Creating, Understanding and Using Spectral Energy Distributions

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Background

Some key items used in studying stars are spectral type, temperature, radius and distance. These terms may be defined for students, but understanding how astronomers use data to determine these items is not as obvious. We want to create a project that helps students understand, determine, and learn how to apply information about spectral type, temperature, radius and distance to answer deeper questions.

Further, dust is a topic relatively unexamined in introductory Astronomy courses, but an important component of our Universe. Extending our study to include two component SED curves will expose students to the existence of dust disks and how we detect them. We hope that examining dust disks will help students further understand the use of SED curves, raise awareness as to where dust exists in the Universe, and develop questions such as: What kinds of stars have dust disks? How are they formed? Do they provide information about the star/planet they surround? And, Is space truly a vacuum, or is dust everywhere?

Our advisors, Dr. Howell and Dr. Hoard will help us develop an educational archive of SED data and SED templates. Students will use the data to learn what a SED is and how to use a SED to determine spectral type, temperature and distance. Once students are comfortable with the process, students will learn how to access archival data, convert data to standardized flux units, plot data to create a SED, and use the SED to determine spectral type, temperature, distance, radius of dust disk, membership, and other broader questions.

Science Goals:
Students understand basics of astronomical observations/procedures learning parameters, such as photometric band passes, spectral type, log plots, and parallax.

Part I: Determine membership to a cluster by calculating distance.

Part II: Students start to understand more complicated star systems. Examples: distinguishing 2 component systems from single component systems, identifying white dwarfs, studying the affect of temperature on SED with a dust disk, and others.

Part III: Use the skills developed in parts I and II to study planetary nebula and white dwarfs; giving students the opportunity to learn about the evolution of stars, the links between stages, and how the characteristics of a star at one stage of its evolution can influence its appearance later on.

Proposed Project

Part I
Familiarization with SED curves: obtaining information

Objective: determine membership to a cluster by calculating distance

Archival Data: UBVRIJHK fluxes from Optical and 2MASS of 10 single stars photometrically calibrated. Three stars from Pleiades, two stars from another cluster, 5 stars with no shared membership with other stars in this data set. Stars must have known radius from Allen's Astrophysical Quantities and known distance from Simbad Hipparcos Parallax.

Templates: several standard spectral types at 10 parsecs

Procedure: A data set of UBVRIJHK fluxes of 10 single stars from varying constellations and clusters is created. Students access the data and plot the data in Excel. They look up radius of the star from Allen's Astrophysical Quantities. Students identify star spectral type by the shape and peak of the SED. Students estimate the temperature of the star from max wavelength: $T = 3E6/\lambda_{max}$ (units T in Kelvin, λ in nm). Then, students compare calculated temperature and spectral type to see if they are consistent. (For example, a student may think the SED is an A type star, but find the temperature to be 7500K. This is inconsistent and the student should check both their λ_{max} measurement and their interpretation of the SED curve) Once students are confident in their choice of spectral type, they choose a template and compare shapes. Students may have identified a star as spectral type A, but there may be an AI and an AIII template. Since the templates are from a distance of 10 parsecs, their flux will be much greater than the single star data, and students will have to multiply template data by some value (less than 1) to make the two SED curves align. The students record this scaling factor. Using the radius of the star previously obtained, students calculate distance from the equation: Scaling factor=$4\pi r^2/d^2$. To check their work, students look up distance in Simbad Hipparcos Parallax or NStED and check their work. Once students have calculated the distance for all the stars in the data set, they compare the distances of each star and predict membership. To verify, students look up right ascension and declination, and see if any stars are members of the same cluster.

Note: while Hipparcos may not have parallax for all members of the Pleiades, the distance is known for the bright stars. The Pleiades was chosen because of its interest and visibility to observers.

Follow up: We hope to have some giant stars in our data set as a second pass. Students would do the same procedure assuming the star is a main sequence star. When they check their distance, they would find a large discrepancy. This would deepen a student's understanding of luminosity class, stellar radii and how astronomers determine these quantities.

Part II

Two component SEDs (Work During visit to Spitzer Science Center)

Objective: Determine Temperature and Variations of Dust Disks

Archival Data: UBVRIJHK fluxes from Optical, 2MASS, and Spitzer of 2 component star systems (star and a dust disk). (Stars must have known radius from Allen's Astrophysical Quantities and distance from Simbad Hipparcos Parallax or determination through spectroscopic parallax.) Stars used in this portion of the project should be a mix of single white dwarfs with dust disk, Vega-like stars, young stars with proto planetary disk, and Saturn. Disks should vary in size, temperature, composition, age, and how formed.

