Below are the abstracts of proposals selected for funding for the Solar and Heliospheric Physics program. Principal Investigator (PI) name, institution, and proposal title are also included. 104 proposals were received in response to this opportunity, and 27 were selected for funding.

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**Spiro Antiochos/NASA, Goddard Space Flight Center**
**Structure and Dynamics of the Coronal/Heliospheric Magnetic Field**

We propose a program of theoretical/modeling research that is designed to attack one of the most fundamental questions in Heliophysics: What are the structure and dynamics of the Sun's open magnetic field? Answering this question is critical for achieving NASA's goals of understanding the Sun and solar system and for interpreting the wealth of new data that are now coming from STEREO and Hinode and soon from SDO.

The proposed work consists of a balance of theoretical and numerical studies using state-of-art simulation codes, in particular, our 3D adaptively-refined MHD solver (ARMS) and our 2.5D solar wind version of ARMS that includes the solar wind and a full energy equation. The proposed work will extend our understanding of the coronal/heliospheric magnetic field to the fully dynamic regime, focusing especially on the effects of topological complexity. We will employ the methodology that we have used previously to attack successfully many fundamental solar/heliospheric problems: first develop insight by investigating idealized models that isolate the key physics of the problem, then use the understanding gained to perform realistic calculations that can be compared directly with observations from the NASA missions.

The Principal Investigator directing this project is Dr. Spiro K. Antiochos of NASA/GSFC. He will be assisted by Dr. Etienne Pariat from GMU and Dr. Daniele Mueller from ESA, as well as Mr. Justin Edmondson, a graduate student from the University of Michigan who will perform part of his thesis research on this project. Dr. Antiochos is an adjunct professor at U. Michigan and is supervising Mr. Edmondson at GSFC.

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**Ara Chutjian/Jet Propulsion Laboratory**
**Measurement of Absolute Electron Excitation Cross Sections in Highly-Charged Ions for Solar Plasma Diagnostics**

The SOHO Mission has provided unprecedented new data concerning the dynamics of our Sun. With the advent of the Hinode, Solar Dynamics Observatory, TRACE, and STEREO Missions, there will be an even greater demand for high quality measurements and calculations of collision strengths, lifetimes, dielectronic recombination rates,
ionization cross sections, charge-exchange cross sections, etc. In particular, there are many density- and temperature-sensitive line ratios used to characterize the solar plasma. Their underlying collision strengths are almost always taken from calculation, with only rare comparisons to benchmarking, experimental measurements. It is essential to establish "ground truth" by providing side-by-side experimental and calculated collision strengths. The JPL Highly-Charged Ion Facility (HCIF) will be used to measure absolute excitation cross sections for a prioritized list of HCIs that are needed in solar-plasma diagnostics. The energy range of the measurements is from below threshold, to about 4 x threshold, a region in which excitation of optically-allowed and spin- and symmetry-forbidden transitions dominate. In all cases the JPL measurements are compared with accurate R-matrix results from the IRON Project and from Clark Atlanta Univ. Emphasis is placed herein on high charge state of iron, especially the EUV delta n = 1 transitions in Fe VIII, X, XII, and XIV that are needed for SOHO/EIT, Hinode/EIS, SDO/AIA, and the STEREO EUV imager. In addition, JPL will initiate measurements in high charges states of Si and Mg ions, whose transitions are used to characterize the ionization state of the coronal material.

John Clem/University of Delaware
Charge Sign Dependence of Cosmic Ray Solar Modulation

The steady flux of cosmic rays entering the heliosphere provides a unique probe for studying the magnetic fields carried by the solar wind. Fluctuations in these magnetic fields produce an anti-correlation between cosmic ray intensities observed at Earth and the level of solar activity (solar modulation). Cosmic ray electrons and nuclei respond differently to solar modulation, with the differences being clearly related to reversals of the solar magnetic field, which occur every eleven years. If the large scale heliospheric magnetic field has certain types of structures, the charge sign of cosmic ray particles can affect their propagation. Careful study of the behavior of cosmic ray positrons, relative to negative electrons (which have identical masses) allows for a definitive separation of the effects due to charge sign from the other possible effects.

We propose to determine the extent to which the large scale geometry of the heliospheric magnetic field is important in the propagation of charged particles through the heliosphere. To achieve this goal we plan to continue measurements of the cosmic ray electron flux and positron abundance through a series of annual balloon flights covering the increasing phase of the current solar cycle through solar maximum (2011). These key measurements will extend our observational coverage of particle flux variation revealing important characteristics of the heliospheric magnetic field 22-year cycle. Furthermore balloon flights during this proposed period would provide a direct cross-calibration exposure of our instruments (AESOP and LEE) and Pamela observations. The Pamela instrument is currently operating on a spacecraft and is expected to return data for a 3-year period. To put these observations in context with previous and succeeding measurements related to this work, the AESOP and LEE instruments will provide a means to link Pamela measurements with the past and future.
Steven Cranmer/Smithsonian Astrophysical Observatory
Definitive Tests of Competing Models of Coronal Heating and Solar Wind Acceleration: Waves versus Reconnection in Open Flux Tubes

