Stellar Variability Survey of Kepler Mission Data

Teachers:

John Blackwell
jblackwell@exeter.edu
Phillips Exeter Academy, Exeter, NH.

Stacy DeVeau
deveaus@erau.edu
Arizona NASA Educator Resource Center, Prescott, AZ.

Debbie Edwards
debra.edwards@pulsarsearchcollaboratory.com
Sherando High School, Stephens City, VA.

Mike Ford
mford@holtonks.net
Kickapoo Nation School, Powhattan, KS.

Support Scientists:

Dr. Steve Howell
National Optical Astronomical Observatory, Tucson, AZ and NASA Ames Research Center, Moffett Field, CA.

Dr. David Ciardi
NASA Exoplanet Science Institute, Infrared Processing and Analysis Center, Pasadena, CA.

Abstract:
We propose to study Kepler Mission data releases in survey form to determine the variability and nature of stars within the mission field. Within the time frame allotted for this project, we intend to individually study light curves, frequency domain and phase plots of 200 stars to better categorize the nature of their potential variability. Our research will focus on a random sample of 200 Main Sequence dwarf stars (class V luminosity), which are most like our Sun. Kepler data will be integral to our research as the variances we are interested in studying (1-10 milli-magnitude) are not observable using ground-based telescopes. We intend to determine which of the stars sampled are periodic and to characterize their periodicity. Determining the periodicity of such stars will provide a basis for later comparison against light curves identified as potential planetary transits. We anticipate identifying stars that have no periodicity, are eclipsing binaries, pulsators, have star spots, or transiting planets. We will aim to characterize each of the stars sampled.

I. Scientific Justification

While the Kepler Mission was primarily designed to look for exoplanet transits using photometric measurements of a static field of stars, the data also have a secondary bonus: it is one of the best time-sequence photometric measures of stars in our local Milky Way over an extended period. With the instrument being above the Earth's atmosphere, the instrumental sensitivity has been such that millimagnitude variability in stars is the norm. This wealth of data not only allows astronomers the ability to find extrasolar planets, but also to study the variable nature of stars of all types.

Early Kepler data has shown that dwarf stars are known to have a broad degree of variability (Ciardi et al 2011). Our research will focus on determining the variability of dwarf stars (Luminosity Class V Main Sequence) with a selection of stars from other better known types to aid in classification and to reduce potential for error in analysis. Initial survey target stars will be chosen by Ciardi and Howell with an estimate of 200 or more targets for analysis.

It is well known that as stars age, they leave Luminosity Class V and become giants or supergiants depending on their initial mass. Kepler data have already shown that there are variable stars of luminosity class V in the program (Ciardi et al 2011 Figure 6). Our interest in this stems from the fact that we on Earth orbit a luminosity class V star which is very stable in luminosity, so much so that we often consider it to be non-variable. Kepler data have shown that spectral type G stars like our sun have a significant percentage of members which are variable in some form or another with brightness ranges between 1 – 10 mmag or more. Our aim is to sample these stars and categorize their variability within the limits of the Kepler mission's data. Jenkins et al 2010 places an upper limit on the magnitude of stellar variability discernable in Kepler data using the mission's 30-minute samplings. This limit is a function of the stars' Kepler magnitude and its spectral type. For Sun-like G dwarfs, Kepler data can discern variability of 0.01 mmag at Kepler magnitudes of 6 and brighter. As the Kepler magnitudes become fainter, this level of discernment decreases. For example, G dwarf stars of Kepler magnitude 16 have an upper limit on variability placed at approximately 1.00 mmag. Our hope is that our better quantifying and analysis of stellar variability of G dwarf stars in this sample will assist scientists to better understand Main Sequence variability.

II. Data Analysis

Most of the data analysis will be performed using freely available Web-based software located on the IPAC Database. From here, individual star's light curves can be retrieved from each Kepler data release. The light curves can then be analyzed to produce a power spectrum and then a phased light curve to look for periodicity. The data are also fully available in downloadable formats which will allow us to use external tools as needed.

