Estimation of the surface gravitational redshift of a neutron star with the broad spectral feature detected during the thermonuclear X-ray burst

NSMAT 2016

21-23, Nov.

Tohoku Univ.

Masachika Iwai

(ISAS/JAXA)

T. Dotani, M. Ozaki, Y. Maeda (ISAS/JAXA),

H. Mori (NASA GSFC), and S. Saji (Nagoya Univ.)

Introduction

- <u>Past studies</u>

Tried to detect absorption lines in the burst spectra → Identification of the lines → Surface gravitational redshifts can be derived immediately.

Corresponding to the mass-radius ratio of a neutron star

- <u>Difficulties</u>

Most of burst sources are rapidly spinning: ~200-600 Hz

Absorption lines formed on the neutron star surface may be smeared out and may not be detected.

→ We must carefully select a slowly spinning burst source.

Terzan 5 X-2 (11 Hz): a transient source.

- <u>Breakthrough in this study</u>

We will focus on absorption edges in the burst spectra.

Intrinsically broad!

Absorption edges may be detected even from the rapidly spinning burst sources.

An X-ray burst from GRS 1747−312 detected with Suzaku

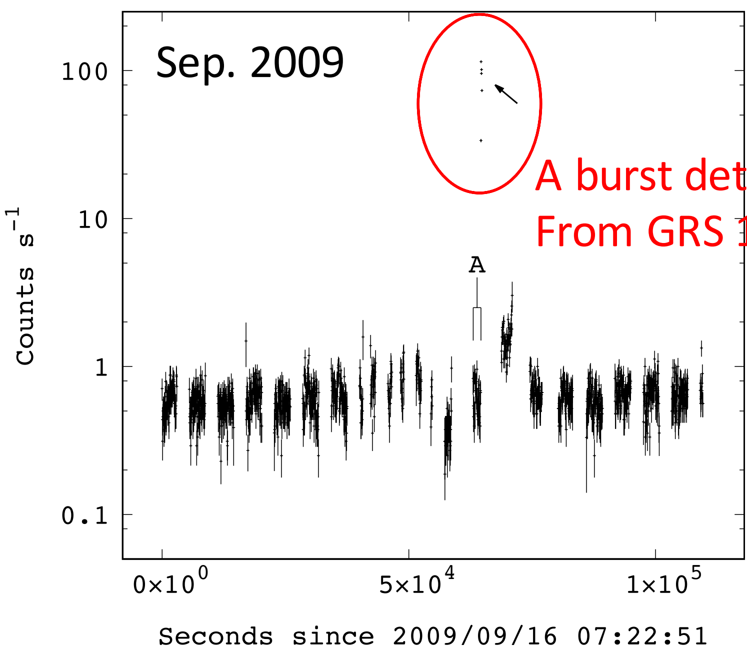
- GRS 1747−312 is a transient source in the globular cluster Terzan 6 (Predehl et al. 1991; Pavlinsky et al. 1994).

In a low-luminosity state

- During a part of Galactic bulge mapping observations, GRS 1747−312 was included in Suzaku field of view and a long X-ray burst was unexpectedly detected.