The goal of the proposed investigation is to construct models of solar wind acceleration that test specific proposed processes such as waves, turbulence, magnetic reconnection, and nanoflare energy injection. Despite many years of study on these individual processes, there has been no systematic "proving ground" that would allow the full range of these models to be tested and compared against one another. It is still unknown whether the solar wind is fed by flux tubes that remain open (and are energized by footpoint-driven wavelike fluctuations) or if mass and energy is input more intermittently from closed loops into the open-field regions. The work will consist of 3 tasks. (1) Existing wave/turbulence models will be extended by including two-fluid effects and refining the description of strong imbalanced MHD turbulence. (2) The reconnection/loop-opening idea will be developed by constructing statistical models of intermittent mass, momentum, and energy deposition from closed loops undergoing magnetic reconnection with open flux tubes. These two sets of models will be developed to a point of sophistication that will either drastically reduce the need for "free parameters" or will relegate those parameters to be determined from specific observations. (3) Both kinds of models will be implemented in full-Sun reconstructions of the 3D magnetic field for specific time periods where large amounts of data are available. Thus, this project will provide key information that allows the determination of the relative contributions of waves, turbulence, and reconnection to solar wind acceleration in specific regions (coronal holes, quiet Sun, and active regions). The proposed work will feed directly into improving the physical realism of global 3D corona-heliosphere models, as well as answering the fundamental questions addressed in the NASA SMD strategic sub-goals 3B.1 and 3B.3.

Ashley Crouch/NorthWest Research Associates
Local Helioseismology of Small-Scale Magnetic Elements

The primary objective of the proposed research is to determine the internal and subsurface structure of the small-scale agnetic elements that populate the solar photosphere. This will be achieved through a combination of local helioseismic measurements and theoretical modeling of the interaction between solar oscillations and small-scale magnetic elements. We will measure the helioseismic signature of the small-scale magnetic elements with time-distance helioseismology and Hankel analysis by applying ensemble-averaging techniques, which have been demonstrated recently with existing data from MDI instrument on the NASA-ESA SOHO mission. Subsequently, we will develop models for the small-scale magnetic elements that are consistent with the helioseismic measurements. Simplified theoretical models, based on the thin flux tube approximation as a starting point, will be used to interpret the observational measurements and to guide the development of numerical simulations for models more complex than thin flux tubes. The information that will be obtained about the internal and subsurface structure of the magnetic field and flows associated with small-scale magnetic elements is fundamental to testing magnetoconvection simulations, understanding
irradiance variation, and developing models for supergranulation, network, and plage. In addition, the improved understanding of the interaction between solar oscillations and small-scale magnetic elements, that we expect to achieve, will help to identify the mechanisms responsible for the solar cycle variation of global mode properties and to constrain theories for heating of the solar atmosphere. The project described here will also greatly improve the understanding of the interaction of solar oscillations with magnetic fields in general, which directly impacts the analysis and interpretation of existing data in the public domain from the MDI experiment onboard the NASA-ESA SOHO mission. In addition, the models will be critical for interpretation of data expected from the upcoming Helioseismic and Magnetic Imager (HMI) onboard the NASA Solar Dynamic Observatory mission.

Giuliana de Toma/NCAR
On the Initiation and Dynamic Evolution of Coronal Mass Ejections

We propose an investigation of CMEs which focuses on their initiation and trigger mechanisms. We are interested in understanding how the pre-CME magnetic configuration and plasma structure affects the CME onset and development.

We will use a combination of observations and models to address the questions: What are possible triggering mechanisms for CMEs and filament eruptions? What is the role of the overlying coronal magnetic fields on the eruption dynamic? How well do CME models reproduce the observed CME signatures?

We will take advantage of the new observations from STEREO and HINODE which give a unique and unprecedented opportunity to study CMEs from multiple views at high spatial and temporal resolution. We will select well observed events and compare the CME dynamics and the evolution of the CME source region with 3D MHD numerical models. Simulations of CME initiations by Fan & Gibson (2007) show that the loss of equilibrium and eruption of a coronal flux-rope can take place via either the onset of the torus instability or the kink instability. Which instability set in first depends on the twist of the flux-rope and how rapidly the external potential magnetic field confining the flux-rope decreases with height.

We will use PFSS extrapolations to examine the height profile of the external magnetic fields confining filaments prior to eruption to see how the magnetic configuration relates to the type of eruptions (kinking or non-kinking) that takes place. Our model-data comparison will include: the acceleration profiles, the rotation of prominences/filaments, and the evolution of X-ray sigmoids, post-flare loops, and coronal dimmings. We will then select 2 or 3 cases for which there is optimal data coverage and run specialized data-driven simulations where the ambient coronal magnetic field and the magnetic flux transport at the lower boundary (such as flux emergence, and twisting or shearing motions) are prescribed by observations.
Gordon Emslie/Oklahoma State University
Hard X-Ray Imaging Spectroscopy of Solar Flares

A comprehensive understanding of the fundamental processes leading to energy release in solar flares, in particular the processes that lead to such copious particle acceleration, is essential not only for the study of the fundamental processes of particle acceleration in astrophysical plasmas, but also for the reliable prediction of potential hazards to spacecraft and humans in space. The overall goal of the proposed research is to probe the nature of the physical processes associated with the acceleration and propagation of energetic electrons in solar ares, and hence to achieve a deeper understanding of the underlying causes and effects of impulsive magnetic energy release. We will address this goal through quantitative interpretation of the spatial, temporal and spectral signatures of hard X-ray radiation observed by the NASA Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI). In particular, we propose to apply a recently-developed procedure for imaging spectroscopy analysis of hard X-ray emission; this procedure utilizes source visibilities (two-dimensional spatial Fourier transforms of the source) and is optimized to the manner in which RHESSI encodes imaging information. This new and innovative approach to imaging spectroscopy results in images of the electron flux spectrum throughout the flare volume.

