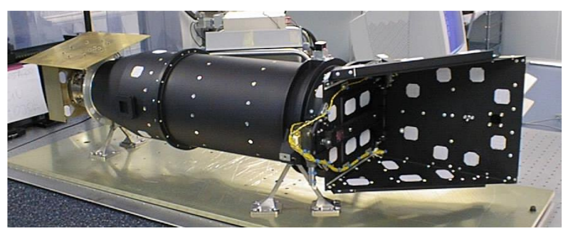
# INTEGRAL/OMC Legacy Archive


**Albert Domingo*, Julia Alfonso-Garzón, J. Miguel Mas-Hesse**

*Centro de Astrobiología (CAB), CSIC-INTA, Madrid, Spain*

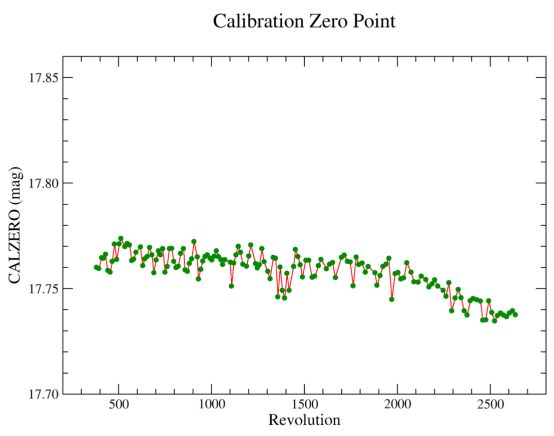




The Optical Monitoring Camera (OMC) has been providing simultaneous Johnson V-band photometry with the X-ray and gamma-ray instruments on board the International Gamma-Ray Astrophysics Laboratory (INTEGRAL) since its launch on 17 October 2002. The observations include both the primary targets of the gamma-ray instruments and approximately 100 additional objects of scientific interest within the 5°×5° OMC field of view of each exposure, the majority of which are optically variable or suspected variable sources. After two decades of operations, the OMC Archive contains light curves for approximately 105 000 scientific objects, with more than 50 photometric points for each.

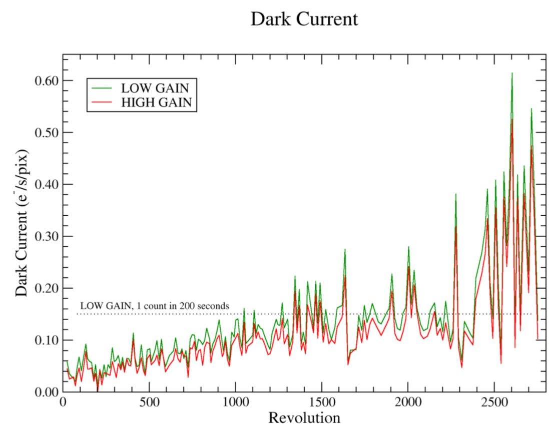
The INTEGRAL/OMC Legacy Archive at CAB will contain all derived data products from the OMC. The light curves for all objects observed by OMC, including the identified counterparts of INTEGRAL-detected high-energy sources, and a result catalogue of detected OMC sources, comprising information on coordinates, source classification and average source magnitude, will be made available. All of these OMC data products will be incorporated into the INTEGRAL Legacy Science Archive (ISLA), the final and official archive of all data collected during the course of INTEGRAL's scientific operations.

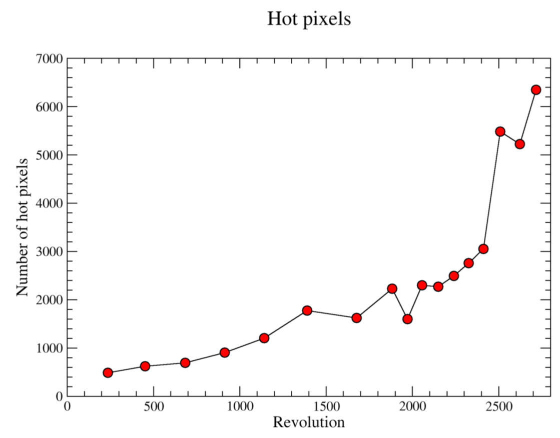
In this contribution, we provide a summary of the ongoing work to construct the INTEGRAL/OMC Legacy Archive. This includes the reprocessing of all OMC scientific data from the beginning of the mission with updated calibrations and an updated version of the Offline Scientific Analysis software package (OSA).

