DEVELOPMENT OF pETSI: PROTOTYPE EXOPLANET TRANSMISSION SPECTROSCOPY IMAGER

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ABSTRACT

The goal of this project was to build a device, called pETSI, which is a prototype of ETSI (Exoplanet Transmission Spectroscopy Imager). It is specifically designed to identify and directly measure atmospheres around a large number of exoplanets orbiting bright stars. Light from the telescope will enter pETSI and be collimated by a 200 mm focal length. The collimated beam will pass through a prism, which provides a precise amount of dispersion (high enough to separate the resulting multi-band images). After dispersion, the light passes through a multi-band filter and the filter will transmit a large number of well-defined bands onto a detector. From the resulting spectra, we will be able to observe hundreds of transits and use the presence of known atmospheric features to signify the presence of an exoplanet atmosphere. In future work, after prototyping and additional development ETSI will be used for a campaign to observe hundreds of targets from the Transiting Exoplanet Survey Satellite (TESS). ETSI will observe these identified targets using relatively small telescopes (1-2m-class), with the goal of determining which targets are most valuable for follow-up by larger and more precious resources such as James Webb Space Telescope (JWST) and large ground-based facilities.

INTRODUCTION

The study of exoplanet atmospheres is relatively new and exciting because it offers the chance to determine atmospheric composition, climate, potential habitability, and other insights in environments different from any found in our solar system. During an exoplanet transit, the exoplanet's atmosphere imprints an absorption spectrum of the stellar light and then the light that is transmitted to our detector will contain information about the atmospheric composition of the exoplanet [1], like Figure 1. TESS will produce a large amount of targets, so it will be crucial to examine the candidates on smaller telescopes, where observing time is plentiful, and determine which are the most valuable for follow-up on larger telescopes.

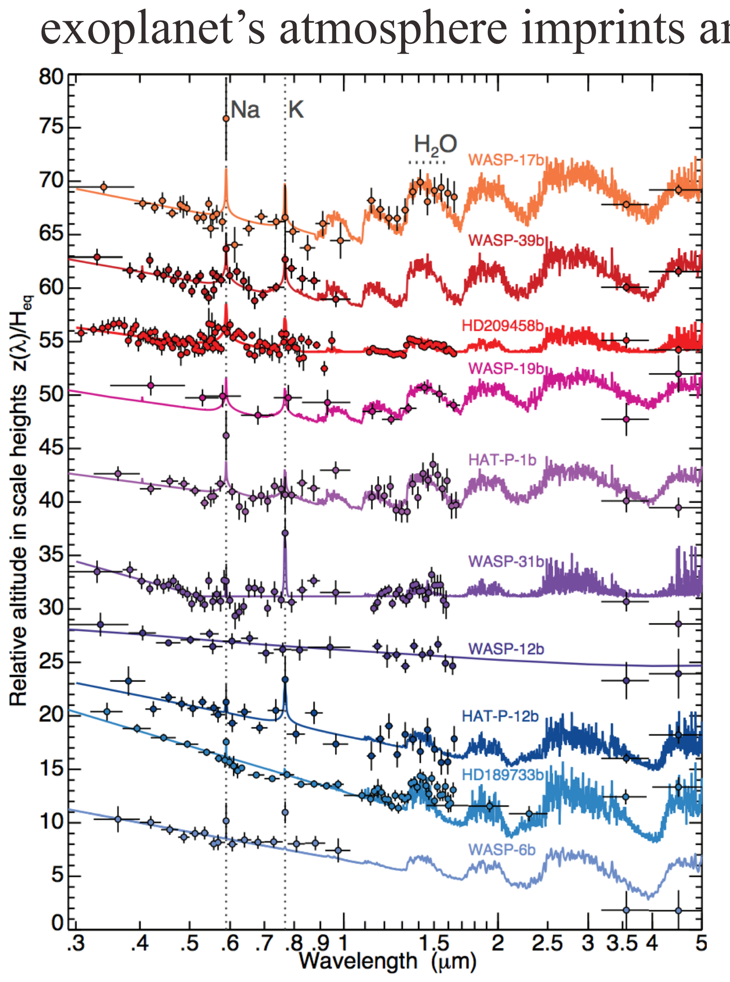

Figure 1. Examples of exoplanet atmospheric transmission spectra [2].

