RADAR-BRIGHT CHANNELS ON TITAN A. Le Gall[1], M.A. Janssen[1], R.D. Lorenz[2], H. Zebker[3], L. Wye[3], P. Paillou[4] and the Cassini Radar Team. [1]Jet Propulsion Laboratory, California Institute of Technology, CA, [2]Space Department, Johns Hopkins University Applied Physics Laboratory, MD, [3]Stanford University, CA, [4]Observatoire Aquitain des Sciences de l'Univers, University of Bordeaux I, France

Abstract: In June 2008, during the T44 swath, the Cassini SAR (Synthetic Aperture Radar) observed sinuous channels in the South-west of the Xanadu region (Fig. 1 and 2). Some parts of these channels exhibit very large radar cross-sections, up to 5 dB whereas the angle of incidence was ~20°. This is larger than allowed by the coherent backscatter model considered to explain the unusual reflective and polarization properties of the icy satellites [1] and only a few radar scattering mechanisms can be responsible for such high radar returns.

We propose the presence of (transparent) rounded, icy rocks with size larger than the radar wavelength (2.18 cm) in the channels to explain the large radar cross-sections measured in these units, and discuss the geological implications.

This paper is intended to contribute to understanding the anomalously high radar backscatter measured in several regions of Titan and discussed in a companion paper [2].

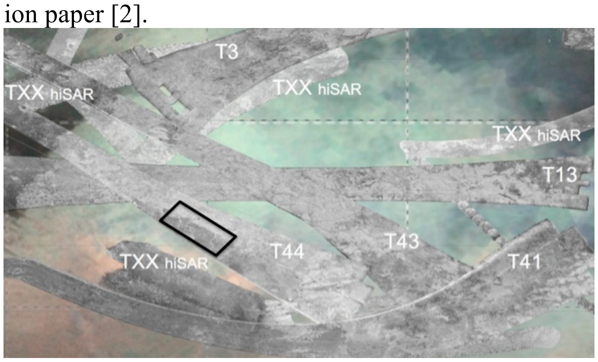

Fig. 1: Xanadu region observed by the Cassini SAR superimposed on a combination of VIMS and ISS observations. Radar-bright channels revealed during the T44 radar swath are outlined in black.

Radar-bright channels in South-west Xanadu: The channels revealed during the T44 swath are among the brightest units observed by the Cassini radar anywhere on Titan. Fig. 2 depicts their measured backscatter values. The highest radar cross-sections are close to 5 dB. Since parts of these channels probably have widths smaller than the pixelization of the radar reflectivity, their radar cross-sections may be underestimated.

The flows appear to originate from rugged terrains consisting of overlapping mountain ranges. Their origin is likely to be fluvial, formed by rainfall of methane. The meandering morphology suggests a low regional southward gradient [3].

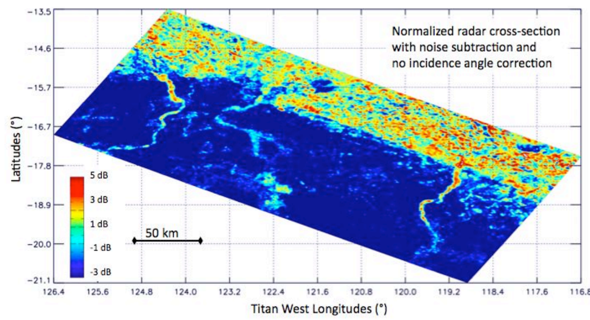

Fig. 2: Radar-bright rivers observed during the T44 radar swath with corresponding normalized radar cross-sections in dB.

Backscattering interpretation: On Titan, the effective averaged dielectric constant is low (~1.7) [4]; surface materials are hydrocarbons, tholins and, in some places, water ice, possibly with ammonia. In such conditions, it is difficult to explain the measurements of radar brightness higher than 3 dB at incidence angles of ~20°.

We might think of Titan's surface as similar to the surfaces of highly reflecting icy satellites such as Europa and Enceladus [5] which have been modeled with some success as low-loss inhomogeneous media that lead to multiple scattering and depolarization of incident radar signals. Coherent backscattering has been argued to explain the high reflectivities seen [1]. However, coherent backscattering cannot account for radar cross-sections in excess of 3 dB. Double bounce effect on the wall of the rivers will be a more efficient scattering mechanism but it is unlikely to occur in many places. We propose another hypothesis: channels are filled with rounded rock mainly composed of water-ice similar to those observed by the Huygens probe at its landing site.

Water-ice is a low loss medium; its microwave dielectric constant ε' is 3.13 and its loss tangent (ε''/ε') is less than 10^{-3} [6]. It has long been known that transparent (or low-loss) spheres with diameter larger than the wavelength backscatter significantly more (of about an order of magnitude) than metal spheres of the same size [7][8][9]. This results from internal reflection on the rear surface of the sphere (Fig. 3). Scattering by transparent spheres has been well described by the Mie theory. Fig. 4 shows the theoretical Mie radar cross-section for a wavelength of 2.18 cm as a function of a, the radius of the spheres, for values ranging from 0.1 to 150 cm. The radar cross-section σ of the ice spheres is normalized with respect to the corresponding geometric cross-section πa^2. It reaches a maximum of ~15 dB for a sphere radius of ~20 cm at the wavelength of 2.18 cm. For a sphere with radius values ranging from ~ 2 cm to 20 cm, the radar cross-section is higher than 5 dB. As the sphere grows larger (a>50 cm), its normalized cross section approaches the reflectivity of a plane surface and thus its geometric optics limit (~ -5 dB). The scattering properties of transparent spheres is commonly exploited in the manufacture of reflective paint.

