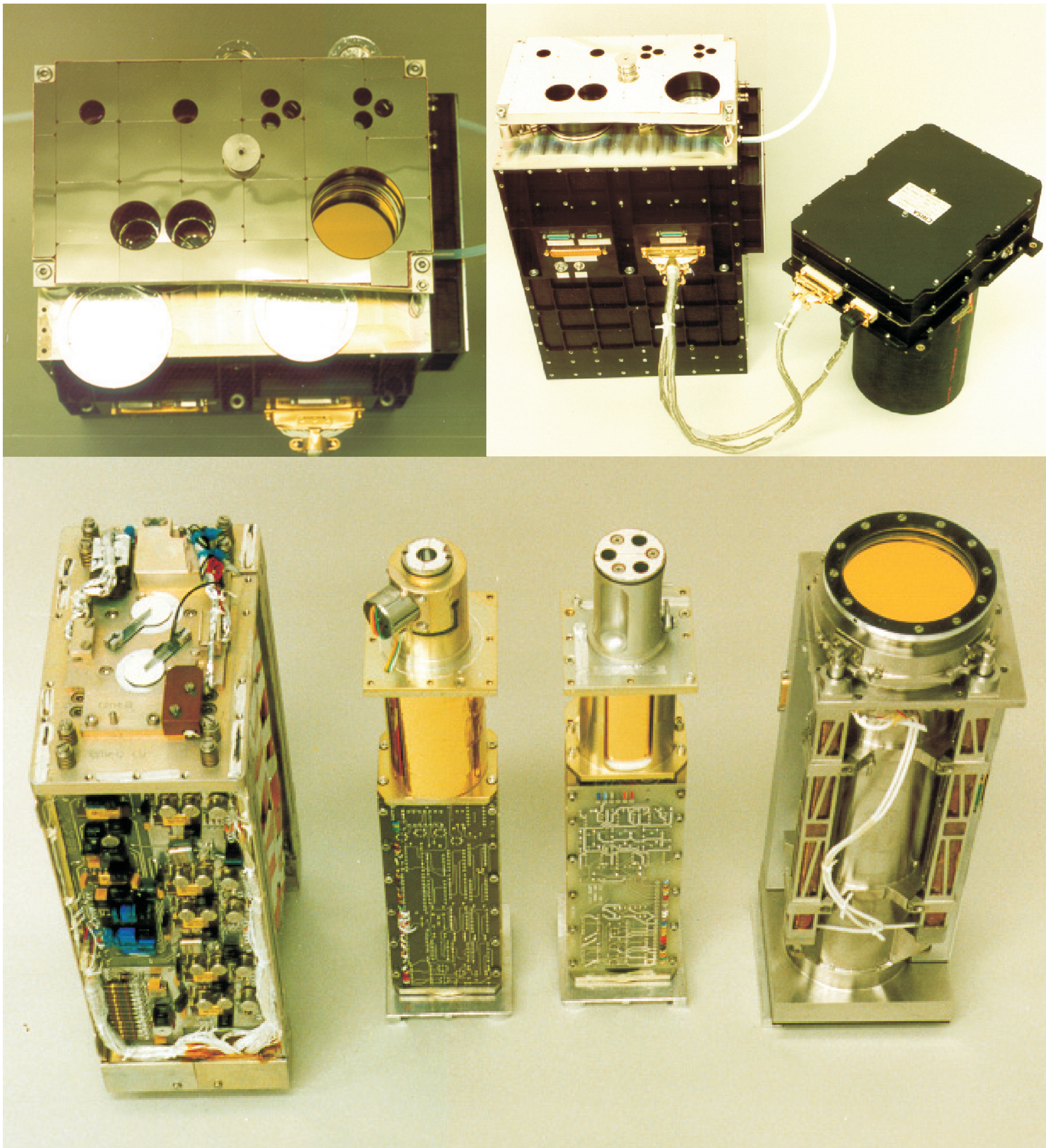
VIRGO II^{+} / PIT

Variability of Solar Irradiance and Gravity Oscillations II-plus



Submitted in response to the Announcement of Opportunity AO 02-OSS-01, for Solar Dynamics Observatory, April 24, 2002

Front cover:

VIRGO sensor package with its protective covers opened. Upper row of apertures are for PMO6 radiometers and SPM filter radiometers, lower row apertures for DIARAD radiometer and LOI instrument.

VIRGO sensor package (left) and power supply (right) put on a stand depicting their arrangement on the SOHO spacecraft.

VIRGO II^{+} flight hardware, comprising the two total solar irradiance monitors DIARAD and PMO6, the 3-channel Sun-Photometers and the Luminosity Oscillation Imager LOI (from left to right). The latter one will be upgraded with a 1000 x1000 APS detector.

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1. Scientific Goals and Objectives

1.1 Executive Summary

We propose VIRGO II^+ for the Solar Dynamics Observatory (SDO) in response to the AO for a generically called Photometric Imaging Telescope (PIT). VIRGO II^+ is based on the (partly upgraded) flight spares of the very successful VIRGO (Variability of solar IRradiance and Gravity Oscillations) investigation that has been operating flawlessly for more than 6 years on SOHO (SOlar and Heliospheric Observatory). By upgrading the detector of the Luminosity Oscillation Imager (LOI) to LOI^+, to provide significantly better image resolution, specific questions related to spatially resolved observations combined with highest photometric accuracy can be addressed. This LOI^+ combined with the existing flight spare of the already proven VIRGO instrument forms the basis of the VIRGO II^+ proposal.

Background: The most important discovery of the two and half decade long irradiance observations is that total irradiance varies over the solar cycle, being higher during maximum solar activity conditions (Willson & Hudson, 1988). Based on these irradiance measurements, proxy studies have suggested that solar variability could be on the verge of producing significant terrestrial climate change (Schlesinger & Ramankutty 1992; Hansen et al. 1993; Lean et al. 1995; Crowley & Kim 1996; Reid 1991; 1997; Solanki & Fligge 1998). In addition, theoretical considerations and study of the variability of solar-type stars indicate that we cannot rule out the possibility of significantly larger variations, in the range of 0.4-0.7% (e.g. Nesme-Ribes et al. 1994; Zhang et al. 1994; IPCC 1995 Report, Lockwood et al. 1992; Radick et al. 1998), than the 0.1% change observed over the last decades. The well-documented Maunder minimum in the late 1600's (Eddy 1988) which coincided with the ‘Little Ice Age' in Europe and the North Atlantic regions also illustrates the potential climate impact of solar irradiance fluctuations.

Scope of Investigation: Given that the solar energy output establishes the Earth's radiation environment, controls its temperature and atmospheric composition, and is the ultimate natural driving force for terrestrial climate, we **propose a new way to measure and understand the role of solar variability in climate change**, which is a major component of NASA's "Living with a Star" (LWS) program. The VIRGO II^+ experiment will examine the mechanisms by which energy is stored and luminosity is modulated in and by the solar convection zone. The Sun's fundamental energy source is the nuclear conversion of H to He in the core. Given the long photon diffusion time scale of the order of a million years from the interior to the outer boundary of the core, there is no doubt that the energy production cannot influence the solar output. However, observations show that the solar output varies globally as well as locally and hence there must be an intermediate reservoir. There are different possible mechanisms for storing energy over time scales of years and all of them perturb the equilibrium stellar structure in a distinct way, which may change the solar radius (e.g. Spruit 1982, Lydon & Sofia 1995; Sofia 1998). They also produce different distributions of brightness on the solar surface. Thus, determination of solar radiances over the whole disk, the solar radius changes as well as simultaneous solar irradiance observations will reveal the physical mechanisms responsible for variations of the solar energy output.

Instrumentation: The VIRGO II^+ package includes (a) two absolute radiometers, DIARAD and PMO6-V, as in SOHO/VIRGO to measure total solar irradiance; (b) a 3-channel filter radiometer to measure spectral irradiance at three selected wavelengths, as in SOHO/VIRGO, and (c) LOI^+, a significantly improved version of the SOHO Luminosity Oscillation Imager, equipped with a 1000x1000 APS detector. The telescope is designed in an optically straightforward way and uses a spectral filter, which selects a region in the spectrum that is dominated by the continuum. This simple design avoids most limiting factors encountered for measurements of solar radius and shape changes with an instrument like SOHO/MDI. The LOI$^+$ wavelength range will be identical to one of the filter radiometers' channel. In this way both the irradiance and the radiance over the whole solar disk are measured simultaneously, so that the spatial source of the irradiance variations can be followed.

Measurements: VIRGO II$^+$ on SDO will trace luminosity variations from the base of the convection zone up through the photosphere during the six year mission from the next activity minimum to the following maximum. Accurate total irradiance measurements and photometry will detect magnetically induced entropy fluctuations on daily and longer time scales as well as the solar oscillations on time scales of hours. By additionally observing small changes in the solar interior structure caused by the solar cycle, we can investigate the physical mechanisms governing luminosity and radiance changes. Accurate total irradiance measurements and spectral photometry will detect magnetically induced entropy fluctuations on daily and longer time scales as well as the solar oscillations on time scales of hours. LOI$^+$ measures the intensity perturbations on the limb caused by the oscillation and we may be able to finally detect and identify low frequency oscillations, such as low order p and g modes.

VIRGO II$^+$ team: The investigation team is very experienced and comprises most of the SOHO/VIRGO team members. The team is well-qualified to realize all aspects of the experiment. This includes defining the scientific program, prioritizing objectives, quantifying observing requirements, projecting realistic instrument performance, updating the instruments to improved performance, operating the instruments on-orbit, and analyzing and interpreting the scientific data for both solar physics and climate studies. The PMOD/WRC takes the lead for the modification of the VIRGO II$^+$ package supported by the other hardware institutes and in particular by the ESA Research and Science Support Department that is responsible for the modification of the LOI to the VIRGO II$^+$/LOI$^+$. We expect a broader science community to be involved in much of the analysis and interpretation of the VIRGO II$^+$ data set and therefore, we will implement an open data policy. The VIRGO II$^+$ data will be collected and stored at the VIRGO Data Center at the Institute of Astrophysics (IAC) at Tenerife, Spain.

Education/Public Outreach (E/PO): The E/PO activities will be carried out as a cooperative effort between the U.S. and European team members. The VIRGO II$^+$ E/PO plans will be coordinated with other SDO and general LWS E/PO activities as well as with ESA Education Office. In particular, the VIRGO II$^+$ E/PO activities will involve (a) graduate student summer programs; (b) colloquium lectures to undergraduate and graduate students; (c) popular science articles and lectures, (d) media relations, and (e) limited partnership with the Smithsonian National Art and Science Museum (NASM) in form of displaying SDO results in NASM and hosting public lectures.

1.2 Statement of the Problem

Questions like "Why does the solar luminosity vary and could it change on human timescales by enough to affect terrestrial climate?" play a critical role in the LWS investigations. As important as these questions are, we don't have answers yet since the Earth's climate is the result of a complex and incompletely understood system of external inputs and interacting internal parts. Climate change can occur over a range of time scales, may be driven by natural variability – including solar variability – and/or anthropogenic causes and may be identified through the study of a variety of measurable parameters. Global climate change in response to human influences is one of the pressing threats facing science today. Predictions of climate change in response to greenhouse-gas emissions by the current generation of climate models roughly agree on prospects for globally warmer climates and more vigorous hydrologic cycles. However, climate models are limited, in general, by incomplete understanding of physical processes and their relative importance, insufficient data coverage, and intrinsic instabilities and chaotic behaviors. In addition, the precise magnitudes and combinations of forcing that determine global climate variation on the scale of anthropogenic climate change remain elusive.

Since the solar energy flux at various wavelengths is one of the measurable parameters, it is an important issue to which degree solar variability may affect climate. Although the Sun supplies most of the energy for the Earth's atmospheric and climate system, the measured 0.1% level of the long-term total irradiance changes is considered to be too small to cause changes in the Earth's climate above its intrinsic noise. However, despite the measured small changes in total irradiance, some evidence in the climate record does point to a solar influence on time scales of decades to centuries. For example, Friis-Christensen & Lassen (1991) found a direct correlation between the Northern Hemisphere temperature anomalies and the length of the solar cycle, while Reid (1991) showed a correlation between global sea surface temperature anomaly and the envelope of the sunspot number record over the last 150 years. White et al. (1997) indicate that sea-surface temperatures and upper-ocean heat contents in each major ocean basin have responded coherently and with similar sensitivities to solar irradiance variations on 11-yr, 22-yr, and secular time scales. Based on the observed near-surface temperature changes during the past 140 years, Schlesinger & Ramankutty (1992) estimated the climate sensitivity and found that the change in global-mean near-surface temperature due to a radiative forcing was equivalent to that for a doubling of the CO^2 concentration. Andronova & Schlesinger (2000, 2001) found that if solar irradiance varied from 1610 to 1978 as constructed from so-called "proxies" (Lean et al. 1995), the so called climate sensitivity is about 50% smaller than if solar irradiance did not change. Accordingly, in terms of anthropogenically induced climate changes and impacts, and policies to abate them, it is important to determine whether solar irradiance varied before the beginning of satellite observations in 1978 by more than it has since 1978.

One of the largest obstacles to understand the climate impact of solar irradiance variations is the lack of understanding of its physical origin, especially when we do not know the physical mechanisms responsible for the solar cycle with sufficient clarity to predict even the well-observed global-scale solar magnetic field evolution. Our understanding of solar luminosity and irradiance evolution rests largely on a foundation built from many years of correlative modeling of irradiance proxies based on solar magnetic activity features, like sunspots and faculae (most accurately obtained from space). Only a few limited, direct observations with the needed high spatial resolution and high photometric precision have been obtained to directly assess physical solar models. There are fundamental limitations to correlative studies which use proxies for physically important observables. For example, such efforts cannot generate answers to questions such as: "Could the solar irradiance vary by more than 0.1% over decades or longer (centuries to interglacial) timescales?" This problem obviously has implications far beyond academic questions related to stellar astrophysics.

Since we cannot wait a century to find out what the solar effect is – a necessary step in assessing the seriousness of greenhouse warming – we must adopt alternate methods to expedite getting this information. Models of the solar interior with variable internal fields indicate that all global parameters (luminosity, radius, and effective temperature) vary as a consequence of structural changes. However, models of the solar interior also indicate that the relationships between variations of the global parameters depend on the details of the internal mechanisms (depth, magnitude of the field, etc.). Consequently, the research strategy should concentrate on measuring solar total irradiance, radius/shape changes and solar oscillations concurrently to determine their relationship experimentally.

VIRGO II+ will investigate how changes in the solar interior and at the surface affect energy flow from the radiative and convection zones out through the photosphere. VIRGO II+ will reveal deep solar interior and surface changes while addressing several long-standing astrophysical problems:

- expansion of our understanding of the long-term solar variability, by incorporating sensitive photometric irradiance measurements from the absolute radiometer and filter radiometer instruments with previous total solar irradiance data, and in particular with photometric images of the radiance;
- measurement of small changes in the solar radius and shape to probe minute variations in the solar gravitational potential and interior stratification,
- the measurement and exploitation of the low-frequency gravity and Rossby wave branches of the solar oscillation dispersion relation with a sensitivity that is at least an order of magnitude greater than previous studies,
- the visualization of solar cycle changes that develop near the base of the convection zone.

1.3 Science aim

We have divided the observational tasks into eight parts below. Task divisions are motivated by distinct scientific questions and by the technical capabilities of the instrumentation. The key questions which VIRGO II⁺ will address are:

1) SOLAR RADIUS: Does the Sun's radius vary over the stable timescale of the SDO mission? Between eclipse periods of the spacecraft we expect to have a radius-change measurement accuracy of about 1 milliarcsec and on longer timescales we can measure 10 milliarcsec radius changes. The detection of radius changes could help us to understand how and where the solar luminosity is gated or stored in the radiative or convection zone?
2) SOLAR SHAPE: Do the solar quadrupole and hexadecapole shape terms vary with the solar cycle and are higher angular order shape terms of significant amplitude? How does the time evolution of the gravitational potential affect our understanding of the convection zone?
3) LATITUDE SURFACE BRIGHTNESS DEPENDENCE: What is the source of the approximately 1K solar latitudinal surface brightness variation? How does it change the total and spectral irradiance?
4) LOCAL BRIGHTNESS CHANGES: On solar rotation timescales, do transient quiet photospheric surface brightness changes follow the distribution of the surface magnetic field or can they be used to predict future photospheric magnetic structure, as some models suggest based on thermal or "antithermal" shadows caused by evolving magnetic structure from near the base of the convection zone?
5) SOLAR IRRADIANCE: What is the spectral distribution of total irradiance variability? How do the transient surface brightness changes affect the total and spectral solar irradiance? To what extent are short- and long-term irradiance changes accounted for by surface magnetic activity, versus global changes, e.g. those described in (1), (3) and (4)?
6) ENERGY AND ENTROPY TRANSPORT: How do magnetic fields near the photosphere and in sunspots and faculae perturb the Sun's emergent energy flux or affect the transport of entropy near the photosphere? How effective is the blocking and channeling of the energy flux by magnetic flux tubes? Astrometric and photometric data of the Sun at this spatially resolved precision have never before been obtained, but are critical for addressing the physical mechanisms for entropy transport near the top of the magnetized convection zone.
7) LOW FREQUENCY HELIOSEISMOLOGY: Can the stellar r- or g-mode dispersion relation be measured from the limb displacement time series – thereby providing a new diagnostic of the dynamic properties (differential rotation and global-scale flows) in the solar convection zone? By combining limb data with the irradiance and LOI⁺ observations can we uniquely identify p modes of very low order – thereby accurately measuring thermodynamic conditions

below the radiative/convection zone boundary?

