

# RTS2-F Primer Version 25

25 September 2015

## ABSTRACT

This document describes the RTS2-F system for autonomous operation of the FLWO 1.2m telescope with KeplerCam.

RTS2-F users are in one of two categories, with two distinct levels of requirements. Users interact with RTS2-F at two available layers of functionality. Category 1, the majority, interact with RTS2-F at the upper layer. These users operate on the target database and observing queues; they add input catalogs to the database and targets to the queues, monitor the progress of observations and eventually retrieve their data. Category 2 users interact with RTS2-F at the lower layer. These users include observers on-site, such as the 1.5m remote observers and occasionally Category 1 users, who may need to recover from system problems. This primer provides instructions on the usage of RTS2-F for both categories of users.

If you have comments or requests, please send them to Emilio Falco. To skip the details and read about starting/stopping RTS2-F, see §3.1. For troubleshooting guidelines, see Appendix 2.

## 1. Introduction

Petr Kubanek developed and deployed the RTS2 system over the past several years (see [www.rts2.org](http://www.rts2.org)). RTS2 is a software package that operates telescopes autonomously. A primary goal of RTS2 is to observe GRBs autonomously, reacting to detections such as by SWIFT as quickly as possible. Other targets of opportunity (TOOs) such as SNe are also ideal targets for RTS2. RTS2-F is Petr's adaptation of RTS2 to the FLWO 1.2m. We envision observations with the 1.2m similar to other RTS2 TOO observations, in addition to queues to direct the system to observe other targets from projects approved by the TAC.

Petr spent several weeks at FLWO in 4 separate visits; he continues working remotely on RTS2-F updates. Observers use RTS2-F for programs such as planetary transits, supernovae, monitoring gravitational lenses and gamma-ray sources, and GRB follow-up.

RTS2-F observes targets in its database. Each database entry is a target name with coordinates and constraints that control observations (e.g., priority, times of observation, cadence, filters, numbers of exposures). There are 5 modes of observations each night: (1) basic mode automatically selects targets based on their accessibility and priority, unless modes 2-5 are in control; (2) calibration queue (§2.8.4) observes photometric standards; (3) manual queue (§2.8.4) observes targets

such as planetary transits at specified times; (4) service queue (§2.8) observes targets in a specified sequence, e.g. a list of SNe; and (5) if an observer enables TOO interrupts, TOO mode (§2.10) observes targets of opportunity (TOOs), e.g. in response to a GCN GRB for a TAC-approved project.

Weather constraints (humidity, wind and precipitation) measured with the 1.5m/1.2m Vaisala station and with the MEarth Vaisala station determine whether the robot may operate, or whether it must shutdown the telescope until weather conditions return to acceptable. The robot also monitors additional weather measurements such as the MEarth sky temperature sensor, and the HAT rain sensor. Sky temperatures higher than a set limit indicate clouds, and if enabled, shutdown the telescope. On flwo48, watchdog jobs monitor the robot’s activity. They verify that the robot is running, that data are being acquired at night, that the dome is not open under weather conditions over closing thresholds (wind, RH, precipitation, clouds) and that the CCD is operating normally.

The robot may be used for all types of observations with Keplercam. We continue upgrading RTS2-F as we gain experience.

A pipeline system that will provide a standard reduction using standard calibrations of each night’s data remains a possibility, although it has not received excessive attention.

The following sections describe the RTS2-F database, the input catalogs used to build or update the database, the tools to set up queues, tools to monitor the status of observations and change the status of the system, the scripts that run the telescope, and additional tools to address nightly operations as necessary.

## **2. Category 1 users**

### **2.1. Modus operandi**

When it is enabled to operate (mode is ON or STANDBY), RTS2-F follows a prescribed sequence with appropriate waiting periods between activities (e.g., between dome flats, opening the dome slit and sky flats). The core of the system is its database of targets, built from user catalogs. The database and the catalogs are described in the following sections. RTS2-F classifies days into a repeating cycle of 6 states: day, evening (twilight), dusk, night, dawn, morning (twilight).

RTS2-F checks each exposure for counts below normal bias levels. If this rare condition occurs, the robot stops with an error message, because exposures will be useless unless the problem is corrected (e.g., the CCD software is restarted), see the Keplercam documentation for details.

RTS2-F prints in the Telshell command window each command it executes. It also records these in nightly files labeled /home/observer/ROBOT/LOGS/run-YYMMDD (in any xterm, SHOWlogs [YYMMDD] prints a log for today or for YYMMDD).

### 2.1.1. *Nightly observing sequence*

The RTS2-F servers should always be running. If they are not, first start them as described in §3.4.

Start by first enabling the robot, i.e., changing the system mode to ON with the “GOweather” GUI (§2.8.6) or the “MONrobot” xterm tool (§3.2) or with RTS2-G in a browser, and then typing “GOrobot” at the Telshell command window. This command invokes a script to perform the sequence that follows.

1. Anytime: Observers enter targets into the catalogs (§2.5) and/or the queues (§2.8.)
2. Anytime: Once started with “GOrobot” the robot continually tests for an on/off flag indicating that the command “STOProbot” (an alias to rts2-abort) has/has not been issued. If it finds the flag on, RTS2-F stops. The robot may also be stopped in an emergency by changing its mode to OFF with GOweather, MONrobot or RTS2-G. If this change occurs, RTS2-F closes the dome slit, stops exposing, stows the telescope and closes the mirror covers, in that order. Such a change of mode may also be triggered automatically by adverse weather, such as wind, humidity or sky temperature above current limits (§3.3). Weather conditions are best monitored with the GOweather GUI (§2.8.6). Notice that GOweather is different from STARTweather, which restarts weather sensing.
3. Afternoon: about one hour before dusk, with the dome slit closed and if the mode is ON or STANDBY, acquire standard biases and dome flats (number of biases and default BVri filters are listed in /home/observer/RTS2-F/FLATS/DOMEFILT). This step is performed regardless of weather conditions, as the dome slit remains closed. Skip this step with “GOrobot -D.” You can use an alternate file with the flag “-d” which uses the filters listed in /home/observer/RTS2-F/FLATS/ALTFILT, a link to a file of your choice.
4. Afternoon: the Keplercam dewar is filled automatically between 5 and 5:30 pm (varying seasonally).
5. Dusk: open the dome slit if the weather allows, and wait until it is sufficiently dark for sky flats.
6. Dusk: Acquire skyflats; exposures are adjusted to obtain mean levels of about 15K counts. The files /home/observer/ROBOT/FLATS/SKYFILT<sub>x</sub>, where x=1,2 contain the names of the skyflat filters, which may be changed by observer. The defaults are filters u and i. Skip evening (morning) sky flats with “GOrobot -e” ( “GOrobot -m”).
7. Dusk: after skyflats, reference the telescope position (find zenith) if requested. Request this step with “GOrobot -R” (see §2.9); the default is to skip it.
8. Dusk: measure the FWHM of stars at different telescope focus values and adjust focus to minimize the FWHM. Run by default. Skip this step with “GOrobot -F.”

9. Night: select accessible targets from the RTS2-F database (see §2.2) or use lists specified in the calibration, manual or service queues (see §2.8). Inclement weather may cause the telescope to shut down. Adjust focus after each exposure as a function of temperature, as described below.
10. Night: if the robot stops for any reason and is restarted later, it checks the status of the slit and mirror covers, and opens them if necessary. It then continues observations as in the previous step.
11. Dawn: about 20 minutes after the onset, if evening sky flats were not collected the previous evening, acquire sky flats.
12. Morning: stow the telescope and close the dome slit.
13. Morning: about 60 minutes before the dewar fill, if dome flats were not collected the previous evening, acquire dome flats.
14. Morning: the Keplercam dewar is filled automatically between 7 and 7:30 am (varying seasonally).
15. Day: at about 8am MST, software running at the TDC in Cambridge automatically transfers the night’s data to the archive in Cambridge. The process takes up to about 3 hours, depending on the number of files.

## 2.2. Database

The RTS2-F database contains one entry for each target. The contents may be viewed from any browser at CfA in Cambridge or at FLWO, but not from other sites. The home page is viewed with RTS2-G (G for GUI) on flwo48.sao.arizona.edu:8889. Access is restricted by username (rts2obs) and password (please request it from the staff). The database keeps track of observations and provides snapshots of the data.

The RTS2-G main page displays the links shown in Fig. 1. The most useful link to users, “Targets,” lists the contents of the database, as shown in Fig. 2.

The columns in Fig. 2 for each target are a Select box (for altitude plots at the bottom of the page), an internal ID number, Target Name, NOBS or number of observations in the database, the Priority, the Bonus (additional priority value determined from observing conditions), the status (Enabled), RA, DEC, and live altitude, azimuth and Violated or Satisfied constraints (airmass or lunarDistance).

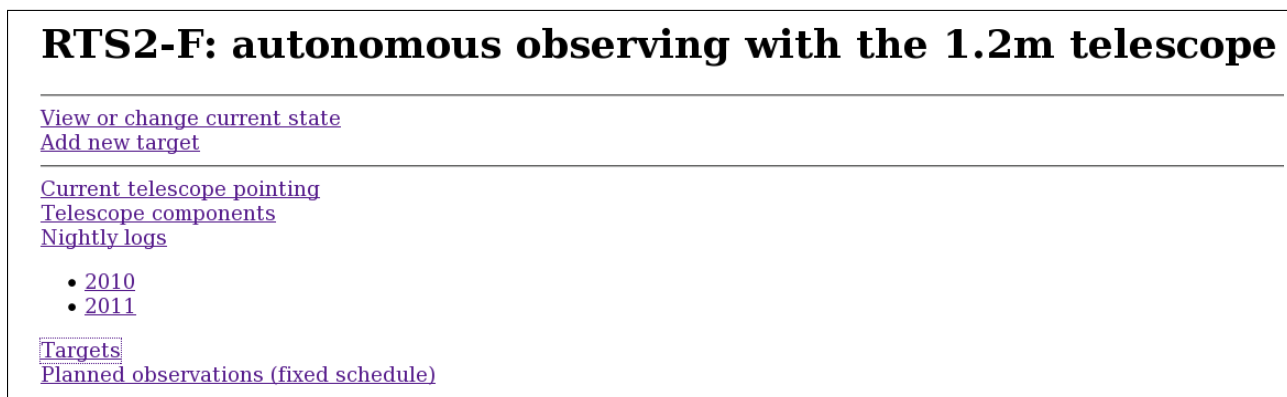


Fig. 1.— RTS2-G main page.

### 2.3. Science targets

Targets in the RTS2-F database may be viewed via the “Targets” link in RTS2-G. The description of each target includes an internal ID (assigned automatically), a name, a priority value (1-10 where 1 is lowest), a flag indicating the target is enabled or disabled, RA and DEC, as well as airmass and lunar distance constraints. For each target, the system lists the current number of observations, as well as its live altitude and azimuth. It also shows whether the constraints are currently violated or satisfied.

A summary for each target may also be viewed on any xterm with the *rts2-targetinfo* command (see §3.2).

Observers may monitor the progress of observations during the night with RTS2-G. For each target, there is a link with detailed information, such as the target RA, DEC, Alt, Az, Priority, as well as LST and JD. Additional links shown in Fig. 3 provide more detailed target information:

1. The “details” link provides all the information necessary for observations, based on the input catalog that provided the target to the database.
2. The “statistics” link shows the dates of the first and the last observation, the total number of existing observations and images, and the total shutter open time for these observations.
3. The “images” link provides thumbnail JPG views of the existing observations.
4. The “observations” link shows the existing observations with links to the thumbnails.
5. The “plan” link shows the list of entries observed or to be observed at fixed dates and times over long periods (not implemented yet).
6. The “altitude plot” link shows what its name suggests for the current night.

