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11 years observing with OMC, the Optical Monitoring Camera on board the INTEGRAL satellite

Julia Alfonso-Garzón [1], Albert Domingo[1], and J. Miguel Mas-Hesse[1]

[1] Centro de Astrobiología (CSIC–INTA), 28691 Villanueva de la Cañada, Spain

Abstract

The Optical Monitoring Camera (OMC) on board the INTEGRAL observatory provides photometry in the Johnson V band, complementing the high-energy instruments which take images and spectra in hard X-rays and soft gamma–rays. After 11 years of mission operations, it has been possible to compile optical photometric light curves for a very large number of objects, with observational time spans of more than a decade and with a stable and consistent photometric calibration. In this contribution, we present a summary of some of the most interesting scientific results reached with INTEGRAL/OMC data, including the compilation of a catalogue of optically variable sources, some results on the analysis of temporal correlations between different energy ranges and the OMC monitoring of the supernova SN 2014J.

1 Introduction

The Optical Monitoring Camera, (OMC, [13]) on board the INTEGRAL satellite [19], observes the optical emission from the prime targets of the gamma–ray instruments on board the ESA mission INTEGRAL: the IBIS imager ([16]) and the SPI spectrometer ([17]), with the support of the X-rays JEM-X monitor [12]. With an aperture of 50 mm and a field of view of $5^\circ \times 5^\circ$, OMC is able to detect optical sources brighter than V$\sim$18, from a previously selected catalogue, the OMC Input Catalogue (OMC–IC; [8]). OMC provides photometry in the Johnson V band (centred at 5500 Å) and it is able to monitor sources from V $\simeq$ 7 mag (for brighter sources saturation effects appear) to V $\simeq$ 16-17 mag (magnitude limit for 3σ source detection in nominal pointings). Typical observations are taken performing a sequence of different integration times, which provides photometric uncertainties below 0.1 magnitude for objects with V $\leq$ 16.

2 OMC data

After the propietary period of one year, all INTEGRAL data are open to the scientific community. As all the INTEGRAL observational products, OMC data can be accessed primarily from the general INTEGRAL Science Data Centre (ISDC) Archive. We have provided two additional tools that make getting OMC data easier for the scientific user: the OMC Archive and the first INTEGRAL/OMC catalogue of optically variable sources.

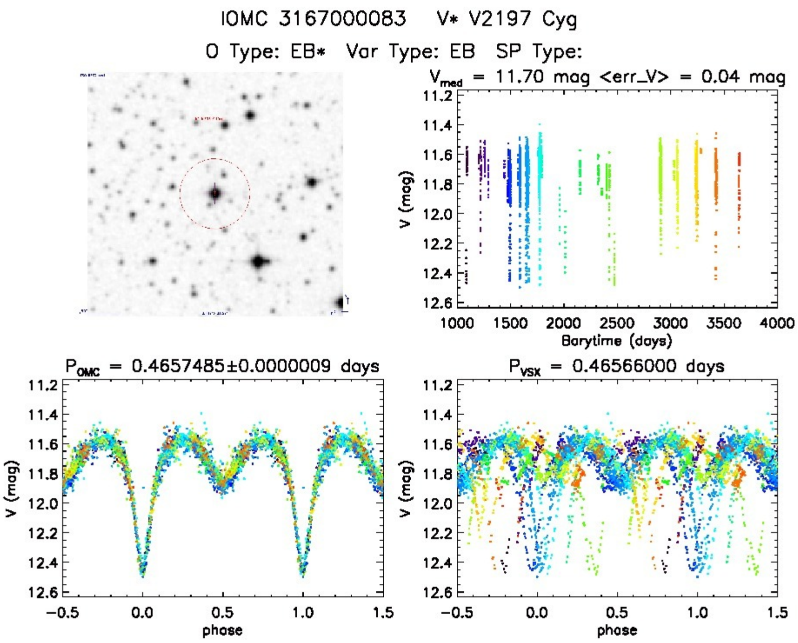

Figure 1: Example of one of the charts published within the OMC–VAR catalogue: V* V 2197 Cyg, a beta Lyrae-type eclipsing binary. In this case the period derived from the OMC light curve improves significantly the value provided by the VSX and yields a much better folding.

2.1 The OMC Archive

After 11 years of operations, the OMC Archive [10] contains photometric observations for 147 110 potentially variable sources. The OMC Archive contains light curves with more than 50 photometric points for around 80 000 sources. It was developed in the framework of the Spanish Virtual Observatory project and is maintained by the Data Archive Unit of Centro de Astrobiología (CAB, INTA-CSIC). All the OMC public data are available in http://sdc.cab.inta-csic.es/omc/.

