Eclipse timing variations - results of the Dwarf project

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Abstract: Eclipsing binaries are powerful tools for studying a wide spectrum of astrophysical problems. We present the results of an eclipse timing variability study on ~50 dwarf binaries. The long-term ground-based photometric survey supplemented with TESS data revealed a presence or absence of these changes in studied systems. Alternative explanations are also discussed.

The **Dwarf project** is an observational campaign aimed at the detection of circumbinary extrasolar planets around short-period eclipsing binaries with dwarf components (Pribulla et al. 2012, AN, 333, 754). We looked for the Light travel time effect (LITE) in the eclipse times data.

In this campaign, we collected light curves (LCs) with an extensive network of more than 30 1-metre class telescopes on many collaborating observatories. We cleaned the LCs and transformed the time to BJD TDB. For each star, we constructed the synthetic LC using the Roche code (Pribulla, 2012, IAUS, 282, 279). We extended the Roche code by the TESS long-pass filter and by logarithmic limb darkening and gravity darkening coefficients. We fitted the synthetic LC to the observed data and determined the eclipse times.

Based on new eclipse times, we improved the linear ephemeris of our targets and re-started the observations of all targets from season 2023.

Our long-term study led to different results for low-mass eclipsing binaries. We found systems that do not show a light travel time effect during the project duration. There are also eclipsing binaries that show O-C variations and do not show changes in their LCs on our target list. We also found a group of binaries that show LITE together with a significant variation of their LCs.

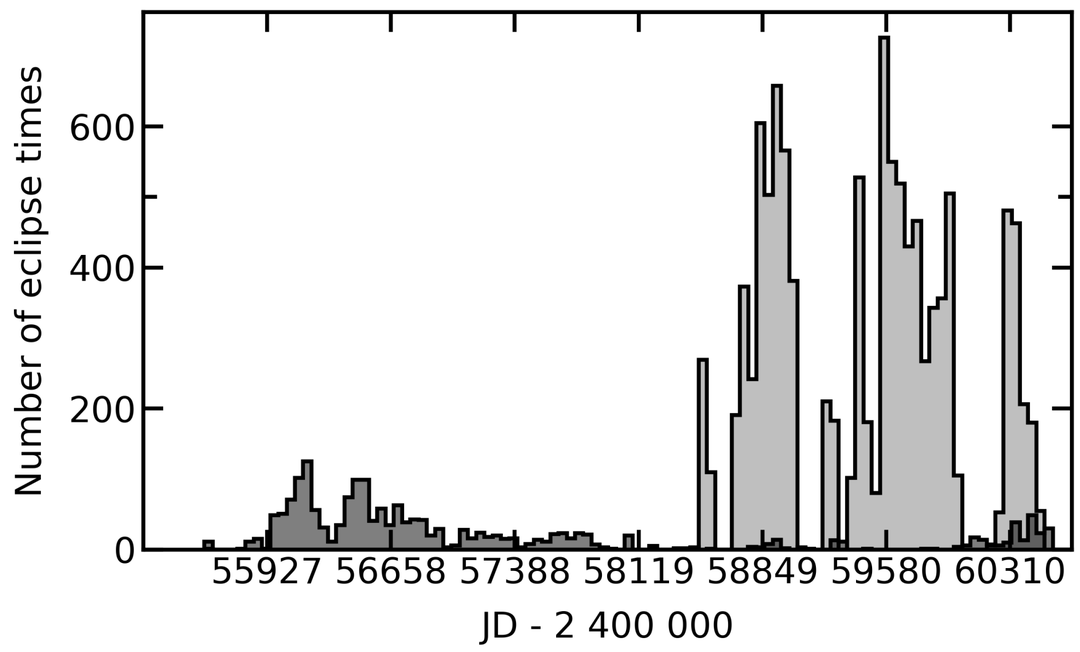

Fig. 1 Statistics of observations since 2010. In total, 12 721 eclipse times were collected. The majority (85.6%) comes from the TESS data (light grey). We continued to add ground-based observations (dark grey) and also added 4 083 previously published times of eclipses.

