VIRGO Science Proposal E1
Solar Radius Variations

Main Investigator

C.Fröhlich

Co-Investigators

T. Appourchaux, V. Domingo, D. Gough, J. Kuhn, J. Pap, A. Vigouroux

Objectives

The LOI instrument of the VIRGO experiment will produce time series of data proportional to the polar and equatorial solar diameters. The oblateness will be measured with a precision of about 0.1". The main objective of the proposed research is to detect and measure the amplitude of solar diameter changes and their relation to the variations observed in total solar irradiance. There have been several theoretical discussions of how dynamical and thermal modulation of the internal structure of the Sun, including the effect of magnetic fields, both visible at the surface and those lingering somewhere inside the convective zone, can lead to changes in the solar radius and luminosity. The relative magnitudes of these changes could provide a diagnostic tool to estimate the location of the primary modulations.

Rationale

Study of solar radius changes is of fundamental interest to astrophysics. Moreover, it is likely to increase our understanding of the associated luminosity changes, which is not only of astrophysical significance but is also pertinent to the terrestrial climate. Radius measurements over the last three centuries (both "historical'" and "modern" measurements) display considerable variations. However the basic questions:

- whether the observed variations have any connection with unknown phenomena deeply seated within the convective zone; or
- with a time-varying asphericity of the Sun; or
- to what degree the observed variations are affected by atmospheric effects, such as the quasi-biennial oscillations, remain still unknown. Theoretical discussions suggest that the relative amplitude of solar radius variations due to convection is as small as 2x10^{-6}. The relative variation associated with dynamical oscillations is probably at most 10^{-8} per mode. The current measurements by the Astrolab Experiment at the CERGA Observatory (France), which started in 1978, indicate that the variations in the solar radius can be of the order of 10^{-5}.

If this observed variation corresponds to the displacement of solar material, it probably implies that the process causing it lies near the base of the convection zone, and is not confined solely to the upper convective boundary layer.

Proposed research tasks

(1) Comparison of VIRGO measurements with ground-based observations in order to estimate the atmospheric effects and to provide a calibration for ground-based observations. This could improve the accuracy of long-term radius observations. Furthemore, those measurements will provide the first continuous monitoring (allowing maximum signal/noise ratio for short time scales) which could be compared to the CERGA Astrolabe Experiment.
(2) Estimation of the contribution of solar active regions close to the limb to the observed radius changes. For this purpose, the MDI data: limb profile and flux budget will be included into the analysis. The goal of this research effort is to remove the signals arising from the effect of solar active regions to make sure that the possible diameter changes are not related to solar activity features. For this purpose, the LOI images will be compared to the MDI high resolution (1024×1024) filtergrams taken near the 676.8 nm Ni I spectral line.
(3) Study the phase relations between the solar radius measurements and other solar activity parameters, such as the magnetic flux, solar total and spectral irradiance, and low degree p-mode frequencies in order to study the sign between these parameters. Former studies have shown, for example, that the radius and the low degree p-mode frequencies are anti-correlated, suggesting the possibilty that dynamical processes detected in the upper solar layers are closely related with perturbations inside the Sun.

To study the relation between solar radius and irradiance as well as variations in the solar magnetic flux, we shall apply the same technique (wavelet analysis) that has been used for studying radius changes observed from the ground. Wavelet analysis allows one to separate efficiently the short-term variations from the long-term ones, and it also will be used as a time-frequency analysis to search for periodicities of 27, 300, 1000 days.

Responsibilities and Management

C. Fröhlich will be responsible for the overall management. T. Appourchaux will be responsible for providing the radius data sets corrected and calibrated for instrument effects. J.Pap will participate in the analysis of solar active regions (spots, faculae, network) and their effect. A.Vigouroux will participate in comparing the LOI measurements with ground-based radius data. She also will participate in the data analysis and comparison of the radius changes with solar irradiance as a collaborative effort with C. Fröhlich and J. Pap. C. Fröhlich, D. Gough and J. Kuhn will be in charge for the theoretical interpretation of the results.