Fakerad User's Guide
Introduction, Tutorial, and Examples

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Abstract

This guide provides an overview of how to run the `fakerad` space VLBI proposal aid software. This version of the software has been designed to match the technical information that appears in the RADIASTRON User's Handbook http://www.asc.rssi.ru/radioastron/documents/rauh/en/rauh.pdf

Typographic Conventions

The following typographic conventions are used in this guide:

- File, program, and directory names are shown in `typewriter` font.
- `Fakesat_menu` sub-menu names are shown in **bold underlined** text.
- `Fakesat_menu` pushbutton or parameter names are shown in **boxes** .

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1 Overview

The launch of RADIASTRON missions will herald a new VLBI age in which VLBI observations on baselines exceeding an Earth diameter will be routinely undertaken. However to successfully observe with these spacecraft requires an understanding of several concepts not encountered in ground-based VLBI. The `fakerad` program and its accompanying interactive menu program, `fakerad_menu`, are intended to enable potential users of the mission understand the mission from a scientific perspective and aid them in the preparation of observing proposals.

2 `Fakerad`: Introduction

The basis of this software is the `fake` program, which is a program contained in the Caltech VLBI Package. The `fake` program was written in 1979 by T. J. Pearson (Caltech) to support simulations of ground-based VLBI experiments. In 1983 D. L. Meier (JPL) added the ability to simulate space VLBI experiments as part of the QUASAT mission studies. In 1989/1990 D. W. Murphy (JPL) added VSOP spacecraft constraints since they have a major impact of the science return from these missions. The program with the spacecraft constraints and several additional features was subsequently renamed `fakesat`. We continued these developments by creating a new branch of the software connected with RADIOASTRON mission; we call this version as "fakerad". Because of moon-perturbed nature of RADIOASTRON orbit it is impossible to use simple Kepler approximation, instead, interpolated table of stat vectors will be used. Therefore, fakesat orbit block was completely replaced. Second, RADIOASTRON spacecraft attitude control system imposes particular constraints different from those applied in VSOP mission. Therefore, software section connected with the analysis of such constraints was essentially rewritten. Other modifications were related with peculiarities of visualization connected with long period RADIOASTRON orbit. In a given version of the fakerad only one RADIOASTRON spacecraft may be treated, while a formal field for VSOP exists.

In order to make `fakerad` easier to run for those inexperienced in using `fake`, an interactive interface, was used `fakesat_menu` written in 1993 by D. W. Murphy. This guide describes how to use this interface program. `Fakesat_menu` works by creating a C shell script, `.fakesat-tmp.csh`, which contains all the commands necessary to run `fakesat`. This script is then executed automatically as a background process.

To make less changes in original Fakesat software we kept old names "fakesat" for most of the files and subroutines.

3 `Fakesat_menu`: Introduction

The `Fakesat_menu` menu is made up of many sub-menus whose names are given at the left hand side of each sub-menu. For example, at the top of the menu are the **mode:**, **spacecraft:**, and **options:** sub-menus. Each sub-menu is either a 'pushbutton' sub-menu that consists of a series of rectangular pushbuttons or is a 'parameter' sub-menu that consists of a series of parameters whose values can be changed. Only those sub-menus needed to accomplish a particular task are ever displayed. The menu is hierarchical in that the sub-menus are ordered such that options selected in a given sub-menu may alter the information in or what sub-menus are displayed below the given sub-menu. Thus in using the menu one proceeds from the top sub-menu through to the bottom sub-menu selecting options or changing parameters until one has the desired parameters and options needed to run a particular simulation. The simulation is then run by selecting the **run** pushbutton of the **mode:** sub-menu.

3.1 Pushbutton Sub-Menus

When a pushbutton from a pushbutton sub-menu is selected it is depressed and has a green color. When it is de-selected it is raised and has the default grey color. There are three different type of pushbutton sub-menus:

1. 'only one ': in this type of pushbutton sub-menu only one sub-menu item may be selected at a time. The **mode:** sub-menu at the top of the menu is an example of this type of sub-menu.

2. 'many': in this type of sub-menu more than one pushbutton may be selected. The **telescopes:** sub-menu is a good example of this. Different telescopes may be selected or de-selected by clicking on the appropriate pushbutton with the telescope name on it.

3. 'toggle': in this type of sub-menu only two pushbutton are displayed. One of the two pushbuttons must be selected. Selecting (or de-selecting) one of the two pushbuttons will de-select (or select) the other. This type of pushbutton is rare.

To select (or de-select in the case of the 'many' and 'toggle' pushbutton sub-menus) a pushbutton simply place the mouse on the sub-menu pushbutton and click any mouse button.

3.2 Parameter Sub-Menus

The 'parameter' sub-menu consists of a series of parameters whose values can be changed if required. The parameter name is shown in a depressed grey box to the right of which is a black box in which the parameter value is displayed in yellow text. To change a parameter value first place the mouse inside the box with the parameter value and click. The box color will now change to yellow to indicate that this parameter value box has been selected and that the new parameter value may be entered. Now type in the new value for the parameter. To correct any mistakes use the BACKSPACE or DELETE keys to delete the incorrect text and then enter the correct text. On pressing the RETURN (or ENTER) key the new value of the parameter will be entered, the box will turn color from yellow to black, and the new value of the parameter will be displayed in yellow text. It is important to note that pressing a mouse button is NOT equivalent to pressing the RETURN (or ENTER) key. If by mistake, you do press the mouse button instead of the RETURN (or ENTER) key then one of the letters A, D, or X will be displayed in the parameter box. To remove this spurious letter press either the BACKSPACE or DELETE key, followed by the RETURN (or ENTER) key.

3.3 On-Line Help Facility

Provided that the user has the programs `latex` and `xdvi` already installed on their machine there is an on-line help facility for each `fakesat_menu` sub-menu. Simply place the mouse in the "FEKERAT: Interactive Menu" box at the top of the menu and click. A description of the sub-menus should then appear.

4 `Fakesat_menu`: Tutorial

The best way to show how to use the menu is to give a brief example. We will create a u-v plot for a simulation not involving any spacecraft. The **mode:** sub-menu, at the top of the menu, controls the user interface. When the **input** pushbutton of the **mode:** sub-menu has been selected, the menu is in input mode and is waiting for mouse button clicks. It is in this mode that pushbuttons may be selected or de-selected and parameter values can changed. To run a simulation select the **run** pushbutton from the **mode:** sub-menu.

By default the menu is in input mode. Select the **ground only** pushbutton (i.e., point and click the mouse in the pushbutton with **ground only** written on it) from the **spacecraft:** sub-menu. It should then turn green and after a few moments all the sub-menus required to create a u-v plot will be displayed. If the **uvplot** pushbutton of the **options:** sub-menu is not selected (i.e., is NOT colored green and depressed) click on it and it will be.

We will now change the observation year from 2011 to 2012. With the mouse click on the first black box of the **observation date:** sub-menu, that is, the black box with 2011 written in yellow text. We call this the obs-year parameter, where obs-year stands for the year of observation. The name of the

parameter, in this case obs-year, is shown in the box to the left of the black box with 2011 inside it. When the black box with 2011 in yellow text is clicked with the mouse, the box turns yellow. If you like you can now move the mouse out of the yellow box so that it can be viewed more easily. Now type 2012 on the keyboard and it will appear in black letters inside the obs-year parameter box. If you make a mistake press the DELETE or BACKSPACE keys and the relevant mistyped character will be eliminated. Once you have typed in the required 2012 press the RETURN key and the parameter will be entered. On pressing the RETURN key, the black text on a yellow background is converted to yellow text on a black background.

Now we will change the source to be observed from 3C345 to 3C273. Simply move the mouse to the **source:** sub-menu, click the mouse inside the source parameter box (the one with 3C345 inside it), type 3C273, and press the RETURN key. The program then looks up 3C273 in the `sources.cat` file, finds the source, and then enters its coordinates in the **RA and Dec** sub-menu. Note that the entry of the source name is case sensitive. If you enter 3c273 instead of 3C273 the menu will not recognize this source name and give you default coordinates of 0 h right ascension and 0° declination.

We will now change the ground array to be used the EVN array of antennas. Now click on the **EVN** option of the **array:** sub-menu and the EVN antennas will be selected.

