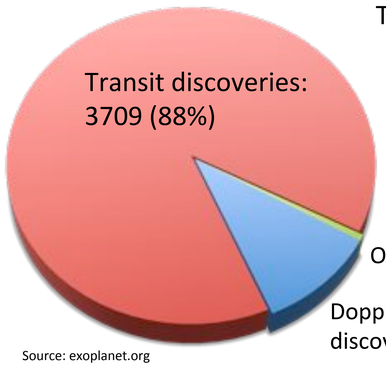
Studying the Atmospheres of Alien Worlds in Extreme Environments

Ming Zhao[1], Jason T. Wright[1], Heather A. Knutson[2], Joseph G. O'Rourke[2]

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

Planet transit and occultation: unique ways to study alien atmospheres



Source: exoplanet.org

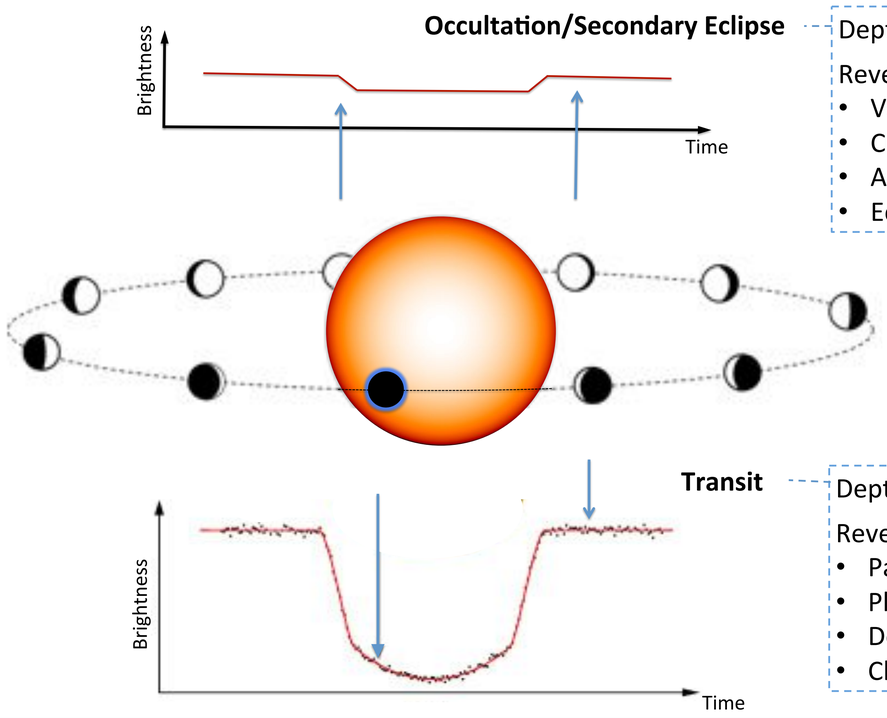
Total number of discovered planets and planetary candidates to date: **4159**

The transit method has discovered 88% of them.

Artist's concept of a planet close to its star, courtesy of ESA.

Giant planet + Close distance to host star = Hot + Extreme environment

Close-in giant planets have relatively large transit or occultation depths, providing a rare opportunity to study their atmospheres.



Occultation/Secondary Eclipse

Depth: ~0.01%

Reveals:
- Vertical temperature structure
- Chemistry and composition
- Atmospheric Dynamics
- Eccentricity of the orbit

Transit

Depth: ~ 1%

Reveals:
- Parameters of the orbit
- Planet-to-star radius ratio
- Density of the host star
- Chemistry and composition

Objectives:

- Detect atmospheric emission from a large sample of extra-solar planets
- Shed light on the physics and chemistry at work in those alien atmospheres
- Comparative study of the ensemble

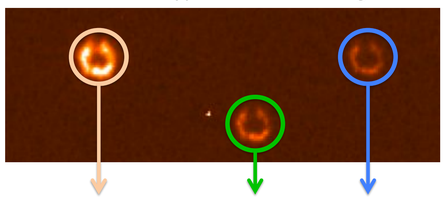
Importance to the field:

- Study the diversity of alien worlds
- Gain important information to their formation histories
- Better define the Solar System's place in the Galactic neighborhood
- Pave the way for future studies of real Earth-like planets

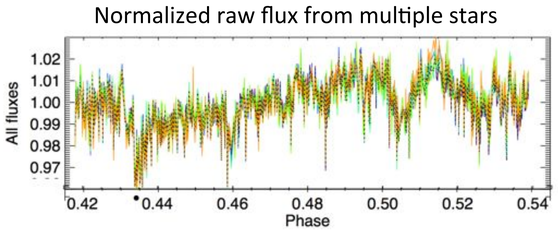
Improving the instrument and observing techniques for cutting-edge science

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

Part of a typical science image



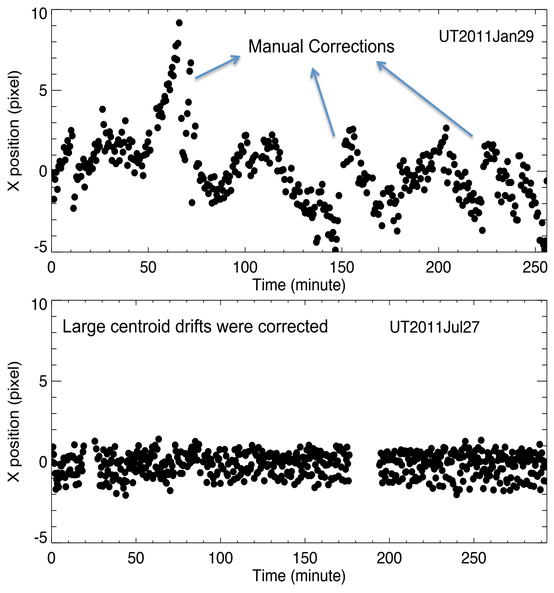
Normalized raw flux from multiple stars



Large flux changes of different stars due to atmospheric turbulence are well correlated and can be corrected. However, the tiny, independent detector related errors are hard to correct.

