Max-Planck-Institut für extraterrestrische Physik

Observations of asteroids and other small SSOs with Herschel

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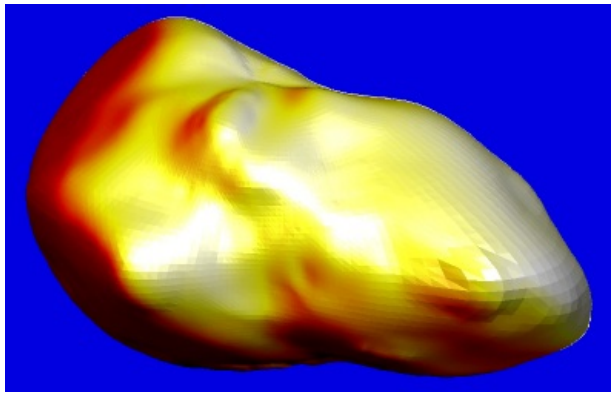
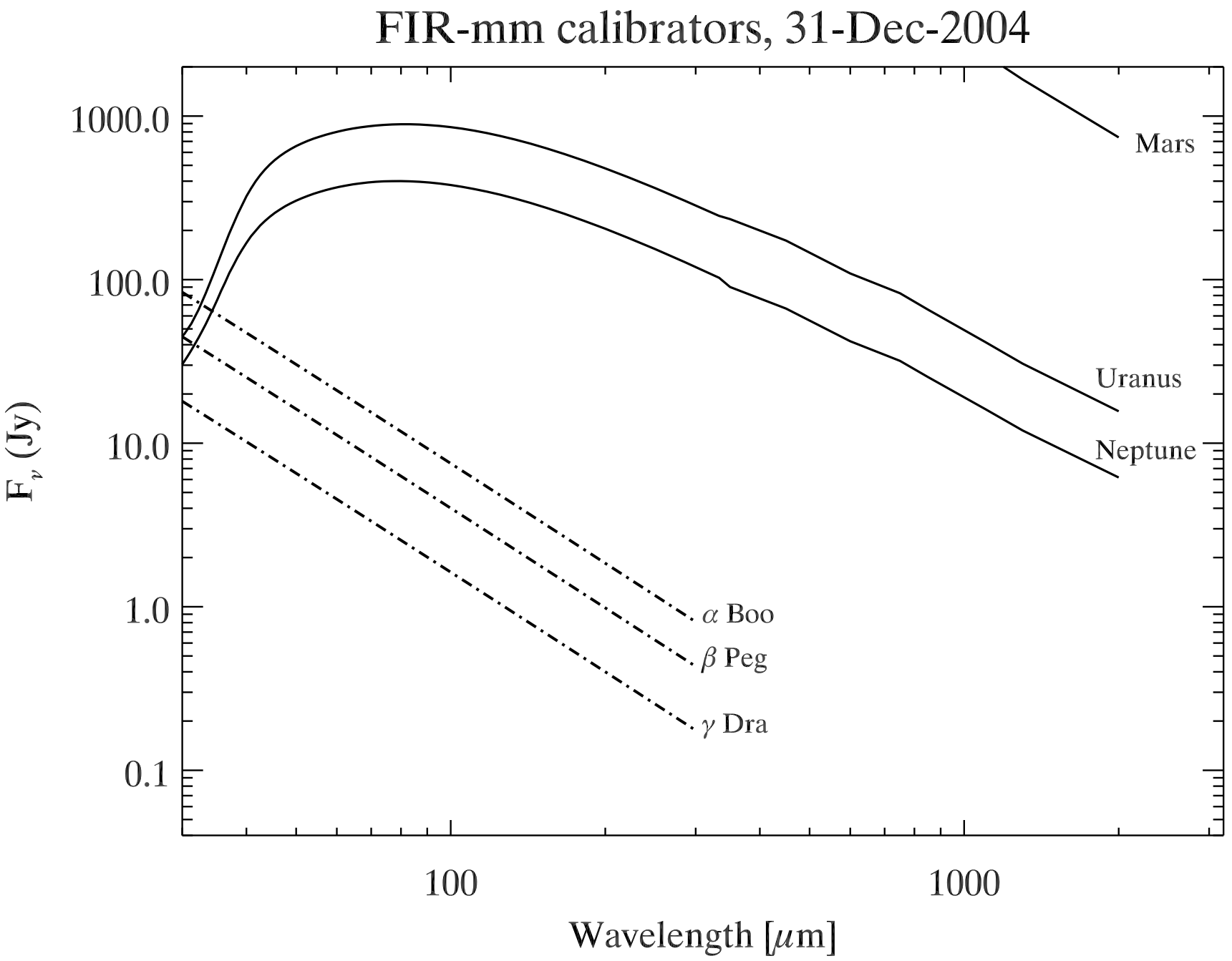
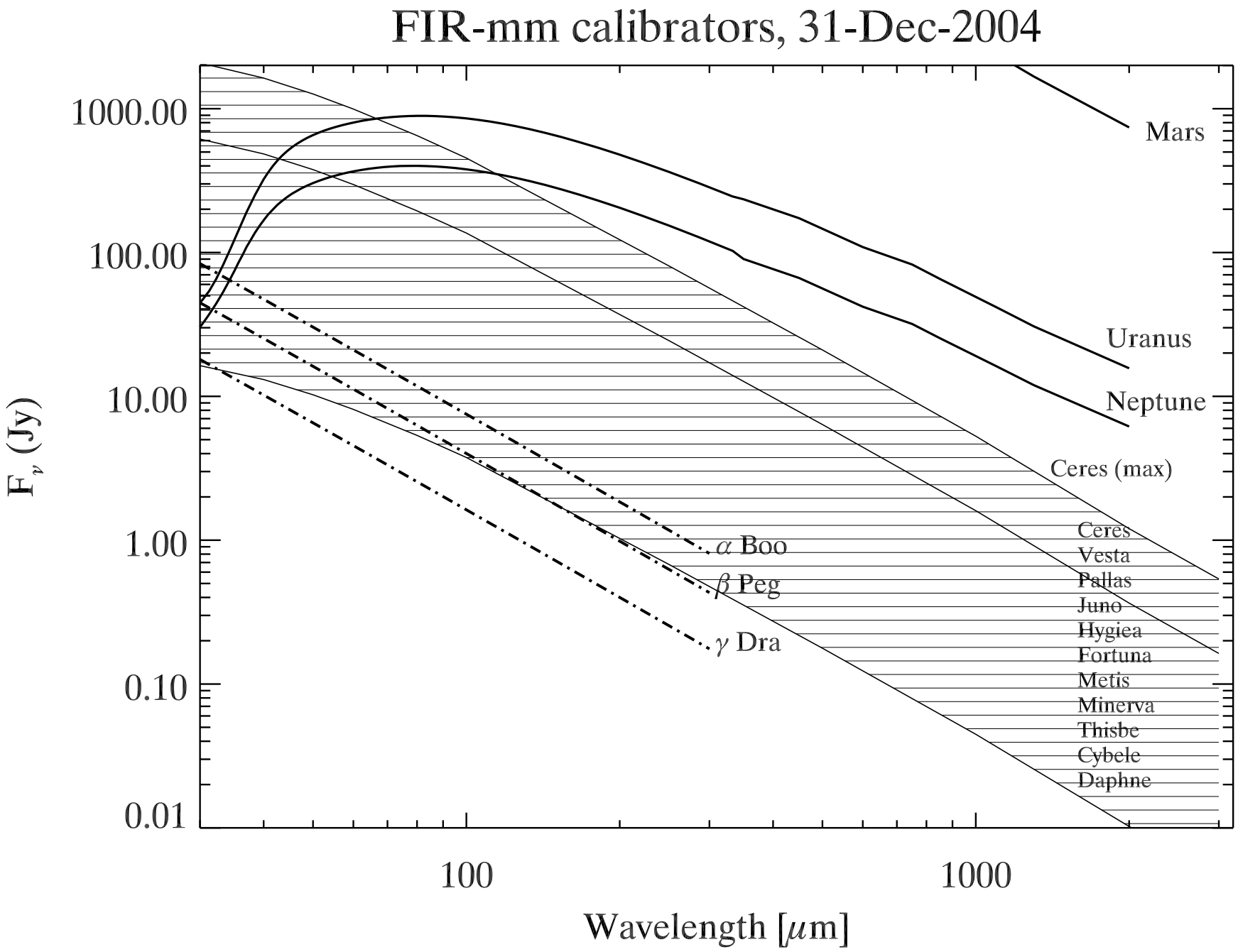


