Living With A Star TR&T
Abstracts of Selected Proposals
(NNH10ZDA001N-LWSTRT)

Below are the abstracts of proposals selected for funding for the Living With A Star TR&T program. Principal Investigator (PI) name, institution, and proposal title are also included. One Hundred Forty-Six (146) proposals were received in response to this opportunity, and 44 were selected for funding.

Solar Dynamics Observatory – AIA/EVE

Markus Aschwanden/Lockheed Martin ATC
Self-Organized Criticality in Solar Physics

The solar corona is a nonlinear dissipative system that exhibits self-organized criticality (SOC), regarding the generation of magnetic flux elements, nanoflares, microflares, large flares, and CMEs. With AIA we can study for the first time extensive statistics of these SOC phenomena with high spatial resolution, high cadence, and comprehensive temperature coverage, which will greatly improve new physical insights into the dynamics and statistics of solar phenomena, such as the role of nanoflares for coronal heating, the universal relationship between the fractal geometry of energy dissipation domains and energy frequency distributions, or scaling laws between geometric and physical solar flare parameters. SOC phenomena are also common in geophysics (earthquakes), magnetospheric physics (auroral emission, substorms), stellar physics (stellar flares), pulsars (giant pulses), and accretion disks around black holes. We propose to analyze and model SOC phenomena from SDO/AIA and HMI data, which have optimum cadence, spatial resolution, and complete time and temperature coverage.

Hugh Hudson/University of California, Berkeley
A Study of White-Light Flares Observed by the Solar Dynamics Observatory

The "white light flare" continuum emission is the most important component of flare luminosity, and arises in a still-mysterious manner within the lower solar atmosphere. With the launch of the Solar Dynamics Observatory, we suddenly have excellent new capabilities for studying the mechanics of white-light flares, in particular the manner in which they launch global waves both into the corona and also into the interior of the Sun.

The most violent solar flares, those that tend to have the greatest impact on modern technological society, usually appear as white-light flares. The intense continuum emission from these flares is known to have a close association with the acceleration of high-energy particles, a fundamental process in flare physics. Helioseismic observations of white-light flares show seismic motions associated with the white-light emission. The coupling has thus far eluded our understanding. We do not know whether chromospheric shocks created by thick-target heating penetrates through the photosphere to produce the seismic signatures, whether backwarming of the photosphere is a major contributor, or whether the newly-discovered magnetic "jerks" are important.

The answers to these questions should give us deep insight into the transient magnetic forces that express themselves in flares and the mechanisms that release them. Because strong white-light flares are sudden and difficult to detect sudden, and their impulsive phases short-lived, they require high-resolution high-cadence imaging spectroscopy at visible wavelengths. This has never previously been available from space. The Solar Dynamics Observatory (SDO) now provides this capablity, along with key Doppler and magnetic measurements from the Helioseismic and Magnetic Imager (HMI), and multiwavelength data from the Atmospheric Imaging Assembly (AIA) and Extreme-ultraviolet Variability Experiement (EVE) instruments. We are fortunate also to have the unique RHESSI hard X-ray and gamma-ray imaging spectroscopy as well. SDO furthermore observes systematically; we therefore expect to extend the statistics to the many flares of GOES M class or above in Cycle 24. With modern computational facilities for modeling flare physics, the SDO is a crucial resource for addressing the seismic waves and many related questions. We propose to develop the basic data-analytical facilities for this task and apply them to the formulation of realistic physical models of flare mechanics in the chromosphere, photosphere and solar interior.

This work seeks to incorporate seismic disturbances into our general understanding of the lower solar atmosphere during a flare, previously characterized best by white-light flare signatures plus model inferences from the hard X-ray and gamma-ray observations. We specifically propose to

* Make systematic multi-wavelength studies of white light flares, with a strong emphasis in the use of the new and powerful capabilities of the Solar Dynamics Observatory;

* Identify which mechanisms for seismic excitation may work, via multi-wavelength observations, and which are feasible via comparisons with simulations;

* Relate our new knowledge to the understanding of the basic physical mechanisms of flares;

* Establish methods for working with future observations, both space- and ground-based, to exploit the seismic signatures for understanding the physics of flares and CMEs.

Therese Kucera/NASA Goddard Space Flight Center
Prominence Dynamics and Structure with SDO/AIA

The question of prominence formation is essential to our understanding of the energetic processes occurring in the solar atmosphere and solar magnetic field. New data from the

Atmospheric Imaging Assembly (AIA) aboard the Solar Dynamics Observatory (SDO) will allow us to make significant progress in this area.

We will use new data from SDO/AIA to answer the fundamental questions: what is the origin of solar prominence mass and how does it evolve? With AIA's unprecedented spatial, temporal, and thermal coverage of the entire disk we will analyze dynamic prominence motions to an extent never before possible. This will enable us to test models of prominence mass formation and energetics, and to make essential advances in understanding the birth and life cycle of these ubiquitous features.

To accomplish this goal we will combine two observational investigations with state-of-the-art prominence modeling. We will perform: 1) a survey of many prominences to determine what proportion of prominences exhibit fast extreme ultraviolet (EUV) motions, at what temperatures they appear, and under what conditions; and 2) an in-depth study of selected prominences in order to determine the life histories of moving prominence features, including measurement of temperature variation, masses, sizes, and velocities. The survey will allow us to describe the general characteristics of prominence motions in temperatures from 10^4 to 4x10^6 K so that we can assess the prevalence of signatures of competing models. The results of the in-depth studies of individual prominences will be used for detailed comparisons with and testing of models of prominence mass formation and energetics. In particular, we will compare our results to detailed predictions made with the thermal nonequilibrium model of prominence formation.

This research is directly relevant to 1.2.3 Science Analysis for the Solar Dynamics Observatory (SDO) in the LWS TR&T NRA in that it is centered on analysis of SDO/AIA data with a goal of understanding an important manifestation of solar magnetic activity. Prominences are a key signature of the magnetic variability and organization of the solar atmosphere. A thorough characterization and understanding of the processes resulting in plasma dynamics will enhance our understanding of the magnetic field in prominence channels and perhaps ultimately the eruptions of these fields.

Ryan Milligan/Catholic University of America/GSFC
Investigating The Influence Of Nonthermal Electrons On Increased EUV Irradiance Observed During Solar Flares Using SDO/EVE and RHESSI

We propose to investigate the physical processes that drive increases in extreme ultraviolet (EUV; 6-36 nm) irradiance during solar flares. As this emission can have a significant effect on Earth's upper atmosphere (Lean et al. 2009, Qian et al. 2010), understanding its origins is a major goal of the Living With A Star program. Previous studies have shown that these increases are greatest during a flare's impulsive phase (Woods et al. 2004; 2006), suggesting that they are driven by nonthermal electrons, although hard X-ray (HXR) observations have never been utilized to confirm this. The main focus of this proposal is therefore to expand upon previous works by combining observations of solar flares from the Ramaty High Energy Solar

Spectroscopic Imager (RHESSI), to characterize the nonthermal electrons through HXR imaging spectroscopy, and the EUV Variability Experiment (EVE) onboard the Solar Dynamics Observatory (SDO) to measure the associated increase in EUV irradiance.

To demonstrate how coordinated observations with these two instruments can address this issue, the preliminary analysis of two low-M-class flares is presented. EVE observations show a small increase (~3%) in the total EUV emission of one flare (an M1.2 on 5 May 2010), and a larger increase of ~11% in the other (an M2.9 on 16 October 2010). In each case, it is shown that chromospheric emission (primarily the He II line at 30.4 nm) dominates this change in EUV irradiance, and that it is temporally correlated with the power contained in nonthermal electrons as determined from RHESSI observations. The RHESSI data show that the 16 October 2010 flare had a considerably harder electron spectrum (delta=4, at energies up to 100 keV), than the 5 May 2010 event which had a softer spectral index (delta=6 up to only 50 keV). These preliminary findings support, and expand upon, previous studies of flare EUV irradiance that only speculated that increased irradiance is driven by accelerated particles. Joint RHESSI and EVE observations are then directly comparable to the radiative hydrodynamic simulations of Allred et al. (2005), which can model the response of the He II line to a beam of nonthermal electrons.

The EVE spectral range also contains a number of density sensitive emission lines with formation temperatures in excess of 10 MK, yielding a potentially powerful and, as yet, unused diagnostic of flare densities at high temperatures. These line ratios were tentatively applied to both of the flares described above, and clear changes in the values of the line ratios were found during the two events.

- The first task of this proposal is to complete the analyses of the 5 May 2010 and 16 October 2010 events to establish the relationship between the properties of the accelerated electrons and the increase in EUV irradiance.

- Secondly, the results of this joint analysis will be directly compared to the model predictions of Allred et al. (2005) to determine the heating mechanism and constrain the total energetics.

- The third task involves investigating the diagnostic potential of the density sensitive line ratios in the EVE spectra to determine the plasma density during the two flares.

- Finally, we will extend this analysis to the 15 other flares of varying magnitudes already jointly observed by both RHESSI and EVE, and others detected during the rise of Solar Cycle 24 to perform a statistically significant comparison of nonthermal electron energies and changes in EUV irradiance.

Philip Scherrer/Stanford University
Probing Coronal EUV Waves and Wave-like Phenomena: SDO/AIA Data Analysis and MHD Modeling

We propose to carry out analysis of SDO/AIA data and complimentary MHD simulation for global EUV disturbances (EIT waves) and fast propagating disturbances (FPDs) discovered by AIA. This work directly addresses the second topic of Targeted Investigation "1.2.3 Science Analysis for SDO" in the 2010 LWS TR&T solicitation, i.e., "Investigate the physics and diagnostic potential of coronal wave-like phenomena made accessible by AIA's high cadence, high signal-to-noise ratio, or large field of view".

We seek answers to the following Compelling Science Questions: (1) What is the physical nature of global EUV disturbances (EIT waves)? Are they real MHD waves or apparent waves caused by CME expulsions? (2) What are the origin and nature of fast (~1000 km/s) propagating disturbances (FPDs) discovered by AIA in EIT wave events? Are they theoretically predicted, but rarely observed propagating fast mode MHD waves? What are their excitation mechanisms? (3) What are the relationships of EIT waves and FPDs with other eruptions, including CMEs and flares? Why do some CMEs lead to EIT waves, while others do not?

Answering these questions will Enable Us to: (1) understand the roles played by EIT waves and FPDs in transport of energy vertically through different layers of the magnetized atmosphere and horizontally across the solar disk; (2) understand their roles in solar eruptions, such as CMEs and flares, which contribute to the dynamic evolution of the corona; and (3) use them as seismological diagnostics to infer otherwise elusive coronal parameters, such as the magnetic field strength.

These foreseen outcomes are highly Relevant to NASA's LWS Program, and in particular, well serve two of the four main goals of LWS's flagship mission SDO: "2. Identify the role of the magnetic field in delivering energy to the solar atmosphere and its many layers", and "3. Study how the outer regions of the Sun's atmosphere evolve over space and time -- ranging from seconds to centuries."

To implement this investigation, we will employ the following Methodology: (1) Analyze SDO/AIA data and complimentary data from SDO/HMI, STEREO, Hinode, and SOHO to study an ensemble of EIT waves for their dynamic evolution, temperature distribution, energy content, and newly discovered duality of diffuse and sharp fronts; (2) Analyze AIA data of FPDs to obtain their statistical properties of propagation, dispersion, damping, and energy flux, and compare the result with predictions from MHD wave theories; (3) Run state-of-the-art 3D MHD simulations of EIT waves and FPDs using the BATS-R-US and NLRAT codes, guided by AIA observations, to distinguish between alternative interpretations and test our analysis algorithms.

