Development of FTOOLS-based software for MAXI/GSC light curves using image fits with point spread function

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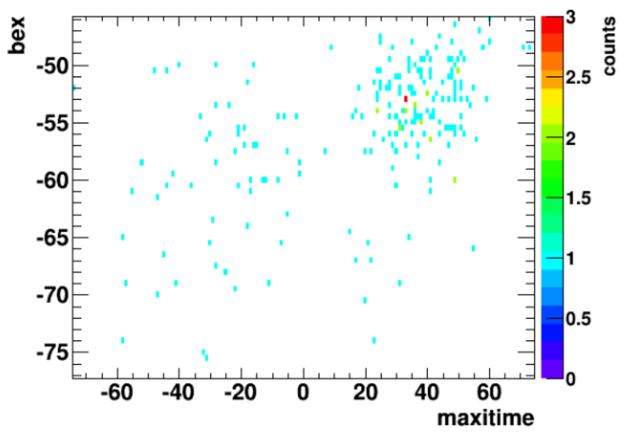
We, Science Satellite Operation and Data Archive Unit (C-SODA) in JAXA, have developed FTOOLS-based software (mxsim_psf and mxsim_bgd), which can make simulations of point spread function (PSF) and non X-ray background (NXB) of MAXI/GSC. These tools will be released from HEASARC, soon. By using these tools, we start to develop a tool to make MAXI/GSC light curves obtained by image-fits using the PSF and NXB. We aim to make the PSF-fit tool used for the search of soft X-ray flashes of novae (Morii et al. 2016) available.

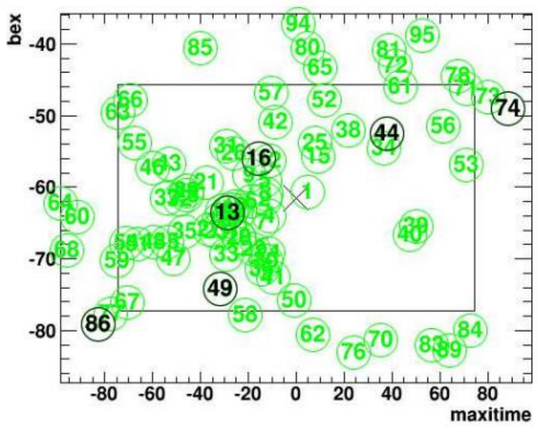
PSF and NXB simulator:
* C-SODA (Science Satellite Operation and Data Archive Unit) in JAXA have developed simulator of point spread function (PSF) and non X-ray background (NXB) of MAXI/GSC (mxsim_psf and mxsim_bgd). These tools will be released from HEASARC, soon.

Hidden tool (mxkwtool):
* M. Morii developed PSF-fit tool called mxkwtool, which contains many functionality as follows:
* Using well-calibrated point spread function model in the two-dimensional coordinate of the detector: "maxitime" and "bex" (Direction of anode wire of gas counter).
* Position determination tool actually used at the time of initial detection of transients, whose position and error regions are reported to ATEL or GCN.
* Combined PSF-fit of data using multi-camera and multi-scans.
* Pick-up of near-by point sources around the target source used in the PSF-fit, with respect to Bayesian Information Criterion (BIC).
* Details of this tool are explained in the appendix of Morii et al. 2016 [1]:

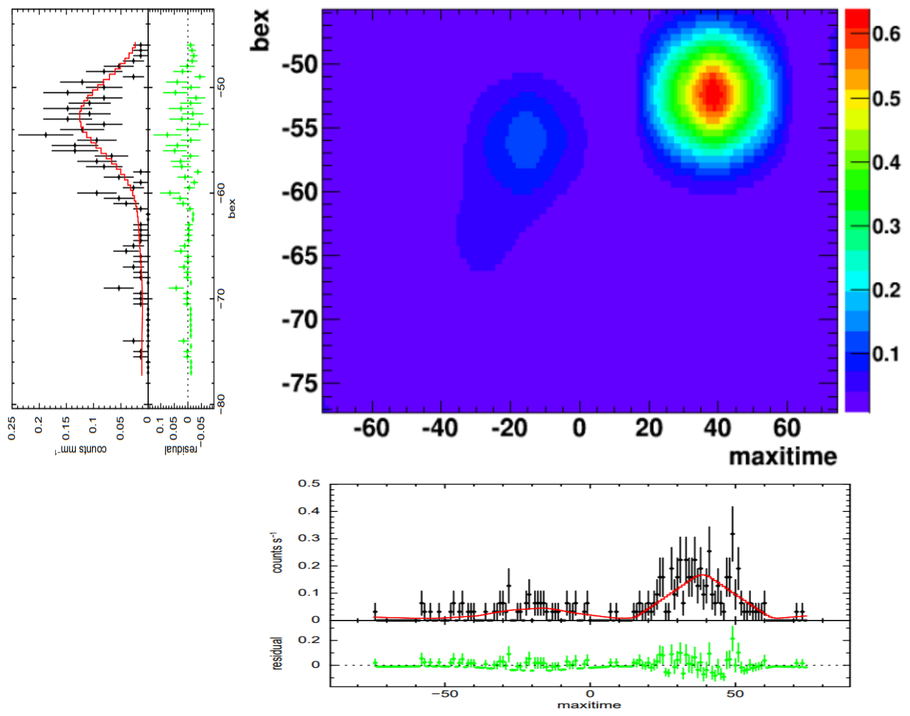
Example of PSF-fit executed by mxkwtool:



Event distribution in the detector coordinate extracted for the PSF-fit for V5586 Sgr on a scan at MJD 55340 by a camera (ID = 0) in the 2 − 4 keV band.



The positions of the nearby source candidates and the selected sources are shown in numerical labels with green and black colors, respectively. The cross label at the center is the position of the target, V5586 Sgr. The area used for the PSF-fit is displayed as a rectangular region.



The best-fit function obtained with the PSF-fit

Problems in mxkwtool:
* Since this tool was developed gradually by taking a long time to satisfy various demands, the source code became patchy and complicated. Now, the modification is difficult even by MAXI team members.
* This tool depends on CERN/ROOT library, whose compile is sometimes difficult for other users. File I/O is based on ROOT file.
* The developer (M. Morii) changed his research field from 2015 and left academia from 2019.
* Only Negoro-san at Nihon-Univ. can run this tool.

Plan of restoration of mxkwtool and inclusion of the PSF model made by mxsim_psf and mxsim_bgd:
* Now, the developer (M. Morii) is working at JAXA/C-SODA as terminable contract on a secondment from a private company. It is a good chance for modification of mxkwtool.
* We have the following plan:
1. Decoupling of the CERN/ROOT library from mxkwtool.
2. Simplification of the source code.
3. Restoration of a functionality of PSF-fit for data of one-scan and one-camera with the point spread function of GSC.
4. Development of PSF-fit for data of multi-scan and multi-camera with a point spread function of GSC made by GSC simulator (mxsim_psf). For Non-X-ray background, output made by simulator (mxsim_bgd) is used.
5. Formatting the tool to be compatible with HEASARC regularation.
6. Restoration of PSF-fit for multiple data of multi-scan and multi-camera with every PSF by combined fitting.

Current status of development of tool:
* We reached at the step 3 listed above.

