Studying the Atmospheres of Alien Worlds in Extreme Environments

**Ming Zhao¹, Jason T. Wright¹, Heather A. Knutson², Joseph G. O’Rourke²**

1. Department of Astronomy & Astrophysics, Center for Exoplanets and Habitable Worlds, Penn State University;  
2. Division of Geological and Planetary Sciences, California Institute of Technology

**Studying the Atmospheres of Alien Worlds in Extreme Environments**

**Planets and occultation: unique ways to study alien atmospheres**

- Total number of discovered planets and planetary candidates to date: 4159  
- The transit method has discovered 88% of them.

**Large flux changes of different stars due to atmospheric observations.**

0.02W0.03%, among the best of ground-allowed us to reach a precision of

- Our improvements to the instrument

**Secondary eclipses from ground.**

From)9)hot)planets)

**Detected atmospheric emission from 9 hot planets — 39% of all planets that have been detected at secondary eclipses from ground.**

**Others’ detections: 14**  
**Our detections: 9**

**HAT-P-32b light curve in H band**

**Future: a diffuser will smooth and stabilizes the images**

**Improve the instrument and observing techniques for cutting-edge science**

**Observing strategy:**  
Monitor the tiny brightness changes of the target with respect to other nearby stars

**Better guiding precision:**  
We developed a new guiding algorithm, and improved the guiding precision by a factor of 5-7.

**Well calibrated detector + Stable stellar images**

**Better detector calibration:**  
We developed a novel calibration scheme to calibrate the peculiar response of the infrared array detector.

**Smoother and steadier images:**

**Current: images change with time**

**Future: a diffuser will smooth and stabilizes the images**

**Results and Future Prospects**

**Detected atmospheric emission from 9 hot planets — 39% of all planets that have been detected at secondary eclipses from ground.**

- Measured light curve at 4 wavelengths

**Example:** Wasp-48b – a hot giant gas planet without a stratosphere (temperature inversion) and has low energy distribution across the globe – very different from the Earth.

**Comparison with atmospheric modes, assuming solar composition, thermodynamic equilibrium, and a plane-parallel atmosphere. Effective temperature-2158 K. (O’Rourke et al. 2013)**

**A promising survey ahead**

**Merely detecting the atmosphere at a single wavelength is not enough.**

Our improved technique will yield a consistent, multi-wavelength, high precision survey of a large sample of planets for comparison studies.

**Blue dots: current published planets with multi-wavelength measurements. Open circles: predicted detection SNR using our new diffuser technique.”**

**Acknowledgement**

Ming Zhao is supported by the Center for Exoplanets and Habitable Worlds (CEHW) of Penn State University and Prof. Jason Wright. Our observing trips were funded by the American Astronomical Society Small Research Grant program. We thank Prof. Sohara Mahadevan of CEHW for insightful discussions of instrumental development.