New rotationally resolved spectra of Pluto-Charon from 350 - 900 nm

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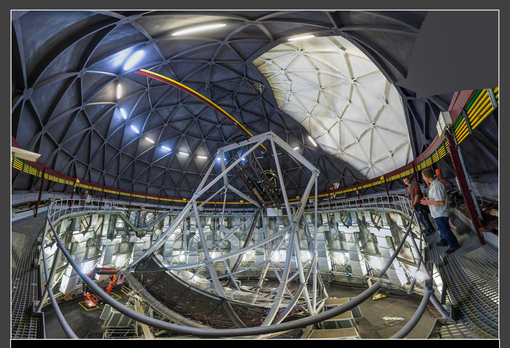
We used the 11-meter Southern African Large Telescope (SALT) to acquire high-resolution rotationally resolved visible spectra of Pluto-Charon. We use the Robert Stobie Spectrograph (RSS) to observe Pluto-Charon from 350 nm to 900 nm. At 500 nm, resolution is 0.05 nm (R ~10,0000) and SNR per spectral resolution element is ~500.

We planned observations for 13 dates during June-September of both 2014 and 2015. The observations for each season were spaced so as to equally sample Pluto's 6.5-day rotational period. We acquired data from 21 nights (13 in 2014, and 8 in 2015). Most of the observations were paired with observations of solar-type star 18 Sco to determine the surface reflectivity.

Our results will provide constraint on the composition and spatial distribution of material on Pluto's surface, enabling comparison to previous epochs and near-infrared results, and give a 'ground truth' for New Horizons' July 2015 flyby. In addition, our data will allow us to search for new spectral features in the range 350 nm to 600 nm, at a sensitivity substantially higher than previously published searches.



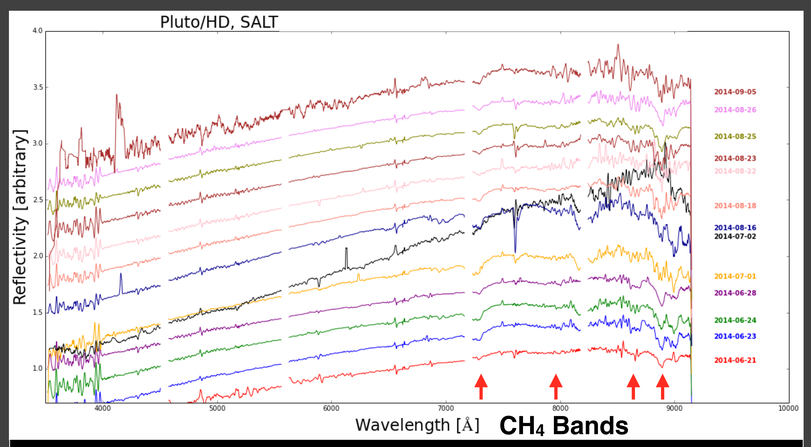
Robert Stobie Spectrograph (RSS)

SALT's RSS is a prime-focus facility spectrograph available to all SALT observers. It has a broad wavelength range, able to cover 350 - 900 nm in two grating tilts at R ~ 10,000. Because SALT does not yet support non-sidereal tracking, we aligned the 2.5" slit so as to be parallel with Pluto's direction of motion.

Southern African Large Telescope (SALT)

The site of the 11-meter SALT telescope in Sutherland is frequently visited by springbok, but large kudu, such as those pictured on the sign, are rare.

