

**New Mexico NASA EPSCoR
Year 3 Progress Report
Contract NNX09AP76A**

- 1. Project Title:** New Mexico Solar and Stellar Seismology
- 2. Grant Number:** NNX09AP76A
- 3. PI name and contact information:**
Dr. Patricia Hynes
New Mexico Space Grant Consortium
New Mexico State University
MSC SG, P. O. Box 30001
Telephone: 575-646-6414
Email: pahynes@nmsu.edu
- 4. Science PI name and contact information:**
Dr. Bernard McNamara
New Mexico State University
Department of Astronomy
MSC 4500, P. O. Box 30001
Las Cruces, NM 88003
Telephone: 575-646-2614
FAX: 575-646-1602
Email: bmcnamar@nmsu.edu
- 5. Grant Institution:** New Mexico State University
- 6. Grant start date:** August 1, 2009
- 7. Date of Report:** 05/09/2012

8. Research Accomplishments measured against proposed goals and objectives

As stated in the prior annual report the objective of this project is to build the infrastructure needed for New Mexico to become nationally competitive in the fields of solar and stellar seismology. Project goals are related 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." Below we discuss progress in each of the project's three research goals.

- a. *Developing theory and software needed to explore the interior structure of the Sun.*
 - New software is being developed to investigate the positional accuracy that can be obtained from Kepler images. These programs will be used to determine the distance and motions of solar analogues. Software has also been written to analyze Kepler measurements of the brightness changes of stars. Specifically, software has been written to produce a power spectrum, and a table of the star's frequencies, amplitudes, and phases.

- Project students Maghala and Al-Ghraibah are continuing to work with Dr. Boucheron (NMSU Electrical and Computer Engineering) on codes that identify transient features in digital images of the Sun.
- A new inversion code has been developed to handle computations of several years of solar seismic data. An optimization scheme is utilized that allows the program to run on parallel processors.
- Significant work has been completed on the construction of an automated software package for the prediction of coronal mass ejections from the Sun. This work serves as the basis of a Ph.D. dissertation for project graduate student Michael Kirk.

b. Broadening the use of solar models to other stars.

Our group continues to make progress in this area. The analysis of data from NASA's Kepler satellite was specifically targeted under our EPSCoR grant. To date we have been competitively awarded guest observer status on 9 Kepler proposals (listed below).

"Measuring the sub-milli-magnitude frequency spectra of pulsating B stars"

1. "Characterizing the Top of the Red Giant Branch using Kepler Drop-List stars"
2. "The structure and global properties of Red Giant Clump stars"
3. "Transition in variable stars: from Solar type to γ -Doradous type"
4. "A search for hybrid γ -Doradus/ δ -Scuti pulsating variables, Improving the Statistics"
5. "Characterizing the amplitude and frequency spectrum variability in hybrid γ Dor/ δ Scuti stars"
6. "Spotted B-stars: Exploring a newly discovered magnetic B-star phenomenon"
7. "Influence of tidal forces on solar-like oscillations of red giants in binary systems"
8. "Investigating the pulsation characteristics of hot variable stars"
9. "Kepler gamma Doradus and delta Scuti stars: Filling the gaps"

A paper describing our B-star work has been reviewed and published in the *Astronomical Journal* (see later listing of papers). A poster discussing this work was also given at the January 2012 meeting of the American Astronomical Society in Austin, Texas.

c. 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 and red giant stars where planetary systems are not likely to be found.

9. Systemic changes related to NASA EPSCoR funding

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

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

Our primary project goal under this category was: "To develop research infrastructure in solar and stellar seismology among New Mexico's universities - New Mexico State University (NMSU) and the University of New Mexico (UNM); national laboratories - Los Alamos National Laboratory (LANL), National Solar Observatory (NSO), and Air Force Research Laboratory (AFRL); and the New Mexico Space Grant Consortium (NMSGC)." The main way the program was to accomplish this goal was through the hiring of two faculty members at NMSU in project related areas. Since the start of this EPSCoR project in 2009 NMSU has exceeded this commitment by hiring three faculty members. They are described below.

