Temperature vs. Frequency Plot of Our Sun

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Introduction

This laboratory exercise was adapted from Whitlock, L. A. and Pulliam, K., 2008, *Listen Up! Laboratory Exercises for Introductory Radio Astronomy with a Small Radio Telescope*.

Purpose

Learn the basics of operating the Small Radio Telescope (SRT), and create temperature vs. frequency plots of the Sun in the SRT software, and using the R statistical analysis package (R Foundation, 2009).

Procedure

Summary

Details

System initialization

1. Power-up the SRT computer and monitor.
2. After the computer shows the desktop, apply power to the SRT digital controller/receiver by putting the power toggle switch into the ***up*** position. The red LED should be on.
3. Double-click on the SRT.exe icon on the desktop. The SRT control panel opens. The upper left-hand corner shows the Azimuth (Az) and Elevation (El) position ***counters*** changing as the dish moves from the Park position (Az=78°, El=87°) to its initialization position at Az=78° and El=2°. This will take at least ***2 minutes***, so be patient, and DO NOT do anything until the dish is in position. Illustration 1 shows the SRT control panel as it moves to the initialization position. Notice the destination position is indicated with a yellow cross in the lower left corner of the planetarium sub-panel. When the dish reaches the initialization position, the upper right-hand corner of the control panel will appear as in Illustration 2. Notice the Antenna coordinates "cmd" match the "azel" in this sub-panel.
4. Go to the Calibrate section on page 3.

Plot of the Sun

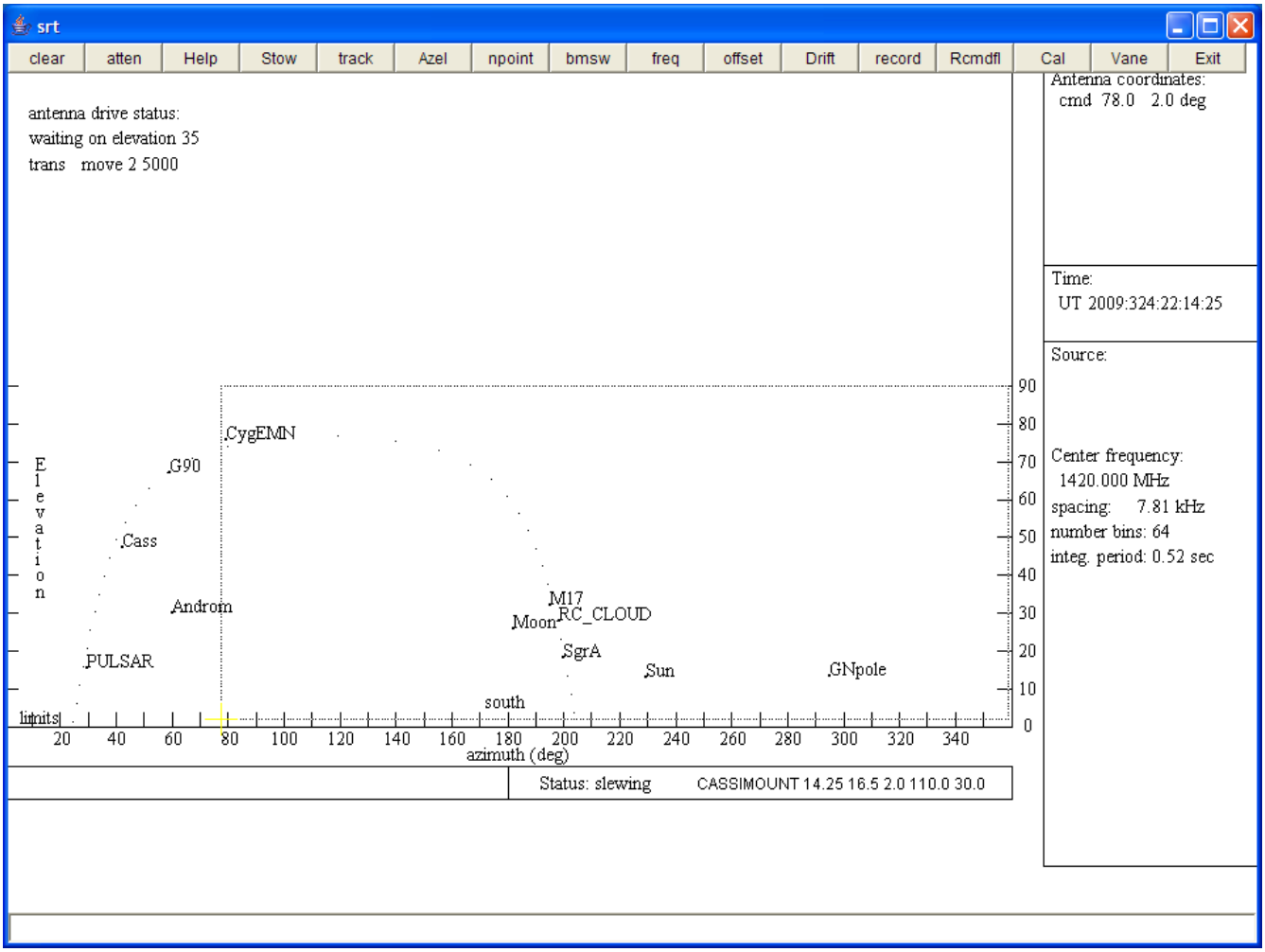

Illustration 1: ***System Initialization****. SRT control panel as the dish moves to the initialization position. Notice the destination position is indicated with a yellow cross in the planetarium sub-panel.*

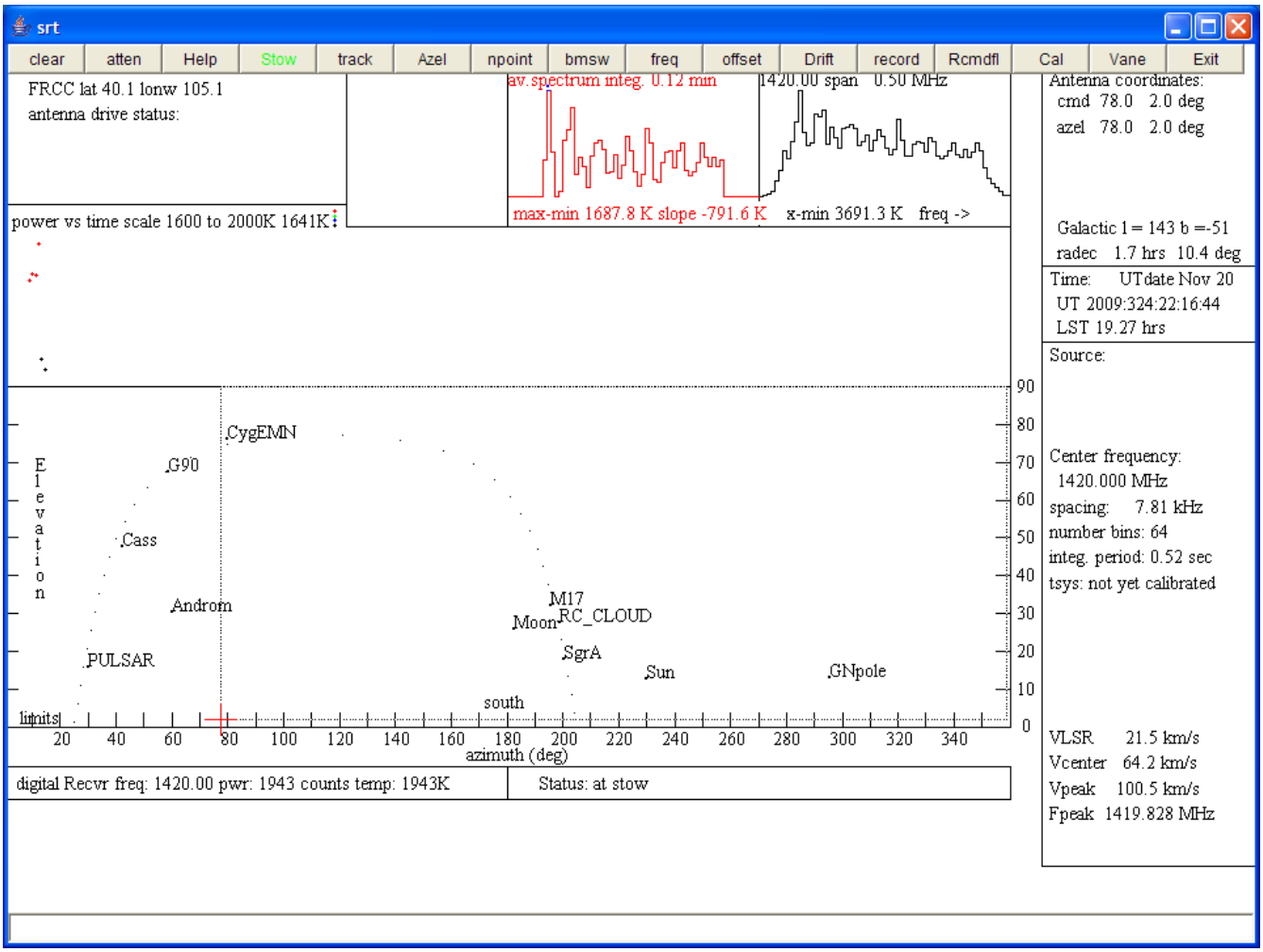

Illustration 2: ***System Initialization****. SRT control panel after the dish arrives at the initialization position. Notice the destination position is indicated with a red cross in the planetarium window. Also note that the Antenna coordinates "cmd" match the "azel" in the upper right-hand corner sub-panel.*

Calibrate the telescope

1. Locate a point in the planetarium window with no sources approximately 30° above the Sun. Click on the "Azel" button at the top of the control panel. The "Azel" button letters turn green. A ***cursor*** appears in the ***data entry panel*** at the lower left-hand corner of the control panel.
2. Enter the ***Az number*** in degrees, then a ***space***, then the ***El number*** in degrees. Press the ***Enter*** key on the keyboard. As an example, the control panel appears as in Illustration 3 as the dish moves to the calibration location. This will take at least ***2 minutes***. Illustration 4 is the control panel after the dish has arrived at the calibration location. Wait until the dish location ***cross*** turns red. DO NOTHING until the dish as finished moving which is indicated by the red ***cross***.
3. Click on the "Cal" button at the top of the SRT control panel. The "Cal" button letters turn green. DO NOTHING while waiting until the right-hand status window gives a value in Kelvin for "tsys". This will take at least ***30 seconds***. It will look similar to Illustration 5.
4. Go to the Record Data section on page 6.

Plot of the Sun

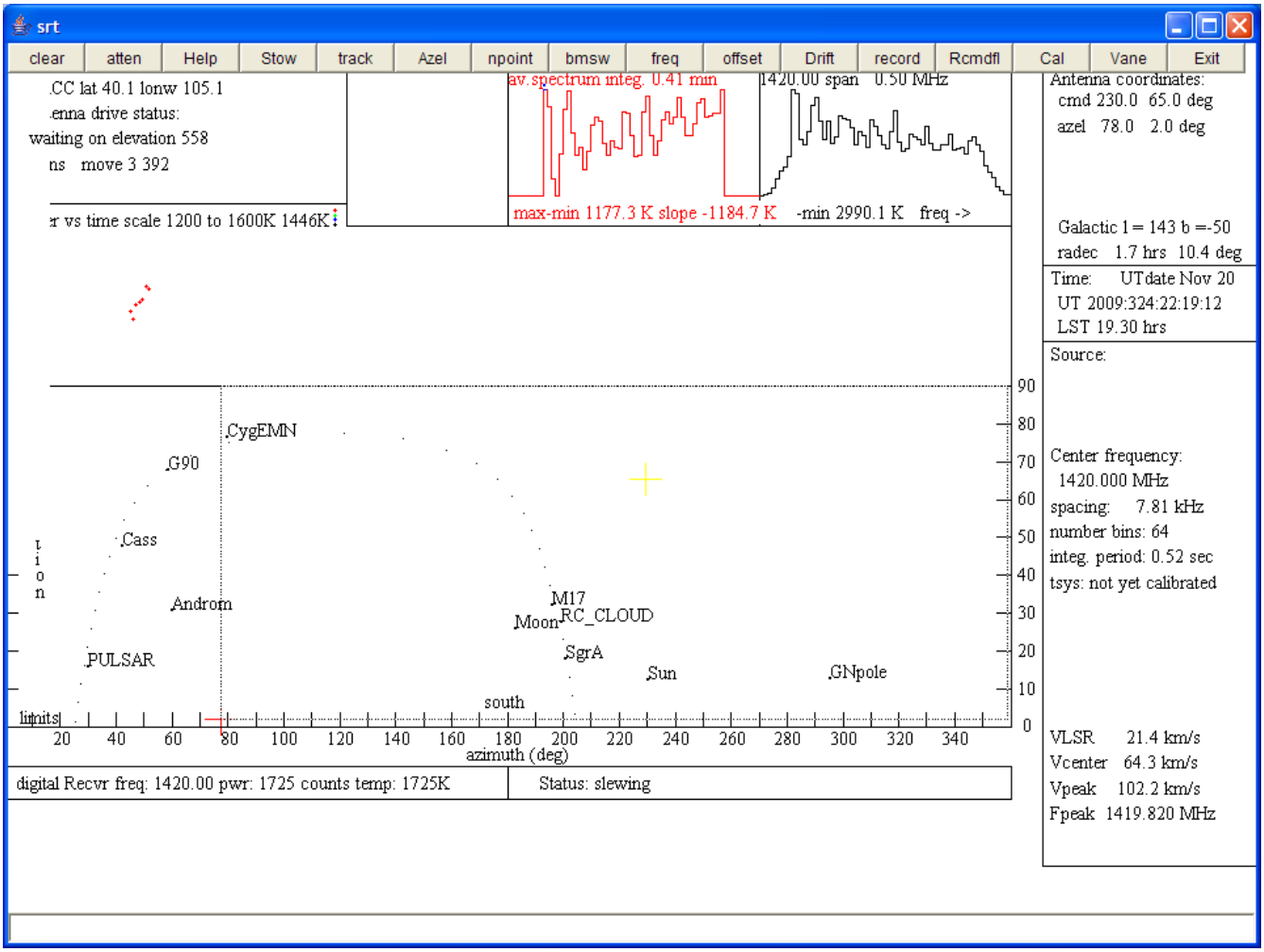

Illustration 3: ***Telescope Calibration****. SRT control panel as the dish moves from the initialization position (red cross) to the calibration location (yellow cross). The "Source" sub-panel on the right-hand side of the control panel shows "tsys: not yet calibrated".*

