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First Images of Titan at 1.3 Micron with the Adaptive Optics PUEO System at the CFHT

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Abstract. The first images of Titan at 1.3 micron were obtained with the PUEO adaptive optics system at the CFHT, on October 26 1998. We have also obtained images of Titan at 1.6 micron. Our diffraction-limited images (about 10 independent resolution elements or 20 pixels on the disk) pertain to Titan's leading hemisphere. We have used narrow-band filters centered outside (1.29, 1.6 μm) and in the wings (1.18, 1.64 μm) of the methane bands, so as to be able to subtract the atmospheric contribution from our data. Images of Titan's surface show the large equatorial region to be bright at both wavelengths. Combined with previous spectroscopic and imaging data, our findings are compatible with the presence of a mountainous plateau, covered with bright ice (perhaps methane), near the equator of Titan and with hydrocarbon deposits in the darker areas.

1. Introduction

Titan, Saturn's largest moon, has a thick atmosphere (1.5 bar), dominated by molecular nitrogen, where an active photochemistry producing hydrocarbons, nitriles and more complicated organics, as well as some oxygenated compounds occurs. As a consequence, the stratosphere of Titan is opaque in the visible spectral range and the surface has escaped direct detection, even in the conditions of a close fly-by (like Voyager 1).

Titan's surface was expected to be covered, at least partially, with liquid hydrocarbons in form of lakes or even a global ocean. A very different picture emerged, however, from recent observations in the near-infrared range, where methane atmospheric "windows" (centered at 0.94, 1.08, 1.28, 1.6 2.0, 2.8 and 4.9 μm) allow us to probe the lower atmosphere and surface of the satellite.

Previous images of Titan taken with the adaptive optics ADONIS system at ESO/Chile, allowed the study of the 1.6-2.0 micron region (Combes et al. 1997). These diffraction-limited images afforded high contrast and showed a) a well-defined bright equatorial region on the leading hemisphere, with 3 or possibly more peaks, and smaller, less contrasted features near the poles, all rotating over 6 consecutive nights at the expected rotation rate of Titan's solid body; and for the first time b) high-latitude bright zones on the trailing hemisphere and possibly all over Titan's disk, like polar caps. These findings were confirmed by the HST observations (Smith et al. 1996; Meier et al. 2000). ADONIS was, however, limited to long-wavelength observations.

2. The PUEO Titan observations

We have used the adaptive optics system, PUEO, at the CFHT, in Hawaii, (http://www.cfht.hawaii.edu/Instruments) to observe Titan in 1998, during excellent seeing conditions ($\sim 0.3''$). With our narrow-band filters we obtained images of Titan's atmosphere alone at 1.18 μm (J2) and at 1.64 μm (H2), and of the atmosphere and the surface together at 1.29 and 1.6 μm (J1 and H1). The FWHM in the filters is 0.15 μm for J1 and H1 and 0.10 μm for J2 and H2.

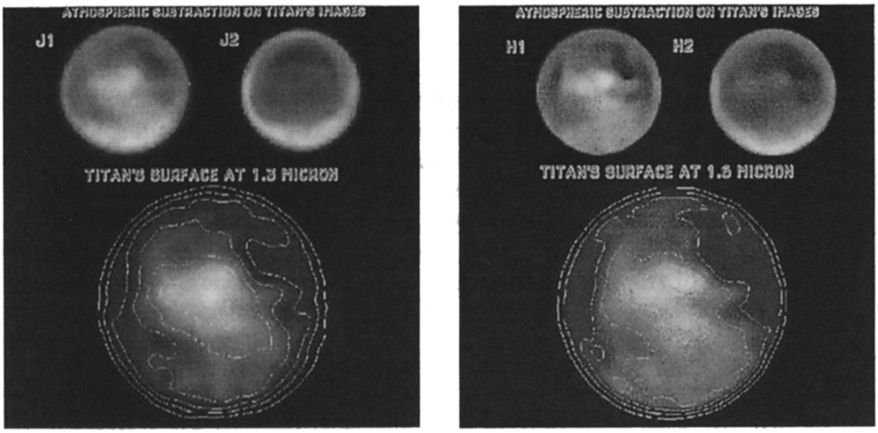

Figure 1. Images of Titan's leading hemisphere at 1.18, 1.29, 1.6 and 1.64 μm. The images were deconvoluted and corrected for center-to-limb effects. J1-kJ2 and H1-k'H2 subtractions allow us to recover images of Titan's surface (shown with isocontours). The bright feature centered at 5° South is observed, extending from 70° to 120° LCM, and over 30° in latitude, with several peaks 15-20% brighter than the surrounding regions. Note the bright extents in the N-W and the S-E regions, and the darker eastern and lower-western inlets.

The high-SNR J2 and H2 images allow us to subtract the atmospheric contribution from J1 and H1, thus recovering information on the surface (Coustenis et al. 2000a). Our Titan and the associated Point Spread Functions images are of high quality: the Strehl ratios are about 35% and 50 % in J and H respectively, while the contrast between the darkest and the brightest regions is of 35-45%, among the highest reported at these wavelengths to this date. As a consequence, we have been able to apply sophisticated reduction to our data and the deconvolution processes have allowed us to recover the full diffraction limit, about 10 individual resolution elements (or 20 pixels) on Titan's disk.

3. Results

The processed images of Titan's surface at Greatest Eastern show the equatorial region bright once more. All our adaptive optics images, at the three wavelengths (1.3, 1.6 and 2.0 μm), show the same morphology. The bright area consists of at least three individual components, or peaks, should this be a mountainous plateau. The very dark terrain in the North-East, at longitudes of about 110° E and close to the equator, is 3 to 3.3 times darker than the bright area. From values of Titan's geometric albedo (from FTS spectra, Coustenis et al., 2000b) and there-on based surface albedo spectra of Titan, we infer that the dark regions must correspond to roughly surface albedos of 0.1-0.3, whereas the brighter terrain albedos could be of 0.5-0.9 in the J and H bands.

By comparison with spectra of various ices that could exist on Titan, we find that only methane ice could account for the bright area observed at 0.94 and 1.08 μm (from HST data), as well as at 1.3, 1.6 and 2.0 μm (from adaptive optics). We are investigating the possibility for the presence of methane ice on Titan's surface at the equator, on top of a mountain, or at higher latitudes, where the temperature is expected to be lower than at the equator.

Photometry processes and more data are required to complete the analysis of Titan's surface spectrum and to infer information on the morphology and the constituents on the ground. Understanding the nature of Titan's surface will provide major clues for understanding the prebiotic chemistry processes in a primitive planetary atmosphere. Our ground-based observations give us an efficient tool to optimize the observing programme of the infrared instruments VIMS and DISR of the Cassini-Huygens ESA-NASA mission.

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