The Major Strengths of the proposed work lie in: (1) AIA's unprecedented capabilities are the best suited for these tasks which previous missions were incapable of; (2) this work is timely since the next one to two years will be the best chance to study these coronal wave(-like) phenomena with a double-quadrature formation of SDO and STEREO; (3) the feasibility and promise of the proposed work is demonstrated in our first AIA results published and in preparation (Liu et al. 2010c,a,d); (4) previously underused Fourier (time-distance) analysis will be applied to the newly discovered FPDs; and (5) this work consists of balanced elements of data analysis and MHD simulation supporting and benefiting from each other.

Yi-Ming Wang/Naval Research Laboratory
Using SDO To Study Active Region Moats, Coronal Cavities, Dimmings, and Coronal Hole Formation

OBJECTIVES/APPROACH: Employing simultaneous, coaligned SDO/AIA and SDO/HMI observations, we will carry out the following four projects: (1) We will study the formation and growth of the dark moats (also known as circumfacular areas) surrounding active regions, in the context of the evolving photospheric field. A particular goal will be to understand the role of supergranular convection, reconnection, and flux cancellation in the transition from fibril structures to PIL-aligned filaments. (2) We will track coronal cavities to determine if they have a tendency to evolve from arcade-like structures to flux ropes with circular cross sections. In addition, we will test our prediction that the preferred direction of the cavity spinning motions changes from equatorward to poleward as the polar fields weaken. (3) We will exploit the multiple EUV channels provided by AIA to study the temperature dependence of coronal dimmings, and to seek further support for our hypothesis that most of the coronal plasma cooler than 1 MK is not expelled in eruptive events. (4) We will study the formation of coronal holes during the emergence of active regions, and determine whether the formation process is accompanied by the expansion of coronal loops or the ejection of mass. In addition, we will investigate the causes of the observed short-term fluctuations in coronal hole boundaries and relate these fluctuations to in situ measurements of the slow solar wind.

METHODS: The AIA and HMI observations will be combined with EUV observations STEREO/EUVI, which provide complementary viewing angles, and with white-light observations from the SOHO/LASCO and STEREO/COR1 and COR2 coronagraphs, which will allow us to determine if coronal hole formation and coronal dimmings are accompanied by expanding loops and ejections into the heliosphere. We will also employ our flux transport code to simulate the evolution of active region moats and coronal holes. PFSS extrapolations of the observed photospheric field will be used to determine the coronal fieldline topology and the locations of open field regions.

RELEVANCE: This proposal directly takes up the LWS TR&T challenge to exploit the SDO data to "characterize the properties, evolution, and terrestrial consequences of the solar magnetic field."

Solar Dynamics Observatory – HMI

William Abbett/University of California, Berkeley
Developing Reliable Estimates of Poynting Flux from HMI Observations of Active Region Magnetic Fields

Ultimately, the magnetic energy in the Sun's atmosphere --- the source of dramatic eruptive events such as flares and coronal mass ejections --- is generated below the photosphere in the turbulent, differentially-rotating convective interior. The emergence of new magnetic flux into the solar atmosphere, the twisting and shearing of emerged magnetic flux by turbulent motions, and Alfven and magneto-acoustic waves from intermittent turbulent eddies are all viable mechanisms that can transport magnetic energy into the solar atmosphere. It is crucial that we understand these physical processes and be able to distinguish between them. Thus, we propose to develop and apply techniques to derive quantitative maps of the flux of electromagnetic energy into the solar atmosphere from below the visible surface. These techniques will be based on the recently-developed poloidal-toroidal decomposition (PTD) method of Fisher et al. (2010), and will use observations of the evolving vector magnetic field at the solar photosphere, and observed Doppler flows.

Specifically, the objectives of this proposal are to (1) incorporate Doppler line-of-sight data and sequences of vector magnetograms from HMI into the PTD formalism to derive reliable estimates of the photospheric electric field and the electromagnetic Poynting flux; (2) validate this method with new state-of-the-art MHD simulations of the solar interior and atmosphere where the electric field and Poynting flux are known; (3) create robust and efficient electric field and Poynting flux mapping software to be released to the Heliophysics community and to be incorporated into the HMI Joint Science Operations Center; and (4) apply this method to HMI data for a diverse sample of active regions.

Graham Barnes/NorthWest Research Associates, Inc.
Using SDO/HMI Data to Investigate the Energization of the Coronal Magnetic Field

The energy to power solar energetic events must ultimately originate at or below the solar photosphere, and is likely to build up in the coronal magnetic field before release in an event. We propose here to use the unique properties of the data from SDO/HMI to follow the flux of free energy from below the photosphere into the corona, and out into the heliosphere, to try to understand the mechanism(s) which lead to the build up of magnetic free energy in the corona.

For this investigation, we will consider a small sample of active regions, on the order of 25. The data from the HMI instrument are new, and subject to artifacts whose influence on our analysis is not yet fully understood. By starting with a small number of active regions, we will be able to consider each in enough detail to determine how artifacts in the data influence the results, and how to correct or account for their effects in the analysis. Promising initial results would warrant a follow-up study of a statistically significant number of active regions, but that is beyond the scope of this investigation.

Our investigation will primarily utilize products produced by the HMI data analysis pipelines. To infer changes in the energy below the photosphere, we will use flow maps at a variety of shallow subsurface depths from local helioseismology, generated both by the pipeline running at Stanford University and the pipeline running at Max-Planck-Institut fuer Sonnensystemforschung.

To track the flow of free energy through the photosphere, we will use the vector magnetic field observations, combined with the flow at the surface obtained from DAVE4VM. These will be used to directly calculate the Poynting flux, to estimate the rate at which free energy is building up in the corona using a topological method, and to estimate the energy in the coronal magnetic field from the virial theorem. Finally, we will use nonlinear force-free extrapolations from the pipeline to estimate the coronal magnetic energy.

Each of these techniques is subject to a different set of assumptions, with different strengths and weakness, so one of the key issues in all of these approaches will be estimating how accurate the results are. In order to do this, we will compare the results of different methods of estimating the flow field close to the photosphere, and also compare the results of the different methods for estimating the free magnetic energy. In addition, we will estimate the uncertainties in the results of the methods.

Once we have the best available estimates of the flows and free energy flux, we will search for spatial and temporal associations between them. Specifically, we will look for whether upflows at different depths are consistently observed before or during the inflow of free energy, or whether predominantly horizontal flows are more closely linked to changes in free energy. These scenarios will be interpreted in the context of whether free energy enters the corona by the transport of nonpotential field from below the photosphere into the corona or if footpoint motions of a line-tied system energize an existing field. In addition, we will characterize how these associations evolve by examining active regions at different stages in their lives.

Finally, we will look for a temporal relationship between the injection of free energy and the occurrence of major flares. Is there a steady build-up of magnetic free energy, or are there episodes in which large amounts of energy are added comparatively quickly? We will attempt to characterize the distribution of time delays between free energy being introduced to the corona, and its release into the heliosphere.

Our investigation is likely to lead to new physical understanding of how the energy which powers solar energetic events is stored in the corona, and may lead to new tools for predicting the occurrence of such events.

David Hathaway/NASA Marshall Space Flight Center, NSSTC
Magnetic Flux Transport in the Sun's Surface Shear Layer

We will investigate the transport of magnetic flux elements embedded in the Sun's surface shear layer using data from HMI. The transport of magnetic flux by flows in the surface shear layer is crucial to the evolution of the Sun's global magnetic field which in turn serves as the inner boundary condition for space weather forecasting. The evolution of the global field is the source of changes involved in producing open field regions (with associated high-speed solar wind streams) and in triggering prominence eruptions and coronal mass ejections. The poleward transport of magnetic flux by meridional flow and diffusion is responsible for producing the polar fields that successfully forecast the amplitude of the following solar cycles.

Recent results indicate that magnetic flux transport is controlled by the supergranules. Supergranules have long been associated with the diffusive random walk of the magnetic elements. We now find that the differential rotation and meridional motion of the magnetic elements are produced in response to the differential rotation and meridional motion of the supergranules themselves - and that these motions are functions of the depth to which the supergranule cells extend. We also find that the motions of the magnetic elements show a dependence on the magnetic field strength - stronger elements appear to be rooted deeper and have motions that reflect those roots.

We will use tools developed for analyzing MDI data to explore these new aspects of flux transport processes with HMI data. These tools include correlation tracking of magnetic elements in the HMI magnetograms; correlation tracking of supergranules in HMI Dopplergrams; correlation tracking of granules in HMI intensity images; and direct Doppler measurements of the photospheric flows. This suite of tools provides detailed information on the flows in the surface shear layer as functions of latitude, time, and depth (size of convective features) along with direct measurements of the associated magnetic element motions. We will also produce and use simulations of the flows in the Sun's surface shear layer to aid in our interpretation of the results. Preliminary results suggest revolutionary changes to our models of the Sun's magnetic dynamo.

Ju Jing/New Jersey Institute of Technology
Forecasting of Solar Eruptive Events

The magnetic structure and its evolution in active regions are determining factors of solar eruptions such as flares and coronal mass ejections (CMEs). Using data from Solar Dynamic

Observatory (SDO) along with other space and ground-based observations, we propose to study the relation between evolution of solar magnetic fields and flares/CMEs, and furthermore establish a system of flare/CME prediction that involves two linked components:

(1) We will establish statistical correlation between magnetic fields measured in solar surface and productivity of flares/CMEs. In the past, we have extensively studied the following parameters: unsigned magnetic flux, magnetic gradient along the neutral line and magnetic energy dissipation. In the proposed study we will expanding the parameters to include (a) magnetic helicity injection (based on tracking the motion of surface magnetic fields) which takes the evolution of magnetic fields into consideration, (b) photospheric excess energy and (c) free magnetic energy which would be the most direct parameter describing the available energy in solar corona to power flares/CMEs. The first two parameters can be derived from photospheric vector magnetograms while the third one requires extrapolating three-dimensional (3-D) non-linear force-free (NLFF) fields using the observed vector magnetograms as the boundary condition. We are cautious that the proposed work will not largely rely on the NLFF extrapolation. The first two parameters can be studied with confidence. We will use SDO/AIA data for validation of NLFF extrapolation and the use of the third parameter. In addition to the correlation study, using the same data sets to follow the evolution of magnetic fields in flare productive regions will likely disclose the triggering mechanism of eruptive flares/CMEs, such as flux emergence, formation of magnetic channel and injection of helicity in the opposite sign.

(2) Using established correlation between magnetic parameters and the flare productivity, we will develop statistical and machine learning techniques to predict occurrence of solar flares. Based on preliminary results obtained so far, a promising tool that we will develop is a combination of ordinal logistical regression and Support Vector Machine (SVM) classification. Although our codes are developed for flare forecasting, they can be adapted for CME forecasting. We will explore the relation between magnetic helicity and CME occurrence.

Our proposed research aligns with the Living with a Star (LWS) strategic goals No.1 in that it helps to ``deliver the understanding and modeling required for useful prediction of the variable solar particulate and radiative environment''. The proposed research addresses the ``Science Analysis for the SDO'' component of the LWS Targeted Research and Technology Program (Tr&T), in particular, the ``Use of observations to predict future solar activity''. Our research will deliver new understanding of solar eruptions through the energy and helicity budgets of active regions, and will therefore contribute to predict flares/CMEs.