With such images, one can:
* study spectral variations amongst source features, and assess the reason for them;
* directly probe of the physical processes affecting the accelerated electrons;
* determine empirically the fraction of particles in the acceleration region that undergo acceleration to hard X-ray producing energies; and even
* probe physical conditions in the acceleration region itself.

Several benefits to NASA's programs ensue:
(1) Our understanding of "the fundamental physical processes in the space environment" (NASA Strategic Goal 3.B.1) will increase;
(2) This new knowledge can be used by researchers concerned with particle acceleration processes in the Sun and in other astrophysical objects;
(3) Our understanding of the underlying causes of solar eruptive events will constitute a substantial contribution to progress in our ability to predict "extreme and dynamic conditions in space" (NASA Strategic Goal 3.B.3). Such knowledge is essential for the safe implementation of NASA's Vision for Space Exploration;
(4) The results of this research, expressed in textbooks and other materials, will be made available through public outreach programs, thereby inspiring the next generation of researchers and increasing public awareness of space research.

S. Gary/Los Alamos National Laboratory
Hybrid Simulation Models of the Heliospheric Termination Shock: Predictions and Interpretations for IBEX

We will use the Los Alamos hybrid computer simulation code to represent the heliospheric termination shock and to study how that shock heats ions. Such ions are the
source population of energetic neutral atoms that will be observed by the IBEX mission, scheduled for launch in 2008. IBEX will measure energetic neutral atoms from charge exchange of predominantly protons heated at the termination shock, with the goal of understanding the global properties of this shock. However, the fluxes of these neutral atoms are sensitive functions of the proton and ion velocity distributions in the heliosheath. Our two-dimensional simulations will model conditions at the termination shock more accurately than previous one-dimensional computations, and will calculate the heated and scattered proton velocity distributions in the heliosheath. This research will enable a substantial increase in the basic scientific understanding of ion heating at this shock, and, in conjunction with Boston University software to calculate synthetic IBEX data, will also provide a critical tool for the interpretation of observations by that spacecraft.

Thejappa Golla/University of Maryland
The Study of Remote and In Situ Wave Emissions Associated with CME-driven Shocks and Flare Accelerated Electrons

In this proposal we seek answers to some of the unsolved problems in solar radioastronomy, namely: (1) How are the flare-accelerated electron beams stabilized, so that they can travel from the inner corona to 1 AU and beyond without losing much of their energy, and (2) What mechanisms are responsible for converting the Langmuir waves excited by electrons, accelerated either by the flares or by the coronal mass ejection (CME) driven shocks, into escaping radiation. We will address these issues by analyzing the high resolution observations of Langmuir and other low frequency waves in the source regions of type II radio bursts (excited by CME shocks), and type III radio bursts (excited by flare-accelerated electrons) obtained by the STEREO spacecraft. We will use the newly emerging hypercoherence, bicoherence, and tricoherence techniques based on FFTs and Continuous Wavelet Transforms (CWTs), and the Hilbert-Huang Transform (HHT) techniques. The data obtained by the improved S/WAVES Time Domain Sampler (TDS) system, in precision, linearity, and sample length and rate will enable us to isolate the high and low frequency modes with a high degree of correlation, which will help to conclusively identify the electrostatic decay, second harmonic generation, and modulational instability and related strong turbulence processes. The ultimate goal is to develop successful, observationally-tested theories for type II and type III radio bursts originating from corona to 1 AU and beyond.

The objectives of this proposal are directly related to the NASA's Research Objectives 3B.1, namely, "Understand the fundamental physical processes of the space environment from the Sun to Earth, to other planets, and beyond to the interstellar medium."
Philip Goode/Big Bear Solar Observatory
Studies of Solar Activity with Coordinated Observations of New Solar Telescope and NASA Solar Physics Missions

In the last two years since the start of our current SR&T grant, Big Bear Solar Observatory (BBSO) has remained highly productive in both science and requisite instrumentation. We have graduated 8 PhD's and produced over 60 publications.

BBSO has reached the final stage in building its 1.6 meter clear aperture, off-axis New Solar Telescope (NST). First light of this telescope is expected in Spring 2008. We will integrate our near-infrared (NIR) imaging vector magnetograph, visible light real-time image reconstruction, and adaptive optics systems to the NST, so as to provide diffraction limited data from the outset of funding. All of these NST efforts are well-timed and focused to provide unique support for current and near future NASA missions including RHESSI, Hinode, STEREO and SDO.

