Solar System Observing With Spitzer

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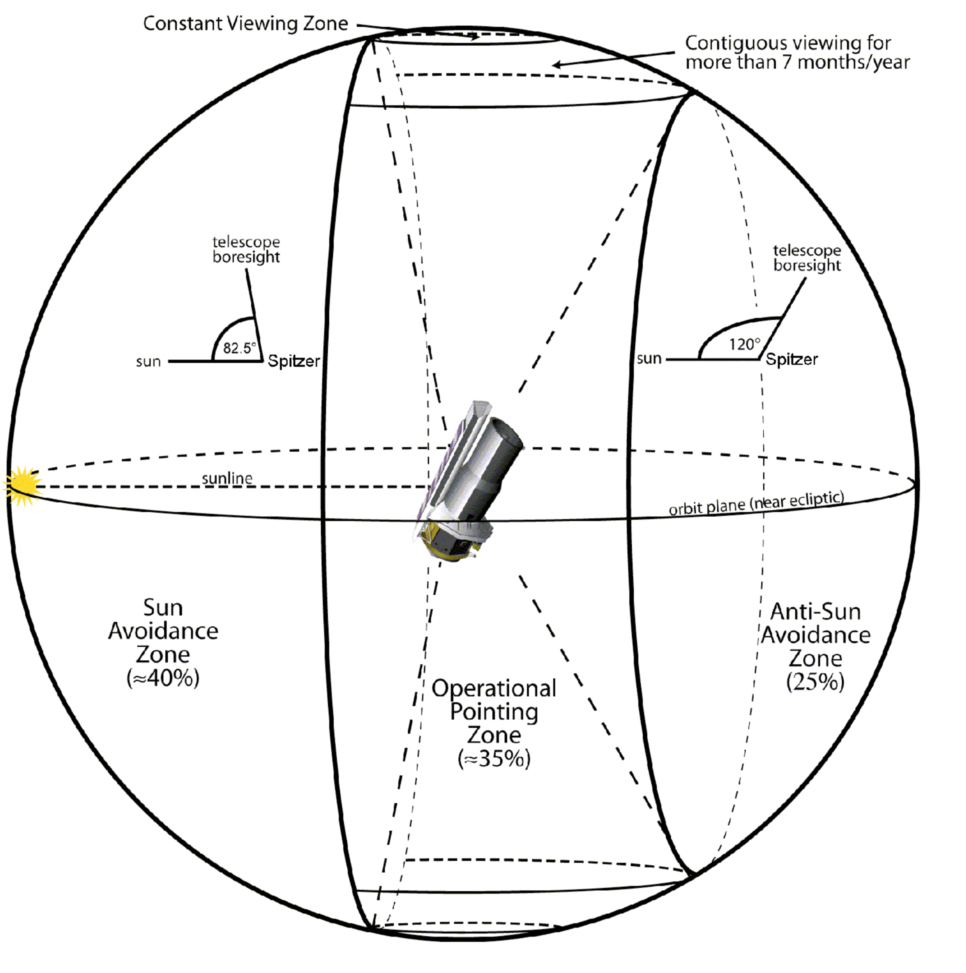
Solar System Observing and the Spitzer Viewing Region

The Spitzer Space Telescope is constrained to point no closer than 82.5° towards the Sun, and no further than 120° 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° 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° and 120° (see Fig 1). As the Spitzer spacecraft orbits the Sun, the OPZ drifts approximately 1° 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° of the ecliptic poles are visible continuously. Note that the OPZ changed slightly in early 2004.



Because of the solar elongation constraint (82.5-120°), 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.

Note that to maintain tracking precision for IRS observations, moving target observation requests must be less than 3 hrs in duration to allow sufficient updates of the spacecraft gyros. MIPS observations are also confined to 3 hrs maximum duration. IRAC moving target observations can be specified for up to 6 hrs.

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, a core set of ephemerides is provided with each new release of Spot, the software that Spitzer observers use for planning observations,

New this year, Spot will now automatically retrieve ephemeredes from Horizons if they are not contained in Spot's original core set. This is done when visibility estimates, or other Spot functions requiring the ephemeris, are requested by a user. The extra step of retrieving a new ephemeris to perform the requested function should be largely transparent to the user, typically taking an extra 3-5 seconds during normal load periods. The way this works is that you simply enter your target into the Spot target window, and then request, say, visibility estimates. Spot will first query the existing cache of ephemeredes. If it does not find your target there, it will automatically send a request to Horizons to generate the ephemeris and deliver it to the cache at the SSC. Your visibility request will then be calculated and displayed, and the ephemeris will remain available in the cache for all future Spot queries for this target.

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 ephemeredes for any targets not already in the Spot ephemeris cache.

Late Ephemeris Updates

For TAC-approved moving target observations that are to be scheduled on the telescope, the ephemeris used to specify pointing and tracking is routinely updated 5 weeks prior to execution of the observations. Ephemeris updates that are closer to the time of execution of the observations can be accommodated if requested by the observer using the Spot Special Overheads button found in the AOT windows, but incur an additional observing time overhead based on the degree of disruption to the preparation of the observing schedule. Note that this feature, the "Late Ephemeris Update," is only required 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.