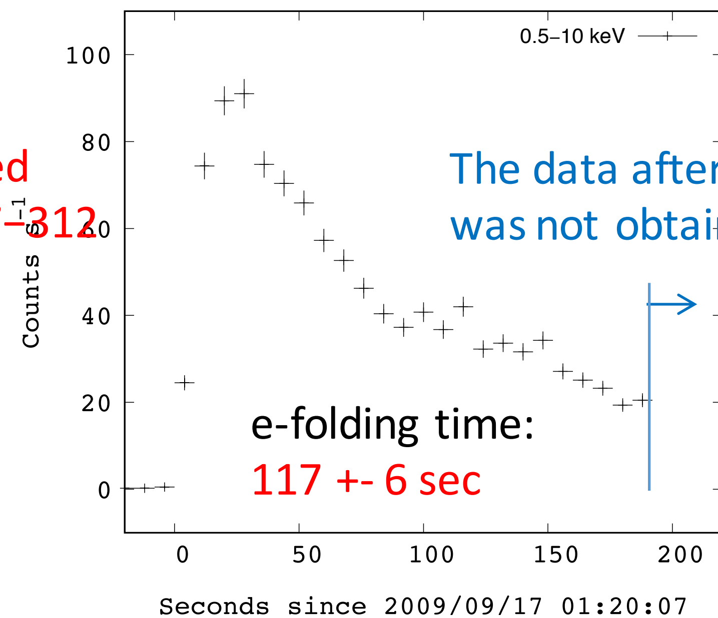
CCD camera onboard Suzaku

Light curve obtained with XIS



A burst detected
From GRS 1747−312

Close-up light curve
During the burst



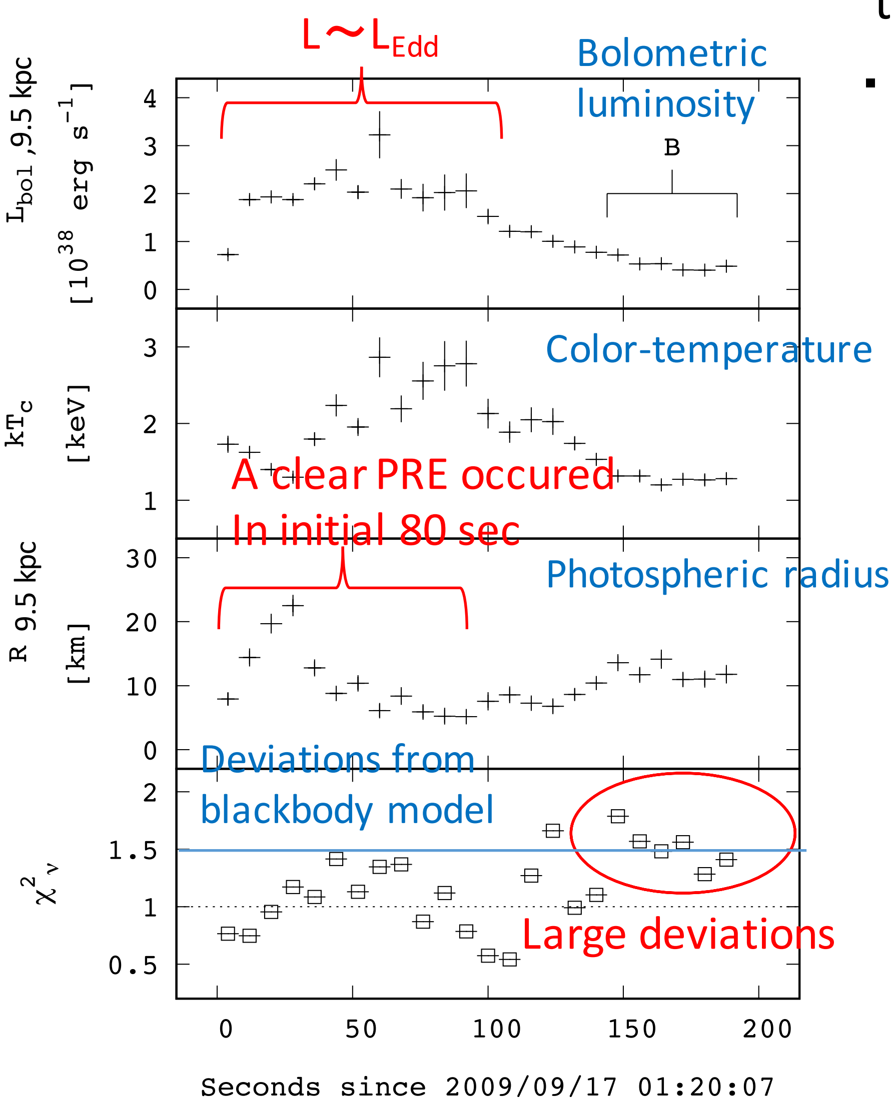
The data after 192 sec was not obtained.