Plot of the Sun

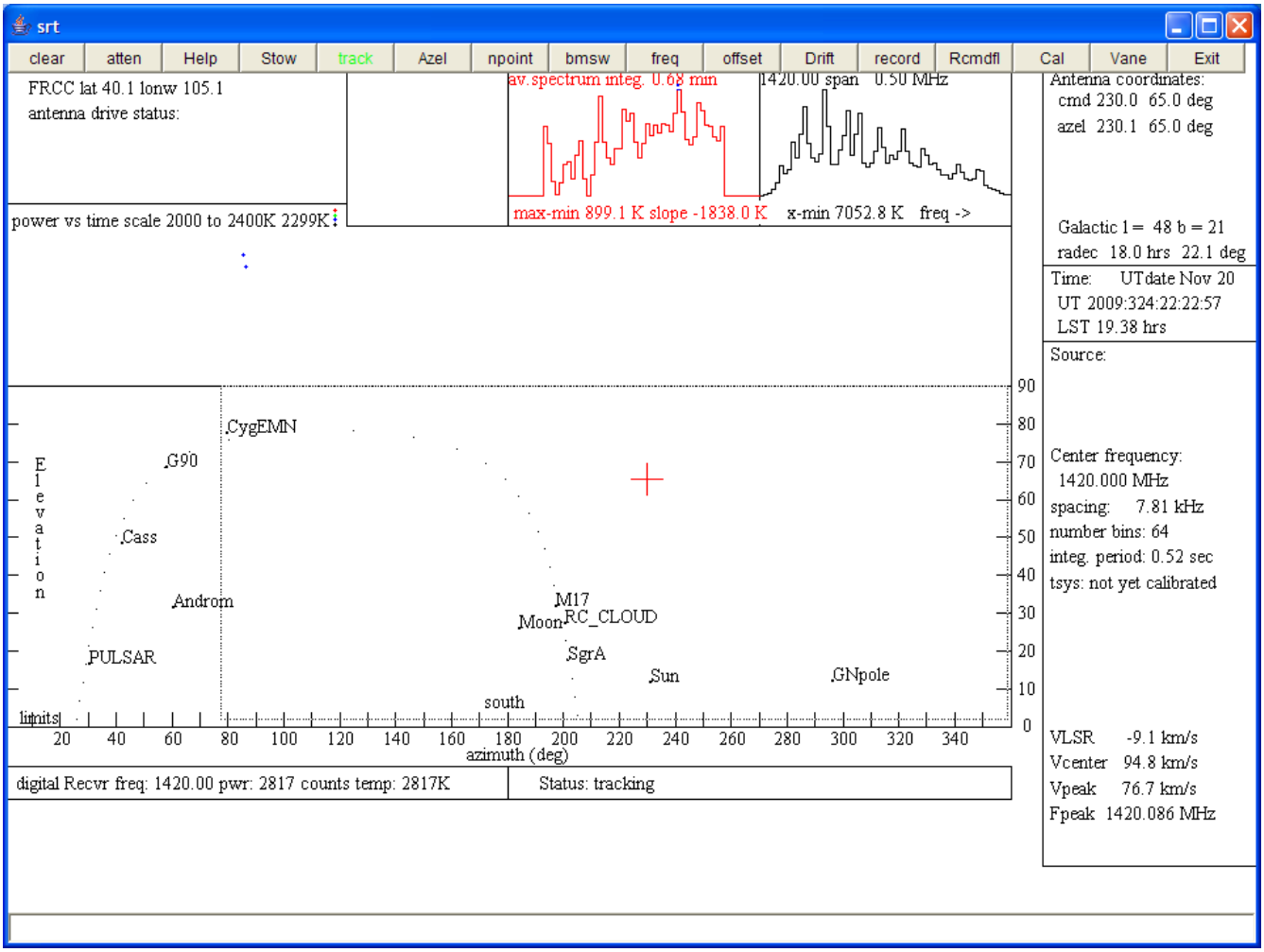

Illustration 4: ***Telescope Calibration****. SRT control panel after the dish arrived at the calibration position (red cross). The "Source" sub-panel on the right-hand side of the control panel still shows "tsys: not yet calibrated".*

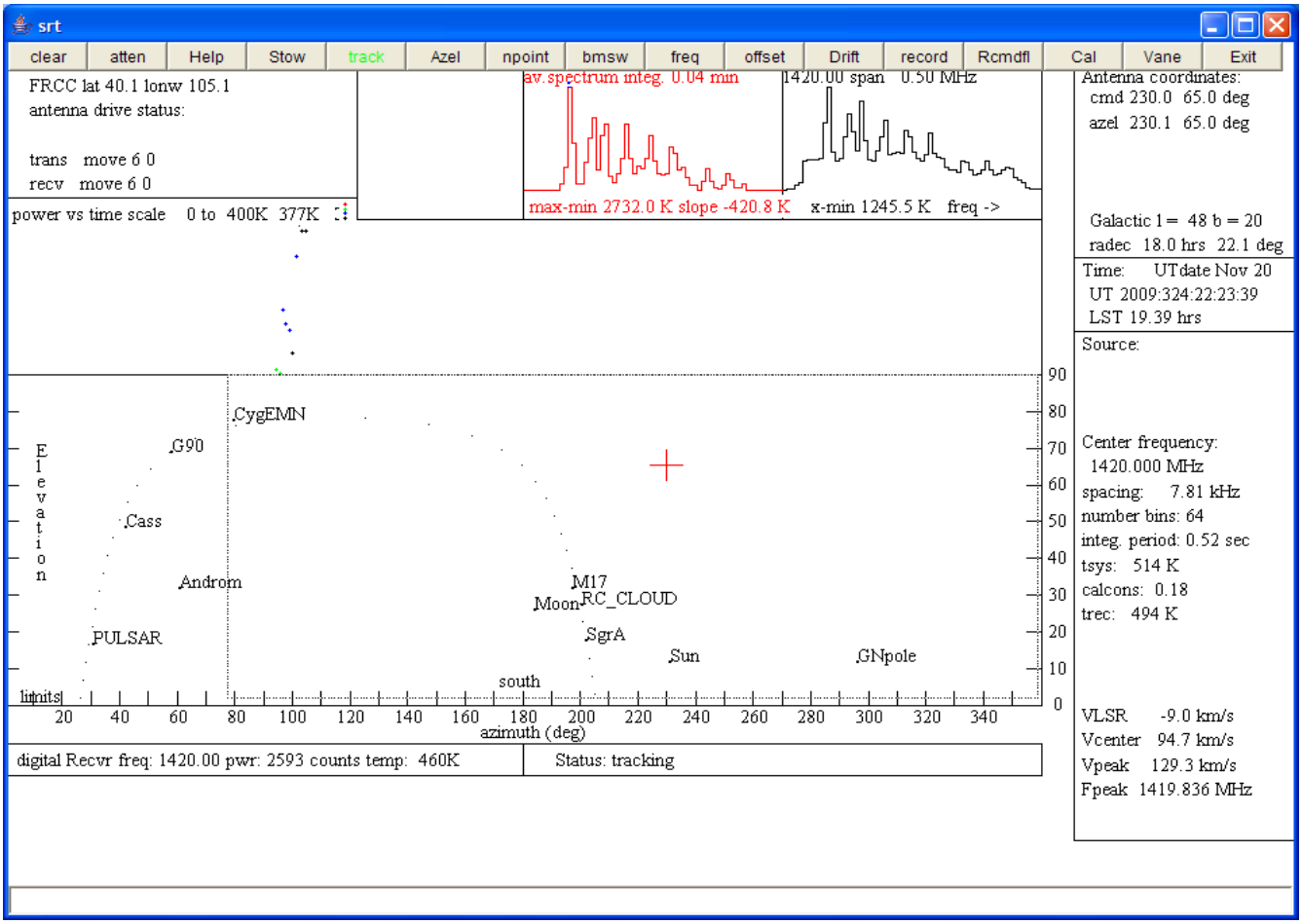

Illustration 5: ***Telescope Calibration****. SRT control panel as the dish moves from the initialization position (red cross) to the calibration location (yellow cross). The "Source" sub-panel on the right-hand side of the control panel now shows "tsys: 494K".* ***Your "tsys" value will most likely be different****.*

Record solar data

1. Select the "Sun" in the planetarium window. The ***cross*** turns yellow at the Sun's location while the calibration location ***cross*** remains red (Illustration 6). DO NOTHING while waiting until the ***cross*** turns red at the "Sun" location. Verify the controller is tracking by noting the "track" button letters are green. This move takes at least ***2 minutes***.
2. ***Left-click*** on the "record" button at the top of the control panel. Either ***type*** in a file name and ***left-click*** the "record" button again, or just ***left-click*** the "record" button again to accept the default file name. The letters in the "record" button turn green. The default file name format is YYDDDHH.rad. This gives the two-digit year, three-digit day of the year, and the two-digit hour. ***Note the file name*** you use as you will need it later. It is in the "Source" sub-panel in the lower right-hand-side of the control panel. See Illustration 7.
3. Record data for at least ***1 minute***, then ***left-click*** the "record" button to stop data recording. The "record" button letters return to **black**, and the file name in the "Source" window disappears.
4. Go to the Park Dish section on page 8.

Plot of the Sun

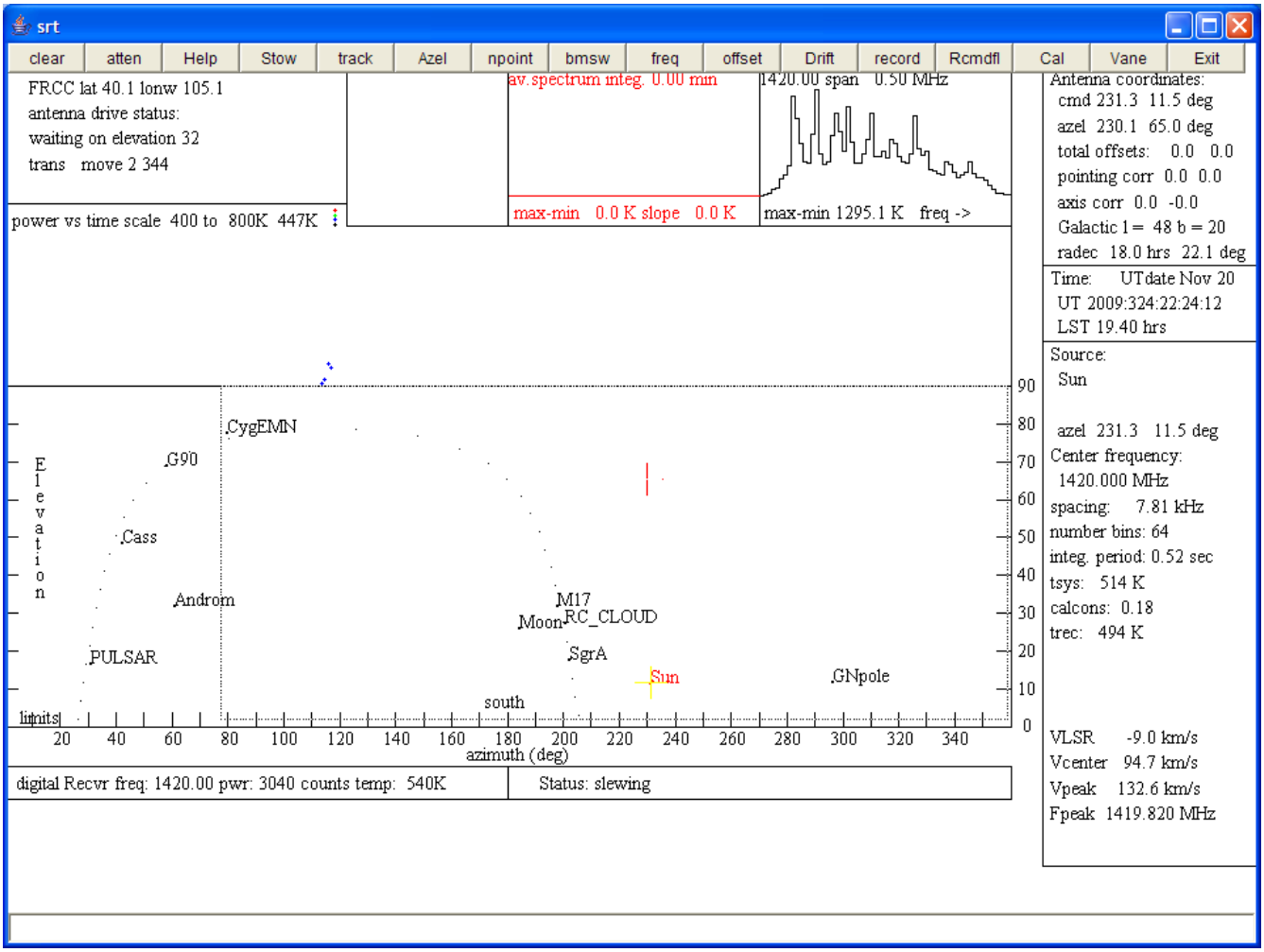

Illustration 6: ***Recording Data****. The cross turns to yellow at the Sun's location while the calibration location cross remains red once you have left-clicked on the "Sun". This indicates the dish is moving to the Sun's location.*

