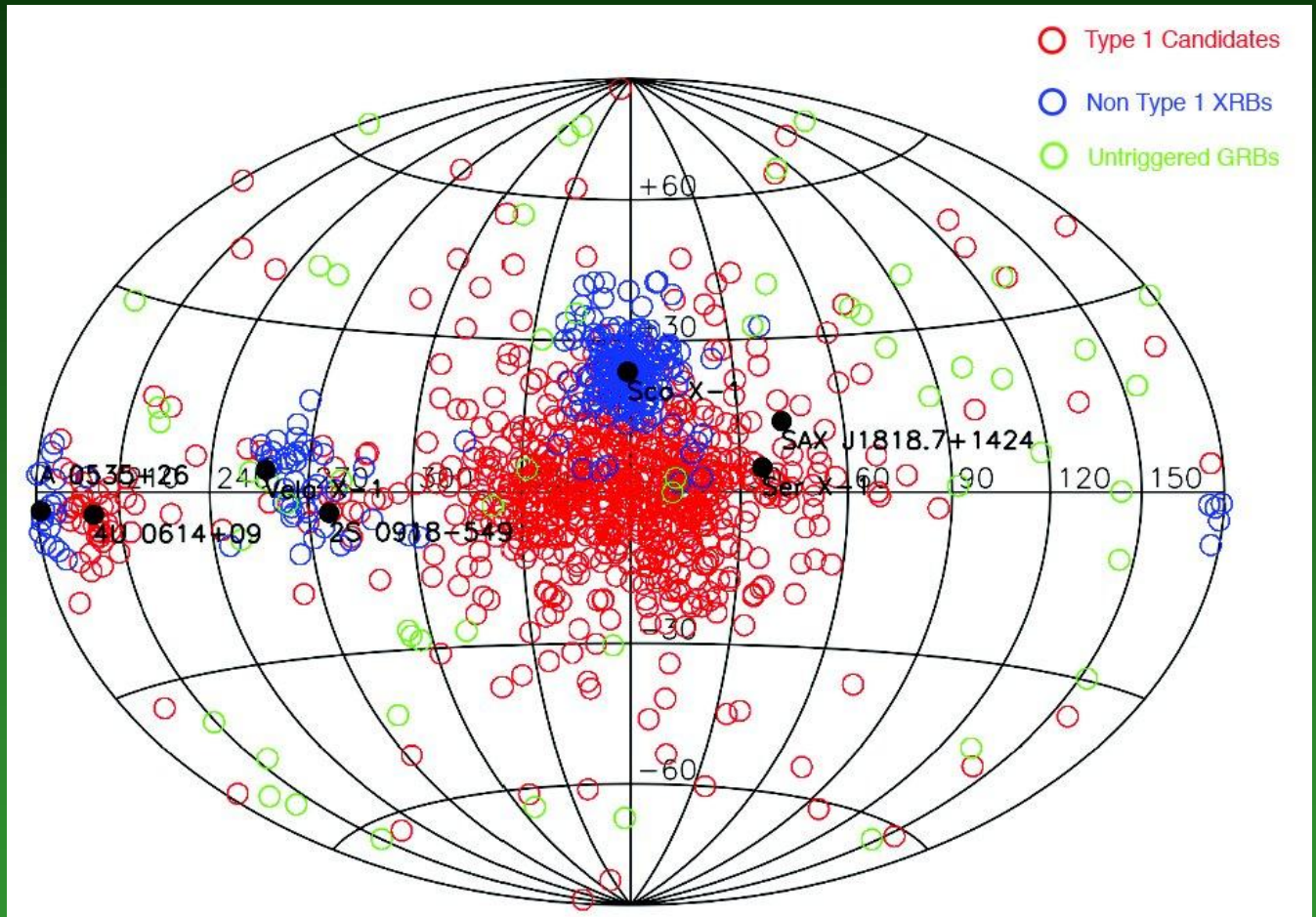
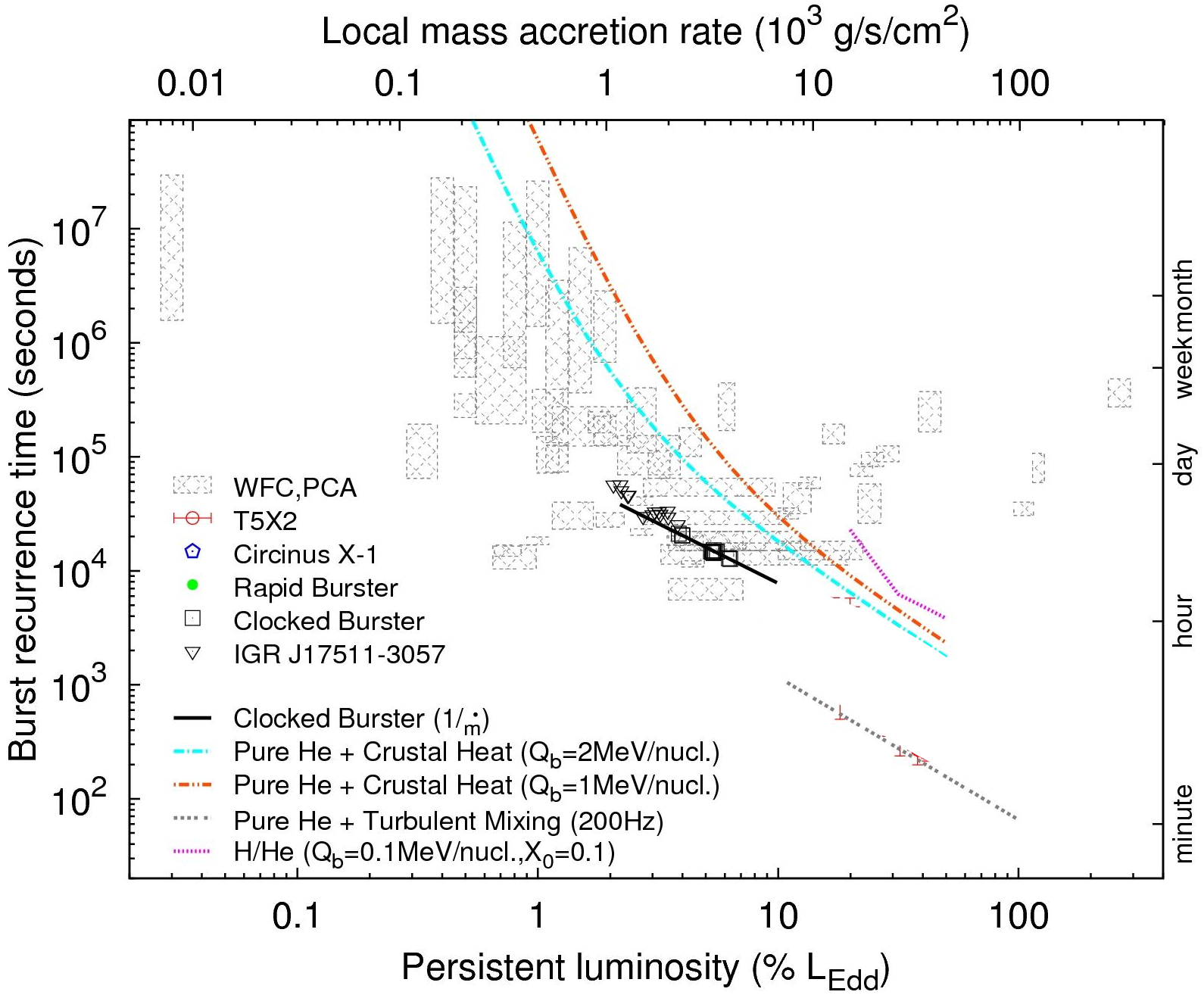
The Fermi-GBM X-ray Burst Monitor



