

QUASI-PERIODIC DIMMING OF THE ~ 130 MYR-OLD DEBRIS-DISK HOSTING STAR HD 240779 IS NOT PERSISTENT

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ABSTRACT

Quasi-periodic (1.5-day) dimming (by circumstellar dust) of the 135 Myr-old AB Doradus moving group member HD 240779 was detected in photometry by *TESS* in late 2018. Similar observations two years later show no such signal, and ground-based photometry indicate that the signal was absent in late 2019. This suggests that the source of the dust did not survive long after 2018, e.g. it was a disrupted planetesimal, or that dust production by the body is episodic, analogous to the “evaporating” planets detected by *Kepler*.

Keywords: exoplanet astronomy — exoplanet astronomy – young star clusters

Many young stellar objects are often highly variable due to rotation of starspots, flares, and time-varying accretion; among these are intermediate-mass UX Orionis-type variables that exhibit transient dimming of up to several magnitudes for intervals of weeks to months due to occultation by circumstellar dust (Herbst et al. 1994). Surveys by space telescopes (*CoRoT*, *Spitzer*, *Kepler*) showed that many low-mass T Tauri stars exhibit analogous variability on timescales of hours to days (Cody et al. 2014; Ansdell et al. 2016). These “dipper” stars typically have “full” or transition disks (Ansdell et al. 2016) and the dimming phenomenon has been explained in terms of occultation by an accretion stream from a highly inclined disk onto the central star (Bouvier et al. 2003; Bodman et al. 2017), or possibly by instabilities in the disk (Meheut et al. 2012; Miranda et al. 2016), or a dusty disk wind (Tambovtseva & Grinin 2008).

The *TESS* mission is surveying the entire sky and stars with more diverse ages, including members of young kinematic moving groups. Gaidos et al. (2019) identified HD 240779, a previously unknown member of the AB Doradus young moving group with a 1.5-day quasiperiodic dimming signal in a *TESS* photometry obtained with Camera 1 during Sector 5 (15 Nov to 11 Dec 2018, Fig. 1). What sets HD 240779 apart from nearly all other dipper stars is its age – the host moving group is ~ 130 Myr old (McCarthy & Wilhelm 2014) and perhaps co-eval with the Pleiades (Ortega et al. 2007) – and the absence of a T Tauri-like disk. Instead, the star hosts a debris disk with $L_{\text{IR}}/L_{\text{BOL}} \sim 10^{-4}$. *TESS* observed HD 240779 again two years later during Sector 32 (19 Nov - 16 Dec 2020), revealing that the dimming signal was absent (Fig. 1). A 4.3-day signal identified with stellar rotation (Gaidos et al. 2019) persists.

Contemporaneous Sloan $g'r'i'$ and Pan-STARRS Z -band photometry was obtained with the 0.4-m telescope network of the Las Cumbres Observatory Global Telescope. Integration times were 17, 10, 20, and 60 sec through the respective filters. LCOGT photometry was also obtained between 21 Oct and 23 Nov 2019, about one year after S5 and one year before S32. Images were reduced and source detection and aperture photometry were performed by the automated BANZAI pipeline (McCully et al. 2018). HD 240779 has a companion, BD+10 714B, only 5" away. The secondary star is not the source of the dipping signal (Gaidos et al. 2019) but the system is not cleanly resolved in 0.4-m images obtained under poor seeing, leading to systematics in photometry of HD 240779. Thus, aperture photometry on the combined system was independently obtained with a fixed circular aperture of 7", centered on the flux centroid. Relative photometry was performed by fitting a linear model as described in Gaidos et al. (2022). The known non-linear response in some 0.4-m detectors at low illumination levels (D. Harbeck, pers. comm.) was mitigated by restricting the comparison stars to those of similar brightness to HD 240779. Although photometry was obtained in

four pass-bands only the g' -band photometry ($\lambda_{\text{eff}} = 4672\text{\AA}$) is shown in Figure 1 because this is most sensitive to extinction by dust relative to the *TESS* bandpass ($\lambda_{\text{eff}} = 7456\text{\AA}$) and this lightcurve has the smallest variation of the four: the outlier-resistant mean absolute deviation is 0.018 and 0.021 mags during 2018 and 2019, respectively. There is no evidence of dimming events in the 2019 LCOGT lightcurve (Fig. 1). The “duty cycle” for dimming in the *TESS* 2018 lightcurve is about 15%. Assuming Poisson statistics for uncorrelated observations, the probability that none of the 83 LCOGT observations in 2019 occurred within a dimming event is 4×10^{-6} . Thus the LCOGT data point to the absence of the dimming signal one year after the *TESS* detection.

Gaidos et al. (2019) proposed that the dust periodically occulting HD 240779 derived from an evaporating planetesimal on a 1.5-day orbit where the equilibrium temperature approaches the silicate vaporization point, $\sim 1500\text{K}$. For energy-limited dust production sufficient to explain the observed occultation depth an object several hundred km across was required, depending on grain size. The disappearance of the signal within a year or two after it was observed would seem to exclude this explanation. The signal and its demise could be explained by the catastrophic disruption of a comet-like object due to thermal or tidal stress. However it is not clear how such an object would arrive on a 1.5-day orbit from a much more distant orbit intact.