Asteroids as far-IR/submm Calibrators

- Asteroids as relative calibrators for **IRAS** (1983) to "transport" the calibration out to 100 μm
- All four **ISO** instruments used asteroids for calibration purposes at mid- and far-IR (Müller & Lagerros 1998, 2002, Müller et al. 2003)
- **Akari**: 55 asteroids are used to provide the flux calibration for the all-sky-survey (IRC and FIS); filter leak tests
- Asteroids as relative calibrators for **Spitzer** to "transport" the 24 & 70 μm-calibration out to 160 μm
- **Herschel**: establishment of about 50 asteroids in 4 quality catagories

  + **HIFI**: a few bright asteroids only
  + **SPIRE**: the bright sub-set of the 50 potential calibrators
  + **PACS**: 10-30 asteroids in the flux range between bright stars and the planets Uranus and Neptune
- **Alma**: asteroids foreseen as calibrators for the highest frequencies


FIR-mm calibrators, 31-Dec-2004
1000.0
100.0
10.0
1.0
0.1
F_ν (Jy)
100
1000
Wavelength [μm]
Mars
Uranus
Neptune
α Boo
β Peg
γ Dra

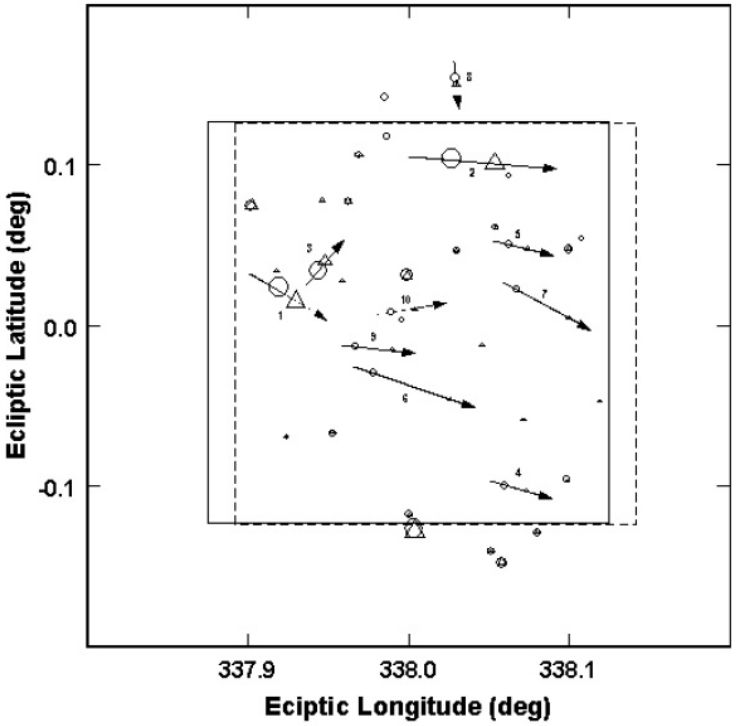

FIR-mm calibrators, 31-Dec-2004
1000.00
100.00
10.00
1.00
0.10
0.01
F$_\nu$ (Jy)
100
1000
Wavelength [μm]
Mars
Uranus
Neptune
Ceres (max)
α Boo
β Peg
γ Dra
Ceres
Vesta
Pallas
Juno
Hygiea
Fortuna
Metis
Minerva
Thisbe
Cybele
Daphne

Serendipitous observations of individual asteroids

The Infrared Space Observatory Deep Asteroid Search
(Tedesco & Desert 2002, AJ 123):

"New study reveals twice as many asteroids as previously believed"

160±20 asteroids per sq deg in the ecliptic plane at 12 μm (0.6 mJy det. limit); in total, the main-belt contains about 1.2 ± 0.5 × 10^6 kilometer-sized asteroids



Estimated asteroid (mainly main-belt astgeroids) counts per sq. deg., assuming the default $5\,\sigma/1$ hour detection limits (3 mJy for PACS, 3-4 mJy for SPIRE), at 90° solar elongation