Rudolf Komm/Association of Universities for Research in Astronomy, Inc.
The Influence of Subsurface (and Surface) Dynamics on the Activity Cycle

We propose to study large-scale sub-surface flows of the Sun determined from SDO data on time scales of days to years in order to investigate the linkage of subsurface features with surface magnetic activity and to predict the properties of the new solar cycle. As shown by helioseismic studies, the zonal and the meridional flow in the upper convection zone vary with the solar cycle. The variation of these flows associated with the new cycle has been detected before any magnetic activity of cycle 24 was present on the surface of the sun.

The high-resolution observations available from SDO/HMI allow us to measure these large-scale flows at a great distance from disk center. Sub-surface flows derived from previous observations have been limited to about 60 degrees latitude, while they can be measured to at least 75 degrees using SDO, which is a substantial improvement. For the meridional flow, we will address the question whether there are multiple cells per hemisphere, which is of great importance for flux-transport dynamos. Second, we propose to derive the variation with depth in order to validate hints of multiple cells in depth. For the zonal flow and its cycle variation, we will focus on the poleward branch of this pattern in addition to the equatorward one. The cycle variations of the zonal and the meridional flow are usually studied separately. We propose to treat both flow components as part of a single system. How are these flow variations related to each other? Is their timing the same with regard to the activity cycle?

We plan to pursue the proposed goals with multiple techniques and data sets. Local and global helioseismic techniques will be applied to HMI Dopplergrams. The ring-diagram analysis will be used to derive subsurface flows in the upper shear layer of the convection zone, while the time-distance analysis will be used to derive the meridional flow in the deeper convection zone. Global helioseismology will be used to derive the zonal flow throughout the whole convection zone. Comparing zonal flows derived from global as well as local techniques allows us to cross-validate the results.

Another key benefit of using HMI observations is that it allows us to measure the near-surface flows with better spatial resolution, which is especially important near active regions. The patch size of the ring-diagram analysis can be a factor of three smaller than the one used with SoHO/MDI observations. Active regions are locations of converging or diverging horizontal flows depending on depth. How much do they contribute to the overall flow patterns? Do the large-scale flow patterns vary with longitude independent of active regions? As a side benefit, we will be able to determine the proper motions of active regions below the surface. It has been established that they rotate faster than the ambient quiet sun at the surface and in shallow sub-surface layers. How far does this extend with depth? Do they move toward or away from the mean latitude of activity? The answers promise to provide insights into the nature of the dynamo and its location (surface vs. base of convection zone).

In addition, we will apply cross-correlation and feature tracking techniques to HMI magnetograms to derive surface flows. This allows us to derive the flows in a consistent manner from the surface to the lower convection zone. The proposed investigation is timely, since the rising phase of the solar cycle is the epoch when large-scale flow patterns migrate with latitude and the flows show the most distinct variation with latitude.

Sylvain Korzennik/Smithsonian Institution
Global Helioseismology in the Era of SDO

With the launch of SDO, that carries HMI -the successor to MDI- we can anticipate being able to precisely characterize p-modes properties throughout solar cycle 24. Such characterization will lead to compelling inferences of the physical properties of the solar interior and their evolution with solar activity.

We propose to carry over to HMI observations our state-of-the-art fitting methodology developed and applied to the MDI observations. We will provide an alternative to the standard pipe-line, known to have produced biased estimates when used on MDI observations. This is a natural carry over of our current efforts funded by NASA grant NNX09AB15G (2008-2011: Time Series Mode Fitting: Improved Methodology Using Long and Very Long Time Series).

In collaboration with Dr. Eff-Darwich we will then exploit these results using our best inversion techniques and further study the internal solar rotation and it's evolution over cycle 24.

The work proposed here will directly contribute to our understanding of the Sun, a key element of NASA Strategic Goals and Research Objectives. More specifically it will help us answer NASA's science question "How and why does the Sun vary?". It will greatly improve the scientific return of NASA's SDO mission by implementing a state-of-the-art mode fitting analysis tool, and carry over from MDI what we have learned about mode characterization.

Derek Lamb/Southwest Research Institute
Near-Surface Flows, Magnetic Evolution, and the Formation of Coronal Bright Points

We propose to study the role that near-surface flows and the evolution of the photospheric magnetic field play in the formation and evolution of coronal bright points on the Sun. We will determine why some magnetic bipoles have bright points and others do not, identify relationships between the properties of bright points and magnetic and flow fields, and determine the difference in the magnetic configuration of bright points in different areas of the Sun. We will use the automated feature recognition algorithms in the SDO pipeline to identify bright points in AIA data, the magnetic features associated with those bright points, and surface and sub-surface flow maps from HMI. Using these high-level data products will allow us to focus our efforts on ensemble imaging and advanced statistical methods, conducting the first large-scale magnetic field and bright point evolution study from a publicly-available bright point database. To date, most studies of bright points have focused either on a small number of bright points and detailed analysis of their properties, or the cursory ensemble analysis of many bright points. We will greatly expand on these past studies by analyzing many bright points in many EUV passbands, developing statistical relationships between the bright points and the associated magnetic and flow fields. Because bright points are thought to be formed by magnetic reconnection, understanding bright point formation will aid in the understanding of reconnection in other heliophysical settings. As part of the proposed work, we will measure the properties and evolution of the solar magnetic field, linking the near-surface flows with magnetic fields in the solar atmosphere. Our effort is directly relevant to the SDO mission goals of determining how the Sun's magnetic field is structured and how stored magnetic energy is released. Our team includes experts in bright point tracking, magnetic feature tracking, and surface flow field measurements and interpretation, making our team ideal for addressing these science questions and their relationship to the LWS program goals.

Solar Energetic Particle Factors (FST)

Len Fisk/University of Michigan
Seed Particle Populations in the Solar Corona

A key factor that is expected to influence the highly variable intensity in the largest solar particle events, usually associated with CMEs, is the availability of a seed particle population. Most mechanisms that effectively accelerate high-energy particles have difficulty accelerating particles directly out of the thermal plasma, or at least are greatly enhanced in their efficiency and effectiveness if there is a suprathermal seed particle population present.

During the last decade, considerable progress has been made in understanding the origin of suprathermal particles in the solar wind. An efficient pump acceleration mechanism has been developed by Fisk & Gloeckler that can account for the observed spectral shape and the intensity of suprathermal tails in the solar wind.

The conditions required for the pump mechanism of Fisk & Gloeckler to operate are quite general and should also prevail in the solar corona and create seed particle populations. We propose to apply the pump mechanism of Fisk & Gloeckler to predict the seed particle populations in the solar corona, and to develop observational tests for the presence of these seed particles. We will develop a model for the acceleration of seed particles in the open corona, where the solar wind originates; this is the region that will be encountered by CME-driven shocks. We will develop a model for the acceleration and release of particles from coronal loops, in impulsive solar energetic particle events. We will also apply our growing knowledge of acceleration at shocks in the solar wind by the pump mechanism to explore the possibility that the pump mechanism could be the dominate acceleration mechanism in producing very energetic particles at CME-driven shocks in the corona.

As has been the case throughout the development of the theory for the acceleration of suprathermal particles in the solar wind, the development of the model for the acceleration of seed particles in the solar corona will only be successful if the assumptions and predictions of the model are continuously checked against observations. The proposed research thus lends itself well to a Focus Team effort, where our assumptions of prevalent conditions and our predictions can be checked against observations, and we have access to and can contribute to the development of other theories and models.

Natchimuthuk Gopalswamy/NASA Goddard Space Flight Center
Intensity Variation of Large Solar Energetic Particle Events: Source and Environmental Factors

The scientific objective of this proposal is to identify the key source and environmental properties that determine the efficiency of acceleration of solar energetic particles (SEPs). Coronal mass ejection (CME) kinematics and flare properties derived using the Solar and Heliospheric Observatory (SOHO) and GOES data will be considered. In particular, the acceleration profiles of CMEs will be considered, which determines the heliocentric distance at which the shock is formed or becomes supercritical. Another property of importance is the CME and flare recurrence rates in the source active regions, for a higher rate would imply more CME interaction. The presence of intervening coronal holes (known to affect the CME trajectory), preceding CMEs, and Alfven speed variability in the corona, are the primary environmental factors that will be considered. The effect of coronal holes on CMEs is the trajectory change of CMEs and shocks, which can make a well-connected eruption to a poorly connected eruption and vice versa.

This proposal is highly relevant to the scientific objectives of the Focused Topic: "1.2.1. (b) Factors that Control the Highly Variable Intensity and Evolution of Solar Particle Events" because it addresses the source and environmental factors that affect the SEP intensity. Specifically, the proposal is relevant to the first two types of investigation:

- Studies of the effect of preconditioning of the interplanetary medium on the characteristics of an ensuing SEP event (particularly multipoint studies), and

- Studies of the solar source and CME characteristics of large SEP events to identify key properties governing the efficiency of SEP acceleration.

The results of this investigation will be useful for other types of investigations pertaining to this FST. The extensive list developed as part of the proposed investigation will be made available to the modeling efforts and theoretical studies.

David Lario/Johns Hopkins University/Applied Physics Laboratory
Preconditioning of the Interplanetary Medium as Responsible for Large Intense SEP Events: Radial and Longitudinal Effects

We propose to study the factors that control both the highly variable intensity of solar energetic particle (SEP) events and the evolution of the SEP events as observed in the inner heliosphere. In particular, we will investigate both observationally and numerically how the preconditioning of the interplanetary (IP) medium determines the particle intensities observed at different locations in the inner heliosphere, paying special attention to those events that lead to the highest particle intensities and fluences observed throughout a solar cycle and those events that have been and will be observed from multiple heliospheric locations at radial distances R<=1 AU.

Solar Cycle 23 has offered us several SEP events with particle intensities above the previously determined streaming limit. Arguments to explain intensities exceeding the streaming limit invoke IP conditions that inhibit the amplification of waves able to scatter energetic particles and/or the presence of IP structures able to confine and/or mirror energetic particles. Therefore, the preconditioning of the IP medium clearly determines the intensity of these events.

Studies of the longitudinal and radial dependence of SEP intensities are required to correctly interpret multi-spacecraft observations. Solar Cycle 24 will provide us with SEP events observed by spacecraft widely separated in longitude at ~1 AU from the Sun (i.e. STEREO and near-Earth spacecraft) and by spacecraft located closer to the Sun (i.e., MESSENGER). The conditions of the IP medium sampled by SEPs arriving at each spacecraft may be different and hence that the characteristic of the same SEP event may differ from one spacecraft to another. The preconditioning of the IP medium leads to radial gradients that diverge from power laws usually inferred either from average statistical samples of events based on Helios and near-Earth observations or from uniform transport simulations.

We propose to combine multi-spacecraft observations with modeling based on two well-tested particle transport codes to (1) examine how the preconditioned IP medium determines the characteristics of the SEP events observed at different heliospheric locations; (2) model the effect that solar wind disturbances have on the transport of SEPs, and (3) determine the radial and longitudinal gradients of both SEP intensities and periods of elevated particle intensities at inner heliospheric locations where spacecraft such as Solar Orbiter and Solar Probe Plus will travel.

The proposed work includes (1) an observational element that involves focused analyses of plasma, magnetic field, and energetic particle data from spacecraft such as ACE, STEREO, GOES, IMP-8, Helios and MESSENGER; and (2) a theoretical element that involves modifying and expanding existing energetic particle transport models to include field configurations and transport conditions representative of those wherein SEP events develop.

The proposed research has a direct impact on the prediction of the highest SEP intensities that can be observed near-Earth and/or at any heliocentric distance <1 AU, with clear implications for particle instruments and spacecraft components on board spacecraft traveling close to the Sun. The proposed study will allow us to (1) understand the role that the preconditioning of the IP medium plays in the observation of SEP events at different heliospheric locations, and (2) modify the current models of SEP events to incorporate specific boundary and transport conditions.

