



Spitzer Space Telescope

Observation Planning Cookbook Version 11.0

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1 Introduction

Welcome to observing with the Spitzer Space Telescope! The purpose of this “Observer's Cookbook” is to provide complete, detailed, worked examples of how to set up observations for the Spitzer Space Telescope. As such, it is written as a “How-To” manual, based around the following concrete examples of typical observations one can do with Spitzer:

- **Small area, deep imaging:** See chapter 4 for imaging from 3.6 and 4.5 micron with IRAC.
- **Wide-field, shallow imaging:** See chapter 5 for imaging from 3.6 and 4.5 micron.
- **Moving object photometry:** See chapter 6.
- **Time series observations:** See chapter 7.
- **Target of opportunity observations:** See chapter 8.

The structure of this manual is based around the worked examples listed above. Each detailed example is presented in a separate chapter. Each example observation is preceded by a short summary of how to design the program, both to provide a road map for observers to find the information they require later in the chapter, and to provide a unified, comprehensive overview of the program for observers who do not require the detail that follows. The overview is followed by an in-depth discussion about all aspects of the observation design process, as well as abundant screen captures of the observation planning software entry windows, hints, and detailed instructions.

Many of the details presented in each chapter are common to all of the observation programs developed here. Nevertheless, we have opted to repeat much of the information in each chapter (e.g., the target entry process within the Spot), so that each example can serve as a stand-alone document, with complete information on the observation design process.

Designing observations with Spitzer is easy! There is a custom-built software tool for designing Spitzer Space Telescope observations (“Spot”; see sections 2.3 and 2.4 for an overview). Spot is versatile, easy-to-use, and includes a host of convenient features, including the ability to resolve object names, calculate target availability (visibility windows), and visualize observations as an overlay on a user-specified image (which you can provide, or grab from the Digitized Sky Survey, 2MASS, etc).

We also include within this Cookbook some background information that might prove useful to Spitzer observers in general:

- **Overview of preparing Spitzer Space Telescope observations:** See chapter 2.
- **Common Observation Planning Errors:** See chapter 3.
- **Best practices:** A step-by-step guide to submitting your proposal; see chapter 9.
- **Unit conversion:** See chapter 10 (appendix).

A few caveats:

- **What this Cookbook is NOT:** a one-stop source of technical information about the Observatory, or its instruments. Several other good resources exist as definitive references (for example, the Spitzer Observer's Manual, and observatory web pages; see: <http://ssc.spitzer.caltech.edu> to get started). However, we have attempted to include some technical information with each worked example, where we felt it was particularly useful to develop the logic of the observations.
- **Updates to technical information:** For the most accurate and up-to-date information re: instrument sensitivity, performance, behavior etc we encourage observers to check the Spitzer website, particularly the instrument web pages. Also, feel free to contact the Spitzer Helpdesk (help@spitzer.caltech.edu) if you have any questions!
- **Spot version:** Please ensure you are running the latest version of Spot! (v19). See section 2.3 for information on obtaining Spot.
- **Notice anything weird?:** Although we've done our best to make sure that this document is 100% correct at time of publication, undoubtedly there are small errors. If you notice anything, please let us know at the Helpdesk (help@spitzer.caltech.edu).

So, without further ado, let's get to it! In the next chapter (chapter 2) we provide some background information needed before we begin designing observations for the Spitzer Space Telescope

2 Getting Started

Before launching into designing, developing, creating and massaging a Spitzer Space Telescope observation, we will first need to gather the tools we will need, and dispense of a few preliminaries.

A good place to start to look for information of all kinds is at the Spitzer Science Center (SSC) webpage: <http://ssc.spitzer.caltech.edu/>. There we find Spitzer observing rules, manuals, documentation, lists of approved observations, and Spot software (the software observers use to prepare observations and submit proposals). Links on this page will lead to general Spitzer information, instrument webpages, observer information, bulletins, and so on. We won't attempt to be comprehensive here, but we would suggest you have a look at the following (at minimum):

- Current Call for Proposals: <http://ssc.spitzer.caltech.edu/warmmission/propkit/cp/>
- Spitzer Observer's Manual: <http://ssc.spitzer.caltech.edu/warmmission/propkit/som/>
- Spot User's Guide: <http://ssc.spitzer.caltech.edu/warmmission/propkit/spot/>
- Leopard User's Guide: <http://ssc.spitzer.caltech.edu/warmmission/propkit/spot/>
- Proposal submission guide: <http://ssc.spitzer.caltech.edu/warmmission/propkit/prosubmission/>
- Proposal Kit webpage: <http://ssc.spitzer.caltech.edu/warmmission/propkit/>
- Instrument Support Team webpages: <http://ssc.spitzer.caltech.edu/irac/>

If you can't find the information you need on any of these websites, or if a link is outdated, please feel free to contact the ever-friendly Spitzer Helpdesk (help@spitzer.caltech.edu).

2.1 Proposing Observations for the Spitzer Space Telescope

See the current Call for Proposals at <http://ssc.spitzer.caltech.edu/warmmission/propkit/cp/> for proposal due dates and information for the current call.

In order to apply for observing time with Spitzer, proposers are required to submit three items in their proposal: cover sheet information, scientific and technical justifications in PDF format, and a set of Astronomical Observation Requests (AORs)—which provide the targets and the mode of operation for each of the observations being requested. All three items and the AORs should be submitted through Spot.

See chapter 9 for a step-by-step guide to submitting your proposal.

2.2 Preliminaries

Designing observations for Spitzer is, in many ways, a familiar process; the necessary steps to follow are common to creating any observing proposal. Assuming you have settled on the science goals of your proposal, the preparatory work includes, at minimum:

- Select targets for observation (including a duplication check against the Reserved Observations Catalog database using Leopard to verify that desired targets have not already been observed, or approved for observations, with Spitzer).
- Determine IR background at the target locations.
- Estimate instrument sensitivity.
- Calculate the exposure time required to reach the desired signal-to-noise ratio (S/N).
- Design the observations.

While the focus of this Cookbook is to provide detailed examples of the last step, in the next section we will provide some background information to make some of the preliminary work easier to accomplish.

2.2.1 Are the Targets Available for Observations with Spitzer?

Assuming you have targets selected for observations with Spitzer, you will need to be armed with a bit of information before launching into designing the observations themselves: first, can Spitzer view your targets?

The short answer is that all locations in the sky will be observable by Spitzer for at least ~80 days per year, even if Bright Object Avoidance is needed near the ecliptic. However, if there are any timing constraints on your program in addition to the visibility windows allowed by this general Sun-pointing constraint (for example, you require a certain position angle for the observations), you will need to make sure that they are consistent with the windows of visibility allowed by the Sun-pointing angles. For example, if your observations are highly sensitive to slit orientation, there might be only a few days in the year when the geometry of the spacecraft will give the desired slit orientation. Or, no days at all (in which case, the observer has to reconsider which slit orientations are required)!

To determine the target's visibility from Spitzer, one can employ the "Visibility/Orientation" button within the "Target window" of the Spot software.

Since the Spitzer Space Telescope has the capability of observing the entire sky at least once per year, your targets will be, at some time, available for observations. Another issue, however, is duplicate observations. In order to ensure the most efficient use of Spitzer, proposed observations that duplicate those already executed, or approved for execution, will not be permitted without the explicit approval of the SSC Director's office. Archival data should be used whenever possible to accomplish the science goals

of any proposed investigation. Precisely what constitutes a duplicate observation is defined in the Spitzer Observing Rules document. For all the details see:

<http://ssc.spitzer.caltech.edu/warmmission/propkit/sor>.

To check for duplicate observations, we need to search the **Spitzer Reserved Observations Catalog** (or ROC, for short) ascii file or use Leopard to query the database. We have created a “Warm” ROC containing observations in only IRAC channels 1 and/or 2. For more information on Leopard, see chapter 2.3 and <http://ssc.spitzer.caltech.edu/warmmission/propkit/spot/>.

We recommend observers check their targets using Leopard, rather than using the ROC. The ROC file is static and reflects the state of our database at the instant we generated the ROC files. Leopard interacts with our operational databases and thus reflects the real-time state of approved observations.

2.2.2 What is the IR Background?

In general, the IR background contribution is a combination of the zodiacal light, interstellar medium, and cosmic background radiation. For IRAC, which lies at the shorter wavelength ‘blue’ end of Spitzer instruments, the background is dominated by zodiacal light, so a general rule-of-thumb is that the background is (qualitatively) “low” near the ecliptic poles (absolute ecliptic latitude greater than about 60°), “high” if it is in the ecliptic plane (absolute ecliptic latitude less than 30°, say), and “medium” for all other ecliptic latitudes.

At high Galactic latitudes, observations can be limited by confusion of your target with background sources, the so-called confusion limit. At present, the SSC has calculated the expected background for three lines of sight, with a range of ecliptic and Galactic latitudes, and quantified the background levels that correspond to the qualitative labels of “low,” “medium,” and “high” introduced above. The results are tabulated and plotted at <http://ssc.spitzer.caltech.edu/warmmission/propkit/som/bg/>.

As we will see in chapter 2.4 we can obtain a quantitative estimate of the background for any target position either within Spot, or with IRSKY. How to do this is described in detail in the worked examples in the chapters that follow. See section 4.4 in particular.

2.2.3 What is the Instrument Sensitivity?

To determine the instrument sensitivity we need to look at the documentation for IRAC. The sensitivity has been estimated for the qualitative background characterizations given in the previous section. See for IRAC: <http://ssc.spitzer.caltech.edu/irac/sens.html>

An online Performance Estimation Tool (PET) has been developed that returns sensitivities for user-configured observing parameters. See: <http://ssc.spitzer.caltech.edu/warmmission/propkit/pet/>.

2.2.4 What is the Required Exposure Time?

Having a qualitative characterization of the background, based on the target ecliptic/Galactic latitude, and an estimate of the instrument sensitivity, all we need now is

the target flux in order to calculate the time required to reach a desired S/N. If you have this in-hand for one of the Spitzer passbands, you are (almost) in business. If not, you will need to use some other mechanism, and we provide some suggestions for that in a moment.

First, though, what is the flux in the Spitzer passbands? For photometry, Spitzer is following the same calibration methodology as used with IRAS (Beichman 1988), COBE/DIRBE (Hauser 1988) and ISO (Siebenmorgen 1999). See the instrument Data Handbooks for more discussion.

With IRAC, we quote flux densities at some nominal wavelengths that are accurate for sources with a flat spectrum,

$$\nu F_{\nu} = \text{const.} \quad (1)$$

$$K = \frac{\int (F_{\nu} / F_{\nu_0}) R_{\nu} d\nu}{\int (\nu / \nu_0)^{-1} R_{\nu} d\nu} \quad (2)$$

where ν_0 is the nominal frequency where we will quote flux densities (see the IRAC Data Handbook), and R_{ν} is the system response function. The form of R_{ν} is tabulated on the SSC webpages. For IRAC, see:

<http://ssc.spitzer.caltech.edu/irac/calibrationfiles/spectralresponse/>.

Finally, then, the quoted flux density (in Spitzer units), F_{ν}^{quot} , for a source with intrinsic flux density F_{ν} will be

$$F_{\nu}^{\text{quot}} = K F_{\nu} \quad (3)$$

More details can be found in the IRAC Data Handbook.

What does this all mean? Well, suppose you wish to do photometry on an object and you know its flux density, F_{ν} . To estimate exposure times, etc., you should convert this to the Spitzer system by calculating the color correction, K , for the passband in question.

Now what if you don't have an estimate for the object's flux density, but instead have a magnitude? For many astronomers, flux densities (for which the units are Jy for point sources, and Jy/arcsec² for extended sources) are rather nebulous quantities. With this in mind, we have explicitly provided the formalism for converting between the various unit systems in an appendix of this Cookbook (see chapter 10.). As well, the SSC has created an online tool for converting between magnitudes (in various systems) and flux densities; see <http://ssc.spitzer.caltech.edu/warmmission/propkit/pet/magtojy/index.html>.

Now what if you don't have a good estimate of your target flux? For example, suppose you wish to detect high-z star-forming galaxies, but are unsure what is the expected flux

at 4.5 micron. The SSC has developed some tools to help with this. Part of the PET is for extragalactic point source objects. Based on the observed SEDs of some "famous" objects in the Universe, as well as composite SEDs of various classes of objects (e.g., ellipticals, LINERs, starbursts, etc.), this tool can serve as a guide for predicting the expected flux in the Spitzer bands. See the SSC tools webpage:

<http://ssc.spitzer.caltech.edu/warmmission/propkit/pet/>.

2.3 Obtaining Spot

One of the critical tools we will need to design Spitzer observations is Spot. Let's deal with that next.

The SSC has developed a suite of software tools for designing observing programs. The various stages e.g., determining windows for scheduling, visualizing the observations via an overlay on existing imaging, and submission of the proposal itself are all done through one main tool: Spot. Spot is similar to the Astronomer's Proposal Tool for HST. With Spitzer, the proposal and design phase are linked: to create an observing proposal for Spitzer, observers will use the SSC tools to actually design a program that is 'ready-to-fly' on Spitzer, including the determination of visibility windows, constraints, etc. With the Spitzer Space Telescope, this format is created initially using Spot.

In addition to Spot, the SSC has developed Leopard, a software package used to query the archive. Before November 2010, Leopard was also used to download data (use the Spitzer Heritage Archive to now access Spitzer data). Together, these two cats, Spot and Leopard, are referred to as "Spitzer Pride."

The Spitzer Pride package is freely available for download from the Spitzer Science Center website "Proposal Kit" page: <http://ssc.spitzer.caltech.edu/warmmission/propkit/spot/>. Look under the section "Getting the Software" and follow the links to download the software appropriate for your platform.

A few notes about Spot (and Leopard): the software is written in the JAVA programming language, and requires a moderately large memory allocation, and a fast processor, in your computer. See the Spot User's Guide for additional information.

The minimum recommended hardware configurations are:

- Sun Workstations: Sun Ultra 5 with 256 MB RAM.
- Windows PC: 512 MB RAM (2000, NT, XP); 1 GB RAM (Vista, 7, 8).
- Linux PC: 256 MB RAM.
- Mac PC: 512 MB RAM (OS 10.4); 1 GB RAM (OS 10.5+).

Even with these minimum requirements, some features i.e., visualizing AORs may be unacceptably slow.

Currently, Spot is supported in a number of operating system configurations, including:

- UNIX: Solaris 2.8+.
- Windows: NT, 2000, XP, Vista, 7, 8.
- Linux: RedHat 8.0, 9.0; Fedora Core; Enterprise.
- Mac: OSX

2.4 *Designing the Observations with Spot*

How do we design observations for Spitzer? In general, the observer interfaces with the Observatory and the instruments by means of Astronomical Observation Templates (AOTs). An AOT permits the user to unambiguously define the parameters of their observing program. Users fill out these AOTs to create "Astronomical Observation Requests" (or AORs), and submit the AORs with the completed observing proposal. For the so-called "Warm Mission" only the IRAC Post-Cryo Mapping AOT will be functioning.

From an observer's viewpoint, the AOT "Front End" is the electronic form observers fill out to define an experiment to be executed by Spitzer. AORs are the result of filling out an AOT form. The AORs themselves are the fundamental scheduling unit for the Spitzer Space Telescope. An AOR can be thought of as a list of parameters that (when properly interpreted) describe an observation completely.

As noted in section 2.3, filling out AOTs to design an AOR is done within Spot. This process consists of entering targets which are individually linked to a desired Spitzer observing mode, or AOT.

To design an observing program for Spitzer with Spot, we will need to:

1. Start the observation planning software, Spot.
2. Enter target information (and, if desired, obtain an IR background estimate at the target location).
3. Fill out an AOT, to create the AORs.
4. Obtain resource estimates.
5. Save AORs, and, when done, submit a full observing proposal (which includes the AORs, together with a coversheet, scientific and technical justifications) to the SSC!

The basic steps in completing an AOR are outlined in the rest of this section.

2.4.1 Start Spot

Assuming for the moment that we have some observation program in mind, and we wish to design a Spitzer observation, we are ready to fire-up the software (Spot) to do so. Under UNIX/LINUX, type **PATH/spot** (where **PATH** is the path to where Spot was installed). On a Mac, simply double-click on the Spitzer icon for the application.

The start-up Spot window should appear, and is illustrated in Figure 1.

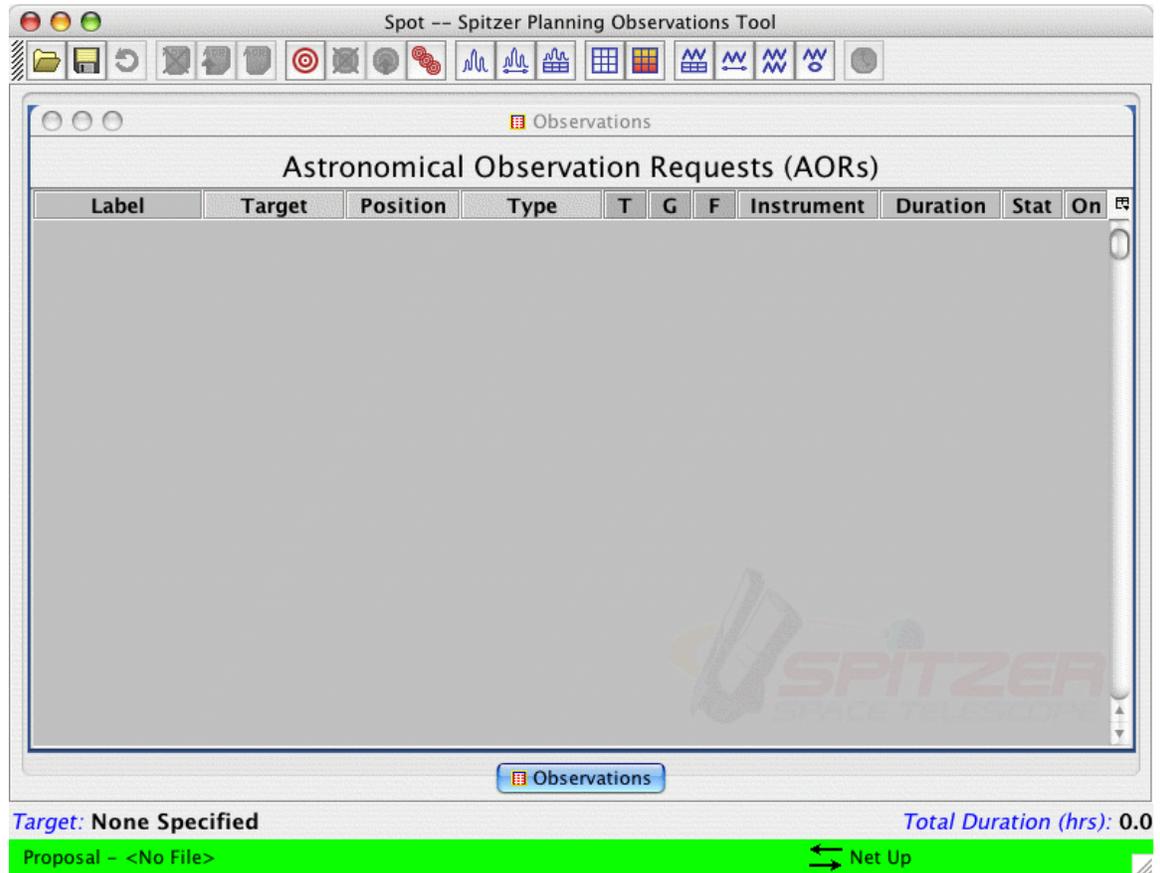


Figure 1: The Spot window after initial start-up.

2.4.2 Enter Target Information

With *any* Spitzer AOT, the target name and coordinates are entered first. As this step is common to any observing proposal, we will provide a bit more detail on target entry in this chapter.

We first launch Spot and bring up the new target window, either by positioning the mouse over the target icon (the bulls-eye icon on the taskbar; see Figure 1), or by selecting “new target” from the “Targets” menu. The target entry window will appear, with entry dialog as shown in Figure 2.

Figure 2: The target entry dialog.

Several features are accessed from the target entry window. These include:

1. Resolve the name: NED/SIMBAD target name resolution. Simply enter the name of the target for which you want the coordinates, select the resolver (NED or SIMBAD), and click "Resolve the Name."
2. Visibility/Orientation: Determine visibility windows for inertial and moving targets.
3. Background: Sky background estimates for inertial targets. You have the option of specifying the wavelength at which to estimate the background, as well as performing the calculation for a specific date, or over the entire range when the object is visible to Spitzer.

4. Option to avoid *bright moving objects* that might be in the target field: Bright objects to be avoided include both the Earth/Moon and 'Others', which are Mars, Jupiter, Saturn, Uranus, Neptune, and the asteroids Vesta, Hebe, Ceres, Iris, and Eunomia. Selecting these options will restrict the observations to preclude times when the target coordinates are within 7° of the Earth and Moon, or within 30' of the objects on the "Others" list.

In the target entry dialog, there are two general choices for the *type of target* (fixed or moving), displayed under five tabs. For fixed targets, these are: **Fixed Single**, **Fixed Cluster**, and **Fixed Cluster - positions**. For moving targets, these are **Moving Single**, and **Moving Cluster**. See Figure 2. These are described in more detail below:

1. Fixed Single: A fixed-single target is one object or map center outside of the Solar System.
2. Fixed Cluster: A Spot 'cluster' does not necessarily mean an astronomical cluster. Rather it defines a group of positions in a region of sky within a radius of 1° to be observed with the same AOT parameters. Targets of this type are sets of objects that have a scientific requirement for observation in close spatial and temporal proximity. By using cluster targets you avoid the per AOR slew tax you might otherwise incur by having separate fixed single targets. The positions are entered as a primary equatorial J2000 right ascension and declination, and the offsets north and east from the primary target. **Note that the east offsets DO NOT follow lines of declination on the celestial sphere. North and east are determined at the primary target position when the observation starts. If it is crucial for your science that you have an exact RA and DEC, you should use a Fixed Cluster - positions target type.**
3. Fixed Cluster-positions: Defines multiple absolute positions where no two positions are separated by more than 2° .
4. Moving Single: A moving single target is a single object that requires Solar System tracking.
5. Moving Cluster: A group of co-moving Solar System targets separated by less than 1° to be observed with the same AOT parameters. The positions are entered as a primary target and offsets east and north from that position. The ephemeris for the primary target determines the tracking rate to be used for the entire cluster, but the primary target itself does not have to be observed as part of the cluster.

A few words about overhead and the "cluster" target type: The cluster option has the advantage of saving a significant amount of overhead in some types of programs. Any set of observations which can be carried out as a cluster target could also be carried out as a string of observations of Fixed Single targets and a set of AORs. Providing science goals can be met, the "cluster" target allows the user to utilize only one AOR. However,

the flight software is built in such a way that doing it as a set of Fixed Single observations can incur additional overhead for each new target (e.g., for target acquisition).

2.4.3 Fill out an Astronomical Observation Template

Select an AOT from the Observation menu. The instrument configuration and integration time parameters are entered in the AOT form. In the warm mission only one AOT is available for Spitzer observations.

- IRAC Post-Cryo Mapping: The IRAC AOT is used for simultaneous imaging at 3.6 and 4.5 micron, over the two 5.2'×5.2' fields of view. See Chapter 4 (deep imaging) and Chapter 5 (wide-field, shallow imaging).

2.4.4 Obtain Resource Estimate

As noted in section 2.4, the fundamental unit of Spitzer observing is the Astronomical Observation Request (AOR). An AOR cannot be subdivided, will not be interrupted for other activities (such as downlinks), and will be handled as a unit by Spitzer. Because an AOR will be executed as a unit, and the need for the Observatory to perform certain activities (such as calibrations, detector anneals, downlinks), there is a maximum duration for an AOR: 24 hours for the IRAC Post Cryo Mapping AOR. AORs that would require longer time-blocks to execute must be divided into separate requests (i.e., shorter duration AORs).

At any time within Spot, you can check how long an AOR (or series of AORs) will take to execute. From the main Spot window (see Figure 1), look in the "Tools" pulldown menu and select "Recompute All Estimates." You will be greeted with a pop-up menu asking you to select what you want to recompute. Most often, you will select "Current AOR," "Selected AORs" or "All AORs." Spot will then churn away in the background, and return you to the main Spot window, with the "Duration" field filled in the lower right-hand corner of the Spot window, and duration estimates listed for each AOR.

To obtain more detailed information about how the total duration is shared among actual integration on-sky, telescope slew time, settle time, and so on, use the "Calc. Obs. Time" button within each AOT entry dialog. See section 4.5 for a detailed example.

2.4.5 Save AORs

Save the AORs! Save the targets! You can do both independently from the "File" pulldown menu in the main Spot window. (Note — you do not have to save your targets separately from the AORs.) Do this not just after you've completely filled out your AOR, but rather do it early, and often! After all, the Big One may hit and a power disruption might mean the end of a beautiful Spitzer program-to-be....

When you are finally ready to actually submit a proposal, make sure that you are submitting a clean set of AORs. If you've been playing around with options and alternate targets, make sure to delete those AORs entirely before submitting your proposal. All the AORs in your Spot window at the moment you submit your proposal will be submitted to the SSC with the other proposal parts.

If you are short on time and require the bare minimum of information, we recommend you read Chapter 9 (which explains how to submit a proposal in more detail) and Chapter 3 (which describes common errors to avoid). But, first, a digression on using already executed observations as a starting point for your own new ones.

2.5 *Using Previous Observations as Templates for New Observations, Or, Learning from Others*

At this point in the Spitzer mission, a large number of observations and data are piling up in the archive. It is quite likely, then, that your otherwise brilliant idea for a proposal and a target list may draw parallels with what's already been done by Spitzer. Once you have a pretty good idea of what you intend to do, search the ROC using Leopard to see if there are similar targets already there. Often, there is no need to recreate a set of successful observations—simply “borrow” how it has already been done, by literally copying and adapting AORs that have already been executed by others.

If the AOR(s) have been executed download these data and use whatever data analysis software you wish to assess the quality of these data. [Note: in November 2010 Leopard will no longer be used as the archive interface. Use the Spitzer Heritage Archive (SHA) to access Spitzer data]. We provide such software and documentation for analysis of both the imaging and spectroscopy data products from our website:

<http://ssc.spitzer.caltech.edu/dataanalystools/>. You should be able to determine what signal-to-noise ratio (S/N) was achieved for what exposure times for IRAC. If you need higher S/N for your target, for instance, you should then be able to determine how much deeper you will need to observe your target to achieve that ratio.

An example is the following: Suppose we want to conduct a survey of a number of rich Abell clusters of galaxies with IRAC. We would guess that several such clusters have already been observed using Spitzer, so we could propose to build on previous observations to produce a more homogeneous overall dataset. Searching through Leopard using various Abell clusters as input, we find that Spitzer program 20439 observed Abell 1689 during Cycle-2 with IRAC. See Figure 3. We can view “quicklook” previews of the post-BCD mosaics for the data by clicking on any of the Preview buttons for any of the AORs. In this example, we click on the “3.6” button for the very first AOR listed in the Leopard window. The preview image is shown in Figure 4. Satisfied with the quality of the preview, we can then proceed to download the data (see Figure 5) using the Spitzer Heritage Archive (<http://sha.ipac.caltech.edu/applications/Spitzer/SHA/>) and analyze them with our favorite photometry software. [In November 2010 data access via Leopard was deactivated. Use the Spitzer Heritage Archive to access Spitzer data.]

Furthermore, in Leopard we can visualize the AOR that produced the data, by selecting “AORs on image” under the Overlays menu. The result is shown in Figure 6. The details of the AOR (mapping and dithering strategy, exposure time, etc.; see Chapter 4) can be viewed by double-clicking on the AOR in Leopard, or clicking on the “I” icon or selecting “Detail Information” under the Info menu. See Figure 7. Again, satisfied that the previous observing strategy is sound without pitfalls (see Chapter 3 for some of

these), we can now turn to Spot to begin to build our own set of AORs for our observing program.

In Spot, select View Programs from the File menu and enter “20439” for this program. The AORs for Abell 1689 that we were viewing in Leopard, plus others, will appear in the Spot window (see Figure 8). If we isolate the first AOR only, we can copy the observing parameters (frame time, number and offset of dithers, etc.) of this AOR and use this as a template for our new observations. Under the Observations menu in Spot, select “IRAC Post-Cryo Mapping.” See Figure 9. Open the new AOR by double-clicking on it in the main Spot window, and then click on the “New Target” button. The result will be the target entry dialog window (see Figure 10) in which we can enter one of the targets we intend for our survey. In this case, it is Abell 2317. When we hit “OK” in the target entry window, the new target will be seen in the AOR window (see Figure 11). Satisfied once again, we can close the AOR window by clicking “OK.” Spot will warn us that we have changed targets for the AOR, but that’s fine—that’s precisely what we wanted to do.

The new AOR has exactly the same observing parameters for IRAC channels 1 and 2 as did the old, already-observed one (see Figure 12). We should visualize our new AOR, to be sure it is adequately providing coverage of the galaxy cluster (see Figure 13). (Furthermore, we should also use the Depth-of-Coverage overlay, under the Overlays menu in Spot, to verify the coverage.) We could further modify the new AOR to vary the mapping or dithering strategy, or change the exposure time, etc. In fact, we emphasize here that you should be careful using exactly the same strategy as a previous observer, unless you have already confirmed that it is suitable for your purposes. Our point in this chapter is that, with so many observations with Spitzer already executed, most of which were highly successful, there’s no need to completely “reinvent the wheel.” Also, there’s no “proprietary” strategy for observing. The parameters for all AORs are relatively fixed, so there are only so many combinations of parameters, such as exposures, dithers, etc., that anyone can make, and which are hardly unique. Especially if pressed for time to create your observing program, there’s a lot you can learn and use from the successes of previous observers.

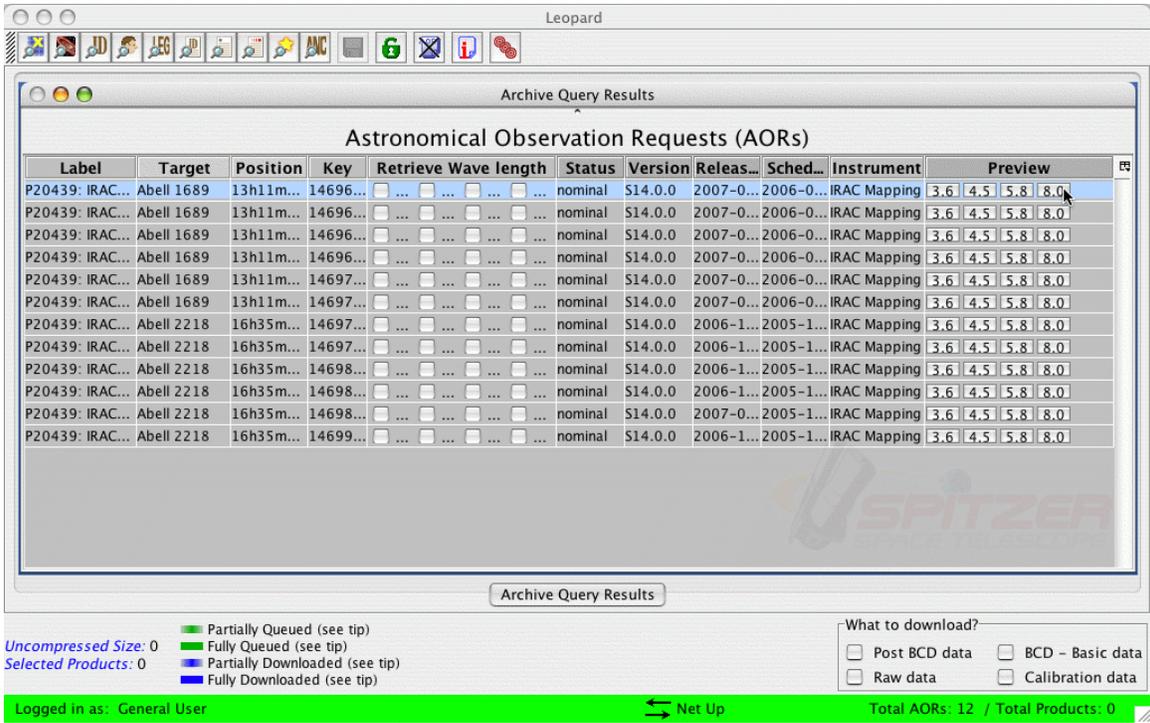


Figure 3: The main Leopard window, showing the observations of and data for Abell 1689 by program 20439 obtained during Cycle-2.

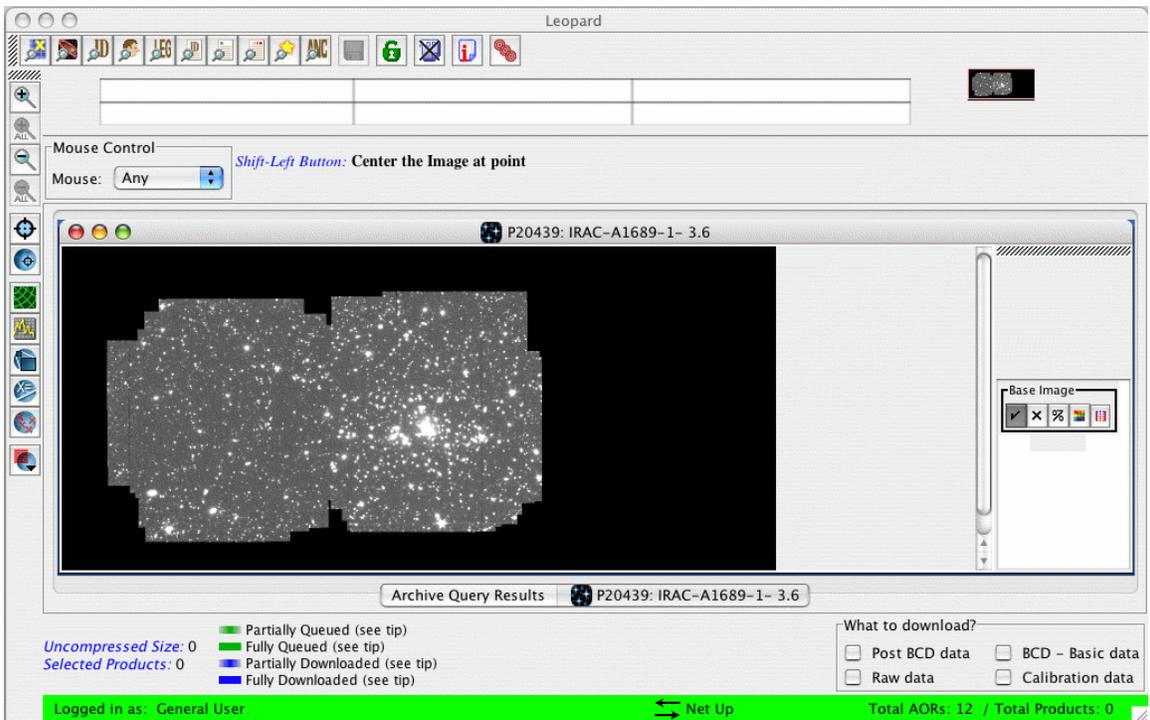


Figure 4: "Quicklook" preview image of the 3.6 micron data for the first AOR listed in the Leopard window seen in Figure 3.

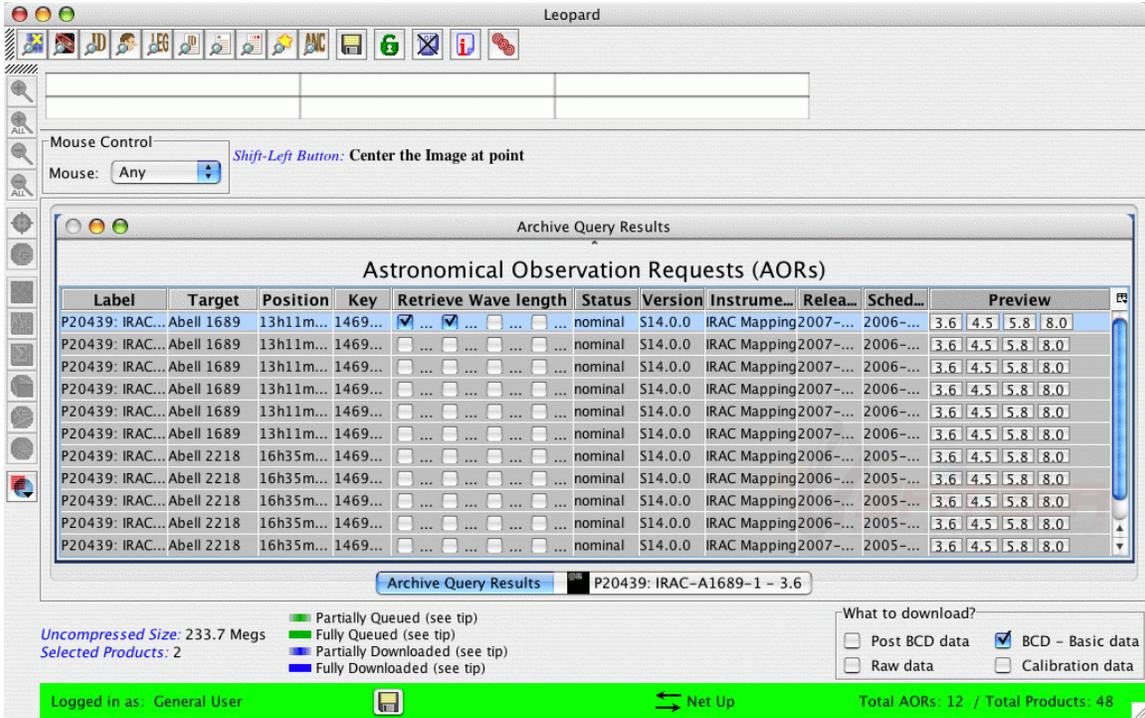


Figure 5: Selecting channels 1 and 2 of IRAC BCD data products to download, corresponding to the AOR in this example. This functionality was deprecated in November 2010. Use the SHA instead.

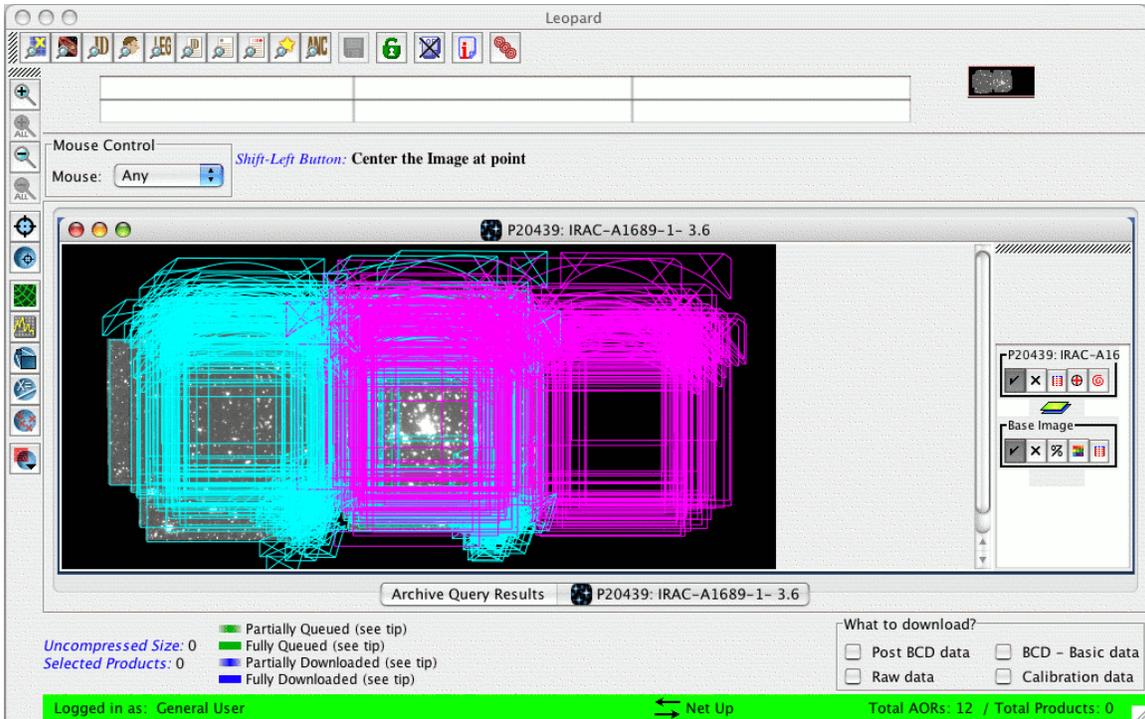


Figure 6: Visualization of the AOR overlaid on the preview image for the data in Leopard.

