Modeling a New Clocked X-ray Burster SRGA J144459.2−604207

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arXiv:2411.10992, 2411.10993; see also Takeda's talk [77] on 12/11 !!

Clocked X-ray burster SRGA J1444

- Type-I X-ray burst (XRB): Thin-shell explosion onto accreting neutron stars (NSs)
- A few bursters show constant light curves and recurrence time Δt (called "Clocked bursters"), which are useful sites to probe the nature of XRBs (Heger+07)

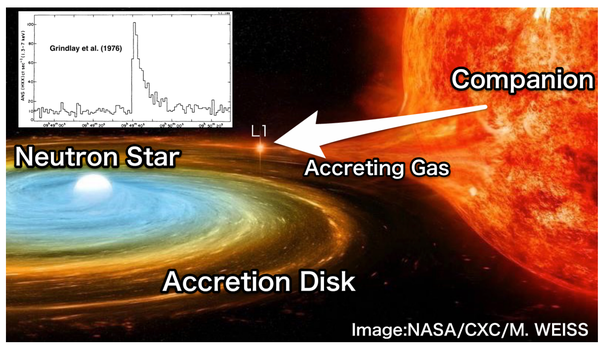


Fig. 1: Picture of low-mass X-ray binary and the first-observed burst light curve

- Six clocked X-ray bursters observed so far:
  - GS 1826−24 (Ubertini+99; Cocchi+01; Cornelisse+03; Galloway+04, 17)
  - IGR J17480−2446 (Chakraborty+11)
  - GS 0836−429 (Aranzana+16)
  - 1RXS J180408.9−342058 (Fiocchi+19)
  - MAXI J1816-195 (Bult+22; Wang+24)
  - **SRGA J144459.2−604207: This year, many XRBs were observed by NICER, INTEGRAL, IXPE, Insight-HXMT, and NinjaSat.**
- About XRBs of SRGA J1444:
  - Decline phase after clocked burster phase ($\Delta t \simeq 1.69$ h)
  - XRB light curves: Platou + rapid decay ($\tau_e \sim 9$ s) ⇒ Unlike traditional clocked XRBs such as GS 1826−24 (linear increase + *slow* decay)
  - NinjaSat observed 11 XRBs in the decline phase, including the last two **continuous** XRBs with $\Delta t = 7.909$ h (Takeda's talk). ← thanks to NinjaSat's great ability for long-term monitoring (Tamagawa+,arXiv:2412.03016)

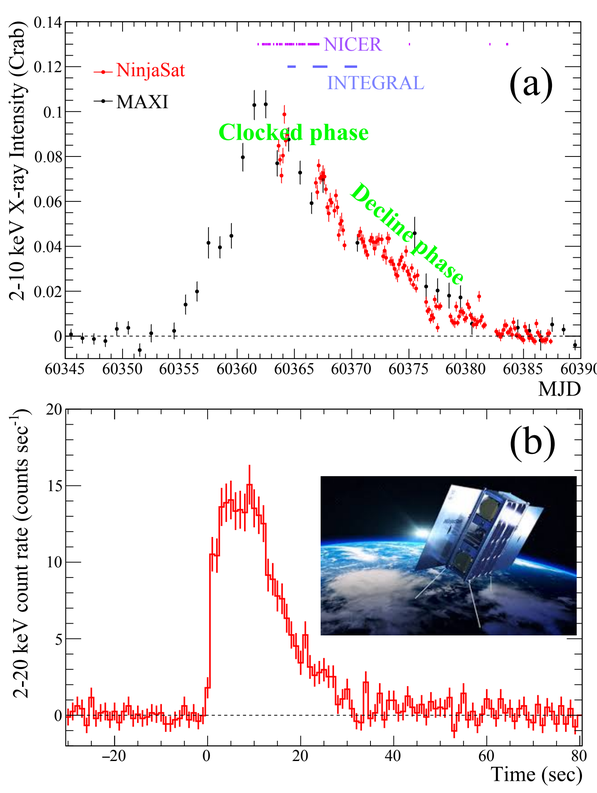


Fig. 2: (a) Persistent flux (b) Averaged burst light curves observed by NinjaSat

Model parameters and Strategy

- Multi-zone XRB Code: HERES (Dohi+20, PTEP 2020, 033E02, Zhen+23, ApJ 950, 110) ⟹ All physics of accreting NSs can be fully incorporated.
- $M_{\rm NS} = 1.4 M_\odot$, $R_{\rm NS} \simeq 11.6$ km
- We focus on compositions of accreted matter following
  * X, Y and $Z_{\rm CNO}$ denote the mass fraction of H, He, and CNO metal, respectively.

