ROBOTIC OBSERVATIONS OF INTEGRAL SOURCES IN THE OPTICAL DOMAIN

Petr Kubánek[1,2,4], René Hudec [1], John French[3,4], Jan Štrobl[1], Martin Nekola[1], and Filip Munz[1]

[1]*Astronomický ústav Akademie věd České republiky, Ondřejov, Czech Republic*
[2]*INTEGRAL Science Data Center, Chemin d'Ecogia 16, Versoix, Switzerland*
[3]*University College Dublin, Dublin, Ireland*
[4]*for the Watcher Collaboration*

ABSTRACT

We present the status of our ground-based instruments (robotic telescopes), which are (among other tasks) used for monitoring of INTEGRAL gamma-ray sources, mostly AGNs and blazars, as well as selected cataclysmic variables, at optical wavelengths. At the same time, these robotic devices serve as fast optical alert systems to follow GRB alerts provided by INTEGRAL.

Key words: robotic telescopes, INTEGRAL.

1. MOTIVATION

Only a fraction of the 209 gamma-ray sources detected by the INTEGRAL satellite are either known sources or have been identified and classified already. From the 56 new (IGR) sources detected by INTEGRAL, only 20% have already been firmly classified, mostly with Cataclysmic Variables (CVs), AGNs, High Mass X-ray Binaries, Low Mass X-ray Binaries, Black Hole Candidates, and Anomalous X-ray Pulsars[1]. One of the methods applied in the past is identification by spectroscopy, which recently provided some new and interesting identifications of INTEGRAL gamma-ray sources such as newly detected symbiotic and cataclysmic variables [5], [6]).

Numerous newly detected and already identified INTEGRAL gamma-ray sources have variable optical counterparts with magnitudes that allow them to be observed by small aperture optical robotic CCD telescopes. As those objects are newly identified, no optical light curves are available, with the exception of automatically generated curves by very small monitoring devices with low accuracy. On the other hand, the analyses of well sampled and accurate optical light curves and their comparison with light curves at higher energies can give valuable additional insights into the related physical processes and evolution of the sources.

The additional prospects of optical monitoring of INTEGRAL sources by robotic telescopes are represented by analysing their light curves for flares and flaring activity, trying to fit the flare profiles, trying to look for possible periodicities and recurrences, and the study of colours and colour changes with time, with consequent discussions and interpretations. The related science includes classification of the observed objects, with conclusions toward physical processes and models.

The last aspect of monitoring by robotic telescopes for INTEGRAL sources is the imaging of positions of non-classified newly detected gamma-ray sources at different times. This can represent an alternative approach to identification and classification of targets, based on the detection of variable optical counterparts inside the error boxes of the sources.

2. INSTRUMENTS

Instruments which are available to us for observations are listed in table 1. All these instruments are controlled by RTS2[4], and are used for TOO observations of GRB triggers distributed by GCN.

Besides these instruments we can also trigger TOO observations on other, larger telescopes.

The sources are monitored with BART[3]. Southern coverage is partly provided by Watcher[2]. BART and Watcher targets statistics is provided in tables 2, 3 and 4, and some images are shown in this paper.

3. DATA PROCESSING

The PostgreSQL database can be searched for images that contain a given object. We have accessed the image archive using a simple WWW based interface. We now aim to create a Virtual Observatory compliant interface, which will provide access to images and light curves.

Name	From	Location
BART	2000	Ondřejov, Czech Republic
BOOTES-1A	2003	El Arenosillo (CEDEA-INTA), Spain
BOOTES-1B	2003	El Arenosillo (CEDEA-INTA), Spain
BOOTES-2	2003	La Mayora (EELM-CSIC), Spain
BOOTES-IR	2005	OSN, IAA-CSIC, Spain
FRAM	2005	Pierre Auger south observatory. Argentina
Watcher	2006	Boyden Observatory, Republic of South Africa

Table 1. Instruments.

4. DATA ONLINE ACCESS

Data is accessible through RTS2-Web interface. An example of it can be seen on BART web, *http://zeus.asu.cas.cz/rts2-web*.

5. FUTURE DEVELOPMENT

We have developed a platform which enables us to operate robotic telescopes, each based on different hardware, performing different tasks, but running the same software.

As our instruments now run in unattended mode for months at a time, we are now trying to manage the data volumes they produce. We are currently developing an autonomous analytic pipeline which will send us reports about deviations of selected sources from expected behaviour. Unfortunately, this task is more difficult than we initially expected, and it will take some time before this pipeline reaches maturity and its results will be of sufficient quality for publication.

6. CONCLUSIONS

The robotic observations of INTEGRAL sources represent a valuable additional data source for investigation of their behaviour and evolution when they are already identified with optical sources with magnitudes within the range of the used telescopes, or, alternatively, for identification and classification of non-identified sources by comparing CCD images taken at various different epochs. This represent huge amounts of acquired data, hence the development of relevant and reliable programmes is necessary. This development is underway.

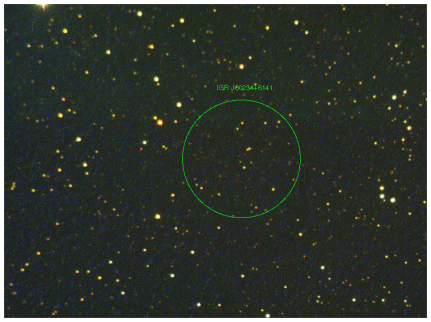

Figure 1. IGR J00234+6141 error box.