Martin Lee/University of New Hampshire
An Analytical Investigation of Factors Controlling the Variability of Large Gradual SEP Events

The large gradual SEP ion events that present major challenges for the safety of astronauts and space assets near Earth orbit are thought to originate from acceleration of solar wind ions and remnant energetic ions at coronal/interplanetary shocks driven by coronal mass ejections. The process of shock acceleration, particularly in the limit of effective particle scattering that guarantees near isotropy of the particle distribution functions, is well understood in general terms and has been successful in accounting qualitatively for most of the energetic particle populations observed throughout the heliosphere. It is therefore puzzling that shock acceleration has had difficulties accounting for the large variability observed in the intensities, fluences, composition and general structure of gradual SEP events. Our contention is that the process of diffusive shock acceleration is extremely sensitive (in part due to nonlinear feedbacks) to the parameters governing the shock, the solar wind plasma environment, and the remnant energetic particle environment. The interplay between these various sensitivities leads to a broad distribution of possible energetic particle characteristics. We propose to investigate with analytical techniques the effects on SEP variability of (1) the injection rates of different solar wind ions into the process of diffusive shock acceleration; (2) the excitation of hydromagnetic waves upstream of the shock by the accelerating ions; (3) the role of magnetic field obliquity at the shock in injection, the rate of acceleration, and wave excitation; (4) the special case of nearly perpendicular shocks; (5) the energy spectrum and composition of the remnant energetic "seed" particle population in the vicinity of the shock; (6) the importance of the shock compression ratio; (7) the magnetic connection geometry of the shock front to the observer; and (8) the "streaming limit" caused by the escape of accelerating ions from the turbulent foreshock.

Richard Mewaldt/California Institute of Technology
Understanding the Variable Intensity and Evolution of CME-Shock-Accelerated Solar Energetic Particles

Comprehensive solar energetic particle (SEP) measurements of the last 10-15 years have clearly revealed that CME-driven shock-accelerated SEP events vary dramatically, not only in terms of their peak intensities and fluences, but also in their spectral shape, elemental composition, rise time and peak intensity times. Orders of magnitude variations have been observed in the proton intensities and Fe/O abundances of SEP events associated with CMEs having similar speeds. In order to improve the ability to accurately forecast intense SEP events and the onset of hazardous radiation conditions, it is critical to assess and understand the contributions to SEP variability made by factors such as CME speed, spatial extent, mass, and kinetic energy; pre-existing interplanetary conditions; shock strength, orientation, spatial extent and evolution; and the presence and characteristics of seed particle populations.

We propose to combine the high-sensitivity measurements made by SEP sensors on the ACE, STEREO, and GOES spacecraft with detailed remote sensing observations of CMEs using instruments on SOHO and STEREO to investigate and characterize the influence of various factors (such as those listed above) on the properties of SEP events. The study's multipoint focus, obtained by utilizing both STEREO and near-Earth spacecraft, will result in a better understanding of the longitudinal evolution of such factors as well as lead to more accurate determinations of CME characteristics. Using results from this study we will suggest improvements for current forecasting tools as well as identify possibly useful or critical measurements to be made in the future.

By working closely with other FST teams we expect to contribute significantly to the joint effort of understanding the causes of SEP variability and to the developing of algorithms and strategies that will allow space weather forecasters to evaluate the potential radiation hazards following the eruption of a CME using the first few hours of real-time CME data. We will provide the FST team with a number of data products related to SEP and CME properties, both as measured by a single spacecraft and, when possible, measured simultaneously at different longitudes relative to the solar source. We will work with the FST teams to adjust our data products in ways deemed most useful to the team effort. Additionally we will provide observational tests for any modeling studies performed under this FST solicitation and secondary measurements for other observational studies as appropriate.

We anticipate that our proposed work will benefit from expertise provided by other teams, including theoretical and modeling knowledge. Studies of solar wind turbulence and its variability, the solar context in which SEP events occur, and radio investigations of coronal and interplanetary shocks will compliment our own work. Such collaborations will augment the knowledge gained by the teams independently.

Within our team we have members of the SOHO, STEREO, ACE, and Wind instrument teams. This allows us complete access to the relevant data and brings to the investigation significant expertise and experience in combining data sets and intercalibrating measurements from different sensors and separate spacecraft.

Tycho von Rosenvinge/NASA Goddard Space Flight Center
Investigation of Solar Energetic Particle Event Properties

This investigation will focus on solar energetic particle (SEP) events that include protons with energies above 25 MeV, and the related solar phenomena. Around a thousand such events since 1967 have been studied and will form the basis of this investigation. Data from the HET instruments on STEREO A and B and SIS on ACE will be used to investigate future cycle 24 events at multiple spacecraft. We will also consider multi-point observations made in cycle 21 by the Helios 1 and 2 spacecraft at 0.3- 1 AU and by near-Earth spacecraft. Among the proposed topics are: the longitudinal variation of SEP events based on the location and properties of the related solar events, coronal mass ejections and interplanetary shocks; the effects of interplanetary structure, including interplanetary coronal mass ejections, on particle propagation in the inner heliosphere; and the possible role of preceding CMEs and seed populations in determining the intensity of SEP events. A foundation of the work will be our previous studies that have already addressed some of the topics of interest to the Focus Team.

Radiation Belts (FST)

Jay Albert/Air Force Research Laboratory
Including Quasilinear and Nonlinear Wave-Particle Interactions in Global Radiation Belt Models

We propose a 4-year project in which a new methodology will be used to include nonlinear wave-particle interactions in kinetic simulations of radiation belt electrons, based on a survey of large-amplitude chorus wave data that we will perform using THEMIS satellite data.

The specific scientific problem addressed in this proposal is modeling the large-scale dynamics of the outer electron radiation belt, coupled to a large-scale kinetic ring current code. The effects of quasi-linear and nonlinear wave-particle interactions are described, using a newly developed technique, as diffusion and advection coefficients respectively, in both energy and pitch angle. The importance of this work lies in the fact that properly treating wave-particle interactions is crucial to understanding, modeling, and predicting the behavior of this energetic, geomagnetically trapped population, and the usual quasi-linear treatment alone cannot capture the specific effects that nonlinear interactions are known to cause. It is necessary to model the ring current accurately for two reasons: it provides the "seed" electrons which become energized to radiation belt energies, and it generates the chorus waves responsible for much of the energization.

The work in this proposal is directly relevant to the scientific objectives of the Focused Science Topic "Incorporating Plasma Waves in Models of the Radiation Belts and Ring Current," which calls for "the development of improved codes to treat the dynamical evolution of the ring current and radiation belt populations, including both the generation and the effects of plasma waves." The goal of modeling radiation belt dynamics is a well-established NASA objective and is articulated in a number of other documents, including the LWS Science Architecture Team report to SECAS (which specifically aims to "understand the processes responsible for the acceleration, loss, and transport of radiation belt electrons and ions responsible for radiation dose and bulk charging effects," with a 5 - 10 year goal of "constructing models describing the local and regional acceleration processes"), and the 2002 NRC Decadal Survey Report "The Sun to the Earth and Beyond" (Challenge 3, and resulting recommendation: "Understanding the energization of the radiation belts"). It is also one of the primary objectives of the upcoming

NASA Radiation Belt Storm Probes (RBSP) mission ("improve and validate physics-based data assimilation and specification models for the Earth's radiation belts").

The approach used in this project avoids the inherent limitations of conventional quasi-linear diffusion, and exploits recently-developed analytical estimates of nonlinear particle behavior to formulate diffusion and advection terms in energy and equatorial pitch angle, which will be directly incorporated in the ring current/radiation belt kinetic formalism of the Ring current-Atmosphere interactions Model (RAM) code. The expressions for the transport coefficients will be evaluated using recent, high time-resolution wave data from the THEMIS spacecraft, and project closure will be obtained by comparing the results of our simulations to actual storms, which so far have only been studied using quasi-linear diffusion.

S. Gary/Los Alamos National Laboratory
Ring Current Instabilities and Their Magnetospheric Consequences

Our proposed research will use satellite data analysis, a comprehensive model of the inner magnetosphere, linear kinetic dispersion theory, hybrid and particle-in-cell (PIC) simulations, and test-particle computations to carry out an integrated study of how kinetic instabilities in the magnetospheric ring current arise, propagate, and scatter both ions and fast electrons. We intend to address two distinct kinetic modes: the Alfven-cyclotron instability which leads to EMIC waves, and the proton Bernstein mode instability which generates magnetosonic waves. We will use geosynchronous observations from Los alamos plasma instruments and the RAM-SCB self-consistent inner magnetospheric model to gain insight into the ion velocity distributions which drive such waves; using such distributions we will use hybrid and PIC codes to generate enhanced field fluctuations and determine how ions are scattered, and test-particle computations to calculate how such fields pitch-angle scatter and accelerate fast electrons. These computations will yield particle transport coefficients which will be fed back into the RAM-SCB code, thereby improving the representations of global transport by that code. This research would make fundamental scientific contributions to the LWS Focused Science Team "Incorporating Plasma Waves in Models of the Radiation Belts and Ring Current."

Richard Thorne/University of California, Los Angeles
Modeling the Global Distribution of Chorus, Plasmaspheric Hiss, and Equatorial Magnetosonic Waves, and their Effect on Radiation Belt Dynamics

In the collision-less magnetosphere, the dynamic variability of energetic electrons in the radiation belts is largely controlled by interactions with plasma waves. Consequently accurate modeling of radiation belt variability, in response to change in the solar wind or geomagnetic activity, requires the development of global models for important magnetospheric waves. We therefore propose to develop improved models for the global distribution and spectral properties of three important waves (Chorus, Plasmaspheric Hiss, and Equatorial Magnetosonic Waves) using data from THEMIS, DE1 and RBSP once it becomes available. We will also attempt to identify the particle distributions responsible for the wave excitation. Chorus is an electromagnetic emission produced in the low-density region outside the plasmapause, which can cause both precipitation loss and local acceleration of energetic electrons. Detailed modeling of nightside chorus has already been obtained from CRRES data, but the satellite coverage was extremely restricted on the dayside, and many important properties of dayside chorus remain poorly established. The five THEMIS spacecraft have excellent spatial coverage for over 3 years over the entire chorus source region. Specifically this data will be used to develop an improved model for dayside chorus, and identify the mechanism for chorus excitation. We will also model the properties of Plasmaspheric Hiss, which provides the dominant loss process for energetic electrons during quiet periods in the extended storm recovery phase, and test the proposed origin of hiss from Chorus. Equatorial Magnetosonic Waves may contribute to local electron acceleration, but our current understanding of the wave properties is limited to a very restricted range of L-shells (Cluster) or wave frequencies (CRRES). The THEMIS data will allow us to develop a comprehensive global model for the power spectral intensity of this important emission and it's relationship to ion ring distributions. The improved wave models will be used to evaluate quasi-linear diffusion rates, which can be incorporated into dynamic models of the radiation belts. The proposed research addresses the NASA Strategic Goal 3.2 listed in the 2007-2016 Science Plan: Understand the Sun and its effects on Earth and the solar system. It also addresses several key scientific problems identified in the 2009-2030 Heliophysics Roadmap:

1) Understand the fundamental physical processes of the space environment from the Sun to Earth.

2) Understand the plasma processes that accelerate and transport particles.