The primary targets of our proposed research are:

1. High-cadence and high-resolution studies of solar flare emissions to provide unique details of flare energy precipitation on 0.2" spatial scales and 0.1 sec temporal scales. NST NIR data will enrich RHESSI and Hinode research.

2. Comprehensive studies of vector magnetic fields associated with flares to understand the triggering mechanism of the eruptions and atmospheric restructuring after the eruptions. The NST will complement Hinode, STEREO and SDO.

3. Study of flow fields in flare productive active regions using near-continuous high-resolution, high-cadence observations. NST is complementary to Hinode and SDO here.

4. Sustained sub-arcsecond resolution studies of the quiet solar atmosphere. (a) We will observe and directly probe the newly discovered, and weaker than intranetwork, transverse magnetic component. (b) We will focus on the energy source of coronal heating, from high-resolution observations of footpoint motion of flux ropes to complement Hinode and SDO data.

The proposed research is clearly related to NASA's strategic goal 3B: to understand the Sun and its effects on Earth.

Charles Havener/UT-Battelle, LLC
Laboratory studies of solar wind charge exchange for heliospheric X-ray emission

Many years of all-sky observations in the soft X-ray band have revealed a rich diffuse background produced by a complex combination of X-ray sources. While much of this emission is due to sources outside the heliopause, models suggest that roughly half of the background originates from within the heliosphere. The origin of the heliospheric X-ray emission is believed to be the same as observed for comets: charge exchange (CX) of
solar wind (SW) ions with ambient neutral species. X-ray diagnostics from the cometary and planetary atmospheres are currently being developed.

To improve the reliability of current X-ray models, we propose to perform benchmark total CX and X-ray emission measurements on several identified systems important for X-ray diagnostics of the heliosphere using a unique ion-atom merged-beam technique at the Oak Ridge National Laboratory Multicharged Ion Research Facility (MIRF). With the addition of the University of Wisconsin's X-ray quantum calorimeter, absolute total and/or X-ray emission measurements for O^7+, O^6+, C^5+, Ne^8+, Ne^9+, N^6+, Mg^10+ + H are proposed in the energy range relevant to the solar wind, 0.1 - 5 keV/u. While other X-ray emission measurements exist for SW ions on He, H_2, and other molecules, X-ray measurements are non-existence for H, the most abundant heliospheric neutral.

Our measurements will benchmark the advanced quantum-mechanical calculations of charge exchange of the dominant SW ions needed to understand the X-ray emission. The experimental and theoretical results of this proposal will then enable the investigation of SW and heliospheric properties and dynamics enhancing the scientific return from NASA space astrophysics missions such as ROSAT, EUVE, CXO, XMM-Newton, Suzaku, Constellation-X, and future X-ray observatories.

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**Darrell Judge/University of Southern California**  
**Degradation Free Spectrometers (DFS) for Solar Physics**

We propose a complete science investigation for better understanding of how and why solar irradiance varies in the Extreme Ultraviolet (EUV) and X-Ray spectral windows. This investigation is a successor proposal to previously granted NASA proposals (NASA NAG5-11807, A Micro-Light X-ray to Far Ultraviolet (FUV) Spectrometer for Atmospheric Science and NASA NNX07AN37G, An Optics-Free Spectrometer). The laboratory prototypes of these advanced degradation-free EUV and X-ray spectrometers will be configured for flight, calibrated at NIST, and integrated into a Black Brant IX rocket payload to test and verify their spectral resolution, signal-to-noise ratios, stability, and suitability for future light-weighted and stable long-lived space spectrometers. The proposed work will be carried out during a three-year LCAS program, and will be supported by two sounding rocket flights, one in 2009 and one in 2010, after the launch of SDO, observing the solar EUV and X-ray spectral lines while qualifying the spectrometers for space flight missions. The observational data from these two new spectrometers will be combined with data from the traditionally flown USC Space Sciences Center’s suite of instruments (SOHO CELIAS/SEM clone, Helium Double Ionization Cell, Neon Rare Gas Ionization Cell) to obtain an absolute solar EUV flux as a reliable cross-reference for continuity of EUV and X-ray measurements being obtained by the SOHO CELIAS/SEM and the USC ESP spectrophotometer on the EVE suite of instruments to be launched on the SDO satellite in 2009.
I propose to extend the mode fitting methodology that I have developed recently for very long time series (Korzennik, 2005), and as a result substantially improve our assessment of the solar internal structure and its dynamics, using the MDI data set.

This new and improved fitting methodology was developed using 2088-day-long time series of spherical harmonics coefficients computed from full-disk Dopplergrams taken by MDI on-board SOHO. The method uses a multi-taper spectral estimator, fits individual modes for each m while fitting all m's simultaneously for a given (l,n). It uses a complete leakage matrix (i.e., includes horizontal & vertical components), fits an asymmetric profile and iterates to include mode contamination (non-fitted modes present in fitting window).

It was originally applied to low degrees (up to \( l = 25 \)). The success of the method and the enthusiastic response of the helioseismic community to a novel and independent peak-bagging approach has motivated me to extend it to higher degrees and shorter epochs. As a result, new issues have arisen that needs to be addressed.