Plot of the Sun

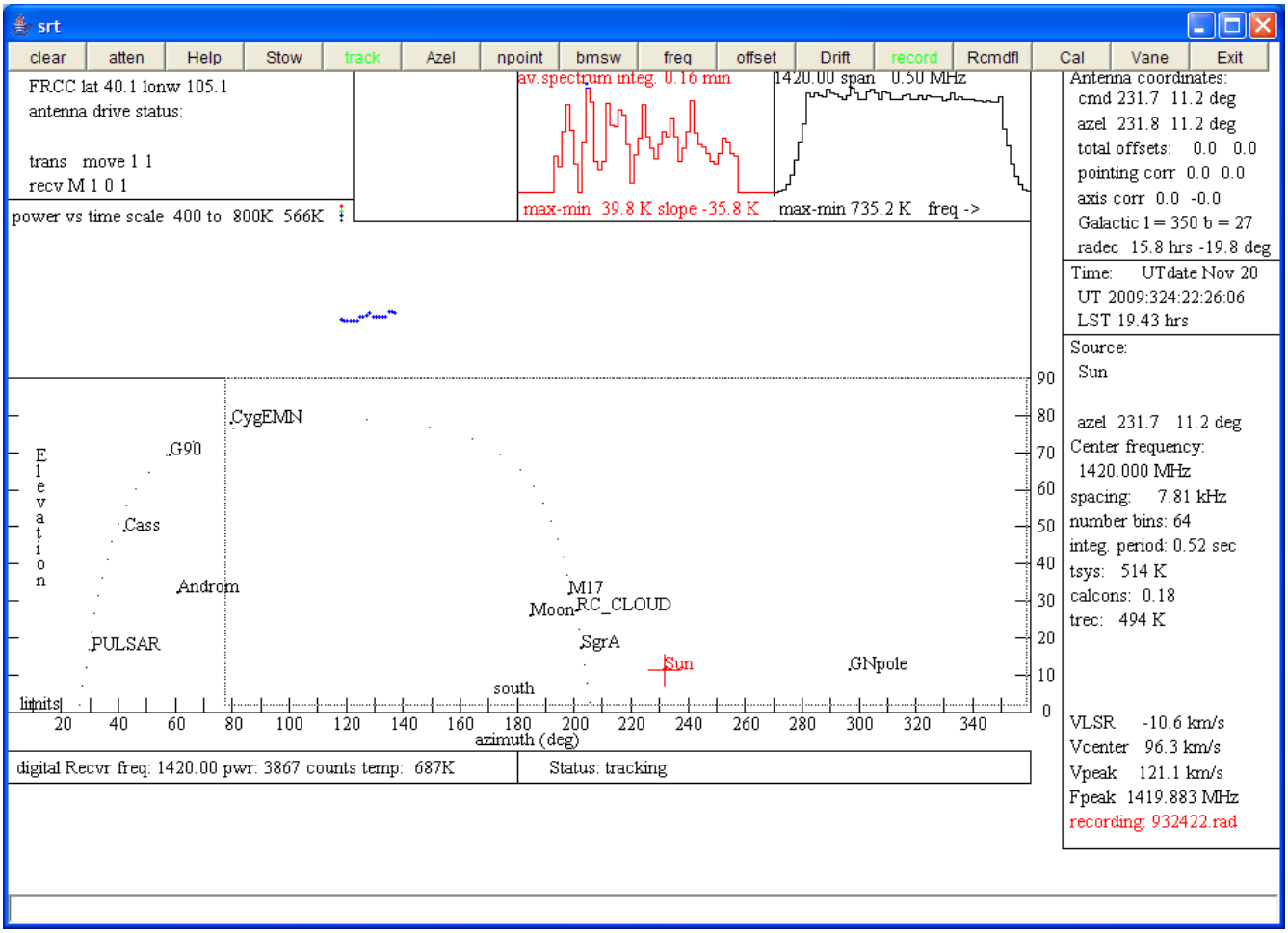

Illustration 7: ***Recording Data****. The cross has turned to red at the Sun's location. Note that the track button at the top of the SRT control panel is green indicating the dish is tracking the Sun. Also, the record button now is green as data are being recorded. The file the data are being saved to is indicated in red at the bottom of the "Source" ("Sun" is indicated) sub-panel located at the right-hand side of the control panel, and in the lowest position in the sub-panel.*

Park the dish

1. ***Left-click*** the "Azel" button at the top of the control panel. Type ***78***, a ***space***, and then ***87*** in the input sub-panel at the bottom of the control panel. This dish position has the least wind resistance.
2. The dish position ***cross*** turns yellow in the upper left-hand corner of the planetarium sub-panel (Illustration 8), so DO NOTHING until a **red** ***cross*** appears at Az=78° and El=87° (Illustration 9). This operation takes at least ***2 minutes***.
3. On the digital controller/receiver, turn off the toggle switch, which is the ***down*** position. The LED turns off.
4. Close the SRT control panel window by ***left-clicking*** on the **red X** in the upper right-hand corner. The control panel will close, and SRT operation ceases.
5. Go to the Open R section on page 10.

Plot of the Sun

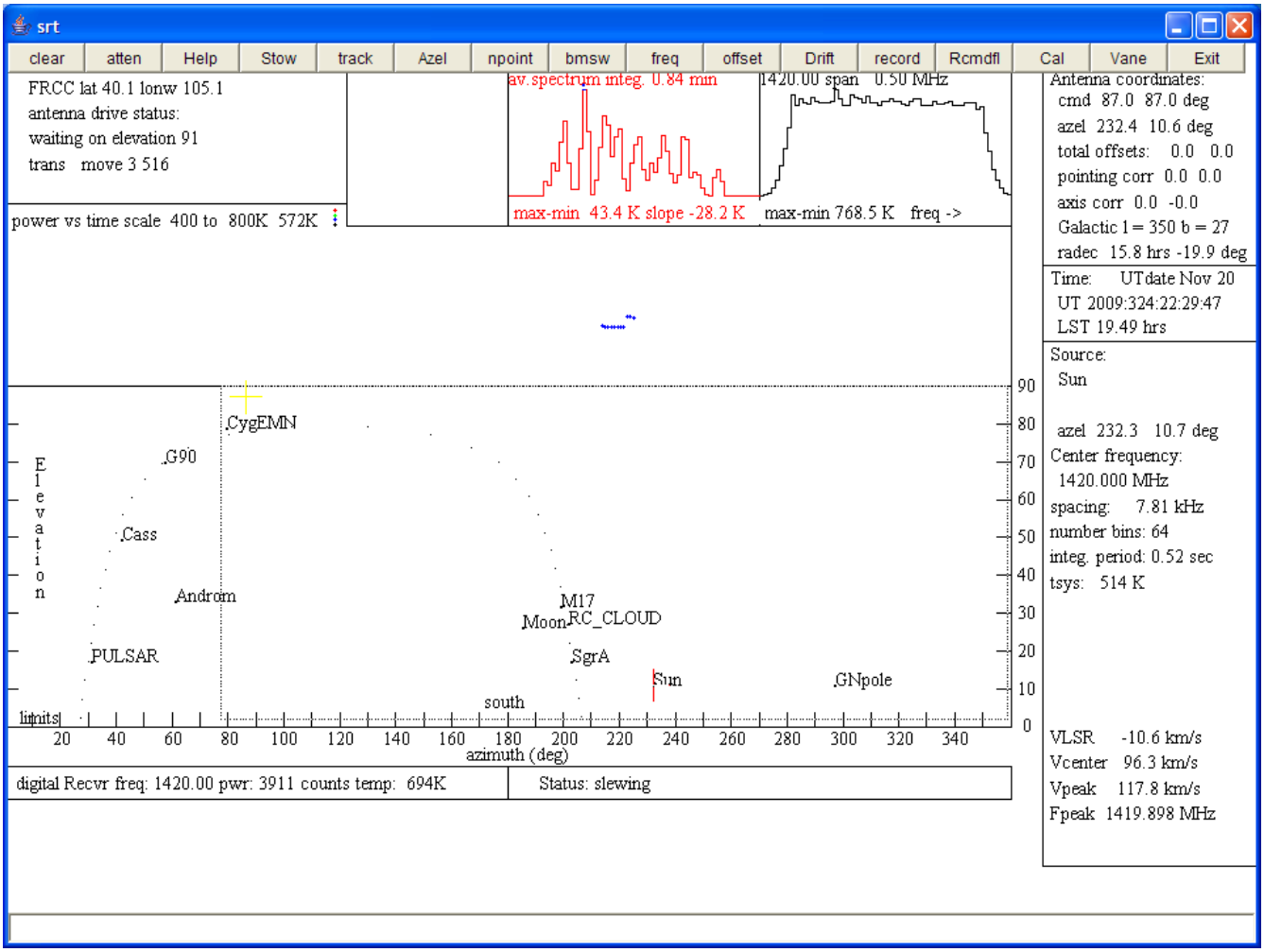

Illustration 8: ***Park the Dish****. The dish position cross turns yellow in the upper left-hand corner of the planetarium sub-panel, indicating that the dish is moving to the Park position of Az=78° and El=87°.*

Plot of the Sun

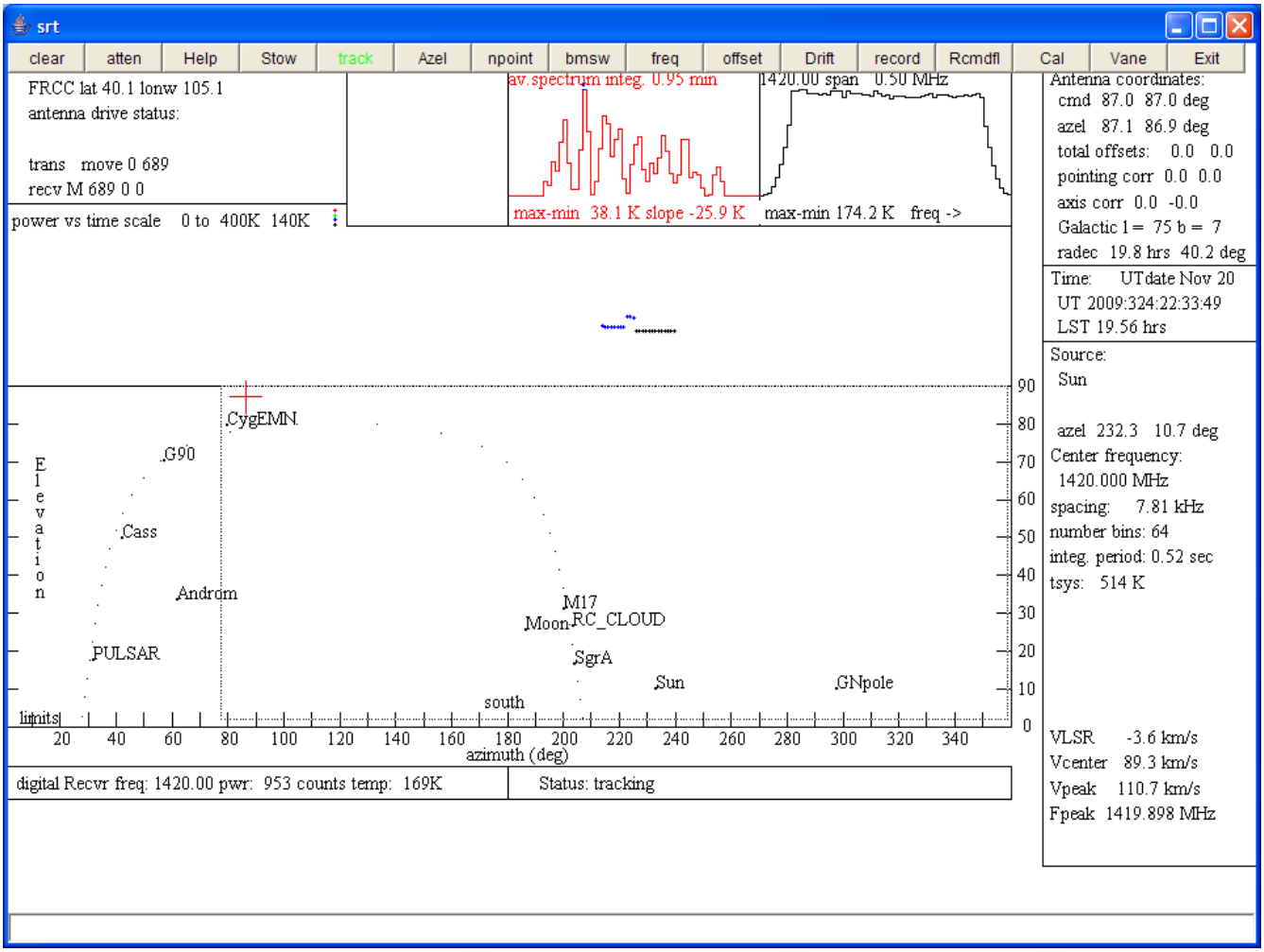

*Illustration 9: **Park the Dish**. The dish position cross turns red in the upper left-hand corner of the planetarium sub-panel, indicating that the dish is at the Park position of Az=78° and El=87°. This dish position gives the least wind resistance.*

Open the R statistical analysis package

1. ***Double-left-click*** on the ***R icon*** on the desktop. The R window opens. See Illustration 10.
2. Select the ***open file icon*** in the command bar at the top of the R window (Illustration 11). Select the ***Desktop icon*** (Illustration 12), then select the ***SRTanalysis.R icon*** (Illustration 13). An editor window opens in the R window (Illustration 14), which contains the data analysis script.
3. ***Right-click*** in the ***R editor*** window, choose ***Select All*** (Illustration 15). The script in the R editor window is ***highlighted*** (Illustration 14).
4. Put the mouse pointer in the highlighted area of the editor window and ***right-click***. Select the ***Run line or selection*** option (Illustration 17). The analysis begins running.
5. Go to the Analyze Solar Data section on page 18.