3) Understand changes in the Earth's magnetosphere, ionosphere, and upper atmosphere to enable specification, prediction, and mitigation of their effects.

The proposed topics for study are directly relevant to the current NASA missions on the Time History of Events and Macroscopic Interactions during Substorms (THEMIS) and the Radiation Belt Storm Probes (RBSP) of the Living With a Star program.

Aleksandr Ukhorskiy/Johns Hopkins University/Applied Physics Laboratory
Ring Current Control of the Outer Radiation Belt: Local Wave-Particle Interactions and Large-Scale Magnetopause Losses

The goal of this project is to advance our quantitative understanding of storm-time variability of energetic electron fluxes in the outer electron belt by developing an improved empirical model of EMIC wave properties, incorporating it into a global 3D test-particle model of the outer belt and conducting detailed numerical simulations of storm-time dropout events in support of the RBSP and BARREL missions. We address the following science questions: (1) How do spatial and spectral properties of storm-time EMIC waves vary as function of geomagnetic activity? (2) What are the relative roles of magnetopause losses and quasi-linear resonant scattering by EMIC waves in causing permanent losses of the outer belt electrons? (3) What are a relative roles of adiabatic and non-adiabatic processes in producing dropouts of the outer belt electron fluxes?

The proposed research is highly relevant to the 2010 TR&T FST 1.2.1(d), which identifies "...the spatial distribution and properties of EMIC waves..." to be the first of the "Major uncertainties..." limiting our understanding of radiation belts and explicitly calls for "... incorporating improved models of plasma waves into our large-scale plasma and field models."

To quantify EMIC wave properties, we use high-resolution magnetic field measurements from 7 NASA missions: DE 1, AMPTE/CCE, CRRES, Polar, Cluster, THEMIS, and RBSP, which provide extensive coverage of the inner magnetosphere for four different solar cycles. Combining data from the 15 spacecraft of these missions, using our existing analysis tools, will result in a more than factor of 6 increase in statistics of storm-time EMIC waves compared to previous analysis. This will enable a detailed parameterization of wave properties including characterization as a function of storm phases.

Our global test-particle model of the outer electron belt (RB-REALM) provides a detailed description of three-dimensional particle motion including rapid magnetopause losses produced by large-scale reconfiguration of the magnetic field due to storm-time ring current and magnetopause compression, and non-diffusive radial transport due to ULF field oscillations. The model also incorporates local energization and pitch-angle scattering due to resonant wave-particle interaction, which is described as a Monte Carlo process based on analytical formulae for the pitch-angle and energy diffusion coefficients in a multi-component plasma. It will include the newly developed empirical model of EMIC waves described above, and existing parameterizations of whistler chorus and hiss.

To address science questions, two main modeling campaigns will be carried out. We first select a set of 15 minor, moderate, and large magnetic storms. For each storm, we use our RB-REALM test-particle model to compute the relative roles of the atmospheric losses due to rapid pitch-angle scattering by EMIC waves and magnetopause escape due to storm-time ring current and increases in the solar wind dynamic pressure. These simulations will quantify the balance of magnetopause and atmospheric losses as function of electron initial location, pitch angle, and energy for different phases of the storm, and will also reveal how losses are affected by the spatial extent of waves producing local acceleration and pitch-angle scattering.

The second part of the investigation provides direct support to the RBSP and BARREL missions. We will use pre-storm fluxes measured at RBSP as initial conditions and simulate storm-time evolution of the belt with RB-REALM. We will adjust model free parameters to match electron losses measured by BARREL. We will compare simulation results and observations at RBSP to determine: (a) what fraction of the observed dropout is produced by permanent losses versus adiabatic deenergization; (b) what are the relative roles of magnetopause escape and pitch-angle scattering by EMIC waves in producing radiation belt dropouts observed by RBSP.

Jichun Zhang/University of New Hampshire
EMIC Waves in the Inner Magnetosphere: Spatial Distribution and Properties

This proposal is in response to the Living With a Star (LWS) Targeted Research and Technology (TR&T) Solicitation of the National Aeronautics and Space Administration (NASA) under the program announcement/solicitation number: NNH10ZDA001N-LWSTRT.

A better understanding of electromagnetic ion cyclotron (EMIC) waves in the inner magnetosphere is critical for understanding and predicting changes in the near-Earth environment, e.g., the scattering loss of relativistic electrons in the radiation belts as well as energetic ions in the ring current. However, due to the lack of sufficient in situ observations and the incomplete picture of wave growth and effects in the magnetosphere, the spatial distribution and properties of EMIC waves are still poorly understood. The Cluster observations can change this. Taking advantage of the abundant in situ measurements of magnetic field and plasma during the Cluster mission (2001 -- current), we propose an extensive data analysis study to investigate EMIC waves and associated plasma properties in the inner magnetosphere. Besides the EMIC waves themselves, three crucial EMIC wave-associated plasma properties will be studied: 1) ion heating, which indicates the effect of the EMIC waves, 2) hot anisotropic H+, which is the free energy provider of the EMIC waves and serves as a necessary condition for the EMIC wave growth, and 3) cold dense plasma, which plays a catalytic role in the wave generation. In the proposed work, the fundamental science question that will be addressed is:

How do the distributions of hot anisotropic H+ and cold dense plasma in the inner magnetosphere control the spatial distribution and properties of EMIC waves, and the resulting ion heating?

To answer this question, we will first obtain a list of all Cluster-observed EMIC wave events and their properties in the inner magnetosphere, then collect lists of wave-associated plasma properties, and next examine the occurrence distributions of all the types of events. In this way, we will be able to identify the plasma conditions that lead to the excitation of EMIC waves, and when and where these conditions are likely to occur in the inner magnetosphere.

The proposed study is expected to improve our present understanding of the spatial distribution and properties of EMIC waves and their interactions with particles. The expected outcome of the proposed research is a detailed occurrence distribution map showing where EMIC waves are likely to be observed over the Cluster orbit in the inner magnetosphere, and what the plasma conditions are when they are observed. The project team, consisting of three scientists from the University of New Hampshire, has the necessary data-analysis resources and experience needed for the successful pursuit of the proposed study.

The outcome of this project is expected to be of high value to NASA interests and programs. In particular, the proposed research is directly relevant to the Focused Science Topics (d) of the 2010 NASA LWS TR&T program: "Incorporating Plasma Waves in Models of the Radiation Belts and Ring Current". By collaborating with other members in the Focused Science Topic Team, we will perform both case and statistical studies of the Cluster-observed events. The key wave and plasma parameters of the EMIC waves will also be used as both input and output to test existing and updated wave theories and models. The results are crucial to the success of the Focused Science Topic Team.

Sun Climate

Scott England/University of California, Berkeley
Impact of the 11 Year Solar Cycle on the Gravity Wave Driven Circulation

Understanding the coupling of solar-variability to climate is a challenge that must be met to gauge the response of the climate to both natural and anthropogenic forcing. It is a complex problem and we do not yet understand several of the critical physical and chemical pathways within the atmosphere through which this coupling may be channeled. These pathways can involve interactions across multiple altitude regions of the atmosphere. Circulation driven by gravity waves plays an important role in coupling the middle atmosphere to the upper atmosphere and is likely sensitive to solar-cycle variations, thus playing an important role in solar-climate coupling. Here we detail a three-year modeling study to investigate the effect of the solar-cycle on gravity waves and the mesospheric circulation using the Whole Atmosphere Community Climate Model (WACCM). We have assembled a team with the experience in modeling gravity waves, atmospheric circulation and extensive experience of using WACCM. Preliminary model results offer encouragement that significant progress in our understanding of this can be made using a comprehensive atmospheric model and WACCM is a prime candidate. This model includes all of the components essential to study these effects meaningfully because it simulates the impact of the solar-cycle on both stratospheric O3 and planetary wave propagation, and also simulates gravity wave effects throughout the mesosphere. We will identify which regions respond most strongly to the solar input, how these impacts vary with altitude and period of the waves and how these effects vary with season. We will identify the relationship between changes in gravity wave activity and planetary wave activity at lower altitudes. This study will lay a crucial framework for further investigations by identifying which observational parameters associated with gravity wave activity offer the most robust constraints on the simulation of solar-cycle effects on gravity wave activity. This work is essential for understanding both how the whole wave-driven residual circulation in the middle atmosphere responds to the solar cycle and how this may influence other processes such as the transport of NOx to lower altitudes.

Charles Jackman/NASA Goddard Space Flight Center
Atmospheric Effects of Solar Proton Events and Galactic Cosmic Rays and Galactic Cosmic Rays

The proposed work will extend studies begun three years ago under the LWS investigation entitled "Long-term Atmospheric Effects of Solar Proton Events and their Contribution to the Polar Solar Cycle Variations." The proposed work will provide further quantification on solar proton events (SPEs) and their atmospheric influence. The work will also quantify the chemical influence on the atmosphere from galactic cosmic rays (GCRs). The objectives of this effort will be to answer the following questions:

1) How do SPE effects on middle atmospheric ozone depend on high-latitude interannual dynamical variability?

2) How does the upper mesosphere respond to SPE-induced changes in the middle atmosphere, including the effect on polar mesospheric clouds?

3) How do GCRs influence the chemical composition of the atmosphere over decadal time-scales?

We will use a global model, the NCAR Whole Atmosphere Community Climate Model (WACCM), as well as satellite measurements to address these questions. WACCM is a global chemistry climate model, whose domain extends from the ground to about 140 km. WACCM includes the chemistry and physics of the troposphere, stratosphere, mesosphere, and lower thermosphere and incorporates a module for the computation of polar mesospheric clouds. WACCM can also be utilized in a new 'Specified Dynamics' version (SD-WACCM), which is driven by assimilated winds and temperatures, to more closely reproduce actual dynamical conditions for particular time periods. This will enable us to better separate the impacts of SPEs and GCRs from other atmospheric variations for specific time periods.

Previously computed daily average ion pair production rates for SPEs, which were calculated from proton flux data, will be used in studies addressing the first two questions. The third question will be addressed with ionization rates for GCRs from the NASA Langley Nowcast of Atmospheric Ionizing Radiation for Aviation Safety (NAIRAS) investigation.

The proposed work is directly relevant to the Living With a Star Sun Climate Theme. It will improve the understanding of how SPEs and GCRs impact the middle atmosphere, whose coupling with the troposphere can influence the climate system.

Fabrizio Sassi/Naval Research Laboratory
Impacts of Stratospheric Dynamics on Atmospheric Behavior from the Ground to Space under Solar Minimum and Solar Maximum Conditions

Dynamical response to solar radiative forcing is a crucial and poorly understood mechanisms. We propose to study the impacts of large dynamical events on both the troposphere and the thermosphere during different phases of the solar cycle. The scientific objectives of this proposed research are intimately connected with the integrated response of the whole atmosphere to solar variability. In particular we compute and analyze the solar-induced variations of the following: (1) the penetration into the thermosphere of wave dynamics associated with disturbed events in the stratosphere; and (2) the influence of the stratosphere on the tropospheric climate during different phases of the solar cycle. In addition, a third objective of our research plan is to provide a fiducial simulation of the whole atmosphere up to 500 km which will allow the community to investigate in detail the sources and mechanisms that generate seasonal variations in the thermosphere (annual and semiannual variations). For this purpose, we will exercise the newly developed and updated extension of the Whole Atmosphere Community Climate Model (WACCM-X) to 500 km which provides the most comprehensive ground-to-thermosphere modeling capacity to date. To specify the stratospheric dynamical events as realistically as possible, the meteorology of the atmosphere below 90 km is constrained to the observed state using data assimilation products from the Naval Research Laboratory Atmospheric Variational Data Assimilation System (NAVDAS) or from the NASA Modern Era Retrospect Analysis for Research and Applications (MERRA). The quality of the model simulations (thus constrained) in the thermosphere will be assessed by comparing to the globally averaged mass density dataset developed at Naval Research Laboratory that covers the last 40 years and, where available, to composition, temperature and density profiles from the Global Ultraviolet Imager (GUVI) onboard of the NASA/TIMED satellite.

