They Might Be Giants: An Archival Study of Kepler Light Curves of Giant Stars

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Abstract:
We propose to perform a blind study of 200 giant stars identified as Red Giant Branch (RGB-hydrogen shell burning) or Red Clump (RC-helium core burning) from the asteroseismology study performed by Bedding et al. (2011). In order to complete a blind study, the students and teachers participating in the study will not know the classification of the stars until after the initial study and grouping has been performed We will use the NASA Exoplanet Archive to retrieve the Kepler data and perform period searches using the periodogram tool for each of the stars. As a prelude to ground-based studies, we plan to study patterns in the periodograms for the longer periods (> 10 days), rather than the shorter periods used by Bedding et al.. We will phase and phase-bin the strongest periods, examine their general shape and period distribution, and then perform a comparison of the top three periods by amplitude, phase, and power. In addition, we will build spectral energy distributions (SED) of each star to look for other characteristics that may help astronomers distinguish these two types of red giants. Characterizing giants using longer periods and SEDs will help astronomers identify them from ground-based observations. Our proposed study will help us characterize and classify the giants and then allow an "after-the-fact" comparison to the Bedding et al. results where >200 giants evolutionary state is known.

I. Introduction

The variety of stars can be illustrated on an H-R Diagram (Fig. 1). Giants, an evolutionary end of life stage of low mass stars, occupy a broad region on the right portion of Figure 1, lying above the G to M type main sequence. Though an H-R Diagram alone groups all giant stars together in a broad region, in actuality there are distinct paths and ages through which each low mass star proceeds during its stellar evolution.

