RXTE follow-up observations of new MAXI sources

MAXI J1659-152 and MAXI J1409-619

Kazutaka Yamaoka (Aoyama Gakuin U.), Philip E. Kaaret (Univ. of Iowa), Ryan Allured (Univ. of Iowa), Satoshi Nakahira (AGU), Atsumasa Yoshida (AGU), Hitoshi Negoro (Nihon Univ.), Yoshihiro Ueda (Kyoto Univ.), and the MAXI team
Abstract

The MAXI is a high sensitive X-ray all-sky monitor with a detection sensitivity of $\sim$15 mCrab in a day and $\sim$6 mCrab in a week. To unveil characteristics and population of faint X-ray sources, we have an approved RXTE ToO program (AO 14 and 15) of new MAXI sources with the 5-50 mCrab flux. This observation can be triggered up to five sources and the net exposure is 30 ksec for each. We triggered two observations so far: the black hole candidate MAXI J1659-152 and the possible superfast X-ray transient MAXI J1409-619 and started their observations soon after the discovery. In this presentation, we will report on preliminary results from both observations.
RXTE follow-up observations of MAXI discovered faint sources

- To identify the nature of faint X-ray sources discovered by MAXI through RXTE spectral and timing capabilities.
- Up to five sources with the 5-50 mCrab flux for each AO.
- The net exposure is 30 ksec for pointed observations in AO14 and 40 ksec (10 ksec for cross-scan observations plus 30 ksec for pointed observations) in AO15.
- Two triggers so far: MAXI J1659-152 and MAXI J1409-619 in AO14.
MAXI J1659-152 -- Introduction --

- Swift/BAT discovered a new source as GRB 100925A on Sep 25, 2010 (Mangano et al. GCN #11296).
- MAXI/GSC found a new hard X-ray source as MAXI J1659-152 (Negoro et al. Atel #2873).
- RXTE follow-up observations reveal it as a **black hole candidate**. (Kalamkar et al. Atel # 2881)
- Many multi-wavelength observations are performed due to the Swift/BAT GRB trigger and its source location well above the Galactic plane.
- RXTE ToO observations
  - Sep. 28, 2010 ~ Nov. 8, 2010
  - Observation ID: 95358, 95108, and 95118
  - 65 pointed observations.
    In total 134.6 ksec exposure.
  - Initial and latter low/hard states were not covered.
  - We use the standard 2 data from the PCU2 alone for spectral analysis, and the event data for timing analysis.
MAXI J1659-152
-- PCA light curve and hardness-intensity diagram --

The PCA flux reaches about 400 mCrab. The MAXI data (showed by the black open circle) are also consistent with the PCA data. Hardness-Intensity diagram (HID) shows the Q-shaped curve which is similar to other BHCs.
MAXI J1659-152
-- Examples of the PCA energy spectra --

Typical observations:
95358-01-02-00 Sep.28
95358-01-03-01 Oct. 2
95108-01-18-00 Oct.8
95108-01-30-00 Oct. 14
95118-01-07-00 Oct. 21
95118-01-14-00 Oct. 28
95118-01-16-01 Nov. 1
95118-01-21-00 Nov. 8

Energy spectra and spectral states dramatically change with time. The Soft (from the accretion disk), and hard (from the high temperature Corona) component are visible in the spectra.
MAXI J1659-152
-- Examples of power spectra --

- Type-C and Type-B low-frequency QPOs were observed in the intermediate states.
- About 25 observations show LF QPO features.
- Frequency range: 1-8 Hz
MAXI J1659-152

-- Evolution of spectral and timing properties --

- Fits the PCU2 spectra with
  1) MCD+power-law*smeared edge
  2) MCD*simpl Comptonization (Steiner et al. 2009)*smeared edge