1. Dr. James McAteer was selected to join the NMSU Astronomy Department in Fall 2010. He has expertise in heliophysics and space weather and works with researchers at NMSU, UNM, NSO, LANL, and the AFRL.
2. Dr. Laura Boucheron joined the NMSU Department of Electrical and Computer Engineering in Fall 2011. Her research field is the automated recognition of features in digital images. She strengthens collaborative ties between NMSU and the AFRL.
3. Dr. Huiping Cao joined the NMSU Computer Science Department in Fall 2011. Her hire did not involve EPSCoR funds, but her research field is closely tied to project activities. Her expertise is in the area of large data-base management. This area is of interest to our EPSCoR partners NSO, LANL, and AFRL as well as Sandia National Laboratory (SNL).

In addition to these new faculty members, three post-docs have recently joined our group. Dr. Aleksandra Andic conducts observational studies of the Sun's chromosphere and the interaction of solar magnetic activity with solar oscillations. Dr. Vigeesh Gangasharan computes MHD simulations of the solar atmosphere. Dr. Patrick Gaulme works in the field of asteroseismology using Kepler data. They will strengthen research connections between NMSU, LANL, AFRL, and the NSO.

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 are for three years and provide two months of summer support.
- AFRL supports 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 Rimmele 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.
- An Educational Partnership agreement was signed in Fall 2011 between NMSU and the AFRL to conduct joint research projects in heliophysics and space weather. To date two research awards have been made to NMSU faculty on the basis of that agreement.

c. Response of activities to NASA jurisdiction priorities

We are engaged in several activities related to jurisdiction priorities.

- 1) 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 Science co-I) is a member of the SDO Analysis Team.
- 2) Jackiewicz has been working on a major new variable star initiative called SONG (Stellar Observations Network Group). This international project involves collaborators with European and Chinese institutes. SONG will be able to detect extra-solar planets using precise radial velocity measurements, a technique that is complementary to the light curve approach being used by the NASA Kepler satellite.
- 3) Research ties between NMSU and LANL continue to be strengthened through the submission of joint NASA Kepler proposals. Dr. P. Gaulme was hired using funds provided by LANL to assist in our stellar work. He has spent time discussing his activities with our LANL collaborators.

d. Re-ordered jurisdiction and/or institutional priorities

The AFRL Center for Excellence in Space Weather now recognizes NMSU and UNM as important sites to address their future workforce needs. AFRL has signed a memorandum of understanding for joint educational and research efforts with both of these universities. The University of New Mexico is our EPSCoR partner. AFRL has already sent staff members to teach graduate level units in space physics at both of these institutions. NMSU and UNM participated in the AFRL building dedication ceremony in Albuquerque, NM. At the request of the New Mexico Space Grant Consortium our group sent representatives to the dedication ceremony of Spaceport America in Upham, NM.

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 and LANL supports a Post-doc at NMSU in asteroseismology.
- 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 on adaptive optics with an NSO mentor (Taylor, G)
- d. NMSU has one undergraduate student working at the AFRL as part of its summer outreach program (Delgado, F).
- e. 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.
- f. Sandia National Laboratory's Plasma Physics Division has expressed an interest in working with NMSU on the measurement of the opacity in high temperature plasmas. This effort has the potential for generating post-doc appointments funded by Sandia.
- g. Student contacts have developed with staff at the Goddard Space Flight Center, George Mason University, Queen's College (Belfast, Ireland), the Harvard-Smithsonian Observatory, and the Max-Planck Institute for Solar System Research

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

The New Mexico Space Grant Consortium helps identify colleagues at institutions within the district that have similar research goals to those of the project. It holds 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, administrative support, and assist 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. Bloomfield, D., McAteer, J, et al. "Toward Reliable Benchmarking of Solar Flare Forecasting Methods", 2012, ApJ, 747, 41.