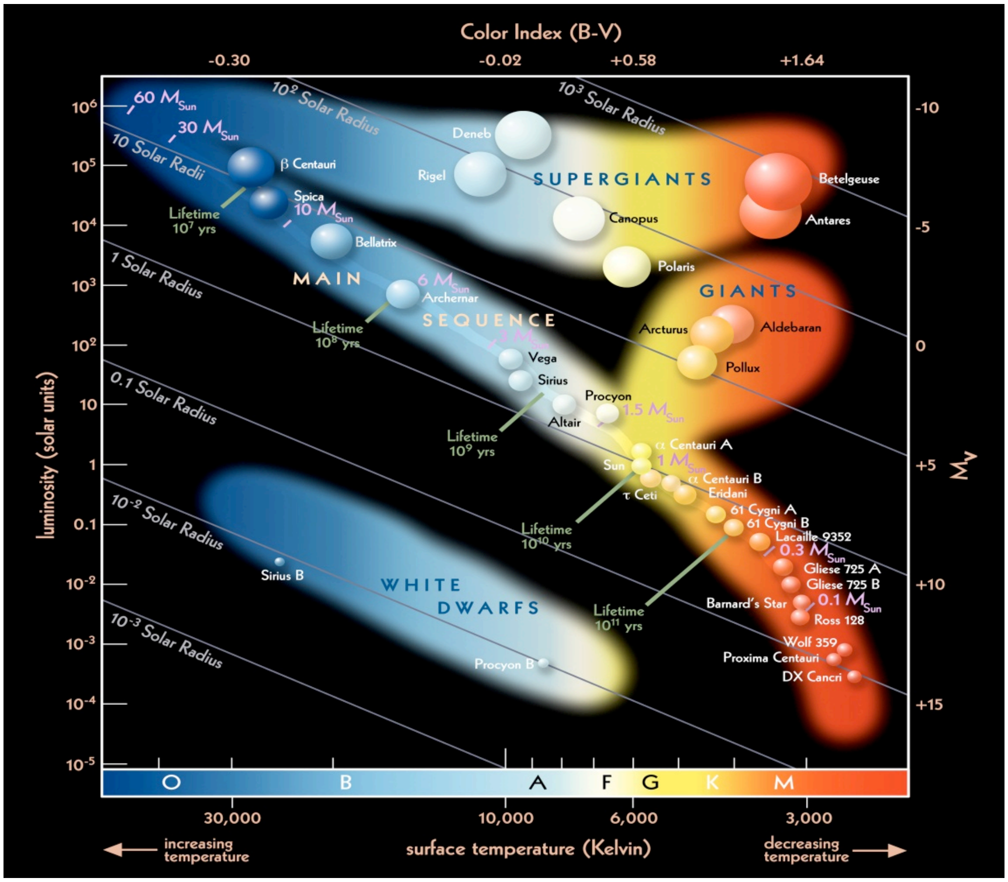


Figure 1
H-R Diagram

Figure 2 illustrates the stages the Sun will pass through as a giant star. Once core hydrogen is exhausted, the Sun's core will contract, causing the star to become more luminous. This will cause the outer portions of the sun to expand in size and the giant sun to move up the red giant branch (RGB) until the temperature near its core is hot enough for Hydrogen shell burning. Continued core contraction, will lead to Helium core burning (at the tip of the RGB - the Red Clump) and stability will return as helium begins to fuse and the Sun will migrate onto the Horizontal Branch (HB).

If all stars were of the same mass and age, simple observations of their spectral type and giant status would allow a determination of their evolutionary situation. However, stars of different masses and ages cause the simple single evolutionary track to blur into a multitude of tracks, thus making the location of giant stars a broad region on the H-R Diagram, spanning G to M spectral types and a range in luminosity. Without a precise distance determination, a spectral type alone cannot allow a precise evolutionary status to be assigned to any given giant star.

