Helio-STELLA Heliophysics Spectrometer Kit Preparation Sheet

Kit parts

Line	Item	Quantity	Added
1	Thing Plus RP2040 microcontroller	1	☐
2	PCF8523 real time clock	1	☐
3	CR1220 clock battery	1	☐
4	AS7341 spectrometer	1	☐
5	LTR390 UV sensor	1	☐
6	128 x 32 pixel OLED display	1	☐
7	i2c button module	1	☐
8	power switch	1	☐
9	battery	1	☐
10	qwiic/ STEMMA-QT cables	6	☐
11	micro sd card	1	☐
12	micro sd card reader	1	☐
13	USB C cable	1	☐
14	ping pong ball, white	1	☐
15	double stick mounting tape, 4 piece squares	2	☐
16	Helio-STELLA layout sheet	1	☐
17	kit build sheet and operation guide	1	☐

Tools and supplies needed

Line	Item	Available
1	Glue stick	☐
2	Craft knife	☐
3	Scissors	☐
4	Clear tape	☐

Figure 1.

qwiic cable — Clock battery — Clock module — Reset button — Boot button — Microcontroller

Get the software

Line	Item	Done
1	Download the Helio-STELLA software .ZIP file, and uncompress it. (Available at https://landsat.gsfc.nasa.gov/stella/helio-stella/)	☐
2	Download and install the Mu editor (available at http://codewith.mu)	☐

Preparation Instructions

Line	Item	Done
1	Select kit parts in the quantities listed, combine them into a package.	☐
2	Select the microcontroller and the USB C cable from the package. Use the cable to connect the microcontroller to a computer.	☐
3	While holding the **Boot button**, press and release the **Reset button**, then release the **Boot button**. A drive named **RP1-RP2** should appear in your computer's drive list. (See figure 1.)	☐
4	From the software package, copy the file in the **UF2_file** folder to the **RP1-RP2** drive. The drive will self-eject, and will reappear as **CIRCUITPY**	☐
5	In the software package, open the **code-and-libraries** folder. Copy the whole **lib** folder to the **CIRCUITPY** drive, replacing the existing **lib** folder	☐
6	Select the clock module and the coin cell battery from the the package. Insert the battery in the clock module, placing the flat side of the battery (+) away from the board.	☐
7	Select a qwiic cable from the kit. Connect the clock to the microcontroller (see figure 1.)	☐
8	Open the Mu editor. It will find the microcontroller and display this message "Detected new circuitpython device."	☐
9	In the Mu editor, click on the Serial button on the top menu bar. A serial dialogue box will open at the bottom of the window.	☐
10	In the software package, open the **test_codes** folder, then open the **00. clock_set** folder. From that folder, copy the **code.py** file to the **CIRCUITPY** drive.	☐
11	Follow the prompts in the serial window to set the hardware clock time. Use UTC to avoid confusion about time zones. (available at http://time.is/UTC)	☐
12	Now open the **code-and-libraries** folder again**,** and select the **code.py** file, and copy it to the **CIRCUITPY** drive. This file is the instrument operating code.	☐
13	In the Mu editor, press the Load button, and select the code.py file on the CIRCUITPY drive to open, to view the instrument code. The first two lines of code should read: SOFTWARE_VERSION_NUMBER = "<some number>" DEVICE_TYPE = "Helio-STELLA"	☐
14	Unplug the two cables from the microcontroller and clock module, and return all parts to the package. Do not remove the battery from the clock module as that will erase the time setting.	☐
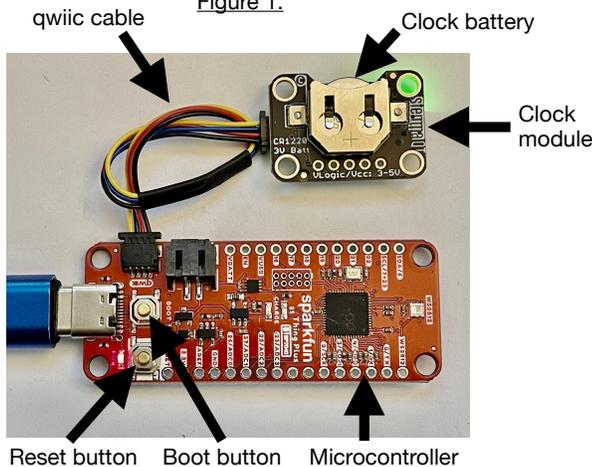
Helio-STELLA Heliophysics Spectrometer Kit Build Sheet

