

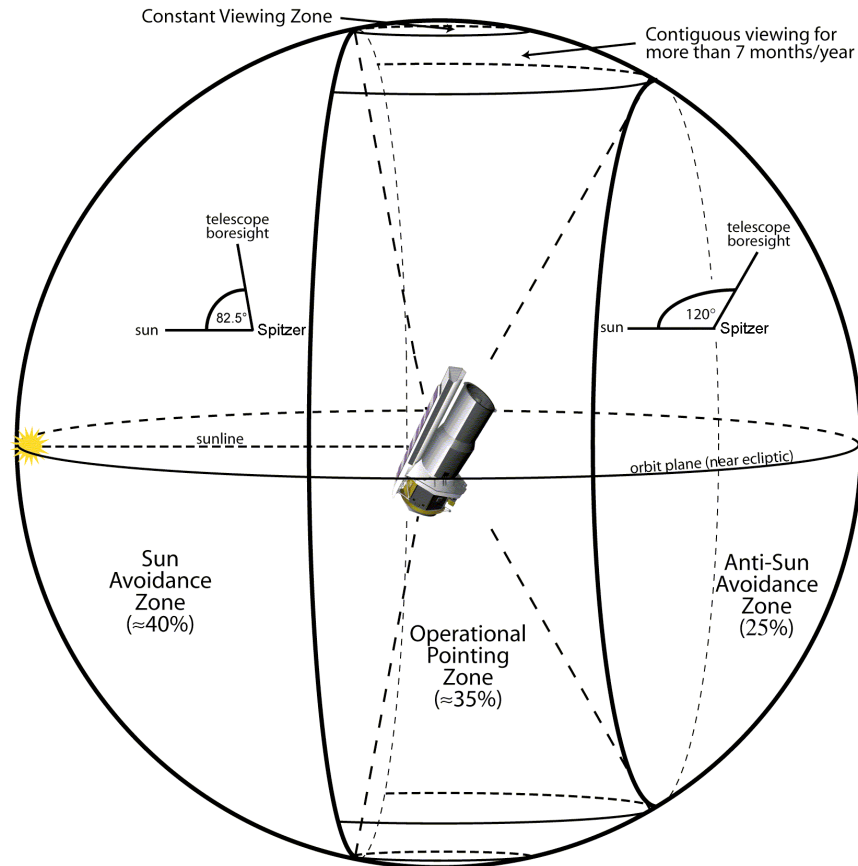
# Solar System Observing With Spitzer

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*6.1, 11 Sep 2014*

The Spitzer Space Telescope is constrained to point no closer than  $82.5^\circ$  towards the Sun, and no further than  $120^\circ$  away from the Sun. These constraints ensure that sunlight never hits the telescope and that adequate solar power is generated for the spacecraft. However, within the solar elongation constraints, the spacecraft can rotate through  $360^\circ$  about the spacecraft-Sun axis. Therefore, at any given time, the Spitzer viewing region, known as the Operational Pointing Zone (OPZ), is an annulus constrained between solar elongations of  $82.5^\circ$  and  $120^\circ$  (see Fig 1). As the Spitzer spacecraft orbits the Sun, the OPZ drifts approximately  $1^\circ$  per day at the ecliptic, so that the entire sky is observable at some time over the course of a year. During a given year, objects in the ecliptic are visible to Spitzer within two approximately 38 day windows separated by about 6 months, and the available spacecraft position angle is limited. Objects at higher ecliptic latitudes are visible for longer periods, and objects at or within  $10^\circ$  of the ecliptic poles are visible continuously. Note that the OPZ changed slightly in early 2004.



Because of the solar elongation constraint ( $82.5\text{-}120^\circ$ ), Mercury and Venus are never visible to Spitzer, and other bodies cannot be observed at or near opposition. However, that still leaves the vast majority of the Solar System for Spitzer exploration, including other major planets, dust

structures, and a myriad of minor bodies, such as satellites, asteroids, comets and Kuiper Belt Objects (KBOs). To this end, Spitzer provides several special features designed to support observations of Solar System objects.

### **Acquisition and Tracking of Moving Objects**

Moving targets are acquired by first slewing the spacecraft to wait at an acquisition point on the object's orbital track, ahead of the object's position. As the object reaches that acquisition point, the spacecraft is accelerated to match the rate and direction of the target. Once the track command has been issued, the onboard system will maintain knowledge of where the telescope should be pointing at what time, allowing it to initially "catch up" with the specified track and maintain it.