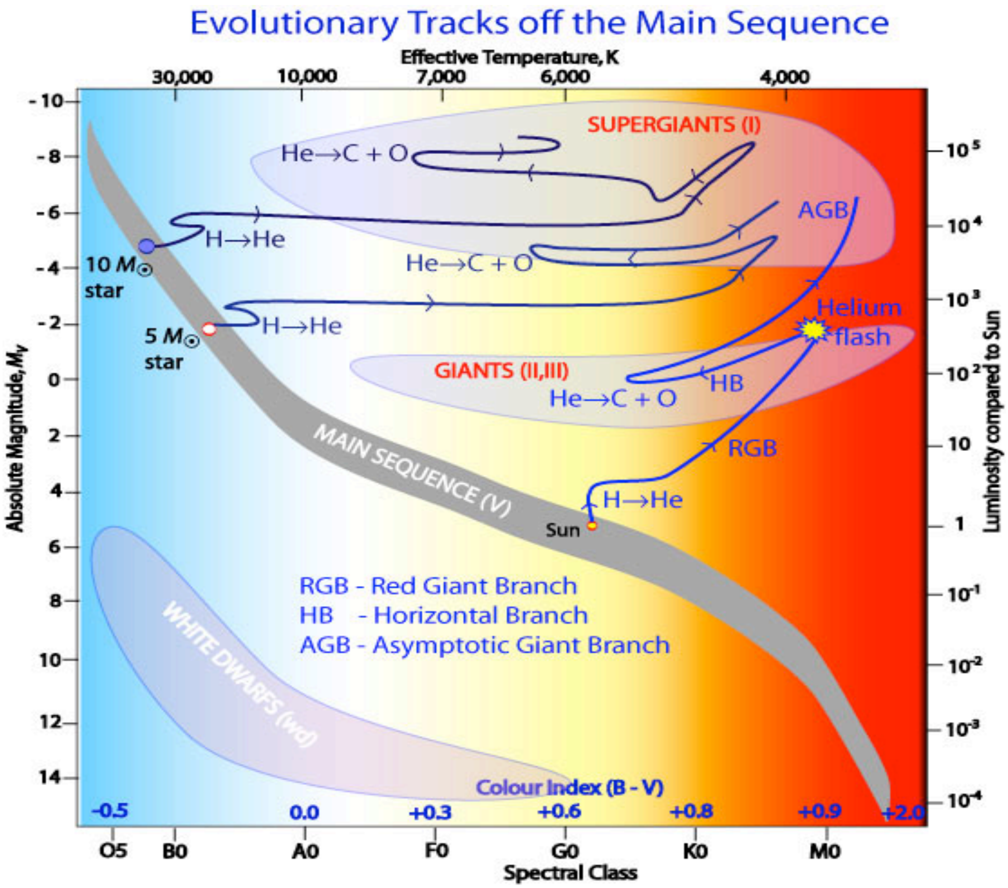


Figure 2

Evolutionary Path of the Sun

Asteroseismology, however, can be used to determine the internal structure that exists in giants and thus provide their evolutionary status. Bedding et al. (2011) used asteroseismology to distinguish RGB stars from Red Clump stars. Using Kepler light curve data, Bedding's group found that gravity mode periodogram spacings fell into two basic groupings. RGB stars had periods that grouped near 50 seconds, while the red clump star periods' grouped near 100-300 seconds. Thus, asteroseismology can be used to differentiate RGB (Hydrogen shell burning) from Red Clump (Helium core burning) red giant stars.

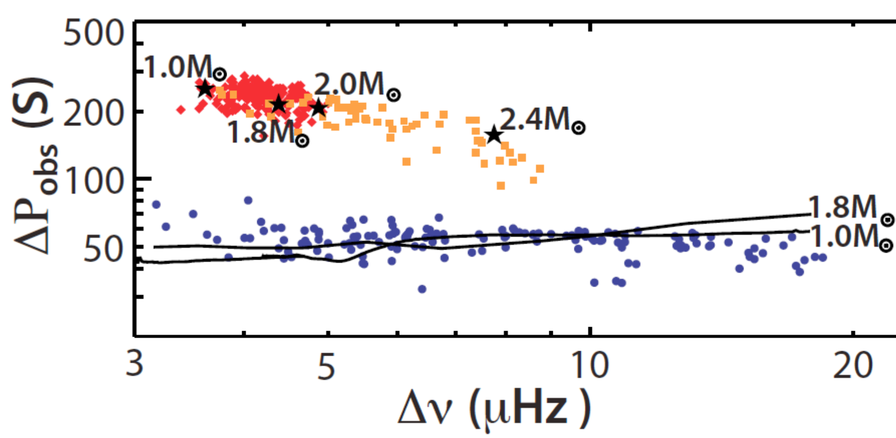


Figure 3

Asteroseismology Diagram

Red = clump stars, <2M_sun, He-core; Orange = secondary clump stars, >2 M_sun, He core;

Blue = RGB stars, 1-2 M_sun, H-shell.

In Figure 3, red and orange points indicate Helium-core burning red giants descending the red giant branch. Blue points indicate stars with Hydrogen shells ascending the red giant branch. Gravity mode spacing is plotted on the Y-axis, with pressure mode spacing on the X. This ability to separate the type (i.e., age) of red giants is the result from the work by Bedding et al. (2011).

