COMPOSITIONAL REMOTE SENSING OF PLANETARY SURFACES WITH SPECTROSCOPY: LIMITS TO OUR KNOWLEDGE AND ABILITIES TO INTERPRET DATA. R. N. Clark, Planetary Science Institute, Lakewood, CO, USA, rclark@psi.edu

Introduction: We are living in a golden age of planetary exploration. We are sending spacecraft to the outer reaches of the Solar System with sophisticated instruments. We also have advanced instruments on earth-orbiting telescopes and on Earth-based telescopes. Sensor technology improves each year. Compute capabilities have increased to a level where scientists can do much of their work on a simple laptop with the computing capability beyond a super computer of a couple of decades ago, and even faster machines are readily available.

The data being returned by these instruments is spectacular, often covering from the far ultraviolet to the mid and far infrared. Yet meeting after scientific meeting, we often see conflicting interpretations of the same or similar data. My assessment is that many of these conflicting interpretations are due to inadequate reference data and/or models that are too simplistic. The questions to be answered are complex.

Spectral Range and Resolution and Physical Conditions: With data from spacecraft covering UV (~0.1 micron) to mid and far infrared (20 to 100+ microns), few laboratories have the capability to measure materials over such a large range, and with spectral resolution that at least matches observational data. Spectra of gases change with both pressure and temperature. Spectra of solids change with grain size, temperature, pressure, crystallinity, and trace substitutions of elements. Planetary surfaces are subjected to bombardment by meteors large and small, as well as UV radiation, cosmic rays, energetic particles from the sun and or trapped in planetary magnetic fields. Few, if any, laboratories have the ability to study the effects of the radiation environments on materials under real-planet/satellite conditions. Even if a lab had the complete capability to measure these conditions with appropriate environment chambers and radiation sources, the time to characterize one even one sample is formidable.

Modeling: Modeling of the spectroscopic signatures of planetary surfaces is complex. Planetary scientists often use “Hapke” theory, or equivalent radiative transfer theories. Radiative transfer models require optical constants in order to model abundances and grain sizes. Classical Hapke theory is limited by geometric optics, but increasingly we are finding sub-micron and nano-particles are in enough abundance in planetary surfaces that more sophisticated models are needed [1]. Few have included coatings and layered media in models of planetary surfaces, but that is becoming a greater need.

Optical Constants: While we have few far UV to far infrared spectra of planetary materials, we have even fewer optical constants over relevant temperature ranges. Our best case optical constants are for water ice where we have pretty good data from [2] as a function of temperature but only for the infrared. Some residual interference patterns are in the data and [1] corrected them for just one temperature. We have only one measured temperature in the UV and no idea how much the spectrum varies with temperature.

Nano-Materials: Chemical bonds at the edge of a particle are affected by different fields than those internal to a particle. As particle sizes get smaller, in the tens of nanometer range and less, the surface to volume ratio changes enough that the spectral properties change. These effects have been well demonstrated for iron oxides [3] but we have no optical constants for such conditions, nor do we have even simple spectra for many other nano-materials, including water ice that is so ubiquitous in the outer Solar System. We have no idea on how this lack of knowledge limits our interpretations.

Unknown Absorptions: We have observed absorptions in spectra of planets/satellites that remain unidentified after many years, including near-infrared absorption bands that appear to be organics, but for which no organic or combination of organics have been identified as well as unknown UV absorptions.

Measurements Needed: The list of needed spectral measurements is too long to list here, but will be discussed in the presentation. Multiple labs need to be upgraded to be able to make needed measurements and the community needs to concentrate on the most needed compounds first. This list will vary by mission and planetary surface under study. For the outer Solar System, the UV absorber is unknown with multiple contenders. For Europa, salts and acids need to be measured over the Europa Clipper instrument range. Water ice is one of the most ubiquitous compounds, yet we need measurements in the UV as a function of temperature. The ice optical constants in the visible are inadequate as they have spectral structure not seen in lab reflectance spectra.