From the **observation time:** sub-menu we notice that we are going to simulate a 24 hour observation. There are several other parameters that can be set but we will ignore these for the time being and concentrate only on the **output options:** sub-menu. Here we have a choice of four pushbuttons. The first pushbutton is to output the required u-v plot to a **Xwindows** window and the other three options will produce hardcopy PostScript output. By default, the **Xwindows** pushbutton should already be selected.

You are now ready to run your first simulation. Go back to the **mode:** sub-menu at the top of the menu and select the **run** pushbutton (i.e., click on it). In the terminal emulator window in which you first started up `fakesat_menu`, there will be some output which shows the contents of the `.fakesat-tmp.csh` file. This output will then be followed by output generated by the `fakesat` program itself. The function of the `fakesat_menu` program is to create the `.fakesat-tmp.csh` C shell script, and then execute this script as a background process. Those familiar with the Caltech VLBI package will recognize the 'keyin' format of the `.fakesat-tmp.csh` file. The output to X windows should be similar to the u-v plot shown in the top half of Figure 1 and the menu set-up used to create the u-v plot should similar to that shown in the bottom half of this figure.

Let's run a second simulation but this time in the **output options:** sub-menu select the **ps: plot+menu** pushbutton. This automatically de-selects the previous chosen **Xwindows** pushbutton as this is an 'only one' pushbutton sub-menu. Having done this, select the **run** option from the **mode:** sub-menu. On doing this the `.fakesat-tmp.csh` C shell script will again be created and executed. Two further files will also be created: `def-uv-c-2011-d32-rastron-3C273` is a `fakesat_menu` defaults file and `plt-uv-c-2011-d32-rastron-3C273.vps` is a PostScript file. This PostScript file contains both the required u-v plot and a copy of the `fakesat_menu` menu that was used to create it. This file should be the same as that displayed in Figure 1. This PostScript output option is to be recommended as it enables the user to see which menu parameters were used, in this case to create a u-v plot. A `fakesat_menu` defaults file is created whenever the pushbutton selected from the **output options:** sub-menu will produce a PostScript file or whenever the **save menu** pushbutton of the **mode:** sub-menu has been been selected.

When the `run` C shell script is used to start up the `fakesat_menu` program it uses a standard `fakesat_menu` defaults file called `menu_defaults` to read in the various parameters that are displayed on the interactive menu. The `menu_defaults` file has new parameters written to it whenever the **save menu** pushbutton of the **mode:** sub-menu is selected. This enables the user to customize the interactive menu to their liking and for these parameters to appear when `fakesat_menu` is run subsequently. It is also possible to start up `fakesat_menu` with one of the defaults files previously created. For example if one wanted so start up the interactive menu with the defaults file that was created above ,namely `def-uv-c-2011-d32-rastron-3C273`, one would simply type:

```
run def-uv-c-2011-d32-rastron-3C273
```

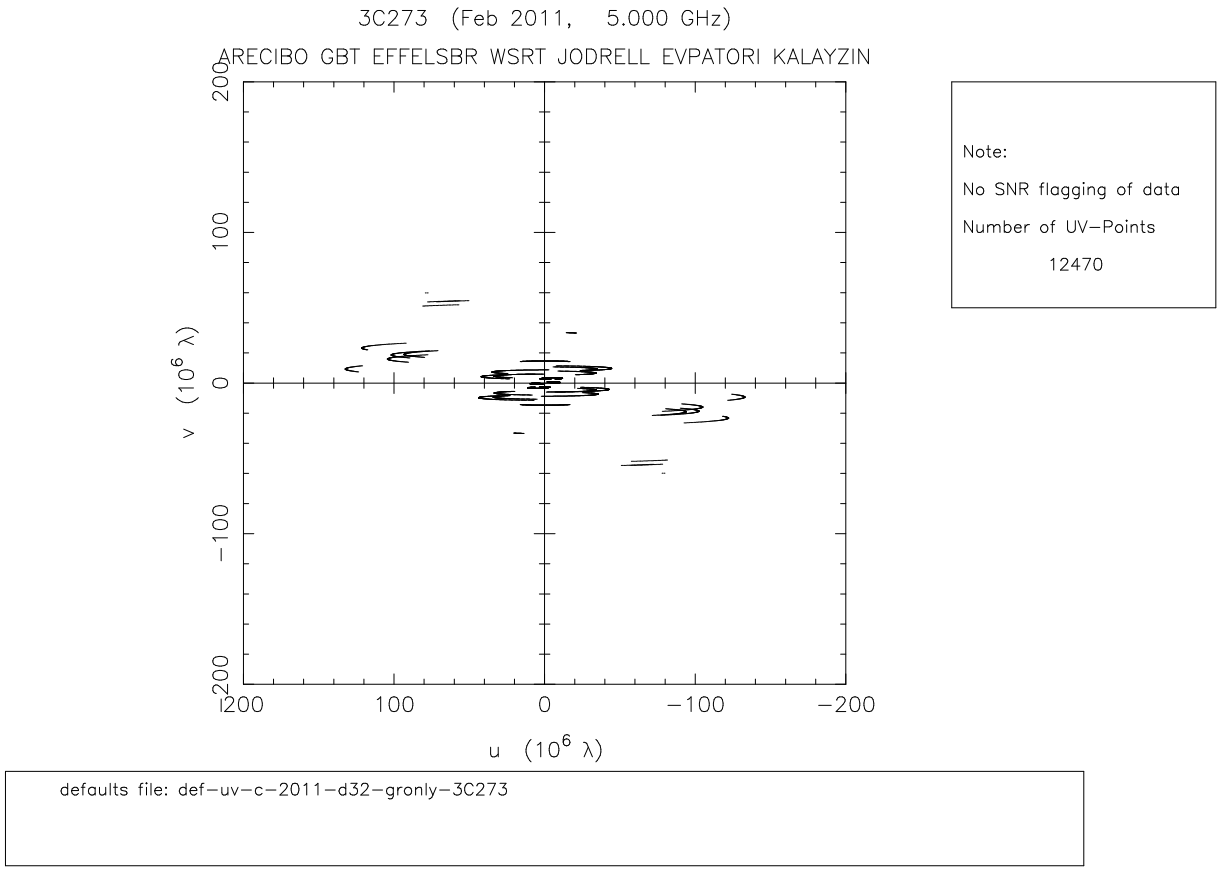


Figure 1: Ground-Only u-v Plot Example.

The defaults and plot files created by `fakesat_menu` and `fakesat` remain in the directory in which the user is working. To delete or print these files, the user must use standard UNIX commands outside of the `fakesat_menu` program.

If you have followed this tutorial you should be in a good position to run the `fakesat_menu` program via the `run` C shell script. To get more information on particular sub-menus please refer to the relevant section in FAKESAT reference Manual. To simulate a VLBI experiment involving the RADIOASTRON spacecraft simply select the the **RADIASTRON** pushbutton from the **spacecraft** sub-menu. The following two sections show examples of simulations that can be undertaken with VLBI experiments that involve the RADIASTRON spacecraft.

The default orbit is located in the directory /fakerad/orbit/ It covers the period from 2011-07-30 to 2012-01-02. All figures are constructed for the default orbit.

5 `Fakesat_menu`: RADIOASTRON Hardcopy Examples

In this section we will examine some examples of the PostScript output produced by the `fakesat` program. These examples are the default output produced by the `fakesat` program when both the **RADIASTRON** pushbutton of the **spacecraft:** sub-menu and the **ps: plot+menu** pushbutton of the **output options:** sub-menu have been selected. To re-create these plots yourself remember to select the **run** pushbutton of the **mode:** sub-menu to create the plot. All the examples presented here and in the following section can be obtained by using the simple version of the `fakesat_menu` menu. If instead of creating a PostScript output file, you want to display the result to an X window; select the **Xwindows** pushbutton from the **output options:** sub-menu.

