JET: JOURNEY TO ENCELADUS AND TITAN

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Introduction: The Cassini-Huygens mission has demonstrated that Enceladus and Titan represent two crucial end-members in our understanding of planet/moon formation that might have habitable environments. Enceladus is a small icy world with active jets of water erupting from its surface (Fig. 1) that might be connected to a subsurface water ocean. Titan is the only moon with a dense atmosphere and the only object besides Earth with stable open bodies of liquid on its surface (Fig. 2). An organic-rich world, Titan has a methane cycle comparable in atmospheric and geological processes to Earth's water cycle.

The questions that JET would answer directly respond to the wealth of discoveries made by the Cassini-Huygens mission. High-resolution mapping of Titan surface is required to determine what processes have shaped and are shaping Titan. High-resolution mass spectroscopy would permit assessment of the astrobiological potential of Enceladus and Titan.

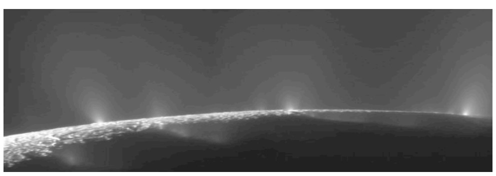

Fig. 1. Jets emanating from faults on Enceladus form a plume that provides access to internally processed material that can be studied in situ.

Concept: The JET mission has been proposed in response to the 2010 NASA Discovery Announcement of Opportunity. In order to achieve JET's rich science return within the Discovery cost cap, a planetary orbiter with a simple, two-instrument, but powerful payload would make a total of 16 flybys of Enceladus and Titan. The only new technology is the NASA-provided Advanced Stirling Radioisotope Generator (ASRG) that would be validated as part of the Discovery Program's engineering goals.

Along with making new observations of Enceladus and Titan, JET would fill a critical temporal gap in our understanding of the Saturnian system. Enceladus and Titan have near-equatorial orbits around Saturn, and Saturn has an inclination of 26º relative to its orbital plane around the Sun. Consequently, Saturn and its moons have seasons. Voyager briefly observed Saturn and its moons during the Saturnian Vernal equinox. Cassini observations extend from winter solstice to the summer solstice. JET would observe Titan during autumnal equinox, an opportunity that will not arise again until 2054. Observations during the Autumnal equinox are critical to understanding the fate of lakes and seas, Titan's complex meteorological cycle, and the fate of organic molecules.

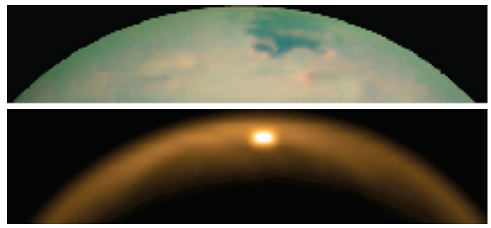

Fig. 2. Specular reflection at 5 µm from Jingpo Lacus, Titan [1] demonstrates the lack of scattering in Titan's atmosphere at 5 µm (Credit: NASA/UA). JET exploits this unexpected "window."

Science: The three goals of the mission are to determine the processes that have shaped and are shaping Titan, to assess the astrobiological potential of Enceladus and Titan, and to investigate the formation and evolution of Enceladus and Titan. These three goals are then detailed in eleven science objectives and thirty-one science questions that cannot be answered by the Cassini mission. Three examples are given. First, the Cassini mission has discovered that mass 28 in Enceladus' plume has possible CO, N_2 and/or hydrocarbon components. JET would confirm what fraction is CO vs. N_2 vs. hydrocarbons. Second, the Cassini-Huygens mission has discovered that rivers and valleys are carved into plateaus and mountains. JET would search for sedimentary layering in valleys to determine the history of the flows. Third, Cassini has discovered that heavy molecules (m>100 Da) are produced in Titan's upper atmosphere. JET would determine the nature of these molecules. This list of questions includes ten of the major discoveries of the Cassini mission that await a more capable mission to unveil the geological history and astrobiological potential of these two unique moons in the solar system. JET's payload—a camera (TIGER [Titan Imaging and Geology, Enceladus Reconnaissance]) and a mass spectrometer (STEAM [Spectrometer for Titan and Enceladus Astrobiology Mission]—would provide the capability for achieving these science goals.

