

**New Mexico NASA EPSCoR  
Year 2 Progress Report  
Contract NNX09AP76A**

- 1. Project Title:** New Mexico Solar and Stellar Seismology
- 2. Grant Number:** NNX09AP76A
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- 5. Award Institution:** New Mexico State University
- 6. Award Date:** August 1, 2009
- 7. Date of Report:** 05/09/2011

**8. Research Accomplishments measured against proposed goals and objectives**

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. Project goals are tied to NASA Strategic Goal 3B "Understand the Sun and its effect on Earth and the solar system" and the NASA program "Living With a Star". The project has three major research goals. These goals and progress in achieving them is provided below.

*1. Developing theory and software needed to explore the interior structure of the Sun.*

- Software has been written that uses a star's light curve as input to produce a power spectrum, and a table of the star's frequencies, amplitudes, and phases. The errors in these value are also provided, the plots of the computed frequencies superimposed on the star's light curve are generated so that the validity of the computed values can be visually confirmed. A separate software package (based on Dr. Balona's work) has also been written to confirm these results.
- A new inversion code has been developed to handle computations of several years worth of solar seismic data. An optimization scheme is utilized so that the program runs on parallel processors.

- A program to write the software that computes the theoretically expected pulsation spectrum of high mass stars has been initiated with the assistance of our Los Alamos National Laboratory collaborators.
- Significant work has been accomplished in the construction of an automated software package for the prediction of coronal mass ejections from the Sun. This work will serve as the basis of a Ph.D. dissertation for project graduate student Michael Kirk.

## 2) *Broadening the use of solar models to other stars.*

A good start has been made in this area. Our group has received six awards under the NASA Kepler solicitations for cycles 1 through 3 guest observer program. The project titles illustrate the scope of our work in this area,

1. "Measuring the sub-millimagnitude frequency spectra of pulsating B stars"
2. "Characterizing the Top of the Red Giant Branch using Kepler Drop-List stars"
3. "The structure and global properties of Red Giant Clump stars"
4. "Transition in variable stars: from Solar type to  $\gamma$ -Doradous type"
5. "A search for hybrid  $\gamma$ -Doradus/ $\delta$ -Scuti pulsating variables, Improving the Statistics"
6. "Characterizing the amplitude and frequency spectrum variability in hybrid  $\gamma$ Dor/ $\delta$ Scuti stars"

In addition to these awards a three year grant (approx \$215K) has been received from LANL to hire a post-doc fellow in asteroseismology. In December we received our Kepler data for our main-sequence B-star project. We are in the process of writing a paper on their pulsation characteristics. A poster on this work will be given at the May 2011 meeting of the American Astronomical Society in Boston, MA.

## 3. *Characterizing stars that have been discovered to possess planetary systems.*

None of the Kepler stars studied so far show evidence of planetary systems. Our current work has been confined to upper main sequence stars where planetary systems have not previously been discovered. Our results support the view that planets around these stars are still likely to be beyond our detection capabilities. We are in the process of expanding our effort to the examination of lower main sequence stars where planets are known to exist.

## **9. Systemic changes related to NASA EPSCoR funding**

Changes in each of the areas specified in the yearly report guidelines are discussed below.

### a. *Improvements in the jurisdiction's research and development infrastructure:*

Our primary project goal under this category was: "To develop the research infrastructure in solar and stellar seismology among New Mexico's universities (NMSU, UNM), national laboratories (LANL, NSO, AFRL) and the New Mexico Space Grant Program." The main way in which this goal was to be accomplished was through the hiring of two new faculty members at NMSU. Since the start of this EPSCoR project in 2009 NMSU has exceeded this goal by adding three new faculty members in areas related to the project.

1. The first EPSCoR supported hire was authorized in Fall 2009. Dr. James McAteer was selected to join the NMSU Astronomy Department. Dr. McAteer has expertise in heliophysics and space weather: areas of interest to NMSU (New Mexico State University), UNM (University of New Mexico), NSO (National Solar Observatory), LANL (Los Alamos National Laboratories, and the AFRL (Air Force Research Laboratory).
2. The second EPSCoR supported faculty hire was authorized in fall 2010. Dr. Laura Boucheron was selected and will join the NMSU Department of Electrical and Computer Engineering in Fall 2011. Her research field is the automated recognition of features in digital images. She will strengthen collaborative ties between NMSU, AFRL, and the NSO.
3. A third faculty member Dr. Huiping Cao joined the NMSU Computer Science Department in Fall 2011. This hire was not directly supported by EPSCoR funds, but her research is directly related to project activities. She is a regular participant in our weekly solar physics group discussions. Her field of expertise is large data-base management. This area is of interest to our EPSCoR partners NSO, LANL, and AFRL as well as Sandia National Laboratory.

