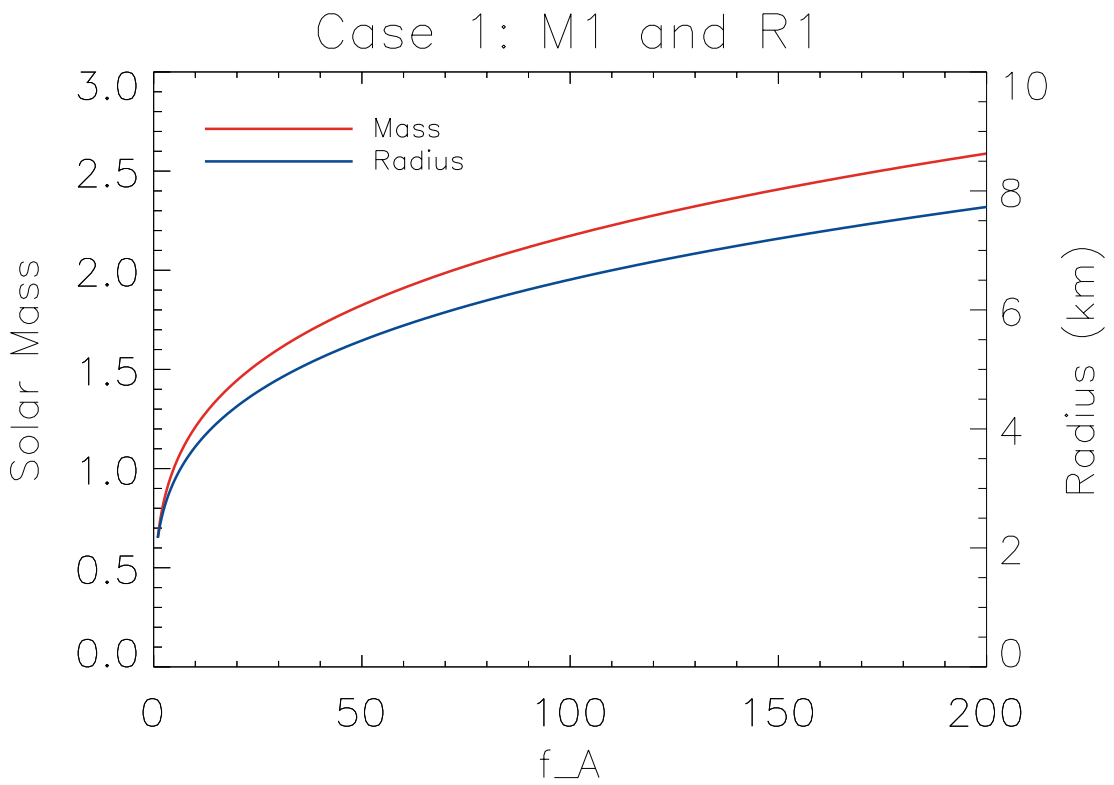
$$F_{\infty,1} \leq F_{\infty,2}$$

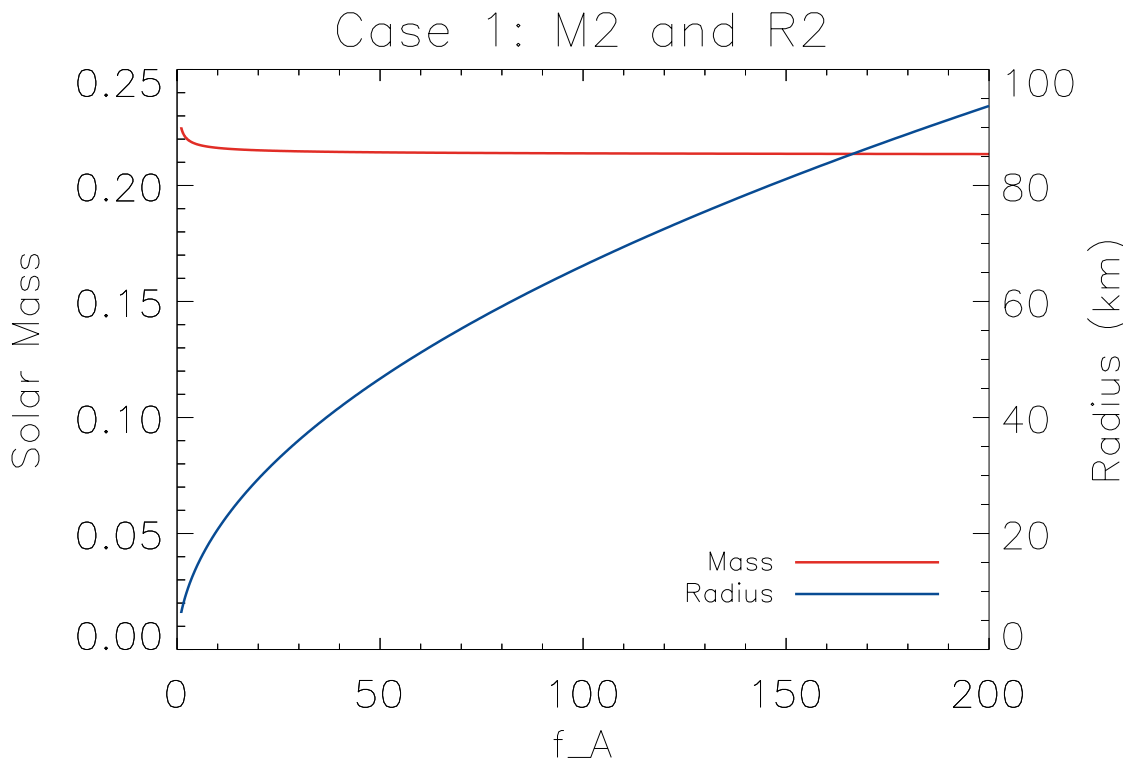
$$T_{bb,1} \leq T_{bb,2}$$

$$A \equiv \frac{F_\infty}{\sigma T_{bb,\infty}^4}$$

Case 1

- F_TD_1 = F_TD = F_TD_obs A_1 = f_A * A_obs



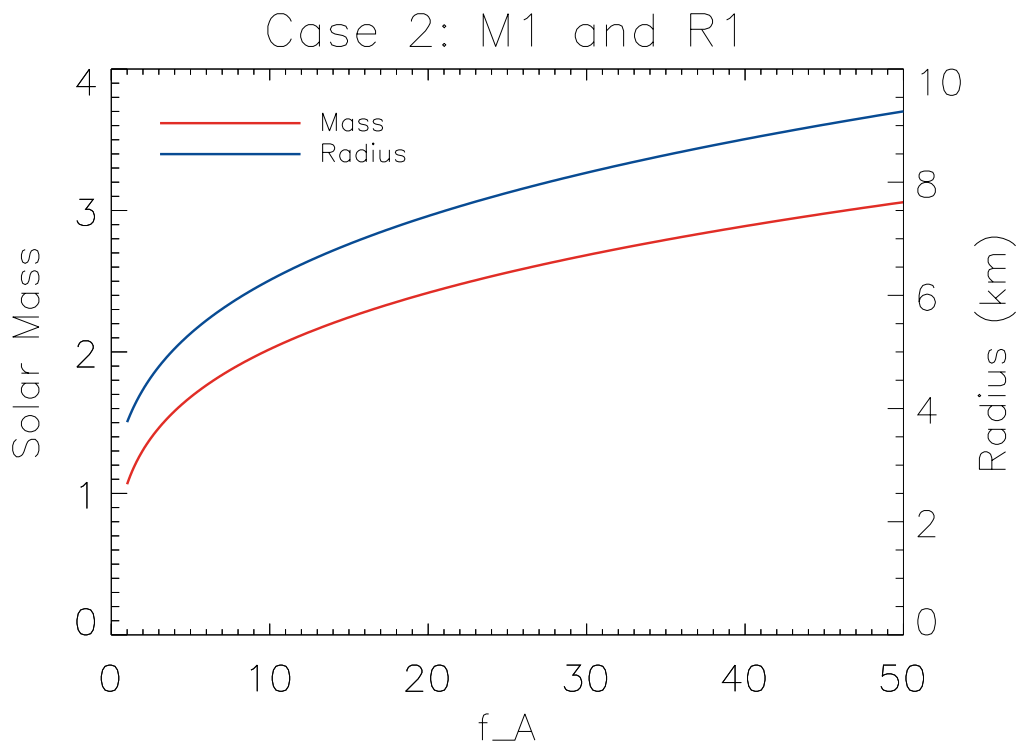


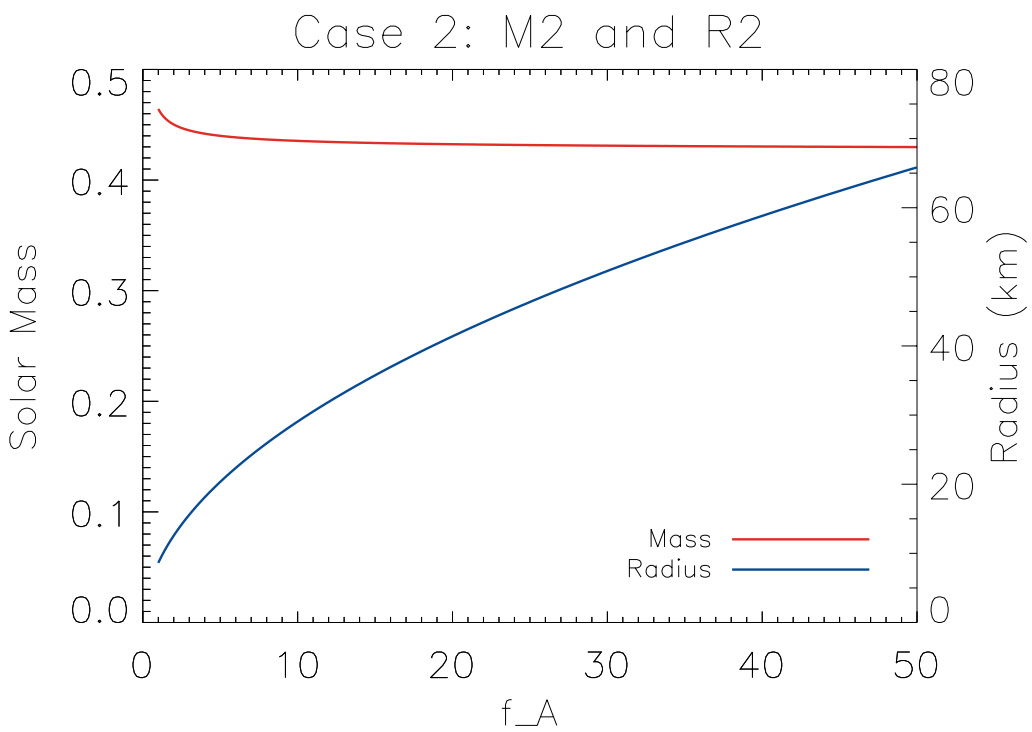
Case 2

F_TD_1 = $F_{\mathrm{TD},\infty,\mathrm{mod}} = f F_{\mathrm{TD},\infty,\mathrm{obs}}$

A_1 = f_A * Amod, $A_{\mathrm{mod}} = f A_{\mathrm{obs}}$

f = 2.0





Conclusion and ongoing work

- By considering observational uncertainty, it is possible to estimate new mass and radius of a neutron star in 4U 1746-37 which is close to the canonical value.
- Other cases are currently under investigation.
- Need to check whether f_A for Source 1 (showing PRE XRB) results in reasonable X-ray source for Source 2 (emitting just a background X-ray flux).
- Need to check whether our (M1, R1) solutions violate the causality limit.
- X-ray observation with high spatial resolution will reveal the population of X-ray sources in NGC 6441, but this observation is challenging due to the distance to this GC.

Thank you from Jin- Kyum, Seo, and Woo!