The spacecraft does not carry target ephemerides on board, so that all tracking information is defined at the time of scheduling. Tracking is performed in linear segments at rates ranging from 0.1 milliarcsecond/sec to 1"/sec (from 0.36"/hr to 3600"/hr). This allows tracking of objects ranging from KBOs to Near Earth Asteroids (NEAs). During Science Verification, Spitzer successfully acquired, tracked and obtained spectroscopy on a solar system target moving at over 200"/hr.

Spot will automatically include a 180-sec overhead to AORs observing moving targets, in addition to the normal 210-sec slew overhead, to account for the acquisition and tracking requirements.

### **Ephemeris Management**

#### *NAIF IDs*

Spitzer uses the NAIF identifier to specify a particular moving target for observation. NAIF IDs can be obtained from Spot within the "Target" entry window. NAIF name/ID resolution is performed with an interactive query to the JPL Small Body Database Browser. As this database is updated daily, even very recently discovered objects will have NAIFID/name available resolution in Spot.

#### *Ephemerides*

Spitzer uses ephemerides derived from the Horizons database, maintained by the Solar System Dynamics Group at JPL. For proposal planning purposes, Spot can retrieve ephemerides for a specified target, by resolving the NAIF ID.

If you are planning a proposal with a large number of potential targets this can also be handled through Spot. To manage a large list of targets, first prepare a simple ascii list of your target names or NAIF IDs and use the "Import Moving Single Target List" option under the "File" menu in spot to read that list into Spot (See the Spot Help menu for information on acceptable file format). Once you have your target list, you can run visibility calculations in batch by using the "Calculate Visibility Windows for All" under the "Targets" menu to generate your visibility windows for observational planning. In this process, you will also retrieve ephemerides for any targets not already in the Spot ephemeris cache.

If the object is newly discovered, is not released through the Minor Planets Center (MPC), and does not yet have a NAIF ID, the observer needs to send the orbital elements to the Spitzer Helpdesk and request generation of an ephemeris for planning purposes. Requests received at the SSC for non-standard ephemerides during the last week of the Proposal Call will be supported on a best effort basis.

### *Late Ephemeris Updates*

The ephemeris used to specify pointing and tracking is routinely updated 5 weeks prior to execution of the observations. A late ephemeris update may be needed if your object's position is 1) likely to become significantly uncertain during the period 5 weeks prior to the execution of the observation, as might be the case for objects with strong non-gravitational forces, or 2) if crucial data required to update the ephemeris would not become available until sometime within that 5 week period prior to execution. In either case, in the warm mission, observations that require a late ephemeris update must be submitted as a Director's Discretionary Time proposal with the appropriate special overheads applied to the AOR(s).

### **Checking Ephemeris Accuracy**

Some Solar System targets can have orbital solutions with relatively large positional errors, usually due to an overall lack of observational data, or insufficient recent observational data. *Spitzer will not schedule targets whose anticipated rms positional errors at the time of scheduling exceed the acquisition array, or map dimensions.* Before proposing to observe a Solar System target with Spitzer, it is *strongly* recommended that the observer check for available information on the ephemeris positional accuracy. Positional errors for the fraction of Solar System targets that are likely to have the largest errors can be obtained through JPL's Horizons software. Horizons has been updated to provide positional error information for comets, NEOs, KBOs, and radar targets (options 36-40 in the Table Quantities). For detailed information on how to use Horizons to check ephemeris accuracy, please see the Horizons Tips for Solar System Observers document at <https://irsa.ipac.caltech.edu/data/SPITZER/docs/files/spitzer/horizons.pdf>

The Horizons positional error information can be used to identify whether the proposed target is likely to be acquired by the planned Spitzer instrumentation, or whether further ground-based support observations would be needed before Spitzer could successfully acquire the target. Typically, if the 3-sigma radial positional error returned by Horizons exceeds half the Spitzer acquisition aperture, i.e., half the IRAC then the object can still be proposed, but should be flagged as having a large positional error at time of proposal. An effort should then be made to provide the required observational information to improve the ephemeris prior to Spitzer observing, if at all possible. If this information is not able to be obtained more than 5 weeks prior to the target observation date, then the observation must be proposed as part of a Director's Discretionary Time proposal with the appropriate Late Ephemeris Update applied to the observation(s). Late ephemeris updates are not allowed in warm mission GO programs. If no positional error information is available at time of the proposal deadline but is expected to be obtained more than 5 weeks prior to the target observation date, then an object can still be proposed, but the lack of positional error information should be stated in the proposal.