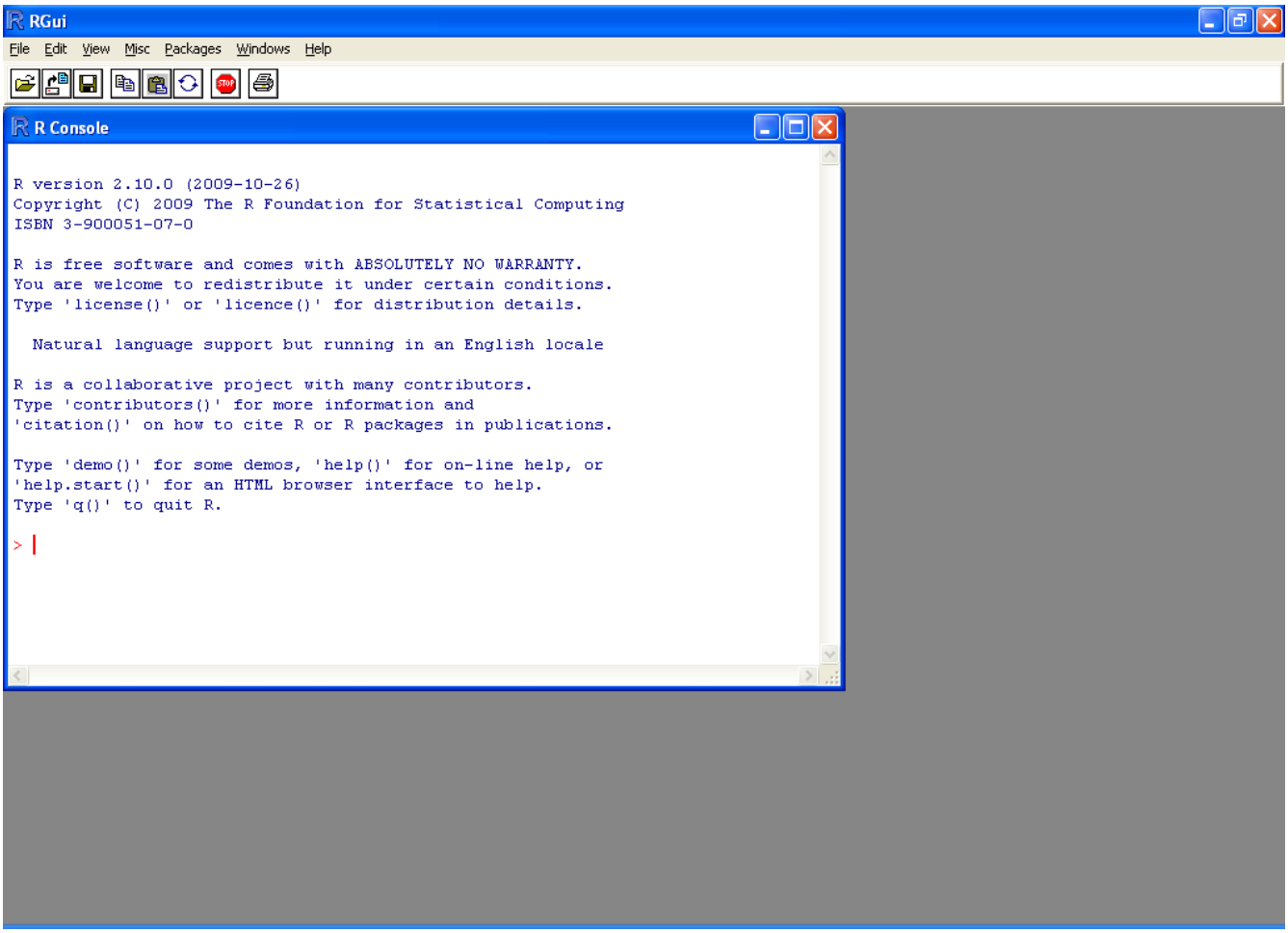

Illustration 10: ***R Statistical Analysis****. The R window.*

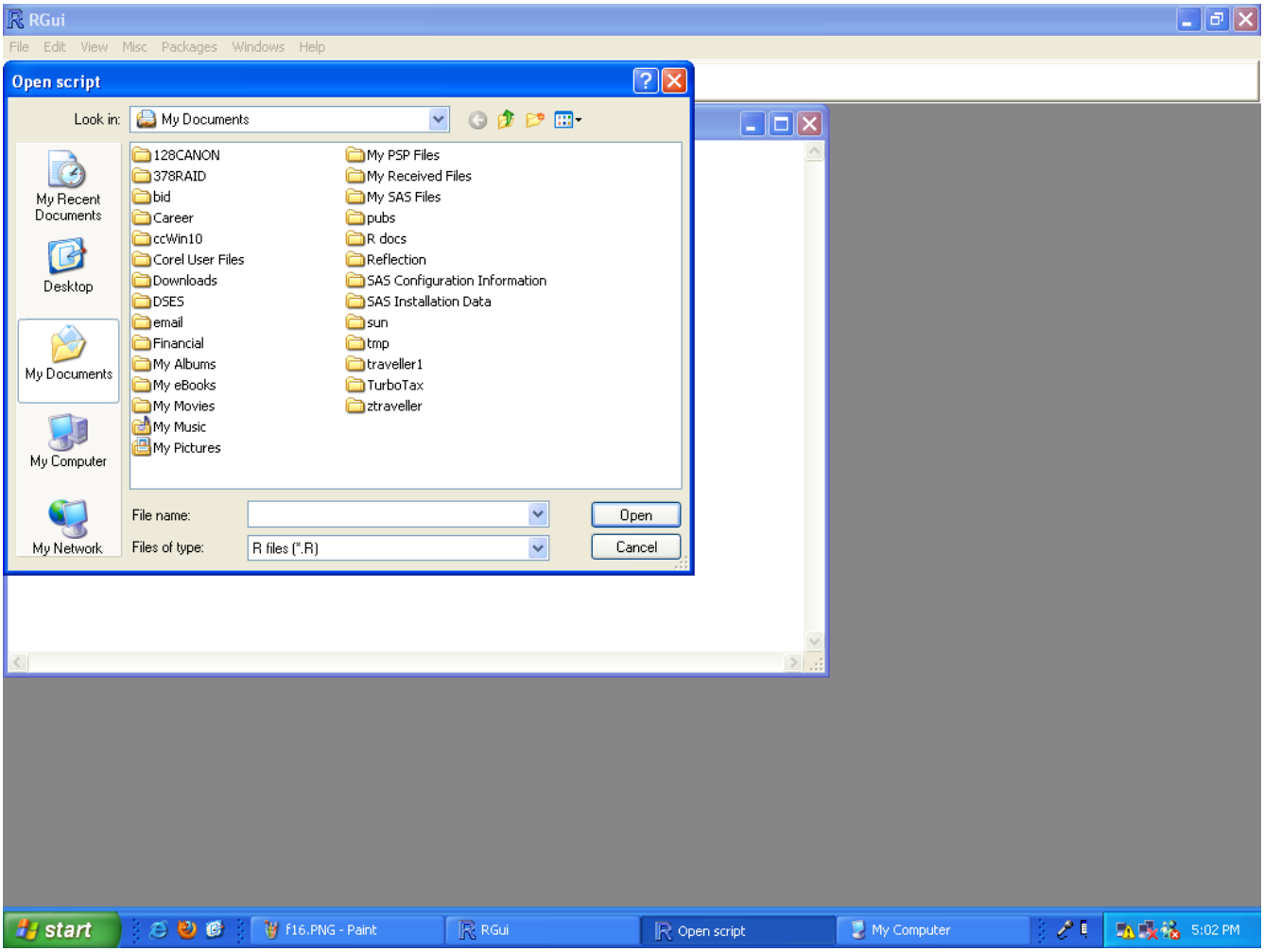

Illustration 11: ***R Statistical Analysis.*** *Open file icon in the command bar at the top of the R window.*

