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ZTFJ201538.86+362025.6: A candidate binary with strong reflection effect

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Abstract: ZTFJ201538.86+362025.6 is a probable short-period eclipsing binary system exhibiting a pronounced reflection effect. The associated ephemeris for this system is Min I = 2458280.9035(5) + E* 0.1714952(30).

Introduction

In certain close binary star systems, particularly those characterized by significant temperature disparities between their constituent stars, a phenomenon known as the "reflection effect" becomes manifest. This effect occurs when the intense radiation from the hotter primary star impinges upon and is subsequently re-emitted by the cooler secondary star. On occasions, the presence of eclipses can be discerned as a consequence of this interaction. However, when eclipses are not apparent, the reflection effect gives rise to nearly sinusoidal light patterns that align with the orbital dynamics of the stars. The peak brightness occurs when the hotter star passes in front of its cooler counterpart. In the General Catalogue of Variable Stars, these stars are categorized as type "R" due to their pronounced reflection-induced variations [1], [2]. Typically, these stars exhibit variations in brightness within the range of 0.5 to 1.0 magnitudes, are relatively scarce, and have not been extensively researched. As of November 2023, the AAVSO's International Variable Star Index has listed only 164 such stars, with a mere 11 displaying an amplitude exceeding 1.0 magnitude in any optical passband [3].

Binary systems with substantial reflection effects generally possess orbital periods of less than half a day. The light curves of R-type variables are generally sinusoidal in nature, albeit with intricate features. The complexity of these light curves arises from several factors, including the re-emission of light from the primary star, the heating of the secondary star's irradiated surface, and the redistribution of heat across the cooler star's surface, all of which influence the observed light curve patterns. Consequently, the study of the reflection effect also yields insights into the characteristics of the stars' outer layers.

Observations and Data Analysis

The Zwicky Transient Facility (ZTF) at Palomar Observatory, which has been operational since 2017, has succeeded the Palomar Transient Factory and is tasked with surveying the northern sky. It employs a camera equipped with e2v CCD231-C6 devices mounted on the 48-inch Samuel Oschin Schmidt Telescope, enabling the collection of high-quality data in the g and r passbands. These data are made publicly available [4], [5], [6]. The ZTF's data, which are particularly suitable for the study of variable stars, have led to the creation of a catalog encompassing 781,602 periodic variables and a suspected variables catalog, which comprises 1,381,527 objects [7]. The catalog of suspected variables lists ZTFJ201538.86+362025.6 as a suspected variable star, but does not specify its type of variability, noting only a period of 0.17149 days.

We identified ZTFJ201538.86+362025.6 as a likely R-type variable during a systematic examination of short-period variables in the ZTF suspected variables catalog. The object is listed as Gaia DR3 2060450946113876480 (20 15 38.868 +36 20 25.668, J2000, Gmag = 19.278, BP-RPmag = 0.908564) in Gaia DR3, Part 1 Main source [8].

Other Cross-IDs:

= URAT1-632430601

= GSC2.3 N335054447

= PS1 151603039119579147

For the present photometric analysis, we analysed the original ZTF frames[1] by using the Lomb-Scargle Generalized Lomb-Scargle (GLS) method, implemented in MuniWin[2][9].

ZTFJ201538.86+362025.6 appears as a faint bluish star in a Pan-STARRS Data Release 1 (DR1) color image (Fig. 1).