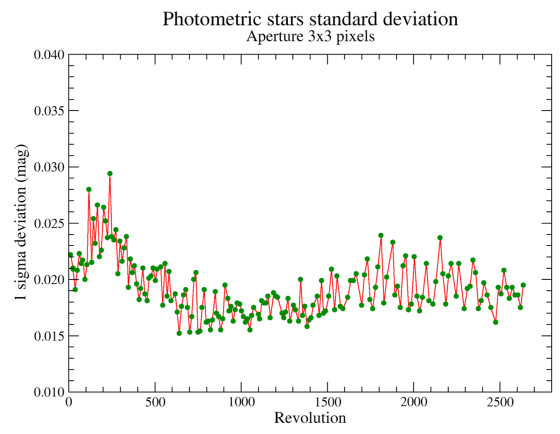

## OMC hardware performance after 22 years of operations




After 22 years of operations, no CCD columns have been lost. The CCD temperature range remains within predictions (-85 C to -70 C). The optics are still clear. Only a minimal decrease of the photometric zero point (sensitivity) is noticeable over the last few years. The effects of radiation (dark current, hot pixels) are still moderate, and their impact on the scientific performance is still negligible. We note that the OMC CCD image is formed by 1024×1024 pixels.



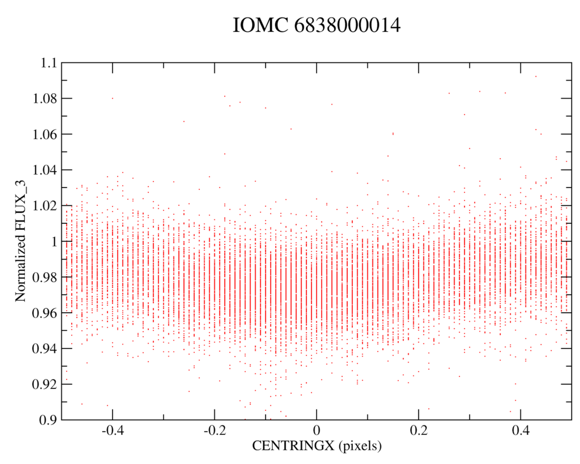




## Offline Scientific Analysis (OSA)

### Photometric aperture correction

The flux extraction algorithm applies an aperture correction to account for the finite size of the extraction mask. As can be seen in the figure, after applying the photometric aperture correction, there is a residual trend as a function of the source position in the pixel (CENTRINGX). This is probably due to a deviation of the Point Spread Function (PSF) from the assumed Gaussian shape when calculating the standard aperture correction. In order to correct this trend, a second order aperture correction is being implemented in OSA.

