



1231 - Surface composition of mid-sized TNOs: searching for ammonia

Cycle: 1, Proposal Category: GTO

INVESTIGATORS

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OBSERVATIONS

<i>Folder</i>	<i>Observation</i>	<i>Label</i>	<i>Observing Template</i>	<i>Science Target</i>
Observation Folder				
	1	Orcus	NIRSpec IFU Spectroscopy	(1) ORCUS
	2	2003AZ84	NIRSpec Fixed Slit Spectroscopy	(2) 2003AZ84

ABSTRACT

This program will focus on constraining the surface composition of 2 Charon-like objects, i.e. mid-sized Transneptunian objects (TNOs) with possible presence of ammonia at their surface. The recent observations of the NASA/New Horizons probe have shown that Charon's surface is possibly indicative of past cryovolcanic activity. Ammonia and ammonia hydrates, common antifreezes, have been detected in the spectra obtained both from the probe and ground-based facilities. We have selected 2 targets, Orcus and 2003 AZ84, with physical properties similar to Charon, for which past cryovolcanism could have been an interesting evolutionary path. Traces of volatiles such as ammonia and/or hydrates have been found in ground-based spectra of Orcus. We will further investigate this possibility, and open a new window into constraining the inventory of volatiles at the surface of Orcus by observing the 3-5micron range, where fundamental absorption bands of C-H-, N-H- and O-H-bearing ices can be found. Recent occultation results suggest that 2003 AZ84 may hold a canyon-like feature at its surface, similar to the large canyon seen on the surface of Charon. Given its other physical characteristics, this object is selected as our second target. Ground-based observations of this fainter TNO suggest that crystalline water ice may be the dominant volatile species present at its surface, though minor species cannot be constrained.

OBSERVING DESCRIPTION

--- DESCRIPTION OF OBSERVATIONS ---

Both targets will be observed with the integral-field spectroscopy (IFS) mode of the JWST/NIRSpec instrument. For Orcus, we plan to use 3 high-spectral resolution configurations covering the 1.0-5.2 microns range with resolutions around 2700. For 2003 AZ84, which is fainter, we will cover the same spectral range but only at medium spectral resolution (~1000). We will also obtain low spectral resolution (30-300) spectra covering the 0.6 to 5.3 microns range in one shot.

*** Instrument mode: to minimize the overheads and to be robust with respect to errors in the astrometry of the target, we have decided to use the NIRSpec/IFS mode with a “point-and-shoot” observing strategy.

*** Dither / nodding pattern: to be more robust with respect to detector cosmetics, we do not want to obtain all the spectra of a given configuration at the same location on the detectors. As our targets are point-like, we have decided to use a 4-point nodding pattern.

Note that background subtraction may be more complicated than usual due to the fact that these are moving targets and that the background scene will change with time and may even be “trailed”.

*** Spectral configurations: in order to obtain information on multiple volatile species, we need good quality spectra covering broad spectral coverage and we have decided to typically cover the 1.0 to 5.0 microns range. To disentangle the signatures of the various species and to detect changes in the bands/lines profiles we need a minimum spectral resolution of ~1000. Although not strictly necessary, obtaining higher spectral resolution spectra could give us access to very interesting additional information.

Taking into account the impact of using the high-spectral resolution configuration on the signal to noise ratio per pixel of the spectra, at this stage we are planning to obtain high spectral resolution spectra for the brighter of the 2 objects (Orcus) and medium spectral resolution spectra for 2003 AZ84. Note that we will take another look at that before April 1st and we may decide to use only medium spectral resolution configurations.

We have also decided to acquire CLEAR/PRISM spectra for both objects. They are not necessary for the science case of this program but we consider that: (1) they will provide a useful sanity check with respect to the grating spectra (especially early in the mission where not all the calibration may be in place); (2) they will be very important to assess the usefulness of the low spectral resolution spectra for this type of program and will allow us to provide interesting feedback to the community on the use of NIRSpec and the choice of spectral configurations.

--- SCIENCE JUSTIFICATION ---

Transneptunian objects (TNOs), i.e. icy bodies orbiting the Sun beyond Neptune, are remnants of the planet formation process, analogous to the material found in debris disks (McClure et al. 2015), holding invaluable clues on the conditions prevailing in the early phases of the solar system formation and evolution. In comparison to planets, TNOs have undergone much less alteration, having been exposed to fewer evolutionary processes that acted preferentially at their surface. This statement is not entirely true though, and certainly wrong for the largest TNOs, which may have sustained some cryovolcanic activity. Similarly to volcanism on Earth which plays an important role in reshaping the surface of our planet, cryovolcanism is the process by which liquid water and other volatiles are brought to the surface of icy bodies. Because it is a clear marker of extensive geological activity, objects showing evidence of cryovolcanism (Titan, Europa or Enceladus) are the subject of intense investigation. Indeed, cryovolcanism requires the persistence of fluid for a significant amount of time, either in subsurface oceans or as localized pocket of fluid in an icy mantle. The proximity of subsurface oceans to a hot rocky core implies the possibility of hydrothermal circulation, similar to «black smokers» at the bottom of the Earth's ocean where specific ecosystems developed.

