TESS Observations of Spots and Flares in Active Binary Systems

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Introduction

Active binary stars are cool stars characterized by strong chromospheric, transition region, and coronal radiation. Activity is typically seen in the optical as excess emission in Ca II H+K line cores as well as in the Balmer lines; the active lines are sometimes rotationally modulated, and in the most active cases, emission can extend above the continuum (Zhang & Gu 2008). As in the Sun, a dynamo mechanism converts the energy of rotation and convection into magnetic energy, which powers the various forms of activity visible. However, in active binaries tidal interactions between the components mean that the stellar rotation rates are much faster than in solar-like field stars, and activity levels consequently much higher (Rodono 1992). For example, spot coverage can be two orders of magnitude higher than the 0.2% seen on the Sun (Solanki & Unruh 2004). Photometrically, the stars are variable primarily due to the presence of starspots. Spots trace the surface magnetic flux, and spot observations yield insights into rotation rates, differential rotation, and activity cycles, along with activity levels, flux emergence, and spot morphology. In addition, active binary stars display flares which are larger and more frequent (Buzasi, Ramsey, & Huenemoerder 1987, Linsky 2017) than those seen in single field stars. While solar white-light flares are rare (Kretzschmar 2011), active stars commonly show such flares, though rates are not yet well-established (Gao et al. 2016). The higher activity levels seen in these active binaries make these stars a natural laboratory for the study of magnetic activity.

We focus our TESS investigation on two primary types of active binary stars, RS CVn and BY Dra systems. BY Dra systems are late-type (K/M) main sequence binary stars, which are generally tidally locked and which have periods of 2 – 10 d. RS CVn stars are similar, but of earlier spectral type (G/K), with at least one component evolved off the main sequence. "Classical" RS Cvn systems have orbital periods of 14 days or less, though there are also longer-period systems. Both systems are widely enough separated that interactions between the components are minimized and do not generally dominate the activity seen.

Regular photometric monitoring (and somewhat less regular spectroscopic monitoring) of active binary stars has been carried out for decades (Berdyugina 2005), but typically occurs on a star-by-star basis, because high-precision ground-based monitoring of large numbers of targets simultaneously is complicated by issues of field of view, systematic errors, weather, time allocation, etc. TESS offers us the opportunity to begin to remedy this situation. Our two-minute cadence target list includes systems for which we have an expectation of them being observed for at least three times the longest of the known periods. All have $5 < \text{Tmag} < 10$, and our Cycle 1 target list contains 38 RS CVn systems and 12 BY Dra, of which 8 are eclipsing systems.

Here we present an initial look at representative members of our sample, focusing on spot evolution, eclipses, and flares.

Rotation

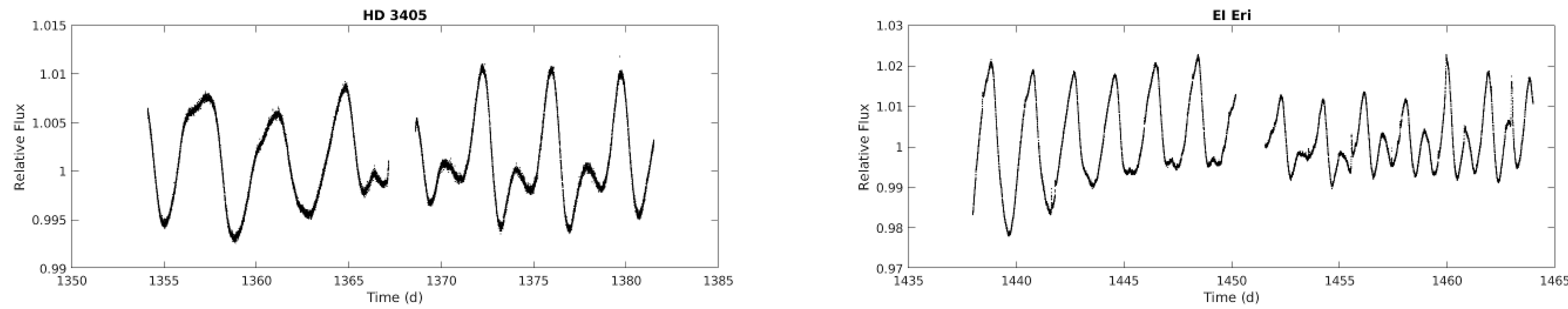

Fig. 1: The left panel shows the RS CVn system HD 3405 (P_{orb} = 3.74 d), while the right shows the RS CVn system EI Eri (P_{orb} = 1.947 d). Spot evolution is apparent in the light curves of both stars, while a flare is also visible in the EI Eri light curve near day 1463.

