ESA INTEGRAL AND CATACLYSMIC VARIABLES *

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ABSTRACT. The satellite INTEGRAL is ESA project operating since January 2003. It is dedicated to high energy astronomy. INTEGRAL is able to detect and perform astrometry, photometry and spectroscopy of sources from X-ray to gamma-ray regime (nominal range of sensitivity is 15 keV – 10MeV) via its multiple instruments. Moreover, it's equipped with an X-ray event monitor and a small optical telescope to provide a full multi-wavelength satellite observatory.

Mission abilities are interesting for any object emitting Gamma-rays or X-rays. One of them are Cataclysmic Variables (CVs), which are X-ray and some of them probably even gamma-ray sources. Cataclysmic variables were included into "Core Science Programme" of INTEGRAL and even though they are not a main mission goal (and INTEGRAL will not focus on observing them directly, with some exceptions), we assume to have good results from the periodical surveys. This contribution should introduce the mission INTEGRAL and our intentions in field of related CVs research.

Key words: Stars: binary: cataclysmic; X-rays; Gamma-rays.

1. Introduction

The modern astrophysical projects bring us the great opportunity to explore more specific or unexplored properties of various types of objects, or even to discover something unexpected. This is valid also for the INTEGRAL - space observatory, dedicated to concurrent observing of the space - mainly in gamma-rays, but also in X-rays and optical. The Cataclysmic Variables represent an example of objects it can study. At least some of them have been proposed to have Very High Energy (VHE) emission, and many of them are known to have an X-ray emission. Therefore, INTEGRAL could give us valuable information about behaviour and configuration of these binaries and about the processes standing behind the potential VHE activity.

Dr. René Hudec (e-mail: *rhudec@asu.cas.cz*) has been delegated as a responsible scientist (R_Sci) for this area within the INTEGRAL Core Programme team. He has founded a wide international working group, containing 29 scientists from 17 countries, capable to collaborate on solving this task. Everything is still at the beginning and research is in it's first stage – reducing the raw data.

This contribution will introduce the mission INTEGRAL and our intentions in related research of cataclysmic variable stars.

2. ESA INTEGRAL

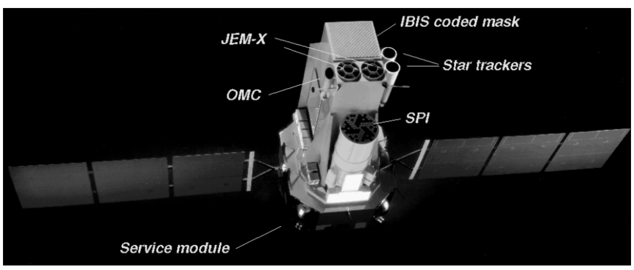

Figure 1: Artist's impression of the INTEGRAL spacecraft. (Credits: ESA)

*Based on observations with INTEGRAL, an ESA project with instruments and science data centre funded by ESA member states (especially the PI countries: Denmark, France, Germany, Italy, Switzerland, Spain), Czech Republic and Poland, and with the participation of Russia and the USA.

Table 1: Key performance parameters for SPI, IBIS, JEM-X and OMC.

	SPI	IBIS	JEM-X	OMC
Energy range	18 keV - 8 MeV	15 keV - 10 MeV	4 keV - 35 keV	500 nm - 600 nm
Detector	19 Ge dets, cooled at 85 K	16384 CdTe dets, 4096 CsI detectors	Microstrip Xe/CH_4-gas det.	CCD + V-filter
Detector area (cm^2)	500	2600 (CdTe), 3100 (CsI)	500 for each of the two JEM-X detector	CCD: 2061×1056 pix., Imaging area: 1024×1024 pixels
Spectral resolution (FWHM)	3 keV at 1.7 MeV	8 keV at 100 keV	2.0 keV at 22 keV	
Field of view	$16°$	$9° \times 9°$	$4.8°$	$4.98° \times 4.98°$
Angular resolution (FWHM)	$2.5°$ (point source)	$12'$	$3'$	$25''$
10σ source location (radius)	$< 1.3°$ (depending on source strength)	$< 1'$	$< 30''$	$6''$
Mass (kg)	1309	746	65	17

2.1. The satellite

The INTErnational Gamma-Ray Astrophysics Laboratory (INTEGRAL) is a 15 keV – 10 MeV gamma-ray observatory mission with concurrent source monitoring in the X-rays (4 – 35 keV) and in the optical range (V band, 500 – 600 nm). All instruments, centered to cover an identical field of view, simultaneously monitor a very broad energy range to study the high energy astrophysical sources. The payload consists of the two main gamma-ray instruments (the high energy resolution spectrometer SPI and the imager IBIS) and of two monitors (two X-ray JEM-Xs and the optical monitoring camera OMC). The imaging by the X and gamma ray detectors is base on the coded mask technique to provide a wide field of view with appropriate angular resolution of the observed sources.

