CENTRO DE ASTROBIOLOGÍA · CAB

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20 years of *INTEGRAL*/OMC complementary science

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The Optical Monitoring Camera (OMC) has been observing the optical emission from the prime targets of the gamma-ray instruments on-board the INTErnational Gamma-Ray Astrophysics Laboratory (*INTEGRAL*) since its launch on 17 October 2002. Simultaneously to these observations of the prime targets, OMC has been acquiring data from about 100 objects of interest within its 5º×5º field of view of each exposure, mainly optically variable or suspected variable sources. The analysis of these complementary observations has led to many interesting scientific results. After 20 years of *INTEGRAL*/OMC observations, the OMC Archive, publicly available at http://sdc.cab.inta-csic.es/omc/, contains the light curves of about 98 000 scientific objects with more than 50 photometric points. Furthermore, in 2012 we published the first *INTEGRAL*/OMC catalogue of variable sources, where we provided a compilation of clean and ready-to-use OMC light curves of a selected sample, together with some useful information on the variability and periodicity of these sources.

In this contribution we summarise the present contents of the OMC Archive and review some of the most interesting results on OMC complementary science using data from the OMC Archive and/or the first *INTEGRAL*/OMC catalogue, obtained by the scientific community so far for different types of variable sources.

The OMC Archive

The OMC Archive (Domingo et al. 2010, Gutiérrez et al. 2004) contains observations of around 178 000 scientific sources observed by OMC from which ~98 000 have light curves with more than 50 photometric points.

The query form allows complex searches by using several parameters, e.g. object name (or list of objects), object type, coordinates, observing date, number of photometric points in light curve…

http://sdc.cab.inta-csic.es/omc/

Variable stars	
Variable star of irregular type	498
Eruptive variable star	295
Rotationally variable star	791
Pulsating variable star	9550
Star suspected of variability	37
Peculiar star	905
Others or unknown type	7359

Galaxies	
Radio galaxy	460
Emission-line galaxy	417
Active galaxy nucleus	2010
Possible active galaxy nucleus	742
Others or unknown type	318

Composite objects	
Eclipsing binary	3191
Cataclysmic variable star	588
X-ray binary	304

The physical nature of the objects observed by OMC is very diverse. The tables above show a summary of the object types for those sources having more than 50 photometric points which are included in the SIMBAD database.

The *INTEGRAL*/OMC catalogue of optically variable sources

The first catalogue of variable sources observed by OMC (OMC-VAR, Alfonso-Garzón et al. 2012) was published in 2012. This first version of the catalogue provided ready-to-use light curves and informative charts of 5263 variable sources, out of which we obtained a period determination for 1137 objects. We cleaned the light curves removing those observations affected by different problems, including saturation, low signal to noise, cosmic rays, etc. These clean light curves and our period determinations have been used in many optical analyses.

The final catalogue of OMC variable sources will be published after the end of the mission and will contain the ready-to-use light curves of all the objects observed during the mission life, along with complete information on their variability, periodicity, and object type classification.

Eclipsing binaries

The light curves observed by OMC provide a great opportunity to study and estimate the basic physical parameters of eclipsing systems. Zasche 2009, 2010, and 2011 analysed and studied the OMC light curves of a few dozen previously neglected eclipsing binaries (see Fig. 1). This author found that about one half of the investigated systems have the luminosity of the third unseen body above a statistically significant value about 5%.