5.1 Output from the options: Sub-Menu

In this sub-section the PostScript output from various of the options from the **options:** sub-menu is presented. For more details on any of the options described below please refer to the relevant section in FAKERAD Reference Manual.

all-sky uvplot In Figure 2 is plotted the default RADIOASTRON 'all-sky' u-v plot. This plot show u-v coverages as a function of right ascension and declination, for a given epoch. When the **ps: plot+menu** pushbutton of the **output options:** sub-menu is selected, a copy of the `fakesat_menu` menu used to create a particular plot is placed directly below the plot.

time-uvplot In Figure 3 is plotted the default RADIOASTRON 'time' u-v plot. This plot show u-v coverages, for a given source, at equally space intervals of time. This type of plot is very useful for planning monitoring observations.

uvplot In Figure 4 is plotted the default RADIOASTRON u-v plot.

constraints In Figure 5 is plotted the default constraint plot. The constraint plot shows how the spacecraft constraints are met as a function of time and which tracking station or stations can track the spacecraft. This plot is useful for determining how the spacecraft constraints impact the amount of VLBI data that can be obtained for a particular observation.

5.2 Output from the telescope options: Sub-Menu

In this sub-section the PostScript output from various of the options from the **telescope options:** sub-menu is presented. This sub-menu is revealed once the **telescope >** option of the **options:** sub-menu has been selected. For more details on any of the options described below please refer to the relevant section in FAKERAD Reference Manual.

timeline In Figure 6 is plotted the default RADIOASTRON telescope timeline. This plot shows when and what percentage of the time the selected radio telescope, including the spacecraft, can observe the source.

N vs t In Figure 7 is plotted the default RADIOASTRON 'N vs t' plot. The 'N vs t' plot shows how many telescopes can observe the source as a function of time, There are two graphs. The lower one just considers just ground radio telescopes. The upper graph plots the number versus time, when at least one of the antennas is the spacecraft. These graphs are useful for determining how well a given ground array of telescopes can support a particular RADIOASTRON observation. Above these graphs is a plot of the spacecraft altitude as a function of time. This plot shows that it is difficult to collect VLBI data from the spacecraft when it is near perigee.

F(>N) plot In Figure 8 is plotted the default RADIOASTRON 'F(>N)' plot. This plot is the integral over time of the previous plot and shows what fraction of the time at least N telescopes can observe the source. Again two curves are plotted, one considers only the ground radio telescopes and the other considers the case when at least one of the antennas that can observe is the spacecraft. This plot is useful for determining what fraction of the time closure phase and amplitude information will be obtained with a RADIOASTRON experiment.

GRT map In Figure 9 is plotted the default ground radio telescope (GRT) plot. This plot shows the geographical location of the selected ground radio telescopes.

5.3 Output from the data options: Sub-Menu

In this sub-section the PostScript output from various of the options from the **data options:** sub-menu is presented. This sub-menu is revealed once the **data >** pushbutton of the **options:** sub-menu has been selected. For more details on any of the options described below please refer to the relevant section in FAKERAD Reference Manual.

uv-distance In Figure 10 is plotted the default RADIOASTRON 'uv-distance'. This plots shows the correlated flux of a source model specified in the **model info:** sub-menu as a function of the projected baseline length. If the **SNR-flag** parameter of the **model info:** sub-menu is greater than zero then data with a signal to noise ratio (SNR) less than this will be flagged.

SNR-plot In Figure 11 is plotted the default RADIOASTRON 'SNR-plot' plot. This plots shows the Signal to Noise Ration (SNR) as a function of the projected baseline length. Again the source model and SNR below which to flag data is specified from the **model info:** sub-menu.

If the **SNR-flag** parameter of the **model info:** sub-menu is greater than zero then data with a signal to noise ratio (SNR) less than this will be flagged.

5.4 Output from the extra plots: Sub-Menu

In this sub-section the PostScript output from the **ground track** option from the **extra plots:** sub-menu is presented. This sub-menu is revealed once the **extra plots >** option of the **options:** sub-menu has been selected. For more details on this option please refer to the relevant section in FAKERAD Reference Manual.

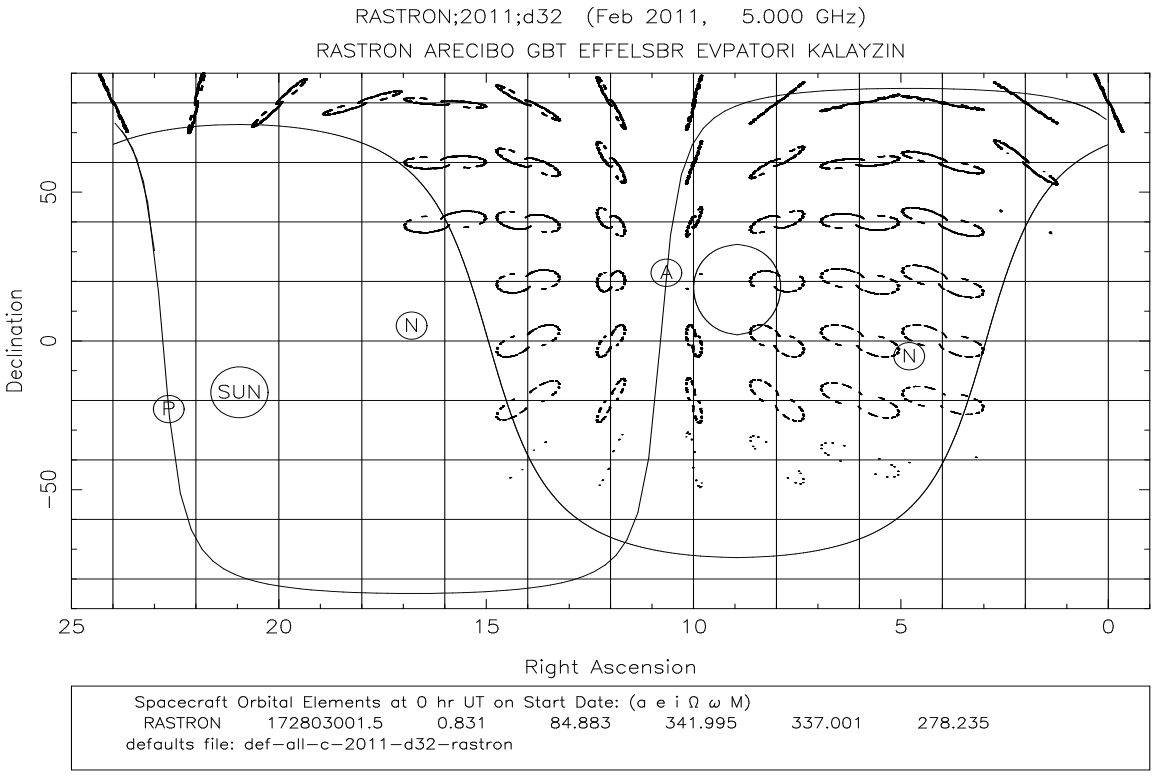
ground track In Figure 12 is plotted the default RADIOASTRON sub-satellite ground track. At each instant the spacecraft is at the zenith at some point on the earth. This point is called the sub-satellite point and the sub-satellite ground-track is simple the set of these points for a given period time.

6 `Fakesat_menu`: RADIOASTRON X Windows Examples

All of the above hardcopy examples can be displayed to X windows if the **X windows** pushbutton of the **output options:** sub-menu is selected, except that in this case only the plot is displayed and not the menu used to create it. There are however two options from the **extra plots:** sub-menu that can only be displayed to X windows. Below we describe these options:

source view When this pushbutton is selected a 'movie' of the rotating earth as seen from the source is displayed. This option is very useful for getting an overall feel of what space VLBI is all about.

sat view When this pushbutton is selected a 'movie' of the rotating earth as seen from the spacecraft is displayed.



