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The Atmosphere of Triton Observed With ALMA

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Abstract

Thermal continuum and spectral line observations of Triton were performed in the 870 micron window in October 2016 using the Atacama Large Millimeter/Submillimeter Array (ALMA). We find an average brightness temperature of 31.9±2.5 K for the surface, very similar to that found for Pluto in 2015 with the same ALMA spectral setup. We also detect emission from the CO(3-2) and HCN(4-3) rotation transitions, originating in Triton's atmosphere. The CO mole fraction ranges from 30-230 ppm, depending on the assumed surface pressure.

1. Introduction

Triton, along with Pluto, holds unique clues for understanding the composition and evolution of the outer solar system. They represent two of the largest known and most easily observed KBO members (from Earth, but with caveats), and they are similar in many ways; for one example, they both possess thin (10 microbar class), N_2-dominated atmospheres.

The surface, atmospheric structure, and escape rate are tightly connected on these bodies. The N_2 atmosphere, in at least bulk vapor-pressure equilibrium with N_2 ice, depends critically on surface temperature. Minor species (CH_4, CO) and photochemical products (such as HCN) control the temperature structure, and thus the escape rate. Escape rates of volatiles are powerful tools for understanding surface evolution on Triton, Pluto, Charon, Eris, Orcus and other KBOs [5]. While only Pluto and Triton have known atmospheres, other dwarf planets and large KBOs may retain enough volatiles to develop sublimation atmospheres near perihelion. Such atmospheres may be common in other stellar systems as well.

2. ALMA

The Atacama Large Millimeter/Submillimeter Array consists of a main array of fifty 12-m antennas with baselines up to 16 km, located on the Chajnantor plateau at 5000m altitude in northern Chile. The unprecedented sensitivity and resolution of ALMA now allows for detailed investigations of even small distant worlds like Triton, Pluto and Charon, and other larger (>250 km) KBOs in thermal emission, as well as molecular line emission from atmospheric species such as CO and HCN on Triton and Pluto. While not approaching the extreme detail and complex science suite provided by New Horizons in the Pluto system flyby ([6], etc.), ALMA does provide the capability to resolve Triton/Pluto sized bodies by up to 10 linear resolution elements in thermal emission [1], and 2-3 elements for spectral line observations from minor atmospheric species [4].

3. Triton

In 2015 we obtained very successful observations of the Pluto system using ALMA just one month prior to the New Horizons flyby. Highlights included very high SNR imaging of the thermal continuum of Pluto and Charon separately [1], as well as the confirmation of atmospheric CO (515 ppm) and the first detection of HCN, which suggested it was highly supersaturated above 400 km altitude [3].

Our success with Pluto atmospheric observations motivated a new study of the atmosphere and surface of Triton using the same techniques [2]. While larger and possessing a similar atmosphere to Pluto, high dynamic range observations of Triton are difficult due to the proximity of Neptune, whose flux density is order 10^3 that of Triton. Observations were obtained October 25 and 26, 2016 using ALMA, providing baselines ranging from 19 m to 1.4 km. During the observations Triton ranged between 13.6″ and 16.6″ from Neptune, and was just over 127 mas in diameter. The spectral coverage was nearly identical to the 2015 observations of Pluto, covering CO(3-2) and HCN(4-3). The FWHM of the ALMA primary beam is about 18″ at these frequencies; thus Neptune was not fully excluded, and significant sidelobes affected the imaging. Using a spatial high-pass visibility filter (using spatial frequencies >400 kλ), we effectively eliminated confusion from Neptune, providing high dynamic range imaging of Triton at 155 mas x 122 mas resolution. The thermal continuum of Triton was 27.1$\pm$0.3 mJy at 355.6 GHz, equivalent to a mean TB of 31.9$\pm$0.4 K (formal error, systematic error $\sim$2.5 K); for comparison this is (within errors) the same as Pluto's brightness temperature measured in 2015 [1], further emphasizing their similarity.

These observations also yielded strong, spectrally resolved detections of both CO and HCN line emission (Figure 1). While dependent on the atmospheric surface pressure (which is not determined from these observations since N_2 is not detectable by ALMA), the CO mole fraction is between 30 ppm (30 microbar surface pressure) and 230 ppm (11 microbar surface pressure), a range suggested by stellar occultations. The HCN line, unlike on Pluto, does not suggest any supersaturation in the upper atmosphere of Triton. Analysis of both lines is still ongoing, and will also yield a temperature profile for the lower 200 km of Triton's atmosphere.

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Figures

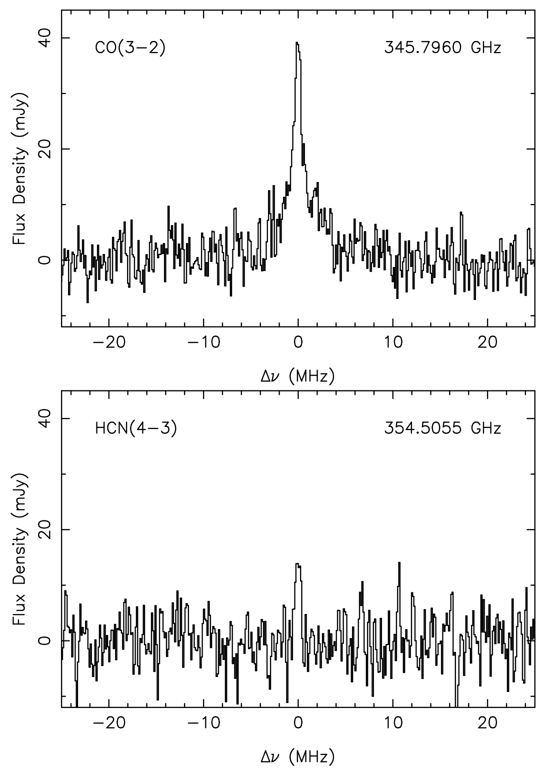

Figure 1: Figure 1. CO(3-2) (*top*) and HCN(4-3) (*bottom*) rotational line emission above continuum from the atmosphere of Triton.