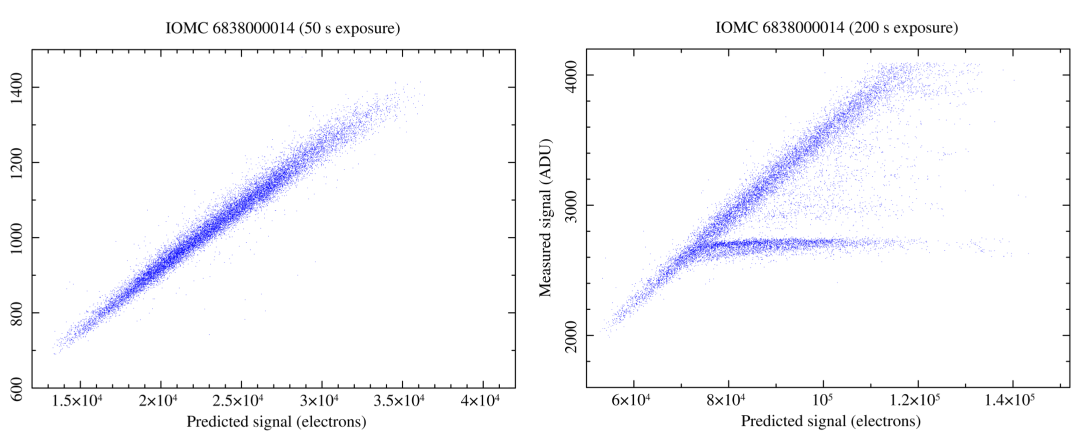



### Saturation properties

We analyzed the saturation properties of the CCD pixels to improve the calibration when bright stars are present in the field of view. Surprisingly, we found an effect that is difficult to explain: pixels sometimes appear "saturated" at a number of counts well below the full well capacity of the CCD (4095 ADU, ~120 000 e-). The effect is detected over the whole CCD, and is not related to specific pixels. Furthermore, while a value of around 72 000 e-/pixel is the most common value at which this effect occurs, this value of pseudo-saturation seems to be quantized at levels between the full well capacity and this base level.

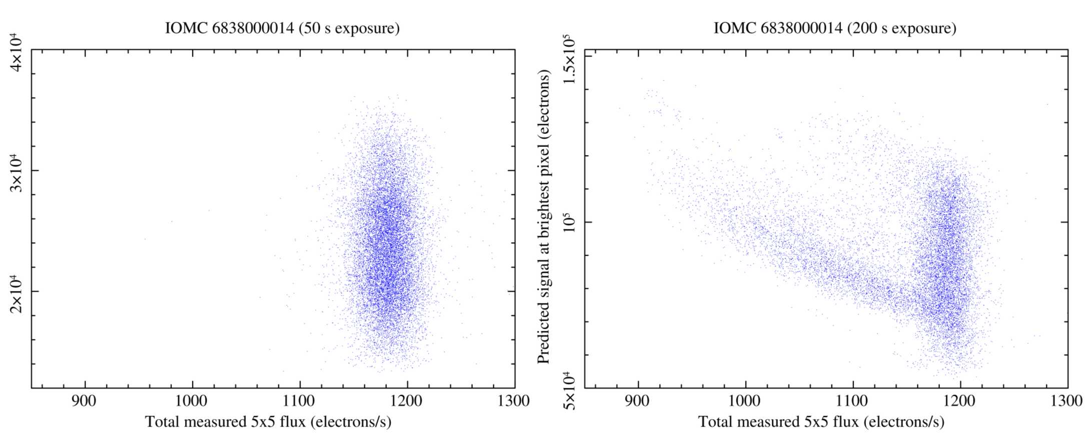
In the following figures we show an example of this pseudo-saturation effect for a reference star (V=10.05 mag), which has been observed regularly during 18 years of operations (~15 000 individual observations). Each point corresponds to one observation, with the star falling on different sections of the pixel. From one observation to another, the star can fall on any part of the CCD. The predicted signal on the brightest pixel was calculated from the reference magnitude for each exposure time. The maximum signal is reached when the star is in the centre of the pixel, and the minimum when it falls on the corner of 4 pixels.

These plots show that the agreement between predicted and measured signal is excellent when we are far from saturation (50 s exposure). However, for predicted signals greater than ~72 000 e-/pixel, the effect of pseudo-saturation appears (200 s exposure).



