Thermonuclear bursts on neutron stars: News from Terzan 5

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RXTE Puffed Accretion Disk Version 2 with NO Wobble

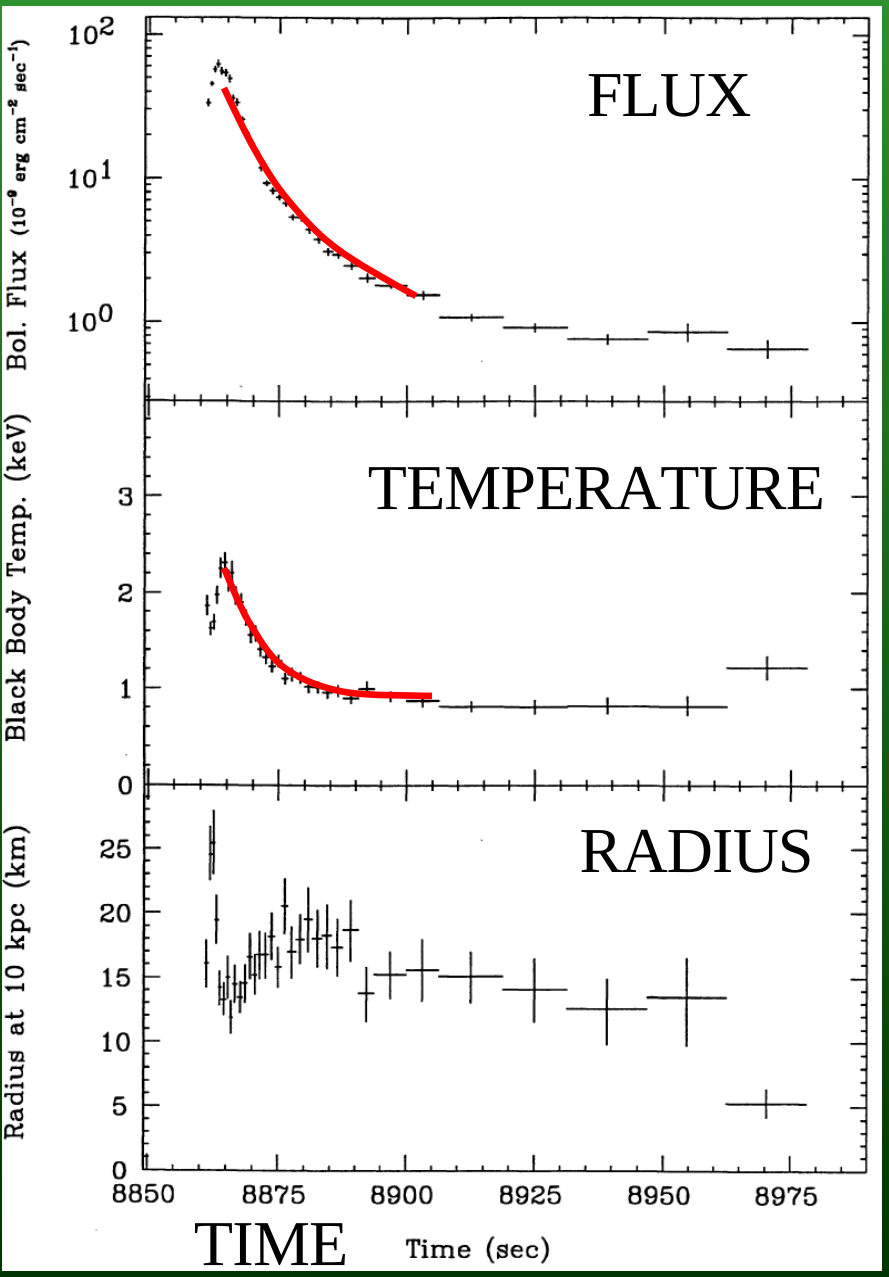
Animation by

Dana Berry

SkyWorks Digital Animation

310-441-1735

Thermonuclear bursts on neutron stars