William Swartz/Johns Hopkins University/Applied Physics Laboratory
The Impact of Spectral Solar Irradiance Variations on the Atmosphere and Climate: Model Simulations and Observations

We propose a coordinated analysis of atmospheric observations and targeted simulations obtained from a state-of-the-art atmospheric chemistry and climate model in order to quantify the impact of solar output variations on global climate over a wide range of timescales, including both direct and indirect effects of the solar cycle and the spectral dependence of the solar irradiance. This proposed work addresses several objectives of the Living With a Star Targeted Research and Technology program. Two spectral solar irradiance (SSI) datasets will be used in this investigation: (1) a reconstruction (Lean et al.) based on satellite observations, long-term proxies of solar activity, and a solar model, and (2) SSI from the partial solar cycle observed by the SOlar Radiation & Climate Experiment (SORCE) inferred for a complete solar cycle. These SSI datasets are quite different in the amplitude and phase of their spectral dependence. Recent studies based on these datasets show that the Lean and SORCE SSI can produce very different atmospheric and climate responses in models, and initial comparisons with observations of stratospheric temperature and ozone appear more consistent with the SORCE SSI. There are inconsistencies between the recent studies in the patterns of atmospheric response, however. What other fingerprints of solar cycle response can be confirmed by observations in order to clarify our understanding of this problem? What are the implications for solar cycle sensitivities under different atmospheric conditions, such as pre-industrial times?

Using the Goddard Earth Observing System Chemistry-Climate Model (GEOS CCM), with fully coupled radiation-dynamics-chemistry, we will investigate the atmospheric response to the 11-year solar cycle as represented by the Lean and SORCE SSI. We will: (1) Investigate the mechanism of the 11-year solar cycle on direct atmospheric heating and photolysis. (2) Simulate stratospheric responses to the Lean and SORCE SSI datasets and compare the model output with satellite and ground-based observations of ozone, temperature, and other constituents to determine which view of the SSI is more consistent with observations. (3) Extend the investigation into the troposphere and compare model output with observations for evidence of the solar cycle and its mechanism(s) of impact. (4) Simulate the sensitivity of the atmospheric response to solar cycle variations under atmospheric conditions representative of earlier eras (e.g., pre-CFCs, pre-industrial). This sensitivity study will allow us to infer historical solar cycle effects, such as during the Maunder Minimum.

Guoyong Wen/Morgan State University
Investigation of Climate Response to Solar Spectral Variability on Decadal, Centennial, and Millennium Time Scales

This investigation is in the category of the Sun-Climate Theme of the Living With a Star (LWS) Program. We propose to evaluate the spectral details necessary for proper treatment of the radiative and photochemical response to solar spectral variability in climate models, and to investigate climate responses to solar spectral variability for a range of time scales ranging from decadal to centennial to millennial time scales. We will apply the existing coupled ocean-atmosphere radiative convective model (RCM) and GISS GCM Model 3 (GCMAM) to different spectral solar forcing scenarios on decadal, centennial, and millennium time scales, focusing on understanding the pathways of solar impacts from upper atmosphere through the troposphere and into the land and oceans. By analyzing the GCM simulation results we explore and test recent proposed amplification mechanisms for solar impacts on climate.

Dong Wu/Jet Propulsion Laboratory
Observational Study of Solar Variability Impacts on the Troposphere, Stratosphere and Mesosphere

In response to the LWS Program call on the Sun-Climate Theme, we propose to characterize and investigate impacts of solar variability on short (e.g., 27 days) and long (11 years) time scales with new observations from advanced satellite sensors. We analyze the high-quality solar spectral data acquired by NASA SORCE (Solar Radiation and Climate Experiment) SIM (Spectral Irradiance Monitor) and TIMED (Thermosphere Ionosphere Mesosphere Energetics and Dynamics), as well as global atmospheric data from MLS (Microwave Limb Sounder), MISR (Multiangle Imaging SpectroRadiometer), ISCCP (International Satellite Cloud Climatology Project), and FTUVS (Fourier Transform Ultraviolet Spectrometer), together with long reanalysis records, to derive, characterize and better understand atmospheric and cloud responses to the solar variability at different spectral wavelengths. As indicated in the recent SORCE SIM observations, the increasing of solar irradiance at near infrared spectral bands during the TSI (total solar irradiance) declining phase of solar cycle 23. Impacts of the spectral solar irradiance variations become even more complicated than as originally thought, and atmospheric responses to this forcing need to be investigated as a whole. We propose to explore atmospheric photochemical, radiative, and dynamical processes, and their responses to each spectral region of the solar irradiance variances over the solar cycle, and focus on coupling mechanisms that may act to amplify the solar signals in Earth's climate system. We will explore the solar-cycle responses in the GISS AR5 version of ModelE GCM, which are simulated from new observed spectral solar irradiance variations, to better understand how the coupled mechanisms work by comparing the solar signals from the observations with those from the model simulations.

Fangqun Yu/University at Albany
Climate Impacts of Solar Variation-Induced Changes in Tropospheric Particle Formation, CCN, and Cloud Properties

Sun supplies most of the energy for the Earth's atmospheric and climate system. The meas-ured 0.1% level of the long-term total solar irradiance (TSI) variations (i.e., solar direct effect on climate change) is generally considered to be too small to account for the apparent correlation between observed historical solar variations and climate changes, which may imply an indirect solar forcing unaccounted for. In order to clearly defined the consequences of human activity on climate and accurately predict the climate change on decadal and longer time scales, possible indirect impacts of solar activity on Earth’s climate have to be identified, formulated, and in-cluded in the climate models. The main objective of this project is to investigate solar indirect climate impacts via solar variations-induced changes in tropospheric particle formation, CCN, and cloud properties.

There are two main research objectives of this proposal. The first one is to study impact of solar variations (both TSI and cosmic ray flux) on global new particle formation and cloud con-densation nuclei (CCN) concentration, using a recently developed global size-resolved aerosol model (GEOS-Chem +APM). It is well known that particle nucleation rates are sensitive to T, RH, and precursor gas concentration ([H2SO4]). The ion-mediated nucleation (IMN) rates also depend on ionization rates. Our recent global modeling study indicates that IMN may contribute significantly to the number abundance of particles in most part of troposphere. We propose to study the possible response of CCN concentrations to solar variations via nucleation and growth of secondary particles. Our initial study indicates that solar variations can lead to CCN change at a magnitude that can cause important climate forcing. Our second research objective is to incor-porate this solar indirect radiative forcing associated with CCN change into the recently released Community Earth System Model (CESM). CESM is a coupled climate model composed of four separate models simultaneously simulating the earth's atmosphere, ocean, land surface and sea-ice, and one central coupler component. The CESM allows researchers to conduct fundamental research into the earth's past, present and future climate states. By including a physics-based me-chanism of solar variation-induced change of CCN concentrations in the CESM, we will study the magnitude of this solar indirect radiative forcing under different atmospheric conditions (pre-industrial, present, and future emission and climate).

This project is highly relevant to the strategic objective of the Sun-Climate Theme of the NASA LWS, which is to “deliver the understanding of how and to what degree variations in the solar radiative and particulate output contribute to changes in global and regional climate over a wide range of time scales.”

Solar Jets (FST)

Bart De Pontieu/Lockheed Martin Corporation
Formation and Impact of Type II Spicules

We propose to study the formation and impact on the solar atmosphere of so-called type II spicules using a broad range of observations that cover all temperatures between photosphere and corona, in combination with state-of-the-art radiative 3D MHD numerical simulations of a domain encompassing the convection zone through the photosphere, chromosphere into the corona. Type II spicules are the most ubiquitous jets in the solar atmosphere with the largest potential for playing a significant role in the mass and energy balance of the corona and solar wind. We will build on our recent discovery of this novel, more violent type of spicules that appear to be associated with rapid upflows with velocities of order 50-100 km/s in the lower solar atmosphere including the transition region and corona. These upflows may be the "missing link" at the heart of the solar plasma energization quandary, and are specifically called out in the description of Focused Science Topic (c) of the TR&T Announcement of Opportunity (AO). We will investigate what role the magnetic field and photospheric dynamics play in their formation, and whether these chromospheric jets play a major role in providing the corona and solar wind with hot plasma.

We will use an arsenal of coordinated observations, covering the temperatures between photosphere and corona - including data from Hinode/SOT-EIS-XRT, SDO, Swedish Solar Telescope, and the Interface Region Imaging Spectrograph (IRIS, to be launched in December 2012). We will exploit our discovery of the disk counterpart of type II spicules (so-called rapid-blueshifted events, or RBEs) to avoid the enormous line-of-sight superposition that has plagued spicule studies at the limb for many decades. We will use already developed automated detection software to determine and develop a database of detailed properties of thousands of these jets for a variety of solar targets. We will combine these measurements with magnetic field measurements in both the photosphere and chromosphere to investigate the role of reconnection and flux emergence in the formation mechanism(s) of these jets. To gauge the impact of chromospheric jets on the corona and solar wind, we will study the association of these jets with brightenings in TR/coronal images of the footpoints of coronal loops, and with high velocity blue-wing asymmetries of TR/coronal spectral line profiles at the loop footpoints. We will exploit the presence of a weak, but significant, coronal response to chromospheric jets to provide an accurate estimate of the mass and energy flux carried into the corona by heating events associated with spicules. The observations will be rigorously compared with synthetic observables of jets from radiative 3D MHD numerical simulations (from our no-cost collaborators in Oslo) that include seed magnetic fields derived from our photospheric observations. The combined results of these investigations will help reveal how these jets form and whether they play a significant role in the heating of plasma to coronal temperatures.

The proposed research is highly relevant to the scientific goals of the Focused Science Topic (c) on Jets in the Solar Atmosphere and will be a strong contribution to the Focus Team's efforts. Our research will directly involve three of the four different types of investigations listed in the AO. We will "characterize the properties of chromospheric jets", "study the statistics of the jets and their role in providing mass and energy to the corona and solar wind", and "develop physical models of jet acceleration". We will directly advance "our understanding of the origins, structure and dynamics of chromospheric jets", and the combination of observations and modeling will lead to "models for the UV-X-ray emission from jets and their contribution to the mass and energy flux of closed and open fields in the corona and solar wind". All of these are direct measures of success outlined in the AO.

Edward DeLuca/Smithsonian Institution
Dynamics and Physical Properties of Coronal Jets and Plumes

Coronal jets and plumes are ubiquitous examples of reconnection in the solar corona as well as possible important contributors to the solar wind. The goal of this proposal is to provide the observational support and data analysis tools needed to address the following outstanding questions with respect to coronal jets and plumes.

(1) What is the connection between coronal jets and plumes? How do jets and bright points (BP) at the plume base influence its life cycle, evolution, and variability? Using focused dynamics studies concentrating on single events of simultaneous jets and plumes, including but not limited to, light curves and the evolution of differential emission measures, we will address the jet/plume relationship.

(2)What is the contribution of jets and plumes to the solar wind in terms of mass, energy and heat input? Are jets and plumes the main mechanism for mass and energy input in open flux regions? These are addressed by statistical studies of the physical properties of jets and plumes, such as velocities, sizes, lifetimes and column densities based on SDO, Hinode, and STEREO data.