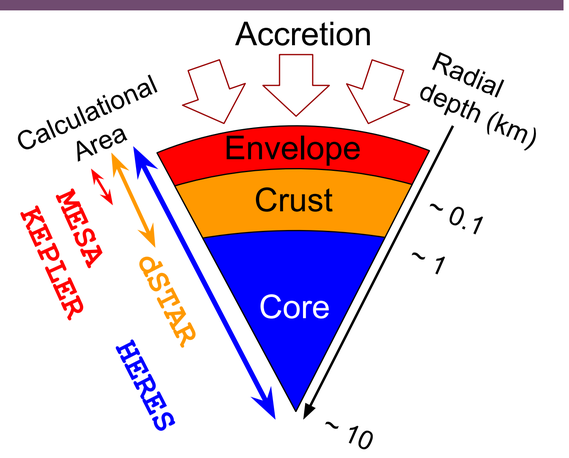


Fig. 3: Schematic NS structure and covered areas for a few XRB codes

1. Solar compositons $(X/Y, Z_{\rm CNO}) = ((X/Y)_\odot, Z_\odot)$
2. He-enhanced scenario $(0.5(X/Y)_\odot, Z_\odot)$
3. High-metalicity scenario $((X/Y)_\odot, 4Z_\odot)$

* $(X/Y)_\odot \equiv 2.9$
* $Z_\odot \equiv 0.015$

○ Two-step strategy for modeling of SRGA J1444

- Clocked burster phase (high $\dot{M}$) observed by INTEGRAL/NICER
  - $\dot{M}_{-9} \equiv \dot{M} / \left(10^{-9}\ M_\odot\ {\rm yr}^{-1}\right) = 3$ and 4 (c.f. Dohi+24, ApJ 960, 14)
- Decline phase long-term monitored by NinjaSat
  - $\dot{M}_{-9} \propto \Delta t^{-\eta}$ with $\eta \sim 0.8$-0.9 (Papitto+24, Takeda+) ⟹ $\dot{M}_{-9} = 0.8$ and 0.9 (only 10th and 11th XRBs are focused)

Modeling SRGA J1444 by HERES

- Clocked burster phases

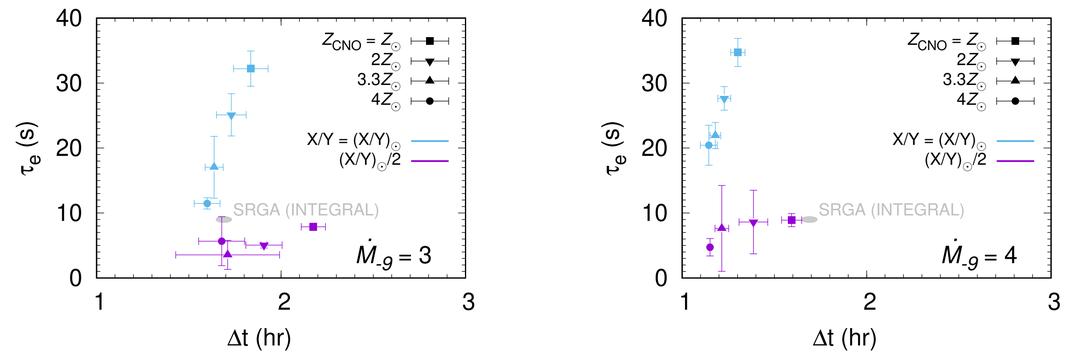


Fig. 4: Comparison with $(\Delta t, \tau_e)$ measured by INTEGRAL (Sanchez-Fernandez+24)