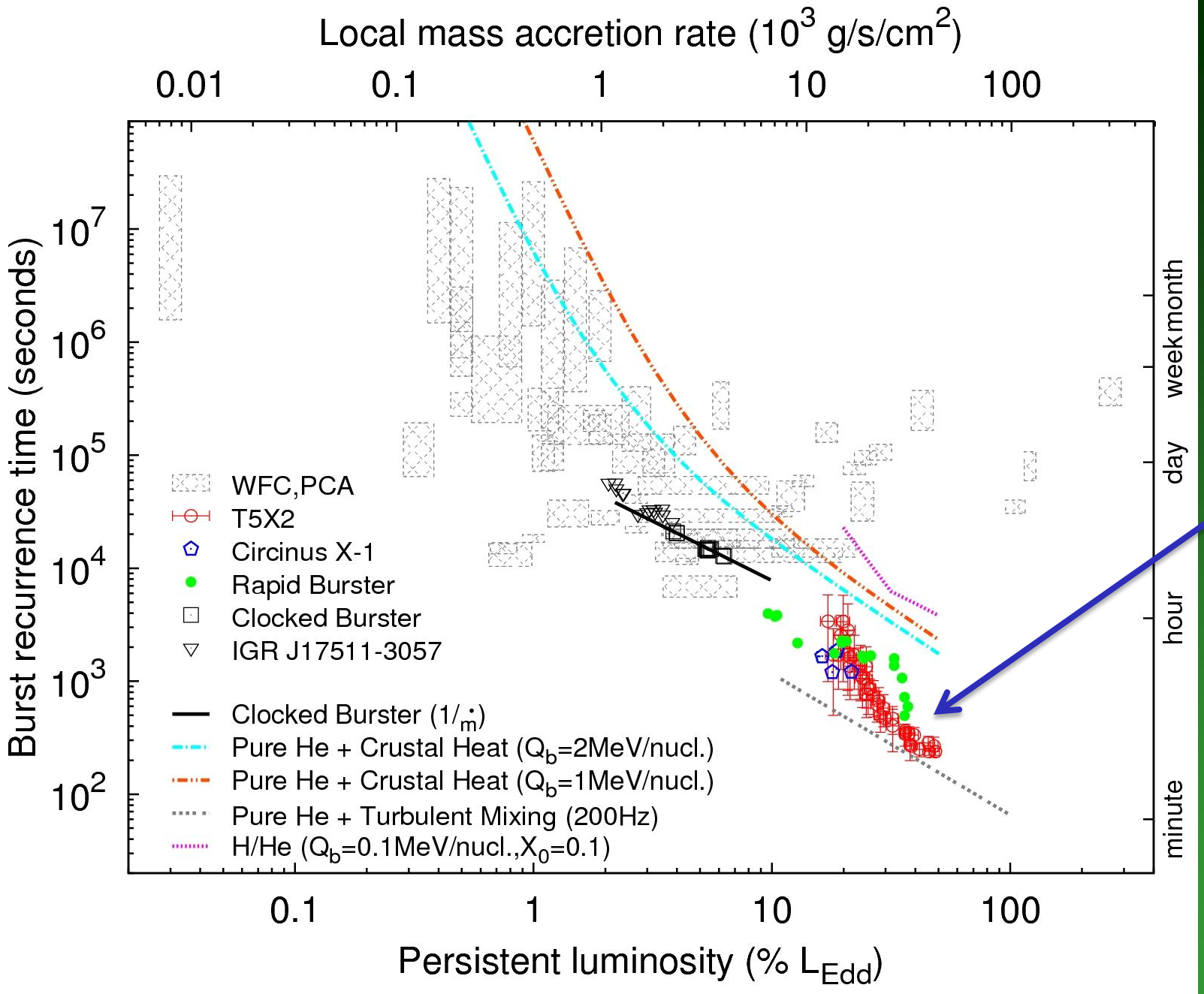
Manu Linares – IAC, Spain
Pete Jenke, Valerie Connaughton, et al. (UAH/MSFC)

ESAC, 40 years of X-ray bursts, June 2015

The University of Alabama in Huntsville

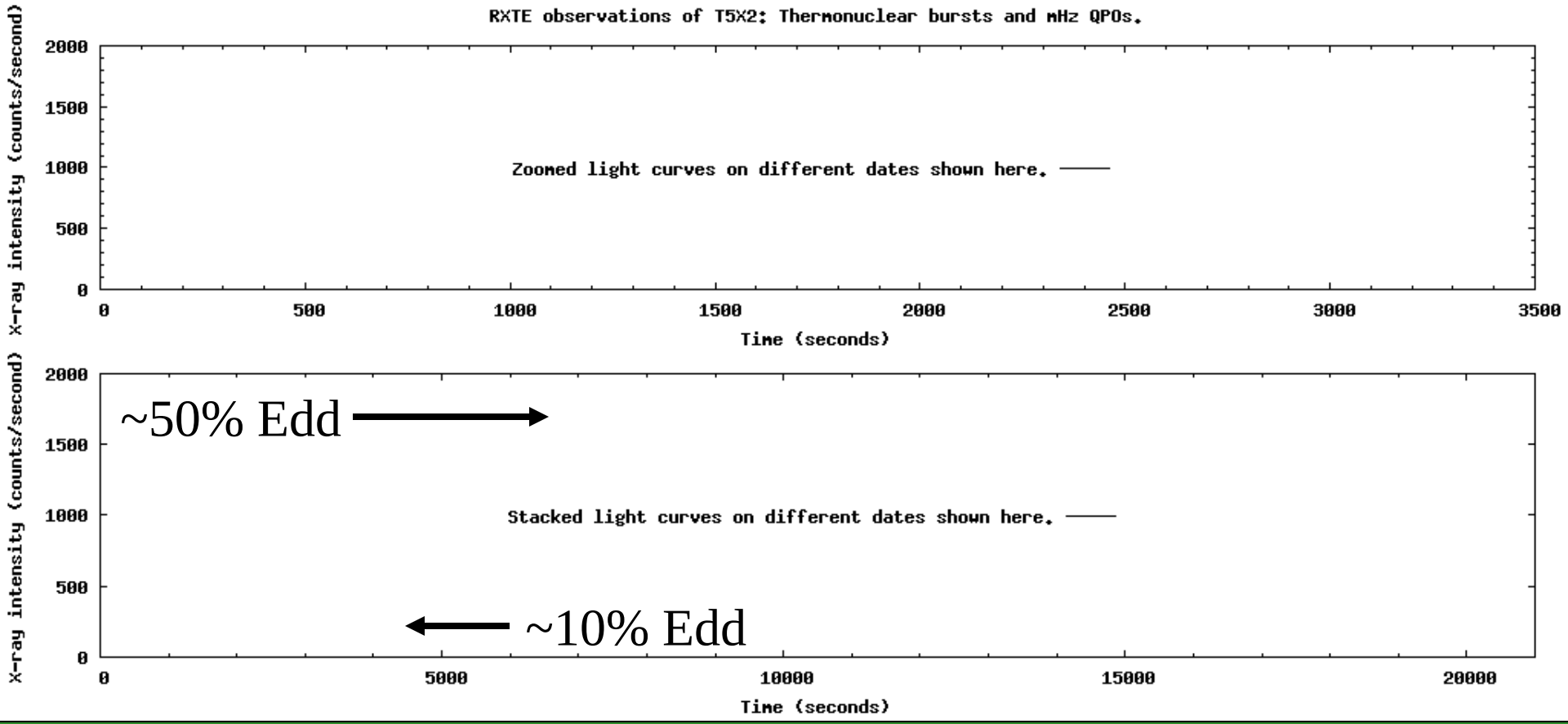


Compilation: Linares; Refs: in't Zand ea (2007); Galloway ea (2008); Galloway ea (2004); Chenevez ea (2009); Linares ea (2010,2012); Bagnoli ea (2014); Models: Cumming & Bildsten (2000); Piro & Bildsten (2007)