Inversions for the solar internal structure and dynamics using these results when compared to the standard fitting products clearly show substantial improvements, as systematics like "horns" and the 3.4 mHz "anomaly" are not present in these determinations.

At the dawn of the next helioseismic mission, HMI that will fly soon on SDO, we ought to soberly reassess the significances of our past inferences and test rigorously how well they are reproduced once these systematics are resolved.

This proposal requests funding to extend this method to a longer time series, as we are now in a position double the 2088-day long span to 4176 days; to continue its extension to higher degrees; and, of course, resolve the associated issues. Results will be analyzed using state of the art inversion procedures to re-assess the solar internal structure, its dynamics and their variation with solar activity.

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 the MDI mission, and indirectly help gear up for the processing of the HMI data.
Alexander Kosovichev/Stanford University
Investigation of subsurface flows and their effects on magnetic flux transport on the Sun

Recent observational and theoretical results show that the magnetic flux transport processes on the Sun are significantly more complicated than it is assumed in the current flux-transport models of the solar cycle. These processes are a key to understanding the mechanism of the solar cycle. The primary objective of this investigation is to investigate how the magnetic flux is dispersed and transported to the polar regions of the Sun by large-scale and meridional flows. Our goals are using the time-distance helioseismology diagnostics of the large-scale subsurface flows to investigate the structure and dynamics of the flows around active regions during various stages of the active region evolution, from flux emergence to flux dispersion; the relationship between these flows and the solar-cycle variations of meridional circulation; and the effects of these flows and variations on the magnetic flux transport on the Sun. To accomplish this we formulate the following three main tasks: 1) investigate the structure and dynamics of large-scale subphotospheric flows around active regions at various stages of their evolution, from the initial emergence stage through the flux dispersion stage; investigate the difference between leading and following polarities in terms of the flow characteristics and flux transport; 2) investigate the variations of the meridional flows with depth, latitude, longitude and time, and the relationship between these variations and the large-scale flows around active regions; 3) investigate the relationship between the meridional and large-scale flows and the magnetic flux dispersion and transport during Solar Cycle 23, using magnetic and helioseismic measurements from SOHO/MDI, and during the rising phase of Cycle 24 using data from SDO. The results of this investigation will provide us with better understanding of the basic mechanisms of solar activity, and also important input parameters for solar flux-transport dynamo models improving their predictive capabilities.

Jozsef Kota/University of Arizona
Acceleration and Transport of Energetic Particles: Shocks vs. Turbulence

We propose to carry out a set of focused investigations intended to increase our physical understanding of arguably the most important elements of the heliosphere: the mutual interaction of shocks, turbulence, energetic particles, magnetic fields. The first two of these are the basic drivers of physical processes in the plasma and energetic particles are one of the major results of interactions of the turbulence and shock waves. Energetic particles accelerated by shocks or other processes on the Sun and in the heliospheric plasma, or coming from the galaxy are, because of their mobility, valuable probes of regions of the heliosphere not accessible to spacecraft.

Recent observations in the inner as well as in the outer Heliosphere, such as the crossing of the solar wind termination shock (TS) by Voyager-1 and -2 brought several surprises, and some of these are likely associated with the fact that the TS is not a simple, steady 1-dimensional shock. Turbulence, ripples of the shock, topological features between the shock and the magnetic field may play important role and cause deviations from the
paradigm based on a simple steady 1-D picture. These will be targeted in the present proposal.

The proposed work shall address the TS, as well as shocks in the inner Heliosphere and near the Sun. We will use a combination of basic theory, modeling and computer simulations. We propose the following specific, interrelated projects:

1. Study the effects of broadband, large-amplitude pre-existing upstream turbulence on particle acceleration at shocks.

2. Use galactic and anomalous cosmic rays to probe large-scale heliospheric structures and broadband turbulence through their effects on particle transport.

3. Investigate effects of small-scale turbulence on the acceleration and transport of charged particles, especially the constraints imposed by the observed $f(v)\sim 1/v^5$ suprathermal spectrum.

KD Leka/NorthWest Research Associates, Inc.

**Stopping and Asking Directions: Exploiting div(B)=0 for Azimuthal Ambiguity Resolution**

Research into solar magnetic field evolution, plasma velocities, helicity injection, and coronal energy build up require well-determined time-series of vector field data. These time-series must be free of spatial and temporal discontinuities for successful interpretation. As demonstrated with recent SOT/spectropolarimetric data from Hinode, the interpretation of physical mechanisms responsible for solar phenomena is disturbingly subject to the azimuthal ambiguity resolution for the vector field data.

We propose to fully exploit the divergence-free condition for magnetic fields, coupled with sophisticated polarimetric inversion techniques, to further refine ambiguity resolution algorithms. Special attention will be paid to time-sequence requirements. There is no approach available that ensures temporally smooth and consistent results for the ambiguity resolution of time-series vector field data, and the lack thereof easily produces large, but unphysical, changes in sequences of the vector magnetic field. As such, we request research funds to continue the progress made on algorithm comparisons, multi-height inversions of chromospheric data, and algorithm development. We have asked directions in the past and proceeded well, and now recognize an approaching crossroad.

