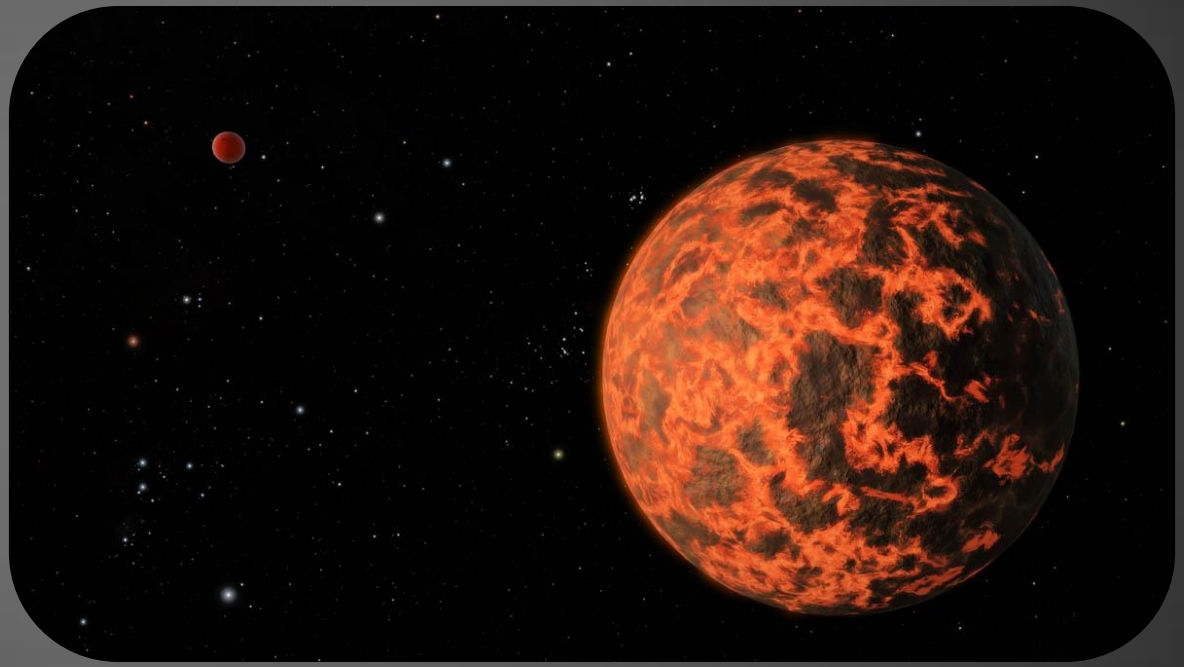
# One Earth, Two Earth, Red Earth, Blue Earth: The Taxonomy of Extrasolar Planets



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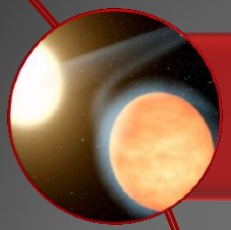
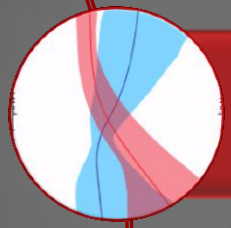
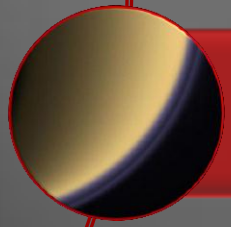
# Outstanding Issues in Exoplanet Atmospheres



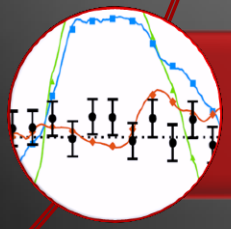
Constraining the atmospheric metallicity and C-to-O ratio.



Definitively proving the existence of thermal inversions and identifying the relevant physical mechanism(s).



Understanding the prevalence of hazes and aerosols for different planet temperatures and surface gravities.

