PROBING THE SURFACE COMPOSITION OF TRANS-NEPTUNIAN OBJECTS WITH JWST/NIRSPEC

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Trans-Neptunian Objects (TNOs)

- ~1600 known TNOs and Centaurs (between Jupiter & Neptune).
- Sub-populations defined according to dynamical properties.
- Dynamical models of the solar system evolution suggest they are the parents of many other small-body populations (comets, asteroids, Trojans...)
- No physical link among populations, very little understanding of physical properties at all
A variety of sizes and albedos

Credit: “TNOs are cool” survey - Herschel

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The nature of TNOs – What can we learn from their surface composition?

- There are a lot of open questions on the nature of TNOs as well as on their formation and evolution.
- Their surface is one of the main windows to probe their composition.
- Various visible and near-infrared surveys using 8-m class telescopes to study the spectrum of TNOs.
  - As an example, ESO large program to obtain near-infrared spectra of a sample of 21 TNOs with SINFONI (Guilbert et al. 2009).
The nature of TNOs — Probing the surface composition

- Light absorbed by the surface at characteristic wavelengths
  ↓

- Identification of compounds present at the surface thanks to absorption bands

- A variety of diagnostics are available in the near-infrared:
  - Vibrational transitions,
  - fundamental and overtones
  - C-H, O-H, N-H bounds = ices
The nature of TNOs – Probing the surface composition

- Near-infrared spectra currently available for 70 objects.

- 3 categories of surface compositions:
  - dominated by methane ice (largest objects)
  - dominated by water ice
  - featureless (but some with very poor SNR)
The nature of TNOs – Probing the surface composition

- But observationally difficult from the ground, even for big telescopes and large TNOs.
- And some key ice near-infrared ice signatures are simply not observable from the ground…
The nature of TNOs – Surface composition

Orcus

Barucci et al., 2008

Orcus

Delsanti et al. 2010

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Looking at the next step...

- JWST (NASA/ESA/CSA mission) will be a powerful infrared observatory.
  - 6.5-meter diameter space telescope.
  - Optimized for infrared (0.6-28 micron) observations.
  - Very low background environment (L2 orbit and the full telescope is passively cooled down to 30K).
  - Will be launched in 2018 by and Ariane rocket.

- A huge jump in sensitivity compared to existing facilities in the same wavelength range (on-ground and in space).

- Taking a look at what could be done with one of the JWST instruments: NIRSpec.
Overview of JWST/NIRSpec

- Near-infrared spectrograph for JWST covering the 0.6-5.0 micron wavelength range.
  - Part of the European contribution to the JWST mission.
  - Manufactured for ESA by a European consortium of industrial companies led by EADS Astrium Germany (with two sub-systems provided by NASA).
  - Flight instrument delivered to NASA on the 20th of September 2013.
Overview of JWST/NIRSpec

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- **MOS**:
  - 9 square arcmin. field of view
  - Low spectral resolution (30 to 300), prism-based mode covering the 0.6-5.0 micron range in one exposure.
  - Medium spectral resolution (500 to 1300), grating-based mode covering the 0.7-5.0 range

- **IFU**:
  - 3”x3” field of view
  - Low spectral resolution (30 to 300), prism-based mode covering the 0.6-5.0 micron range in one exposure.
  - Medium (500 to 1300) and high (1400-3600) spectral resolution modes, covering the 0.7-5.0 range in 4 exposures.
  - IFU and MOS cannot be used at the same time.

- **SLIT**:
  - 5 slits available
  - All spectral resolution modes available.
  - SLIT can be used simultaneously to IFU or MOS.

(IFU made of 30 slices for a total of 900 “spaxels”)

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Overview of JWST/NIRSpec

- **JWST/NIRSpec main config.**
  - Wavelength (microns)
  - 1 2 3 4 5

- **Low spectral resolution (30-300)**
  - 0.6-5.0

- **Medium and high spectral resolution (500-1300) and (1400-3600)**
  - 0.7-1.2
  - 0.7-1.2
  - 1.0-1.8
  - 1.7-3.0
  - 2.9-5.0

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Searching for water-ice signatures…
A potential JWST/NIRSpec program.

- Are the “featureless” TNO spectra really featureless? Can we get good constraints on the amount of water-ice present on their surface?
  - Looking for water ice signatures in a sample of 50 “small” TNOs with JWST/NIRSpec.
  - Obtain high-quality spectra covering the full 0.6 to 5.0 micron domain.

- 100-110 hour program with JWST/NIRSpec (conservative duration including all overheads).
- IFU spectroscopy at low spectral resolution (30-300).
Focusing specifically on water-ice signatures in the near-infrared.

Signatures are clearly detectable even at low spectral resolution sampling of the NIRSpec R=30-300 mode.
Searching for water-ice signatures…
A potential JWST/NIRSpec program.

- Taking advantage of the sensitivity of NIRSpec.

Orcus

$S/N=30$ per spectral pixel in 3 exposures of 970s.

Very good $S/N$ needed to probe diluted water-ice signatures.
Searching for water-ice signatures...
A potential JWST/NIRSpec program.

Very simple simulations to estimate which water fraction is detectable for a given object size (roughly equivalent to a magnitude).

- 5% down to H-band magnitude of 19
- 10% down to H-band magnitude of 21
Searching for water-ice signatures…
A potential JWST/NIRSpec program.

- This first look at this potential JWST/NIRSpec program is very promising.
  - Good sensitivity to water-ice signatures, in particular thanks to the access to the 3-micron band.
  - Extremely good instrument sensitivity allowing to probe 1-2 magnitudes deeper than on the ground with an excellent signal to noise ratio (detecting diluted signatures is not easy!).
Detailed studies of the surface composition of large TNOs. A potential JWST/NIRSpec program.

- Looking at larger objects with a much richer spectrum with various volatile species.
  - Detailed study of a sample of 20-30 “large” TNOs.
  - Obtain high-quality medium-resolution spectra covering the 1.0-5.0 micron domain (3 different spectral configuration).

- < 100 hour program with JWST/NIRSpec (conservative duration including all overheads).

- IFU spectroscopy at medium spectral resolution (700-1300).
Detailed studies of the surface composition of large TNOs. A potential JWST/NIRSpec program.

- Example of an Orcus-like object.
  - H-band magnitude of ~17.7.
  - Simulation based on Guilbert et al. 2009.

- Very good spectral resolution, very good sensitivity.

Orcus-like object at 4.5 a.u. of the Sun with a diameter of 900 km.
Searching for water-ice signatures...
A potential JWST/NIRSpec program.

- Another very promising potential JWST/NIRSpec program.
  - No existing competition in terms of wavelength coverage.
  - Very interesting spectral resolution.
  - Extremely good instrument sensitivity allowing to reach the high signal to noise ratio necessary for these detailed studies.
Next steps…

- Refining the simulations and the program “details”.
  - A more realistic subtraction of the spectrum of the solar analog.
  - We used very conservative overheads levels, going for more realistic (flight-like) ones.

- Looking in more details at the “samples” using existing TNO censuses.
  - Should have been ready for today…

- Publish…

- And in 5-6 years from now try to move from “virtual science” to “real observations”!

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