I. Summary

Our team consists of a consortium of five universities, two other domestic institutions and three foreign institutions. The five are New Jersey Institute of Technology (NJIT), University of Maryland (UM), University of New Hampshire (UNH), California Institute of Technology (Caltech), and University of Alabama in Huntsville (UAH). The domestic partners are Naval Research Lab and Lucent Technologies. The central theme of our proposal is to develop world-wide, ground-based solar observing systems for continuous, real-time monitoring of the key solar activity inputs to Space Weather, and to use these data along with space-based solar and heliospheric data to forecast and predict the initiation of space weather events, follow their propagation and development in the heliosphere, and predict their likely impact on the near-earth environment. In this, we propose to develop a basic understanding of the processes underlying Space Weather –beginning at the source. We propose to utilize NJIT's existing, unique optical and radio observing facilities at Big Bear Solar Observatory (BBSO) including our various magnetographs, and our global H-alpha network, and Owens Valley Radio Observatory (OVRO) solar array for microwave radio imaging spectrometry. We also propose to further extend these in two key areas – microwave radio spectrometry and optical vector magnetograpy – with world-wide networks capable of 24-h coverage of the sun.

For heliospheric observations, we will rely on spacecraft data from SOHO, TRACE, Yohkoh, Wind, ACE and IMAGE. To forecast and predict the initiation of events, their propagation, and potential impact at the earth, we will perform correlative studies, numerical and theoretical modeling encompassing the entire solar-surface-to-magnetosphere system.

Using the expertise of our team, we will emphasize: (1) the physical cause of and correlations among different types of solar activity (flares, filament eruptions, and Coronal Mass Ejections (CMEs), (2) prediction and/or forecasting of solar activity, (3) real-time prediction of properties of magnetic clouds resulting from CMEs, (4) study and perhaps forecast of >10 MeV proton (SEP) events, and (4) prediction of likelihood and magnitude of geomagnetic storms.

II. The Science Team

1) From NJIT, which operates BBSO and the Solar Array at OVRO, the members are Phil Goode, Director, BBBSO, Distinguished Professor of Physics; Haimin Wang, Associate Director, BBSO, Associate Professor of Physics; and Dale Gary, Director, Solar Radio Array, Associate Professor of Physics

2) Paul Bellan, Professor of Applied Physics, Caltech does laboratory modeling and theory of filament destabilization.

3) Terry Forbes, Research Professor, UNH does MHD Modeling of filament eruptions, flares, and magnetic reconnection

4) Profs. Stephen White and Mukul Kundu, UM, do radio observations, modeling, and interpretation of radio data

5) S.T. Wu, Director, CSPAR, Distinguished Professor, UAH, does modeling of CMEs and the solar wind.

6) Dr. James Chen, (title?) (NRL), does CME modeling, magnetic cloud modeling, and the prediction of geomagnetic storms.

7) Dr. Louis J.Lanzerotti, Distinguished Member of Technical Staff, Lucent Technologies does heliospheric research.

8) International Partners (we are currently negotiating with other possible partners for radio and magnetograph sites) in Kanzelhohe Solar Observatory in Austria, Beijing Observatory and Yunnan Observatory in China

III. Instruments

1. Halpha Network

Based on our successful experience in making high resolution full disk Halpha observations at BBSO, and the urgent need to monitor the evolution of the solar chromosphere continuously during the solar maximum, we have deployed a network for Halpha full disk observations utilizing existing facilities at BBSO in California, Kanzelhohe Solar Observatory (KSO) in Austria, and Yunnan Observatory (YO) in China. Each of these observatories has over 300 sunny days a year, good seeing conditions, competent observing staffs, and well-established Halpha telescope systems. 2K$\times$2K digital cameras have replaced the film systems in KSO and YO. The upgrade in BBSO is a new 2K$\times$2K digital camera with 14 bits instead of 8. We also provided KSO and YO the data reduction software and analysis techniques already developed at BBSO, which have significantly improved their data quality, while providing a consistent and linked data set. KSO and YO provide the manpower required to collect and reduce their data. With this network, we can monitor solar chromospheric activity with $1''$ pixel resolution and one minute cadence round-the-clock for most of the year, with the best available data quality. The network hardware is supported by National Science Foundation, and the network is in full operation. The three observatories are in ready e-mail contact for prompt forecasting and reporting.

2. Vector Magnetograph Network

BBSO and Huairou Observing Station (HSO) of Beijing Observatory have collaborated in round-the-clock vector magnetograph observations since 1988. Our night gap is 4-8 hours. We are seeking a third partner to form a 3-station vector magnetograph network.

The requirement of the station is: provide a telescope (20cm or larger), a tunable narrow bandpass filter ($<$0.25A). If the proposal is funded, we will provide liquid crystal modulators, a 1K$\times$1K 12-bit SMD camera, computer system and the software. The partner will then operate and maintain the system, do the calibration, acquire data and participate in data reduction.

