Mid-infrared spectroscopy of primitive asteroids in the outer edge of the main belt

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Abstract

This work aims at the characterisation of a group of fourteen asteroids observed by the CanariCam instrument, mounted on the Gran Telescopio Canarias. These objects have been observed both photometrically and spectroscopically, in the wavelength range of mid-infrared, using specifically the 10 µm atmospheric window.

There are two ultimate goals of this project. The first one, to obtain values for their size (diameter) and geometric visible albedo through the application of a simple thermal model (the NEATM); and the second one, to look for spectral features in their emissivity spectra that might suggest some surface structure in these objects.

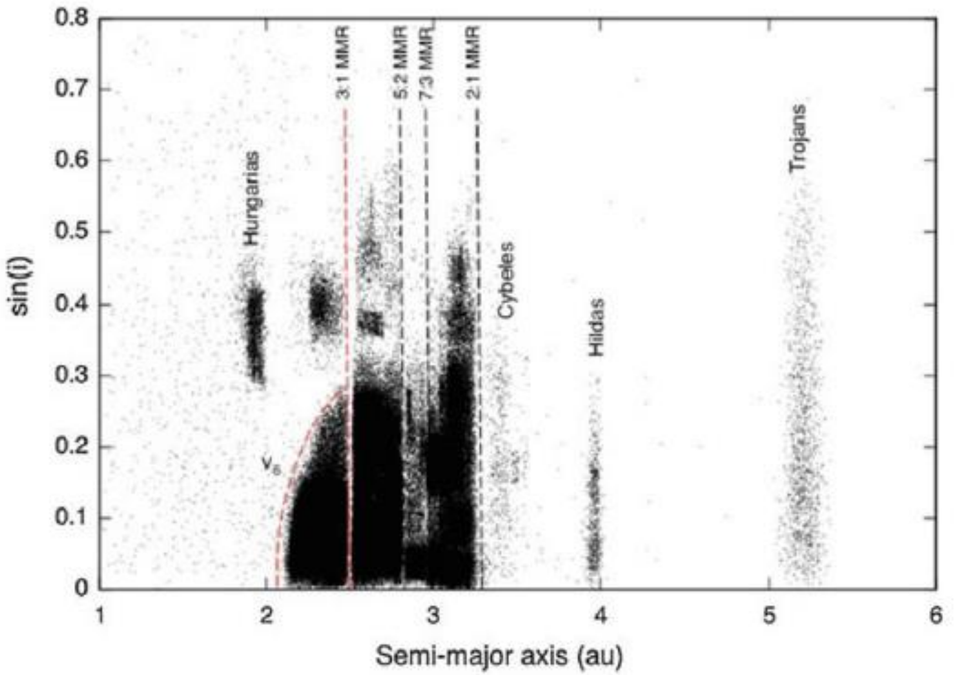
1. Context of the research

Primitive asteroids:

- Outer edge of the main belt (less density and heating) = more pristine objects → clues about **formation and early stages** of the Solar System.

Cybele and Hilda populations

- **Dynamical group:** asteroids with similar orbits due to resonances. Includes several families (same progenitor).
  - **Cybele**: 3.27-3.7 AUs, 4 families.
  - **Hilda**: 3.7-4.5 AUs, 2 families.



Distribution of the first 200.000 asteroids, in terms of inclination of their orbit and semi-major axis.

Objective:

To study **both asteroids populations** in the mid infrared (10 μm) through photometry and spectroscopy

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Obtain their **size**, **albedo** and **surface composition** (regolith)

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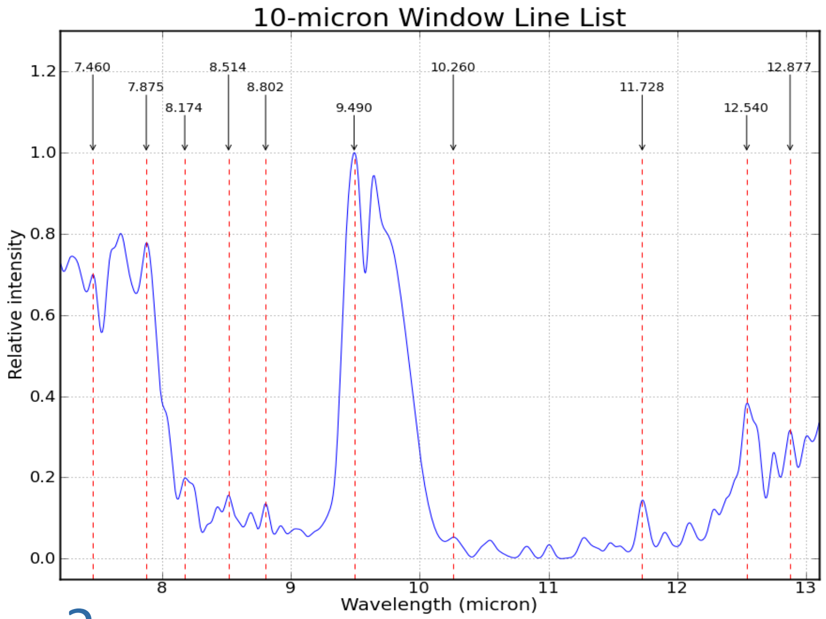
Their origin: to confirm if they are **primitive asteroids**