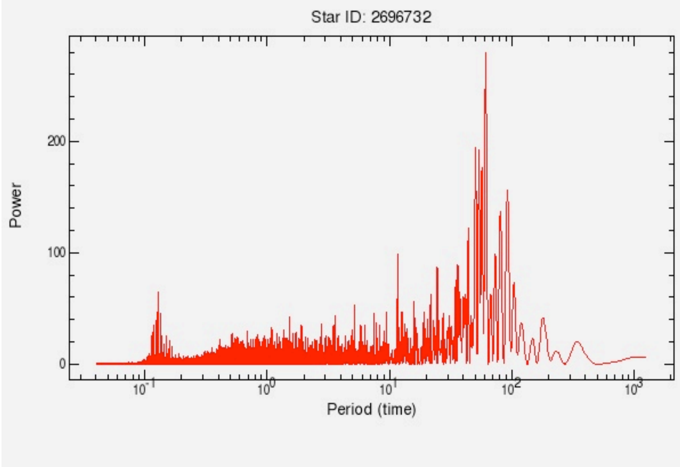
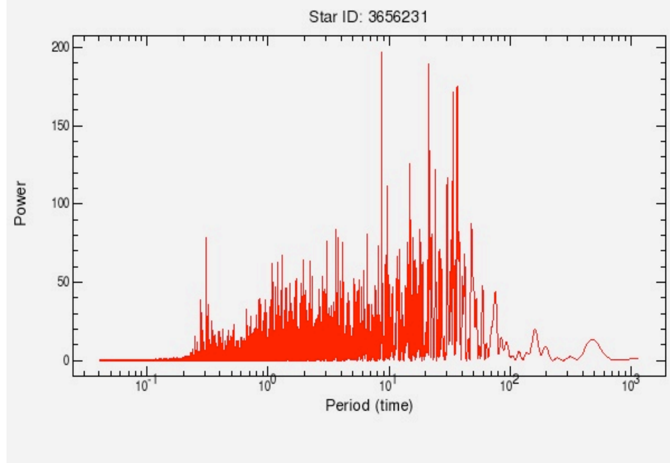
Mosser, Goupil et al. (2012), using ensemble asteroseismology, measured rotational split tings in a sample of red giants (n=300) from Kepler data. Results indicated that mean core rotation actually increased slightly during ascent of the red giant branch, but slowed significantly as it approached the red clump phase, thus suggesting a major change occurring internally at that stage of development. In a similar study of 200 red giants, Mosser et al. (2012) concluded that the accurate measurement of the gravity-mode period spacing by Kepler provided an effective probe of the inner, g-mode cavity. The derived value of the coupling coefficient between the cavities was discovered to be different for red giant branch and clump stars, again showing that asteroseismology data unique to Kepler's short cadence, high precision protocol, provides a reliable and important probe of the hydrogen-shell burning region that surrounds the helium core.

The high photometric precision and nearly continuous observations provided by Kepler light curves allow astronomers to measure both p-modes and g-modes of oscillations in Red Giants. G-modes from the deep interior can be used to differentiate internal structures (due to internal energy generating mechanisms) for Helium core and Hydrogen shell burning giants, providing separable evolutionary states. However, asteroseismology cannot be performed on all giants across the sky. In order for the asteroseismology to be effective, very high precision and short cadence observations, akin to only what Kepler can deliver, are required. However, the precision associated with asteroseismology cannot be performed easily from the ground or on all giants across the sky. We are, therefore, striving to find a diagnostic that might be observable from the ground.

The internal structures and energy generating mechanisms of the various types of red giants cause the outward variations in the atmospheres of these stars. We intend to search for patterns in the photometric data, at longer periods and larger amplitudes accessible from ground-based telescopes, in an attempt to distinguish the atmospheric structures of Helium core and Hydrogen shell burning giants. If successful, this study will provide guidelines that will help astronomers distinguish these classes using ground-based observations alone.

II. Pilot Study

Our pilot study focused on four giant stars; Kepler Input Catalog (KIC) ID numbers 1864183, 2696732, 3656231, and 3660820. All four stars have previously been identified as either a RGB or Red Clump star (Bedding et al. 2011). Using the NASA Exoplanet Archive – Kepler light curve web pages, we produced normalized light curves data and created periodograms for these four stars. Once periodograms were obtained, our first step was to look for a pattern or patterns in the periodogram of each star, other than the previously identified short period asteroseismology patterns. Next, we identified and recorded the top three periods (greater than ten days) along with the power of each. We produced phased light curves for each of the strongest periods. Two representative stars are shown in figures 4 and 5.