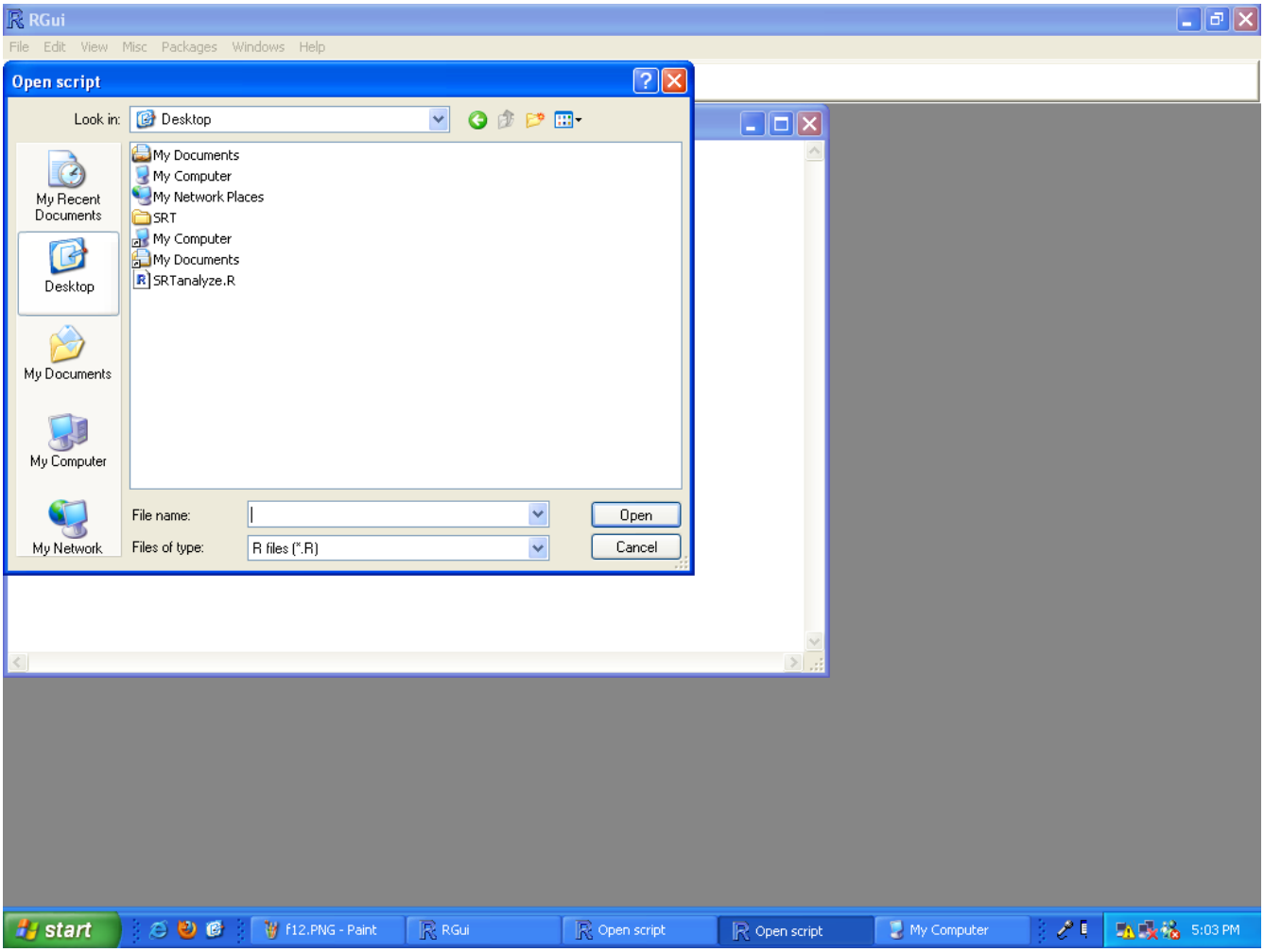

Illustration 12: ***R Statistical Analysis****. Select the Desktop icon.*

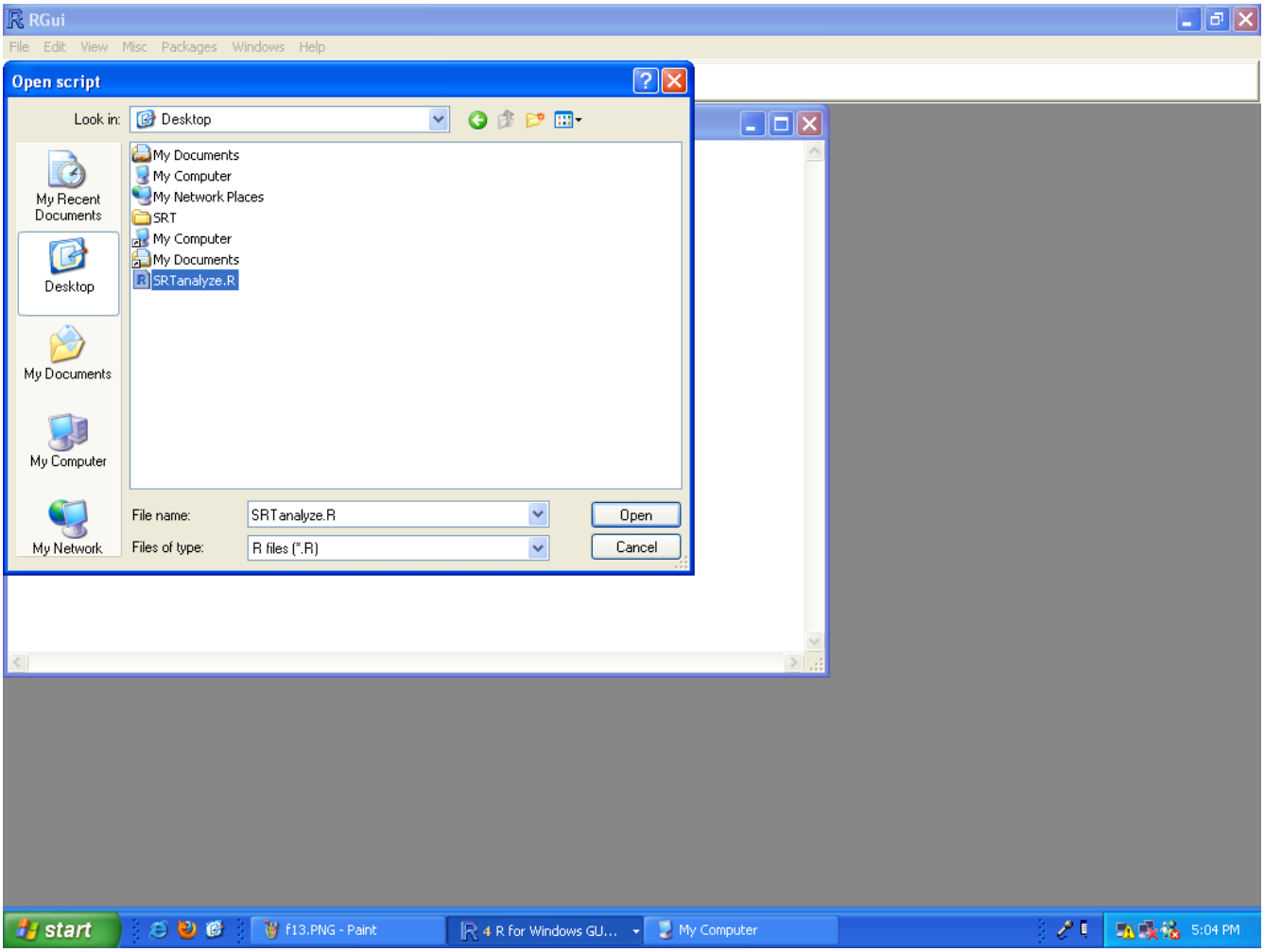

Illustration 13: ***R Statistical Analysis****. Select the SRTanalysis.R icon.*

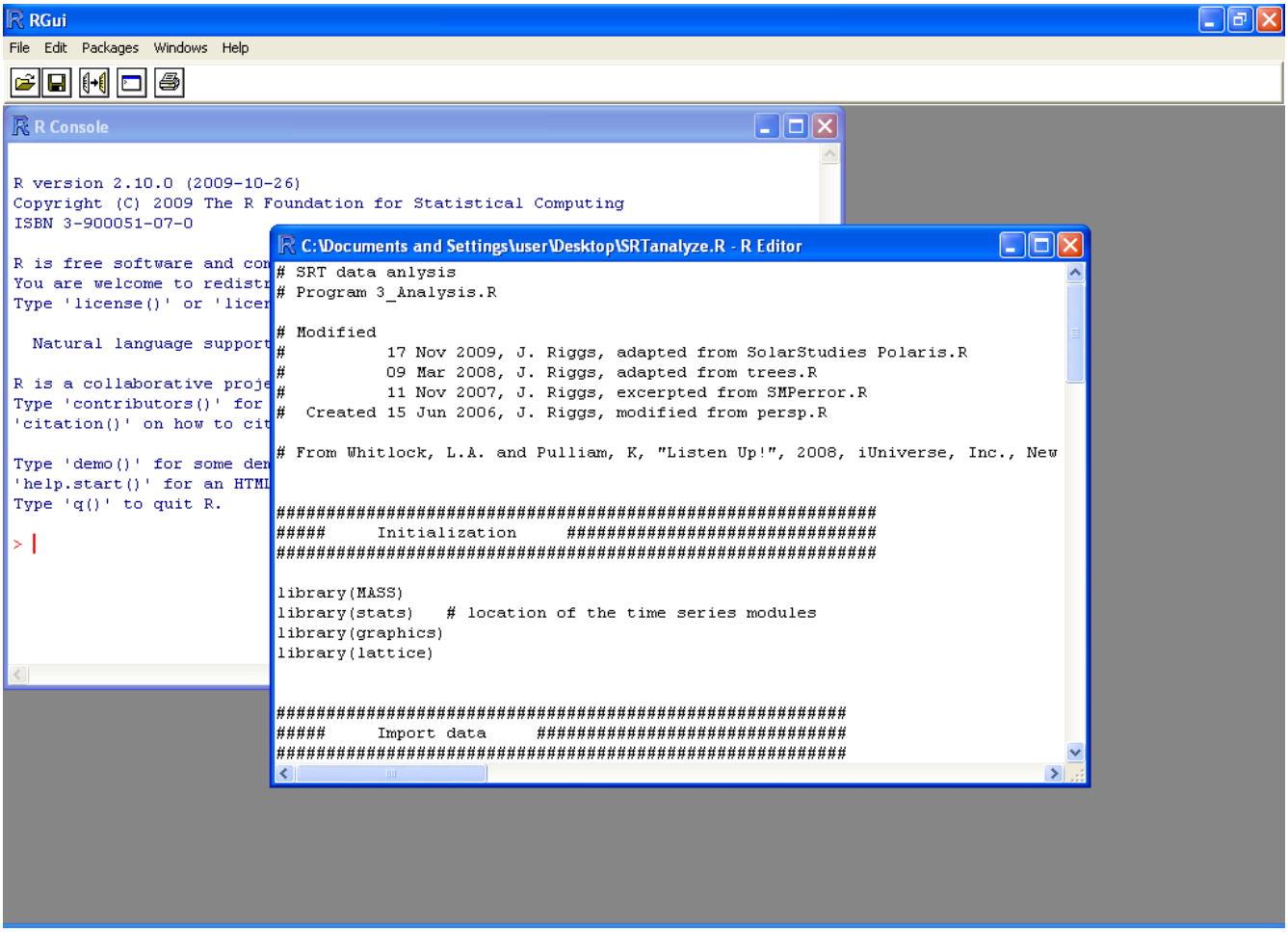

Illustration 14: ***R Statistical Analysis****. The data analysis script.*

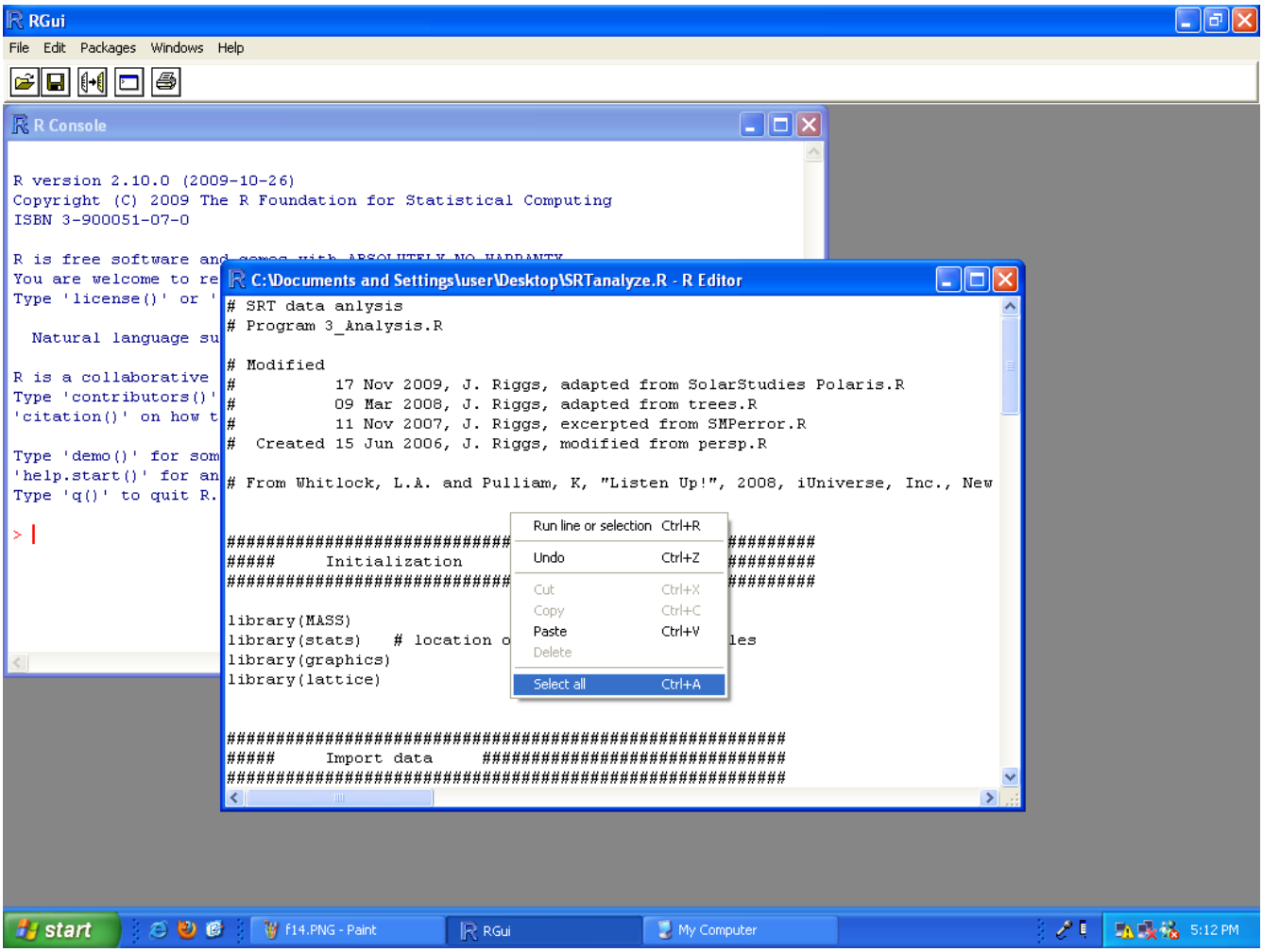

Illustration 15: ***R Statistical Analysis****. Right-click in the R editor window and choose the Select all option.*

Plot of the Sun

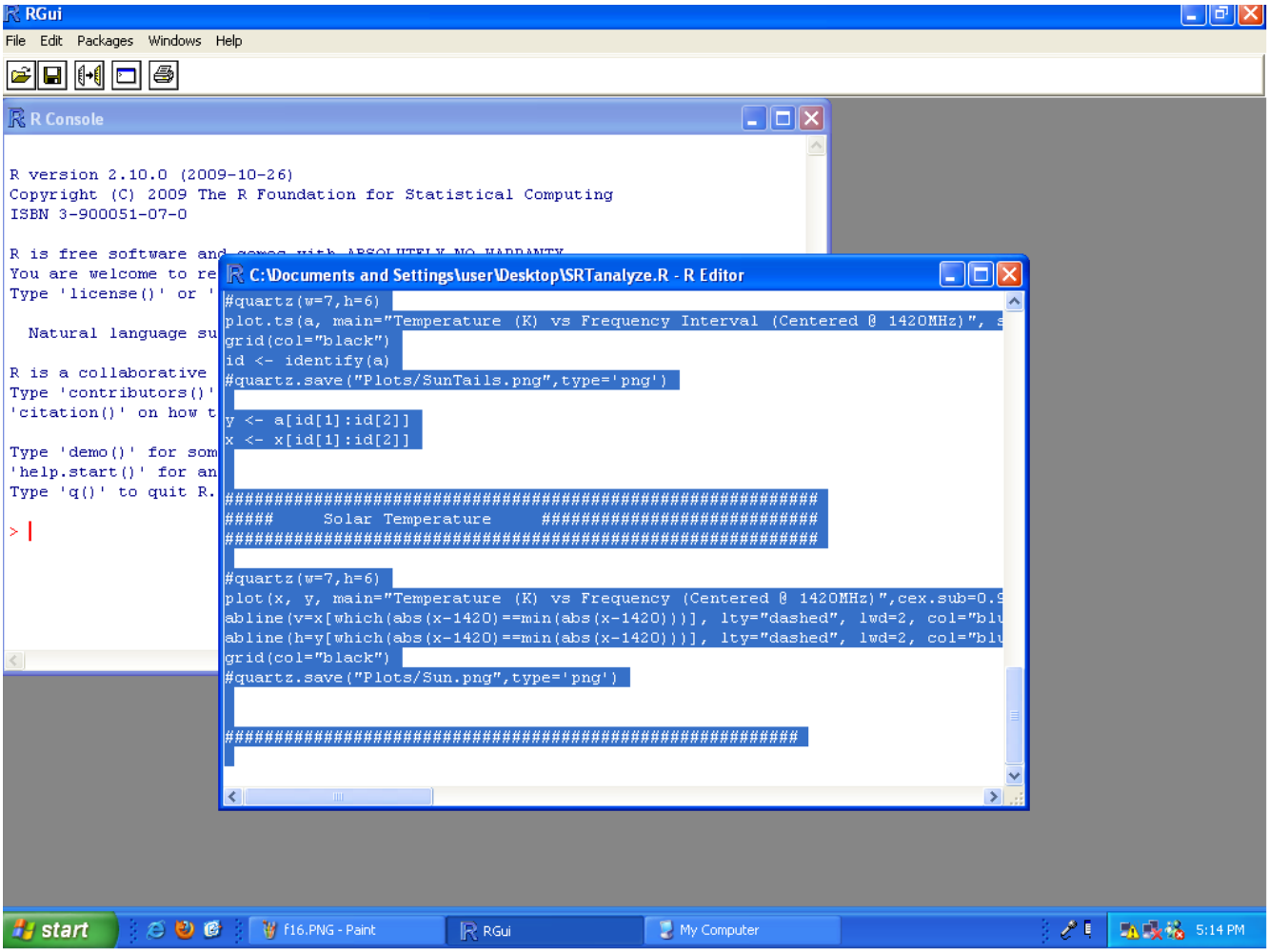

Illustration 16: ***R Statistical Analysis****. The highlighted data analysis script.*