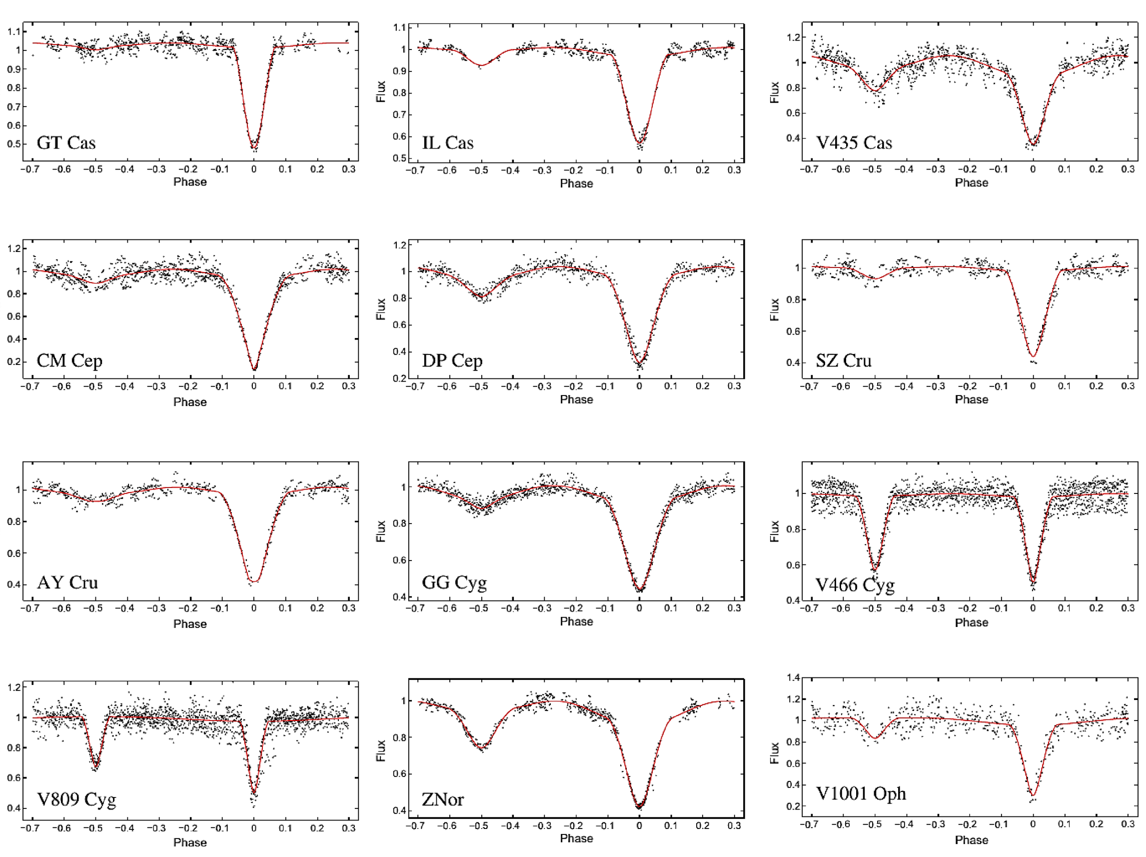

Figure 1. OMC light curves of previously neglected eclipsing binaries. Adapted from Zasche 2009.

These well-defined eclipses can also serve as ideal clocks to measure precise time intervals. The eclipse timing variation (ETV) method involves studying the deviations from the predicted ephemerides and can be used to reveal some of the hidden properties of these systems. In a recent work, using data from OMC, ASAS and ASAS-SN surveys, Zasche et al. 2020 analysed a collection of more than 60 minima of AZ Vel covering 20 years, and clearly found the ETV variation with a periodicity of 5.65 years that can be attributed to a hidden distant component.

Other studies have made use of the time of minima calculated from OMC observations and other surveys to derive the apsidal-motion periods in eccentric eclipsing binaries (EEBs). This is the case of Zasche and Wolf 2011 who performed a detailed photometric and period analysis of the EEBs V456 Oph and V490 Cyg, and managed to estimate the parameters of the apsidal motion with periods of about only 23 and 19 years, respectively. This result makes V490 Cyg the system with the shortest period among the EEBs.

Pulsating stars

Among the pulsating stars, Classical Cepheids (DCEPs) are important astrophysical objects not only as standard candles in the determination of cosmic distances, but also as a testbed for the stellar evolution theory. This is based on the strict connection between their pulsation and stellar parameters. The long OMC temporal coverage allows to correctly classify them as DCEP stars and perform a detailed analysis of the pulsation periods.

