

New Mexico NASA EPSCoR Year 1 Progress Report

Project Title: New Mexico Solar and Stellar Seismology
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Overview: Mission and Goals

The objective of this project is to build the infrastructure needed for New Mexico to become nationally competitive for funding in the fields of solar and stellar seismology. These are two of the quickest growing research areas of astrophysics because they provide essential information about the structure of the Sun and other stars that has never before been available. No other university-based effort currently exists within the country that targets these areas. Project goals are tied to NASA Strategic Goal 3B "Understand the Sun and its effect on Earth and the solar system" and its space-weather focused "Living With a Star" program. The importance of these research areas is reflected in the number of major current and future NASA space missions devoted to them. These include the Solar and Heliospheric Observatory (SOHO), the NASA Solar Dynamics Observatory (SDO), and the Kepler mission. This NASA EPSCoR proposal leverages the scientific talent within the state by forming a partnership among scientists at New Mexico State University (NMSU), the University of New Mexico (UNM), Los Alamos National Laboratory (LANL), the National Solar Observatory (NSO), and the Air Force Research Laboratory Center for Excellence in Space Weather (AFRL). Our NASA center partner is the Goddard Space Flight Center (GSFC). In accord with the EPSCoR goal of creating infrastructure, two new tenure-track faculty members with expertise in the project research areas will be hired at NMSU. Currently, very few university faculty members in New Mexico have expertise in solar and stellar seismology. These new faculty members will provide a nucleus around which state-wide proposals will be developed. This group will also lead state efforts to increase collaborations with our partner institutes. We have three major research goals:

- 1) Develop the theory and software needed to explore the interior structure of the Sun
- 2) Broaden the use of the solar model to other stars through the analysis of the pulsation spectra of solar-like and more massive stars
- 3) Characterize the stars that have been discovered to have planetary systems and to contrast their likely planetary environment with that of the solar system

A longer-term project goal is to use the New Mexico Computing Applications Center's supercomputer, Encanto, to develop a near real-time analysis pipeline of the Sun's sub-structure as one tool for the eventual prediction of severe space weather. Specific NASA EPSCoR objectives addressed by our effort include:

- 1) Developing the research infrastructure of solar and stellar seismology among New Mexico's universities (NMSU, UNM), national laboratories (LANL, NSO, AFRL) and the New Mexico Space Grant Program
- 2) Establish self-sustainability from sources such as the NSF, NASA, and the AFRL
- 3) Strengthen ties between New Mexico and out-of-state NASA centers through increased scientific collaborations
- 4) Contribute to the NASA Education Strategic Coordination Framework by increasing the number of under-represented students in astronomy, by providing faculty and students with research support, and through targeted investments in the state's academic infrastructure.

1. Research accomplishments

A. Science related

- a) *Developing theory and software needed to explore the interior structure of the Sun.*
Some software work has been done in this area (see below). The main focus has been on the construction of programs that use a star's light curve as input and produce a power spectrum as output. Furthermore, a new inversion code has been developed to handle computations of several years worth of solar seismic data. To do this, an optimization scheme was utilized so that the process runs fully on parallel processors.
- b) *Broadening the use of solar models to other stars.* A good start was made in this area. Our group has received five awards under the NASA Kepler cycle 1 and 2 guest observer program. The projects are titled "Measuring the sub-millimagnitude frequency spectra of pulsating B stars" (PI McNamara), "Characterizing the Top of the Red Giant Branch using Kepler Drop-List stars" (PI. Jackiewicz), "The structure and global properties of Red Giant Clump stars" (PI. McNamara), "Transition in variable stars: from Solar type to Gamma-Doradous type" (PI. Guzik), and "A search for hybrid Gamma-Doradus/Delta Scuti pulsating variables, Improving the Statistics" (PI Guzik). In March we received our first 90 days of data for the main sequence A and B star project. We are in the process of computing their pulsation frequency spectra using the widely accepted Period04 program. Although this is a tedious process, the software has been extensively tested. We are also developing our own software packages that provide a quick look at the spectra.
- c) *Characterizing stars that have been discovered to possess planetary systems.* Work on this topic relies on discoveries by the Kepler Team. It also follows from the activities described under areas of 1 and 2. Therefore, project work has not progressed to this stage.

