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The double face of Triton: new observational results

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Abstract. Triton is one of the most peculiar satellites of the Solar System, for several reasons. First of all, for its retrograde orbit that makes of Triton a plausibly captured satellite. Moreover, Triton is synchronously rotating, so we can speak of leading and trailing sides. The analysis of the Voyager images showed remarkable differences between the two hemispheres, being the leading side much more cratered that the trailing one. The origin of this huge asymmetry is still not clearly understood. We think that some hints can arise from a spectral investigation of Triton's two faces. To this end, we obtained new observations of Triton with the ESO New Technology Telescope (La Silla, Chile) in October 2002. We discuss here the spectra and the differences between the two faces, and the implications of these findings for a better understanding of the surface composition of Triton.

Key words. Solar System

1. Observations and data reduction

The observations were made with the New Technology Telescope (NTT) in October 2002. The instrument used for the visible was EMMI with the Grism #1 and a slit of 1.0 arcsec. The resulting spectral range was from 0.38 to 1.0 μm with a resolution of 270 at 0.6 μm. For the near–infrared we used SOFI with a slit of 1.0 arcsec for both the Grism Blue and Grism Red. The spectral range was 0.95–1.64 μm and 1.53–2.52 μm respectively, with a resolution of about 1000 in both modes. Notice that the three parts (VIS, NIR B, NIR R) of the spectra overlap, making easier to build up the composite spectra.

We were interested to detect differences between the trailing side and the leading one of Triton, so we carefully selected two dates for which the maximum portion of each face was visible. Notice that Triton, owing to its inclination and to the obliquity of Neptune, always shows both faces to the Earth at the same time. However, for the selected dates, Triton showed us about 75% of one or of the other face (namely the maximum achievable from the ground, see fig. 1). Moreover, we wanted to observe for each night the full spectral range (0.4–2.4 μm) and at the minimum possible air mass, in order to minimize any external variation. This has been possible because of the quick instrument change, that took just half an hour.

The best dates to fulfill our requirements, based on visibility and orbital constraints, were 10th October 2002 (UT=00:00) for the leading side and 13th

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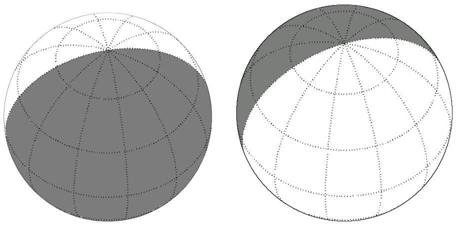

Fig. 1. The exact positions of Triton at the dates of observation (see text). The leading side is the shadowed hemisphere, so the picture on the left corresponds to 10 October (UT=00:00) and the picture on the right corresponds to 13 October (UT=00:00).

October 2002 (UT=00:00) for the trailing one. For each night, two solar analogues were observed for each instrument setting. The data have been reduced with standard techniques. We estimate that the final precision in wavelength of our spectra is of the order of 10 Å. Concerning the solar analogues, a good fit between their spectra has been achieved, indicating that the data were reliable and that the reduction was carried out in a proper way. In the final reduction, we gave more weight to the solar analogue which airmass closer to that of Triton. Finally, we got the *reflectivity* as division of Triton spectra by those of solar analogues.

2. The Spectra

In our spectra we detected the ices of N_2, CO_2, CH_4, H_2O and CO, as discussed in many works (see in the following). The overall behavior of the two faces of Triton is quite similar, although we found some interesting differences that we shall discuss with details in the following.

VISIBLE. In figure 2 the VIS and NIR spectra of the two faces are plotted one over the other (vertically shifted for clarity). The two faces seem similar, although subtle differences can be noted. First of all, both spectra are reddish shortward of 0.6 μm and become flat (trailing side) to slightly reddish (leading side) longward of 0.6 μm. The slope carries meaningful information. It is basically affected by mineral compounds placed on the surface or mixed with the upper layers of the surface ices. Differences in slope between the two faces can be explained by several ways. They can reflect differences in Triton's original composition, but they can originate also from the interior of Triton, because Triton has volcanic activity, or finally they can result from external process.

Moreover, a clear absorption band at 0.43 μm is seen only in the leading side (see tab. 1). The nature of this band is not yet understood, but it resembles a band observed in some E or C–type asteroids, usually attributed to troilite (FeS). In particular, another Saturn's satellite, Phoebe, shows a similar band (see Jarvis et al. (2000)) which has been attributed to Fe^{3+} spin–forbidden transition as observed in the spectrum of the iron sulfate jarosite ($KFe_3^{3+}(SO_4)_2OH)_6$). In both explanation this band does not seem related with the ices but rather with minerals. Notice that in previous visible spectrophotometry the band at 0.43 μm is not always present (e.g. see Tryka and Bosh (1999)), but it seems to be evident on Bell et al. (1979) and Cruikshank et al. (1979) data, in spite of their poor spectral resolution. Another weak absorption band is present at 0.81 μm only in the trailing side. Finally, a weak absorption band, stronger in the leading side than in the trailing one, is center at 0.89 μm. This band was also detected by Apt et al. (1983), although not so evident as in our spectra, and attributed to methane ice.

NEAR–INFRARED. Table 1 shows the detailed list of the identified NIR bands.