EXPERIMENTAL SETUP

To detect the signatures of exoplanet atmospheres during transits, pETSI obtains separate images of the host star and the comparison stars using a prism and a multiband filter to attain a low-resolution spectrum of the exoplanet host star during transits. pETSI is designed with the following parameters: 6' field of view, 400-1000 nm wavelength coverage, and resolution ($\lambda/\Delta\lambda$) ≈ 30. The large field of view will allow measurement of several bright reference stars simultaneously with the host star; these measurements will be used to remove the effects of the Earth's atmosphere. For ease of assembly, Nikon lenses were used for the prototype; custom optics will be used for the final ETSI instrument.

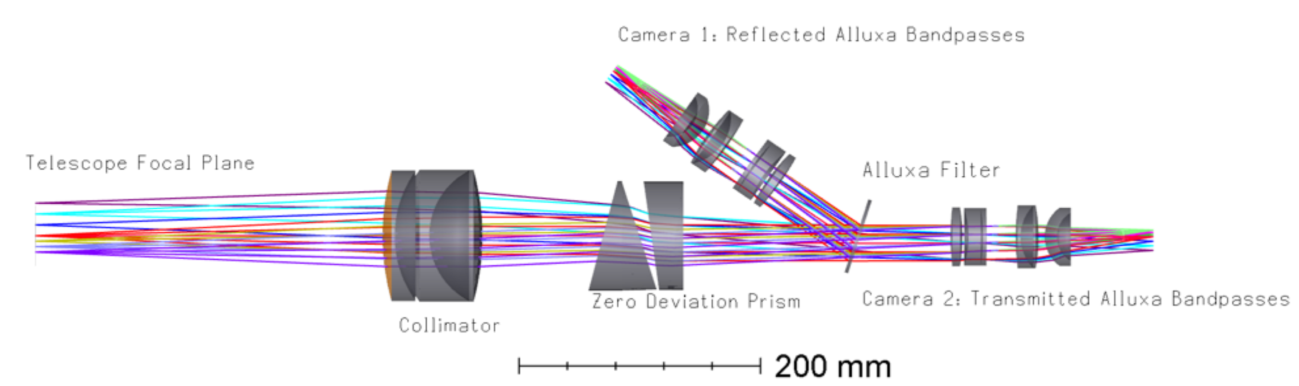

Figure 2. The conceptual design of ETSI. For pETSI only the transmitted bandpasses were used.

