Opacity and spectra in hot Jupiters

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We are developing a set of tools for generating absorption coefficients for hot Jupiter atmospheres. We focus on the visible spectrum, where we plan to use the routines for generating "first guess" models for the upcoming transmission spectra of hot Jupiters (HST program in progress, PI: Sing). We also plan to study the atmospheric temperature-pressure profile of hot Jupiters (Heng et al. 2011)[1], with a focus on the effects of various types of clouds.

The transmission spectrum of an exoplanet allows us to probe the atmosphere for elemental and molecular species. In the visible spectrum, sodium, potassium, titanium oxide and vanadium oxide are expected to be dominant [2], (depending on the composition and temperature). Absorption due to clouds/hazes can also be relevant [3].

In this project, we seek "first guess" models to guide the ongoing observations of transmission spectra of transiting planets with HST. We seek to link the transmission spectrum with the "reflection spectrum" in the visible, and compare the effects of scattering due to grains and absorption due to gasses.

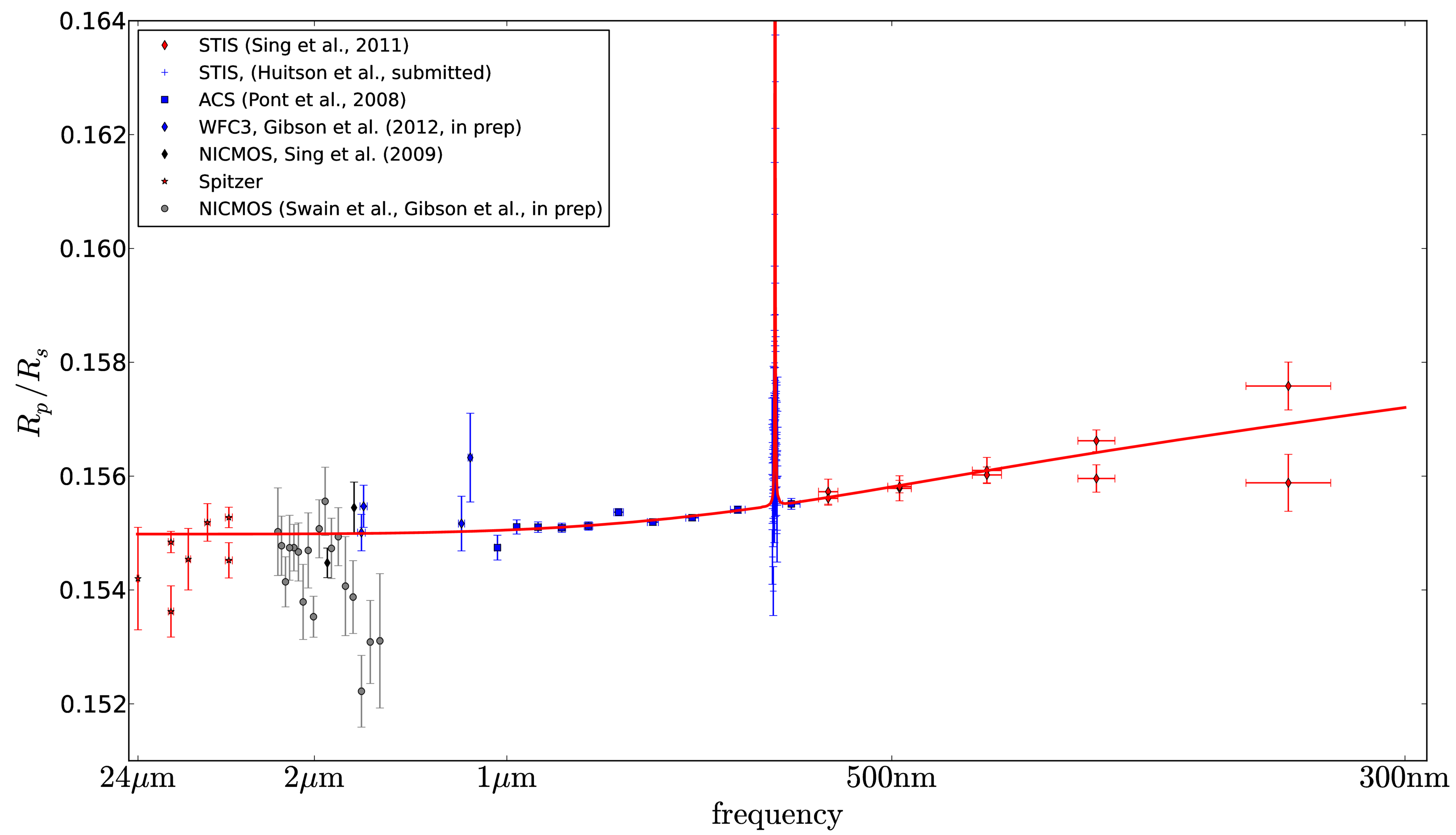

Figure 1: Plot showing the latest reduction of the transmission spectroscopy for HD 189733b (our group, in prep), with a possible model shown. We apply a coherent set of corrections for the stellar activity and use the same system parameters from Agol et al. (2010) [9].

Transmission spectrum

We perform finite element integration for visible light rays that travel in a grazing geometry through the planet's atmosphere to generate the transmission spectrum. Absorption from the radiatively active species in the atmosphere causes wavelength-selective dimming in the light. Figure 1 shows an example of a transmission spectrum (HD 189733b), where we have plotted a model that includes the sodium D lines, and Mie scattering for small particles ($r \ll \lambda$), giving the Rayleigh regime. We also used a distribution of grain sizes.

We plan to extend this to look at other conditions, such as highly absorbing and highly scattering clouds, and different grain components such as MgSiO3, MgSiO4, NaS, etc.

Temperature-pressure profile

Heng et al. (2011)[1] computed the temperature-pressure profile for an exoplanet atmosphere, using the dual band approximation. This assumes a constant shortwave opacity and a constant longwave opacity. Given that the population of radiatively active gasses in the visible changes at higher temperatures (VO and TiO become important), the constant shortwave opacity assumption may have to be revised.

We plan on carrying out a coherent calculation of the profile, the transmission spectrum by iterating between calculating coherent absorption coefficients for the T-P profile, and the corresponding T-P profile for that absorption spectrum. We should then also be in a position to compute the emission spectrum given some assumptions (eg: molecular emission lines, molecular absorption lines, or no molecular lines). As in the case of the transmission spectrum, we want to include scattering due to various types of clouds.

Future

1. We plan to include the atomic line due to potassium, and molecular lines due to potassium, TiO and VO.

2. We are implementing a correlated-k algorithm to speed up the calculations, because the line-by-line calculations on ~20 million lines are slow.

3. We plan to use these routines to provide a "first guess" model for transmission spectra to be collected with HST in the near future.

4. We plan to use this model iteratively with the work of Heng et al. (2011) to study the effects of real gas absorption and cloud scattering on the temperature structure of the atmosphere of hot Jupiters.

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