An improved image fit method to create MAXI/GSC light curves and the search for embedded transient sources using more than 15 years MAXI data

Yuno Kudo, Hitoshi Negoro (Nihon U.), Mikio Morii (JAXA/DATUM STUDIO) and MAXI team.

MAXI has discovered 35 new X-ray transients. Sources in source-crowded regions such as the Galactic center region, however, have not been investigated intensively because of relatively low spatial resolution (~ 1 deg) X-ray cameras. We are therefore trying making light curves in the Galactic bulge and ridge regions at equal intervals using more than 15 years MAXI data to discover undetected X-ray novae and other transient objects. We are improving an image-fit method to produce correct light curves. In the new method, we introduce an asymmetric point spread function of the Gas-Slit Cameras to fit images taking account of the X-ray incident angle to the detector and energy dependence of the mean free path of X-ray photons. As a result, we are able to obtain 10-20 keV light curves much better than those provided from RIKEN. Furthermore, by applying a correction of a source position in 2-4 keV, we will be able to obtain the best GSC light curves to find embedded transients.

X-ray novae detected by MAXI

MAXI has discovered 35 new X-ray transients by the Nova-Alert System (Negoro et al. 2016). Sources in source-crowded regions such as the Galactic center region and around bright objects have not been investigated intensively. We are trying to discover X-ray novae and other transient objects by creating light curves in the Galactic bulge and ridge regions at equal intervals using more than 15 years GSC data (Fig.1).

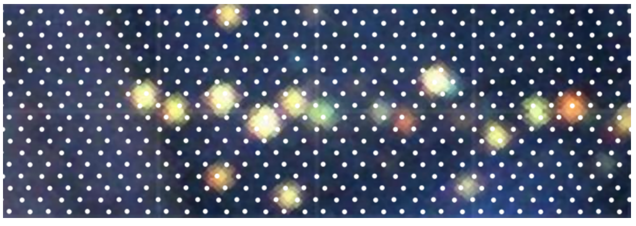

Fig.1 The Galactic bulge and ridge region (-10 deg < ℓ < 10 deg, -30 deg < *b* < 30 deg) and points (example) at which light curves are created at equal intervals.

Image fit method

We use an image-fit method (Morii et al. 2016) to create light curves. In the method, we can obtain curves little affected by surrounding objects. There are however some problems in the current system.

Problem 1: The effect of surrounding objects depends on a direction.

We made light curves centered on MAXI J1631-479 and within ±0.5 degrees, at approximately 0.1 degree intervals (Fig. 2). On the left side of the source, curves at distances larger than 0.2 degrees are hardly affected by a bright central source flux, while on the right side, those are much affected, resulting in a fake outburst.

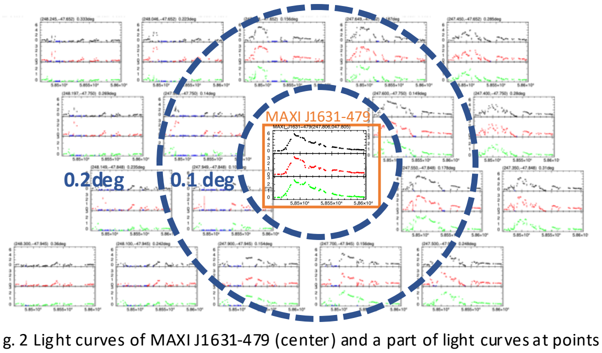

Fig. 2 Light curves of MAXI J1631-479 (center) and a part of light curves at points around it (black: 2-10 keV, red: 2-4 keV, green: 4-10 keV).

Problem 2: We can not create light curves in 10-20 keV.

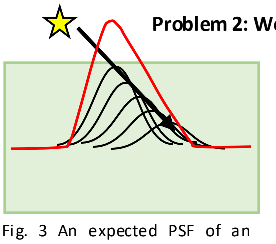

Fig. 3 An expected PSF of an anode direction for high energy X-rays.