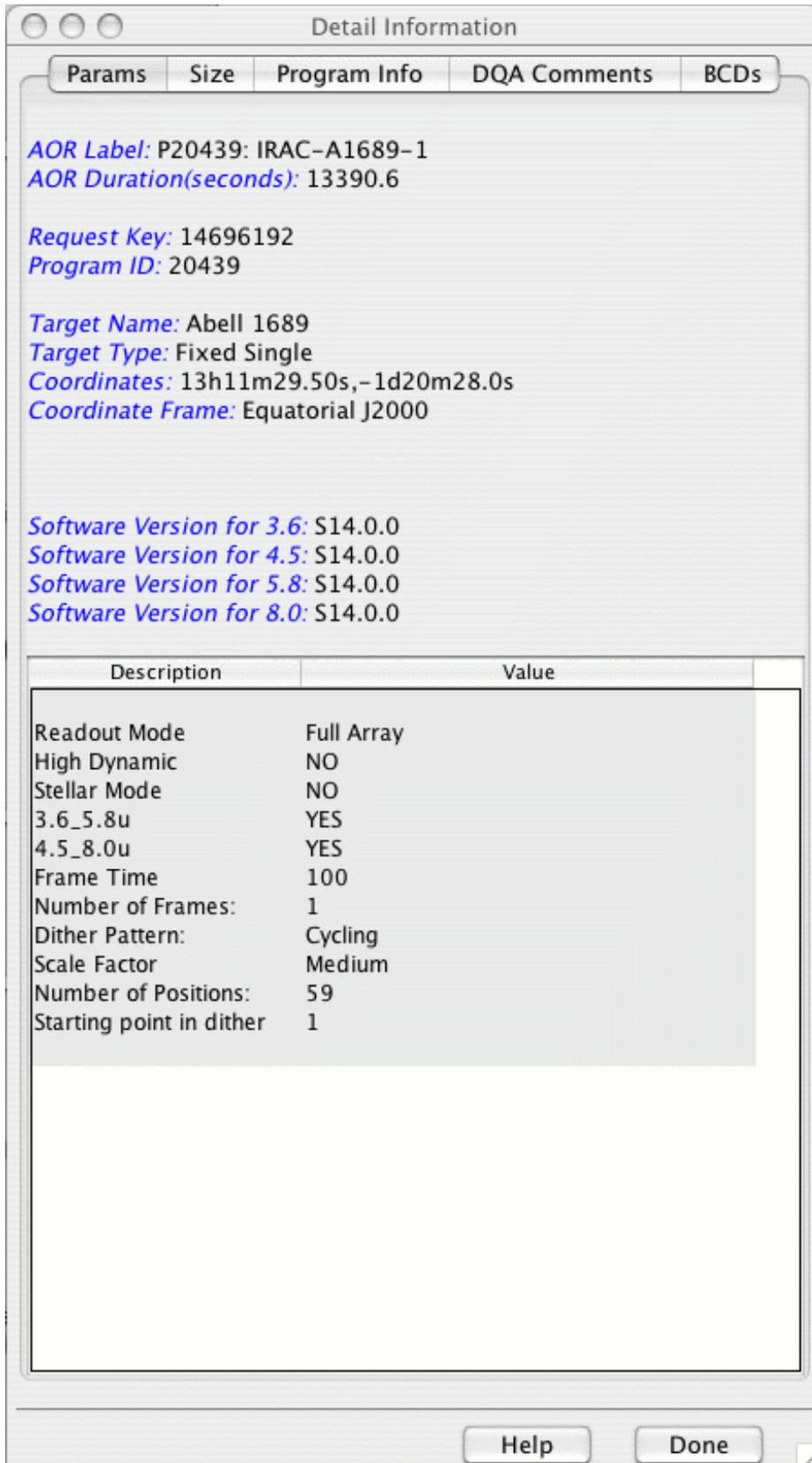


Figure 7: The detail information in Leopard about the AOR we are analyzing.

The screenshot shows the 'Spot -- Spitzer Planning Observations Tool' window. The main content area is titled 'Observations' and displays a table of 'Astronomical Observation Requests (AORs)'. The table has columns for Label, Target, Position, Type, T, G, F, Instrument, Duration, Stat, and On. Below the table, there is a status bar with information about the current target and project.

Label	Target	Position	Type	T	G	F	Instrument	Duration	Stat	On
IRAC-A1689-1	Abell 1689	13h11m29...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Mapping	13391	nomi...	<input checked="" type="checkbox"/>
IRAC-A1689-2	Abell 1689	13h11m29...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Mapping	13391	nomi...	<input checked="" type="checkbox"/>
IRAC-A1689-3	Abell 1689	13h11m29...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Mapping	13391	nomi...	<input checked="" type="checkbox"/>
IRAC-A1689-4	Abell 1689	13h11m29...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Mapping	13391	nomi...	<input checked="" type="checkbox"/>
IRAC-A1689-5	Abell 1689	13h11m29...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Mapping	13392	nomi...	<input checked="" type="checkbox"/>
IRAC-A1689-6	Abell 1689	13h11m29...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Mapping	13168	nomi...	<input checked="" type="checkbox"/>
IRAC-A2218-1	Abell 2218	16h35m49...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Mapping	13395	nomi...	<input checked="" type="checkbox"/>
IRAC-A2218-2	Abell 2218	16h35m49...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Mapping	13395	nomi...	<input checked="" type="checkbox"/>
IRAC-A2218-3	Abell 2218	16h35m49...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Mapping	13395	nomi...	<input checked="" type="checkbox"/>
IRAC-A2218-4	Abell 2218	16h35m49...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Mapping	13395	nomi...	<input checked="" type="checkbox"/>
IRAC-A2218-5	Abell 2218	16h35m49...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Mapping	13388	nomi...	<input checked="" type="checkbox"/>
IRAC-A2218-6	Abell 2218	16h35m49...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Mapping	13172	nomi...	<input checked="" type="checkbox"/>

Target: Abell 1689 Type: Fixed Single Total Duration (hrs): 44.5

Existing Project - 20439 ↔ Net Up Total AORs: 12 / Active: 12

Figure 8: Viewing the Spitzer program in Spot that we were previously viewing in Leopard.

The screenshot displays the 'Spot -- Spitzer Planning Observations Tool' window. The main panel is titled 'Observations' and contains a table of 'Astronomical Observation Requests (AORs)'. The table has columns for Label, Target, Position, Type, T, G, F, Instrument, Duration, Stat, and On. Two rows are visible, both for the target 'Abell 1689' at position '13h11m29...'. The first row is 'IRAC-A1689-1' with instrument 'IRAC Mapping' and duration '13391'. The second row is 'IRACPC-0000' with instrument 'IRAC Post-Cry...' and duration '13291'. Below the table, a status bar shows 'Target: Abell 1689 Type: Fixed Single' and 'Total Duration (hrs): 7.4'. At the bottom, a green bar indicates 'Existing Project - 20439', 'Net Up', and 'Total AORs: 2 / Active: 2'.

Label	Target	Position	Type	T	G	F	Instrument	Duration	Stat	On
IRAC-A1689-1	Abell 1689	13h11m29...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Mapping	13391	nomi...	<input checked="" type="checkbox"/>
IRACPC-0000	Abell 1689	13h11m29...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Post-Cry...	13291	new	<input checked="" type="checkbox"/>

Figure 9: Creating an IRAC Post-Cryo Mapping AOR with the same parameters as an already-executed AOR.

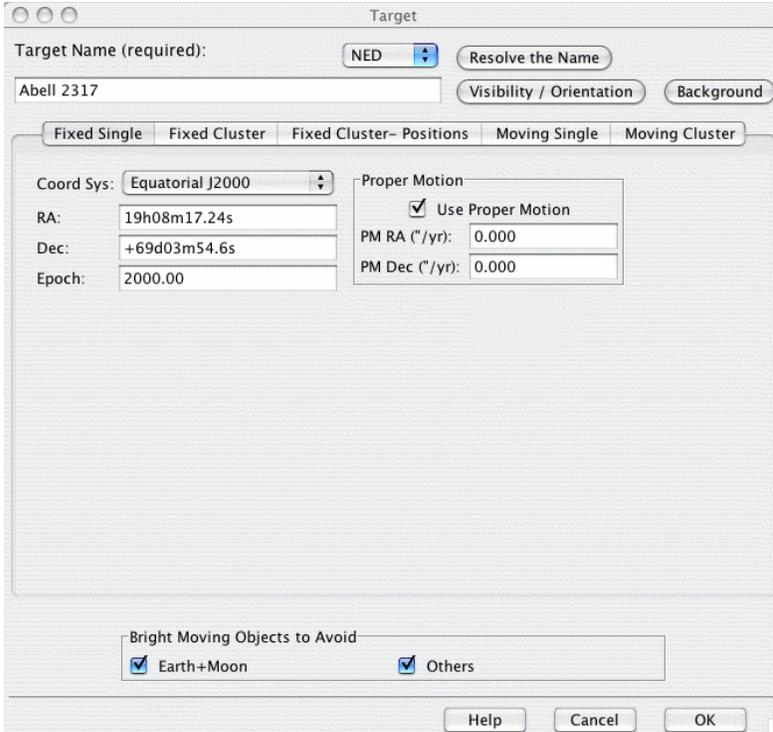


Figure 10: The target entry window in Spot—entering a different Abell cluster for our AOR.

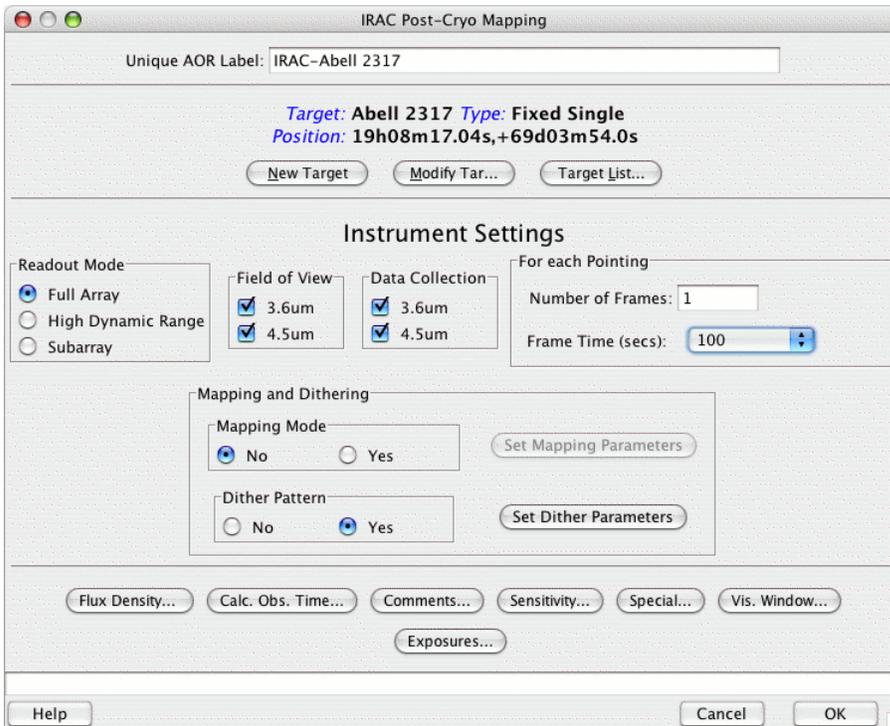


Figure 11: The IRAC Post-Cryo Mapping AOT, with our new target substituted in. Note: we have also changed the AOR label to reflect the substitution of the new target.

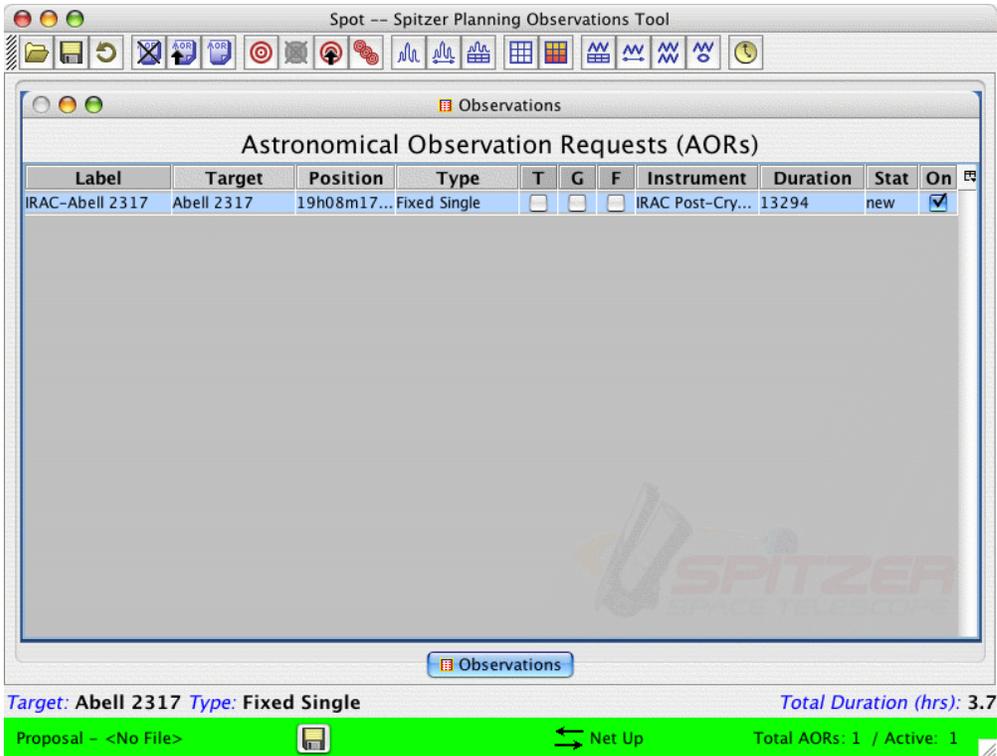


Figure 12: The main Spot window, showing our modification of the old AOR. The status of this new AOR for our program is “new.”

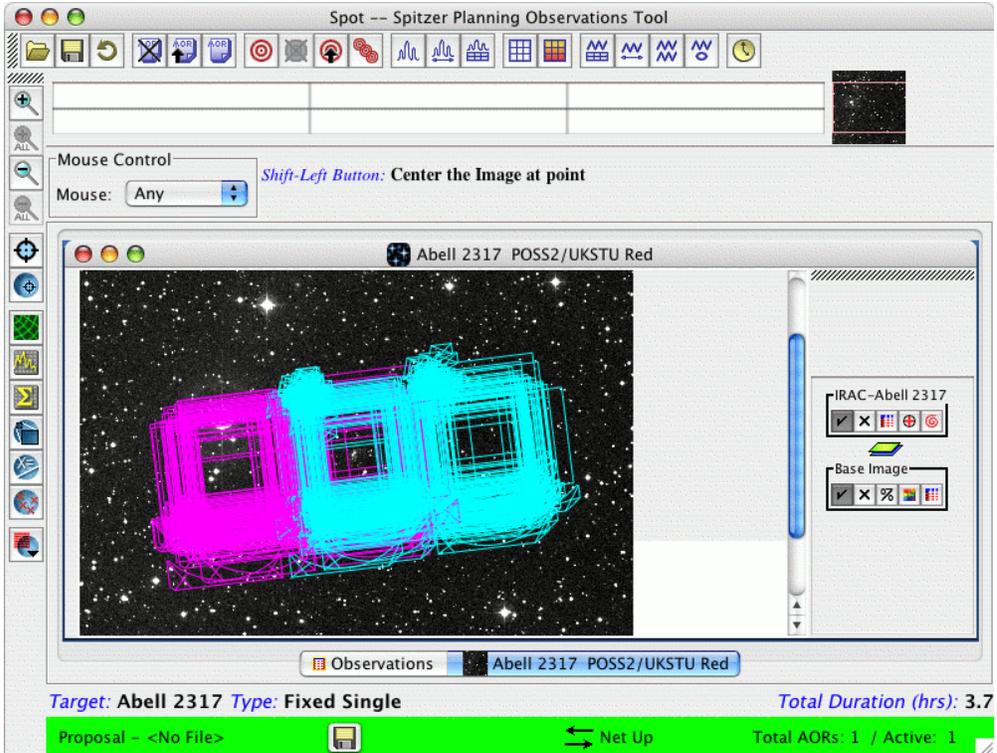


Figure 13: Visualization in Spot of the new AOR with the new target on a DSS image.

3 Common Observation Planning Errors

In this chapter, we have collected a list of common errors seen in proposals in the previous four Spitzer cycles. Make sure your proposal does not include them!

3.1 Duplications

This is the most common and frustrating problem we encounter. Before you submit a proposal *please, please, please* check that you are not duplicating existing observations. You must check your targets against the Reserved Observations Catalog database using Leopard to verify that your desired targets have not already been observed, or approved for observations, with Spitzer. In the warm mission we will not be able to check every single AOR against the Reserved Observations Catalog ourselves before we release that AOR for scheduling. AORs that we do find to be duplicate observations will be removed from an observing program, and the proposer's funding is reduced accordingly. Please take the few minutes required to check your targets for duplications ahead of proposal submission.

3.2 Visualization

You should always visualize your observations. Make sure your intended target is actually spatially covered by the intended number of exposures. Be absolutely sure the AOR is doing what you think it is. Be sure there are not (extremely) infrared-bright sources in the field which will compromise the quality of your observation.

3.3 Orientation

Be aware of focal plane location. If you need the same orientation for several adjacent AORs on the sky, set group within or similar constraints if your target is not very close to the ecliptic plane. Otherwise there is no guarantee that your AORs will be observed at a similar orientation in the sky, and you could end up with nasty gaps in your data.

3.4 IRAC

3.4.1 Use Dithers

Unless your science calls for a series of observations where your target needs to fall on the same IRAC pixel (e.g., observing extrasolar planet transits), you should use dithers, rather than repeats, in IRAC observations.

3.4.2 Dither Size

Use medium- or large-offset, rather than small-offset, IRAC dithers if you have a pointed observation (not a map) to better protect against image artifacts.

4 Deep Imaging of Five Clusters of Galaxies at 3.6 and 4.5 Micron Using IRAC

In this chapter (and the next), we document the full procedure one might follow in developing a Spitzer observing proposal. We will design a deep imaging observation that covers a relatively small area of sky. This example will illustrate how to perform a deep, small area imaging campaign with the IRAC (3.6, 4.5 micron) Post-Cryo Mapping AOT.

In order to mimic more closely the complete procedure an observer might follow, we develop a test case “real observation.” The science background is as follows:

The goal is to survey selected regions of the sky to study the formation and evolution of normal galaxies to redshifts $z \geq 3$, and probe the high- z population of star-forming galaxies. We will choose well-studied regions of the sky, where deep spectroscopy has been obtained from 10-m class telescopes, and observations are extant in the radio, optical and X-ray. The objective will be to obtain deep IR imaging to ≈ 0.2 mJy (1s) at 4.5 micron. This will enable us to address a number of science goals. For example, Spitzer imaging to this depth, combined with spectroscopic data (obtained elsewhere), would allow us to construct a luminosity function for normal galaxies at $z \approx 3$.

Such a program has been performed, e.g., in the Spitzer GTO program (“The IRAC Deep Survey,” PI: G. Fazio; see <http://adsabs.harvard.edu/abs/2004sptz.prop....8F> for details) by imaging a wide area (multiple fields) in the Groth strip. Here we describe a complementary approach to image a smaller total area of the sky, but to greater depth, using the magnification by foreground clusters to probe deeply into the IR sky.

The gravitational lensing by a massive, low- z cluster magnifies background sources, and hence galaxies that would fall below the sensitivity limit of blank field observations are boosted above the detection threshold. For simplicity we ignore this effect for this example.

In the remainder of this chapter, we develop the observations at 3.6 and 4.5 micron using the InfraRed Array Camera (IRAC). The post-cryo IRAC is the two-channel camera that provides simultaneous $5.2' \times 5.2'$ images at 3.6 and 4.5 micron. The pixel size is $\approx 1.2''$ in both bands and both detector arrays in the camera are 256×256 pixels in size.

4.1 Overview of the Program

In this section, we summarize the steps followed to design the deep imaging IRAC program. This will serve both as a one-stop resource for those requiring only an overview of how to do such a program, and also as a roadmap of where to find more detailed information later in this chapter.

The post-cryo IRAC is a two-channel camera that provides simultaneous $5.2' \times 5.2'$ images at 3.6 and 4.5 micron. Two adjacent fields of view are imaged in pairs (3.6

micron; 4.5 micron) using a dichroic beamsplitter. Both detector arrays in the camera are 256×256 pixels in size, with a pixel size of 1.2".

Observing programs with IRAC are designed with the IRAC Post-Cryo Mapping AOT, supporting both mapping and dithering schemes, a choice of full, subarray, or high dynamic range modes, and a selection of frame times, ranging from 0.4–400 sec in full-array mode, 0.02–2 sec in subarray mode, and 6–400 sec in high dynamic range mode. Users can design single pointing observations, or a mosaic, subject only to the constraint that each AOR must have a duration of less than 24 hours; longer duration programs must be split into separate AORs.

- **Target Selection:** For this example, we observe in the fields of rich, low- to moderate-*z* galaxy clusters. After a duplication check using Leopard (<http://ssc.spitzer.caltech.edu/warmmission/propkit/spot/>), we see that these fields already have scheduled observations with Spitzer, and hence we would need to carefully design observations so as not to violate the Spitzer Duplicate Observation Rule. See section 4.2.
- **Background Estimate:** We use Spot to obtain a background estimate at each of the target positions. In general, the background is characterized qualitatively by three levels (low, medium and high), and for these targets, the IR background is low/medium/high for the targets. We compare these estimates with what we see in IRAS Sky Survey Atlas images of the target field. See section 4.4.
- **Exposure Time Estimate:** Armed with the background characterization above, we look at the IRAC sensitivities for low, medium and high backgrounds, respectively. This enables an estimate of the required exposure time to reach a desired signal-to-noise ratio for point source detection. In this case, for medium background, to reach ≈ 0.2 mJy (1s) in the 4.5 micron band, we require $t_{\text{tot}} \approx 50 \times 100$ sec. (Note that this is beyond the confusion limit for this band.) See section 4.5.
- **Filling out the IRAC AOT:** The observations themselves are designed within Spot. We complete the IRAC Post-Cryo Mapping AOT, and a screen capture of the completed AOT is shown in Figure 33. For each target, we observe the cluster central region in both passbands, and hence select **both the 3.6 micron and 4.5 micron fields of view**. The objects we wish to detect are intrinsically faint, so we select **bright object avoidance**, and read-out in **full array mode**; see section 4.6.1. To reach the desired depth with the integrations, we require ≈ 5000 sec total integration. We select a **frame time of 100 sec**, and a **50-point dither** using the **cycling dither pattern**, with **medium scale factor**; see section 4.6.4. To image the central region, we explore the possibility of using either a **simple map** (1 column, 2 row array coordinates map, with row/column spacing of 410.2"), or **no mapping** with both fields-of-view selected; see section 4.6.3.

- **Duration:** The total time required, per target, to execute these observations is 11299 seconds, which is well under the limit of 24 hours for the IRAC AOR. See section 4.7.
- **Visualization:** We visualize the observations via an overlay of the IRAC fields-of-view on Digital Sky Survey images of the clusters; see section 4.8.

4.2 Target Selection: Massive, Intermediate Redshift, Galaxy Clusters

The first task involves the selection of targets for the observations. There are many low- z clusters with existing multiwavelength observations and spectroscopy. Without attempting to be exhaustive in a target list, let us concentrate on the candidates, listed in Table 1.

Table 1: The targets for the IRAC deep imaging program.

Target	z	RA (2000)	DEC (2000)	In ROC?
Abell 2218	0.176	16:35:53.99	+66:13:00.2	Yes
ZwCl0024.0+16.52	0.4	00:26:36.01	+17:08:36.1	Yes
Abell 665	0.18	08:30:45.19	+65:52:55.3	Yes
Abell 1689	0.18	13:11:34.20	-01:21:55.5	Yes
AC 114	0.31	22:58:52.34	-34:46:54.6	Yes

As with all observations, we need to determine if the targets are already scheduled for observations with the Spitzer Space Telescope. To check for duplicate observations, we use the Leopard search tool: <http://ssc.spitzer.caltech.edu/warmmission/propkit/spot/>.

We find that all of the above targets already do have reserved/scheduled/accepted IRAC mapping programs. To propose to observe the targets in Table 1 again, we would need to comply with the Spitzer Observing Rules by, for example, reaching to a sensitivity ≥ 2 than the observations already proposed. However, for the purpose of this example, we will not worry about violating the duplicate observation rule (but you will need to!), and will proceed as if all targets have not been observed already.

4.3 Target Entry

We start by launching the Spitzer observation planning tool (Spot), and entering the target information.

As described in section 2.4.2, we first start Spot and bring up the new target window, either by clicking on the target icon (the bulls-eye icon on the taskbar; see Figure 2, or by selecting “new target” from the target menu.

In this example, we wish to consider observations of the galaxy clusters listed above, at a single position, with small dithers for cosmic ray rejection, which we will configure in a moment. Hence we choose the “Fixed Single” target type. We enter the first target, Abell 2218, and hit the “Resolve the name” button. Spot finds the RA/Dec of the cluster center (16:35:53.99, +66:13:00.2, J2000 for Abell 2218—note that this seems to be

somewhat offset from the optical center of the cluster, but we will accept it anyway for the purposes of this example).

Since we will be looking for faint, high-z galaxies, we select also the boxes to avoid bright moving objects during the observations (both the Earth/Moon and 'Others', which currently includes Mars, Jupiter, Saturn, Uranus, Neptune and the asteroids Vesta, Hebe, Ceres, Iris, and Eunomia). This choice will restrict the observations for scheduling to preclude times when the target coordinates are within 7° of the Earth and Moon, or within $30'$ of the objects on the 'Others' list). The completed entry dialog is shown in Figure 14.

The screenshot shows a 'Target' dialog box with the following fields and options:

- Target Name (required):** Abell 2218
- Coordinate System:** Equatorial J2000
- RA:** 16h35m53.99s
- Dec:** +66d13m00.2s
- Epoch:** 2000.00
- Proper Motion:**
 - Use Proper Motion
 - PM RA ("/yr): 0.000
 - PM Dec ("/yr): 0.000
- Bright Moving Objects to Avoid:**
 - Earth+Moon
 - Others

Buttons at the bottom include 'Help', 'Cancel', and 'OK'. There are also buttons for 'Resolve the Name', 'Visibility / Orientation', and 'Background' near the top right.

Figure 14: The target entry dialog.

After entering the target name, coordinates, and clicking 'OK', we are returned to the main Spot menu (see Figure 15). A few features to notice: in the bottom banner, the selected target name is displayed "Abell 2218," with target type "Fixed Single."

4.4 Background Estimate

As with all observations, we will need to determine the IR background at the location of the targets. In general, the IR background contribution is a combination of the zodiacal light, interstellar medium, and cosmic background radiation. At IRAC wavelengths, the background is dominated by zodiacal light, so a general rule-of-thumb is that the background is “low” near the ecliptic poles (absolute ecliptic latitude greater than about 60°), “high” if it is in the ecliptic plane (absolute ecliptic latitude less than 30°), and “medium” for all other ecliptic latitudes.

We obtain a more quantitative estimate through the Spot Target entry dialog. Within the target entry/modification window, clicking on “Background” (see Figure 14), brings up the “Background Dialog” window, which we display in Figure 16.

We enter 4.5 micron as the wavelength to do the estimate, leave the “Calculate Range When Visible” button selected, and click “Do Estimate.” This is shown for Abell 2218 in Figure 17, and the results for all of the targets are given in Table 2. The 4.5 micron maximum backgrounds vary by a factor of three (0.233 MJy/sr for Abell 2218, to 0.630 for Abell 1689), and are classified by the SSC as “low” to “high” backgrounds respectively (see <http://ssc.spitzer.caltech.edu/warmmission/propkit/som/bg/> for plots of the IR background at various Galactic latitudes, and the SSC's classification of low/medium/high backgrounds).

It is a good idea to verify the background estimate provided by Spot with a visual check of observations provided by IRAS. To do this, we first retrieve the IRAS Sky Survey Atlas (ISSA) image of the target field (in this case, we do it for Abell 2218). To do this, select “ISSA image...” from the “Images” pull-down menu. The ISSA image retrieval pop-up window, shown in Figure 18, will appear.

Table 2: The 4.5 micron background at the target positions.

Target	Maximum Background [MJy/sr]	Background Level
Abell 2218	0.233	Low
ZwCl0024.0+16.52	0.579	High
Abell 665	0.370	Medium
Abell 1689	0.630	High
AC 114	0.480	Medium

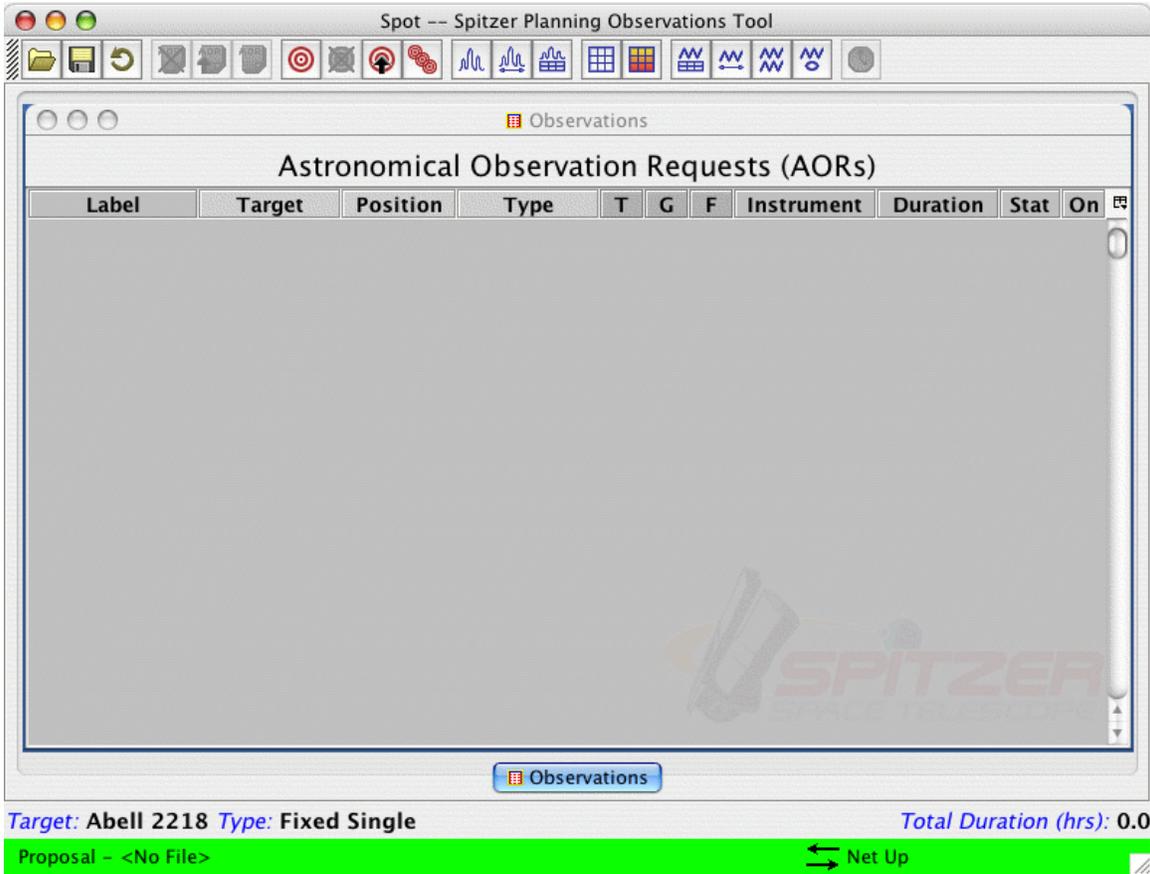


Figure 15: Spot menu after Abell 2218 target entry.

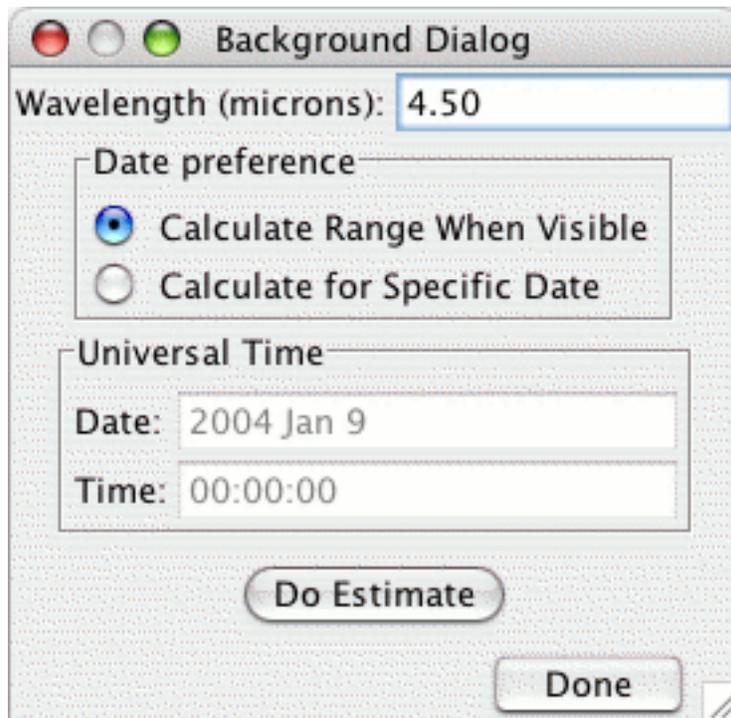
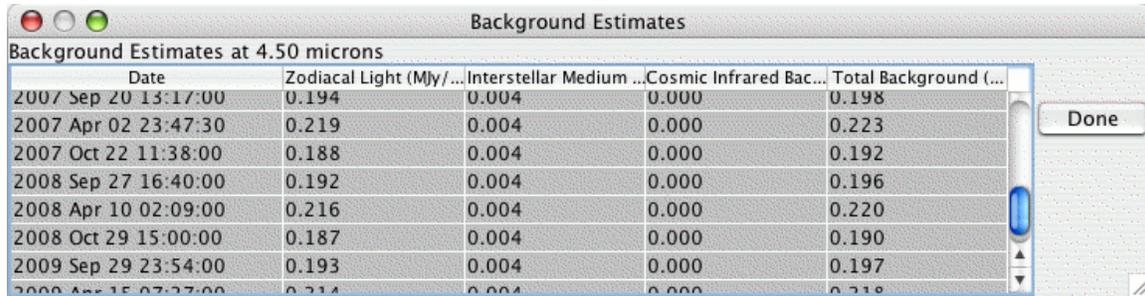


Figure 16: The background entry dialog.



Date	Zodiacal Light (MJy/...	Interstellar Medium ...	Cosmic Infrared Bac...	Total Background (...)
2007 Sep 20 13:17:00	0.194	0.004	0.000	0.198
2007 Apr 02 23:47:30	0.219	0.004	0.000	0.223
2007 Oct 22 11:38:00	0.188	0.004	0.000	0.192
2008 Sep 27 16:40:00	0.192	0.004	0.000	0.196
2008 Apr 10 02:09:00	0.216	0.004	0.000	0.220
2008 Oct 29 15:00:00	0.187	0.004	0.000	0.190
2009 Sep 29 23:54:00	0.193	0.004	0.000	0.197
2008 Apr 15 07:27:00	0.214	0.004	0.000	0.218

Figure 17: The 4.5 micron background at the Abell 2218 central position.

We select all wavelengths (12, 25, 60 and 100 micron), choose a 1° FOV, put all plots in a current frame, no zoom, and hit “OK.” When Spot has retrieved the images, you will note that there are now large black arrows and a slider bar in the upper right; see Figure 19. This is how you can flip between images loaded into the same window. If you load fewer than four images into the same window, then the slider only includes those images as options.

Putting the slider on 12 micron (closest to the IRAC bands), and increasing the zoom (by hitting the magnifying glass icon with the “+” sign on the left hand side of the main Spot window), allows us to examine the structure of the IR emission in the target field. Now the ISSA pixels are $90''$, so the resolution is only a few pixels per IRAC FOV. Nevertheless, we see no evidence of very bright spots in the emission.

Why is there a difference between Spot's estimates and that seen in the ISSA maps? Ignoring the slight difference in wavelength, there are some differences in how the background is estimated with Spot that may be important for your science. For a detailed discussion, see section 5.4.2.

4.5 Sensitivity and Exposure Time

Armed with the characterization of the background level (see section 4.4), we can proceed to estimate the required exposure time. The first step is the IRAC webpage for the instrument sensitivity. See: <http://ssc.spitzer.caltech.edu/irac/>.

For IRAC, the current estimate of the confusion limit is ≈ 0.6 mJy (this does not represent a hard sensitivity limit, but rather indicates where source confusion affects the reliability of source extractions; see the IRAC chapter of the “Warm” SOM for more information). At 3.6 micron, we reach the limit quickly: with a single cycle of the 100 sec frame time for low background. At 4.5 micron, we reach the confusion limit in 4×100 sec total integration (for low background). See the Warm SOM for more information.

We determine the exposure time required for this proposal to reach ≈ 0.2 mJy (1s) at 4.5 micron. For medium background, with a 100 sec frame time, the 1 sigma IRAC point-source sensitivity is 0.73 and 1.4 mJy for the 3.6 and 4.5 micron bands, respectively. For long frame times, the noise essentially scales with $t^{-1/2}$. Hence, to reach ≈ 0.2 [Jy (1 f)

in the 4.5 micron band, we require 50×100 sec. **Note: The 200- and 400-sec frame times are not available in the warm mission.**

One word of caution, however: while our science goal is to probe deeply at 4.5 micron, the 3.6 and 4.5 micron arrays will be well below the confusion limit with $t_{\text{tot}} \approx 50 \times 100$ sec. We must be aware that we will not be increasing the S/N as $\propto \text{sqrt}(t)$ in the 4.5 micron data once the confusion limit is reached in that waveband. A similar argument applies for 3.6 micron data.

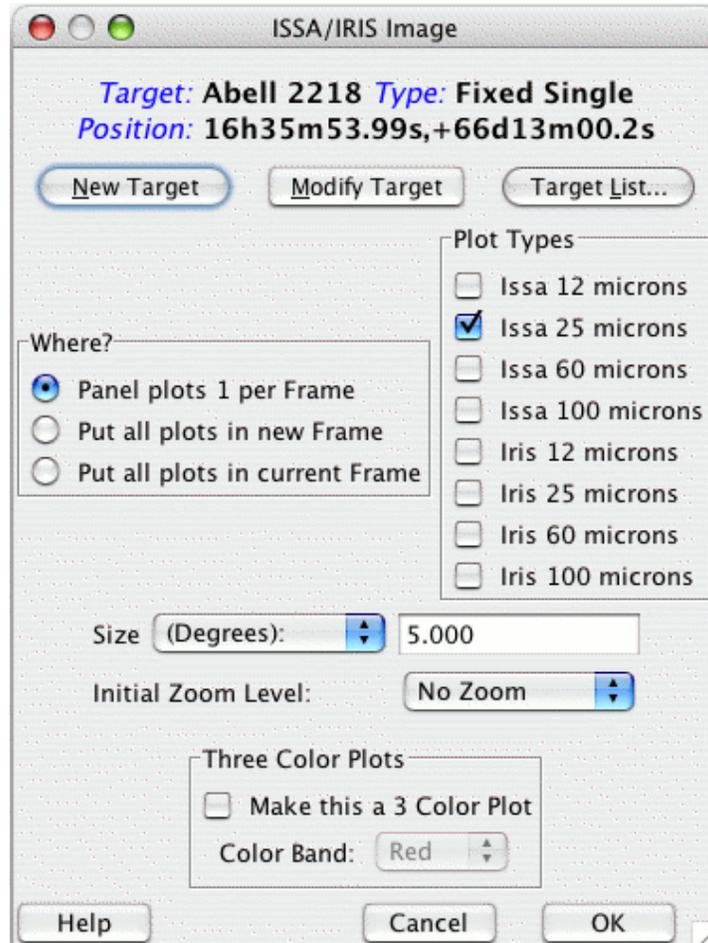


Figure 18: The ISSA image retrieval entry dialog.



Figure 19: Flipping between 12, 25, 60, and 100 micron images.