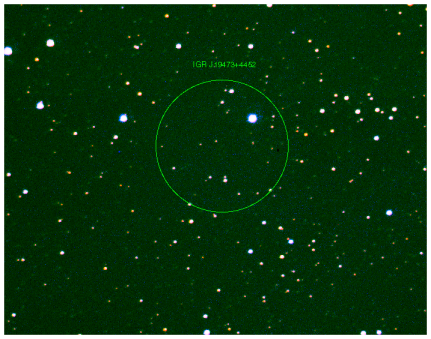

Figure 2. IGR J19473+4452 error box.

7. ACKNOWLEDGEMENTS

We acknowledge the supports by grant A3003206 of the GA AV ČR and ESA PECS Project 98023.

REFERENCES

[1] A. J. Bird et al. The Second IBIS/ISGRI Soft Gamma-Ray Survey Catalog. *The Astrophysical Journal*, 636:765–776, January 2006.

[2] J. French et al. Watcher: A Telescope for Rapid Gamma-Ray Burst Follow-Up Observations. In E. Fenimore and M. Galassi, editors, *AIP Conf. Proc. 727: Gamma-Ray Bursts: 30 Years of Discovery*, pages 741–744, September 2004.

[3] M. Jelínek et al. BART: an intelligent GRB and sky monitoring telescope (2000-2004). *Astronomische Nachrichten*, 325:678–678, October 2004.

[4] P. Kubánek et al. RTS2 – Remote Telescope System, 2nd Version. In *AIP Conf. Proc. 727: Gamma-Ray Bursts: 30 Years of Discovery*, September 2004.

[5] N. Masetti et al. Igr J12349-6434 = RT Cru ? *The Astronomer's Telegram*, 528:1–+, June 2005.

[6] N. Masetti et al. Optical observations of BQ Cam (=V0332+53) in outburst. *The Astronomer's Telegram*, 388:1–+, January 2005.

Name	RA (J2000)	DEC (J2000)	Images	Processed
	HH MM SS.ss	DEG MM SS.s		
0ES 2132+50.9	21 33 43.68	+51 07 24.8	296	199
IGR J00234+6141	00 23 24.00	+61 41 32.0	75	35
IGR J00291+5934	00 29 03.06	+59 34 19.0	34	9
BD+60 73	00 37 09.64	+61 21 36.5	42	16
IGR J01363+6610	01 36 18.00	+66 10 36.0	123	28
IGR J06074+2205	06 07 24.00	+22 05 00.0	133	36
IGR J12391-1612	12 39 06.24	-16 10 47.3	47	1
NGC 4992	13 09 05.52	+11 38 02.8	483	138
1H 1726-058	17 30 21.60	-05 59 34.0	22	20
IGR J01363+661	01 36 18.00	+66 10 36.1	121	29
IGR J06074+2205	06 07 24.00	+22 05 00.0	154	33
IGR J12391-1612	12 39 06.24	-16 10 47.3	53	1
NGC 4992	13 09 05.52	+11 38 02.8	338	93
1H 1726-058	17 30 21.60	-05 59 34.0	11	10
IGR J18539+0727	18 53 54.00	+07 27 29.0	62	48
IGR J19140+0951	19 14 04.32	+09 52 58.3	53	37
IGR J19308+0530	19 30 46.08	+05 30 07.0	11	11
IGR J19473+4452	19 47 19.44	+44 49 42.2	1618	1328
IGR J21247+5058	21 24 31.92	+50 58 08.0	296	177
IGR J21335+5105	21 33 30.00	+51 05 30.8	279	209

Table 2. Targets in BART database with observations.

Name	RA (J2000)	DEC (J2000)	Images	Processed
	HH MM SS.ss	DEG MM SS.s		
V* RT Cru	12 34 53.74	-64 33 56.0	2355	2261
CD-57 3057	10 11 02.95	-57 48 13.9	3561	3485

Table 3. Targets in Watcher database with observations.

Name	RA (J2000)	DEC (J2000)
	HH MM SS.ss	DEG MM SS.s
IGR J07506-1547	07 50 35.04	-15 47 17.2
IGR J07506-1547	07 50 35.04	-15 47 17.2
IGR J17331-2406	17 33 06.00	-24 07 00.1
IGR J17418-1212	17 41 50.88	-12 11 46.0
IGR J17513-2011	17 51 17.04	-20 11 17.2
IGR J17597-2201	17 59 46.08	-22 01 53.0
IGR J18027-1455	18 02 46.08	-14 56 34.1
IGR J18027-2016	18 02 46.08	-20 17 38.0
IGR J18048-1455	18 04 50.88	-14 54 50.0
IGR J18135-1751	18 13 26.88	-17 50 56.0
IGR J18214-1318	18 21 22.08	-13 18 29.2
IGR J18256-1035	18 25 36.96	-10 35 12.8
IGR J18259-0706	18 25 55.92	-07 06 22.0
IGR J18325-0756	18 32 28.08	-07 56 24.0
IGR J18406-0539	18 40 36.00	-05 39 00.0
IGR J18410-0535	18 41 00.48	-05 35 46.8
IGR J18450-0435	18 44 58.08	-04 36 07.0
IGR J18483-0311	18 48 14.88	-03 10 08.0
IGR J18490-0000	18 49 04.08	-00 01 30.0
IGR J19284+0107	19 28 24.00	+01 07 08.0

Table 4. Targets in BART database, which were not yet observed due to observational constraints.