Alternatively, the transient nature of the dimming signal could be because dust production is episodic, analogous to the behavior of the “evaporating” planets detected by *Kepler* (Rappaport et al. 2012, 2014) and *K2* (Sanchis-Ojeda et al. 2015). Another possibility is volcanic activity on the body where gas-driven ejection of tephra occurs at speeds exceeding the escape velocity of the body. Explosive volcanism has been invoked to explain the loss of partial melts and sulfur from the parent bodies of certain asteroids (Wilson et al. 2010). Heating by any primordial ^{26}Al ($t_{1/2} = 0.75$ Myr) has vanished by 130 Myr but magnetic induction (Bromley & Kenyon 2019; Kislyakova & Noack 2020), or, at least transiently, tides could be important. This scenario makes the prediction that dimming will re-appear at some point in the future. It also raises the exciting possibility that observations of such events could probe the composition and petrology of distant worlds in the (un)-making.

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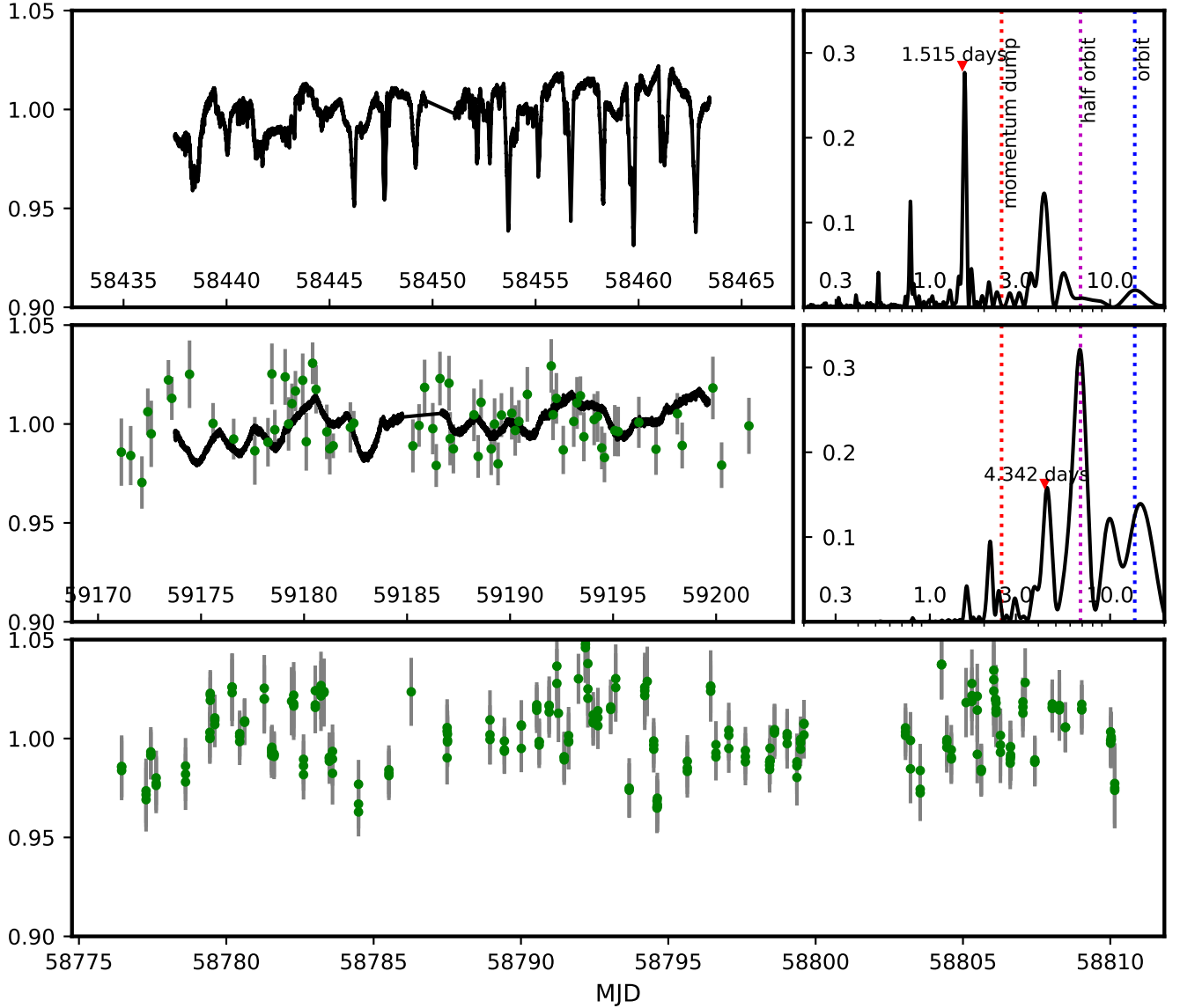


Figure 1. Normalized lightcurves of HD 240779 showing changes in variability over two years. Top left: Pre-search Data Conditioned Simple Aperture Photometry lightcurve from *TESS* Sector 5 observations in late 2018 containing a quasi-periodic occultation (dipping) signal. The Lomb-Scargle periodogram of the lightcurve (top right) contains the 1.5-day dipping signal and a 4.3-day likely to be the rotational variability of the star (Gaidos et al. 2019). The vertical dashed lines mark the periods of typical artifacts in *TESS* data. Middle left and right: same as top, but for *TESS* Sector 32 observations in late 2020. The dimming signal has largely disappeared but the rotational variability is unchanged. The green points are contemporaneous Sloan g' -band photometry obtained with the LCOGT 0.4-m telescope network. Bottom panels: LCOGT g' -band photometry obtained in late 2019 showing no evidence of dimming events.

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