

12.425

Lecture 15

Tuesday November 20, 2007

The focus of this lecture is to discuss the origin of absorption and emission lines in the exoplanetary spectra and what they represent mathematically. Students will become familiar with Kirchhoff's Law, a second solution of the radiative transfer equation, and the mathematical approach to understanding thermal emission spectra.

The first in-class exercise asks students to look through exoplanet thermal emission spectra or photometry data, explain the y-axis in each case, and argue for which examples represent a positive emission or absorption feature.

Students will note in the first examples that the spectral data and model do not match well and no spectral features are evident. Students did note that the detector read better at shorter wavelengths so it would be hard to make a critical reading from the range presented. It is interesting to note that the y-axis is star-planet contrast and in this case the planet is quite bright; it emits 1/1000 of the star's light. This can be compared to the Earth-sun planet-star contrast of 1/1 million at mid-infrared (thermal) wavelengths.

Example two represents the same issue for an exoplanets spectrum: apparent lack of prominent spectral features. One point just below the 10-micrometer wavelength is raised indicating a possible emission feature, and led to the question if the outliers were removed, would the peak still be significant as it is here at one sigma? The y-axis is the same as in example 1.

The third exoplanets spectral plot is a ratio of planet and star flux as the planet is going behind the star. The default model data in black is opposite the data modeled in red, which shows

a slight emission possibility at a few points below 10 microns again. The polarity of models raises the question, students noted, that there might be other models to fit this data as well.

The final example of the theoretical spectra shows that the temperature of the atmosphere is not constant as represented by the plot on the right. The plot on the left shows how the brightness of the body relates to the differential densities due to different temperatures and amount of particles in layers of the atmosphere. This plot is better assessed in the second exercise.

The second in-class exercise asks students to look at the emissions spectra for Earth first and find the altitudes that correspond to absorption and emission features. Students will see that absorption features occur closest to the ground where the atmospheric density is high. Emission features originate much higher in the atmosphere, in the temperature inversion layer. It could be argued the same trends are represented as the temperature inversions change at higher altitudes, but not likely in reality because there is less material there for the photons to interact with.

The next two examples ask students to return to two of the examples from the first exercise and sketch their own altitude versus temperature profile based on the given spectra. For the Spitzer data from HD 209458, students choose one model to graph. Here the spectra represents basically straight emission so graphs will show a rise in altitude as the temperature rises; this ultimately models a temperature inversion on the planet, at least using the red model of emission spectra.

Charting the theoretical spectra, students again can choose which spectral line to use to plot altitude versus temperature. The blue line would be a constant horizontal representation between temperature and altitude with possibly a slight bow; it is isothermal and shows no absorption lines. The black model spectra would show an inverse exponential relationship

between temperature and altitude. The right-hand-side plots would look similar to Earth's temperature versus altitude plot, representing a warm, cool, warm trend depicted in the cross sections of the longitude versus latitude plots.

The main idea of this lecture is to become familiar with the spectrum, to know what it means, and to know whether emission or absorption is represented.