The search for exocomets in photometry using *CHEOPS*
No detection around 5 Vul

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ABSTRACT

The interest in minor bodies has grown significantly in the past decade, thanks to the growth of the exoplanetary field and their relevance in planetary system formation and architecture. Particularly, the presence of exocomets has been detected in spectroscopy as variable absorption events in metallic lines (mainly Ca II K and Na D) in several A-type stars. While spectroscopy allows the detection of the gas component of cometary tails, it wasn't until the appearance of intensive exoplanet search photometric missions that the dust counterpart of these events was found, first with Kepler and then with TESS.
Still, there is only one star where exocomets have been detected simultaneously using the two different techniques: Beta-Pic. In an attempt to enlarge this number, we proposed observations of the bright exocomet-host star, ***5 Vulpeculae***, with ***CHEOPS*** for a time span of almost 2 full days. We present here the negative results of the observations, and what have we learned from the experiment.

CONTEXT

Exocomets

Minor bodies have been indirectly detected over the past 40 years in the form of infrared light emitted by the dust grains in the asteroid and Kuiper belt analogues of exoplanetary systems, i.e. ***debris disks***. When observing the spectra of the debris disk host star Beta Pic, Ferlet et al. (1987) found variations in the Ca II K line (3933 AA), that they attributed to *Falling Evaporating Bodies* or *FEBs*. To this day, we have observed similar variations in the Ca II K and other metallic lines approx. 30 A-type stars (Rebollido et al. 2020, Strøm et al. 2020). We attribute this events to the evaporation of icy bodies, i.e. ***exocomets***.
Lecavelier Des Etangs et al. (1999) predicted that exocomets could be detected as well in photometric lightcurves due to their dusty counterpart, but it wasn't until the extensive exoplanet survey instruments, such as Kepler, that the first exocomets were found in photometry (Rappaport et al. 2018, Zieba et al. 2019, see Fig. 1).