*b) Increased financial commitment from the jurisdiction, industry, and participating institutions.*

- LANL has agreed to support two NMSU computer science faculty members to work on software development related to solar activity. These positions will be for three years and will provide two months of summer support.
- AFRL has agreed to support one graduate student at UNM and NMSU to work on problems associated with heliophysics.
- LANL has awarded NMSU a three-year post-doc position in asteroseismology.
- An internally competed multi-year graduate student fellowship has been awarded to project graduate student Greg Taylor by NMSU to work with Dr. Rimmile (NSO).
- An internally competed research award has been given to Drs. McAteer and Boucheron by NMSU to work on a solar limb adaptive optics project (with Rimmile NSO).
- An internally competed a research award has been given to Drs. Jackiewicz and Cao by NMSU to work on large base management solar physics problems.

*c) Response of activities to NASA jurisdiction priorities*

We have been working with Dr. Dean Pesnell of Goddard Space Flight Center. Dr. Pesnell is the PI of NASA's newly launched Solar Dynamics Observatory (SDO). Dr. Jackiewicz (NMSU EPSCoR co P.I.) is a member of the SDO Analysis Team. Secondly, Jackiewicz and McNamara have been working with NSO staff on a major new variable star initiative called SONG (Stellar

Observations Network Group). This international project involves collaborators from Europe and China. SONG will be able to detect extra-solar planets using precise radial velocity measurements. This technique is complementary to the light curve approach being used by the NASA Kepler satellite. Third, additional ties between NMSU and LANL were strengthened through the joint NASA Kepler awards. In many of these cases, PIs and Co-PIs from LANL and NMSU were co-investigators.

*d) Re-ordered jurisdiction and/or institutional priorities*

The AFRL Center for Excellence in Space Weather now recognizes NMSU and UNM as potential sites to address its future workforce needs. They are in discussions with NMSU and UNM about the development of curricula that will meet its long-term research goals. NMSU has added three new faculty members who work in project related areas since 2010. New faculty hired in these fields since 2009 now total four. NMSU has adopted space weather and heliophysics as strategic growth areas.

**10. Examples of successful technology transfer to the private sector**

None

**11. Extent to which collaborations with jurisdiction agencies, industry, research and academic institutions, and NASA have evolved.**

Several collaborations have evolved as a result of this effort

- a. A more extensive collaboration with LANL has developed around the Kepler program. NMSU and LANL scientific staff are co-Is on several jointly submitted proposals to this program.
- b. NMSU and UNM graduate students are supported by AFRL to conduct research in space weather with AFRL mentors.
- c. NMSU has one graduate student working at the NSO facility at Sunspot, NM and another has worked with NSO staff in Tucson.
- d. NMSU is playing a more active role in the Virtual Solar Observatory work at Goddard and the NSO.
- e. NMSU has conducted preliminary discussions with Ball Aerospace about summer internships.
- f. NMSU serves as the host institute for students requesting travel support to all national solar meetings. This resulted from the submission of successful joint NMSU/NSO proposal to the NSF.
- g. NMSU is working with Sandia National Laboratory's Plasma Physics Division on the measurement of the opacity in high temperature plasmas. This effort has the potential for generating post-doc appointments funded by Sandia.

## 12. Discussion of interaction between and cooperation with the jurisdiction's Space Grant Consortium.

The NM Space Grant Consortium helps identify colleagues at institutions within the district that have similar research goals to those of the project. They hold a yearly meeting at which EPSCoR groups report project results and seek additional contacts. They also provide technical support on the expenditure of project funds. Finally, they provide administrative support on the submission of project reports.

