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Wavelength Choice for Titan Surface Imaging from a Future Orbital Mission

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Meta-Abstract

Tracking hazy light:
direct, additive, and blurred.
5 microns sees best.

1. Abstract

Titan's hazy atmosphere prevented *Voyager 1* from seeing much of its surface at visible wavelengths (Richardson et al., 2004). *Cassini*'s Visual and Infrared Mapping Spectrometer (VIMS) and Imaging Science Subsystem (ISS) have demonstrated that Titan's surface is visible in the near-infrared with resolution better than 1 km (Barnes et al., 2008; Karkoschka et al., 2018). Future Titan missions, however, will need to image Titan's surface with resolution better than 100 meters – perhaps as fine as 10 meters. We set out to determine whether such resolution is possible from orbit, and, if so, what the best wavelength(s) would be for such imaging.

Analytical approaches indicate that at a wavelength of 5 μm, at least 50% of photons arrive at the orbiter directly from the surface without having been scattered on the way out (using DISR-extrapolated extinction (Tomasko et al., 2008)). We call this the direct component. These photons carry full, diffraction-limited resolution at the surface. That fraction of direct photons rises to 88% using VIMS-measured atmospheric optical depths (Barnes et al., 2013). The fractions at 2 μm fall to 33% and 55% respectively using the two optical depth determinations – still respectable.

Confounding that direct component are the additive and blurred components. The additive component of the signal represents light that scatters off of atmospheric aerosols and emerges at the detector without ever having encountered Titan's surface. This component therefore is the same irrespective of the reflectivity of that surface, and it adds a constant bias signal across each individual image. That additive signal decreases contrast, and adds noise, but does not inherently inhibit fine-resolution imaging.

The blurred component is the troublesome one. These photons encounter the surface, but, on their way out, get scattered again by atmospheric haze. Thus they contain surface information, but not at full resolution. This component dominates the ISS surface imaging at 0.94 μm (Turtle et al., 2011), inhibiting its imaging of the surface at the diffraction limit.

To test the analytical calculation, we simulated Titan surface imaging using the Monte Carlo radiative transfer algorithm `SRTC++` (Barnes et al., 2018b). Initial, preliminary results are shown in Figure 1. These calculations indicate that full surface resolution, up to and including arbitrarily fine diffraction limits, can be recovered from imaging even at 2 μm. Viewing is even better at 5 μm, because higher contrast and less-significant additive and blurred components lead to higher signal-to-noise ratios (S/N) for a given integration time.

We therefore conclude (1) that imaging of Titan's surface at 10-meter scale resolution is possible from orbiting spacecraft, and (2) that both the 5 μm and 2 μm windows can work, with 5 μm achieving the necessary S/N at lower integration and/or with a smaller aperture.

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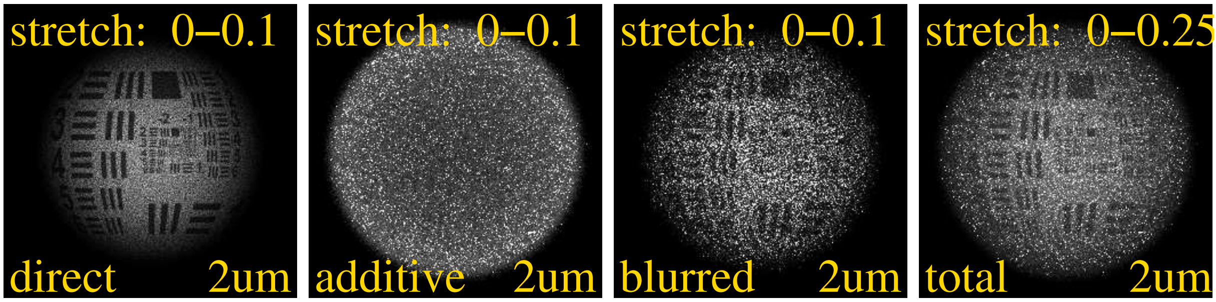

Figure 1: Initial results from `SRTC++` (Barnes et al., 2018a) showing the direct, additive, and blurred components of light coming to an orbiting detector from Titan's surface.

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