2014: 13 Pluto Visits



2014 Observations

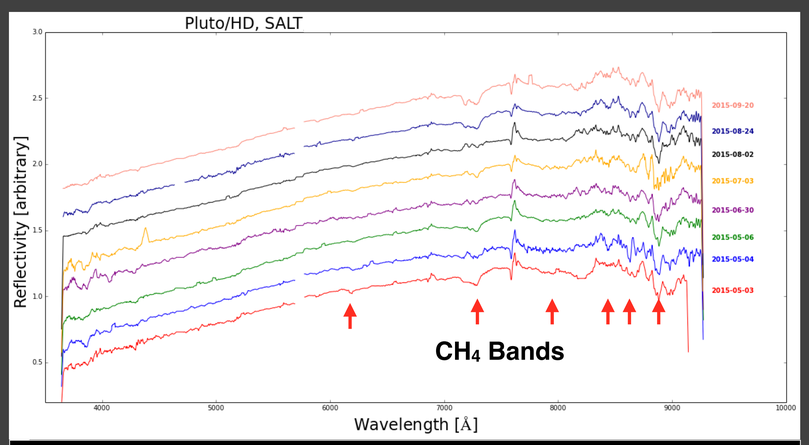
We used SALT on 13 nights during June-September 2014. The visits were arranged so as to sample Pluto uniformly in rotational longitude. Because SALT is queue-scheduled, our visits took only a small fraction of the night. Each visit consisted of 4 x 600-second integrations on Pluto (two grating tilts), reaching a spectral SNR ~500 in the visible. To obtain a normalized reflectivity, we also observed the solar analog star 18 Sco (HD 146233) on five nights. Because SALT points at a fixed elevation of 53°, our analog star was often observed several hours before or after Pluto. The spectra shown here are binned by 30 spectra elements, to a resolution of ~15 Å in the visible.

All spectra above show clearly the four CH_4 bands from 700-900 nm. The 720 nm band is cleanest, but a seam in the RSS detector array caused it to be only partially observed. Spectral bands toward 900 nm are visible, but affected by instrumental fringing.

Fringing, calibration, and/or atmospheric artifacts are seen at the far red and blue ends, and can probably be removed with improved reduction. The anomalous black curve in the middle is probably contaminated.

All spectra are for Pluto + Charon combined; the latter contributes ~15% of the total flux.