	PACS			SPIRE		
λ_c	75	110	170	250	360	520
$\beta_{ecl} = 0°$	27	14	6	4	3	<1
$\beta_{ecl} = 10°$	6	4	1	1	<1	<1

→ **diameter and albedo determination**

→ **size-frequency distribution**

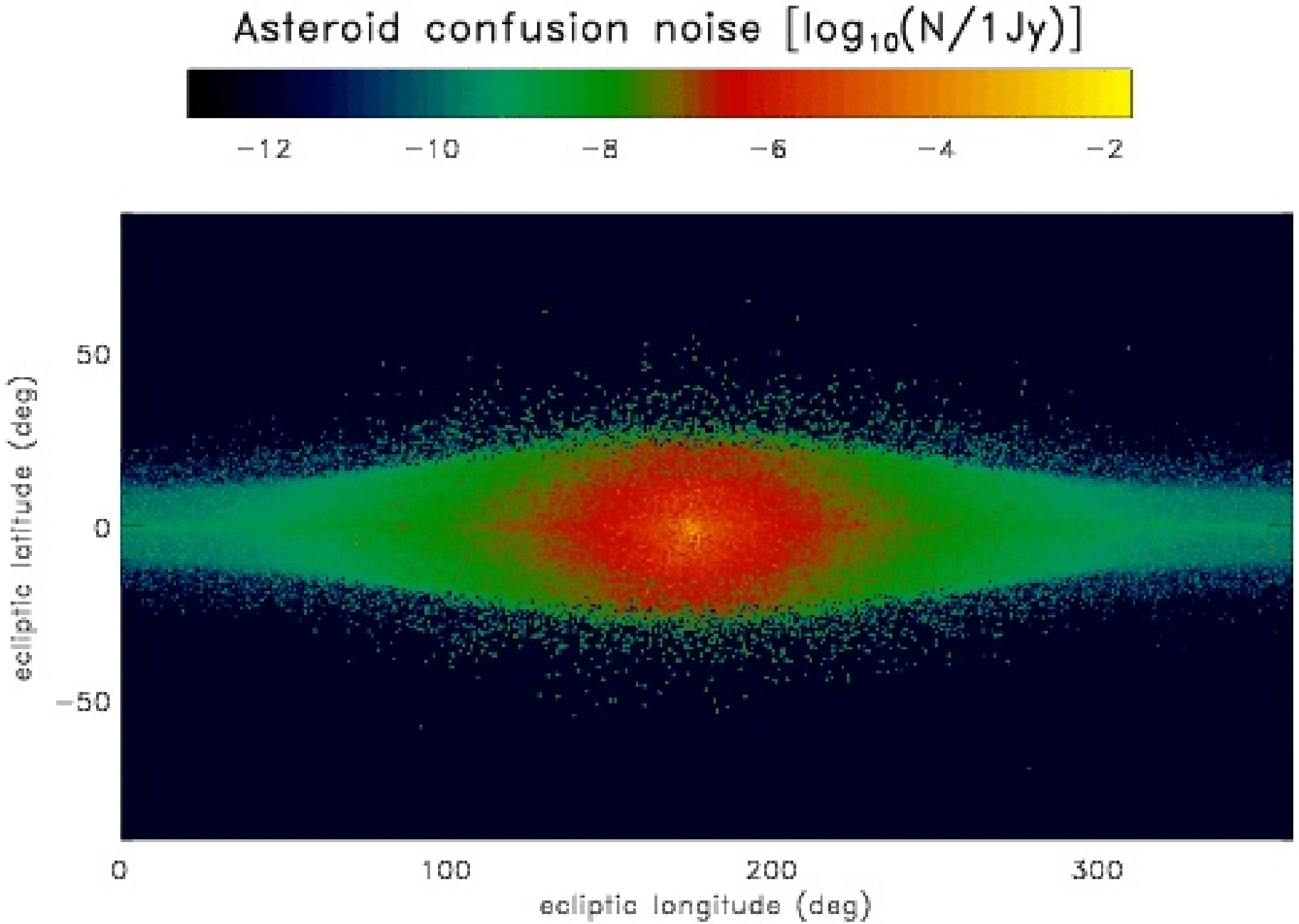
→ **taxonomic studies**

→ **thermal studies**

The Asteroid Confusion Noise Model

(in collaboration with C. Kiss, Konkoly Observatory)