2. Methodology

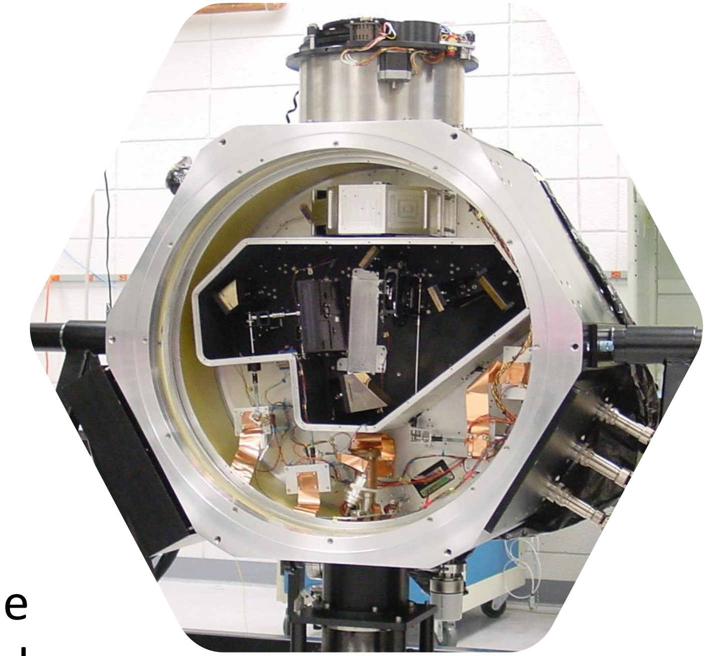


Why mid infrared?

- Very **cold** objects (emission peak at λ>10 μm)
- To observe the **emissivity plateau** (due to the vibrational absorption of Si-O → presence of surface fine dust).

How?

- **Chopping:** fast and small tilting of the M2 to sustract sky. F ~ 1 Hz.
- **Nodding:** new pointing to compensate temporal variability. F ~ 2/min.
- **Radiometry:** using the Near-Earth Asteroid Thermal Model (**NEATM**).
- **Emissivity spectrum:** deviation of the asteroid's actual emission from the hypothesis of **constant emissivity**. It is obtained by dividing the real spectrum by the model given by the NEATM and scaled.



CanariCam. Credit: IAC.

3. Results (I)

Observed asteroids

- **11 Cybeles:** 65 Cybele, 107 Camilla (Sylvia family), 260 Huberta, 909 Ulla and others not associated to known collisional families (76, 168, 225, 536, 713, 721, 790).

- **3 Hildas:** 153, 334, 748.