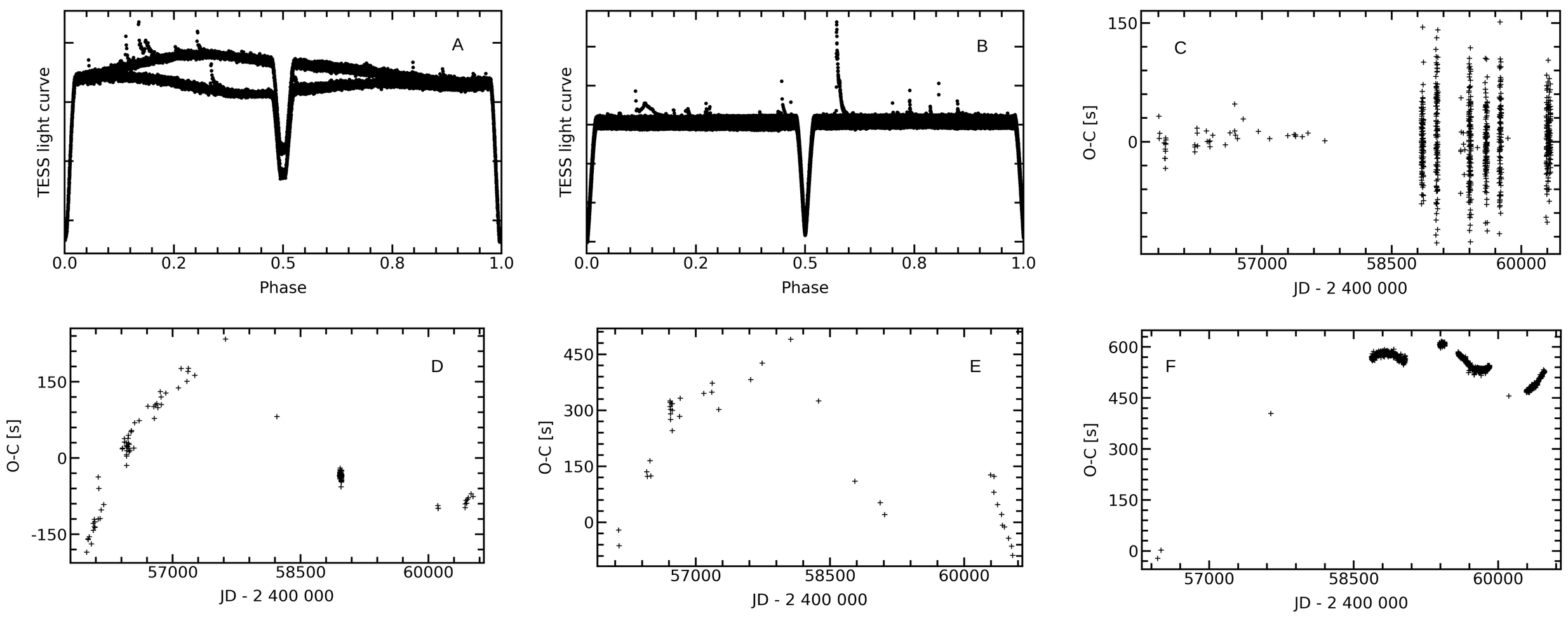

Fig. 2 Light curves and O-C diagrams of selected stars studied within the Dwarf project. Significant change in the LC covered by TESS observation is visible on Panel A. Panel B shows stable LC with flare activity in the TESS LCs. Panel C shows constant, zero O-C values. The scatter of TESS eclipse times in the dense right part of this plot is due to long 120-second TESS exposure times and short binary period. Panels D, E and F show O-C diagrams with significant changes on long and short scales.

In our study, we included 10 896 TESS eclipse times from 2019 till June 2024, 1 825 ground-based eclipse times and 4 083 data from the literature. The **TESS observations** significantly improved the time coverage of studied O-C variations. The continuous satellite observations can reveal a short-term variation of the O-C values. However, a 120-second resolution of photometric points is insufficient for some of our eclipsing binaries, e.g. white dwarf eclipses. The ground-based observations covered only the eclipsing part of the LC, mainly the primary eclipses in phases 0.9-1.1 with better data sampling. In contrast, the TESS data also revealed variations of LCs due to spots and flares. Most of the studied eclipsing binaries showed an O-C variation only on a long-time scale prolonging the project duration to 14 years.

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