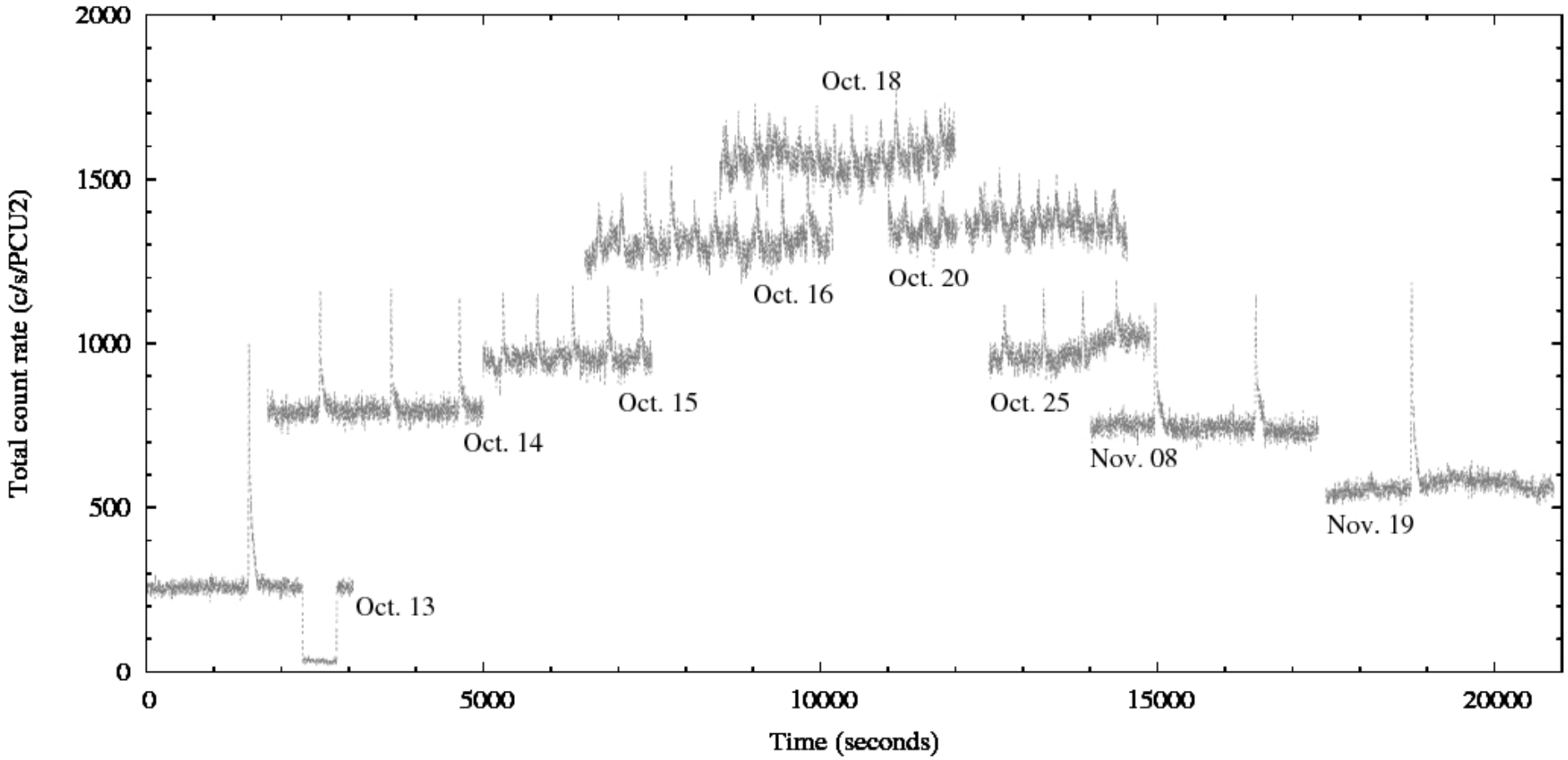
Type I X-ray burst ↔ thermonuclear burst

Defining property:
thermal (~0.5-3 keV) spectrum
+ cooling along the decay: “cooling tail”

Cooling of the neutron star photosphere after the fast injection of heat during thermonuclear runaway

From Oosterbroek in Lewin et al (1993); Hoffman et al (1978)