Extracted spectra

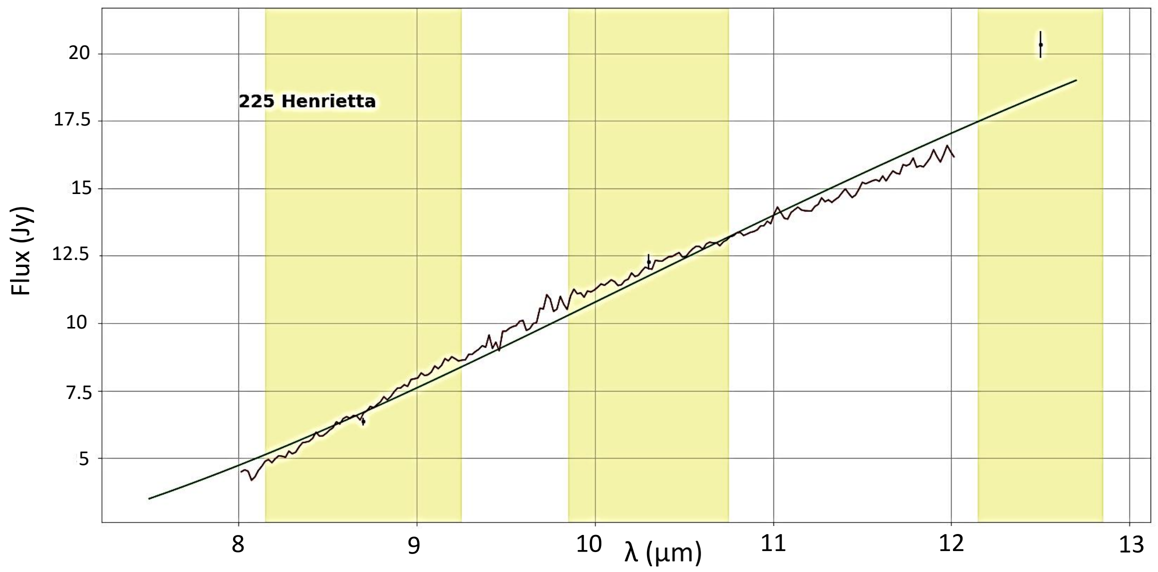
- **Low resolution:** unable to recognize individual features.
- Flux re-calibrated to the **photometric points.**
- Useful to extract better **emissivity spectra** and parameters by using NEATM.

Asteroide	$D_{phot}(km)$	$p_{v_{phot}}$	η_{phot}	$D_{spec}(km)$	$p_{v_{spec}}$	η_{spec}
65*	278.4 ± 40.0	0.051 ± 0.016	0.983 ± 0.180	281.4 ± 5.9	0.050 ± 0.002	1.052 ± 0.025
76	162.8 ± 58.5	0.046 ± 0.048	0.625 ± 0.328	169.0 ± 0.5	0.043 ± 0.000	0.7 (FIJO)
107	247.1 ± 31.1	0.043 ± 0.014	1.089 ± 0.166	219.2 ± 0.5	0.054 ± 0.000	1.0 (FIJO)
153	219.3 ± 28.6	0.037 ± 0.010	0.933 ± 0.152	250.6 ± 6.6	0.029 ± 0.002	1.101 ± 0.031
168	153.8 ± 168.7	0.050 ± 0.043	0.870 ± 0.964	154.7 ± 0.5	0.049 ± 0.000	0.9 (FIJO)
225	135.2 ± 6.5	0.031 ± 0.003	1.192 ± 0.077	107.0 ± 2.1	0.050 ± 0.002	0.887 ± 0.023
260	164.0 ± 11.6	0.017 ± 0.002	1.396 ± 0.116	156.3 ± 2.9	0.019 ± 0.001	1.279 ± 0.027
334	212.1 ± 25.0	0.033 ± 0.007	0.997 ± 0.147	239.7 ± 4.4	0.026 ± 0.001	1.169 ± 0.021
536	178.01 ± 20.1	0.029 ± 0.006	0.868 ± 0.128	207.6 ± 4.1	0.022 ± 0.001	1.277 ± 0.027
713	106.2 ± 4.8	0.040 ± 0.004	1.046 ± 0.058	99.3 ± 2.9	0.046 ± 0.003	1.014 ± 0.036
721	86.1 ± 8.1	0.047 ± 0.008	0.920 ± 0.109	87.6 ± 1.9	0.046 ± 0.002	0.930 ± 0.023
748	120.7 ± 11.8	0.030 ± 0.007	1.240 ± 0.151	123.8 ± 12.5	0.029 ± 0.006	1.280 ± 0.154
790*	139.8 ± 15.4	0.057 ± 0.013	0.730 ± 0.121	139.0 ± 3.0	0.058 ± 0.003	0.714 ± 0.020
909*	90.9 ± 10.4	0.056 ± 0.013	0.762 ± 0.114	93.04 ± 0.22	0.054 ± 0.000	1.0 (FIJO)

3. Results (II)

Parameters determination:

- Visible geometric albedo (**p_v**), diameter (**D**) and beaming parameter (**η**) determined by applying NEATM to the spectra.
- Great **agreement** between our results and the previous literature (WISE/IRAS)