8) MEDIUM TO HIGH FREQUENCY HELIOSEIMOLOGY: What is the phase shift at all frequencies between velocity, temperature and opacity fluctuations in the solar atmosphere? Is it possible to use the highest frequency ($\approx$ 10 mHz) phase shifts as diagnostic probes of the solar atmosphere at high spatial resolution?

Solar Radius

Key Scientific Questions

- Does the Sun's radius vary over a time scale of a year at the level of 0.1 milli-arcseconds?
- Can these changes be used to understand how and where the solar luminosity is gated or stored in the radiative or convection zone?

Observations of the Total Solar Irradiance (TSI), helioseismic studies, and precise solar photometric measurements all show that the Sun varies globally, as well as locally at the photosphere, during an 11-year solar cycle. Only very recently have helioseismic studies empirically shown that much of the Sun, at least from the top of the interior radiative zone to the photosphere, participates in the solar cycle (Howe et al. 2000). The Sun's likely solar cycle energy storage mechanism (e.g. gravitational or magnetic fields) will change its radius (e.g. Dearborn & Blake 1980; Spruit 1982; Lydon & Sofia 1995; Sofia 1998) with an amplitude which is characteristic of the depth and nature of the perturbation. Thus, sensitive radius-change measurements will greatly improve our ability to isolate and understand the changes in the interior structure caused by the solar magnetic/luminosity cycle.

While ground-based measurements of the solar radius over the last 300 years exist (e.g. Ribes et al. 1991), the results are neither consistent nor conclusive. Historical data show that the Sun's radius may have been larger during the Maunder Minimum, which coincided with extremely cold periods in Europe and the Atlantic regions (Ribes et al. 1991). These results are also suggested by the French CERGA radius measurements which found a larger solar radius during solar minimum (e.g. Laclare et al. 1996; Pap et al. 2001). In contrast, Ulrich & Bertello (1995) found a positive correlation between apparent radius changes and the solar activity cycle. There are also hints of periodic solar radius variations over time scales of 1,000 days to 80 years (Gilliland 1980), but the measurements are generally neither consistent nor conclusive (Parkinson et al. 1980; Brown 1987; Ribes et al. 1991). These controversial results underscore the necessity of more sensitive efforts to measure the Sun's radius changes. The limitation of ground-based measurements due to ‘seeing’ from the Earth's atmosphere has also been recognized by Sofia and his collaborators in their development of the balloon borne Solar Disk Sextant (Sofia et al. 1994).

The MDI experiment offered, for the first time, the promise of very accurate solar radius measurements obtained from space. Figure 1-1 shows the residual MDI radius determination after correcting for the apparent variation due to the SOHO orbit. Residual instrumental errors due to a small yearly solar heating variation of the MDI front window, and larger “jumps" due to internal focus optics changes within the instrument are apparent. After correcting for these errors using an empirical thermal model for the front window, the radius measurements shown in Fig. 1-2 was recovered. The unmodeled linear residual radius change is about 0.008 arcsec/year, but because of the MDI instrument limitations we must treat this as the systematic measurement uncertainty and an upper bound to possible cyclic or secular solar cycle variations. The MDI measurements represent the most sensitive observation of possible solar radius changes that have been obtained, but they do not have sufficient accuracy to detect solar cycle variations.

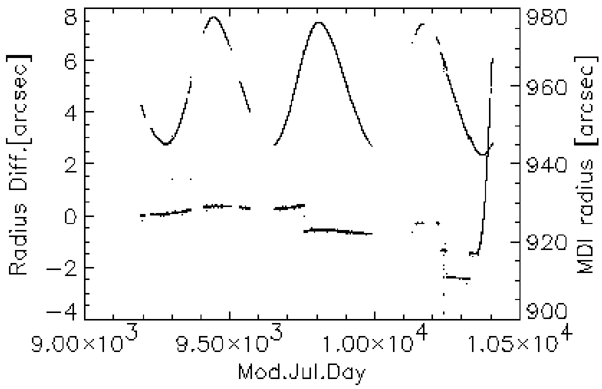

Fig. 1-1. MDI solar radius measurements versus modified Julian day number. The left hand scale shows the residual radius measurement (lower points) after the expected apparent solar radius (upper points and right hand scale) is subtracted. Approximately 3 years of data are shown here.

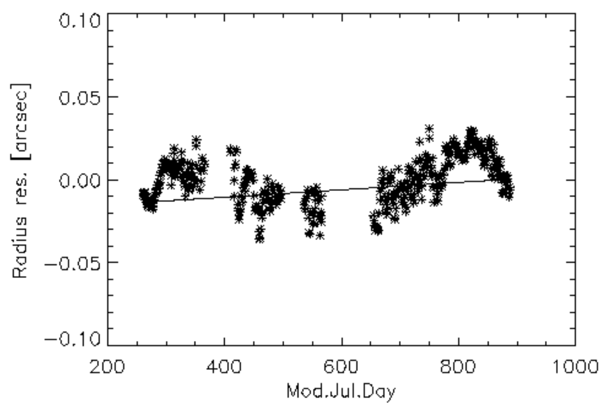

Fig. 1-2. Solar Radius Variation. Derived after applying an empirical instrumental thermal model and focus corrections. The residual solar radius variations (solid line) correspond to 0.008 arcsec/year, although it may be instrumental and non-solar.

In contrast to MDI, the LOI^+ instrument we propose here has a simple and stable optical configuration. We expect it to achieve astrometric accuracy comparable to MDI and the relative radius-change measurements to be more accurate than those of MDI. Because the wavelength setting of LOI^+ at 782 nm is not near and in Fraunhofer lines, LOI^+'s photometry is insensitive to velocity and magnetic field contamination.

VIRGO II^+ Task 1 – SOLAR RADIUS

Radius-change measurements with an rms accuracy of 1 milliarcsec over a timescale of one solar rotation period (27 days) are required. Peak-to-peak systematic radius errors will be smaller than 10 milliarcsec over the mission duration.

Some stellar model calculations suggest that a deeply seated solar luminosity perturbation with an amplitude of 4×10^{-4} can cause approximately a 10^{-6} fractional change in the photospheric solar radius. It may be possible to test these models with a measurement accuracy of 1 milliarcsec. The temporal resolution of these measurements should be at least one solar rotation, although faster radius changes are physically possible and the baseline operation mode should allow this.

Solar Shape

Key Scientific Questions

- Do the solar quadrupole and hexadecapole shape terms vary with the solar cycle?
- Are higher angular order shape terms of significant amplitude?
- How does the time evolution of the gravitational potential affect our understanding of the convection zone?

The theory of the solar limb shape is well established, although current solar shape measurements (also from MDI astrometry) are marginally inconsistent with the shape deduced from the helioseismic solar interior rotation determinations (Armstrong & Kuhn 1999). This is an important problem since the limb shape is a sensitive function of the Sun's gravitational potential and its interior rotation. Thus, the measurement of solar cycle changes in the shape is another important tool for seeing how the solar magnetic cycle causes global changes in the solar interior stratification and dynamics.

Only two high order shape experiments (Lydon & Sofia 1996; Kuhn et al. 1998) have been successful, and they were not consistent. Since these data were obtained at different phases of the solar cycle, they suggest a temporal variability in the solar hexadecapole term. In order to reconcile the solar interior mass and rotation models with the observations, we require shape data that allow the possibility of measuring temporal solar cycle variations.

Progress on this problem depends on measurements obtained with a single instrument over several years. VIRGO II$^+$ will be launched during an optimum part of the solar cycle for this purpose. The most accurate shape measurements are obtained when solar activity does not obscure the photosphere. The SDO mission is launched when the solar activity will still be low and when sunspots and faculae will not dominate the limb shape measurements. Our experience with MDI proves that during this phase of the cycle we will be able to study both the deeper interior changes, whereas we also are sensitive to and can follow the increasing surface activity up to the maximum. While we cannot be certain at what level the gravitational potential or the rotational interior stratification changes will occur at, the evidence from MDI and the known shape-model discrepancies imply that limb coefficient measurement accuracy of better than 0.1 miliarcsec will either establish or refute the hexadecapole variations while extending limb shape measurement sensitivity into a regime where physical changes may be expected.

VIRGO II$^+$ Task 2 – SOLAR SHAPE

Angular harmonic limb shape terms of order 2 – 20 will be measured with a precision of 0.1 milliarcsec rms on solar rotation timescales. This requires occasional rotation of the instrument with respect to the Sun-pointing direction in fixed increments of 9 degrees, in order to calibrate and correct for the instrumental distortion.

The required solar limb shape accuracy is driven by the need to establish or refute hints from other measurements that the gravitational potential varies. The duration of a composite shape measurement which consists of individual limb measurements at various roll angles must be no longer than a few hours because of the requirements imposed by the phase demodulation technique used to separate instrument shape noise from the solar signal (Kuhn et al. 1998). The timescale for global potential changes is long, so that multiple measurements, at least over solar rotation timescales, can be combined.

Solar Irradiance & Brightness Variations

Key Scientific Questions

- How do the transient surface brightness changes affect the total and spectral solar irradiance?
- To what extent are short- and long-term irradiance changes accounted for by surface magnetic activity, versus global changes, such as those of radius and temperature?
- Is the approximately 1K solar latitudinal surface brightness variation seen at the limb due to an intrinsic temperature increase of the whole plasma, or is it caused by the superposition of many localized brightenings caused, e.g., by surface magnetic fields? If the former, then does it change with the solar cycle as predicted by earlier helioseismic solar asphericity determinations?
- On solar rotation timescales, do transient quiet photospheric surface brightness changes predict future photospheric magnetic structure, as some models suggest based on thermal or ‘antithermal’ shadows caused by evolving magnetic structure from near the base of the convection zone?
- How does the non-periodic solar background signal change with solar activity and solar latitude?
- What is the spectral distribution of total irradiance variability?

Relative changes in TSI have been precisely measured for more than two decades by several space experiments, such as the Nimbus-7/HF, SMM/ACRIM I, UARS/ACRIM II, ERBS, EURECA/SOVA, SOHO/VIRGO and most recently by ACRIMSAT (Fig. 1-3). These measurements show that TSI varies over the solar cycle by 0.1%, being higher during maximum activity conditions (Willson & Hudson 1988). Short-term changes on scales of days to months are mainly attributed to the effect of active regions as they evolve and move across the solar disk (Chapman 1987; Fröhlich & Pap 1989, Fligge & Solanki 1998).

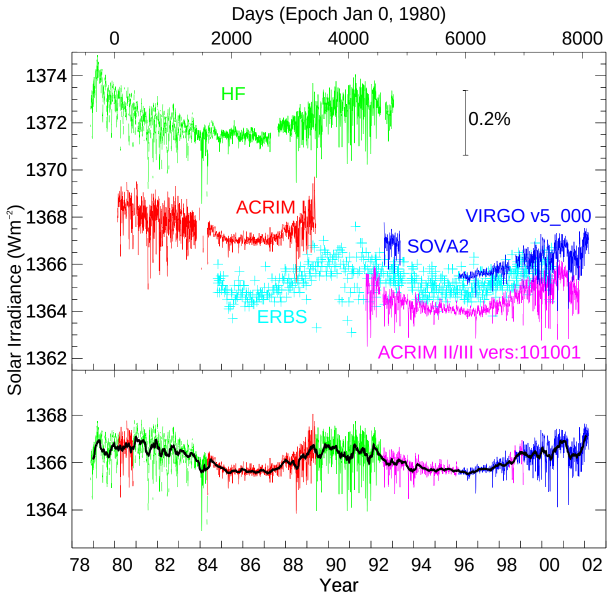

Fig. 1-3. Top panel: Compared are daily averaged values of the Sun's total irradiance TSI from radiometers on different space platforms since November 1978: HF on Nimbus7 (Hoyt et al. 1992), ACRIM I on SMM (Willson 1984), ERBE on ERBS (Lee et al. 1987), SOVA2 on EURECA (Crommelinck et al. 1993), ACRIM II on UARS (Willson 1994), VIRGO on SOHO (Fröhlich et al., 1997) and ACRIM III on ACRIM-Sat (Willson & Helizon 1999). The data are plotted as published. Note that only the results from the three ACRIM, the SOVA and VIRGO radiometers have inflight corrections for degradation. Bottom panel: Daily values of the composite shown on the same scale as the original data above (the data and the plot can be downloaded from ftp://ftp.pmodwrc.ch/data/ irradiance/composite/composite_d24_00.asc).

On time scales of minutes to hours, the variance is determined by granulation and supergranulation and in the 5 min range by the p modes (Fröhlich et al. 1997). On yearly or solar cycle time scales irradiance variability could be related to changes of the solar luminosity directly (e.g. Lydon & Sofia 1995; Kuhn 1996; Lydon et al. 1996).

While considerable descriptive information exists on solar irradiance variations, we lack a consensus on the correct physical model for the observations. For example, some authors find that empirical irradiance models based solely on a ‘tally’ of the surface manifestations of magnetic activity cannot explain all TSI changes (Fröhlich & Pap 1989; Kuhn 1996; Pap 1997; Fröhlich et al. 1997; Wehrli et al. 1998, Fox 2002). Proposed mechanisms for the residual variability range from photospheric temperature changes (Kuhn et al. 1988, Gray & Livingston 1997), convective cells (Ribes et al. 1985), large scale mixing flows (Fox & Sofia 1994) to radius changes (Delache et al. 1986; Ulrich & Bertello 1995; Kuhn et al. 1997; 1998). Very high precision photometric and astrometric data with spatial resolution over a significant portion of the activity cycle are needed to disentangle these sources in the TSI variance.

Recently, Fligge et al. (2000a, b) have been able to reproduce both solar rotation and solar cycle scale variations with models based on the assumption that the surface magnetic field causes the irradiance changes. One of the major uncertainties is caused by the fact that the wavelength channels in which the irradiance is measured (e.g. by the VIRGO SPMs) and the high resolution brightness images currently available (from MDI) refer to different wavelengths. Model calculations are needed to bridge this gap and a free parameter is introduced. VIRGO II$^+$ will provide simultaneous high-precision measurements of the irradiance and of radiances on a 1000x1000 array at the same wavelengths. A direct comparison between the two data sets will be possible, without the added unreliability produced by intermediary models. The results from such a comparison will allow the constraints on surface magnetic-field-based models of solar irradiance to be sharpened significantly. VIRGO II$^+$ will thus provide (together with HMI magnetograms) the data needed to stringently test the magnetic origin of solar irradiance variations.

The temporal and spatial resolution possible with space experiments reveals new (and apparently fundamental) features of the solar convection zone. For example Fig. 1-4 shows a striking dip in the temperature of the extreme south pole (the Sun’s north pole was not visible to SOHO at the time of these measurements).

SDO/VIRGO II$^+$ will allow snapshot observations of higher angular resolution and greater photometric dynamic range throughout its 6 year mission than was available from MDI. We will see the dynamic evolution of entropy perturbations from the base, and throughout the convection zone. Entropy 'shadows' (Parker 1995) or 'antishadows' (Kuhn & Stein 1996) of magnetic changes occurring at the top of the solar interior radiative zone will be revealed from these extremely precise photometric views of the limb. Models, which explain how the solar luminosity is gated by interior magnetic fields as it diffuses and convects to the photosphere, will be directly tested by the VIRGO II$^+$/LOI$^+$ limb photometry.