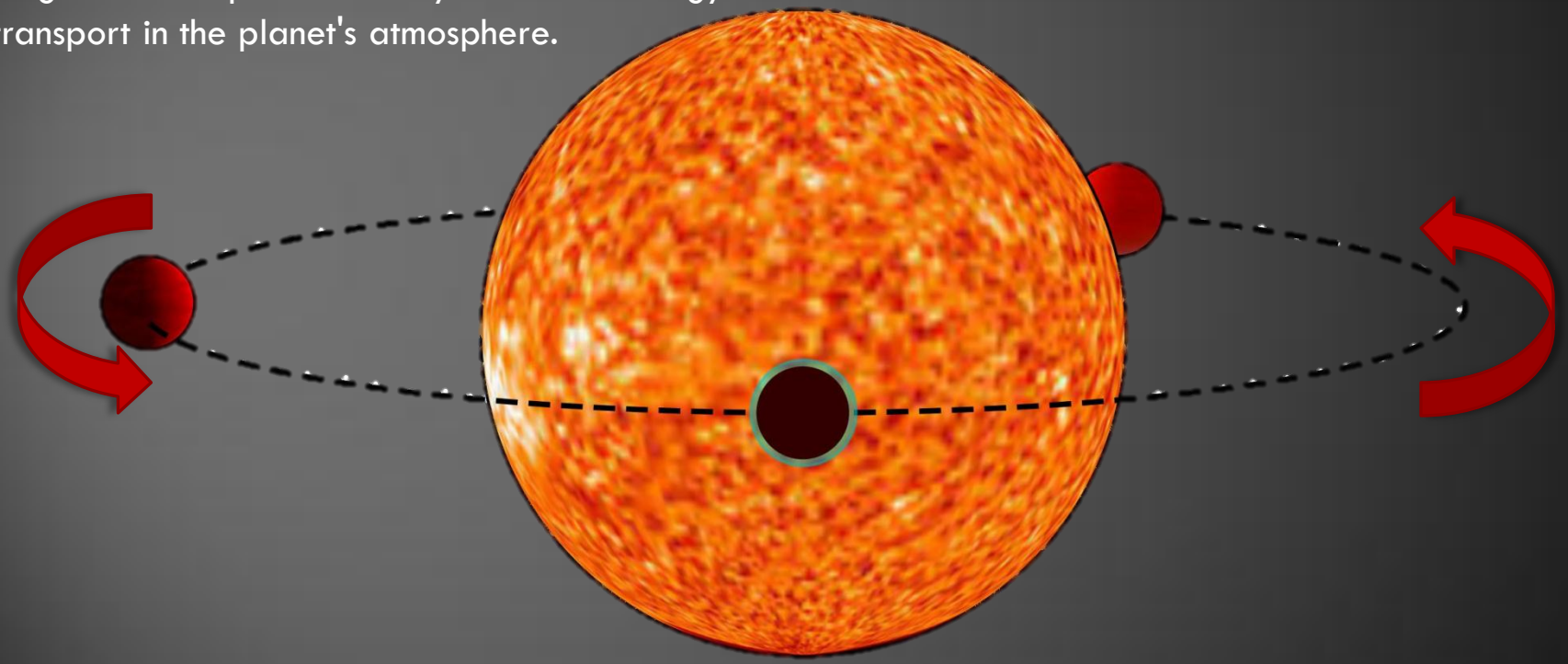


Determining the nature of atmospheres surrounding super-Earths.

# Geometries For Studying Exoplanet Atmospheres

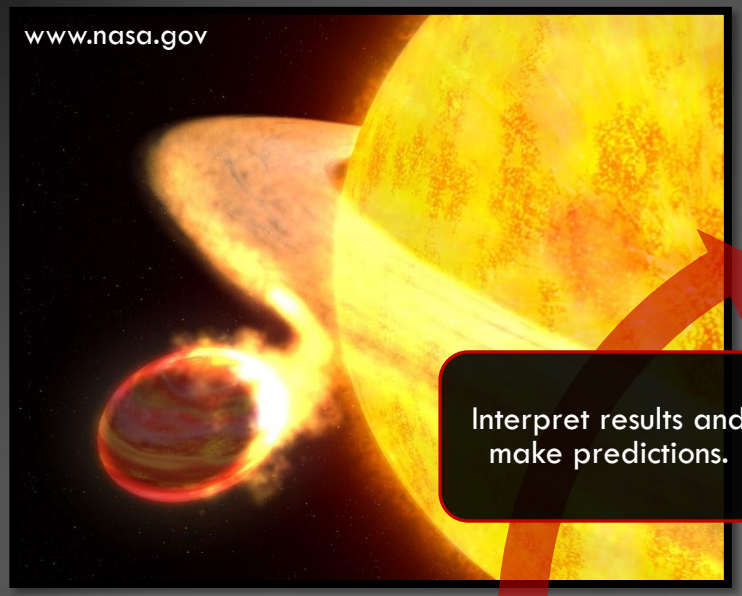
**Phase Curve**: We observe the phase variation to map the planet's emission as a function of longitude. This probes the dynamics of energy transport in the planet's atmosphere.

**Secondary Eclipse**: As the planet's light is blocked, we measure its dayside emission spectrum. Emission spectroscopy is sensitive to the absolute chemical abundances and the thermal profile.



