EPSC Abstracts
Vol. 13, EPSC-DPS2019-955-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Volatile composition and outgassing in comet 46P/Wirtanen: Keck 2 observations with the newly upgraded NIRSPEC instrument

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Abstract

A major upgrade to the NIRSPEC instrument at the Keck 2 telescope was successfully completed in time for near-infrared spectroscopic observations of comet 46P/Wirtanen during its "historic" close fly-by of Earth in December 2018. These studies revealed compositional abundances of several parent volatiles, including C_2H_2, C_2H_6, CH_3OH, NH_3, HCN, H_2CO, and H_2O. Measured spatial distributions for some of these species are especially valuable to test for the presence of icy grains in the coma that may cause "hyper-activity" of 46P/Wirtanen, and for understanding whether different volatiles are associated with common or distinct outgassing sources.

1. The 2018 Apparition of 46P/Wirtanen

Being both highly active and one of the easiest comets to reach by spacecraft, 46P/Wirtanen has often been a proposed spacecraft target, and it remains a plausible future mission target. The 2018 apparition of this comet had long been anticipated because 46P/Wirtanen passed within only ~30 Lunar distances (0.077 AU) from Earth with outstanding observing geometry. These factors together resulted in one the best apparitions for any Jupiter-family comet in modern history. 46P/Wirtanen was a priority target in a coordinated worldwide observing campaign [6]. As part of this campaign we conducted near-infrared (IR) observations at the W. M. Keck Observatory atop Maunakea, Hawaii, close in time with the comet's closest approach to Earth. These studies resulted in detections of a suite of volatiles, taking advantage of both long-slit capability, needed for measuring spatial distributions of various species, and sensitivity on a 10-m telescope.

2. A major upgrade to the NIRSPEC instrument

NIRSPEC at Keck 2 [9] has enabled a number of comet studies in the last two decades. Importantly, in 2018 the W.M. Keck observatory completed a major upgrade to this instrument [8], with the (challenging) goal to have it on sky specifically in time for the 46P/Wirtanen fly-by of Earth in December. The upgrade replaced the spectrograph's 1024 x 1024 pixel Aladdin III detector with a 2048 x 2048 Hawaii-2RG, significantly improving sensitivity, readout electronics, and spectral grasp. A remarkable effort by the NIRSPEC team completed the upgrade on time, so the spectrograph was tested on sky in engineering runs (UT Dec. 9, 14, and 15, 2018) immediately before our scheduled observations of Wirtanen (UT Dec. 17 and 18, 2018).

3. Results

We will present results for three science tasks focused on better understanding the composition and outgassing of volatiles of 46P/Wirtanen:

(1) **Composition**. We will present production rates (or stringent upper limits) and relative abundances among various volatiles, including C_2H_2, C_2H_6, CH_3OH, NH_3, HCN, H_2CO, and H_2O.

(2) **Coma temperatures and outgassing of water**. Our measured spatial distribution of H_2O rotational temperature (T_{rot}) is especially diagnostic for the role of icy grains (ejected into the coma) as a source of H_2O [3]. Importantly, an icy grain source could explain why 46P/Wirtanen has released more water than expected if H_2O sublimates directly from its small (<1 km) nucleus, similar to the *EPOXI* mission's target 103P/Hartley 2 [1, 5, 6]. Our spatial profiles of T_{rot} can test for icy grains as the root cause of this suggested "hyper-activity" of 46P.

(3) **Spatial inter-relationships among volatiles**. When measured together, the spatial distributions (profiles) of the column density can test whether the sampled species are connected with common or distinct outgassing sources, thereby providing clues as to how species might be associated as ices in the comet nucleus [2, 4, 7, 10]. Distinct sources may be revealed as different (non-correlated) spatial profiles along the slit (Figure 1). These studies are especially valuable because of the very favorable spatial scale (~8 km pix^{-1}) near closest approach to Earth.

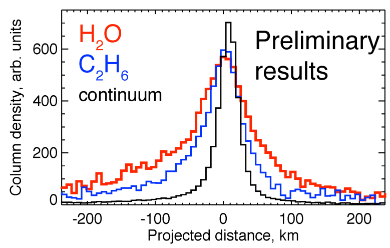

Figure 1: Spatial distributions of H_2O (red), C_2H_6 (blue), and continuum at ~ 3.3 μm in 46P/Wirtanen, measured near closest approach to Earth.

Acknowledgements

We are especially grateful for the outstanding effort of the entire team that completed the NIRSPEC upgrade in time for the 46P/Wirtanen observations. This work was supported by a NASA Keck PI Data Award, administered by the NASA Exoplanet Science Institute. Data presented herein were obtained at the W. M. Keck Observatory from telescope time allocated to the National Aeronautics and Space Administration through the agency's scientific partnership with the California Institute of Technology and the University of California. The Observatory was made possible by the generous financial support of the W. M. Keck Foundation, and is managed by the California Association for Research in Astronomy. We are most fortunate to have the opportunity to conduct observations from Maunakea, recognizing the very significant cultural role and reverence that it continues to have within the indigenous Hawaiian community. Various authors of this work gratefully acknowledge support from the NSF Solar and Planetary Research Grants (AST-1616306, AST-1615441, AST-1614471), the NASA SSO (15-SSO15_2-0028, 80NSSC17K0705), SSW (NNX17AC86G), and NESSF (NNX16AP49H) Programs, and from the International Space Science Institute (Bern, Switzerland).

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