4.6 Filling Out the IRAC AOT

We now fill out the IRAC AOT, starting with selecting the AOT type. This is accomplished either by selecting “IRAC Post-Cryo Mapping” from the “Observation” pull-down menu, or by clicking on the “Infrared Array Camera 3.6 and 4.5 micron imaging of single or multiple fields” icon (the “sunburst” checkerboard icon, sixth from the right on the icon taskbar). The IRAC Post-Cryo Mapping AOT entry window will appear as illustrated in Figure 20.

The IRAC AOT itself consists of an (optional) dither pattern superposed on an (optional) rectangular-grid raster. In this section, we will discuss each of the AOT entry options, and the activities that the spacecraft and telescope will perform when the specified AOR is executed. Let us consider these in turn.

Figure 20: The IRAC Mapping AOT entry dialog.

4.6.1 Readout Modes and Frame Times

For most observations, each of the 256×256 arrays is read out in its entirety; this is the full array mode. In full array mode, there are eight selectable frame times: 0.4, 2, 6, 12, 30, 100, 200, and 400 sec.

In this example, we are searching for intrinsically faint objects, hence we choose full read-out mode, and, for each pointing, the deepest possible frame time. However, see the note in section 4.5 — the 100 second frame time should be used in proposals. Now to reach our desired depth at each pointing, we calculated above that we need 49 repeats. Therefore we *could* enter “49” in the “Number of Frames” dialog box. However, to do this would be a very bad idea indeed!! This would mean that the observations would be executed with no offsets. For most observing scenarios, to obtain a good quality final image it is *essential* to have offsets between exposures, for cosmic ray rejection, for mitigation of scattered light and long- and short-term latents, and for image artifact masking. We thus use the dithering option, as described in section 4.6.4, and set “1” in the “Number of Frames” dialog box; see Figure 27.

4.6.2 Field of View

The two IRAC arrays are fed by two entrance apertures, which are located one above the other in the focal plane with a gap of about 1.5'. For the subarray mode, there are two separate fields of view (FOVs), corresponding to the subarray section of each of the arrays.

The observer can select a primary group of detectors for the observation by checking one, or both, of the field-of-view (FOV) boxes, which are labeled by the wavelengths of the detectors in each group. In subarray mode, there are two FOVs, because the subarray portions of the detectors do not overlap on the sky. Note for Full Array, subarray, and HDR mode you can also specify in which channel you wish to collect data.

Note: the way the AOR will be executed depends *both* upon the map and field of view choices (i.e., they are co-dependent). For the moment, let us leave aside the choice of field of view and discuss the mapping implications.

4.6.3 Mapping

The choices for mapping and field of view are co-dependent. Selecting one of the fields of view as primary ensures that the map you define will be centered on the target coordinates in your primary field of view. All four fields of view collect data, however, so an offset map will be imaged by the other field of view.

For example, for a single pointing observation (i.e., no mapping), by selecting the 3.6 micron field of view as primary, the specified target will be imaged with the 3.6 micron field of view, while a nearby portion of sky will be covered with the 4.5 micron FOV. By selecting both fields-of-view (still with no mapping), we request that the same piece of sky be covered by *each array*, and in this case, there will be ‘offset’ fields that are imaged only by either the 3.6 micron or 4.5 micron FOVs.

In mapping mode, selecting both fields of view *does not guarantee that the same sky is covered at both wavelengths*. If you select the celestial coordinates map, the map grid is executed once with the 3.6 micron field of view centered on the map positions, and then again with the 4.5 micron field of view. This can lead to significant redundancy, as the same area of sky is imaged more than once by the same aperture. If you select array

coordinates and both fields of view, then the map will be centered on the point midway between the two IRAC fields of view.

Confused? A few examples are in order. From the main IRAC AOT entry window (see Figure 20), under the "Mapping and Dithering" section, clicking the "Yes" radio button under "Mapping Mode" brings up the mapping entry dialog in Figure 21.

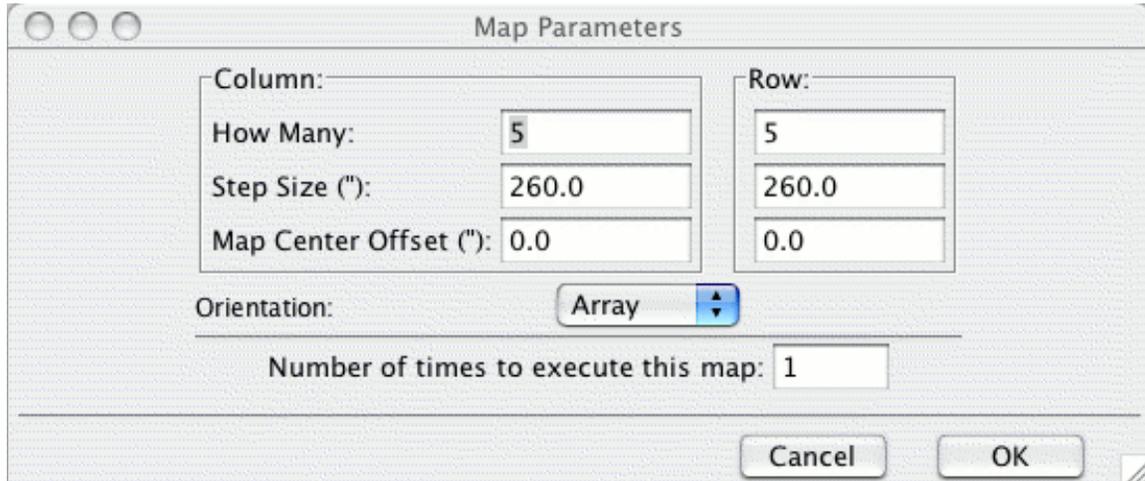


Figure 21: The IRAC Mapping AOT map parameter entry dialog.

We have choices of the number of rows and columns of the map, the map spacing, and the coordinate system for the offsets: array or celestial. As alluded to above, how maps are executed depends upon the field of view selection, as we illustrate below. For this example, all choices will be done with the rectangular grid.

Case 1: no mapping. The easiest case first. If both fields of view are selected, the observations are executed with the target in each aperture successively. With either the 3.6 micron or 4.5 micron field of view selected, the target is centered in the chosen aperture only. A simple illustration of these three cases is shown in Figure 22, where the 'X' marks the target location, and the two apertures are shown as the squares.

Case 2: single position (1×1) map. A tricky thing can happen if you choose both fields of view, and do a 1 row, 1 column map in array coordinates. In this case, the target is placed midway between the two fields of view. Choosing one or the other field of view only centers the target coordinates at the center of that field of view. This is illustrated in Figure 23.

Case 3: simple map. Let's consider a map consisting of 2 rows, 1 column, with offsets of 260" in array coordinates. This should be sufficient to illustrate more complex mapping strategies. Choosing both fields of view centers the target in the middle of the overlap region of both fields of view. Conversely selecting one of the 3.6 micron and 4.5 micron fields of view centers the map in the center of the overlap region for that field of view. The maps are illustrated in Figure 24.

No mapping

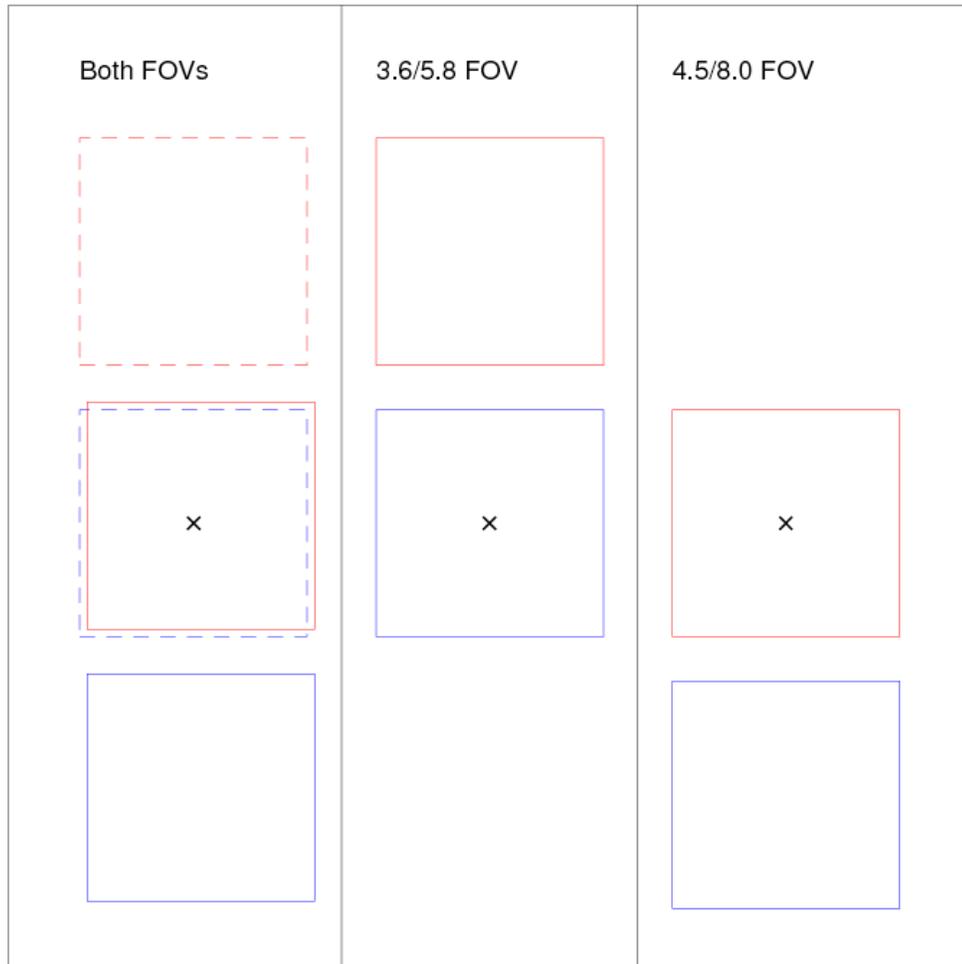


Figure 22: No mapping. The dependence of the sky area covered in no-map mode on the field of view selection. The “x” marks the target position in each case, and the squares show the 3.6 micron and 4.5 micron apertures. In the first panel, the second pointing has been shown as dashed lines, to aid in the visualization.

Single position (1 column, 1 row) mapping

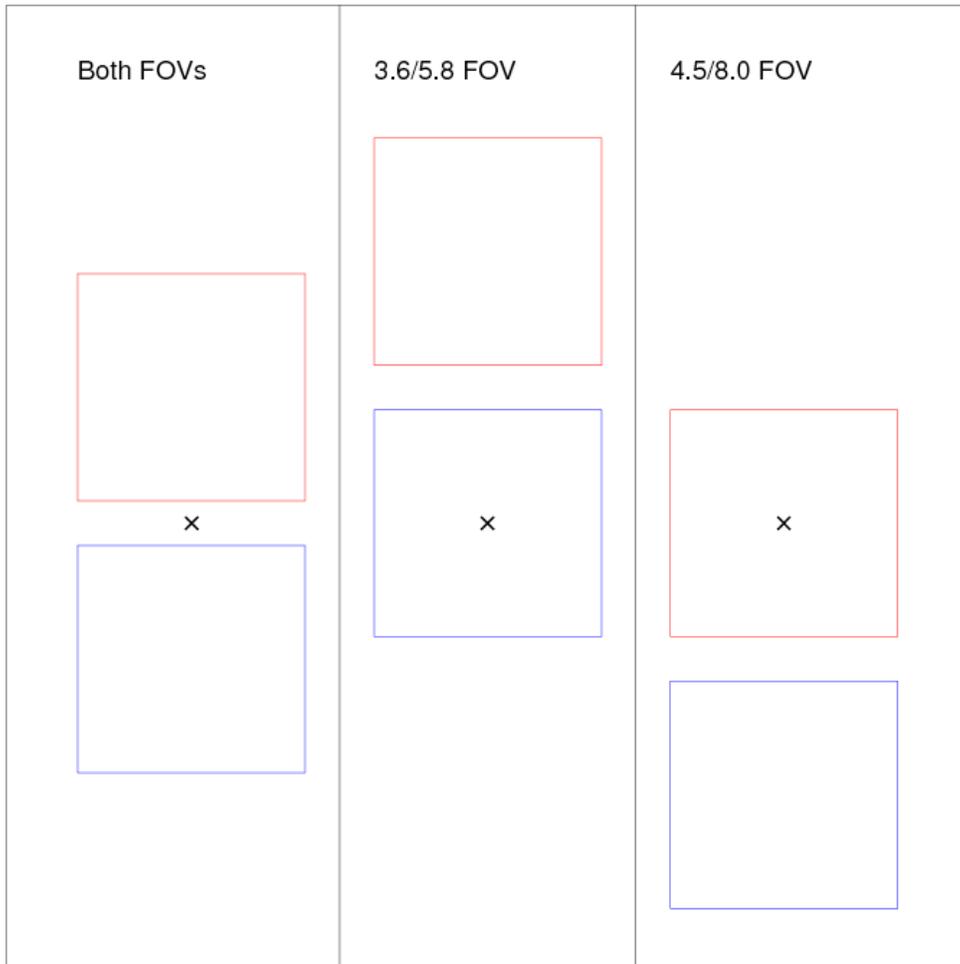


Figure 23: Single position map. The dependence of the sky area covered with a single position (1 column, 1 row) array coordinate map. The “x” marks the target position in each case, and the squares show the 3.6 micron and 4.5 micron apertures.

Simple map: 1 column, 2 rows, offsets = 260"

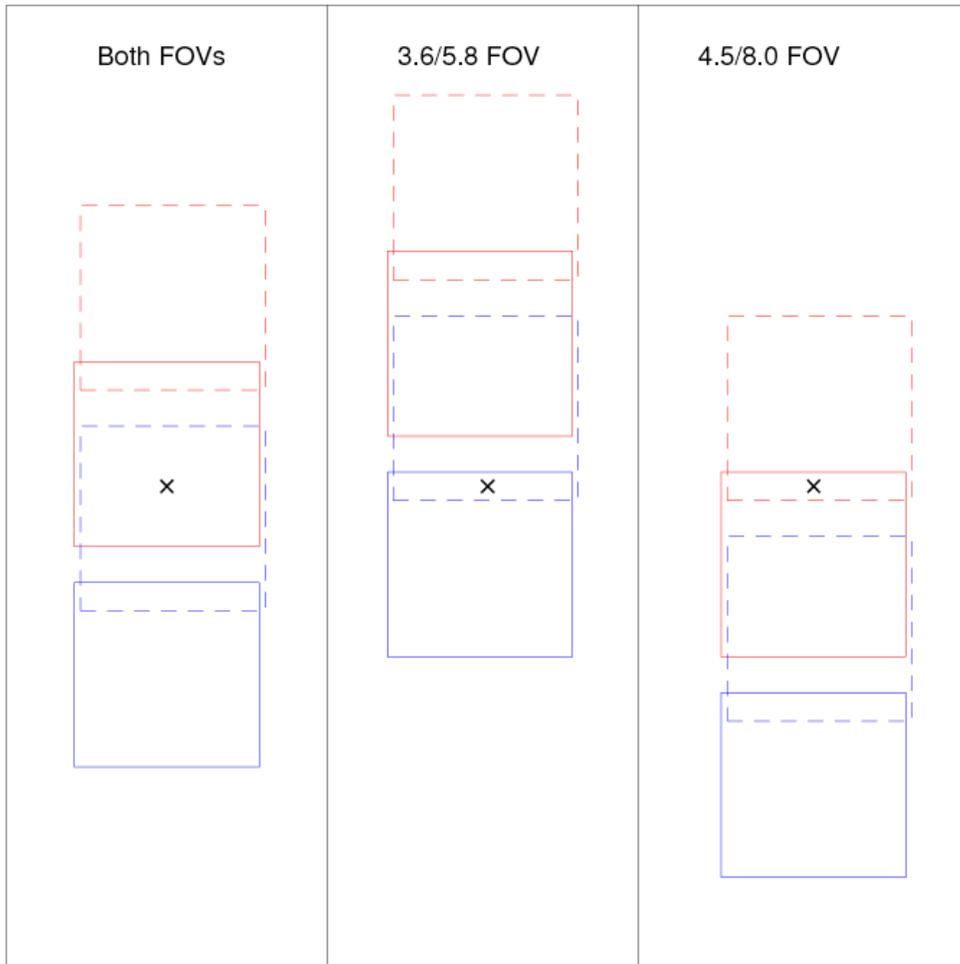


Figure 24: Simple map. The dependence of the sky area covered with a simple map (1 column, 2 rows with offsets = 260" in array coordinates). The "x" marks the target position in each case, and the squares show the 3.6 micron and 4.5 micron apertures.

So, what does this all mean? You should choose a map scheme such that you obtain sky coverage in the passbands you wish, obviously. What about if you want exactly the same sky to be covered in both apertures? This is possible, although at the added expense of constraining when your observations can be performed. The Spitzer Space Telescope has a restricted roll angle, such that it must be positioned so that the solar shield offers protection from the Sun. Hence to 'flip' the relative orientations of the 3.6 micron and 4.5 micron apertures, effectively we must wait \approx six months for the observatory to be on the other side of the Sun. You can do this with Timing Constraints, or, equivalently, by creating two AORs with position angle constraints. However, **do so at your own risk!** The more constrained a program is, the less likely it can be scheduled. **The preferred**

method is to make a map large enough, so that there is sufficient overlap in both fields of view without constraining the observations.

For the purposes of the example we are developing in this chapter, we could do one of the following (which are equivalent). The first way is the simplest: do the observations with no mapping, but select both fields of view. The sky coverage is given as in the left panel of Figure 22.

An equivalent way to implement this using mapping is to perform a 1 column, 2 row array coordinates map. We adjust the offsets to be one array width, plus the spacing between the arrays $\approx 310'' + 90'' = 400''$, and select both fields of view. This will mean that the second pointing places the 4.5 micron aperture at the position of the 3.6 micron aperture in the first pointing. The end result is uniform coverage over a 5.2 sq. arcsec. FOV at both 3.6 and 4.5 micron, with flanking fields imaged for half as much time in either the 3.6 or 4.5 micron channel. The resulting sky coverage map is illustrated in Figure 25.

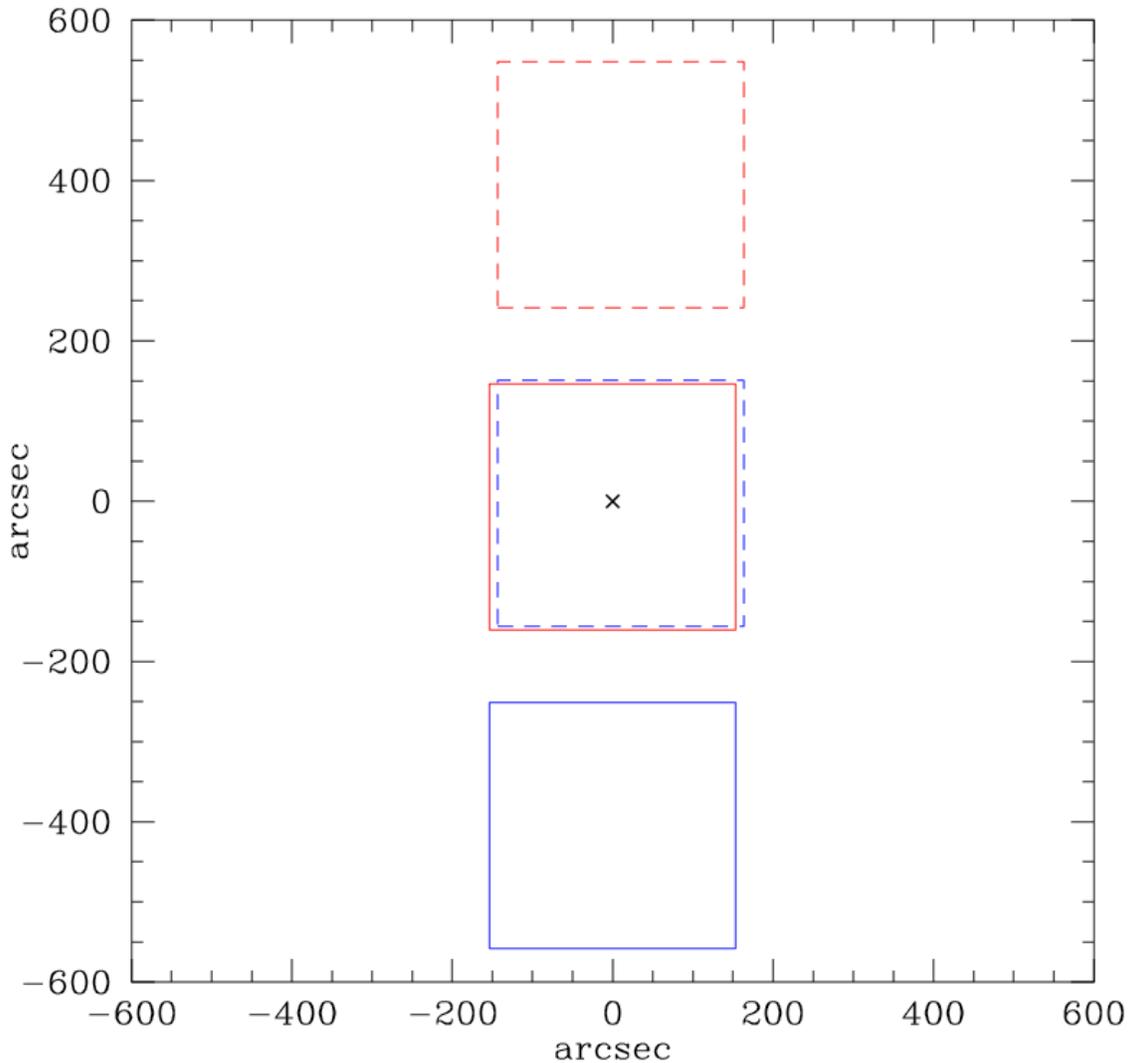


Figure 25: The sky area covered either with no mapping, selecting both fields of view, or a simple map: 2 columns, 1 row, offsets 410" in array coordinates, and both fields of view selected as primary. The "x" marks the target position, and the squares show the 3.6 micron and 4.5 micron apertures. The second pointing in the map has been shown as a dashed line, and offset slightly in the x-direction, to aid in visual recognition of each pointing.

4.6.4 Dithering

Finally, we wish to implement a dither scheme. At each of the positions defined by the single position, map, or cluster in the target specification section, the telescope is pointed to a series of offset positions that define the dither pattern. The purpose of the dither is to minimize the effect of pixel-to-pixel gain variations, help with cosmic ray identification and removal, and aid in removal of image artifacts on the detector. Several pre-packaged dithering options are available in either the full array or subarray readout modes. Clicking on dither pattern "yes" brings up the dither selection dialog illustrated in Figure 26.

The dither patterns for IRAC in full array mode currently include a five-position Gaussian pattern, two sizes of Reuleaux triangle, a 9-point random, a 16-point spiral, and a cycling dither pattern; see the IRAC chapter in the Warm SOM for more information.

For the Gaussian, Random, and Reuleaux patterns, the same dither pattern is performed at each map grid position. The “cycling” pattern consists of a table of 311 unique offsets, drawn at random from a Gaussian-normal distribution; for each dither, the observations are obtained at the next entry position in the table. The dither pattern can vary quite a bit, depending on the number you choose as the “starting point in the dither table,” so if you don’t like any given pattern, try changing that number and re-visualize the observation.

For the Cookbook example we are developing here, in the dither selection dialog window (Figure 26), selecting “Cycling,” with “Number of Positions” set to “49,” and “Starting point in dither table” set to, for example, 10 would mean that at the first map position, exposures are taken with dither-offsets 10–58. At the second map position, exposures are taken with dither-offsets 59–107 in the dither table.

In addition, the selected dither patterns may be scaled using one of the “large, medium, small” options, which select pre-determined scalings of the dither patterns, which for cycling dithers are 5:2:1. The offsets in the Gaussian-normal distribution that generates the cycling pattern can be as large as ≈ 160 pixels from the (0.0) position. In general, well-dithered observations will mitigate much of the effect of latents, scattered light, and image artifacts, and so we select the “medium” scaling option.

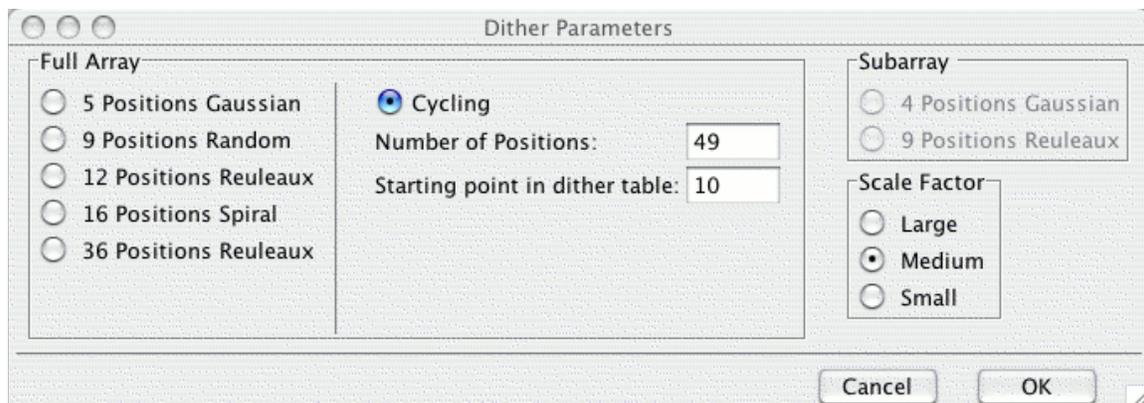


Figure 26: The IRAC Post-Cryo Mapping dither pattern dialog.

4.7 Duration

The completed AOT is displayed in Figure 27.

Hitting “OK” on the AOT entry dialog window returns us to the main Spot window, as shown in Figure 28.

Hint: In this example, we gave the AOR the title “IRAC mapping - a2218.” Note that all alpha-numeric characters are not permitted in the AOR name. Periods and colons are not

allowed. Also, make sure to give each AOR a unique, short and yet insightful name. The AOT entry dialog will assign a label by default, but we highly recommend changing this to more reflect the nuances of your observations.

A feature to notice: under duration, there is no estimate of time required to execute this AOR. Easy enough to fix: under the "Tools" pulldown menu of the main Spot window, select "Recompute All Estimates." You will be greeted with a pop-up menu asking you to select what you want to recompute. Select "Current AOR." Spot will then churn away in the background, and return you to the main spot window, with the "Duration" field now filled (11080 seconds, for this example). Also the Total Duration report on the bottom right of the Spot window will be filled. In this example, we use 3.1 hrs, which is less than the maximum of 24 hours per AOR allowed for IRAC observations. This is shown in Figure 29.

Hint: An alternative way of obtaining the AOR duration is to click on the "Calc. Obs. Time" button from within the main AOT entry window (see Figure 27). The duration estimate returned will now include a breakdown of slew time required, settle time, total AOR duration, and the integration depth in seconds, per pixel, for each of the passbands. See Figure 30.

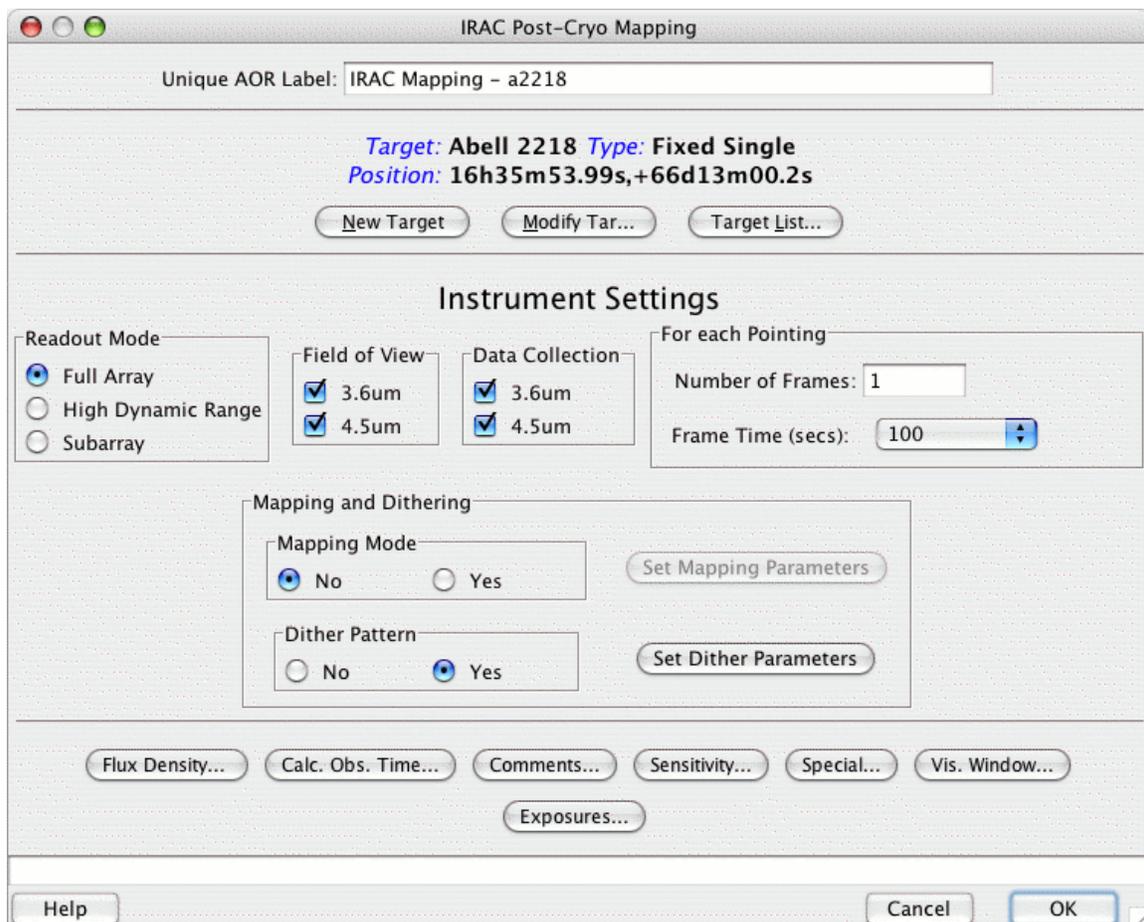


Figure 27: The completed IRAC AOT for Abell 2218.

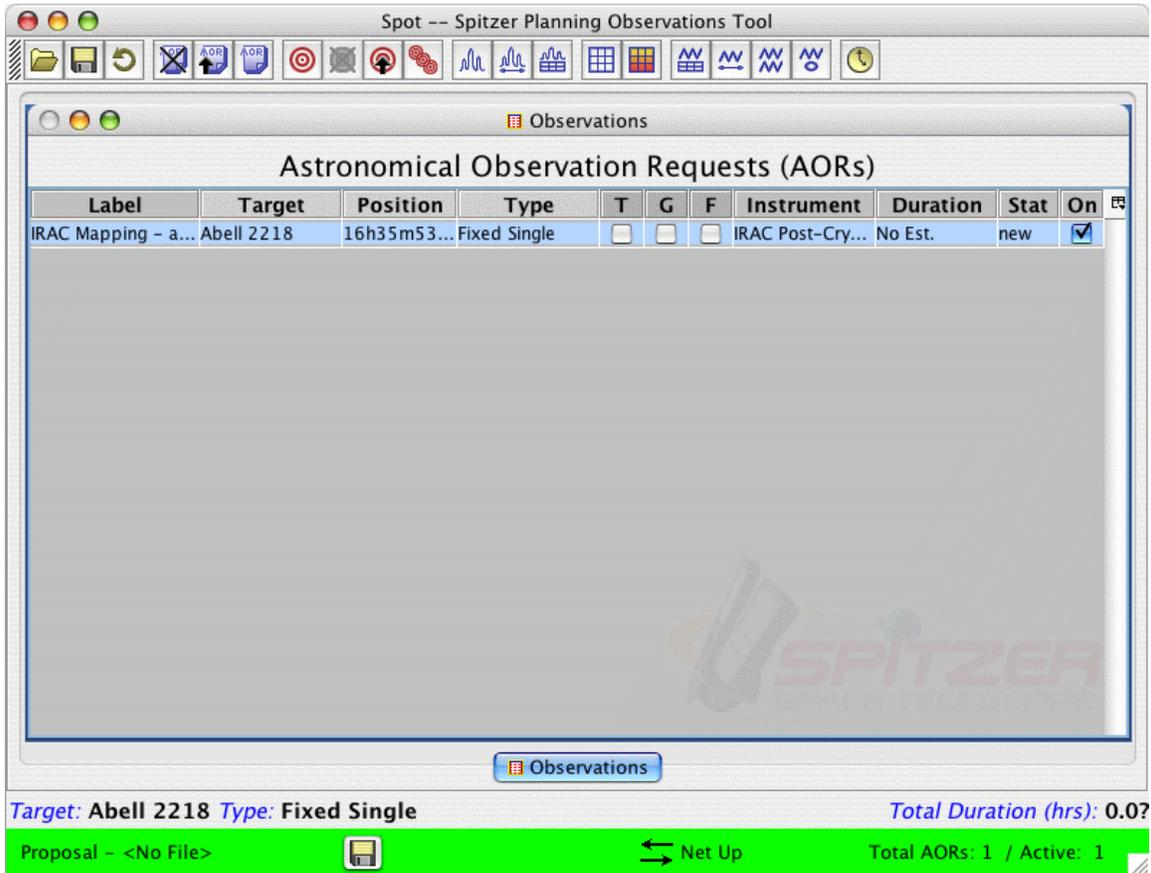


Figure 28: The Spot menu after the IRAC AOT parameters have been entered.

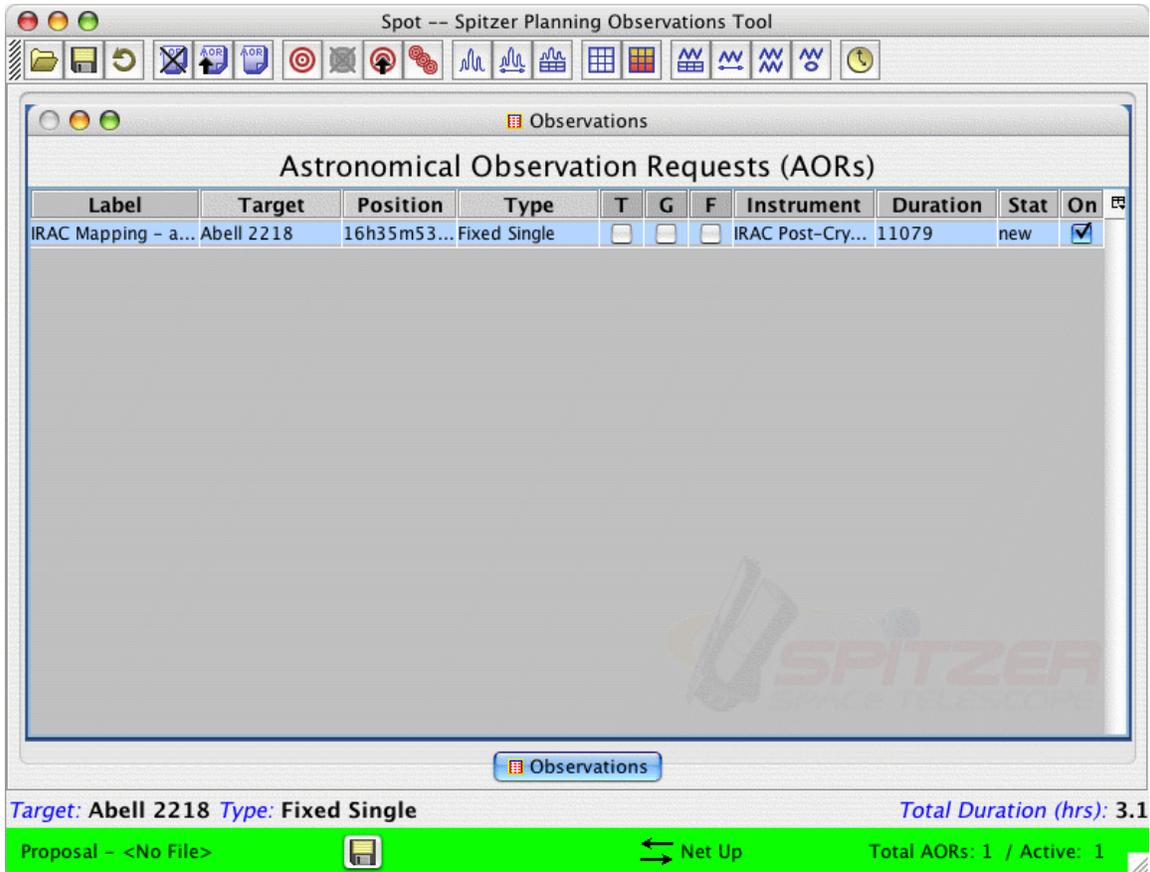


Figure 29: The Spot menu after the IRAC AOT parameters have been entered, and the AOR duration computed.

Resource Estimates	
Slew Time (sec):	399.1
Settle Time (sec):	410.0
Slew Overhead (sec):	215.0
Special Overhead (sec):	0.0
AOR Duration (sec):	11,079.2
Downlink Vol.(Kbytes):	14,765.0
Estimator Version:	S18.0.1

Integration Time	
IRAC_3_6(sec):	4,900.0
IRAC_4_5(sec):	4,900.0
IRAC_5_8(sec):	0.0
IRAC_8_0(sec):	0.0

Done

Figure 30: The AOR duration calculated from within the AOT entry window.

4.8 Visualization

We have a completed AOR for one of our targets, determining the background and hence the sensitivity of the instrument, calculating and specifying within Spot the required exposure (frame) time, a dither pattern, and number of repeats. We calculated the total duration of this program, and it is less than the maximum allowed per AOR. So what next?

We will use this AOR as a template for the other targets in the list. However, first, we might want to visualize the observations with an overlay on the optical or infrared sky.

First, we need to obtain or specify an image to use for the overlay. We can obtain ISSA, 2MASS, MSX, or DSS images through Spot. Click on the "Images" tab on the toolbar, and, for example, select "DSS Image." You will see a pop-up window, asking you to specify the parameters for the image; see Figure 31. After clicking "OK," Spot will work away, and return with an image in the main window.

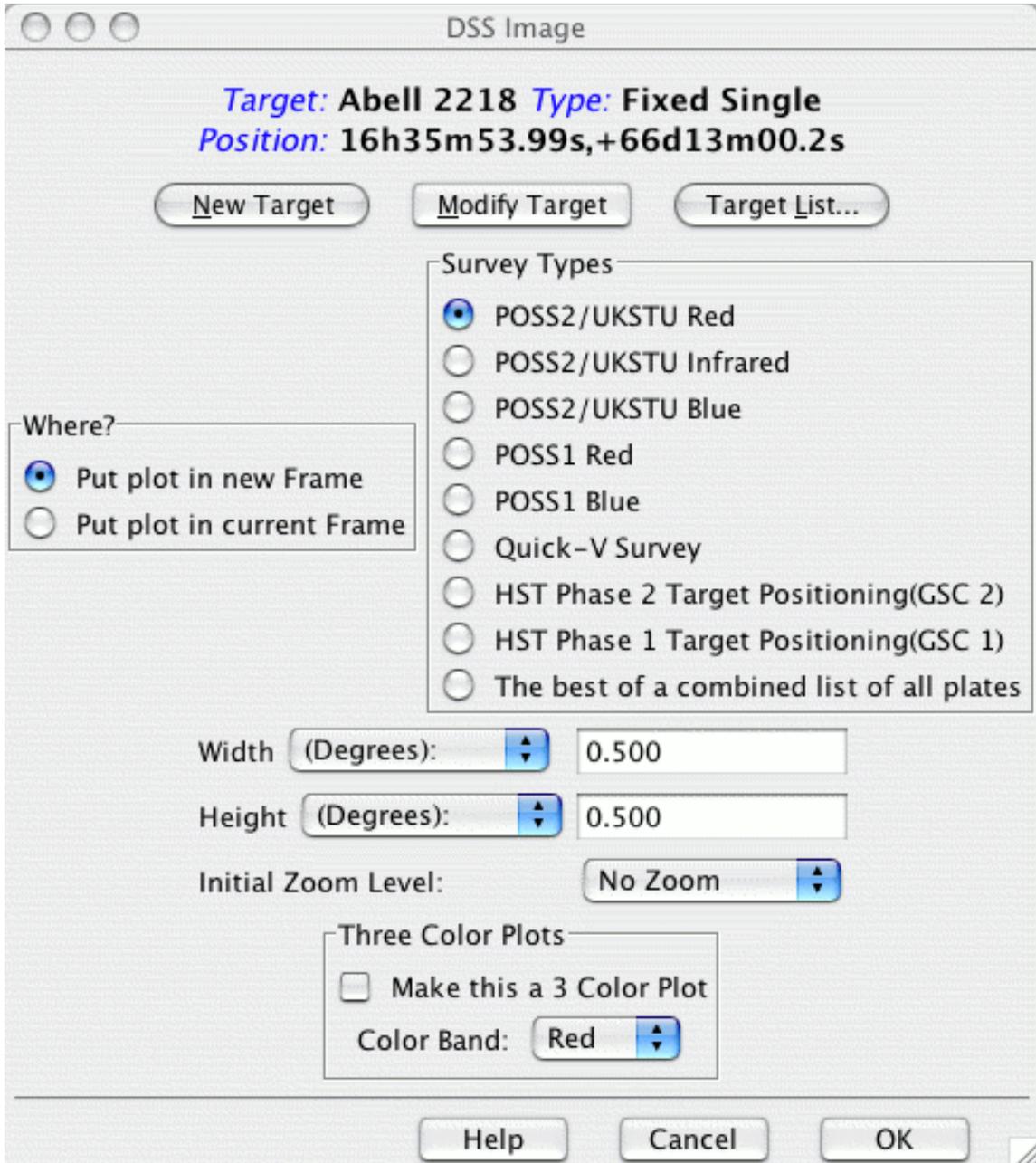


Figure 31: A Spot image menu dialog, in this case, for DSS image retrieval.

