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IRTF/iSHELL campaign for comet 46P/Wirtanen

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Abstract

The 2018 apparition of comet 46P/Wirtanen provided an unprecedented opportunity to characterize and track over time the overall activity, volatile chemistry, temperatures, and spatial distributions of species in the coma for this Jupiter-family comet. Obtaining data during the 2018 apparition of 46P was of the highest importance because observing circumstances for this study were by far the most favorable to date and for the forseeable future. Observations with the iSHELL spectrometer at the NASA Infrared Telescope Facility (IRTF) provided two important advantages that maximized the science return of this investigation: 1) flexible scheduling that allowed a comprehensive study over many dates; 2) observations that combined high spectral resolution ($\lambda/\Delta\lambda \sim 40{,}000$), with broad spectral coverage (all the target species are sampled within three grating settings), and high efficiency (~ 75% on-source time to clock time). An overview of the campaign and the data collected is discussed.

1. Introduction

The iSHELL instrument at the NASA/IRTF is a high-resolution ($\lambda/\Delta\lambda \sim 40{,}000$) infrared spectrometer that is well-suited to the task of detecting molecular emissions of parent volatiles in cometary comae between ~ 2.8 and 5.2 µm. Optimal times for observing 46P and addressing important science goals were during the 2018B and 2019A semesters at the IRTF. We proposed the following scientific investigations. (1) Determine relative abundances and coma spatial distributions for parent volatiles including H_2O, CH_3OH, H_2CO, C_2H_2, C_2H_6, HCN, NH_3, and OCS near closest approach of 46P to Earth. (2) Determine or constrain abundances of hypervolatiles CH_4 and CO when the velocity of 46P relative to Earth was sufficient to shift cometary lines from their atmospheric counterparts. (3) Explore the relationships between parent volatiles (e.g. C_2H_2, HCN, NH_3) detected at infrared wavelengths and their product species (e.g. C_2, CN, NH, NH_2) detected from observations at optical wavelengths (e.g. McDonald, TRAPPIST, APO). (4) Clarify the chemistry, and when possible, coma spatial distributions of sulfur-bearing species in 46P through contemporaneous observations of OCS (iSHELL), and H_2CS, H_2S, SO_2, SO, and CS (e.g. ALMA, IRAM). (5) Measure chemical and activity changes over time scales of hours to months. (6) Measure the spatial variability of rotational temperatures in the coma to assess the importance of icy grain release from a high activity comet.

2. Overview of 46P Observations

Observations of 46P/Wirtanen were obtained on eleven dates between UT 2018 December 6 and 2019 February 5 (Table 1). Five instrument settings were used in this study. Three primary settings were extensively used and were sufficient for addressing our science goals. These settings were L_{custom} (2.82 – 3.1 µm; sampling H_2O, C_2H_2, HCN, and NH_3; see Fig. 1), Lp1 (3.28 – 3.66 µm; sampling CH_3OH,

H_2CO, C_2H_6, and CH_4), and M2 (4.52 – 5.25 µm; sampling H_2O, OCS, and CO). Two additional customized settings, slightly shifted from the L-band primary settings, were used on December 16 and 18 to target specific spectral regions while still accomplishing the primary science. These settings were $Lp1_{custom}$ (3.1 – 3.38 µm), and $L3_{custom}$ (3.3 – 3.6 µm). To assure a connection between the chemistry and activity over time, C_2H_6 and CH_3OH were sampled on every date and H_2O was sampled on all dates except February 5 (due to poor weather). Over the eleven nights, more than forty-two hours on-source were obtained, including extensive total time on-source for each primary setting. This remarkable amount of time on-source allowed us to accomplish all of our primary science goals as well as determine abundances or meaningful constraints for additional minor species that are not typically reported at infrared wavelengths. This presentation provides an overview of these observations, points to specific investigations presented here reporting preliminary results, and suggests additional studies that will be addressed in the future.

Table 1: **Summary of 46P Observing Circumstances and Data Obtained with iSHELL**

UT Date	R_h	Δ	Δ_{dot}	On-source time in each iSHELL setting (minutes)*				
	AU	AU	km/s	L_{custom}	Lp1	$Lp1_{custom}$	$L3_{custom}$	M2
Dec 6	1.059	0.099	-6.3	92	40			
Dec 14	1.056	0.079	-1.8	138	84			122
Dec 16	1.056	0.078	-0.2	96		94	116	
Dec 18	1.058	0.078	+1.4	76			96	
Dec 19	1.059	0.079	+2.2	68	144 (76/68)			114
Dec 21	1.062	0.083	+3.7	284(136/148)	16			
Jan 11	1.128	0.179	+10.1	52	116			110
Jan 12	1.133	0.185	+10.3		116			140
Jan 13	1.138	0.191	+10.4	104	48			74
Feb 4	1.271	0.339	+13.2		80			78
Feb 5	1.278	0.346	+13.3		60			
TOTAL				**910**	**704**	**94**	**212**	**638**

* Approximate wavelength range of each setting is given in the text. The slit orientation for all settings was along the extended heliocentric radius vector except for the Lp1 setting on December 19 and the L_{custom} setting on December 21 when observations were obtained with two slit orientations (along the extended heliocentric radius vector and perpendicular to this). The total time on-source and the time in each slit orientation are given.

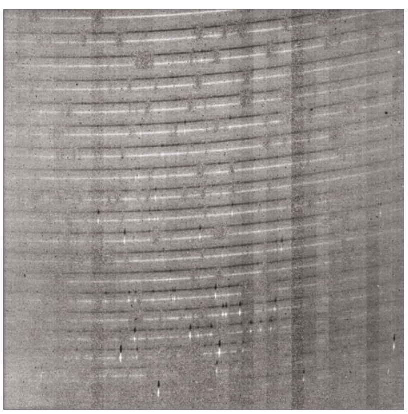

Figure 1: iSHELL A – B spectrum of 46P on UT 2018 December 6 in setting L_{custom} (~2.82 – 3.1 µm). Many emission lines are apparent (mostly H_2O and HCN) as knots with vertical extension. The telescope was nodded 7.5″ along the 15″ slit so that the comet is seen in both the A (white) and B (black) positions.

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