Primary investigation tools are provided online and include:

- The NStED: Exo-Planet Transit Survey Kepler Search page at: http://nsted.ipac.caltech.edu/applications/ETSS/Kepler_index.html

- The NStED Light Curve Viewer (Accessible only after a search using the NStED: Exo-Planet Transit Survey Kepler Search page is complete).
- The NStED Periodogram Service Power Spectrum page (Accessible only after a search using the NStED: Exo-Planet Transit Survey Kepler Search page is complete).
- The NStED Periodogram Service Phased Plot Viewer (Accessible only after a search using the NStED: Exo-Planet Transit Survey Kepler Search page is complete).

Initial analysis will occur during the spring of 2011 and will be done by the program teachers and their students. The intended survey target stars will be equally divided among team members, comprised of teachers and their students, for analysis with a random sample of overlap between teams to catch systematic errors in our program. Once targets have been assigned, we will generate a light curve for each target star using whatever datasets are available at the time. Power spectra will then be plotted for each star and then any variability will be determined by using the power spectrum and phase plots.

Our team is geographically widespread. As a result, we will collaborate over long-distance via phone and e-mail communication. We plan to correspond with each other one-on-one and make use of teleconferencing and web conferencing programs to collaborate collectively. Documents will be shared via e-mail. Training on procedures and methods will occur during the spring and early summer months using the resources previously listed as well as additional sites including:

- The AAVSO web pages.
- Introductory astronomy texts:
    - Carroll, Bradley W., and Dale A. Ostlie. *Modern Astrophysics.*
    - Sparke, L. S., and J. S. Gallagher, III. *Galaxies in the Universe*.
- Texts specific to photometry:
    - Warner, Brian. *Lightcurve Photometry and Analysis*.
    - Henden, Arne A., and Ronald H. Kaitchuck. *Astronomical Photometry*.

Our team will meet during the first week of August 2011 for three days in Pasadena, California to work cooperatively face-to-face and with our lead scientists. This will also provide us with the opportunity to have students involved in the project meet for the first time and work collectively. The primary goal will be to go over our collected survey and validate results as well as to further study any stars in our survey which are not readily able to be characterized. Plans for poster/s and papers will also be discussed and drawn up in preparation for the January 2012 AAS meeting in Texas.

III. Educational Rationale

Literature and anecdotal evidence strongly suggest that the United States is lagging in the education and preparation of students in scientific, engineering, and technical fields (*Trends in International Mathematics and Science Study)*. This is reflected in the number of university graduates (2003 College Graduates in the U.S. Workforce: A Profile), but

certainly begins before they enter college. Along the K-12 education pipeline, few students are interested in pursuing a science or engineering major in college. For underrepresented groups, the situation is even worse. The same observation can be made for the number of students interested in becoming science teachers. Even those certified to teach science in high school leave the profession in alarming numbers, with many leaving in their first five years (Ingersoll 2003).

Large numbers of adults lack the basic scientific education they require to be able to understand specific scientific advances and issues. The danger is that they will develop uninformed opinions, or perhaps in many cases make no decision at all about important issues that involve the economic and technical success of our country.

Education is the vital link to improving both situations: the lack of trained scientists and science teachers and a better-informed populace. Both students and teachers need a vision of the benefits of choosing a career path in scientific and engineering fields. The challenge is to communicate the excitement of science, the necessity of science and engineering to our technological society, and the tangible and intangible rewards associated with a career in science.

This project provides a chance to convey a number of these aspects to teachers, to a number of talented students and to the public at large. In addition, aspects of the training that the teachers receive as a result of this program will be communicated in both formal and informal educational settings to a much larger number of educators and students. In this way the program will reach a much larger number of students and teachers, and will also reach the general public through media outlets. Through participation in this project, teachers and students will gain an appreciation and understanding of the process of scientific research while contributing to new scientific knowledge.

Below are specific details describing the activities of the teachers who will be involved at the "first tier" level of developing the proposal, reducing and analyzing the data, and publishing the results. In addition to their classroom activities, each teacher will complete specific outreach activities designed to educate other teachers and the public on the results of the Kepler stellar variability survey and the scientific methods used to complete the project.

John A. Blackwell
Director Grainger Observatory
Chair of Science Department
Phillips Exeter Academy, Exeter, NH.