Hajdu et al. 2009 discovered the double-mode nature of three pulsating variable stars observed by OMC previously classified as RR Lyrae. Based on their period ratios, periods and the shape of the light curves, they found that two of the stars (V767 Sgr and V363 Cas) pulsate simultaneously in the first and second overtones and are, in fact, short-period Cepheid stars.

More recently, Catanzaro et al. 2020 re-analysed the accumulated OMC observations and confirmed the classification of V363 Cas as a multi-mode DCEP (see Fig. 2). Furthermore, these authors found that the period of V363 Cas is increasing, with a strong acceleration after HJD=2 453 000. They interpret this result as a clear indication of a first crossing of the instability strip.

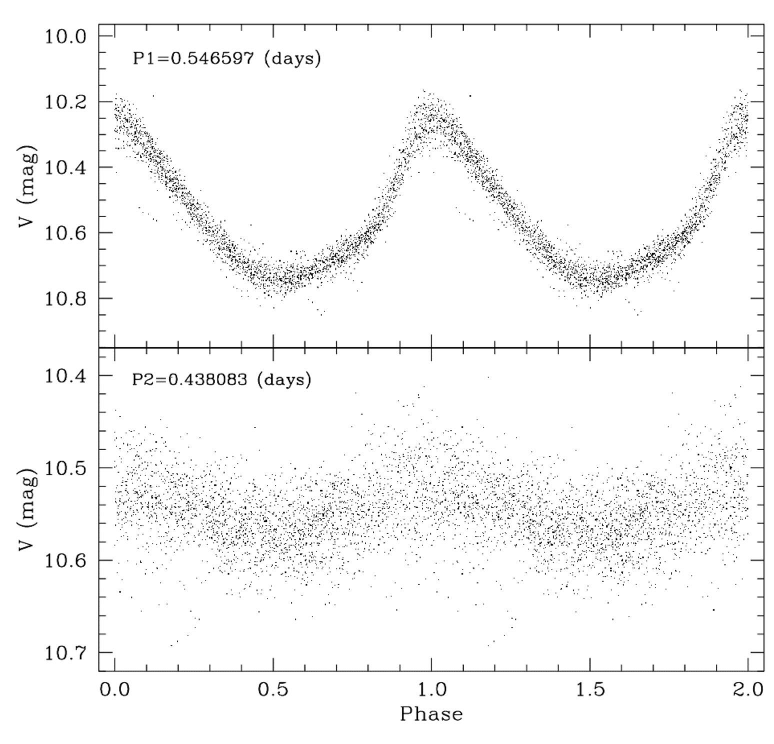

Figure 2. OMC light curves of V363 Cas. The top and bottom panels show the folded light curves on the first (P1) and second (P2) overtone periods, respectively. Taken from Catanzaro et al. 2020.

OMC scientific publications

A search for OMC related publications on the ADS database yields a total of 312 papers. These publications include both multiwavelength analyses combining optical and X-ray data (see the OMC poster by Alfonso-Garzón et al.), and other purely optical studies which we have grouped as OMC complementary science, thus covering a wide range of topics and objects. The tables on the right show the classification of OMC publications by topic/object type.

INTEGRAL/OMC main objectives	
X-ray binaries	28
Novae/Supernovae	10
Cataclysmic variable stars	22
AGNs/Blazars	30

OMC complementary science	
Eclipsing binaries	42
Pulsating variable stars	43
Other optical variable stars	14

Other OMC related papers	
Catalogues and Archives	31
OMC instrument	17
Review papers	18
Before launch	41
Others	16

Cataclysmic binaries

Cataclysmic variables (CVs), and especially intermediate polars (IPs), have been frequently observed by *INTEGRAL*. In some cases, the OMC flux has been used to build the Spectral Energy Distribution. Other times, optical variability has been observed in the OMC light curves.

- Rapid variability was observed in the OMC light curve of RS Oph by Simon et al. 2004 (see Fig. 3). These authors found that the amplitude of the flickering in RS Oph tends to increase with increasing mean intensity level.