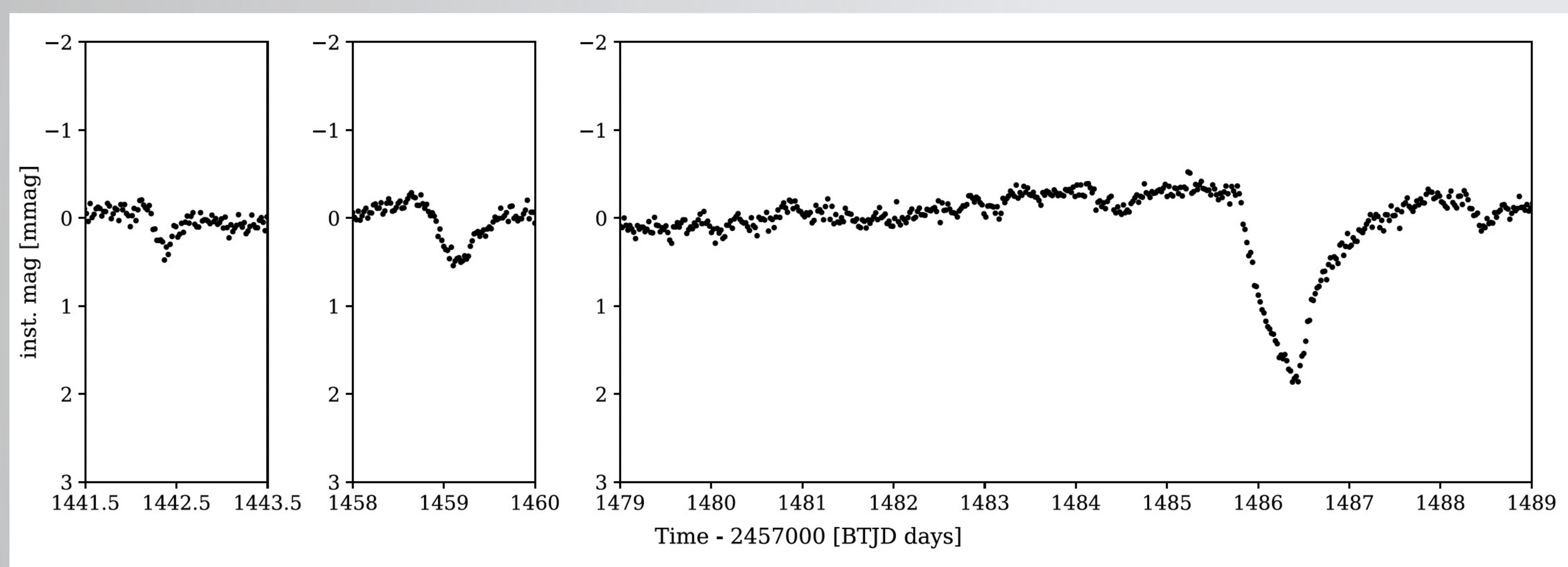

Fig. 1. Exocomets observed in the TESS lightcurve of the Beta Pic star. Zieba et al., 2019

The exocomets of 5 Vul in the literature

Exocometary-like absorptions have been detected in multiple occasions when investigating the spectra of the A-type star 5 Vulpeculae (HD 182919).
The first time was in Montgomery & Welsh, 2012 and later in Rebollido et al. 2020.
Montgomery & Welsh, 2012 reported one clear exocometary event in 4 different spectra, giving a detection rate of ~25%, as well as variations in the intensity of a stable component, that would correspond to stable gas in the inner region of the system. Rebollido et al. 2020 collected 39 spectra along 2 years, and 20 different days (Fig. 2). There are variations in the stable component in 3 different days, similar to the variations reported in M&W12, and there is one exocometary-like absorption at 25 km/s in one of the days. The frequency of exocometary events is much lower than for other stars, like Beta Pic, but still gives 4 detections in 20 days, i.e. 1 detection every 5 days.