John teaches three college level research-based astronomy courses and manages the school's research observatory. Phillips Exeter Academy is a boarding preparatory school with approximately 1030 students, 33% of whom receive full financial aid packages and/or scholarships to attend. Over 90% of the students receive some form of financial aid.

John's intent is to use the NITARP experience as a method to teach authentic scientific research while allowing the students full access to the data to accomplish their own research goals. Students involved in the more advanced Astronomy-II & III courses will be taught about variable stars and the various methods to perform photometry in order to study the stars' magnitude variations with time. Analysis of light curves will also be studied with an emphasis on variable star type identification and the math needed to perform such research.

John intends to perform the following outreach activities:

- One hour talks to students in our local astronomy club about the nature of the project and its scientific merit.
- Select two students to work on the project. Students must be 2nd or 3rd year students with an astronomy interest and a willingness to research through the summer and the following year.
- Evening lectures and presentations at the McAuliffe-Shepard Discovery Center (Concord, NH) to the general public about this specific project and infrared astronomy in general: Attendance averages over 100 persons for events of this type.
- Day-long teacher education seminars at the McAuliffe-Shepard Discovery Center. John will contact the Director of Education, David McDonald, at the planetarium and schedule a teacher workshop to present infrared astronomy and this Kepler project. The audience will be high school teachers in southern New Hampshire, eastern Vermont and all of Massachusetts. This has the potential to reach over 50 teachers. Teachers will be presented with lesson plans, lab routines and an extensive bibliography for use at their schools.
- The Annual Math and Science Colloquium at Phillips Exeter Academy (June 2011 & 2012): This annual event is a series of intensive training seminars for high school and college teachers which is hosted by the Academy and taught by academy and external teachers. Topics range across all disciplines. Over 25 teachers are expected to register for this course.
- At least one lecture to the New Hampshire Astronomical Society, which has over 150 members. The first is tentatively scheduled for the late summer of 2011.

Stacy N. DeVeau
Director Arizona NASA Educator Resource Center
Embry-Riddle Aeronautical University - Prescott, AZ

Stacy provides NASA-themed professional development workshops for Arizona educators as well as provides student outreach opportunities in her community, including three school districts.

Stacy's intent is to utilize the NITARP experience as a method to provide an example of how research is conducted using authentic scientific data and as a springboard for educating the education community about the science embedded in the project. Students involved in the project will be engaged in analysis of data in order to conduct research.

Stacy intends to perform the following outreach activities:

- Information about the project will be incorporated into a future teacher professional development workshop regarding both the Kepler mission and stars, including sample light curve analysis.
- Stacy will work with students to create an outreach activity (or activities) that can be used to engage middle and/or high school students and teachers in understanding the underlying concepts of the research project.

Debbie Edwards
Earth Science/Astronomy Teacher
Sherando High School- Stephens City, VA

Debbie teaches ninth grade Earth Science and upper-level Astronomy to students at Sherando High School in Frederick County, Virginia. Sherando is a public high school (grades 9-12) of approximately 1200 students. Most students who come to Sherando take Earth Science during their ninth grade year. During this time, they receive approximately 8-9 weeks of instruction in astronomy. Later on, during their 11^{th} and 12^{th} grade years, students have the option to enroll in Earth Science II, which is an elective science course. During this course, students receive a half year of instruction in astronomy and a half year instruction in environmental science. The vast majority of students who take Earth Science II are not college-bound and express little interest in pursuing a career related to science, technology, math or engineering.

Frederick County is very interested in adopting inquiry and hands-on learning experiences into its curricula. Debbie intends to use the NITARP project as a means to both create interest in her students for science, technology, engineering, and mathematics (STEM) careers and to incorporate inquiry learning into the science classroom. Students will be provided with the unique opportunity to study real-world data collected from the Kepler telescope, to collectively create a research project, and present their results at the American Astronomical Society Convention in January 2011.

Debbie also intends to create a professional development workshop that will help other science teachers in her school division incorporate data from the Spitzer telescope into their astronomy curriculum. Debbie will work in conjunction with Tracy Sawyer, chair of the science department and Kelley Aitken, Supervisor of Science and Visual Arts of Secondary Schools in Frederick County, to create a professional development workshop for science teachers within the county. Teachers will be presented with ideas for lesson plans and resources that they may incorporate into their astronomy curriculum.

