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Title: How Clouds Impact the Characterization of Low-mass, Low-density Planets
Type: Contributed Talk
Session: Characterizing Transiting Planets

Abstract: How Clouds Impact the Characterization of Low-mass, Low-density Planets
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The Kepler Mission has revealed huge populations of low-mass, low-density planets, but their compositions remain elusive. For example, the density of GJ 1214b is consistent with either a water-world with a water atmosphere or a rock-iron core with a H/He envelope. Other super-Earths must contain hydrogen and helium to match their observed masses and radii. To understand this population of objects, we must be able to characterize their compositions through spectroscopy.

The formation of clouds in exoplanet atmospheres significantly changes their observable spectra. For exoplanets, the opacity of hazes or clouds has been invoked as a possible explanation for the observed flat transmission spectrum of transiting super-Earth GJ 1214b, Neptune-class planets GJ 436b and GJ 3470b, as well as in a number of hot Jupiters.

Here, we examine the effect of clouds on low-mass, low-density exoplanet spectra, for planets from ~2-20 M_Earth. We include the condensates that are present in chemical equilibrium for objects at these temperatures (500-900 K) which include minerals like sulfides and alkali salts. The most important of these clouds are sodium sulfide, potassium chloride, and zinc sulfide. These clouds should be most prominent at low surface gravity, strongly super-solar atmospheric abundances, and at the slant viewing geometry appropriate for transits. Hence they could be quite important for affecting the transmission spectra of cool low density super-Earth and Neptune-class planets.

Another class of clouds may also dramatically alter the spectra of irradiated planets: photochemical hazes, which could be present over a very wide temperature range. For the GJ 1214b example, we additionally include a hydrocarbon haze layer similar to the tholin haze in Titan’s atmosphere. We calculate the location and density of the haze layer using photochemical models.

We present new results that show that for enhanced metallicity atmospheres, either the clouds that form in equilibrium or a hydrocarbon haze layer could become sufficiently optically thick to reproduce the observations of GJ 1214b. We also present predictions for other low-mass, low-density exoplanets which will be targets of future detailed observational campaigns: HD 97658b and GJ 3470b.