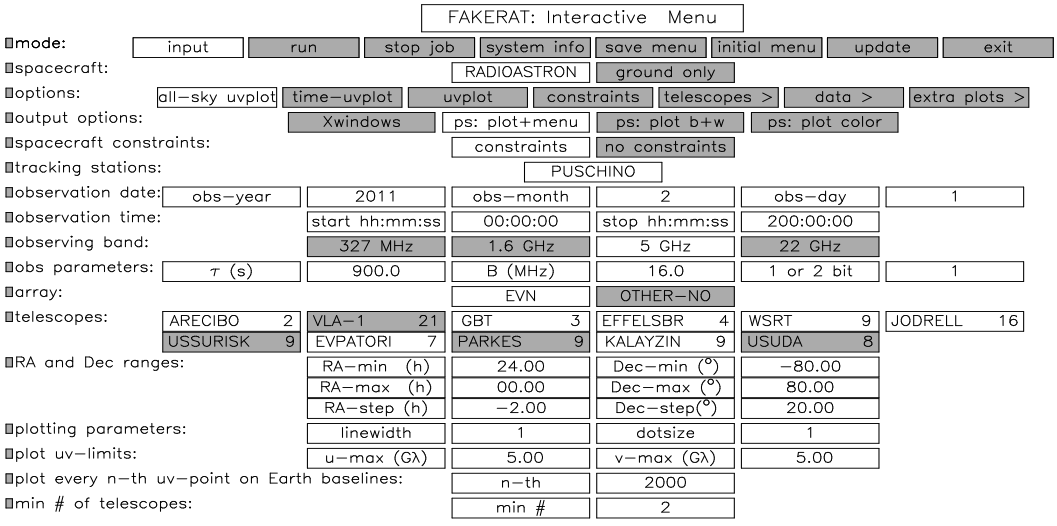


Figure 2: All-Sky *u-v* Plot Example.

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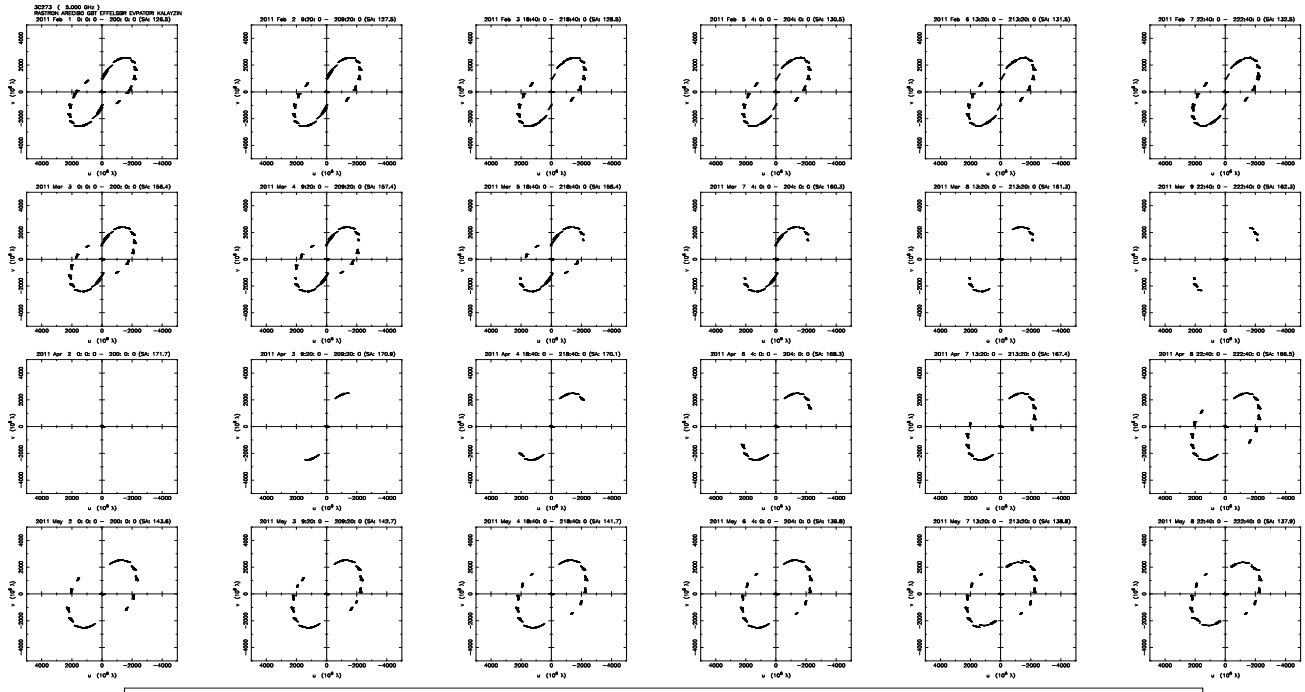


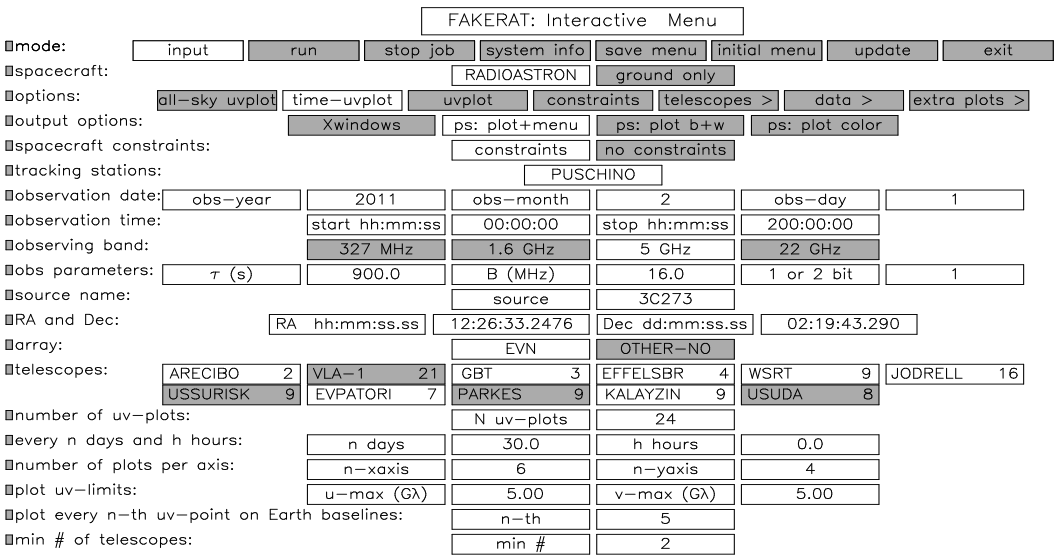
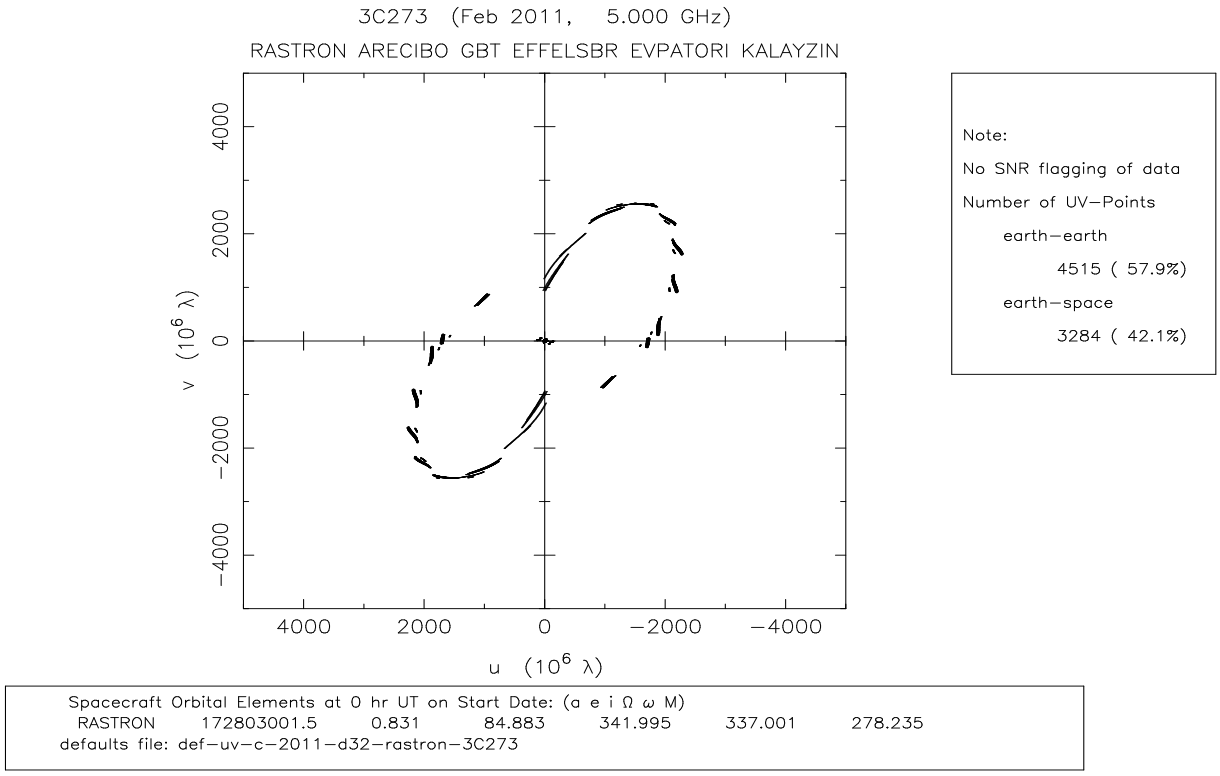


Figure 3: Plot as a Function of Time Example.