VIRGO II$^+$ Task 3 – LATITUDE SURFACE BRIGHTNESS DEPENDENCE

Limb brightness observations with a relative accuracy of 5×10^{-5} will be obtained with a time resolution of a solar rotation period. This requires rotation of the instrument with respect to the Sun pointing direction in fixed increments of 9 degrees. This requirement follows from the magnitude of the known surface brightness variations and will yield measurements of sufficient accuracy to measure the expected solar cycle changes over a 6 month time period during the ascending portion of the solar cycle when SDO/VIRGO II$^+$ operations are anticipated. The angular resolution is required to fully isolate and resolve changes in the extreme polar thermal 'dip' anomaly (cf. Fig. 1-4). These solar cycle brightness variations require data with a 6 month cadence. Calibration cycle data (obtained during eclipse periods) can be combined to generate the required precision.

VIRGO II$^+$ Task 4 – LOCAL BRIGHTNESS CHANGES

Limb brightness observations with a relative accuracy of 1×10^{-4} will be obtained with a time resolution of 1/4 of a solar rotation period. This requires rotation of the instrument with respect of the Sun-pointing direction in fixed increments of no more than 9 degrees. In contrast with Task 3, better temporal resolution (7 days or less) but relaxed photometric precision is required. This task uses the same data sequence as Task 3 but addresses larger amplitude limb brightness changes that occur on active region evolution timescales.

To obtain thermal "snapshots" of the interior entropy perturbations the coarsest temporal sampling should be about 6 - 7 days. The angular resolution of these measurements will allow the photospheric thermal perturbations of deep magnetic fields, or emerging active regions, to be resolved in latitude and time.

VIRGO II$^+$ Task 5 – IRRADIANCE

The SPM spectral irradiance will be obtained with a 1 minute cadence during the 6 year duration of the mission. The total irradiance is available at a cadence of 2 and 3 minutes for PMO6 and DIARAD, respectively, with a short term precision of <10 ppm and long term stability of <50 ppm. By flying photometers and radiometers with almost the same design as on SOHO, a homogeneous irradiance data set can be built up over more than a solar cycle. This will allow subtle differences between the two cycles to be identified.

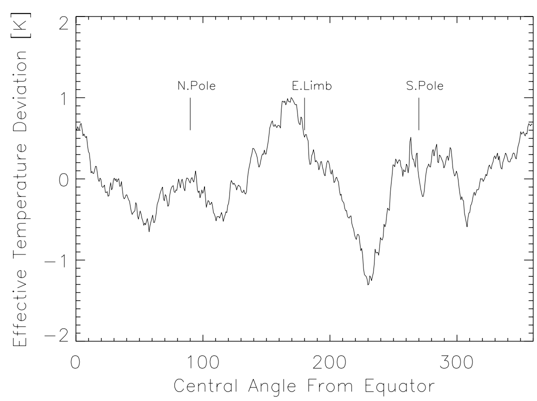

Fig. 1-4. Latitudinal Solar Limb Brightness Variations.

Identifying magnetic and bolometeric origins of the irradiance changes requires full-disk observations with LOI$^+$. The comparison of spatially resolved differential photometry with irradiance changes caused by magnetic features (e.g. sunspots and faculae) requires a photometric accuracy of about 0.5% for the 2 arcsec pixels of LOI$^+$. A cadence for the full disk measurements of 10 - 12 minutes (time averaged) will be used to sample magnetic evolution timescales.

One of the major goals of this irradiance task is to maintain NASA's long-term total irradiance data base for climate studies. Because of the limitations of the radiometric absolute accuracy, we must ensure that continuous, overlapping measurements with no interruptions exist in order to compile a composite irradiance time series. Any gaps in the data sets, like the two year gap between SMM/ACRIM I and UARS/ ACRIM II, may decrease significantly the long-term precision of the measurements and may lead to inadequate conclusions regarding small secular trends (see details by Willson 1997; Fröhlich & Lean 1998; Pap & Fröhlich 1999). The advantage of the VIRGO II^{+} package is that it contains two differently designed radiometers to ensure redundancy and VIRGO II^{+} will extend TSI measurements from the maximum of solar cycle 21 to the maximum of cycle 24.

Energy and Entropy Transport

Key Scientific Questions

- How do magnetic fields near the photosphere and in faculae and sunspots perturb the Sun's emergent energy flux?
- How do magnetic fields affect the transport of entropy near the photosphere?

Solar astrometric and photometric data at this spatially resolved precision have never before been obtained. These data are critical for addressing the physical mechanisms for entropy transport near the top of the magnetized convection zone and to clarifying surface magnetic activity's contribution to the observed changes in solar luminosity.

The magnetic structure in the photosphere perturbs the steady convective and radiative heat transport from the interior. The total energy budget of sunspots, faculae and active regions is also not well understood. For example, we know that surface magnetic fields are associated with both positive and negative irradiance changes, depending on the timescale. On short times scales (<60 days) magnetic fields decrease the irradiance, while on longer times scales an increase in the photospheric magnetic flux increases the irradiance. The effects of faculae and sunspots on the Sun's luminosity (its total energy integrated over all angles) and its irradiance (the energy radiated into the ecliptic plane) are likely very different. We need long time series of precise photometric measurements of solar active regions as they rotate from limb to disk-center to solve simple questions like, "Does an active region change the solar *luminosity* differently than its effect on the *irradiance*?"

Longstanding problems like, "Why does the Sun rotate differentially?" depend on understanding how the solar convection zone transports flux from the interior. Careful observations of excess or missing flux around sunspots and active regions show how anisotropic the effective solar conductivity really is. We will use these data to construct global models of the energy flux circuit in the Sun. Such studies will finally allow us to make realistic comparisons between what we learn with small scale numeric solar experiments, our most important tools for understanding magneto convection, and the global solar luminosity problem.

VIRGO II^{+} Task 6 –
ENERGY AND ENTROPY TRANSPORT

Full disk observations with 2 arcsec pixels, in 1 nm bandwidth in the continuum at 782 nm wavelength, with at least a 12 minute cadence, and 0.5% photometric accuracy are required. Temporal low-pass filters must be applied to reduce the effects of 5-min oscillations on the full-disk photometric data.

Continuous temporal coverage with approximately 12 min cadence will be used for studies of entropy perturbations in the convection zone due to surface magnetic fields. With these data we will observe the emergent radiation as it varies due to solar rotation and the evolution of photospheric fields. For example, the exploration of the transport properties of the Sun's convection zone (in particular Task 6) is likely to occupy researchers for several years.

Low Frequency Helioseismology

Key Scientific Questions

- Can g-modes be detected and reliably identified?
- Can their dispersion relation be measured from the limb displacement time series – thus providing new insight into the innermost core of the Sun. Can the

marginal r-mode identification obtained using SOHO/MDI be confirmed? If so, this may provide a new diagnostic of the dynamic properties (differential rotation and global-scale flows) in the solar convection zone.

- Can we uniquely identify p modes of very low order – thereby accurately measuring thermodynamic conditions below the radiative/convection zone boundary and in particular the solar core - by combining limb data with the irradiance and LOI$^+$ observations?

Coherent long period oscillations are more readily detected from shape observations than from Doppler measurements. At low frequencies solar Doppler data are dominated by the incoherent velocity noise from the convection zone. On the other hand, at low temporal frequencies even a low velocity oscillation can be extracted from the convective noise in an astrometric measurement. This is because the limb displacement amplitude grows linearly with oscillation period (for a constant velocity amplitude) while the astrometric convection noise contributes only incoherently on shorter timescales. Thus, the most sensitive measurement of low frequency solar oscillations (periods longer than about 1-2 hours) comes from the MDI limb shape time series. Figure 1-4 shows the mean temporal limb displacement oscillation spectrum, converted to an equivalent rms velocity amplitude spectrum. The broad power “bump" in Fig. 1-5 corresponds to periods near 11 hours and is not likely to be caused by low order g modes since they more efficiently penetrate the convection zone to reach the photosphere at periods of one to a few hours (Kumar et al. 1996). The most likely cause for the observed excess power at the lowest frequencies is solar r modes (‘Rossby modes’). These are nearly incompressible low frequency oscillation modes which are driven by Coriolis forces in a rotating star. The possibility of such long period oscillations, which are likely to be mode-locked with the rotating photosphere, was first suggested by Wolff (1974, 1998).

Phase coherence of the MDI limb displacement power spectrum at low frequencies supports this interpretation (Kuhn et al. 2000) but the higher sensitivity observations from VIRGO II$^+$ will allow us to measure the r-mode properties. With the r-mode ‘k-ω’ dispersion relation we will have a new tool for directly inferring the convection zone rotation and large scale interior flows (Wolff 1998).

Solar gravity modes hold the key for understanding the deepest interior conditions of the Sun (Gough 1994). Their detection will empirically reveal the thermodynamic conditions in the energy generating core of the Sun, and the central boundary condition for the solar luminosity. From the low frequency data of the MDI and VIRGO experiments on SOHO no g modes or very low order p modes could be detected, only an upper limit was stated by

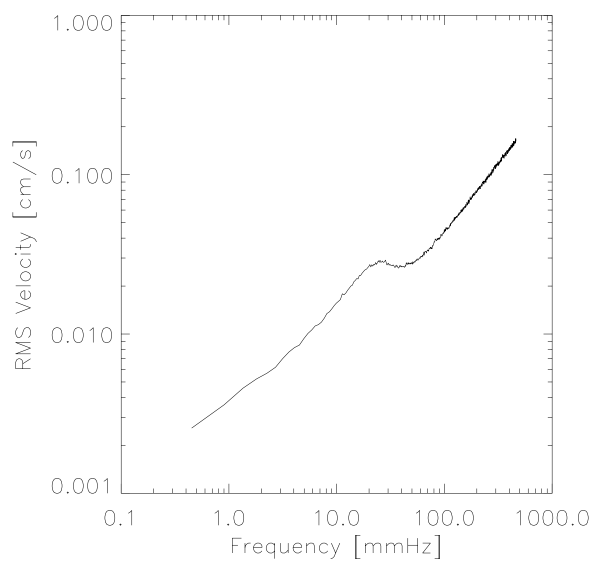

Fig. 1-5. Average Displacement Power. The average displacement power between angular frequencies of 20-256 radian^{-1} has been converted to an rms velocity by scaling the amplitude by the temporal frequency. This is plotted on a logarithmic scale here to reveal the mean effective velocity background from 800 days of MDI astrometric observations.

Appourchaux et al. (2000). As the solar noise in irradiance observations increases more slowly towards low frequencies than in the velocity signal and by combining SPM and absolute radiometer data with the LOI$^+$ limb data we will improve the detection threshold for low order p and g modes with periods between 20 minute and 1hour.

At periods of 1 - 2 hours the most sensitive detection limit on g modes was demonstrated by MDI (Fig. 1-5). It is also in this frequency regime that we expect the greatest improvement in the MDI noise background from VIRGO II$^+$. While we do not know the actual surface amplitude of solar g modes, there are suggestions (Kumar et al. 1996) that low order modes could have amplitudes near 0.1 mm/s. For angular harmonics higher than 4, VIRGO II$^+$ will achieve an equivalent instrumental sensitivity of 0.05 mm/s over its 6 year lifetime. If solar noise sources do not dominate, then VIRGO II$^+$ may yield the first detection of buoyancy waves (g modes) in the Sun.

Our experience with MDI indicates that the instrumental noise limitations of VIRGO II$^+$ data are likely to result from: 1) residual flat-field calibration errors, and 2) time series interruption and contamination from other instrument and spacecraft experiment requirements. For angular harmonics larger than l = 3 and at frequencies higher than 30 μHz MDI achieved an astrometric noise power density which was within a factor of two of the estimate based on flat-fielding noise and the pixel size. The VIRGO II$^+$ instrument noise background power density will be significantly lower than MDI at low frequencies. The simpler optical design of LOI$^+$, improvements in flat-fielding, and noise reduction from satellite system contamination will reduce the higher frequency astrometric noise by more than one order of magnitude over MDI.

The VIRGO II$^+$ astrometric oscillation time series should yield a completely new probe of the solar convection zone. The likely measurement of r-mode dispersion, and the possible detection of solar g modes, opens new windows into the Sun. As the VIRGO II$^+$ data become available, we expect that it will stimulate scientific activity in the new field of ‘low frequency helioseismology’.

VIRGO II$^+$ Task 7 – LOW FREQUENCY HELIOSEISMOLOGY

The data from VIRGO, MDI and GOLF on SOHO as well as ground based networks have shown that Doppler shift measurements are superior to radiance/irradiance measurements in the detectability of low frequency p modes. This is due to the fact that the frequency dependency of the solar background signal ("solar noise") increases more slowly with decreasing frequency for the p-mode range in Doppler measurements than in radiance. This is most certainly the case down to a frequency of 150 μHz, but may not be true at lower frequencies. There are indications that instrumental noise may be a significant contribution to VIRGO data in the 20 – 60 μHz region. This may, at least partly, be caused by the readout chain of the data, this will be designed differently in the instrument proposed here. So currently we do not know the detailed shape of the solar noise spectrum in this region. This will be measured by the proposed investigation.

The ratio of the vertical to horizontal displacements in solar oscillations changes with frequency, the p modes being predominantly vertical and the lowest frequency g modes mostly horizontal. This will clearly influence the amplitude of the different modes at the limb. But the solar background signal will also change at the limb. At medium to low frequency, the major source of solar noise will be the supergranulation signal. This is dominated by horizontal motions at the surface and will therefore be a significant source of noise in Doppler measurements at the limb. Even for direct measurements of solar oscillations at these frequencies at the limb there is evidence that radiance measurements may be better than Doppler shift measurement.

VIRGO II$^+$ will obtain time series of limb brightness, limb displacement, and irradiance observations with a cadence of 30 sec and a duration of 6 years. The limb intensity and displacement will be determined in 512 position angle bins with a limb displacement accuracy of 5 milliarcsec per bin per measurement. This per pixel limb displacement accuracy requires a detector with 2 arcsec pixels. In addition, the SPM data will provide parallel measurements with a 30 sec cadence. The instrumental noise of both SPM and LOI$^+$ is below 0.03 ppm in the 5-minute range and increases towards lower frequencies as 1/f. At intermediate frequencies (periods less than one hour) the comparison of the limb oscillation data with the intensity oscillations data will allow the assessment of low frequency p-mode oscillations (and possibly g-modes).

The quoted astrometric accuracy is required to unambiguously identify the low frequency r-mode oscillation spectrum. These data will also reduce the background noise power near 100 µHz to an equivalent velocity amplitude of less than 0.1 mm/s. According to some calculations (Andersen 1996; Kumar et al. 1996), g modes may be visible with this sensitivity.

Medium/High Frequency Helioseismology

Key Scientific Questions

- What is the phase shift at all frequencies between velocity, temperature and opacity fluctuations in the solar atmosphere?
- Is it possible to use the highest frequency (≈ 10 mHz) phase shifts as diagnostic probes of the solar atmosphere at high spatial resolution?
- What are the structure of the high frequency modes in Doppler and intensity?
- Is it possible to resolve some of the surface ambiguity of local area helioseismology by combining measurements in Doppler shift with true continuum measurements?

VIRGO II$^+$ Task 8 – MEDIUM/HIGH FREQUENCY HELIOSEISMOLOGY

The HMI will provide Doppler shift measurements of unprecedented quality for the whole disk. However the understanding of the wave propagation and damping in the solar atmosphere requires high quality information in addition about both the temperature and opacity variations. This is difficult to disentangle from spectral line measurements. The VIRGO II$^+$ investigation will provide the best high spatial resolution radiance measurements of the solar surface. Since the measurements are done in a spectral region dominated by continuum opacity the ambiguity between temperature and opacity variations is straightforward to resolve.

There are no high frequency and high quality measurements in continuum radiance. The observed phase shifts at high frequency are well enough understood to attempt their use as a means of atmospheric diagnostics. VIRGO II$^+$ will, together with HMI, provide the means to do this.

1.4 Relevance to NASA's "Living with a Star" Program, the Solar Dynamics Observatory, and Other Missions

Ever since the earliest telescopic observations, the solar variability in the form of sunspots and related magnetic activity has been the subject of careful study. As the nearest star, the Sun is the only star where we can observe and identify a variety of structures and processes which lead to irradiance variability on time scales from minutes to decades. High spatial and temporal resolution observations conducted by various experiments on SOHO, along with other space observations, like YOHKOH and TRACE, and also from the ground, have demonstrated that the surface of the Sun and its outer atmosphere are highly dynamic on almost all spatial scales.

In conjunction with these solar imaging experiments, the Sun's radiative output has also been monitored at various wavelengths over the last two and half decades. The VIRGO experiment on SOHO has been measuring solar irradiance in the entire solar spectrum and at specific narrow wavelength bands in the near-UV (402 nm), visible (500 nm), and near-IR (862 nm) since 1996 (Fröhlich et al. 1997). While the VIRGO spectral observations are the first continuous space observations in the visible and infrared, the VIRGO total irradiance measurements have provided an important segment of NASA's long-term irradiance data base for climate studies. The VIRGO measurements, along with other irradiance monitoring experiments, have demonstrated that solar irradiance varies on time scales from minutes to years, confirming that our Sun is indeed a variable star.