(3) What are the necessary parameters of jets and plumes that are needed for modeling of these phenomena? This issue will be addressed by focused topological studies of individual jets and plumes locations of energy release, energy distribution and propagation in jets and subsequent propagation of jets and plumes in AIA "coronograph" movies.

Judy Karpen/NASA Goddard Space Flight Center
Modeling Reconnection-Driven Jets and their Coronal/Heliospheric Consequences

We propose to model reconnection-driven solar jets and their impact on the corona and heliosphere. A combination of analytic theory and 3D numerical modeling, guided by recent observations from Hinode, STEREO, and SDO, will be used to determine the energetic and dynamic consequences of reconnection in an embedded-bipole magnetic configuration. We will test the hypothesis that reconnection-driven jets can contribute significant mass and wave flux to the corona and solar wind, as well as heat coronal loops. We will work closely with the team to determine the most appropriate range of bipole scales, initial null heights, and combination of topologies (open-closed vs closed-closed) for our simulations, and to define observable signatures that can serve as definite tests of our models.

Alphonse Sterling/NASA Marshall Space Flight Center, NSSTC
Investigation of the Production and Evolution of Chromospheric, EUV, and X-Ray Jets using Observations from Hinode, STEREO, and SDO

We propose a four-year program in response to the Living With a Star (LWS) Targeted Research and Technology (TR&T) solicitation, a Targeted Investigation under Focused Science Topic 1.2.1.(c): “Jets in the Solar Atmosphere and their Effects in the Heliosphere.” We will study solar jets, using data primarily from the Hinode, SDO, and STEREO satellites. The solar jets include chromospheric spicules, especially type II spicules; EUV (transition region) jets; and X-ray (coronal) jets. We will use data from all three Hinode instruments: SOT, EIS, and XRT; from AIA and HMI on SDO, from SECCHI on STEREO; and we will also use data from other sources, such as SOHO/LASCO. Our study will focus on four main study topics: (1) the origin and evolution of spicules on and just inside the limb, using SOT/Ca ii data and image processing techniques; (2) the location of polar spicules (and other jets when possible)

relative to the magnetic network, using mainly SOT/Ca ii data with SOT spectropolarimeter (SP) and HMI vector magnetograms; (3) the connection between jets and features at chromospheric, EUV, and soft X-ray (SXR) wavelengths; and (4) the detailed nature of the X-ray jet mechanism and the implications for the same mechanism occurring on the size scale of chromospheric spicules, and also the connection between X-ray jets (and other jets) and coronal outflows into the heliosphere visible in coronagraph images. Most of our projects can be completed with already-identified or readily-available data sets. New observations from Hinode may be requested but are not required for the success of the project. Both the P.I. and Co-I have extensive experience with the type of data sets to be used, and a worker at the postdoc level will be supported.

This work will address the Targeted Investigation objectives by increasing our understanding of jet origins, development, manifestations in different wavelength regimes, and connections to the coronal outflows at the base of the heliosphere. This work is relevant to NASA in that it will result in scientific output from several NASA-related satellites, and in that--in studying solar jets--this work will yield new insights into a likely major source of the solar wind, which is an important component of ``space weather."

Haimin Wang/New Jersey Institute of Technology
High-Spatial and High-Spectral Resolution Study of Small-Scale Jets

Small-scale dynamics in the solar chromosphere are believed to play an important role in the energy balance and structuring of the corona as well as the mass transport in the solar wind. In particular, jets, in a variety of forms, may be responsible for providing the upward flux of energy and momentum necessary for the observed heating and flows. The recently discovered type II spicules are of special importance due to their high speed, rapid heating, and large vertical extent. The jet-like structures may also have their on-disk counterpart in the large upward velocities identified in the blue wings of chromospheric spectra, termed Halpha upflow events (UFE) in earlier publications by the PI, or by more recent authors Rapid Blueshifted Excursions (RBE). These small-scale jets share some common properties with the microflare associated jets in active regions, the most prominent of which has the magnetic reconnection as the driving mechanism.

It is now possible to obtain the unprecedented data from Hinode and the Solar Dynamic Observatory (SDO) simultaneously with high-resolution imaging spectroscopic data from medium to large-aperture ground-based telescopes equipped with adaptive optics. This makes it an opportune moment to quantitatively analyze small-scale chromospheric and coronal jets along with the corresponding magnetic field evolution in the photosphere. Imaging spectropolarimetric observations are immediately available from NSO/SP using the Interferometric BIdimensional Spectrometer (IBIS). Within the time frame between one and two years, the New Solar Telescope (NST) at Big Bear and the GREGOR solar telescope at Tenerife will finish their commissioning and allow us to study, for the first time, physical processes at a spatial resolution below 0.1 arcsec. The scientific objectives of this study include:

1. Through imaging spectroscopy with IBIS at NSO/SP (and NST and the GREGOR Fabry-Perot Interferometer in later years), we will study the properties such as velocity, temperature, statistical spatial distribution, and occurrence frequency of small-scale ejections and associated heating. This will be enhanced by high spectral resolution spectrograph observations with GERMAN VTT. The response of the corona will be investigated using Hinode EUV Imaging Spectrometer (EIS) and SDO Atmospheric Imaging Assembly (AIA) data.

2. Using high-resolution, high-cadence magnetograms (initially from IBIS, the Hinode SOT/SP, and SDO/HMI, and then subsequently from BBSO/NST and GREGOR), the photospheric magnetic structures associated with jets will be investigated. In particular, the chromospheric response to magnetic reconnection on small scales will be characterized.

3. In order to gain a better physical understanding of the quiet Sun jets, especially the properties of their accelerated electrons which are not directly observable, we will study the electron energy distribution of microflares in active regions using hard X-ray spectroscopic data obtained with RHESSI and investigate the physical interpretation of the association between some microflares and type III radio bursts, the signature of jets through the outer corona. As microflare associated jets may be larger version of quiet Sun jets, this will allow us to analyze their heating in the atmosphere and acceleration through corona.

The proposed research responds to the topic of "Jets in the Solar Atmosphere and their Effects in the Heliosphere". We will contribute to the focused team effort by providing and analyzing high-quality imaging spectropolarimetric data of small-scale jets and associated dynamics obtained with the state-of-the-art instruments. This will help to address some fundamental question in LWS science goal such as source of plasma to the corona and solar wind. Our team has profound expertise in analyzing multi-wavelengths and spectropolarimetric data as proposed in this study.

Vasyl Yurchyshyn/New Jersey Institute of Technology
Linking Photospheric Dynamic Magnetic Fields to Chromospheric Jetting Activity

With increasingly finer resolution, the solar chromosphere shows an even richer ceaselessly changing character with small-scale energetic events occurring constantly all over the solar surface. These events are expected to hold the key to unlocking the mystery of chromospheric and coronal heating. Such chromospheric activity is thought to be the result of the relentlessly changing photospheric magnetic field driven by turbulent solar flows.

Big Bear Solar Observatory (BBSO) group proposes to utilize our 1.6 m clear aperture New Solar Telescope (NST) and data from various NASA missions to explore the connection between chromospheric activity and photospheric dynamics.

The main goal is to advance our understanding of how a variety of chromospheric events originate. These events include spicules, rapid blue shifted events (or spicules II), anemone jets as well as tiny intergranular jets recently discovered using BBSO's NST. In particular we will constrain the driving mechanisms of chromospheric upflows.

We will achieve this goal by analyzing high resolution NST, Hinode, and SDO data for CHs and quiet Sun areas.

Task 1. Studies of chromospheric jet properties (such as velocities, association with the magnetic field, time evolution)

Task 2. Studies of chromospheric response to photospheric dynamics (e.g., bright point sudden horizontal acceleration, appearance/disappearance, collision, etc).

Task 3. One of the major goals of this research plan is to organize several joint campaigns between NST, Hinode and SDO. We believe that these joint observations and data analysis should be one of the major strengths of the NASA LWS focus science team (FST).

The NASA LWS solicitation intends to form science teams focused on a specific topic. The potential contribution of the BBSO group to the LWS focused science team will include:

1) Data sets. The focused team ‘jets’ will most certainly benefit from these unique data sets provided by the largest 1.6m open aperture solar telescope at BBSO.

2) Organizing joint campaigns between BBSO, Hinode and other observatories.

3) Data analysis. BBSO group will perform data analysis and the results will potentially contribute to the success of the team. For example, results of statistical studies of observed magnetic fields can be compared to those derived from simulated magnetograms. Such comparative studies could lead to a significant improvement of existing MHD models.

The PI and Co-I of this proposal have the valuable experience of having previously worked in two successful LWS teams. We expect that NST data will enable us to see details on the solar surface with unprecedented clarity. Thus, we can expect knowledge that has escaped us, because of lower resolution of the existing data, to be revealed on the dynamics of small-scale magnetic fields in the photosphere and the chromosphere.

Other broad impact includes: i) NST data will be made available for solar community and support from NASA will enable us to perform observations per requests from outside researchers; ii)education and outreach. Recent high quality NST data has already generated significant interest among general public.

Ionosphere Turbulence (FST)

David Fritts/NorthWest Research Associates
Modeling of Gravity Wave and Tidal Influences on Low- and Mid-Latitude Plasma Dynamics

The central objectives of this proposal are to advance our understanding of gravity wave (GW) and tidal motions, their interactions, and their influences on plasma dynamics and instabilities, specifically traveling ionospheric disturbances (TIDs), equatorial plasma bubbles (EPBs), and sporadic-E layers and their coupling to the F layer, occurring in the low and mid-latitude E and F regions. Specific objectives include:

1. How does GW propagation and filtering induced by tides enable neutral and plasma perturbations having orientations conducive to plasma bubble seeding at the bottomside F layer, and what are the plasma responses?
2. How do GWs, perhaps via tidal filtering, contribute neutral perturbations that trigger TIDs at low- and mid-latitudes, and what are the plasma responses to these neutral motions?
3. How do tides and GWs contribute to descending shear layers that induce neutral turbulence, and how do these contribute to sporadic-E-layer formation and coupling to the F layer?

We will employ a versatile, anelastic code describing 2D or 3D neutral GW dynamics spanning multiple scale heights and a local representation of tidal motions providing the GW propagation environment. The neutral fields generated by this code will be employed as inputs to the SAMI3 and SAMI3/ESF plasma models to examine the plasma responses to these neutral fields. Initial efforts will focus on the larger-scale dynamics in objectives 1 and 2. Capabilities for modeling of small-scale neutral shear layers are in place and will support plasma studies of sporadic E layers as the plasma code achieves a potential for higher spatial resolution. Our anelastic code is the only code at present that has the ability to define these nonlinear dynamics spanning multiple scale heights and dynamical scales in 3D. SAMI3 is likewise the only plasma code capable of simulating plasma bubble development on a global scale.

Additionally, we will perform direct comparisons of our model results with observations and work with the community addressing the Focused Science Topic "Low- to Mid-Latitude Ionospheric Irregularities and Turbulence" in addressing the following science objectives:

1. understanding the connection between large-scale ionospheric processes and the development of electron density irregularities;

2. quantifying the role of E and F region coupling on these instabilities; and

3. improving models of F region plasma instabilities.

Our proposed studies will address three topics that are poorly understood at present and which are central to an improved characterization of neutral-plasma interactions at multiple latitudes, altitudes, and spatial scales. We expect our results to significantly advance both our understanding of, and our modeling capabilities for describing, these dynamics in a quantitative manner.