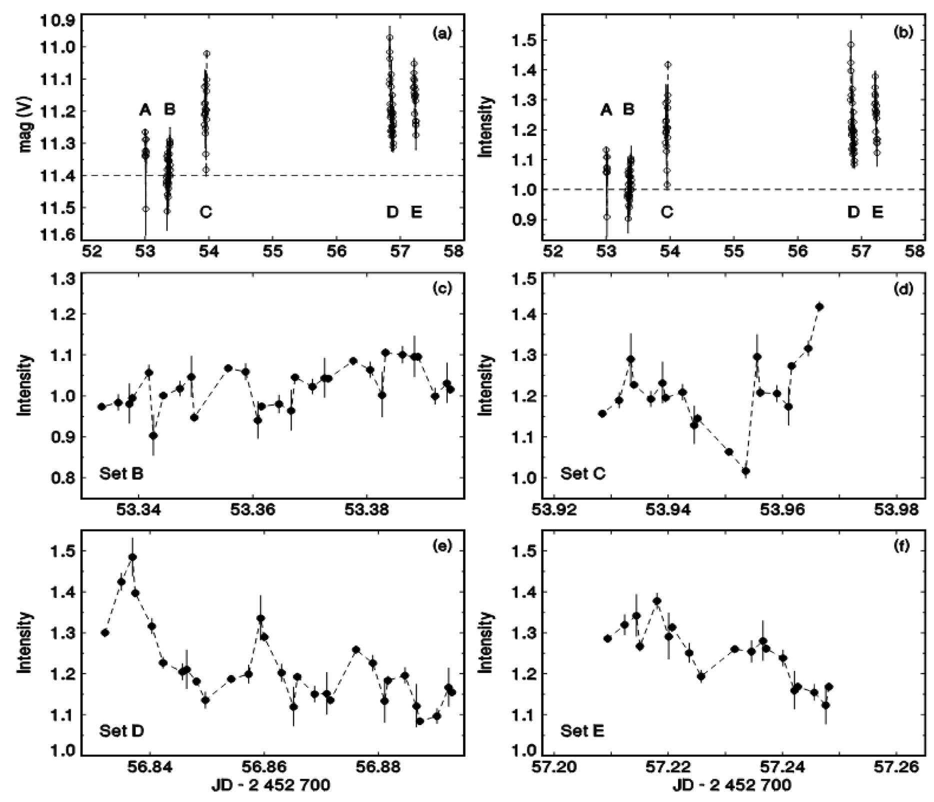

Figure 3: OMC light curve of RS Oph. Taken from Simon et al. 2004.

- Simon et al. 2006 analysed the OMC data of IX Vel covering an outburst and a short episode of a faint state (see Fig. 4). They proposed that both the outburst and the faint state of IX Vel are caused by mass transfer variations, and not by the thermal instability of the disk (see Fig. 4).

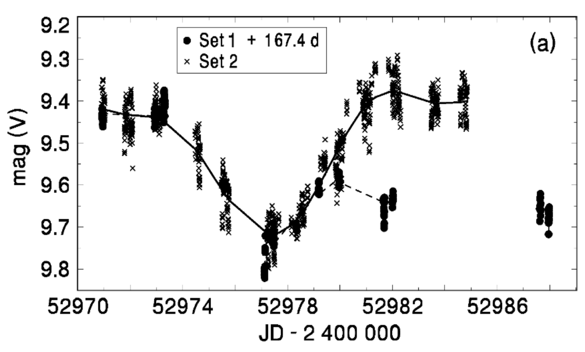

Figure 4: Superposition of an outburst (duration <14 days) and a short episode of a faint state in IX Vel. Taken from Simon et al. 2006.

X-ray binaries

Most of the X-ray binary studies including OMC observations combine the OMC data with X-ray data from other *INTEGRAL* instruments (see the OMC poster by Alfonso-Garzón et al), but some purely optical studies of theses systems with OMC data have also been performed. In Fig. 5, the OMC light curve of LMXB Her X-1 folded on its orbital period is shown, together with an orbital sketch of the system (Rísquez et al. 2008). On the other hand, the optical variability of the microquasar SS 433 looks irregular, but separated trends can be identified selecting the points according to their phase within the jet precession period (see Fig. 6 and Rísquez 2008).