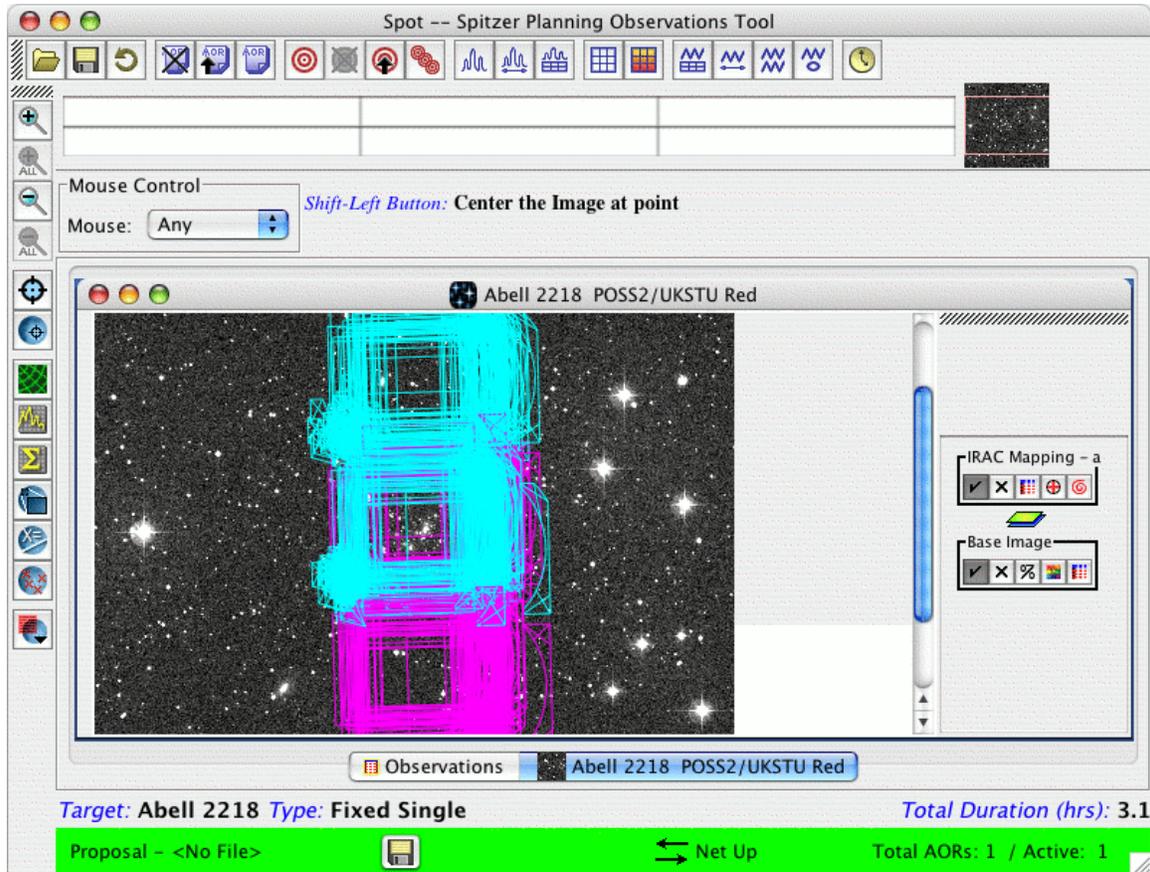


Figure 32: The overlay of the IRAC mapping observations on the Abell 2218 field.

To place the overlay on the image, click on the “Overlays” tab, and select “AORs on current image.” You will be prompted for an observation date. Choose anything reasonable (this will be more important for constrained observations; however, since we have placed no timing or orientation constraints on the AOR, we can simply choose whatever dates are available to get a visualization of the observations). The resulting overlay (after zooming out) is shown in Figure 32.

The overlay shows that the central position has been observed twice, once with the 3.6 micron field of view (large, cyan squares), and once with the 4.5 micron FOV (large, magenta squares). There are a few neat visualization aids which we highlight here: Firstly, click on the “Show Side Bar on Current Frame” under “Options.” This will bring up a sidebar with “IRAC-Mapping” and “Base-Image Options” if it is not already visible. Look under “IRAC-Mapping” and you will see four buttons, including one that looks a bit like a tiny grid with red lines. Click that and you will see a pop-up window with options to animate the overlay on an image-by-image basis, animate with a trail, showing the cumulative observations, and the opportunity to select only a subset of the dithered pointings to overlay on the image.

Hint: The visualization tool within Spot is a great, simple way of understanding what all of the AOT options really mean. For example, the various mapping/field of view options

described in section 4.6.3 can be easily sorted out simply by selecting various combinations of options, and seeing what the resulting visualization looks like. Combined with the detailed duration tool from within the AOT entry window, you are presented with a unified picture of how the sky is mapped with your observations, and what depth, per pixel, you are obtaining.

Hint: In the visualization, you will notice a few crescent-shaped arcs containing X's, approximately one arcminute from the main fields of view. These are the scattered light regions, highlighting locations where bright point sources will scatter light into the IRAC FOVs. If a bright star falls in one of those crescents, it is recommended that the observations be adjusted to move the object out of the troublesome regions by, e.g., constraining the date of the observations. Well-dithered observations will also mitigate scattered light problems.

A similar exercise can be done to examine the local IR sky at the target position. Instead of selecting a DSS image from the "Image" pulldown tab, select 2MASS or ISSA instead.

4.9 Duplicating the A2218 AOR to Design the Complete Program

Finally, we need to duplicate this AOR for all of our other targets. To do this we can use the AOR replication tool. Click on the "Edit" tab, and select "Copy current AOR." In the main Spot window, a second AOR, appearing to be exactly the same as the first we just created, will appear. Double click on it to edit, and the IRAC Mapping AOT entry dialog will appear. We need to change the target for this AOR, so we click on "Target List" which brings up a pop-up window with the list of targets we entered earlier (see section 4.3). Select, for example "Abell 1689." Also, adjust the AOR Label to whatever you like (e.g., "IRAC Mapping: a1689 central position"). Hitting "OK" returns you to the main Spot window with the new AOR listed.

We repeat this procedure for all of the targets in the list and recalculate the duration necessary for the entire program. This is shown in Figure 33.

That's it! **Don't forget to save both the target and AOR list** (otherwise, all of this work will be lost when you exit Spot). For reference, we show the ascii text .aor file for this set of observations in Chapter 11. For reference, the ascii text .aor file for this set of observations is available at the SSC website:

<http://ssc.spitzer.caltech.edu/warmmission/propkit/cookbook/>.

Spot -- Spitzer Planning Observations Tool

Observations

Astronomical Observation Requests (AORs)

Label	Target	Position	Type	T	G	F	Instrument	Duration	Stat	On
IRAC Mapping - a...	Abell 2218	16h35m53...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Post-Cry...	11079	new	<input checked="" type="checkbox"/>
IRAC Mapping - a...	Abell 1689	13h11m34...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Post-Cry...	11075	new	<input checked="" type="checkbox"/>
IRAC Mapping - a...	Abell 665	8h30m45...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Post-Cry...	11076	new	<input checked="" type="checkbox"/>
IRAC Mapping - a...	AC114	22h58m52...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Post-Cry...	11074	new	<input checked="" type="checkbox"/>
IRAC Mapping - C...	ZwCl0024.0+...	0h26m36...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IRAC Post-Cry...	11074	new	<input checked="" type="checkbox"/>

Observations

Target: ZwCl0024.0+16.52 Type: Fixed Single Total Duration (hrs): 15.4

Proposal - <No File> Net Up Total AORs: 5 / Active: 5

Figure 33: The main Spot screen after the complete IRAC imaging program has been designed

5 Large-Area Mapping in the Trapezium at 3.6 and 4.5 microns with IRAC

We're going to design an observation that will cover a relatively large area of sky. This example will illustrate how to do a large area imaging survey with IRAC (3.6 and 4.5 μm).

For this project, we will use IRAC to survey the Orion Nebula Cluster (ONC), which surrounds (and includes) the Trapezium. Our goal is to survey this region and obtain photometry for G stars therein. This region is well-studied at many wavelengths ranging from IRAS to Chandra, and is expected to produce a *very* high flux in the specific Spitzer bands. In fact, it is likely to be rather astonishingly bright, as many Galactic star-forming regions are in the thermal infrared.

The GTOs, not surprisingly, have snapped up the ONC region with all the instruments already. However, because we would like to demonstrate certain specific features, and even though similar observations of the cluster are already in the ROC (and are likely to be saturated at least in part), we will plunge ahead in this example anyway; the authors of this cookbook, at least, found this exercise useful, especially if you are coming from an optical background, since Spitzer infrared considerations (sensitivity and backgrounds in particular) can be significantly different from those of optical observations.

In planning these observations, we will use Spot to estimate background and exposure times. We will take into account possible detector saturation and latency effects.

This example can be applied to wide-field mapping of nearly any Galactic star-forming region and/or regions of high background.

IRAC's images are at 3.6 and 4.5 μm , with bandwidths of 0.7 and 1.0 μm , respectively. Each pixel is $\sim 1.2''$; each image covers a total of $\sim 5.2' \times 5.2'$. Recall that the 3.6 μm and 4.5 μm channels are on different entrance apertures of the focal plane.

We want to cover a large area, but still be able to reject cosmic rays, so we'll need to dither with at least 3 images per patch of sky.

5.1 Overview of the Program

- **Target Selection:** We check the Reserved Observations Catalog (ROC) using Leopard before planning any observations. Unfortunately, the Trapezium region has pretty thoroughly been covered in all of the Spitzer instruments already with GTO observations. However, for purposes of this example, we will carry onward nevertheless. See section 5.2 for a discussion of target selection.
- **Background Estimate:** Since we are developing observations for IRAC, and these wavelengths are all shorter than the IRAS wavelengths, Spot's estimates of background (rather than IRSKY) are preferable here. See section 5.4.2.

- **Filling the IRAC AOT:** A screen capture of the completed IRAC AOT entry dialog is shown in Figure 41. We require wide-area coverage, so we need “Full Array” mode. We expect to have bright objects over the whole large area covered here, so we choose “High Dynamic Range” mode. We observe in both passbands, selecting **both the 3.6 μm and 4.5 μm fields of view**. A $1^\circ \times 1^\circ$ region can be covered by a 14×14 **map grid**, stepping 85% the width of the array, 260”, and using **dithering** (3 per position, using Cycling); see section 5.5.
- **Durations:** It takes 4.1 hours; see section 5.6.
- **Visualization:** We overlay the planned AORs on an ISSA image of the Trapezium. Visualization of the planned AOR helps us verify that we are really doing what we think we are doing! See section 5.7.

5.2 Target Selection: Orion Nebula Cluster

Technically, we should check the Reserved Observations Catalog (ROC) using Leopard (<http://ssc.spitzer.caltech.edu/warmmission/propkit/spot/>) before planning any observations. Enter your target and choose “search programs” from the file menu.

We find that the Trapezium region has pretty thoroughly been covered in IRAC already. Had this been a real proposal, the next step should have been checking the Duplicate Observations Rule, to see if the specific proposal idea we have in mind qualifies as a new observation—perhaps we would like to go deeper or over a larger area than previous observations, in which case our observation might not be considered a duplicate.

However, for purposes of this example, we will plunge onward nonetheless with a shallow, large-area survey of the Trapezium. The Trapezium is very bright. Spot can help us find objects which are officially classified as “bright”. More on this below.

5.3 Target Entry

Start up Spot on your platform of choice (see section 2.4.1). Enter a new target either by clicking on the bulls-eye target icon on the taskbar, or selecting “New Target” from the “Targets” menu.

As shown in Figure 34, we type “Trapezium” into the target name box, select SIMBAD for name resolution (since this is a Galactic object), and click on “Resolve the Name.” We should leave the boxes checked that avoid all bright moving objects; as in other examples here, this restricts the observations to avoid times when the targets are within 7° of the Earth or Moon, or within 30’ of other bright Solar System objects.

The default “Fixed single” target type is fine. It might appear that, since we’re doing a map of a large region, what we really want instead is a “Fixed Cluster-offsets” or “Fixed Cluster-positions.” However, those options are more appropriate for people who are, for example, mapping a small region of space or chasing down a set of specific young stellar objects (YSOs) scattered through the cloud; rather than submitting each specific pointing or YSO as a separate AOR, submitting the set as offsets from a center results in much

less slew overhead. But, in our current case, the scan mode takes care of assigning the offsets we want, and the target type we should use is “Fixed Single.”

Figure 34: The target window after entering Trapezium.

After entering this information, we click “OK” and we return to the main Spot screen. Note that the bottom of the Spot screen now tells us which target and target type we have entered. We might save our target list now, just in case.

5.4 Exposure Time

In order to decide on an exposure time, we need to consider what the limits of the detectors are, what flux we expect from the background, and what flux we expect from the objects.

5.4.1 Saturation Limits

To find the instrument saturation levels, we check the SSC IRAC website. See <http://ssc.spitzer.caltech.edu/irac/> for the very latest in saturation limits for IRAC. These

limits are subject to slight changes, so please do check the website and/or the Warm Spitzer Observer's Manual (SOM) for updates.

Table 3: IRAC Point Source saturation limits (mJy).

Wavelength micron	0.02 s	0.4s	2 s	12 s	30 s	100 s
3.6	20000	1000	190	32	13	3.8
4.5	17000	820	200	33	13	3.9

5.4.2 Background Estimates

Especially in the ONC, background is really going to matter, although at IRAC wavelengths it is not as big a concern. From within Spot, there are two ways to get a background estimate. First, while entering the target (as above) we can click on the "Background" button, producing a window such as Figure 35. Alternatively, once a series of targets are entered, we can get a complete list of targets via either the "Targets/Target List" menu or the bulls-eye icon on the toolbar; see Figure 36. In the target list window, we can click on "Calculate Background for All," then "Show Background" and get the same window as in Figure 37.

We start entering "4.5" in the wavelength box in the "Calculate Background Estimates" dialog box in Figure 35. We don't need to constrain these observations to be at a specific date, so we will allow Spot to calculate the range of background estimates when our target is visible. Click on "Do estimate" (not "Done," a common mistake) to actually calculate it. Spot works in the background and notifies us when complete. It tells us the minimum and maximum contributions separately for Zodiacal light, interstellar medium (ISM), and the cosmic infrared background; see Figure 37. In this case, again, the ISM clearly dominates! The flux expected in 4.5 μm from the ISM alone is returned as ~ 7 MJy/sr. We should repeat this Spot estimate for the 3.6 μm . See Table 4 for the results.

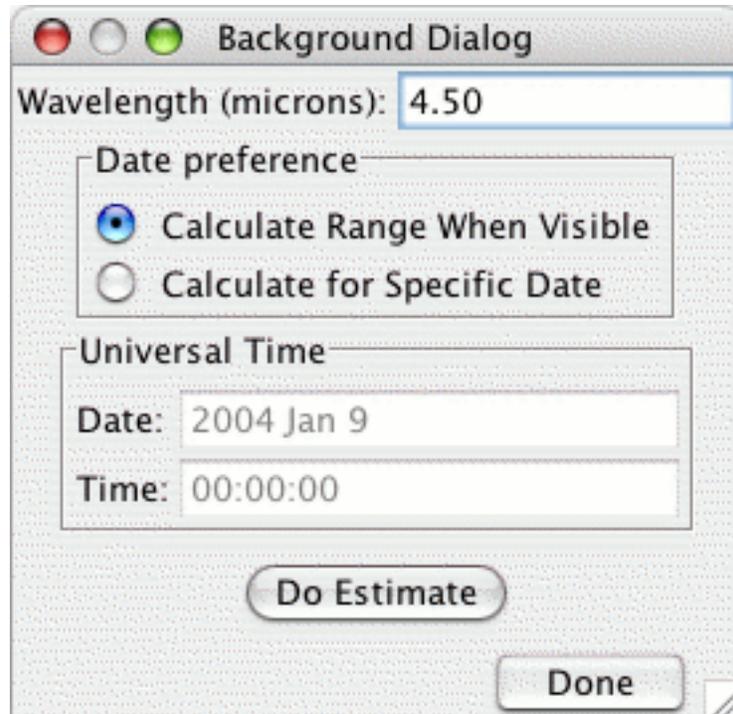


Figure 35: The background estimation window.

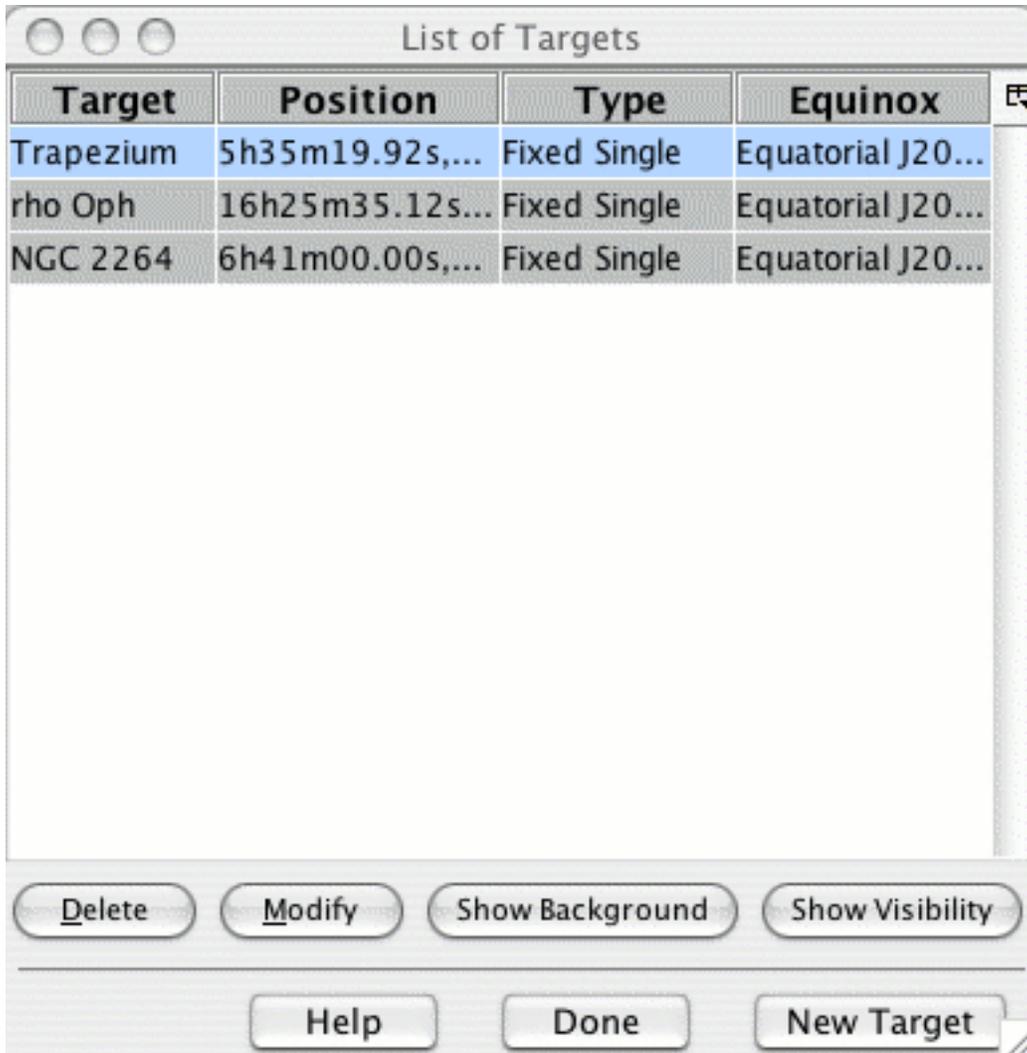


Figure 36: The target list window.

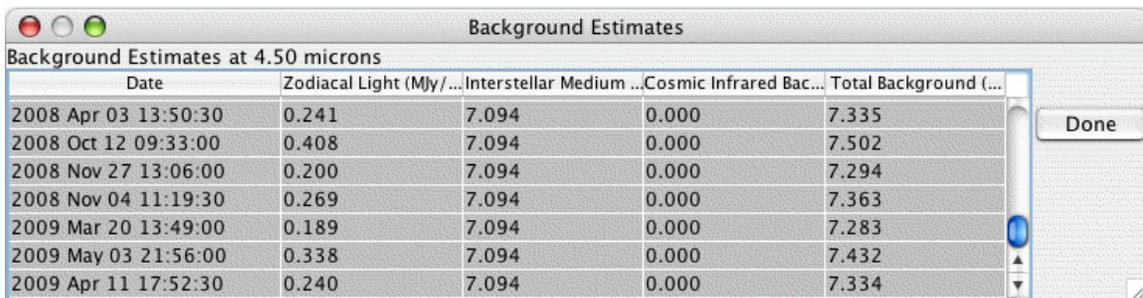


Figure 37: The output of background estimation for the Trapezium at 4.5 micron.

Table 4: ONC IRAC background levels from Spot.

Wavelength (μm)	ISM (MJy/sr)	Total range (MJy/sr)
3.6	5.2	~ 5.3
4.5	7.1	7.3–7.5

Spot is working specifically at the exact coordinates we gave it, e.g., right on top of the center of the Trapezium (Θ Ori). For purposes of background estimates, Spot doesn't care whether we are taking a single "snapshot" or a $5^\circ \times 5^\circ$ map, it evaluates the background specifically at the RA and Dec entered in the Targets list.

For comparison to saturation limits, we need to convert the background estimates to mJy/pix using IRAC pixel sizes and the conversions from Chapter 10; we get 3.4×10^{-11} sr/pix.

We note that the contribution from the background alone will not saturate the detectors, but it will eat up dynamic range, leaving less room for counts due to objects. Now, we need a better estimate of counts due to the objects.

5.4.3 Source Count Estimates

Recall that our minimum science goal is to obtain photometry for G stars in the ONC region. A small number of G stars (like four or five) have been measured from the ground to have L ($3.4 \mu\text{m}$) ~ 9 mag and M ($4.8 \mu\text{m}$) ~ 7 mag. These wavelengths conveniently bracket the IRAC wavebands. Using the conversions in the Spitzer online Mag-to-Jy search tool or in Chapter 10, these magnitudes convert to 0.072 and 0.27 Jy, respectively.

Now, admittedly the ground-based detections are going to pull off only the very brightest stars. We note that (check the IRAC website!) the point-source saturation limits are given in *milliJanskys*, and even under the high-background conditions, the 1σ sensitivities are measured in *microJanskys*. Evidently we ought to worry not so much about simply detecting these stars, but about whether or not they will be too bright! Fortunately, we happen to know (from painful personal experience) that there are quite a number of late-type stars in Orion with M magnitudes not detectable from the ground. Even if these four or five stars detected from the ground saturate the detector, we expect that there will be other stars that do not saturate.

5.4.4 Sensitivity Estimates

Now we will use the sensitivity estimator on the Spitzer web pages here, specifically the IRAC portion: <http://ssc.spitzer.caltech.edu/warmmission/propkit/pet/>. We enter the shortest whole frame (as opposed to subarrays) time with High Dynamic Range (HDR) option, 6 seconds, with 1 repeat and high background. The resulting 1σ sensitivities at 3.6 and 4.5 μm are 9.8 and 13 μJy . Let's say we only believe 5σ detections, i.e., 49 and

65 μ Jy. Backgrounds have already been included in this estimate. The aforementioned ground-detected stars will obviously be easily detected, assuming they don't saturate the detector. The additional frame from the HDR mode will help us obtain calibrated data for even those brightest stars that will saturate at 6 seconds. If we don't expect to care about those brightest stars, we can use a 2 second Full Array exposure instead and save a reasonable amount of time.

5.4.5 Final Decision on Exposure Time

We're still in this to cover as much area as possible, and there are likely to be bright objects all over the place. The shortest exposure time available for a full-array readout in HDR mode is 6 seconds, so we will go with that. Note also that the sub-array options are not useful here, as we are aiming to cover a large area.

5.5 Filling in the AOT

Now we're ready to fill in the IRAC AOT. We can either look under the Observation menu and select "IRAC Post-Cryo Mapping" or click on the IRAC icon on the toolbar. See Figure 38 for the default values.

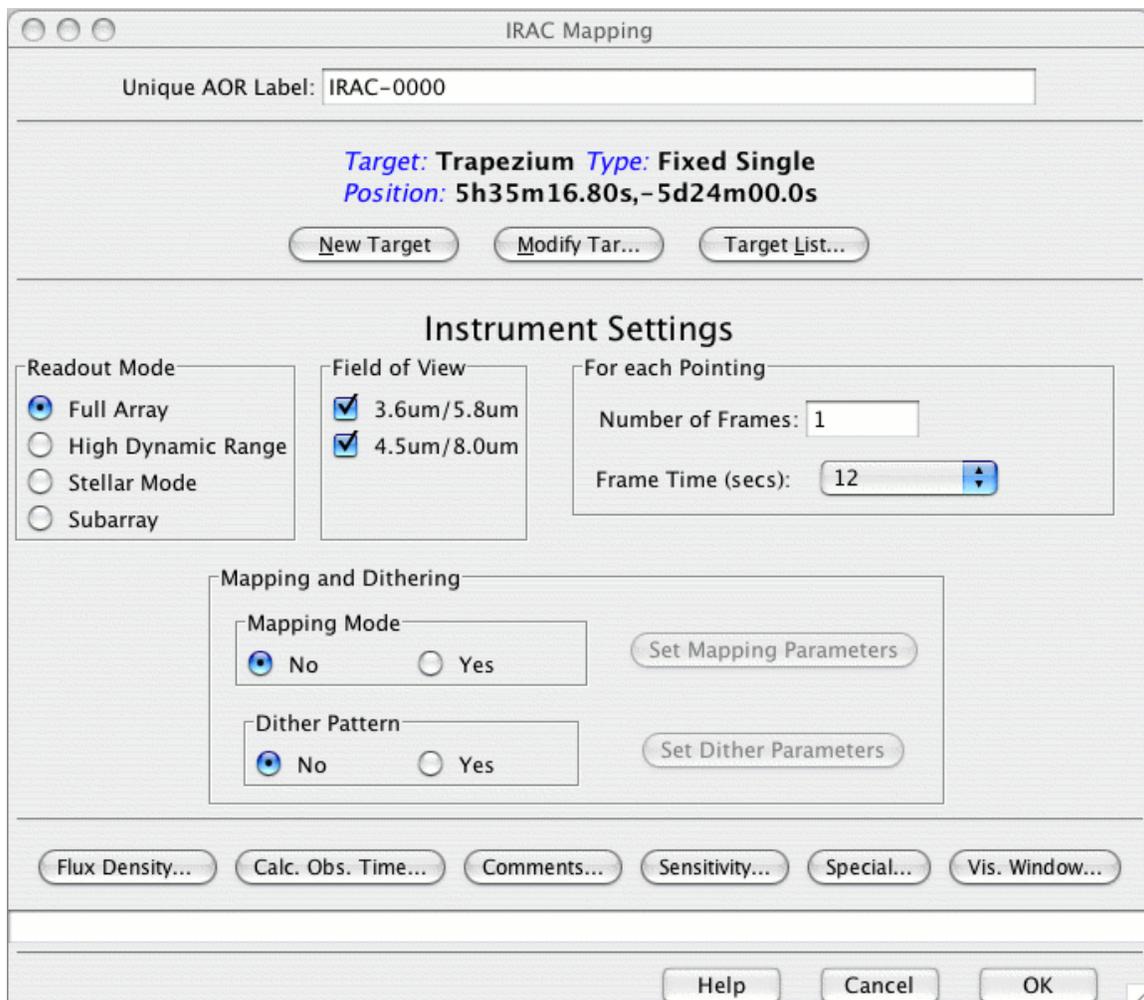


Figure 38: IRAC Post-Cryo AOT window, default values.

5.5.1 Basic Identification

Note that Spot has pre-assigned an AOR label, starting with “IRAC.” To ensure sanity when we go back to this a year or 6 from now, it makes sense to pick a label that is actually descriptive and not just something like “number 463205sprime.” Note that we should not use periods or colons in the label.

5.5.2 Instrument Settings

We are going for areal coverage here, so we choose “High Dynamic Range” readout mode, and make sure that both fields of view are checked, because we do indeed want both wavelengths. Both detectors are always taking data, but the fact that we have checked both fields of view affects exactly how the map is executed, in exactly what pattern.

For each pointing, we select 1 frame, with a 6 second frame time.

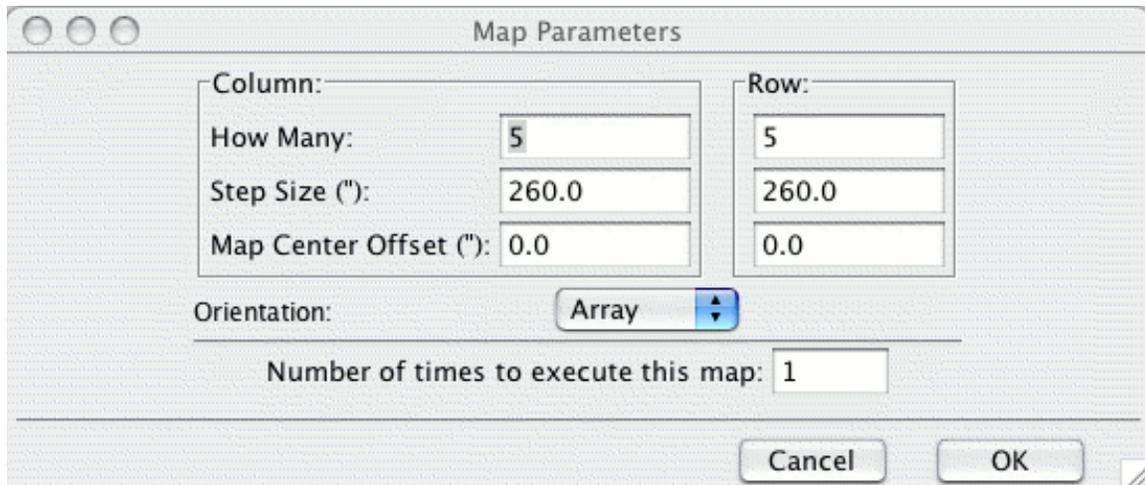


Figure 39: IRAC mapping parameters.

Now, we want to do both mapping and dithering. Clicking “yes” for mapping mode produces the window in Figure 39. We obtain more uniform coverage when mapping in array coordinates.

We want to cover as much of a $1^\circ \times 1^\circ$ patch covering the Trapezium. We’ll grid the region, stepping 85% the width of the array, 260”. This will allow enough overlap to match up the tiles afterward, but still cover the area. In order to do this, we will need a 13×13 grid.¹

¹ Using more grid elements than this (e.g., 14×14) results in an error in Spot—to see the detailed error, we pull up the AOR, increase the grid elements to 14, and explicitly ask Spot to calculate observing time. It checks on the number of commands, the number of strings, the size of the command sequence, and the number of instructions for the spacecraft we’re generating via this AOR. We may run over on the number of instructions. We can break our AOR up into pieces, or we can just reduce the size of our map slightly, which is what we have done here.

We don't want any map center offset, and we should use array (rather than celestial) orientation; this is because we don't want funny gaps in the map (see the IRAC chapter of the Warm SOM for more discussion). And, finally, we want to execute this map only once. After clicking "OK," now that we have set some mapping parameters, note that the button "set mapping parameters" is now clickable (it used to be greyed out). To retrieve the window from Figure 39, click on this button.

Note: We avoided the use of "repeats," which are tantalizingly available as "number of frames" on the IRAC AOT. This option results in multiple observations without moving the telescope and should be avoided. Instead, we want to "dither" to ensure good cosmic ray rejection, mitigation of scattered light, long- and short-term latents, and artifact masking. Do NOT set number of frames to anything other than 1 here!

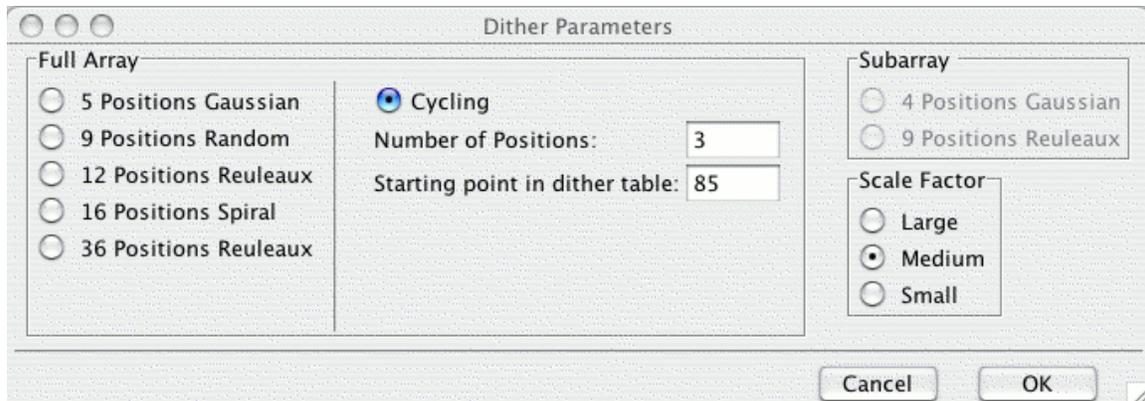


Figure 40: IRAC dither parameters.

Clicking "yes" for dither pattern produces the window in Figure 40. We click on the button to impose "Cycling," and choose the recommended minimum of three dither positions from the dither table. (We can let it start any place it wants, it doesn't matter.) Since there is only small overlap between map tiles, we chose a "medium" scale factor. Now we do want to keep the dithers small to keep the coverage as uniform as possible, but, conversely, we also need large dithers to separate large-scale photometric variations from sky variations. A reasonable compromise is "medium" scale dithers.

As with the mapping parameters, after clicking "OK," we have set some dither parameters, and the button "set dither parameters" is now clickable (it used to be greyed out). To retrieve the window from Figure 40, click on this button.

5.6 Time Estimates

The completed IRAC Post-Cryo AOT is shown in Figure 41.

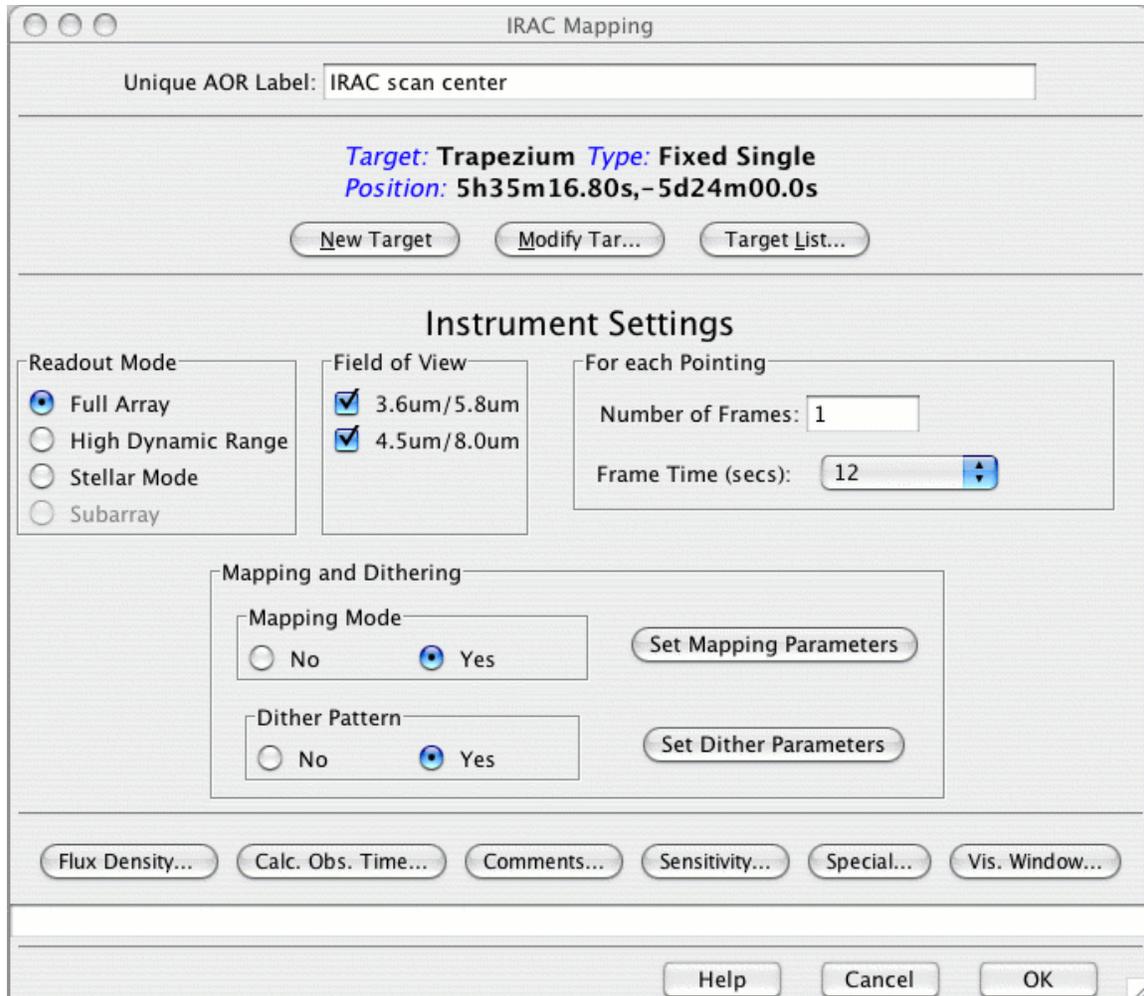


Figure 41: The completed IRAC AOT window.

We calculate the total time to execute this AOR by clicking on “Calc. Obs. Time” in the AOT window or via “Tools/Recompute All Estimates.” By doing this, we learn that we come in at about 2.9 hours for this AOR. The limit for an IRAC Post-Cryo AOR is 24 hours, so we're fine.

Save your AOR(s) early and often. Now would be a good time.

5.7 Visualization

We can overlay this AOR on the ISSA 12 μm image. If you are viewing this document on the web (and it's in color), the magenta is the 4.5 μm field of view, and the cyan is the 3.6 μm field of view. Note there are regions at either end where there is incomplete wavelength coverage.