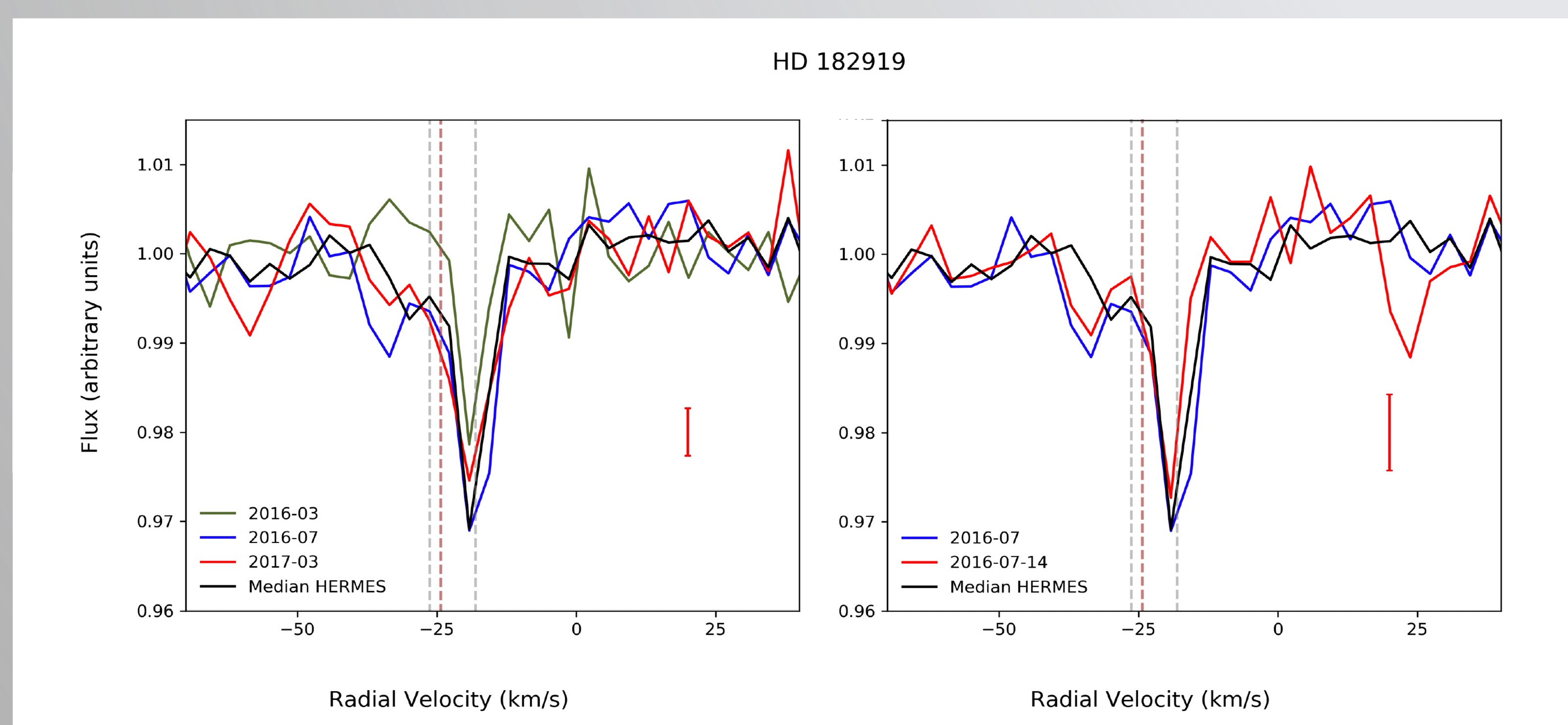

Fig. 2. Exocomet-like variability observed in 5 Vul (HD 182919) in different observing campaigns. The plot shows the bottom of the Ca II K line, where the photospheric line had been subtracted. Rebollido et al. 2020.

OBSERVATIONS

Target selection

By the AO-1 CHEOPS deadline, around ~26 stars had been reported to have exocometary variability in their spectra. Out of those, only Beta Pictoris had exocomets reported both in spectroscopy and photometry.
The target selection was based both in the CHEOPS capabilities, including brightness and visibility of the potential targets; and the TESS observing plan, in order to maximize the number of exocomet host stars that would be observed. 5 Vul was not initially planned to be in the FOV of TESS, and had exocomets reported in two different works, with a 20-25% chance of exocomet detection in spectroscopy. It's high brightness (V magnitude of 5.6) allowed for a high SNR, and thus seemed like a perfect candidate.