Select	ID	Target name	NOBS	Priority	Bonus	Enabled	RA	DEC	Alt	Az	Violated	Satisfied
<input type="checkbox"/>	2	<a href="#">flat target</a>	0	0	0	<input checked="" type="checkbox"/>	05:55:28.66	+37°25'44.82"	+60° 248°			airmass
<input type="checkbox"/>	3	<a href="#">Focusing frames</a>	0	0	0	<input checked="" type="checkbox"/>	00:00:00.00	+00°00'00.00"	+30° 68°	airmass		
<input type="checkbox"/>	4	<a href="#">Default model</a>	1	1	1	<input checked="" type="checkbox"/>	03:26:43.44	-20°37'26.40"	+37° 01°	airmass		
.....												
<input type="checkbox"/>	1287	<a href="#">sn11an</a>	2	1000	1032.763	<input checked="" type="checkbox"/>	07:59:24.48	+16°25'08.41"	+30° 268°	airmass		lunarDistance
<input type="checkbox"/>	1288	<a href="#">sn11ao</a>	5	1000	956.018	<input checked="" type="checkbox"/>	11:53:51.12	+33°21'46.80"	-05° 225°	airmass		lunarDistance
<input type="checkbox"/>	1289	<a href="#">sn11U</a>	0	900	1062.538	<input checked="" type="checkbox"/>	04:13:33.84	+27°32'38.41"	+82° 301°			airmass lunarDistance
<input type="checkbox"/>	1290	<a href="#">sn10lt</a>	0	700	775.488	<input checked="" type="checkbox"/>	06:06:09.12	+83°50'27.60"	+36° 184°	airmass		lunarDistance
<input type="checkbox"/>	1291	<a href="#">sn09kn</a>	1	1000	990.186	<input checked="" type="checkbox"/>	08:09:42.96	-17°44'52.81"	+09° 297°	airmass		lunarDistance
<input type="checkbox"/>	1292	<a href="#">sn10lq</a>	0	700	672.661	<input checked="" type="checkbox"/>	08:32:41.04	-24°02'45.60"	+01° 299°	airmass		lunarDistance
<input type="checkbox"/>	1293	<a href="#">sn10kr</a>	3	700	684.856	<input checked="" type="checkbox"/>	10:47:38.16	+38°55'26.40"	+08° 229°	airmass		lunarDistance
<input type="checkbox"/>	1294	<a href="#">sn08by</a>	4	800	767.539	<input checked="" type="checkbox"/>	12:05:20.88	+40°56'45.60"	-01° 218°	airmass		lunarDistance
<input type="checkbox"/>	1295	<a href="#">sn10U</a>	3	800	756.335	<input checked="" type="checkbox"/>	12:15:41.04	+36°20'02.41"	-06° 219°	airmass		lunarDistance
<input type="checkbox"/>	1296	<a href="#">sn09an</a>	1	800	831.134	<input checked="" type="checkbox"/>	12:22:47.52	+65°51'03.60"	+14° 199°	airmass		lunarDistance
<input type="checkbox"/>	1297	<a href="#">sn10aj</a>	2	800	678.643	<input checked="" type="checkbox"/>	12:40:15.12	-09°18'14.41"	-41° 252°	airmass lunarDistance		lunarDistance
<input type="checkbox"/>	1298	<a href="#">sn10cr</a>	2	800	696.577	<input checked="" type="checkbox"/>	13:29:24.96	+11°47'45.60"	-35° 222°	airmass		lunarDistance
<input type="checkbox"/>	1299	<a href="#">sn07cu</a>	2	800	794.832	<input checked="" type="checkbox"/>	16:06:00.72	+55°25'26.40"	-02° 177°	airmass		lunarDistance
<input type="checkbox"/>	1300	<a href="#">sn10dt</a>	2	800	753.257	<input checked="" type="checkbox"/>	16:43:14.64	+32°40'30.00"	-24° 166°	airmass		lunarDistance
<input type="checkbox"/>	1301	<a href="#">sn10bq</a>	2	800	756.595	<input checked="" type="checkbox"/>	16:46:55.44	+34°09'36.00"	-22° 166°	airmass		lunarDistance
<input type="checkbox"/>	1302	<a href="#">sn10ag</a>	1	800	754.128	<input checked="" type="checkbox"/>	17:03:53.52	+31°30'07.20"	-24° 161°	airmass		lunarDistance
<input type="checkbox"/>	1303	<a href="#">sn10db</a>	0	800	770.012	<input checked="" type="checkbox"/>	18:26:09.36	+30°14'13.20"	-17° 144°	airmass		lunarDistance
<input type="checkbox"/>	1304	<a href="#">tcp18102</a>	1	1000	967.192	<input checked="" type="checkbox"/>	18:10:28.32	+31°00'32.41"	-18° 147°	airmass		lunarDistance
<input type="checkbox"/>	1305	<a href="#">167-129863</a>	5	1000	862.426	<input checked="" type="checkbox"/>	13:50:22.08	-06°54'00.01"	-53° 233°	airmass		lunarDistance
<input type="checkbox"/>	1306	<a href="#">sn11ap</a>	1	1000	967.191	<input checked="" type="checkbox"/>	18:10:28.32	+31°00'32.41"	-18° 147°	airmass		lunarDistance
<input type="checkbox"/>	50035	<a href="#">GRB 110312.747</a> <a href="#">GCN #449074</a>	0	100	200	<input checked="" type="checkbox"/>	10:29:55.68	-05°15'46.80"	-12° 268°	airmass		
<input type="checkbox"/>	50036	<a href="#">GRB 110315.998</a> <a href="#">GCN #449399</a>	0	100	-1	<input checked="" type="checkbox"/>	18:36:46.32	+17°32'20.41"	-25° 133°	airmass		

Fig. 2.— Sample RTS2-G targets page, top and bottom.

## 2.4. Calibration targets

In addition to science targets, the RTS2-F database contains permanent calibration targets, including one for skyflats (with variable coordinates optimized for the time when sky flats are ac-

main page <a href="#">details</a> <a href="#">statistics</a> <a href="#">images</a> <a href="#">observations</a> <a href="#">plan</a> <a href="#">altitude</a> <a href="#">plot</a>		
Name	PS1-001	Camera KCAM:ampcen=2 autoguide=OFF tempdisable 3d filter=i for 2 { E 300 } filter=r for 2 { E 300 }
RA DEC	10:53:56.400 +58:35:16.20	
ALT AZ	+00°17'17.42" 178°49'52.08"	
Bonus	5000.583008	
Priority	5000.000000	
Sidereal Time	06:08:29.02	
JD	2455597.3817802086	
Violated constraints	airmass	
Satisfied constraints	lunarDistance	
PI	Falco et al.	
PROGRAM	RTS2-F PS1 targets	
Enabled	yes	

Fig. 3.— RTS2-G single target page.

quired) and photometric standards that may be specifically requested, or are selected and observed automatically if no science targets are accessible.

## 2.5. Input catalogs

Science targets may be inserted in the database using input catalogs. The RTS2-F database is built from input catalogs in a format derived from the old .mct catalogs, with extension .mctR to indicate they are RTS2-F catalogs. Appendix 1 shows an example catalog.

Columns 1-15 of input catalogs contain for each target, respectively, a name, RA, DEC, epoch, proper motion values, comma-separated sets of 3-tuples with filter, exposure time and number of consecutive repetitions, number of repeats for each set, time between each of these repeats, CCD amplifier, autoguide flag, priority (1-10 where 1 is lowest), limits for seeing, airmass and lunar angular distance. **Notes:**

1. As for classic observations, ensure that the filters you put in your catalog will be mounted.
2. Exposure times must be integers and must not be less than 5 sec (see the Keplercam documentation).

Columns 16 and 17 in a catalog are optional. If present, column 16 is the defocus in mm to be applied to the target, with a default of 0. It is applied only to the target in question. Defocus is useful, e.g. for transits, if the target would saturate the CCD when the telescope is in focus. A “1” in column 17 directs RTS2-F to obtain “acquisition” (§2.6) exposures before science images. (If acquisition is desired, there must also be a value in column 16, 0 for no defocus.)

RTS2-F skips observations in the database when a requested filter is absent from the filter wheel list. Observers should request other filters by email to the staff, at least one working day in advance of when their observations will take place.

Once the TAC allocations for a given trimester are posted in the schedules, users who were awarded time may submit input catalogs via sftp to flwo48 as observer. Catalogs must be placed in the directory /home/observer/ROBOT/CATALOGS. The system automatically harvests catalogs daily at 2 pm MST (an arbitrary time that may be changed if it proves unpopular) and adds their contents to the RTS2-F database. As they are harvested, input catalogs are also verified to avoid formatting errors; if any are found, email is sent to the observer account with a diagnostic.

Catalogs may also be entered into the database when queues are built, as described in the following section.

## 2.6. Astrometry

RTS2-F uses `astrometry.net` software to calculate astrometric solutions for each exposure, based on the Tycho-2 astrometric reference catalog ([tdc-www.harvard.edu/catalogs/tycho2.html](http://tdc-www.harvard.edu/catalogs/tycho2.html)) and on the stars in the full Keplercam frame. The results are accurate to better than  $1''$ . Thus, RTS2-F finds the difference between the actual and commanded pointings. The RA and DEC offsets between them can then be used to correct the telescope pointing.

Astrometry offsets are not applied when autoguiding is used. In turn, the offsets are usually sufficiently accurate to maintain pointing that is nearly as accurate as autoguiding. We are working on refinements of this procedure to provide an alternative to classic autoguiding.

Acquisition images are intended for cases when the precise location of the target on the CCD is required within a few arcsec of a given pixel (e.g., the center of amp 2). If an acquisition image is requested for a given target (§2.5), RTS2-F obtains a 15-second exposure before science exposures begin. RTS2-F calculates offsets using the first acquisition image; if they are above  $3''$ , it applies the offsets and takes more acquisition images until they are  $3''$  or less, and then proceeds with science exposures. After the acquisition sequence, the first science image and subsequent images have the target at the desired pixel location.

RTS2-F has the capability to fix the pointing. The idea is analogous to the manual procedure of old, slew to a bright star, place it at the center of amp 2, say, and once there, issue a “tele set” at the Telshell, or use the TCS GUI and click on “Set TelePos” under the TeleTasks menu. The robot does all this by slewing to a field near zenith, taking a 10-sec exposure with the r filter, calculating the astrometry for the field, determining any offsets, adding these offsets to the pointing, and finally issuing a “tele set.” This can be done in several ways:

1. Use command `FIXpoint` in Telshell.
2. Use “GOrobot -P” when you start observations. `FIXpoint` is first to run once the state is NIGHT.
3. Add the target “FIXpoint” to a queue. You may add it more than once with different “FROM” times (see §2.8).

## 2.7. Autoguiding

The autoguiding routines have been refined to ensure that available guide stars are found in the guider “horseshoe” and are used optimally. Now, when the robot starts guiding, the guider’s remote gain is turned on to its maximum. The flux detected from the guide star is monitored, and if it is found to saturate (flat profiles in the yellow ntc window), the gain is reduced progressively, until the star is no longer saturated, which yields the best possible guiding.



For successful autoguiding, the following critical conditions need to be satisfied:

1. Pointing needs to be within 10 arcsec of nominal to guarantee that the expected GSC guide stars fall within the expected guider segments. Guiding may succeed for worse pointing, but GSC stars too close to the edges of a guide segment may fall outside it, which will likely result in guiding failure. Use of FIXpoint (see §2.6) will minimize the chance of such failures.
2. GSC stars with magnitude  $V < 14$  mag must fall within the guider “horseshoe.”
3. Thick clouds must be absent, which is also true for most targets to obtain useful observations.

## 2.8. Queues

A queue is a list of targets to be observed in a sequence. The observer specifies the targets and optionally the timing of their observations, and enables the queue for the desired night. The observing sequence and mode for each target are subject to the constraints in the database for filters, exposures, autoguiding, etc., visibility and weather permitting as usual.

The RTS2-F selector runs each queue. It follows one of 6 rules: FIFO (first-in first-out in the order of appearance in the queue), Circular (repeats the sequence), Highest (selects first the targets with highest priority), West-East (selects first the targets that are closest to setting, taking into account the exposure times), Meridian west-east (selects first the targets that are closest to the meridian) or First set first (selects first the target that will set first). As of October 2014, we have used FIFO exclusively.

The properties of any target in the database may be changed in 3 ways: modify a catalog (§2.5) and re-enter it, use the *rts2-target* command (§3.2), or use the optimal way, the queue management GUI that follows.

### 2.8.1. Queue management

Observers may add/drop targets to/from the queue with the “GOqueues” GUI. Fig. 5 shows the initial window after you type the command. The choice are “calibration”, “manual” or “service” queues. The calibration queue is for photometric standards, the manual queue is for near-term targets, e.g. for the current night, the service queue is for targets that would be observed in service mode in classic observations. The “automatic” button indicates that the selector will select accessible targets from the database, once the queues are exhausted. The selector will check each queue in the order shown from top to bottom, and will observe targets that satisfy the constraints in the database and in the queues. Each queue may be en/disabled by clicking on its “enabled” button.

To edit a queue, click on its “Edit” button; that brings up a window like that shown in Fig. 6. At the top right, “Total time” shows the duration of the exposures for the complete queue. Just below that are buttons for the 5 possible rules for the queues, only one of which may be selected. Next are 3 boxes, any of which may be selected. The boxes are labeled as “Skip targets” (if NOT checked, targets that do not satisfy the constraints in the database are removed from the queue), “Test constraint” (if NOT checked, targets are checked for visibility and are removed if “Skip targets” is NOT checked) and “Remove observed” (if checked, targets are removed from the queue after one sequence of exposures to observe a target such as a transit repeatedly, leave it unchecked). As of October 2014, we have found no case that required the “Skip targets” and “Test constraint” boxes to be unchecked. They are best left checked.

The following lists the operation of the 7 buttons at the bottom, right of each queue window.

1. “Load from server” loads targets that were saved previously to the server.
2. “Add catalog” prompts for the directory of your catalog; in the window that pops up find the catalog, click on its name, then click on open. You will see the targets appear in the queue window. The processing of the list is the same as for harvesting: if the target is in the database, its sequence of filters and exposures is updated, otherwise it is added to the database. If you are NOT taking multiple exposures of a target (as you would, e.g., for transit observations), make sure that “Remove observed” is ticked.
3. “Add targets” brings up a window as in Fig. 6. The targets in the database appear (the window takes a minute to pop up). You may need to expand these windows to get a good view; use the corners and drag with the mouse. Find your targets by scrolling down; you can select RA, DEC or name ordering by clicking on the appropriate button at the top of the window. You may also start typing the target name, at which point the focus in the list will move to the first matching entry. The bar at the top, right of the window shows the type of targets listed. If you click the bar, a window pops up showing the names of each PI. If you click a PI, only those targets associated with the PI name are listed, which unclutters the target list. If you are NOT taking multiple exposures of a target (as you would, e.g., for transit observations), make sure that “Remove observed” is checked.

Select targets by CTRL+clicking them and then ”Add” at the bottom right of the window. If you have a sequence of contiguous targets, click the first one, then SHIFT+click the last one, then “Add.”

If you are using FIFO, the system checks the visibility of each target as you add it. In each case, the system suggests observing times, or if the target will not be visible, it shows a window stating that the target cannot be scheduled.

Your targets should now be in the queue window. Those that are not visible are highlighted in red. You can delete any target by clicking the trashcan symbol. You can rearrange your targets with the arrows at right, but that is only relevant if you use the usual FIFO (e.g., if

you selected Meridian West-East, the scheduler determines the observing order). Notice that if you require specific start times for your targets, you should set them with the “T” button after clicking on Edit for the queue you are using. If you left “Remove observed” checked, you need not set the stop time; if unchecked you must set a stop time, otherwise the observations will keep repeating until the end of the night.

Use the “Simulate” queue facility (§2.8, 8) to check what the scheduler will observe. “MON-robot” also shows the schedule but in a less visual way. The barred arrow moves the target to the top of the queue. The “T” button allows you to set times “from” and/or “to” for observations of each target. You can use just one of these to tell the robot to start by about the “from” or to end by about the “to” time. If you use Meridian West-East mode, a target must be at the top of the queue for the system to take into account any time that you entered. In West-East or Highest modes, the outcome may not be what you expect.