## 13. Research success of individual investigators as measured by:

### *a) Articles submitted to or published in refereed journals*

1. Ahluwalia, H., "Sunspot cycle 23 descent to an unusual minimum and forecasts for cycle 24 activity" *Advances in Space Research*, (accepted April 2011)
2. Kirk, M., "An Automated Algorithm to Distinguish and Characterize Solar Flares and Associated Sequential Chromospheric Brightenings, *Solar Physics* (submitted March 2011)
3. Moradi, Baldner, Birch, Braun, Cameron, Duvall Jr, Gizon, Haber, Hanasoge, Hindman, **Jackiewicz**, et al. "Modeling the subsurface structure of sunspots". *Solar Physics*, Volume 267 (2010).
4. Long, D., **McAteer, R.T.J.**, Bloomfield, D.S., Gallagher, P.T. Globally Propagating Disturbance in the Solar Corona, *Astronomy & Astrophysics*, in press (2011)
5. Byrne, J. P., Maloney, S.A., **McAteer, R.T.J.**, Refojo, J.M., Gallagher, P.T. Propagation of an Earth-directed coronal mass ejection in three dimensions, *Nature Communications*, Volume 1, Issue 6, pp. 74 (2010).
6. Conlon, P.A., **McAteer, R.T.J.**, Gallagher, P.T., Fennell, L. Quantifying the Evolving Magnetic Structure of Active Regions, *The Astrophysical Journal*, Volume 722, Issue 1, pp. 577-585 (2010).
7. Milligan, R.O., **McAteer, R.T.J.**, Dennis, B.R., Young, C.A., Evidence of a Plasmoid-Looptop Interaction and Magnetic Inflows During a Solar Flare/Coronal Mass Ejection Eruptive Event, *The Astrophysical Journal*, Volume 713, Issue 2, pp. 1292-1300 (2010)

### *b) Talks, presentations, or abstracts at professional meetings*

1. Calabro, B., "Automated Detection of Oscillatory Behavior in the Corona", *Solar Physics Division Meeting of American Astronomical Society Meeting*, May 2010
2. DeGrave, K., "F-mode seismology of solar simulations", *Solar Physics Division Meeting of American Astronomical Society Meeting*, May 2010

3. Ghraibah, A., “Fields, Flares, and Forecasts”, Solar Physics Division Meeting of American Astronomical Society Meeting, May 2010
4. Guzik, J., “Observations of 14 Delta Scuti and Gamma Doradus Star Candidates for the Kepler Guest Observer Program Cycle 1”. Third Kepler Asteroseismology Workshop: Kepler Asteroseismology in Action.” Aarhus, Denmark, June 2010.
5. Guzik, J., “Helioseismology of Sunspots: An Extended Analysis of AR9787.” Conference: “A New Era of Seismology of the Sun and Solar-like Stars.” Aix-en-Provence, France, June/July 2010
6. Jackiewicz, J., “Space Weather Related Research at New Mexico State University”. AFRL, Albuquerque, NM, March 2010
7. Jackiewicz, J., “Time-distance helioseismology inversions around sunspots – no consensus”, Aug 2010, NSO
8. Jackiewicz, J., “Imaging the depths of the Sun with helioseismology”, Boston College, Sept 2010
9. Jackiewicz, NSF panel member, 2010
10. Jackiewicz, J., “Solar Oscillations and acoustic power measured in H-alpha”, Solar Physics Division Meeting of the American Astronomical Society Meeting, May 2011
11. Kirk, M., “Characterizing Chromospheric Flares and Sequential Brightenings”, Solar Physics Division Meeting of of American Astronomical Society Meeting, May 2010
12. Kirk, M., “Connecting Ephemeral Chromospheric Brightenings to Coronal Loops”, Solar Physics Division Meeting of of American Astronomical Society Meeting, May 2010
13. Kirk, M., “Automated Characterization of Large Flares and Associated Sequential Chromospheric Brightenings,” Solar Image Processing Workshop V, September 2010
14. Kirk, M., “Properties of Solar Flares and Associated Sequential Chromospheric Brightenings,” AGU Fall Meeting, December 2010
15. McAteer, J., “The 3D CME: Lessons learned, confirmed, and unearned from STEREO”, invited colloquium at National Solar Observatory, University of Arizona, Tucson, Arizona, Oct 2010
16. McAteer, J., NSF panel member 2010
17. McAteer, J., “The 3D CME: Lessons learned, confirmed, and unearned from STEREO”, invited colloquium at National Solar Observatory, Sunspot, Tucson, New Mexico, Nov 2010

18. McNamara, B., "The influence of Rotation on the Pulsation Spectra of B stars", Solar Physics Division Meeting of the American Astronomical Society Meeting, May 2011
19. McNamara, B., "The Pulsation Spectra of Kepler B-stars", Summer meeting of the American Astronomical Society, May 2011, Boston, MA
20. McNamara, B., NASA Kepler Guest Observer's panel member 2010-2011
21. Pevtsov, A., "Coronal Loop detection and seismology", Solar Physics Division Meeting of the American Astronomical Society Meeting, May 2010