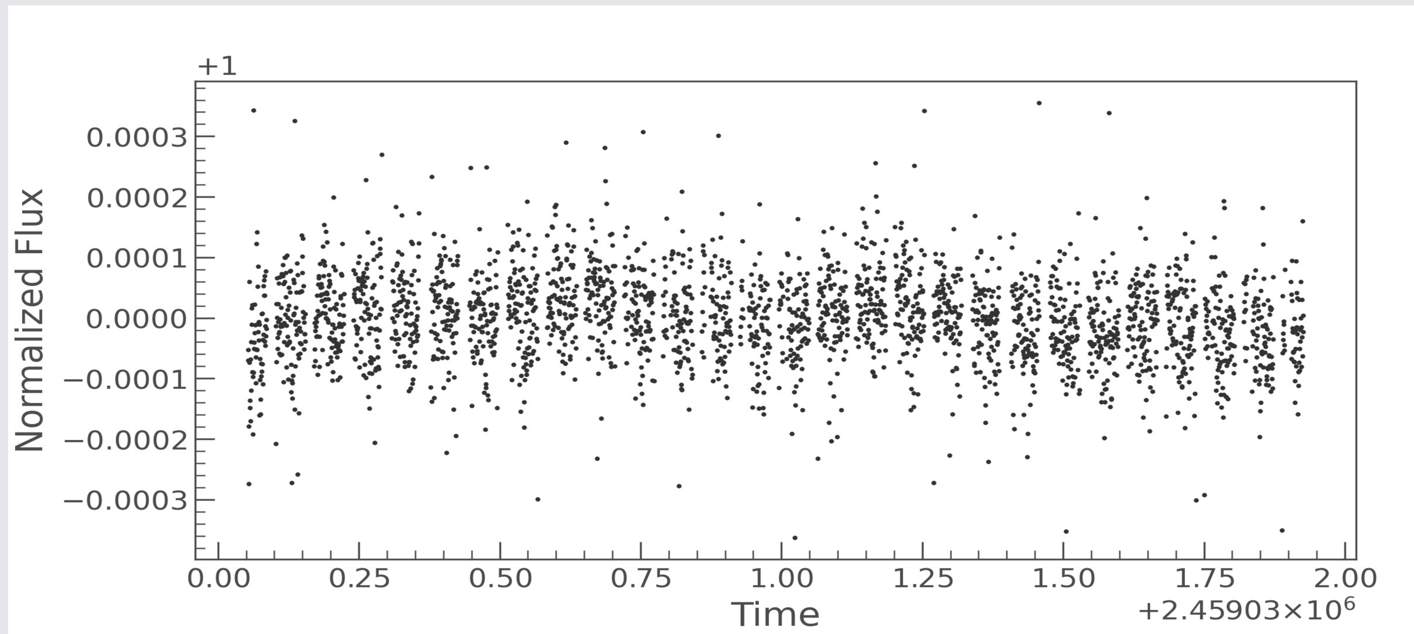

Fig. 3. CHEOPS lightcurve of 5 Vul though the full observing period (~45h).

Observations with CHEOPS and TESS

The target star was finally observed with both missions, covering a total time span of almost 30 days.
The differences in the optics and instruments led to significant variations in the rms for both lightcurves:

- CHEOPS: 46 ppm (Fig. 3)
- TESS: 195 ppm (Fig. 4)

The observations were not consecutive, and unfortunately we didn't detect any exocomet-like transits or remarkable features in any of them.