When done, click the “Exit” button.

4. “Clear” erases the contents of the queue shown in the queue window.
5. “Save to server” saves the contents of the queue shown in the window. Previous contents on the server will be replaced by the new contents.
6. “Nightlog” shows the targets that have been observed, the number of images recorded, and the start and end times for each observation (Fig. 9). Pick a night by clicking “Select night,” which pops up a calendar with bold dates indicating nights with available data (click on the “x” top, right, to close it). Click on a night to see a list of images. Click an image and “Show Images” to see a list of the images along with start time, exposure time, filter and path to the files. Another window pops up, as shown in Fig. 10. Click on an image, or if you wish to display more, SHIFT-click (selects a list starting with the first image) or CTRL-click (adds each clicked image to the list). Click “Run DS9” to display your list of images. If you select more than one image, DS9 displays them as a mosaic. Click “Done” then “Exit” to quit.
7. “Save to file” saves the current queue to a file. You enter the name of the file in a pop-up window.
8. “Load from file” loads a queue that was saved previously to a file. You enter the name of the file in a pop-up window.

In the GOqueues window, click “Update” or in the queue window, “Load from server” to update the windows. Automatic updates are planned, so this button will be phased out.

### 2.8.2. Calibration queue

For targets such as photometric standards, use the calibration queue. Its properties and GUI buttons are identical to those of the manual queue.

### 2.8.3. *Manual queue*

The manual queue is best for all time-critical targets. Follow the directions in §§2.8.1 and the following specific steps to build it:

1. Add targets to the queue as needed.
2. Select FIFO mode (top right corner of the queue window).
3. Click on “T” to specify times. Enter MST 24-hour times in the boxes after “from” or “to.” For observations after midnight, specify the next civil day in the calendar (see Fig. 7). Click “Set” when done, or “Clear/Cancel” to clear the time window.
4. Click on “i” to view all the information on each target. This button shows many useful properties for each target. Figs. 11, 12, 13 and 14 show the various options available. The “KCAM” button (Fig. 12) allows the observer to view the properties of each target, and to change them. With the “KCAM” button on the left of the window, you may view/change ampccen and autoguide by selecting the option from the menu to the right of “KCAM.” In the Filter and Exposure windows, you may change the values. For other than “KCAM” there are many options, but they are best left alone.
5. Click on the trash symbol (rightmost button) to delete a target
6. If the robot is active and the state is night, near the top of the main GOqueues window you see the next target picked by the selector, and which queue it is selected from. If “automatic” appears instead of “calibration,” “manual” or “service”, the autonomous scheduler picked it, which indicates that there was an error in the queue.

### 2.8.4. *Service queue*

The service queue is for targets that are to be observed at specified dates and times (see also §2.9). For an observation of target B to be executed, if an exposure for target A is underway, the priority of B must be higher than that for A. An ongoing exposure that is part of an observation sequence (such as multiple exposures of a transit) is completed before the sequence is interrupted.

Follow the directions in §§2.8.1 to build the queue.

The service queue allows for recurring, monitoring observations of targets such as SNe or gravitational lenses. You may load as many targets as you wish, but only those that satisfy their constraints during holes in the manual queue will be observed. The queue is currently reloaded (via a cron job) each day with a list stored in circular.q in the QUEUES directory.

To set up recurring observations in the service queue, type GOcircular in any xterm.

- To add targets to the file, type:  
GOcircular TARGET1 TARGET2 ...
- To remove targets from the file, type:  
GOcircular -TARGET1 -TARGET2 ...
- You may mix add/remove, e.g.:  
GOcircular TARGET1 -TARGET2 ...

The command prints out circular.q, shows the syntax to load targets, and prompts to reload the service queue; hit RETURN if satisfied. GOcircular updates the file /home/observer/ROBOT/QUEUES/circular.q.

A cron job loads this file into the service queue each day at 14:00MST.

If you wish to raise the likelihood that a target in the service queue will be observed, you may do so by editing circular.q and placing the target in question at or near the top of the file (make sure not to disturb the formatting of the file).

### 2.8.5. Simulator

Once you have built your queues, in the GOqueues window, click “Simulate” to calculate the sequence of observations for the night, based on the contents of the queues. The simulations emulate the behavior of the robot throughout each night, thus allowing users to verify that their targets will be observed as planned.

A simulation may take from very little time to a few minutes to finish, depending on the number of targets in the queues. Once it is finished, again click “Update” and the total number of targets in all the queues appears by the “Simulator” button. Click “View” at the opposite, top corner button to see the output of the simulation. Each target is shown with the timing of each observation in the sequence that the robot would conduct it. The simulator shows only observations that would be executed and thus violate no constraints (e.g., airmass). Once the simulator window pops up, you may need to click on its own “Update” button to view the full list for the night.

### 2.8.6. GOweather

The GOweather tool is an interactive GUI. As shown in Fig. 4, it displays the status of the system. Notice that GOweather is different from STARTweather, which restarts weather sensing after a KILLweather or after any failure.

On the left side of the GUI are two webcam views. The top one shows the chamber, the bottom one the MMT skycam, with a red square for the current pointing of the 1.2m. The images refresh about every 10 seconds, so you should be able to track clouds with the MMT skycam and see if the dome is rotating and the telescope is moving. If there is insufficient light, you can turn on (off) a dome light with the `lightdome` (`darkdome`) command. Clicking on the skycam displays a standalone window with a full size skycam image. System state

The right side of the GUI shows the system state. Clicking on a box triggers an action. Lines connecting system modes display the mode inside the weather sub-system. Thick lines mark active paths, thin ones show inactive ones which can be triggered back on if the system mode changes.

The topmost box shows the mode, ON, STANDBY or OFF. If the mode is OFF, a click on the box switches the mode to either STANDBY or ON. This is a master switch for RTS2-F operations - RTS2-F will NOT operate on its own if the mode is OFF. If the mode is ON, RTS2-F opens the dome in the evening (and closes it in the morning), and runs observations through the night. If the mode is STANDBY, RTS2-F takes dome flats at the appropriate time, and it decides on its own to switch to the ON state, weather permitting, if the state is night.

Below the master mode box is a switch to decide whether the telescope should reopen on good weather. If the switch is ON, RTS2-F issues commands to open if the bad weather (causing the STANDBY mode) dissipates.

The block on the right shows boxes with weather-related limits and settings. Green values are within weather limits. If a value violates its limit, meaning bad weather, it is red (see Fig. 4). Clicking on a box displays a dialog allowing the user to change the limit or setting value. RTS2-F updates the display about every 60 seconds. The weather system has builtin timeouts, so if weather data aren't received for 5 minutes, the system turns into bad weather mode, triggering a shutdown.

At the bottom of the block are the maximum number of dome slit closings permitted each night, and a weather timeout value. The number of closings is limited to prevent too many of these draining the battery that operates the slit. The weather timeout counts down to prevent observations starting if the weather turns just marginally good.

You can reset the max number of closings and the weather timeout by clicking on the corresponding box.

## 2.9. Calibrations

RTS2-F performs a standard set of calibrations each night, as follows.

1. It takes a standard set of 10 biases and BVri dome flats (10 for each filter) each afternoon. The dome flats achieve a median level of about 10,000 counts. RTS2-F also takes u-band

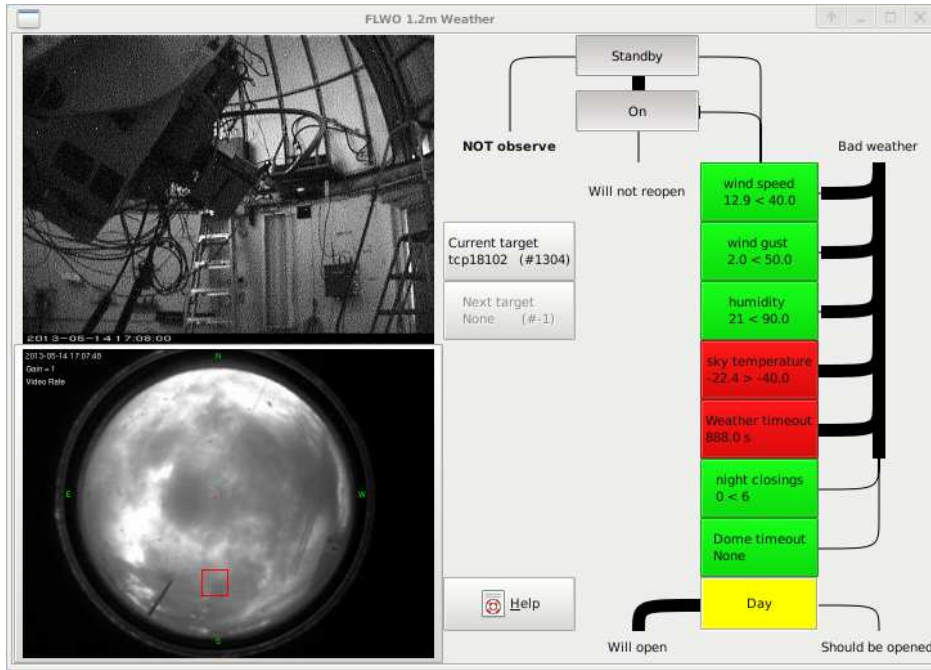


Fig. 4.— RTS2-F: GOweather window, showing views, weather conditions and thresholds. In this example, the telescope is taking dome flats and the sky temperature reflects the cloudy sky.

sky flats each evening, again with a median level of about 10,000 counts. Other bands may be requested. RTS2-F is also able to take sky flats in the morning. Sky flats start about 20 minutes after dusk or dawn, or 80 minutes after (before) sunset (sunrise) and end about 10 minutes later. RTS2-F records statistics and the numbers of biases and dome (sky) flats it acquires in the directory `/home/observer/RTS2-F/FLATS/` and files labeled `domes-YYMMDD` (`skies-YYMMDD`) which may be viewed in any xterm with command `SHOWdomes` (`SHOWskies`) [`YYMMDD`].

2. If commanded with flag `-R`, it references the telescope to zenith at the beginning of the night.
3. It focuses the telescope based on measurements of the FWHM of stars with the same method as the standard `kfindfwhm` script, which requires acquisition of exposures after twilight. It first sets the focus with the `tempfocus` script as a starting point; it then acquires a sequence of exposures and uses `Sextractor` to measure the FWHM of stars in the sequence. If the measurement fails, e.g., because of clouds, RTS2-F tries again after each sequence of exposures. After it is successful, it switches to `tempfocus` to adjust the focus as a function of temperature. The script uses a linear function that was fitted to a run of several months of measurements of temperature and focus with `kfindfwhm`. After each exposure, `tempfocus` adjusts the telescope focus if the temperature changes by more than 0.4C since its last adjustment.
4. It automatically processes each exposure with astrometry software. The pointing for each

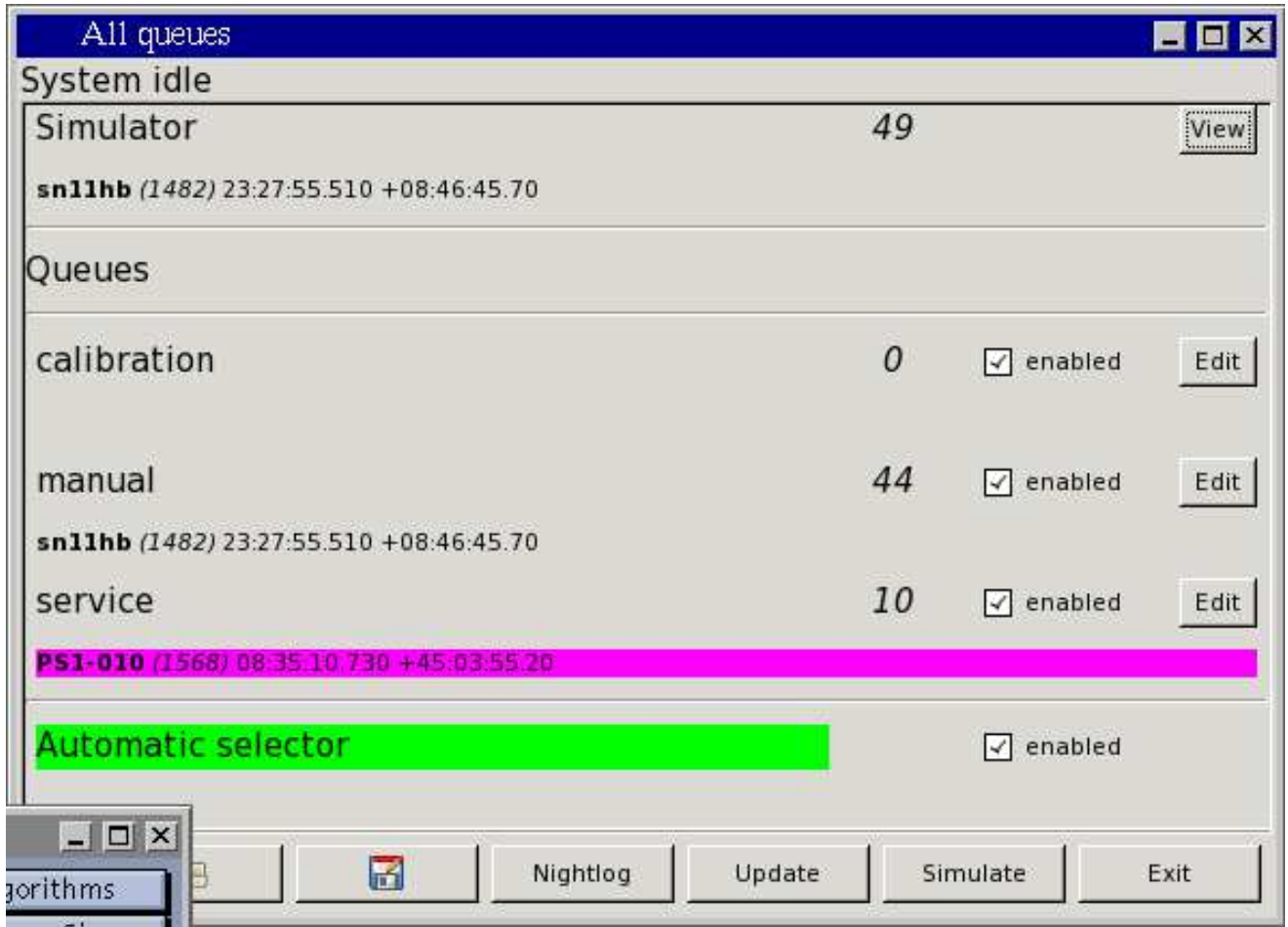


Fig. 5.— RTS2-F: queues GUI, initial window with 44 (10) entries in the manual (service) queue as an example. The first target in the queue is shown. It is highlighted in magenta if it is currently not observable.

exposure following each calculation may be corrected with offsets based on the astrometry for the full CCD frame (see §2.6). The offsets are shown in the Telshell window during observations, recorded in the logs, and may be viewed with RTS2-G or with GOview for each exposure.