B. Related to NASA EPSCoR goals

- a. *Developing the research infrastructure of solar and stellar seismology among New Mexico's universities (NMSU, UNM), national laboratories (LANL, NSO, AFRL) and the New Mexico Space Grant Program.* One of the main elements promised in the proposal to improve research infrastructure of New Mexico in solar and stellar seismology is a new faculty hire. Despite the intense fiscal environment NMSU faces, this new hire was authorized in Fall 2009. A total of 17 candidates from across the world applied for this position. Four people were brought to NMSU for interviews: one from the U.S., one from Germany, one from Austria, and one from Ireland. NSO Director Dr. Steve Keil, NSO Associate Director Marc Giampapa, and AFRL Chief Scientists Richard Radick served as an external advisory committee during this process. Dr. James McAteer was selected and in April 2010 formally accepted the position of assistant professor at NMSU. Dr. McAteer has expertise in areas of interest to NMSU, the NSO, and the AFRL. Additionally, ties with LANL were strengthened through the submission of the Kepler proposals listed above. In each case, PIs and Co-PIs from LANL and NMSU were on these proposals. We have been working with Dr. Dean Pesnell of Goddard Space Flight Center. Dr. Pensell is the PI of NASA's newly launched Solar Dynamics Observatory. Dr. Jackiewicz (NMSU EPSCoR co-PI) is a member of the SDO Team. Finally, Jackiewicz and McNamara have been working with NSO staff on a major new variable stars initiative called SONG (Stellar Observations Network Group). This international project involves collaborators from Europe and China. In spring 2010, Dr. Jackiewicz traveled to China for a two week team meeting. An NSF MRI proposal requesting support for SONG was submitted in April 2010.
- b. *Establishing self-sustainable model:* As the above discussion demonstrates much work has been directed toward the post-EPSCoR period. Major successes include the five Kepler projects listed above and support for a NMSU graduate and UNM graduate student from AFRL. An additional proposal requesting post-doc support has been submitted to the LANL IGPP. Its decision date is the end of July 2010.
- c. *Strengthening ties between New Mexico and out-of-state NASA centers through increased scientific collaborations.* This initiative is still relatively new and is focused on the SDO project at Goddard and with Ball Aerospace in Colorado. The latter effort is intended to provide industrial experience to our students. Dr. Jackiewicz submitted a NASA proposal in Dec. 2009 as Co-I with PI (M. Marley) from NASA/Ames to study planetary seismology techniques. This proposal is pending.
- d. *Contributing to the NASA Education Strategic Coordination Framework by increasing the number of under-represented students in astronomy:* Three of our student participants are URMs. Rose Perea is Hispanic, Rosemary Burns is Hispanic, and Son To is Vietnamese. In all 3 of the 6 students currently in our program are URMs.

2. Research Success

- a. Articles submitted to or published in refereed journal:
 - *Hybrid gamma Doradus-delta Scuti pulsators: New insights into the physics of the oscillations from Kepler.* Grigahcene, A. et al. (co-authors Jackiewicz, Guzik). *Astrophysical Journal Letters*, 713, L192 (2010).
 - *Multichannel three-dimensional OLA inversion for local helioseismology.* J. Jackiewicz et al. Submitted to *Solar Physics* (2009).
- b. Talks, presentations, or abstracts at professional meetings

Poster Presentations:

- January 2010: American Astronomical Society meeting, *Understanding the Physics of Sequential Chromospheric Brightenings of the Sun Through Automated Recognition*, Michael Kirk · K. S. Balasubramaniam · J. Jackiewicz · B. J. McNamara
- December 2009: American Geophysical Union meeting, *Automated Characterization of Sequential Chromospheric Brightenings*, Michael Kirk · K. S. Balasubramaniam
- June 2009: AAS Solar Physics Division meeting, Automated Detection of Polar Coronal Holes in the EUV (Honorable Mention, Student Poster Competition) Michael Kirk · Dean Pesnell

Oral Presentations:

- April 30, 2010, “Models of Solar Activity”, Michael Kirk, NSO, Sunspot, NM
- April 30, 2010, “Asteroseismology using Kepler Data”, Rose Perea, NSO Sunspot
- April 30, 2010, “A Solar and Stellar Data Management System, Son To, NSO Sunspot
- April 5, 2010, “Magnetic Fields in the Solar Atmosphere,” NMSU Pizza-Lunch Seminar, Las Cruces, NM
- March 29, 2010, “The U.S. Contribution to SONG,” J. Jackiewicz, The Third SONG Workshop, Beijing, China
- November 5, 2009, “Solar Interior Seismology,” J. Jackiewicz, Department of Physics, NMSU, invited colloquium
- October 22, 2009, “Seismology of the Sun,” J. Jackiewicz, Embry-Riddle Aeronautical University, Prescott, AZ
- August 13, 2009, “Seeing the Solar Surface: The Physics of Sequential Chromospheric Brightenings and their Automated Recognition,” NSO Summer Colloquium, Sunspot, NM
- September 2009: NMSU Talk, *Stellar and Solar Seismology*, B.J. McNamara
- October 2009: NSO Sunspot, *Stellar and Solar Seismology*, Jason Jackiewicz, Bernard McNamara
- October 2009: NSO Tuscon, *Stellar and Solar Seismology*, Jason Jackiewicz, Bernard McNamara

- c. Patents and patent applications: None
- d. Follow-on grant proposals submitted/funded
 - “Measuring the sub-milli-magnitude frequency spectra of pulsating B stars” NASA, \$54K
 - “Characterizing the Top of the Red Giant Branch using Kepler Drop-List stars” NASA, \$53K
 - “The structure and global properties of Red Giant Clump stars”, NASA, None
 - “Transition in variable stars: from Solar type to Gamma-Doradous type”, NASA, \$58K
 - “A search for hybrid Gamma-Doradus/Delta Scuti pulsating variables, Improving the Statistics” NASA, \$58K
 - “Automatic Recognition of Solar Features for Developing Data Driven Prediction Models of Solar Activity and Space Weather,” AFOSR, \$47K
- e. Formal professional recognition: None

3. Demographic information on participants

- a) Faculty
 - Bernard McNamara: Anglo-NMSU Department of Astronomy, Regents Professor
 - Jason Jackiewicz: Anglo-NMSU Department of Astronomy, Assistance Professor
 - David Voelz: Anglo-NMSU Department of Electrical and Computer Engineering, Professor
 - Patricia Hynes: Anglo-NMSU Space Grant
 - Thomas Duvall: Anglo, Goddard Space Flight Center
 - Joyce Guzik, Anglo-Staff scientists, Los Alamos National Laboratory
 - Harjit Ahluwalia, American (India), UNM Department of Physics
 - K. Balasubramaniam, American (India), Staff scientists, AFRL
 - Han Uitenbroek, Anglo-Staff scientists, NSO
- b) Post-doctoral students
None
- c) Students
 - Owen Boberg: Anglo-NMSU Undergraduate Senior physics major. Owen has been assisting the PIs with the reduction of photometric measurements obtained by the NASA Kepler satellite. Although the primary mission of this spacecraft is to search for planets around solar-like stars, light curves obtained of its target stars can also be used for their seismic study. This task meets the objective of our project’s research area titled “Understanding the origins and the predictions of stellar activity”. Owen was recently awarded a Fulbright Scholarship. He is working with project PI McNamara.
 - Michael Kirk: Anglo-NMSU Astronomy graduate student. Michael is developing algorithms for the prediction of coronal mass ejections. He makes