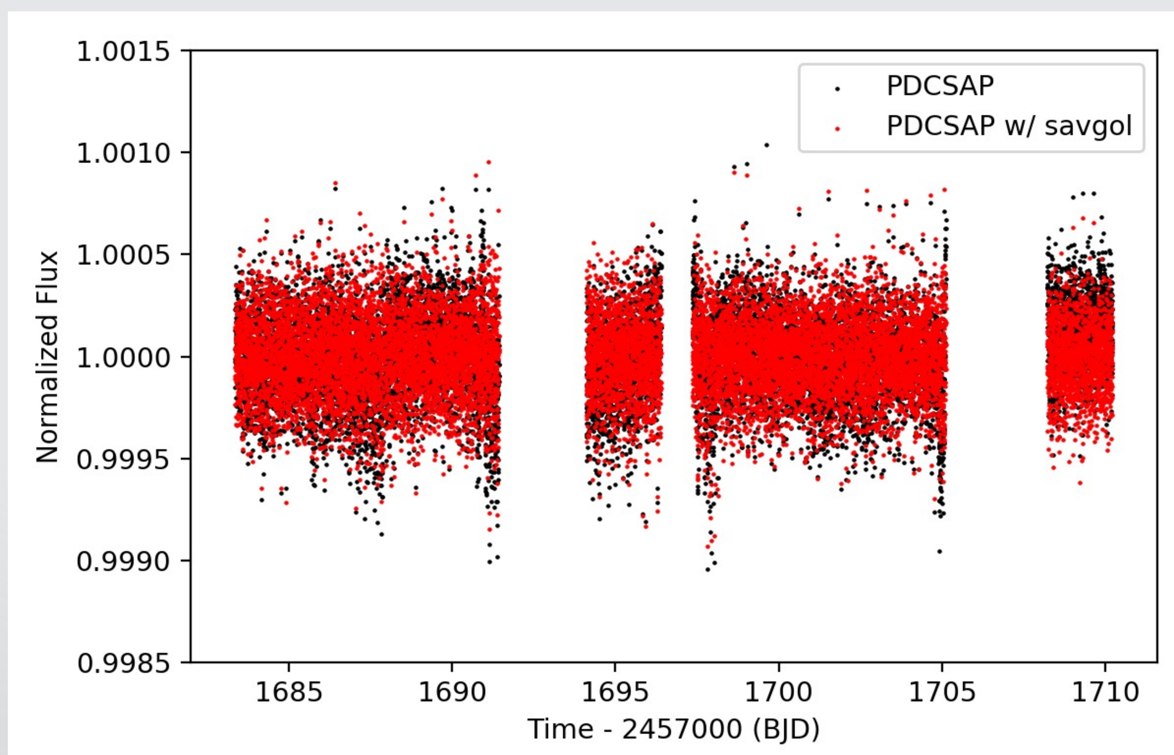

Fig. 4. TESS lightcurve of 5 Vul. Due to the design of the TESS mission, the time coverage is considerably larger (> 25 days).

RESULTS

We didn't detect any evidence of exocomet-like transits in neither of the available datasets (CHEOPS &TESS).
However, we detect in the periodogram a small peak at 2 days frequency, that could be due to stellar pulsation (Fig. 5). Despite it could be possible to observe stellar pulsations with such frequencies given the spectral type of 5 Vul, the periodic signal is not observed in TESS data, and it could arise due to uncharacterized systematics.

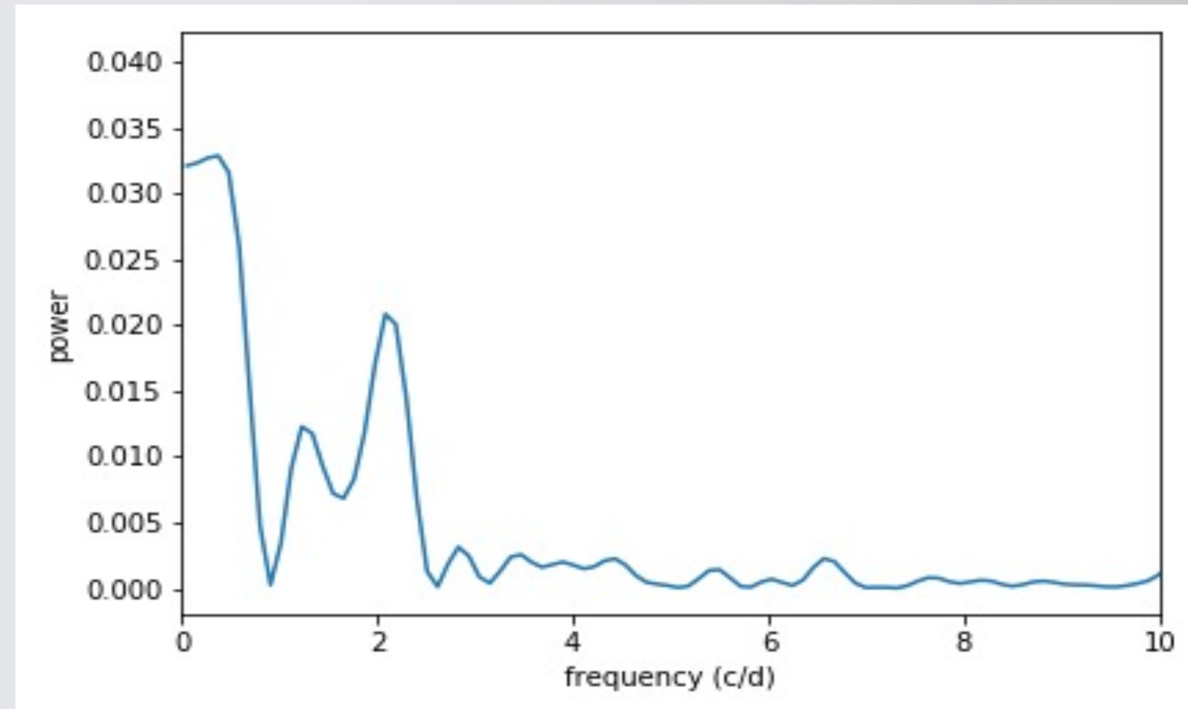

Fig. 5. Periodogram of CHEOPS data. The peak at 2 days is most likely caused by systematics, as it is not observed in the TESS data, but further investigation is required

Following Boyajian et al. 2016 and Iglesias et al. 2018, we estimated the limits of detection of exocometary bodies for both instruments (Fig. 6).
With the given constrains on the rms of each of the lightcurves, we can confirm that no large bodies transited at short distances during our observations.