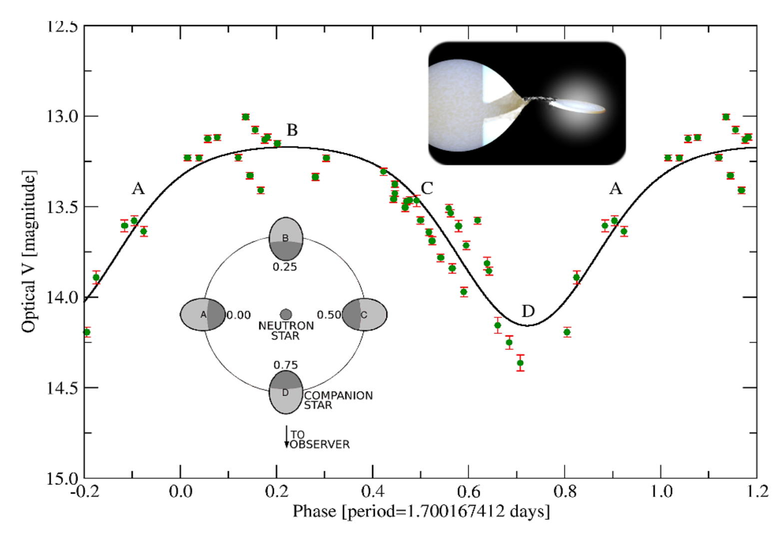

Figure 5: Her X-1 OMC optical light curve and orbital sketch. Taken from Rísquez et al. 2008.

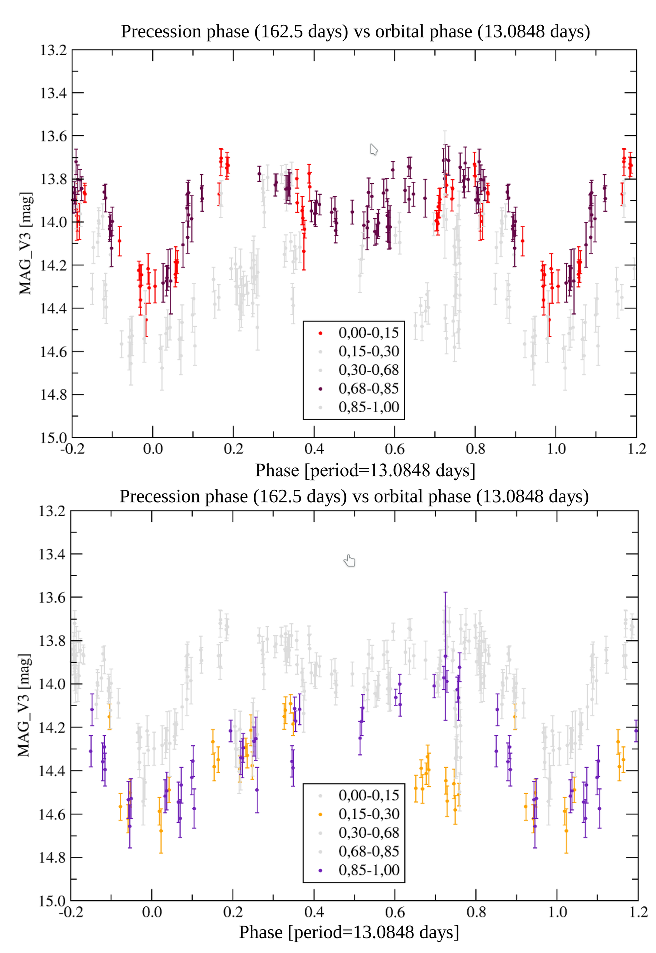

Figure 6: SS 433 OMC light curve folded on the orbital period. Different phases of the emission lines from the jet are marked with different colours. Adapted from Rísquez 2008.

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