Example of command line to make 2 day light curve of Crab Nebula

```
% mxdownload_wget.pl -coordinates 83.633083,22.0145 ¥
-date_from 2010-01-01 -date_to 2010-01-02
% mxproduct 83.628700 22.014700  2010-01-01 2010-01-02
% mxpsffit  event_gti_file_list  catalog_file
```

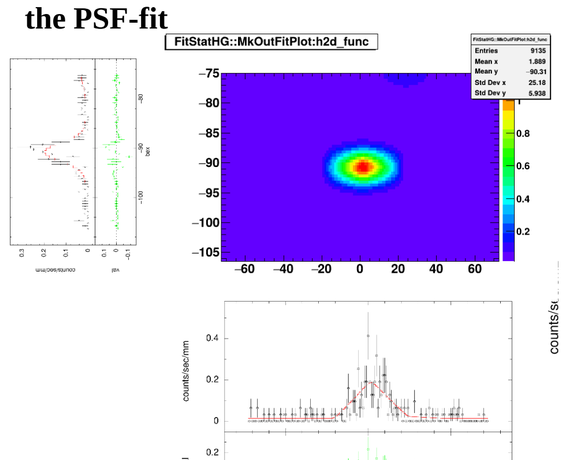
Catalog file

```
# srcname  ra  dec function
Crab_Nebula  83.628700 22.014700    SankakuBexSigmaFunc
1A_0535+262  84.727  26.316         SankakuBexSigmaFunc
! BackgroundConst2d
```

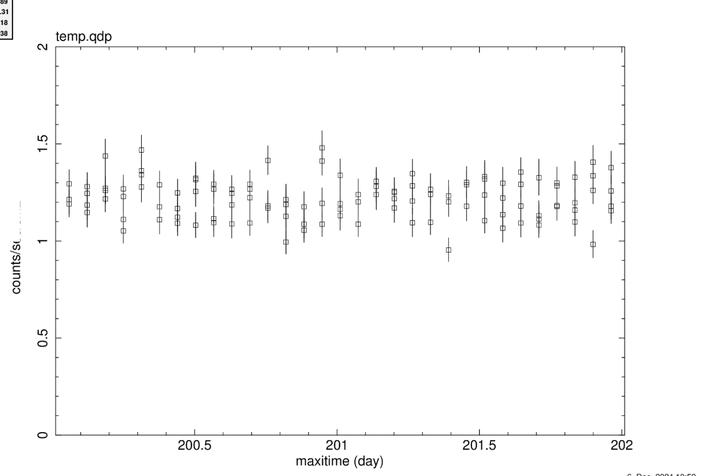
Event and GTI file list

```
# evtfile  gtifile
target_g1_low.evt  target_g1_low_gti.fits
target_g2_low.evt  target_g2_low_gti.fits
target_g7_low.evt  target_g7_low_gti.fits
target_g8_low.evt  target_g8_low_gti.fits
```

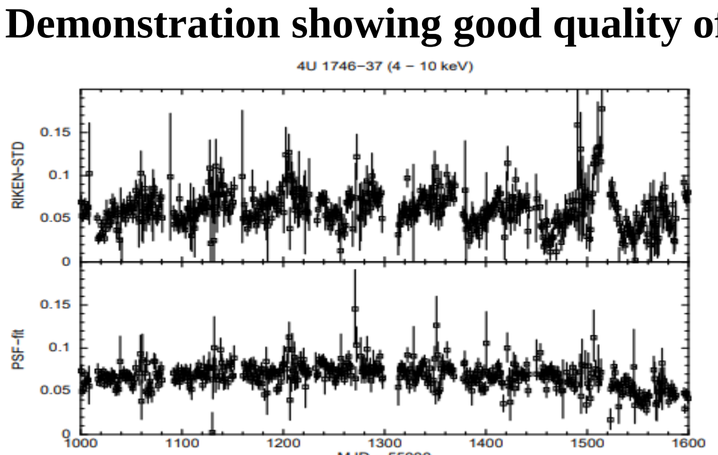
The best-fit function obtained with the PSF-fit



Output: Two days light curve of Crab Nebula



Demonstration showing good quality of mxkwtool



Standard light curve shown in RIKEN web site

Light curve made by mxkwtool

References

[1] M. Morii et al. (2016) "Search for Soft X-ray Flashes at Fireball Phase of Classical/Recurrent Novae using MAXI/GSC data," PASJ, 68, S11.