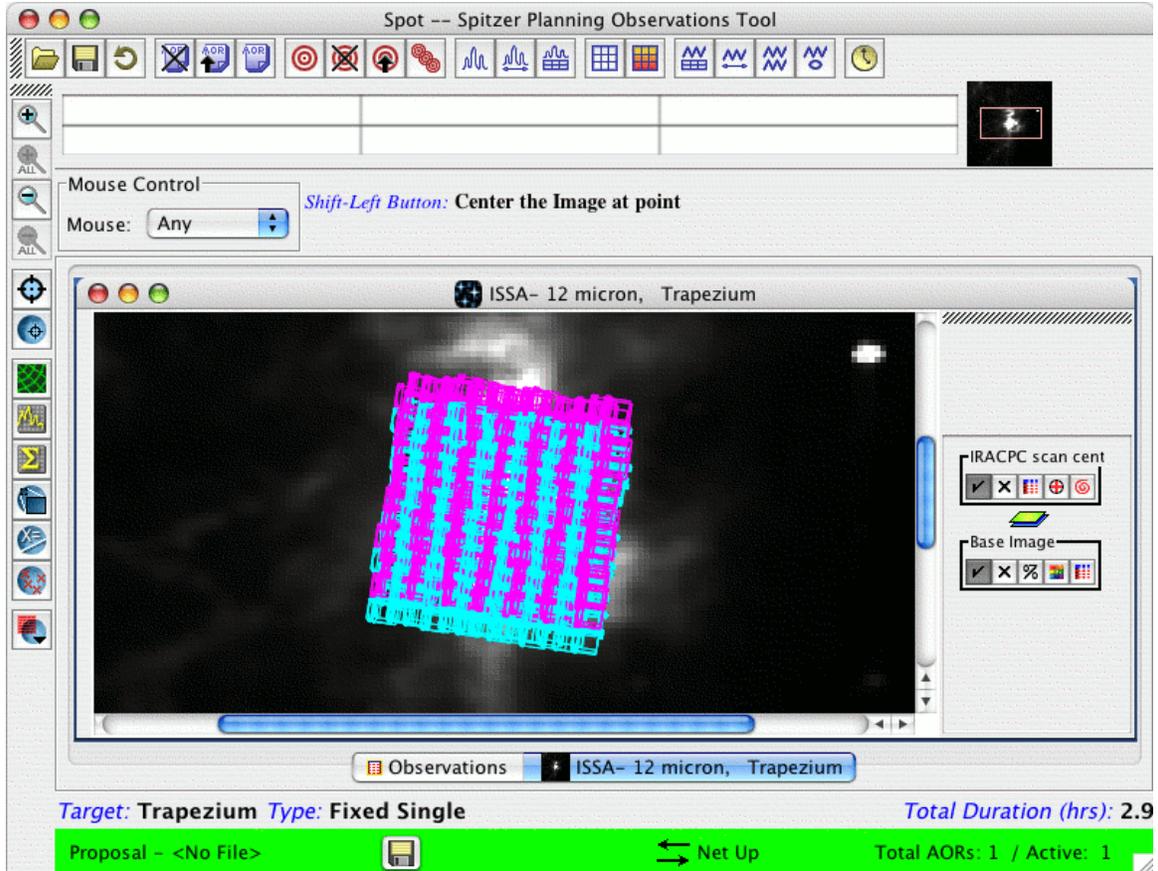


Figure 42: Visualization of the IRAC observation.

If you dare (and you have enough RAM), select the pointings table (the red and blue table icon that appears on the right of the ISSA image window when you overlay this AOR) and choose “Animate” to watch it dither three times per pointing. Make sure that it isn't dithering with too large of an amplitude that leaves spaces between tiles. See Figure 42. If the spacing isn't what we want, we can change to small (or large) amplitude dithers.

And we're off!! Write a GREAT justification and submit this thing.

Note: When you finally go to actually submit your proposal, make sure that you are submitting a clean set of AORs. If you've been playing around with options and alternate targets, make sure to delete those AORs and targets entirely before submitting. If you had any constraints, be sure to strongly justify those in the proposal as well.

The file, ready to be loaded into Spot, containing the raw AORs developed in this chapter can be downloaded from the SSC webpage:

<http://ssc.spitzer.caltech.edu/warmmission/propkit/cookbook/>

6 Photometry of Moving Object Centaur 8405 Asbolus using IRAC

In this Cookbook, we have not yet tried imaging a moving target. Spitzer can observe Solar System targets, by tracking in linear segments at rate up to 1"/sec, while superposing any requested mapping motions onto the track.

In this chapter, we will describe the steps needed to create an AOR for a moving target. Because imaging with IRAC has been covered thoroughly in earlier chapters (see Chapters 4 and 5), we will not spend as much time on those aspects of these observations here; this chapter is meant primarily to give an example of observing a Solar System object.

We will plan an observation of the Centaur 8405 Asbolus. Centaurs are objects whose perihelion is outside Jupiter's orbit (5 AU) and whose semi-major axis is less than that of Neptune (30 AU). Asbolus is thought to have a diameter of about 72 km and an albedo of about 0.12, i.e., it is quite dark and red. IRAC observations offer the best means to constrain the material responsible for the spectral slopes seen for these objects. The question arises whether the spectral shape favors nitrogen-rich tholins or more oxygen- or C-H-rich silicates or organics. Distinguishing surface composition is crucial for probing the distribution of organics in the solar system, which has bearing on chemistry and chemical processes in the solar nebula.

The collection of Spitzer resources for observers can be found in the Proposal Kit area of the SSC website: <http://ssc.spitzer.caltech.edu/warmmission/propkit/>. This includes (among other things) an overview of things Solar System observers should know about observing with Spitzer, and a document called "Horizons Tips for Spitzer Solar Systems Observers." The JPL Horizons ephemeris tool has been modified to allow specification of Spitzer as a coordinate center. This is valuable, because although Spot can provide basic information on Solar System objects to help you plan, specify, and visualize your observations, it cannot provide detailed object-specific geometric information (e.g., planet phase, range, solar elongation, ephemeris positional error) which may also be important for planning your observations. Instructions on how to specify and request this sort of detailed Spitzer-centric information for your target can be found in the Horizons Tips document.

Horizons tips also includes instructions for the tool, ISPY, which allows you to query for known Solar System small bodies in your Spitzer data, at a given time. The ISPY capability has also been incorporated into Spot visualization. To visualize the position of other known moving targets in your planned observations (regardless of whether your target is fixed or moving), use the Spot "overlay" option "Show all moving objects at a given date".

The observations we construct here follow closely those used for program 20769.

6.1 Overview of the Observations

- **Target Selection and Suitability:** Before being selected for potential Spitzer observation, targets should be checked for duplications with previous observations, and also for the positional accuracy of the object's ephemeris.
- **Target Entry:** Spot can resolve NAIF names and return the NAIF ID. See section 6.3.
- **Completing the AOT:** We will integrate for 900 sec on the target. This will consist of 9 medium-offset dithers with a 100-sec frame time in Full Array mode. We will observe the target twice. The completed AOT is displayed in Figure 50.
- **Constraints:** We will use a shadow constraint to link the two observations of the target. The second observation will provide a background, or shadow, observation, which is treated as a kind of constraint. See section 6.5.3.3.
- **Visualization:** An overlay of the planned AOR on an image helps us not only verify that we are really doing what we think we are doing, but also actually plan the moving object observation itself. See sections 6.4 and 6.5.

6.2 Target Selection and Suitability: Asbolus

As with all other observations, we need to first check the ROC using Leopard. We find that Asbolus observations with IRAC have already been taken by another observer. Had this been a real proposal, we could then check the Duplicate Observations Rule to see if the specific proposal idea we have in mind qualifies as a new observation—perhaps we would like to go deeper than previous observations, in which case our observation might not be considered a duplicate. Or, perhaps the Solar System target we are planning to observe is known to be time variable, and we feel we could make an excellent scientific case for why it would need to be observed more than once during the Spitzer mission. However, for purposes of this example only, we will ignore the potential duplication, and continue planning a simple IRAC photometry observation of Asbolus.

Another thing that is important to check is the known positional accuracy of your target at the time you propose. Although Spitzer's pointing accuracy is extremely good (typically less than an arcsecond), the position of your Solar System target as a function of time (the ephemeris) may have a relatively large error. This could either be because the target is newly discovered, and has had relatively few observations made to determine its orbital parameters, or because the object has not been seen for quite some time and/or it is subject to unpredictable, non-gravitational forces, as is the case for comets close to perihelion. Even observations with IRAC we cannot ignore potential positional errors.

Positional error information for ephemerides can be obtained for many objects, especially those likely to have large positional errors such as comets and NEOs, using Horizons. Instructions on how to do this can be found in the Horizons Tips document in the Solar System area of the website; there is additional information on this issue in the Warm SOM. We do this for Asbolus, and discover that it has 3σ positional error ellipse

of no more than $\sim 2.7''$ throughout 2009–2011. For our planned IRAC observations with a $5' \times 5'$ field, this positional error is insignificant, so we do not need to worry about it. Causes for concern would include 3σ radial errors that are more than half of the linear size of the measurement aperture, e.g., $2.5'$, in this case, or a lack of any available error information. However, even with large errors or no available error information, we could still have proposed for this target, on the proviso that we clearly note in the proposal that the object had large errors or no available error information at the time of proposal.

6.3 Target Entry

Start up Spot and enter a new target either by clicking on the bulls-eye target icon on the taskbar, or selecting “New Target” from the “Targets” menu.

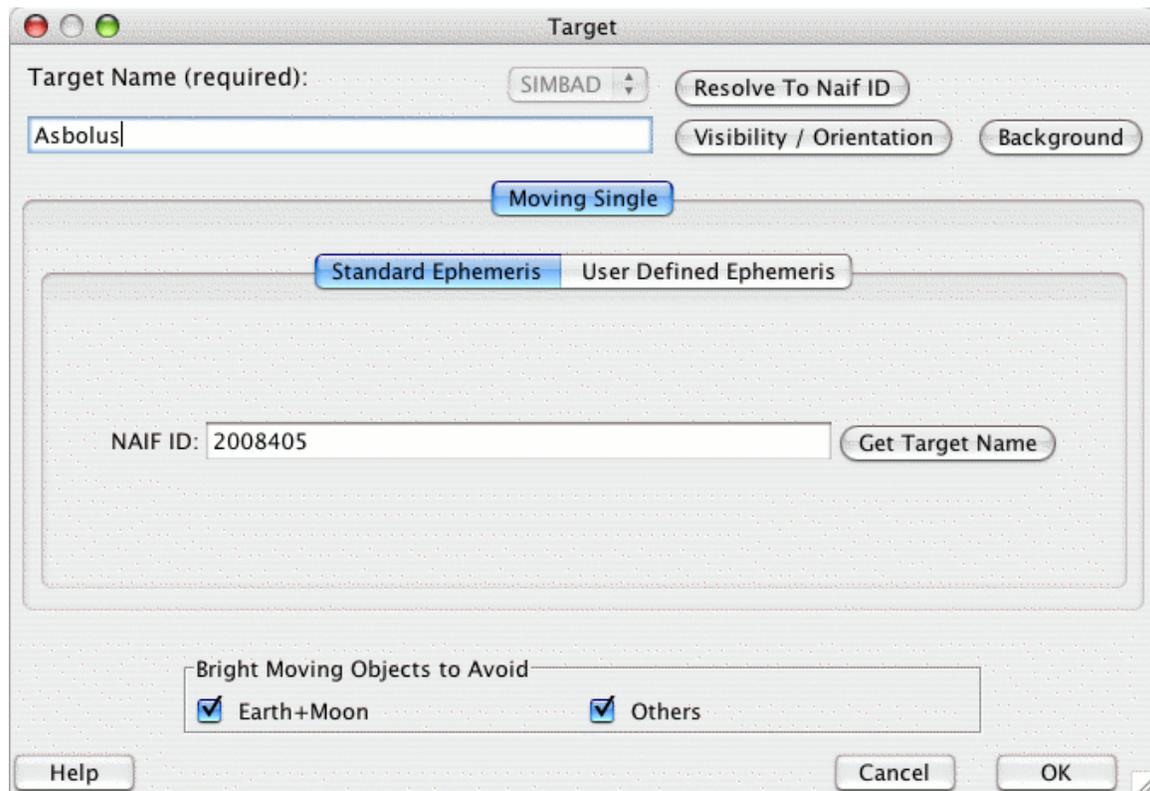


Figure 43: The target window after entering Asbolus.

Click on the “Moving Single” tab to pull up the window shown in Figure 43. Enter “Asbolus” in the Target Name box. Note that, unlike in other chapters, we cannot resolve the name using NED or SIMBAD. This time, Spot contacts HORIZONS directly to resolve the NAIF ID. Clicking on “Resolve to NAIFID” in Figure 43 fills in the NAIF ID box.

Note that, to be able to return accurate time estimates, or calculate visibility and visualization, Spot needs to have access to that object’s ephemeris. Spot is capable of retrieving ephemerides from Horizons automatically. When you request a function that requires an ephemeris, such as a moving target visibility window calculation, Spot will first search its core ephemeris database, and if it does not find the target there, it will

query Horizons and retrieve an ephemeris to be used subsequently. Horizons ephemeris retrieval through Spot typically takes about 3–5 seconds.

If you have a large list of targets that you would like to enter in to Spot or obtain visibility windows for, this can probably best be achieved by using Spot's "Import Moving Single Target List" capability in its "File" Menu, and then using the "Calculate Visibility Windows for All" function under the "Target" menu. While running the batch visibility function, ephemerides will be retrieved as needed and will then be available within Spot for all subsequent planning.

But, getting back to our example—after entering our target information, we click "OK," and we return to the main Spot screen. Note that the bottom of the Spot screen now tells us which target and target type we have entered. Save your target list, just in case. To retrieve the target list at any time, we can click on the icon that looks like three bullseyes on the toolbar.

To find exactly when the target is visible to Spitzer, we can click either on the "Visibility/Orientation" button in the target entry window, or from the target list window, "Calculate Visibility Windows for All" and then "Show Visibility." This shows us a list of the dates when Spitzer can actually observe Pholus. Next, we will visualize Asbolus to see where it is on one of those dates.

6.4 Visualizing Your Target

Visualizing your target with respect to the background, and the required image retrieval to support this has been discussed above in detail (e.g., section 4.8), but Spot has some extra features for Solar System objects that merit review. Here we will not walk through retrieving images in detail, since that is covered in earlier chapters (and in the Spot manual). We will use ISSA images since we are planning IRAC observations of this object, and the long-wavelength background is likely to matter.

From the Images menu, we select ISSA, and ask for all four wavelengths in one frame; see Figure 44. After clicking OK, Spot will ask what date we would like to visualize and the number of data points to be distributed along the orbital arc. For purposes of this example, we pick "2009 Oct 2", and 100 points; see Figure 45. Finally, then, we get the images and tracks shown in Figure 46. The tracks show Asbolus' position as a function of time, as seen from Spitzer. Note that because Spitzer tracks in *linear segments*, if a given source track has significant curvature during a planned AOR, the observation may need to be broken up into smaller AORs. Visualizing the orbital track of your object in Spot can help you determine whether an observation will need to be split into multiple AORs.

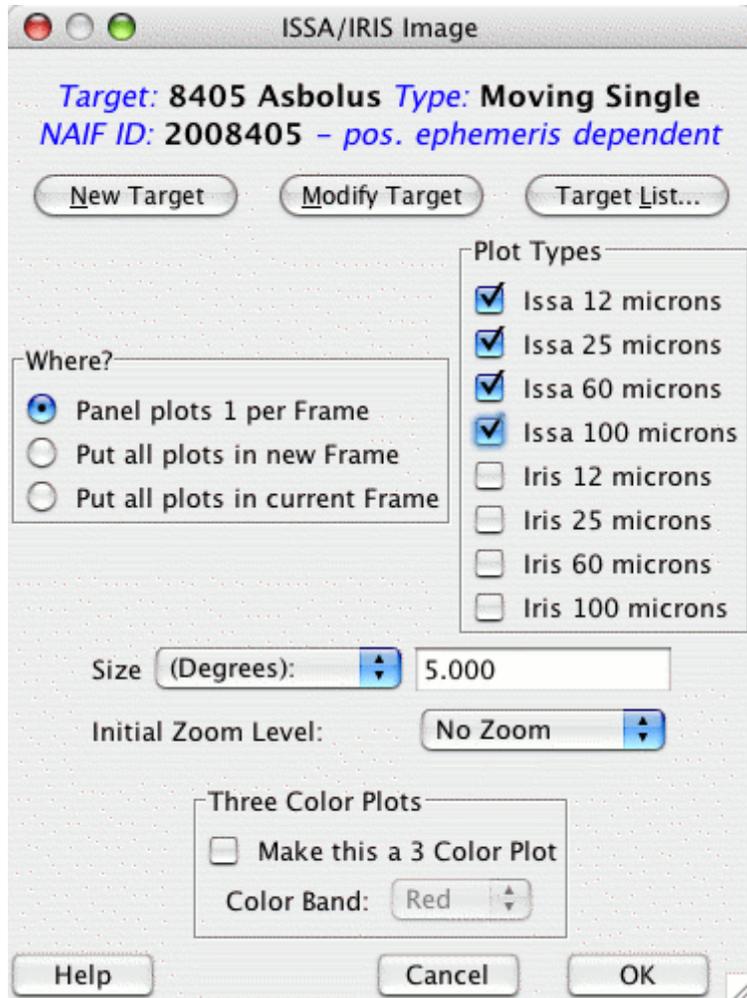


Figure 44: Retrieving an image from ISSA.

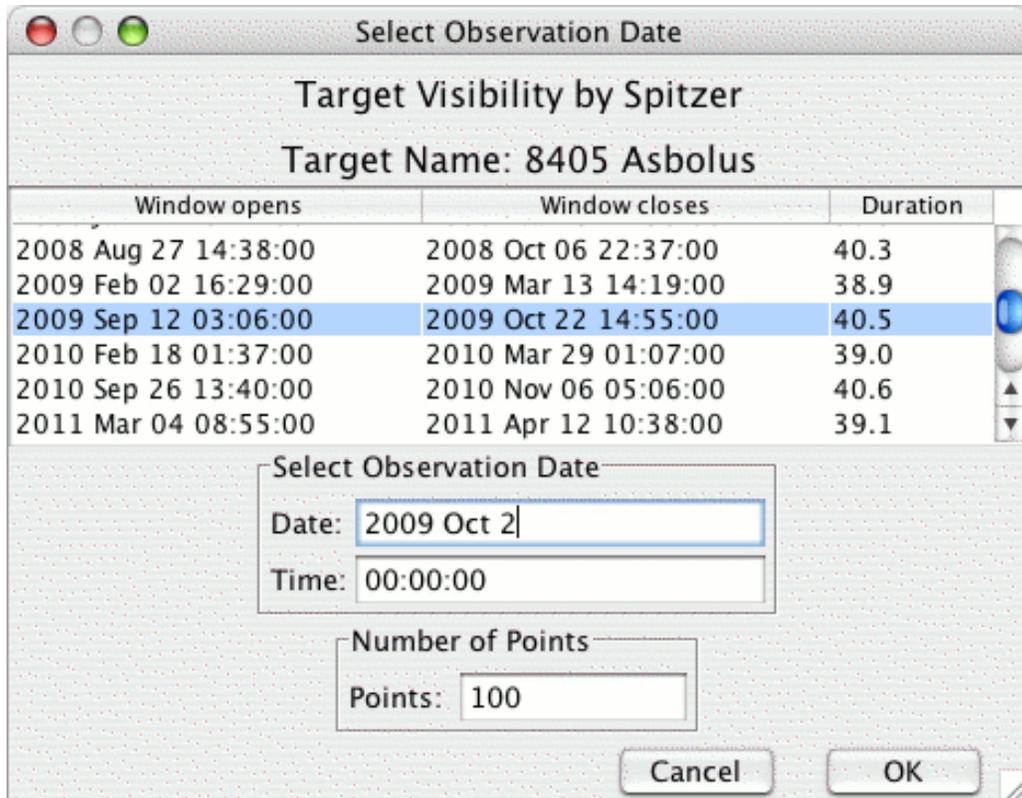


Figure 45: Picking the date to visualize.

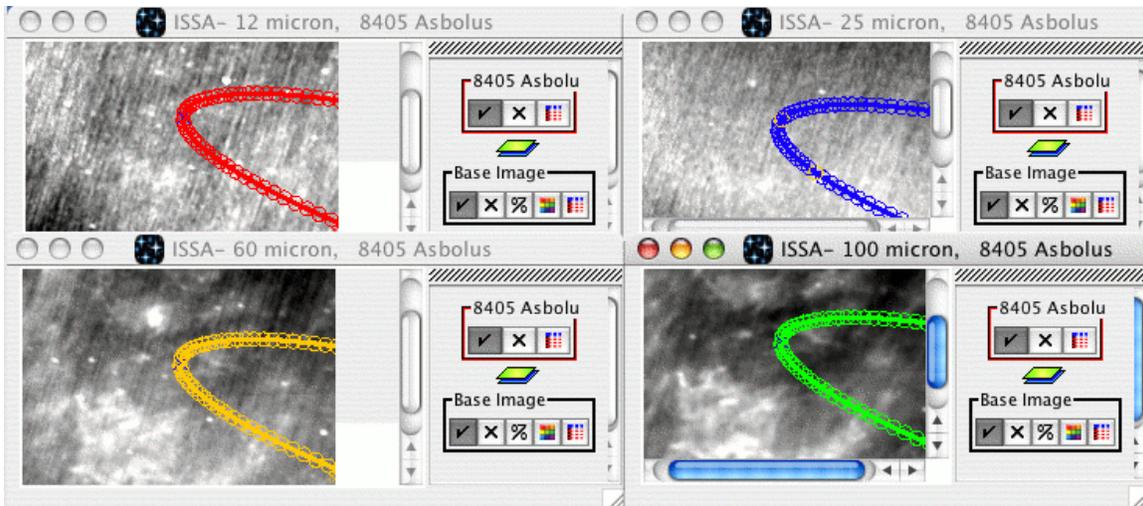


Figure 46: Asbolus orbital track visualization in all four ISSA bands.

If we click on the tiny red-and-blue table icon associated with the Asbolus orbital track overlay in one of the ISSA images, we produce the window in Figure 47, which lists the specific dates associated with each of the points in Figure 46.

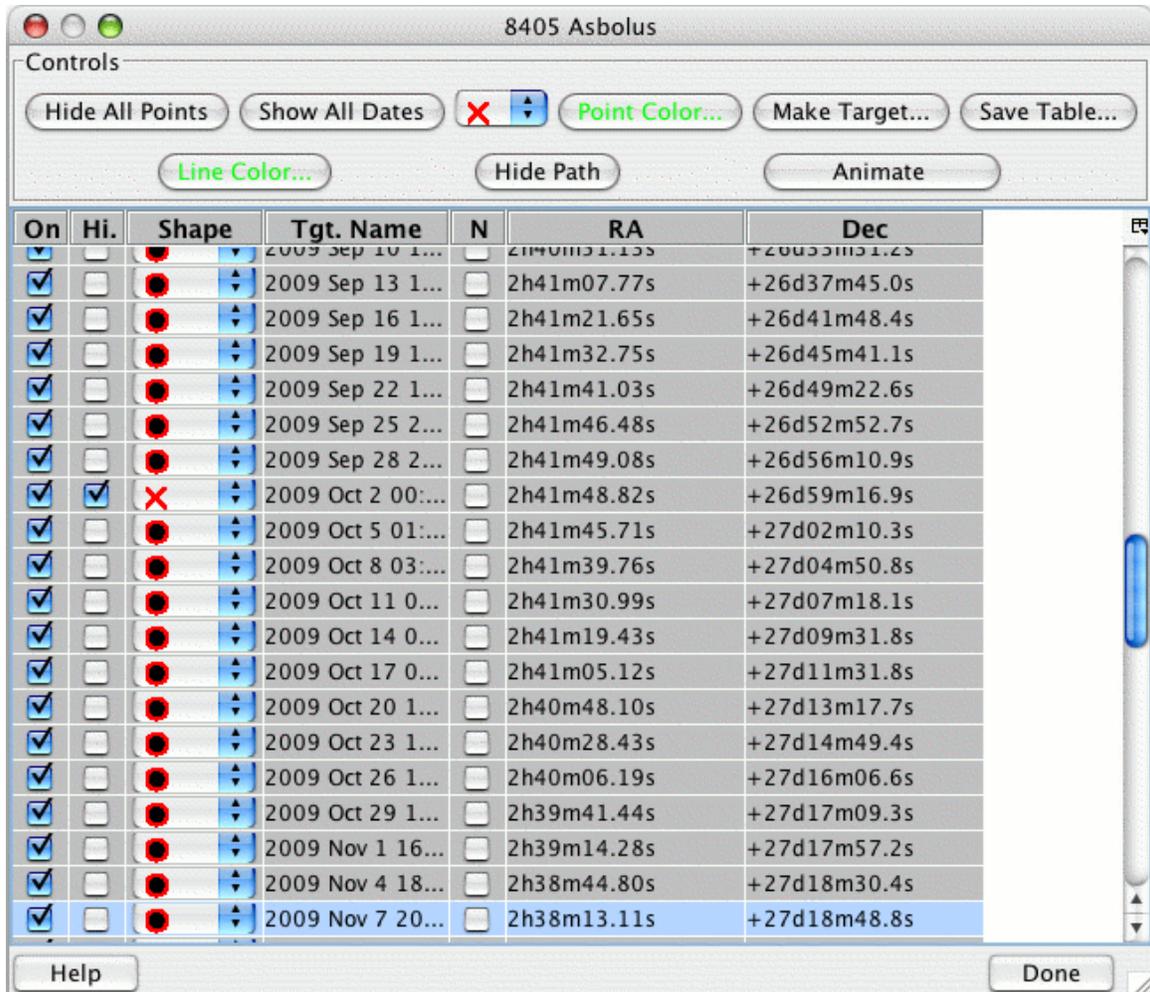


Figure 47: Asbolus point identifications.

The controls in this window do several things to the overlay in the corresponding ISSA window. “Hide All Points” or “Show All Points” turns off and on the points in the overlay. “Show All Dates” or “Hide All Dates” turns on and off the dates associated with the specific points in the overlay. The next option, a pull-down menu, refers to the symbols used in the points in the overlay. “Point color” allows the user to select the point color in several different ways (“swatches,” “HSB,” and “RGB,” just like in Adobe Photoshop or the Gimp). Similarly, “Line Color” allows us to choose the color of the track, and “Hide Path” or “Show Path” turns the track off and on. “Save Table” writes the object’s position information as a function of time to an ASCII file. The individual entries for each point can be turned off and on, temporarily highlighted with a different color and symbol (“Hi” column checkboxes), have its shape changed, and have its individual date notation turned off or on. Most of these features will be useful for us in a moment as we consider background contamination.

6.5 IRAC Photometry

6.5.1 Exposure Time and Saturation

To estimate how bright your Solar System target will be, it may often be necessary to use specialized scientific models, such as Standard Thermal Models for asteroids, to estimate the brightness of your target at mid-IR wavelengths. These models are not provided by the SSC, and must be provided by you (or your carefully chosen collaborators!). For the purpose of this example, we use such a model, and the Spitzer online Performance Estimation tools to determine instrument sensitivities for a given background. With these two tools, we figure that we can detect Asbolus with sufficient S/N (≥ 100) for our purposes in ~ 900 seconds at both 3.6 and 4.5 μm . Note also, that if we were willing to approximate our target as a blackbody, then the Spitzer extragalactic PET, EX-PET, could have also been used to estimate IRAC sensitivities, saturation limits, and confusion limits.

These objects are so cool that saturation by these kinds of objects themselves is not a concern. But, they do move across the sky, necessarily in the ecliptic. Zodiacal light and intersection with the Galactic plane can both be a problem.

6.5.2 Background

IRAC is very sensitive. It's really important to get a good estimate of the background flux at the wavelengths we care about for our science goals. Recently, background estimates have become available from within Spot for moving targets; this can be obtained identically as for fixed targets, discussed above. Although we can calculate background levels for a moving target for a specific date, calculation of background levels over a range of dates is not supported for moving targets. See especially section 4.4 for a discussion about backgrounds in Spot. However, it is also a good idea to make a manual check of the background.

The very first thing we can do is make sure that our object is not in the Galactic plane at a time when we are planning for Spitzer to observe it. We can check to see if any given Solar System object is in the Galactic plane by overlaying the object's location on an all sky map in Spot. From Spot's Images menu, select "All Sky Images" and select the DIRBE survey for an all-sky image, *NOT* the ISSA image. Although it seems that Zodiacal light and the Galaxy are clearly visible in both, only the DIRBE image has reliable zodiacal fluxes. The ISSA images retrieved from IRSA or Spot *already* have the Zodiacal light removed and so can't be queried directly for reliable background estimates.

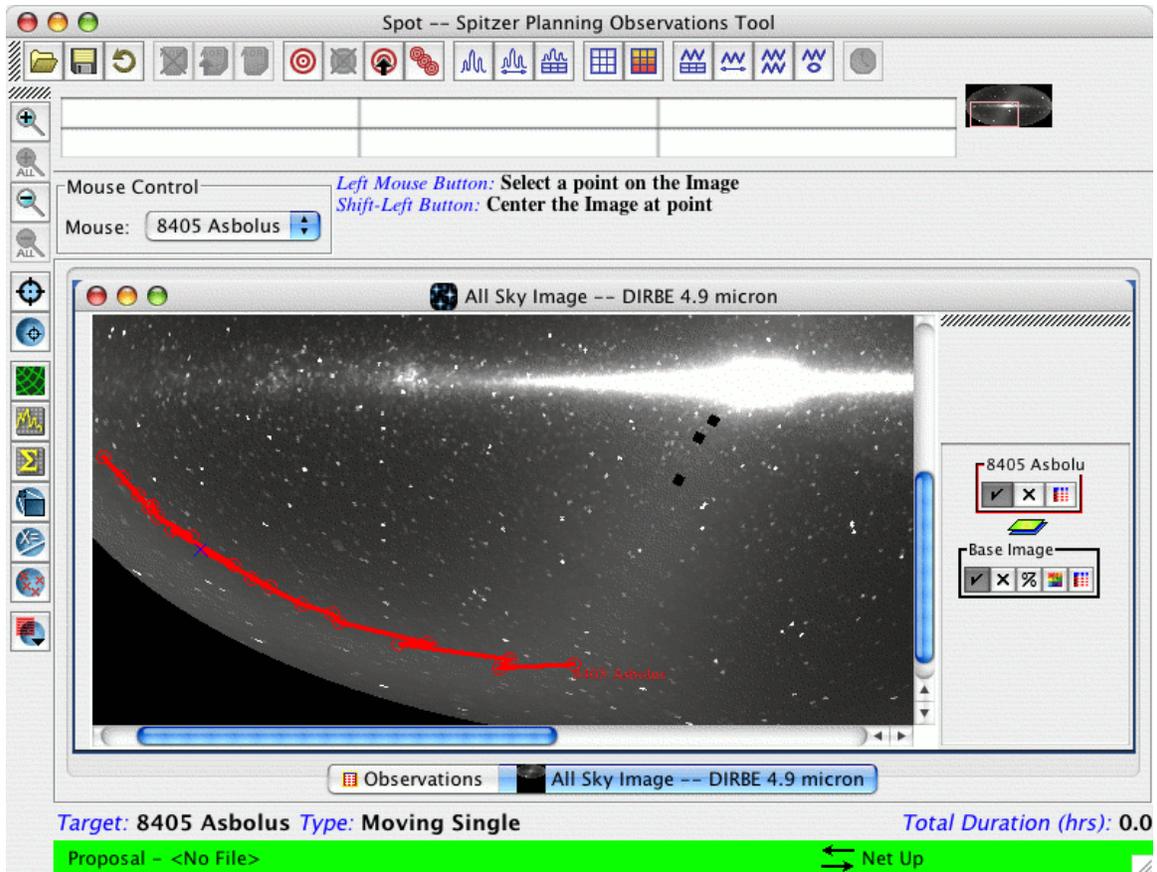


Figure 48: DIRBE all-sky image with Asbolus overlaid.

Once the all-sky image has been retrieved, from Spot's "Overlays" menu, select "Add Moving Target" and select a target from the Targets window. Spot will calculate visibilities and enquire as to the specific date of observation. It will then overlay the track points on the all-sky image, often spanning several years; see Figure 48. Asbolus, fortunately, is not in the Galactic plane, and it's even reasonably far away from the brightest part of the ecliptic at this point as well. For the sake of example, some readers may also want to plot the position of Chiron on the all sky plot. It should become readily apparent why observations of Chiron will become successively more sensitive over the duration of the Spitzer mission.

The DIRBE (*NOT* the ISSA!) all-sky image can be used for background Estimates. First, zoom in on the target using the little magnifying glass icons on the left of the Spot window. The DIRBE all-sky image is calibrated, and will give us correct backgrounds, providing our target is at a Solar elongation of 90° . If our object has a Solar elongation of 80° , the zodiacal background could be brighter by 20%, and if it's at a Solar elongation of 120° , the zodiacal background could be fainter by 50%. Since we don't know exactly when Spitzer will schedule our observation, we can't tell *exactly* what the elongation will be, but that's the possible range of backgrounds. Note also that this DIRBE image is at 4.9 micron, so technically it's only accurate at that wavelength. However, visualizing the track of Asbolus over the extent of Cycle-6, and even into Cycle-7, we see from the

DIRBE image that the background in IRAC channel 2 should be no more than $\sim 0.8\text{--}0.9$ MJy/sr.

6.5.3 Filling in the IRAC Post-Cryo Mapping AOT

Now we're ready to fill in the AOT in Spot. Click on the IRAC Post-Cryo icon or select it as an option under the "Observation" menu. We obtain the window in Figure 49.

The screenshot shows the "IRAC Post-Cryo Mapping" window. At the top, there is a text field for "Unique AOR Label:" containing "IRACPC-0000". Below this, the target information is displayed: "Target: 8405 Asbolus Type: Moving Single" and "NAIF ID: 2008405 - pos. ephemeris dependent". There are three buttons: "New Target", "Modify Tar...", and "Target List...".

The "Instrument Settings" section is divided into several panels:

- Readout Mode:** Three radio buttons: "Full Array" (selected), "High Dynamic Range", and "Subarray".
- Field of View:** Two checked checkboxes: "3.6um" and "4.5um".
- Data Collection:** Two checked checkboxes: "3.6um" and "4.5um".
- For each Pointing:** "Number of Frames:" is set to 1, and "Frame Time (secs):" is set to 12.

The "Mapping and Dithering" section has two panels:

- Mapping Mode:** Two radio buttons: "No" (selected) and "Yes". A "Set Mapping Parameters" button is to the right.
- Dither Pattern:** Two radio buttons: "No" (selected) and "Yes". A "Set Dither Parameters" button is to the right.

At the bottom, there is a row of buttons: "Flux Density...", "Calc. Obs. Time...", "Comments...", "Sensitivity...", "Special...", "Vis. Window...", and "Exposures...". At the very bottom are "Help", "Cancel", and "OK" buttons.

Figure 49: IRAC Post-Cryo Mapping AOT window, default values.

6.5.3.1 Basic Identification

Working from the top, we can enter our own "Unique AOR label" or it will create one for us. To ensure sanity when we go back to this a year or six from now, it makes sense to pick a label that is actually descriptive and not just something like "number 463205sprime." Note that we should not use underscores or colons in the label.

If we have more than one target entered, we should verify that the target it has selected is indeed Asbolus, and that it is a "Moving single" target type. (If you need to change the target, click on "target list," and if you need to change the target type or position, click on "modify target.")

6.5.3.2 Instrument Settings

We would like to image this object at both IRAC wavelengths. We will want to visit the target twice, (1) to ensure identification of Asbolus by its motion relative to the background, (2) to provide for background subtraction, since we are observing a relatively faint source at low ecliptic latitudes, (3) provide for usable data in at least one of the two observations, in case Asbolus is projected against a brighter background source in at least one observation, and (4) to provide rotationally-resolved observations to investigate Asbolus' surface heterogeneity.

Following program 20769, which already successfully imaged Asbolus with IRAC, we set the frame time at 100 sec and select 9 medium-offset dithers, for a total integration time in both the 3.6 and 4.5 μm channels of 900 seconds. The completed AORs are displayed in Figure 50. We can check the exposure time by clicking on "Calc. Obs. Time," producing Figure 51. The total duration of one observation is 2560 seconds. By clicking on the "Copy AOR" button, we obtain a duplicate AOR. The two IRAC AORs together are 5120 seconds, or about 1.4 hours.

Note: For the warm mission there is a special overhead per AOR of 300 sec. This is in addition to the standard slew overhead ("tax") of 180 sec placed on every AOR, whether observing a moving or inertial target. This extra overhead accounts for the target acquisition and tracking requirements for moving targets.

Save your AOR(s) early and often. Now would be a good time.

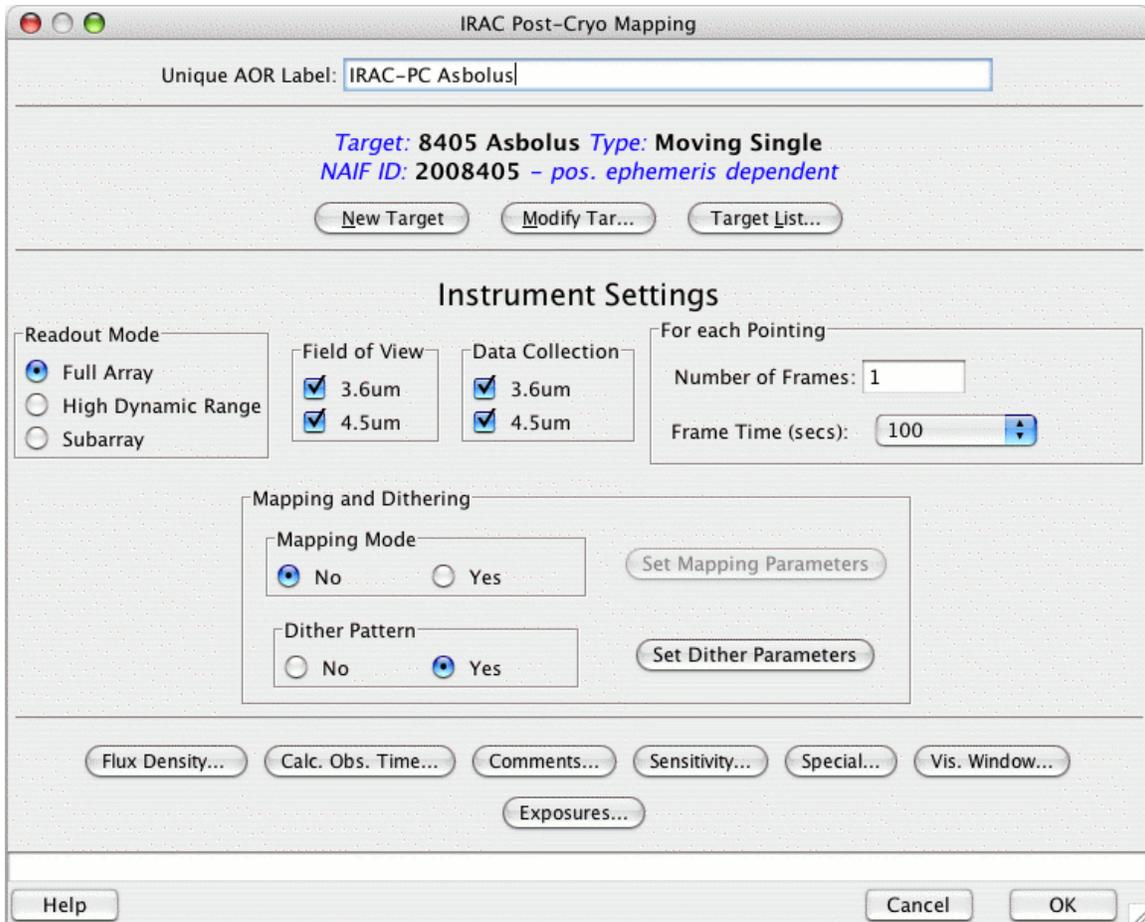


Figure 50: IRAC Post-Cryo Mapping AOT window, filled-in values.

The screenshot shows a window titled "Resource Estimates" with two main sections: "Resource Estimates" and "Integration Time".

Resource Estimates	
Slew Time (sec):	88.1
Settle Time (sec):	77.0
Slew Overhead (sec):	515.0
Special Overhead (sec):	0.0
AOR Duration (sec):	2,560.2
Downlink Vol.(Kbytes):	2,953.0
Estimator Version:	S18.1.0

Integration Time	
IRAC_3_6(sec):	900.0
IRAC_4_5(sec):	900.0
IRAC_5_8(sec):	0.0
IRAC_8_0(sec):	0.0

A "Done" button is located at the bottom right of the window.

Figure 51: The resource estimate for the IRAC SSO observations. Note that the total slew overhead (515 sec) includes both the standard “slew tax” (180 sec) and an additional special overhead for moving targets only (300 sec).

6.5.3.3 Shadow Observations

We are not necessarily done yet! If we expect to not have enough sky in the images we obtain, or if we expect a very patchy background, or if we are attempting to distinguish our moving object from confusing sources in the images, or if we expect the object to be extended and diffuse (e.g., a comet) and therefore need a really good background subtraction to meet our science goals, we can obtain so-called “shadow” observations. As we have pointed out above, we indeed wish to image Asbolus twice. Shadow observations are repeated observations of this same field at a later time, without the object (or at least with the object having moved with width of several PSFs), so as to better subtract off the background. If we request this option, Spitzer follows exactly the

same track as it does for the actual observations we have planned of Asbolus, just after (or just before) Asbolus has already moved on (or gotten there). When using shadow constraints, it is easier to schedule observations if your shadow (background) observation comes AFTER the main observation. If it doesn't matter to your science whether your shadow observation comes before or after the object, put it after. Here we put it after.

