TNOs are Cool:
A Survey of the Transneptunian Region

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The TNOs-are-Cool Team
(37 members, 19 institutes, 9 countries)
Overview

- OT KP with 370 hours
- PACS and SPIRE photometric point-source observations
- characterisation of about 140 Trans-Neptunian Objects (with known orbits)
- target with a few mJy up to 400 mJy
- Key element: highly reliable photometric accuracy in 3 (6) bands
- time-critical observations with follow-on constraint (confusion noise)
Science Goals in a Nut Shell

- **Radiometric size and albedo solutions**
  - accurate sizes (→ volumes) of TNOs
  → primordial (D > 200 km) size distribution
  - accurate spectroscopic and polarimetric modeling
  - albedo vs Size vs Colour vs Composition vs Orbit vs Binarity vs ...
  → probe formation and evolution processes

- **Thermophysical properties** (from 3 to 6 Pacs/Spire bands)
  - temperatures & thermal inertia
    → ice vs rock surface, surface type
  - emissivity → grain size information
  - beaming parameter → surface roughness

- **Binary densities:** mass from Kepler’s 3rd law, volume from Herschel
  → basic geophysical parameter
  → interior structure/composition
  → binary formation mechanism

- **Thermal lightcurves**
  → disentangle albedo/shape
  → spin-axis orientation
  → thermal inertia
  → large surface structures
Herschel Study of the Kuiperbelt & TNOs:

→ a benchmark for understanding the solar system debris disk, and extra-solar ones as well!

Müller et al. 2009, Earth, Moon & Planet 105, 209-219
Overview SDP TNO Programme (∼ 25 h)

- **PACS (1\textsuperscript{st} part, completed)**
  - chop-nod point-source photometry with dither, tracking
  - 2 or 3 band photometry, repetition factors 10...36
  - 7 targets, including Pluto, Typhon and Makemake

- **PACS (2\textsuperscript{nd} part, partly scheduled)**
  - mini scan map, array angles 63/117 deg (grouped)
  - 3.5′ length, 10 scans, 4″ separation
  - 3...10 repetitions, follow-on in selected cases
  - 7 targets, including Haumea lightcurve

- **SPIRE (SDP completed)**
  - Mode: Large Map, Scan Angles A and B, 4′ length, 12 rep.
  - repetition (follow-on) after 44/66 hours, tracking
  - 2 targets: 90482 Orcus and 136472 Makemake
SPIRE Results

- Both SPIRE targets are nicely detected: "Follow-on" is the key technique for these faint moving targets!
- Flux density of both TNOs at 250 and 350 µm is about 10 mJy (not final)
- Preliminary thermophysical analysis of Spire photometry already indicates the very high scientific potential: the measurements will constrain the size, albedo, thermal properties, surface properties, ... in an unprecedented way
- analysis of multi-band photometry has just started
Makemake

Negative image

Positive image
136472 (2005 FY9), SED vs. Geometric Albedo

R = 51.9 AU, Δ = 51.9 AU

η = 1.25
η ≈ 0.78
η = 0.25

Block Body: 5.92 km, 56.6 K

24 μm Fits
20.18 ± 0.83
Diam = 1932.2 977.0

70 μm Fits
118.63 ± 210.70

2005 FY9/Makemake, SED vs. Geometric Albedo

R = 51.9 AU, Δ = 51.9 AU

5.92 km, 56.6 K Blackbody

1 - STM: p_v = 10%, η = 0.65, q = 0.36, f = 2%
2 - ILM: p_v = 80%, η = 1.50, q = 0.90, f = 95% - -

1514 km Planetoid

24 μm Fits
118.63 ± 210.70

135472 Makemake: Model fits for combined Spitzer/Herschel fluxes
90482 Orcus (2004 DW), SPIRE scan maps 250 µm
90482 Orcus (2004 DW), differential neg./pos. image

Rough flux for negative source 
-13 mJy
and for positive source about 
14 mJy

\(^1\)the negative [background minus (background + TNO)] and positive [(background + TNO) minus background]
• **90482 Orcus**: has a significantly higher albedo than previously assumed (→ larger size)

• Dwarf planet **136472 Makemake**: belongs to the 3 biggest TNOs (Eris, Pluto), but among these ”giant dwarf planets” it is the only one without satellite.

The Spire 250 μm measurement can either be explained by a very extreme albedo (>0.8), leading to a diameter between 1500 and 2000 km, or by a high thermal inertia, indicative of a bare rock or densely packed ice surface (the Pacs/Spire multi-band analysis will give the answer).
PACS Results

- very nice and highly accurate measurement of Pluto in 3 bands (just before Pluto entered the galactic plane/centre region)
- 6 targets analysed (based on own flux calibration/color correction):
  - 2 are significantly fainter than predicted
  - 3 are about at the right flux level
  - 1 was significantly brighter than predicted
- just below 10 mJy was the faintest detected target
- improvement in analysis still needed
- poor or no detections in the red channel (single measurement, no follow-on)
- in general: S/N values are significantly lower in chop-nod mode than expected from HSpot
42355 Typhon
70 & 100 micron

208996 2003 AZ84
70 & 160 micron
Outlook & Conclusions

- SPIRE programme can go ahead, but AORs require timing constraints and have to be split for the implementation of "follow-on"
- PACS programme will be switched to "mini scan maps" for better sensitivity and better background characterisation

TNOs are Cool!

... and waiting to be observed by Herschel!