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Searching for Compositional Heterogeneity in DIXI Target Comet 103P/Hartley Using High Resolution Optical Spectroscopy

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Abstract

We present high resolution optical spectroscopy of DIXI target 103P/Hartley taken throughout its recent apparition in Fall 2010. We obtained observations designed to detect any rotational modulation of gas production rates, seasonal changes in gas production, and spatial asymmetries in the coma that may be present. These observations can be used to assess the degree of chemical heterogeneity in the composition of the nucleus.

1. Introduction

Comets can provide insights into how our solar system formed due to their primitive composition, which has been essentially unalterred since the formation of the solar system. A vital question in understanding cometary composition is the degree of chemical heterogeneity in the nucleus. This is ideally determined using spatially resolved spectroscopy of the nucleus, but direct observations of the nucleus are only available for a few comets. However, chemical heterogeneity can manifest itself in observable characteristics of the coma. These include rotational modulation of gas production rates, seasonal changes in gas production, and spatial asymmetries in the coma.

Comet 103P/Hartley provided a unique opportunity to assess the degree of chemical heterogeneity in a cometary nucleus using both ground-based observations and spacecraft observations from the DIXI flyby. In September 2010, the comet was near opposition and thus available for observation throughout an entire night. Therefore a long baseline of observations could be obtained that would be sensitive to rotational modulation of gas production. The comet also passed very close to Earth, providing a small enough spatial scale ($\sim$ 100 km/arcsecond) over which spatial asymmetries in the coma could be detected. As 103P was observable both pre- and post-perihelion, any seasonal variations in gas production would also be observed. Comet 103P/Hartley was also the target of the DIXI mission, which performed a flyby of the nucleus on UT November 4, 2010. This provides a unprecedented opportunity to compare ground-based and spacecraft measurements of the degree of heterogeneity in a cometary nucleus.

We present high resolution optical spectroscopy of comet 103P/Hartley sensitive to these indicators of chemical heterogeniety in the nucleus.

2. Observations

We obtained optical spectra of 103P/Hartley using the ARCES echelle spectrometer mounted on the Astrophysical Research Consortium 3.5-m telescope at Apache Point Observatory. ARCES has a very large spectral range (3500-10,000 Å) and a spectral resolution of R $\sim$ 31,500.

We observed the comet eight times throughout the apparition from September-November 2010. The observations are summarized in Table 1. In September 2010, we obtained all observations on the optocenter

Table 1: ARCES Observations of 103P/Hartley

Date (UT)	Δ (AU)	R (AU)
September 8, 2010	0.34	1.26
September 30, 2010	0.19	1.13
October 1, 2010	0.18	1.12
October 18, 2010	0.12	1.07
October 20, 2010	0.12	1.06
October 26, 2010	0.13	1.06
November 4, 2010	0.15	1.06
November 26, 2010	0.26	1.13

of the comet. In October and November 2010, we also obtained spectra at offset positions $\sim$ 1000 km east and west of the optocenter, which correspond roughly to the solar and antisolar directions, respectively. This was necessary in order to extract spatial information from our spectra, since the 3.2" $\times$ 1.6" slit was too small for spatial information to be extracted within the slit.

3. Results

We present detections of CN, C_2, C_3, CH, and NH_2 in the coma of 103P/Hartley. We observe spatial asymmetry in the coma on UT October 26 and UT November 4, but these spatial asymmetries are not the same for all species. This can be seen in figures 1 and 2. This suggests that the active regions do not all have the same composition, and that 103P's nucleus is heterogeneous. The spatial asymmetries are different on each of the two dates, possibly due to rotational modulation of gas production.

We also present an analysis of these data pertaining to the degree of rotational modulation and to a possible seasonal effect for 103P.

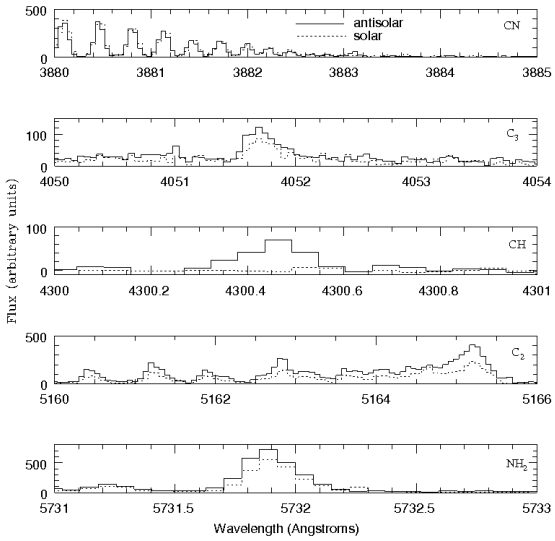

Figure 1: Spectral regions containing transitions due to CN, C_3, CH, C_2, and NH_2 for the November 4 observations. Spectra taken in the antisolar direction from the optocenter are shown by the solid line and spectra taken in the solar direction are plotted with a dashed line. Note the differences in flux in each part of the coma for the various species, and that these asymmetries are not the same for all species.

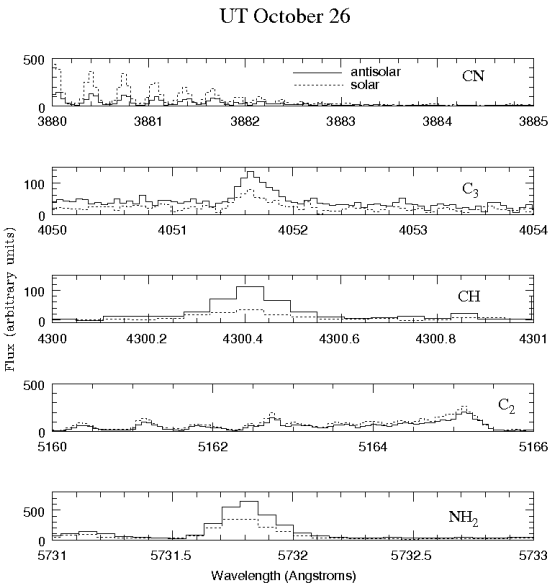

Figure 2: Spectral regions containing transitions due to CN, C_3, CH, C_2, and NH_2 for the October 26 observations. Spectra taken in the antisolar direction from the optocenter are shown by the solid line and spectra taken in the solar direction are plotted with a dashed line. Note the differences in flux in each part of the coma for the various species, and that these asymmetries are not the same for all species. The nature of the asymmetries is also different from those shown on November 4.

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