2. Calabro, B., “3- and 5- Minute Oscillatory Behavior in the Solar Corona”. Submitted to Solar Physics Journal (2011).
3. Gallagher, P, McAteer, J. et al., “Coronal mass ejection detection using wavelets, curvelets, and ridgelets: Applications for space weather monitoring”, 2011, AdSpR 47, 2118.
4. Harrison, T, McNamara, B., et al. “Spitzer Observations of GX17+2: Confirmation of a Periodic Synchrotron Source”, 2011, ApJ. 736, 54.
5. Higgins, P., McAteer, J. et al. Solar magnetic feature detection and tracking for space weather monitoring”, 2011, AdSpR 47, 2105.
6. Jackiewicz, J., et al. “Multichannel Three-Dimensional SOLA Inversion for Local Helioseismology”, 2012, SoPh, 276, 19.
7. Kirk, M., “An Automated Algorithm to Distinguish and Characterize Solar Flares and Associated Sequential Chromospheric Brightenings”, Submitted to Solar Physics (2011).
8. Kirk, M., “Properties of Sequential Chromospheric Brightenings and Associated Flare Ribbons”, Accepted to the Astrophysical Journal (2012).
9. Long, D., McAteer, J. “Deceleration and dispersion of large-scale coronal bright front”, 2011, A&A, 531, 42.
10. Martens, P., McAteer, J., “Computer Vision for the Solar Dynamics Observatory (SDO)”, 2012, Solar Physics, 275, 79.
11. McNamara, J., “The Dynamical Distance, RR Lyrae Absolute Magnitude, and Age of the Globular Cluster NGC 6266”, 2011, AJ, 142, 163.
12. McNamara, B., “Erratum: The Dynamical Distance, RR Lyrae Absolute Magnitude, and Age of the Globular Cluster NGC 6266”. 2012 AJ, 143, 53.
13. McNamara, B., et al, “A Search for an Intermediate Mass Black Hole in the Core of the Globular Cluster NGC 6266”. 2012, ApJ, 745, 175.
14. McNamara, B., et al, “The Classification of Kepler B-Star Variables”, 2012, AJ, 143, 101.
15. McNamara, B., et al, “The Internal Proper Motions of Stars in the Open Cluster M35”, 2011, AJ, 142, 53.
16. Uytterhoeven, K.; Jackiewicz, J. et al. “The Kepler characterization of the variability among A- and F-type stars. I. General overview”, 2011, A&A, 534, 125.

b. Talks, presentations, or abstracts at professional meetings

1. Al-Ghraibah, A., "Automated Classification of Flaring Behavior in Solar Active Regions: Preliminary Results", American Astronomical Society Conference, January 7-13, 2012.
2. Andic, A., "Waves and Flares", American Astronomical Society Conference, June 10-14, 2012.
3. Andic, A., "Speckle Reconstruction Technique", NMSU Solar & Stellar Physics Group Meeting, Las Cruces, New Mexico, March 1, 2012.
4. Calabro, B., McAteer, J., Pevtsov, A., "Why is the Sun hot?", Undergraduate Research Conference Poster Session, September 30, 2011.
5. Calabro, B., "3- and 5- Minute Oscillatory Behavior in the Solar Corona", American Physical Society 4 Corners Section Meeting, October 21-22, 2011.
6. Calabro, B., "Detecting Flows, Waves and Nanoflares in the Solar Corona", American Astronomical Society Conference, January 7-13, 2012.
7. Calabro, B., "Oscillations", NMSU Society of Physics Students (SPS) Undergraduate Lecture Series, Las Cruces, New Mexico, February 8, 2012.
8. Gangadharan, V., "Acoustic emission from flux tubes in the solar network", NSO Workshop #26, May 4, 2012.
9. Hao, Y., "Intelligent Search of Solar Data", American Astronomical Society Conference, January 7-13, 2012.
10. Jackiewicz, J., "Suitability of the Apache Point Observatory 1m telescope for the Song Spectrograph", Fourth SONG Workshop, September 15-21, 2011.
11. Jackiewicz, J., Gangadharan, V., "LWS Workshop 2012: Local Helioseismology-Data Analysis, Modeling and Comparison", Invited Colloquium, Tucson, Arizona, March 27-30, 2012.
12. Jackiewicz, J. & Gangadharan, V., "Seismology of small-scale magnetic features from simulations", LWS Workshop 2012, Tucson, AZ, March 27-30, 2012.
13. Jackiewicz, J., "'Oscillatory power observed in flares and filaments.'" 26th NSO Workshop, Sac. Peak, NM, April 30 - May 4, 2012.
14. Jackiewicz, J., "Oscillatory power observed in flares and filaments." 26th NSO Workshop, Sac. Peak, NM, April 30 - May 4, 2012.

