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Wate-Ice Distribution in the Coma of 46P/Wirtanen

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Abstract

Comet 46P/Wirtanen made a close approach to the Earth in December 2018 (Δ=0.077 au ; r=1.056 au), providing a unique opportunity to collect spatially resolved spectra. We created a NIR spectral data cube near close approach to better understand the water-ice grain properties of the comet coma.

1. Introduction

Comets contain some of the most primitive material in our Solar System [2]. They are icy bodies believed to have formed beyond the snow line [3]. The primary component of cometary nuclei is water ice, yet it is difficult to make direct observations of cometary nuclei. The pristine material lies within the nucleus [4, 8] and might be different than that observed on the processed outer layer of comets. Most comets are small Solar System bodies with elongated elliptical orbits that bring them close to the Sun and then out beyond the water-ice line. When a comet makes a close passage to the Sun, volatiles are outgassed and water-ice grains can sometimes be detected in the coma (e.g., [13, 11]).

Investigations of cometary nuclei at close range, which typically can only be achieved by space missions, are required to validate, disprove, or improve various formation models because of the high spatial resolution they can achieve. [7] propose that different formation mechanisms may have occurred at different places within the nebula, and this may have led to diversity in the physical properties of cometary nuclei. However, if there was instead a common formation mechanism for all cometary nuclei, evidence of diversity due to the differences in the physical and chemical conditions at different heliocentric distances during formation (e.g., collisional environment, chemical composition, radiation environment) would still be observable [7]. Determining water-ice grain sizes from comet nuclei will allows us to inform these formation scenarios (e.g., Tempel 1 [12]).

Comet 46P/Wirtanen made a close approach to the Earth on UT 2019-12-16 coming within 0.077 au, providing an unusual opportunity to obtain a spatially resolved spectral map of water-ice characteristics across the coma.

2. Observations

We collected near-infrared spectra using the low-resolution (R$\sim$200) near-infrared prism spectrograph, NIHTS, on the 4.3-m Lowell Observatory Discovery Channel Telescope in Happy Jack, AZ. We used the $1''.34\times12''$ slit which covers 0.86–2.4 microns in a single order. NIHTS is fed by a dichroic at the center of the instrument cube which enabled simultaneous visible imaging with the Large Monolithic Imager (LMI; FOV= $4'\times6'$) in the r' filter (0.545–0.695 microns).

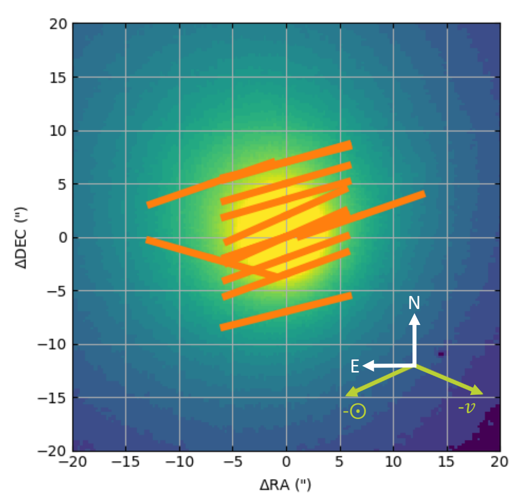

Figure 1: LMI image of 46P in r′ on UT 2018-12-19 (Δ=0.079 au) with (0,0) defined as the peak of the brightness profile. Overplotted in orange is the NIHTS grid created by stepping the $1''.34\times12''$ slit across the coma. The anti-sunward and negative velocity vectors are shown in green.

A spectral data cube of observations was created by performing a slit scanning technique (i.e., stepping the slit across the comet after each exposure sequence) to obtain spatially resolved data around the nucleus (Figure 1). The spectral map of 46P is not a full coverage map, but probes the radial and azimuthal variability across the coma.

Observations were collected three days after 46P made its closest approach with Earth (UT 2018-12-19; Δ=0.079 au). Simultaneous LMI+NIHTS observations in the narrow-band comet filters were utilized for determining real time coma morphology and slit placement with NIHTS.

3. Modeling

We intend to perform data reduction using a modified version of Spextool [6] specific for NIHTS spectra. Where water-ice absorption features are identified in the extracted spectra at 1.5 microns and 2 microns, the absorption features will be modeled to derive water-ice purity, abundance, and grain size. We use Hapke Radiative Transfer or Mie theory to model the observed spectra, similar to what has been done by [11] and [10] to characterize the water-ice grains in comet 103P/Hartley 2 and C/2013 US10, respectively. We simultaneously fit particle size, volume fraction of the carbon grain, and coma temperature. The output of the modeling will be grain size estimates which we can use to constrain the possible comet formation models which best describe our findings.

4. Expected Results

Due to the combination of the high spatial resolution and small heliocentric distance at close approach, we anticipate $\sim$50% probability for a positive water-ice detection, consistent with results from [9, 10]. Where we find a positive detection, we expect to obtain spatially resolved grain size measurements down to 1-2 microns, comparable to the wavelength of the measurements. A spatially resolved map of water-ice grain size versus position will be created which samples radially and azimuthally across the coma.

Where we do not detect water-ice absorption bands, we will use the model to place limits on the amount of allowable water ice that would escape detection. These constraints will provide information on the coma environment that we will use to better understand the physical properties of the comet including water-ice abundance and the gas to dust ratio.

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