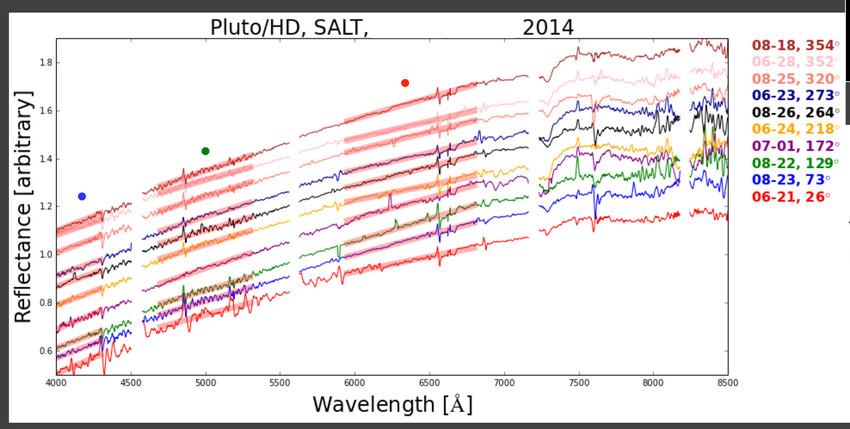
2015: 8 Pluto Visits

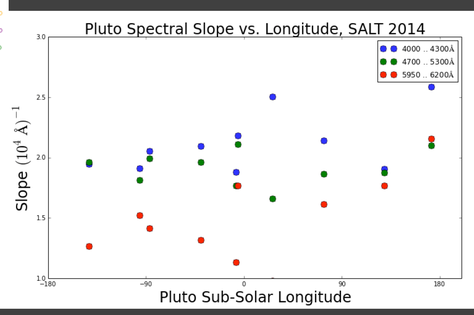


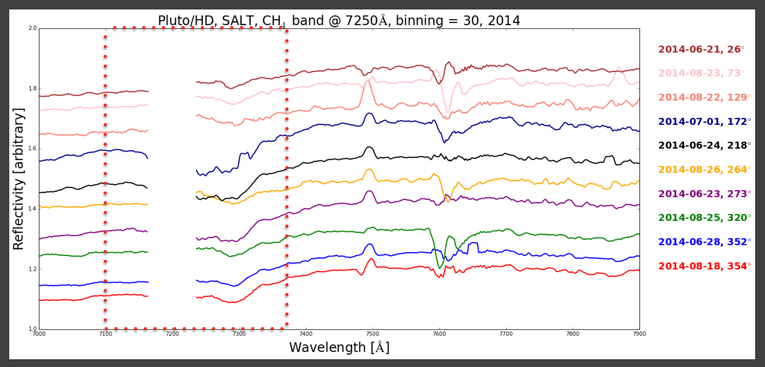
2015 Observations

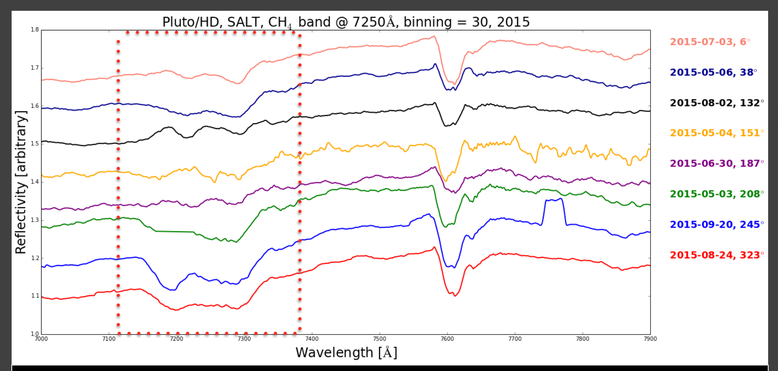
These observations again monitored Pluto for changes in its rotational spectrum. We improved on the 2014 observations by using multiple red tilts to cover the 720 nm CH4 band completely. We also took spectra of our 18 Sco solar analog after every visit to Pluto, to improve atmospheric subtraction.

These observations appear to show the faint 620 nm CH_4 band, first identified on Pluto by Cruikshank (2014).







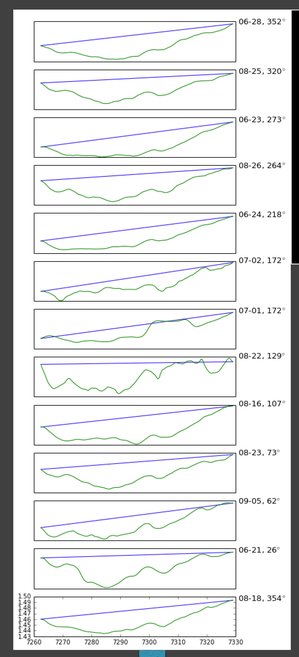


730 nm CH_4 Band

Marked here is the 730 nm CH_4 band, which is the cleanest of several CH_4 bands covered. The band (seen fully in 2015, but partly obscured in 2014 by a detector seam) has a distinct 'W' shape which is not seen in earlier spectra of Grundy & Fink (1994), which had a Gaussian-like shape. We are investigating the origin of this shape, and whether it could be diagnostic of surface properties, or an instrumental effect.

Continuum Spectral Slope

The region of Pluto from 400 - 700 nm is relatively free of spectral bands. However, the slope of the spectrum in these regions may be diagnostic of surface properties. Here we show the average slope in three broad spectral bands (red, green, blue, marked with colored dots). The spectral slope changes with rotational phase, but no consistent trend is seen.