15. Kirk, M., “Automated recognition of Solar features for developing data driven prediction models of coronal mass ejections and space weather”, AFOSR Space Science Program review, June 2011.
16. Kirk, M., “Connecting Ephemeral Chromospheric Brightenings to Coronae Loops”, 27th Annual New Mexico Symposium, October 2011.
17. Kirk, M., “Physics of Ephemeral Chromospheric Brightenings”, Invited Colloquium at Air Force Research Laboratory, Albuquerque, New Mexico, October 12, 2011.
18. Kirk, M., “Extracting Physics of Flares Through Sequential Chromospheric Brightenings”, New Mexico Symposium, October 14, 2011.
19. Kirk, M., “Sequential Chromospheric Brightening: An automated approach to extracting physics from ephemeral brightening”, ATST EAST Meeting, Washington, DC, November 10, 2011.
20. Kirk, M., “Mapping the dynamics of chromospheric flares”, AGU Fall meeting December 2011.
21. Kirk, M., “Chromospheric Explosions: Linking Observations Toward a Physical Model”, American Astronomical Society Conference, January 7-13, 2012.
22. McKeever, J. “Unusual Pulsation Properties of Red Giant Branch Stars in Kepler”, American Astronomical Society Conference, January 7-13, 2012.
23. McKeever, J., “The Pulsation of Red Giant Branch Stars ”, Fourth SONG Workshop, September 15-21, 2011.
24. McNamara, B., “Pulsating B Stars observed by Kepler”, American Astronomical Society Conference, January 7-13, 2012.
25. Pevtsov, A., “Coronal Loop and Seismology”, American Physical Society Four Corners Section Meeting, October 21-22, 2011.
26. Pevtsov, A., “Coronal Loop Detection and Seismology”, American Astronomical Society Conference, January 7-13, 2012.
27. Taylor, G., “Solar Limb AO: A Test of a Phase-Diversity Sensor and Algorithms”, ATST/EAST Conference, November 9-11, 2011.
28. Taylor, G., “Nick Arge (AFRL): Solar Wind”, Invited Colloquium at New Mexico State University, Las Cruces, New Mexico, March 26-28, 2012.

c. Articles submitted to NASA venues

None

d. Patents and patent applications

None

b) Follow-on grant proposals submitted/funded including funding amounts

1. Boucheron, L. "A database and image processing approach to the management of large image collections", AFRL (declined due to a lack of agency funding)
2. Delgado, F., "New Mexico Space Grant Consortium Undergraduate Scholarship", NASA, \$5,000, 1 year, accepted
3. Jackiewicz, J. (CoI), "MRI Consortium: Development of the SONG spectrograph and installation on the 1 meter telescope at Apache Point Observatory", NSF, \$1,000,000, 3 years, pending
4. Jackiewicz, J., "Probing the three-dimensional structure of solar supergranulation with local helioseismology", NASA, \$90,000, pending
5. Jackiewicz, J. (CoI), "The influence of sub-surface and surface dynamics on the activity cycle", NASA, \$33,270, 3 yrs
6. Jackiewicz, J. (CoI), "Developing physics-based procedures for local helioseismology probing sunspots and magnetic regions", NASA, \$2,800,000 (NMSU \$150,000), 4 yrs.
7. Jackiewicz, J., "Influence of tidal forces on solar-like oscillations of red giants in binary systems", NASA, 1 year, awarded Kepler targets
8. Jackiewicz, J., "Investigating the pulsation characteristics of hot variable stars", NASA, 1 year, awarded Kepler targets
9. Jackiewicz, J. (CoI), "Kepler gamma Doradus and delta Scuti stars: Filling the Gaps", NASA, 1 year, awarded Kepler targets
10. McAteer, J., "Solar Terrestrial Observations and Relations Monitor (STORM)", DoD, \$429,000, declined
11. McAteer, J., "Novel Approaches to Understanding Coronal Structure", NASA, \$103,000, declined
12. McAteer, J., "Neutron Monitors for New Mexico", NASA, \$749,000, declined

