SED Fitting playground

ASTR222/522

Introduction

In this lab, we will use the SDSS Sky Explorer SED Builder from the Italian Space Agency to examine spectral energy distributions for a set of astrophysical sources. Spectral energy distributions are a way of directly comparing the emission from an object across the entire electromagnetic spectrum. Having an intuition for the different emission processes that we measure in astronomy and how they are manifested in SEDs is an important step in building your astrophysical knowledge.

SEDs are typically plotted in units of vFv or, ideally, vLv on the y-axis vs. frequency (v) on the x-axis. Note that vLv is a wavelength-independent measure of luminosity like erg/s or Jy*Hz, so a SED plot allows you to directly observe the energy budget of an object across wavelength space. Common shapes may be blackbodies or power-laws, but there also exist SED templates either derived experimentally or analytically for suites of objects like galaxies of different types, stars of different spectral classes, and AGNs. There is a nice, if somewhat dated, overview of SED fitting here, which includes links to many of the online spectral template databases.

Plotting the SED of a quasar

Enter the object '3C273' into the SED Builder and click "Create SED". Click "Load Data". This default plot is in units of flux, but it would be more reasonable in luminosity units. The redshift of 3C273 is z = 0.158. Enter this value, select rest frame, and vLv in erg/s for the y-axis, then update the plot. You can see quite a few features in the data, in addition to some large gaps where there is no wavelength coverage. In what range are these gaps and why?

Note the peak luminosities and at which energy bands they are emitted. Also note any variability and the energy band at which it is observed. In AGNs, the emission in visible wavelengths comes from the accretion disk around the black hole diluted by starlight from the companion galaxy, whereas both the low and high frequency emission comes from physical processes much more closely coupled to the black hole itself, either synchrotron or cyclotron emission induced by the magnetic field or Compton up-scattering UV photons.

Try adding a template spectrum. The Composite QSO spectrum should do. The tunable parameter aro is the spectral index of the radio to optical flux ratio, and functions like a normalization. Try tweaking that until you have a good fit. Once you're happy, experiment with various models from the models tab and see if you can add any additional components. Record all relevant data and save an image of your plot.

Plotting the SED of a galaxy

Return to the SED Builder and enter M51 and build its SED. The distance to M51 is 8.4 Mpc. Convert this to redshift so you can put this plot in the same units as the 3C273 plot. You should notice some significant differences between the two. What differences do you notice? What does this tell you about the fraction of optical light likely to come from the host galaxy in 3C273?

The emission from M51 comes from three significant components: the integrated starlight from the whole galaxy, a LINER nucleus, and X-ray emission that comes from a combination of hot gas and integrated light from X-ray binaries. Because these three components are (likely) unique, you would not expect a single model to fit the spectrum well across all wavelengths.

Try adding a template spectrum. There are several galaxy types to choose from. What works best? Again try adding a model and see what works. Record all relevant data and save an image of your plot.

Astrophysical speculation

Let's compare the SEDs of a pair of quasars and a pair of galaxies. To contrast with 3C273, load the SED of 3C279, z=0.536. What are the significant differences between these spectra and what might they tell us about the objects?

Let's repeat this with M51 vs. the elliptical galaxy M87 at a distance of 16.4 Mpc. What are the significant differences between these spectra and what might they tell us about the objects?

There is no particularly detailed, specialized knowledge about galaxies or AGNs that is necessary to answer the questions in this section. Think about what you know about starlight, stellar types, and galaxy types in the broadest sense. Feel free to look up information about these objects in NED or SIMBAD to help answer the questions.