Shadow observations are a separate form of constraint, like a group/follow-on constraint. In order to set up a shadow constraint, first we need two identical AORs to link via this constraint. We select our IRAC AOR with both wavelengths, and then copy it (via the Edit menu or the toolbar icon). Then, having done that, from the Tools menu, we select "Group/Follow-on Constraints" to pull up a dialog box. We select the "shadow" tab to pull up the right options. We then choose "Add Shadow." We want to make these observations sufficiently later in time that Asbolus has moved at least the width of several PSFs, but as close as possible in time to minimize changes in the zodiacal background and the instrument calibration.

It is also important to try to specify a shadow interval that is (preferably much) less than a typical IRAC campaign—this is good both scientifically and for our scheduling process. For IRAC, campaigns will be 14 days on average. So, we ask for shadow observations to be taken some time between 16 hrs and 3 days after our original observations; we can also choose to have the shadow observations taken before the main observations. See Figure 52.

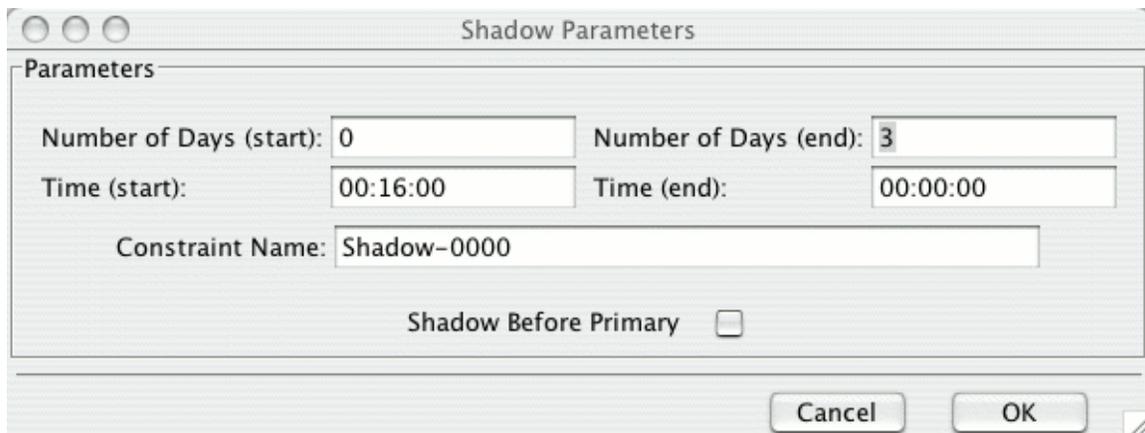


Figure 52: The options for shadow constraints.

To accept these parameters, we click OK, and then click-and-drag the main AOR and its new copy into this constraint, using the constraint editor window (see Figure 53).

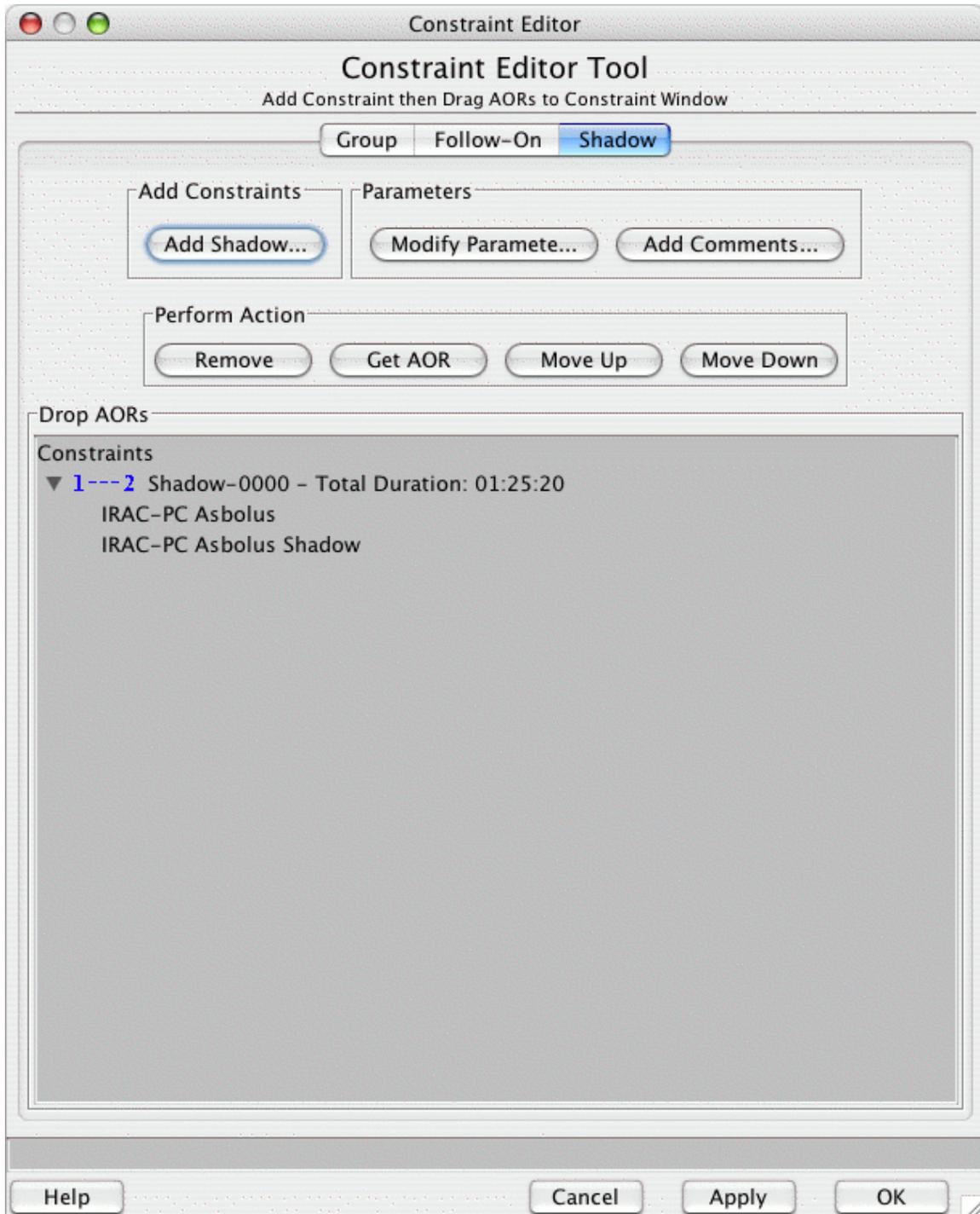


Figure 53: The imposed shadow constraint.

To impose the constraint, we click “OK.” Having done this, now we see in the AOR list that the Follow-on constraint box (“F”) is checked.

6.5.4 Visualization

As in all of the earlier chapters, to verify that we are doing what we think we're doing, we can visualize the observation. We retrieved an ISSA image above, and certainly it was

useful to examine the background at this location. However, the whole field covered by our IRAC observation is approximately 30 IRAS pixels total. To obtain a higher resolution view, we can also retrieve a DSS or 2MASS image. We have retrieved a DSS image for the following example, but a 2MASS image could also be useful. Once we have the image, we then select our AOR, click on the “Overlays” menu, and overlay the current AOR. By choosing the AOR which observes Asbolus in both wavelengths, we obtain Figure 54. If this is too confusing, we can select the tiny crosshairs that have appeared with the overlay on the right side of the image window, and selectively turn off and on the individual pointings by wavelength. The visualizations by wavelength are shown in Figure 55 and Figure 56 for the 3.6 and 4.5 μm observations, respectively.

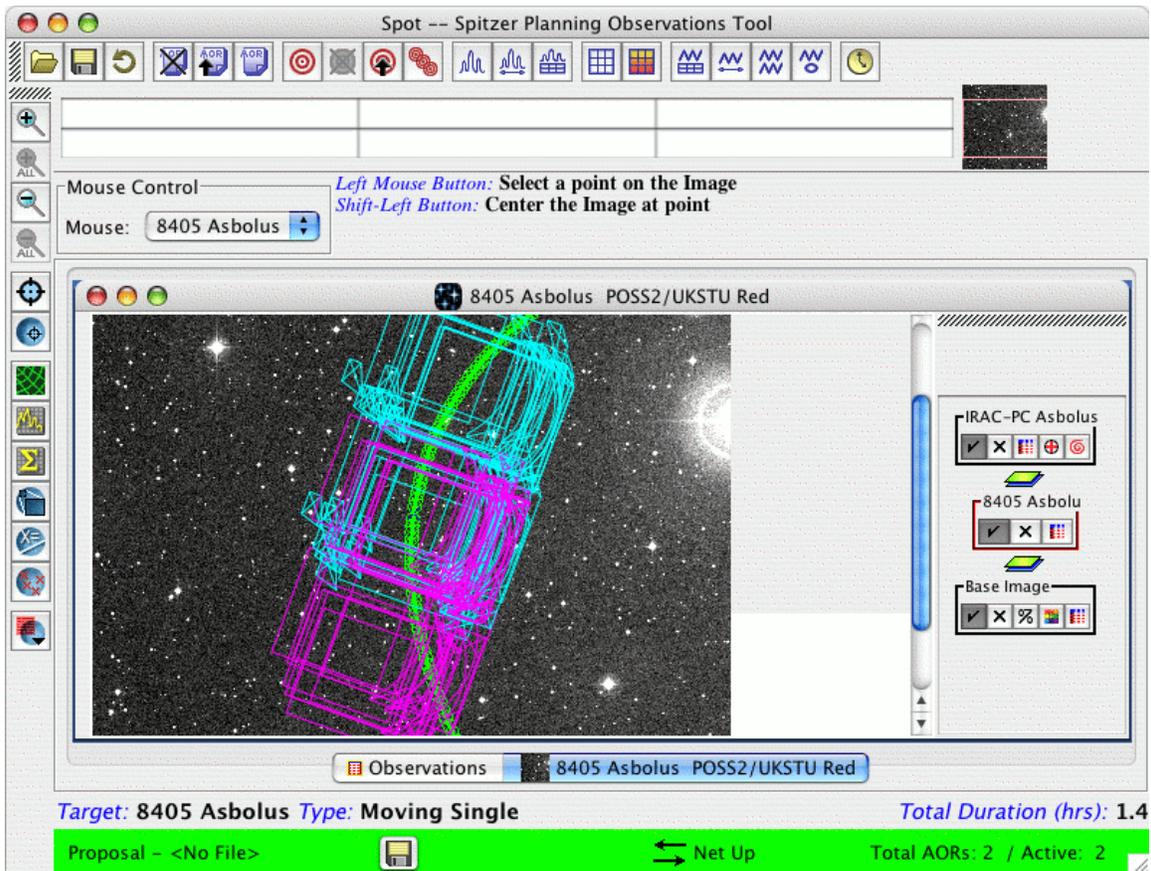


Figure 54: The overlay of the IRAC observations on a DSS image of the field.

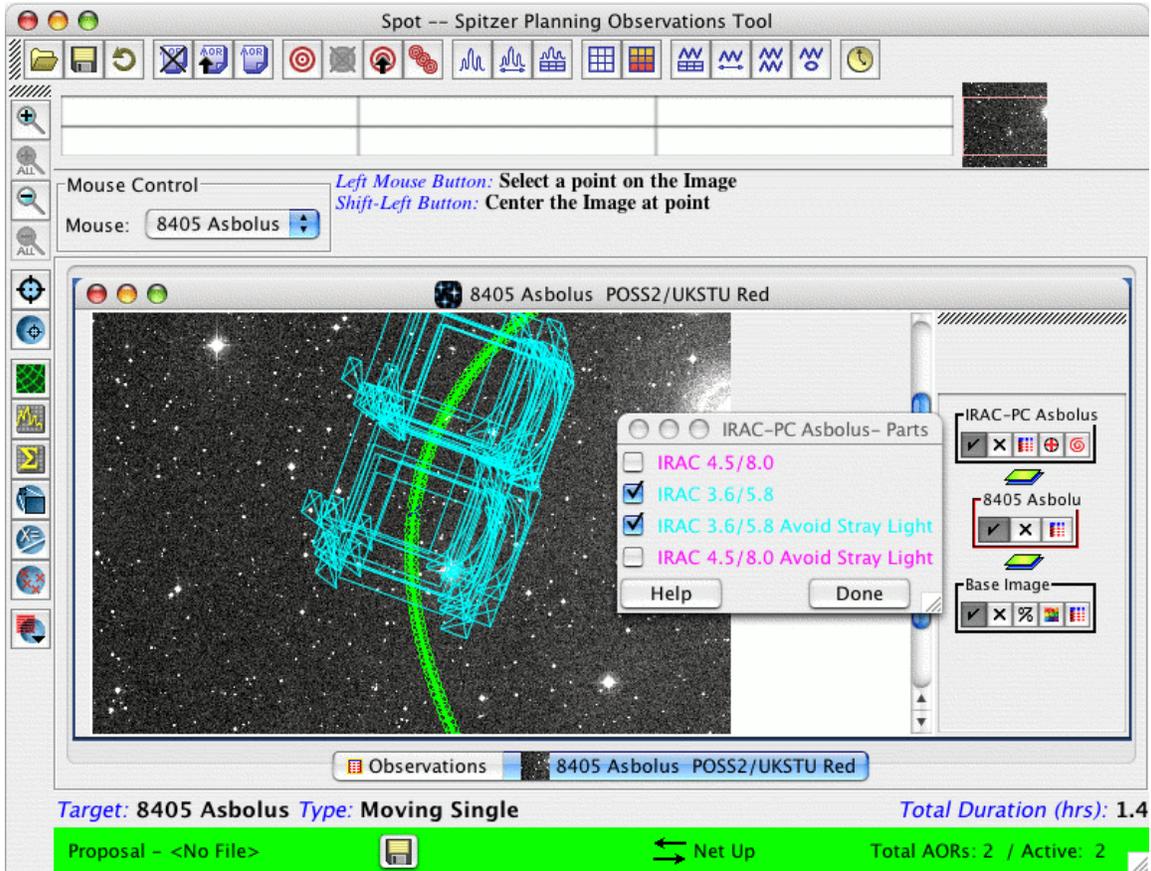


Figure 55: The overlay of the 3.6 micron IRAC observation on the DSS image of the field.

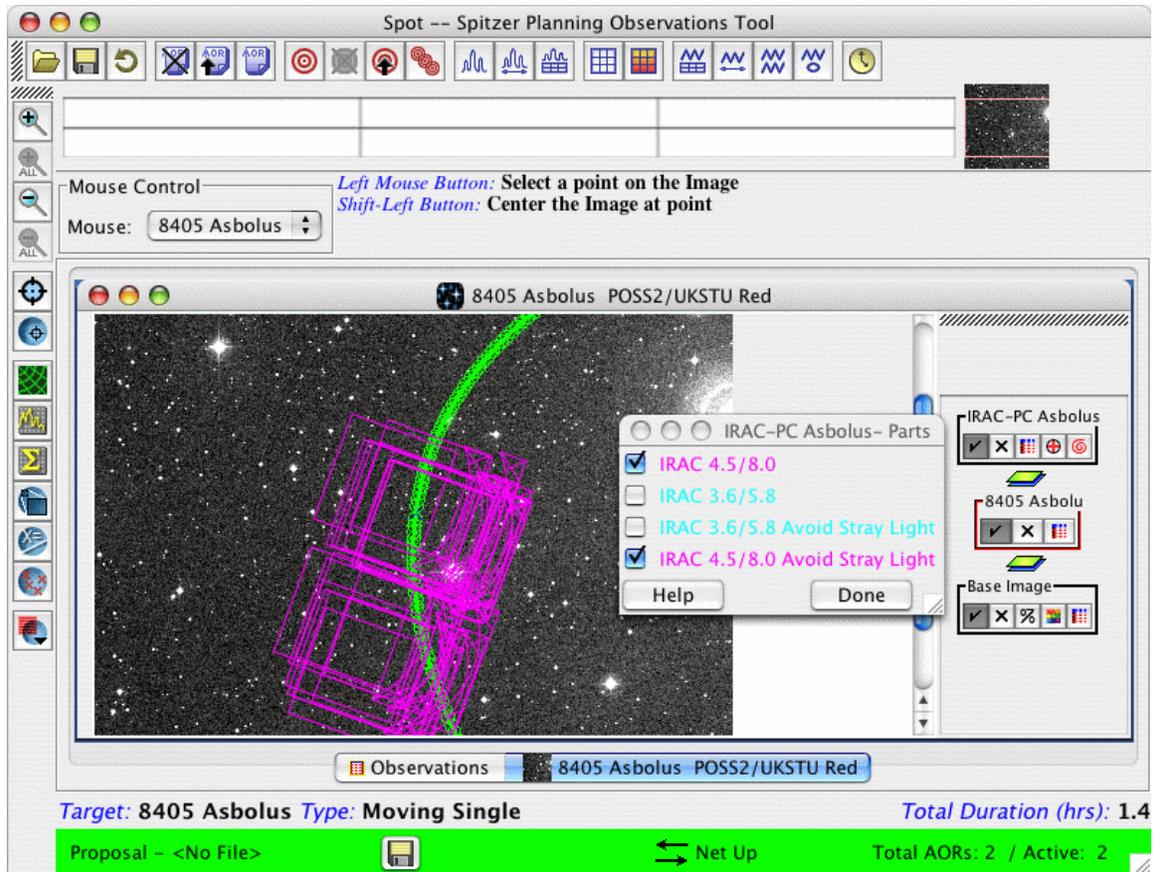


Figure 56: The overlay of the 4.5 micron IRAC observations on the DSS image of the field.

The file, ready to be loaded into Spot, containing the raw AORs developed in this chapter can be downloaded from the SSC Cookbook webpage:

<http://ssc.spitzer.caltech.edu/warmmission/propkit/cookbook/> .

7 Time Series Observations

Repeated observations of (inertial) celestial objects that vary with time have become a popular proposal topic. In this chapter, we build up an observation of the phase curve of a hypothetical planet around the IRAC calibration star BD+60 1753. The AORs can be downloaded as part of this Cookbook.

Because imaging with IRAC has been covered thoroughly in earlier chapters (see Chapters 4 and 5), we will not spend as much time on those aspects of these observations here; this chapter is meant primarily to give an example of staring at the same object for an extended period of time (days), and using Spot to tell Spitzer exactly how you want the observations carried out.

We will plan an observation of the IRAC calibration star BD+60 1753 to monitor it over roughly three consecutive days and look for smooth variations in the light level. Note that several other useful hints about time series observations are given in the IRAC High Precision Photometry section of our website: <https://irachpp.spitzer.caltech.edu/>. After you have finished building your AORs, a good way to quickly check if there are any glaring problem is to use the `check_peakup_aors.pl` perl script in the Contributed Software section of the Spitzer Documentation website at <https://irsa.ipac.caltech.edu/data/SPITZER/docs/dataanalysis/tools/contributed/irac/>

7.1 Overview of the Observations

- **Target Selection:** Before being selected for potential Spitzer observation, targets should be checked for conflict with previous observations. See Section 7.2.
- **Completing the AOTs:** With IRAC, we create a short, dithered initial 30-minute AOR to allow the telescope pointing to settle and to obtain a local-in-time dark frame that can be used to remove persistent images and thereby to increase the photometric precision. Following the initial dithered AOR, we then create three long staring mode AORs to cover the whole three-day period. Finally, we create a short ~ 13 minute dithered AOR to assess changes in the dark during the observation. We use the two second frame time in subarray mode to avoid saturation and to avoid producing excessive amounts of data.
- **Constraints:** We impose as broad constraints as possible. We place a timing constraint on the first AOR of the series, and then chain the rest to the first one. See section 7.5.

7.2 Target Selection and Suitability

As with all other observations, we need to first check the ROC using Leopard. By looking here, we find that, of course, BD+60 1753 has already been observed (many times!). Had this been a real proposal, we could then check the Duplicate Observations Rule to see if the specific proposal idea we have in mind qualifies as a new observation—perhaps we feel we could make a good scientific case for why it would need to be observed more than it already has been during the Spitzer mission. However, for

purposes of this example only, we will ignore the potential duplication, and continue planning these time series observations of BD+60 1753.

7.3 Target Entry

Start up Spot and enter a new target either by clicking on the bulls-eye target icon on the taskbar, or selecting "New Target" from the "Targets" menu. See Figure 57.

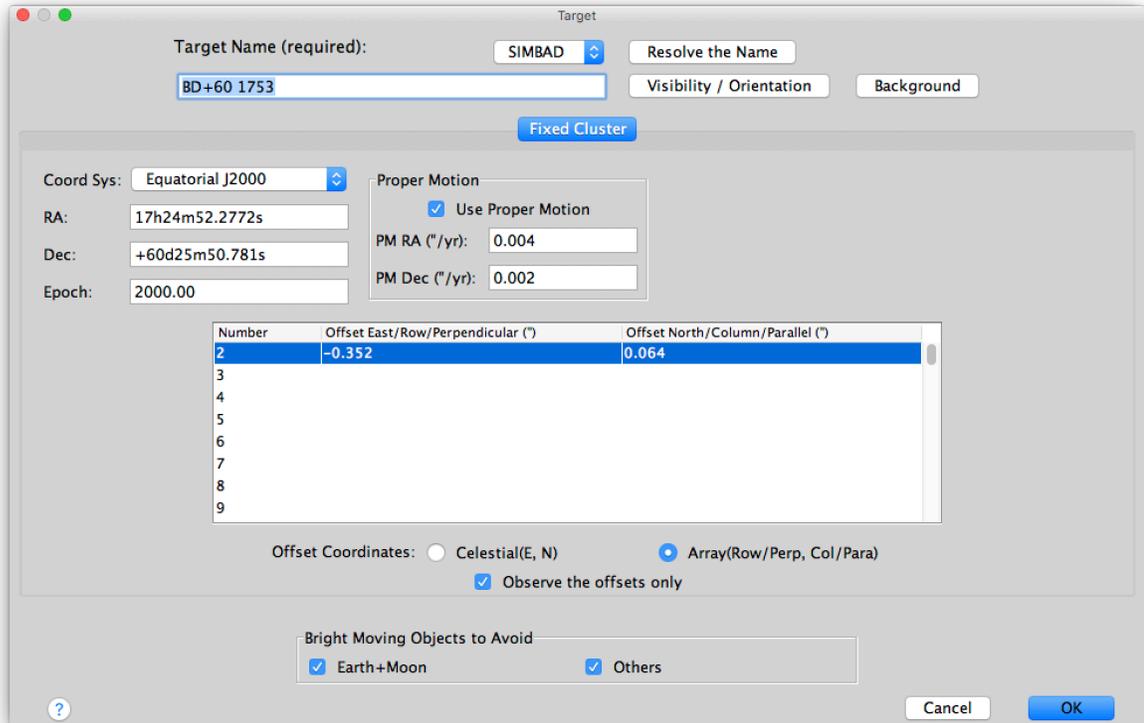


Figure 57: The target window after entering BD+60 1753.

Click on the "Fixed Cluster" tab to pull up the window, and enter the name "BD+60 1753" and Resolve the Name using SIMBAD. The proper motion will be taken from the latest SIMBAD values that source the latest Gaia data release. This is especially important if you are observing objects that have a large proper motion. Note that if you are observing objects that are closer than 20 pc away from us (have a large parallax) then you will need an additional correction, see Section 7.6.

You then need to specify the offsets to the subarray sweet spot. These can be found at <https://irachpp.spitzer.caltech.edu/page/Obs%20Planning>. The sweet spot is a position of maximum sensitivity where the Spitzer Science Center has invested a substantial amount of calibration time to build high precision maps of the intrapixel photometric sensitivity. Here we use the offsets for channel 1 subarray (offsets for full array are different).

You need to also select the "Array(Row/Perp, Col/Para)" button and the "Observe the offsets only" button. After entering our target information, we click "OK" and we return to the main Spot screen. Note that the bottom of the Spot screen now tells us which

target and target type we have entered. Save your target list, just in case. To retrieve the target list at any time, we can click on the icon that looks like three bullseyes on the toolbar.

To find exactly when the target is visible to Spitzer, we can click either on the "Visibility/Orientation" button in the target entry window, or from the Targets pulldown menu select "Calculate Visibility Windows for All" and then from the target list window select "Show Visibility". This shows us a list of the dates when Spitzer can actually observe our target (in this case it shows the whole mission range as our target is in the continuous viewing zone, CVZ).

7.4 Building The IRAC AORs: Exposure Time and Observing Strategy

7.4.1 Dithered Pre-Observations

The IRAC team recommends that the observation sequence starts with a dithered 30-minute long observation at coordinates that are slightly offset from the target (the target is not within the field of view). We therefore specify another target, call it "BD+60 1725_sky," that is centered at coordinates R.A. 17h24m48.1s, Dec +60d26'45.0" (see Figure 58). We make it also a cluster-offset type target and specify a set of 11 cluster offset positions (see the AOR file that comes with this example). The offsets specify a "custom dither" pattern and take about 30 minutes of time, and allow enough frames to be taken for a custom-built dark, if such a dark is desired. No Peak-Up or dither or mapping pattern is specified for the starting AOR. Check the 3.6 micron field of view and the 3.6 micron data collection buttons and set the Number of Frames = 1 and keep the frame time the same as in the longer science observations, 2 sec subarray.

Target Name (required): SIMBAD Resolve the Name

BD+60_1753_sky Visibility / Orientation Background

Fixed Cluster

Coord Sys: Equatorial J2000

RA: 17h24m48.1000s

Dec: +60d26m45.000s

Epoch: 2000.00

Proper Motion

Use Proper Motion

PM RA ("/yr): 0.000

PM Dec ("/yr): 0.000

Number	Offset East/Row/Perpendicular (")	Offset North/Column/Parallel (")
2	-3.000	3.000
3	-3.000	0.000
4	-3.000	-3.000
5	0.000	-3.000

Offset Coordinates: Celestial(E, N) Array(Row/Perp, Col/Para)

Observe the offsets only

Bright Moving Objects to Avoid

Earth+Moon Others

Cancel OK

Figure 58: The target window for an empty sky target near BD+60 1753.

7.4.2 Staring Light Curve Observations

In this example, we are looking for tiny variations in the signal from the star+planet system. We could be fooled by flux density variations due to the movement of the object on the array (pixel position). In order to limit these effects, we would like the object to stay in the same place on the array, so we have chosen NOT to dither. We have also placed the target, as specified in Section 7.3, on the subarray “sweet spot”, where the sensitivity of the pixel has been highly characterized to allow an accurate correction to the obtained flux density levels. Instead of dithering we use the “repeats” (Number of Frames) option on the AOT window, located just above the frame time setting. Finally, we wish to have as continuous coverage as possible, and keep the object as close to the sweet spot as possible. Therefore, we choose to only use one field of view; we choose 3.6 micron here. We also select to collect data only in that channel and turn off data collection in the 4.5 micron channel (because we have only selected the one field of view; this reduces the amount of extraneous data being saved by the mass memory card onboard the spacecraft).

For the long science AORs we specify also a PCRS Peak-Up in the AOT. This will put our target very precisely on the sweet spot in the subarray (again, see page <https://irachpp.spitzer.caltech.edu/page/Obs%20Planning> for statistics about how accurately the peak-up procedure puts the target on the sweet spot), which allows for an accurate correction of the flux density levels, depending on where the target is on the pixel. We will do this for all the long staring AORs (and use the cluster offset target). To specify the PCRS Peak-Up here we click in the main AOT window under “Peak-Up Settings” “PCRS Peak-Up” and then in the “Peak-Up Target” window we select “Offset” and leave the RA and Dec offsets to 0.000 (this means that the peak-up will be performed on the target itself, see the link above for information on what the requirements for the peak-up star are). We also add the V-band Vega magnitude of the peak-up star (the target itself; in this case, 9.65 mag). In cases where the target itself is not suitable for peaking up on, we can select a PCRS Peak-Up star by clicking the “PCRS selection...” button and selecting a suitable star from the list that comes up. Or we can specify our own Peak-Up star (but again see the criteria for the Peak-Up star in the link given above). More information about the intrapixel sensitivity corrections is available at <https://irsa.ipac.caltech.edu/data/SPITZER/docs/irac/calibrationfiles/pixelphase/>.

We select a 2 second subarray frame time not only because the source will not saturate but because we want to avoid filling up the mass memory card onboard the spacecraft (2s subarray yields the smallest volume of data of all currently available integration modes). We enter the information into the AOT window; see Figure 59. We select the subarray, just the 3.6 micron field of view, and 330 repetitions of 64 frames of 2 sec each, with no mapping or dithering. We choose “Calc. Obs. Time” to see how long this AOR takes. It is about 43,100 seconds. We make the long AORs close to 12 hours in duration, as recommended in <https://irachpp.spitzer.caltech.edu/page/Obs%20Planning>. When we click “OK” at the bottom of the AOR window, we will, however, get a warning message

(Figure 60) that the best practice with IRAC is to use only one frame, not 330. We can ignore this warning (since it does not apply in this science case) by clicking “OK” to close the warning window.

We are planning a time series covering almost three days. After creating the first AOR, we choose “copy AOR” five times, and change the labels of each one so that we can keep track of which AOR is which. We adjust the number of repeats to 330 in all of these six AORs to stay under the recommended 12-hour duration for a single staring mode AOR when the Peak-Up target is the science target (again, this recommendation can be found at the afore-mentioned web page <https://irachpp.spitzer.caltech.edu/page/Obs%20Planning>).

7.4.3 Dithered Post-Observations

Finally, we create an end AOR as recommended in the link above. This AOR should be about ten minutes in length and consist of dithering with the same frame time as the long staring observation. We specify a new target, this time using the Fixed Single target type at the same coordinates as the first AOR in the sequence (the sky position). For this AOR we go to the AOT template and select the 2-sec subarray frame time and a dither pattern for which we specify a Medium 4-position Gaussian dither. This final AOR should be about 10-15 minutes in length to assess changes in the dark measured in the initial 30-minute dither.

If we did not already calculate the total elapsed time for this program, we should choose “Recompute All Estimates” from the “Tools” menu so that we know how long the total program is.

As in all of the earlier chapters, to verify that we are doing what we think we are doing, we should visualize the observation. Since visualization is thoroughly covered elsewhere in this Cookbook, we do not repeat that information here.

Save your AOR(s) early and often. Now would be a good time.

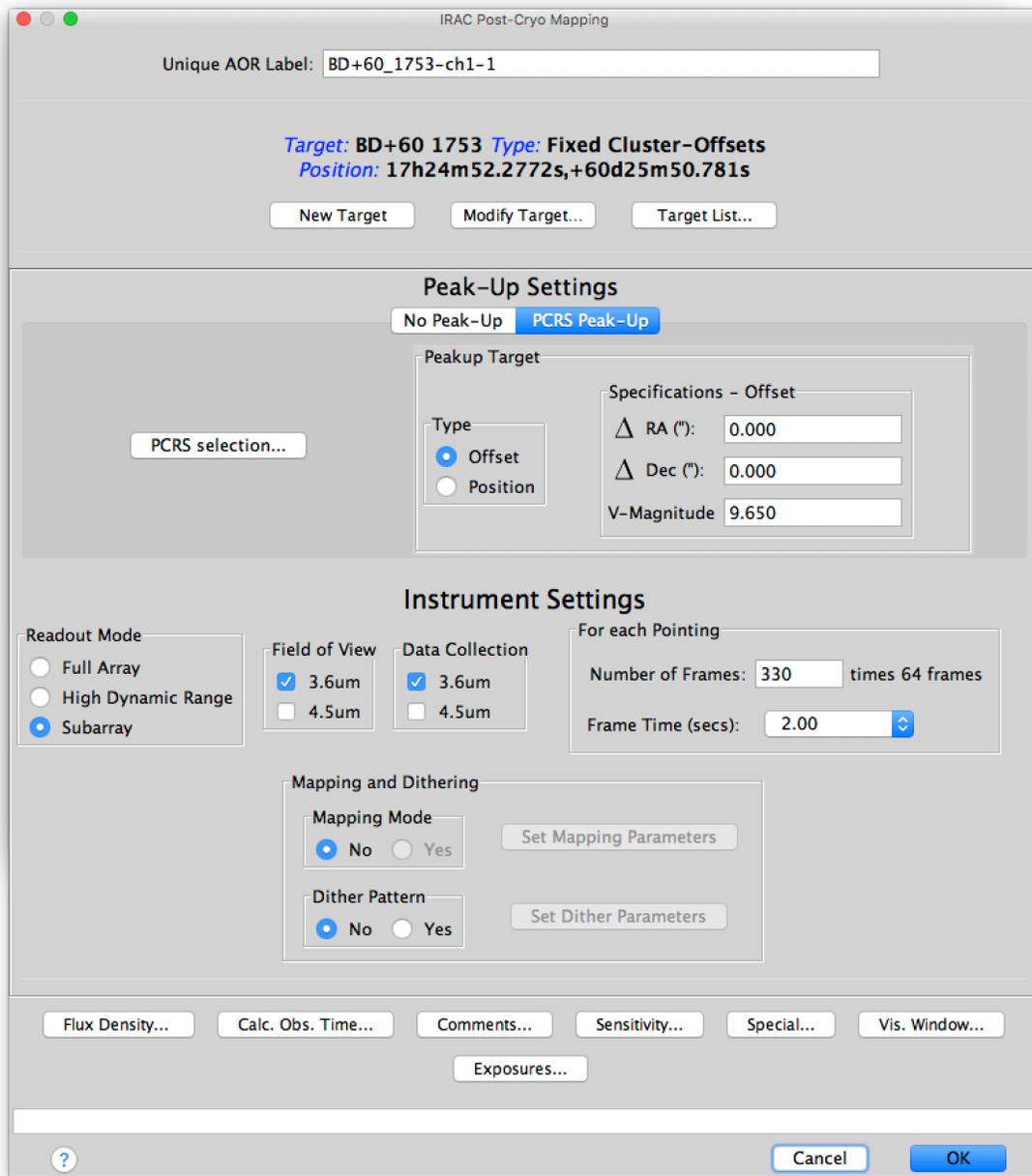


Figure 59: IRAC Post-Cryo Mapping AOT window, filled-in values for the first long staring AOR.

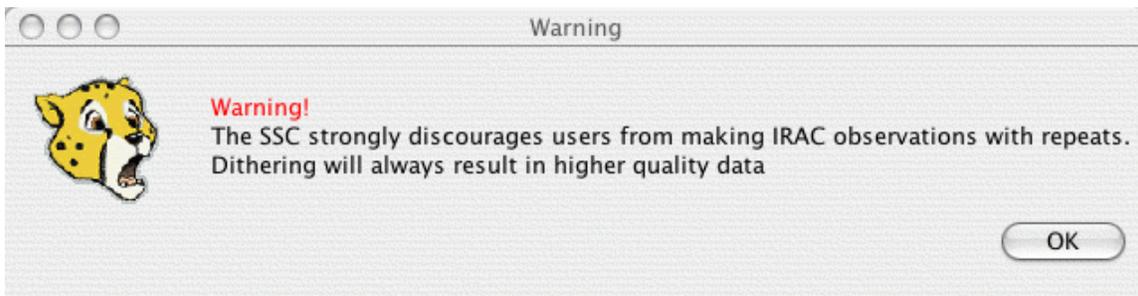


Figure 60: Warning that appears when you have entered in the AOT window Number of Frames >1. For this observation, you can simply click “OK” and ignore the warning.

7.5 Constraints

In order to accomplish our science, of course we need to ask Spitzer to complete these observations at the right time. We go away and calculate when we would like these observations to start. For time series measurements, we probably want to make sure that expected events, such as known transits and secondary eclipses, do not occur when we are switching from one AOR to another (and repointing the telescope). We also need to be sure that the timing windows we give are consistent with when Spitzer can view the object (in this case it is always available and visible).

Note: In order to accomplish this observation, we do not have to time-constrain each observation! In fact, it provides the most flexibility for scheduling, and the best possible data quality, if we time-constrain the first AOR in the series only, and then chain together the rest of the AORs in the series to the first.

7.5.1 Timing Constraints

In order to impose a timing constraint on the first AOR, we select the first (start) AOR in the list, and then from the "Tools" menu, we select "Timing Constraints." It helpfully provides us with a list of the visibility windows for this object (in this case the target is always visible). We also look at the list of possible BD+60 1753 planet orbits and consider the largest possible window when these observations could start.

We then enter a series of start and end dates and times, and then click OK; see Figure 61. To regain this window at any time in the future, select "Timing Constraints" from the Tools pulldown menu as above. Typically exoplanet observations have a start timing window 30 minutes long. If you think you need a shorter window, please provide a good justification in your proposal.

In the main Spot window (see Figure 63), you will note that the checkbox is now checked for this AOR under the "T" column.

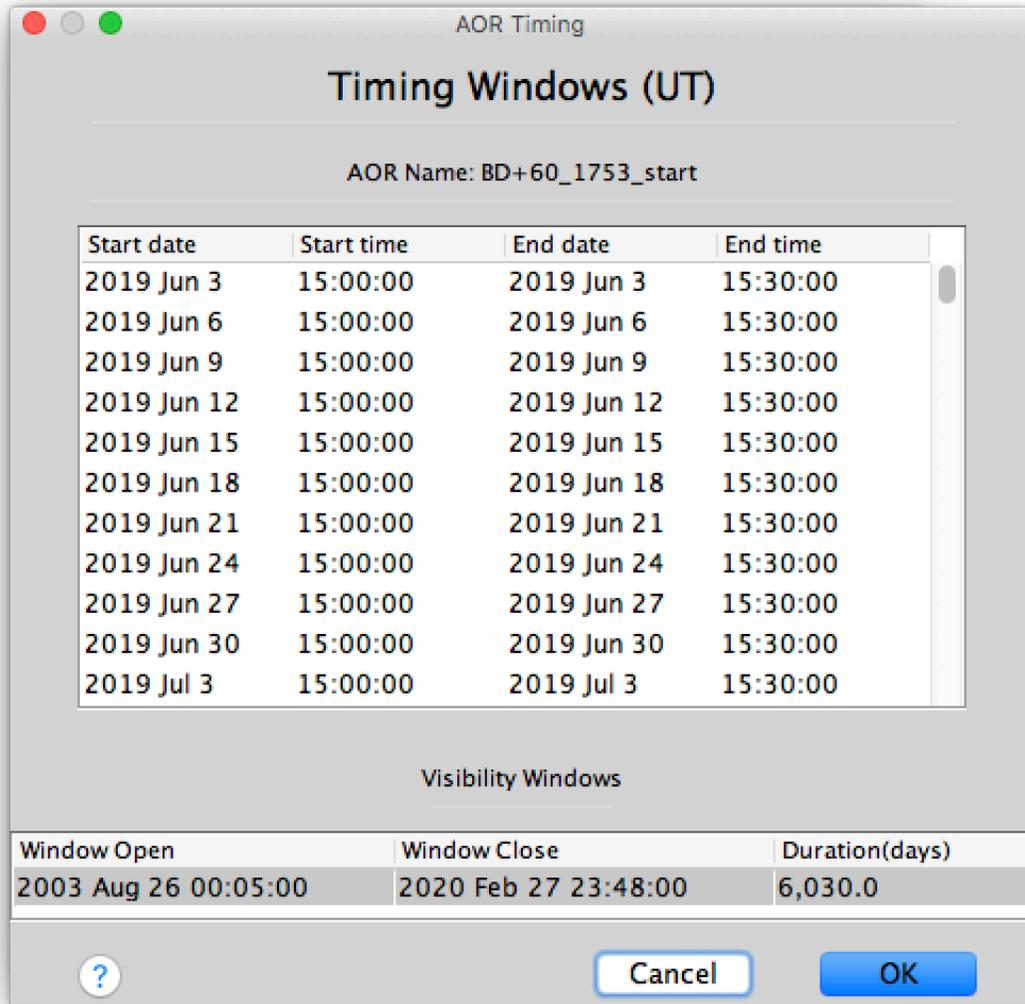


Figure 61: Imposing timing constraints.

7.5.2 Chaining AORs

We are not done yet! Next, we need to tell Spitzer that we need to do the rest of these observations in order, without breaks. We would like this series of observations to be done as an ordered non-interruptible group because we need continuous monitoring of this object.