The scientific goals of INTEGRAL are attained by high resolution spectroscopy with fine imaging and accurate positioning of celestial gamma-ray sources. The high resolution spectroscopy over the entire energy range permits spectral features to be uniquely identified and line profiles to be determined for physical studies of the source region. The fine imaging capability of INTEGRAL within a large field of view allows an accurate location and hence identification of the gamma-ray sources with their counterparts at other wavelengths, enables extended regions to be distinguished from point sources and provide considerable serendipitous science which is very important for an observatory-class mission.

Specific parameters of individual main instruments onboard INTEGRAL are presented in Table 1, their placement on the spacecraft is marked on Figure 1. More information can be found on www pages of ESA INTEGRAL (*http://sci.esa.int/integral/*), ISOC (*http://astro.estec.esa.nl/Integral/*) or ISDC (*http://isdc.unige.ch/*).

2.2. Observing with INTEGRAL

INTEGRAL is an observatory-type mission with a nominal lifetime of 2 years with possible extension of up to 5 years. Most of the observing time (65% during first year, 70% of second year and 75% of additional years) is awarded competitively to the members of the wide scientific community. Typical observations duration takes from thousand of seconds up to about two weeks and the participating observer will receive data from all the simultaneously operating instruments onboard INTEGRAL. Proposals for observations are selected on their scientific merit only by a single Time Allocation Committee (TAC). The first call (AO-1) for observation proposals was issued on November 1st, 2000 with a proposal submission deadline by February 16th, 2001. The first call was extremely successful as it resulted in an oversubscription of the proposed observing time by a factor of 19. The final AO-1 programme still carries an oversubscription of a factor 2. The call for 2nd year observation proposals AO-2 has been released in summer 2003, with deadline on September 5th, 2003. The AO-2 will run for 12 months, starting in December 2003.

The remaining fraction of the observing time (not covered by AO programme) is reserved for INTEGRAL Science Working Team (ISWT) as the Core Programme. It is a return to those scientific collaborations and individual scientists who contributed to the development, design and production of the satellite. The Core Programme during AO-1 consists of the following elements: a deep exposure (4.3 Msec) of the Galactic central radian, scans of the Galactic plane (2.3 Msec), pointed observations (Vela region, 1 Msec) and TOO (Target of Opportunity) follow-up observations (1.7 Msec).

In accordance with ESA's policy on the data rights, all scientific data will be made available to the scien-

tific community one year after they have been released to the observer.

3. Cataclysmic Variables in the INTEGRAL Core Programme

3.1. Cataclysmic Variables basic properties

Cataclysmic Variables are close interacting binaries, where the compact primary star is a White Dwarf (WD). The typical system consists of a WD, a secondary (donor) star and an accretion disk (but there are subtypes without the disk) – and all of this takes an essential part in the final luminosity. The disc is often unstable and causes significant radiation variability in the whole spectrum (causes Dwarf novae variability – outbursts etc.). Occasionally, but very dramatically can be luminosity affected by the thermonuclear runaways of accreting material on the surface of the WD (nova eruption). Next common phenomenon able to affect configuration and consequently even behaviour of CV is the strong magnetic field of the WD.

CVs can be basically assigned to these types (Warner, B., 1995, review) – Classical Novae, Dwarf Novae (subtypes Z Cam, SU Uma, U Gem), Recurrent Novae, Nova-like Variables, Magnetic CVs (subtypes Polar, Intermediate Polar) – depending on the behaviour and/or the system configuration.

3.2. Observability of CVs with INTEGRAL

ESA INTEGRAL brings us the unique opportunity to observe activity of CVs in optical, X-rays and Gamma-rays simultaneously. Of course we can't expect INTEGRAL to spend time on systematical observation and monitoring of CVs (with some exceptions, for example AE Aqr) implicitly. But we can try to use the data from the Core Programme. Most useful appear to be the Galactic Plane Scans (GPS). GPS are performed once a week in a sawtooth pattern with an inclination of 21° with respect to the Galactic plane, each subsequent scan being shifted by 27.5° in galactic longitude. A schematic view of two consecutive scans is shown in the Figure 2. As a result, GPS cover the strip ±13° in the latitude. INTEGRAL makes only short ($\sim 2 \times 10^3 s$) exposure during the GPS, but we can add up the particular images to get an acceptable sensitivity. We have identified about 80 observable CV candidates in FOV of suitable observations planned for the first year.

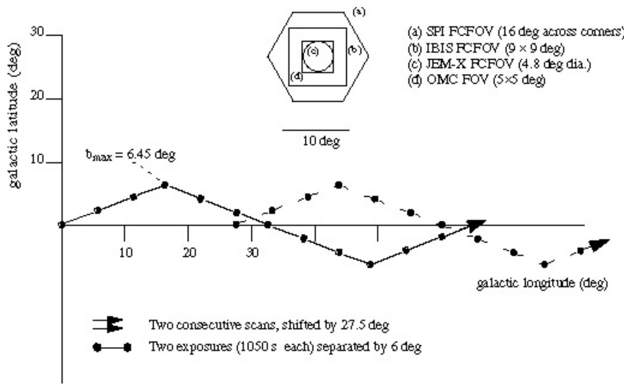

Figure 2: Galactic Plane Scans for INTEGRAL.