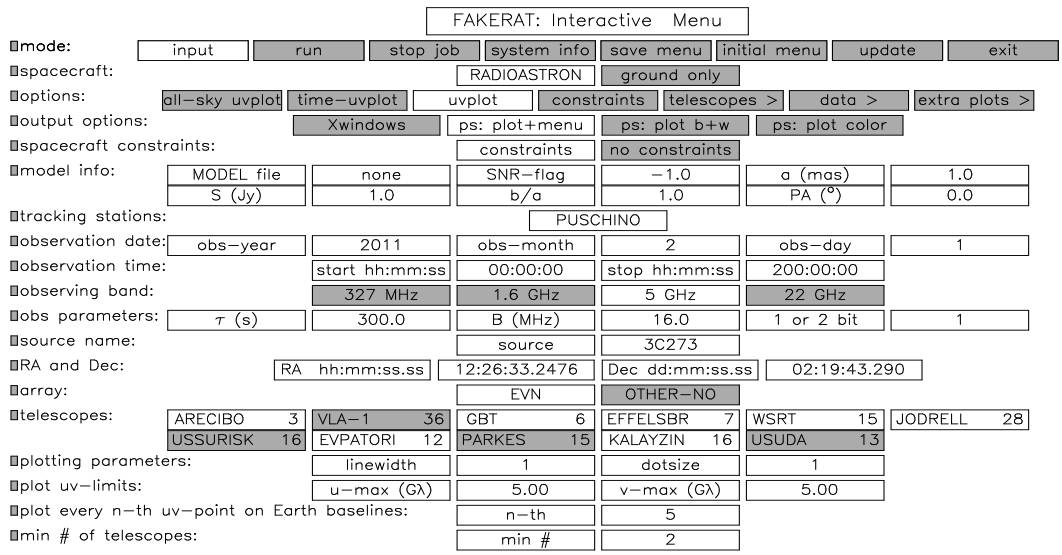


Figure 4: *u-v* Plot Example.

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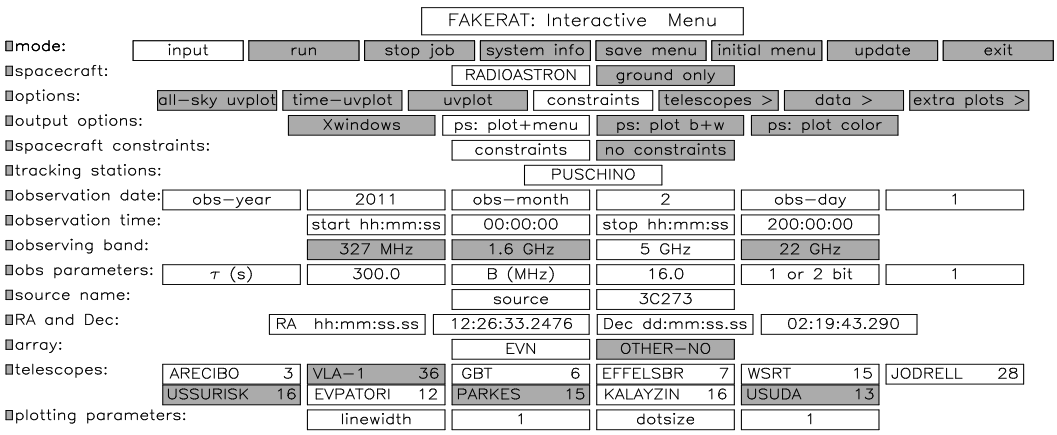

Figure 5: Constraint Plot Example.

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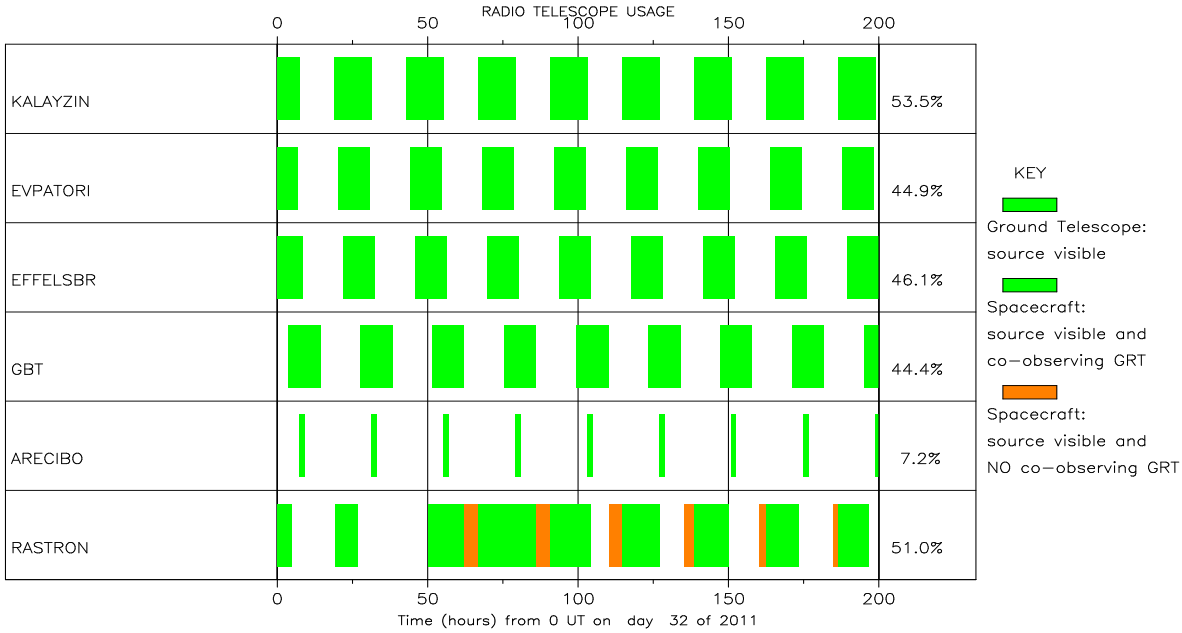

Spacecraft Orbital Elements at 0 hr UT on Start Date: (a e i Ω ω M)
RASTRON 172803001.5 0.831 84.883 341.995 337.001 278.235
defaults file: def−grt−c−2011−d32−rastron−3C273

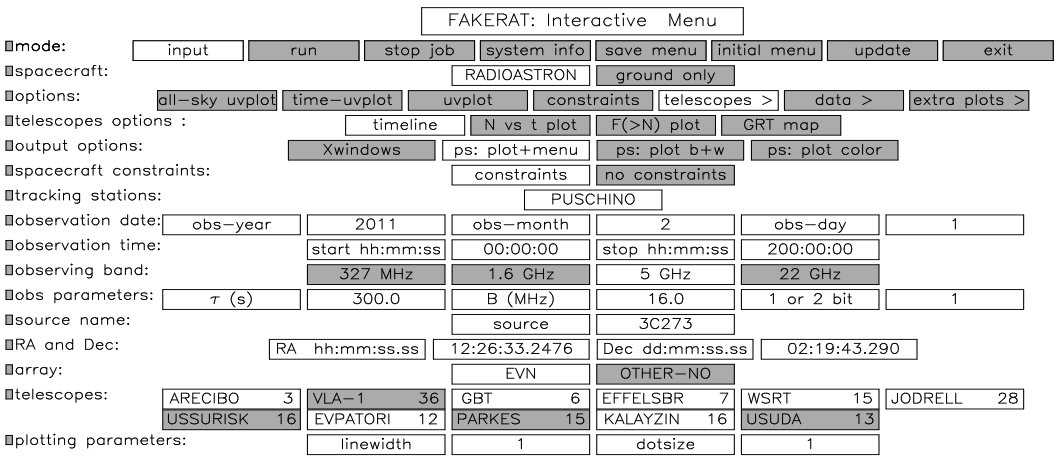

Figure 6: Telescope Time-Line Example.

