

Astrophysical neutron star mass-radius measurements from X-ray bursters

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Low-Mass X-ray Binary systems



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Thermonuclear X-ray bursts

We observe short (~30s) X-ray bursts from LMXBs (e.g. Lewin+93, Strohmayer & Bildsten 06)

Bursts can be used to measure the emitting area (i.e., **radius)** of the object (e.g., Ebisuzaki 87, Damen+ 90, van Paradijs+ 90)

3 methods exist:

- **Touchdown method** (used e.g., in Özel+ 06,09,16, Guver+ 10)
- **Cooling tail method** (e.g., Suleimanov+ 11, 17, 19, Poutanen+ 14, JN+ 16)
- **Direct spectral fits** (JN+ 17)



Fig. 3.6. An X-ray burst from 4U 1728–34 observed with the PCA onboard RXTE. The main panel shows the X-ray counts observed by the PCA in (1/32) s bins. The inset panel shows the power spectrum in the vicinity of 363 Hz (after Strohmayer et al. 1996).

Thermonuclear X-ray bursts

Method is able to recover NS radius with unprecedented accuracy of dR <0.5km...

...but as the 'no free lunch' theorem states there are always the if's:

We need to:

- take into account burst states
- be aware of the fit degeneracies
- Assume that burning is uniform



X-ray burst observations







Mass-radius measurements of bursters



Problem #1: Disk state



Poutanen+JN+2014 Kajava+JN+ 2014 Nättilä+ 2016







Problem #2: Soft state burst can still be used to (incorrectly) measure radius

In-built warning signals of incorrect fits



In-built warning signals of incorrect fits





 $R = 2 R_s = 4 G M / c^2$



Problem #3: How robust are the fits?

Calibration of mass-radius measurements

1) Generate mock data with known parameters

Take M, R, D, X Generate synthetic burst spectra



Calibration of mass-radius measurements



Calibration of mass-radius measurements

- 1) Generate mock data with known parameters
- 2) Fit the (mock) data
- 3) Analyze possible sources of bias



Mass-radius measurements for 4U 1702-429



Mass-radius measurements for other bursters



Summary

X-ray bursts can be used to measure NS M-R

Burst parameters show strong dependency on accretion state

Selecting the hard state/passively cooling bursts can give strong radius constraints

For 4U 1702-429 we obtain R=12.4 +- 0.4km; In general we see R=11-13km