KIC 2696732 RGB Giant	**KIC 3656231** Red Clump Giant
	

Rank	Period	Power
1	61.244019	280.163982
2	92.102106	181.540435
3	44.161713	122.543578

Rank	Period	Power
2	21.365071	189.715827
3	36.617607	175.421823
4	14.904572	125.553932

Figure 4

Comparison of Periodograms and Exoplanet Archive Most Significant Period Data
Note asteroseismology clumping on left of each periodogram with periods <10 days. The periods are the top candidate periods for this time series. The power is the magnitude associated with the periods detected for this time series.

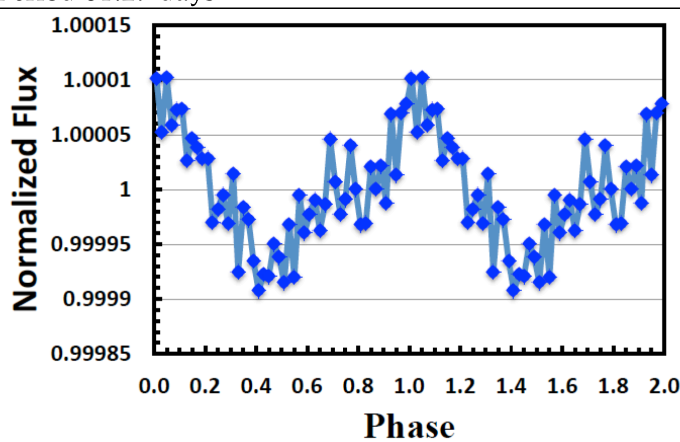
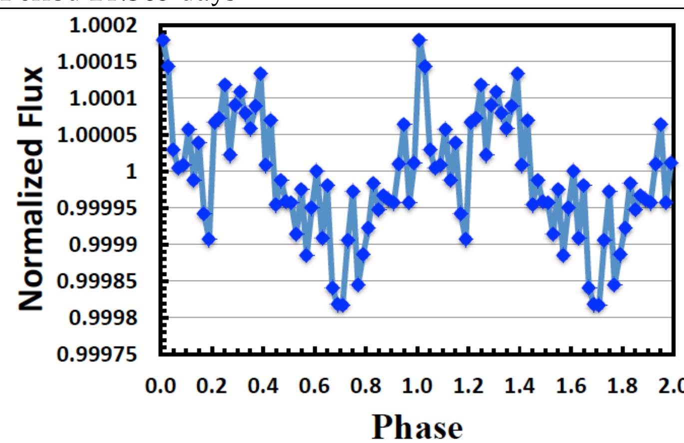
KIC 2696732 RGB Giant Period 61.29 days	**KIC 3656231** Red Clump Giant Period 21.365 days
	

Figure 5

Comparison of Phased Binned Light Curves.
Phase=0.0 is arbitrary as the start of the variability cycle is undetermined.

Our initial findings from the small pilot study indicate that a RGB star (H-shell burning) periodogram has a definite Gaussian shape centered on the strongest period. The Red Clump Giant (He-core burning) periodogram has an irregular shape and dominant periods between 20 – 30 days or less. Other notable findings from our initial assessment include possible relationships in the three strongest periods of the RGB star, while the Red Clump giants demonstrate an apparent unrelated period distribution in their top three periods. We can also see that the phased period for the RGB star seems well-defined while that for the strongest period of the Red Clump Giant is not.

III. Analysis plan

Given our initial assessment and findings, we plan to perform a similar analysis for 200 additional red giants from the Bedding et al. study. We will engage in a blind study, that is, we will not have prior knowledge of the Bedding et al. results and will attempt to classify the 200 giant star light curves into 2 (or more) categories.

To analyze the Kepler data of each of the 200 stars in our study, we will first look for patterns in the star's periodogram. We will then record the power and period of each of the three strongest peaks with periods greater than ten days. Using the archive's phase curve tool, we'll look more closely at each peak. The phase curve tool does not have the ability to phase bin, so we wrote a phase bin program in Excel. (Examples shown in Figure 5.) We plan to use our phase bin program to explore the data from the star's strongest periods. Additionally, we plan to build Spectral Energy Diagrams (SEDs) to help search for other signatures, such as dust shells, which may also help differentiate between the types of red giants.

