TESS DATA AND GROUND-BASED OBSERVATIONS. J. M. Terpstra[1,3], B. H. Foing[2,3,5,6,7], A. M. Heras[2], V. Foing[4], Y. J. Rusticus[4,3], C. Hönes[4,3] and I. Schuring[1,3], [1]Amsterdam University College, [2]ESA ESTEC, [3]VU Amsterdam, [4]University of Amsterdam, [5]Leiden Observatory, [6]ILEWG EuroMoonMars, [7]IAS CNRS

Introduction: Since the Transiting Exoplanet Survey Satellite (TESS) [1] was launched in 2018, it has provided a great number of valuable data on stars and possible exoplanets, and it will continue to bring us much more. We can combine the information we get from TESS's data with information from telescope observations, to understand the observed object better as a whole. In this research, we have started from TESS observations of the stars WASP-140 [2,5] and AU Mic, observed them with telescopes from the Faulkes Telescope Network [4], and combined the knowledge gained from them both.

Differences between space-based and ground-based observations: Satellite observatories like TESS are unobstructed by the earth's clouds and atmosphere, allowing them to make less noisy observations, and to observe 24 hours a day. However, because TESS observes large sectors of the sky at once, and only samples once every 2 minutes, the data on each star is not as detailed as data coming from ground-based observatories. Telescopes on earth can sample more often, resulting in a more detailed view of the star system's activity. This can be helpful for analyzing planet transits. Furthermore, all of TESS's observations are done in the clear filter, while ground-based observations can be done in different types of color filters. This allows us to gather different and novel information about the star, that TESS can't observe.

WASP-140: WASP-140 b is a hot Jupiter orbiting the star WASP-140 (a K0 dwarf cooler than the Sun, with effective temperature 5260 K, and radius 0.87 Rsun, with age 0.7-3 Gyr [3]), in an orbital period of around 2.2 days. It was discovered in 2016 by a network of ground-based telescopes united through the "Wide Angle Search for Planets" (WASP).

TESS observations. WASP-140 was observed by TESS in 2018, for around 54 days during several sectors. The result of this observation can be seen in figure 1.

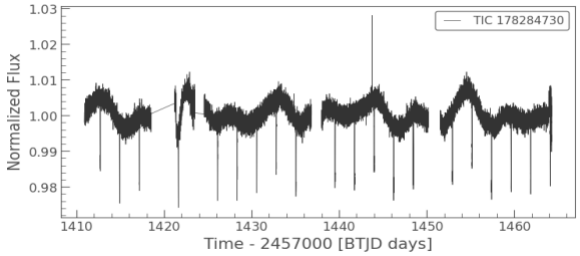

Fig 1: WASP-140 as observed by TESS.

The transits can clearly be seen in these data, and the orbital period of 2.2 days is readily extracted. More complicated is the remaining shape of the lightcurve, which shows a strong variation even outside transits. For the K0 V star , we see the effect of the rotational modulation, where magnetic sunspots rotating in and out of view cause large differences in perceived brightness. The rotation period is estimated to be around 10.4 days (consistent with [5]) This estimate can be confirmed by folding the lightcurve to this period, which indeed shows the pattern that repeats itself in the data (fig 2).

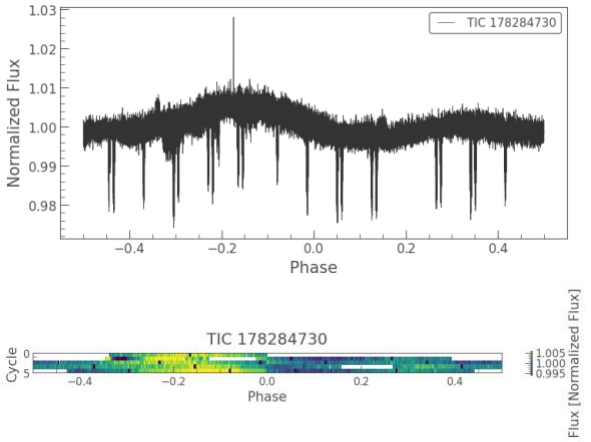

Fig 2: the folded lightcurve for WASP-140

Ground-based observations. In November 2020, we observed WASP-140 using the Faulkes project, using a 40 cm telescope at Siding Spring Observatory in Australia. It was observed during a transit of the planet WASP-140b. Since WASP-140 is a K-type star, which peaks in the red part of the spectrum, the observation was done using a red filter. The results are visible in figure 3, where it is shown unbinned and in bin sizes 2 and 3. The transit is clearly visible, and becomes even clearer when binned. We aim to further analyze this data to gain more information on WASP-140 and its planet, by comparing the apparent size of the planet in our data in the red band to information from other observations.

