EPSC Abstracts
Vol. 6, EPSC-DPS2011-1279-1, 2011
EPSC-DPS Joint Meeting 2011

Analysis of High Resolution Spectra of Eris: Possible Evidence for Cold Phase CH_4 Ice

J. C. Cook (1,2), R. M. Mastrapa (1), D. P. Cruikshank (1), A. Alvarez-Candal (3), and N. Pinilla-Alonso (2)
(1) NASA Ames Research Center, MS 245-6, Moffett Field, CA, 94035 (Jason.C.Cook@nasa.gov), (2) SETI Institute, Mountain View, CA, USA, (3) European Southern Observatory, Santiago, Chile.

Eris, formally known as 2003 UB_{313}, is one of the largest known Kuiper Belt Objects (KBOs) and it is one of a few known KBOs with a radius $\gtrsim$1000 km and a surface covered in CH_4 ice. CH_4 bands have been observed from 0.6 μm to 2.5 μm by several groups (*e.g.*, 1; 2; 3; 4). Compared to Pluto and Triton, these features appear deeper, suggesting a greater abundance of CH_4. In addition, (5) showed that the central wavelength of several bands around 800 nm were different from (2). Similar band shifts have been seen in spectra of Pluto and Triton (6; 7), which match laboratory observations of CH_4 diluted in N_2 (8). Using new lab measurements to derive optical constants for CH_4 in N_2, (9) showed that the bands near 800 nm are consistent a N_2:CH_4 dilution of 90:10. While the spectral shifts on Eris are consistent with dilution of CH_4 in N_2, it is not exclusive to dilution in N_2. Indeed, N_2 is yet to be detected on Eris.

In August and September 2009, (4) obtained new spectra of Eris using X-Shooter, a new VLT instrument. X-Shooter is an echelle spectrograph which is capable of obtaining spectra from 0.3 to 2.5 μm in a single observational setup (10). The data obtained by (4) have a resolving power ($\lambda/\Delta\lambda$) of 5000, much greater than previous observations, and a signal-to-noise ratio (SNR) ~20-30 from from 0.4 to 1.8 μm. The SNR in K-band is much lower ($\lesssim$ 3) and do not clearly show the CH_4 absorption features at 2.20, 2.32 and 2.38 μm. The band-by-band analysis of Eris' spectrum discussed in (4) for the CH_4 bands showed that the bands around 800 nm are shifted to shorter wavelengths by about 4 Å compared to pure CH_4 at 30 K. These findings are consistent with the 4 Å shift measured by (9) when compared to pure CH_4 measurements. The shifts at longer wavelengths (*i.e.*, 1720 nm) were measured around 10 Å. An increase in spectral shift at longer wavelengths is similar to what (8) measured in lab spectra for CH_4 ice diluted in N_2 ice at 40 K and lower dilution. However, the results presented by (4) are limited by the optical constants available for analysis.

Optical constants for pure CH_4 have been measured by (11). These optical constants cover the temperature range $20 < T < 90$ K at 10 K intervals. At the time of the observations, Eris' heliocentric distance was 96.7 AU. For an object with *zero* albedo, its blackbody temperature would be 29 K. The albedo of Eris has been estimated between 60 and 80% (12; 13; 14), which corresponds to a temperatures between 19 and 23 K. In this temperature range, CH_4 ice is likely to undergo a phase transition. Plase II CH_4 ice (hereafter CH_4(II)) occurs at temperatures below 20.4 K, where the CH_4 molecules form a cubic crystal. Phase I CH_4 ice (hereafter CH_4(I)) is stable between 20.4 K and the melting point at 90.7 K, and is an orientationally disordered phase (11). Comparison of the lab spectra from (11) show that the CH_4(II) ice spectrum is much like CH_4(I), but the absorption features are narrower and deeper. The possibility exists that the cold phase of CH_4 ice is present on Eris and it may not be detectable at low resolution ($\lambda/\Delta\lambda \lesssim 1000$).