Our scientific target is to discriminate between models of filament formation, supplementing recent studies from Hinode with additional analysis based on our results, and eventually with additional SDO/HMI high cadence data. En route we propose to investigate the determination of spatial gradients from high-quality spectropolarimetric data, the application of that information to the azimuthal ambiguity resolution, and refinement of techniques for single-height time-series data as is expected from SDO/HMI.
Robert Lin/University of California, Berkeley
Gamma-Ray Imager Polarimeter for Solar Flares

We propose to develop the Gamma-Ray Imager/Polarimeter for Solar flares (GRIPS), the next-generation instrument for high-energy solar observations. GRIPS will provide a near-optimal combination of high-resolution imaging, spectroscopy, and polarimetry of solar-flare gamma-ray/hard X-ray emissions from ~20 keV to ~10 MeV. GRIPS directly addresses key elements in NASA's Strategic Plan, Sub-goal 3B: "Understanding the Sun and its effects on Earth and the solar system", through study of "powerful flares and coronal mass ejections", in particular, the flare energy release and the acceleration of particles to high energies. GRIPS combines 3D position-sensitive germanium detectors (3D-GeDs) with a new single-grid imaging system, called the Multi- Pitch Rotating Modulator (MPRM). The MPRM provides a near-ideal point response function (thus excellent image quality) with twice the throughput per cm² of detector area compared to RHESSI. The angular resolution of the imager at gamma-ray energies (12.5 arcseconds) is sufficient to separate the footpoints of 2.2 MeV line sources for all gamma-ray flares, and thus further investigate the apparent spatial separation between accelerated electrons and accelerated ions first seen in a number of RHESSI flares. The 3D-GeDs enable reconstruction of the Compton scattering of incident photons, thus providing significant sensitivity to polarization at gamma-ray energies (150-650 keV), as well as providing background rejection. These measurements of polarization can provide a powerful diagnostic of electron beaming in solar flares. In the first three years the GRIPS instrument will be developed. In the fourth year (2012) the balloon gondola will be fabricated and the GRIPS instrument integrated and flown on a continental-US test flight. In following years 2013-2015 we plan yearly Antarctic long-duration flights or ultra-long duration flights (if available) for solar flare studies.

Petrus Martens/Smithsonian Astrophysical Observatory
Diagnostic Modeling of Flaring and Quasi-static Coronal Loops

Solar flares and the heating of the X-ray emitting solar corona have been two major mysteries in solar physics for almost a century. The main objective of our research program is to calculate diagnostics for the main theoretical explanations that have been proposed for these phenomena. Diagnostic in this context means a prediction for an observable that is sufficiently different for different theories so that observations from current NASA and international space missions can be used to discriminate between the competing theories.

To achieve this goal we have developed the first hybrid numerical computer code that couples the hydrodynamic evolution of the plasma in loops to the transport and emission from the very high energy particles that are produced in flares and that also may be involved in heating the corona.

Here we propose to use our hybrid code to simulate the response of the solar plasma to the theoretical mechanisms mentioned above, and therefrom calculate the diagnostics that
we can use to determine which theory best fits the data from the current fleet of solar physics missions.

Understanding the basic physical mechanisms of solar flares and coronal heating is a main objective of NASA's science program. The practical reason for that is that only a full physical understanding of flares will allow us to predict these events, which is of great importance for astronauts going to the moon, and for airline passengers on polar routes, since flares pose a potentially lethal radiation hazard for them.

Mark Miesch/University Corporation for Atmospheric Research
Three-Dimensional Babcock-Leighton Dynamo Models with Turbulent Solar Convection

We propose to develop the first solar dynamo model which incorporates both MHD simulations of turbulent convection and mean poloidal field generation due to the decay of photospheric active regions, the latter known as the Babcock-Leighton mechanism. In the process we will address several fundamental issues which are essential to mean-field solar dynamo models including whether the advection-dominated assumption is justified and whether dynamo action in the convection zone may overwhelm the surface processes represented by the Babcock-Leighton source term. Based on high-resolution three-dimensional simulations of turbulent convection in rotating spherical shells, our approach is unprecedented and our team is uniquely qualified to carry it out. Our work will provide a link between Babcock-Leighton flux-transport (BLFT) dynamo models which have demonstrated a remarkable ability to reproduce many aspects of the solar activity cycle and high-resolution, three-dimensional MHD simulations which continue to provide new insights into the complex, often unexpected, dynamics exhibited by turbulent dynamos. Since BLFT dynamo models currently represent one of the most promising paradigms for how the solar dynamo may operate, our work will directly address some of the fundamental tenets of solar dynamo theory and the origins of solar magnetism.