e-folding time:
117 +- 6 sec

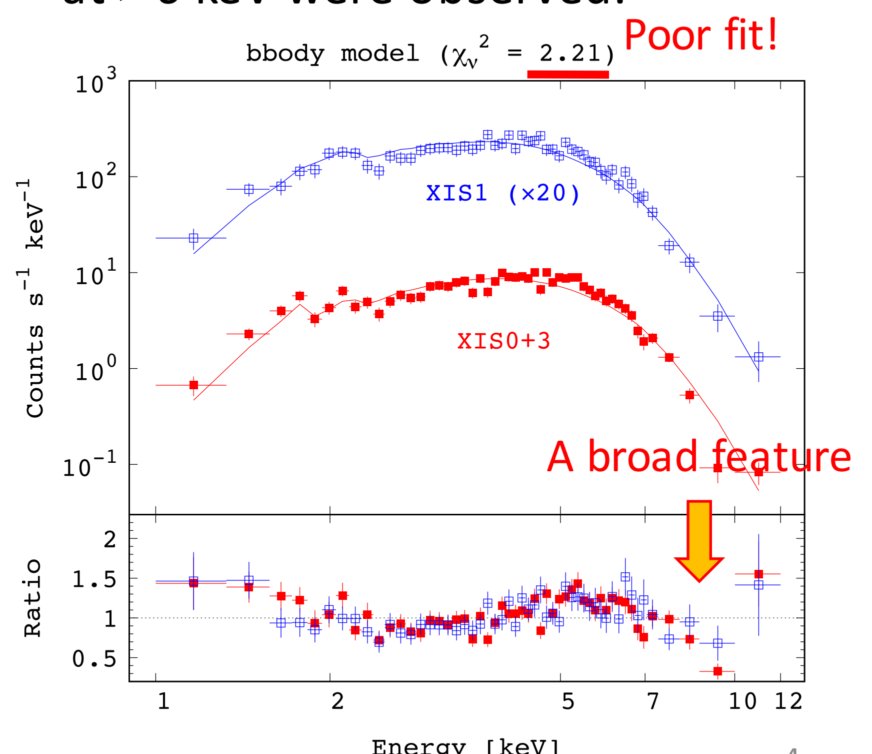
Properties of the X-ray burst

- First half of the burst
  - ✓ A clear PRE (Photospheric Radius Expansion)
  - ✓ The burst spectra are well-reproduced by the blackbody model.
- Latter half of the burst
  - ✓ No PRE
  - ✓ Large deviations due to a broad feature at > 6 keV were observed.

Photosphere returns to the neutron star surface.



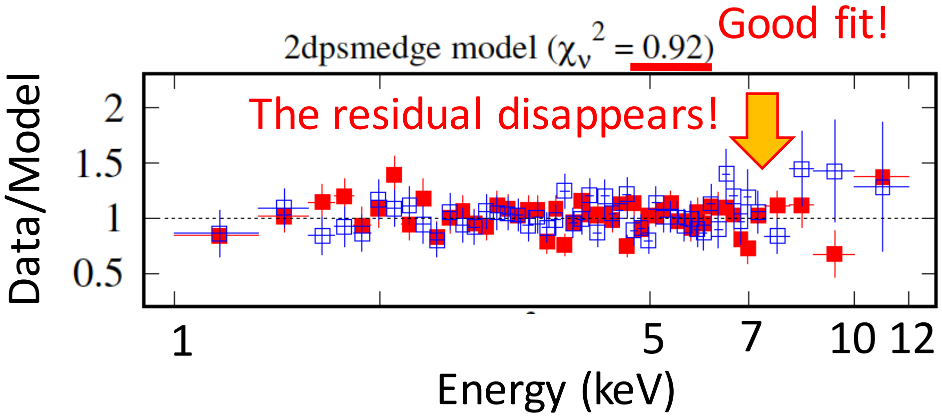
Burst parameters and their time-variations



Average burst spectrum during time-region B

A likely origin of the spectral feature

We tried various models and found that the double absorption edges smeared by the rapid neutron star spin is the most likely scenario.



Other scenarios cannot be rejected completely due to the lack of high-energy coverage in the latter half of the burst.

- Emergence of the spectral feature was explained naturally by <u>the change of the ionization degrees</u>

  Fully ionized in the first half ➡ H-like/He-like ions in the latter half

- Obtained parameters:
  - ✓ Continuum : ~2 keV bbody with Nh = ~1.3E22 cm-2
  - ✓ Absorption edges : 6.1+-0.2 keV with τ_{opt} = ~1 & 7.8+-0.2 keV with τ_{opt} = ~3
  - ✓ Spin frequency : 800+-200 Hz

Estimation of the surface gravitational redshift

Ions responsible for the edges are determined by referring numerical calculations.