## Observing Modes Available for Moving Target Observations

As with fixed target observations the IRAC Post-Cryo AOT can be used for moving target observations. Spitzer also provides several specific features that support and facilitate Solar System observing. These are summarized below.

### Shadow Observations

#### *Rationale*

The infrared flux from background sources, and particularly small-scale structure in that background, frequently limits the sensitivity of Spitzer. Spitzer Solar System observers can specify “Shadow” background observations. A shadow observation allows the track across the sky taken during observation of a moving target to be replayed or pre-played when the target is not there. Shadow observations should allow the observer to remove background small-scale structure, thereby improving moving target sensitivity (and in fact exceeding that attainable for fixed targets). In general, a shadow observation is most effective when taken as close in time to the primary observation as is practically possible. This improves the accuracy of background subtractions by minimizing differences in the observed background due to time-dependent changes in the zodiacal light, and instrument characteristics and calibration. Finally, shadow observations requested as close as scientifically possible to the primary have a larger possible scheduling window for the primary-shadow pair, maximizing the probability that the observation can be scheduled on the spacecraft.

#### *Estimating Sky Backgrounds*

Estimating backgrounds and small-scale structure (confusion) is a required part of observation planning (and a Spitzer proposal), and observers are advised to use the tools available through Spot and the IRSKY utilities to determine whether shadow observations would benefit their moving target observations. Information on both software packages is available in the “Proposal Kit” section of the Spitzer public web site. The URLs for these are given in the final section of this document.

#### *Specifying a Shadow Observation in Spot*

Information on how to specify a shadow observation is provided in detail in the Spot User’s Guide. When the shadow is executed, at an observer-specified time interval either before OR after the primary observation, Spitzer will be commanded to replicate the path across the sky taken during the observation of the primary, on the date that the primary was observed. Note also that shadow observations must be specified using an AOR that is *identical* to the primary (scientific target) observation.

#### *Spot Feature to Calculate Shadow Visibility Windows.*

Spot has the capability to determine the extent of a shadow visibility window, given a nominal observing date for the primary. Because of the nature of shadow observations, the shadow visibility window may be much shorter than the primary visibility window. This is because even though the moving target may still be visible at the time of the shadow observation, the arc on the sky where the primary observation was taken may have been overtaken by the 1 degree a day

movement of the OPZ, depending on whether the target was moving with or against the OPZ motion, and at what rate.

Using this capability is *not required* to specify a shadow observation, but could help users with moving target timing constraint planning by warning of very small or unschedulable windows for a shadow, if a given primary date is selected. This feature is available in Spot under the moving target “Visibility/Orientation” window in the “Target” entry window. Detailed instructions on how to use this new facility are provided in the Spot User’s Guide, but in summary, enter the nominal primary observation date into Observation Date and click the “Calculate Shadow Visibility” button. A new Visibility Window will open containing the visibility windows for the shadow.

### *Justifying Shadow Constraints*

As with all observing constraints, the need for a shadow constraint must be scientifically justified. Shadows specified to execute BEFORE the primary observation are much more difficult to schedule than shadows executed after the primary, and require even more compelling scientific justification in the proposal than shadows executed after the primary.

### **Observe Offsets Only**

Spitzer allows users to specify “cluster” observations for a group of positions close together on the sky that require the *same observational parameters*. The cluster is specified as a central target position and one or more offsets. Spitzer allows moving target observers to track on the centrally specified object, but observe only the offset position(s) from that central object. This feature may be of use for comet observations, when you may want to track on, but not observe, a bright nucleus. It may also assist any imaging observations that require you to move the target object from the center of the image field to displace a nearby bright source off the detector (e.g., when observing the satellites of major planets).

### **User-Defined Ephemeris**

If an object does not yet have a NAIF ID, observers can specify observations for objects for which they provide the orbital elements. Ultimately, for scheduled observations, the orbital elements entered at the time of proposal submission will be updated and converted into a Horizons ephemeris for use in scheduling and execution of the observations.

### **Flexible “Bright Moving Object Avoidance”**

To preserve the quality of astronomical data, Spot generally precludes observations of a science target that is too close to a known bright moving object, which includes Earth, Mars, Jupiter, Saturn, Uranus, and Neptune and a small subset of bright asteroids. However, for those wishing to observe major planets or their satellites, Spot will intelligently preclude the major planet in a target system from bright object avoidance calculations, but Earth avoidance and avoidance of the other bright objects may be maintained, if desired. Obviously *choosing* to observe close to a bright object carries inherent risk of poor-quality data, and such observations should be carefully planned to maximize data quality. Scattered light and latent image behavior is described in the Warm Spitzer Observer’s Manual (SOM) and in the corresponding instrument Data Handbooks.