Cryovolcanism on mid-sized TNOs is an intriguing prospect though, as these objects are generally deemed too small to sustain any geophysical activity. However, several compounds detected due to specific signatures in the near-infrared spectra of TNOs are suggestive of past or recent cryovolcanic activity:

- crystalline water (detected in abundance at the surface of Quaoar first (Jewitt & Luu, 2004) and other TNOs later) is converted into amorphous water ice by solar radiation and galactic cosmic rays in several Myr (Mastrapa & Brown, 2006, Cook et al. 2007). Its presence at the surface of TNOs has been suggested as evidence for recent resurfacing.
- ammonia hydrates detected on the surface of Charon (Cook et al. 2007), and possibly Orcus (Delsanti et al. 2010). These hydrates should also be destroyed on timescales shorter than 1-50 Myr (Strazzulla & Palumbo, 1998). For Charon, no mechanism other than recent localized emplacement at the surface by cryovolcanism has been able to conclusively explain the observations (Jewitt & Luu, 2004, Cook et al. 2007, McKinnon et al. 2008, Desch et al. 2009).

In addition, the possibility for mid-sized TNOs to sustain cryovolcanism was confirmed by the flyby images provided by the NASA/New Horizons spacecraft, which show evidence for a complex geology with diverse landforms, terrain ages, glacial flows, tectonics, both on Pluto and Charon.

If cryovolcanism is a definite possibility, confirmed both by observations and theoretical studies (Desch et al. 2009, Robuchon & Nimmo, 2011, Shchuko et al., 2014, Malamud & Prialnik, 2015), for the largest TNOs like Pluto, Eris or Makemake, and now Charon, we need to perform a thorough study for the rest of the population. In addition, because the largest TNOs have surfaces dominated by the presence of volatile species like

methane, which act as a veneer hiding the main constituents found underneath, we need to turn to mid-sized TNOs to constrain the possible differentiation and cryovolcanic activity amongst the whole TNO population. Brown (2012) showed that there may be an inherent change of surface composition for objects larger than 600-650km, possibly due to different physical processes dominating their evolution. Therefore, studying cryovolcanism among mid-sized TNOs should lead to significant progress in our understanding of how the whole population formed and evolved.

*** Immediate Objective

As of today, only a few mid-sized TNOs have been characterized by spectroscopy with a quality sufficient to draw conclusions on the processes responsible for their current surface composition. Most mid-sized TNOs have surfaces dominated by water ice. Traces of other volatiles can be found: the variety of chemical compounds expected to be present at the surface of mid-sized TNOs have been detected so far through the overtones and combination bands present up to 2.5 microns (the only window accessible from the ground), but they can more easily be identified by their fundamental absorption bands in the 3-5 micron region. For example, ammonia has been detected on Charon and possibly Orcus (feature at 2.2 microns), and was postulated to be due to the flow of ammonia-rich liquid water onto the surface of these objects. Evidence that mid-sized TNOs sustained cryovolcanic activity would include the presence of ammonia on every mid-sized objects on which substantial water ice absorption is present. On objects like Quaoar or Sedna, the presence of ammonia in the spectra may be hidden by the dominating methane absorption feature at similar wavelength. However, both compounds (ammonia and methane) can be discriminated owing to different features beyond 3 microns. The objective of the observations carried out with JWST/NIRSpec is to constrain the presence of volatiles indicative of possible past cryovolcanism (including but not restricted to ammonia, pure and hydrates, and methanol) on a few well-chosen targets among mid-sized TNOs, so to constrain the occurrence of differentiation and cryovolcanism on these objects in particular, and the population as a whole. We will, for the first time, access a wavelength range (3-5m) which will allow us to constrain the surface composition of TNOs with an accuracy never achieved before since most volatiles have fundamental bands in this region.

Proposal 1231 - Targets - Surface composition of mid-sized TNOs: searching for ammonia

Solar System Targets	#	Name	Level 1	Level 2	Level 3
	(1)	ORCUS	TYPE=ASTEROID,A=39.46808413270765,E=0.2180 157282989784,I=20.56455635133965 ,O=268.5747600490993,W=72.95516036825188,M=1 74.7596053110064,EQUINOX=J2000,EPOCH=28- JAN-2016:00:00:00,EpochTimeScale=TDB <i>Comments: Orcus is a binary system. Its satellite - Vanth - will be at 259mas at best.</i> <i>Extended=NO</i>		
(2)	2003AZ84	TYPE=ASTEROID,A=39.58145602401422,E=0.1784 245068089003,I=13.57911624458645 ,O=252.1104480127618,W=13.88332094807367,M=2 30.4190310331718,EQUINOX=J2000,EPOCH=19- OCT-2016:00:00:00,EpochTimeScale=TDB <i>Comments: Extended=NO</i>			

Proposal 1231 - Observation 1 - Surface composition of mid-sized TNOs: searching for ammonia

