Statistically combining SEDs

In this worksheet, you will learn how to statistically combine groups of SEDs into an average SED with Iris. You will also learn how to redshift and normalize SEDs in bulk.

SED Stacker is a simple population analysis tool which lets one redshift, normalize, and combine a group of SEDs into an average SED. This is useful for combining low signal-to-noise spectra to study the average characteristics of a similar population of objects, or create templates from spectra or SEDs.

Note: the `<path-to-iris>` refers to the full path to the directory in which the Iris demo material was downloaded. If you used Github to download the sources, `<path-to-iris>` will be `<path-to>/aas229iris`. If you downloaded the data from the thumb drive, it'll be `<path-to>/iris`.

Grouping SEDs 1

Launch Iris if it is not already open.

```
$ source activate iris-workshop
(iris-workshop) $ iris
```

Setup

1. Load the following files to the **SED Builder** by clicking "**New,**" then "**Load File**," and adding the following files with "**Load Spectrum/SED**":

```
$ ls <path-to-iris>/worksheets/sedstacker/
   GN_IRS36.vot
   GN_IRS37.vot
   GN_IRS39.vot
   GN_IRS41.vot
   GS_IRS10.vot
   GS_IRS12.vot
   GS_IRS3.vot
   GS_IRS6.vot
```

These are AGN-dominated sources found in the GOODS-N and GOODS-S fields that show almost pure power law spectra in the mid IR. The data comes from A. Kirkpatrick et al. (2012).

Creating the Stack

2. After having loaded the files, open SED Stacker by clicking on the "**SED Stacker**" icon on the desktop.

3. On the left side, click "**Add...**". The redshifts for most of the SEDs should already be shown. This is because the redshifts were assigned within Iris before, using the **Science Tools** redshifter. You can edit

the redshifts by clicking on the cells underneath "**Redshift**" column. Set the redshift for **GS_IRS3** to **0.55**.

4. Click "**Select All**" to add all the SEDs to the Stack. You will see the SEDs have been added to the middle table **Added SEDs** in the SED Stacker frame.

5. You can change the SED redshift at any time. For example, add **0.55** as a redshift for **GS_IRS6**.

Please note that if you shift a Stack, then change a redshift, that the Stack is not automatically de-shifted and re-shifted; you will have to shift the Stack again yourself. Do this by clicking "**Reset**" under the "**Management**" panel in the bottom-left corner. This will reset all redshifts and normalizations.

6. Change the name of the Stack to **"Featureless AGN"** by right-clicking the name in the "**Open Stacks**" list.

7. Add the Stack to the builder at any time by clicking "**Create SED**" under the "**Management**" panel in the bottom-left corner of the frame. You will see each SED in the Visualizer.

Redshift and Normalize

Before combining the SEDs together, we will shift the SEDs to rest frame and normalize them. This is an optional step; SEDs may be stacked without shifting or normalization.

To redshift the SEDs: In the top portion of the SED Stacker frame are the redshift options. You can input a target redshift, and choose whether or not to correct the flux do to shifting the SED closer/farther away. The flux correction ensures that the energy (integral under) remains the same; the shifted SED flux is multiplied by the ratio of the integrated flux before and after the red/blue-shift. By default, the Iris Science tools correct the flux.

8. Keep the **target redshift** at **0.0**. Select "**Correct flux.**" Check "Create SED" to create a new dataset of the shifted SEDs in the Builder and Visualizer.

To normalize the SEDs: Iris provides two methods of normalization: by integration or by point.

The ***at point*** method pins-down the SEDs to a certain flux level at a given spectral value. The ***by integration*** method takes an integral of each SED, then normalizes the integrals to a specified value:

$$A = value \,/ \int_{xmin}^{xmax} SED(x)\, dx$$

where *x* is the variable spectral value, *value* is the specified value the user inputs in the field next to "**Normalize to**", and *A* is the normalization constant.

Each method allows the user to normalize to a specified flux value, or to the average or median flux of the SEDs.

9. First normalize the SEDs with the ***at point*** method. Pin the SEDs down to 10 mJy at 170 microns.

9.1. For the spectral values: choose **X: 170** and select "**mJy**" from the units drop-down menu.

9.2. For the flux: choose **Y: 10** and select "**mJy**" from the units drop-down menu.

9.3. Select the "**Create SED**" box.

9.4. Click "**Normalize**." The normalized SEDs should appear in the Builder and Visualizer. Also note that the normalization constants in the Added SEDs table have been updated.

Note: at this time, the user must keep track of the normalization constant units.

10. Reset the Stack by clicking "**Reset**" in the bottom-right corner. This resets the SEDs back to their original redshifts and removes the normalization.

11. Under the "**Redshift**" section, uncheck "**Create SED**" so we don't create a new SED. Then shift the Stack back to rest frame again, without changing any of the parameters.

12. Normalize the SED with the ***by integration*** method. Integrate each SED over its full spectral range, and normalize them to the median integrated flux of the Stack.

12.1. Keep **Xmin** and **Xmax** to **-INFINITY** and **INFINITY** to integrate each SED over its full spectral range.

12.2. In the **Normalize to:** drop-down menu, select "**Median"**. Leave the units at **erg/s/cm2/Angstrom**.

12.3. Click "**Normalize**." The SED should display once again in the Builder and Visualizer.

Stacking SEDs

On the right side of the SED Stacker frame are the "**Stacking Options**". SED Stacker combines SEDs by binning photometric points along the spectral axis, and either adding, averaging, or computing the weighted average of the points in each bin. The errors are the standard deviation of flux values in a bin.

Note: because the stacked uncertainties are based on the standard deviation of flux values in a bin, a stacked point with only one point in it will have a deceivingly small flux uncertainty. Uncertainty statistics (e.g., Lasso statistics) will be added to the stacked results in the future.

13. Choose "**Average**" in the **Statistic** drop-down menu.

14. Choose "**mJy**" for the **Y Axis** unit.

15. Use a **Bin Size** of **0.15** in units of **um**.

16. Stack the SEDs by clicking the "**Stack**" button. You should see a new stacked SED in the Builder and Visualizer.

17. Switch from "**Average**" binning to "**Sum**." Stack the SEDs to create a new SED in the Builder/Visualizer.

18. To inspect the differences between the shifted, normalized SEDs and the averaged/summed SEDs, co-plot the following (from the Visualizer, select **Display** → **Coplot** and highlight the SED IDs to coplot):

```
Featureless AGN_normalized.1
Featureless AGN_stacked_Average
Featureless AGN_stacker_Sum
```

Grouping SEDs 2 - following the demo

Using the Elvis et al. (1994) quasar templates from the demonstration, play around with stacking the SEDs. The SEDs are located in `aas229iris/worksheets/sedstacker/`

```
$ ls <path-to-iris>/worksheets/sedstacker/Q*vot
Q0003+158_redshifted.vot
Q0134+329_redshifted.vot
Q0414-060_redshifted.vot
Q1100+772_redshifted.vot
Q1545+210_redshifted.vot
Q2135-147_redshifted.vot
```

In short, the demonstration did the following to the quasars:

1. Add each SED to a Stack
2. Shift the SEDs to rest frame
3. Stack the SEDs using Average, a logarithmic bin size of 0.2, and no smoothing.

If you have your own data -- spectra or SEDs -- play around with these too! Feel free to ask for help in setting up your stack.

For more information on stacking SEDs in Iris, see the documentation at cxc.cfa.harvard.edu/iris/threads/sedstacker