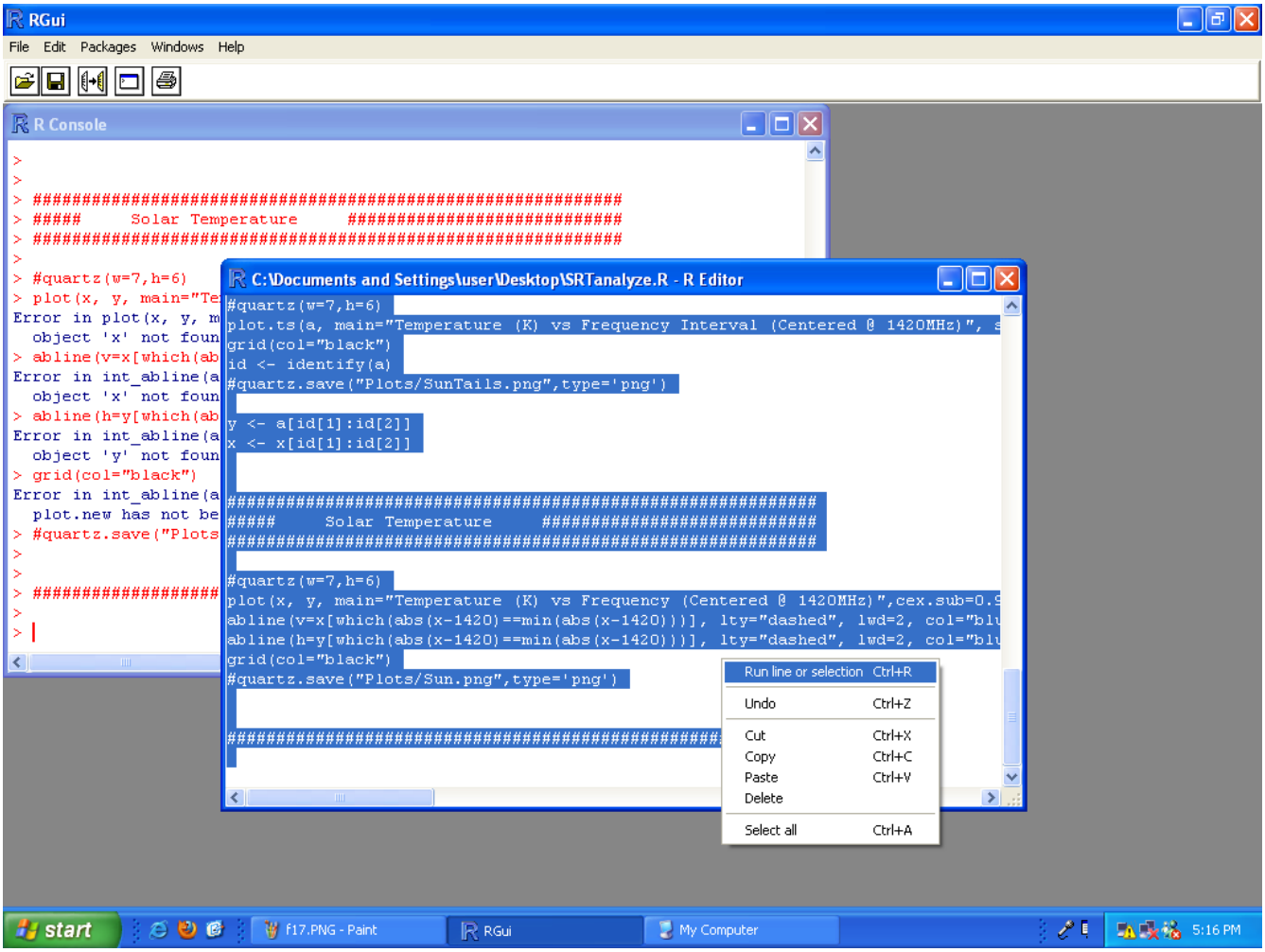

Illustration 17: ***R Statistical Analysis****. Choose the Run line or selection option. The data analysis runs interactively.*

Analyze the solar data

1. The analysis begins by opening a window to select the ***file*** to analyze (Illustration 18). Select the ***My Computer icon*** (Illustration 19), select ***Local Disk (C:)*** (Illustration 20), then select the ***C:\SRTcassi directory*** (Illustration 21).
2. Select your ***data file***. The analysis script copies your data file from C:\SRTcassi to Desktop\SRT\Data. Once your file is in the SRT\Data folder, the script deletes your data file from C:\SRTcassi. See Illustration 22.
3. The script then prepares the raw data for analysis by formating and conditioning the data, including averaging within frequency band bins (64 centered at 1420 MHz).
4. A ***Graph*** entitled Temperature (K) vs Frequency Interval (Centered @ 1420 MHz) appears as shown in Illustration 23. Note that the graph has ***tails*** at the extreme left side and right side of the plot. This is due to the response time of the receiver. We must remove these tails for an accurate view of solar activity.
5. Move the ***mouse*** into the graphics window. It changes from an ***arrow*** into a ***cross***. Place the ***cross*** on the ***first point that is not on the heft-hand tail*** and ***left-click*** the mouse. Note that a

number appears indicating which integration interval you selected. Illustration 24 shows an example.

6. Now place the ***cross*** on the ***last point before the right-hand tail*** of the graph. ***Left-click*** the mouse, and you will see a second number appear similar to the example in Illustration 25.
7. ***Right-click*** the mouse and select ***Stop***. The ***cross*** changes back to an ***arrow***.
8. ***Print*** this graph by choosing ***File*** from the command bar at the top of the R window, and select ***Print***. BE SURE THE PRINTER IS ON.
9. After printing is complete, close the graph window by ***left-clicking*** on the red X in the upper right-hand corner of the graphics window. Another graph appears with the tails removed similar to Illustration 26. ***Print*** this graph. ***Close*** the R window. Select ***No*** to saving the R environment.
10. This ends the computer-based portion of this lab.
11. Go to the Interpret Plots section on page 27.

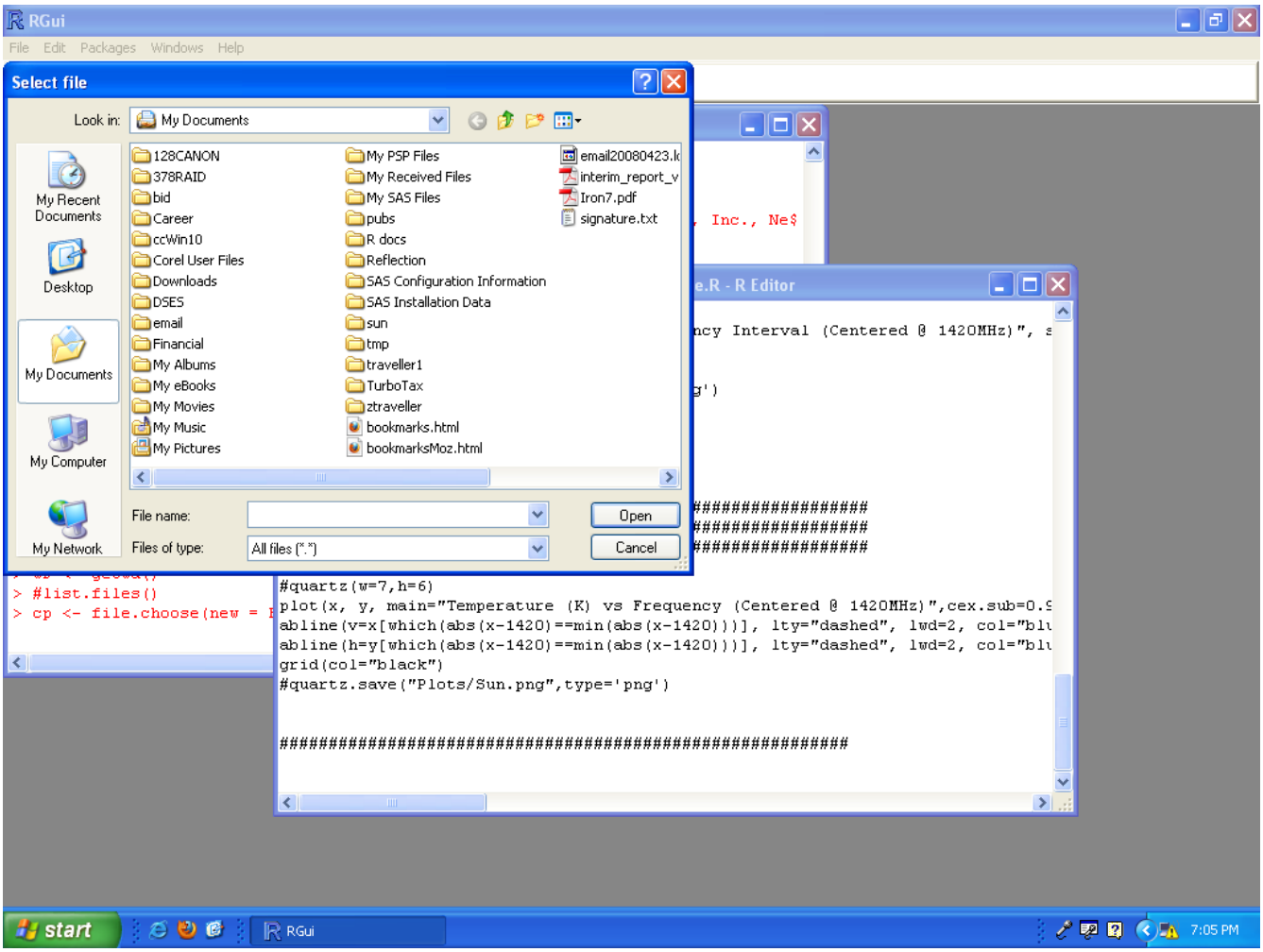

Illustration 18: ***Solar Data Analysis****. Window to select the file to analyze.*