- calculated for the Herschel-PACS bolometer, red channel (130-210 μm, pixel size $\sim 6.5'' \times 6.5''$) with sensitivity 3 mJy (5σ, 1 h)
- based on the Statistical Asteroid Model (SAM, Tedesco et al. 2005) with $\sim 1.9 \times 10^6$ asteroids, obtained from the complete known asteroid sample plus extrapolation of the size-frequency distributions of 15 asteroid dynamical families and three background populations, to a diameter limit of 1 km + simple thermophysical model
- red colour: contribution from asteroids in each pixel is about 10 μJy (red region), 10 mJy (yellow region)
- **Result:** the asteroid confusion noise for Herschel is very low compared to the cirrus and extragalactic components (not considered in the Herschel Confusion Noise Estimator)


Asteroid confusion noise [log10(N/1Jy)]
−12
−10
−8
−6
−4
−2
50
0
−50
ecliptic latitude (deg)
0
100
200
300
ecliptic longitude (deg)

Comet programmes

Water in comets (J. Crovisier + HIFI solar system team)
a GT key programme for HIFI (about 150 hours) with complementary PACS and SPIRE observations

→ study of water in comets

→ evolution of the water production over a large range of heliocentric distances

→ kinematics of the water production (557 GHz water line)

→ water excitation and physical conditions (several water lines)