5. It automatically measures stellar FWHMs in each exposure, using the SExtractor software ([www.astromatic.net/software/sextractor](http://www.astromatic.net/software/sextractor)). The run of FWHM each night is recorded and may be viewed with RTS2-G.



## 2.10. TOOs

TOOs by definition may not be in the RTS2-F database until shortly before they must be observed. There are two different timescales: for targets such as SNe (daytime before observations are requested), and for targets such as GRBs (minutes before observations are requested or as soon as possible within the constraints for observations that would be interrupted).

GCN TOOs are inserted automatically in the database as they become available, e.g. GRBs from Swift. We have added a mechanism that will interrupt the observing queue for TOOs. The default for all observations is that interruptions are disabled. They must be explicitly enabled for targets in the RTS2-F database, e.g., in the case of a planetary transit that requires uninterrupted exposures. The priority of each target will also determine the possibility of interruption. A sufficiently high priority (value to be determined) will prevent any interruption.

## 2.11. Special targets

There are two special targets that may be moved to the top of a queue, to be used as soon as possible after the current sequence of exposures is completed.

1. Focus target: When the robot selects this target, the `kfindfwhm` script is executed to measure the FWHM and optimal focus of the telescope. This target thus allows to re-measure the focus without having to stop the robot.

## 2.12. Data archive

All data obtained with the 1.2m and Keplercam are automatically transferred at the end of each night to the archive in Cambridge, directory `/data/kepler/Archive/rawdata/keplercam/` in the TDC storage system. Data obtained with RTS2-F will be similarly archived.

Eventually a pipeline system based on the current system for SN will produce standard reductions of all data that will also be archived. Once we begin to address the pipeline system, we will also address issues of proprietary data.

## 3. Category 2 users

This section describes the lower layer of RTS2-F and the procedures that Category 2 users need to know to control the system if necessary.

### 3.1. Controls

GOweather or RTS2-G may be used to change the mode (ON/OFF/STANDBY) of RTS2-F, e.g. in case of sudden inclement weather requiring an immediate shutdown although its constraints (see §2.9) are not violated, or to enable RTS2-F. The controls are accessed via the “View or change current state” link in the home page. The options are shown in Fig. 15. You change the mode by clicking on one of the 3 buttons shown.

### 3.2. Commands

In addition to RTS2-G, a number of scripts are available under RTS2-F to control and monitor the system from the observer account. Some of these scripts replicate the GOQueues capabilities. It is generally not necessary for the observer to use these commands, but remote monitoring may be useful, especially during TOO observations that may require a rapid response, e.g., to acquire additional data or to communicate results.

Detailed descriptions of commands such as *rts2-target* may be viewed by typing *man* followed by the name of the command in any xterm on flwo48. These are the most commonly used commands:

1. *GOQueues* starts a GUI that performs the functions of *rts2-queue* and more (see §2.8).
2. *MONrobot* (alias to *rts2-mon*) is an “ncurses” (see [www.gnu.org/software/ncurses/](http://www.gnu.org/software/ncurses/)) xterm tool for controlling devices available in RTS2-F. One may read and modify the values of system variables in these categories: ephemeris, weather, dome status and database status. Just as under RTS2-G, one may also change the mode of the system, with the F2, F3 and F4 keys for OFF, STANDBY and ON, respectively. To view the available menu entries, use F9 and to quit F10 or CTRL-C if F10 fails. Note that this tool runs as a client and provides a visualization of the hardware, but it does not control observations. Figs. 16–19 are snapshots of MONrobot running in an xterm. <sup>1</sup>
3. *rts2-nightreport* provides a report of events and observations for a given night, by default for the current date. For other nights, the options are *-n YYYY-MM-DD* to specify a log from the night of YYYY-MM-DD, or *-f YYYY-MM-DD* and *-t YYYY-MM-DD* to specify a range of nights (dates are local, MST). With the *-i* flag *rts2-nightreport* prints out useful information about targets and available observations.

---

<sup>1</sup>If you are working via VNC, for variants other than TightVNC, make sure you have the proper settings to do this, otherwise, for example, the F keys or other CTRL+key or SHIFT+key combinations may not work as expected. “Chicken of the VNC” for Macs is known to have these problems.

4. *rts2-target* manages targets in the RTS2-F database. For example, one may enable/disable targets in the database (-e/-d options), delete targets (-delete-targets option) **with care**, and perform various other target management tasks, for example:

```
-p priority
--pi PI name
--program program name
--proper-motion proper motion
--delete-targets
--tempdisable seconds
--airmass lower:upper
--lunarDistance lower:upper
--lunarAltitude lower:upper
--maxRepeats maximal number of observations
```

5. *rts2-targetlist* lists all the targets in the database.
6. *rts2-targetinfo X* lists the information in the database for target X. For example:

```
flwo48 54> rts2-targetinfo SDSS1029
1110 0 10:29:13.350 +26:23:31.80 -02:37 1.22 +55 18 28.08 268 29 54.44 rising SDSS1029
      KCAM:'ampcen=2 autoguide=OFF tempdisable 1d filter=r for 4 { E 300 } '
      \-- expected duration: 20m 00.000s
```

Or, for a detailed view for a particular date and time:

```
rts2-targetinfo -e -d 2011-06-06T19 SDSS1029
ID                1110
SEL_ID            1110
NAME              SDSS1029
TYPE              0
PI                Falco
PROGRAM           RTS2-F tests
RA                10:29:13.350
DEC               +026 23 31.80

ALTITUDE          +074 17 31.65
ZENITH DISTANCE   +015 42 28.35
```

AZIMUTH +074 37 51.16  
HOUR ANGLE 01:07:46.396  
AIRMASS 1.038740

SET 2011-06-07T01:05:41.000 MST  
RISE 2011-06-07T10:35:12.000 MST  
TRANSIT 2011-06-07T17:48:29.000 MST  
MIN ALT -031 55 37.00  
MAX ALT +084 42 40.60

MIN ALT +014 10 30.81  
MAX ALT +084 42 40.60

MIN\_OBS\_ALT 25.000000

RISE, SET AND TRANSIT ABOVE MIN\_ALT

SET 2011-06-06T22:49:51.000 MST  
RISE 2011-06-07T12:51:02.000 MST  
TRANSIT 2011-06-07T17:48:29.000 MST

\*\* HOUR, ALTITUDE, AZIMUTH, MOON DISTANCE, SUN POSITION table  
from 2011/06/06 00:00:00.000 UT \*\*

H	-1	00	01	02	03	04	05	06	07	08	09	10	11	
ALT	64	77	85	75	62	50	37	25	13	1	-9	-19	-26	
AZ	274	290	9	73	87	95	101	107	113	121	129	139	151	
AIR	1.1	1.0	1.0	1.0	1.1	1.3	1.7	2.4	4.5	nan	nan	nan	nan	
LD	31	31	30	30	30	29	29	28	28	28	27	27	27	
SD	75	75	75	75	75	75	75	75	75	75	75	75	74	
SAL	41	28	16	4	-7	-17	-26	-32	-35	-35	-31	-24	-15	
SAZ	94	100	107	114	122	132	144	158	174	191	207	220	231	
H	12	13	14	15	16	17	18	19	20	21	22	23	24	
ALT	-30	-32	-30	-25	-17	-7	3	15	27	39	52	65	77	
AZ	166	181	197	211	223	233	241	248	254	260	267	275	291	
AIR	nan	nan	nan	nan	nan	nan	nan	nan	3.9	2.2	1.6	1.3	1.1	1.0
LD	26	26	25	25	25	25	24	24	24	23	23	23	23	
SD	74	74	74	74	74	74	74	74	74	74	74	74	74	
SAL	-4	7	19	32	45	57	70	80	78	66	54	41	28	

SAZ 240 248 255 261 268 277 291 331 46 74 86 94 100

GAL. LONGITUDE +206 41 24.84  
GAL. LATITUDE +058 55 18.25  
GAL. CENTER DIST. +117 27 53.70  
SOLAR DIST. +073 54 40.47  
SOLAR RA DIST. +082 39 20.48  
LUNAR DIST. +022 09 35.08  
LUNAR RA DIST. +016 36 45.50  
LUNAR PHASE +115 57 40.09

SYSTEM CONSTRAINTS /home/petr/rts2-sys/etc/rts2/targets/constraints.xml  
SYSTEM CONSTRAINTS used  
GROUP CONSTRAINTS /home/petr/rts2-sys/etc/rts2/targets/groups/0.xml  
GROUP CONSTRAINTS used  
TARGET CONSTRAINTS /home/petr/rts2-sys/etc/rts2/targets/1110/constraints.xml  
TARGET CONSTRAINTS used  
CONSTRAINTS not met  
VIOLATED lunarDistance  
SATISFIED airmass maxRepeats

Of the properties listed above, observers are most likely to wish to see the last 3 entries, which indicate whether, when and which constraints are satisfied or violated.

### 3.3. Hardware controls

RTS2-F controls telescope hardware such as the dome slit, mirror covers and flat lamps as needed. New Telshell commands operate the hardware and are used by RTS2-F, but are also available at the Telshell window:

- *opensesame/closesesame* (aliases to *openslit/closeslit*)
- *opencovers/closecovers*
- *tele incandon/incandoff*

The close and open commands save the status of the slit or covers after they have executed. There are also commands to control the dome slit and check its status and that of the mirror covers:

- *closeslit* may also be issued in any xterm to close the dome slit; it is useful for an emergency shutdown.

- *openstatus* in any xterm prints out OPEN/CLOSED for the dome slit and the mirror covers, depending on their status.

RTS2-F monitors the telemetry of the 1.5m/1.2m Vaisala weather station (temperature, wind speed and direction, RH and rain). If RH rises over a threshold set as a parameter in *MONrobot* (normally 90 %) or the wind speed rises above a similarly set threshold (normally 40 mph sustained, or 50 mph gusting), or any precipitation is detected, it sets the mode of RTS2-F to STANDBY, stopping exposures as soon as possible, stowing the telescope, closing the mirror covers and closing the dome slit.

RTS2-F also monitors the HAT rain detector and the MEarth Vaisala weather station and its cloud sensor. Currently these measurements are just monitored. The sky temperature as an indication of cloudiness is a weather trigger.

If there is a failure in the weather sensors, you may advise the 1.5m observer and disable weather sensing by typing `KILLweather` in any `flwo48` xterm. The 1.5m observer will be your weather monitor after that. To restart weather sensing after a `KILLweather` or after any failure, type `STARTweather` in any xterm.

For an additional layer of protection, a process runs continually on `flwo48` during each night to monitor the “heartbeat” of the telescope (dome, slit, position), its telescope control system (TCS) and the CCD. For example, it watches for a changing ST, which signals the system is active. When the heartbeat process finds a fault, it warns the 1.5m observer with a sound and a popped xterm that shows the type of failure, and what needs to be done to correct it. The process records its activity in a file `.heartbeat` in each night’s directory; it may be displayed from any xterm with the command `SHOWheart`.

### 3.4. How to Start RTS2-F

Type `Rstatus` in any xterm to find out whether the RTS2-F servers are running. The servers should run all the time and must be running before `GOrobot` (see below) is issued. Hereinafter, RTS2-F refers to the servers.

1) If RTS2-F has crashed, make sure the robot is not running in Telshell, if it is, stop it with `CTRL-C`, then in any xterm type: `Rstop`  
NOTICE: `Rstop` clears the queues but it also saves them to a file that `Rstart` uses to reload the queues.

2) To restart RTS2-F and the monitoring, first ensure that the real-time system is up, otherwise in any xterm type `gokep`; once the system is up, in any xterm type `Rstart`. Then type `GOrobot` in Telshell. Also type `GOWeather` and `GQueues`. Then click the box at the top of

the GOweather GUI, to set the state to ON (or Standby if the weather is inclement).

NOTICE:

a) Rstart will reload the queues from the last file that Rstop saved. Double-check their contents.

b) GOweather is different from STARTweather, which restarts weather sensing, see the next paragraph.

3) If the robot senses the weather is inclement (see GOweather) but you are CERTAIN (using the MMT skycam and confirming with the 1.5m observer) that the weather is clear and the sensing is broken, you may use the command KILLweather to disable ALL weather sensing. Use with great caution. To restart weather sensing after a KILLweather or after any failure, type STARTweather.

4) On flwo48, watchdog jobs monitor the robot's activity. They verify that the robot is running, that data are being acquired at night, that the dome is not open under weather conditions over closing thresholds (wind, RH, precipitation, clouds) and that the CCD is operating normally. If there is any violation, the robot warns the 1.5m observer, and requests a clearing of the violation every 10 minutes, until the observer clears the violation and issues a clear\_robot command on flwo48. On flwo60, /var/log/chk.robot.log shows the status of any violation every 10 minutes, and on flwo48, /var/log/rob.clear shows when the violation was cleared.