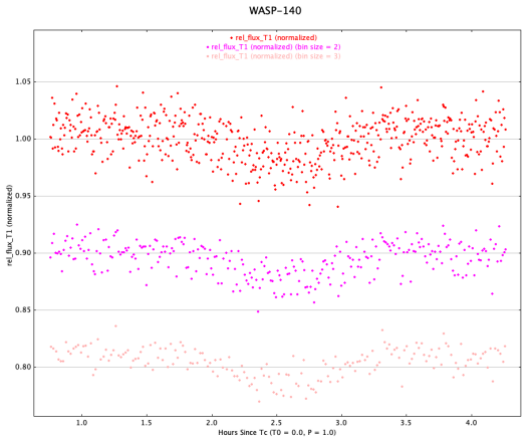

Fig 3: WASP-140 from a ground-based observatory.

AU Mic: AU Mic is a small but very active star, (M1Ve, R=0.75 R sun, T=3700 K) [3] known to have many stellar flares and sunspots. It has been confirmed to have at least one exoplanet.

TESS observations. TESS has made two observations of this star, of which one can be found in figure 4. Again, the rotation period of the star is clearly visible, as are the many stellar flares, visible as horizontal upward lines.

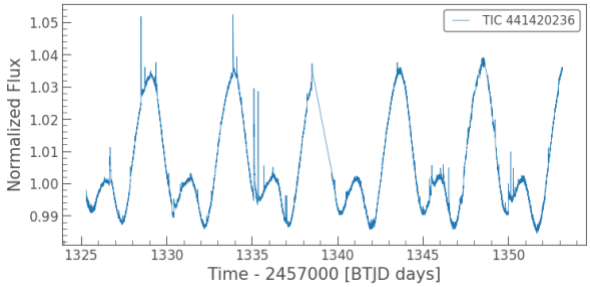

Figure 4: AU Mic as observed by TESS.

Ground-based observation. We observed this star using the Faulkes Telescope Network, and the observation was this time carried out by the Cerro Tololo observatory in Chile. It was done using a clear filter. Since it is only visible for a short time at the time of year in which we observed it, we only have data for around 18 minutes. The results are plotted in figure 5.

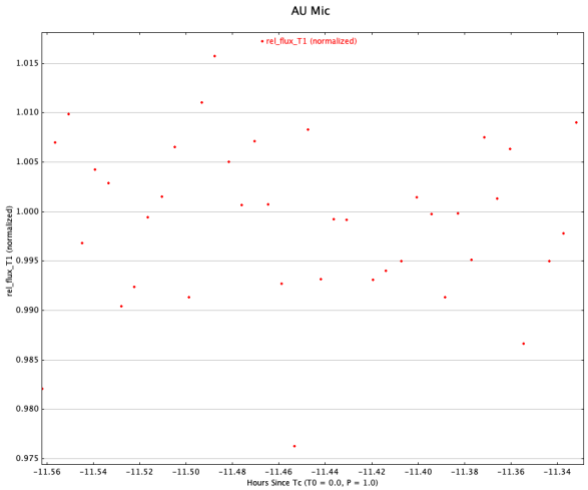

Fig 5: AU Mic from a ground-based observatory.

Conclusion: WASP-140 and AU Mic were observed with both the satellite TESS and ground based telescopes, giving us different types of data to work with, the comparison of which can lead to new conclusions. Further analysis of the WASP-140 data, and possible re-observation of AU Mic, could allow us to bring new information to the table. We could further restrict the estimated size of the planet WASP-140 b with our observation from the red light band, as opposed to TESS's clear one.

References:

[1] Ricker et al. (2014) *JATIS*, 1.1.014003
[2] D.L. Pollacco et al. (2006) *PASP* 118, 1407
[3] Schneider et al. (2011) *A&A* 532, A79
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