Terzan 5: smooth burst evolution

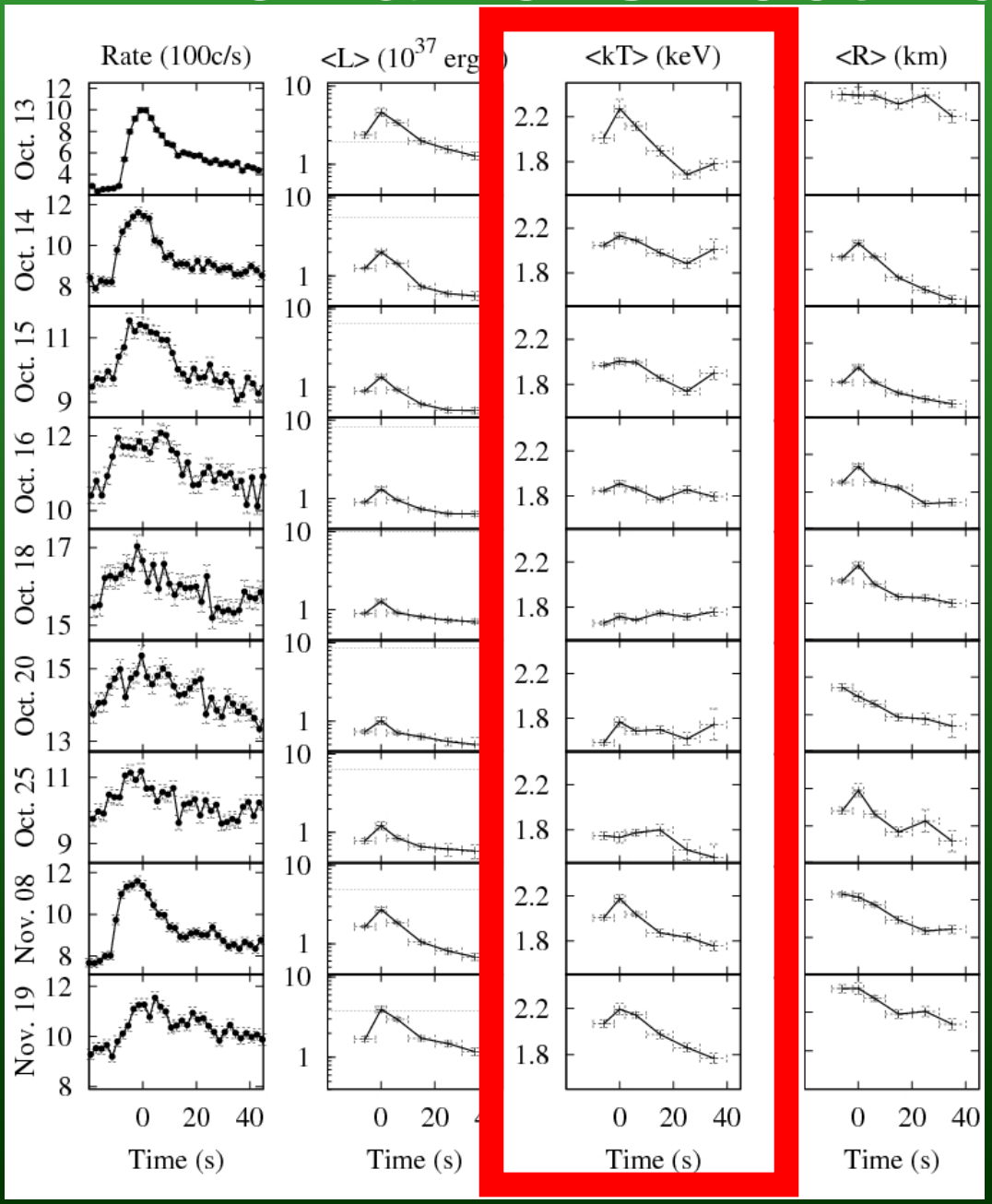


Linares et al (2011)

11 Hz pulsar in a ~21hr orbit (Strohmayer et al. 2010; Papitto et al. 2011) showing MANY X-ray bursts (~400 between Oct. 13 – Nov. 19, 2010)