Compilation: Linares; Refs: in't Zand ea (2007); Galloway ea (2008); Galloway ea (2004); Chenevez ea (2009); Linares ea (2010,2012); Bagnoli ea (2014); Models: Cumming & Bildsten (2000); Piro & Bildsten (2007)

T5X2: smooth burster



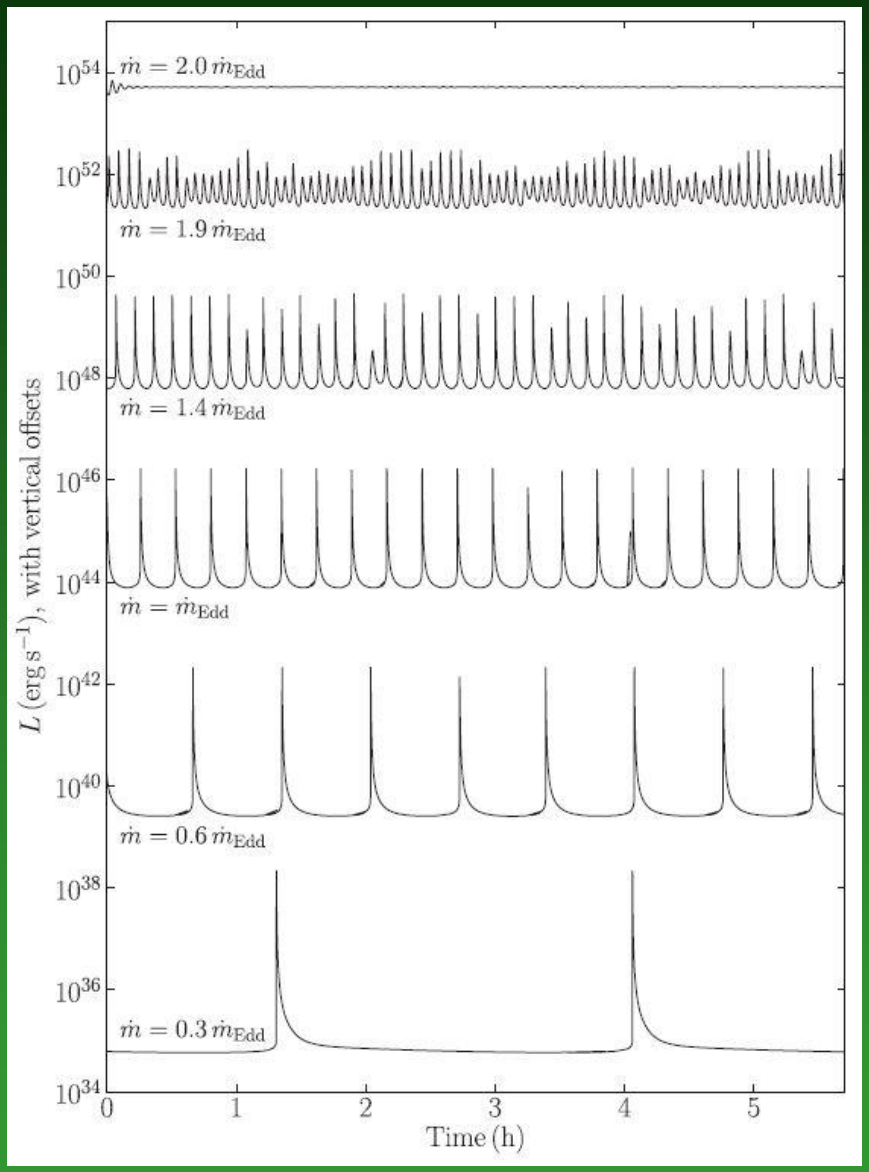
Energetics: thermonuclear ($\alpha \equiv E_{accretion}/E_{burst} \sim 100$).

Burst timescales, energy, luminosity, all evolved smoothly.

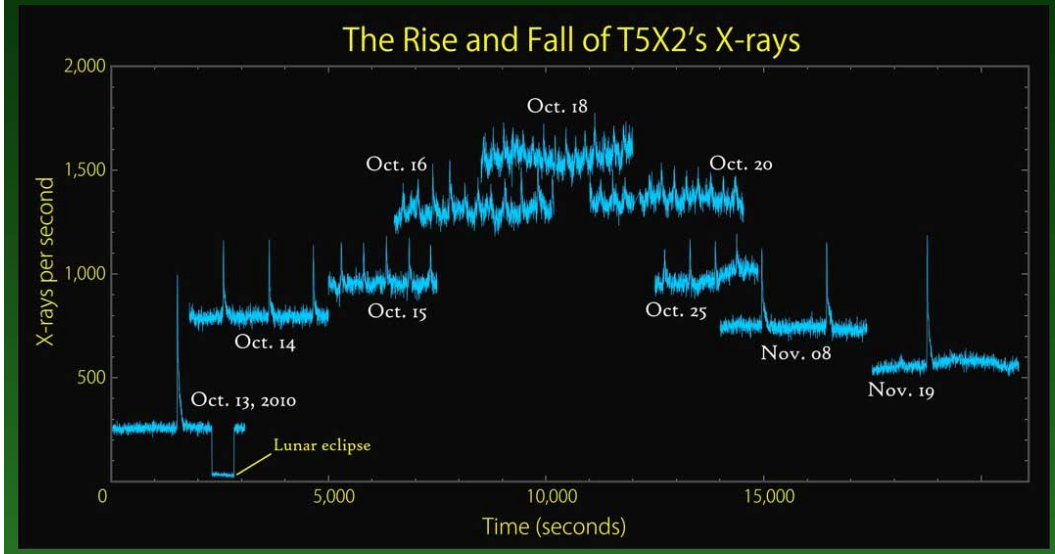
Expected high mdot (>10%Edd) behavior, seen for the first time.

Ignition every few minutes!

T5X2: smooth burster



Zamfir et al. (2014); see also Heger et al. (2007)



Linares et al. (2012)

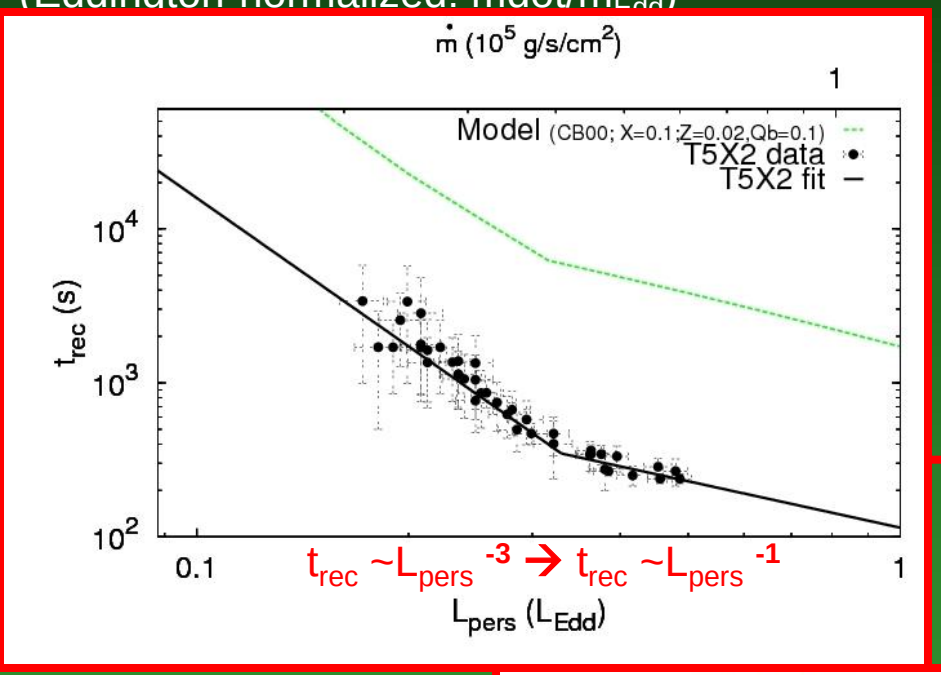
Models and simulations predict marginally stable (oscillatory) burning at the boundary between unstable and stable He burning.