In order to start a chain, we first select "Group/Follow-on Constraints" from the "Tools" menu. The default first tab that appears is the Group tab; we could also select Follow-ons or Shadows (were this a Solar System target) from this same dialog. We want to impose chaining constraints, so we select "Add Chaining." We get a pop-up asking for a name of the constraint. We name our chain constraint "Chain-BD+60_1753_ch1." An icon and text now appears in the lower part of this Constraint Editor. It tells you the total duration of this chained series of AORs. Note that the longest possible uninterrupted group of

IRAC AORs, without getting a warning message, is 24 hours. If you need a chain that exceeds this amount of time, simply ignore the warning message.

Now, we select the first AOR in the series and drag-and-drop it into the window. It now appears under the "Chain-BD+60_1753_ch1" entry. Next, we drag-and-drop the second AOR in the series here too. We note that the total duration is keeping track of how long this will take. We repeat this for each of the six long staring mode AORs. We then note (Spot helps us notice this, if we forget) that the total duration exceeds 24 hours!

Make sure that the first AOR in your chain is the short 30 minute start AOR to allow the detector to stabilize, and the last AOR is a short 10–15 minute end AOR.

We click "Apply" to impose this constraint, and Spot will remind us that the chain takes too long. See Figure 62.

NOTE: You have to click apply, not just OK, for the constraints to actually stick to the AOR.

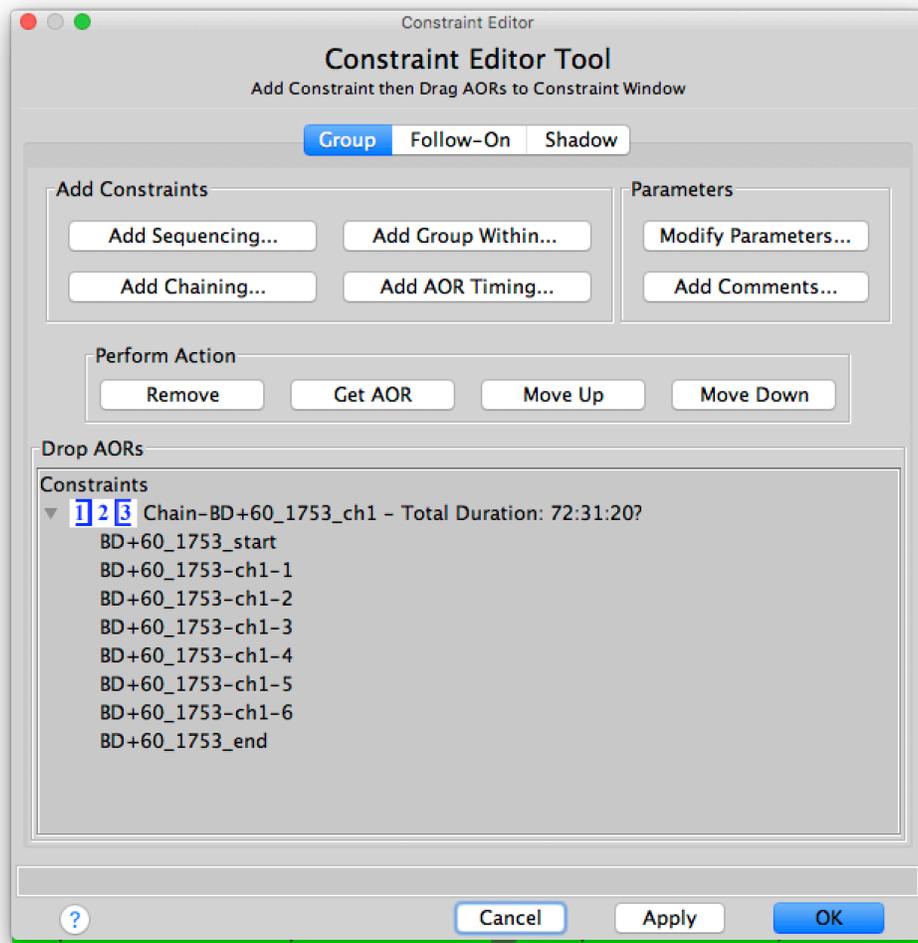


Figure 62: The imposed chaining constraints.

Having done this, now we see in the AOR list in the main Spot window (Figure 63) that the Group constraint box (“G”) is checked.

Label	Target	Position	Type	T	G	F	Instrument	Duration	Stat	On
BD+60_1753_start	BD+60_1753_sky	17h24m48.1...	Fixed Cluster-Of...	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	IRAC Post-Cryo...	1718	new	<input checked="" type="checkbox"/>
BD+60_1753-ch1-1	BD+60_1753	17h24m52.2...	Fixed Cluster-Of...	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	IRAC Post-Cryo...	43099	new	<input checked="" type="checkbox"/>
BD+60_1753-ch1-2	BD+60_1753	17h24m52.2...	Fixed Cluster-Of...	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	IRAC Post-Cryo...	43099	new	<input checked="" type="checkbox"/>
BD+60_1753-ch1-3	BD+60_1753	17h24m52.2...	Fixed Cluster-Of...	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	IRAC Post-Cryo...	43099	new	<input checked="" type="checkbox"/>
BD+60_1753-ch1-4	BD+60_1753	17h24m52.2...	Fixed Cluster-Of...	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	IRAC Post-Cryo...	43099	new	<input checked="" type="checkbox"/>
BD+60_1753-ch1-5	BD+60_1753	17h24m52.2...	Fixed Cluster-Of...	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	IRAC Post-Cryo...	43099	new	<input checked="" type="checkbox"/>
BD+60_1753-ch1-6	BD+60_1753	17h24m52.2...	Fixed Cluster-Of...	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	IRAC Post-Cryo...	43099	new	<input checked="" type="checkbox"/>
BD+60_1753_end	BD+60_1753_s...	17h24m48.1...	Fixed Single	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	IRAC Post-Cryo...	768	new	<input checked="" type="checkbox"/>

Target: BD+60_1753_sky Type: Fixed Cluster-Offsets Total Duration (hrs): 72.5

Proposal - File Name: example.aor Net Up Total AORs: 8 / Active: 8

Figure 63: The Spot window showing the final AORs and the set constraints.

Now we are done! The AOR file, ready to be loaded into Spot, containing the raw AORs developed in this chapter can be downloaded from the SSC Cookbook webpage:

<http://ssc.spitzer.caltech.edu/warmmission/propkit/cookbook/> .

7.6 Adjusting nearby object coordinates for parallax correction

For stars and brown dwarfs within a distance from the Sun less than 20 pc, the position in the sky can change enough during the course of the year to be placed slightly off the desired calibrated pixel location if not using self Peak-Up. As of 2018, Spitzer was over 1.5 AU from Earth, which causes Spitzer to see the nearby targets at a different apparent position compared to its coordinates as seen from the Earth. We have created an IDL procedure called “make_parallax_coords.pro”, available in the ‘General’ section of <https://irsa.ipac.caltech.edu/data/SPITZER/docs/dataanalysisitools/tools/contributed/> which uses the positions of Earth and Spitzer to calculate the Spitzer-seen coordinates of your object at a specific observational epoch. We recommend asking the Spitzer Helpdesk to notify you of preliminary scheduling dates of your observation, allowing you to work with the Spitzer Science Center to update your target coordinates in the AORs well before the observations are taken.

8 Target of Opportunity (ToO) Observations

8.1 Overview of the Observations

- **Completing the AOT—IRAC, one epoch:** We plan the simplest kind of ToO, a single epoch with IRAC.
- **Completing the AOT—IRAC, multiple epoch:** We plan an even more sophisticated ToO, using IRAC, but observing the same object multiple times.

8.2 Target Selection and Suitability

ToOs, by their very nature, are transient events. Thus, the duplication rule “escape clause” applies, and re-observation of an object already in the ROC is likely to be approved because it is intrinsically changing.

8.3 Impact Definitions

Targets of Opportunity are categorized by the extent to which the execution of such an observation affects normal Spitzer scheduling and observing procedures. Therefore, as part of the proposal submission, *we must identify in our proposal* each ToO request, based upon the maximum delay—in our judgment—that is scientifically acceptable between the activation of an approved AOR and the execution of the observation.

The normal Spitzer scheduling process begins 5 weeks prior to when a sequence begins execution on the observatory (since the sequences run from Wednesday to Wednesday, this process usually begins on the Monday of the sixth week in advance). We do not expect any changes in this process for the Warm Mission.

Therefore, if we choose to activate an approved ToO with comfortably more than 8 weeks' notice, then this is *a low-impact ToO*. In order to truly have no impact on scheduling, the ToO must be activated more than 8 weeks before *the scheduling process for that week begins*, not just 8 weeks before *the desired observation date*.

Spitzer is designed to operate autonomously for periods of about a week, so the schedule is developed in units of weeks. A ToO that is activated less than 8 weeks in advance therefore affects scheduling for not just the *entire week*, but perhaps *the weeks before and after as well*. Because the SSC only communicates with the spacecraft once or twice a day, the fastest possible response for a ToO activation is 48 hours. **A ToO that is activated with less than a week's notice requires considerable effort to implement.**

Therefore, to summarize,

- High-Impact is < 1 week (normally a minimum 48-hour turnaround)
- Medium-Impact is 1–8 weeks
- Low-Impact is > 8 weeks.

Apart from the overhead burdens applied to all Spitzer observations, the SSC imposes no additional overheads on low-impact ToO observations.

Because of the heavy impact that high-impact ToO observations have on the short- and medium-term Spitzer schedule, **there is a maximum number of medium- and high-impact ToOs permitted per cycle.** We currently anticipate supporting only 1 to 2 per year.

NOTE: In the warm mission and up high- and medium-impact ToO observations cannot be included in GO proposals. They must be requested via Director's Discretionary Time. See the current Call for Proposals. Low-impact ToO observations can be requested through the GO proposal process. There is no limit on the number of these low-impact ToO observations that can be approved for the Cycle.

In general, the more disruptive the ToO observation is to normal Spitzer scheduling and operations, the stronger the scientific justification must be to approve the proposed observation.

8.4 *Single Instrument, Medium Impact*

For our first example, we will design an IRAC observation. We decide, based on our science case, that we can live with a 1–8 week window for activation, so we settle on a medium impact ToO.

First, we design our IRAC observation. The IRAC observation in **Error! Reference source not found.** nominally takes 456 seconds.

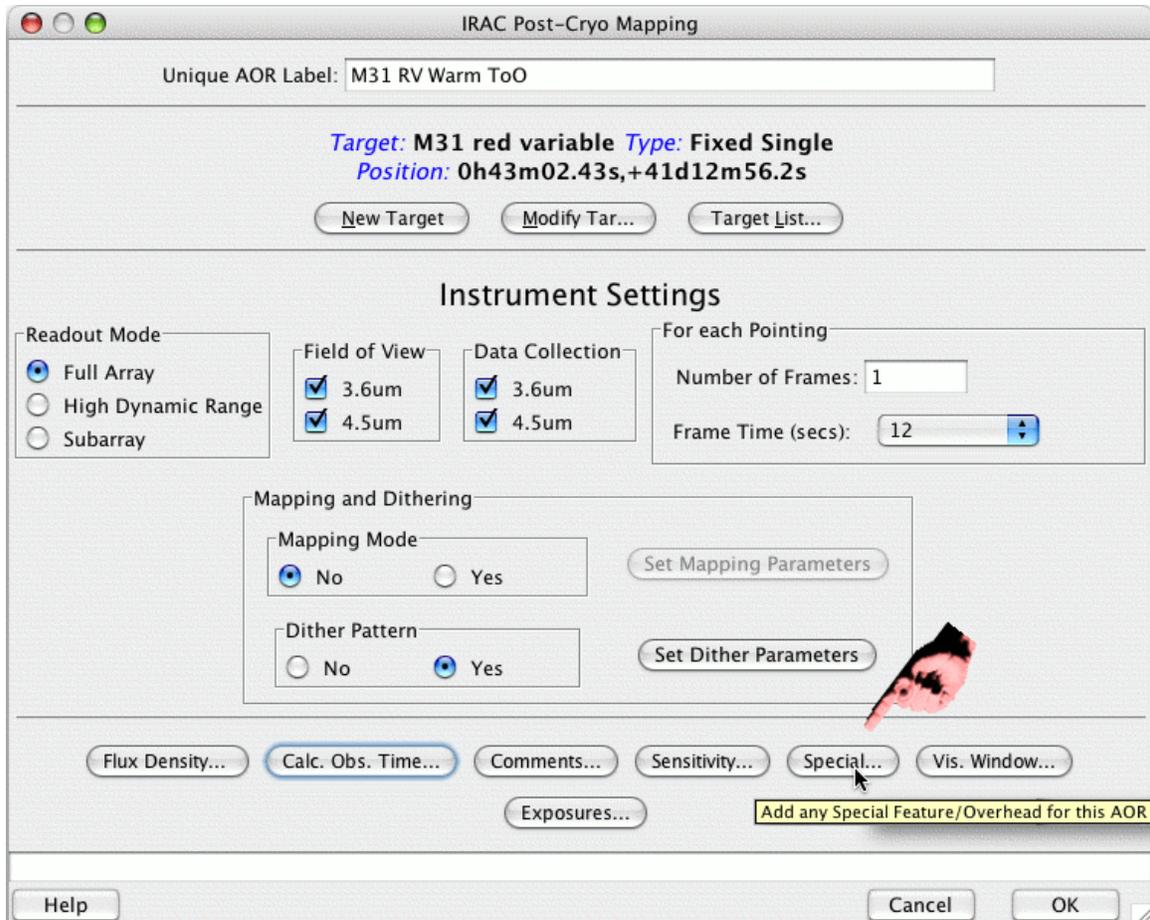


Figure 64: The IRAC Post-Cryo Mapping AOT window. Note the “special” button on the lower right!

Figure 64 shows the IRAC AOR that we have designed. But before clicking “OK” (or at any time while editing the AOR), we need to click on the “Special” button in the lower right of the AOT window as indicated in Figure 64. Doing so results in a new dialog box. In Figure 65, we have selected “Medium Impact Target of Opportunity 1 Instrument. (There is no longer more than one instrument during the Warm Mission!)

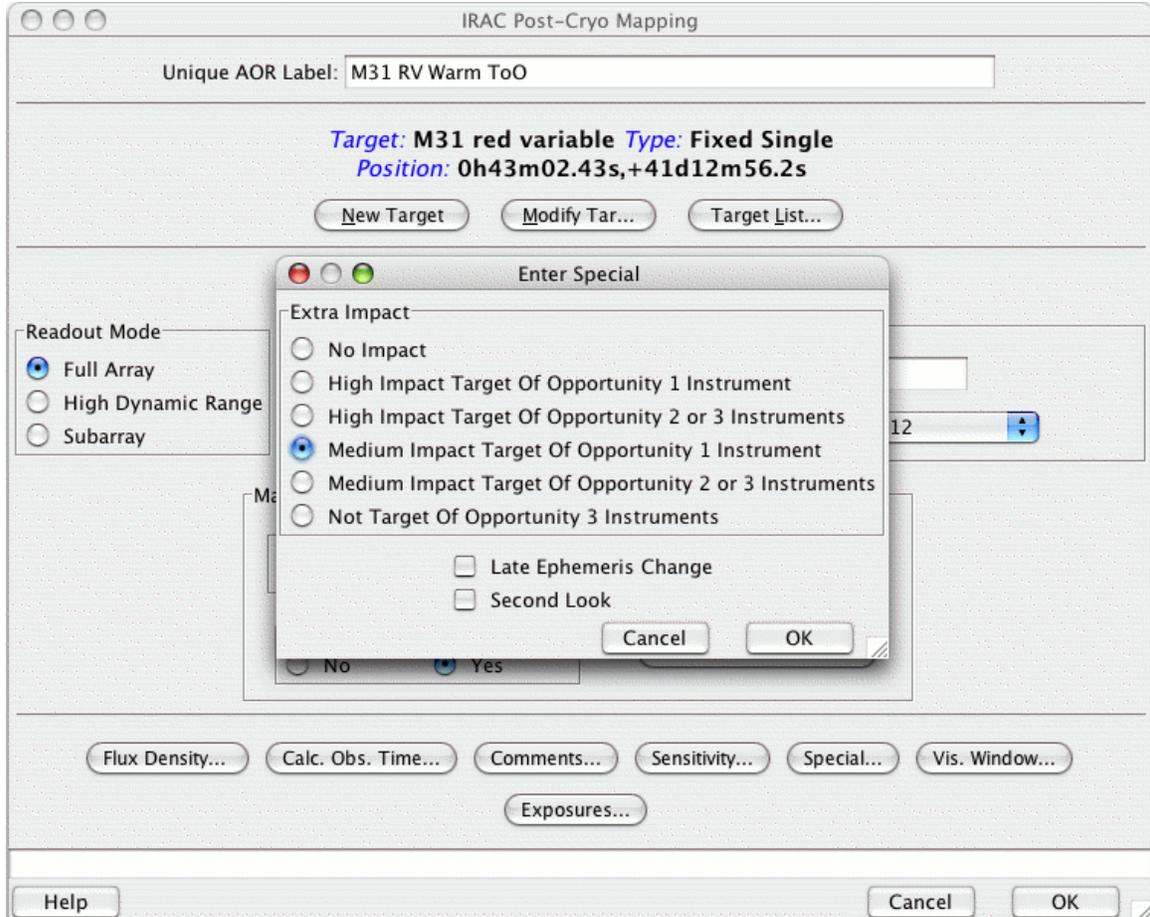


Figure 65: The special overhead window which results from clicking on the “Special...” button shown in the previous figure.

Before selecting the impact option via the “Special” button, the AOR as designed took only 456 sec = 7.6 minutes. But now, having selected the overhead, the AOR takes 9816 sec = 163.6 min = 2.7 hrs. These 156 “extra” minutes are the special overhead charged to our observing program for having requested a medium impact ToO with one instrument. *The proposal we write using this AOR must ask for 2.7 hours, not 7.6 minutes.*

8.5 Single Instrument, Multiple Epoch

What if we want to plan an observation that follows the light curve of a transient event, such as a supernova? Maybe we need an observation soon after a SN, then we want another observation a week later, and then 3 weeks after that. In order to do this, **we need to apply the special overhead to each AOR in the sequence**, because each one of them, on their own, is a high- or medium-impact ToO.

So, we create again (for purposes of this example) some very simple AORs for IRAC; we create three basically identical AORs. Again, they bear a striking resemblance to the ones designed above, e.g., each takes 2120 seconds before adding any additional ToO overhead.

In order to realize our vision of the first one going as soon as possible after we trigger it, the second going 1 week later, and the third going 3 weeks after that, we need to impose some constraints. More detail on constraints is included in other sections (e.g., section 7.5), but we summarize these steps here.

8.5.1 Setting Constraints

The loosest, best constraint to use to accomplish our goals here is the follow-on constraint, e.g., do this second AOR no sooner than time x , and no later than time y after the first AOR.

After creating all three of our IRAC AORs, we select the first one and choose “Group/Follow-on constraints” from the Tools menu. We then click on the “Follow-on” tab at the top of the window, then the “Add Follow On” button. For this first window, we want the second AOR to go no sooner than 5 days and no later than 10 days after the first, so we enter that information in the “Follow-On Parameters” pop-up window that appears (Figure 66). We then drag-and-drop the two relevant AORs into the constraint, resulting in Figure 67.

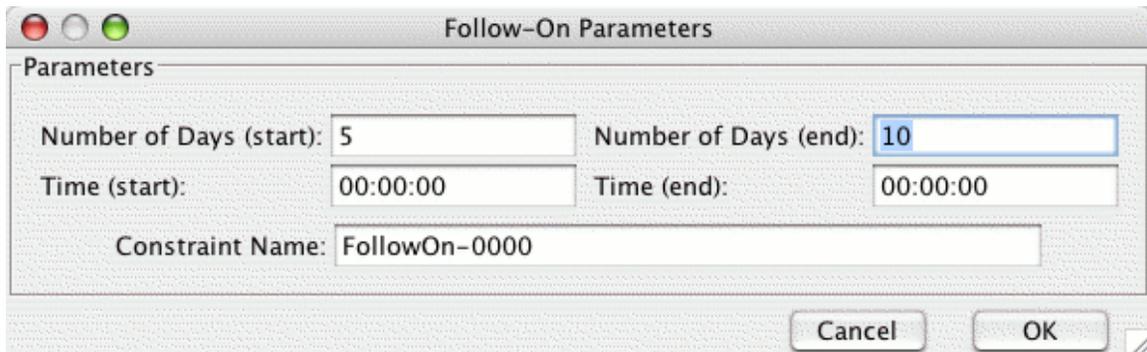


Figure 66: Filling in the follow-on constraint dialog.

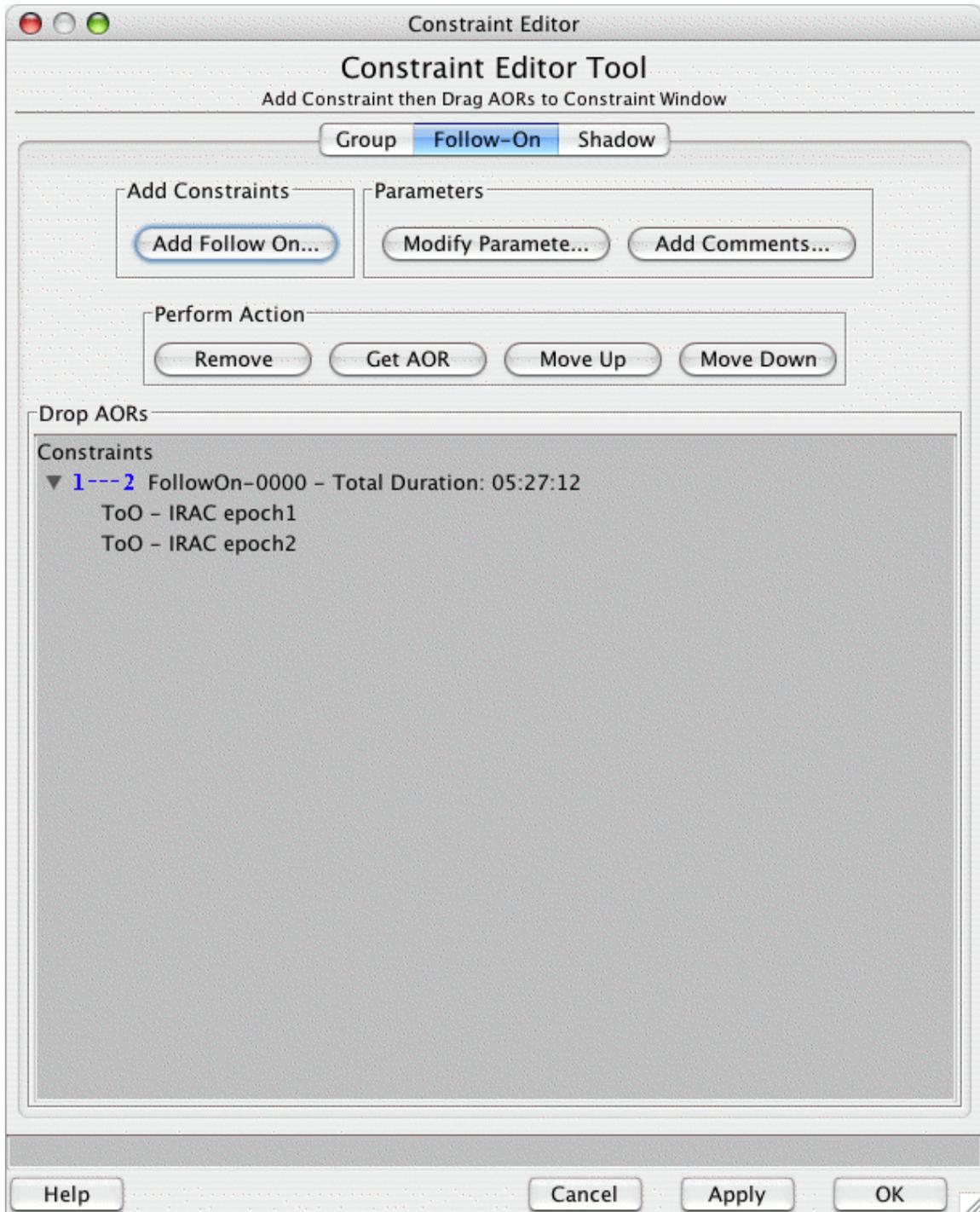


Figure 67: The first follow-on constraint.

We repeat this process, but now we want to link the 2nd and 3rd AORs with a gap of no less than 18 days and no more than 25 days; see Figure 68.

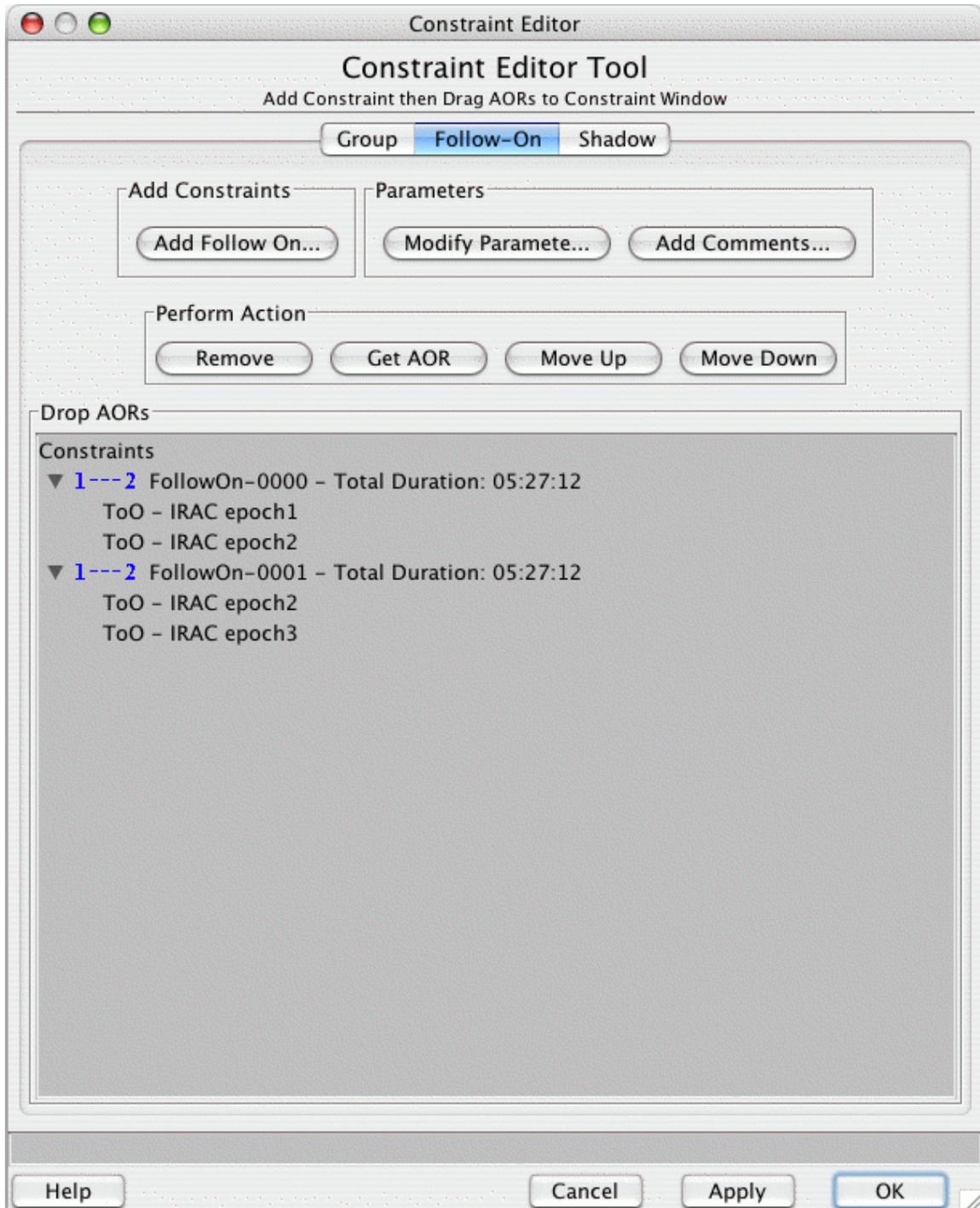


Figure 68: The second follow-on constraint.

We click “Apply” and then “OK.” Note that the boxes under “F” are checked in the main Spot window now.

8.5.2 Special Overhead

Now, note that when we initiate the first AOR in the sequence, we are impacting a schedule with <1 week's notice, a schedule with <2 weeks' notice, and a schedule with <8

weeks' notice. This means that *each* of these AORs qualifies as a ToO; the first is a high-impact, and the other two are medium impact. We edit the AORs, click the “special” button, and select the corresponding overhead. This program, with all the overheads (two high-impact and one medium-impact, single instrument) comes now to 12.1 hrs.

8.6 Hints and Tips

While writing our ToO proposal, we don't know *when* the observations will be needed. Some programs will know *where* the object is (watching for flaring in a given source), and some will not (nova outburst follow-up). In our proposal, we must describe the trigger criteria clearly, e.g., this observation will be triggered if a comet of the right family and size is discovered during this Cycle and is within this distance of the Sun.

A description of the target provenance and schedulability for ToO targets is required for Exploration Science GO proposals.

Even if we don't know where we will need to point Spitzer, we still need to create representative IRAC AORs.

The total time we need to request in our proposal is the total time *including* the special overhead, not just the elapsed time of the solitary observations.

The “special overhead” for multiple AORs *occurring as close in time to each other as possible* need only be applied to one of the group of AORs, not to each one.

The “special overhead” for multiple AORs *occurring with a specified number of days between them* need to be applied *to each AOR in the set*.

Once our interesting object does whatever we're waiting for it to do, the very first thing we should do is pull up Spot, enter it as a target, and *check the visibility windows*. Calling in an activation request won't do much good if Spitzer can't view the object.

8.7 Obtaining the AOR File

The AOR file, ready to be loaded into Spot, containing the raw AORs developed in this chapter can be downloaded from the SSC Cookbook webpage:

<http://ssc.spitzer.caltech.edu/warmmission/propkit/cookbook/>.

9 How to Submit a Spitzer Proposal

The Call for Proposals and the Spot User's Guide, both available on the SSC website, provide important information on many things relevant for proposal submission. The SSC provides a mandatory template (available on the same web page as the Call itself) for observers to use in preparing their PDF proposal attachment. Proposers must use the template—there are no exceptions. Note that the inclusion of an Observation Summary Table is mandatory, and a tool is online from the Proposal Kit webpage on the SSC website for creating this Table from your AORs. If you read no other documentation, be sure to *read the template instructions and follow them*. That is the best advice we can give for submitting a successful proposal!

A step-by-step proposal submission guide is available online at <http://ssc.spitzer.caltech.edu/warmmission/propkit/propsubmission/>. That page has many embedded links to other resources. The content from this website is repeated below, along with some hints and tips for creating good proposals.

9.1 Planning Stages

- Think of some science that has to be done with Spitzer after the cryogen runs out.
- Read all of the relevant documentation (and there is a fair amount of it). The six most essential documents are Call for Proposals (CP), Warm Spitzer Observer's Manual (SOM), Spot User's Guide, Warm Reserved Observations Catalog (ROC), the Leopard User's Guide, and the Warm Spitzer Observing Rules. Many other helpful documents are also available for download in the Proposal Kit area of the SSC web site.
- Download and install Spot. Do this early! Get to know your Spot and the Spitzer science instruments well before the deadline of the Call.
- Check the Reserved Observations Catalog (ROC). Avoid duplicating approved observations. Duplications are generally not allowed. See the Observing Rules for more details on duplication of approved observations. It's always best to use Leopard to search the ROC.
- Check that your favorite target(s) are not too bright or too faint for Spitzer. Remember that the sky background can be significant at some infrared wavelengths. Sensitivity charts are available in the Spitzer Observer's Manual and in the Proposal Kit area (see the Tools page). Observers can use Spot and/or IRSKY to estimate the infrared sky background in regions of interest.
- Use Spot to fill out the AOT to create AORs. (There are lots of examples of how to do this on this site; particularly in the document you are reading now!) Check the visibility of your observations, especially if you need to use an observational constraint (hints and tips about constraints). Use Spot to visualize your AORs—this is always a good thing to do. Are they doing what you expected?

- Start writing the scientific and technical justification. This must be in PDF format when submitted as part of the proposal. See the Call for Proposals for details on what to include in the justification. All of this information must be in a PDF file that is less than 10 MB total.
- Early on, open the Proposal Tool in Spot (see more below). Fill in some information and save it to disk. This is the coversheet part of the proposal. Get comfortable editing the information and changing it if needed.

9.1.1 Hints and Tips

Spitzer Proposal Submission is a one-phase process (for exceptions, see the CP). Proposers for Spitzer observing time must include the details of their proposed observations in the form of AORs. By reading this Cookbook, you are well on your way to preparing final AORs to submit with your proposal.

Your scientific and technical justification must be in PDF format. Note that there is a file size limit of 10 MB (see the Call). In practice, what this means is that ultra-high resolution color figures may not be allowed to be submitted in your proposal! If you are having trouble making things fit, note that resolution of any figures need not be more than 300 dpi; also try black-and-white figures, rather than color.

Note that your proposal will be provided to the peer reviewers in CD-ROM form. This means that a reasonable fraction of the proposal reviewers will be reading your proposal on a computer screen. There are a few very easy tips for creating screen-readable PDF documents available online at <http://ssc.spitzer.caltech.edu/warmmission/propkit/cp/pdf/>. Anyone not reading your proposal on the computer screen will most likely have sent it to a black-and-white printer. Make sure your color figures are also intelligible in black-and white (which, by the way, also helps color-blind readers decipher your plots).

9.2 *Proposal Submission*

- Think of a nifty shorthand proposal user name (not your personal username) for your proposal. It must be unique within the Spitzer mission. Check the ROC list of science programs for proposal user names other observers have used. Also think of a password. You will need to use this proposal user name and password to update your submitted proposal (possible throughout the Call, see below) and to modify your approved proposal, if necessary. Be sure to use usernames and passwords you can remember, or log them somewhere.
- Start up Spot.
- Load the AORs to be submitted into Spot. Be sure there are not any junk or test AORs, just the good ones you want to be executed with Spitzer if your proposal is approved.

- Open the Proposal Tool from the Tools menu in Spot. **Please note that if you are submitting a DDT proposal, you do not use Spot. See <http://ssc.spitzer.caltech.edu/warmmission/ddttoo/howddt/>.**
- Load your coversheet file into the Proposal Tool (File →Open Proposal), or input the information that is requested. Double-check that the information looks correct, especially the Hours Requested and the justification file that is to be submitted.
- Click on the Submit menu in the Proposal Tool and select Submit proposal to SSC.
- Save your coversheet file, as requested by Spot. Name it something you will remember, such as username_submitted_01oct08.cs. Spot will save the file with your chosen proposal user name (that you're about to enter in the next step) included within it. You will need to use this particular saved coversheet file to submit any modifications to your proposal.
- Enter the proposal user name and password and your email address (used by SSC in case a problem is detected during submission).
- Spot will inform you when it has successfully submitted the proposal to the SSC. You will also receive a confirmation via email.

9.2.1 Hints and Tips

Because you can update your proposal during the Call (see below), and because this process of getting your basic information into the database can take several minutes during periods of extremely heavy load, it will make things easier if you submit a preliminary proposal and get into the database early on.

Don't choose any password you would like to keep ultra secure—don't use a PIN, don't use expletives or pejoratives—others, besides yourself, will see these. This password will be emailed to the Principal Investigator (PI) and Technical Contact (TC) of your proposal if changes to your program are required.

Are you writing the proposal, but you expect someone else (a grad student? someone who spends less time on travel than you do?) to be doing the nitty gritty work of the program? Put that person in as the Technical Contact (TC) for the program. This may make your life easier later on—for example, only PIs and TCs are authorized to make decisions or changes to accepted programs, and if the SSC later requires a quick decision on something, maybe your TC will be around when you are not.

Spot is very conducive to experimentation when creating AORs. However, all of the AORs in the AOR window are submitted with your proposal. Make sure any junk or test AORs have been deleted from your final set.

Make sure that the total hours requested in the cover sheet is what you expect it to be. This number is NOT automatically grabbed from the Spot window for several very good reasons, not the least of which is that for Exploration Science programs, a complete set of AORs is not required. If you discuss other amounts of time in your proposal, these other numbers are likely to be ignored in favor of the number entered here on your coversheet.

Confirmation email is sent to the PI, the TC, and the person self-identifying as submitting the proposal. Make sure there aren't any typos in your email addresses, otherwise you won't get this confirmation email.

9.3 Updating Your Submitted Proposal

At any time during the Call for Proposals you may modify any aspect of your submitted proposal, except proposal user name and password. You can submit a revised justification, an updated set of AORs, or corrected coversheet information.

- Start up Spot.
- Load in new set of AORs if updating AORs.
- Open the Proposal Tool under the Tools menu in Spot.
- Read in the coversheet file saved from earlier submission (i.e., username_submitted_01oct08.cs) by clicking on File → Open Proposal.
- Make any desired changes to the coversheet information. Be sure the Hours Requested entered is accurate and that the Tool is pointing to the proper justification file (if submitting an updated file).
- Click on the Submit menu and then Update proposal at SSC.
- Enter your password and email address when requested.
- Spot will again require you to save your coversheet file. Call it something useful like username_submitted_10oct08.cs.
- Spot will inform you when it has successfully transferred your updated proposal to the SSC. You will also receive an email confirmation.
- You may submit as many updates as needed prior to the deadline of the Call for Proposals. Submissions after the deadline will be automatically rejected by the software and an error message will be returned by Spot.

9.3.1 Hints and Tips

At any time during the Call for Proposals you may modify any aspect of your submitted proposal, except proposal user name and password. You can submit a revised justification, an updated set of AORs, or corrected coversheet information.

Because you can update your proposal during the Call, and because this process of getting your basic information into the database can take several minutes during periods of extremely heavy load, it will make things easier if you submit a preliminary proposal and get into the database early on.

9.4 Common Errors and FAQs

We provide a list of Frequently Asked Questions, particularly, regarding Proposals and the Proposal Kit. A link to our FAQ is on our main page: <http://ssc.spitzer.caltech.edu/>. Please take 5 minutes to quickly read through these to prevent either the failure of your observations, or your proposal being rejected entirely.

10 Appendix: Conversion of Units

A number of units are employed in astronomy for photometry, including:

$$\begin{aligned} & \text{magnitude} \\ & \text{W m}^{-2} \text{ micron}^{-1} \\ & \text{W cm}^{-2} \text{ micron}^{-1} \\ & \text{erg second}^{-1} \text{ cm}^{-2} \text{ micron}^{-1} \\ & \text{erg second}^{-1} \text{ cm}^{-2} \text{ \AA}^{-1} \end{aligned}$$

The purpose of this section is to explicitly tabulate the conversion formulae among them.

First, recall that $1 \text{ Jy} \equiv 10^{-26} \text{ W m}^{-2} \text{ Hz}^{-1} \equiv 10^{-26} \text{ erg second}^{-1} \text{ cm}^{-2} \text{ Hz}^{-1}$

10.1 Conversion Between Flux Densities

The spectral flux density, F_ν , is defined as the energy per unit area, per unit time, per unit frequency at frequency ν and is related to the object magnitude as

$$F_\nu \equiv dF / d\nu = F_{\nu_0} 10^{-0.4m} \quad (7)$$

where m is the magnitude, and F_{ν_0} is the zero-point flux in a given photometric band. In the cgs system, F_ν is in Jy. Then

$$F_\lambda \equiv dF / d\lambda = \frac{dF}{d\nu} \frac{d\nu}{d\lambda} = F_\nu a_\lambda / \lambda^2 \quad (8)$$

The conversion factor, a_λ , is not really mysterious; it is simply $1 \text{ Jy} \cdot c$, the speed of light, expressed in the appropriate units. For completeness, we tabulate a_λ for various unit choices for F_λ . The results are displayed in Table 5 (where λ is in μm).

Table 5: The conversion between F_ν and F_λ where λ is in μm

F_λ	a_λ
$\text{erg second}^{-1} \text{ cm}^{-2} \text{ \AA}^{-1}$	3×10^{-13}
$\text{erg second}^{-1} \text{ cm}^{-2} \text{ micron}^{-1}$	3×10^{-9}
$\text{W cm}^{-2} \text{ micron}^{-1}$	3×10^{-16}
$\text{W m}^{-2} \text{ micron}^{-1}$	3×10^{-12}

10.2 Converting Between Flux Density and Magnitudes

Table 6: The photometric zeropoints for the Spitzer/IRAC instrument

λ (μm)	$F_{\nu 0}$ (Jy)	$F_{\lambda 0}$ ($\text{erg second}^{-1} \text{cm}^{-2} \text{micron}^{-1}$)
3.6	280.9	6.50×10^{-8}
4.5	179.7	2.66×10^{-8}

The conversion between magnitudes and flux density F_{ν} is given explicitly in equation 7. All we need is to specify the zero-point flux, $F_{\nu 0}$.