3. Radio Network

We are currently building at NJIT, for Lucent Technologies, a small (2 meter diameter) radio telescope for monitoring solar bursts, called the Solar Radio SpectroPolarimeter (SRSP). This telescope is highly automated, based on a similar system being deployed by the US Air Force, called the Solar Radio Burst Locator (SRBL–see the web page at http://srblserver.caltech.edu/). The telescope that we are building, the SRSP, is somewhat different from SRBL, in that improves on sensitivity to weaker bursts by replacing the spiral feed with a linear one. The trade-off is that it does not have the capability to locate bursts on the disk, but the linear, dual-polarized feed allows a continuous recording of the full burst spectrum from 1-18 GHz in two polarizations. Thus, it is complementary to the Air Force SRBL system.

As an equipment procurement associated with this proposal, we propose to build two additional dishes to be placed in strategic locations, at existing radio sites, one in Europe and one in the Asia/Pacific region, to provide continuous 24-hour coverage of solar bursts.

The system is designed for unattended operation for up to weeks at a time, with the data being taken in a single, standard mode that does not normally require intervention. Each day the telescope goes through some calibration tests, does an interference survey to avoid "problem" frequencies, acquires the Sun, and takes data. It has an automatic warning system when it detects a flare. The data would normally be accessed from a central location over the internet. Repair and maintenance of the telescopes would be the responsibility of the selected sites, with consultation with the NJIT group.

4. Space Data

SOHO: LASCO, EIT and MDI

Wind and ACE

IMAGE

IV. Basic Optical Observational Scientific Objectives

1. We will use the data from our new, three-station Hα network to continuously monitor the whole sun with 1 arcsec pixel resolution and 1 minute cadence. This unique data set will enable us to provide real-time reports of all flux emergences, filament disappearances and flares – all with high resolution and cadence. Based on the detailed structure of the active regions and filaments, we will predict the probability of flaring in each particular region, and the probability of the eruption of filaments. Our software for data analysis will be available to the ISOON project, and our data will supplement and complement those which will come from ISOON.

2. We will use combined high resolution vector magnetograph data from BBSO and Huairou Solar Observatory in China (and possibly the 3rd station) to monitor the magnetic structure of solar active regions almost continuously. Depending on the time of year, the night gap is between 4 and 8 hours for our present two station network. Based on real time monitoring of the magnetic evolution and structures, we will make forecasts of solar flares. The quantitative parameters that we will develop, which will aid forecasts, include integrated magnetic shear, total and net vertical electrical currents in the target active regions. Both current and shear represent free energy stored in magnetic fields.

3. We will carry out a statistical study of filament eruptions and flares, their underlying magnetic structure, the onset of Coronal Mass Ejections, interplanetary magnetic clouds and geomagnetic storms. The results from this statistical study will provide better tools for predicting solar activity and geomagnetic storms. Filament eruptions and flares will be compared with magnetic field data observed by ACE and Wind, and with geomagnetic indices.

4. We will upgrade the daily forecasts we now place on our web page to include the above mentioned forecasting and monitoring information: curves of electric currents and shears of the most important active regions; a list of all filaments and filament disappearances; a list of new flux emergences, activity reports and warnings from each of the three stations of our network. We will also provide data and forecasts to ISOON.

V. Basic Radio Observational Science Objectives

1. The microwave spectral data will pertain to the high-energy component of solar flares, and diagnostics of the energy release region such as magnetic field and plasma parameters. We will use the microwave spectroscopic data to do a correlation analysis of microwave spectral characteristics with other characteristics such as optical, hard X-ray, and heliospheric (SEP) events. Successful correlation of robust characteristics in the radio spectra (e.g. spectral hardening through the burst, or the presence of highly polarized, coherent emission in the spectrum) with later production of interplanetary protons will allow us to forecast when such damaging radiation may occur near the Earth. We anticipate that with a world-wide network we can give a warning tens of minutes to hours ahead of the arrival of these particles.

2. More subtle characteristics of radio phenomena, such as spatial characteristics of interacting magnetic loops, will be studied with the multi-frequency imaging data available with the Owens Valley Solar Array (OVSA), to shed light on the development of instabilities in the solar atmosphere that lead to interplanetary events. The goal is to understand these interactions and recognize the important pre-event geometries that signal the likelihood of activity.

3. Assuming that our proposed world-wide radio network is available, we will compare the 1-18 GHz spectral characteristics of solar bursts with the metric radio events that are observed in Europe and the Asia/Pacific region. There are presently no meter-wave spectrographs in North or South America with which to compare, so without the network this aspect will not be possible. With the network, we will be able to link solar radio events near the surface with type II/IV events seen in ground-based metric spectrographs that are clearly associated with CMEs and interplanetary shocks. We will also follow these events into interplanetary space when they are observed with the radio spectrograph on the Wind spacecraft. We will seek signatures in such events, as well as magnetic geometries predicted by our heliospheric modeling, that are predictive of highly geo-effective CMEs and interplanetary shocks. We will incorporate any observable parameters into a prediction model that can be used to give real-time forecasts and warnings of impending activity.

VI. Solar Events in the Laboratory

Prof. Bellan (Caltech) can produce filaments in the laboratory replicating what happens on the sun. This work has helped motivate observational and theoretical work. We intend to use the observational results to guide laboratory studies and vice-versa. Also, the output of the theoretical modelling of filaments and CMEs will be be tested in the laboratory.

7. Theoretic modeling: (Forbes, Wu, Chen)

8. Geospace part (Lanzerotti?)

9. Others: B.C. Low, Joselyn, Russ Howard, Rutten, Neidig, Englemann