12.425
Lecture 18
Tuesday December 11, 2007

The focus of this lecture is to review emission and absorption spectra by looking at the theoretical projection of the Earth's spectra and how it changed over time. The central concept of this class is to determine whether scientists can draw conclusions about alien life based on spectra of exoplanets and what considerations should be made when discussing "life" and its components.

The first in-class exercise asks students to review Earth's reflection spectra and its thermal emission spectra and then study theoretical data of the evolution of the spectra from what one journal paper calls Epoch 0, which is the Earth's early history billions of years ago, up to Epoch 5, which is the present time. Students should decide which spectral signatures they can clearly identify, which are the same over time and which differ. The students can then attempt draw conclusions about the presence of life in Earth's past and present if trying to consider it as an exoplanet.

The first two plots represent real data of Earth, which students reviewed to refresh their memory about spectral features and their appearance on a black body curve. The class noted the high presence of water and ozone in the reflection spectrum and the major features of carbon dioxide, water, and ozone in the emission spectrum. Note the different wavelength bands running along the x-axis of these plots.

The next two graphs represent the different wavelength ranges, respectively; the first absorption or reflectivity, the second emission. The graphs illustrate how the altitude of clouds influences the spectra. Students noted that the high cloud peaks of the spectra in each range of wavelengths seemed to crest where the lower cloud heights showed troughs or bites in the

projected black body; height of clouds is relative to planet surface. The effect seen is due to the concept of radiative transfer, which was discussed in previous lectures. The data represents a one-dimensional model, which the class decided represented uniformity in the hypothetical cloud cover. The clouds are not uniform on Earth, however, so the graph would be more scattered if it were an actual representation of spectra based on cloud height and abundance.

The final series of four charts are spectra of Earth through time in first the visible-near IR wavelengths. The first is spectra without influence of clouds; the second is spectra with clouds. The same is represented at the longer wavelength region. Students noticed that in the visible wavelength, methane (CH_4) appears in the middle epochs, but its spectral signature disappears as oxygen enters and increases in the atmosphere during the last two epochs. The class also described the increased reflectivity during the last epoch as a direct result of growing forest and land vegetation that would cover the planet and reflect more light.

The graphical representation of spectra with clouds has the same signature patterns as the graph without clouds, but students noted the reflectivity in from the plot graph doubles in the second as the layers of atmosphere and subsequent clouds would increase the reflectivity. The evolution-based shift in reflectivity due to vegetation is not as apparent in the second plot because the clouds block the major reflectivity from the planet surface.

The final two groups of graphs represent thermal emission spectra and its changes over time. In this longer wavelength spectral region, students noted that in the first epoch not much of any molecule was abundant to produce a bite in the black body. Gradually carbon dioxide, methane, and water created more apparent features and interestingly, methane, and ozone, coexist somewhat at this wavelength region. In the graph with clouds, the features do not change

much over time, but the ozone representation does deepen from epoch 3 to epoch 4, and students noted that water overtook the methane signature in the last epoch of this graph.

From this presentation of thermal spectra, students concluded that it would be hard to tell whether life evolved and when it first was established on this planet if a scientist were considering this an exoplanet and assumed water was necessary for life. The signature of water is difficult to distinguish in the early spectra and it not completely evident as carbon dioxide is in the longer wavelength. One might argue that the appearance and disappearance of methane denotes the possibility of methanogenic life that would use methane as energy such the way aerobic creatures use oxygen. Aerobic organisms, correlating to the shift in spectral features on the graphs, could have wiped out these methane-loving creatures. Students ultimately could conceptualize the difficulty of making conclusive decisions about the possibility of life using this data, and the exercise enabled them to discuss qualifications and definitions of life as well as how challenging, but rewarding, it would be to collect the data that positively identified alien creatures.

From this lecture, students will walk away with a better appreciation of how difficult it is to determine if life exists on places aside from Earth and also get a sense of the different methods and opinions of whether and if scientists can successfully search for signatures of life based on exoplanetary spectra.