Studying the Sun's variability is important for both solar physics and solar-terrestrial physics. Even tiny changes in total solar irradiance give us information about the internal processes by which energy is transported from the core, while analyses of spectral irradiance observations from UV to infrared help us to understand the changes taking place in the photosphere and chromosphere. In addition to the solar physics aspects, the terrestrial implications of solar irradiance variability are equally important. Since the Sun's radiative output establishes the Earth's thermal environment, knowing the source and nature of its variability is essential to understand and predict the interactions in the Sun-Earth system, which in turn are vital for assessing the impact of human activities.

The VIRGO II$^+$ experiment will provide an important segment of the "Living with a Star" science objectives, addressing the question: “How solar variability may influence climate?” In addition to the total irradiance measurements, VIRGO II$^+$ and the ‘Spectrometer for Irradiance in the EUV’ (SIE) experiment will cover the solar spectrum from its EUV part into far UV, near-UV, visible, and near IR, providing information about the spectral distribution of irradiance variations and their effect on the Earth's thermosphere, mesosphere, oceans and land. We underscore that the SDO Science Definition Team (SDT) acknowledged the importance of total solar irradiance measurements. According to the SDT report, Chapter 4.9, p. 39: "The total solar irradiance must be accurately and precisely monitored to determine the nature and source of the irradiance variations (Section 3.1.1.2). These observations are of highest priority to SDO but will likely be obtained from both SORCE (Section 7.4) and GOES/NPOESS (Section 7.5) during the SDO mission and are therefore not included as part of SDO. If, however, it appears that these observations will not be provided by these alternative sources then a Total Solar Irradiance Monitor should be placed on SDO." In addition, the SDO SDT report underlines (see Overview, p. 7.) that "a Total Solar Irradiance (TSI) Monitor" should also be included if redundant observations are not available concurrently with SDO." As shown in the subsections to follow, the VIRGO II$^+$ radiometers (and to a certain extent the SPMs) are required on SDO not only to ensure redundant measurements of total solar irradiance, but also to bridge the gap between SORCE and NPOESS.

Relevance to SORCE and NPOESS

A new type of radiometer “Total Irradiance Monitor (TIM)" on SORCE (Lawrence et al. 2000, Woods et al. 2000) will be launched in November 2002 with a 2 year nominal and 5 year long anticipated measurement time interval, extending the current long-term NASA irradiance data base till 2004 -2007. The NPOESS measurements, using a TIM type of instrument, will start only in the time frame of 2009 - 2011. At the time of completing this proposal, the SORCE follow-up mission, called as EOS-IV, has not formally been approved. Therefore, the VIRGO II$^+$ experiment on SDO has to be considered as a highest priority experiment since it may even be the only experiment that will provide TSI measurements during the gap between SORCE and NPOESS, not to mention redundancy as required in the SDT report. Implementation of the VIRGO II$^+$ radiometer package fulfills both of the SDT requirements: it would make sure the continuity of TSI measurements between SORCE and NPOESS or in the better scenario; it would provide redundant TSI measurements if EOS-IV is approved. In addition to the radiometers, VIRGO II$^+$ will also carry sunphotometers (SPM) to monitor spectral irradiance in the near-UV, visible and infrared. The SPM spectral measurements would also ensure redundant spectral irradiance measurements along with the "Spectral Irradiance Monitor" (SIM), which is part of the SORCE instrument package. These parallel total and spectral irradiance measurements on SORCE and SDO are especially important since neither TIM nor SIM had previous flight experience.

Relevance to PICARD

The French PICARD experiment, a 2-year mission which is planned to be launched in 2006, is designed to measure total irradiance with a DIARAD-type radiometer and UV and visible spectral irradiances using filter-radiometers. PICARD will also be taking high resolution solar images at various wavelengths to measure the solar diameter. Although PICARD will have some overlap with SORCE (2006 - 2007), there is no guarantee that it will operate well into the time frame of 2009 - 2011 when NPOESS will take over the SORCE measurements. Therefore, PICARD alone will not be able to ensure redundant irradiance measurements during the potential gap between SORCE and NPOESS, even if EOS-IV is approved. Furthermore, PICARD is not a NASA-endorsed mission and it has not been addressed how the PICARD data product will be distributed and integrated into the long-term NASA data base. Although measurements of PICARD are important, they by no means can replace irradiance measurements on SDO.

We note that PICARD will also measure the solar diameter which is one of the objectives of LOI$^+$ on VIRGO II$^+$. Since the diameter variations are tiny, parallel diameter measurements by PICARD and VIRGO II$^+$ will be complementary, in case they will operate simultaneously at least a year. We recall that the Nimbus-7/ERB experiment recorded the sunspot-related irradiance dips during its early operation (December 1979 and April 1980), however, these temporary irradiance fluctuations were considered as measurement noise. Parallel measurements of the SMM/ACRIM I radiometer were necessary to confirm that indeed the ERB events had solar, rather than instrumental, origin. It must be emphasized that we face similar problems when measuring small radius changes. Therefore, it is desirable that PICARD and VIRGO II$^+$ are operating simultaneously for a certain amount of time to provide much needed complementary and redundant solar diameter measurements.

Relevance to HMI

A key element of the VIRGO II$^+$ instrument package is an advanced version of the "Luminosity Oscillation Imager" (LOI$^+$) which will take 1000×1000 pixel images at 782 nm. The VIRGO II$^+$ experiment package will provide complementary science to the "Helioseismic and Magnetic Imager" (HMI) from several points of view. While highly precise photometry, provided by HMI, will detect magnetically induced entropy fluctuations in the deep solar convection zone from their faint thermal shadows visible at the photosphere, the VIRGO II$^+$ will provide the full-disk calibration needed to interpret the integral of the spatially resolved photometry from HMI. Since HMI provides only accurate differential photometry, we can rely on full-disk VIRGO II$^+$ data to diagnose the temporal stability of HMI photometry. The very accurate limb photometry and astrometry from LOI$^+$ give critical wavelength dependence information for interpreting the HMI photometry. Once again the spectral signature derivable from the combination of HMI photometry and LOI$^+$ may be used for distinguishing physical irradiance mechanisms. These combined studies by VIRGO II$^+$ and HMI will enable us to replace the current empirical models to construct irradiance variations back to the time of the Maunder Minimum and predict future solar-induced climate changes – a research effort which requires complementary experiments and is one of the centerpieces of the LWS program of NASA.

Relation to Space Weather Forecasting

The VIRGO II$^+$ experiment is primarily related to the climate implications of the LWS program and will be a key element of SDO in this respect. Its data product has no direct relation to space weather applications. However, analysis of the LOI$^+$ images, together with HMI data products, will make it possible to study the structural, magnetic field strength, and intensity changes of magnetic features during their evolution. Comparison of these photospheric magnetic field changes with coronal changes and understanding their dynamics will definitely help in predicting eruptive events important in space weather forecasting.

2. Science Implementation

2.1 Instrumentation

The Sensor Package

The VIRGO II+ experiment comprises a suite of three instruments: LOI+, two types of absolute radiometers, and two filter radiometers with three spectral channels.

The following measurements are performed by these instruments:

1) The luminosity oscillation imager (LOI+) measures the radiance distribution over the solar disk with a 1000 × 1000 pixel detector, and is used for the determination of the solar diameter and shape, and to identify solar activity features,
2) Two types of absolute radiometers (one DIARAD with two measuring channels and two PM06-V) to measure the total irradiance and its variations with high accuracy and precision;
3) The two 3-channel filter-radiometers (SPM) to measure with the continuously exposed SPM solar oscillations with high precision and with the backup SPM the spectral irradiance with high accuracy. The latter is also used to track the degradation of the continuously exposed instrument.

The instruments are packaged in a sensor package (SP) which also contains the controller and the data acquisition system. The power supply (PS) is located in a separate box which now also houses a new controller for LOI+ and a spacecraft interface. In the following subsections the instruments and subunits are described in detail together with their performance.

The Mounting of the Sensor Package

In order to guarantee the precision of the LOI+ its optical axis has to be kept aligned with the Sun's disk center to 1 arc min (or better). In order to achieve this in orbit the VIRGO II+ SP is mounted in a frame that can be tip-tilted to adjust the pointing-alignment within ±8 arcmin. The SP has now the following dimensions (without frame) B×W×H: 293 × 236 × 396 mm and a total weight of 17.4 kg (including the frame). The SP with the frame is shown in Fig. 2-1 and the footprint of the mounting frame is given in Fig. 2-2, where also the overall envelope is defined.

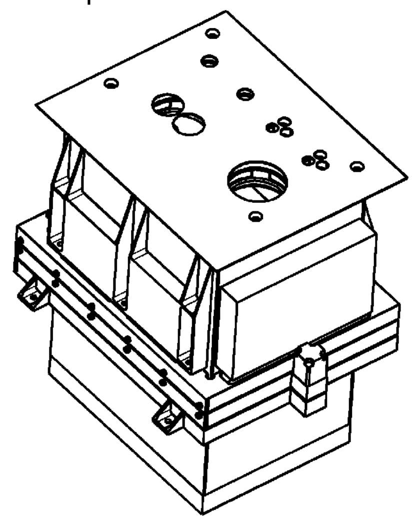

Fig. 2-1. 3-D-view of the VIRGO II+ sensor package with the mounting frame.

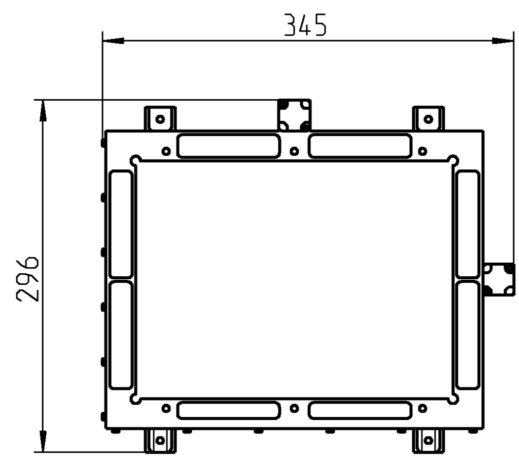

Fig. 2-2. Footprint of the mounting frame of the VIRGO II+ sensor package.

Absolute Radiometers

Absolute radiometers are based on the measurement of a heat flux by using an electrically calibrated heat flux transducer. The radiation is absorbed in a cavity, which ensures a high absorptivity over the spectral range of interest for solar radiometry. During practical operation of the instrument, an electronic circuit maintains the heat flux constant by accordingly controlling the power fed to the cavity heater. This is called the active mode of operation; hence also the name: 'active cavity radiometer'. The irradiance can be calculated from the shaded and irradiated electrical powers P_s and P_i according to: $S=C\cdot (P_s - P_i)$, with C being the reciprocal of the aperture area times a correction factor for the deviations from ideal behavior. The correction factor accounts for different effects such as the reflectivity and efficiency of the cavity, the losses due to diffraction at the apertures, stray-light in the view-limiting muffler, heating of leads and the non-equivalence of electrical and radiative heating. The procedure to determine these factors is called characterization of the radiometer, and it provides both the correction factors and their uncertainty, the sum of the latter determining the absolute accuracy of the radiometer.

The radiometers used in VIRGO II^+ are fully characterized and their measurements are individual realizations of the SI unit Wm^{-2}. As stated above, the absolute accuracy is estimated from the sum of the uncertainties of the experimentally determined correction factors and of the uncertainty of the area of the precision aperture. For the DIARAD and PMO6-V type instruments this amounts to ±0.15% and ±0.17% (Brusa & Fröhlich, 1986), respectively. The disadvantage of this approach is that incompletely understood or even unknown effects in the radiometer will yield an unknown bias, because either an unreliable correction factor or even none at all is applied. In the case of the PMO6-V radiometers comparison of the flight instruments with cryogenic radiometers in vacuum will be performed. This will allow to transfer the SI scale to space with a lower uncertainty than before.

Although the designs of the two radiometer types are based on the same principle, the physical realization is different. Indeed, it is this difference that is the main reason for having both. Major differences between them are the arrangements of the compensating cavities and the forms and coatings of those cavities. This means that one needs at least one spare sensor for each radiometer type (DIARAD is using the compensating cavity and for PM06-V a second instrument is included) to be able to track these sensitivity changes. This evidently also increases the redundancy of the radiometric measurement. The backup sensors will be exposed only very rarely. The combination of two instrument types (to assess instrument specific changes) and backup instruments (to determine their exposure-dependent sensitivity changes) is ***imperative*** to enable the unambiguous detection of long-term trends of the solar total irradiance by accurately correcting for the inherent long-term changes of the radiometers.

Experience with SOHO

The analysis of the VIRGO radiometry on SOHO is an instructive example of how the long-term behavior can be investigated if simultaneous results from two types of radiometers are available. The level-1 data show that the long-term behavior of the four radiometers differs substantially and that corrections are needed to deduce a reliable TSI from these data. The correction for exposure-dependent changes can be determined by comparison of an operational radiometer with a less exposed spare of the same type. A major result of the investigation of the VIRGO radiometers is that hyperbolic functions describe the behavior much better than the usually used exponential functions (see e.g. Fröhlich and Finsterle 2001). Moreover, these functions allow us to take the actual accumulated UV radiation dose into account which is thought to be the origin of these kind of changes (normally termed degradation). In the case of VIRGO this analysis can be performed for both radiometer types separately yielding two independent time series. These can then be combined to determine a better estimate for TSI. However, this will not improve the intrinsic absolute uncertainty of the radiometers of the order of ±0.15%, but it allows us to decrease the uncertainty of the long-term changes if all significant systematic trends have been removed. This condition can only be fulfilled if the temporal behavior of the two radiometers is different enough so that a sensible allocation of the share of the observed differences to each radiometer can be made. The radiometers on VIRGO/SOHO meet this condition since the time constants of the sensitivity changes differ by more than an order of magnitude. However, some uncertainties – especially for DIARAD – remain as far as the physical origin of the exposure-independent changes are concerned. A corresponding investigation has already started and the results will be available in phase A to take the necessary measures.

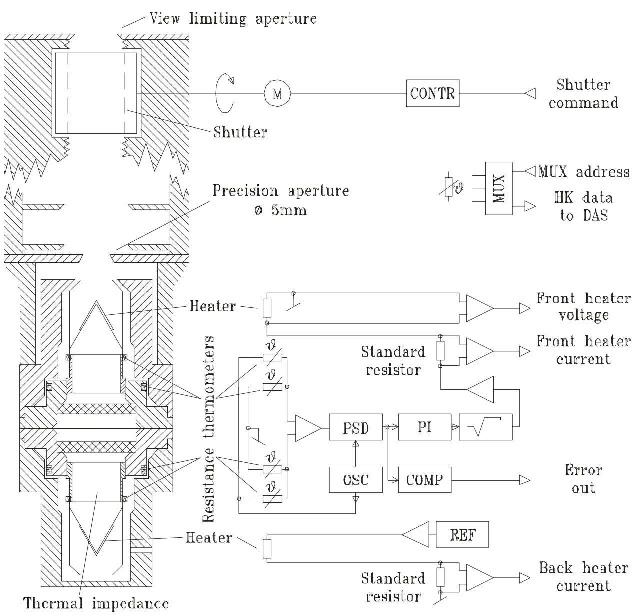

Fig. 2-3. Block diagram of the PMO6-V absolute radiometer with the arrangement of the sensor and the control analogue electronics.

PMO6 Radiometer

A detailed description of the PMO6 type radiometer can be found in Brusa & Fröhlich (1986). The block diagram of Fig. 2-3 shows how the radiometer is operated. The back cavity is heated with a constant power from the D-A converter and a servo loop adjusts the front heater in such a way that the temperature difference between the cavities always remains zero. The shutter is operated with a stepper motor. The radiometer is operated with 60s shutter closed and 60s shutter open periods. Thus an irradiance value is obtained every two minutes. Due to a failure of the shutter mechanism another procedure had to be implemented on VIRGO/SOHO while in orbit. The instrument cover was used as shutter which closes the radiometers for only 6 minutes every 8 hours. This operation procedure proved to work perfectly well on SOHO, which has an extremely quiet thermal environment. However, we will update the driver for the shutter mechanism and operate the PMO6 radiometers as originally planned.