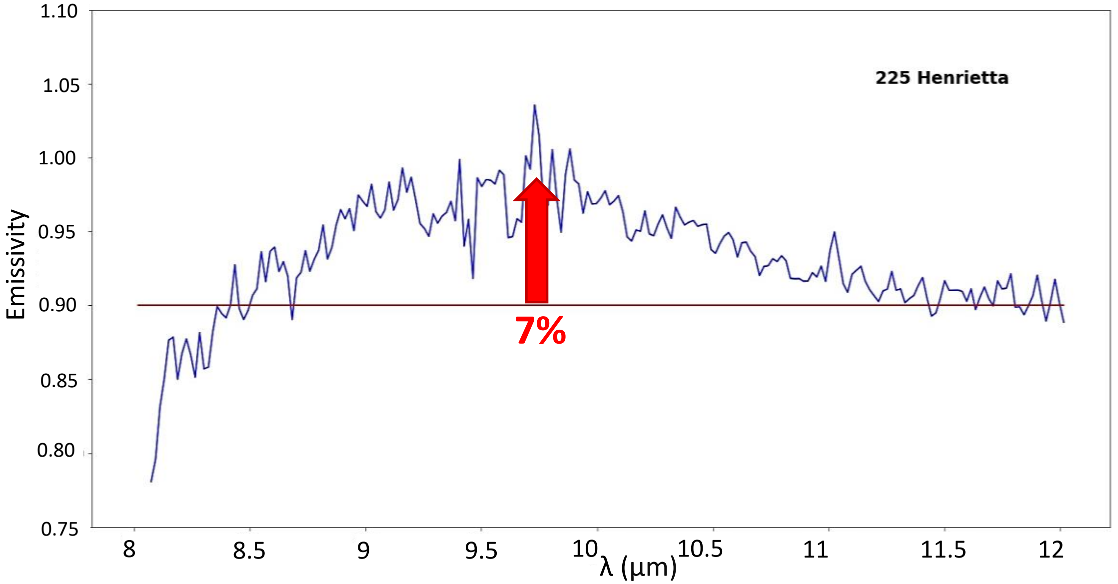


Main feature:

Emissivity plateau (9-11.5 μm), due to the presence of regolith covering its surface, found in the 10 asteroids with good SNR.

Polynomical fitting to calculate the **contrast** (height) of the plateau → Average : **10.8 ± 3.5 %**

→ λ_{max}: **9.5 ± 0.2 μm**



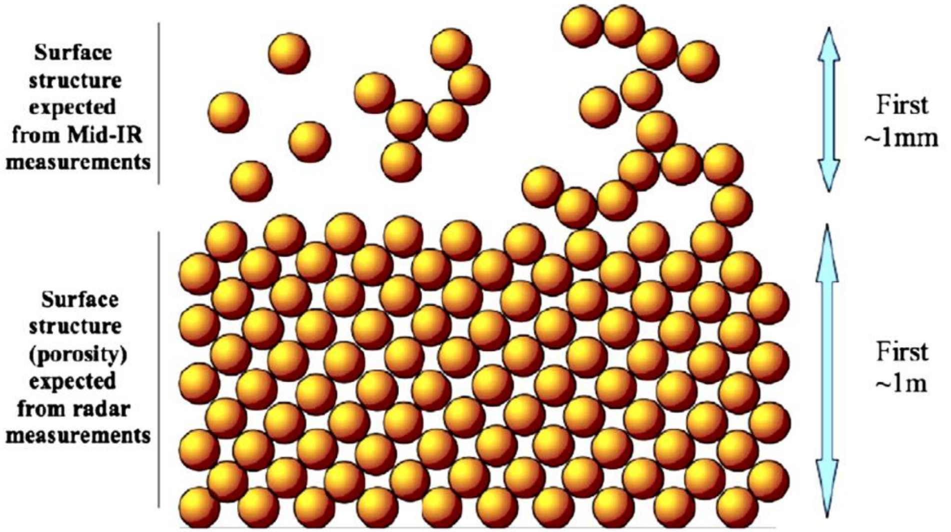
4. Impact and prospects for the future

Conclusions:

- ○ Determination of parameters (D, pv, η)
- ○ Existence of emissivity plateau

Surface infra-dense structure:

- **"Fairy castle" structure**: under dense regolith. Unknown mechanism: transparent matrix? Electrostatic forces? Solar radiation pressure?
- **High contrast (very fine dust)**. More similar to Trojans than to main belt families (Themis, Veritas)
- Possibly **cometary-like** dust mantle



Fairy castle structure. Credit: Vernazza et al. (2012).

Prospects for the future:

- ○ To extend the size of the sample of asteroids (in process)
- ○ To submit a refereed paper with the complete results (in process)