Interesting burst properties, mHz QPOs…

Terzan 5: smooth burst evolution



Energetics: thermonuclear

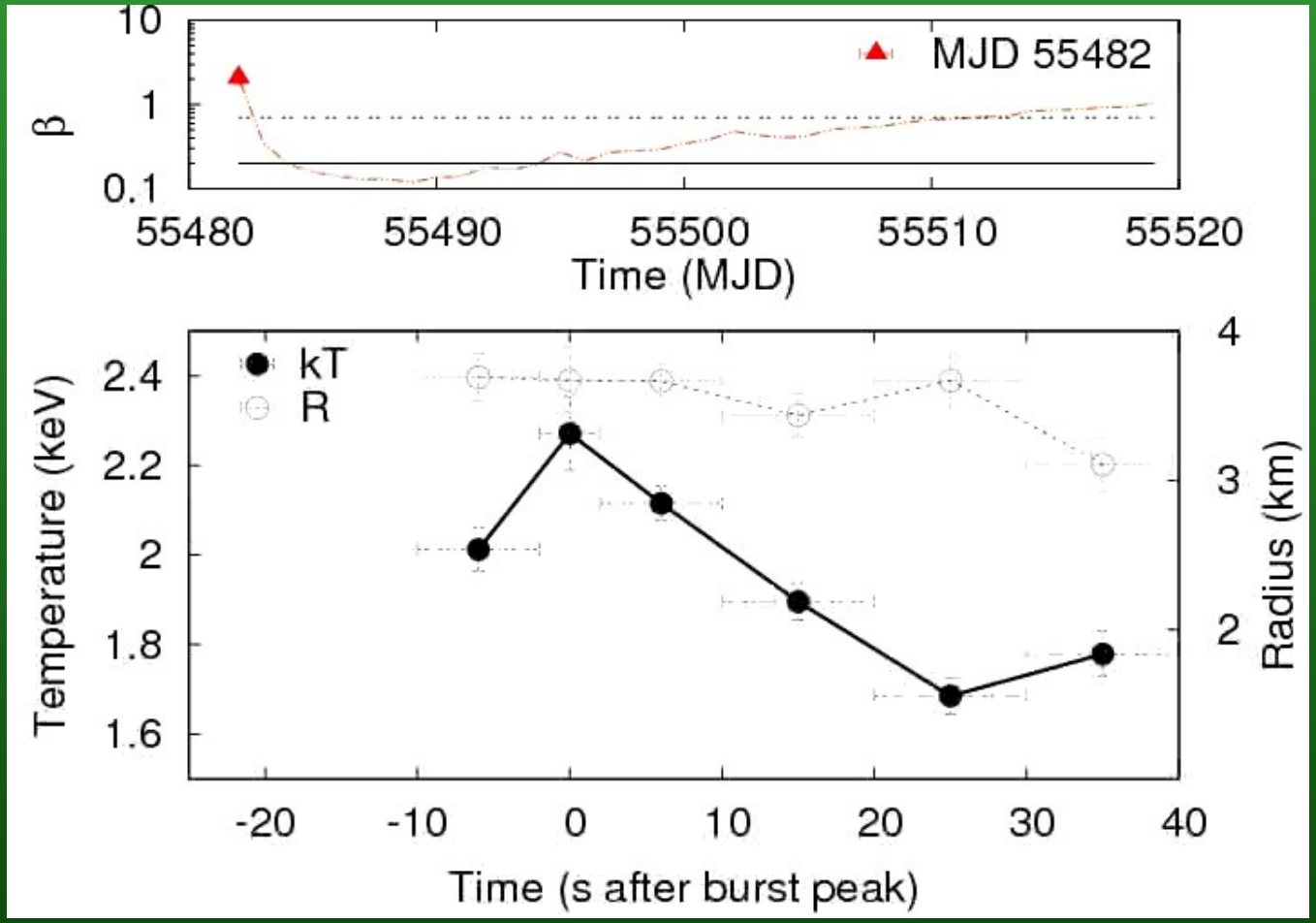
($\alpha \equiv E_{accretion}/E_{burst} \sim 100$)

Smooth evolution from type I to 'non-cooling' X-ray bursts, and vice versa.

→ First X-ray bursts without cooling tail identified as thermonuclear!