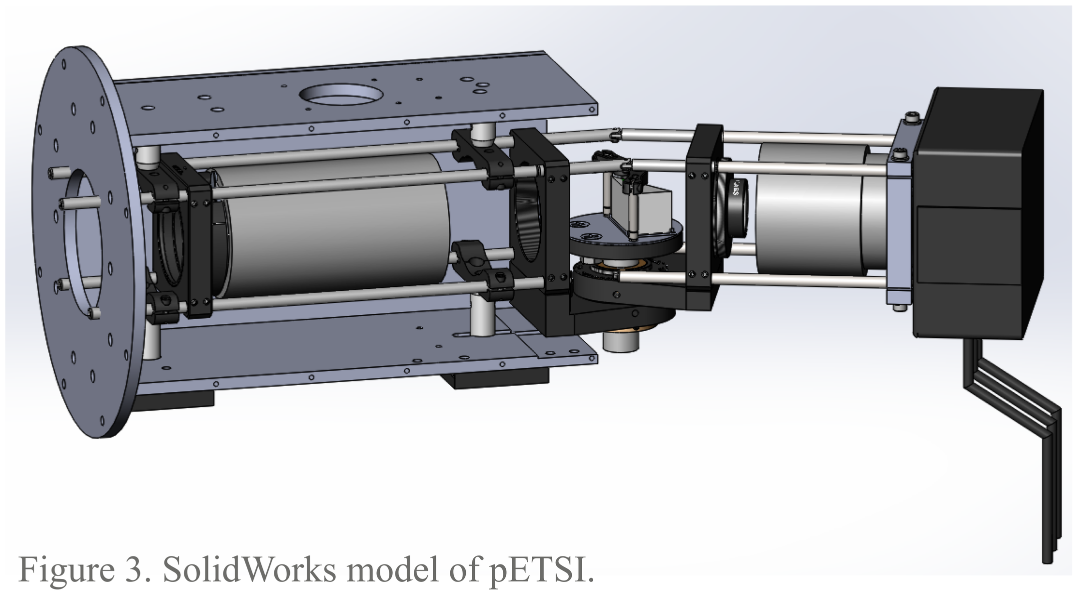

Figure 3. SolidWorks model of pETSI.

From the resulting spectra, we will be able to observe hundreds of transits and use the presence of known atmospheric features to signify the presence of an exoplanet atmosphere. Figure 3 and 4 show the final design of pETSI.

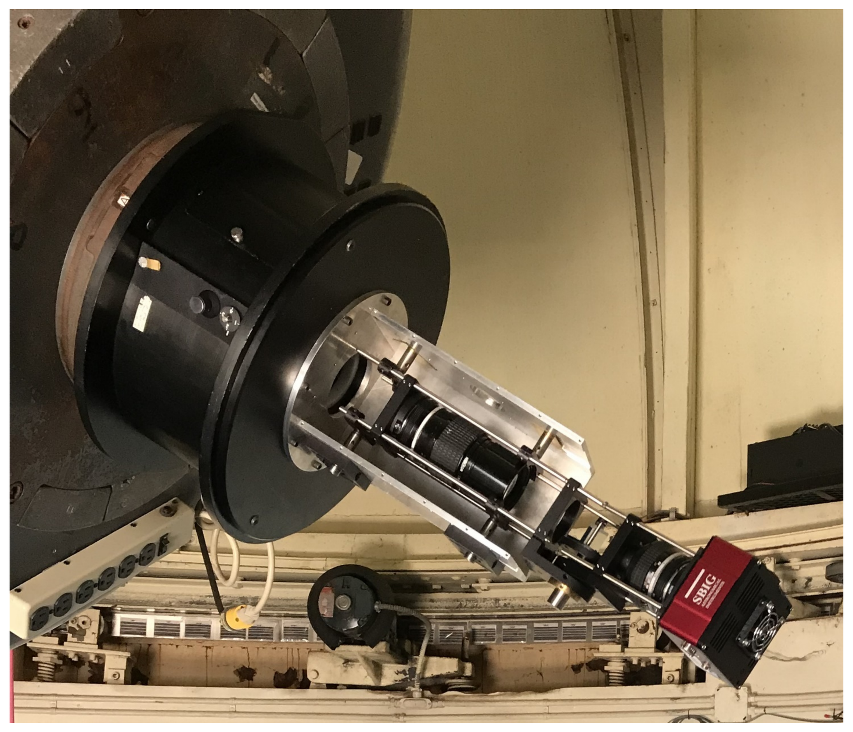

Figure 4. View of pETSI when mounted on the 0.9m telescope at McDonald Observatory.

RESULTS

Observational data was first taken with pETSI on the 0.9m telescope at McDonald Observatory. There were some technical difficulties with the focus of the telescope at first, but we were able to obtain a relatively focused image. As seen in Figure 5, we were able to attain a focused image of an 11.7 magnitude star with comparison stars surrounding it. Thus, we can confirm that pETSI works and we were able to achieve roughly 5 hours of the 7 hour transit for a 0.127 R_J planet. We obtained a spectrum in five bands, where these five bands correspond to the five bright dots shown in Figure 5 and the bands are displayed in Figure 6.