Elena Moise/University of Hawaii at Manoa
Using the Near-Sun Neutral Helium to Probe the Corona

This project will support the PI to finish the final analysis and publication of coronal spectropolarimetric neutral helium measurements from the Haleakala SOLARC imaging IR spectropolarimeter. In the last 18 months an extensive set of data has been obtained, which confirms the detection of a cool Helium component in the solar corona. This one-year project plan will complete the analysis of these data and allow comparison with space-based ionized He measurements of the corona. Neutral helium has never before been detected this close to the Sun. Thus, important exploratory modeling and careful analysis to confirm this small infrared signal have been required. The potential of developing a ground-based tool to observe the heliospheric plasma could have a significant impact on future space NASA missions devoted to this task.
The Extreme Ultraviolet Normal Incidence Spectrograph (EUNIS) sounding rocket instrument is a two-channel imaging spectrograph that observes the solar corona with high spectral resolution and a rapid cadence made possible by unprecedented sensitivity. The rapid cadence of EUNIS is the key to its power to explore the time-variable and spatially inhomogeneous heating mechanisms that define the frontier of coronal energetics. We propose to build on the success of the first two flights of EUNIS (in 2006 and 2007) by continuing to analyze data and publish results; by making all the calibrated data freely available over the internet; by completing the radiometric calibration of Hinode/EIS; and by upgrading and flying EUNIS for the third time. The third flight will focus on the puzzling connection between the transition region and the corona and on oscillatory and transient structures. EUNIS will again co-observe with Hinode/EIS and instruments on SOHO (CDS, EIT, and SUMER) and provide on-orbit radiometric calibrations of these instruments.

The modeling of interplanetary energetic particle transport has long been hampered by an incomplete understanding of turbulent magnetic field-line (MFL) wandering (FLW) and of the microphysics of particle pitch-angle scattering (PAS). In the classical description of particle transport where the particles are scattered in pitch angle while roughly following the wandering field lines, FLW is described only on the largest size scales and PAS is assumed to be produced mostly by the far shorter resonant size scales of the wave-particle interaction. The deficiency of this description is that the effects of all the intermediate scales of the turbulence over orders of magnitude are ignored and a large fraction of the turbulence spectrum is left out of the description.

The objective of the proposed research is a realistic description of the dynamics of charged energetic particles in turbulent fields typical of the solar wind (SW) between the Sun and 1 AU, including all the intermediate nonresonant scales that were neglected earlier. This description requires understanding the MFL transport and dispersion on a very broad range of size scales, and the scattering and dispersal of particles in those fields.

Using ACE and Wind data, a detailed analysis of solar flare particle-intensity time profiles will be carried out to search for direct observational clues about SW FLW and particle scattering, and to test innovative theoretical/numerical developments. These developments include the simulation of wandering MFLs and particle trajectories together in the same turbulence to quantify the effects on the particle transport of MFL cross-field displacement, MFL separations from each other, drifts and pure particle scattering across and along MFLs, and the analytical evaluation of each of these effects, without assumption of single finite correlation length.
This Solar and Heliospheric Physics SR&T project addresses the NASA strategic goal 3B of "understanding the Sun and its effects on Earth and the solar system" with the strategic outcome 3B.1 of "understanding fundamental physical processes of the space environment from the Sun to Earth, to other planets, and beyond to interstellar medium."

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**John Raymond/Smithsonian Institution Astrophysical Observatory (SAO)**

**Post-Eruption Heating of CME Plasma**

Four independent types of observations -- UV spectroscopy, EUV imagery, in situ ionization states and in situ temperature measurements -- show that the plasma in Coronal Mass Ejections is strongly heated long after it leaves the surface of the Sun. In all cases where the comparison has been made, the energy added as heat is comparable to or larger than the kinetic energy of the CME ejecta. Therefore, it is necessary to investigate this heating in order to determine the energy budget of flare/CME events and understand the physics of the eruption.

The observational studies have been limited to a handful of events for each type of observation, and no event has been analyzed with more than one type of data. We propose to remedy this by increasing the sample of events and by combining UV spectroscopy, EUV imaging and X-ray imaging for some of the events. We will also improve the models used to extract heating rates by updating the atomic rates, by better incorporating acceleration, and by improving the treatment of thermal conduction.

Finally, we will investigate one potential heating mechanism, the dissipation of free energy in a twisted flux rope, to obtain estimates of the spatial and temporal profiles of the heating rate.

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**Daniel Savin/Columbia University**

**Laboratory Measurements of Dielectronic Recombination and Electron Impact Ionization in Support of NASA's Heliophysics Research Program**

Much of our knowledge of the outer solar atmosphere and solar wind rests on our understanding of the underlying charge state distribution (CSD) for the observed gas. This in turn depends on accurate rate coefficients for dielectronic recombinantion (DR) and electron impact ionization (EII), the dominant processes which determine the CSD. To address this need, we have been continuously funded for the past 8 years by NASA's Solar and Heliospheric Physics Supporting Research and Technology (SR&T) program. During this time we have made major progress towards generating more reliable and accurate CSDs. For the past two years of our current SR&T grant, the bulk of our efforts have focused on laboratory DR measurements but recently we have expanded our efforts to include EII. We have published DR data for Fe XIV, Fe XV, Fe XXII, and Si IV. We are currently analyzing DR data for Fe VIII, Fe IX, Fe X, Fe XI, and Fe XVII. For EII, we have published measurements for C III, N IV, and O V and are currently analyzing
measurements for C IV, C V, and O VII. Additionally, using state-of-the-art theoretical DR data, the calculation of which was motivated in part by our experimental work, we have generated new CSDs for gas in coronal ionization equilibrium for all elements from H to Zn. We have used these data to re-analyze SUMER coronal observations and have also derived a new and mathematically more rigorous method to derive average emission measures and temperatures from solar observations. Here we propose to complete the DR and EII analysis for the systems listed above and publish the results. Additionally, we will perform DR measurements for Fe XIII, Fe XII, and Fe VII and EII measurements for Na VI, Na V, and Mg V.