DIARAD Radiometer

The DIARAD type radiometer (Crommelynck & Domingo 1984; Crommelynck & Dewitte 1999) is a differential absolute solar radio-meter developed at RMIB. It is the first absolute radiometer operated in space which is based on a fully symmetrical metrological design (two side by side cavities) and operation (successive opened and closed state of the measurement cavity). The functional block diagram in Fig. 2-4 shows the arrangement of the cavities and the electrical measurement scheme. Its radiometric core is formed by two blackened cavities constructed side by side on a common heat sink. In between each cavity and the heat sink a heat flux transducer is mounted. The difference between the two transducers' outputs gives an instantaneous differential heat measurement, in which the common part of the thermal surrounding radiation seen by the two cavities is eliminated. By the symmetrical construction and good insulation thermal asymmetry is minimized.

Equilibrium between the two cavity heat fluxes is maintained by controlling the electric power in one of the two cavities with a servo system. In the default measurement sequence a constant electric power is fed into one cavity, the "reference" cavity, while its shutter always remains closed. The electric power in the other cavity, the "measurement" cavity, is continuously controlled, while its shutter sequentially opens and closes (both open and close phases take 90 seconds). Accurate electric power measurements are obtained by separate measurement of the voltage over and the current through both cavity heating resistors. The current through a heating resistor is derived from the voltage measurement over a known precision measurement resistor which is placed in series with the heating resistor.

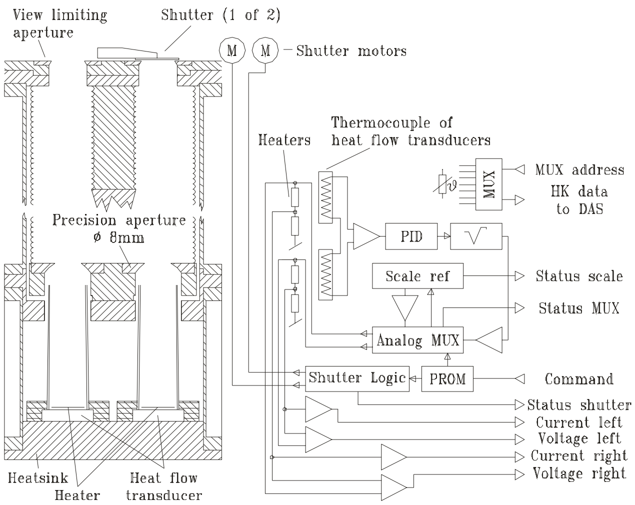

Fig. 2-4. Block diagram of the DIARAD absolute radiometer with the arrangement of the sensor and the control analogue electronics.

The two voltages over the heating resistors, and the two voltages over the measurement resistors, are measured simultaneously with four separate electric measurement chains. The electric measurement chains can be calibrated using three reference voltages, derived from a single, temperature stabilized, high accuracy reference voltage.

More details on the determination of the characteristics of the DIARAD type radiometer can be found in Crommelynck (1982).

Filter-Radiometers

The design of the filter-radiometers in VIRGO II+ (SPM) remains the same as in the original VIRGO experiment described below, except for the filter specifications, which are re-defined to match the channels foreseen for LOI+ and in other space experiments such as the PICARD/PREMOS experiment. Presently, we select 285, 402, and 782 nm, but the final decision of the wavelengths and bands is made during phase A.

The SOHO/VIRGO/SPM has three independent channels consisting of a silicon-diode interference-filter combination, mounted in a common body that is heated with constant power and always remains a few degrees above the temperature of the heat sink. A block diagram of the SPM is shown in Fig. 2-5.

One SPM is operated continuously; the second SPM provides a backup in case of failure of the first. The second SPM is exposed briefly about once every month in order to check the degradation of the continuously exposed primary SPM and to determine the spectral irradiance and its variability. The radiometric sensitivities are calibrated by two NIST traceable FEL standard irradiance lamps. Temperature coefficients are determined in flight, as they were for the VIRGO experiment on SOHO, by setting 3 different levels of heating power.

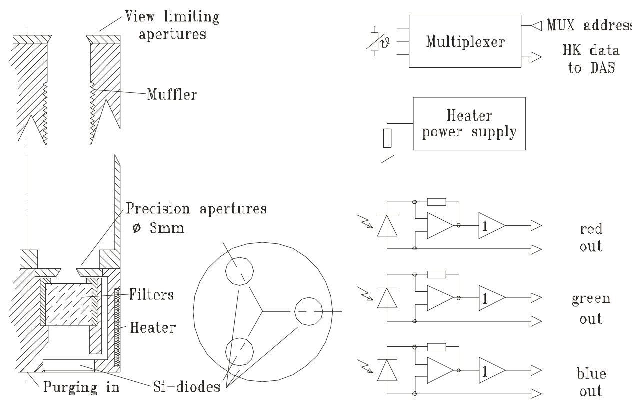

Fig. 2-5. Block diagram of the SPM arrangement of the detector (Si-diodes)/filter combination and the control of the analogue electronics.

Similar SPM, used in earlier experiments, showed rather strong degradation of the sensitivity. In the case of the continuously exposed SPM of the SOVA2 experiment on EURECA (total exposure time of about 180 days), this degradation amounted to 17%, 49% and 95% for the 862, 500 and 335 nm channels respectively.

The following measures have been taken for the VIRGO/SOHO SPM to prevent degradation as much as possible:

- the shortest wavelength is 402 nm permitting the use of a different blocking glass instead of the rather unstable UG11;
- to protect the filter against energetic particle flux and UV radiation below 380 nm, a 3 mm thick radiation resistant

BK7-G18 glass is used as front element;

- a SOHO/ESA approved optical cement is used in the filters;
- a compartment within the instrument containing the filters and detectors is physically separated from the rest of the SPM and the sensor package with their electronic circuitry; before launch this compartment is continuously purged with 5.5-grade nitrogen.

Experience gained from the ongoing SOHO/VIRGO experiment has demonstrated that these precautions, together with a strict cleanliness control during manufacturing and integration of both the SoHO satellite and the VIRGO hardware, were successful. After more than 6 years of continuous operation, the loss of sensitivity is similar or smaller than on EURECA in just 6 months.

Two channels in VIRGO II$^+$ will be retro-fitted with filters manufactured the same way as for the original VIRGO experiment. One channel is foreseen for the ultraviolet range where the first two measures are not applicable and a faster degradation of this channel is unavoidable.

For helioseismological investigations, the excellent signal-to-noise ratio obtained (Fröhlich et al. 1995) has permitted very accurate determination of p-mode characteristics, including their variation over the solar cycle.

Luminosity Oscillation Imager

The Luminosity Oscillations Imager (LOI) on SOHO is a high stability solar photometer, resolving the solar disk into 12 spatial elements at 500 nm, and currently flying on SOHO/VIRGO (Fröhlich et al 1995). Twelve of the LOI elements are shaped specifically to allow detection of radiance variations on

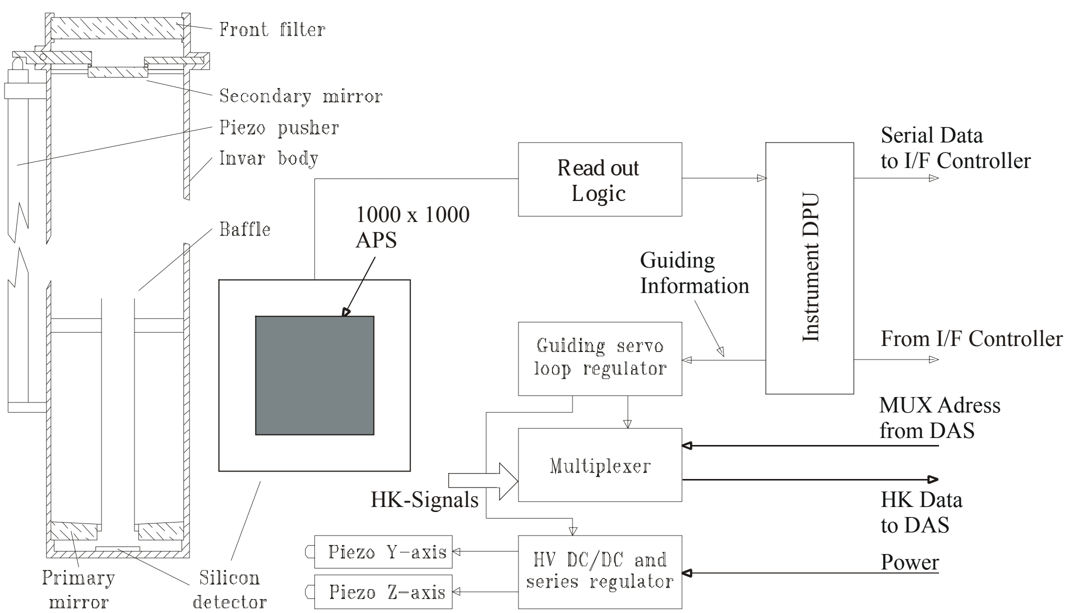

Fig. 2-6. Block diagram of the Luminosity Oscillation Imager (LOI$^+$). The Ritchey-Chretien telescope makes a 13-mm diameter image of the Sun through a 1 nm pass band filter at 782 nm (The final wavelength selection will be done in phase A). The detector at the focal plane is an Active Pixel Sensor of 1000 by 1000 pixels. In a fashion to that of the former LOI, guiding pixels at the solar limb will provide error signals that will be digitally processed by the central DPU and then fed back to the guiding loop for providing the signals to the piezoelectric actuators that move the secondary mirror of the telescope. The digital loop should be fast enough to cope with movements up to 100 Hz. The optical axis secondary mirror will be kept as close as possible to that of the primary mirror using the mounting feet of the VIRGO II$^+$ package; this will ensure that the cylindrical symmetry of the telescope is kept.

spatial scales corresponding to spherical harmonics up to degree 7 (Appourchaux & Andersen 1990). The LOI+ will have a 1000 × 1000 pixels APS detector. That will be the main difference to SOHO/LOI. The block diagram in Fig. 2-6 shows some details of the mechanical, optical and electrical setup of LOI+.

The LOI+ optics is designed for simple imaging through a stable narrow-band filter in true continuum. The photometric calibration procedures which involve spacecraft roll maneuvers around eclipse periods will work to the advantage of both, LOI+ and HMI. The same algorithms will be used for flat-field generation in HMI and LOI+. The red 782 nm photometry band pass with a 1 nm width (the definitive wavelength and band pass is to be determined in phase A) of LOI+ in combination with a pass band at shorter wavelength for HMI will allow the broadband spectral signature of photospheric irradiance contributions to be determined with relative surface brightness accuracy better than 10^{-3}. The hypothesis that most surface brightness features are approximately thermal will be accurately tested.

The photon noise effect on the LOI+ radius measurement will be less than 3 milliarcsec (@ 3 sigma) for a single image taken every second. This is an extremely conservative estimate. The main sources of noise or systematic errors will be coming from temperature effects on the front filter and on the VIRGO II+ feet. Other temperature effects should be much smaller because the telescope structure is made of Invar and the telescope optics of Zerodur. Since the LOI+ structure was not specifically designed for absolute astrometry, the temperature effects should obviously be monitored instead of being minimized by the design. Nevertheless, we are confident that the implementation of numerous temperature sensors on the various part of the VIRGO II+ package will provide the means for disentangling spacecraft temperature effects from solar effects.

The solar limb position is obtained by comparing the limb-darkening function (LDF) from a restricted position angle on the solar disk to the full-limb mean LDF. The limb is sampled over a 20-pixel annulus for this purpose. The limb position as a function of angle is obtained from 2-D least square fit of the mean LDF. For deriving the figure of the Sun, this limb position can be decomposed onto spherical harmonics or using regular FFT (Toner et al. 1999). This latter decomposition will be used for detecting solar g modes (Kuhn et al. 2000, Spheris proposal). It is worth mentioning that we do not wish to measure the limb displacement for g-mode detection, but the intensity perturbation caused by the oscillations at the limb; there the signal is enhanced and amplified (Toner et al. 1999 and references therein).

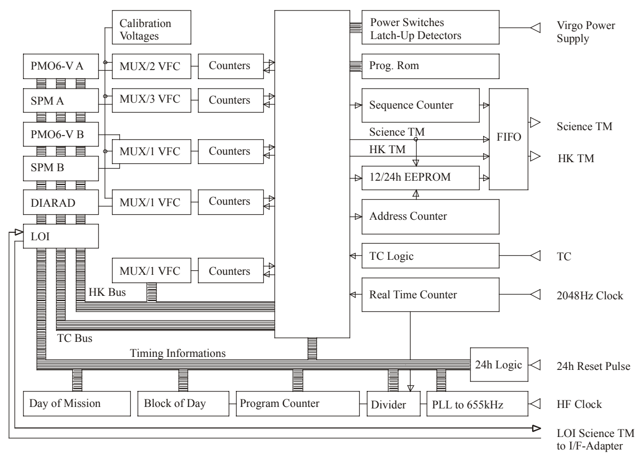

Fig. 2-7. Block diagram of the data acquisition and control system.

Data Acquisition and Instrument Control

The data acquisition and control system (DAS) is shown in Fig. 2-7. The only change from VIRGO/SOHO is that the data from LOI+ are no longer passed through DAS and that the covers are operated from the interface controller (IC, see below) in order to overcome problems encountered on SOHO. The controller within DAS is based on a hardware sequencer which will operate the same way as on SOHO. It has a 2 Mbit memory (electrically erasable PROM-type) for 25 h autonomy of the basic (without LOI+) data. The data are routed from the DAS to the interface controller (IC) shown in Fig. 2-8 located in the upper part of the extended power supply. IC provides all the signals presently received from SOHO (timing signals) and receives the science and HK data from DAS. Moreover, it provides the S/C interface for data and TC transfer.

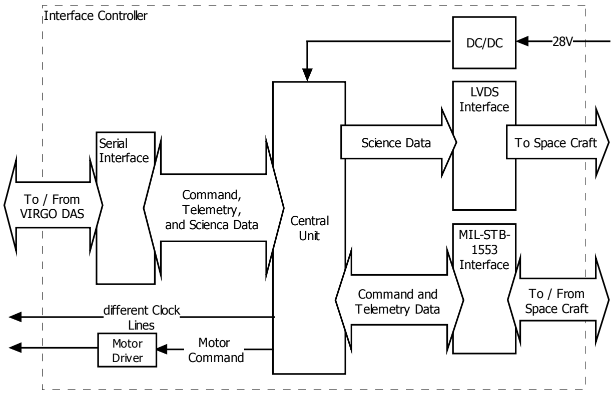

Fig. 2-8. Block diagram of the interface controller.

The scientific objectives of VIRGO II+ rely on long and uninterrupted time series. These time series are analyzed by calculating power spectra, the noise in which depends strongly on the way the sampling is carried out. Ideally, one should integrate the signal during the whole sampling interval, otherwise high-frequency noise leaks into the power spectrum. Technically, this is best achieved with voltage-to-frequency converters (VFC) which allow for true integration over a given time interval. The data acquisition is performed by 11 parallel VFC with a full-scale frequency of about 320 kHz. The basic sampling period is 10 sec, allowing for a theoretical resolution of 0.3 ppm for one reading. Within the 10 sec period the signals are integrated during 9.4 sec, the rest of the period being used for the calibration of the VFC with reference signals and the reading and resetting of the counters. This timing allows for a continuous electrical calibration and a high duty cycle of the reading (94%). The electrical calibrations are performed in turn at three points, namely zero, half full scale and full scale, allowing for a first-order correction of the non-linearity (approx 5-10 ppm) of the VFC during the evaluation of the data. With this system it is necessary to have as many parallel channels as signals to be measured simultaneously. There are 10 VFC for the science data and 1 VFC for the housekeeping (HK) channel. The accuracy of the electrical calibration has been tested thoroughly, and on SOHO it has been proven to be <30 ppm of full scale.

Another important aspect of time series analysis is the fact that accurate knowledge of the timing is necessary. This is derived from SDO time information and the corresponding clock signals provided to DAS. The SPM readings are integrated over one minute, which is centered around the full minute. The radiometer data are acquired during the last 10 sec of each shutter phase.

Every three minutes – the basic time interval of the VIRGO II+ sequencer – the following data are produced and transmitted to the IC for further formatting and transmission: 3 Science (SC) packets of 512 bytes each containing of real time, 12.8 and 25.6 hour delayed science data and 1 HK-packet of 192 bytes of housekeeping data. This corresponds to 80 b/s. The LOI+ data amounts to 0.8 Mb/s ($1000 \times 1000 \times 24$ bit every 30 sec).