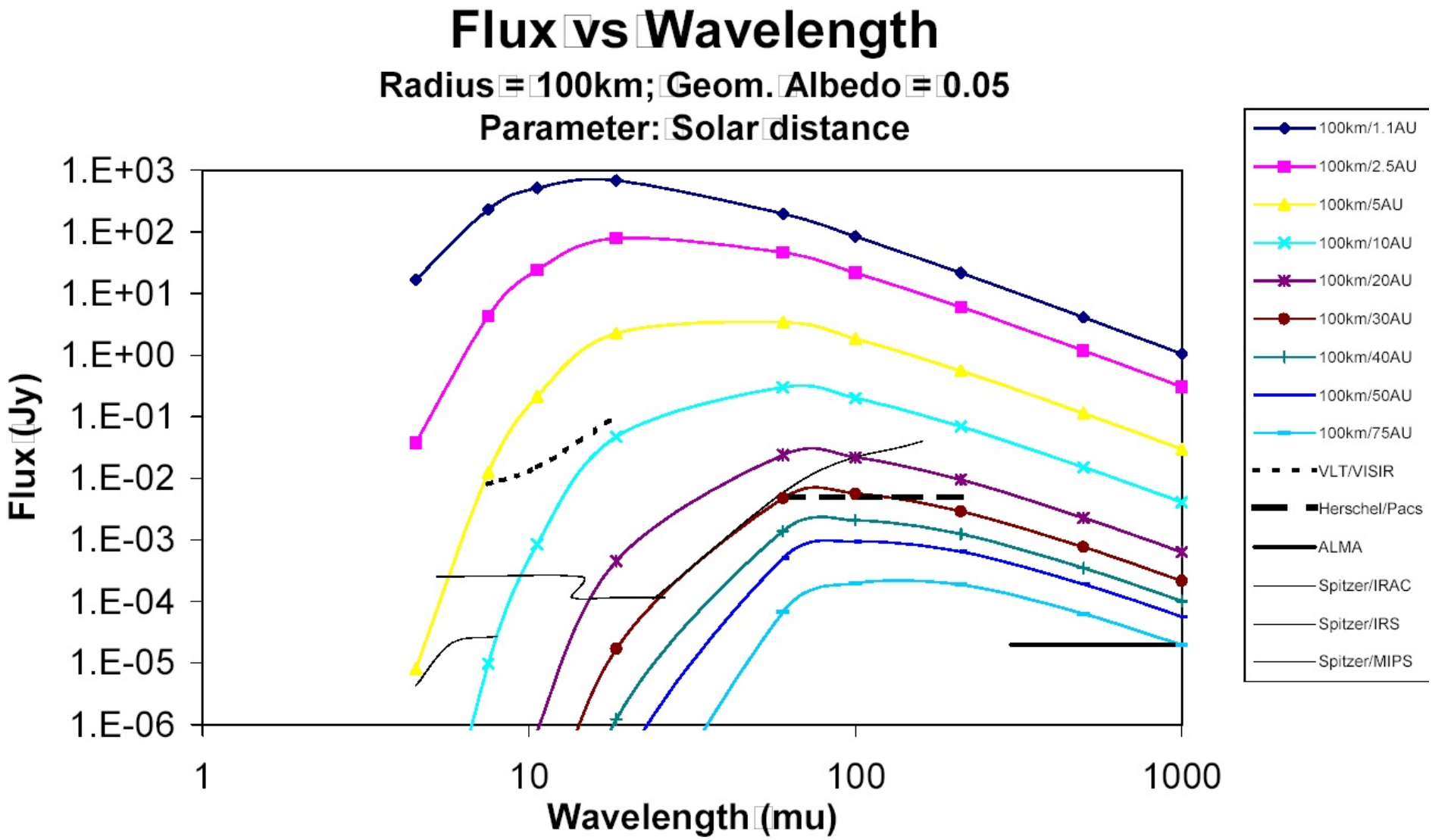
→ D/H isotopic ratio, searching for HDO

- PACS continuum measurements
  $\longrightarrow$ to probe the dust component of the cometary material
- HIFI full spectral survey:
  $\longrightarrow$ unbiased observation of water and its isotopes and of several other cometary species
  $\longrightarrow$ a serendipitous search for parent and daughter species
- Targets
  - short period comets (with strong and weak activity)
  - unexpected comets as 'target-of-opportunity'