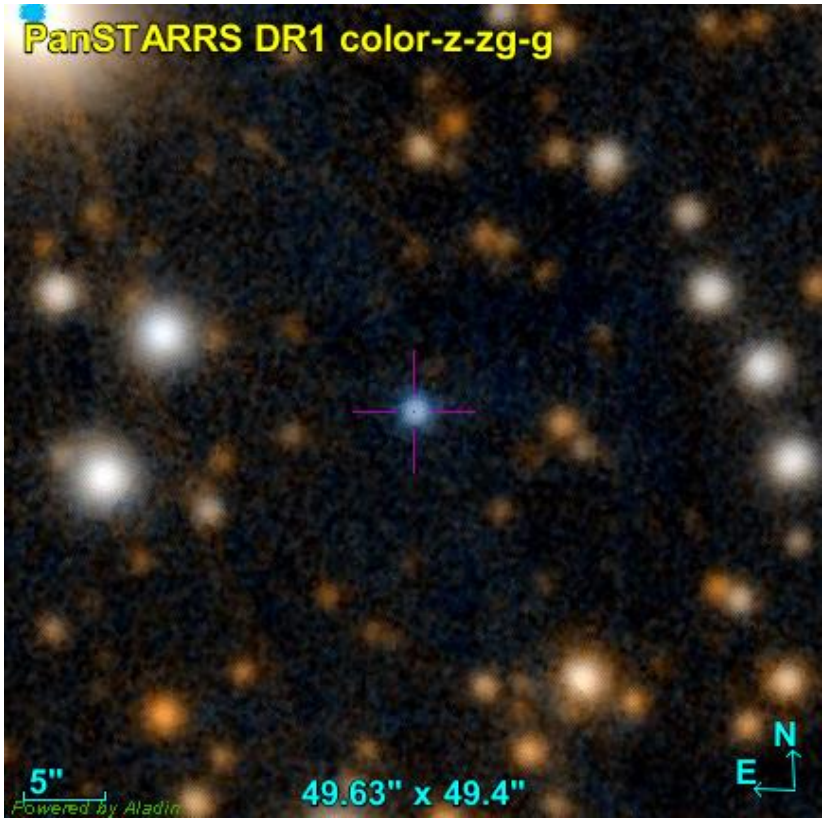

Fig. 1: Pan-STARRS DR1 colour frame of ZTFJ201538.86+362025.6 (Aladin, [11])

[1] Downloaded via IRSA https://irsa.ipac.caltech.edu/Missions/ztf.html
[2] Motl, David: MuniWin http://c-munipack.sourceforge.net

Results

Our elements derived from ZTF essentially confirm the very short period previously published in the catalog of suspected variables based on a shorter time span:

(1) **HJD Min I = 2458280.9035 (3) +E* 0.1714952 (30)**

We reduced the light curve using these elements, as shown in Fig. 2 and Fig. 3, and it exhibited the typical sinusoidal appearance expected for a high-amplitude eclipsing R-type star. Notably, the amplitude in the r passband (~1.5 mag) significantly exceeded that in the g passband (~1.0 mag). This finding aligns with other high-amplitude R-type binary stars, such as ZTFJ190048.52-105815.1, which we identified as a very likely candidate in 2020 [10].

Fig. 2 displays the phased ZTF light curve of ZTFJ201538.86+362025.6 in g, r and i filters, while Fig. 3 offers a detailed view of the phased ZTF light curve between phases 0.75 and 1.25.