- bi-weekly trips to the NSO headquarters in Sunspot, NM to work with AFRL scientist K.S. Balasubramanian who is serving as his off-site mentor. Michael is currently finishing his second year of graduate work. He is working under the project area “Understanding the origins and the prediction of stellar activity”.
- Rose Perea: NMSU Hispanic Physics graduate student. Rose is completing her master’s degree in physics. Her project tasks are to compute the frequency spectra of our sample of Kepler observed B stars and to compare these spectra with those predicted from stellar models. The first part of this task is well underway, but the second was just started in the spring 2010 semester so more work will be required. Rose is working with McNamara under the project area “Understanding the origins and the prediction of stellar activity”.
 - Son To: NMSU Vietnamese-American Computer Science graduate student. Son is working closely with project PI Jackiewicz on the construction of a solar/stellar data base. The intent is to make SDO satellite data, NSO GONG data, and Kepler data available in a user friendly fashion to researchers. This project is progressing well with the HST data archive site searching as an example for the solar/stellar data base. Son is working in the project area “Computational Astrophysics”.
 - Kyle DeGrave: NMSU Astronomy graduate student. Kyle joined the project in spring 2010. He will be working most closely with Dr. Jackiewicz. His focus will be in project area “Computational Astrophysics”.
 - Rosemary Burns: NMSU Hispanic Computer and Electrical Engineering graduate student. Rosemary joined the project in spring 2010, although her primary work will not begin until this summer when she will work with AFRL Contractor Cosmiac (Configurable Space Microsystems Innovations and Applications Center). This company is located in Albuquerque, NM and specializes in “cubesats” for the measurement of space weather. Rosemary will be working in the project area “Instrument Development”.
 - John VanderLaan: Anglo-Electrical and Computer Engineering candidate graduate student: Airfare and accommodations were paid for the recruitment of Electrical and Computer Engineering graduate student John VanderLaan.

4. Systemic change as evidenced by:

- a) Further and/or reordered institutional priorities:
- NMSU has decided to make solar and heliospheric physics one of its strategic research areas. It has authorized the hiring of an astronomy faculty member in this field.
 - NMSU has similarly authorized the hiring of a computer science faculty member in high performance computing, specifically in the field of large data base management. The NSO is keenly interested in this area because of its Virtual Solar Observatory program and its upcoming Advanced Technology Solar Telescope. Los Alamos National Laboratory and the New Mexico Consortium are considering contributing to this person’s start-up package.

- UNM and NMSU have hosted two meetings with staff from the AFRL Center for Excellence in Space Weather. Their primary goal was to discuss collaborative research ideas and educational programs. The Center for Excellence in Space Weather is relocating its entire staff from Massachusetts to New Mexico. This move is expected to be completed by 2011-12.
 - NMSU has hired four faculty members in EPSCoR project areas. Given the economic conditions within the state, this is an extraordinary commitment. In accord with the interdisciplinary nature of this program, these hires have been in different departments, the NMSU Department of Astronomy (2 positions), Computer Science (1 position), and Aerospace Engineering (1-position). NMSU has also committed three internally funded graduate student positions to solar physics.
- b) Development of collaborations with jurisdiction agencies, industry, research and academic institutions and with NASA
- Five joint proposals have been submitted to the NASA Kepler program in asteroseismology with a LANL and NMSU Co P.I.
 - Two NMSU graduate students will be conducting summer work at Cosmiac, a private company located in Albuquerque, NM that is engaged in solar research
 - We will have at least one student working with an NSO mentor during summer 2010.
 - Drs. Jackiewicz, McNamara, and Guzik have submitted a proposal to LANL to fund a post-doc in the project areas.
 - Dr. McAteer, the new astronomy faculty hire, has expertise in areas of interest to the AFRL and NSO and we expect further collaborations to develop once he joins the department in fall 2010.
 - We are working with AFRL to increase the number of undergraduate and graduate students working in the field of space weather.
 - Dr. Jackiewicz and McNamara have joint a major international effort to construct a new spectroscopic telescope system that will be able to collect radial velocity data on variable stars in a continuous fashion. Collaborators include in the NSO.

5. Technology Transfer

None to report

6. Discussion of Interaction and cooperation with the jurisdiction's Space Grant

Discussions have taken place about the linking the jurisdiction's interest in suborbital flight with researchers at Los Alamos National Laboratory. This is seen as a possible future source of funding for student led payload projects. The PIs also attended a meeting hosted by the Space Grant Consortium with Cosmiac, and Albuquerque based company involved in near-Earth space flight. This connection led to two NMSU graduate students working with mentors at this company during summer 2010.