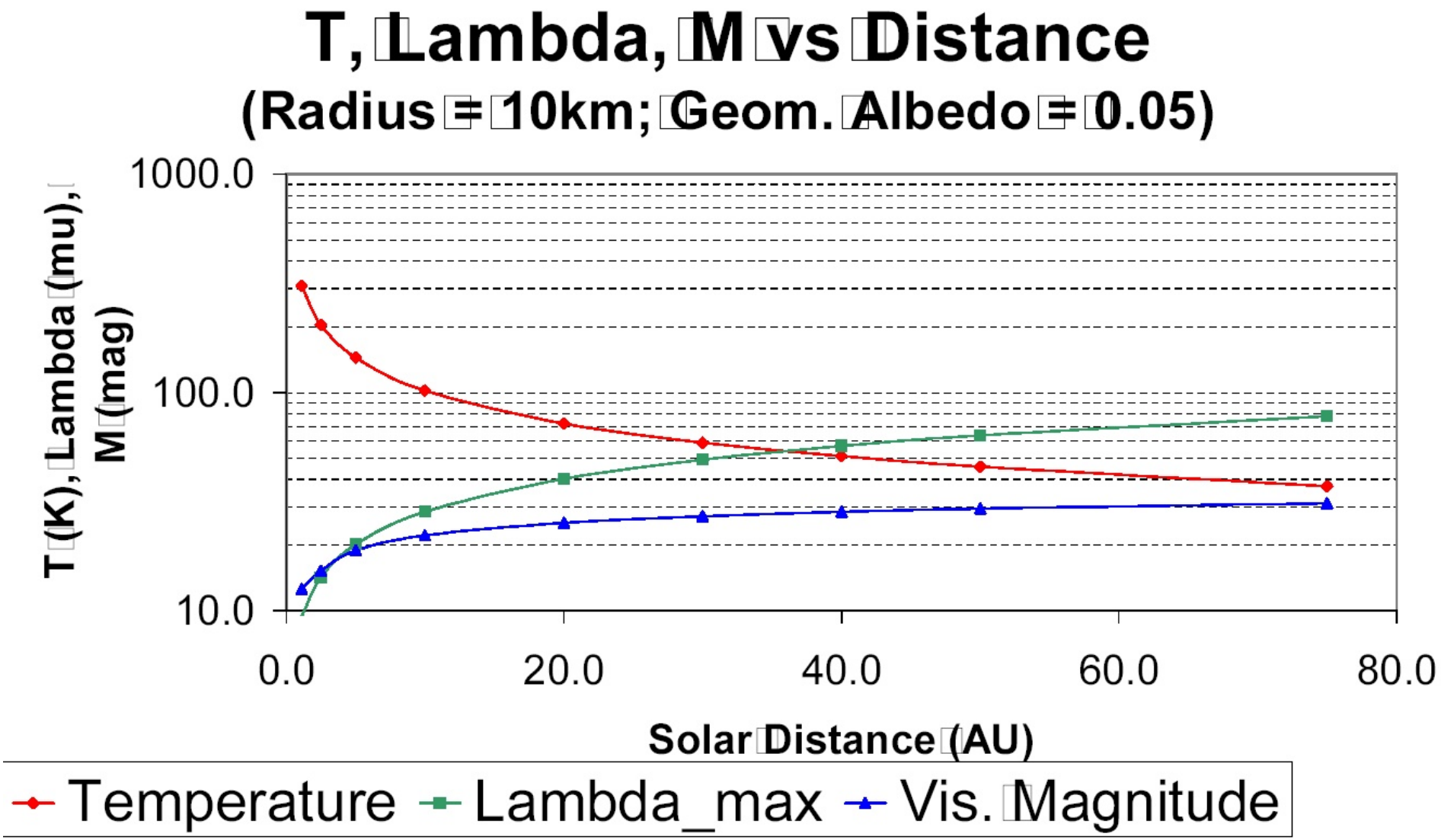
Possible Asteroids/TNO projects

- Dedicated, repetitive deep imaging of a small field in the ecliptic plane to extract all moving targets (similar to ISO and Spitzer programmes)
  → number counts, ecliptic plane scale heights
  → zodiacal light as a function of ecliptic latitude
  → size-frequency distribution
- Studies of asteroid-comet transition objects
  → connections between comets and asteriods, fate of extinct comets
  → compositional studies
- Far-IR/submm spectroscopy of different asteroid groups (NEAs, MBA, TNOs, different taxonomic types)
  → thermal studies, emissivity behaviour, regolith properties
  → mineralogic studies? dust/grain size features?
  → pristine material in the outer solar system

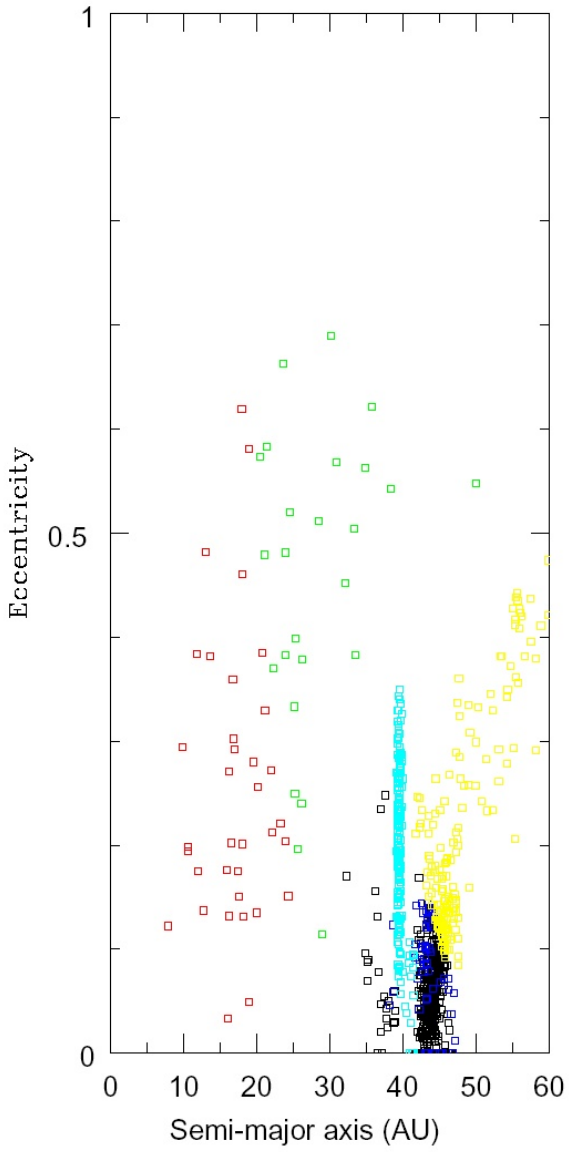
- TNO programme: Characterisation of objects in the outer Solar System (possibly as OT key programme)
  - → diameters and albedos
  - → surface temperature distribution, thermal properties
  - → comet-like dust trails?
  - → compositional information, surface properties
  - → detailed studies of dwarf planet candidates, contributions to the definition of new dwarf planets, comparison with Pluto
  - → size distribution of large TNOs primordial or affected by collisions?

