N92-10836

ANOMALOUS SCATTERING OF LIGHT ON TRITON

Paul Helfenstein, Pascal Lee, Derek McCarthy and Joseph Veverka
Center for Radiophysics and Space Research, Cornell University, Ithaca, NY 14853

Introduction: Since Voyager II's 1989 encounter with the Neptune system, significant progress has been made toward identifying and understanding the diverse color and photometric properties of Triton's terrains. Color variations on Triton's surface were recognized early on[1], and several detailed studies have since applied color analysis as a means of classifying different terrain units[2,3]. Recent photometric investigations of Triton have focused on average global properties of the surface[1,2,3,4,5,6]. Preliminary whole-disk phase curves for Triton[1] revealed an unusual upturn at large phase angles ($\alpha > 140°$) attributed to forward scattering from Triton's thin atmosphere. The photometric behavior of Triton's atmosphere has now been modeled[4,5] and average photometric properties of Triton's surface expressed in terms of the parameters of the well-known Hapke[7,8,9] photometric model for rough, particulate surfaces.

Surface-resolved variations in the photometric properties of individual terrains on Triton have not been studied in detail with the exception of an unsuccessful search for specular reflections as potential indicators of relatively smooth glazed ice patches on Triton's surface[10]. With the advent of an accurate photometric model for Triton's atmosphere[6], we have begun to study detailed differences in photometric properties of individual terrains. We report here the discovery of an isolated region of anomalously forward scattering materials on the surface of Triton.

Analytical Methods: We have employed two methods to examine phase-angle dependent differences in the photometric properties of Triton's terrains. The first, which we call the photometric ratio method, is an image processing technique by which we identify the presence, photometric character, and areal extent of a terrain whose photometric behavior with phase angle contrasts that of average Triton materials. We select two images obtained in the same Voyager filter wavelength, but at significantly different phase angles. Following the approach of Lee et al.[10], average global photometric parameters (for the specific Voyager wavelength) are applied to correct for broad-scale limb-to-terminator changes in brightness associated with varying incidence and emission angles. We reproject one of the "shading corrected" images to the other's viewing geometry, geometrically register common features, and then construct an image ratio. Albedo differences are eliminated (bland) in the photometric ratio images while regions that differ in photometric behavior with phase angle are accentuated in appearance.

Contrasting photometric behavior with phase angle may be caused by differences in regional macroscopic surface roughness (Hapke's $\bar{\theta}$ parameter) or/and the phase functions (characterized by the asymmetry factor g of the Henyey-Greenstein particle phase function) of constituent regolith particles. In our second analytical method, we attempt to distinguish quantitatively these two possible causes by performing least-squares fits of the Hapke model to disk-resolved observations over a wide variety of incidence, emission, and phase angles.

The boundary and interior of a distinctive region in a photometric ratio image is used as a location map for restricting photometric observations to the identical area in other Voyager images obtained over a range of phase angles. Best-fits of θ and g, as well as the average particle single scattering albedo ϖ_0, to these data can then be compared to average Triton parameters in order to see which properties best account for the anomaly.

Results: In the present investigation, we focus on the analysis of Voyager green-filter (λ=0.56 μm) images, for which the effects of atmospheric contributions are relatively minor[6]. Our photometric ratio image constructed from FDS 11394.16 (α=66.4°) and FDS 11396.11 (α=99.7°) reveals a large area of unusual scattering extending from about 10°N to 40°N in latitude and at least 60°E to 40°W in longitude (see Figure 1). At α=99.7°, this region's brightness relative to the surrounding bright frost material is greater than at α=66.4°. We've identified the region in five green-filter Voyager images covering phase angles 28°,39°,63°,67° and 100°, and sampled its brightness in each image over a variety of incidence and emission angles. To these data we obtained Hapke parameter fits of ϖ_0=0.978±0.001, g=-0.05±0.05, and $\bar{\theta}$=0°±22° (compared to ϖ_0=0.995, g=-0.23, θ=11.5° for average Triton materials[6]). Our one-sigma error estimates show that ϖ_0 and g are well-constrained, but constraints on $\bar{\theta}$ are poor. On the basis of present data, we can say only that the anomalous region's roughness is statistically indistinguishable from that of average Triton materials.

We have compared our photometric ratio image to Voyager green/violet color ratio images of Triton. In location, the area corresponds approximately to McEwen's[2] unit 1, and Thompson and Sagan's[3] class III, units 16, 22, and 24, which were classified on the basis of color *and* albedo. At large phase angles the anomalous region coincides with a distinct area of comparatively large green/violet color ratios. Its green/violet ratio at α=99.7° is 12% higher than for Frost Band materials and 6% higher than for average South Polar Cap materials. Not surprisingly, the contrast in green/violet ratios between the anomalous region and other terrains changes at different phase angles. While the anomalous region's green/violet ratio is uniformly larger than for any other visible terrain at α=99.7°, at α=28°, its green/violet ratio is typically 6% lower than for South Polar Cap materials, but 19% higher than for Frost Band materials.