The zero-point flux, $F_{\nu 0}$, is determined for a number of photometric systems. In Table 6 we tabulate the zeropoints, $F_{\nu 0}$ and $F_{\lambda 0} = a_{\lambda} F_{\nu 0} / \lambda^2$, for IRAC.

In Table 7, we display the zeropoints in the 2MASS passbands (see http://www.ipac.caltech.edu/2mass/releases/second/doc/sec4_5.html).

Table 7: The photometric zeropoints in the 2MASS filters

Band	λ (μm)	$F_{\nu 0}$ (Jy)
J	1.235	1594
H	1.662	1024
Ks	2.159	666.7

In Table 8 we tabulate the zeropoints, $F_{\nu 0}$ and $F_{\lambda 0} = a_{\lambda} F_{\nu 0} / \lambda^2$, adopted for NICMOS, based on the CIT system (Beckwith et al., 1976, ApJ, 208, 390).

Table 8: The photometric zeropoints in the CIT system

Band	λ (μm)	$F_{\nu 0}$ (Jy)	$F_{\lambda 0}$ ($\text{erg second}^{-1} \text{cm}^{-2} \text{micron}^{-1}$)
V	0.56	3540	3.39×10^{-5}
R	0.70	2870	1.76×10^{-5}
I	0.90	2250	8.83×10^{-6}
J	1.25	1670	3.20×10^{-6}
H	1.65	980	1.08×10^{-6}
K	2.2	620	3.84×10^{-7}
L	3.4	280	7.26×10^{-8}
M	4.8	150	1.95×10^{-8}
N	10.1	37	1.09×10^{-9}
Q	20.0	10	7.5×10^{-11}

In Table 9, we display the zeropoints in the Johnson UBVRI+ system (see: Allen's Astrophysical Quantities, Fourth Edition, 2001, Arthur N. Cox (ed.), Springer-Verlag; Campins, Rieke, & Lebofsky 1985, AJ, 90, 896; Rieke, Lebofsky & Low 1985, AJ, 90, 900).

We have developed an online magnitude \leftrightarrow flux density converter. Check the SSC tools website: <http://ssc.spitzer.caltech.edu/warmmission/propkit/pet/>.

Table 9: The photometric zeropoints in the Johnson UBVR_I+ system

Band	λ (μm)	F_{v_0} (Jy)
U	0.36	1823
B	0.44	4130
V	0.55	3780
R	0.71	2941
I	0.97	2635
J	1.25	1603
H	1.60	1075
K	2.22	667
L	3.54	288
M	4.80	170
N	10.6	36
O	21.0	9.4

10.3 Conversion Among Surface Brightness Units

Typically in IR astronomy, surface brightness is measured in

magnitude/arcsec²

Jy/arcsec²

MJy/steradian.

The conversion between the latter two is straightforward:

$$S_v [\text{Jy}/\text{arc sec}^2] = 2.35 \times 10^{-5} S_v [\text{MJy}/\text{sr}] \quad (9)$$

Converting between Jy/arcsec² and magnitude/arcsec² is also straightforward. Using equation 7 we have

$$S_v [\text{mag}/\text{sq. arc sec}] = 2.51 \times \log_{10}(F_{v_0}) - \log_{10}(S_v [\text{Jy}/\text{sq. arc sec}]) \quad (10)$$

and hence

$$S_v [\text{mag}/\text{sq. arc sec}] = 2.51 \times \{\log_{10}(F_{v_0}) - \log_{10}(S_v [\text{Jy}/\text{sq. arc sec}]) + 4.63\} \quad (11)$$

For example, in the K-band, $F_{v_0} = 620$ Jy (see Table 8) and hence

$$18 \text{ mag}/\text{sq. arc sec} = 3.9 \times 10^{-5} \text{ Jy}/\text{sq. arc sec} = 1.7 \text{ MJy}/\text{sr} \quad (12)$$

11 Appendix: The AORs

We include here the AORs developed in the various preceding chapters. The ascii files ready to be loaded into Spot, can be downloaded from the SSC website:

<http://ssc.spitzer.caltech.edu/warmmission/propkit/cookbook/> .

11.1 Deep Imaging AORs

```
# Please edit this file with care to maintain the
# correct format so that SPOT can still read it.
# Generated by SPOT on: 8/6/2008 17:7:20

HEADER: FILE_VERSION=17.0, STATUS = PROPOSAL

      AOT_TYPE:  IRAC Post-Cryo Mapping
      AOR_LABEL:  IRAC Mapping - a2218 center position
      AOR_STATUS:  new

MOVING_TARGET:  NO
TARGET_TYPE:    FIXED SINGLE
TARGET_NAME:    Abell 2218
COORD_SYSTEM:   Equatorial J2000
      POSITION:   RA_LON=16h35m53.99s,  DEC_LAT=+66d13m00.2s,
PM_RA=0.0", PM_DEC=0.0", EPOCH=2000.0
OBJECT_AVOIDANCE:  EARTH = YES, OTHERS = YES

      READOUT_MODE:  FULL_ARRAY
                  ARRAY: 36u=YES, 45u=YES
      DATA_COLLECTION: 36u=YES, 45u=YES
      HI_DYNAMIC:  NO
      FRAME_TIME: 100.0
      DITHER_PATTERN: TYPE=Cycling, N_POSITION=49, START_POINT=10
      DITHER_SCALE: medium
      N_FRAMES_PER_POINTING: 1
SPECIAL: IMPACT = none, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
RESOURCE_EST: TOTAL_DURATION=11079.2, SLEW_TIME=399.1,
SETTLE_TIME=410.0, SLEW_OVERHEAD=215.0, SPECIAL_OVERHEAD=0.0,
UPLINK_VOLUME=4075, DOWNLINK_VOLUME=15119600, VERSION=S18.0.1
INTEGRATION_TIME:
IRAC_3_6=4900.0, IRAC_4_5=4900.0, IRAC_5_8=0.0, IRAC_8_0=0.0

      AOT_TYPE:  IRAC Post-Cryo Mapping
      AOR_LABEL:  IRAC Mapping - a1689 center position
      AOR_STATUS:  new

MOVING_TARGET:  NO
TARGET_TYPE:    FIXED SINGLE
TARGET_NAME:    Abell 1689
COORD_SYSTEM:   Equatorial J2000
      POSITION:   RA_LON=13h11m34.20s,  DEC_LAT=-1d21m55.5s, PM_RA=0.0",
PM_DEC=0.0", EPOCH=2000.0
```

OBJECT_AVOIDANCE: EARTH = YES, OTHERS = YES

READOUT_MODE: FULL_ARRAY
 ARRAY: 36u=YES, 45u=YES
 DATA_COLLECTION: 36u=YES, 45u=YES
 HI_DYNAMIC: NO
 FRAME_TIME: 100.0
 DITHER_PATTERN: TYPE=Cycling, N_POSITION=49, START_POINT=10
 DITHER_SCALE: medium
 N_FRAMES_PER_POINTING: 1
 SPECIAL: IMPACT = none, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
 RESOURCE_EST: TOTAL_DURATION=11075.0, SLEW_TIME=394.9,
 SETTLE_TIME=410.0, SLEW_OVERHEAD=215.0, SPECIAL_OVERHEAD=0.0,
 UPLINK_VOLUME=4075, DOWNLINK_VOLUME=15119600, VERSION=S18.0.1
 INTEGRATION_TIME:
 IRAC_3_6=4900.0, IRAC_4_5=4900.0, IRAC_5_8=0.0, IRAC_8_0=0.0

AOT_TYPE: IRAC Post-Cryo Mapping
 AOR_LABEL: IRAC Mapping - a665 center position
 AOR_STATUS: new

MOVING_TARGET: NO
 TARGET_TYPE: FIXED SINGLE
 TARGET_NAME: Abell 665
 COORD_SYSTEM: Equatorial J2000
 POSITION: RA_LON=8h30m45.19s, DEC_LAT=+65d52m55.3s, PM_RA=0.0",
 PM_DEC=0.0", EPOCH=2000.0
 OBJECT_AVOIDANCE: EARTH = YES, OTHERS = YES

READOUT_MODE: FULL_ARRAY
 ARRAY: 36u=YES, 45u=YES
 DATA_COLLECTION: 36u=YES, 45u=YES
 HI_DYNAMIC: NO
 FRAME_TIME: 100.0
 DITHER_PATTERN: TYPE=Cycling, N_POSITION=49, START_POINT=10
 DITHER_SCALE: medium
 N_FRAMES_PER_POINTING: 1
 SPECIAL: IMPACT = none, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
 RESOURCE_EST: TOTAL_DURATION=11075.9, SLEW_TIME=395.8,
 SETTLE_TIME=410.0, SLEW_OVERHEAD=215.0, SPECIAL_OVERHEAD=0.0,
 UPLINK_VOLUME=4075, DOWNLINK_VOLUME=15119600, VERSION=S18.0.1
 INTEGRATION_TIME:
 IRAC_3_6=4900.0, IRAC_4_5=4900.0, IRAC_5_8=0.0, IRAC_8_0=0.0

AOT_TYPE: IRAC Post-Cryo Mapping
 AOR_LABEL: IRAC Mapping - ac114 center position
 AOR_STATUS: new

MOVING_TARGET: NO

TARGET_TYPE: FIXED SINGLE
 TARGET_NAME: AC114
 COORD_SYSTEM: Equatorial J2000
 POSITION: RA_LON=22h58m52.34s, DEC_LAT=-34d46m54.6s,
 PM_RA=0.0", PM_DEC=0.0", EPOCH=2000.0
 OBJECT_AVOIDANCE: EARTH = YES, OTHERS = YES

READOUT_MODE: FULL_ARRAY
 ARRAY: 36u=YES, 45u=YES
 DATA_COLLECTION: 36u=YES, 45u=YES
 HI_DYNAMIC: NO
 FRAME_TIME: 100.0
 DITHER_PATTERN: TYPE=Cycling, N_POSITION=49, START_POINT=10
 DITHER_SCALE: medium
 N_FRAMES_PER_POINTING: 1
 SPECIAL: IMPACT = none, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
 RESOURCE_EST: TOTAL_DURATION=11074.4, SLEW_TIME=394.3,
 SETTLE_TIME=410.0, SLEW_OVERHEAD=215.0, SPECIAL_OVERHEAD=0.0,
 UPLINK_VOLUME=4075, DOWNLINK_VOLUME=15119600, VERSION=S18.0.1
 INTEGRATION_TIME:
 IRAC_3_6=4900.0, IRAC_4_5=4900.0, IRAC_5_8=0.0, IRAC_8_0=0.0

AOT_TYPE: IRAC Post-Cryo Mapping
 AOR_LABEL: IRAC Mapping - C10024+16 center position
 AOR_STATUS: new

MOVING_TARGET: NO
 TARGET_TYPE: FIXED SINGLE
 TARGET_NAME: ZwC10024.0+16.52
 COORD_SYSTEM: Equatorial J2000
 POSITION: RA_LON=0h26m36.01s, DEC_LAT=+17d08m36.1s, PM_RA=0.0",
 PM_DEC=0.0", EPOCH=2000.0
 OBJECT_AVOIDANCE: EARTH = YES, OTHERS = YES

READOUT_MODE: FULL_ARRAY
 ARRAY: 36u=YES, 45u=YES
 DATA_COLLECTION: 36u=YES, 45u=YES
 HI_DYNAMIC: NO
 FRAME_TIME: 100.0
 DITHER_PATTERN: TYPE=Cycling, N_POSITION=49, START_POINT=10
 DITHER_SCALE: medium
 N_FRAMES_PER_POINTING: 1
 SPECIAL: IMPACT = none, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
 RESOURCE_EST: TOTAL_DURATION=11073.8, SLEW_TIME=393.7,
 SETTLE_TIME=410.0, SLEW_OVERHEAD=215.0, SPECIAL_OVERHEAD=0.0,
 UPLINK_VOLUME=4075, DOWNLINK_VOLUME=15119600, VERSION=S18.0.1
 INTEGRATION_TIME:
 IRAC_3_6=4900.0, IRAC_4_5=4900.0, IRAC_5_8=0.0, IRAC_8_0=0.0

11.2 Survey AORs

```
# Please edit this file with care to maintain the
# correct format so that SPOT can still read it.
# Generated by SPOT on: 8/7/2008 18:23:14

HEADER: FILE_VERSION=17.0, STATUS = PROPOSAL

      AOT_TYPE:  IRAC Post-Cryo Mapping
      AOR_LABEL:  IRACPC scan center
      AOR_STATUS: new

MOVING_TARGET: NO
TARGET_TYPE:  FIXED SINGLE
TARGET_NAME:  Trapezium
COORD_SYSTEM: Equatorial J2000
      POSITION:  RA_LON=5h35m19.92s,  DEC_LAT=-5d23m06.0s,
PM_RA=0.0020", PM_DEC=-0.0010", EPOCH=2000.0
OBJECT_AVOIDANCE:  EARTH = YES, OTHERS = YES

      READOUT_MODE: FULL_ARRAY
                  ARRAY: 36u=YES, 45u=YES
DATA_COLLECTION: 36u=YES, 45u=YES
      HI_DYNAMIC: YES
      FRAME_TIME: 6.0
      DITHER_PATTERN: TYPE=Cycling, N_POSITION=3, START_POINT=85
      DITHER_SCALE: medium
      N_FRAMES_PER_POINTING: 1
MAP: TYPE=RECTANGULAR, ROWS=13, COLS=13, ROW_STEP=260.0,
COL_STEP=260.0,
      ORIENT=ARRAY, ROW_OFFSET=0.0, COL_OFFSET=0.0, N_CYCLE=1
SPECIAL: IMPACT = none, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
RESOURCE_EST: TOTAL_DURATION=10381.2, SLEW_TIME=2661.6,
SETTLE_TIME=2311.0, SLEW_OVERHEAD=215.0, SPECIAL_OVERHEAD=0.0,
UPLINK_VOLUME=22285, DOWNLINK_VOLUME=153312744, VERSION=S18.0.1
INTEGRATION_TIME: IRAC_3_6=18.0, IRAC_4_5=18.0, IRAC_5_8=0.0, IRAC_8_0=0.0
```

11.3 SSO AORs

```
# Please edit this file with care to maintain the
# correct format so that SPOT can still read it.
# Generated by SPOT on: 8/18/2008 12:4:23

HEADER: FILE_VERSION=17.0, STATUS = PROPOSAL
```

```
      AOT_TYPE:  IRAC Post-Cryo Mapping
      AOR_LABEL:  IRAC-PC Asbolus
```

```

AOR_STATUS:  new

MOVING_TARGET:  YES
TARGET_TYPE:  MOVING SINGLE
TARGET_NAME:  8405 Asbolus
EPHEMERIS:  NAIF_ID=2008405, NAIF_NAME=8405 Asbolus
OBJECT_AVOIDANCE:  EARTH = YES, OTHERS = YES

      READOUT_MODE:  FULL_ARRAY
              ARRAY:  36u=YES, 45u=YES
DATA_COLLECTION:  36u=YES, 45u=YES
      HI_DYNAMIC:  NO
      FRAME_TIME:  100.0
      DITHER_PATTERN:  TYPE=Cycling, N_POSITION=9, START_POINT=1
      DITHER_SCALE:  medium
      N_FRAMES_PER_POINTING:  1
SPECIAL:  IMPACT = none, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
RESOURCE_EST:  TOTAL_DURATION=2560.2, SLEW_TIME=88.1, SETTLE_TIME=77.0,
SLEW_OVERHEAD=515.0, SPECIAL_OVERHEAD=0.0, UPLINK_VOLUME=1217,
DOWNLINK_VOLUME=3023920, VERSION=S18.1.0
INTEGRATION_TIME:
IRAC_3_6=900.0, IRAC_4_5=900.0, IRAC_5_8=0.0, IRAC_8_0=0.0

```

```

AOT_TYPE:  IRAC Post-Cryo Mapping
AOR_LABEL:  IRAC-PC Asbolus Shadow
AOR_STATUS:  new

```

```

MOVING_TARGET:  YES
TARGET_TYPE:  MOVING SINGLE
TARGET_NAME:  8405 Asbolus
EPHEMERIS:  NAIF_ID=2008405, NAIF_NAME=8405 Asbolus
OBJECT_AVOIDANCE:  EARTH = YES, OTHERS = YES

```

```

      READOUT_MODE:  FULL_ARRAY
              ARRAY:  36u=YES, 45u=YES
DATA_COLLECTION:  36u=YES, 45u=YES
      HI_DYNAMIC:  NO
      FRAME_TIME:  100.0
      DITHER_PATTERN:  TYPE=Cycling, N_POSITION=9, START_POINT=1
      DITHER_SCALE:  medium
      N_FRAMES_PER_POINTING:  1
SPECIAL:  IMPACT = none, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
RESOURCE_EST:  TOTAL_DURATION=2560.2, SLEW_TIME=88.1, SETTLE_TIME=77.0,
SLEW_OVERHEAD=515.0, SPECIAL_OVERHEAD=0.0, UPLINK_VOLUME=1217,
DOWNLINK_VOLUME=3023920, VERSION=S18.1.0
INTEGRATION_TIME:
IRAC_3_6=900.0, IRAC_4_5=900.0, IRAC_5_8=0.0, IRAC_8_0=0.0

```

```

CONSTRAINT:  TYPE=SHADOW, NAME=Shadow-0000, SHADOW_BEFORE_PRIMARY=NO

```

```
RANGE_START: DAYS=0, TIME=00:16:00
  RANGE_END: DAYS=3, TIME=00:00:00
    AORS: AOR_PRIMARY=IRAC-PC Asbolus, AOR_SHADOW=IRAC-PC Asbolus
Shadow
```

11.4 Time Series AORs

```
# Please edit this file with care to maintain the
# correct format so that SPOT can still read it.
# Generated by SPOT on: 11/16/2018 18:39:16
```

```
HEADER: FILE_VERSION=17.0, STATUS = PROPOSAL
```

```
  AOT_TYPE: IRAC Post-Cryo Mapping
  AOR_LABEL: BD+60_1753_start
  AOR_STATUS: new
```

```
MOVING_TARGET: NO
  TARGET_TYPE: FIXED CLUSTER - OFFSETS
  TARGET_NAME: BD+60_1753_sky
  COORD_SYSTEM: Equatorial J2000
  POSITION1: RA_LON=17h24m48.1000s, DEC_LAT=+60d26m45.000s,
PM_RA=0.0", PM_DEC=0.0", EPOCH=2000.0
  OFFSET_P2: EAST_ROW_PERP=-3.000", NORTH_COL_PARA=3.000"
  OFFSET_P3: EAST_ROW_PERP=-3.000", NORTH_COL_PARA=0.000"
  OFFSET_P4: EAST_ROW_PERP=-3.000", NORTH_COL_PARA=-3.000"
  OFFSET_P5: EAST_ROW_PERP=0.000", NORTH_COL_PARA=-3.000"
  OFFSET_P6: EAST_ROW_PERP=3.000", NORTH_COL_PARA=-3.000"
  OFFSET_P7: EAST_ROW_PERP=3.000", NORTH_COL_PARA=0.000"
  OFFSET_P8: EAST_ROW_PERP=3.000", NORTH_COL_PARA=3.000"
  OFFSET_P9: EAST_ROW_PERP=0.000", NORTH_COL_PARA=3.000"
  OFFSET_P10: EAST_ROW_PERP=0.000", NORTH_COL_PARA=0.000"
  OFFSET_P11: EAST_ROW_PERP=-3.000", NORTH_COL_PARA=2.000"
  OFFSET_P12: EAST_ROW_PERP=-3.000", NORTH_COL_PARA=-2.000"
OFFSETS_IN_ARRAY: YES
OBSERVE_OFFSETS_ONLY: YES
OBJECT_AVOIDANCE: EARTH = YES, OTHERS = YES
```

```
  READOUT_MODE: SUBARRAY
    ARRAY: 36u=YES, 45u=NO
  DATA_COLLECTION: 36u=YES, 45u=NO
    HI_DYNAMIC: NO
    FRAME_TIME: 2.0
  DITHER_PATTERN: TYPE=none
  N_FRAMES_PER_POINTING: 1
SPECIAL: IMPACT = none, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
RESOURCE_EST: TOTAL_DURATION=1717.7, SLEW_TIME=15.0, SETTLE_TIME=40.0,
SLEW_OVERHEAD=210.0, SPECIAL_OVERHEAD=0.0, UPLINK_VOLUME=840,
DOWNLINK_VOLUME=761915, VERSION=S19.7.5
INTEGRATION_TIME: IRAC_3_6=128.0, IRAC_4_5=0.0, IRAC_5_8=0.0, IRAC_8_0=0.0
TIMING1: START_DATE=2019 Jun 3, START_TIME=15:00:00, END_DATE=2019 Jun
3, END_TIME=15:30:00
```

TIMING2: START_DATE=2019 Jun 6, START_TIME=15:00:00, END_DATE=2019 Jun 6, END_TIME=15:30:00
TIMING3: START_DATE=2019 Jun 9, START_TIME=15:00:00, END_DATE=2019 Jun 9, END_TIME=15:30:00
TIMING4: START_DATE=2019 Jun 12, START_TIME=15:00:00, END_DATE=2019 Jun 12, END_TIME=15:30:00
TIMING5: START_DATE=2019 Jun 15, START_TIME=15:00:00, END_DATE=2019 Jun 15, END_TIME=15:30:00
TIMING6: START_DATE=2019 Jun 18, START_TIME=15:00:00, END_DATE=2019 Jun 18, END_TIME=15:30:00
TIMING7: START_DATE=2019 Jun 21, START_TIME=15:00:00, END_DATE=2019 Jun 21, END_TIME=15:30:00
TIMING8: START_DATE=2019 Jun 24, START_TIME=15:00:00, END_DATE=2019 Jun 24, END_TIME=15:30:00
TIMING9: START_DATE=2019 Jun 27, START_TIME=15:00:00, END_DATE=2019 Jun 27, END_TIME=15:30:00
TIMING10: START_DATE=2019 Jun 30, START_TIME=15:00:00, END_DATE=2019 Jun 30, END_TIME=15:30:00
TIMING11: START_DATE=2019 Jul 3, START_TIME=15:00:00, END_DATE=2019 Jul 3, END_TIME=15:30:00

AOT_TYPE: IRAC Post-Cryo Mapping
AOR_LABEL: BD+60_1753-ch1-1
AOR_STATUS: new

MOVING_TARGET: NO
TARGET_TYPE: FIXED CLUSTER - OFFSETS
TARGET_NAME: BD+60 1753
COORD_SYSTEM: Equatorial J2000
POSITION1: RA_LON=17h24m52.2772s, DEC_LAT=+60d25m50.781s,
PM_RA=0.0040", PM_DEC=0.0020", EPOCH=2000.0
OFFSET_P2: EAST_ROW_PERP=-0.352", NORTH_COL_PARA=0.064"
OFFSETS_IN_ARRAY: YES
OBSERVE_OFFSETS_ONLY: YES
OBJECT_AVOIDANCE: EARTH = YES, OTHERS = YES

PCRS_PEAK_UP: RA_OFFSET=0.0", DEC_OFFSET=0.0", FLUX_DENSITY=9.65
READOUT_MODE: SUBARRAY
ARRAY: 36u=YES, 45u=NO
DATA_COLLECTION: 36u=YES, 45u=NO
HI_DYNAMIC: NO
FRAME_TIME: 2.0
DITHER_PATTERN: TYPE=none
N_FRAMES_PER_POINTING: 330
SPECIAL: IMPACT = none, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
RESOURCE_EST: TOTAL_DURATION=43099.152, SLEW_TIME=18.5,
SETTLE_TIME=13.653619, SLEW_OVERHEAD=210.0, SPECIAL_OVERHEAD=0.0,
UPLINK_VOLUME=639, DOWNLINK_VOLUME=22857450, VERSION=S19.7.5
INTEGRATION_TIME:
IRAC_3_6=42240.0, IRAC_4_5=0.0, IRAC_5_8=0.0, IRAC_8_0=0.0

```

AOT_TYPE: IRAC Post-Cryo Mapping
AOR_LABEL: BD+60_1753-ch1-2
AOR_STATUS: new

MOVING_TARGET: NO
TARGET_TYPE: FIXED CLUSTER - OFFSETS
TARGET_NAME: BD+60 1753
COORD_SYSTEM: Equatorial J2000
POSITION1: RA_LON=17h24m52.2772s, DEC_LAT=+60d25m50.781s,
PM_RA=0.0040", PM_DEC=0.0020", EPOCH=2000.0
OFFSET_P2: EAST_ROW_PERP=-0.352", NORTH_COL_PARA=0.064"
OFFSETS_IN_ARRAY: YES
OBSERVE_OFFSETS_ONLY: YES
OBJECT_AVOIDANCE: EARTH = YES, OTHERS = YES

PCRS_PEAK_UP: RA_OFFSET=0.0", DEC_OFFSET=0.0", FLUX_DENSITY=9.65
READOUT_MODE: SUBARRAY
ARRAY: 36u=YES, 45u=NO
DATA_COLLECTION: 36u=YES, 45u=NO
HI_DYNAMIC: NO
FRAME_TIME: 2.0
DITHER_PATTERN: TYPE=none
N_FRAMES_PER_POINTING: 330
SPECIAL: IMPACT = none, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
RESOURCE_EST: TOTAL_DURATION=43099.152, SLEW_TIME=18.5,
SETTLE_TIME=13.653619, SLEW_OVERHEAD=210.0, SPECIAL_OVERHEAD=0.0,
UPLINK_VOLUME=639, DOWNLINK_VOLUME=22857450, VERSION=S19.7.5
INTEGRATION_TIME:
IRAC_3_6=42240.0, IRAC_4_5=0.0, IRAC_5_8=0.0, IRAC_8_0=0.0

```

```

AOT_TYPE: IRAC Post-Cryo Mapping
AOR_LABEL: BD+60_1753-ch1-3
AOR_STATUS: new

MOVING_TARGET: NO
TARGET_TYPE: FIXED CLUSTER - OFFSETS
TARGET_NAME: BD+60 1753
COORD_SYSTEM: Equatorial J2000
POSITION1: RA_LON=17h24m52.2772s, DEC_LAT=+60d25m50.781s,
PM_RA=0.0040", PM_DEC=0.0020", EPOCH=2000.0
OFFSET_P2: EAST_ROW_PERP=-0.352", NORTH_COL_PARA=0.064"
OFFSETS_IN_ARRAY: YES
OBSERVE_OFFSETS_ONLY: YES
OBJECT_AVOIDANCE: EARTH = YES, OTHERS = YES

PCRS_PEAK_UP: RA_OFFSET=0.0", DEC_OFFSET=0.0", FLUX_DENSITY=9.65
READOUT_MODE: SUBARRAY
ARRAY: 36u=YES, 45u=NO
DATA_COLLECTION: 36u=YES, 45u=NO
HI_DYNAMIC: NO

```

```

FRAME_TIME: 2.0
DITHER_PATTERN: TYPE=none
N_FRAMES_PER_POINTING: 330
SPECIAL: IMPACT = none, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
RESOURCE_EST: TOTAL_DURATION=43099.152, SLEW_TIME=18.5,
SETTLE_TIME=13.653619, SLEW_OVERHEAD=210.0, SPECIAL_OVERHEAD=0.0,
UPLINK_VOLUME=639, DOWNLINK_VOLUME=22857450, VERSION=S19.7.5
INTEGRATION_TIME:
IRAC_3_6=42240.0, IRAC_4_5=0.0, IRAC_5_8=0.0, IRAC_8_0=0.0

```

```

AOT_TYPE: IRAC Post-Cryo Mapping
AOR_LABEL: BD+60_1753-ch1-4
AOR_STATUS: new

```

```

MOVING_TARGET: NO
TARGET_TYPE: FIXED CLUSTER - OFFSETS
TARGET_NAME: BD+60 1753
COORD_SYSTEM: Equatorial J2000
POSITION1: RA_LON=17h24m52.2772s, DEC_LAT=+60d25m50.781s,
PM_RA=0.0040", PM_DEC=0.0020", EPOCH=2000.0
OFFSET_P2: EAST_ROW_PERP=-0.352", NORTH_COL_PARA=0.064"
OFFSETS_IN_ARRAY: YES
OBSERVE_OFFSETS_ONLY: YES
OBJECT_AVOIDANCE: EARTH = YES, OTHERS = YES

```

```

PCRS_PEAK_UP: RA_OFFSET=0.0", DEC_OFFSET=0.0", FLUX_DENSITY=9.65
READOUT_MODE: SUBARRAY
ARRAY: 36u=YES, 45u=NO
DATA_COLLECTION: 36u=YES, 45u=NO
HI_DYNAMIC: NO
FRAME_TIME: 2.0
DITHER_PATTERN: TYPE=none
N_FRAMES_PER_POINTING: 330
SPECIAL: IMPACT = none, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
RESOURCE_EST: TOTAL_DURATION=43099.152, SLEW_TIME=18.5,
SETTLE_TIME=13.653619, SLEW_OVERHEAD=210.0, SPECIAL_OVERHEAD=0.0,
UPLINK_VOLUME=639, DOWNLINK_VOLUME=22857450, VERSION=S19.7.5
INTEGRATION_TIME:
IRAC_3_6=42240.0, IRAC_4_5=0.0, IRAC_5_8=0.0, IRAC_8_0=0.0

```

```

AOT_TYPE: IRAC Post-Cryo Mapping
AOR_LABEL: BD+60_1753-ch1-5
AOR_STATUS: new

```

```

MOVING_TARGET: NO
TARGET_TYPE: FIXED CLUSTER - OFFSETS
TARGET_NAME: BD+60 1753
COORD_SYSTEM: Equatorial J2000

```

POSITION1: RA_LON=17h24m52.2772s, DEC_LAT=+60d25m50.781s,
 PM_RA=0.0040", PM_DEC=0.0020", EPOCH=2000.0
 OFFSET_P2: EAST_ROW_PERP=-0.352", NORTH_COL_PARA=0.064"
 OFFSETS_IN_ARRAY: YES
 OBSERVE_OFFSETS_ONLY: YES
 OBJECT_AVOIDANCE: EARTH = YES, OTHERS = YES

 PCRS_PEAK_UP: RA_OFFSET=0.0", DEC_OFFSET=0.0", FLUX_DENSITY=9.65
 READOUT_MODE: SUBARRAY
 ARRAY: 36u=YES, 45u=NO
 DATA_COLLECTION: 36u=YES, 45u=NO
 HI_DYNAMIC: NO
 FRAME_TIME: 2.0
 DITHER_PATTERN: TYPE=none
 N_FRAMES_PER_POINTING: 330
 SPECIAL: IMPACT = none, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
 RESOURCE_EST: TOTAL_DURATION=43099.152, SLEW_TIME=18.5,
 SETTLE_TIME=13.653619, SLEW_OVERHEAD=210.0, SPECIAL_OVERHEAD=0.0,
 UPLINK_VOLUME=639, DOWNLINK_VOLUME=22857450, VERSION=S19.7.5
 INTEGRATION_TIME:
 IRAC_3_6=42240.0, IRAC_4_5=0.0, IRAC_5_8=0.0, IRAC_8_0=0.0

AOT_TYPE: IRAC Post-Cryo Mapping
 AOR_LABEL: BD+60_1753-ch1-6
 AOR_STATUS: new

MOVING_TARGET: NO
 TARGET_TYPE: FIXED CLUSTER - OFFSETS
 TARGET_NAME: BD+60 1753
 COORD_SYSTEM: Equatorial J2000
 POSITION1: RA_LON=17h24m52.2772s, DEC_LAT=+60d25m50.781s,
 PM_RA=0.0040", PM_DEC=0.0020", EPOCH=2000.0
 OFFSET_P2: EAST_ROW_PERP=-0.352", NORTH_COL_PARA=0.064"
 OFFSETS_IN_ARRAY: YES
 OBSERVE_OFFSETS_ONLY: YES
 OBJECT_AVOIDANCE: EARTH = YES, OTHERS = YES

PCRS_PEAK_UP: RA_OFFSET=0.0", DEC_OFFSET=0.0", FLUX_DENSITY=9.65
 READOUT_MODE: SUBARRAY
 ARRAY: 36u=YES, 45u=NO
 DATA_COLLECTION: 36u=YES, 45u=NO
 HI_DYNAMIC: NO
 FRAME_TIME: 2.0
 DITHER_PATTERN: TYPE=none
 N_FRAMES_PER_POINTING: 330
 SPECIAL: IMPACT = none, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
 RESOURCE_EST: TOTAL_DURATION=43099.152, SLEW_TIME=18.5,
 SETTLE_TIME=13.653619, SLEW_OVERHEAD=210.0, SPECIAL_OVERHEAD=0.0,
 UPLINK_VOLUME=639, DOWNLINK_VOLUME=22857450, VERSION=S19.7.5
 INTEGRATION_TIME:
 IRAC_3_6=42240.0, IRAC_4_5=0.0, IRAC_5_8=0.0, IRAC_8_0=0.0

```

AOT_TYPE:  IRAC Post-Cryo Mapping
AOR_LABEL:  BD+60_1753_end
AOR_STATUS: new

MOVING_TARGET:  NO
TARGET_TYPE:  FIXED SINGLE
TARGET_NAME:  BD+60_1753_sky_single
COORD_SYSTEM:  Equatorial J2000
POSITION:  RA_LON=17h24m48.1000s,  DEC_LAT=+60d26m45.000s,
PM_RA=0.0",  PM_DEC=0.0",  EPOCH=2000.0
OBJECT_AVOIDANCE:  EARTH = YES,  OTHERS = YES

READOUT_MODE:  SUBARRAY
ARRAY:  36u=YES,  45u=NO
DATA_COLLECTION:  36u=YES,  45u=NO
HI_DYNAMIC:  NO
FRAME_TIME:  2.0
DITHER_PATTERN:  TYPE=SubGaussian4
DITHER_SCALE:  medium
N_FRAMES_PER_POINTING:  1
SPECIAL:  IMPACT = none,  LATE_EPHEMERIS = NO,  SECOND_LOOK = NO
RESOURCE_EST:  TOTAL_DURATION=768.2,  SLEW_TIME=4.9,  SETTLE_TIME=12.0,
SLEW_OVERHEAD=210.0,  SPECIAL_OVERHEAD=0.0,  UPLINK_VOLUME=588,
DOWNLINK_VOLUME=277060,  VERSION=S19.7.5
INTEGRATION_TIME:  IRAC_3_6=512.0,  IRAC_4_5=0.0,  IRAC_5_8=0.0,  IRAC_8_0=0.0

CONSTRAINT:  TYPE=CHAIN,  NAME=Chain-BD+60_1753_ch1
AORS:  AOR1=BD+60_1753_start,
AOR2=BD+60_1753-ch1-1,
AOR3=BD+60_1753-ch1-2,
AOR4=BD+60_1753-ch1-3,
AOR5=BD+60_1753-ch1-4,
AOR6=BD+60_1753-ch1-5,
AOR7=BD+60_1753-ch1-6,
AOR8=BD+60_1753_end

```

11.5 Target of Opportunity AORs

```

# Please edit this file with care to maintain the
# correct format so that SPOT can still read it.
# Generated by SPOT on:  8/18/2008    15:24:1

```

```

HEADER:  FILE_VERSION=17.0,  STATUS = PROPOSAL

```

```

AOT_TYPE:  IRAC Post-Cryo Mapping
AOR_LABEL:  ToO - IRAC epoch1
AOR_STATUS: new

MOVING_TARGET: NO
TARGET_TYPE: FIXED SINGLE
TARGET_NAME: M31 red variable
COORD_SYSTEM: Equatorial J2000
POSITION:  RA_LON=0h43m02.43s,  DEC_LAT=+41d12m56.2s,  PM_RA=0.0",
PM_DEC=0.0",  EPOCH=2000.0
OBJECT_AVOIDANCE:  EARTH = YES,  OTHERS = YES

READOUT_MODE: FULL_ARRAY
ARRAY: 36u=YES, 45u=YES
DATA_COLLECTION: 36u=YES, 45u=YES
HI_DYNAMIC: NO
FRAME_TIME: 12.0
DITHER_PATTERN: TYPE=Gaussian5
DITHER_SCALE: medium
N_FRAMES_PER_POINTING: 1
SPECIAL: IMPACT = medImpactToo1, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
RESOURCE_EST: TOTAL_DURATION=9815.5, SLEW_TIME=39.0, SETTLE_TIME=38.0,
SLEW_OVERHEAD=215.0, SPECIAL_OVERHEAD=9360.0, UPLINK_VOLUME=848,
DOWNLINK_VOLUME=1663156, VERSION=S18.1.0
INTEGRATION_TIME: IRAC_3_6=60.0, IRAC_4_5=60.0, IRAC_5_8=0.0, IRAC_8_0=0.0

```

```

AOT_TYPE:  IRAC Post-Cryo Mapping
AOR_LABEL:  ToO - IRAC epoch2
AOR_STATUS: new

MOVING_TARGET: NO
TARGET_TYPE: FIXED SINGLE
TARGET_NAME: M31 red variable
COORD_SYSTEM: Equatorial J2000
POSITION:  RA_LON=0h43m02.43s,  DEC_LAT=+41d12m56.2s,  PM_RA=0.0",
PM_DEC=0.0",  EPOCH=2000.0
OBJECT_AVOIDANCE:  EARTH = YES,  OTHERS = YES

READOUT_MODE: FULL_ARRAY
ARRAY: 36u=YES, 45u=YES
DATA_COLLECTION: 36u=YES, 45u=YES
HI_DYNAMIC: NO
FRAME_TIME: 12.0
DITHER_PATTERN: TYPE=Gaussian5
DITHER_SCALE: medium
N_FRAMES_PER_POINTING: 1
SPECIAL: IMPACT = medImpactToo1, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
RESOURCE_EST: TOTAL_DURATION=9815.5, SLEW_TIME=39.0, SETTLE_TIME=38.0,
SLEW_OVERHEAD=215.0, SPECIAL_OVERHEAD=9360.0, UPLINK_VOLUME=848,
DOWNLINK_VOLUME=1663156, VERSION=S18.1.0
INTEGRATION_TIME: IRAC_3_6=60.0, IRAC_4_5=60.0, IRAC_5_8=0.0, IRAC_8_0=0.0

```

```

AOT_TYPE: IRAC Post-Cryo Mapping
AOR_LABEL: ToO - IRAC epoch3
AOR_STATUS: new

MOVING_TARGET: NO
TARGET_TYPE: FIXED SINGLE
TARGET_NAME: M31 red variable
COORD_SYSTEM: Equatorial J2000
POSITION: RA_LON=0h43m02.43s, DEC_LAT=+41d12m56.2s, PM_RA=0.0",
PM_DEC=0.0", EPOCH=2000.0
OBJECT_AVOIDANCE: EARTH = YES, OTHERS = YES

READOUT_MODE: FULL_ARRAY
ARRAY: 36u=YES, 45u=YES
DATA_COLLECTION: 36u=YES, 45u=YES
HI_DYNAMIC: NO
FRAME_TIME: 12.0
DITHER_PATTERN: TYPE=Gaussian5
DITHER_SCALE: medium
N_FRAMES_PER_POINTING: 1
SPECIAL: IMPACT = medImpactToo1, LATE_EPHEMERIS = NO, SECOND_LOOK = NO
RESOURCE_EST: TOTAL_DURATION=9815.5, SLEW_TIME=39.0, SETTLE_TIME=38.0,
SLEW_OVERHEAD=215.0, SPECIAL_OVERHEAD=9360.0, UPLINK_VOLUME=848,
DOWNLINK_VOLUME=1663156, VERSION=S18.1.0
INTEGRATION_TIME: IRAC_3_6=60.0, IRAC_4_5=60.0, IRAC_5_8=0.0, IRAC_8_0=0.0

CONSTRAINT: TYPE=FOLLOW_ON, NAME=FollowOn-0000
RANGE_START: DAYS=5, TIME=00:00:00
RANGE_END: DAYS=10, TIME=00:00:00
AORS: AOR_FIRST=ToO - IRAC epoch1, AOR_SECOND=ToO - IRAC epoch2

CONSTRAINT: TYPE=FOLLOW_ON, NAME=FollowOn-0001
RANGE_START: DAYS=18, TIME=00:00:00
RANGE_END: DAYS=25, TIME=00:00:00
AORS: AOR_FIRST=ToO - IRAC epoch2, AOR_SECOND=ToO - IRAC epoch3

```