M. Linares. X-Universe 2011

Terzan 5: smooth burst evolution

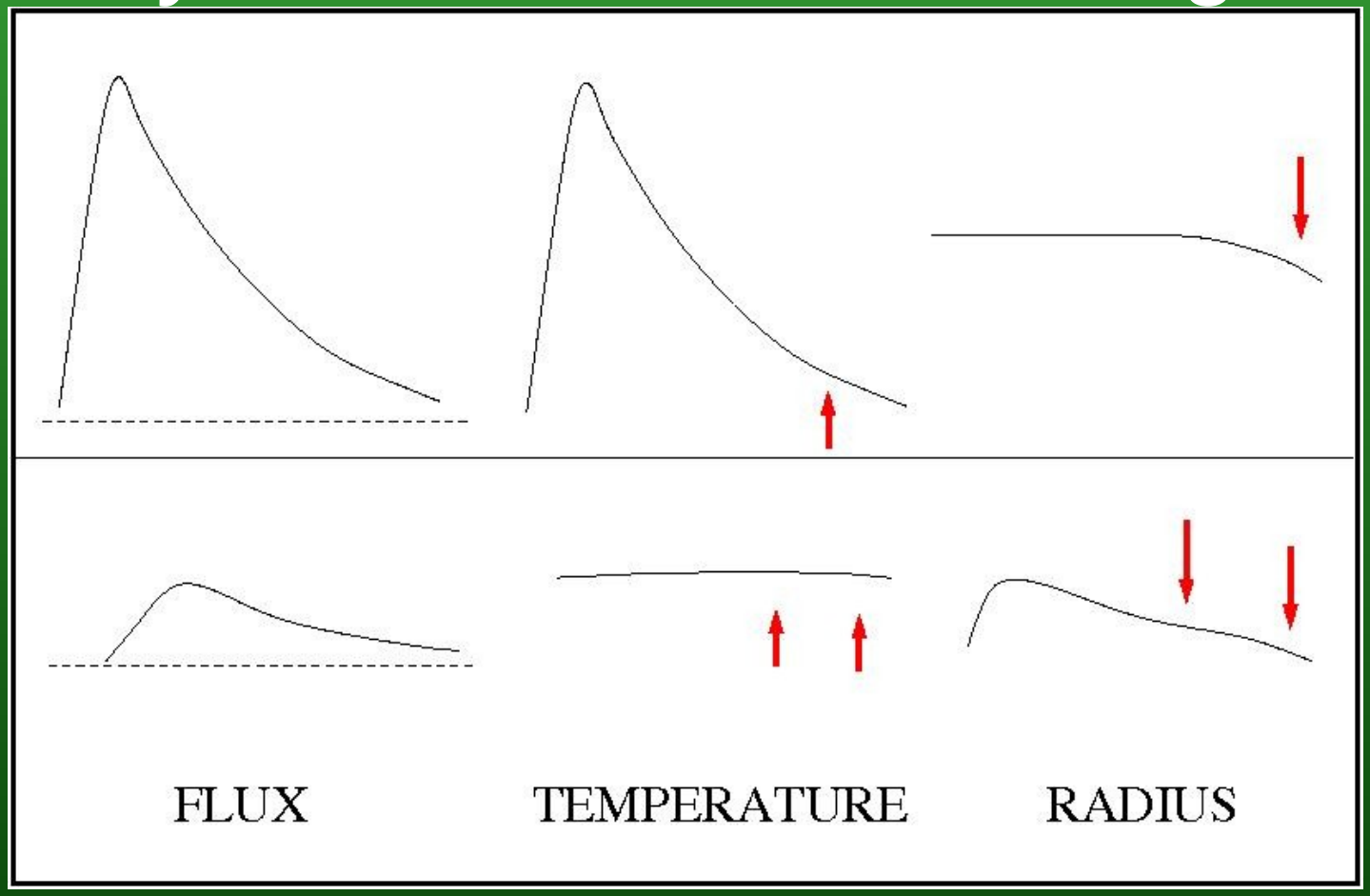


β ≡ Peak burst luminosity / Persistent luminosity

- β>0.7: type I X-ray bursts.
- 0.2<β<0.7: single bursts DON'T but daily averages DO show cooling.
- β<0.2: no cooling.