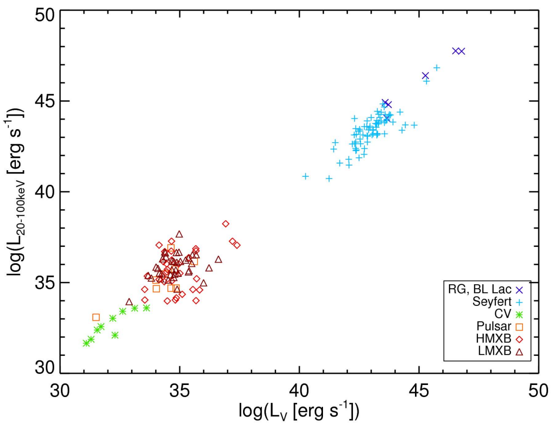

Figure 2: L_X vs. L_V for the different kind of objects present in the fourth IBIS/ISGRI soft gamma-ray survey catalogue.

2.2 The first INTEGRAL/OMC catalogue of optically variable sources

In the first version of OMC–VAR, the catalogue of optically variable sources observed by OMC [1], we provide for each object the median of the visual magnitude, the magnitude at maximum and minimum brightness in the light curve during the window of observations, the period when found, as well as the complete intrinsic and period-folded light curves, together with some ancillary data. This first version of the catalogue contains photometric data and information for more than 5000 objects observed from October 2002 to February 2010. We analysed only those objects with a given SIMBAD object type in the OMC–IC and some quality criteria were applied (see details in [1]). Applying these filters we obtained 6071 sources with high-quality light curves to be analysed and we detected variability for 5263 of them. We estimated a period for 1337 objects developing a method based in the Phase Dipersion Minimization technique (PDM [15]). The periods found vary from a few hours to some hundreds of days, with a peak in the histogram of typical periods around 15 h.

We created for each source in the catalogue a chart showing basic information on the type of object, variability type and spectral type and some plots including the DSS red image of the field of view, the OMC V band light curve without folding, and the light curves folded with our estimation of the period an the period found in the Variable Star Index (VSX [18]) when available. An example of one of these charts is shown in Fig. 1. The charts and the complete light curves in machine readable format for all the sources contained in the OMC–VAR Catalogue can be retrieved from http://sdc.cab.inta-csic.es/omc/.

The catalogue will be updated at the end of the mission and we expect to produce a final catalogue with variability information for more than 25 000 objects monitored over a long time period, with consistent and well calibrated photometry from space.

3 Science with OMC

Since OMC has observed many different types of objects, a very varied science can be performed with its data. We present here some examples of what has been done until this moment and what is being carried out now.

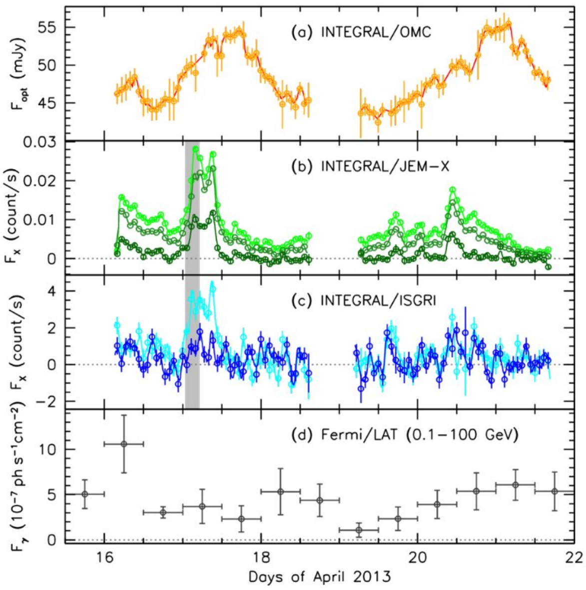

Figure 3: Lightcurves of Mrk 421 in April 2013. The figure has been taken from [14].

3.1 INTEGRAL/OMC observations of pulsating components in eclipsing binaries

A large variety of objects can be found in the OMC–VAR catalogue, but the most frequent ones are pulsating stars and eclipsing binaries. We performed an analysis to find eclipsing systems showing evidences of pulsations in one of their components. Five objects were found and a detailed analysis of one of them, DY Aqr, was performed, as discussed in [3].

3.2 High-energy emission of variable objects in the OMC–VAR catalogue

A multi-wavelenth study of the sources observed by OMC was performed in [9] and in [2]. We cross-correlated OMC–VAR with the 4th IBIS/ISGRI soft gamma-ray survey catalogue [5], and the IBIS and OMC luminosities and their ratios were analysed looking for potential correlations. In Fig. 2 the dispersion diagram of L_X vs L_V is plotted. While the apparent correlation between both luminosities is certainly driven by the distance effect, it is remarkable that the same trend is observed for all kind of objects over more than 15 dex in luminosity, indicating that the mean L_X/L_V ratio remains similar for very different kinds of sources.