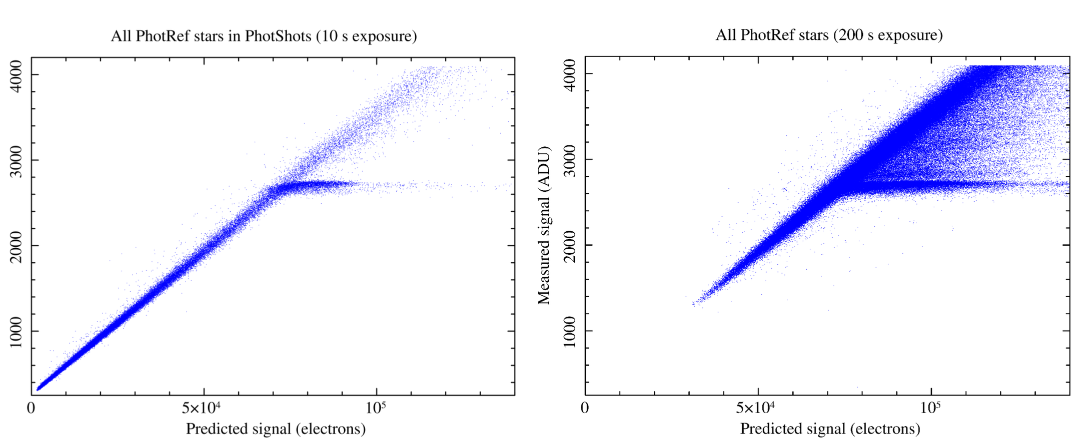

OMC photometry in OSA is performed using three aperture masks: 1×1, 3×3 (default) and 5×5 pixels. To test whether the lost photons moved to adjacent pixels when pseudo-saturation was observed, we analysed the measured fluxes extracted with the 5×5 photometric mask.

We found that even with the largest aperture mask we did not recover the expected flux when pseudo-saturation was observed (200 s exposure figure), suggesting that the electrons have not moved to adjacent pixels, but have simply been lost or not accounted for. The 50 s exposure figure is shown for reference (no saturation).




All observed reference stars are shown in the last two figures. It can be seen that the same pseudo-saturation effect also appears in 10 s exposures for brighter stars.

We are updating the OSA software to detect and remove all photometric measurements affected by this pseudo-saturation effect.