Discussion: Our best-fit Hapke parameters indicate that regolith particles in the anomalous-scattering region are not only less backward scattering, but also slightly lower in single scattering albedo than average materials on Triton's surface. While it may be possible to account for such differences in terms of differences in particle size and transparency, it is also possible that the anomalous region is compositionally distinct from other terrains. It is noteworthy that, for the anomalous region, there exists a distinctively strong spatial correlation between the photometric ratios and green/violet color ratios at large phase angles, and that, relative to other terrains, the anomalous region reddens at a different rate with increasing phase angle.

We are currently analyzing additional Voyager violet and clear filter data in order to better distinguish how composition, particle-size, and particle structure may contribute to the distinctive photometric properties of the anomalous region. We are also investigating the relationship between color and photometric ratios as a means of globally mapping the areal extent of anomalous scattering materials. Our continued work on Hapke analysis of Voyager disk-resolved observations for other terrains on Triton offers the greatest promise for characterizing the physical properties that distinguish terrains, and for ultimately relating these properties to the geological and/or climatological agents responsible for their emplacement.

Acknowledgements: This research was supported by NASA Grants NAGW 2084, NSG 7156 and the Voyager project. We thank J. Hillier for use of his Triton atmosphere photometric model.

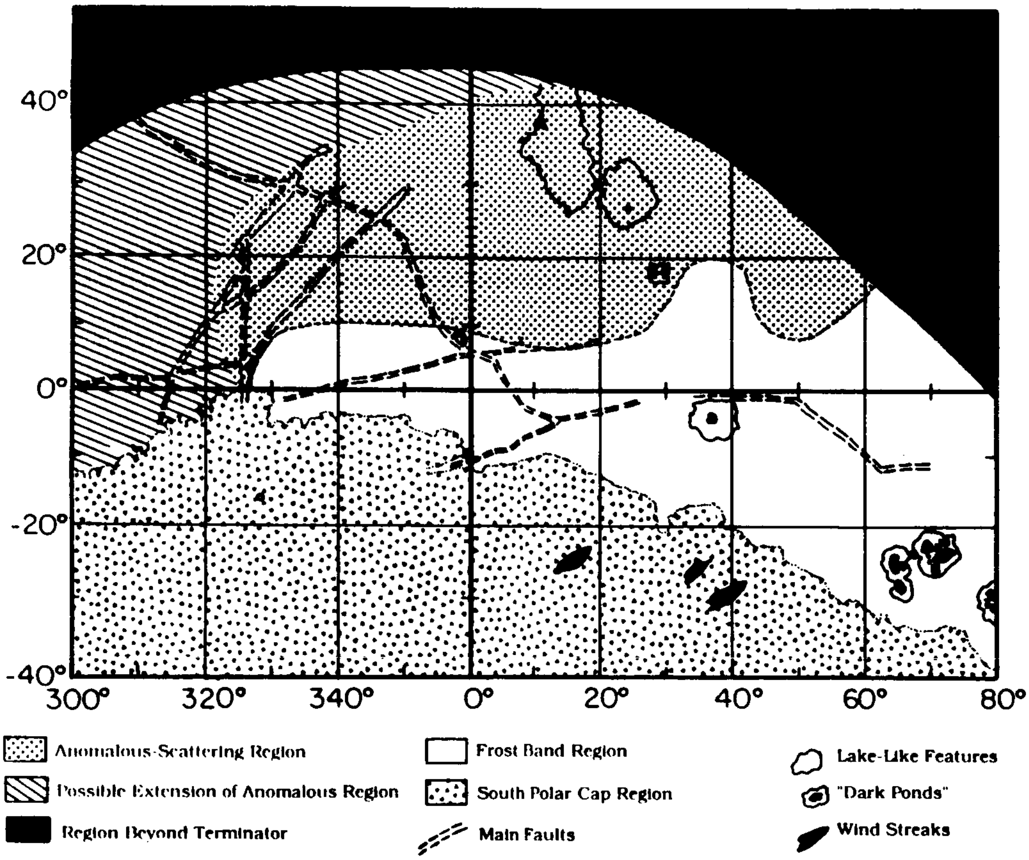

Fig. 1: Preliminary sketch map showing location and observed spatial extent of the region of anomalous light scattering.

REFERENCES: [1]Smith et al. (1989), Science **206**, 1422-1449. [2]McEwen, A. (1990), GRL **17**, 1733, [3]Thompson, W.R. and C. Sagan (1990), Science 250, 415-418. [4]Hillier et al.(1990), Science **250**, 419-421. [5]Hillier et al.(1991a), JGR submitted, [6]Hillier, J. et al.(1991b), JGR, submitted. [7]Hapke, B. (1981), JGR **86**, 3039-3054., [8]Hapke, B. (1984) Icarus **59**, 41. [9]Hapke, B. (1986) Icarus **67**, 264. [10]Lee, P. et al.(1991), JGR submitted. [11]Verbiscer et al. (1990), Nature **347**, 162-164.