3.3 Optical monitoring of high-energy sources

OMC has been monitoring high-energy sources simultaneously to the IBIS camera and the JEM-X monitor. After more than 11 years of INTEGRAL operations, many sources have light curves in these different energy bands. Comparing the optical, X-rays and hard X-rays light curves provides very valuable information about the physical processes powering these high-energy events [4].

A representative example of the kind of correlations expected to be found in these sources is Mrk 421. In 2013, this blazar underwent a prolonged state of high activity, with a peak around January 2013, and revived episodes in April 2013. This activated the programme for INTEGRAL follow-up of blazars in outburst, and Mrk 421 was observed between April 16-21 with the IBIS, JEM-X, and OMC instruments. The results of this campaign were presented in [14]. The INTEGRAL light curves are shown in Fig. 3.

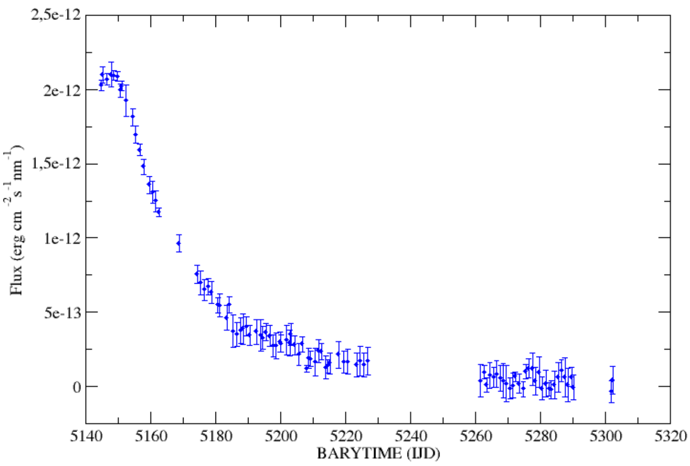

Figure 4: OMC light curve of SN 2014J.

3.4 OMC observations of SN 2014J

In January 2014, SN 2014J was detected in M82, being the closest type-Ia supernova discovered in the past 42 years. Early gamma–ray emission from SN2014J during the optical maximum was observed by INTEGRAL [11], [7], and in a later phase radioactive cobalt was detected for the first time in good agreement with the models [6]. OMC performed optical observations of this event simultaneously to the high-energy instrument observations (see Fig. 4). In order to estimate properly the flux coming from the supernova, the OMC images were corrected for the contribution of the background produced by M82. This background was estimated using the images taken before the explosion. In addition, in order to get a higher signal-to-noise ratio, the optical data were binned into 1 day intervals.

4 Conclusions

OMC provides long-term visual photometric light curves for a large amount of sources of very different nature. These data are public and can be accessed from the OMC Archive and from the OMC–VAR web pages. Very diverse science has been performed with OMC data, but many studies are still to be done. The OMC team invite the scientific community to take advantage of the OMC data and we offer our help with the treatment of the light curves.

Acknowledgments

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References

[1] Alfonso-Garzón, J., Domingo, A., Mas-Hesse, J. M., & Giménez, A. 2012, A&A, 548, A79

[2] Alfonso-Garzón J., Domingo A., Mas-Hesse J. M., 2012, Proceedings of the 9th INTEGRAL Workshop, PoS(INTEGRAL 2012)087

[3] Alfonso-Garzón J., Montesinos B., Moya A., Mas-Hesse J. M., Martín-Ruiz S., 2014, MNRAS, 443, 3022

[4] Alfonso-Garzón J. et al. (in prep.)

[5] Bird A. J., et al., 2010, ApJS, 186, 1

[6] Churazov E., et al., 2014, Natur, 512, 406

[7] Diehl R., et al., 2014, Sci, 345, 1162

[8] Domingo A., et al., 2003, A&A, 411, L281

[9] Domingo A., Alfonso-Garzon J., Mas-Hesse J. M., 2010, PoS(INTEGRAL 2010)068

[10] Gutiérrez R., Solano E., Domingo A., García J., 2004, ASPC, 314, 153

[11] Isern, J., Knoedlseder, J., Jean, P., et al. 2014, The Astronomer's Telegram, 6099, 1

[12] Lund N., et al., 2003, A&A, 411, L231

[13] Mas-Hesse, J. M., Giménez, A., Culhane, J. L., et al. 2003, A&A, 411, L261

[14] Pian E., et al., 2014, A&A, 570, AA77

[15] Stellingwerf R. F., 1978, ApJ, 224, 953

[16] Ubertini P., et al., 2003, A&A, 411, L131

[17] Vedrenne G., et al., 2003, A&A, 411, L63

[18] Watson C., Henden A. A., Price A., 2012, yCat, 1, 2027

[19] Winkler C., et al., 2003, A&A, 411, L1