Build Instructions

Step	Do this:	Done
1	Use a small sharp knife to cut the LED trace on the back of the AS7341 spectrometer module to disable the green LED on the front. (Fig. 1.)	☐
2	Cut a piece of corrugated cardboard to 8.5 x 11" or a little larger.	☐
3	Apply glue stick to the back of the layout sheet, then stick the layout sheet to the cardboard.	☐
4	Cut the two holes marked on the layout sheet, through the sheet and the cardboard.	☐
5	Apply pieces of double sided foam mounting tape to the back (flat side) of the modules. Trim the excess.	☐
6	Stick the modules to their corresponding locations on the layout sheet.	☐
7	Connect the modules using the cables provided. The cables are built so they only connect in one orientation. Don't force the connections. (Fig. 2.)	☐
8	Slide the micro SD card into the slot on the back of the microcontroller.	☐
9	Click the power button to turn the Helio-STELLA instrument on. If it's already on, it's helpful to turn it off, wait a second, and turn it on again.	☐
10	The instrument should start up, showing the display screens in the boot cycle. See the operating instructions for more information on the screens.	☐
11	Cut the ping pong ball in half, leaving some tabs for taping it down. (Fig 3.)	☐
12	Position the ping pong ball over the AS7341 spectral sensor, and tape it down at the edges or on the tabs. Don't run tape over the surface of the ping pong ball, to keep the tape from affecting the light reaching the sensor. (Photo TBD)	☐
13	Place the instrument in direct sunlight. Leave it running throughout the eclipse!	☐

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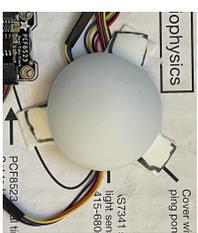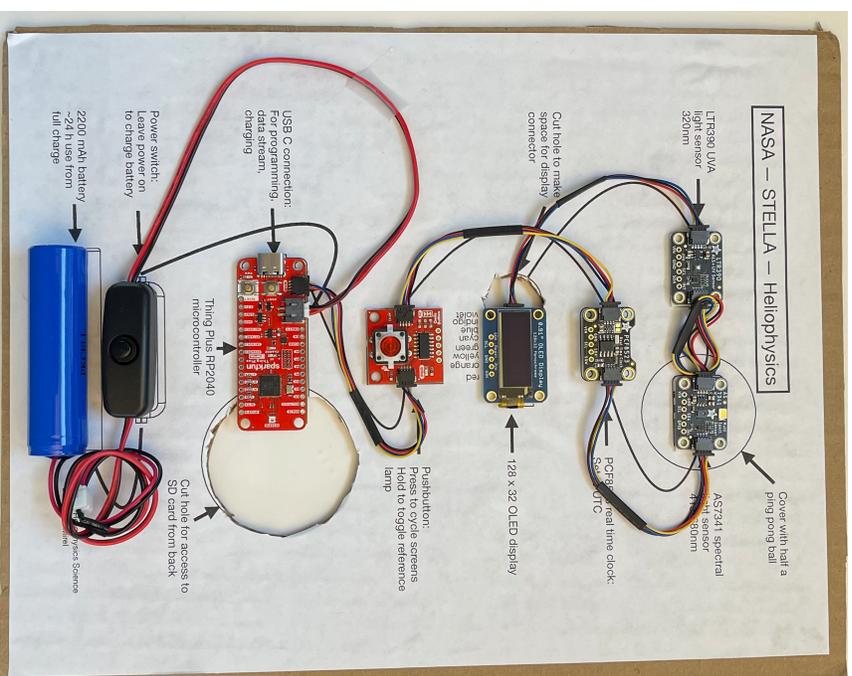Figure 1.

Cut this trace to disable the green LED

Cut the ping pong ball in half, leaving mounting tabs

Figure 2.

Figure 3.