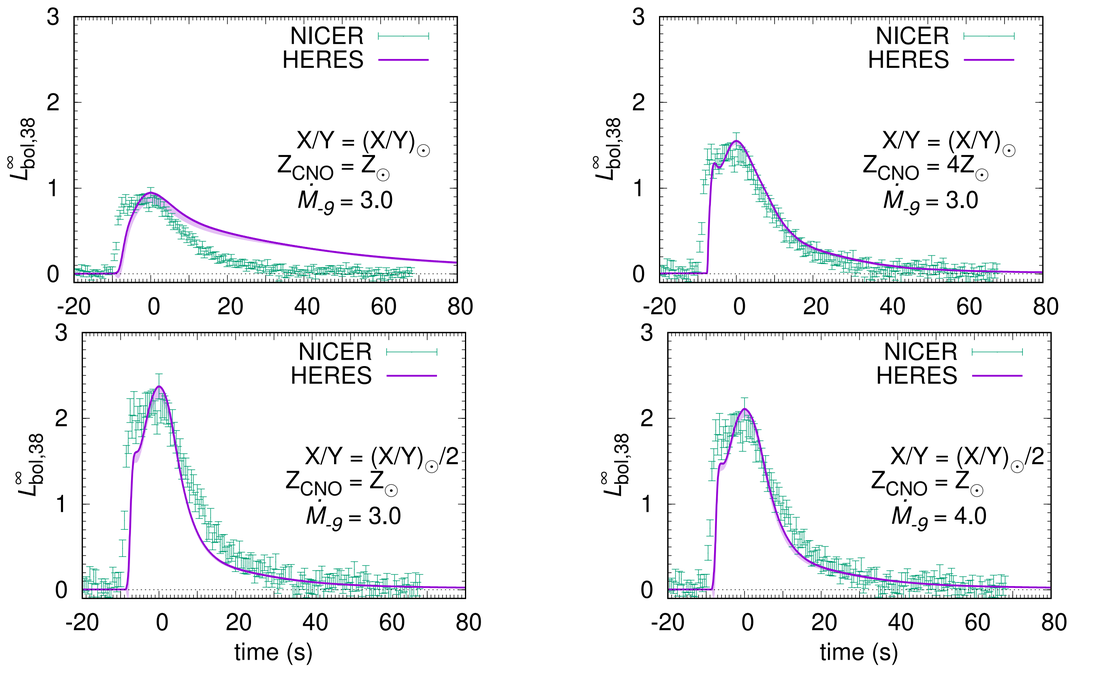


Fig. 5: Modeling SRGA J1444 observed by NICER (Ng+24)

- Solar composition models show too long burst duration because the rp process can efficiently work due to H rich environment. ⟹ He enhanced ($\dot{M}_{-9} = 4$) v.s. high metalicity ($\dot{M}_{-9} = 3$)
- In a high metalicity scenario, a double-peak structure tends to appear, which seems to be preferred.

- Decline phase long-term monitored by NinjaSat

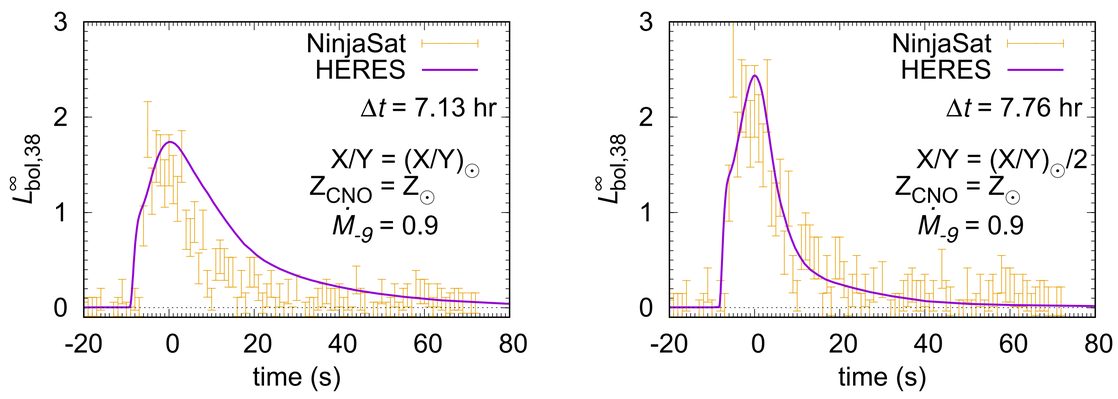
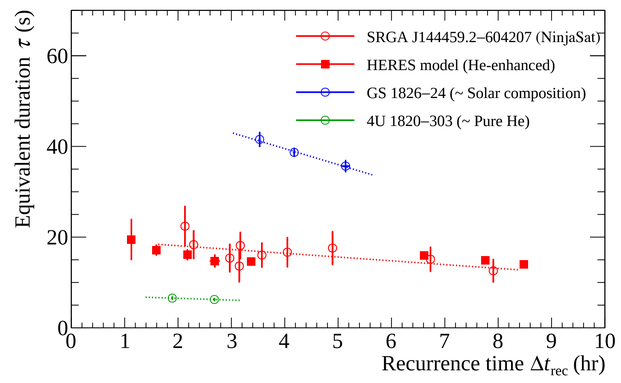


Fig. 6: Modeling SRGA J1444 observed by NinjaSat

- NinjaSat observations imply SRGA J1444 has a He-rich companion with $X/Y \approx 1.5$.
- The high metalicity scenario: $\Delta t > 10$ h (relevant with the hot CNO cycle)



Conclusion

- Using the HERES code, we made models for the new clocked X-ray burster SRGA J1444, focusing on the composition of accreted matter.
- SRGA J1444 is the first clocked burster with non-solar compositions.
- Long-term monitoring by Ninjasat ⟹ He-enhanced companions
- This result derives from the great ability of CubeSat (Takeda's talk).