**John Seely/Naval Research Laboratory**

**Ultra-Stable Extreme Ultraviolet Solar Monitor using Zone Plates**

An ultra-stable EUV solar monitor using Fresnel zone plates will be developed and tested to the TRL 6 readiness level. The diffraction efficiency, imaging, and robustness properties of zone plates will be developed and optimized for the measurement of the absolute solar emission in the soft x-ray and extreme ultraviolet (EUV) wavelength regions. Zone plate support meshes will be designed, implemented, and vibration tested that are capable of surviving launch. The zone plate efficiencies will be measured using high-resolution, monochromatic, polarized synchrotron radiation and will be modeled using the PCGRATE computer code. An optimized EUV solar monitor will be designed and fabricated that implements a robust zone plate on a support mesh and a solar-blind SiC detector. The end product will be a prototype flight solar monitor that is absolutely calibrated, robust, small, and light weight. This work will solve the problems associated with present solar monitors using transmission gratings (visible light sensitivity, low EUV signal to noise, off-axis sensitivity variations) and reflection gratings (efficiency changes from surface contamination and oxidation, large size and mass, high cost). The end product is an absolutely calibrated prototype flight radiometer for the 30.4 nm He II emission and tested to the TRL6 readiness level.

**Meredith Wills-Davey/Smithsonian Institution**

**Tackling the Quandary: What are Coronal EIT Waves?--Using Multi-Spacecraft Combined Data Analysis to Determine the Physics of Transient Solar Global Events**

Coronal EIT waves are global disturbances of the solar corona, and are strongly correlated with the origins of Coronal Mass Ejections (CMEs). Despite much work, a satisfactory understanding of coronal waves continues to elude researchers. There are an array of dramatically different suggested theoretical models, each of which find support in observational evidence. Regardless of the different interpretations, there has consistently been consensus in the literature that two types of expanding bright fronts exist - (i) semi-isotropic and diffuse, and (ii) arc-like and sharp - and are both considered EIT waves; however, this differentiation is purely morphological, with little understanding of the physical reason behind the duality. It is also widely acknowledged that, in spite of the strong EIT wave-CME connection, not every CME has an accompanying EIT wave.
We will consider the following objectives:
- Whether there is a true dichotomy between the two types of EIT waves and, if so, its physical nature.
- Whether the various models for EIT waves can be constrained using new observational analysis.
- Whether new high spatiotemporal resolution data can determine why every EIT wave has an associated CME, but the converse does not apply.

This study is timely, as it will be conducted in the rise phase of the new solar cycle, which SOHO/EIT has shown to provide some of the best conditions for observing coronal wave events. The launch of SDO/AIA will also provide the opportunity to study EIT waves at higher spatiotemporal resolution than ever before. With these results, we will be able to conclusively determine which EIT wave models are unphysical and substantially narrow the range of viable candidates for which current EIT wave theory correctly describes the phenomenon.

Ming Zhang/Florida Institute of Technology
An investigation of cosmic ray modulation and acceleration in the global heliosphere

The goal of this research is to understand what causes cosmic ray modulation in the outer heliosphere and heliosheath. The study will lead to better understanding of space radiation environment at Earth too. A broader goal is to gain physical understanding of the solar wind, magnetic field and energetic particles in the heliosphere, particularly the heliosheath.

We do calculation of cosmic ray modulation and acceleration in 3-d realistic heliospheric magnetic fields from a MHD model with interstellar neutrals. With the simulation of Markov processes to particle transport, we can separate or identify the effects of particle acceleration by the termination shock and modulation by the solar wind and the heliosheath. Tasks: (1) Rebuild our existing 3-d modulation code with output from a more realistic multifluid MHD heliosphere model that incorporates the effect of interstellar neutrals. Validate model calculations. (2) Perform investigations of modulation mechanisms, which include the effects of particle transport (diffusion and drift) in the heliosheath, propagating GMIR, the deceleration of solar wind by interstellar neutrals ahead of the termination shock and the acceleration of cosmic ray by the shock. (3) Analyze cosmic ray data (spectra, gradients, and time profile) to test models of the heliosphere, cosmic ray propagation, and particle transport coefficients.

This project combines research areas from two separate groups: MHD-neutral modeling of the heliosphere and simulation of cosmic ray propagation in 3-d. The combination will enable us to make significant advances on problems whose scope exceeds the ability of individual groups. Additional data analysis efforts ensure us to make the best physical insight out of observations in the outer heliosphere. The results should also have impacts to other areas of space physics and high-energy astrophysics, such as solar energetic particles and cosmic ray acceleration and propagation in the interstellar medium.