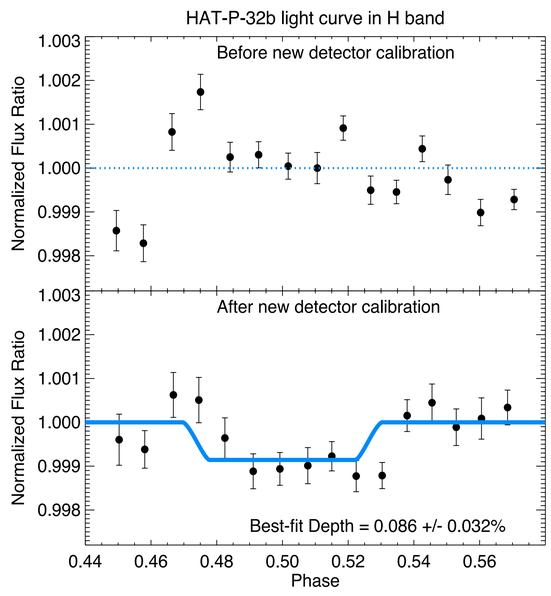
Key to high precision: Precise guiding + Well calibrated detector + Stable stellar images

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



Zhao et al. 2012

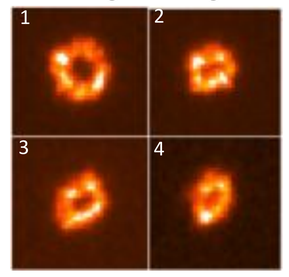
Better detector calibration:
We developed a novel calibration scheme to calibrate the peculiar response of the infrared array detector.



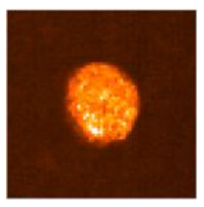
Zhao et al. 2013 in prep.

Smoother and steadier images:
We are developing a novel diffuser assisted photometry technique for much higher precision.

Current: images change with time

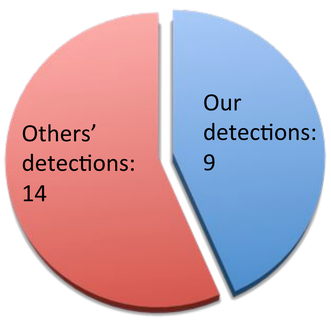


Future: a diffuser will smooth and stabilizes the images



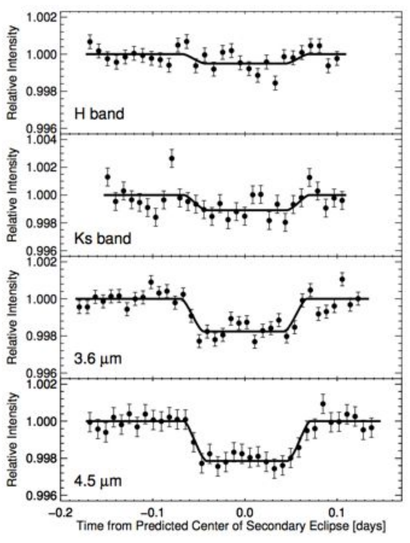
Results and Future Prospects

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

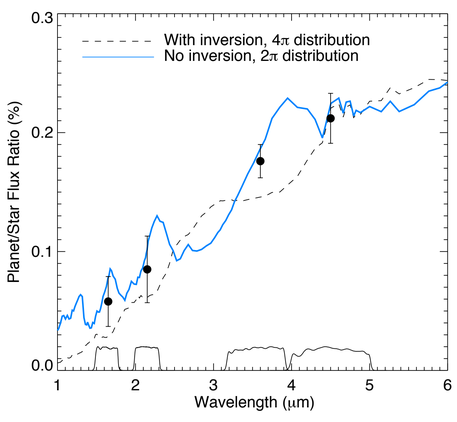


Our improvements to the instrument allowed us to reach a precision of 0.02-0.03%, among the best of ground-based observations.

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.

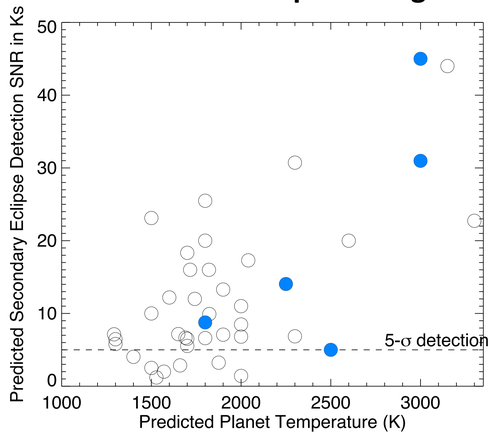


Measured light curve at 4 wavelengths



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.

References:

O'Rourke, J. G., et al. 2013, ApJ, submitted.
Zhao, M. et al. 2012, ApJ, 748, L8
Zhao, M. et al. 2013, ApJ, in preparation.

Acknowledgement

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