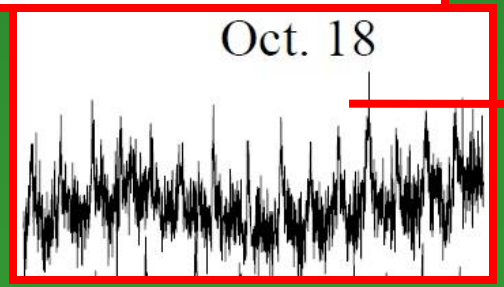
Striking qualitative agreement!

T5X2 vs. burning regimes

mdot=accreted mass/time/area

(Eddington-normalized: mdot/m_{Edd})





Increasing mdot

•Unstable H burning:

mdot/m_{Edd}<0.01

Thermally unstable H burning.

Previous (atoll) mHz QPOs? 5% Edd

(Revnivtsev'01, Altamirano'08, +talk)

•Pure He ignition:

0.01<mdot/m_{Edd}<0.04

He ignites in the absence of H.

He → H/He ignit. transition! 30% Edd

•Mixed H/He ignition:

0.04<mdot/m_{Edd}<1

He ignites in a mix of H&He.

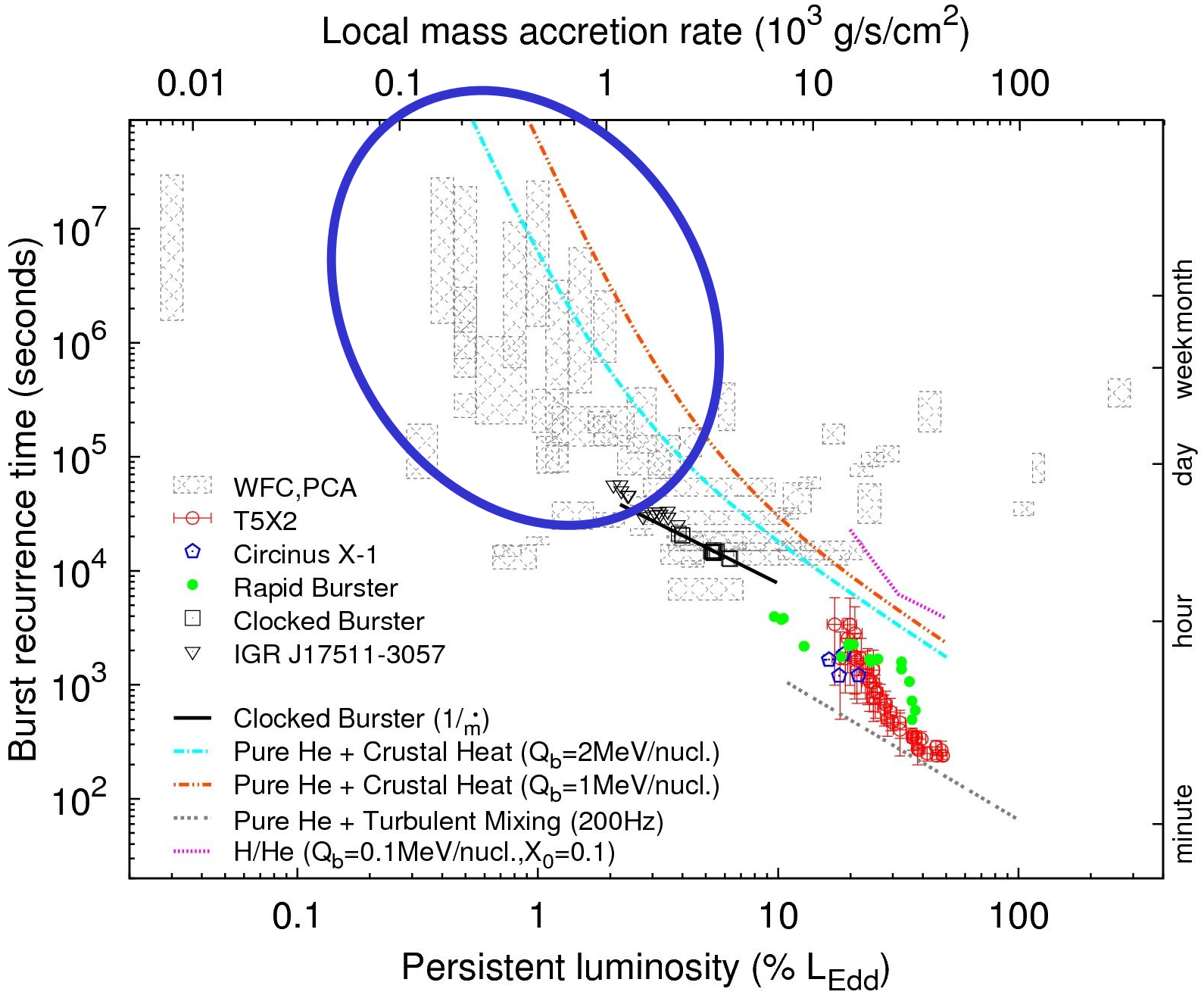
Marginally stable burning! 50%Edd

•Stable H&He burning:

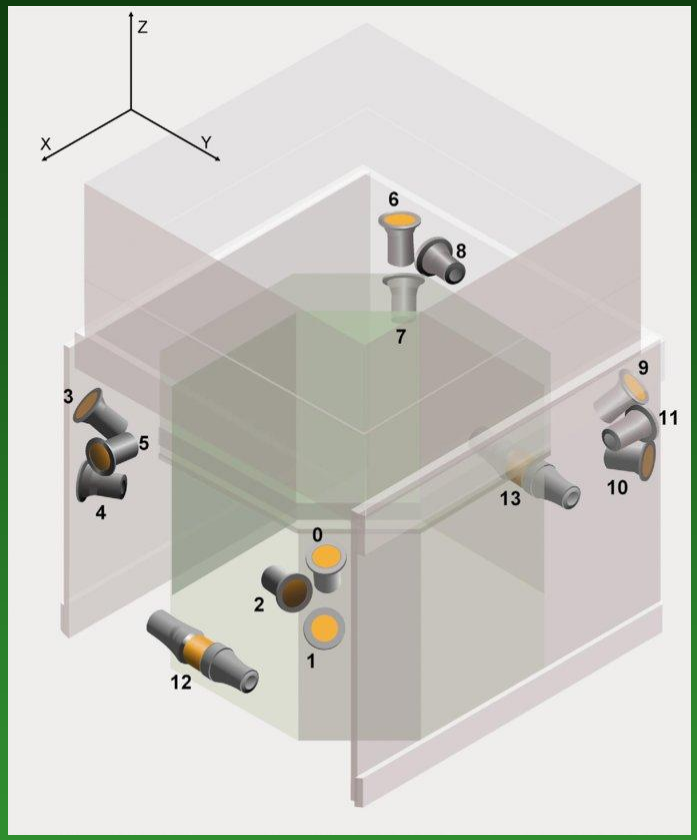
mdot/m_{Edd}>1

Both H and He burn stably. No bursts.