Templates: same as part I with additional templates for dust disks (simple black bodies at a specified temperature)

Procedure: Students obtain data from archives, convert data and template fluxes into Janskys, and plot their data in Excel. They should see a two-component system. Students will notice that the slope and overall shape will not be that of a single black body. They will follow the procedure from Part I to analyze the star component: identify spectral type, calculate temperature, and calculate distance.
Students calculate temperature of dust disk by noting λ_{max} of the second component in the SED and calculating temperature from Wien's law as in part I. Students then choose a template to match the dust disk (i.e. 200K dust disk, 500K dust disk, etc). Students find a scaling factor to make template curves match the data. They use the

scaling factor and the calculated star distance to determine the radius of the dust disk. Students compare dust disks and try to determine characteristics of dust disks from a single white dwarf with dust disk, a Vega-like star, a young star with a proto-planetary disk, or a planet like Saturn.

Part III (to be executed in 2011)

The first two parts of this proposal will set up the SED project, the software tools needed (such as Excel tools) and move from a simple, one-component model, to the slightly more complex two-component model. This will lay the foundation to research challenging, multi-component SEDs of objects such as, planetary nebulae. Parts I and II of the proposal will require time, and by fall of 2010, after our summer SSC visit, we will be in a position to present the project at the AAS as both an educational tool (with materials placed on the Spitzer education website) and as a research tool with varying applications. We will then use the tools and learning experiences to start research projects with our students.

As examples of the possible research topics we could explore, we present below two possible projects. These are easy to develop, build on the learning and tools developed in parts I and II, use multi-wavelength data (including Spitzer), and would provide a true research experience for the participants.

1) Two (or three) component SED modeling for planetary nebulae.

Construct a simplified, two component (central star(s) + dust) SED for a sample of planetary nebulae. Advanced work here might include the third, gas (emission line) component. Students would construct the central star(s) SED using stellar models as learned in part I and archival Spitzer data of the planetary nebula's dusty disk. Optical through 2MASS would be the starting point. The archival Spitzer data might come from the GLIMPSE (Galactic Legacy Infrared Mid-Plane Survey Extraordinaire).

The idea is to analyze the resultant 2 component SEDs to investigate the relationship between the temperature of the central star, the dusty disk composition and relate these to the size, shape, and age of the planetary nebula.

2) Two (or three) component SED modeling of white dwarfs

Construct a simplified, two component (white dwarf + dust disk) SED for a sample of white dwarfs. Some of these would be known to have a dust disk and others would be exploratory projects. Advanced work here might include SED models for binary stars with dust disks, adding in the secondary star component. Students would construct the white dwarf SED using possibly black bodies at first and then white dwarf stellar models as learned in part I, and archival Spitzer data of the mid-IR. Optical through 2MASS would be the starting point.

The idea is to analyze the resultant 2 component SEDs to investigate the relationship between the temperature (age) of the white dwarf star, the dust disk, and form relationships between these parameters and the size and composition of the dust.

Each of these SED projects, after completion, would be added to our original SED training and test cases on the educational pages to illustrate how the SED projects can be extended to research tasks. When completed, student research projects would be presented at subsequent AAS and other meetings as well as used for science fairs and senior projects.

Educational and Public Outreach

College of San Mateo (CSM) and San Mateo High School (SMHS) students will learn how to reduce archival data, create a SED, use a SED to determine spectral type, temperature, and distance of star, and apply this information to answer questions about origins of stars in a cluster and how dust helps us understand star evolution.

The educational archival data sets, templates and lesson plans (Parts I and II) will be posted on the CSM website and presented at the 2011 Jan AAS meeting. These will be accessible to all teachers and other interested parties, and will be a valuable tool for teaching spectral type, SED curves, and how to determine distance and temperature of stars. Sharing of these materials will occur through Astronomy Education Review (AER) article publications and presentations at California Science Teachers Association (CSTA) and other educational conferences. These data sets will be updated to include new SED data obtained by students. This will continue indefinitely as student interest and archival Spitzer data allows.

Further outreach will be organized by the lead teachers in this project. CSM has many public outreach programs – monthly planetarium shows, star gazing parties, college for kids programs, and Astronomical Society meetings. During one of the planetarium shows, Darryl Stanford will highlight this work to show visitors how astronomers use light to gain astronomical information. CSM students will be encouraged to give presentation(s) at the Astronomical Society meetings to share their research projects. Our team plans to share our activities and results with local chapters of the Astronomical Society and other community groups like American Association of University Women (AAUW) and Rotary.