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Temporal Variability of Titan's High-Altitude Zonal Winds Detected using ALMA

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Abstract:

Using spectrally and spatially resolved observations of Titan made with the Atacama Large Millimeter/submillimeter Array (ALMA) in August 2016 and May 2017, we obtained global snapshot maps of emission lines from atmospheric CH_3CN, HC_3N and HNC gases. High-altitude wind fields (in the altitude range ~300-1000 km) were retrieved through Doppler mapping, confirming the existence of high-velocity superrotating zonal winds on Titan, with speeds in the range 180-390 m/s near the equator (speeds increasing with altitude). At the highest, thermospheric altitudes probed by HNC, a ~50% reduction in the equatorial zonal wind speed was measured over the 9-month period covered by these observations. This is consistent with a dramatic slowing of the recently-discovered thermospheric equatorial jet. The implications of this result for our understanding of Titan's global circulation, and the forcing mechanisms impacting the uppermost atmosphere, will be discussed.

1. Introduction

Saturn's largest moon, Titan has an unusually thick, dense (1.45 bar) atmosphere comprised predominantly of molecular nitrogen and methane, subject to a complex atmospheric chemistry and seasonally-evolving pattern of winds and global circulation [1]. The presence of zonal winds on Titan was initially inferred from stellar occultation observations [2], and later confirmed by in-situ Doppler measurements during the descent of the Cassini-Huygens probe [3]. More recently, Lellouch et al. [4] took advantage of the extremently high sensitivity and resolution of the Atacama Large Millimeter/submillimeter Array (ALMA) to derive the first Doppler wind maps of Titan's thermosphere. An unexpectedly intense, superrotating equatorial jet was discovered at thermospheric altitudes (~1000 km), with a velocity of ~350 ms-1. Here we present new measurements of Titan's high-altitude wind field using ALMA observations from May 2017, compared with a re-analysis of the August 2016 data from Lellouch et al. [4].

2. Results

We used Gaussian fits to the observed sub-mm emission lines to determine line-of-sight velocities for the CH_3CN, HC_3N and HNC gases as a function of spatial coordinate across Titan. The resulting Doppler maps are shown in Figure 1, where the color of each pixel indicates the line-of-sight radial velocity, dominated by west-to-east (zonal) flow. The 2016 and 2017 ALMA data were convolved to a common (~1600 km) beam FWHM.

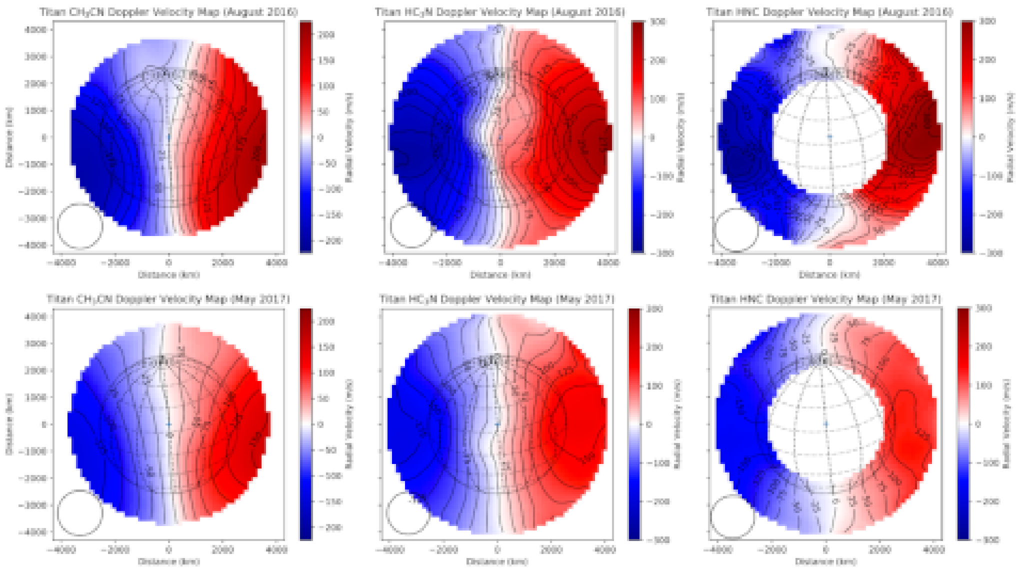

Figure 1. Doppler wind velocity maps based on ALMA observations of CH_3CN, HC_3N and HNC in August 2016 and May 2017. Velocity contours are labeled in units of $m\,s^{-1}$. Wire-frame sphere indicates Titan's orientation with respect to the ALMA field of view. The spatial resolution (FWHM of the elliptical Gaussian beam) is shown lower left for each panel.

Due to their differing vertical abundance distributions, the observed gases preferentially emit from different altitudes on Titan. The CH_3CN molecule emits most strongly in the upper stratosphere, whereas HC_3N is sensitive to the mesophere/thermosphere, and HNC probes the highest, thermospheric altitudes (around 1000 km) [4]. In 2016, there was a clear trend for increasing equatorial zonal wind speed with altitude, which is less apparent in the 2017 data. The greatest temporal variation is for HNC, which showed a dramatic (~ factor of two) reduction in wind speed over the 9-month period between the two epochs: after correcting for the obliquity of Titan's polar axis, the mean, beam-averaged equatorial HNC wind speed was 294±10 ms-1 in 2016 and 159±7 ms-1 in 2017. Deconvolution with respect to the finite ALMA spatial resolution element is required in order to derive the true wind speeds as a function of latitude, which will be presented in a future article [5].

3. Conclusion

Capitalizing on the high sensitivity and resolution of ALMA, we have generated Doppler maps of three different molecules, from which Titan's zonal wind field was derived as a function of latitude, altitude and time, in the range ~300-1000 km (upper stratosphere to thermosphere). Rapid changes in wind speeds were observed over a 9-month period from 2016-2017, the most striking of which is a ~50% drop in the velocity of the recently-discovered thermospheric equatorial jet. In this presentation, we will focus on the detailed wind field variations as a function of altitude and will discuss their implications for our understanding of Titan's global circulation, and the dynamical coupling between the lower and upper atmosphere.

References:

[1] Horst, S. M. 2017, Journal of Geophysical Research (Planets), 122, 432

[2] Hubbard, W. B., Sicardy, B., Miles, R. et al. 1993, A&A, 269, 541

[3] Bird, M. K., Allison, M., Asmar, S. W. et al. 2005, Nature, 438, 800

[4] Lellouch, E., Gurwell, M. A., Moreno, R. et al. 2019, Nature Astronomy, 3, 614

[5] Cordiner, M. A, Garcia-Berrios, E., Cosentino, R. et al. 2020, in prep.