A BAND FOR DETECTING CARBON MONOXIDE MIXED WITH N2. J. Hanley[1], T. Stufflebeam[2], W. Grundy[1], S. Tegler[2], R. Dillingham[2], and E. Quirico[3]. [1]Lowell Observatory, Flagstaff, AZ; jhanley@lowell.edu, [2]Northern Arizona University, Flagstaff, AZ, [3]Université Grenoble Alpes / CNRS – IPAG, Grenoble, France.

Introduction: With the recent flyby of the Pluto system by the New Horizons probe, laboratory data of ices at cryogenic temperatures are required to adequately understand the data being returned. Little spectroscopic data exist over the range of temperatures expected in the outer solar system, and even less takes into account mixtures (Figure 1). To that end, we have started to systematically measure spectra of ices that are present in the outer solar system. While measuring a mixture of carbon monoxide (CO) and nitrogen (N_2), we noticed a band previously identified by Quirico and Schmitt [1], who had marked it with a question mark. With our systematic investigation, we believe to have a better understanding of the cause of this band now. An example of this spectrum is seen in Figure 2.

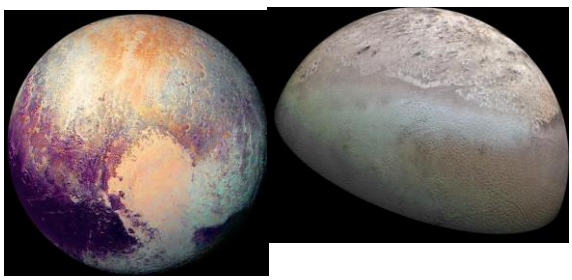

Figure 1. *Enhanced color views of Pluto (left) and Triton (right), two outer solar system worlds with surfaces sculpted by cryogenic ices N_2, CH_4, and CO.*

Methods: Carbon monoxide (CO) was mixed in varying concentrations with Nitrogen (N_2) as shown in Table 1. The gases were mixed by pressure, assuming the ideal gas law. For more information about the laboratory setup, see [2]. The 2 cm-thick cell was cooled to 65 K, just above nitrogen's freezing point, allowing the gases to condense as liquid in the cell. The sample was then cooled to 60 K and transmission spectra were acquired from 0.8-3.8 µm (12000-2600 cm^{-1}). A background was acquired with an empty cell at the same temperature after evacuation. After the background is divided out a Hamming filter is used to reduce the noise. The absorption coefficients are obtained from:

$$\log(I/I_0) * \log(10)/ L, \qquad (1)$$

Where I and I_0 are the initial and final beam intensities and L is the path length.

Results and Discussion: A band occurs at 2.239 µm (4466 cm^{-1}) when CO and N_2 are mixed, but does not occur in either endmember state. The band area ($(cm^{-1})^2$) increases as the percentage of CO increases, up to 50%. Then the area decreases symmetrically (Table 1, Figure 3). This implies that it is an interaction between the solid states of CO and N_2. The band is present when N2 is in both the beta and alpha phases. To further test this, we used different isotopes: ^{13}C in the CO (^{13}CO), ^{18}O in the CO ($C^{18}O$) and enriched $^{14}N_2$. The results are seen in Figure 4. The peak shifts with both the carbon and oxygen isotope. However, it does not change when $^{15}N_2{}^{14}N_2$ is depleted ($^{14}N_2$ enriched). The areas $(cm^{-1})^2$ for the band near 2.239 µm are 0.32 for 4% 13CO in N_2, 0.18 for 4.5% $C^{18}O$ in N_2, and 1.085 for 30% $^{14}N_2$-30% N_2 and 40% CO. We can also say it is not a simple matrix effect, as the band did not show up when Argon was mixed with either N_2 or CO.