IV. Proposed Timeline

March to July 2013:
Select 200 objects from the Bedding et al. study. Use the Exoplanet archive tools to make periodograms of each, and phase bin the top periods. Gather archival photometric data and produce an SED for each object. Through weekly telecons and exchange of information, we will organize our findings and discuss the project as we proceed.
August 2013 (NITARP visit):
Compare all periodograms, phased curves, and SEDs and group objects by similarities. Reveal the identities of all objects and see if groupings are indicative of H-shell or He-core burning giants.
September to December 2013:
Finalize analysis and conclusions and prepare a poster presentation for the AAS meeting in January 2014.

V. Educational Rationale

Our research team is comprised of teachers from all over the country; Gahanna, OH, Orlando, FL, Medford, OR, and San Mateo, CA. We are all dedicated to improving science education. Along with the working professionals there will be approximately 8-12 high school aged students involved in the research and presentation. Both educators and student learners will experience authentic scientific research. Upon completion of this research process, team members will work collaboratively to produce both a science and an education poster summarizing their work. These posters will be presented at the 2014 American Astronomical Society Winter Meeting in Washington, D.C. Beyond the research project studying red giants, we further propose to study the relationship between astronomical research and the preferred learning style of participating students.

V.1 Proposed Educational Study

For years, educators have studied learning styles of students. In science, Felder (Felder and Silverman, 1988, Felder and Brent, 2005) has distinguished himself as trying to determine how style affects student learning in the engineering fields. He has developed a fairly quick Learning Style Inventory (Felder and Soloman, nd) that can be administered on-line to high school students to evaluate students according to the following thinking constructs: 1) sequential vs. global; 2) active vs. reflective; 3) sensing vs. intuitive; and 4) visual vs. verbal. This assessment provides a "snap shot" of a student's general approach to learning.

These thinking constructs seem applicable to scientific research as well as engineering. We expect global students, who tend to see patterns in data, to be more comfortable studying periodograms, light curves, and SEDs than sequential students. Sensing students tend to memorize facts and may have trouble looking for something unidentified. Intuitive students who hunger for opportunities to discover relationships or novel ideas may thrive in a research environment or be frustrated by the number of twists and turns in the scientific process. Further, the role a student plays on a research team (making plots, organizing data, looking up archived data, finding patterns, etc) seems likely to be affected by their learning style. Thus, as a group, we plan to conduct a study of the relationships between astronomical research and the influence of learning style.

V.2 Analysis Plan

- Students take initial Felder Learning Style Inventory, to identify their preferred learning style(s). Each set of student results identified by number, not student name.
- Students participate in the "Giant" research project.
- Teachers observe the work of students on the Giants research project during this time, noting roles or actions for which they volunteer or to which they naturally gravitate, with the following constructs in mind:
    - What type of information does the student preferentially perceive: sensory (sights, sounds, physical sensations) or intuitive (memories, thoughts, insights).
    - What type of sensory information is most effectively perceived: visual (pictures, diagrams, flow charts, demonstrations) or verbal (written and spoken explanations)?
    - How does the student prefer to process information: actively (through engagement in physical activity or discussion) or reflectively (through introspection)?
    - How does the student characteristically progress toward understanding: sequentially (in a logical progression of incremental steps) or globally (in large "big picture" jumps)?
- Interview students who participate in the 3-day research project at CalTech about their own perceptions of how they approach learning during a research project (using similar constructs/thinking as above).
- Administer same ***Felder Learning*** Style Inventory to students at end of summer work and compare to their initial test and relate to collected anecdotal data. (Data will also be collected from the Felder Inventory on a control group of students of similar age and educational classes/experiences to ensure any differences are not just a result of increasing maturity or educational experiences in the regular classroom environment.)