David Hysell/Cornell University
Electrodynamics of Equatorial Plasma Instabilities

A four-year research program is proposed to study the electrodynamics of plasma instabilities that develop in the nighttime equatorial ionosphere and can lead to the onset of equatorial spread F (ESF). Understanding and modeling ESF is important because of its impact on space weather: the associated electron density irregularities can scintillate radio wave signals which can adversely impact communication and navigation systems. The primary scientific objective is to address the question, what is the electrodynamic nature of equatorial F region plasma instabilities? In particular we will investigate the difference between two-dimensional and three-dimensional electrodynamic effects on the onset and evolution of equatorial instabilities. This study will combine the 3D electrodynamics model developed at Cornell University with the Naval Research Laboratory (NRL) ionospheric codes SAMI3 and SAMI3/ESF.

To achieve closure we will continually compare model results to data (e.g., radar measurements, in situ satellite data) to assess the validity of the model results for explaining ESF day-to-day variability.

The proposed research directly addresses several objectives of the Living With a Star Targeted Research and Technology Focused Science Topic "Low- to Mid-Latitude Ionospheric Irregularities and Turbulence" by improving models of F region plasma instabilities, quantifying the role of E and F region coupling on these instabilities, and understanding the connection between large-scale ionospheric processes and the development of electron density irregularities.

Thomas Immel/University of California, Berkeley
Towards a Predictive Capability for Equatorial Plasma Bubble Locations

Equatorial plasma bubbles are among the most important elements of space weather because of their impact on telecommunications. Concrete steps towards an ability to predict the occurrence and location of such irregularities is a key goal of the Living With a Star Focus Science Topic A. The three key elements of such a forecast are the prediction of the onset, growth and motion of a plasma bubble. This study will address the third of these, which has received comparatively little attention in recent years. We propose a short study of just 2 years in order to address this. Our group has already performed the critical preliminary work and developed all of the tools and the database that will be needed to ensure success in a timely manner. The product of this work will be a new empirical model of the drift velocity of plasma bubbles derived from IMAGE-FUV observations. This model will be a critical element for future forecasting and will provide a new benchmark for theoretical and numerical modeling efforts.

Endawoke Kassie/Boston College
Investigation of the Low-Latitude Electrodynamics and Seeding Conditions of Plasma Structures by Utilizing Multi-Instrument Observations

We propose to conduct multi-instrument observations of the low-latitude ionosphere to address two fundamental areas of thermosphere-ionosphere-magnetosphere coupling physics: (1) to understand the control that the atmosphere and its dynamics have on the day-to-day variability and the longitudinal dependence of the low-latitude electrodynamics and the large-scale structuring, and (2) to investigate regionally the main seeding conditions for equatorial plasma bubbles and scintillation activities in Africa and South America. The physical mechanisms that cause large-scale density irregularities and scintillations at the equatorial regions are not yet fully understood. Especially, the longitudinal variability of bubble occurrence is still an outstanding question. This is evident in satellite observations that show very unique and more intense equatorial anomaly structures and scintillation activity in the African region than any other regions. In addition, recent measurements of TEC depletions over South America have revealed that usually they occur in patches extending for 100s of km, but quite often they occupy the whole continent.

Therefore, to address the above fundamental problems, data from several different ground- and space-based instruments will be utilized. Pairs of magnetometers in the American and African sectors will be used to estimate vertical drifts. Data from Ion Velocity Meter (IVM) and Vector Electric Field Instrument (VEFI) instruments on board C/NOFS will also provide vertical drifts at different altitudes. Simultaneously, ACE satellite data will help understand the role of the penetration electric field, for processes governing equatorial ionospheric electrodynamics during storm conditions. GPS receivers on the ground and in space (LEO satellites) will resolve space-time ambiguity and will be able to track the evolution of equatorial ionospheric irregularities. New ionosondes recently installed in the African and South American equatorial and anomaly peak regions will provide bottomside densities, drifts near sunset times and the meridional winds. The PLP sensor on C/NOFS and the density instrument on DMSP will give information about the maximum penetration altitude of plasma bubbles.

This 4-year proposal aims to use this instrumentation to quantify the effect that the upper thermosphere in the form of propagating migrating/non-migrating tides and planetary waves, originated in the troposphere, have on the ionospheric dynamics and on the development and decay of plasma bubbles. This investigation aims to relate the day-to-day variability of F-region dynamics to the variability of the inputs from below. This complete specification of the driving winds will allow us to calculate plasma drifts for longitudes and times that do not have direct plasma drift measurements. During disturbed conditions, the more complete assessment of the thermospheric inputs in two continents (e.g. disturbed dynamo effect) will make it possible to single out effects due to prompt penetration electric fields. We will also utilize the capability of existent GPS receivers and ionosondes in Africa and South America to observe gravity waves (GW) and study their seeding conditions in these two continents.

By adopting an observational strategy rich in instrumental diversity and a scientific initiative that seeks the primary causes of the day-to-day variability and the longitudinal dependence of the occurrence of the plasma bubbles, we will be addressing the focused science topic (a) "Low- to Mid-Latitude Ionospheric Irregularities and Turbulence."

Meers Oppenheim/Boston University
Kinetic 2D and 3D Simulations and Theory of Low- to Mid-Latitude Ionospheric Irregularities

Plasma turbulence in the ionosphere often disrupts and distorts GPS and radio communication between space and Earth. Typically, this arises when solar-terrestrial interactions create strong density gradients or wind shears that, in turn, drive plasma instabilities. The Boston University (BU) research group proposes to contribute to a Focus Team Effort by exploring the development, evolution, and effects of ionospheric turbulence on spatial scales ranging from centimeters to kilometers and temporal scales from milliseconds to minutes. They will do this using large-scale kinetic simulations, theory and modeling. This will help scientists and engineers better understand fundamental physical processes of the space environment and further adapt our space-based technological systems.

The BU team can most easily contribute to the first two types of investigations outlined in section 1.2.1(a) of the ROSES "Living With a Star Targeted Research and Technology Simulations:"

1. Theoretical studies of the linear and nonlinear development of ionospheric instabilities,

2. First-principle modeling of ionospheric irregularities and turbulence in 2D and 3D

They can also contribute to "observational studies identifying regions of ionospheric irregularities and possible causal mechanisms, "particularly as users of Jicamarca Radio Observatory (JRO) data. Their research should advance all of the measures of success listed in 1.2.1(a), but in particular their research will enhance the following:

1. Development of improved models of E and F region plasma instabilities and turbulence;

2. Understanding of the connection between large-scale ionospheric processes and the development of electron density irregularities (e.g., equatorial spread F); and

3. Development of a predictive capability for irregularity onset and evolution.

The research group at BU has developed an electrostatic, massively parallel, particle-in-cell (EPPIC) plasma simulator that also has the ability to apply hybrid techniques (e.g., PIC ions & fluid electrons). It works equally well in 1D, 2D and 3D and has been used for a broad range of plasma problems. This code runs efficiently on some of the world's largest super-computers, scaling to tens of thousands of processors. It allows them to simulate ionospheric plasmas spanning a range of scales that were impossible until the current generation of supercomputers came on-line.

Due to its effects on communication and GPS, Equatorial Spread-F (ESF) is the most important of these instabilities. While there are currently computer models that simulate the evolution of large-scale spread-F phenomena (1000km-to-kilometer), no such models exist for medium and short-scale irregularities (kilometer-to-meter). These small irregularities are what radars and spacecraft instruments measure, and they have a direct impact on the propagation of radio waves. This project aims to fill this gap by simulating ESF from the smallest physically important scale (~10 cm) to kilometer scales and develop a better understanding of how these irregularities evolve and dissipate. In order to accurately model short wavelength dissipation, such computations must be kinetic, at least for ions. As a secondary investigation, the BU team can also explore E-region instabilities. In particular, they can study the evolution of large-scale gradient-drift waves and also at how mid-latitude shear-driven sporadic-E irregularities develop, evolve, and couple to the F-region. For all investigations, they will compare simulation and model results to measurements, both spectrally and spatially. This will allow them to appraise the accuracy of their techniques and to suggest new approaches and measurements. These studies will further scientist's ability to model and predict the onset, evolution, and effects of ionospheric irregularities.

Workshop – Cross Discipline

Pete Riley/Predictive Science, Incorporated
From Sun to Ice: A Cross-Disciplinary Workshop on the Causes and Consequences of Extreme Solar Events

Extreme solar eruptive events, while rare, can have monumental effects all the way from the Sun to Earth's polar ice caps. They have been implicated in the depletion of ozone and cloud formation, and their occurrence can be seen directly in ice core records spanning more than 400 years into the past. Their effects at other planets, and elsewhere in the solar system can be important, and violent flare activity can even be observed at other stars. Yet the basic physical processes that lead to these events, the acceleration and transport of energetic particles, and their effects at Earth and elsewhere remain poorly understood. With recent advances in theory and the availability of new datasets, together with society's continually increasing reliance on technology, a coordinated study of extreme events and their impacts at Earth is both timely and necessary. We propose to convene two workshops on this interdisciplinary topic to address several fundamental questions, including: (1) What makes these events extreme? (3) Why are some events extreme in some aspects (e.g., CME speed) but not others (e.g., SEP fluxes)? (3) How should the solar activity record in ice cores be interpreted? and (4) What possible effects could the so-called "super-storms," such as the Carrington event of 1859, have had on ozone levels? To ensure the success of the workshops, we will invite leading experts representing experimenters, data analysts, theoreticians, and modelers in a range of sub-disciplines, including solar, stellar, planetary, heliospheric, magnetospheric, ionospheric physics, astrophysics, and ice-core chemistry. In addition to studying basic science questions in the chain of events from the Sun to the ice, we will focus on the boundaries between the different regions, where there has been little cross fertilization of ideas, and groups have often reached substantially different conclusions, based on the same available measurements. We anticipate that the first workshop will introduce the main outstanding issues in each field, define the boundaries between each field, and identify how cross-disciplinary studies can lead to new insight. During the second workshop (approximately one year later), the progress made during the previous year will be reported and new questions and issues resulting from these studies will be addressed.

Maria Spasojevic/Institute for Magnetospheric Physics LLC
Support for the Inner Magnetosphere Coupling Workshop 2012

We are requesting $7.9K to convene the Inner Magnetosphere Coupling (IMC) workshop to be held at the University of California, Los Angeles on March 19-23, 2012. Support from the NASA LWS program is being requested to cover salary and travel costs for an administrative assistant, who will be responsible for managing and organizing logistics in advance as well as during the workshop. Support from NASA LWS will translate into significantly reduced registration fees for participants. In addition, this workshop will leverage support from UCLA, which will be providing conference facilities at no cost. It is expected that the workshop will attract about 100 participants.

The second Inner Magnetosphere Coupling (IMC) workshop is being organized to bring together researchers studying the various coupled plasma populations of the inner magnetosphere and ionosphere. The IMC Workshop is both timely and important to NASA science and especially its LWS program. The workshop topics are directly relevant to NASA's Research Objective 3B: "Understanding the Sun and its effect on Earth and the solar system", and are central to NASA's interests in understanding the dynamic response of the near-space environment to solar activity. These workshop topics are also central to the NASA Living with a Star Program. In particular, the workshop will advance our understanding of Priority 1 of the LWS general objective from the SAT report WG1-5 and 6, WG2-4 ("understanding the acceleration, global distribution, and variability of energetic electrons and ions in the inner magnetosphere").

The workshop topics are cross disciplinary in nature, bringing together researchers who work on the physics of the solar wind, inner magnetosphere, ionosphere, waves, and plasma populations ranging from very cold to extremely energetic.