Model-Free Identification of Two Classes of Exoplanets. J. Harrington[1] and the UCF Exoplanets Group[1], [1]Planetary Sciences Group, Department of Physics, University of Central Florida, Orlando, Florida, jh@physics.ucf.edu.

Introduction: The Spitzer Space Telescope has measured numerous eclipses of exoplanets, and ground-based telescopes and Hubble are now in the game. These measurements give the planetary flux in the observation filter. In combination with the planetary radius, known from transit, one can determine a brightness temperature, Tb. We compare these Tbs with the planets' predicted equilibrium temperatures, Teq, calculated assuming zero albedo and uniform reradiation of absorbed energy from the entire planetary surface. Measurements deviate from the simplistic Teq prediction because of the composition and thermal profiles present in the atmosphere, but other effects like clouds may play important roles as well. By comparing Tb and Teq, and without reference to any interpretive model, we have identified two distinct classes of exoplanets, with cooler exoplanets having similar Tb and Teq while hotter exoplanets have higher Tb than Teq. We discuss possible explanations, such as thermal inversions and clouds.

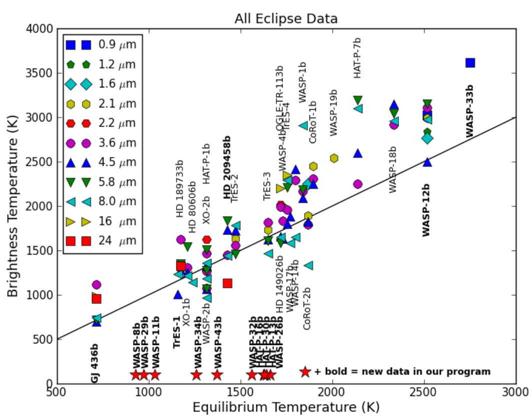

Figure 1: Observed brightness temperature, Tb, vs. predicted equilibrium temperature, Teq, for many planets. The line is Tb = Teq. Boldface type indicates new data in hand.

Introduction: Even without resolving an exoplanet from its host star, the atmosphere's emitted flux can be measured by monitoring the total system flux as the star eclipses the planet. Over 230 planets are known to transit (pass in front of) their stars, and Kepler has identified thousands of additional candidates. Most transiting systems exhibit eclipses.

In 2005, two teams simultaneously published the first measurements of photons from exoplanets [1, 2]. Both used the Spitzer Space Telescope. The planetary flux can be interpreted as a brightness temperature, Tb, given the planetary radius measured in transit. Most of the successful eclipse measurements have been made in the six Spitzer photometric channels (3.6, 4.5, 5.7, 8, 16, and 24 μm). Working with planet discoverers, our Spitzer Exoplanet Target of Opportunity (ToO) program measured dozens of eclipses. There are now many ground-based measurements as well (e.g., [3, 4]). Combining all these measurements, we can now seek trends and groupings in the population of exoplanetary atmospheres.

Tb vs Teq: The most basic comparison is between the predicted equilibrium temperature, Teq, and the observed Tb. Teq is a proxy for the stellar flux at the planet. We use it because temperatures are more familiar than flux levels and are more meaningful in terms of their effects on atmospheres and their chemistry. We calculate Teq assuming zero albedo and uniform redistribution of absorbed light around the planet.

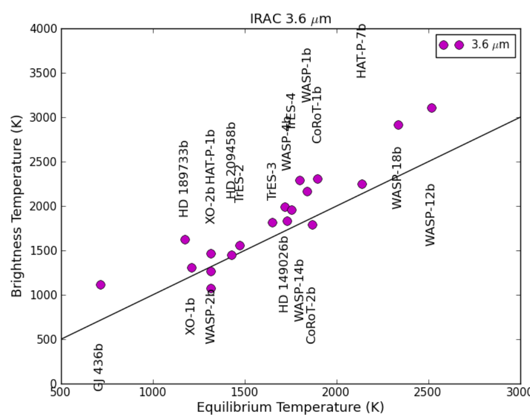

Figure 2: Same as Figure 1, but only Spitzer 3.6 μm data.

Figure 1 shows the Tb vs. Teq comparison for over 30 planets. The basic trend confirms that planetary temperatures are near where we expect them, but with large scatter even for a given planet in different bandpasses. If all the points for a planet are high, it indicates that more than half the received radiation re-emits from the day side, and vice versa. Individual high and low points indicate emission or absorption in particular bandpasses, with the former indicating a strong thermal inversion. A tight cluster of points indicates a nearly isothermal atmosphere, with correspondingly little information on structure or composition in the spectrum.

Figure 2 shows just the data at 3.6 μm. At both the low and high ends of the temperature range, all the points lie well above the Tb = Teq line. The data at low and very high temperatures are sparse. We are filling them in, but we need more data, and better data for these planets.

Other Comparisons: There has been much discussion on the presence of thermal inversions in exoplanetary atmospheres [5, 6, 7] and some on the relationship to metallicity or surface gravity [8]. Surface gravity enters the atmospheric scale height in the denominator, and high gravity would indicate fast-falling precipitation and high rates of convection for a given density contrast. High metallicity would produce more absorbers capable of making a thermal inversion. These hypotheses can now begin to be tested.

Summary and Conclusions: The collected atmospheric data from dozens of exoplanets measured by Spitzer and from the ground are starting to show possible trends, independent of any interpretive modeling. The elevated Tb at high Teq is curious, but needsconfirmation with more data. If real, several hypothese could explain it.

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