V.3 Timeline:

- *March:* Students take initial Felder Learning Styles Inventory
- *April-June:* Students begin training and work, teachers collect anecdotal data on how each student approaches their work on our project
- *July*: Collate initial survey and anecdotal data from teachers
- *August:*
    - Video and interview students who participate in research at Cal Tech
    - Students take Felder Survey at end of summer session
    - Collate all data, look for patterns, changes, etc.
- *September-October*: Finalize analysis and conclusions
- *November:* Prepare presentation for the AAS meeting in January
- *December*: Organize groups for presentation at AAS meeting

VI. Teacher Commitments

Education Component at St. Mary's School (H. Bensel)

Astronomy Club members from St. Mary's School in Medford, Oregon will be participating in this project as part of their club's activities. They will work together to create periodograms, phase bin, plot SED's, and analyze scientific results. They will work with other teachers and students across the United States through teleconferences and the internet. In addition to the astronomy club, this research experience will be included in physics and astronomy classes.

This experience will be shared with a larger audience, through general interest presentations to local astronomy clubs and the Science Works Museum. As a regional director on the Oregon Science Teacher Association board, Ms. Bensel will talk to student teachers at local universities about her research and programs similar to NITARP and how authentic research can impact the lives of their students. As part of the Oregon Science Teacher Association, Ms. Bensel will share her experiences at state-wide in-service conferences and the 2013 Western Regional NSTA Conference. Using the data acquisition and analysis activities from her physics and astronomy classes, Ms. Bensel will write lessons for publication in The Oregon Science Teacher magazine and the Oregon Science Teacher Association website.

Education component at Gahanna Lincoln High School (F. Donelson)

Fred Donelson has been teaching science for 37 years and is an Ohio Master Teacher, as well as a National Board Certified Teacher. Donelson serves as coordinator of the Gahanna Lincoln Science Academy, and is the primary instructor in the robotics track. He currently is the Science Chair at Gahanna Lincoln High School and teaches Microbiology, Space Technology, Underwater Robotics, Honors Bionics, and Special Aspects.

“Mr. D” plans on using Kepler data with his Space Technology and Microbiology class as they learn about stellar evolution and study exoplanet formation and exobiology. His students will present their red giant research at several forums/symposiums, both locally and at the regional and state level. They will also plan and present a unit on stellar evolution at the GLHS Community University, a special set of classes designed for students to teach adults in the Gahanna community. Donelson plans on teaching a summer school introductory astronomy class using Kepler data to 30-50 native Chinese students in an exchange program with Gahanna Lincoln High School over the next two summers. Donelson is a frequent presenter of using technology in the classroom at state and local conferences and plans on presenting the NITARP program and its benefits at the State Technology Conference and the State School Board and Administrators conference next year.

Education component at University High School (D. Miller)

Ms. Miller has been teaching for seven years and currently teaches Honors Astronomy and Physical Science. Miller also serves as National Honor Society Sponsor.

Several students chosen as part of the research team will be highly involved with both the science and education research portions of the project, in the end understanding their learning style and becoming proficient and analyzing scientific data. In addition to the educational research component of the project, Ms. Miller plans to share the NITARP experience at the school level with students in Honors astronomy class, the Girls in Engineering, Math and Science (Club) and members of the Girl’s Robotics Team. Miller also has plans to present teacher workshops at her school, county, the Orlando Science Center, and the Kennedy Space Center Educator Resource Center.

Education component at San Mateo High School (S. Seebode)

Selected students will become proficient at making periodograms, phase binning, plotting SEDs, and sharing their results. These students are members of an active astronomy club and will use their acquired skills to do future research working with NExScI tools as well as educate future club members to continue their projects. Future research will be shared through local science fairs and AAS meetings.

The experience and information learned through this project will be shared at the California Science Teachers Association's (CSTA) meeting in 2013 and 2014, our school board, as well as local chapters of the Astronomical Society and community groups like Rotary and American Association of University Women (AAUW).

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