Electrical Design

In order to comply with the expected radiation environment, radiation-hardened parts have been used in all sections of the DAS electronics in which a loss of information would disable the continuity of the timing, and in the interfaces to the instruments and sub-units in order to avoid back currents in case of a latch-up in the instruments. The remaining parts are protected by detectors which switch off the corresponding circuit immediately after a latch-up occurs, and will switch them on again either automatically for circuits that are important for maintaining the continuity of the measurements or by telecommand for the others.

Thermal Control

The SP is thermally controlled through the sunshield in front which is coated with conductive SSM (PS344) with $\alpha = 0.09/0.15$ (BoM/EoM) and $\varepsilon=0.81$. It is assumed that the front shield has 2π view of deep space. The PS is either collectively controlled by the S/C or has to be mounted in such a way that the top side is shaded from the Sun in all phases and can radiate to space with an unobstructed view to deep space of at least 1.8sr. The PS dissipates 11.2 W and will have a non-op heater (powered from the S/C) providing this power during switch-off. For the SP we need a thermal control heater of 10 W which is used to compensate for degradation of the SSM on the radiation shield. The SP has an internal power dissipation of 7.8W and receives 1.6W from the sun during normal measurements. It will have a non-op heater (powered from the S/C) with 7.8 W during switch-off.

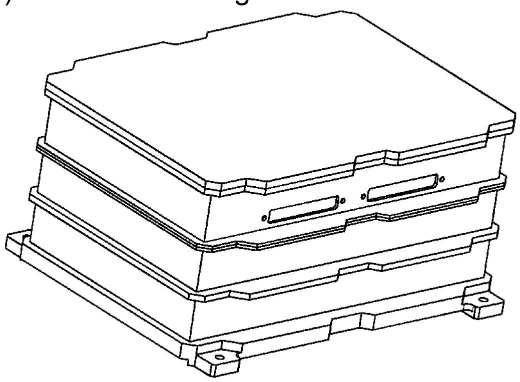

Fig. 2-9. Power Supply and Electronic Box.

Power Supply and Electronic Box

The VIRGO II$^+$ power supply (PS) is a modified copy of the SOHO/VIRGO PS to allow for the difference in the power quality supplied by SDO (Fig. 2-9). The PS converts the 21 to 35 V unregulated DC power into five regulated output voltages, ±7.4 V, 5 V, and ±9.6 V, which are current limited and over-voltage protected. The PS consists of two redundant DC/DC converter modules which operate in cold redundancy

The PS is packaged in a box of size 250 × 184 × 125 mm that is modified from the VIRGO version by enlarging its dimensions in order to accommodate the IC and the LOI$^+$ image and control processor (ICP). The ICP reads out and processes the sensor data (1000 × 1000 pixels), operates the adjusting mechanism (coarse and fine) and communicate with S/C-interface directly. The package weights 3.7 kg and the total power consumption at nominal voltage is 19.0 W.

Electrical Ground Support Equipment

The Electrical Ground Support Equipment (EGSE) is to support the electrical verification and operation of VIRGO II$^+$ during the development and verification phase at instrument and system level. The EGSE is interfaced either to the Spacecraft Interface Simulator for stand-alone operation or to the Common Check-out System during system tests. Moreover, the EGSE can be used during the commissioning phase of the mission. The software is written in Modula-2 and most can be re-used. The part for the treatment of LOI$^+$ has to be developed.

Table 2-1. Summary of the VIRGO II$^+$ specifications.

	Dimensions L x W x H (mm)	Mass (kg)	
Sensor package Box	293 x 236 x 396	17.4	
Sensor Package footprint	345 × 296		
Power Supply & Electronic Box	250 × 184 × 125	3.7	
SP & PS / El.Box total weight		21.1	
	Continuous El. Power (W)	Peak El. Power (W)	Duration Repetition Rate
Sensor Package	7.8		
Shutters		13	0.8 s/1min
Covers		13	1.6 s/1week
Launch lock		70	0.8 s / once at start of mission
Frame alignment adjustment		23	1 s / 1week
Power Supply	11.2		
Thermal control	0…10		
Non-op heaters SP	7.8		
Non-op heaters PS	11.2		

Summary of VIRGO II+ Packages.

The Table 2-1 summarizes the VIRGO II+ specifications.

The total mass is 21.1 kg, the operational (average) power consumption 19.0 W plus max 10 W for thermal control and the data rate is 0.8 Mbit/s.

2.2 Mission

Description of VIRGO II+ Observations

VIRGO II+ will observe the Sun continuously during the SDO mission, with the exception of the short periods when the Sun is eclipsed by the Earth for a few minutes per orbits. The basic idea is to operate VIRGO II+ continuously by running the instruments without interruption. The PMO6 and DIARAD radiometers, the SPM and LOI+ will observe the Sun at all times when in view. The redundant PMO6 and DIARAD radiometers and the redundant SPM will make similar observations much less frequently as they do on SOHO (at present backup operations on SOHO are performed once a week for the PMO6, once per moth for DIARAD and SPM). The basic observation cadence of VIRGO II+ is 30sec for LOI+, 1 min for the SPM, and 2 and 3 min for the PMO6 and DIARAD, respectively.

LOI+ Periodic calibrations

Systematic instrument errors introduced into the base measurements are measured and removed from the solar data through observations at different S/C roll angles and from off-pointed full-disk images at much lower cadence. During commissioning, two of these calibrations will be taken with at least a week in-between. Later, if the instrument stability allows, calibrations will be taken twice a year in conjunction with the eclipse periods.

The measurements can be made during a <12 hour roll sequence (when 40 equally spaced roll angles are sampled by the working optical channel) and will determine the instrument induced limb brightness and shape errors. To the extent that the instrument does not change between calibration sequences, roll measurements allow the accurate correction of the limb data for distortion systematic errors. Spatially offset images are used to measure the differential optical throughput (the “flat-field” calibration) using least squares techniques now successfully applied to MDI and PSPT full-disk data (Kuhn et al. 1991).

Operations

After initial S/C and instruments check-outs, VIRGO II+ will be operated through SDO Mission Operation Center from the VIRGO Data center (VDC) at IAC Tenerife which is also charged with the Science Operation Capability (SOC). Under normal circumstances operations it requires only occasionally tele-commanding. The raw data stream (68 Gbit/day) will be unpacked and sorted out in such a way that all the data from the instruments excluding those from LOI+ together with HK data can be transmitted via internet to the VDC. For the LOI+ data a small selection will also be transmitted via internet to track the operational health and the rest will have to be transmitted finally by mass storage media to the VDC. The ancillary data from the S/C are transferred via internet to the SOC.

Spacecraft requirements

VIRGO II+ complies fully with the SDO S/C as defined in the AO. A requirement for the placement of the sensor package is an unobstructed view from the front part of about 60 degree full angle in order to avoid stray light. For the calibration of LOI+ we need roll maneuvers at 9° angular increments and off pointing sequences for flat fielding. Both could be performed in connection with the eclipse periods.

2.3 Data Collection, Analysis, and Archiving

LOI+ Data Products

LOI+ will generate a single science data stream made of intensity images of 1000×1000 pixels coded on 24 bits every 30 sec. This will produce a data rate of about 0.8 Mbits/s or about 68 Gbits per day. This data rate is likely to be an upper limit because loss-less compression can reduce this volume by a factor 2 to less than 34 Gbit. In the course of the Phase A a trade-off between onboard computing and the effective data rate allowed to VIRGO II+ will be made.

On ground, from LOI+ data we will generate 4 science data streams derived from the single original stream:

- Full-disk calibrated intensity images with a 30 sec sample interval.
- Limb photometry data with a basic cadence of 30 seconds. Approximately 1500 × 20 limb pixel intensity measurements of 14 bits each are generated per minute. These data are used for Tasks 1-4, and 6.
- Full-disk intensity images are acquired with a 30 sec sample interval then low-pass filtered to generate 12 min cadence, 16 bit images. These data are required for Task 6, but will be used in conjunction with all other tasks.
- On a weekly cycle, for about 12 hours, LOI+ will generate focus, distortion, flat-field, and filter calibration data. During the calibration cycle approximately 50 full-disk images will be generated for flat-fields, 120 limb pixel records for distortion, 12 full disk images for focus calibration, and 6 full-disk images for filter calibration. These data are required for all tasks.

Irradiance Data Products

Spectral irradiance measurements by SPM are generated with a 1 min cadence. The PMO6 and DIARAD total irradiance data are generated with a 2 and 3 min cadence, respectively. These data are required for Task 5 and the associated part of Task 6, but will be used in association with all tasks. The raw data volume generated by these instruments is less than 1 Mbyte per day.

The VIRGO II+ data product time series are corrected for all a priori known effects such as temperature, pointing, Sun distance and relative velocity (for level 1 data). Inferred effects such as instrument degradation are taken into account for level 2 data, which can be provided only somewhat later than the actual measurement, when the instrument degradation has been characterized.

The products of the VIRGO II+ investigation are the following data:

- Continuous high precision, high stability and high accuracy measurements of solar total and spectral irradiance and their variation.
- Accurate power spectra of spectral irradiance in the range from 0.03 μHz to 8 mHz and total irradiance in the range from 0.03 μHz to 4 mHz.
- Frequencies, amplitudes and phases of oscillation modes in the frequency range of <100 μHz to 8 mHz

2.4 Science Team

The VIRGO II+ science team comprises most of the SOHO/VIRGO team members: Bo N. Andersen, Thierry Appourchaux, Pål Brekke, Werner Däppen, Steven Dewitte, Vicente Domingo, Bernhard Fleck, Claus Fröhlich, Douglas O. Gough, Antonio Jimnez, Andrew R. Jones, Alexandre Joukoff, Natalie A. Krivova, Jeffrey R. Kuhn, Torben Leifsen, Judit M. Pap, Janine Provost, Teodoro Roca Cortés, Eugene V. Rozanov, Isabelle Rüedi, Michael E. Schlesinger, Werner K. Schmutz, Sami K. Solanki, Thierry Toutain, Christoph Wehrli.

The team is well qualified to realize all aspects of the experiment. The roles of the team members is identified in Section E, in particular in Table E-1, and the experience of the Co-Is are included in their resumes (Section G1). The involvements of the U.S. team members in current and pending projects are also listed in Section G1 as an addition to the resume.

D. Education and Public Outreach (E/PO)

1. Overview and Objectives

Study of the Sun's variability has captured the interest of mankind over centuries. Sunlight supplies the energy that sustains life on Earth and drives the dynamics of terrestrial climate.

It is now established that the terrestrial climate, radiative environment, and upper atmospheric chemistry are influenced by the varying luminosity of the Sun. One of the most important questions in climate research is whether the recently measured global warming trend is dominated by anthropogenic effects or has a significant solar component. Human consequences are such that quantitative study of the Sun over many solar cycles is imperative for societal planning. The ultimate goal is to uncover how and why the Sun is changing on human time scales, in order to reconstruct the solar-induced climate changes – and to estimate their magnitude compared to those apparently resulting from anthropogenic activities – important questions of great interest to broad communities beyond that of our scientific peers.

The goal of this Education/Public Outreach (E/PO) plan is therefore to explain and broadcast, to an audience as wide as possible, the most recent results of solar-terrestrial physics research, with special attention to the Living with a Star program. We should reach schools and the general public via articles, lectures, media connections, world wide web sites, videos, brochures, planetarium shows, and as many other innovative ways as possible. An important aspect of E/PO activities is to include young college / university students in the development of our investigation as early as possible -- not only to call their attention to the importance of Sun-Earth connections and associated investigation programs, but also to better introduce them to various aspects of engineering, time series analysis, and solar terrestrial physics, just to name a few basic research areas.

In addition to such direct outreach to the general public and involvement of college / university students in science investigations, an extremely effective way to publicize scientific results, including the results of solar-terrestrial research, is to reach out to younger school children. Capturing their interest is the best avenue to informing their parents about the importance of this program and support of science in general. In this sense, children can be our best advocates. To capture their attention is also important, since today's children will take over our mission in the future, namely to carry out the research and to educate our public about the changing universe and our small part: the solar system and its central part, the closest variable star – our Sun.

The proposed E/PO plan is a collaborative effort between the Goddard Earth Sciences and Technology Center (represented by Judit M. Pap), University of Hawaii (represented by Jeffrey Kuhn), and University of Southern California (represented by Werner Däppen). In addition to the U.S. E/PO effort, European Co-Investigators will also contribute to the proposed E/PO activities. Judit M. Pap leads the U.S.-part of the VIRGO II+ E/PO effort, whereas Pål Brekke leads the European part of the effort.

2. Outreach Initiatives

Our E/PO program is a collaborative effort between the participating U.S. and European institutes. The leading institute of the U.S. E/PO part is the Goddard Earth Sciences and Technology Center (GEST), whereas the European activities are organized and coordinated by ESA's Educational Office. **The VIRGO II^{+} team has a strong commitment to work together with other SDO investigation teams and the LWS Program E/PO activities which is being planned to be carried out through NASA/GSFC.** Although we ask for separate funding of the U.S. E/PO activities by NASA and European E/PO activities by ESA and/or individual EU countries, we intend to exchange E/PO data products to expedite public outreach and reduce the cost by avoiding duplication of our efforts.

U.S. E/PO Activities:

The U.S. E/PO leading institute, GEST, is a consortium of five organizations, managed by the University of Maryland, Baltimore County (UMBC), and which also includes Howard University in Washington, DC, Hampton University in Hampton, Virginia, Caelum Corporation in Rockville, MD, and Northrop Grumman Corporation in Baltimore, MD. In addition to performing scientific research, its charter includes responsibility for conducting Education and Public Outreach programs. These currently include activities such as organizing and managing four summer courses, conducting seminars and workshops, employing and mentoring graduate students, and maintaining an educational website. E/PO activities associated with the VIRGO II+ experiment and the Sun-Earth Connection (SEC) program in general will be natural extensions of the vigorous programs already under way. Participation of Howard University and Hampton University will also enable us to reach and involve student bodies in predominantly minority schools. In addition to these GEST-related activities, University of Hawaii and University of Southern California will also participate in the E/PO effort.

The proposed VIRGO II+ Co-Investigator (Dr. Judit M. Pap) will participate personally by delivering colloquium lectures at the three GEST consortium universities; by serving as a mentor for students enrolled in GEST graduate summer courses. The U.S. Co-Is will volunteer to lecture and mentor at local High Schools. Specifically, Judit Pap (GEST) will work in the local Washington D.C. area, Co-I Werner Däppen (USC) will assist with the distribution of educational material to schools in the Los Angeles area, while Jeffrey Kuhn (University of Hawaii) will help to provide web access and exposure through the University's observatory site at Hawaii. A major portion of the U.S. E/PO activities involves collaboration with the Smithsonian National Air and Space Museum in the form of preparing displays and public lectures. Many of these activities will require little or no funding.

European Activities:

In an effort to promote and reinforce European educational excellence in the space-related field, ESA has created a dedicated office, the ESA Education Office. Its work includes promoting the inclusion of space-related topics in the curricula of students at all levels and to reach the general public throughout Europe. Part of the European E/PO activity is to provide information, popular science articles, power point presentations to the ESA Education Office and to EDUSPACE. EDUSPACE – The European Earth Observation web site has been developed under the umbrella of EURISY by ESA and its national and industrial partners.

It aims to provide European students and teachers with new learning and teaching tools and to offer an entry point to space-based observations. As of today, its focus is on Earth observations, but since global changes is a main topic; solar variability will be incorporated, since ESA has endorsed the International Living with a Star program into the EDUSPACE objectives. By collaborating with the ESA Education Office and EDUSPACE, we can rely on professionals to make sure that our science and results will reach students and teachers in all European countries. Other possible collaboration with the ESA Education Office could be a summer school for students or workshops for teachers.

Together with the ESA Science Communication Service, we also suggest a possible traveling exhibit with a Sun-Climate theme in line with the very successful EPOS - The European Project on the Sun (http://www.ecsite.net/epos/public/homepage.htm).

The next section presents a more detailed listing of the E/PO activities that are planned as part of this proposal.

3. Specific E/PO Activities

3.1 Education

Graduate Student Summer Program

This is a ten-week program of GEST extending from mid-June to mid-August, for graduate students of science or mathematics, in which one or more students will be assigned to work with Dr. Pap on an intensive project, while also interacting with other students and mentors in related research subjects. The program is nationally advertised, and typically attracts local, national, and international candidates, with a high percentage of minorities. It is a program that is subsidized by the NASA Goddard Space Flight Center, Earth Sciences Directorate and will not require VIRGO II+ Experiment funds.

Colloquium Lectures

Dr. Pap has been invited to speak at a UMBC Physics Department colloquium during the Fall Semester. Similar invitations are expected from Howard and Hampton Universities. These will be an opportunity to describe the objectives, importance, and features of the SDO and LWS programs to a wide range of undergraduates and graduates, including minorities, who may be influenced to choose related career paths. Similar activities are planned by other VIRGO II+ Co-Is in their Universities.