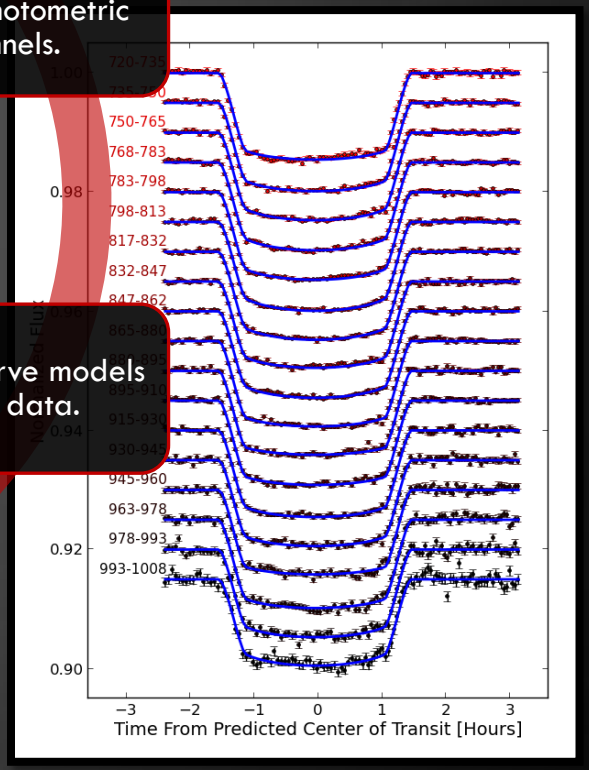
**Primary Transit**: We measure the transmission spectrum of the planet as light from the host star is absorbed by chemical species in the planet's atmosphere. These data are sensitive to the relative chemical abundances and the presence of cloud or haze particles.

# Improving Our Understanding of Exoplanets




Acquire time-series data of an exoplanet during transit.


Bin spectra into spectrophotometric channels.



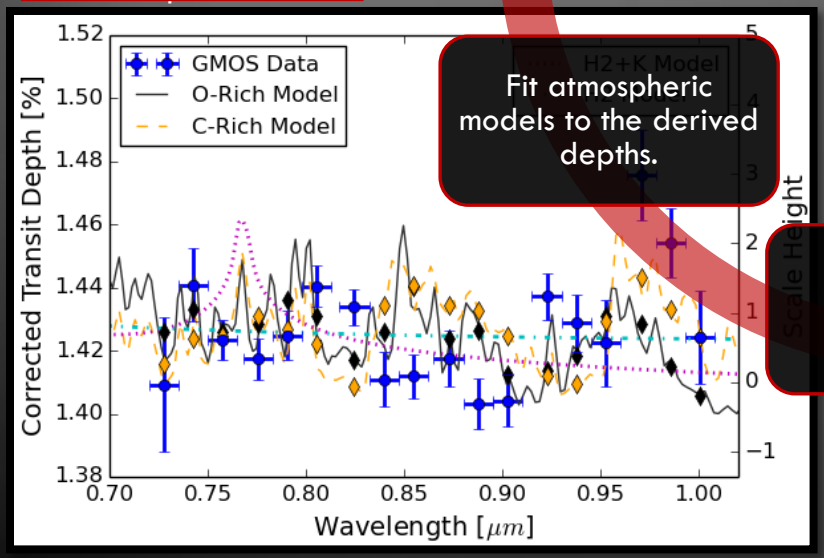

Spectroscopic light curves of a transiting exoplanet.

Fit light-curve models to the data.

Measure transit depth at each wavelength.

Fit atmospheric models to the derived depths.

Exoplanet transmission spectrum with atmospheric models.




Interpret results and make predictions.

# The Taxonomy of Extrasolar Planets

**Problem**

- Performing extensive atmospheric characterizations of all known transiting exoplanets is both impractical and an inefficient use of resources.

**Solution**

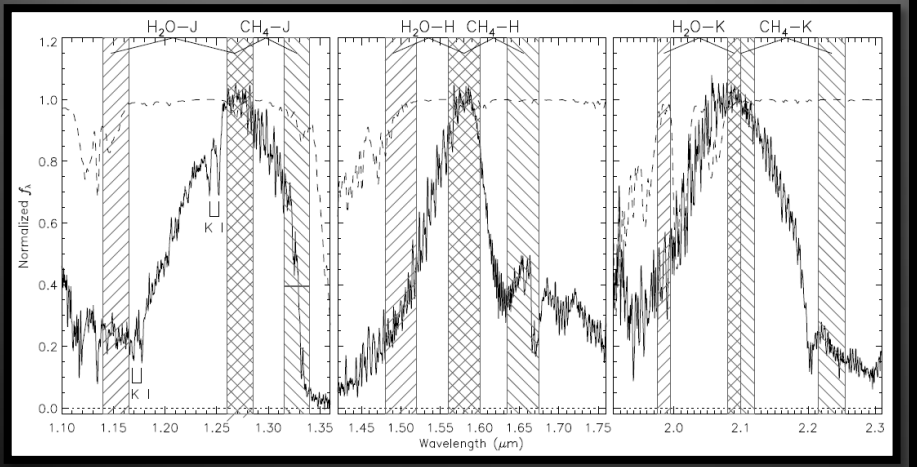
- Deep characterization of a representative sample could lead to the identification of key atmospheric markers that can then be targeted in other uncharacterized atmospheres.

**Result**

- An exoplanet classification scheme would enable atmospheric statistical studies on a large exoplanet population and lead to a deeper understanding of planet formation and evolution.

| Examples of taxonomy in astronomy |
| --- |
| Tholen classification scheme for asteroids (C, S, X, M) |
| Brown-dwarf classification scheme (M, L, T, Y) |

Example brown-dwarf classification scheme using spectral indices




Burgasser et al. (2006)

Phase curve with uncertainty regions.