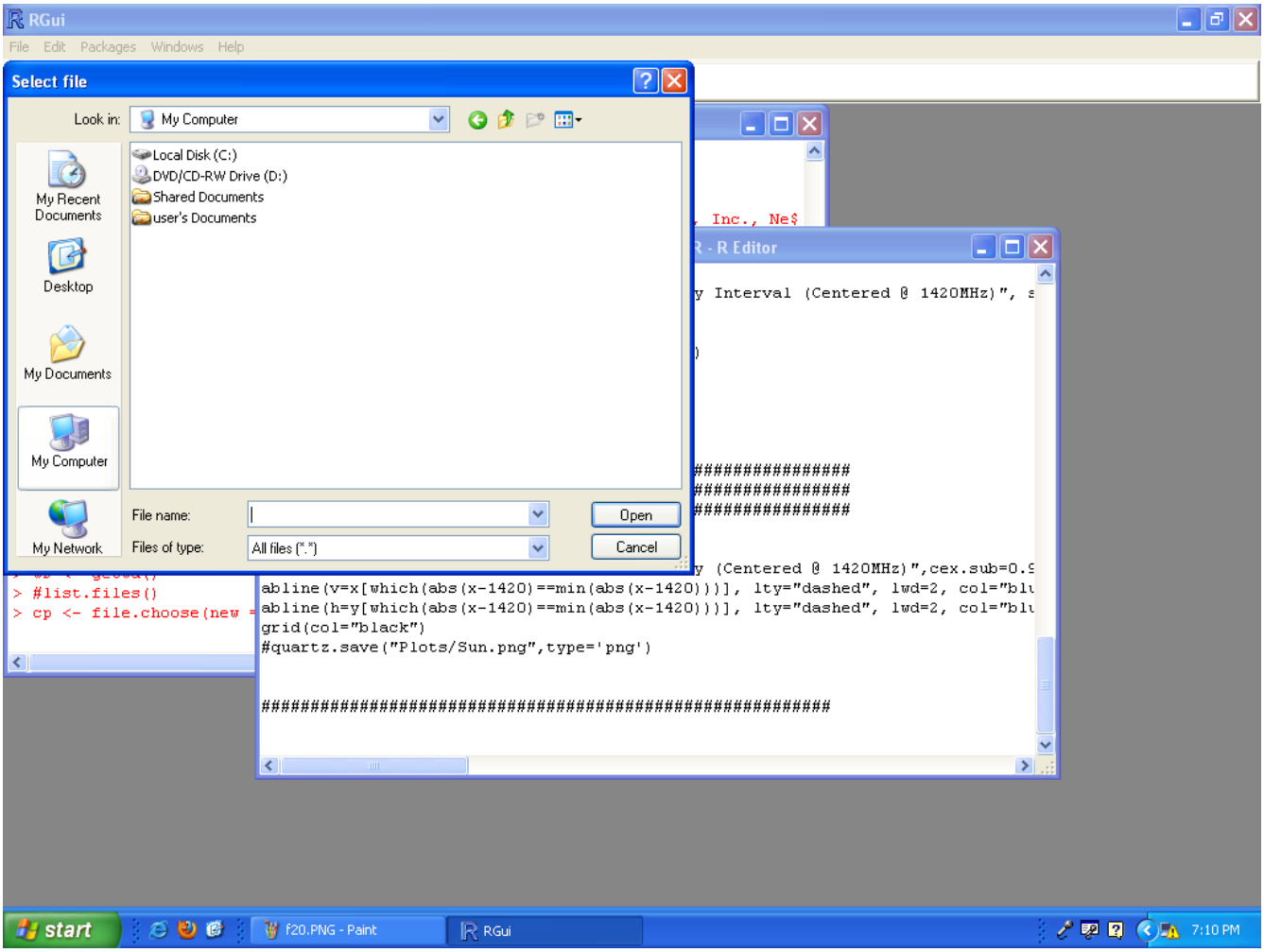

Illustration 19: ***Solar Data Analysis****. Select the My Computer icon.*

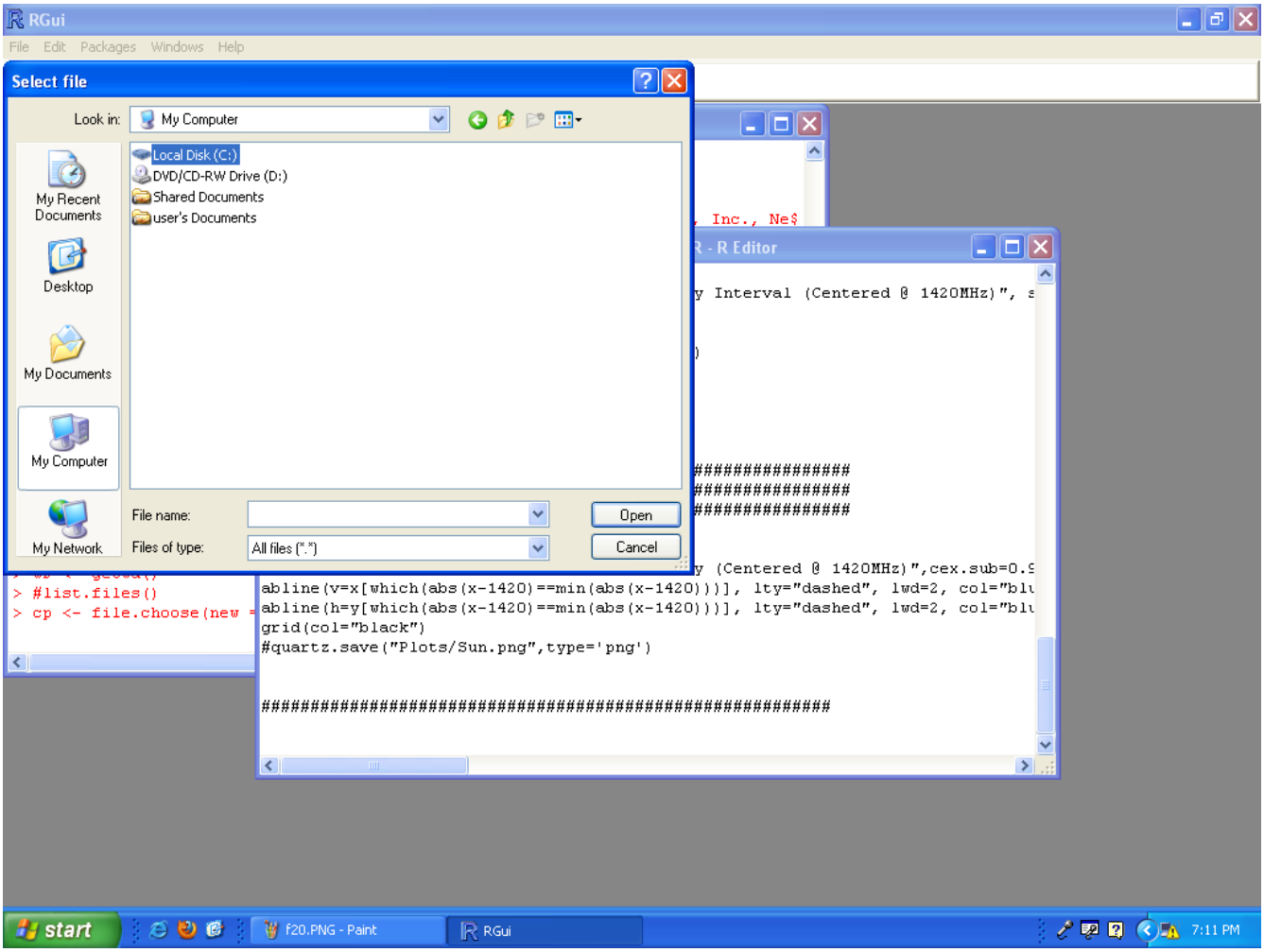

Illustration 20: ***Solar Data Analysis****. Select Local Disk (C:).*

Plot of the Sun

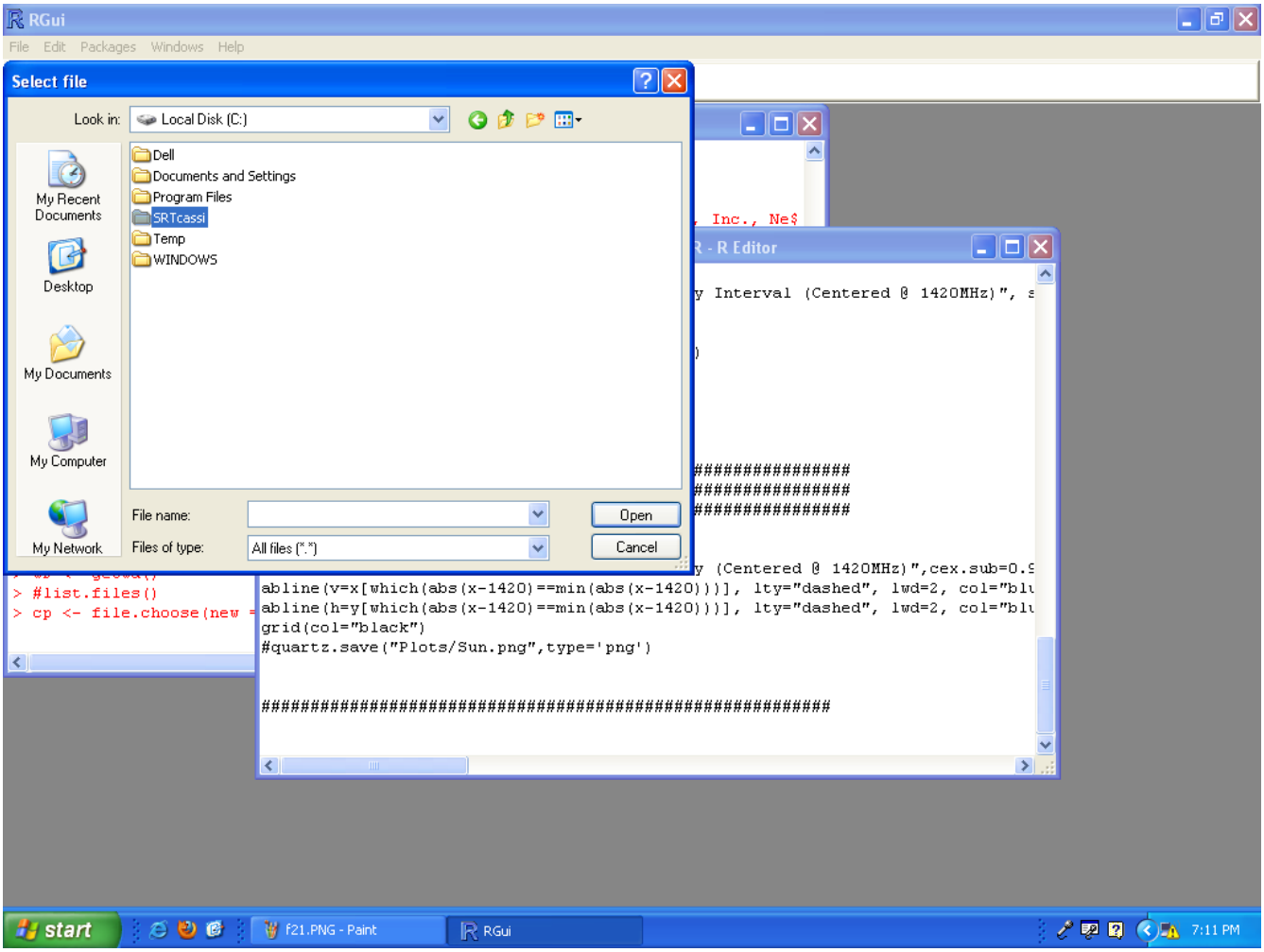

Illustration 21: ***Solar Data Analysis****. Select the folder SRTcassi.*

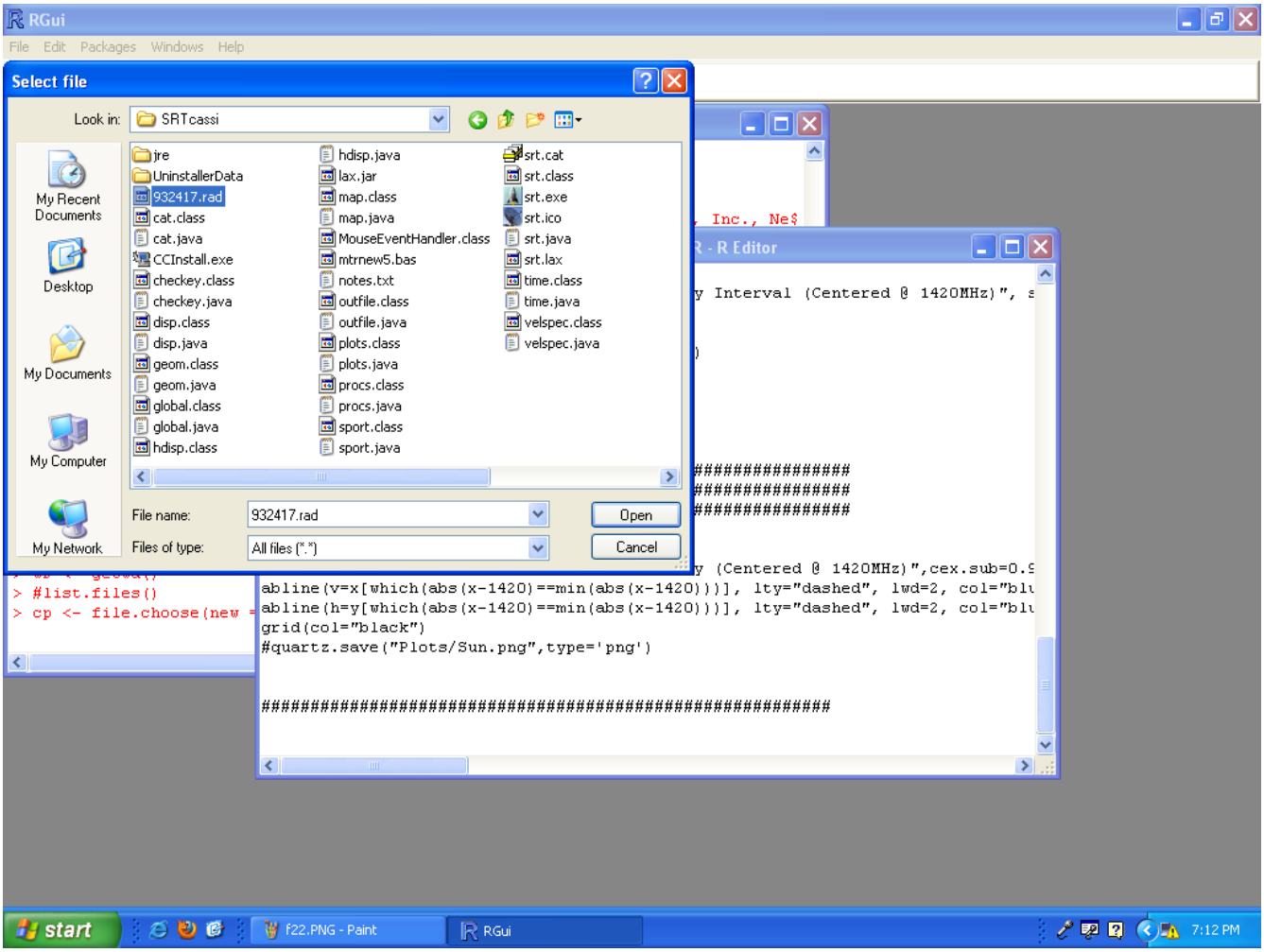

Illustration 22: ***Solar Data Analysis****. Select your recorded data file. The analysis script copies your data file from C:\SRTcassi to Desktop\SRT\Data. Once your file is in the SRT\Data folder, the script deletes your data file from C:\SRTcassi. The script then prepares the raw data for analysis by formating and conditioning the data.*

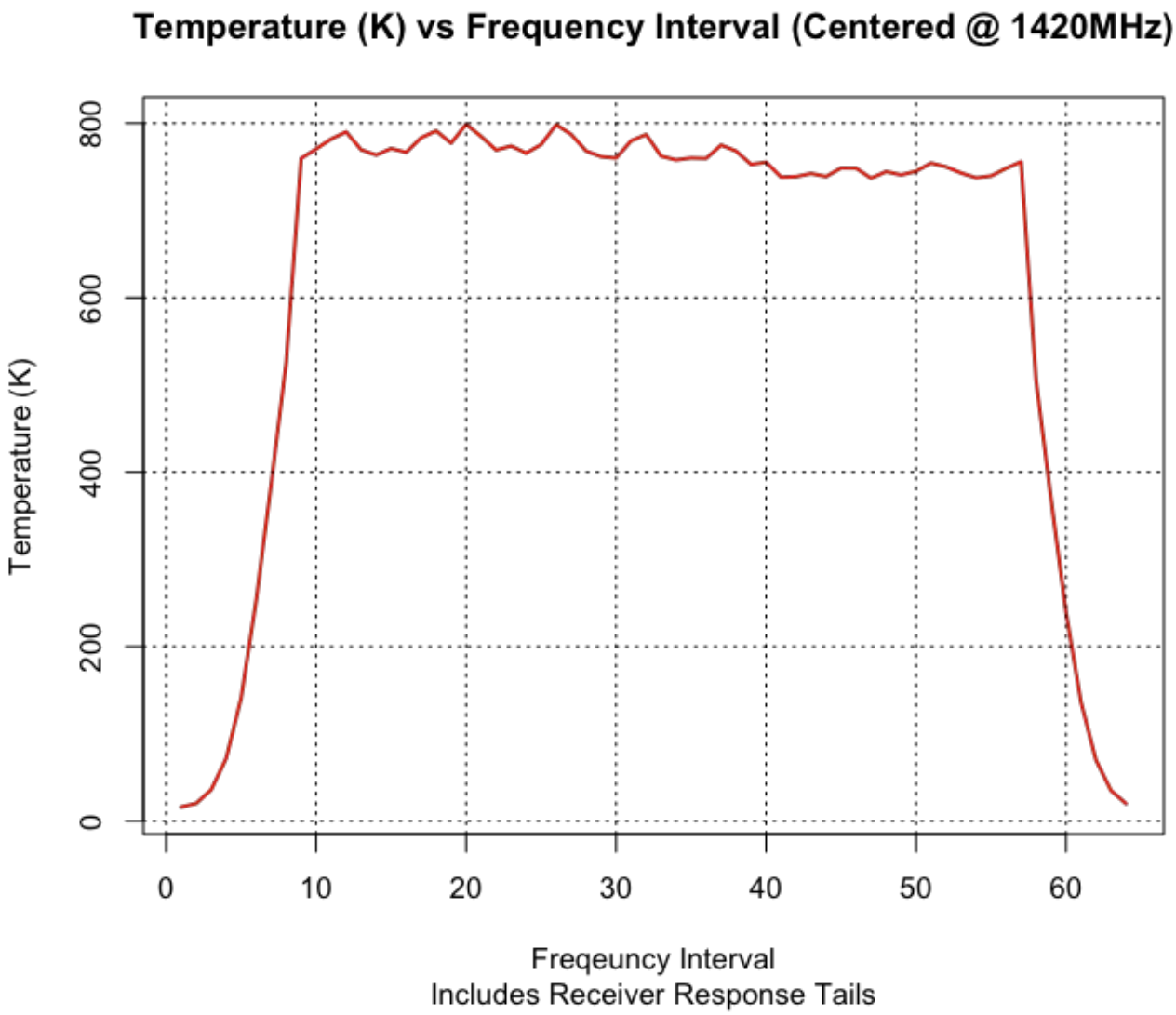

Illustration 23: ***Solar Data Analysis****. Temperature (K) vs Frequency Interval (Centered @ 1420 MHz). Note that the graph slopes up and slopes down at the extreme left and right. This is due to limitations in the response time of the receiver. These slopes, or tails, must be removed for an accurate view of solar activity.*