Mentor and Lecture at local High Schools

Arrangements will be made to collaborate with science teachers and administrators at local High Schools to teach, provide demonstrations, and involve students in analyzing and interpreting SDO data.

3.2 Popular Science Articles and Lectures

The Co-Is will contribute regularly to popular science magazines on solar variability and climate effects. The team members will also give public lectures at local museums, universities, schools and planetarium. Furthermore we will develop basic, but fascinating, power point presentations on the Sun-Climate topic. This presentation will be distributed to all team members and will be used at local events. It will also be offered to the ESA Education Office and the EDUSPACE network. Some of the team members have already developed a similar presentation with science highlights from SOHO. This was used successfully in many places in the U.S. and Europe during the 5-year anniversary of SOHO.

An Education web site on basic solar variability and effects on the Earth's Climate will be designed by the science team. We will collaborate with and build on existing Internet resources for outreach. Based on this web site we suggest, together with ESA Science Communication, to develop a CD-Rom. The content could be HTML coded or a more elaborated programming technique could be used. The advantage of an HTML coded version is that it can be done by team members and be based on the education website. We will argue that the CD as a medium is still very useful and we can reach larger groups of students this way since many schools still don't have Internet access. A Sun-Climate poster should be designed in collaboration with the ESA Science Communication Service and the ESA education office. The backside should include basic information about the Sun-Climate topic in line with the very popular SOHO or Space Weather posters developed at GSFC.

http://www.istp.gsfc.nasa.gov/istp/outreach/cmeposter/. The cost of the designs of the posters is being negotiated with ESA; upon its success, the VIRGO II+ U.S. E/PO funding will be used for their production.

3.3 Media Relations

A powerful way of reaching the public is through good media coverage. To achieve this, it is important to establish contact with a large number of key science journalists throughout the U.S. and Europe. A network like this has already been created for the SOHO mission and has proved to be very efficient. We will work with existing public affairs offices to produce packaged media releases describing new results in a timely, exciting, and accessible manner. In Europe we will in particular collaborate with the ESA Science Communication Service using their expertise to further develop and improve media relations. In the U.S., we will work with the LWS E/PO office in media relations.

3.4 Displays and Public Lectures at the Smithsonian National Air and Space Museum

As shown by the attached letter from the Smithsonian National Air and Space Museum (NASM), we will establish a "limited" partnership with NASM. Using the VIRGO II$^+$ results, and other SDO results, the "Exploring the Universe" exhibit will be updated to bring the latest results of Sun-Earth connections to the public. In addition to displaying results from VIRGO II$^+$ (and possibly from other SDO investigations), NASM will host public lectures, which will highlight results from VIRGO II$^+$/ SDO and other LWS missions.

Additional educational programs will be considered on case-by-case basis, like to produce special tours related to solar studies.

4. E/PO Relations to SDO Investigations and LWS

Upon the approval of the VIRGO II$^+$ proposal and its E/PO activity, we will coordinate our efforts with other SDO investigation teams and the LWS Program E/PO activities, which are being planned to be carried out through NASA/GSFC. Close collaboration with the GSFC led E/PO Office is especially important in the case of collaborative efforts with NASM which would provide opportunities not only for VIRGO II$^+$ but to the entire LWS community. Considering that NASM is one of the largest centers of public education within the U.S., this activity has a unique opportunity to reach out to the American public on the research area of solar-terrestrial physics. The proposed collaborative effort with ESA will make it possible to inform both the U.S. and European public about their on-going and future joint and national space science activities.

E. Management and Schedule

The VIRGO II$^+$ management approach stems from the successful planning and implementation of experiments in previous solar missions like IPHIR on PHOBOS, SOVA2 on EURECA, and VIRGO on SOHO, where PMOD/WRC took the lead role as principal investigator institute.

The hardware partner institutes RMIB and RSSD/ESA have themselves long-standing experience in planning, managing and successful implementation of space experiments, e.g. on Spacelab-1, EURECA, SOHO, and Ulysses.

Each of these programs included international collaboration with scientists participating from European countries and the U.S.A. The lessons learned from these experiments and missions, combined with in-place infrastructure, are directly applicable to a low-risk and high-science return investigation like VIRGO II$^+$.

1. Management Team – Roles, Responsibilities and Experience

The VIRGO II$^+$ investigation team is led by Dr. Werner Schmutz as Principal Investigator (PI) and a Technical Manager (PM) Hansjörg Roth, both from PMOD/WRC. The PI ensures that the mission is implemented and executed to achieve science objectives within the levied resource constraints. The PM is responsible for technical and business management. Fig. E-1 shows the mission management structure. Each institution's effort is directed by that group's lead scientist. Clear accountability and responsibility are assigned to enable effective decision-making.

- *VIRGO II$^+$ package:* The Project is managed by H. Roth, PM at PMOD/WRC, working in close cooperation with the PI, W. Schmutz, and C. Fröhlich, the SOHO/VIRGO-PI. The PM leads the refurbishment and extension of the experiment package, along with its functional and environmental testing and technical calibration that will be performed at PMOD/WRC.
- *PMO6 and SPM* refurbishments are lead by the instrument-PIs I. Rüedi and C. Wehrli, respectively. They are responsible for the characterization and calibration of the instruments.
- *DIARAD:* A. Joukoff, instrument-PI at RMIB, leads the refurbishment and investigation efforts of the VIRGO/ DIARAD radiometer.
- *LOI$^+$:* T. Appourchaux, instrument-PI at RSSD, leads the major upgrade of the VIRGO/LOI to a 'Photometric Imaging Telescope'. He is assisted by B. Andersen for the design and development of the read out electronics and by J. Kuhn for astrometric instrument performance.
- LOI$^+$ electronics: B. Andersen is directing the design and development of the LOI$^+$ read out electronics
- EGSE, SOC, and Data Center (VDC): A. Jimenez, CoI from IAC, leads the refurbishment of the power supply (PS), the EGSE S/W, and re-organization of the VIRGO Data Center (VDC).

The VIRGO II$^+$ science team is led by the Experiment Scientist (ES), Bo Andersen, who has already assumed this role for VIRGO / SOHO. The ES coordinates the science efforts during Phase E on data processing, analysis, interpretation, and archiving to deliver VIRGO II$^+$ data products.

The roles of all VIRGO II$^+$ CoIs are identified in Table E-1.

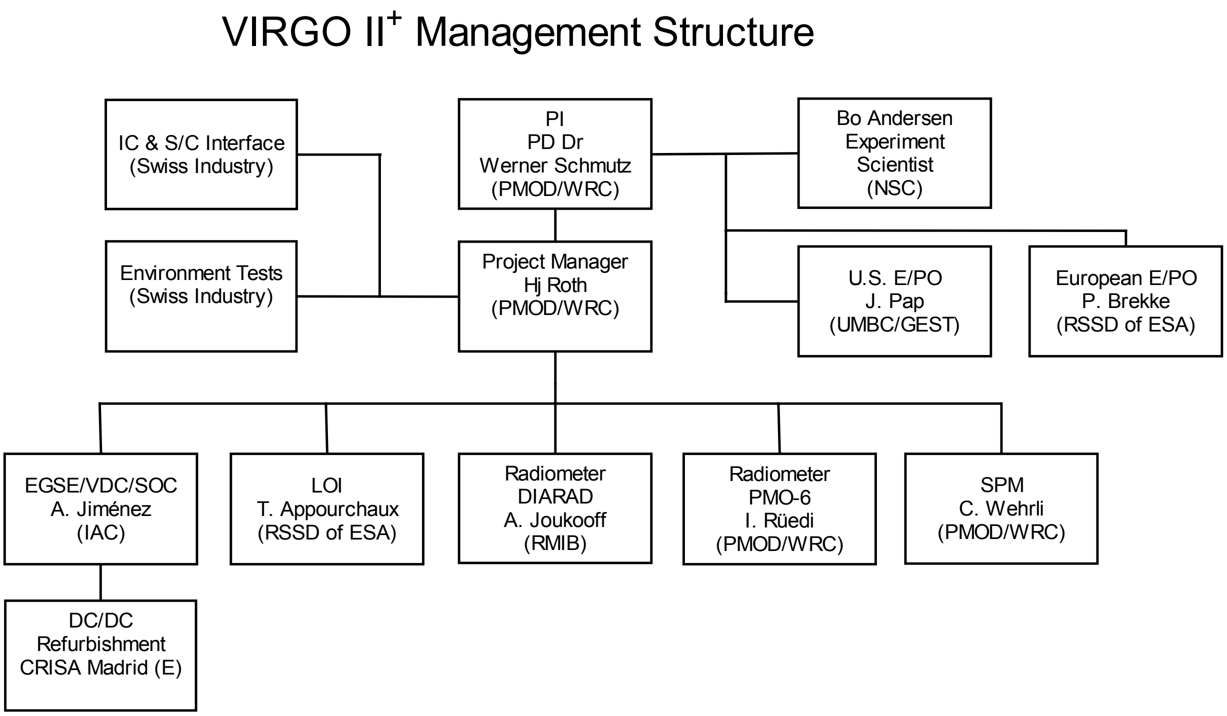

Fig. E-1. VIRGO II+ Management Structure.

2. Institutional Experience

Physikalisch-Meteorologisches, Observatorium Davos and World Radiation Center (PMOD/WRC)

- Development of instruments and characterization procedures for absolute total and spectral solar and terrestrial long-wave radiometry
- Investigation of the solar total irradiance, its spectral distribution and variability for global climate research, solar physics, and helioseismology (IPHIR, SOVA and VIRGO Experiments)
- Investigation of radiation within the atmosphere and at the ground for the determination of its spectral distribution and variability in the UV.
- Theoretical investigation of the Sun-climate connection

Royal Meteorological Institute of Belgium (RMIB) National Meteorological Service and Regional Radiation Center (WMO)

- Development of absolute differential radiometers, including conception, construction and full characterization
- Investigation of the total solar irradiance in space since 1983 for climate studies
- Earth radiation budget studies (participation in CERES and GERB)
- Ground based routine radiation measurements, including spectral distribution.

Research and Science Support Department of ESA (RSSD)

- Development of numerous payloads for science mission (LOI/SOHO, Beppo/SAX, Eureca, Ulysses, etc.)
- Development of detectors such as the Superconducting Tunnel Junctions
- Scientific support for ESA science missions
- Optical, electronics laboratory
- Research performed in astrophysics, solar system and solar physics
- Access to the ESA technical support

Table E-1. VIRGO II+ science team members.

Name	VIRGO II$^+$ role
Werner Schmutz PMOD/WRC Switzerland	Principle Investigator, overall responsible for the VIRGO II$^+$ package
Hansjörg Roth PMOD/WRC Switzerland	Technical Manager, overall responsible for the technical functioning of VIRGO II$^+$
Claus Fröhlich PMOD/WRC Switzerland	PI-SOHO/VIRGO, expert advisor for all aspects of the experiment
Bo Andersen Norw. Space Centre Norway	Leader science investigation team
Thierry Appourchaux RSSD ESA	Instrument-PI LOI$^+$, responsible for the technical design, operation, and data products of LOI$^+$
Alexandre Joukoff RMIB Belgium	Instrument-PI DIARAD, overall responsible for DIARAD
Isabelle Rüedi PMOD/WRC Switzerland	Instrument-PI PMO6-V Responsible for operation, and data products of PMO6
Christoph Wehrli PMOD/WRC Switzerland	Instrument-PI SPM Responsible for operation and data products of SPM
Paal Brekke RSSD ESA	Science team member, European E/PO coordinator
Werner Däppen USC U.S.	Science team member, theoretical support in phase E (unfunded)
Steven Dewitte RMIB Belgium	DIARAD CoI, responsible for DIARAD total solar irradiance determination
Vicente Domingo Unif. of Barcelona Spain	Science team member, data analysis in phase E, TSI, LOI$^+$
Bernhard Fleck RSSD ESA	Science team member, data analysis in phase E, TSI, helioseismology
Douglas Gough Univ. of Cambridge United Kingdom	Science team member, theoretical aspects of solar variability
Antonio Jimenez IAC/VDC Spain	Head VIRGO Data Center (VDC), responsible for upgrade of Power Supply, data analysis in phase E, TSI, helioseismology
Andrew Jones USC U.S.	Science team member, data analysis in phase E, TSI, helioseismology
Natalie Krivova MPAE Germany	Science team member, data analysis in Phase E TSI, SSI and modeling
Jeffrey R. Kuhn Univ. of Hawaii U.S. (NASA funded)	Advisor of PI, definition of astrometric- and photometric instrument performance, advisor of instrument design and configuration. In phase E contributions to analysis algorithms for astrometry and irradiance procedures
Torben Leifsen Univ. of Oslo Norway	Science team member, data analysis during Phase E, helioseismology
Judit M. Pap GEST/UMBC U.S. (NASA funded)	Science team member, data analysis in phase E, TSI, SPM and LOI$^+$ U.S. E/PO coordinator
Janine Provost Obs. Côte d'Azur France	Science team member, theoretical aspects of helioseismic data
Teodoro Roca Cortés IAC/VDC Spain	Science team member, responsible for upgrade of Power Supply, data analysis in phase E, helioseismology
Eugene Rozanov PMOD/WRC Switzerland	Science team member, representative of the climate community interested in VIRGO II$^+$ total and spectral irradiance data products
Michael Schlesinger U. o. Illinois at Urbana-Champain U.S. (NASA funded)	U.S. representative of the climate community expert advisor in team meetings in 02, 03, and 07
Sami Solanki MPAE Germany	Science team member, data analysis during Phase E, SSI, TSI, LOI$^+$ and modeling
Thierry Toutain Univ. of Oslo Norway	Science team member, data analysis during Phase E, helioseismology

Instituto de Astrofisicas de Canarias (IAC)

- Management of VIRGO power supply manufacturing.
- Development of Electric Ground Support Equipment (EGSE) for VIRGO experiment.
- Development and operation of VIRGO Data Center.
- Active astrophysical research including helioseismology

3. Top Level Schedule

Fig. E-2 shows our Master Schedule. It is based on a critical path network that establishes task interrelationships, event time-phasing and key activities.

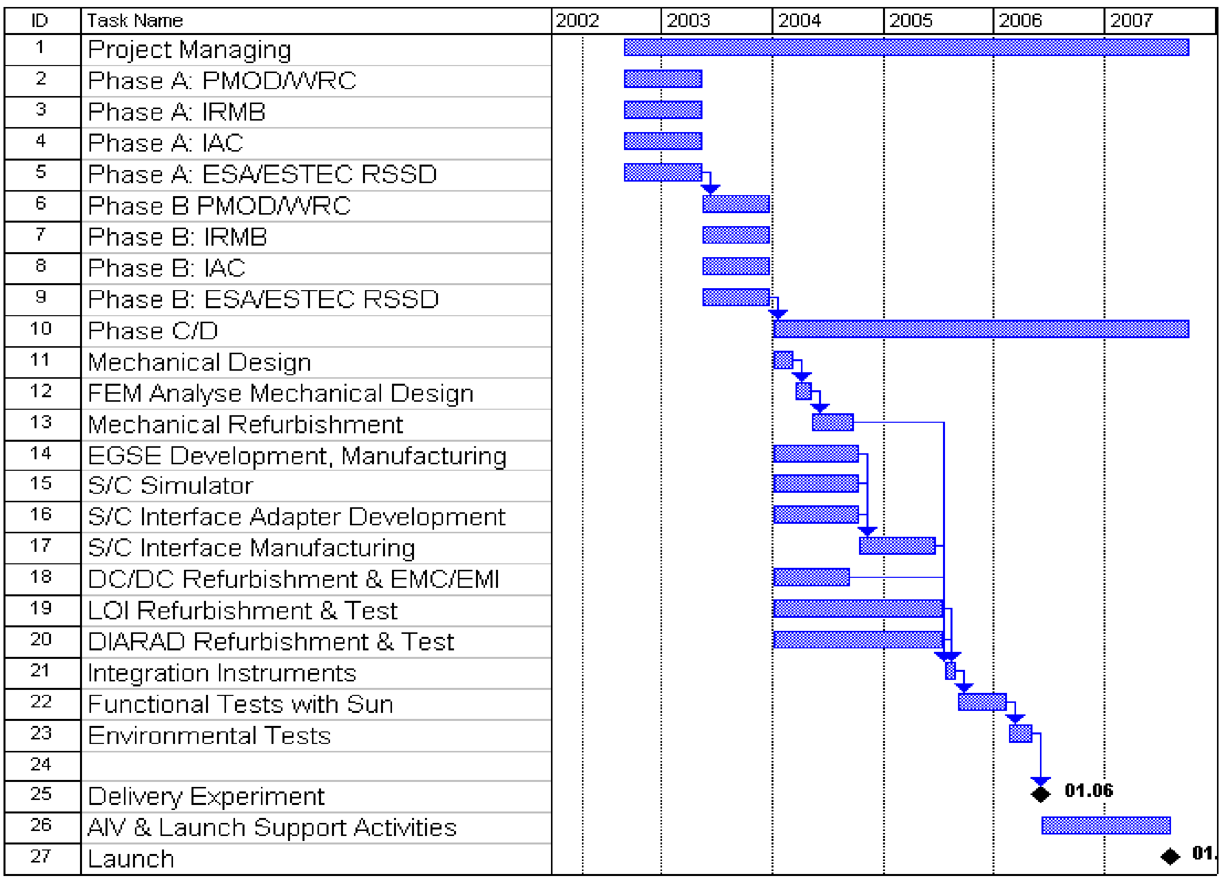

Fig. E-2. VIRGO II+ Program.