\*\*\*\*\*STATES and MODES of RTS2-F (once Rstart is issued)

You will find RTS2-F in one of several possible modes listed in the table below. The robot's actions depend on the mode, which may change with the state (e.g., night), through observer input, or as a function of weather conditions. The modes are displayed with the GOweather GUI or with MONrobot in any xterm.

mode	state	weather	action
-----	-----	-----	-----
ON	day	any	wait for domeflats
ON	dusk	bad	wait for good weather
ON	dusk	good	open, take skyflats
ON	night	bad	if open and flag close_bad_weather (under DOME) is true, stop and close
ON	night	good	open if needed, observe
OFF	any	any	wait for observer input
STANDBY	day	any	wait for domeflats
STANDBY	dusk	bad	wait for weather; if flag weather_open (under DOME) is true, switch to ON upon good weather

```
STANDBY dusk    good    wait for ON, remain closed
STANDBY night   bad     wait for weather; once flag weather_open
                (under DOME) is true, switch to ON upon good weather
STANDBY night   good    wait for ON mode. If weather_open flag (under DOME)
                is true, switch to ON, open if needed, observe
```

\*\*\*\*\*STARTING THE ROBOT

To start, enable the robot to allow it to run. There are 3 ways to do it, with GOweather (preferred; click ON at the top of the GUI), or MONrobot (the "curses" xterm), or RTS2-G (the RTS2-F web GUI).

- 1) GOweather: This GUI shows the weather status and allows you to change the state to ON (good weather) or STANDBY (bad weather), see the instructions in the ROBOT USERS GUIDE. Notice that GOweather displays the weather status is different from STARTweather, which starts weather sensing.
- 2) MONrobot: In any xterm, type MONrobot. You may enable (disable) the robot there with F4 (F3); press F10 or CTRL-C to exit MONrobot. You may also leave MONrobot running and put its xterm in the background. If you use VNC, in some variants the F keys may not work. If that's your case, just type "on" inside the MONrobot window, then RET.
- 3) RTS2-G: on the Seamonkey browser on flwo48, click on RTS2-F in the top menu bar to bring up the main page. Then click on "View or change current state" and finally on the appropriate button. The username is observer with the usual pwd.

Once the state is "ON" type "GOrobot" in Telshell to run the robot. Several default actions of GOrobot can be modified with the following flags:

- D Skip dome flats
- d Use alternative dome flats list: /home/observer/RTS2-F/FLATS/ALTFILT
- e Skip evening sky flats
- m Skip morning sky flats
- R FORCE tele reference
- F Skip focus run at the start
- P Run FIXpoint at the start, to fix the pointing
- E get 2 defocused images for collimation

The syntax is, e.g., GOrobot -D -F.

In addition to "tele ref" the Telshell "FIXpoint" command adjusts



the pointing using astrometry on a short exposure near zenith. The same may be achieved by adding the target "FIXpoint" in your queues (more than once if so desired by setting a period for repeats or the time of observation).

The Keplercam dewar is filled automatically at about 5 pm and 7 am. These times vary seasonally to allow for dome flats before the evening LN2 fill. When the telescope points at the flat screen, a lot of LN2 spills out of the dewar if it's full, so it's best to be at zenith for each fill.

The drives are always enabled. No need for human intervention as in the drudgy past. Dome flats will start about 2 hours before sky flats and take about 30 minutes for the standard set. Stop the robot with STOProbot in any xterm. It can be stopped and restarted (type "GOrobot" in Telshell) at will.

Type ftime to see when the robot will start dome and sky flats. To see how long dome flats will take, type showdt (showdt -h provides help).

Unless disabled with a flag, first u and then i sky flats are attempted at dusk; if they fail, they are attempted again at dawn, i first, then u. The filters used for skyflats may be changed by changing the contents of files ~observer/ROBOT/FLATS/SKYFILTx where x=1, 2.

#### \*\*\*\*\*VIEWING ROBOT LOGS

To view a night's detailed log, use SHOWlogs [yymmdd]

To view a log of dome flats, use SHOWdomes [yymmdd]

To view a log of sky flats, use SHOWskies [yymmdd]

To view a list of a night's exposures, use GOqueues and click on Nightlog, or type rts2-nightreport (use -h to view help for this command).

To view the .heartbeat file showing the health of the system, type SHOWheart.

#### \*\*\*\*\*DATABASE

If you have a catalog that you wish to add to the database, you can have it harvested, or enter it with the queue GUI (see next section). See an example catalog in ~observer/ROBOT/RTS2-F-example.mctR.

To add targets from a catalog file to the database, harvest it: sftp the file to ~observer/ROBOT/CATALOGS. If you do this before 2pm MST, the harvester will process your catalog at that time. For manual entry, after the sftp, in any xterm type harvestcat. After it runs, you see some messages and your catalog is moved to CATALOGS/PROCESSED. Catalogs are checked for formatting errors. The harvester sends an email to observer at flwo48 with a brief diagnostic. If there is a problem with your catalog, it is not moved to PROCESSED.

You may modify a number of the properties of a target in the database with command "rts2-target." Use "man rts2-target" to view its many options. Some of these are:

```
rts2-target -p priority
      --pi PI name
      --program program name
      --proper-motion proper motion
      --delete-targets
      --tempdisable seconds
      --airmass lower:upper
      --lunarDistance lower:upper
      --lunarAltitude lower:upper
      --maxRepeats maximal number of observations
```

\*\*\*\*\*QUEUES: general options

To use queues, set up your queue each night as a manual queue (OR see below for recurring observations).

The guts of the system are the "selector" and the "scheduler" which pick targets to observe. The scheduler selects targets automatically from the database, unless queues are populated. Automatic scheduling follows the rules for each target in the database, including their priorities.

The options available in the G0queues GUI are calibration, manual or service queues. Queues are always enabled, but do nothing unless they are populated with targets. The selector visits each queue and observes available targets under the constraints for each queue. The order is a repeating cycle of calibration, manual and service queues, until all queues are empty.

To see what you wrought, simulate a night's run: once you have created and saved queues, click the "Simulate" button to see how your queues will be executed. Also click "Update" in the simulator window. With

this option, you can go back to each queue GUI to correct any problems in your queues.

If the queues are all empty and "Automatic selector" is enabled in the queues GUI, RTS2-F selects targets from the database and observes them until the end of the night. If "Automatic selector" is disabled, the robot idles unless and until a target is available in the queues. It prompts so you may let it wait, or just exit (with ctrl-C in Telshell or STOProbot in any other xterm).

To enter targets into a queue, in any xterm type GOqueues. The queues are shown top to bottom in the order the selector follows, checking them for available targets: calibration, manual and service.

There are then 4 options:

a) Manually, click "Add targets", bottom right, third entry from the top. All the targets in the database appear (the window takes a minute to pop up). To expand the original window and the target window for a better view, click the corners and drag with the mouse. Find your targets by scrolling down; you can select RA, DEC or name ordering by clicking on the appropriate button at the top of the window. You may also start typing the name of a target and the list is moved to the targets whose names start with what you typed.

Select targets by CTRL+clicking on them and then on "Add" at the bottom middle of the window. If you have a sequence of contiguous targets, click on the first one, then SHIFT+click on the last one, then "Add." For VNC other than the preferred TightVNC, make sure you have the proper settings to do this (some may just not work). You now see your targets in the queue window. Targets that are currently not visible are highlighted in magenta; a window pops up and asks whether you would like to switch its start time to an appropriate value (click Yes or No). Targets that will not be visible during the current night normally should not go into a queue; a warning window pops up (usually click skip); if you are adding a target to the service queue, you may want to click "add anyway" but be careful.

b) From a catalog, click "Add catalog" which will prompt you for the location of your catalog; click on open once you find it and click on its name in the window that pops up. The targets entered from a catalog into a queue are also added to the database if they are not in it already. The information for a target in the catalog replaces that in the database if the target is already there, except

for records that show, e.g., when and how many times the target was observed.

It is critical that, if you are not repeating observations such as for a transit, you make sure to check "Remove observed" before you load your catalog. If you try to load a catalog and "Remove observed" is not checked, the load will fail, GOqueues will hang, and you will have to Rstop/Rstart, type GOweather, switch the mode to "ON" by clicking on the GOweather button for the state (or "Standby" if the weather is bad), check "Remove Observed" and reload your catalog, all of which will waste significant time.

c) From a file, click "Load from file." This is useful if you have previously saved a queue with the "Save to file" button or if you wish to restore an "autosaved" queue. The latter are written automatically as observations proceed each night.

d) From a file again, if you have previously saved all the queues with the 2nd button from the bottom left corner of the GOqueues window, the 1st button lets you reload all the queues.

If you use FIFO, rearrange your targets with the arrows (the barred arrow takes the target to the top). If you selected Meridian West-East, the observing order is decided by the scheduler; see below to check what the scheduler will observe. You can delete any of the targets you entered by clicking the trash can symbol (it may be hidden, it's top+right). Once done with the adding, close the targets window by clicking "Exit." Once you are happy with your targets, click the "Save to server" button, then "Done."

If you wish to analyze your night, click "Simulate." Once updated to the total number of targets in your queues, click "Edit" to view the simulation. It will show your targets with the times of execution of observations and with red highlighting violations of constraints (which may render the targets unobservable) or when a target is planned to be observed at the same time slot as another.

If you would like your targets observed at fixed times, use the "T" for each target and enter values in the "from" and "to" boxes. You can use just one of these to tell the robot to start by about the "from" or to end by about the "to" time. But, be aware that if you use Meridian West-East mode, a target has to be on top to have its time taken into account by the system. A better approach is to put all time-critical targets into the manual queue:

(1) select again the main queue window, or relaunch it (type "GOqueues" in

any xterm)

- (2) click Edit next to manual queue (e.g. NOT service queue, as before)
- (3) add targets to the queue, select FIFO mode (top right corner of the window)
- (4) click on the T button to specify start/stop MST times. For observations after midnight MST you must specify the next day. Click "Set" once done, or Cancel/Clear to cancel the time
- (5) make sure that targets in the manual queue are arranged as they should be observed. The system will not re-arrange their order
- (6) make sure to leave enough time between targets so all the exposures you are scheduling can be taken before the start time for the following exposure (command `rts2-targetinfo TARGETNAME` shows an estimate of the time required for each target, including overheads)
- (7) in a case such as a transit, leave the number of exposures in your catalog set to 1, but uncheck "Remove observed" (right, near bottom) so the target remains in the queue until the "to" time and is observed repeatedly
- (8) if you are not repeating observations such as for a transit, make sure to check "Remove observed" before you load your targets
- (9) click "Save to server"

\*\*\*\*\*QUEUES: A new option, the Scheduling Window

The Scheduling Window (SW) is used to coordinate start/end times with other queues. The SW allows targets from the bottom (in terms of priority), e.g. service queue, to overrun the start time of targets in an upper, e.g. manual or calibration queue. It should be used if you don't need exact start times for your observations - the robot will then optimize the schedule. An SW may be specified for each queue, in a box marked "Window", just above the "Skip Targets" button.

As an example, consider target C1 in the calibration queue with start time 22:00 MST, and targets S1, S2 and S3 in the service queue without start times. Assume it is 21:50 MST, and S1, S2 and S3 have scheduled durations of 20 minutes. If SW is set to 0, the robot will be idle or will select short-duration targets from the database to fill the 10 minutes remaining until 22:00, when C1 is scheduled to start. If you set SW to 10 minutes, at 21:50 the robot will pick up S1, and delay the start of C1 to 22:10.

The general rule is to set SW slightly larger than the durations you see in the service queue, with typical durations of 20 minutes. For such durations, 25 minutes would be a good choice. Then targets with start time T can start from T till T+SW, and the system uses those extra SW minutes to optimise the overall schedule.

If you want your target to start strictly at a given time, set SW to 0. If you want to start your target no later than some given time, subtract SW from the given time and use it as start time.

The SW does not affect end times.

\*\*\*\*\*QUEUES: recurring observations

To set up recurring observations in the service queue, type GOcircular in any xterm.

To add targets to the file, type:

```
GOcircular TARGET1 TARGET2 ...
```

To remove targets from the file, type:

```
GOcircular -TARGET1 -TARGET2 ...
```

You may mix add/remove, e.g.:

```
GOcircular TARGET1 -TARGET2 ...
```

The command prints out circular.q, shows the syntax to load targets, and prompts to reload the service queue; hit RETURN if satisfied.

GOcircular updates the file:

```
/home/observer/ROBOT/QUEUES/circular.q.
```

A cron job loads this file into the service queue each day at 14:00MST.

If you wish to raise the likelihood that a target in the service queue will be observed, you may do so by editing circular.q and placing the target in question at or near the top of the file (make sure not to disturb the formatting of the file).

\*\*\*\*\*MONITORING THE ROBOT

With the GUI:

(1) Type "GOqueues" in any xterm.

(2) If the robot is active and the state is night, near the top of the window you will see the next target picked by the selector, and which queue it is selected from ("automatic" if from the autonomous scheduler, which is unlikely to be your choice; this indicates that you arrange the target incorrectly in the queue).

(3) In the "queue" window (after you click on the "Edit" button next to the queue name), you will see current order of targets. This might change during the night; if you are using "Highest elevation", "West-east", "Meridian West-east", the queue order will be changed during the night. The queue order will not change if you use "FIFO" or "Circular".

(4) You can access the night-logs by clicking the "Nightlog" button in the queue window. Please make sure you are viewing the current night (select night start date by clicking "Select night", you will see nights with observations in bold).

(5) Click "Update" or "Load from server" frequently to update the screen. Automatic updates will be added soon.

(6) You can run the real-time GUI with the command GOweather. The system updates the weather values shown in the window.

With MONrobot:

In any xterm, type MONrobot to view a cornucopia of detail. There are 3 sub-windows in the MONrobot window:

```
.-----.  
| | 2 |  
.1|-----.  
| | 3 |  
'-----'
```

Move down to "SEL" in sub-window 1 (with the down arrow key), then hit TAB to go to sub-window 2, then use the down arrow to move down to the service queue. There you will see your targets lined up. Another 2 TABs will bring you back to sub-window 1.