## **Targets of Opportunity**

Please see the Target of Opportunity section of the Spitzer Observing Rules:

- Cryogenic mission:  
[https://irsa.ipac.caltech.edu/data/SPITZER/docs/files/spitzer/SpitzerObsRules\\_cryo.pdf](https://irsa.ipac.caltech.edu/data/SPITZER/docs/files/spitzer/SpitzerObsRules_cryo.pdf)
- Warm and Beyond missions:  
[https://irsa.ipac.caltech.edu/data/SPITZER/docs/files/spitzer/SpitzerObsRules\\_warm.pdf](https://irsa.ipac.caltech.edu/data/SPITZER/docs/files/spitzer/SpitzerObsRules_warm.pdf)

## **Visualizing the Position of Known Moving Targets**

Spot is capable of visualizing known moving targets in a given field, either in advance of observations, using the images provided within Spot, or to help identify known moving targets in your data, by uploading your Spitzer fits file data into Spot. To bring up the image, select the “Images” menu and either load one of our catalog images, or select “Fits file image” and load your Spitzer imaging data. Then select “Overlays” and “Show all known moving objects at a date”. Enter the date and time of your observation, and the search radius for object identification.

## **Using JPL’s Horizons to Plan Your Spitzer Observations**

Spitzer can be requested as an observatory (i.e., a coordinate system center) using the telnet, e-mail and now web interfaces to JPL’s Horizons Ephemeris software. Consequently, Horizons’ large range of geometric information and observing parameters for Solar System objects can be calculated for the Spitzer observer. Other additions to the Horizons software to support Spitzer observations include solar elongation clipping to allow observers to output Horizons observer table information only for times when their object is visible to Spitzer, the ability to save Horizons program settings between Horizons sessions, and the generation of positional uncertainty and error ellipse information for your target position based on the ephemeris information available (see the section “Checking Ephemeris Accuracy” in this document for more details).

Another Horizons tool for Spitzer observers is the “ISPY” capability for asteroid identification. This tool identifies the position of known asteroids, as seen from Spitzer, for a given field and time of Spitzer observation. This output file can also be potentially reformatted and read into Spot to provide a form of catalog overlay on Spitzer data, to assist with identification of known asteroids. Detailed information on how to use the above features in Horizons can be found in Horizons Tips for Solar System Observers at [https://irsa.ipac.caltech.edu/data/SPITZER/docs/files/spitzer/Spitzer\\_coords.pdf](https://irsa.ipac.caltech.edu/data/SPITZER/docs/files/spitzer/Spitzer_coords.pdf)

## **Further Information Available on the Web**

See the Spitzer documentation for more information:  
<https://irsa.ipac.caltech.edu/data/SPITZER/docs/>

Horizons Tips For Spitzer Solar System Observers - for Spitzer observation planning, and to identify known moving targets in your Spitzer data:  
<https://irsa.ipac.caltech.edu/data/SPITZER/docs/files/spitzer/horizons.pdf>

Horizons Tips For Spitzer Extrasolar Planet Observers - to calculate Spitzer's heliocentric position as a function of time:

[https://irsa.ipac.caltech.edu/data/SPITZER/docs/files/spitzer/Spitzer\\_coords.pdf](https://irsa.ipac.caltech.edu/data/SPITZER/docs/files/spitzer/Spitzer_coords.pdf)

Estimates of infrared backgrounds can be found using 'Background Model' at

<https://irsa.ipac.caltech.edu/applications/BackgroundModel/>

JPL's Small-Body Database Browser - provides name, NAIF ID resolution and other information on comets and asteroids: <http://ssd.jpl.nasa.gov/sbdb.cgi>

Asteroid and NEO Count Estimates:

<https://irsa.ipac.caltech.edu/data/SPITZER/docs/spitzermission/observingprograms/solarsystemprograms/>

The Spitzer First Look Survey was executed very early in the mission. Information on the ecliptic plane component of this survey, which targets main belt asteroids, can be found at

<https://irsa.ipac.caltech.edu/data/SPITZER/docs/spitzermission/observingprograms/firstlooksurvey/ecliptic/>

For a list of all the targeted observations of solar system objects made with Spitzer, please see the solar system observing log at

<https://irsa.ipac.caltech.edu/data/SPITZER/docs/files/spitzer/SolarSystemAORs.txt>