Plot of the Sun

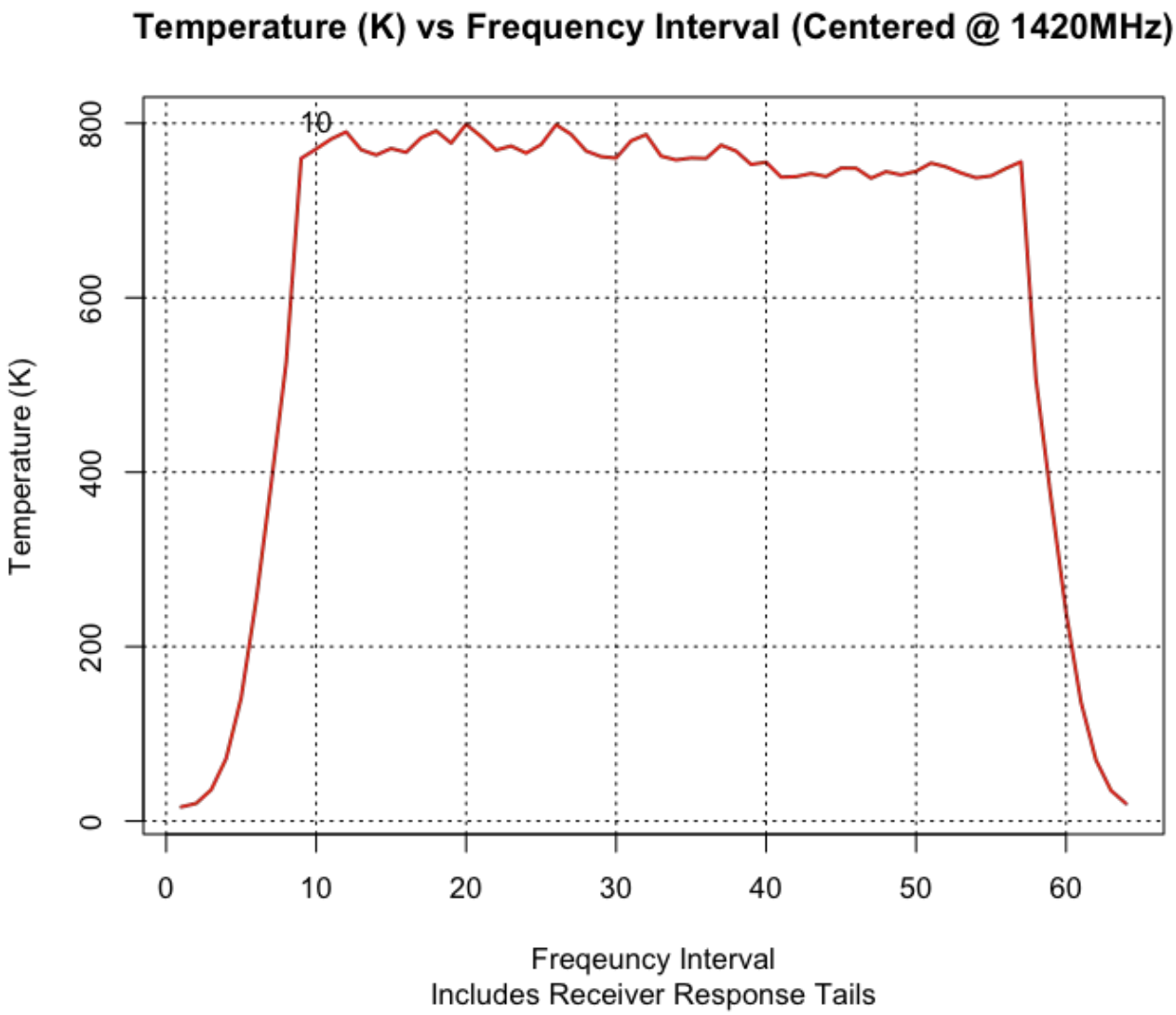

Illustration 24: ***Solar Data Analysis****. Place the cursor on the first point that is not on the upward tail and left-click the mouse. Note that a number appears indicating which integration interval you selected.*

Plot of the Sun

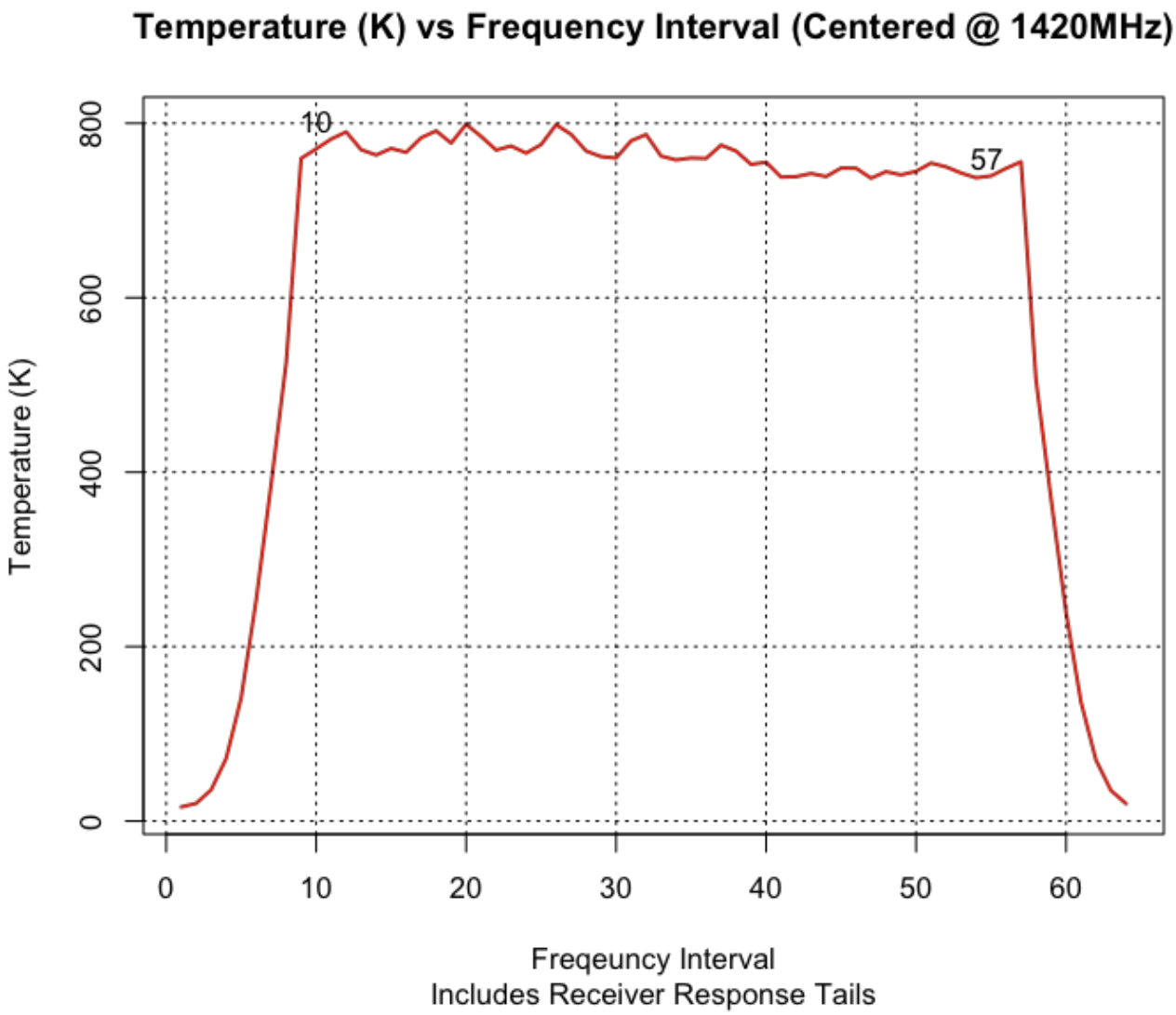

Illustration 25: ***Solar Data Analysis****. Place the cursor on the last point before the graphs begins to slope downward, left-click the mouse, and you will see a second number appear. Right-click the mouse and select Stop. The cursor changes back to an arrow.*

Plot of the Sun

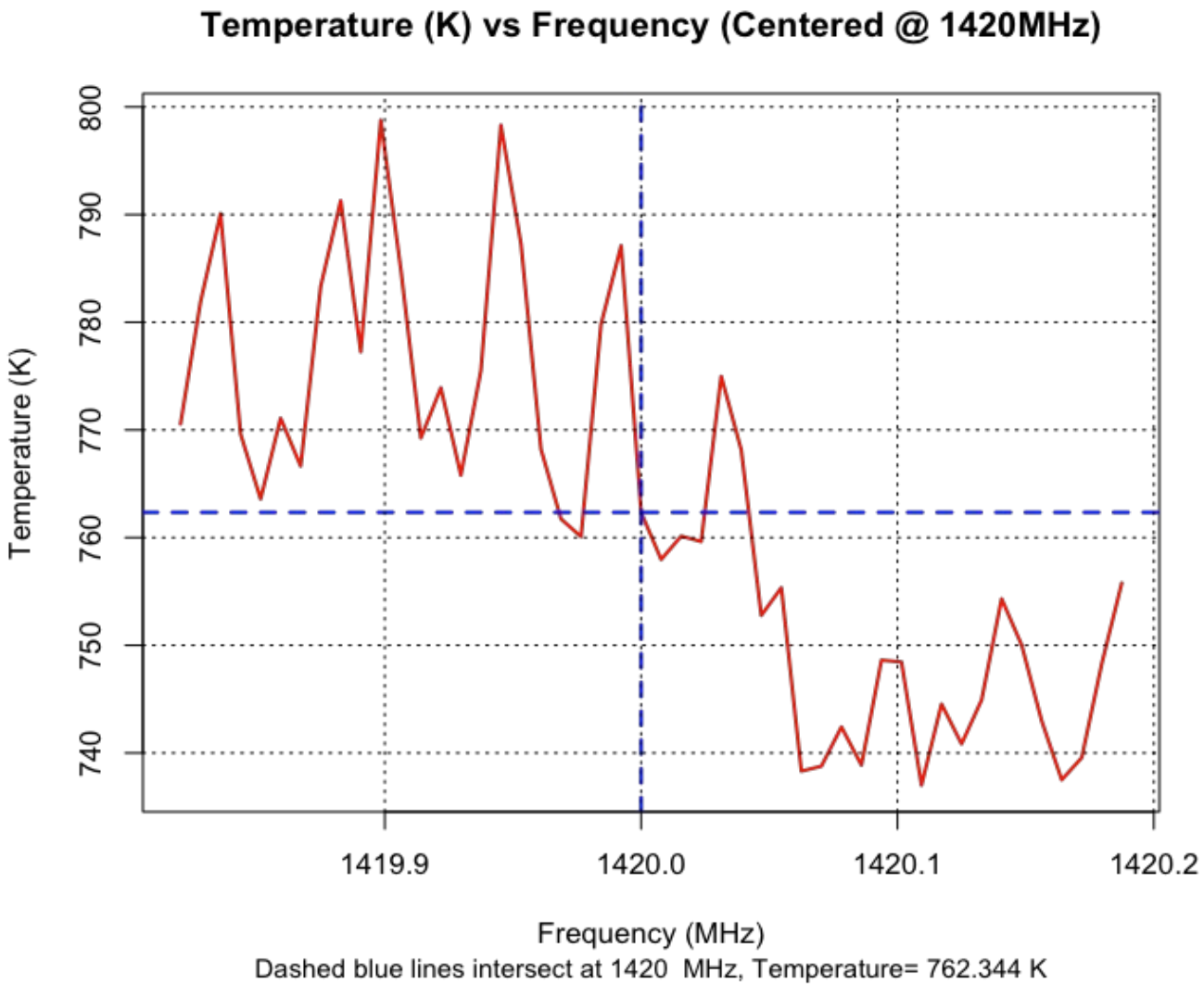

Illustration 26: ***Solar Data Analysis****. An example of solar activity. The dashed blue cross intersects at the temperature at the HI 1420 MHz frequency. Note, the temperature scale does not necessarily represent the actual temperature of the Sun.*

Questions

1. Compare the two graphs you printed. What differences do you notice in the graphs and why do you think these differences exist? What are the tails in the first graph from?
2. In the graph with no tails, is there a difference between the left-hand side of the plot and the right-hand side of the plot as separated at the 1420 MHz demarcation? If so, describe the difference.
3. If a difference from Question 2 exists, why do you think this difference exists? If no differences exist, why is this?
4. In the graph with no tails, will the horizontal blue dashed line be at the same level in another graph of the Sun with the tails removed? Explain.

References

R Foundation, 2009, Comprehensive R Archive Network, http://www.r-project.org/.

Whitlock, L. A. and Pulliam, K., 2008, *Listen Up! Laboratory Exercises for Introductory Radio Astronomy with a Small Radio Telescope*, New York: iUniverse, Inc., pp 19, 22-25.