Pic: Horowitz; Refs: Woosley & Taam (1976); Fujimoto ea (1981); Taam (1981); Bildsten (1998); Cumming & Bildsten (2000); Woosley ea (2004)


Local mass accretion rate (10^3 g/s/cm^2)
0.01
0.1
1
10
100
Burst recurrence time (seconds)
10^7
10^6
10^5
10^4
10^3
10^2
minute
hour
day
week
month
WFC,PCA
T5X2
Circinus X-1
Rapid Burster
Clocked Burster
IGR J17511-3057
Clocked Burster ($1/\dot{m}$)
Pure He + Crustal Heat (Q_b=2MeV/nucl.)
Pure He + Crustal Heat (Q_b=1MeV/nucl.)
Pure He + Turbulent Mixing (200Hz)
H/He (Q_b=0.1MeV/nucl.,X_0=0.1)
0.1
1
10
100
Persistent luminosity (% L_{Edd})

The Fermi-GBM X-ray Burst Monitor

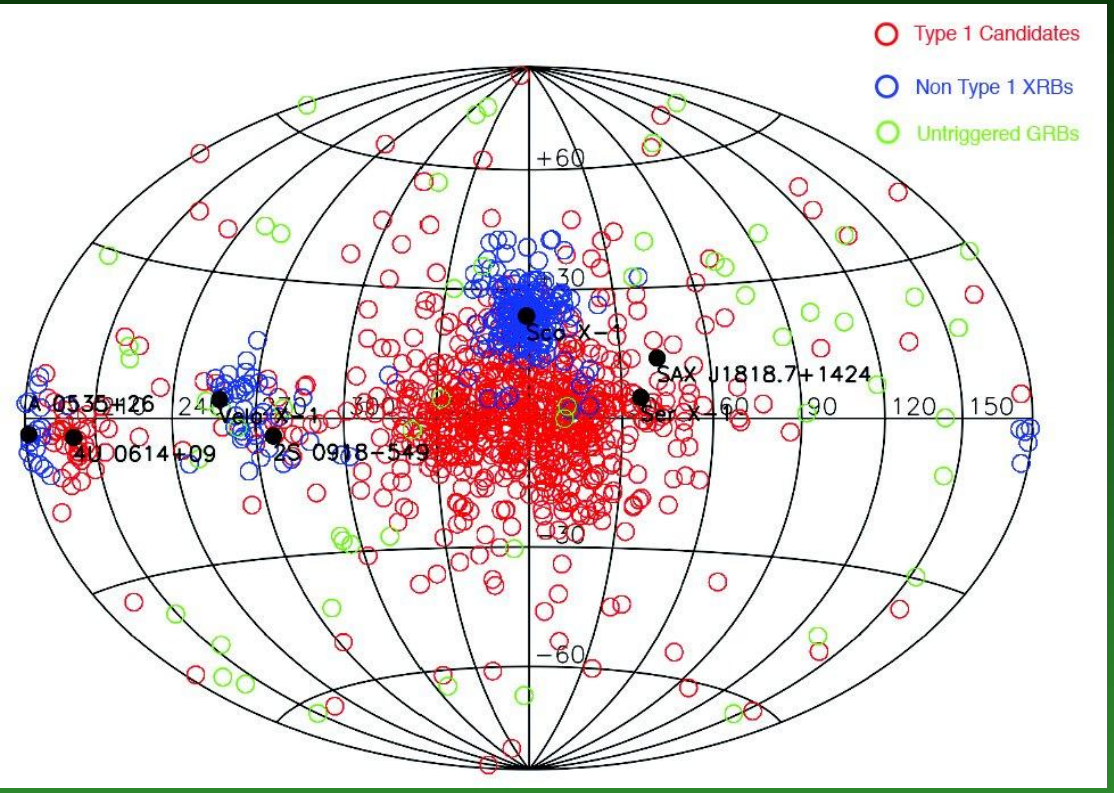


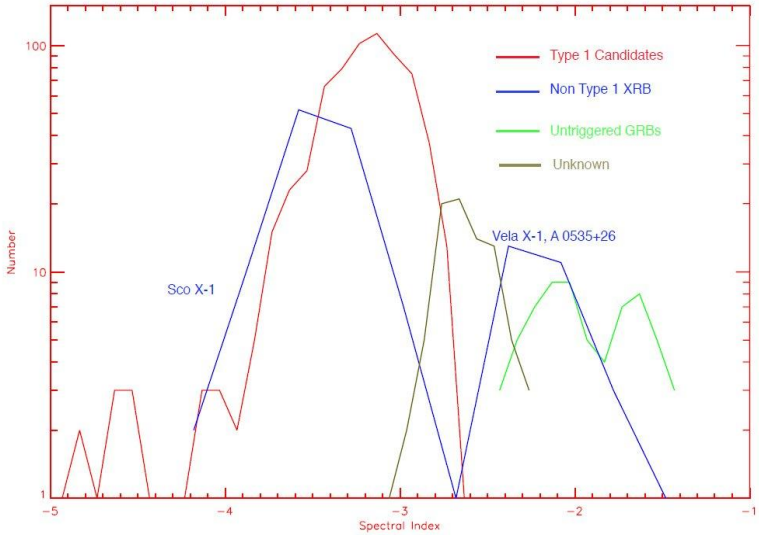
World English Dictionary:

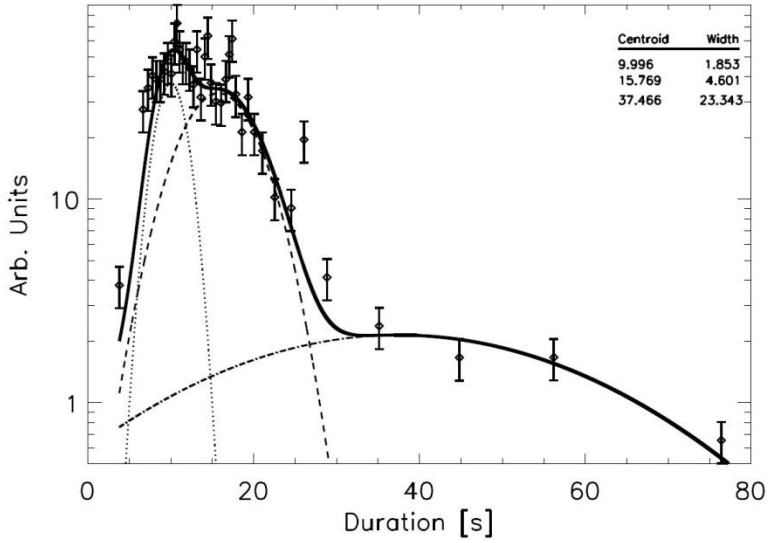
monitor — ***n*** 1. a person or piece of equipment that warns, checks, controls, or keeps a continuous record of something.

- Field of view: all unocculted (75%) sky.
- X-ray response: down to 8 keV.
- Optimal instrument to detect rare & bright X-ray bursts.

