VIRGO Science Proposal E4
Total solar and spectral irradiance variability related to solar magnetic activity

Main Investigator

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Objectives

The SOHO/VIRGO experiment will provide measurements of solar irradiance in the entire spectrum and at various wavelengths. The PMO6-V and DIARAD active cavity radiometers will perform measurements of total solar irradiance. The solar spectral irradiance will be measured by three-channel SunPhotometers (SPM) at 402, 500 and 862 nm. The main objective of the proposed research is to (1) incorporate the VIRGO data into the long-term high precision total irradiance database maintained for climate studies; (2) study the influence of solar active regions and large- scale structures on total solar and spectral irradiance on time scales of days through the mission's lifetime; and (3) to determine the contribution of spectral irradiance changes to the variations observed in the entire solar spectrum. In addition to understanding the underlying physical mechanism of solar irradiance variations, our goal is to develop models of both total and spectral irradiances (near-UV, visible and infrared) to study and understand the climate impact of solar variability.

Scientific rationale

Synoptic observations of total irradiance from space within the last one and half decades led to the discovery of changes in the total solar energy flux from minutes to the 11-year solar cycle. Although considerable information exists about variations in total irradiance, the underlying physical mechanisms are not well understood as yet. One of the outstanding problems in studying irradiance changes is the lack of adequate quantitative physical models. Therefore, empirical models, using full disk surrogates, are used to study and predict the changes in total irradiance. However, the current models do not fully explain the observed irradiance changes during solar maximum. In addition, considerable remaining variability exists in total irradiance after removing the effect of sunspots and bright magnetic features over a broad range of periods. It is not clear whether this residual variability is caused by additional effects, such as large scale structures, radius changes and/or temperature changes.

Although studying solar irradiance in near-UV, visible, and infrared wavelengths is important for both solar and atmospheric physics, no information has been gathered until now on the variations in these wavelengths because of excessive instrument degradation.

Proposed research tasks

The main goal of the proposed research is to identify and characterize the physical properties the various components of the changes observed in solar total and spectral irradiances. Since the VIRGO instruments will observe the Sun as a star, high resolution spatially resolved data will be required to study the observed variations in detail. For this purpose, we will use the images taken by the LOI and SOI/MDI and these space images will be compared and calibrated with high resolution solar images taken from ground-based observatories (Mt. Wilson Observatory, National Solar Observatory at Sac Peak, San Fernando Observatory at Northridge).

Task 1: Separate real solar signals in solar total and spectral irradiance from instrumental effects. A recently developed statistical method: the Singular Spectrum Analysis (SSA) will be applied as an additional tool for separating instrumental noise from real solar signals. SSA gives adaptive spectral filters associated with the dominant oscillations of the system and clarifies the noise characteristic of the data. This method will enable us to study and model the former variations in great detail and isolate the part of irradiance changes of the greatest interest. Contribution of various components of the spectral irradiance changes to the variations in total irradiance will be studied as well.

Task 2: Study the energy budget of active regions. The main goal of this effort is to study the phase difference between irradiance deficits related to sunspots and excess flux associated with faculae. These studies will help to identify the physical mechanism of the re-radiation of the missing energy in the sunspot-related irradiance dips, namely we expect to clarify whether the missing energy is stored in the convective zone or there is a simple re-distribution of solar energy as the active regions evolve and move across the solar disk. This research task will include the classification of sunspots and plages due to their evolution using the high resolution images and the flux budget and line depth parameters from MDI and ground-based observatories.

Task 3: Study the effect of sunspots and faculae on total solar and spectral irradiance as a function of their heliographic coordinates (longitude and latitude). Former studies indicate that the most complex active regions tend to be separated 180 degrees apart, this problem will be addressed during the proposed investigation. Study of the latitude dependence of active regions may help to clarify the degree of irradiance changes related to active regions and to large-scale structures and/or temperature changes. Since a phase-shift has been recognized between the full disk solar magnetic flux and solar total and UV irradiances at the beginning of the rising portion of solar cycle 22, a detailed comparison of irradiance values with high resolution solar images and magnetic maps will be carried out. These investigations will give a better understanding of the underlying physical processes inside the Sun (solar dynamo).

Supporting ground-based observations: (1) Observations at the san Fernando Observatory, California State University at Northridge by the Cartesian Full Disk Telescopes at 672.3 and 472 nm for observing sunspot characteristics and at 393.3 nm for observing plage characteristics; (2) Precision Solar Photometric Telescopes (PSPT) at the National Solar Observatory at sacramento Peak that will provide full-disk, broad-band photometric observations of sunspots and bright magnetic features; (3) On-going routine CaII K-line observations at Sac Peak and Big Bear Solar Observatories. Current observations at the Mt. Wilson Solar Observatory generate daily spot, plage and quiet-Sun indices based on magnetic field strengths and areas. The current synoptic Mt. Wilson data also include spatially resolved magnetograms taken simultaneously in FeI 525 nm and CrII 523.7 nm lines.

Supporting space observations: (1) high resolution solar images from SOI/MDI; (2) Data from LOI on VIRGO.

Responsibilities and Management

The proposed research will be a collaborative effort between the VIRGO and MDI teams as well as participating ground-based observatories. The generation of the PMO6-V and DIARAD total irradiance will be the responsibility of J. Romero and D. Crommelynck. R. Helizon and J. Pap will help to incorporate of the VIRGO data into the long-term irradiance database via the mutual intercomparison of the ACRIM and the proposed DBSIM total irradiance data. The generation of the SPM spectral irradiance data will be the responsibility of C. Wehrli. J. Pap will be responsible for the overall integrity and management of the proposed research. Analysis of solar images will be carried out with P. Scherrer, T. Hoeksema, G. Chapman, and J. Kuhn based on state-of-the-art automated image processing technique currently under development. Study of the evolutionary effects and modelling efforts as well as application of SSA will be the responsibility of J. Pap in collaboration with C. Frohlich and R. Ulrich.