



Observing Solar System Objects with Herschel

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Solar System Objects in HSpot

- **What can and cannot be observed?**
 - Only the Superior Planets can be observed.
 - **Mars, Jupiter, Saturn, Uranus and Neptune**
 - The satellites of these planets can be observed, if resolved
 - **For the brightest planets, scattered light and saturation from the primary are the major problems.**
 - **Some satellites are too close in to their primary to be resolved easily**
 - At 90 microns the spatial resolution of Herschel is 6 arcseconds.
 - **Phobos and Deimos, Triton and several of the satellites of Uranus will difficult or impossible to resolve. It will be challenging except at greatest elongation.**

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Solar System Objects in HSpot



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- Many asteroids and NEOs can be observed.
 - Some tens of Main Belt asteroids will be used as primary calibrators for Herschel.
 - But very close-approach NEOs may be impossible to track.
- Several hundred TNOs are theoretically observable.
 - Approximately 350 are potentially detectable in at least one PACS band.
- Many comets can be observed.
 - ☑ But usually only if they are outside the Earth's orbit.
 - ☒ Bright comets with perihelion inside the Earth's orbit will, unfortunately, almost never be observable close to perihelion.

Entering Solar System Objects



- Solar system objects offer the problem that, unlike stars, galaxies and nebulae, they move.
 - The Observation Planning System must calculate their position at the moment of observation.
 - It has to calculate a tracking rate for the moment of observation and maintain the tracking during the observation.
 - The visibility windows are complicated.
 - Objects in the ecliptic may have close encounters with bright planets that interrupt their visibility.
 - But, HSpot *does not take into account* the times when a satellite is behind its primary when calculating visibility windows!
- HSpot uses the NAIF identifier code for Solar System Objects. It does not present a sample position.





NAIF Identifiers (NAIF ID)

- What is the NAIF identifier?
 - NAIF stands for “Navigation and Ancillary Information Facility”.
 - NAIF offers the SPICE information system.
 - This is the system used by NASA for spacecraft navigation.

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Observation Planning

- The Observation Planning System takes the NAIF ID and makes a series of calculations:
 - It calculates the X, Y, Z coordinates of the object for the date of observation.
 - The visibility, position and tracking rate are calculated for the position of Herschel on that date.
 - It checks visibility constraints for the date of observation (proximity to the Earth, Moon, planets and bright asteroids)

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NAIF Identifiers (NAIF ID)

- **What constitutes a NAIF ID?**
 - It is a unique 1, 3 or 7-figure identifier for each Solar System Object.
 - Integers from 1-9 for the barycentre of planetary systems (Mars = 4, Jupiter = 5, Saturn = 6, etc.)
 - Physical centres of planets are 3-figure integers
 - Mars = 499, Jupiter = 599, Saturn = 699, etc.
 - In no case is the difference between the physical and barycentre significant for Herschel.
 - 7-digit numbers beginning with “1” for comets
 - 7-digit numbers beginning with “2” for numbered asteroids
 - 7-digit numbers beginning with “3” for unnumbered minor bodies.

Observation Planning

- **What are the problems?**
 - **Objects with a NAIF ID starting with “3” may not have an orbit of high enough quality to be observable.**
 - **Positional errors that may be of arcminutes, or in extreme cases, even degrees for some comets, asteroids and TNOs.**
 - For PACS the maximum acceptable position error for photometry is 25 arcseconds.
 - For HIFI observations in the smallest aperture, a position uncertainty of even 2 arcseconds may be unacceptable.
 - **Uncertain ephemerides = uncertain tracking rate.**



What Solar System Objects does HSpot Support?

- There are several hundred thousand objects with a NAIF ID.
 - Many of them are not observable by Herschel.
 - At present the ephemeris for each new Solar System Object (SSO) that is added has to be processed by hand, so we have had to be selective.

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What Solar System Objects does HSpot Support?

- About 600 SSOs are currently supported by HSpot
 - All observable planets and their principal satellites provided that the satellite reaches an elongation of at least 15 arcseconds from the centre of the disk.
 - Numbered comets brighter than magnitude 13 during the expected duration of the Herschel mission.
 - About 50 of the brightest Main Belt asteroids
 - All NEOs with a close pass to within 0.15AU during the expected duration of the Herschel mission.
 - About 350 TNOs observable with PACS.
 - Additional objects can be entered on request.

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Galactic Latitude Matters

- Even for bright objects, the Galactic Latitude really does matter.
- Avoid observing even the brightest objects at Latitude $<5^\circ$.
- Check the Horizons ephemeris carefully and stay clear - with time constraints – of low Galactic latitudes.
- Always use the Herschel ephemeris, not the geocentric because the parallax makes a big difference in the Asteroid Belt [**put in 500@-486 to get the ephemeris from Herschel**].
- Overlay your SSO on the IRAS 60 or 100 micron image to see the background.

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Beat that Confusion!

- Remember that SSOs can beat the confusion limit for Herschel if you observe the SSO and then the background where the SSO was.
- This observing method also removes the cirrus background effectively.
- However, you need to bear in mind very carefully the rate of SSO motion.
 - Ideally for PACS you want your two observations separated in time by just enough time for the SSO to have moved by about 4 pixels between the "on" and the "off" exposure.

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Timing is Everything!

- To get the best sensitivity out of PACS, look to observe where the cirrus background is dark.
- Time constrain your observations if sensitivity and s/n are an issue.

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