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: http://ssc.spitzer.caltech.edu/documents/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 or MIPS observation area, or half the IRS peak-up array, if peaking up, or half the appropriate slit dimension or spectral map, if observing with no peak-up, 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 able to be obtained more than 5 weeks prior to the target observation date, then a Late Ephemeris Update *does not* need to be requested at the time of proposal. If no positional error information is available at time of proposal, 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

All observing modes available for fixed target observations are available for moving target observations, including full mapping and scanning capabilities. All peak-up modes with IRS are also provided for moving targets. ***Last year, we introduced the new capability to peak-up on an inertial target (a star), and then offset to a moving target.*** Detailed instructions on how to specify this mode of observing are provided in the Spot User's Guide. In addition to the basic observing modes that support both fixed and moving target observations, Spitzer also provides several specific features that support and facilitate Solar System observing. These are summarized below. In addition to peakup on fixed and offset to moving, new capabilities for this year include shadow visibility window estimates in Spot.

Shadow Observations

Rationale

The infrared flux from background sources, and particularly small-scale structure in that background, frequently limits the sensitivity of Spitzer, particularly at the MIPS (24, 70, and 160 μm) and longer IRS wavelengths. Spitzer Solar System observers can specify "Shadow" background observations for all instruments and observing modes. 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. In addition, for IRS observations, shadows taken as soon as possible after the primary will be more effective at removing the effects of rogue pixels, which are highly time variable. 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. There is also a resource for astronomers new to IR astronomy, with a section specifically on infrared backgrounds.

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. *This is true even for IRS observations with peak-up.* In this case, the Spitzer spacecraft command software compensates for the unnecessary peak-up in the shadow observation, and this should not be manually disabled by the observer in the shadow AOR.

New Spot Feature to Calculate Shadow Visibility Windows.

This year, we have added 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 Spitzer Observer's Manual (SOM) and in the corresponding instrument Data Handbooks.

Targets of Opportunity

Targets of Opportunity (ToO) requests are available for unexpected or unpredictable transient phenomena. These include objects that can be generically identified before the onset of the phenomena, and also objects that cannot be specifically identified at the time of the proposal calls. Requests for generically, but not specifically identified, objects can be submitted through the normal proposal process, and completely unexpected phenomena can be requested between proposal calls through Director's Discretionary Time. High, medium and low Impact ToOs can be accommodated, that respectively have less than 1, 1-5, or more than 5 weeks of lead time before activation. The earliest that Spitzer can carry out ToO observations is 48 hrs after an approved proposal is activated. Like the late ephemeris updates, high- and medium-impact ToOs incur an extra observing overhead. The Spitzer Observing Rules can be found online (see URLs at end of this document) and contain the most up-to-date information on ToO policies. Additional information on ToOs can be found in the current call for proposals (see URL at end), and the current extra overhead burdens for ToOs are also online (see URLs at end). Note that high and medium-impact ToOs for Solar System objects already include an automatic late ephemeris update as part of the ToO. This is included at no extra overhead charge to the observer, and does not need to be specified within Spot.

Visualizing the Position of Known Moving Targets

Spot is now also 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).

A recent addition to Horizons tools 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 know asteroids. Detailed information on how to use the above features in Horizons can be found in *Horizons Tips for Solar System Observers* on the SSC website. <http://ssc.spitzer.caltech.edu/documents/horizons.pdf>

Further Information Available on the Web

The Spitzer Science Center Home Page can be found at <http://ssc.spitzer.caltech.edu>, and questions about Spitzer or planning Spitzer observations can always be directed to the Spitzer E-mail Help Desk at help@spitzer.caltech.edu.

When planning Spitzer observations, we strongly suggest that you visit the Proposal Kit web site. To get there from the home page given above, either click on "Proposal Kit," or go directly to http://ssc.spitzer.caltech.edu/propkit/

On the Proposal Kit web site, you can find (among many other things):
The Spitzer Observer's Manual <http://ssc.spitzer.caltech.edu/documents/som/>
Spitzer Observing Rules <http://ssc.spitzer.caltech.edu/documents/rules/>
Spitzer Call for Proposals <http://ssc.spitzer.caltech.edu/propkit/currentcp.html>
Special Overhead Burdens for Targets of Opportunity (TOOs) and Director's Discretionary Time (DDT) <http://ssc.spitzer.caltech.edu/documents/rules/overheads.pdf>
Downloadable Spot software (for planning observations and submitting proposals) <http://ssc.spitzer.caltech.edu/propkit/spot/>
And the *Spot User's Guide: See Spot Run* <http://ssc.spitzer.caltech.edu/documents/spot/>

The Proposal Kit web site also includes a special Solar System Observations section which provides supporting information for specification of Solar System observations with Spot. This includes a browseable NAIF ID-to-name list, tips on how to get NAIF IDs for newly discovered objects, and a list of the ephemerides currently available to the planning software.

Also included here are *Horizons Tips for Solar System Observers:* <http://ssc.spitzer.caltech.edu/documents/horizons.pdf>

Estimates of infrared backgrounds can be found using Spot, or the IRSKY facility, which is found here: <http://www.ipac.caltech.edu/ipac/services/irsky.html>

The Infrared Compendium is a web resource for astronomers new to the infrared, and includes sections specifically on infrared backgrounds and Solar System objects. <http://ssc.spitzer.caltech.edu/documents/compendium/>

The report from the 1999 Dana Point Workshop on "The Solar System and Circumstellar Dust Disks: Prospects for SIRTF," and the SSC's response to recommendations in the report are available at: <http://ssc.spitzer.caltech.edu/SSC/paperstalks/Dana_Point/>

The Spitzer First Look Survey was executed very early in the mission, and the results of this survey will rapidly be made available to the community. Information on the ecliptic plane component of this survey, which targets main belt asteroids, can be found at: <http://ssc.spitzer.caltech.edu/FLS/eclip/>