*c. Articles submitted to NASA venues*

None

*d. Patents and patent applications*

None

*e. Follow-on grant proposals submitted/funded including funding amounts*

1. Cao, H & Jackiewicz, J., "Efficient and Intelligent Management of Solar Data by Utilizing High-Performance Computing Infrastructure and Semantic Knowledge for Data-Intensive Retrieval and Exploration", NMSU, \$50,000
2. Guzik, J., "A search for hybrid Gamma Doradus/Delta Scuti pulsating variables-improving the statistics". NASA. \$100,000. 1 year
3. Jackiewicz, J., "Sounding stars with Kepler", (with PI Joanna Molenda-Zakowics, Univ. of Warsaw) European Union. \$3,500,000. 3 years. Awarded (funding amount under discussion)
4. Jackiewicz, J., "Probing stellar interiors with asteroseismology". Los Alamos National Laboratory. \$215,564. 3 years
5. Jackiewicz, J. "Automatic recognition of solar features for developing data driven prediction models of solar activity and space weather. AFOSR. \$45,000. 1 year
6. Jackiewicz, J., "MRI consortium: Acquisition of the U.S. contribution to SONG: A global telescope network for asteroseismology and exoplanets". Co-PI. Jon Hakkila (College of Charleston), NSF. \$3,269,000. 3 years. Declined
7. Jackiewicz, J., "The National Solar Observatory's annual solar physics workshops of the American Astronomical Society". NSF. \$45,000, 3 years.
8. Jackiewicz, J., "A program to financially support student attendance at solar physics meetings. NASA. \$45,000. 3 years. (pending)

9. McAteer, J., "The Complex Sun", NASA, \$452,000, 3 yrs (pending)
10. McAteer, J., "Coronal oscillations for SDO", Harvard Smithsonian/NASA, \$40,000, 2 yrs
11. McAteer, J., "Adaptive Optics for Solar Physics" NMSU, \$44,000, 3 yrs
12. McAteer, J., "Neutron Monitors for Space Science", NASA, \$747,000, 3 yrs (pending)
13. McAteer, J., "Novel Approaches to Understanding Coronal Structures", NASA, \$356,000, 3 yrs (pending)
14. McNamara, B., "The structure and global properties of Red Giant Clump stars". NASA McNamara (data only)
15. McNamara, B., "Characterizing the top of the Red Giant Branch using Kepler drop-list stars". NASA. \$55,203. 1 year (data only)
16. McNamara, B., "New Mexico education center in space science and engineering. Department of Defense. \$4,830,302. 5 years. Declined
17. McNamara, B., "Creating a 21<sup>st</sup> Century Partnership with the National Solar Observatory for Excellence in Solar Physics", AURA/NSF (pending)

**14. Demographic (ethnicity/race and gender through self identification) information on participants**

*a) Faculty – including names and institutions*

Name	Ethnicity	Gender	Institution
Ahluwalia, Hargit	Anglo	M	University of New Mexico
Balasubramaniam, K	Anglo	M	AFRL
Boucheron, Laura	Anglo	F	New Mexico State University
Cao, Huiping	Asian	F	New Mexico State University
Guzik, Joyce	Anglo	F	Los Alamos National Lab
Jackiewicz, Jason	Anglo	M	New Mexico State University
McAteer, J	Anglo	M	New Mexico State University
McNamara, B	Anglo	M	New Mexico State University
Rimmile, T	Anglo	M	National Solar Observatory
Voelz, David	Anglo	M	New Mexico State University
Uitenbroek, Han	Anglo	M	National Solar Observatory

*b) Graduate and undergraduate students*

<u>Name</u>	<u>Ethnicity</u>	<u>Gender</u>	<u>Institution</u>
Al-Ghraibah, Amani	Asian	F	Graduate student, NMSU
Boberg, Owen	Anglo	M	Undergraduate, B.S. 2010, NMSU
Burns, Rose Mary	Hispanic	F	Graduate student, transferred to UNM
Calabro, Brandon	Anglo	M	Undergraduate, NMSU
DeGrave, Kyle	Anglo	M	Graduate student, NMSU
Kirk, Michael	Anglo	M	Graduate student, NMSU
Madadi, Aditya	Asian	M	Graduate student, NMSU
Mason, Ashley	Anglo	F	Graduate Student, NMSU
Perea, Rose	Hispanic	F	Graduate student, M.S. 2010, NMSU
Pevtsov, Alex	Anglo	M	Undergraduate, NMSU
Taylor, Greg	Anglo	M	Graduate student, NMSU
To, Son	Asian	M	Graduate student, Ph.D 2011, NMSU