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TESSVISIBILITY – WHEN WAS MY FAVORITE STAR OR ASTEROID OBSERVED BY TESS?

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ABSTRACT

While Transiting Exoplanet Survey Satellite (TESS) covers a considerable area of the sky during routine observations and the pointing schedule is easy to follow, it is not obvious to retrieve the current and/or predicted visibility of a bulk amount of objects, considering both stationary and moving Solar System targets like asteroids or comets. The program `tessvisibility` is a small piece of highly portable code implemented in both C an UNIX shell, providing functionalities for such bulk retrievals at the accuracy of a TESS pixel. This accuracy includes the gaps between the focal plane CCDs, the gaps between the cameras as well as at the sector-level treatment to obtain visibility information.

Keywords: Astronomy software(1855), Astrometry(80)

1. BACKGROUND

Launched in April 2018, *Transiting Exoplanet Survey Satellite* (*TESS*, Ricker et al. 2015) performs routine operations since 25 July, 2018 by observing $24° \times 96°$ sections of the sky called *sectors* in anti-solar directions. This large field-of-view (FoV) is provided by four identical cameras, each having a fast lens and an array of four frame-transfer CCDs in the focal plane. Therefore, the instrument FoV is effectively assembled from 16 continuous parts, each having a size of approx. $12° \times 12°$. Because of this unique combination of the fast optics and the focal plane arrangement, the optical axes even do not fall on silicon and significant amount of optical distortions are also needed to be taken into account when one computes the visibility of objects. Even though, the gaps between the CCDs are equivalent to $60 - 100$ pixels, therefore, a naïve check would falsely confirm the visibility of an object with a chance of $8 - 10\%$ just by checking the full per-camera FoV of $24° \times 24°$.

2. IMPLEMENTATION AND AVAILABILITY

The core functionality of the `tessvisibility` toolchain is to perform efficiently the astrometric conversion between J2000 celestial coordinates and CCD pixel coordinates in the frame used by the publicly available raw and calibrated full-frame images (FFIs). Fundamentals and the sub-steps of the process follow the Pál et al. (2020) pipeline implemented for extracting asteroid photometry on TESS FFIs. Namely, a) the spacecraft boresight pointing information is converted into per-camera pointing by simply taking a fixed 24° separation of the intended optical axes, b) a gnomonic projection is applied in the focal plane, followed by a three-term radial Brown-Conrady distortion model, c) a third-order per-CCD polynomial is applied to derive the final pixel coordinates. The employed CCD geometry is in accordance with Fig. 4.3 of Vanderspek et al. (2018), i.e. a visible object should appear between $(44, 0) \leq (x, y) \leq (2092, 2048)$ – in other words, the underclock, overclock and calibration areas are excluded. While the geometric parameters of the final astrometric solutions are kept fixed in the steps a) and b), the polynomial coefficients were derived empirically using an astrometric fit to the GAIA DR2 catalogue (Gaia Collaboration et al. 2016, 2018) by involving the tasks of the FITSH package (Pál 2012). Based on the analysis of the individual per-sector astrometric solutions, the hard-wired polynomial coefficients provide a sub-pixel accuracy for the overall computation of the apparent positions.

Besides the simple conversion between J2000 and plate coordinates, the C version of `tessvisibility` is capable to perform bulk conversation and visibility check on a user-defined input list of coordinates as well as time series of astrometric positions of moving objects by reading simple textual files. In this manner, `tessvisibility` follows the philosophy of the classic UNIX pipelines and can be used in conjunction with various command line utilities

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and any kind of programs implementing such features. Both the C and UNIX shell (`bash`) version of the code has no dependencies, all of the functionalities are implemented within the source code. The only exception is the sector boundary retrieval for the `bash` version, which relies on the FITSH package[1] (Pál 2012) pre-installed. Both implementations have a built-in support for the publicly available pointing data[2] up to the end of the 4th year of the mission (i.e. up to 2022-08-31). In addition, the C version also features a *custom pointing* mode where the boresight pointing is parameterized via an additional argument for the program. In the analysis of ephemerides (i.e. in the "moving object" mode, see above), the user should also supply a corresponding timespan for this particular custom pointing as a mandatory command line argument.

The aforementioned implementations of the `tessvisibility` code are available from the Konkoly Observatory archives[3]. Both implementations are capable to resolve object names using the CDS/Sesame service[4].

Facilities: TESS (Ricker et al. 2015), *Gaia* DR2 (Gaia Collaboration et al. 2018)

Software: FITSH (Pál 2012), EPHEMD (Pál et al. 2020)

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REFERENCES

Gaia Collaboration: T. Prusti et al., 2016, A&A, 595, A1

Gaia Collaboration; Brown, A. G. A.; Vallenari, A.; Prusti, T.; de Bruijne, J. H. J.; Babusiaux, C.; Bailer-Jones, C. A 2018, A&A, 616, A1

Pál, A. 2012, MNRAS, 421, 1825

Pál, A.; Szakáts, R.; Kiss, Cs. et al. 2020, ApJS, 247, 26

Ricker, G. R. et al. 2015, J. Astron. Telesc. Instrum. Syst. Vol. 1, id. 014003

Vanderspek, R. et al. *TESS Instrument Handbook v0.1*, available from https://heasarc.gsfc.nasa.gov/docs/tess/documentation.html.

[1] https://fitsh.net/
[2] https://tess.mit.edu/observations/
[3] https://archive.konkoly.hu/pub/util/tess/tessvisibility/
[4] http://cds.u-strasbg.fr/cgi-bin/Sesame