The Fermi-GBM X-ray Burst Catalog

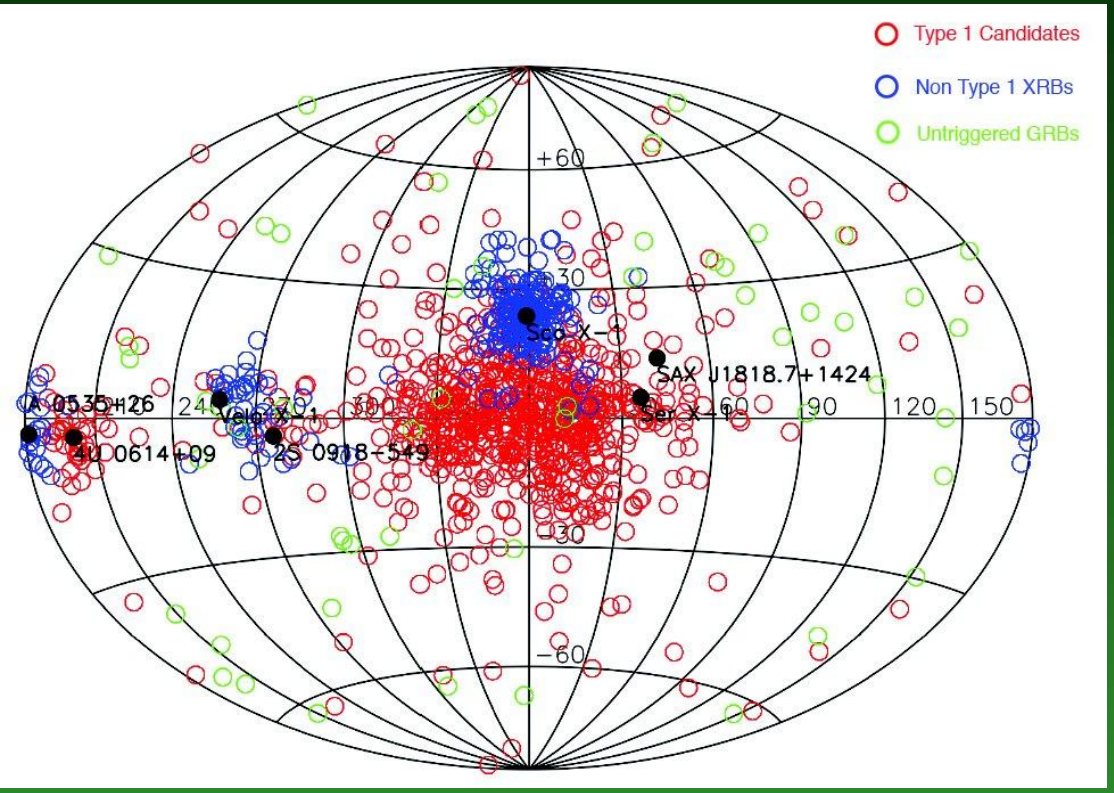






- 3-year catalog (2010-2013, JENKE+)
- 8-50 keV, ~8s time resolution
  - **671 Type I X-ray bursts**
  - **65 Untriggered GRBs**
  - **267 flares/pulses accr. binaries** **(Sco X-1, Vela X-1, A0535+26)**
  - (+thousands of Solar flares rejected)

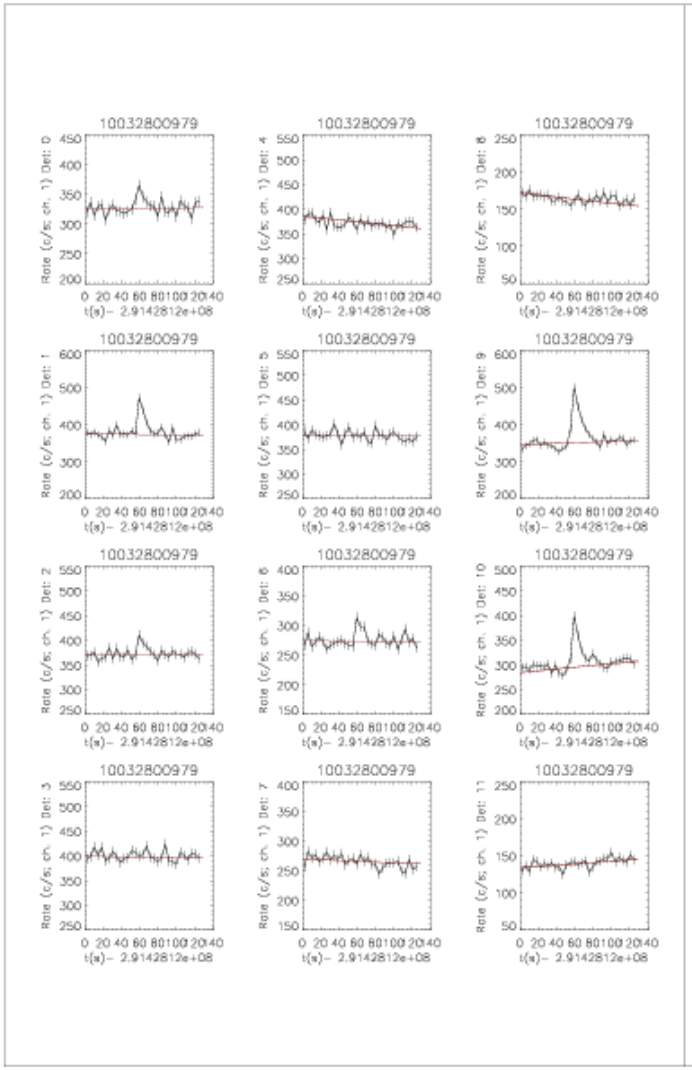
The Fermi-GBM X-ray Burst Catalog

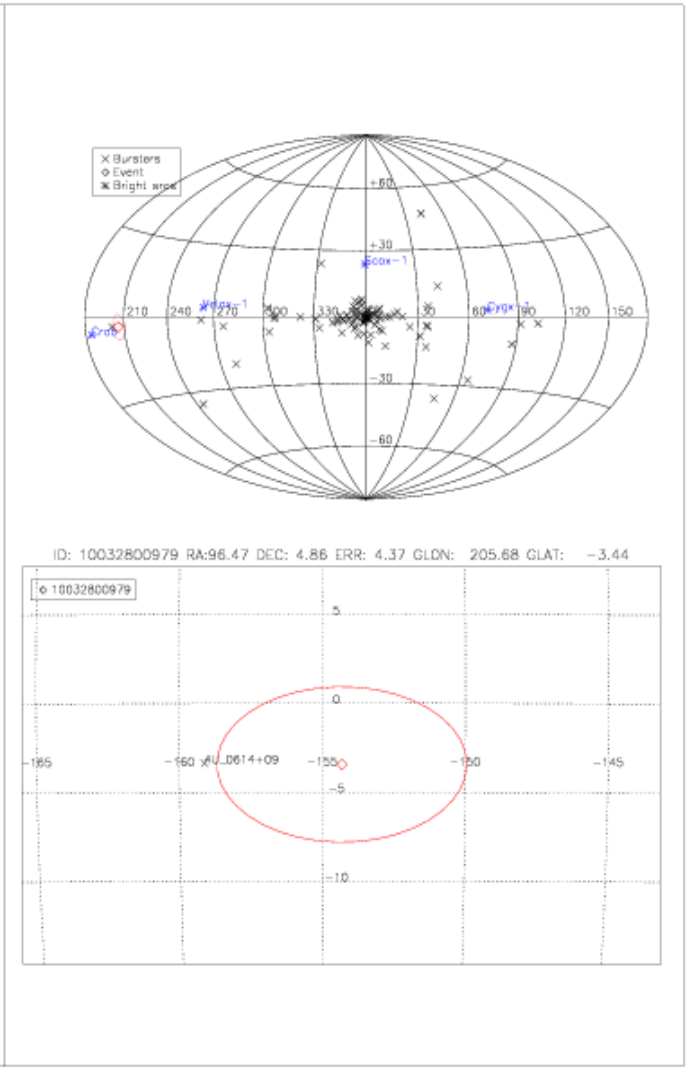


- 3-year catalog (2010-2013, JENKE+)
- 8-50 keV, ~8s time resolution
  - **671 Type I X-ray bursts (50% duty cycle)**