Eclipsing Systems

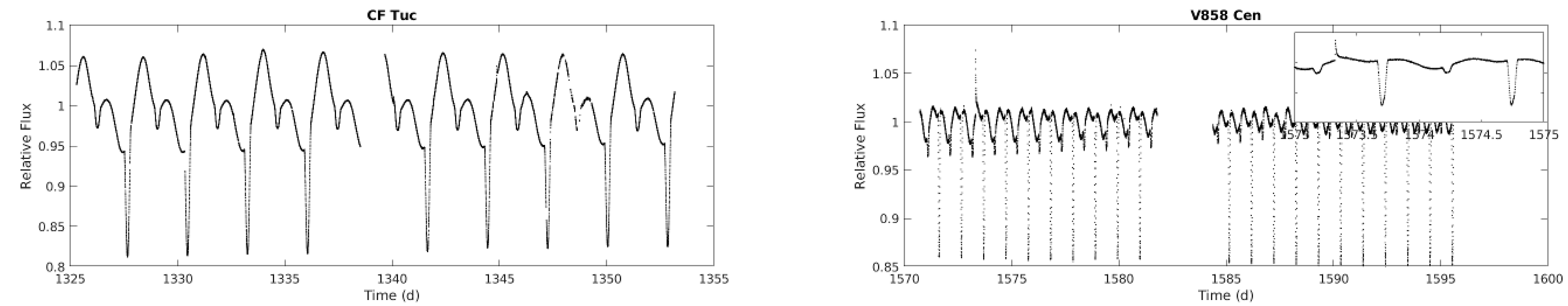

Fig. 2: The RS CVn binaries CF Tuc (left; P_{orb} = 2.798 d) and V858 Cen (right; P_{orb} = 1.044 d). Complex patterns of spots and eclipses dominate both light curves, while V858 Cen also shows a small flare (inset right).

Flares

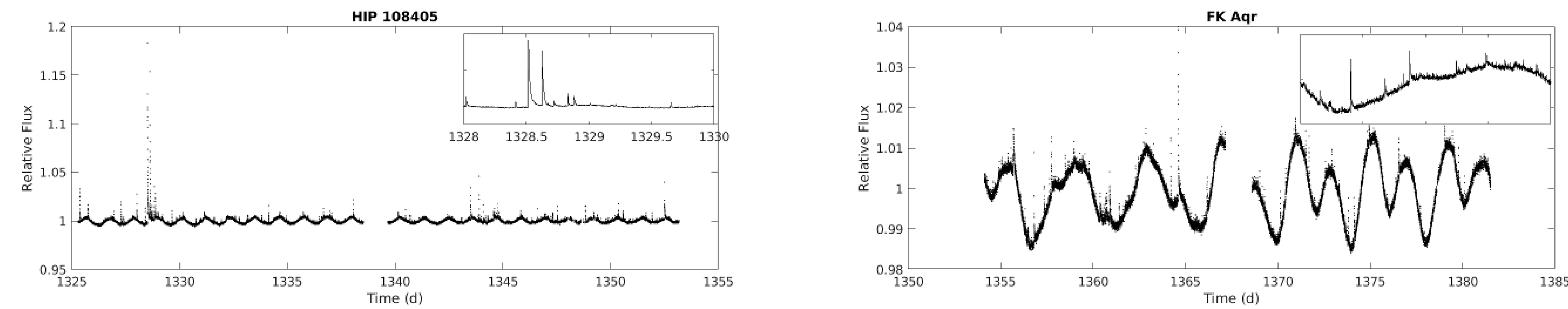

Fig. 3: Two BY Dra systems showing numerous flares. On the left is HIP 108405 (P_{orb} = 1.123 d) and on the right is FK Aqr (P_{orb} = 4.08 d). The inset panels zoom in on representative flares, which in the case of HIP 108405 reach as much as 20% over the continuum level.

References

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