While in the SEL area, you can also view the states of the calibration, manual and service queues. Items with a "W" on their left can be modified by moving down to each item with the down arrow and hitting RET. You will be offered a menu with options you select with the down arrow and hitting RET again. If the item is a number, text or a list of these, you can edit the values and hit RET when done. The "selector\_queue" allows you to switch between the queues the robot will execute (the options are calibration, manual or service). You can switch between these anytime.

Move down to WEATHER in sub-window 1; there you see current weather conditions and limits such as for wind and humidity. Hit TAB to move to sub-window 2, then use the down arrow to view additional readings.

## Appendix 1: Input catalog

```
# Example catalog for RTS2-F
#Key
#Col 01: ID = object name
#Col 02: RA to 100ths (hh:mm:ss.ss OR hh mm ss.ss)
#Col 03: Dec to tenths (dd:mm:ss.ss OR dd mm ss.ss)
#Col 04: Epoch to tenths
#Col 05: Proper Motion Ra sec-cen.nn
#Col 06: Proper Motion dec sec-cen.nn
#Col 07: Comma-separated list: Filter-ExpTime-NumExp,... NOTE Exptime integer>5
#Col 08: Repeats for Col 07
#Col 09: Time between repeats given in Col 08
#      (-1=disable; else time in sec if no units, otherwise give h,d,m,y)
#Col 10: AmpCen (0-4, 0 is centered)
#Col 11: Autoguide (0 or 1)
#Col 12: Priority, (User), 1-10 (1 is lowest)
#Col 13: Seeing Limit
#Col 14: Airmass Limit
#Col 15: Moon Limit: 0 to 90 deg, 90 no observation if moon is up
#Col 16: telescope defocus value in mm (0 if absent) usually < 0.1
#Col 17: take position acquisition images before science images 0 or 1
# test1 (test2) no (yes) acquisition
#
#next 2 lines are REQUIRED keywords in each catalog, start with !
!P.I.: Falco
!Program: RTS2-F tests
test1 10:45:51.92 30:40:56.5 2000.0 0.00 0.00 u-360-3,B-30-4,V-35-4 3 3d 0 0 10 3 2.5 5 +0.05 0
test2 11 21 08.25 06 01 45.6 2000.0 0.00 0.00 V-45-2,R-35-3 1 -1 0 0 8 3 2.7 10 -0.09 1
```

## Appendix 2: Troubleshooting

### .1. Robot-related software

1. If you type GOrobot and you see a message that says the system must be switched to ON, see §2.1.1.
2. If your catalog was not verified as it was harvested, see §2.5. This likely means extraneous characters are in the catalog, or required entries are missing. Please review your catalog.



3. If the robot suddenly stops observing and closes the telescope, the weather is likely not suitable for observations. See §2.1.1.
4. If you are using queues and the robot is not observing your targets, the targets are probably not visible (violate constraints). Verify that the target entries are not currently shown in red in the queue window.

## **.2. Hardware and other software**

1. Please visit [www.sao.arizona.edu/FLWO/48/48rack.html](http://www.sao.arizona.edu/FLWO/48/48rack.html) for problems with the telescope and CCD.
2. If you are unsure of the problem or of its cause, contact the 1.5m observer as quickly as possible. If that fails, try to contact other staff at the phone numbers listed on the 1.2m page.

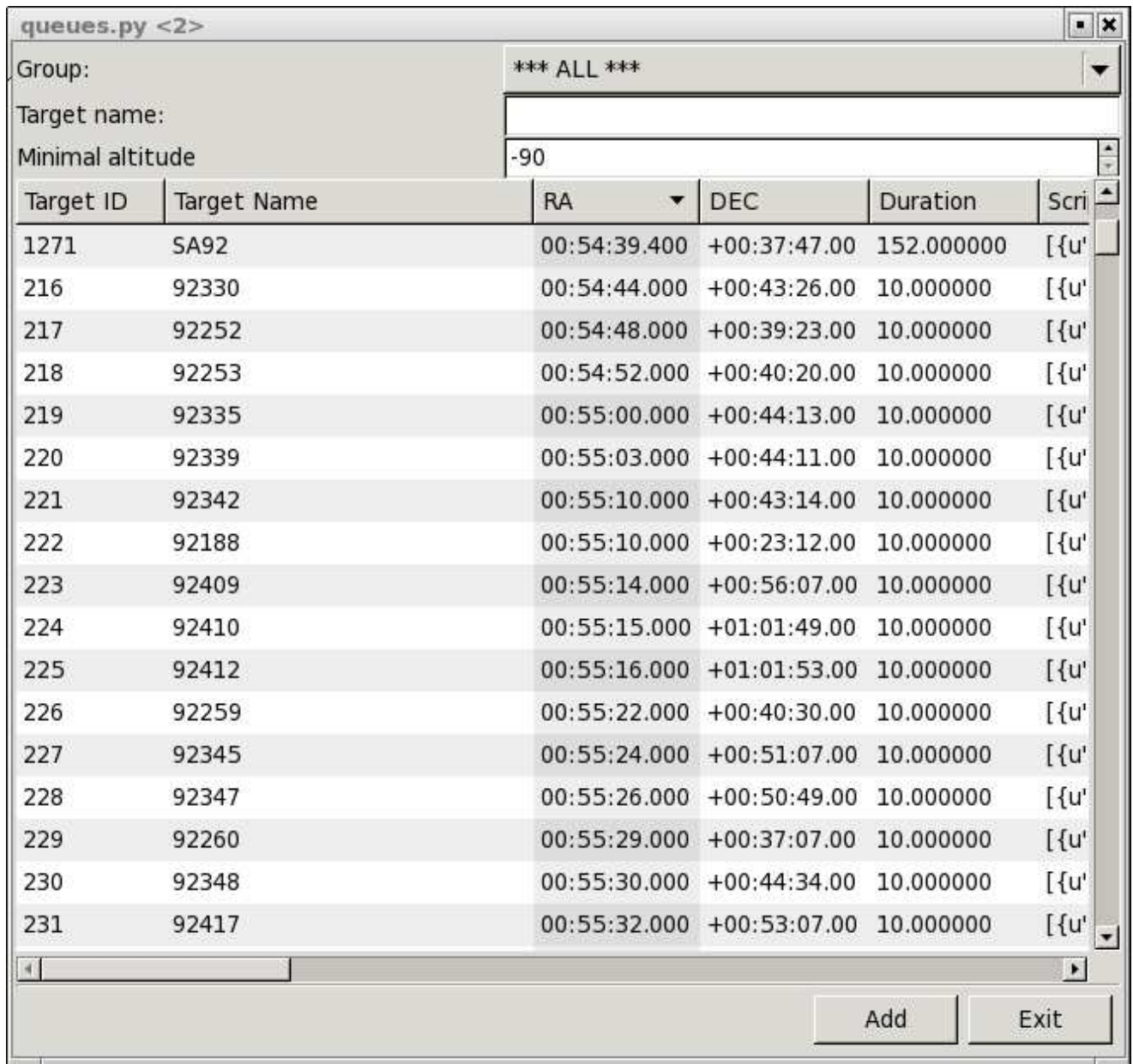


Fig. 6.— RTS2-F: queues GUI, add targets window. The bar at the top right shows \*\*\*ALL\*\*\* to indicate all projects are listed. Click on the bar to show only targets from a particular project. Below this bar is a box where you may also enter the name of a target. Names of targets beginning with what you type are completed automatically.

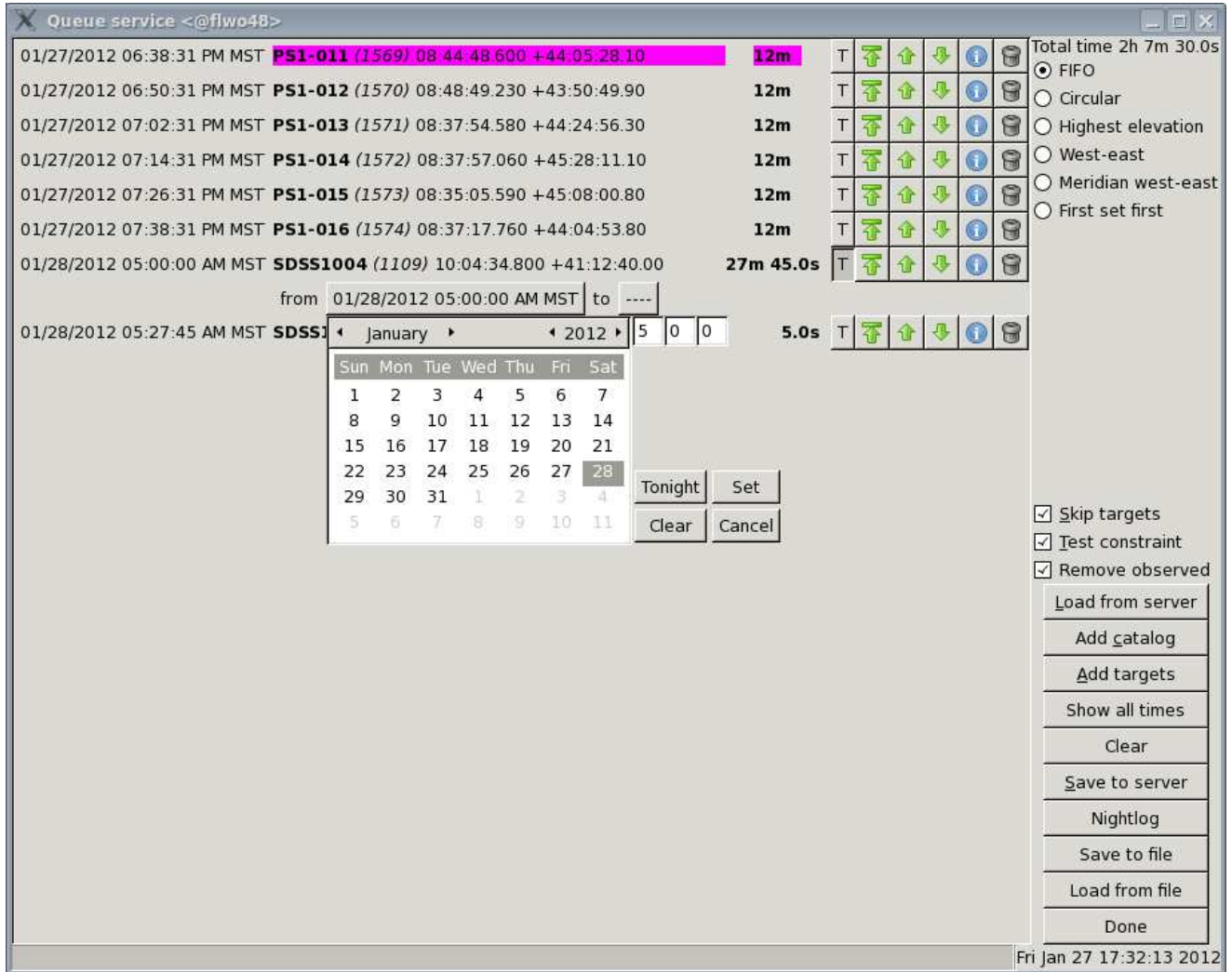


Fig. 7.— RTS2-F: queues GUI, service queue window showing 8 entries as an example, after clicking “T” for SDSS1004 and then the box next to “from.” Enter the time in the boxes where the current time appears. Similarly for the “to” box.

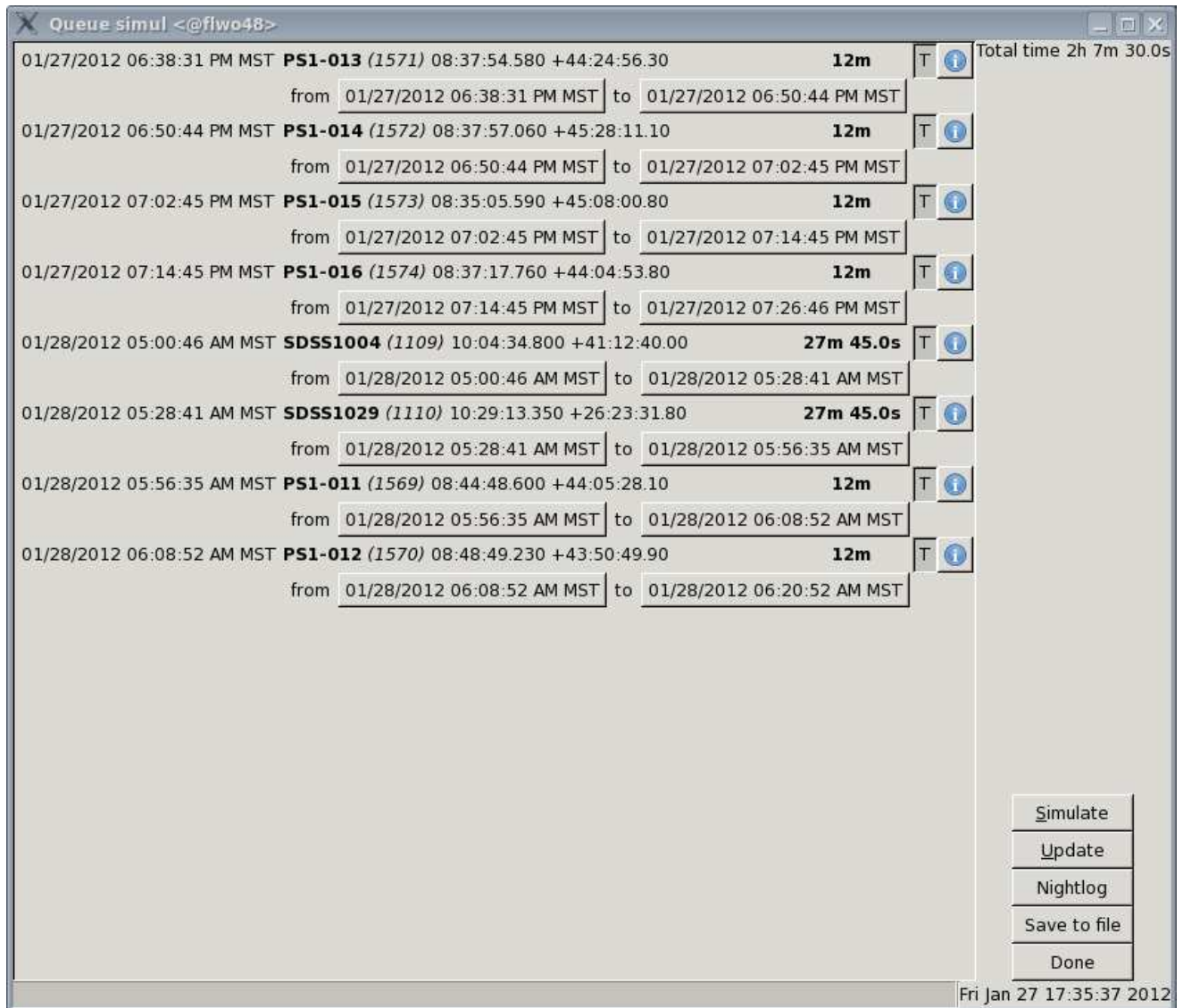


Fig. 8.— RTS2-F: queues GUI, simulator window with the 8 targets in the service queue.