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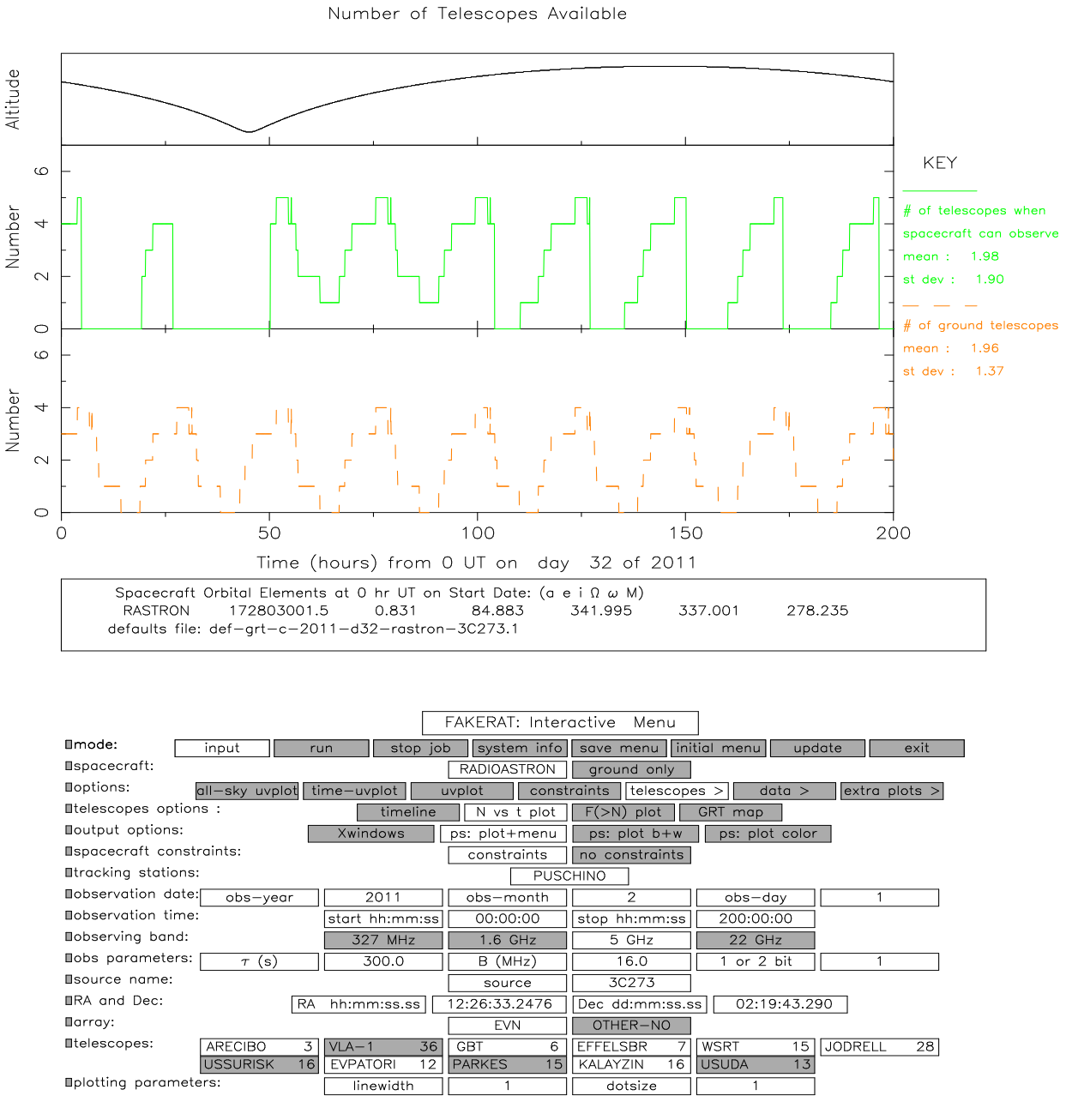
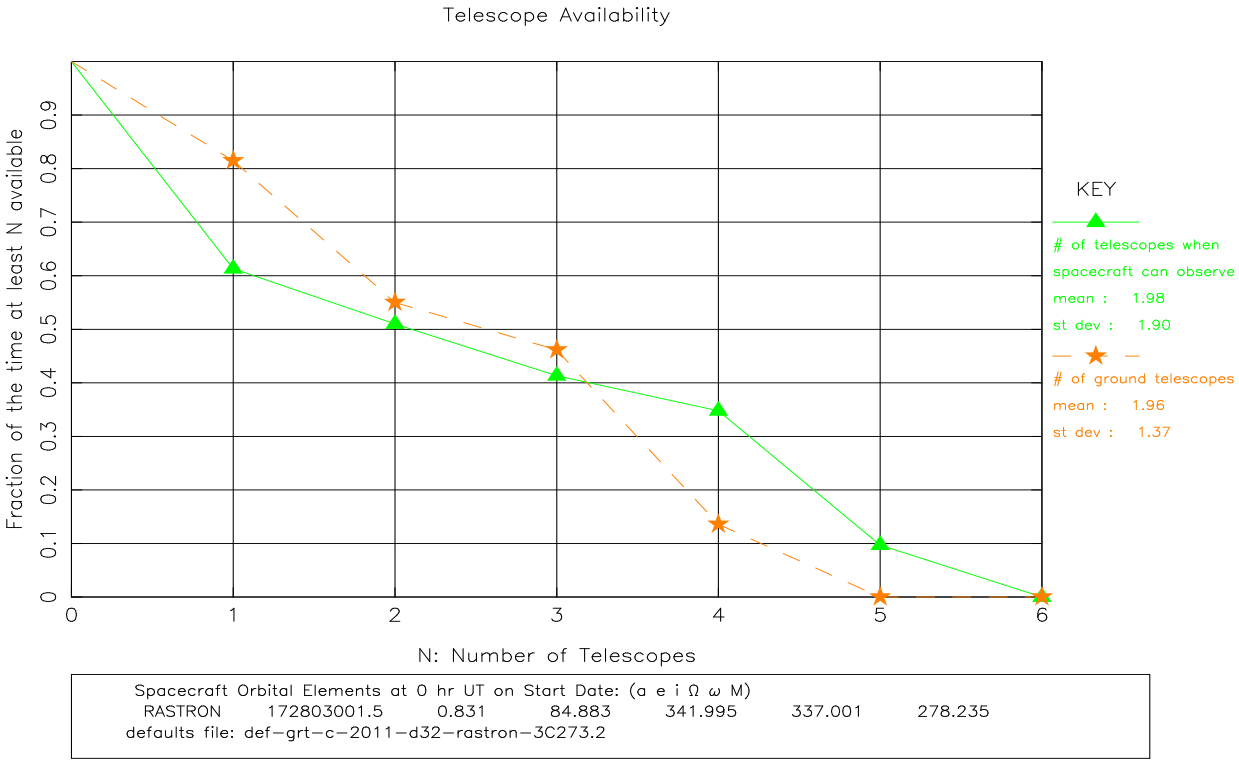


Figure 7: N vs t Plot Example.



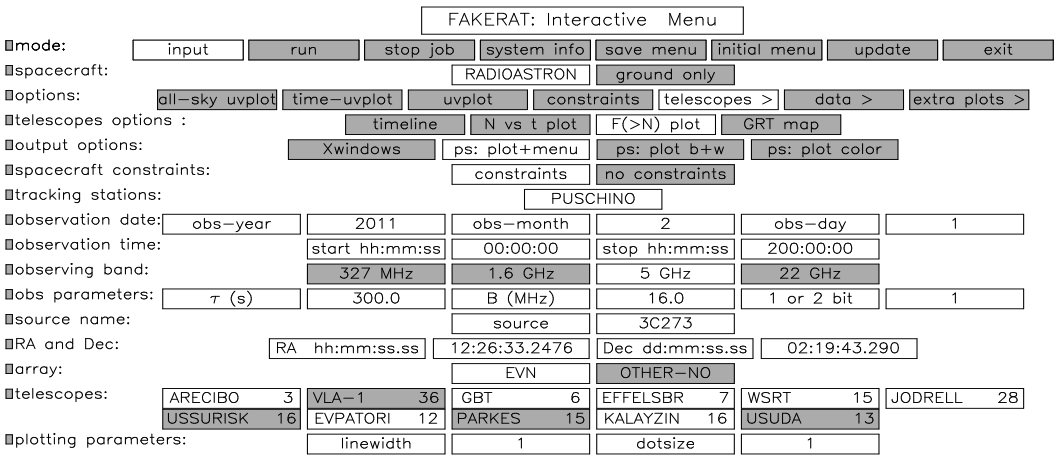


Figure 8: 'F(>N)' Plot Example.