Now let's have a closer look to our expectations about what we can observe in particular spectral bands.

Optical – Optical variability is quite a well known attribute of all CVs. It could be interesting to use the data from the OMC for optical monitoring of CVs, especially in connection with simultaneous monitoring made by high-energy instruments onboard. Even simple optical data (without positive high energy detection) will be valuable, at least for monitoring of the long-term activity. The OMC is observing only in V filter, so it is a good idea to complement these data with simultaneous optical observations from ground-based telescopes. The limiting magnitude of the OMC is ~18 mag in 1000 s exposure.

X-ray – Similar as optical, even X-ray activity is a quite well-known attribute of CVs. Important sources of X-rays are the Dwarf Novae (DN) – in Quiescence, typical luminosities are $L_x \sim 10^{31}\, erg\, s^{-1}$ with variations $0.1 - 3{\times}L_x$ (the brightest case, SS Cyg has $L_x \sim 1.7 \times 10^{32}\, erg\, s^{-1}$), but mainly in outbursts, where the complicated behaviour in X-rays is observed. The other sources are the magnetic CVs (mainly polars), where the strong magnetic field disrupts the accretion disk and the matter is "falling" along the magnetic field lines to the pole(s) of WD, causing consequently emission in soft and even in hard X-rays. As a result, we should be able to monitor activity of some bright CVs in X-rays. The quality and accuracy of these data will be much worse than these from X-ray specialized observatories (like XMM-Newton or Chandra), nevertheless their quantity and especially the simultaneity with other bands could be valuable.

Gamma – This field of CVs activity is quite unexplored and many scientists are rather sceptical about this field. Still, there appear to be some positive VHE detections of CVs:

- AE Aqr – intermediate polar, detection of VHE (∼2.4 TeV) with 33.08 s modulation, luminosity $\sim 1.5 \times 10^{33}\, erg\, s^{-1}$ (Bowden et al., 1992; Meintjes et al., 1992).
- AM Her – polar, possible PeV and TeV gamma-rays (Bhat et al., 1991) with time-averaged luminosities of $\sim 2 \times 10^{32}\, erg\, s^{-1}$ in both energy ranges
- V834 and VV Pup – polars, possible MeV gamma-rays
- and even others potential candidates.

The TeV emission from (at least) some CVs appears to be real. The INTEGRAL has no capability to observe such energetic emission (the top level for detection is ∼10 MeV), but we can expect activity also in lower (reachable) energies. Simultaneous TeV and MeV detections could be quite valuable for detailed analyses of physical models of the sources and related physical processes. The gamma instruments onboard INTEGRAL have bottom level of range from hard X-ray (∼15 keV), so we can expect some results even from this area.

We can summarize our expectations about detectability: OMC will probably observe all selected CVs in its reach, so really many (>70). JEM-X can detect and observe smaller part (>10). IBIS and SPI will hopefully detect some single events (<10?). The scientific importance will increase with time (more data points, more total cumulated exposure, deeper detection limits).

4. The first steps

The first steps in scientific analyses of the INTEGRAL data must be to get the raw data and to make reduction processes on them. There is a need of powerful computer with a mission-specific software installed. The software itself isn't very much intuitive and everybody needs to make some effort to manage it. There are three possibilities for doing this all:

The first, very basic way is to download the required software and manuals from the ISDC web page (*http://isdc.unige.ch/*) and to install it on some computer with OS UNIX/Linux compatible. However, this is not a trivial task, so we can recommend it only to experienced UNIX users/administrators.

The alternative way to work out the INTEGRAL mission data is to visit the Integral Science Data Cetre (ISDC) in Versoix, Switzerland. It is a sticking point between the mission data archive and a scientific community, so there is no need for getting the data via the internet. It is equipped with computers with reduction software installed and there is a staff capable to help anybody with the reduction process.

The last and probably the best way is to use one of the "secondary" data centers located in other places around the world, offering for data analyses similar services as the "main" ISDC in Versoix. We have recently established such data center in Ondřejov, Czech Republic, to cover needs of our research and to be available to the scientific community. It is dedicated mainly to scientists from the central (and potentially East) Europe. It is equipped with one powerful server and four workstations. All interested scientists with access to the INTEGRAL data are welcome!

5. Conclusions

Our goal is to provide a secondary science on INTEGRAL mission data on the field of Cataclysmic Variables. We expect to have good results from the optical telescope OMC and satisfactory results from the X-ray monitor JEM-X. The main importance is in the potential detection of the gamma-ray emission from these objects by mission detectors, which has a crucial importance for understanding the physical processes standing behind the probable VHE in these objects.

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