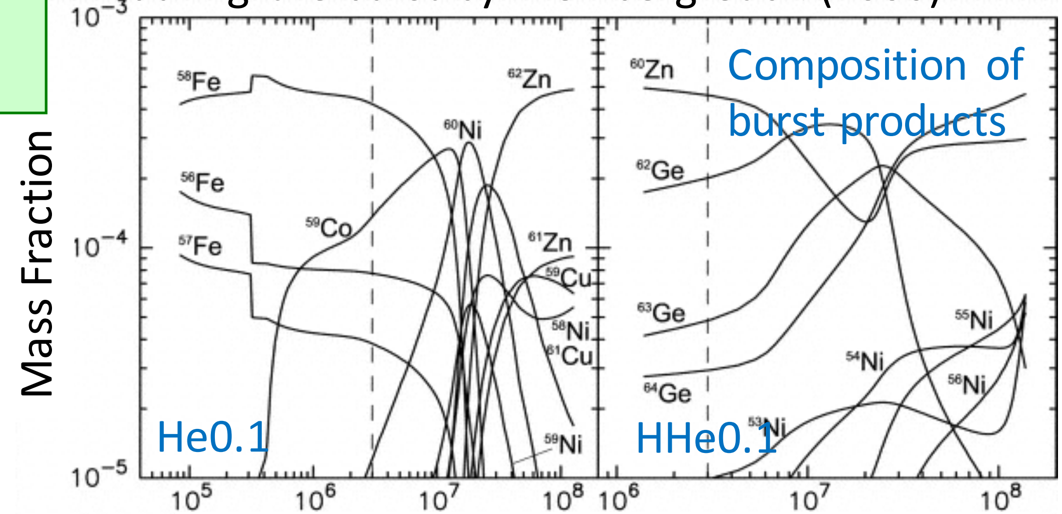
- E_{edge}(6.1 keV & 7.8 keV)
- ΔE_{edge}

Possible combination of ions:
H-like Fe (9.28 keV) & H-like Zn (12.39 keV)

Surface gravitational red shift:
1.56 +- 0.03

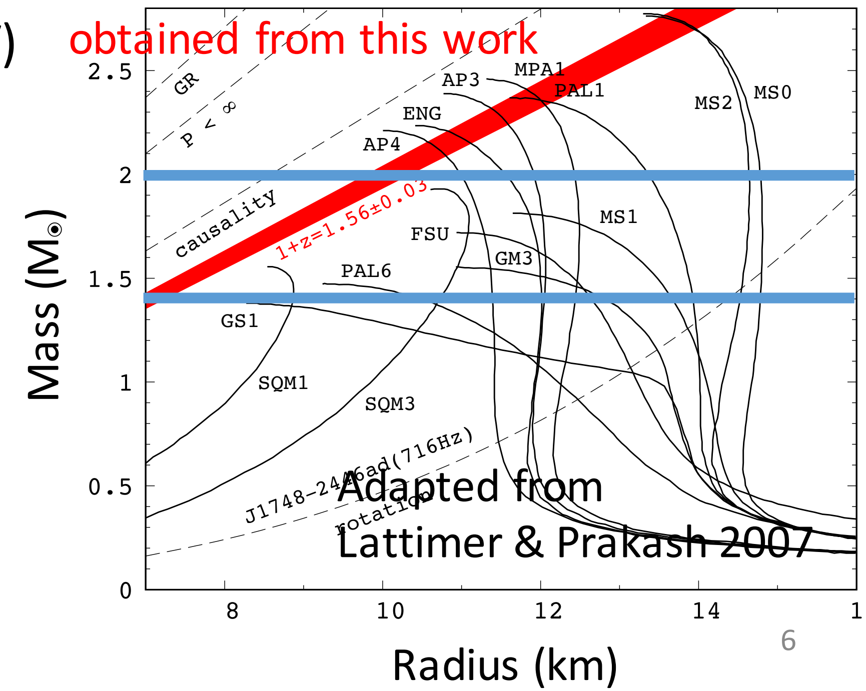
Combining the gravitational redshift with other parameters, we may obtain constraints on the equation of state of the neutron star matter.

Numerical results of nuclear network calculations during the burst by Weinberg et al. (2006)



Depth from Neutron Star surfaces (g cm^{-2})

The observational constraints obtained from this work



Future plans & Summary

Future plans

- We need to increase number of observations of absorption edges in the bursts.
  - ✓ We will plan to use the data of the NuSTAR satellite.

Summary

- We detected the X-ray burst from GRS 1747−312 with Suzaku serendipitously.
- A broad spectral feature was found in the latter half of the burst.
  - ✓ We interpret that the feature is due to double absorption edges, which are smeared by the rapid spin of the neutron star.
  - ✓ If H-like Fe & Zn are responsible for the feature, the surface gravitational redshift is estimated as 1.56+-0.03.

As absorption edges are not completely smeared out even for the rapidly spinning neutron star, this can be a powerful tool to measure the surface gravitational redshifts of a neutron star.