ID	TargetID	Target name	Start	End	Number of images	Number of good in
901	1414	sn11de	01:15:47	01:35:42	4	4
902	1375	sn09fv	01:36:35	01:56:36	4	4
903	1301	sn10bq	01:57:20	02:17:22	4	4
904	1300	sn10dt	02:17:59	02:38:05	4	4
905	1400	sn08dt	02:38:43	02:58:48	4	4
906	1302	sn10ag	02:59:27	03:19:30	4	4
907	1382	sn10gd	03:20:18	03:34:18	2	2

Fig. 9.— RTS2-F: queues GUI, Nightlog dialog window for the night of 07/06/11.

Image	Start	Exptime	Filter	Path
/rdata/kep/2011.0704/0064.sn10dt.fits	02:18:23	240.000000	i	/rdata/kep/2011.0704/0064.s
/rdata/kep/2011.0704/0065.sn10dt.fits	02:22:54	240.000000	r	/rdata/kep/2011.0704/0065.s
/rdata/kep/2011.0704/0066.sn10dt.fits	02:27:29	300.000000	VH	/rdata/kep/2011.0704/0066.s
/rdata/kep/2011.0704/0067.sn10dt.fits	02:32:53	300.000000	BH	/rdata/kep/2011.0704/0067.s

Fig. 10.— RTS2-F: Nightlog selection window for DS9 display. Target sn10dt (ID 904) was selected in Fig. 9

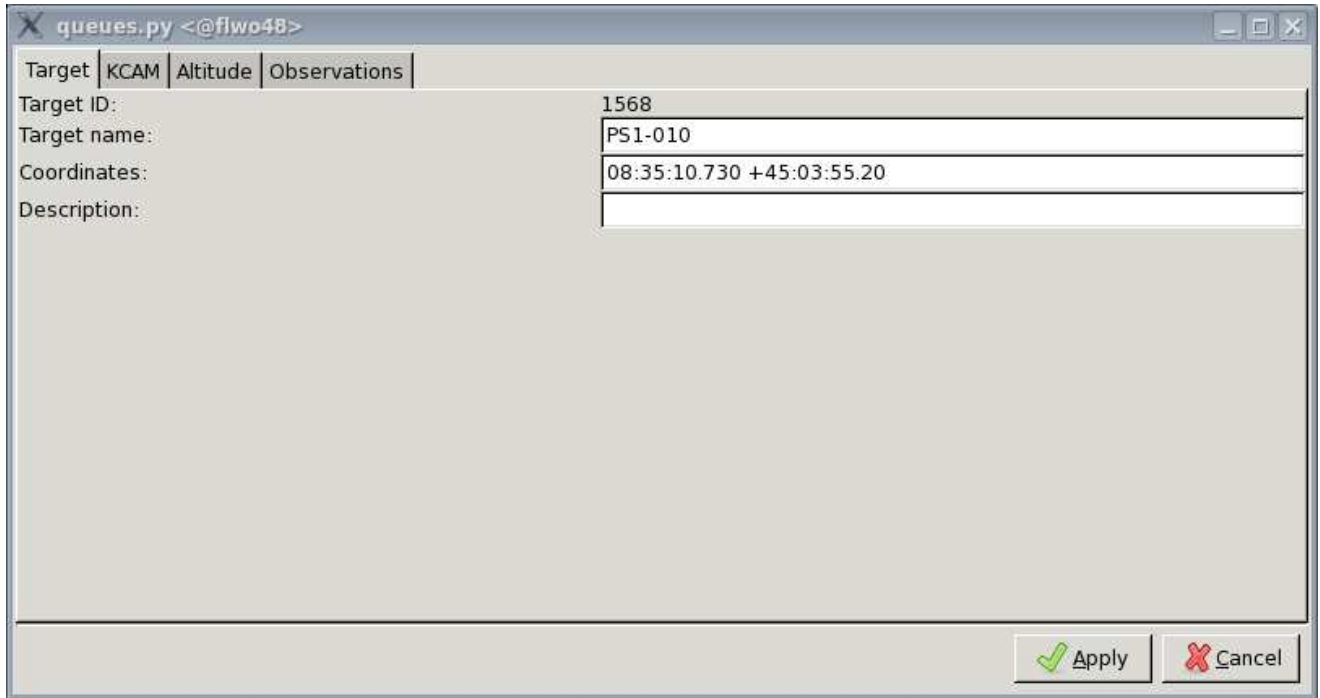


Fig. 11.— RTS2-F: window pops up after clicking “i” in queue window. The target name, number and coordinates are shown.

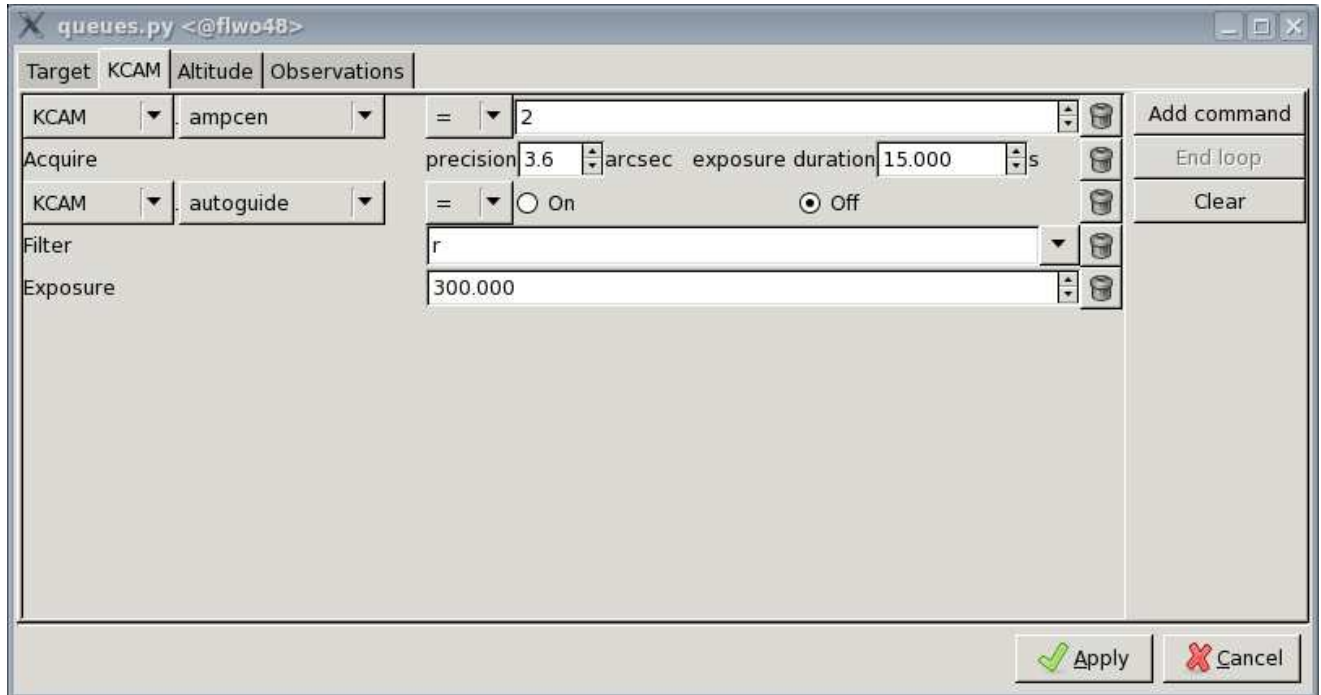


Fig. 12.— RTS2-F: 11 window switches to this view after clicking “Target.” It shows the properties of the target stored in the database, such as ampcen, acquisition, autoguide, filter and exposure. Many other properties may be displayed by clicking “KCAM” or the other buttons visible here.



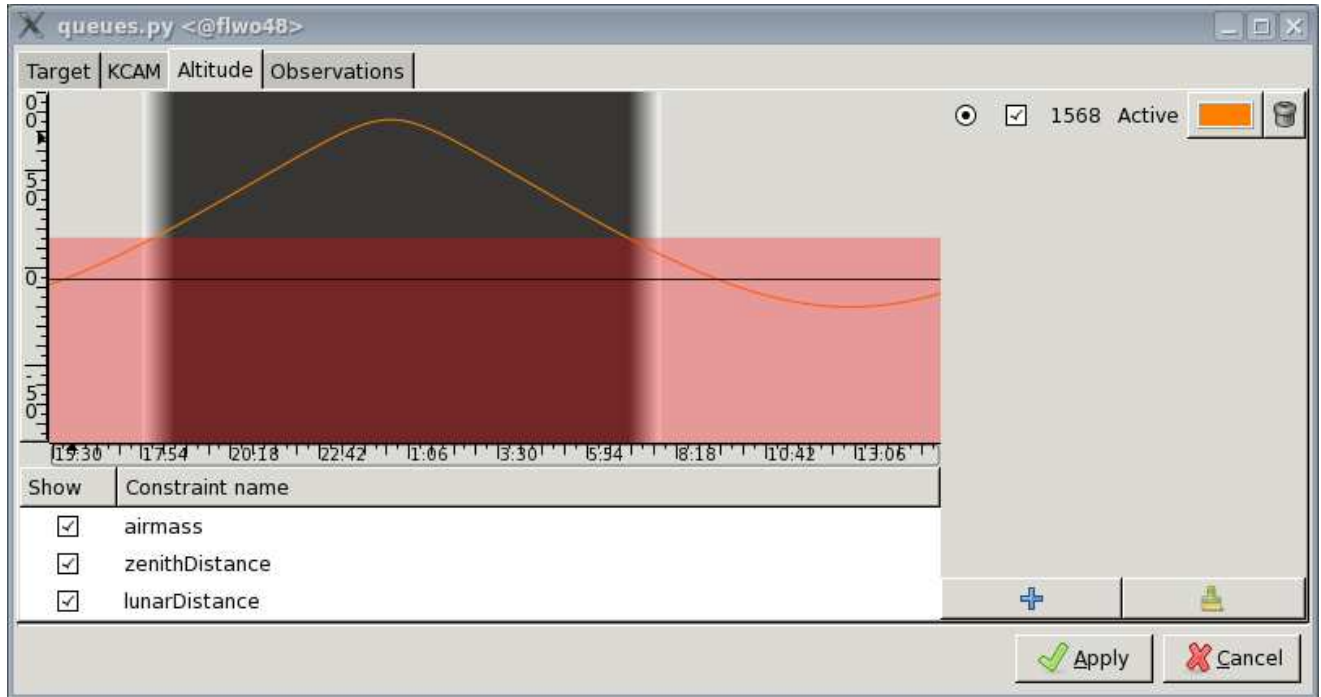


Fig. 13.— RTS2-F: 11 window switches to this view after clicking “Altitude.” It shows the elevation of the target as a function of time for the night. Dark shading indicates night time. Constraints at the bottom may be turned on and off in the display.

Target	KCAM	Altitude	Observations	ID	Slew	Start	End	Number of images	Number of good images
1983	2012-01-11	04:49:36	04:50:28	04:58:02	4	4			
2000	2012-01-13	02:07:36	02:08:16	02:17:52	3	3			
2023	2012-01-18	04:04:42	04:05:30	04:17:49	3	3			
2035	2012-01-19	03:51:56	03:52:40	04:00:11	2	2			
2046	2012-01-19	05:53:38	05:54:44	06:01:20	3	3			
2094	2012-01-20	05:30:08	05:31:15	05:38:08	3	3			
2130	2012-01-22	05:52:02	05:53:09	06:00:52	3	3			
2141	2012-01-23	05:00:12	05:01:19	05:08:46	3	3			
2162	2012-01-25	04:00:52	04:01:56	04:13:27	6	6			
2188	2012-01-27	06:13:14	06:14:19	06:22:06	3	3			
2192	2012-01-29	03:32:15	03:33:03	03:45:33	3	3			
2208	2012-01-30	03:22:08	03:22:56	03:30:52	3	3			

Fig. 14.— RTS2-F: 11 window switches to this view after clicking “Observations.” It lists the number of observations of the target in the database.

Current state is: HARD OFF

Set state to:

OFF

System is off, telescope parked (and not powered, if system allows that).

STANDBY

System is prepared to take observations, but dome is closed. This state is used to end observations in case of bad weather.

ON

System is up and running, taking images during night.

Fig. 15.— RTS2-G mode switching page. Parked means stowed; ignore the statement within parentheses.