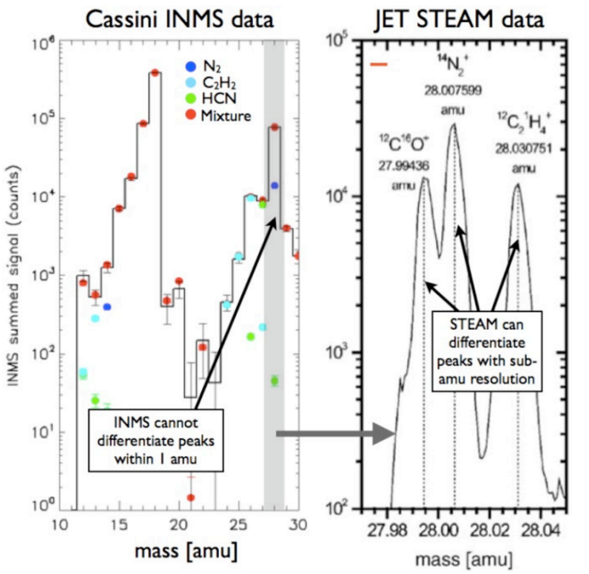

Fig. 3. STEAM (right) has 10^2 better mass resolution and 10^3 better sensitivity than Cassini/INMS (left). Mass 28 and 40 will be definitively characterized.

Instruments: The payload is limited to two powerful instruments and the radioscience investigation. The total data volume would be on the order of 120 Gb during the one year nominal mission.

STEAM: The reflectron time of flight mass spectrometer [2] is the Rosetta flight-spare of the Rosina mass spectrometer. It would characterize elements and molecules including complex organic molecules with a 10× larger mass range, 100× higher resolution, and 1000× better sensitivity than Cassini (Fig. 3). It would resolve fundamental issues related to the chemical composition of Enceladus' jets and their relationship to the structure and evolution of Enceladus' interior. STEAM would also characterize Titan's organic-rich upper atmosphere.

TIGER: This high-heritage IR camera exploits four IR windows through Titan's haze and would image the heat of Enceladus' fractures (Fig. 4). This camera uses the 5 μm window [3] to provide 10× better imaging resolution of Titan's surface than Cassini, yielding 50 m/pix images of 15% of Titan's surface. At each Titan flyby, an area twice as large as France would be mapped at 50 m/pixel in addition to Titan full disk at 500 m/pixel. The 50 m/pixel resolution is achieved at 2250 km from Titan's surface. Currently, only ~10^{-6} of Titan's surface area was imaged at this resolution by the Huygens probe. JET would deliver a five order of magnitude increase in coverage of high-resolution imagery of Titan's surface. Similarly, TIGER would provide 10 m/pix images of selected Enceladus' tiger stripe fractures, permitting detailed thermal modeling.

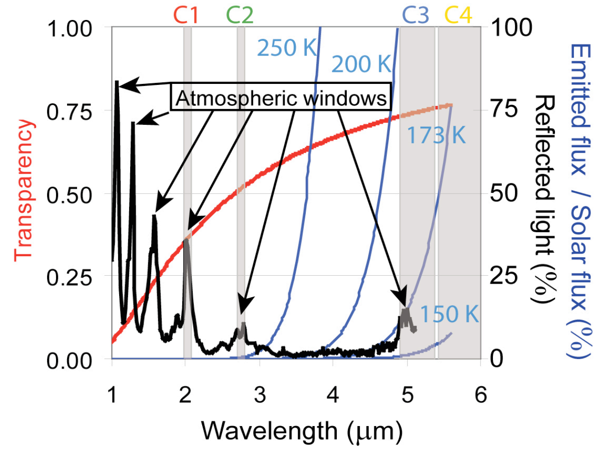

Fig. 4. Cassini/VIMS spectra of Titan revealed a major surprise: the surface is visible in several atmospheric windows. High resolution surface imaging requires a careful balance between spectral regions of high transparency and low absorption, matched appropriately with detector sensitivity. The red curve shows the transparency of Titan's atmosphere. The black curve is a typical reflected spectrum of Titan where high values show low absorption. The four TIGER channels (C1 to C4) shown in grey are optimized for these critical parameters. C3 and C4 provide thermal emission maps of EnceladusJets emanating from faults on Enceladus form a plume that provides access to internally processed material that can be studied in situ

Mission: The mission would be launched in February 2016 and would be inserted into Saturn's system in May 2023. The nominal one-year mission would start with 12 Titan flybys with the closest ones at 900 km from Titan'surface. This distance would vary from one flyby to the other in order to sample different layers of the upper atmosphere. Both Saturn and anti-Saturn hemispheres would be mapped. The Titan phase would be followed by 4 Enceladus flybys to sample the different jets of the South pole. The nominal end of mission would be a Dione disposal. A 6-year science enhancement option would permit to get into Titan orbit, offering the opportunity to further test the ASRG and to relay data from any element present on Titan's surface or in its low atmosphere at that time.

References: [1] Stephan K. et al. (2010) *GRL*, 37, L07104. [2] Scherer S. et al. (2006) *Int. J. Mass Spectrometry*, 251, 73–81. [3] LeMouelic S. et al. (2011) *LPS XLII*.