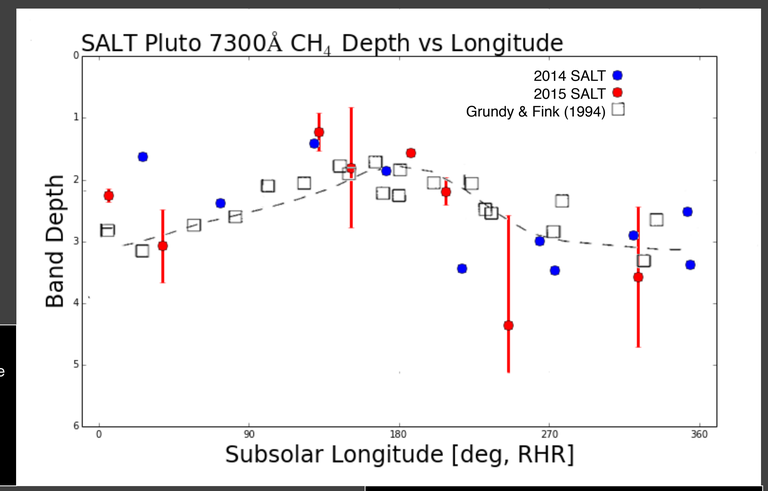


CH_4 Band Strength

We used two methods to measure band depths. At left is an example of band measurements by summing the area under a line spanning the band. Fitting a gaussian to the curve returned comparable results for simple bands, but was less reliable for W-shaped features. The errorbars in red (plot below) indicate the differences in line strength as measured by these two methods.

Significance for New Horizons

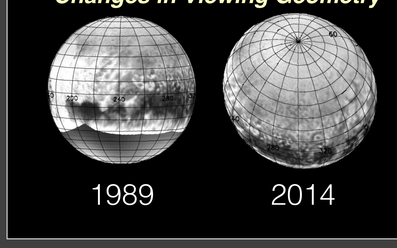
New Horizons carries two spectrometers: Alice (465-1880 Å) and Ralph/LEISA (1.25-2.5 μm). But neither of these instruments cover the visible range, and New Horizons' visible observations are limited to panchromatic or broad-band imaging from LORRI and Ralph/MVIC, and one Ralph/MVIC CH_4 filter at 0.84-0.91 μm. Thus, our observations are complementary to determining the distribution, abundance, and physical state of surface ices on Pluto.

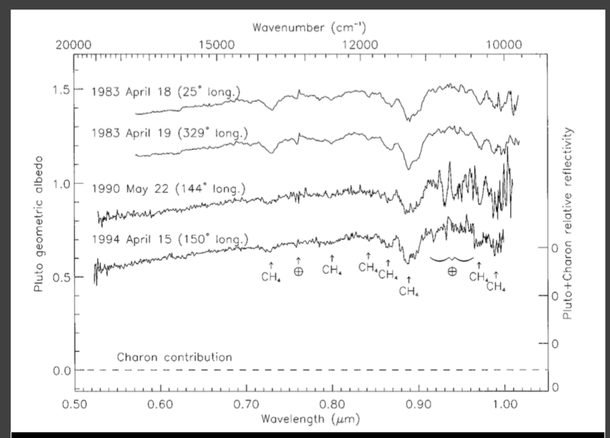


Results: Longitudinal CH_4 Distribution on Pluto

Our 2015 and 2014 band depth curves are plotted here. The rough structure of the curve is similar to that observed in 1994, with a peak in reflectivity near 180° longitude. Our data suggests a shallower CH_4 absorption near 0° longitude. This is consistent with changes in viewing geometry since, which reduce the contribution from Pluto's heterogeneous equatorial region.

Changes in Viewing Geometry





1994 Spectra

For comparison with our spectra, shown above are typical spectra from Grundy & Fink (1996), taken with the 61" University of Arizona telescope. The difference in shape of the CH_4 band at 730 nm is seen.

References

Cruikshank, D. P., Pinilla-Alonso, N., Lorenzi, V., Grundy, W. M., et al. (2014). Spectroscopy of Pluto at six longitudes, 380-930 nm. AAS/Division for Planetary Sciences Meeting.

Grundy, W. M., & Fink, U. (1996). Synoptic CCD Spectrophotometry of Pluto Over the Past 15 Years. *Icarus*, 124(1), 329–343.

Grundy, W. M., Olkin, C. B., Young, L. A., Buie, M. W., & Young, E. F. (2013). Near-infrared spectral monitoring of Pluto's ices: Spatial distribution and secular evolution. *Icarus*, *223*(2), 710–721.

Acknowledgements

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