* E-mail: albert@cab.inta-csic.es

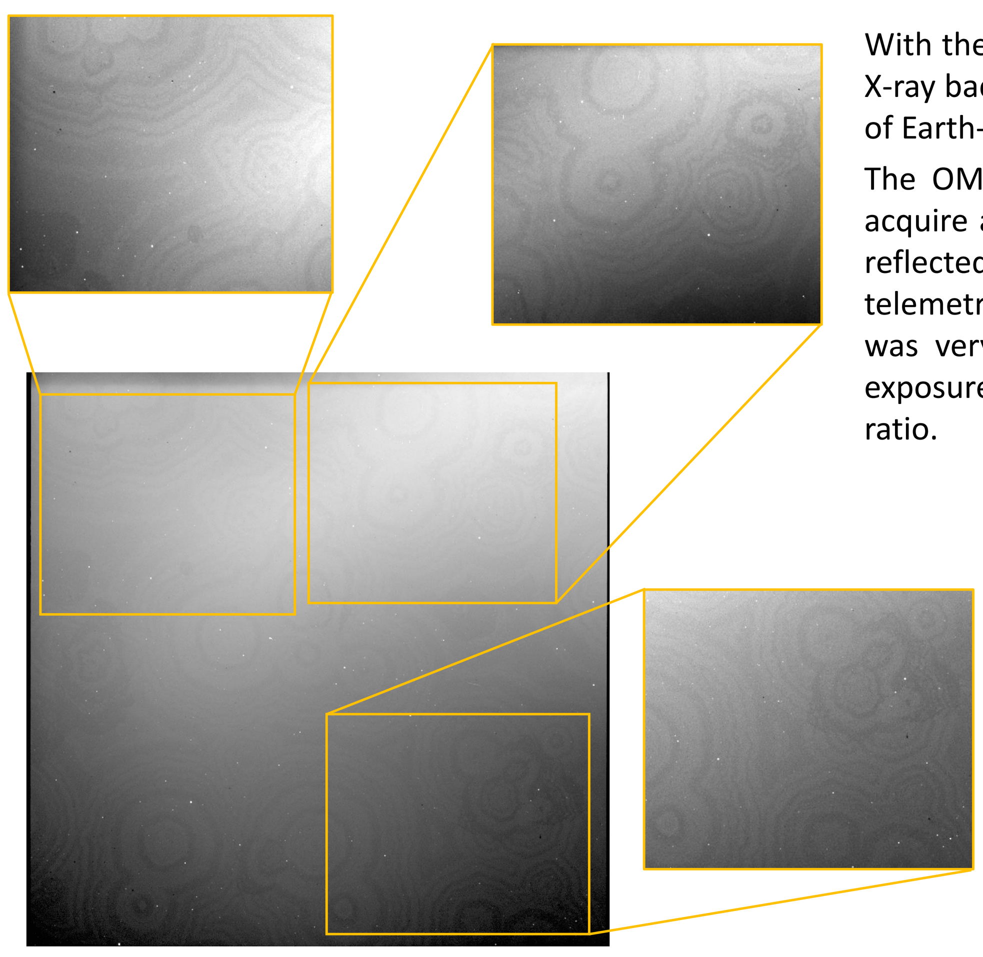

## Instrument calibration

One of the main calibration activities for OMC is devoted to build the CCD pixel-to-pixel sensitivity matrix, also known as the flatfield correction. To this purpose, two LED light sources within the optical cavity were foreseen to provide "flat-field" illumination of the CCD. Unfortunately, during the first months of operations, the OMC CCD suffered the deposition of some contaminants on its surface, which modified somewhat the properties of the anti-reflection coating. As a consequence, the LEDs images alone could not be used to calibrate the pixel-to-pixel sensitivity because the CCD response to the light coming from the LEDs is different to the response to the light coming from the celestial objects. To solve this problem, the OMC team developed new methods and strategies to perform this calibration by combining data from LED illuminated images and long exposure sky images.

In 2017, a new improvement in the calibration observational strategy was implemented. It consisted in the inclusion of a narrow 3×3 dithering pattern (off-pointings in steps of 2 arcmin) for the acquisition of sky images, which allowed us to remove the stars in the field of view, and to obtain the response of the CCD to the incoming radiation from the zodiacal light. When we compared this response with that of the LEDs at the time, we found that both responses were similar, and a new calibration strategy was defined.

In order to trace how the response of the CCD to the LEDs has changed from 2006 to 2016 in comparison with the response of the CCD to an external uniform light, we will analyse the Earth-occultation observations available during this period.

### Calibration with OMC images acquired during the Earth-occultation observations



With the objective of measuring the intensity of the cosmic X-ray background (CXB), INTEGRAL performed several series of Earth-occultation observations between 2006 and 2016.

The OMC team took advantage of these observations to acquire a series of images with the CCD illuminated by the reflected light from the Earth's albedo. Due to the low telemetry rate allocated to OMC (4 packets for science), it was very important to acquire the image with the right exposure at the right time to ensure a good signal-to-noise ratio.

The images acquired in these observations have an illumination profile with a strong gradient, but due to the good signal-to-noise ratio, they are excellent for deriving the CCD pixel-to-pixel sensitivity matrices at small scales.

We plan to use the data from the Earth-occultation observations to derive the pixel-to-pixel sensitivity variations with time, and update all the flatfield calibration matrices between 2006 and 2017.

## The INTEGRAL/OMC Legacy Archive at CAB

The INTEGRAL/OMC Legacy Archive at CAB will be based on the current OMC Archive (Domingo et al. 2010, Gutiérrez et al. 2004). It contains presently observations of around 178 000 scientific sources observed by OMC from which ~105 000 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…

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

| Variable stars | |
|---|---|
| Variable star of irregular type | 507 |
| Eruptive variable star | 310 |
| Rotationally variable star | 818 |
| Pulsating variable star | 10374 |
| Star suspected of variability | 38 |
| Peculiar star | 913 |
| Others or unknown type | 7741 |

| Galaxies | |
|---|---|
| Radio galaxy | 530 |
| Emission-line galaxy | 438 |
| Active galaxy nucleus | 2200 |
| Possible active galaxy nucleus | 849 |
| Others or unknown type | 361 |

| Composite objects | |
|---|---|
| Eclipsing binary | 3346 |
| Cataclysmic variable star | 611 |
| X-ray binary | 306 |

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 (see poster by Aguilar et al.).

## References


Alfonso-Garzón, Domingo, Mas-Hesse, Giménez 2012, A&A 548, A79

Domingo, Gutiérrez-Sánchez, Risquez, et al. 2010, ASSP, 493

Gutiérrez, Solano, Domingo, et al. 2004, ASPCS 314, 153



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