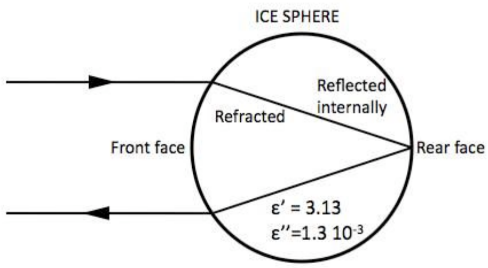

Fig. 3: Diagram of backscattering by ice spheres.

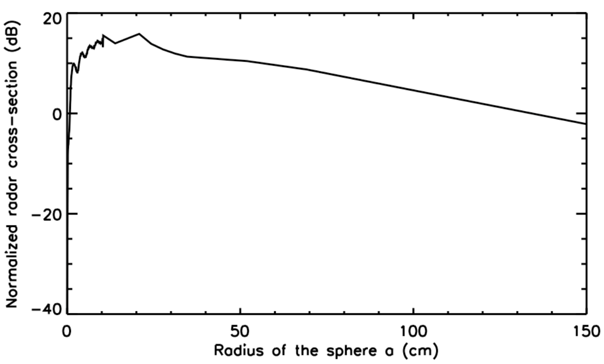

Fig. 4: Theoretical smoothed Mie normalized radar cross-section $\sigma/\pi a^2$ as a function of a for ice spheres at the wavelength of 2.18 cm. Figure adapted from [6].

Geological interpretation: Fluvial erosion on Titan is likely to be similar to fluvial erosion on the Earth [10] and may be responsible for the roundish shape of the (icy) rocks. [11] also points out that the transport of coarse sediments (derived from Titan's water ice crust) during overland flow events may be common on Titan.

Our interpretation of the channels enhanced reflectivity is consistent with the observations made by the Huygens probe on its landing site which has been identified as a dry riverbed or a basin downhill from several channel networks [12][13]. The Huygens probe provided images of a surface covered with rock-like objects ~5-15 cm large and composed of dirty water-ice. Evidence of erosion at the base of these icy rocks also strongly suggest fluvial activity.

Discussion and future work: Huygens images suggest that icy boulders present on Titan surface are sometimes better described as oblate spheroids (cobbles) than as true spheres. Scattering from spheroids is still well described by the Mie theory when their size is on the order of the wavelength but generally departs from this theory when they are much larger [14]. However, since ice spheres can easily have a backscatter cross-section as high as 15 dB, which is much more than needed to explain radar observations, we can reasonably assume that transparent oblate spheroids can also be responsible for the high radar cross-section measured. Some experiments even suggest that oblate ice spheroids can exhibit higher reflectivities than ice spheres for certain attitudes to the beam of radiation [15]. In a near future, we will investigate carefully the scattering efficiency of transparent large spheroids as a function of their size and degree of non-sphericity.

Constraining the channels environment might help in understanding other radar-bright areas of Titan. In particular, triangular radar-bright regions have been identified at the end of some channels. They may be alluvial fans strewn with icy cobbles or boulders transported by rivers. For instance, Leilah Fluctus (Fig. 5), in the vicinity of Ganesa Macula, appears clearly on the 3-D flyover of the digital topographic model of the stereo overlap area between Ta and T23 as an alluvial flow associated with bright channels coming out from the surrounding mountains [16].

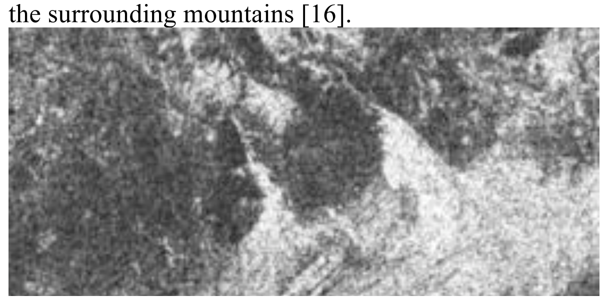

Fig. 5: Leilah Fluctus observed during the Ta swath.

References: [1] Hapke B. (1990), *Icarus* [2] Janssen et al. (2009), this meeting [3] Radebaugh J. et al., in preparation [4] Janssen M.A. et al. (2009), *Icarus* [5] Ostro et al. (2006), Icarus [6] Paillou P. (2008), *GRL* [7] Herman and Battan (1961), *Quart. J. Roy. Met. Soc.* [8] Glover and Atlas (1963), *Journal of applied mathematics and physics* [9] Pettengill and Hagfors (1974), *Icarus* [10] Collins G.C (2005), *GRL* [11] Burr et al. (2006), *Icarus* [12] Lebreton J.P. et al. (2005), *Nature* [13] Keller H.U. et al (2008), *PPS* [14] McGuire and Hapke (1995), *Icarus* [15] Macklin and Ludlam (1961), *Quart. J. Roy. Met. Soc.* [16] Kirk R.L. et al. (2009), this meeting

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