→ ~ 450 PER YEAR intrinsic Galactic BRIGHT burst rate

The Fermi-GBM X-ray Burst Monitor

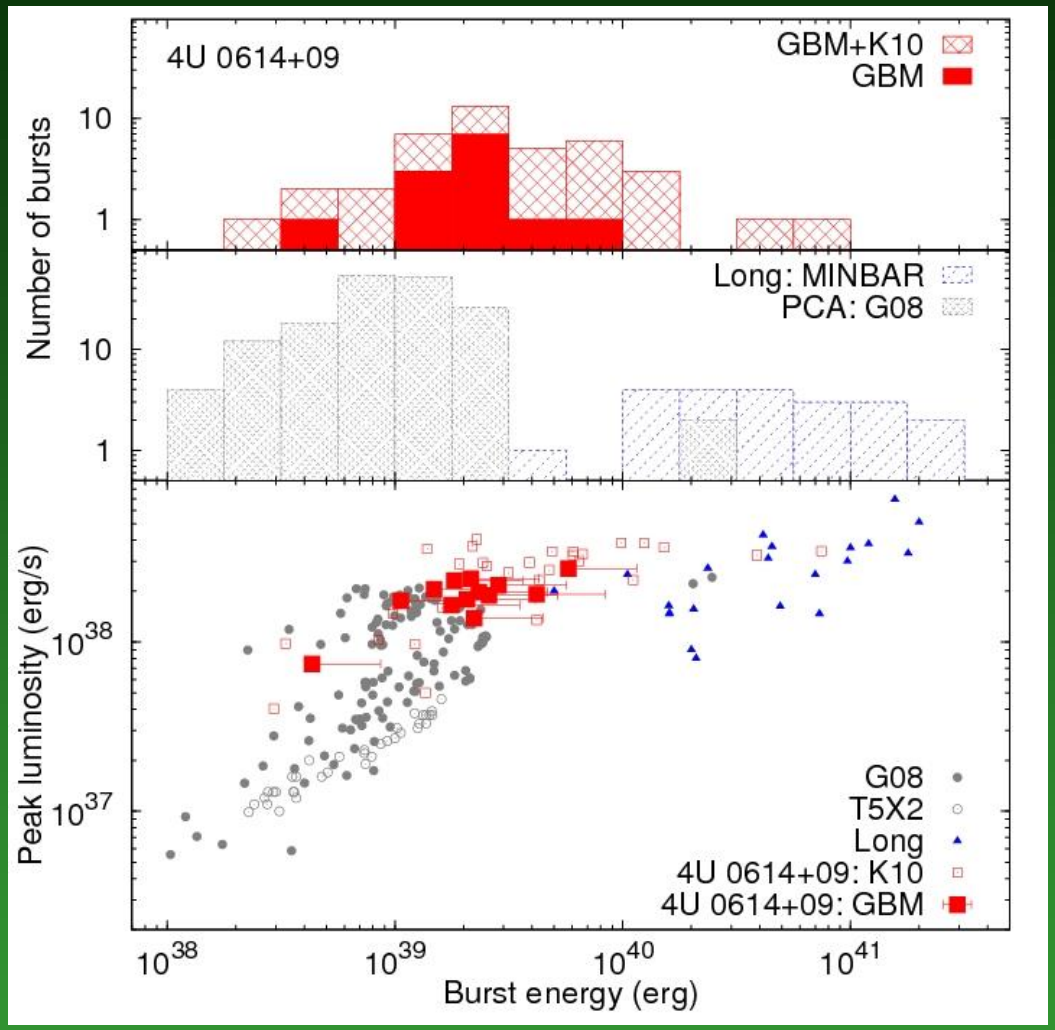




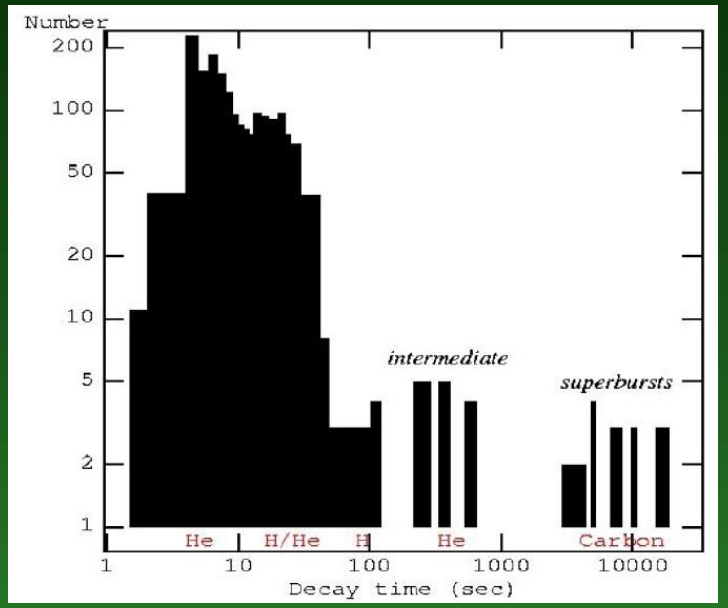
1% Eddington: 15 GBM bursts from 4U 0614+09 in the 1st year!

(33 bursts detected in the previous >30 years; Kuulkers et al. 2010)

GBM & thermonuclear bursts: 4U0614+09



Linares et al. (2012)