The question remains whether the exocomets we detect in spectroscopy, can actually be detected in a lightcurve.

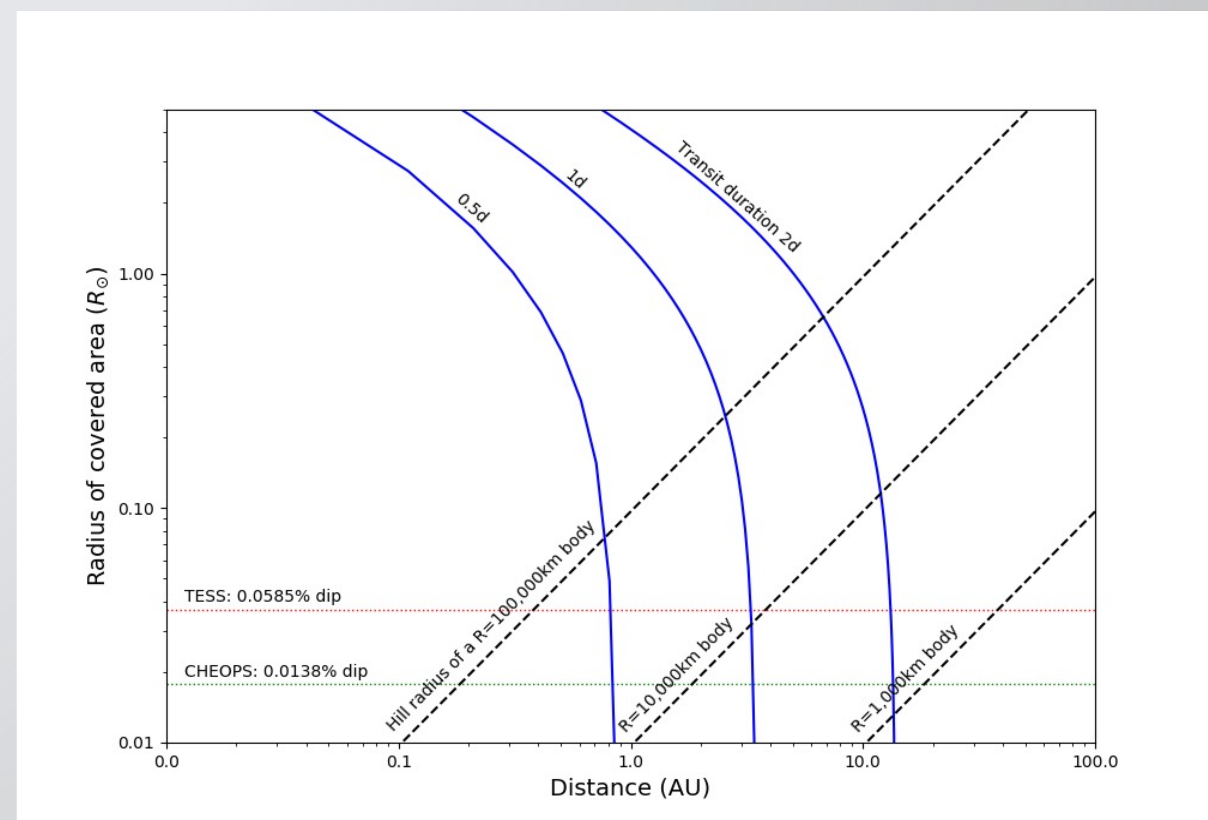

Fig. 6. Detecion limits for cometary radius plotted as a function of Distance and Covered area of the star. Horizontal dotted lines mark the detection limits for both TESS (red) and CHEOPS (green) as 3σ of the rms. Blue lines mark the orbits for 3 possible cases (0.5,1 and 2 days). Dashed lines represent the radius where material is still attached to the comet.