The current system fits a source profile of an anode direction with a approximate form, a Gaussian, of the real point-spread-function (PSF). The actual PSF is asymmetric especially for oblique incident hard X-rays as shown in Fig. 3. As a result, we have not been able to obtain light curves in 10-20 keV.

Introducing a new fitting function

To solve these problems we introduced a new fitting function used to make the GSC catalog (Hori et al. 2013) to match an asymmetric profile of an anode direction. The function takes account of the incident angle and energy dependence of the X-ray mean free path. Fig.4, 5, and 7 show examples of source profiles fitted with the old and the new function in 4-10 keV, 10-20 keV, and 2-4 keV, respectively.

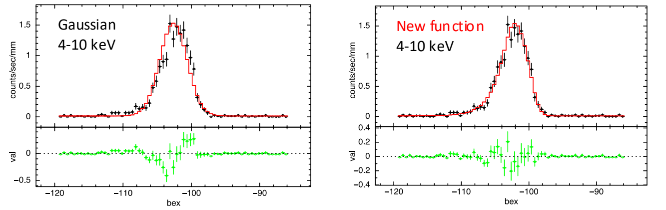

Fig.4 (upper) An anode direction profile of Sco X-1 in 4-10 keV (black) fitted with the old and the new model function (red) for data of incident angle ϕ= 32.7 degrees (MJD 60352). (lower) Residuals between the data and the model (green).

Fig. 4 shows that the new function gives a better fit than the Gaussian in 4-10 keV. The 10—20 keV asymmetric source profile is also well represented by the new function (Fig. 5). A resultant Crab 10-20 keV light curve we obtained for the first time in this method, showing almost constant flux (Fig. 6).

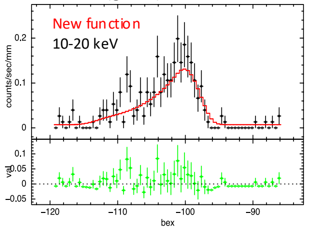

Fig.5 An anode direction profile of Sco X-1 fitted with the new model function (10-20 keV) .

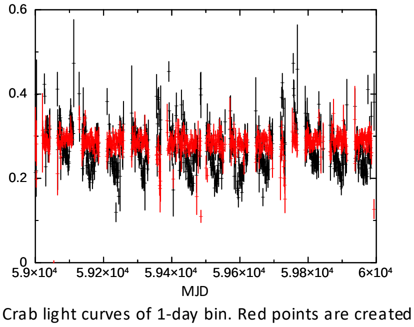

Fig. 6 10-20 keV Crab light curves of 1-day bin. Red points are created by introducing the new PSF function, and black ones are from RIKEN data.

In 2-4 keV the residuals between the data and the model look like a wavy shape (Fig. 7, left), indicating a wrong source position in the original data. We then evaluate shift values (0.82 deg at maximum) depending an anode position of a source in each camera, and fit the data using those values (Fig. 7, right).

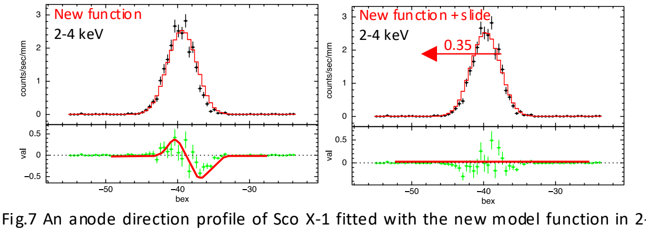

Fig.7 An anode direction profile of Sco X-1 fitted with the new model function in 2-4 keV (left) and with its shifted one (right).

Future Plan

We are testing the new system using various data. Light curves obtained with this improved image-fit method must be helpful not only to discover X-ray novae and other transient objects, but to investigate time variations of various objects.

Reference Negoro, H. et al., 2016, PASJ, **68**, S1 Morii. M. et al., 2016, PASJ, **68**, S11 Hori. T. et al., 2018, ApJS, **235**, 7