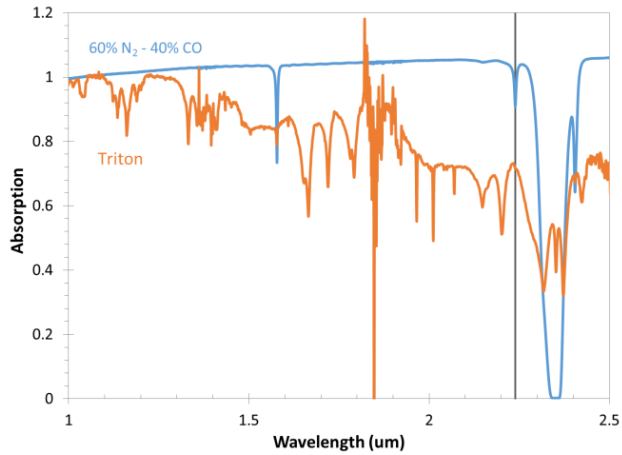

Figure 2*. NIR spectrum of 60% N_2 and 40% CO (blue) compared with cumulative Triton spectra (orange) [3]. The solid line is at 2.239 µm.*

When looking at the Triton spectrum (Figure 2), there appears to be a small band at 2.239 µm; however, it is difficult to tell whether this is within the noise. Unfortunately, the New Horizons probe does not have the spectral resolution required to identify this band, if present, on Pluto. Further high resolution spectroscopy will be required to definitively answer whether this band can be detected in natural systems that are far from the ideal conditions in the lab.

References: [1] Quirico, E. and B. Schmitt (1997) *Icarus*, *128*, 181-188. [2] Hanley, J., et al. (2016) *LPSC*, Abstract #2421. [3] Grundy, W.M., et al. (2010) *Icarus*, *205*, 594-604.

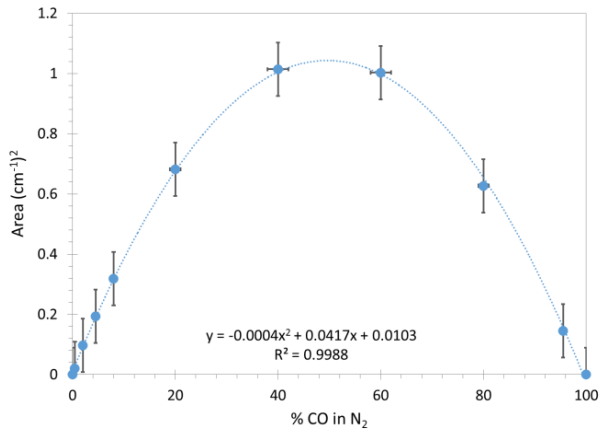

Figure 3. *Plot of band area versus concentration of CO in N_2.*

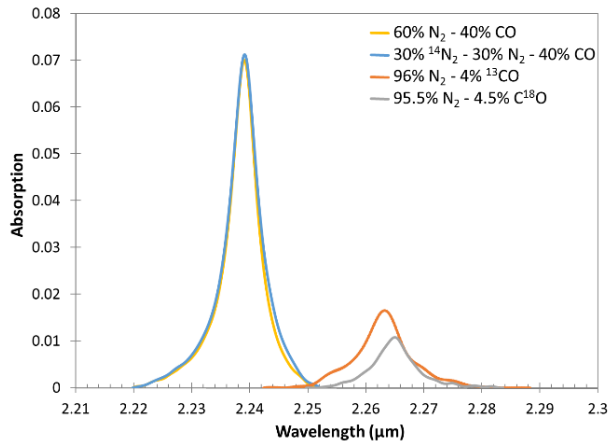

Figure 4. *Plot of 2.239 µm band for various isotopes.*

Table 1. *Area of the 2.239 µm band for the corresponding concentration of CO in N2.*

% of CO in N_2	Area $(cm^{-1})^2$
0	0
0.45	0.021
2	0.097
4.5	0.194
8	0.319
20	0.682
40	1.014
60	1.003
80	0.627
95.5	0.145
100	0