Simulation of the Emission of Titan's Eclipsed Atmosphere

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Titan is unique among the planetary satellites within the solar system in that it has a substantial atmosphere, one which gives the moon a surface pressure of 1.5 bars. This atmosphere, to zeroth order, consists of 98.4% Nitrogen (N_2) and, to first order, 1.4% methane (CH_4), also containing trace amounts of hydrogen and other gasses (Lindal et al. 1983). This atmosphere impacts the climate and temperature of Titan in a number of ways (Lebonnois et al. 2012).

Titan's atmosphere is bombarded by a number of sources of energy, including solar radiation, cosmic rays, and stray particles (electrons, protons, and ions) from Saturn's magnetospheric plasma. These sources can be hard to separate, as high-energy solar radiation often reaches the night side of the satellite, contributing to ionization there as well. (Agren et al. 2009) However, Titan is eclipsed by Saturn on occasion, and these events can be used to observe conditions on Titan with minimal solar interference. Ajello et al. (2012) observed one such event using Cassini in 2009, during the Spring equinox of the Saturnian system, and found that Titan showed a weak but quasi-homogeneous airglow during that eclipse.

There is therefore some evidence that non-solar sources of radiation contribute a significant amount to the ionization in Titan's atmosphere. Lavvas et al. (2014) provided a detailed analysis of said 2009 eclipse data, running simulations of radiative transfer in Titan's atmosphere. These simulations involve Rayleigh scattering from Nitrogen, absorbtion by various Hydrogen-Carbon-Nitrogen compounds (CH_4, C_2H_2, C_2H_4, C_2H_6, C_4H2, C_6H_6, HCN and HC_3N), and aerosol extinction, using values given in Lavvas et al. (2008) for their respective chemical abundances. The results show Titan's emissions to be consistent with those produced by energy input from particles withing Saturn's magnetosphere, particularly from electrons. However, the expected values for emission from their simulations are 3 orders of magnitude less than what is actually observed, a difference which they argue reflectance of direct starlight (from the stellar background) is responsible. (Lavvas et al. 2014)

The original simulations make use of chemical abundances abundances found in Lavvas et al. (2008) I plan to reproduce these simulations of atmospheric emissions from the disk of Titan, simulating radiances along optically thick (height above surface level<300km) and thin (height above surface level>300km regimes. For the higher altitudes, I will simply integrate the emission along the line of sight as a function of ray tangent height in the spherical shell geometry. For the lower (thick disk) altitudes, I will use the DISORT radiative transfer subroutine in the plane-parallel, scalar approximation to compute the intensity of both airglow and reflected light. (Stamnes et al., 1988)

Once I have reproduced their results, I will then rerun the simulations with varying chemical abundances to see if I can get results that vary significantly from those of Lavvas et al. 2014. The scope of this project will ultimately depend on how far I am able to progress with my simulations in the next two months, but I aim to be able to, at a minimum, reproduce the simulated spectra they give in their 2014 paper. More optimistically, I hope to be able to use errors in the measured abundances of some of the molecules in Titan's atmosphere (e.g. Niemann et al. 2010) to get limiting cases for how much the emission can be made to vary using different allowable abundances.

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