Helio-STELLA Heliophysics Spectrometer Operation Guide

Hello and welcome to the Helio-STELLA instrument!

Introduction:

Helio-STELLA measures the spectrum of visible light in 8 channels, from violet to red, plus UVA and total brightness in lux units. Specifically designed for looking upward to measure solar radiation, Helio-STELLA is useful for characterizing sunlight colors and intensities. How does the light change at sunset? Is it different from sunrise? How does the light change as the sun goes behind the moon during an eclipse?

Operation: Startup

Press and release the power button. The red power indicator, on the microcontroller near the USB connector, will light up. Other lights on the microcontroller will flash, and the source lamp on the spectral sensor will flash once.

You'll see a series of startup screens on the display module.
1. Date and time: This should show the current date, and the time at UTC. The data is timestamped in the data file, using the iso8601 standard, and the decimal hour for that day. The decimal hour is there to make it easy to plot data versus time. If you need to set the clock, see line 10 of the Preparation Instructions.
2. UID and Batch: Every individual processor has a unique identification number, set at the factory. We use the last four digits as a unique ID (UID) so that we can keep records of which instrument we are using. The batch number is also logged in the data file. It starts at 0 and increments by 1 every time you start up the instrument. On the change of calendar day, at midnight UTC, the batch number resets to 0. Write this number in your field notes for the measurements you are making, to refer to later when you are reading the datafile. Examples: "Batch 3: direct sunshine, light hazy clouds." or "Batch 15: thick wildfire smoke midday". If the SD card is not in the slot on the back of the microcontroller, this display will show the message "NoSD".
3. Battery charge level: This screen reports the battery charge state, in percent of a full charge. A full charge will allow the instrument to operate for about 24 hours continuously, though if you are taking important data, it's best practice to recharge at a minimum of 25%. If you want to see the amount of charge remaining, restart the instrument and you will see this screen again. See below for instructions on how to charge the battery. If you are reading this screen while the instrument is connected to a power source, the charge state will read near 100%, regardless of the battery state of charge.

Operation: In use

The next screen you see will be the instrument main screen. It shows the shortest and longest wavelengths covered on the graph, with the batch number in the top center. The graph shows relative intensity for each of the 8 colors, versus the wavelength. The color channels, from left to right on the graph, are listed here, with their band center wavelengths, in nm (nanometers) listed below each color:

    violet, indigo, blue, cyan, green, yellow, orange, red.
    415   445   480   515   555   590   630   680

The graph autoscales, to show the maximum and minimum values each time it reads the sensor. The data, and thus the display, update every second. If there is no SD card inserted on the back of the microcontroller, the batch message will be replaced with "no SD card". Insert an SD card, and restart the instrument to let the processor know that the card is there.

Each time a datapoint is written to the datafile, the LED at the end of the microcontroller board will flash green. If it flashes orange, that indicates there is a problem writing to the file: Either there is no SD card, or it is full, or it was removed during use.

If you want to turn on the reference light, hold the pushbutton (some are red, and some are green) for 3 seconds. To turn it back off, hold the pushbutton again for 3 seconds. The reference lamp gives you a repeatable source of light, which you can use as a control for data collection. Record some datapoints with the instrument in a dark place with the reference lamp on, and then record some datapoints of the light you are interested in characterizing with the lamp off.

Press and release the pushbutton (some are red, and some are green) to change screens. The microcontroller is a low power computer, so it takes some practice to press the button so that the microcontroller detects the press. When it does, it will light up the button a little brighter to let you know the press was detected. The screens will show as follows:

1. Lux: Centered at 550nm, this total visible light sensor (part of the LTR390 UV sensor) reports the overall brightness of visible light, in lux units, +/- 10 lux. In direct sunlight on a clear day, the lux sensor saturates. The display will show the message "sat".
2. UVA: Centered at 320nm, this sensor reports UVA brightness in uncalibrated units.
3. Violet: Centered at 415nm, this channel of the spectral sensor (under the ping pong ball) reports the intensity of violet light in irradiance units (W/m^2*nm), +/- 60% of the reading, because different configurations of the instrument, and different ping pong ball sources, will result in different overall responses to light by the instrument. The details for violet are the same for the other visible light channels.

