Abstract SF2A – atelier SF16

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Introduction: On December 25th 2021 the long-awaited James Webb Space Telescope (JWST) was successfully launched. Among a multitude of other extraordinary results, the JWST will give us the opportunity to use transit transmission/emission spectroscopy to attempt atmospheric characterization of small planets around ultra-cool dwarf stars (very low mass stars with spectral type later than M6).

In that respect, with more than 200 hours of guaranteed time granted (including GTO and GO programs), the TRAPPIST-1 system is one of the JWST's prime targets (Gillon et al. (2020)). It is composed of an M8-type dwarf star orbited by seven nearly Earth-sized, temperate planets, three of them being in its habitable zone (Gillon et al. (2017)). Considering their transiting nature, the infrared brightness and the Jupiter-like size of their host star, these planets are extremely promising candidates for the first thorough atmospheric characterization of temperate terrestrial worlds.

More generally, the TRAPPIST-1 system offers a unique laboratory for comparative planetology of terrestrial planets, and may provide insights and constraints on the formation and evolution of terrestrial planets around the lowest-mass stars. However, although it is gradually revealing itself, some big questions still remain, such as: why is the periodic modulation of the star seen in K2 but not in Spitzer light curves? What should we expect the photosphere of the host star to be like, and how significant would be the impact of stellar contamination resulting from its heterogeneity on the interpretation of planetary transmission spectra? How did the system form? Is it stable? Are there other planets?

Aims: To provide some answers to those questions and at the same time prepare the upcoming observations of the system with the JWST (expected in Dec 2022), we present the results from an extensive four-year long follow-up campaign led from the ground with the SPECULOOS and Liverpool Telescopes (respectively 1 and 2m class telescopes). This represents 285 nights of observations, 269 new transits of the seven planets, and includes 3 months of daily monitoring of the star to study its photometric variability.

First of all, to try to understand the origin of the existing inconsistency between K2 and Spitzer photometric variability, we derive the rotation period of the host star in the $I+z$ band and use it to propose a spot variability model that would agree with the observations in each band and at the same time provide insights on the nature (proportion and temperature) of the photospheric heterogeneities on the surface of TRAPPIST-1, in a similar way as in Morris et al. (2018). From those outcomes we discuss the expected impact of stellar contamination on the planetary spectra via the transit light source effect. In parallel, we present our statistics of spot-like and faculae-like crossing events on all observed transits and relate them to the photometric modulations.

In addition, we analyse 269 new transits in order to (1) refine the planets' parameters using individual and global analyses (per planet and all together) and (2) derive precise transit timing variations (TTVs) for the seven planets. We show that recent timings (most recent ones from Nov 2021) of planet h seem to slightly deviate from the predictions by Agol et al. (2021), implying either that planet h's timings have an excess of outliers or that a 7-planet model is no longer a good fit, which could suggest the existence of a putative eighth planet. To figure this out, we show the results of new optimization runs with 7-planet and 8-planet models and including periodic orbit (P-O) - families of solutions to the N-body problem - constraints. Indeed, near-resonant planetary system such as TRAPPIST-1 are expected to reside in the dynamical neighbourhood of stable P-O (Antoniadou et al. (2020)) and such a configuration can be used to yield better constraints on the orbital elements.

Finally, we look at TRAPPIST-1's flaring activity. On one hand, we compute flare occurrence rates and energies to compute flare frequency distribution and complement the work initiated by Ducrot et al. (2020) on placing the TRAPPIST-1 planets relative to the abiogenesis zone introduced by Rimer et al. (2018). On the other hand, we seek correlations between flaring events and periodic photometric variability to state whether the observation of Morris et al (2018) claiming that visible flares seem to occur preferentially when the star is bright, and when the brightness is increasing most rapidly, is confirmed or not.