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REFERENCE FRAME AND TIME STANDARD USED IN INTEGRAL/OMC DATASETS

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The INTEGRAL satellite (Winkler et al. 2003) started its operations in October 2002 and is dedicated to search and study of all kinds of high-energy sources using gamma-ray and X-ray instruments. In addition, there is an Optical Monitoring Camera (Mas-Hesse et al. 2003, hereafter OMC) consisting of a passively cooled CCD (1056×2061 pixels, imaging area: 1024×1024 pixels) working in frame transfer mode. The CCD is located in the focal plane of a 50 mm (diameter) lens including a Johnson V-filter to cover the 500–600 nm wavelength range. The OMC obtains very good long-term series of photometric observations. The public OMC Archive at `http://sdc.cab.inta-csic.es/omc/` (Gutiérrez et al. 2004) contains not only optical measurements of the original high-energy targets, but also many "common" variable stars observed with OMC. However, some OMC data used in the past were unfortunately interpreted in the incorrect time standard. For this reason we decided to write the following short description to help people working in the variable star community.

The data in the public archive are given as binary tables in fits format. The time information is given in two columns in terms of INTEGRAL Julian Date (IJD), which is defined as JD-2 451 544.5 or MJD-51 544.0. The time standard adopted by the INTEGRAL Project, as recommended by IAU Division I, is Terrestrial Time (TT). So, IJD starts on 1 January 2000, but expressed in TT and not in UTC. Since TT differs from UTC by 32.184 sec + 32 leap seconds at the start of year 2000, the UTC origin of the IJD is actually 1999-12-31 T23:58:55.816 (=JD 2 451 544.49925713 UTC).

The first time column is "TFIRST", where no barycentric or heliocentric correction is applied. So, "TFIRST" is the INTEGRAL Julian Date measured in the satellite reference frame and expressed in TT. The second time column "BARYTIME" includes the time after applying the barycentric correction to transform from the accelerated coordinate system of the INTEGRAL satellite into the coordinate system of the solar system barycenter. Following the IAU recommendations for barycentric ephemerides (IAU 2006 NFA glossary, prepared by the IAU Division I Working Group), "BARYTIME" is the Barycentric INTEGRAL Julian Date expressed in the Barycentric Dynamical Time standard (TDB). The difference TDB–TT has a maximum amplitude of 3.4 ms (Eastman et al. 2010), which is orders of magnitude lower than the OMC timing accuracy.

We notice that authors use heliocentric instead of barycentric correction in most papers devoted to variable stars. Heliocentric correction is only accurate to 8 seconds (see Eastman et al. 2010 for details). This difference is negligible for the majority of periodic variable stars with periods of days and longer, but it brings redundant and senseless noise to the data.

In addition to the above considerations, the OMC data user must take into account that times in both columns "TFIRST" and "BARYTIME" are the "starting" time of the integration. Thus, for the commonly used "middle" time of the integration, one must add "TELAPSE"/2 and be aware that TELAPSE is in seconds. An OMC integration consists of one or several individual exposures. Information in the TELAPSE column gives the length of the entire integration in seconds (which can include several exposures), while the EXPOSURE column gives the effective exposure in seconds. The number of exposures co-added to form a given OMC integration is controlled by the "Sampling Time" query parameter shown on the OMC Archive Web page. This parameter must be understood as a code to designate the type of light curve is obtained. There are three different sampling times used for data in the OMC Archive: 1, 630 and 9000 seconds. With 1 second sampling we get a light curve with one photometric point per exposure. With 630 second sampling individual exposures are co-added to obtain roughly one photometric point each 10 minutes, but images with exposures less than 20 seconds are rejected to increase the signal-to-noise ratio. For the 9000 seconds sampling all exposures in a given INTEGRAL pointing are co-added, and exposures shorter than 60 seconds are rejected to increase the signal-to-noise ratio. It should be borne in mind that longer exposures lead to saturation effects for bright sources. Consequently only the shortest possible exposure times should be used for such bright sources.

The OMC Archive is a rich source of photometric information on many variable stars. However, before using the information for a long term study of astronomical events, substantial attention should be devoted to the time scales and reference frames of data used in the analysis. As Bastian (2000), Eastman et al. (2010) and others showed, researchers should take into account the difference between JD based on UTC and TT (or TDB), which can introduce systematic errors of over 1 minute.

More information can be found at the ISDC[1] FAQ list:
`http://www.isdc.unige.ch/integral/support/faq`.

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