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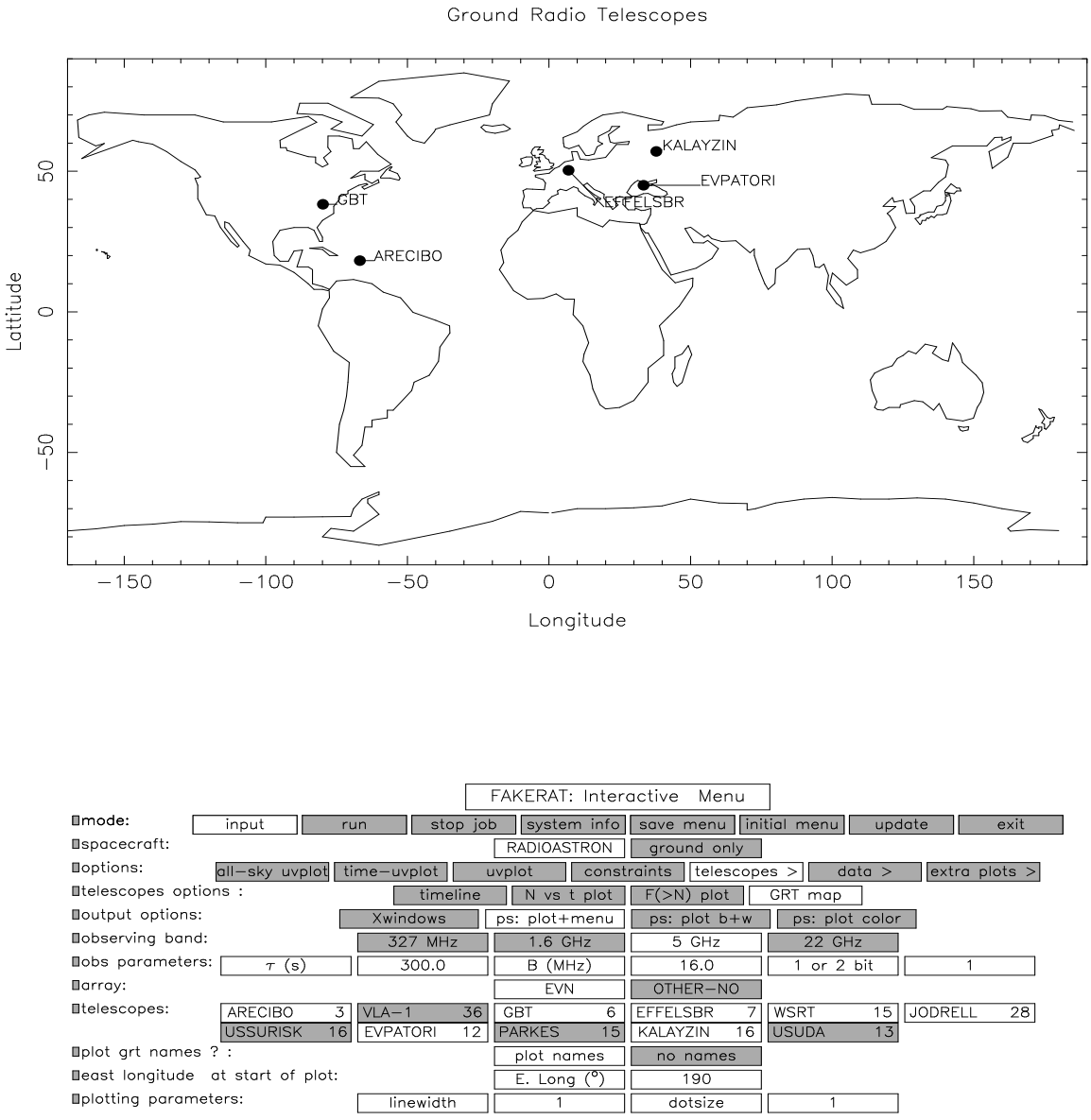

Figure 9: Ground Radio Telescope World Map Example.

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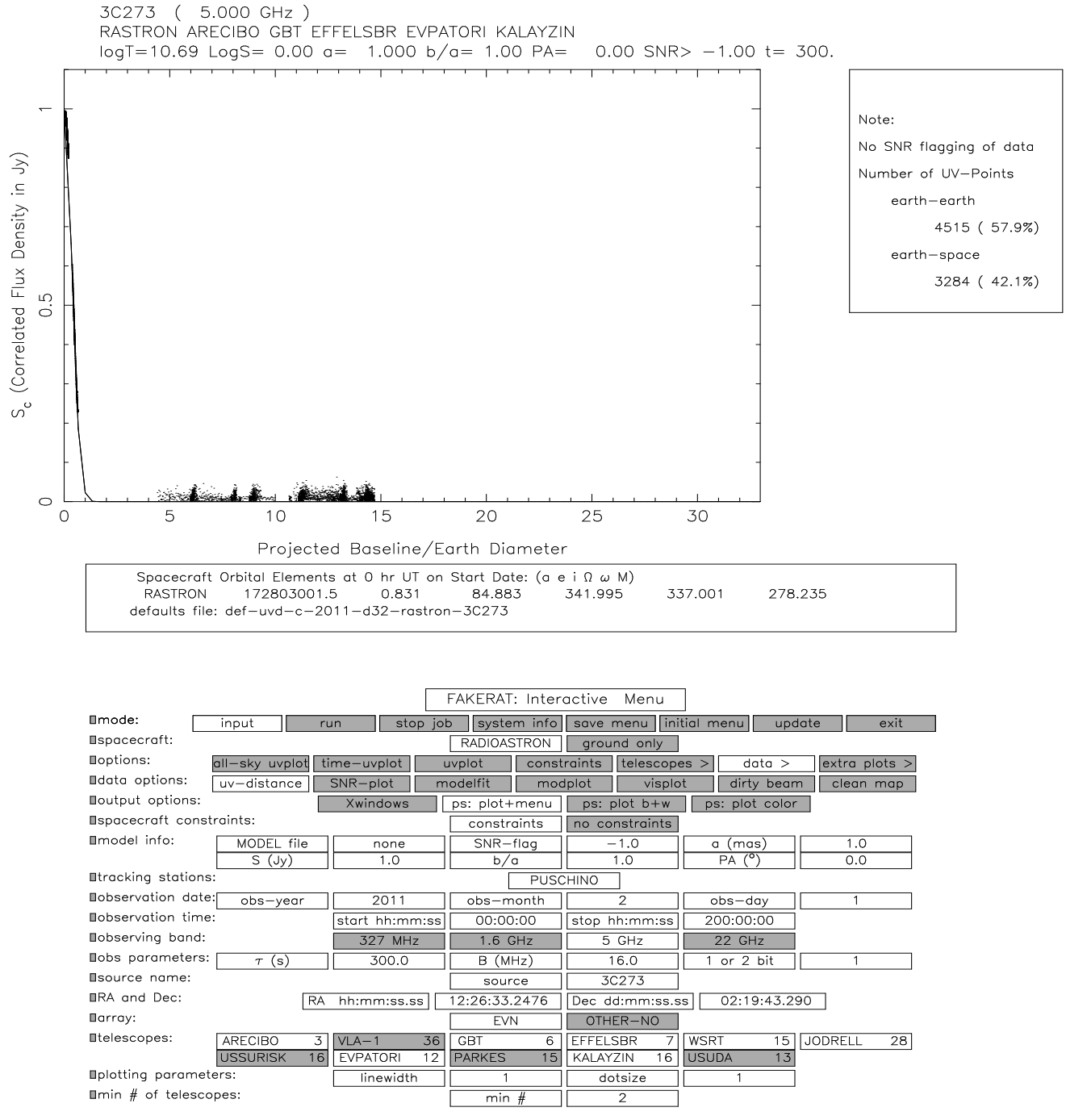

Figure 10: Distance Plot Example.