4. Indigo: 445nm
5. Blue: 480nm
6. Cyan: 515nm
7. Green: 555nm
8. Yellow: 590nm
9. Orange: 630nm
10. Red: 680nm

Press the button again to return to the main graph screen.

Option: If you choose to connect the optional BME280 ambient air sensor, the first screen after the main graph screen will show air temperature in C, relative humidity in %, and barometric pressure in hPa = mbar. All the other screens, starting with Lux, will show in turn. If you choose to add or remove this extra sensor, it's best practice to start a new datafile, so that the headers are correct for the data you are taking.

Operation: Charging

To charge the battery, first turn the instrument on. Then plug it in to a USB-C power source. The amber LED in the center of the microcontroller will come on. When the battery is fully charged, the amber light will go out. If you connect the instrument to power with the battery disconnected, the amber light will show somewhat dimmed. You must turn the instrument on, and leave it running, to charge the battery. Leaving a device running in order to charge it is a bit unusual. This unusual charging method is a side effect of making the instrument using only connectors, without requiring any soldering.

Datafile:

Instrument data recorded to the SD card are stored in a file titled "data.csv", in the comma separated value (.csv) format, which can be opened by any spreadsheet software, or in a text editor.

The data columns are labeled by the following headers:
1. device_type ["Helio-STELLA"]
2. software_version [current software version number]
3. UID [unique ID for this particular microcontroller]
4. batch [current batch number for the data being recorded]
5. weekday [day of the week]
6. timestamp_iso8601 [yyyymmddThhmmssZ, where Z indicates UTC time]
7. decimal_hour [hours and fractions of hours since midnight UTC]
8. lux_center_nm
9. lux [total light intensity in lux units +/-10. If saturated, the value will show 99999.]
10. uva_center_nm
11. uva [UVA unitless intensity]
12. visible_band_center_uncertainty

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13. visible_band_irradiance_uncertainty_% [calculate the uncertainty in each irradiance value by multiplying by this percentage]
14. violet_center_nm
15. violet_counts [violet intensity as measured in detector counts on the analog to digital converter, 0 to 65535]
16. violet_irradiance_W/(m^2*nm)
17. indigo_center_nm
18. indigo_counts
19. indigo_irradiance_W/(m^2*nm)
20. blue_center_nm
21. blue_counts
22. blue_irradiance_W/(m^2*nm)
23. cyan_center_nm
24. cyan_counts
25. cyan_irradiance_W/(m^2*nm)
26. green_center_nm
27. green_counts
28. green_irradiance_W/(m^2*nm)
29. yellow_center_nm
30. yellow_counts
31. yellow__irradiance_W/(m^2*nm)
32. orange_center_nm
33. orange_counts
34. orange_irradiance_W/(m^2*nm)
35. red_center_nm
36. red_counts
37. red_irradiance_W/(m^2*nm)
38. battery_voltage
39. battery_percent

    if the BME280 ambient air sensor is present, the software adds the following columns:

40. air_temperature_C
41. air_temperature_uncertainty_C
42. relative_humidity_percent
43. relative_humidity_uncertainty_percent
44. barometric_pressure_hPa
45. barometric_pressure_uncertainty_hPa
46. altitude_uncalibrated_m
47. altitude_uncalibrated_uncertainty_m

Wrap up:

If you have questions or encounter problems, we do our best to address them in the STELLA forum page: https://github.com/STELLA-Landsat/STELLA/discussions

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Cover with half a ping pong ball

LTR390 UVA light sensor 320nm

LTR390
ALS + UV sensor

SVe SCL INT
VIN GND SDA

AS 7341

GND SDA INT
VIN SCL GPIO

AS7341 spectral light sensor 415-680nm

PCF8523 real time clock: Set to UTC

Cut hole to make space for display connector

128 x 32 OLED display

red
orange
yellow
green
cyan
blue
indigo
violet

Pushbutton:
Press to cycle screens
Hold to toggle reference lamp

USB C connection:
For programming, data stream, charging

BOOT

Thing Plus RP2040 microcontroller

Cut hole for access to SD card from back

Power switch:
Leave power on to charge battery

2200 mAh battery
~24 h use from full charge

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