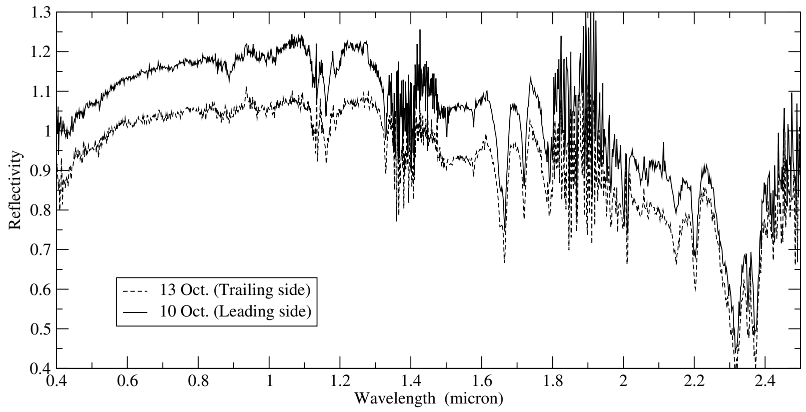

Fig. 2. Visible and near-infrared spectra of the two faces of Triton.

Many of them are well known (see for instance Quirico et al. (1999)), and others have been detected only recently (see Forni et al. (2001)). All these bands correspond to ices of CH_4, N_2, CO, CO_2 and H_2O. No validation of the three undefined bands at 1.7492 μm, 1.6826 μm and 1.5432 μm has been found (as also stated by Forni et al. (2001)). We find no big differences in composition between the leading and the trailing side, being all these bands present in both faces. However, owing to differences in the strengths of the bands, we argue that the two faces have not the same relative abundance of the detected ices. From figure 2, it is clearly seen that all the CH_4 bands in the leading side are slightly more pronounced, indicating a grater concentration of methane ice on this side. The same holds for the wide band at 1.00 μm.

Moreover, the undefined band at 1.50 μm is present only in the leading side. Differences between the two faces are also seen in the region of strong CH_4 absorption at 1.6–1.8 μm and 2.2–2.5 μm, but these regions can also be affected by the presence of the wide H_2O absorption bands. For this reason it is hard to distinguish exactly what is changing. These differences can be explained as a higher CH_4 and/or H_2O concentration in the leading side. Notice that CH_4 alone seems not to be sufficient to explain the differences in the regions 1.6–1.8 μm and 2.2–2.5 μm. For these regions, after rescaling the spectra of the two faces to the same continuum, the depth of the CH_4 absorption bands is greater by a factor of two compared to that of the same molecule found in the region 1.1–1.4 μm. For this reason we think that we are dealing also with differences in water ice between the two faces. Cruikshank et al. (2000) detected water ice on Triton, confirming earlier studies (Cruikshank at al. (1984)). In this work Cruikshank and coworkers tried to understand the nature of water ice on Triton, i.e. whether it is amorphous or crystalline, an issue not yet completely solved. In fact, although the model they used (N_2:CH_4:CO plus crystalline H_2O, see Quirico et al. (1999)) fits well with the observations, no clear evidence of the absorption band at

Region	*Position* (μm)	*Origin*	*Where*	*Region*	*Position* (μm)	*Origin*	*Where*
VIS	0.43	jaros.?	L	**NIR R**	1.78	CH_4	L/T
	0.81	?	T		1.79	CH_4	L/T
	0.89	CH_4	L/T		1.96	CO_2^*	L/T
NIR B	1.00	? w	L/T		2.00	?	L
	1.01	CH_4?n	L/T		2.01	CO_2	L/T
	1.13	CH_4	L/T		2.05	? n	L/T
	1.16	CH_4	L/T		2.05	H_2Ow	L/T
	1.19	CH_4	L/T		2.07	CO_2	L/T
	1.329	CH_4	L/T		2.126	?	L
	1.50	?	L		2.149	N_2	L/T
NIR R	1.55	H_2Ow	L/T		2.20	CH_4	L/T
	1.578	CO	L/T		2.31	CH_4	L/T
	1.655	CH_4	L/T		2.35	CO	L/T
	1.665	CH_4	L/T		2.37	CH_4	L/T
	1.72	CH_4	L/T		2.40	CO	L/T
					2.42	CH_4^*	L/T

Table 1. Bands detected in our Triton's spectra (L=leading, T=trailing, n=narrow band, w=wide band, *=noisy).

1.65 μm due to crystalline ice has been found. They argued that this band could be hidden by the strong CH_4 band at the same position. In our spectra we detected the 1.65 μm band on both faces, and in the leading side it is stronger than in the trailing side, but since this is also true for all the other CH_4 bands, we cannot be sure about the presence of crystalline ices and/or its differences of concentration over the two faces. Concerning CO and N_2, we found no significant difference between the two faces. On the contrary, CO_2 absorption bands at 2.01 μm and 2.07 μm (the 1.96 μm is too noisy) would indicate a major concentration of CO_2 in the leading side. Another interesting result is that the mean slope of our spectra in the NIR, and in particular in the 1.5–1.8 μm region, is much bluer then that of the spectra of Cruikshank et al. (2000).

References

Apt J., Carleton N. P. and Mackay C. D, ApJ 270, 342-350, 1983.

Bell J. F., Clark R. N., McCord T. B. and Cruikshank D. P., Bull. Am. Astron. Soc. 11, 570, 1979.

Cruikshank D. P., et al. Icarus 40, 104-114, 1979.

Cruikshank D. P., Brown H. and Clark R. N., Icarus 58, 293-305, 1984.

Cruikshank D. P., et al. Icarus 147, 309-316, 2000.

Forni O., et al. LPS XXXII, 2001.

Jarvis K. S., Vilas F., Larson S. M. and Gaffey M. J., Icarus 146, 125-132, 2000.

Quirico E., Douté S. and Schmitt B., Icarus 139, 159-178, 1999.

Tryka K. A. and Bosh A. S., Icarus 142, 571-574, 1999.