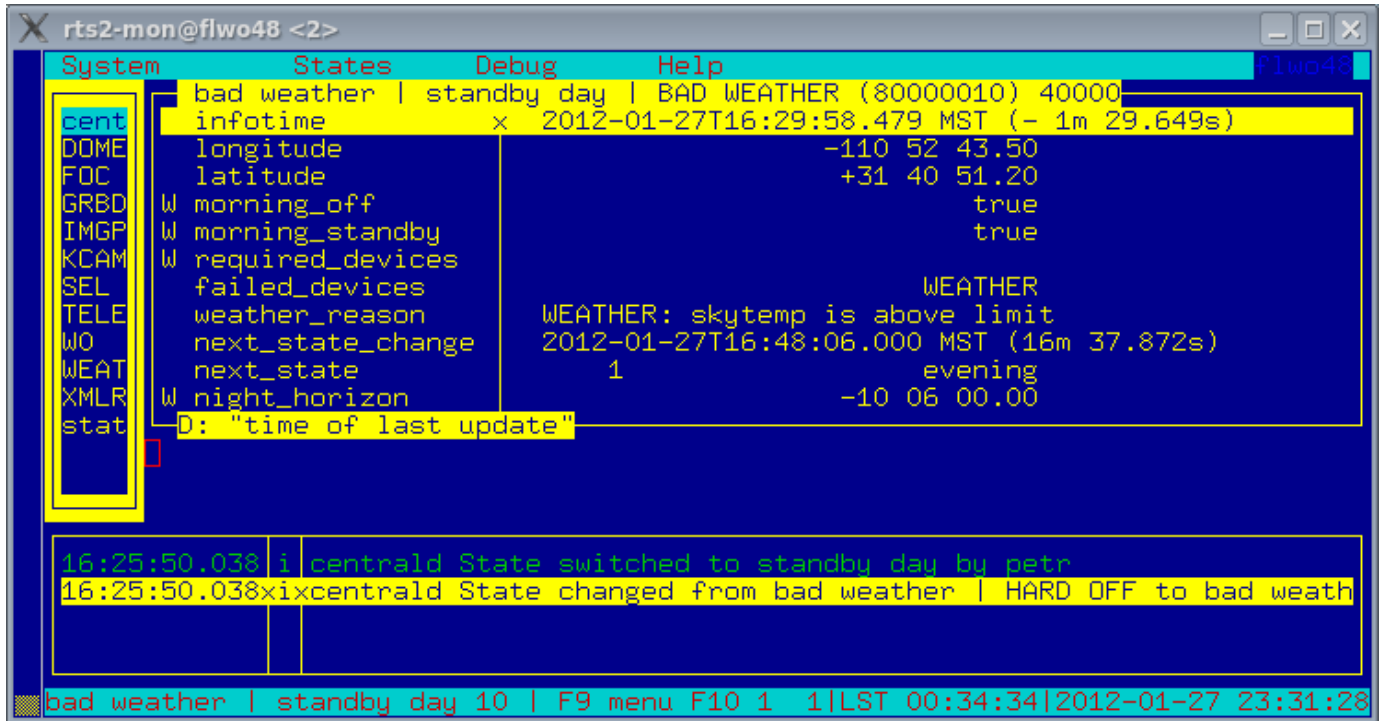


Fig. 16.— MONrobot in action showing the starting (central) screen. The BAD WEATHER condition is on, which prevents RTS2-F from opening the dome slit.

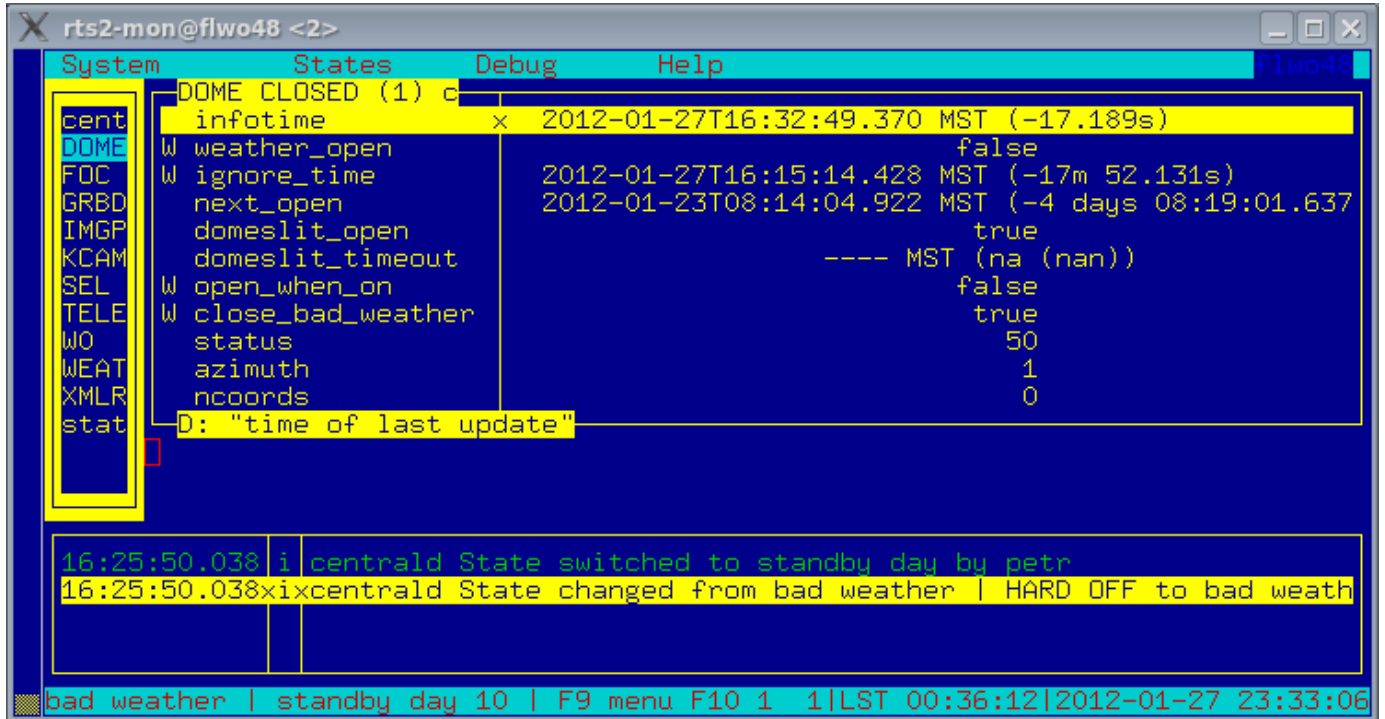


Fig. 17.— MONrobot in action showing the DOME screen.

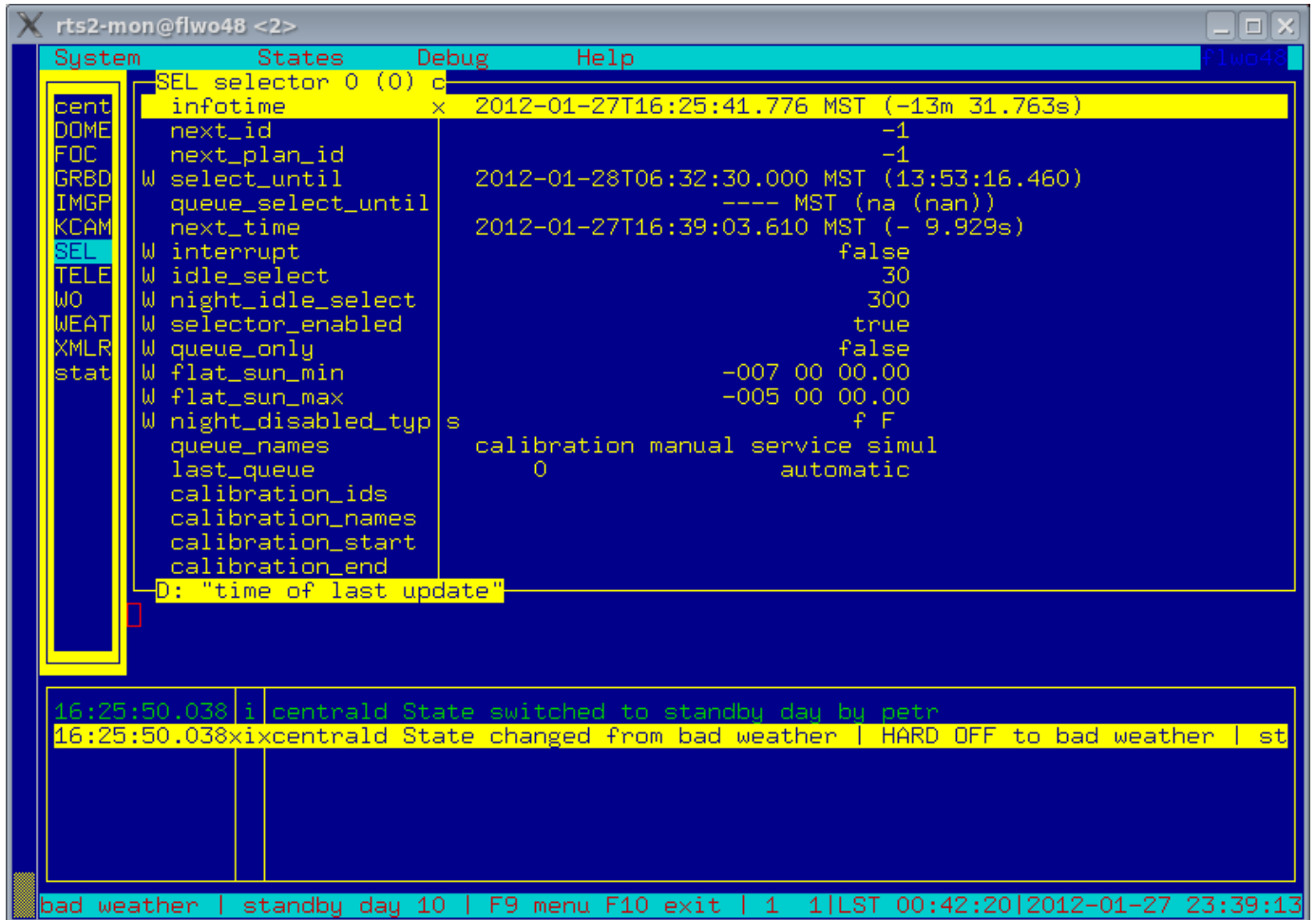


Fig. 18.— MONrobot in action showing the SEL screen.

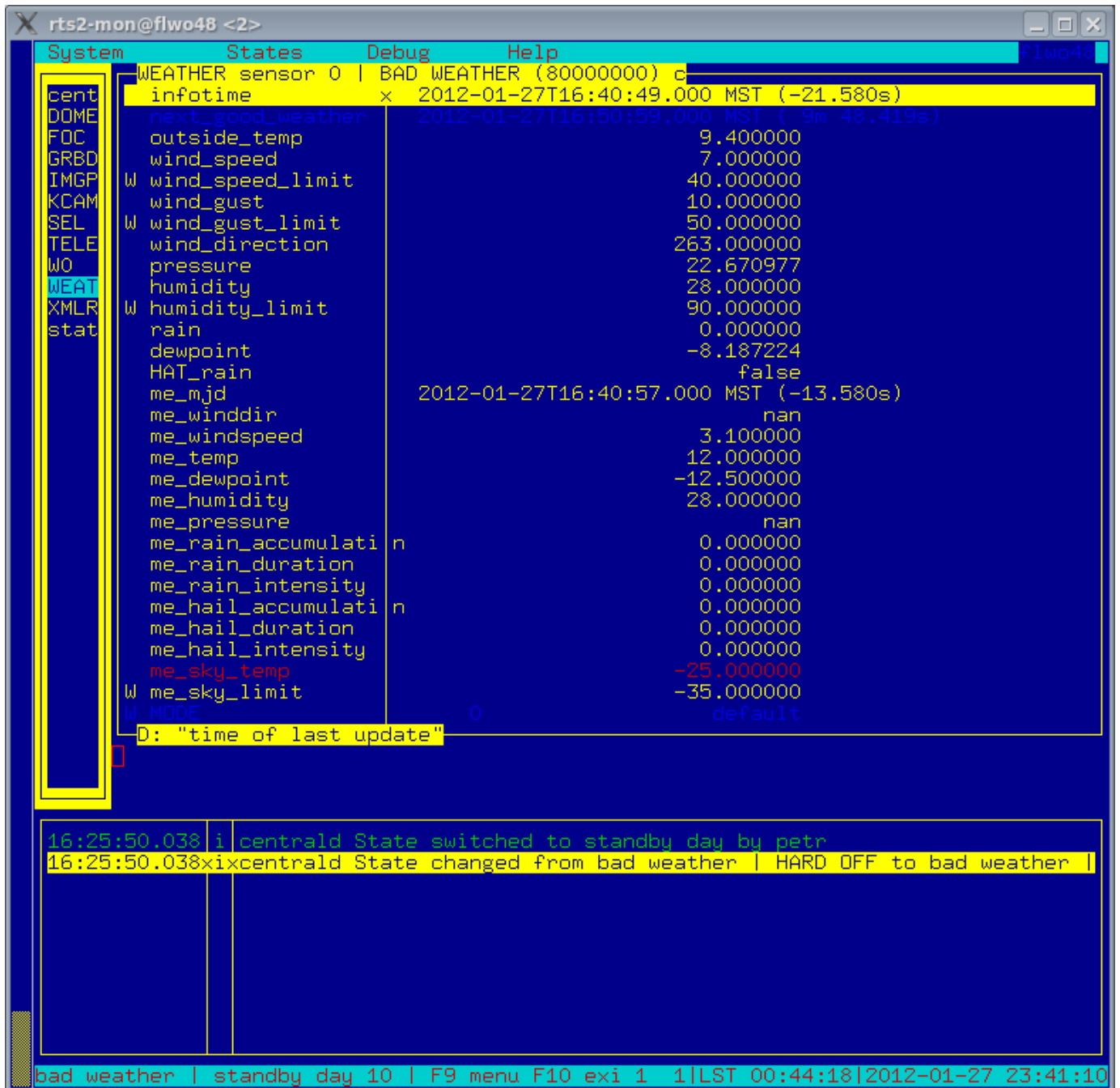


Fig. 19.— MONrobot in action showing the WEATHER screen, showing the cause of the BAD WEATHER condition: the sky temp is higher than the limit, indicating clouds.