Figure 5. A 35 second exposure of Kepler 1274 on the 0.9m telescope. Each number corresponds to a different bandpass on the filter.

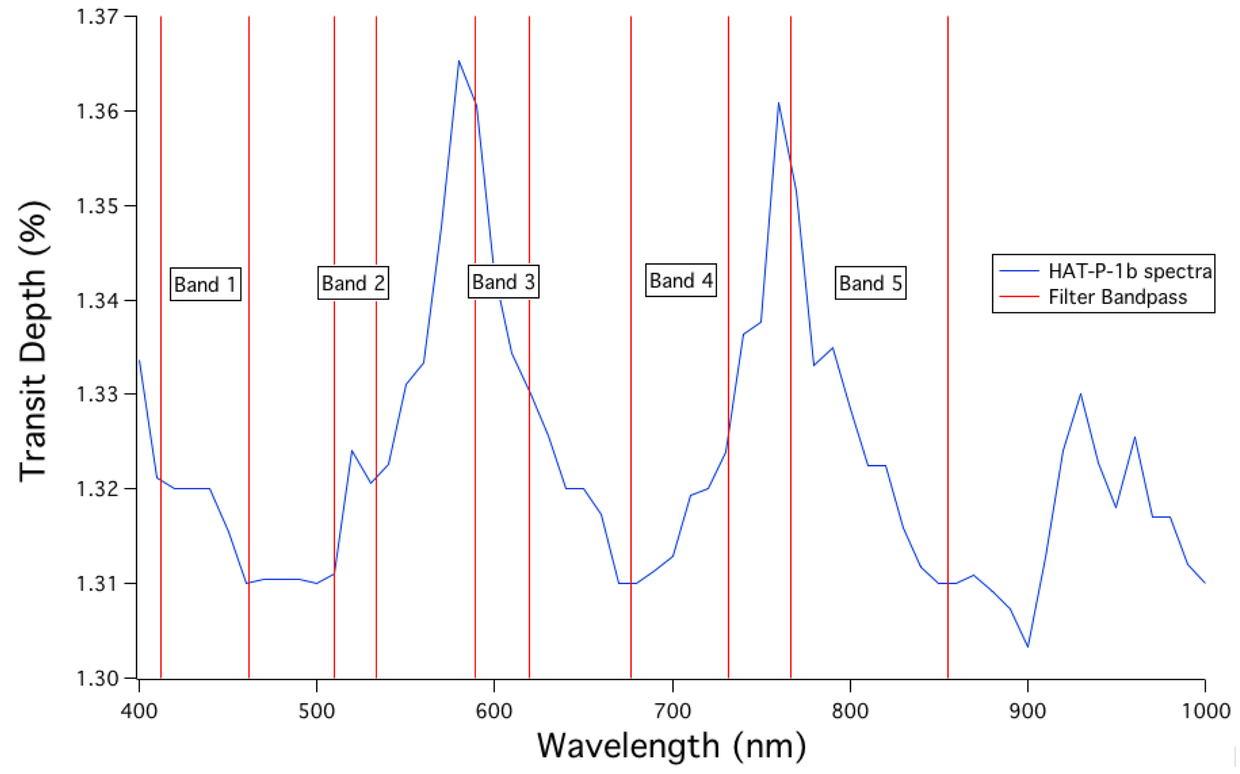

Figure 6. Model of HAT-P-1b's [3] atmosphere, which pETSI is capable of measuring. HAT-P-1b has a 1.23 R_J and a temperature of 1322K. The first peak is a detection of sodium and the second is potassium.

CONCLUSION

This research project confirms that pETSI was indeed successful and works well on smaller telescopes, such as the 0.9m telescope at McDonald Observatory. ETSI will be important when confirming atmospheres of TESS-identified targets with the goal of determining which targets are most valuable for future work by larger telescopes, like JWST and large ground based facilities.

REFERENCES

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