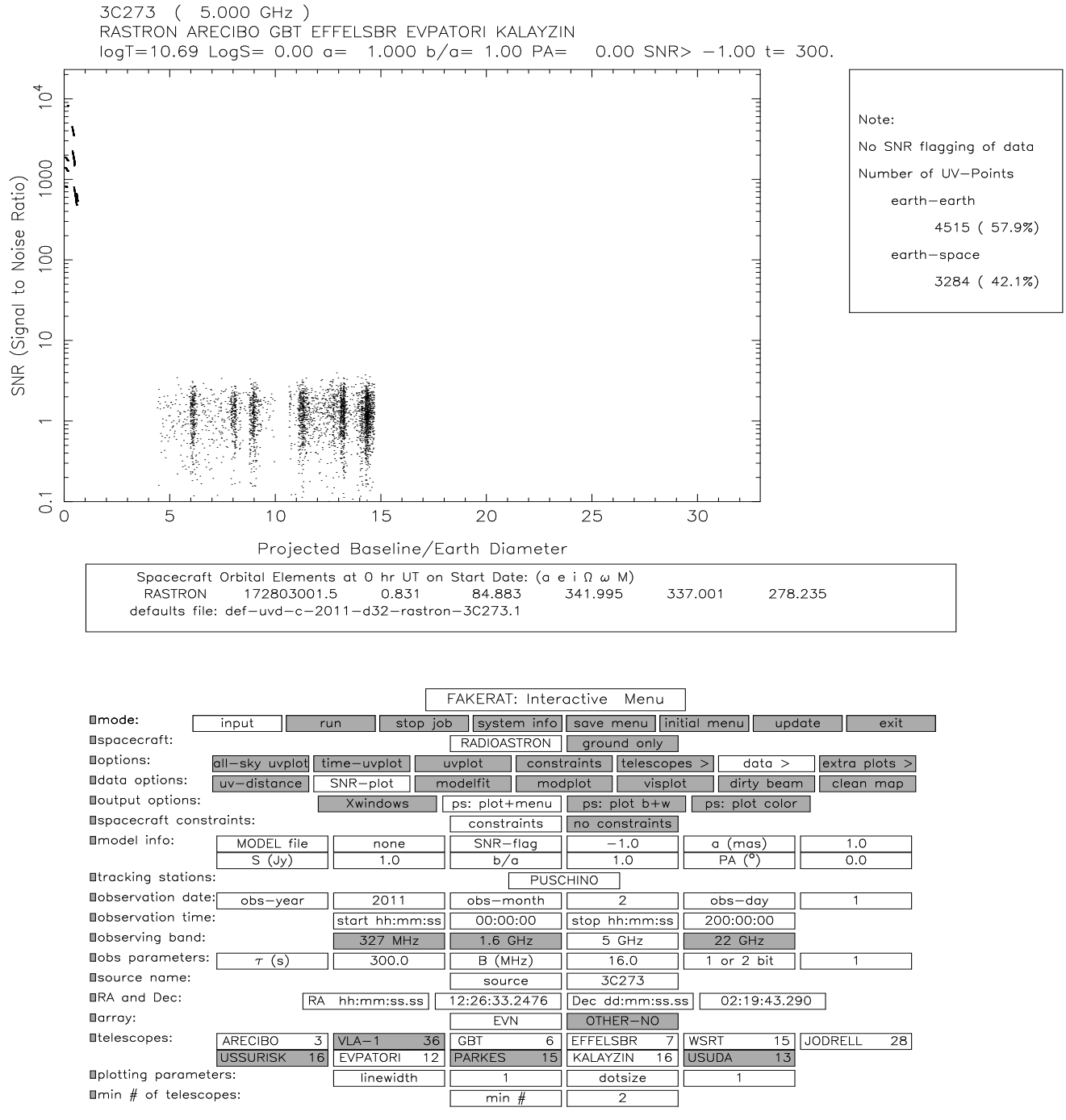

Figure 11: SNR Plot Example.

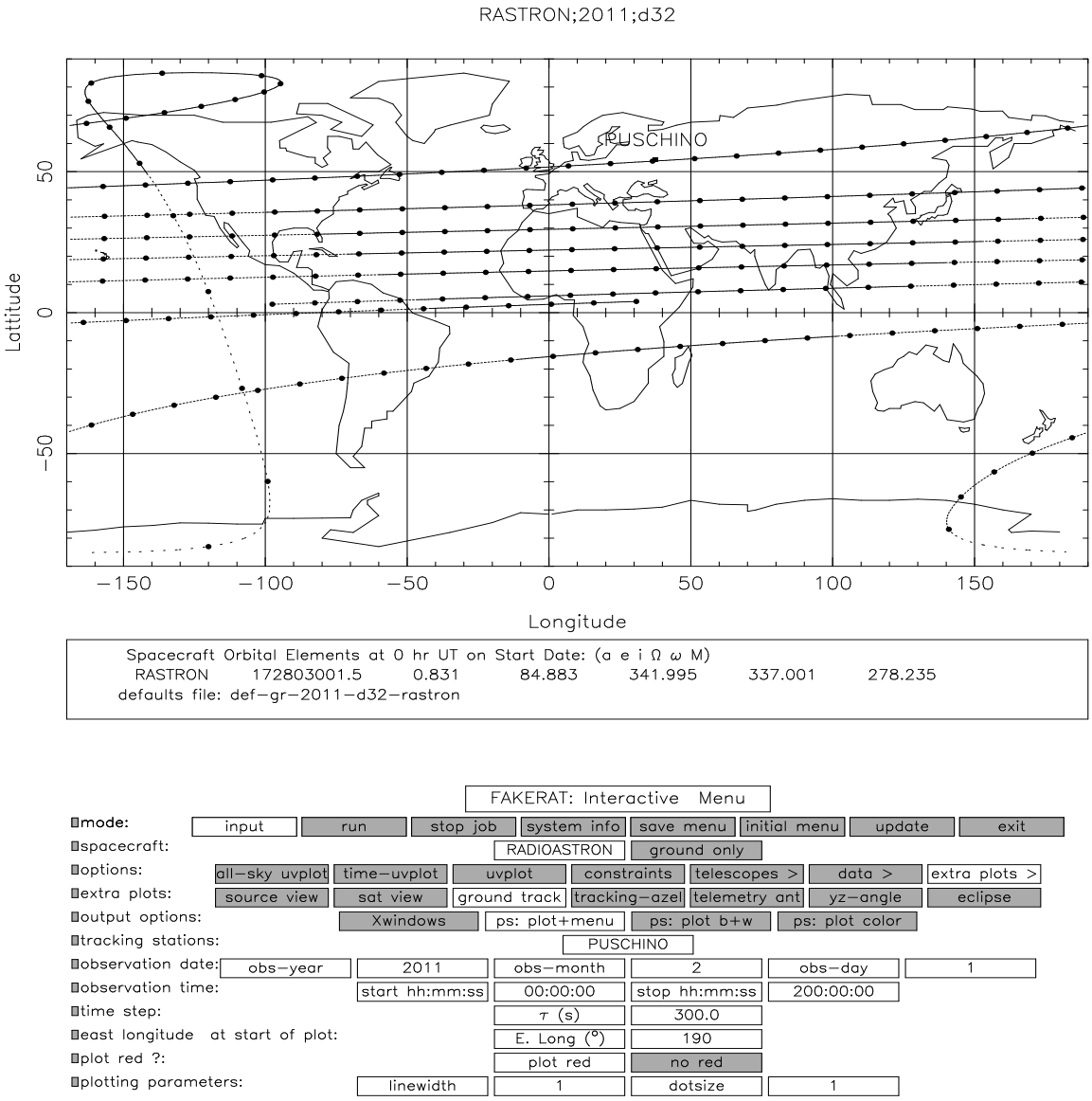

Figure 12: Sub-Satellite Ground Track Example.