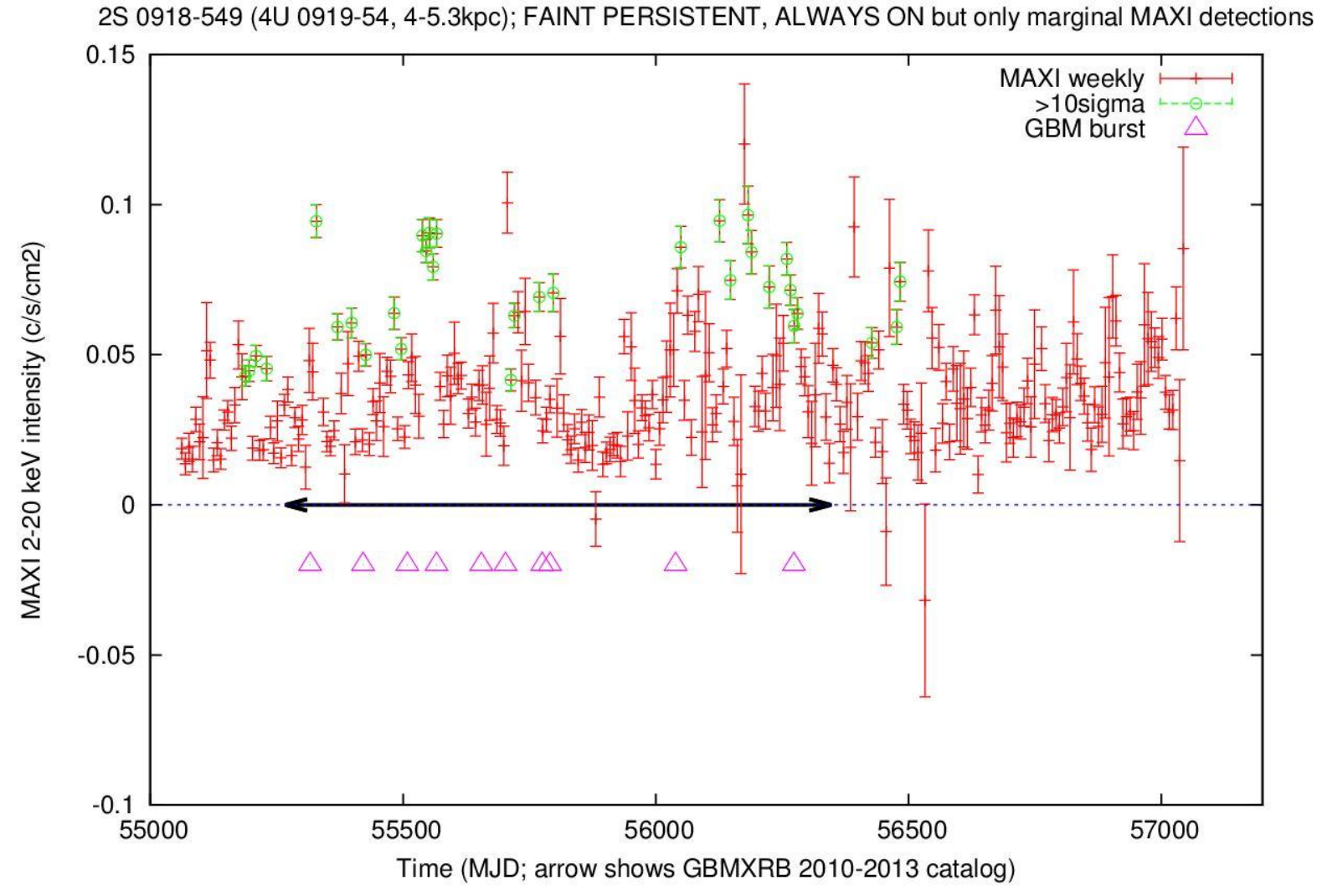
Chenevez et al. (2008)

Does the bimodal *duration* distribution reflect a selection effect?

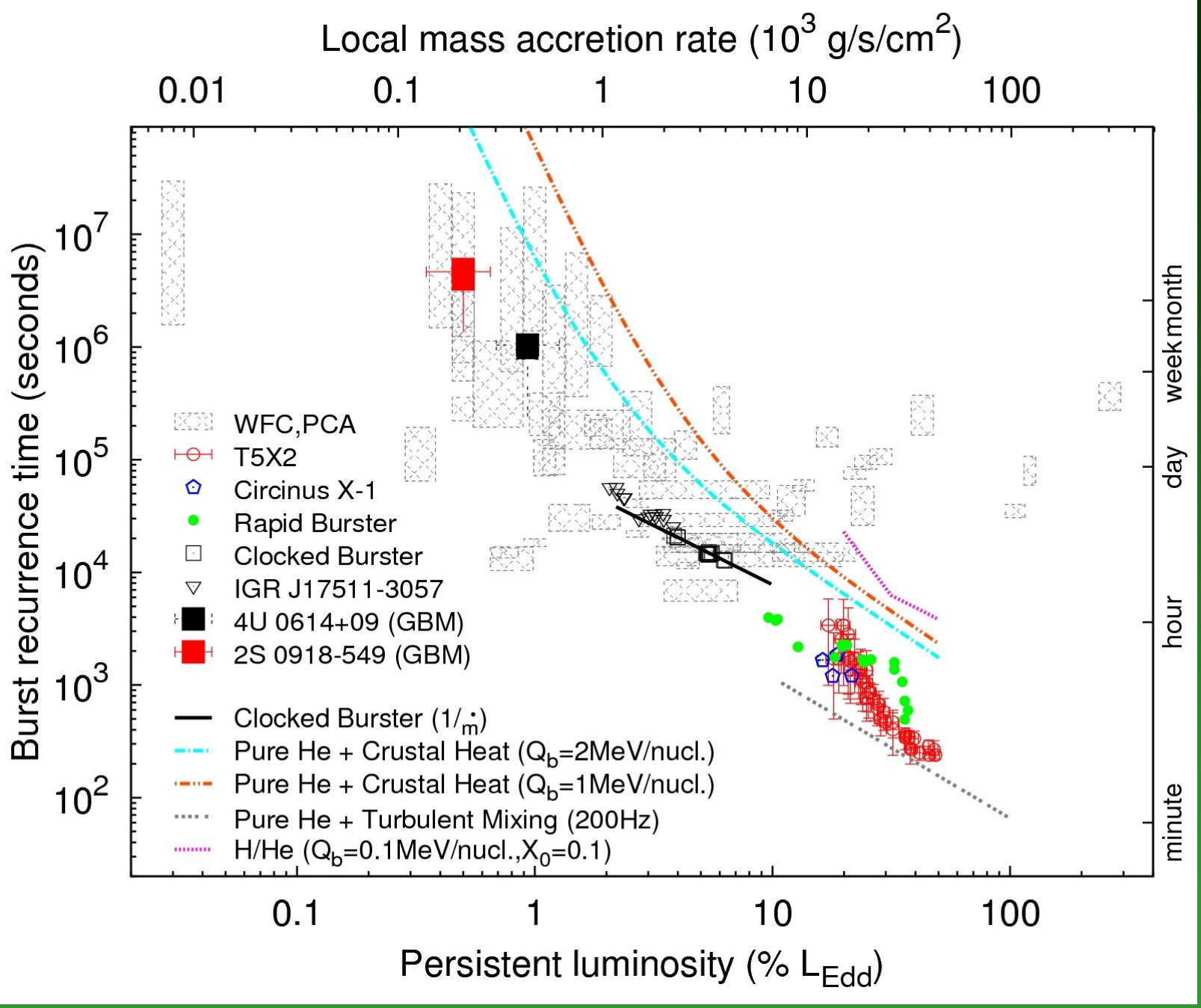
(FLUENCE TRIGGER)

Burst energies in 4U 0614+09 overlap with normal and long burst populations. Long bursts are rare, usually observed in hard X-rays. Burst energy is less sensitive to bandpass than duration.

GBM & thermonuclear bursts: 2S0918-54



0.5% Eddington: 10 GBM bursts from 2S 0918-54 in 3 years!



4U 0614+09: 12+/-3 d (>2.8 d) **2S 0918-54: 54+/-17 d (>16 d)**

Summary & Conclusions

PART I: high-mdot bursts

- Unprecedented burst behavior in the 11 Hz pulsar T5X2, in agreement with theoretical burning regimes.
- Three bursting regimes when mdot increased 10-50% Edd; marginally stable burning, mHz QPOs.

→ *Are burning regimes sensitive to neutron star spin?*

PART II: low-mdot bursts

- Recurrence time in 4U 0614+09=12+/-3d; 2S 0918-54=54+/-17d
- 3-year Fermi-GBM X-ray Burst catalog: ~450 type 1 / year
- OVERLAP in burst energies between normal and long bursts

→ *Implications for crustal heat and Galactic yields?*

Thanks!

Refs:

Millihertz Quasi-periodic Oscillations and Thermonuclear Bursts from Terzan 5: A Showcase of Burning Regimes (Linares et al. 2012, ApJ, 748, 82)

The Fermi-GBM X-ray burst monitor: thermonuclear bursts from 4U 0614+09 (Linares et al. 2012, ApJ, 760, 133)

The Fermi-GBM 3-year X-ray Burst Catalog

(Jenke, Linares, Connaughton et al., in prep.)