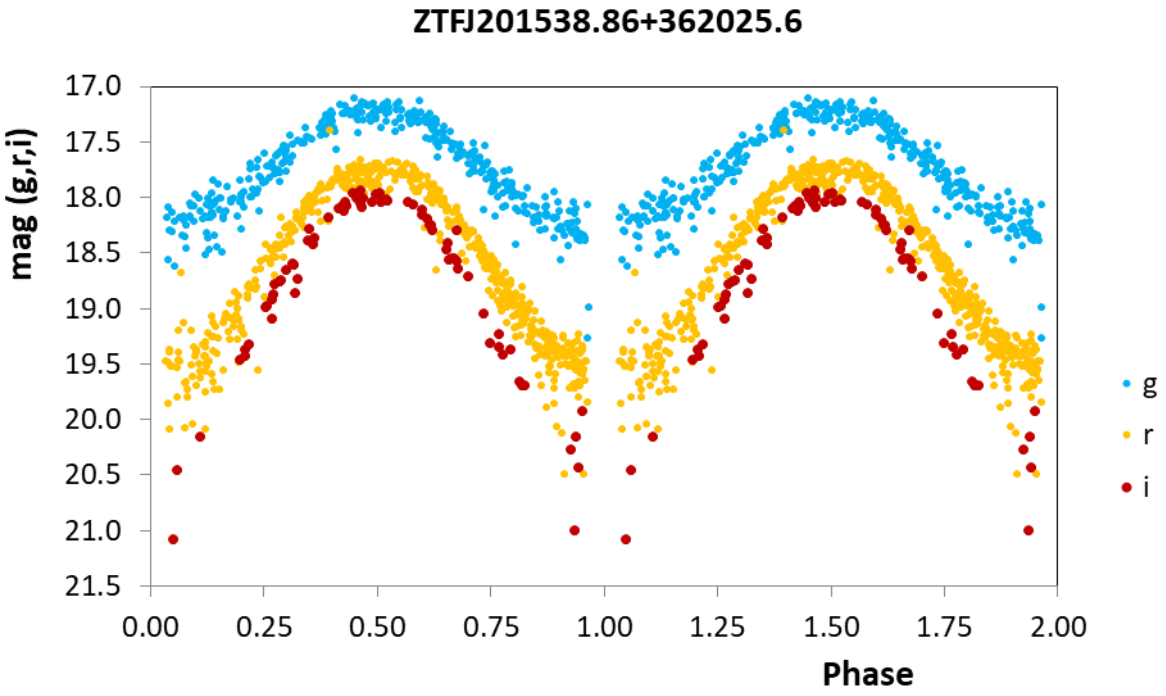

Fig. 2: Phased (g, r, i filter) ZTF light curve of ZTFJ201538.86+362025.6

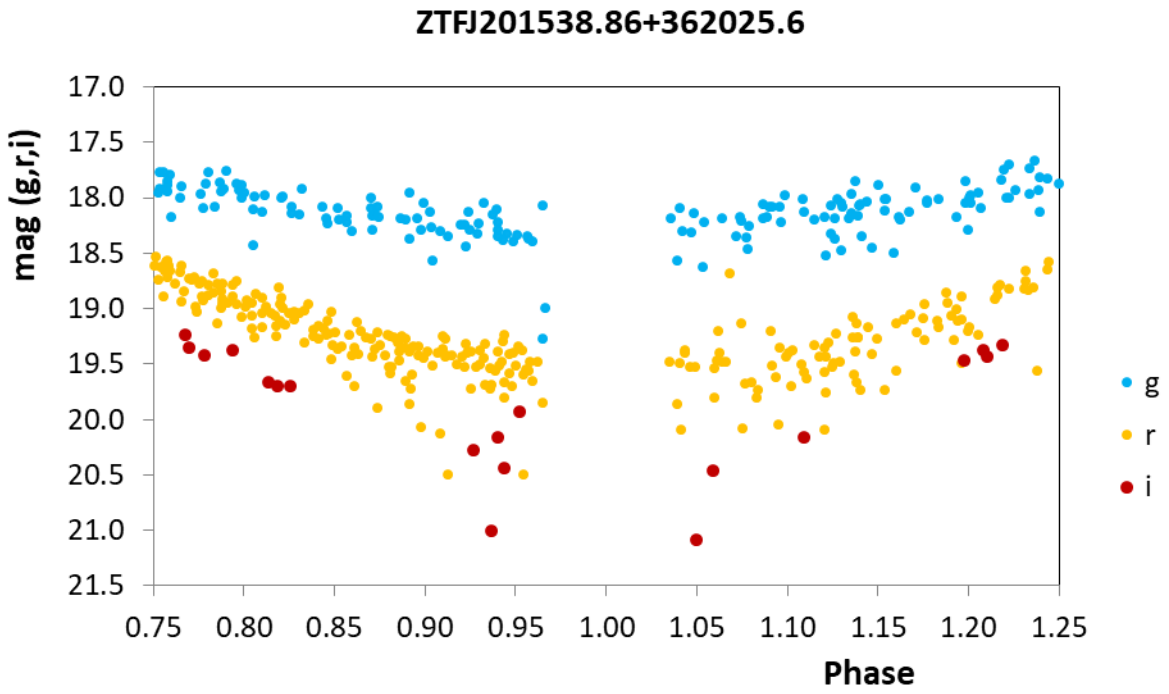

Fig. 3: Detailed view of the phased (g, r, i filter) ZTF light curve between phases 0.75 und 1.25.

ZTFJ201538.86+362025.6 exhibits similarities to ZTFJ190048.52-105815.1 in several aspects, including a similar period (P = 0.184712 days) and a noticeable gap in data around phase 1.0, despite ZTF's expected data recording. Additionally, several data points at phases ~0.95 and 1.05 are significantly fainter. We interpret the gaps around phase 1 for both stars as deep and nearly "vertical" eclipsing minima, which exceed the limiting magnitudes of approximately r ~ 20.6 mag and g ~20.8 mag [4].

Conclusion

This study presents ZTFJ201538.86+362025.6 as a candidate for a rare eclipsing high-amplitude reflection effect variable star. The light variations observed in this star are primarily driven by a strong reflection effect and probably deep primary minima with no trace of secondary minima at phase ~0.5. To definitively classify ZTFJ201538.86+362025.6, further investigations through photometric and spectroscopic studies are encouraged.

Acknowledgements

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