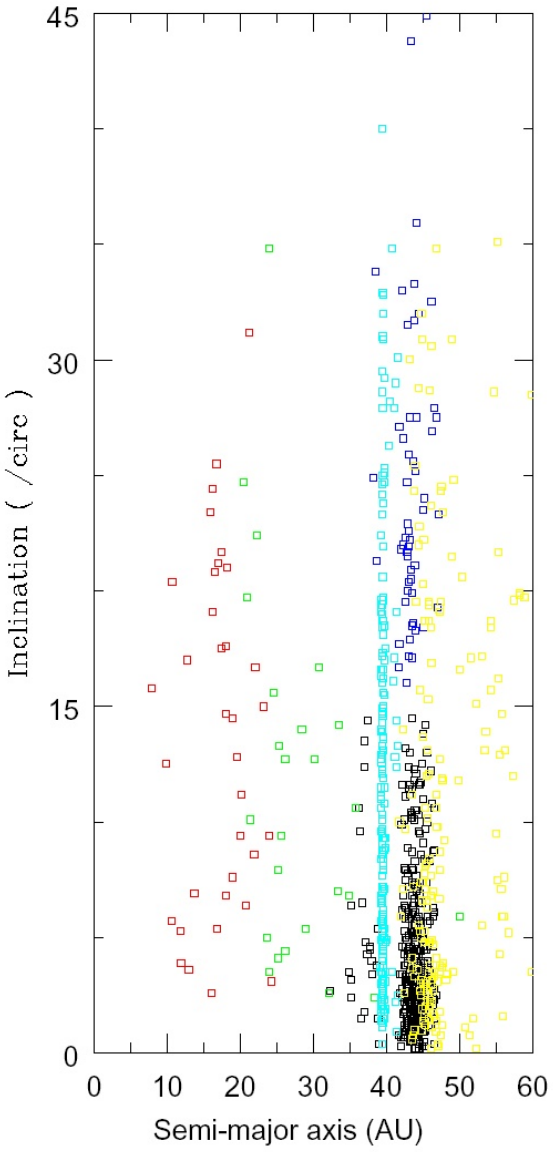


The expected flux fo a 100 km size body with wavelength, parameter is solar distance. Some reference lines for Spitzer, VISIR, PACS and APEX are plotted as well. PACS can detect more than half of the known TNO population.



The temperature, wavelength of maximum of thermal flux and visual brightness of solar system objects are shown as a function of the solar distance.





Red : Inner Centaurs, Green : Outer Centaurs, Yellow : Scattered Disc objects, Cyan : Plutinos, Black : Cold EK disc objects, Blue : Hot EK disc objects.

Number of multi-apparition TNOs(out of the 422 targets) above a certain flux density threshold based on the predicted STM fluxes at PACS/SPIRE wavelengths. Albedo assumptions: $p_V = 0.05$ (left), $p_V = 0.10$ (right).

	Wavelength [μm]						Wavelength [μm]					
FD $\geq$	75	110	170	250	360	520	75	110	170	250	360	520
5 mJy	217	204	127	64	28	16	87	79	50	27	16	8
10 mJy	84	77	46	24	15	7	35	29	21	15	7	2
20 mJy	35	29	21	14	7	2	19	16	11	4	2	0
100 mJy	5	5	2	0	0	0	1	1	0	0	0	0
500 mJy	0	0	0	0	0	0	0	0	0	0	0	0

Conclusions

- Some of the large main-belt asteroids are excellent calibrators in the far-IR/submm (IRAS, ISO, Spitzer, Akari, Herschel, ALMA, ...)
- Individual asteroids will be seen in deep surveys, but they contribute very little to the background confusion
- A large GT key programme has been established on "water in comets"
- Asteroids/TNOs are not part of any GT key programmes: possibility of an OT key programme
- Akari will see more than 10 000 asteroids at thermal wavelengths between 5 and 200 μm (mainly main-belt asteroids), but Herschel is better suited for studies of Trans-Neptunian objects/ dwarf planets

$\rightarrow$ **PACS as the "TNO machine"?!**