We examined the spectrum of Eris by isolating the 1.67 and 1.72 μm CH_4 bands and comparing these to Hapke models. These bands are chosen because (i) CH_4(II) is more distinguished from CH_4(I) at these wavelengths and (ii) the SNR of the observations were higher than the bands longward of 1.8 μm. At the time of writing this abstract, the analysis was performed using optical constants for pure CH_4 because of the lack of optical constants for CH_4 diluted in N_2 between 15 and 30 K. We assume the spectrum of Eris is a spectral blend of both CH_4 phases. To model the spectrum, we used the CH_4 optical constants from (11). CH_4(II) ice is represented by their 20 K measurements, while optical constants for the CH_4(I) ice is estimated from a linear interpolation between measurements at $T > 30$ K, or a second order extrapolation of the data at $T > 30$ to estimate the optical constants at $20.4 < T < 30$ K. Each component is allowed to shift in wavelength.

Figures 1 & 2 show the spectrum of Eris centered

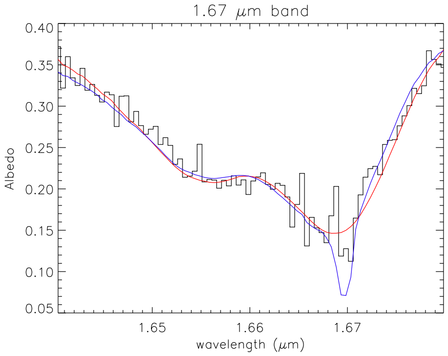

Figure 1: The Eris spectrum shown for then 1.67 μm band. The observations are compared to two models. The red curve is a model using pure CH_4(I) ice at 30 K CH_4 shifted by –6.8 Å. The blue model fits uses CH_4(I) ice at 26.8±4.5 K shifted $-6.0^{+2.5}_{-2.2}$ Å and CH_4(II) ice at 20 K shifted $-12.5^{+2.2}_{-2.0}$ Å

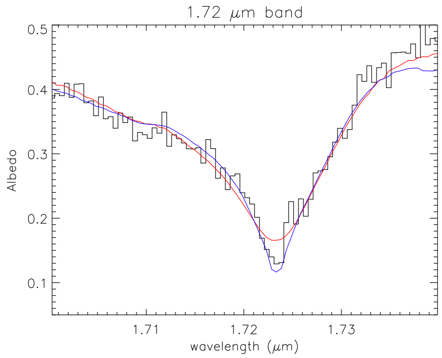

Figure 2: Similar to Fig. 1 but for the 1.72 μm band.

at 1.67 and 1.72 μm, respectively. Hapke models using optical constants for pure CH_4(I) ice at 30 K (red curve) and mixtures of CH_4(I) and (II) (blue curve) are shown in the figures. The addition of CH_4(II) improves the model fits, particularly the narrow minimum in Fig. 2. These preliminary results have led us to measure new optical constants for CH_4-N_2 mixtures at $35 > T > 15$ K. These results will be presented by (15). We will use these new optical constants and present our latest results.

Acknowledgements

JCC would like to acknowledge that this research was supported by an appointment to the NASA Postdoctoral Program at the Ames Research Center, administered by Oak Ridge Associated Universities through a contract with NASA.

References

[1] M. E. Brown, et al., *ApJL*, 635:L97–L100, 2005.

[2] J. Licandro, et al., *A&A*, 458:L5–L8, 2006.

[3] C. Dumas, et al., *A&A*, 471:331–334, 2007.

[4] A. Alvarez-Candal, et al., *A&A*, 2011.

[5] M. R. Abernathy, et al., *Icarus*, 199:520–525, 2009.

[6] S. Douté, et al., *Icarus*, 142:421–444, 1999.

[7] E. Quirico, et al., *Icarus*, 139:159–178, 1999.

[8] E. Quirico and B. Schmitt, *Icarus*, 127:354–378, 1997.

[9] S. C. Tegler, et al., *ApJ*, 725:1296–1305, 2010.

[10] S. D'Odorico, et al., In *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series*, volume 6269 of *Presented at the Society of Photo-Optical Instrumentation Engineers (SPIE) Conference*. 2006.

[11] W. M. Grundy, et al., *Icarus*, 155:486–496, 2002.

[12] F. Bertoldi, et al., *Nature*, 439:563–564, 2006.

[13] M. E. Brown, et al., *ApJL*, 643:L61–L63, 2006.

[14] J. Stansberry, et al., pages 161–179. 2008.

[15] R. M. Mastrapa, et al., In *This meeting*.