

12.425

Lecture 14

Thursday November 15, 2007

The focus of this lecture is to discuss solar system planetary spectra. Students will become familiar with the equation of radiative transfer and one solution to that equation. They will also estimate transmission spectra flux ratios and the exoplanet transmission spectra and/or photometry.

The first in-class exercise asks students to look through spectral data of the planets in our solar system. The data was taken using “direct imaging,” and the exercise allows students to compare and contrast the spectral analysis of the planets at different wavelengths. Students should convert plots reported in wave numbers to wavelength. Wavelength equals 1 divided by the wave number.

What students will notice when comparing Mars, Venus, and Earth, is that all three planets show a strong signature of carbon dioxide in the infrared; yet, only Earth shows ozone and water, which is a key point to emphasize for the search for life and habitability. Plotting spectral data in the visible of all the planets shows how different the signatures are, however, based on cloud cover and position. The spectra of Jupiter and Saturn taken in the visible are strikingly similar, as are the signatures of Uranus and Neptune—all show a strong methane absorption feature. When the visible and infrared are combined, students will again see similarities between groups of planets and might recognize that ammonia and methane appear in all the outer planetary bodies. The last concept to note in reviewing these spectra is that the photochemistry of methane causes signatures of other hydrocarbons, an effect very noticeable in Jupiter’s spectra.

The second in-class exercise asks students to now look through exoplanet transmission spectra, or transmission photometry data. Students will review the plots, read the captions, and determine what the Y-value in each graph represents, from which they can determine what spectra signatures are positively identifying evidence of that molecule in the planet's atmosphere.

The first plot shows strong signatures of sodium, potassium, and water. The y-axis shows that these signatures affect the radius of the planets as a function of wavelength. Students should note this data was taken with the Hubble space telescope. The telescope's response depends on wavelength, so even though water appears to have a strong signature, students should be skeptical due to systematic errors in the detector at this wavelength. The next example represents a plot of how much apparent absorption occurs in the planet's atmosphere based on wavelength and a curve of best fit is placed between four data points. The third plot represents the same data and shows interpretive versus actual data. Without the interpretation curve the data shows much less signal. The remaining plots show alternative data sets for the first exoplanet transmission spectra.

The main points to take from the exercises are: first, the planet appears to be different sizes as a function of wavelength because of molecular absorption, which varies by wavelength; second, determining atmospheric composition of exo-planets can be done by using transmission light curves, but detector errors must be taken into account.