M. Linares. X-Universe 2011

Systematics hides cooling

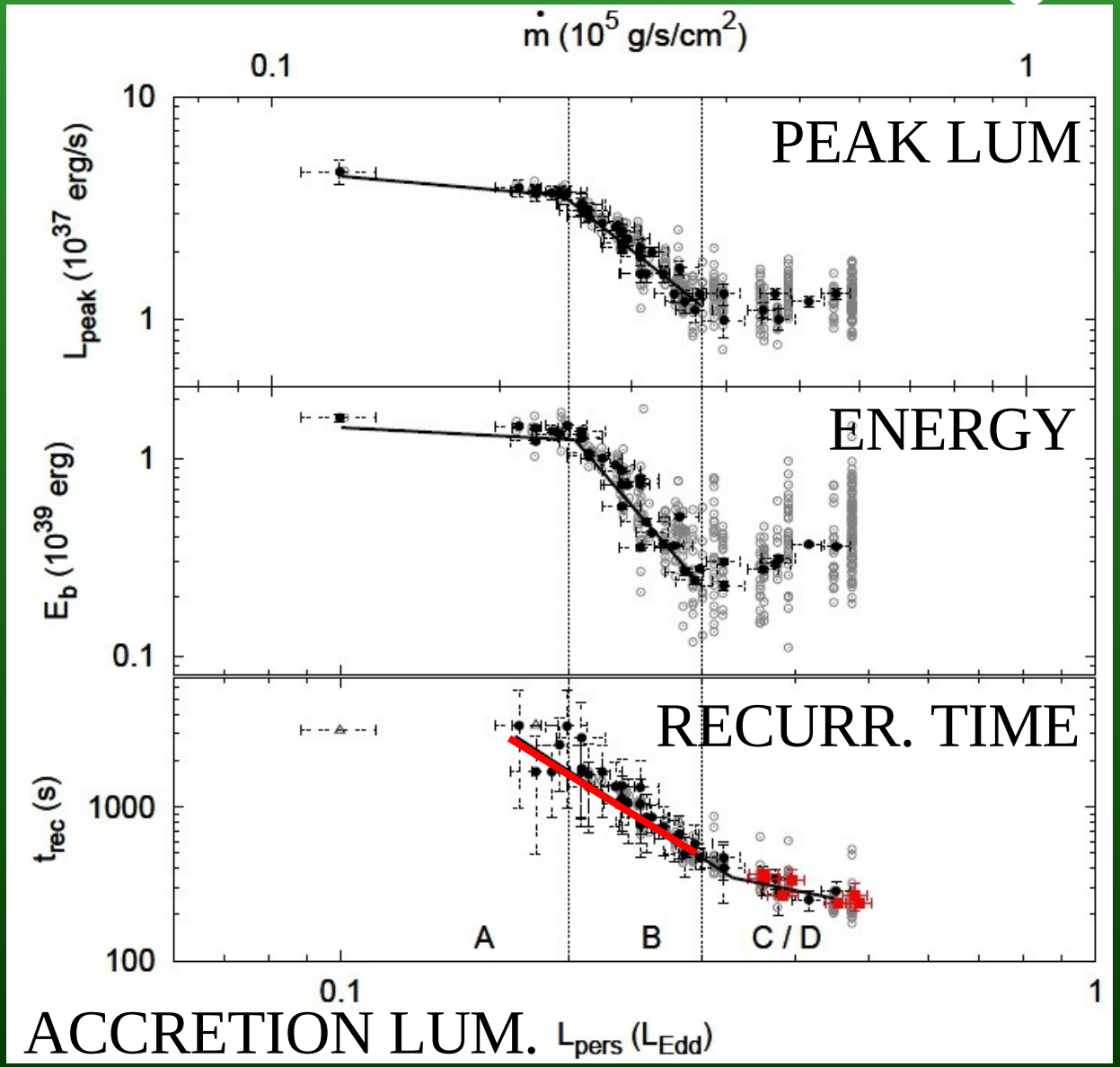


-If persistent NS surface emission dominates, “standard spectroscopy” over[under]estimates T[R] (van Paradijs & Lewin 1986)

→ A hot NS *between* bursts can hide cooling *during* faint bursts.

(Supported by spectral simulations; M. Zamfir priv. comm.)

Terzan 5: bursting regimes



Linares et al. in prep

The highest burst rates, in a regime (persistent luminosity > 0.2 L_{Edd}) where bursts were extremely rare!

$t_{rec} \sim L_{pers}^{-3.2+/-0.5}$

In this regime 'hot CNO' should give constant heating rate: (Cumming & Bildsten 2000)

Need extra heating, from triple alpha? or previous bursts?

Summary

New transient in Terzan 5, unprecedented behavior:

X-ray bursts smoothly evolve from type I to non-cooling.

First non-cooling bursts identified as thermonuclear!

Systematics of standard burst spectroscopy can hide cooling in thermonuclear bursts.

Threshold: $\beta = L_{peak}/L_{persistent} = 0.2$

Cooling (type I) vs. thermonuclear X-ray bursts:

Sufficient but not necessary!

Linares, Chakrabarty & van der Klis (2011), ApJ-L, 733, 17

Extremely high burst rate, $t_{rec} \sim L_{pers}^{-3}$

Extra heating by He burning or ‘hot ashes’?