13. McAteer, J., "Contemplating Coronal Complexity", NASA, \$120,000, declined
14. McAteer, J. (CoI), "Photospheric properties of flaring vs. flare-quiet active regions: can we use HMI vector magnetogram sequences to quantify, when and why does the Sun go boom?", NASA, \$546,000 (NMSU \$50,187), accepted
15. McAteer, J. (CoI), "MRI: Development of an Adaptive Optics System for Solar Stellar Observations", NSF, \$1,462,000, pending
16. McAteer, J., "Rapid Flare Dynamics in the Chromosphere", NASA, \$371,000, pending
17. McAteer, J., " Student travel fund", NASA, \$20,000K, pending
18. McNamara, B., "Spotted B-stars: Exploring a newly discovered magnetic B star phenomena", NASA. 1 year, awarded Kepler targets
19. McNamara, B., "A comprehensive study of the star-burst cluster NGC 3603", NASA, pending
20. McNamara, B., "A targeted search for intermediate mass black holes in two promising clusters", NASA, pending

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

a) Faculty:

<u>Name</u>	<u>Ethnicity</u>	<u>Gender</u>	<u>Institution</u>
Ahluwalia, Hargit	Indian	M	University of New Mexico
Balasubramaniam, K	Indian	M	Air Force Research Laboratory
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) Post docs

<u>Name</u>	<u>Ethnicity</u>	<u>Gender</u>	<u>Institution</u>
Aleksandra, Andic	Anglo	F	New Mexico State University
Gangasharan, Vigessh	Anglo	M	New Mexico State University
Gaulme, Patrick	Anglo	M	New Mexico State University

c) Graduate and undergraduate students

<u>Name</u>	<u>Ethnicity</u>	<u>Gender</u>	<u>Institution</u>
Al-Ghraibah, Amani	Asian	F	Graduate student, NMSU, M.S. 2012
Boberg, Owen	Anglo	M	Undergraduate, NMSU, B.S. 2010
Burns, Rose Mary	Hispanic	F	Graduate student, transferred to UNM
Calabro, Brandon	Anglo	M	Undergraduate, NMSU
DeGrave, Kyle	Anglo	M	Graduate student, NMSU
Delgado, Fernando	Hispanic	M	Undergraduate, NMSU
Hao, Yifan	Asian	M	Graduate student, NMSU
Kirk, Michael	Anglo	M	Graduate student, NMSU
Madadi, Aditya	Asian	M	Graduate student, NMSU
Martinez, Monique	Hispanic	F	Undergraduate, NMSU
Mason, Ashley	Anglo	F	Graduate student, NMSU, M.A. 2012
Meghala, Valluri	Asian	F	Graduate student, NMSU, M.S. 2012
McKeever, J	Anglo	F	Graduate student, NMSU
Perea, Rose	Hispanic	F	Graduate student, NMSU M.S. 2010
Pevtsov, Alex	Anglo	M	Undergraduate, NMSU
Ramesh, Eric	Anglo	M	Undergraduate, NMSU
Taylor, Greg	Anglo	M	Graduate student, NMSU
To, Son	Asian	M	Graduate student, NMSU Ph.D 2011
Towry, Amanda	Anglo	F	Undergraduate, NMSU B.S. 2012