OBSERVING IRON STARS WITH SPITZER

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Description:

Iron stars are unusual stars in which the optical spectra contain emission lines dominated by ionized metals such as iron, chromium and titanium as well as hydrogen. The only two iron stars known at present are XX Oph and AS 325. XX Oph was first observed in 1924 by Merrill. Merrill noted strong, doubly ionized iron emission lines were present in the spectra, thus the name "iron star". Further observations have led to the development of a model for both iron stars, which better explains these emission lines. When observed in the UV, Fe II absorption lines are detected. The current model has the Fe absorption occurring in a strong wind originating from a Be star. The photons are retained and eventually fluoresce and produce the Fe II optical emission lines. This same model (Cool, Howell, Pena, and Adamson 2005) has a giant/supergiant companion and suggests an interaction of the Be wind with the mass loss from the red star and the dust/gas remnant cocoon surrounding them both. Within the past year, spectra have revealed changes in both stars suggestive of increased wind activity (mass loss), resulting in broader and deeper P Cygni profiles in the H and metal emission lines, and continuum variability in the red companion stars. In each case, the two stars are 1000-2000 AU apart and may be a true binary or may simply be close, common age companions. These objects are part of the rho Oph star forming region. Our interest in this topic was generated by our experience in working with students in spectral analysis of data collected through the NOAO/TLRBSE program and our own research experience in participation in this Program. Optical spectra from these stars have been obtained for the past four years as part of the TLRBSE program. This data is then used in our classrooms where we discuss stellar evolution and perform spectral analysis. We plan to collect contemporaneous optical spectroscopy for both of these stars this year as part of the ongoing mentoring program at NOAO.

Targets:

As indicated by the ROC, XX Oph was observed in Cycle One of Spitzer using IRS. We will obtain Spitzer IRS high resolution spectra of AS 325 similar to the data collected for XX Oph. We will use the low resolution capabilities of the IRS on Spitzer to obtain mid-infrared spectral energy distribution (SED). The IRS_Peakup with the moderate option and a blue filter will not only insure accuracy but will also provide an image of the target. We will utilize the Hi_Short, Hi_Long, Lo_Short5, Lo_Short7 features of the IRS with varying exposures and cycles based on a flux density of 60.4 mJy. This value was calculated by comparing AS 325 with XX Oph and then scaled by their relative brightness difference. Total exposure time, including overhead, for this proposal is 1966.7 seconds or 32 minutes. Please see the attached AOR for details.

Scientific Merit:

Using the data obtained, we will examine AS 325 spectra with a desire to understand the chemistry of the stellar environment. In addition, we will compare our spectral results to similar archival spectra of the only other "Iron" star XX Oph. Spectral features of particular interest will be the underlying continuum as a guide for SED production, comparison with 2MASS data and of the UKIRT JHK IFU spectroscopy for both stars obtained in August of 2004 by team support scientist Howell. Also, fitting the one (or a few) blackbodies can provide optically thick material (dust) temperature(s). PAH emission features (6.22, 7.63, 8.63, 11.22, 12.75, and 16.46μm) will be examined and used for estimating the UV radiation field intensity (from the companion Be star) and ratioed to get an idea of grain size. H_2 emission lines will allow us to estimate the local column density and the excitation temperature following prescriptions discussed in Morris et al (2005, ApJS, 154, 339) and references therein. The interaction of the two stars, as the Be star wind collides with mass loss from the (super) giant star in (XX Oph) AS 325, is likely to produce a shock. As a result detection of [Fe II] at 25.9 microns and [Si II] at 34.8 microns is likely. XX Oph was a cycle 1 target and will soon be available to us in the Spitzer archive. If it is available prior to the AS 325 observation, we will begin our work with it. We have planned our AS 325 Spitzer program to match that of XX Oph in order to prove complimentary data sets. AS 325 is not currently in the ROC. Due to the minimal amount of published data regarding both of these stars, the information gained will contribute to the scientific data base.

Educational Merit:

Chapple and Thomas are both middle school science teachers. Topics we teach include the electromagnetic spectrum, chemistry, physics, and astronomy. Rapp and Weehler teach astronomy, chemistry, and physics at the high school level. Roelofsen teaches physical science at the ninth grade level. Combined, we work with approximately 500 students per year. Woven into these broad topics throughout our classrooms,specific lessons are taught utilizing RBSE, TLRBSE, and now Spitzer data. Along with the iron stars project, we will all tie in the same series of six classroom lessons with the brown dwarf project to teach evolution of a typical star and evolution of exotic stars. These lessons include:

- Students use graphing programs (i.e. Excel, Graphical Analysis) to make a best fit $2^{nd} – 4^{th}$ order polynomial curve to a continuum of stars to determine peak wavelength. This will then be used to determine surface temperature via Wien's law. It will then be possible to classify these stars from their surface temperature.
- Students infer from partial black body data where in the continuum this partial curve would fit and thereby predict whether the star's temperature is hotter or cooler than the included spectral window allows.

- Students learn the difference between absorption and emission lines as well as the circumstances under which each is produced via classroom discussion and laboratory demonstration (i.e. spectra of gas tubes).
- Students determine the composition of stars from emission and absorption lines within their spectra.
- Students describe the evolution of low mass, main sequence stars and contrast them with atypical, exotic stellar species like brown dwarf and iron stars.
- Students learn research of archival data, literature searches and extrapolation of accepted theory to explain the evolution of accepted theory to explain the evolution and model of the iron star through several stages of nucleosynthesis.

These classroom activities have been expanded by NOAO into the Teacher Observing Program, which gives students hands-on experiences whereby they conduct data collection through observing at Kitt Peak Observatory. Rapp and Thomas have both had students engage in this research experience this past fall (2004). Rapp, Weehler, and Chapple have had student research papers published in the TLRBSE Journal. We all have implemented the research-based science pedagogy into our classrooms using the topics and lessons mentioned above. Chapple works with students annually within his class on research projects. Some students will utilize Spitzer archives as they self-select their topics. The authentic research process is taught, modeled, and applied in all of our classrooms. These topics are aligned with the National Science Content Standards and associated benchmarks, particularly Standard #1 “Science as Inquiry”.

Presenting this Spitzer research project to students, our colleagues and community at large will further develop and increase science awareness and interest. Within our districts and at the state level, we will all be conducting workshops for teachers, which focus on implementing infrared activities in the classroom and use of the Spitzer Space Telescope archives. Thomas will present a six-hour summer workshop within her district on the electromagnetic spectrum. Attending teachers will experience infrared activities and be introduced to the Spitzer web site and data archive. Chapple and Thomas will also present a two-hour sectional at the 2006 National Science Teacher’s Association meeting in Anaheim, CA. The sectional will relate their experiences with the Spitzer Space Telescope Teacher Program and its implementation in the classroom.

Resources:

Cool, Howell, Pena, Adamson. Lifting the Iron Curtain: Toward an Understanding of the Iron Stars XX Oph and As 325, 2005 (submitted for publication)

Morris, 2005, ApJS, 154, 339

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