Modified with the Galactic absorptions

Very stable

Simpl fits
MAXI J1659-152
-- rough BH mass estimation --

- RXTE PCA spectral fits with the MCD x simpl model shows that the innermost radius (Rin) is stable at about 35 km.
  - Reflects that the innermost radii correspond to the ISCO
- Correction of the MCD model parameters:
  \[ rin = Rin \times f^2 \times \xi \approx 41.5 \text{ km} \times (D/10\text{kpc}) \times (\cos \theta)^{-1/2} \]
  - Electron scattering \(\rightarrow\) hardening factor \(f = 1.7\) (Shimura & Takahara 1995)
  - Boundary condition correction \(\rightarrow\) \(\xi = 0.41\) (Kubota et al. 1998)
- If we assume a Schwartzchild BH, 3 times Schwartzchild radius is the ISCO, so the BH mass is estimated to be about
  \[ 6.3 \times (D/10\text{kpc}) \times (\cos \theta/\cos 60)^{-1/2} \text{ M}_{\odot} \]
② MAXI J1409-619 -- Introduction --

- MAXI discovered a new X-ray transient (Yamaoka et al. Atel #2959)
- Swift confirms a new X-ray source in the XRT field of view (Kennea et al. Atel #2962).

- RXTE follow-up observations (Yamaoka et al. Atel # 2969)
  - 14 pointed observations
    - In total 23.1 ksec
  - Heavily absorbed spectrum
  - No coherent pulsations
  → Superfast X-ray transient ? or long-period pulsar ?

**MAXI/GSC image**

[Image of MAXI/GSC image showing Oct. 12 and Oct. 17 with a 10 deg. separation]

**MAXIGSC light curve**

[Graph showing MAXIGSC light curve with intensity vs. time]

**Swift/XRT image**

[Image of Swift/XRT image with MAXI J1409-619 highlighted]
The PCA light curve shows relatively stable in a time scale of days to week, but highly variable in several hundreds of seconds to hours. But there is no clear coherent pulsations in the power spectrum,
MAXI J1409-619 -- Energy spectra --

- The PCA spectra are well explained by a reflection model or partially absorbed model, suggesting that emissions from the central source are significantly reflected or strongly absorbed.

\[
\text{wabs} \ast \text{pcfabs} \ast (\text{cutoffp} + \text{gau})
\]

- \( N_H \sim 4.4 \times 10^{22} \text{ cm}^{-2} \)
- Covering fraction \( \sim 0.53 \)
- \( N_{H_2} \sim 1.5 \times 10^{24} \text{ cm}^{-2} \)
- Photon index \( \sim 1.22 \)

- Cutoff \( \sim 44 \text{ keV} \)
- Line center \( \sim 6.5 \text{ keV} \)
- \( \chi^2 / \text{dof} = 39/54 \)

\[
\text{wabs} \ast (\text{pexrav} + \text{gau})
\]

- \( N_H \sim 2.7 \times 10^{22} \text{ cm}^{-2} \)
- Solid angle \( \Omega/2\pi \sim 4.6 \)
- Photon index \( \sim 1.19 \)

- Cutoff \( \sim 25 \text{ keV} \)
- Line center \( \sim 6.5 \text{ keV} \)
- \( \chi^2 / \text{dof} = 44/55 \)
Summary

- We present preliminary results from the RXTE ToO observations of two MAXI sources: MAXI J1659-152 and MAXI J1409-619. Detailed analysis is now in progress.
- MAXI J1659-152
  - Black hole candidate, with a short orbital period (?)
  - Dramatically change in spectral and timing properties, associated with spectral transitions.
  - The source is now probably in the low/hard state. The outburst duration is about two months, which is relatively short compared with other black hole candidates.
- MAXI J1409-619
  - Possible super fast X-ray transient (SFXT) or long-period pulsar
  - Stable X-ray flux throughout the RXTE observations
  - The source seems to be still bright at faint X-ray level.
- We will expect more discoveries of new MAXI sources with a good sensitivity of MAXI and more RXTE follow-up observations!