Mon Nov 21 19:00:54 GMT 2022

Observation	<p>Proposal 1231, Observation 1: Orcus</p> <p>Diagnostic Status: Warning</p> <p>Observing Template: NIRSpec IFU Spectroscopy</p>											
	<p>(Visit 1:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.</p> <p>(Visit 1:1) Informational (Form): Visit schedulable, but most scheduling windows are when JWST is pointed in direction of greatest micrometeoroid impact risk. This is likely due to scheduling special requirements.</p>											
Diagnostics												
Solar System Targets	#	Name	Level 1				Level 2				Level 3	
	(1)	ORCUS	TYPE=ASTEROID,A=39.46808413270765,E=0.2180 157282989784,I=20.56455635133965 .O=268.5747600490993,W=72.95516036825188,M=1 74.7596053110064,EQUINOX=J2000,EPOCH=28- JAN-2016:00:00:00,EpochTimeScale=TDB									
<p><i>Comments: Orcus is a binary system. Its satellite - Vanth - will be at 259mas at best.</i></p> <p><i>Extended=NO</i></p>												
Template	TA Method											
	NONE											
Dithers	#	Dither Type		Size		Starting Point		Number of Points		Points		
	1	4-POINT-DITHER										
Spectral Elements	#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Exp	Leakcal	Dither	Autocal	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
	1	PRISM/CLEAR	NRSIRS2RAPID	25	1	false	true	NONE	4	4	1517.245	
	2	G235H/F170LP	NRSIRS2RAPID	30	1	false	true	NONE	4	4	1809.022	
	3	G395H/F290LP	NRSIRS2RAPID	60	1	false	true	NONE	4	4	3559.689	
Special Requirements	<p>Between Dates 01-DEC-2022:00:00:00 and 07-DEC-2022:00:00:00</p> <p>Between Dates 09-DEC-2022:00:00:00 and 16-DEC-2022:00:00:00</p> <p>Between Dates 17-DEC-2022:00:00:00 and 27-DEC-2022:00:00:00</p> <p>Between Dates 28-DEC-2022:00:00:00 and 09-JAN-2023:00:00:00</p> <p>Between Dates 12-JAN-2023:00:00:00 and 23-JAN-2023:00:00:00</p>											
	<p>DEFAULT WINDOW: ANGULAR RATE ORCUS FROM JWST LESS THAN 0.03</p>											

Proposal 1231 - Observation 2 - Surface composition of mid-sized TNOs: searching for ammonia

Mon Nov 21 19:00:54 GMT 2022

Observation	Proposal 1231, Observation 2: 2003AZ84 Diagnostic Status: Warning Observing Template: NIRSpec Fixed Slit Spectroscopy										
	(Visit 2:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.										
Diagnostics											
Solar System Targets	#	Name	Level 1			Level 2			Level 3		
	(2)	2003AZ84	TYPE=ASTEROID,A=39.58145602401422,E=0.1784 245068089003,I=13.57911624458645 .O=252.1104480127618,W=13.88332094807367,M=2 30.4190310331718,EQUINOX=J2000,EPOCH=19- OCT-2016:00:00:00,EpochTimeScale=TDB								
Comments: Extended=NO											
Acquisition	#	Target	TA Method	Subarray	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
	1	SAME	WATA	SUB2048	CLEAR	NRSRAPID	3	1	1	3.628	12192
Template	Slit				Subarray						
	S200A1				FULL						
Dithers	#	Primary Dither Positions					Sub-Pixel Pattern				
	1	3					NONE				
Spectral Elements	#	Grating/Filter	Slit	Readout Pattern	Groups/Int	Integrations/Ex #	Autocal	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
	1	G140M/F100LP	S200A1	NRSIRS2RAPID	35	1	1	NONE	3	3	1575.6
	2	G235M/F170LP	S200A1	NRSIRS2RAPID	60	1	2	NONE	3	3	2669.767
	3	G395M/F290LP	S200A1	NRSIRS2RAPID	80	1	3	NONE	3	3	3545.1
	4	PRISM/CLEAR	S200A1	NRSIRS2RAPID	30	1	4	NONE	3	3	1356.767

Proposal 1231 - Observation 2 - Surface composition of mid-sized TNOs: searching for ammonia

Special Requirements

Between Dates 28-OCT-2022:00:00:00 and 29-OCT-2022:00:00:00
Between Dates 30-OCT-2022:00:00:00 and 01-NOV-2022:00:00:00
Between Dates 02-NOV-2022:00:00:00 and 03-NOV-2022:00:00:00
Between Dates 04-NOV-2022:00:00:00 and 16-NOV-2022:00:00:00
Between Dates 17-NOV-2022:00:00:00 and 19-NOV-2022:00:00:00
Between Dates 20-NOV-2022:00:00:00 and 09-DEC-2022:00:00:00
Between Dates 10-DEC-2022:00:00:00 and 12-DEC-2022:00:00:00
Between Dates 13-DEC-2022:00:00:00 and 17-DEC-2022:00:00:00

DEFAULT WINDOW: ANGULAR RATE 2003AZ84 FROM JWST LESS THAN 0.03