Astromass proposal

Text for justification and yield for TESS follow-up

* Scientific Importance of transit follow up and ephemerides and synergy with JWST. (0.75 pages)

The Transiting Exoplanet Survey Satellite (TESS, Ricker et al. 2014) will launch in March 2018 with the goal of detecting planets transiting bright stars. The primary mission goal of TESS is the detection of more than 50 small planets orbiting stars that facilitate ground-based radial velocity measurements. With a measured radius and mass we can determine bulk-densities and begin to make composition estimates. The mission will observed near-all sky over it’s two year primary mission and observe each star for durations ranging 27–351 days, depending on sky position.

TESS will be a key contributor to NASA’s long term strategic goal of searching for life elsewhere in the Galaxy by providing a treasure-trove of targets for the upcoming James Webb Space Telescope (JWST). Through the use of transmission spectroscopy, the chemical abundance of atmospheres of planets as small as super-earths will be probed by JWST.

However, a key requirement of using JWST for transmission spectroscopy is precise knowledge of when future transit time will occur: even a small uncertainty will lead to massive wasted JSWT resources waiting for a transit to occur (JWST costs more than $100,000 an hour to operate). A transit-time uncertainty of more than 2 hours would make a planet a poor choice for JWST. With TESS observing windows as short a 27 days, many planets will only have two transits measured, rapidly leading to large uncertainties in orbital ephemerides. Figure 1 demonstrates how quickly we can lose our ability to precisely predict future transit times for planets where we see two transits. For a planet with an orbital period of 14-days (a typical planet detected by TESS) our uncertainty in transit time is becomes greater than 8-hours after just one year, and even for long period planets our uncertainty is many hours after only a few years. However, by observing just one or two more transits, the orbital ephemeris of a planet planet can be dramatically refined. For example for a typical TESS target, if we collect a single transit 2-years later we can typically predict future transit times beyond that to with a few minutes, even many years later.

Ground and space-based exoplanet transit detection projects have faced this problem previously and utilized NASA assets for solving the problem. For example, a large *Spitzer* program has been undertaken to ensure that planets detected by Kepler’s K2 Mission (with an observing baseline of 80-days) remain feasible by JWST (Beichman et al. 2016) and have already had success in recovering K2-18b whose ephemeris was more than 2 hours from that predicted from K2 transit observations (Benneke et al. 2017). Additionally, both Spitzer and K2 have been used to recover transits in the TRAPPIST-1 planetary system (Gillon et al. 2017, Luger et al 2017), which would otherwise have been lost. However, Spitzer have ceased operations when TESS is operating, and while a subset of these planets can be observed from the ground, the high precision required to detect small planets necessitates going to space. Therefore, another instrument is necessary to fill the void. This is where Astromass comes in.

Instrumental requirements (0.5 pages)

The aim of this project is recovery of TESS transits, therefore we need an instrument that is at least as sensitive as TESS, and actually more-so because we require detection with one transit whereas TESS saw two transits (i.e. we want to be √2 more sensitive).

The TESS optical design makes use of four 10.5 cm lenses, and will sport large pixels (16x16 arcsec), with typical targets being *I*=8–12. At this brightness the 1-hour noise level for TESS will be equal to or greater than Astromass for all magnitudes, even for stars as faint as 13th mag. Additionally, a higher signal-to-noise is required for detection that for recovery of a transit. While for TESS detection, a combined SNR of 10 over multiple will typically be required for a solid detection, recovery of a transit when we expect it to be within a fixed window is less stringent. A SNR of just 7 will be perfectly adequate for our purposes. Additionally, Astromass will be able to capture multiple transits in order to boost SNR.

With typical TESS transit durations lasting 15—30 minutes, if we follow-up targets within a year of the TESS obsessions, we will require about 10 hours per target on Astromass. This program requires specific observing windows to catch the transits, fortunately this operating procedure is very comparable with the astrometric program where observations can be flexiblly scheduled to fit within the around transits.

* Expected targets and yields (0.5 pages)

We simulated how many targets that TESS observes will be accessible to Astromass. We started with the Sullivan et al (2015) catalog of simulated TESS detections, estimated the observing window for each targets based on the sky position of the host star. Then we search only for those targets where we would observe two transits in TESS data. Then we estimated a the SNR of a single transit and only selected those with a Astromass SNR of greater than 7. In Figure 2 we show the size of the 189 planets that we expect to follow-up as a function of star brightness. There are 50 super-earth and earth-sized TESS planets with just two transits that we can follow-up, in addition to the $>$100 larger worlds. To observe all these will require approximately 2000 hours over two years, which is a total of 40 observing days per year over the two year Astromass mission.