Michiel N. Ford
Chair of Science Department
Kickapoo Nation School - Powhattan, KS

Mike is a retired public school teacher from Holton, Kansas. He taught science for Holton Middle School and High School for 22 years. He is now teaching science for the Kickapoo Nation School. He also developed and built Elk Creek Observatory which houses a 20-inch telescope. The observatory is now in the process of being moved to a darker location. He and his students have worked on several High Energy Astrophysics programs such as FERMI, SWIFT, and XMM-Newton. Because of their work, there were part of a black hole special aired by National Geographic and NOVA.

In addition to public and private education, Mike is also teaching college astronomy and geology for Highland Community College outreach. He integrates lots of his NASA materials in these classes to keep students informed of current research in astronomy and physics.

Mike is going to use NITARP as a program to help students work in real life astronomical research, which will hopefully get them published. He does not like the "canned" lab exercises except for conceptual understanding, but would rather use real life, hands on research that can be used. All of the research he does with kids in an integral part of their understanding of the universe.

Outreach activities for NITARP will included, but not limited to: conducting educational presentations at NSTA National, regional and state conventions; Banner Creek Science Center (which should be completed by May, 2011), and an AAPT National Convention. Activities will also be done at star parties as displays and local town meetings such as Rotary, Lion's Club, etc.

IV. Summary

This project will focus on the study of Kepler Mission data releases to determine the variability of a random sample of up to 200 Main Sequence dwarf stars with class V luminosity. Both teachers and students will be involved in the analysis of light curve data located on the NASA/IPAC/NexSci Star and Exoplanet Database. Through this analysis, the sample stars will be identified and categorized based on their periodicity.

In addition to analyzing and classifying Kepler light curve data, this project will allow both formal and informal educators the opportunity to learn real science by conducting real science research. This research experience will enhance the participating educators' ability to communicate research as a vital component of improving scientific knowledge. Whether through direct participation in the project or indirect awareness about the project, both students of the participating teachers and the public, through outreach programs, will be exposed to the Kepler Mission and the importance of conducting scientific research in order to collect and analyze data to advance the scientific understanding of mankind.

References:

AAVSO. American Association of Variable Star Observers, n.d. Web. 13 Jan. 2011. <http://www.aavso.org/>.

Carroll, Bradley W., and Dale A. Ostlie. *Modern Astrophysics*. New York: Addison-Wesley Publishing Company, 1996.

Ciardi, David R., et al. "Characterizing the Variability of Stars with Early-Release Kepler Data." *Astronomical Journal* 141.4 (2011).

Henden, Arne A., and Ronald H. Kaitchuck. *Astronomical Photometry*. Richmond, VA: Wilmann-Bell, 1990.

Ingersoll, Richard. "Turnover Among Mathematics and Science Teachers in the U.S." *Science Educator* (Mar. 2003).

Jenkins, Jon M. et al. "Initial Characteristics of Kepler Long Cadence Data for Detecting Transiting Planets." The Astrophysical Journal Letters 713:L120-L125, 2010 April 20.

NASA Star and Exoplanet Database (NStED). NASA, n.d. Web. 18 Mar. 2011. <http://nsted.ipac.caltech.edu/applications/ETSS/Kepler_index.html>.

"NStED Services Search NStED for an Individual Star." *NASA/IPAC/NexSci Star and Exoplanet Database*. N.p., n.d. Web. 13 Jan. 2011. <http://nsted.ipac.caltech.edu/>.

Sparke, L. S., and J. S. Gallagher, III. *Galaxies in the Universe*. Madison, WI: Cambridge University Press, 2007.

Trends in International Mathematics and Science Study. IES National Center for Education Statistics, 2003. Web. 18 Mar. 2011. <http://nces.ed.gov/timss/Results03.asp?Quest=4>.

"2003 College Graduates in the U.S. Workforce: A Profile." *2003 College Graduates in the U.S. Workforce: A Profile*. National Science Foundation, Dec. 2005. Web. 18 Mar. 2011. <http://www.nsf.gov/statistics/infbrief/nsf06304/>.

Warner, Brian. *Lightcurve Photometry and Analysis*. Colorado Springs, CO: Springer, 2006.