F. Cost Estimating Methodology and Costs

The WBS served as the cost estimating framework to subdivide the mission into tasks and components.

- *Instrument:* This element includes program management, science support, systems engineering, instrument systems, and instrument integration. The fabrication / refurbishment costs are based on LOI on SOHO and the VIRGO upgrades based on the original development program. For the Power Supply, CRISA, Madrid, offered an estimate for refurbishment and tests and from Alcatel Space, Gals, we have an offer for the interface controller.
- Science analysis and archival costs are contributed by IAC.

1. Full Cost Accounting

Table F-1 summarizes the estimated VIRGO II$^+$ costs by major cost elements.
Table F-2 provides the anticipated total cost and summarizes the Phase A. Table F-3 lists the contributed costs. In Table F-4 the costs of the WBS elements are listed according to the definition of these elements given in Table B-4 of the AO.

Table F-1. VIRGO II$^+$ NASA Costs.

	[$]
Phase A	20’170
US Science Team Support	502’080
Education & Public Outreach	10’445
Total NASA Cost	532’695

Table F-2. VIRGO II$^+$ Cost Totals.

	[$]
Total NASA Cost	532’695
Total European Contributions	1’485’000
Total Cost (TMLCC)	2’017’695

Table F-3. European Contributed Costs.

Description of Contributed Item	[$]
PMOD/WRC: SOHO flight spare VIRGO instrument	0
PMOD/WRC: refurbishment to fix two problems encountered on SOHO: the LOI cover and the PMO6 shutters	80’000
PMOD/WRC: Interface controller between SDO S/C and the existing SOHO interface	318’000
RSSD of ESA: up-dated LOI with high resolution imager	200’000
Norwegian Space Center: read-out- & guiding electronics for LOI$^+$	200’000
IAC: refurbishment of existing Power Supply needed to adapt the wider input voltage range of SDO.	100’000
IAC: up-date of the EGSE S/W and H/W	12’000
IAC: H/W and S/W up-date of the VIRGO data Center (VDC) at Tenerife to enable operation of the SOC.	150’000
RMIB: refurbishment of DIARAD	120’000
PMOD/WRC: spacecraft interface simulator (S/W and H/W) to establish a test link between EGSE and experiment.	90’000
PMOD/WRC: environmental tests for the experiment. (vibration, thermal balance, thermal vacuum, EMI/EMC and FE-analysis)	80’000
Total	1’350’000
Total including 10% contingency	1’485’000

2. Services offered

A key factor for the high science/cost ratio (especially for NASA) is the fact that the VIRGO II$^+$ experiment is based on existing H/W and on contributed hardware, software, and infrastructure from the European partners (see Table F-3). These contributions are shown in the Total Mission Life Cycle Cost (TMLCC), but not in the list of NASA Mission Cost (NMC).

3. Reserves and Margins

The budget contains an overall reserve of 10% on the European program elements.

4. Risk Mitigation

Potential risks to mission success are minor because we are proposing mostly existing and proven flight hardware.

5. De-scope Options

Although Virgo II+ comprises a suite of instruments they cannot be selected individually because all instruments are within the same package and connected to a common data acquisition and control system.

Table F-4. Total Investigation Cost Funding Profile.

Item	FY02	FY03	FY04	FY05	Subsequent Fiscal Years		Total [RY$]	Total [FY02$]
NASA Cost								
Phase A								
WBS 1.3 MS		6'431					6'431	0
WBS 1.3/4.1 JP		6'742					6'742	0
WBS 1.3 JK		6'997					6'997	0
Phase A total	0	20'170					20'170	0
Phase B/C/D								
WBS 1.3: MS			6'688		7'824		14'512	
WBS 1.3/4.1: JP			6'954	7'172	7'397		21'523	
WBS 1.3: JK			7'200	7'423	7'647		22'270	
Phase E								
WBS 1.3: MS					15'648		15'648	
WBS 1.2/1.3/4.2: JP						367'489	367'489	
WBS 1.2/1.3: JK						60'638	60'638	
E/PO:								
WBS 3.0	0	403	417	292	770	8'563	10'445	
Total NASA Cost	0	20'573	21'259	14'887	39'286	436'690	532'695	0
European Contributions								
WBS 1.0								
WBS 1.1								
WBS 1.2								
WBS 1.2.1	10'000	60'000	60'000	35'000	35'000		200'000	10'000
WBS 1.2.2								
WBS 1.2.3		5'000					5'000	
WBS 1.2.4		30'000	30'000	30'000	10'000		100'000	
WBS 1.2.5		10'000					10'000	
WBS 1.2.6	20'000	70'000	148'000	20'000	20'000		278'000	20'000
WBS 1.2.7		25'000	30'000	70'000	70'000		195'000	
WBS 1.2.8	5'000	15'000	20'000	20'000	20'000		80'000	5'000
WBS 1.2.9	5'000	85'000	85'000	62'000	5'000		242'000	5'000
WBS 1.3		40'000	40'000	40'000	40'000		160'000	
WBS 3.0								
WBS 3.1					10'000		10'000	
WBS 3.2					30'000			
WBS 4.0								
WBS 4.1	5'000	5'000	5'000	5'000				5'000
WBS 4.2					20'000			
Total European Contributions	45'000	345'000	418'000	282'000	260'000		1'350'000	45'000
Total European Contributions + Reserve 10% of contributions							1'485'000	49'500
					Total Invest. Cost		2'017'695	49'500

G1. Resumes

This Appendix contains the resumes of VIRGO II $^{+}$ investigators and project manager sorted alphabetically:

- Bo N. ANDERSEN
- Thierry APPOURCHAUX
- Pål Brekke
- Werner DÄPPEN
- Steven DEWITTE
- Vicente DOMINGO
- Bernhard FLECK
- Claus FRÖHLICH
- Douglas O. GOUGH
- Antonio JIMENEZ
- Andrew R. JONES
- Alexandre JOUKOFF
- Natalie A. KRIVOVA
- Jeffrey R. KUHN
- Torben LEIFSEN
- Judit M. PAP
- Janine PROVOST
- Teodoro ROCA CORTÉS
- Hansjörg ROTH
- Eugene V. ROZANOV
- Isabelle RÜEDI
- Michael E. SCHLESINGER
- Werner K. SCHMUTZ
- Sami K. SOLANKI
- Thierry TOUTAIN
- Christoph WEHRLI

Bo N. Andersen

Bo Andersen is Deputy Managing Director and Director of Science and Earth Observation at the Norwegian Space Centre, Oslo, Norway where he has been employed since 1988. From 1985-1988 employed in Space Science Department of ESA as scientist. From 1975-1985 employed at Institute of Theoretical Astrophysics and Oslo Solar Observatory, University of Oslo.

He has published about 100 publications (27 in refereed journals) in the fields of solar and stellar physics, instrumentation and space policy.

Responsible for the development, testing and utilization of ground based instrumentation and software at Oslo Solar Observatory. Responsible for the initial design and breadboard/prototype development of the LOI in the VIRGO experiment on SOHO. Experiment scientist for the VIRGO investigation.

Norwegian delegate to the ESA Science Programme Committee (1988-1999), Vice-Chairman (1993-1997) and Chairman (1999-2002). Delegate to the ESA Council (1999-2002). Member of Space Committee of Research Council of Norway (1989-2002) and Chairman (1996-2002). Chaired international Evaluation of Danish Space Research (1994). Member of several official space and general science policy activities/committees in Norway during the last ten years. Referee to Astronomy and Astrophysics and Solar Physics. Member of Norwegian Academy of Technical Sciences since 1999.

Thierry Appourchaux

Thierry Appourchaux is a staff member of the European Space Agency (ESA) since 1988. He is the Instrument Scientist of the Luminosity Oscillations Imager (LOI) of VIRGO aboard the SOHO spacecraft. For the LOI, he was responsible for the overall design and implementation of the design at the Space Science Department of ESA (now Research and Science Support Department). He has also used the data from the LOI for performing helioseismology. He is the author of 25 referee papers, and about 50 conference papers in helioseismology. He is a member of the Data User Committee of the Global Oscillations Network Group.

In the 90's, he was also the Study Scientist of the PRISMA study (asteroseismoology). His current hardware involvement is related to managing the building of the Data Processing Units of the French COROT mission (asteroseismology and exoplanets), a program of the Centre National d'Etudes Spatiales (CNES). He is also involved in detector technology including Active Pixel Sensors and blind detectors. He is a member of the Science Payload and Technology Division of ESA where he gives support for the assessment of past, current and future payloads of ESA missions.

Pål Brekke

Name of Institution:
European Space Agency

Education:
Dr. Scient. degree in Astrophysics at the Institute of Theoretical Astrophysics, University of Oslo, Norway
Thesis title: Observed Structure and Dynamics of the Solar Chromosphere and Transition Region based on High Resolution Ultraviolet Spectrograms

Professional Background:

- 1985-90: Research Assistant, Institute of Theoretical Astrophysics, University of Oslo.
- 1990-92: Doctoral Research Assistant at the Institute of Theoretical Astrophysics (Grant from the Norwegian Research Council for Science and the Humanities (NAVF)
- 1993-95: Research Fellow at the Institute of Theoretical Astrophysics (Post Doctoral Research Grant from the The Research Council of Norway (NFR)
- April 1994 -- October 1995: Visiting Scientist at NASA Goddard Space Flight Center, Greenbelt, Maryland.
- October 1994 -- April 1995: Visiting Scientist at High Altitude Observatory, National Center for Atmospheric Research, Boulder Colorado.
- 1996 -- 1998: Research Scientist at the Institute of Theoretical Astrophysics
- 1999 -- present: European Space Agency - SOHO Deputy Project Scientist

Relevant Experience:
My main interest is in observational solar physics with particular emphasis on EUV imaging and spectroscopy. This includes photometry, calibration and analysis of HRTS data, irradiance observations from SUSIM and SOLSTICE. I have extensively utilized both CDS and SUMER observations. I have been responsible for outreach activities for SOHO as well as much of the media relations

Relevant Publications
ca 103 publications (40 in refereed journals) and 22 popular science articles.

Quiet Sun Spectral Atlas Between 6600-2500 A (first order): Curdt, W., *Brekke, P.*, Schühle, U., Wilhelm, K., Dwivedi, B.N.: 2001, A&A 375, 591

EUV Full Sun Imaged Spectral Atlas Using the SOHO Coronal Diagnostic Spectrometer: Thompson, W.T., *Brekke, P.:* 2000, Solar Phys. 195, 45

Doppler Shifts in the Quiet-Sun Transition Region and Corona Observed with SUMER on SOHO: *Brekke, P.*, Hassler, D.M., Wilhelm, K.: 1997, Solar Physics, 175, 349-374

The Ultraviolet Spectrum of a 3B Class Flare Observed with SOLSTICE: *Brekke, P.,* Rottman, G.J., Fontenla, J., Judge, P.G.: 1996, Astrophysical journal, 468, 418-432

Werner Däppen

Education:

- Diploma in Physics, ETH Zürich, 1975
- Dr. Sc. Nat. in Theoretical Physics, ETH Zürich, 1978

Research Experience:

- Professor of Physics and Astronomy, USC, Los Angeles, 1998-
- Associate Professor of Physics and Astronomy, USC, Los Angeles, 1991-1998
- Visiting Professor, University of Vienna, Austria, 1991-1992
- Visiting Member, ITP Santa Barbara, CA, Mar.-Apr. 1990
- Visiting Member, ITP Santa Barbara, CA, Dec. 1989
- Visiting Scientist, ESA-ESTEC (Netherlands), 1988-1990
- Visiting Scientist, CEN-Saclay (France), 1987-1988
- Visiting Professor, Observatoire de Paris-Meudon (France), 1986-1987
- Visiting Scientist, High Altitude Observatory, Boulder, CO, 1984-1986
- Postdoctoral Research Fellow, Institute of Astronomy, Cambridge (UK), 1982-1984
- Postdoctoral Research Fellow, Observatoire de Genève (Switzerland), 1978-1981

Honors:

- Overseas Fellow, Churchill College, Cambridge (UK)
- Member, International Astronomical Union

Relevant Papers:

W. Däppen, D.M. Mihalas, and D.G. Hummer: 1988, “The Equation of State for Stellar Envelopes: III. Thermodynamic Quantities", Astrophys.J. 332, 261-270.

J. Christensen-Dalsgaard, W. Däppen, and Y. Lebreton: 1988, “Solar Oscillation Frequencies and the Equation of State" Nature 336, 634-638.

Christensen-Dalsgaard, J., Däppen, W.: 1992, "Solar oscillations and the equation of state", Astronomy and Astrophysics Review 4, 267-361.

Basu, S., Däppen, W. & Nayfonov, A. 1999, “Helioseismic Analysis of the hydrogen partition function in the solar interior", Astrophys. J. 518, 985.

Baturin, V.A., Däppen, W., Gough D.O. & Vorontsov, S.V. 2000 “Seismology of the solar envelope: sound-speed gradient in the convection zone", Mon. Not. R. astr. Soc. 316, 71-83.

Lin, C.-H. & Däppen, W. 2000, “Investigating the excitation of acoustic modes using homomorphic deconvolution", Solar Physics 193, 357-364.

Däppen, W. 2001, “Thermodynamics from the Sun", Contrib. Plasma Phys., 41, 291-294.

Gong, Z.-G., Däppen, W. & Nayfonov, A. 2001, “Effects of Heavy Elements and Excited States in the Equation of State of the Solar Interior", Astrophys. J. 563, 419-433.

Current and Pending Support:

- NSF Stellar Astronomy and Astrophysics Grant AST-9987391 entitled “Theoretical Investigations of the Equation of State for Stellar Interiors”
  Total award amount: $359,953
  Total Award Period covered: 5/1/00-4/30/03
- pending – this proposal: unfunded Person-Months per year committed to the project: 2.0 summer month

Steven Dewitte

Expert in the fields of: Satellite remote sensing, Space techniques, General electronics, Image processing.

Employment:

- 1994 – 2002: Royal Meteorological Institute of Belgium, Assistant section remote sensing from space. Scientific follow-up of meteorological satellite observations: METEOSAT, SEVIRI. Follow-up of instrument development and data processing for measurements of the solar irradiance: SOLCON on the space shuttle, DIARAD on the SOHO satellite, SOVIM on the international space station, SOVAP on the PICARD microsatellite. Project manager for research and development projects, sponsored by the European Union, EUMETSAT and ESA, for the exploitation of GERB and CERES earth observation data.
- 1998 – 2002: Vrije Universiteit Brussel (Free University of Brussels), Part-time lecturer. Responsable for the course ‘Inleiding tot de elektronica’ (Introduction to electronics) voor the second year physics. Responsable for the course ‘Industriële elektriciteit en elektronica’ (Industrial electricity and electronics) for the second year 'trade engineer'.

Diplomas:

- 1987 – 1992: Vrije Universiteit Brussel Electromechanical engineer – specialisation electronics.
- 1994 – 1998: Vrije Universiteit Brussel Doctor in applied sciences. Doctors thesis: ‘Local instantaneous earth radiation budget from geostationary and polar satellites.’

Professional Memberships:
Co-Investigator of SOLCON, VIRGO, CERES, GERB.

Selected Publications:

D. Crommelynck, S. Dewitte, "Temporal and frequency characteristics of the solar constant", Solar Physics, Vol. 173, No. 1, pp. 177-191, June 1997.

C. Fröhlich, D. Crommelynck, C. Wehrli, M. Anklin, S. Dewitte, A. Fichot, W. Finsterle, A. Jimenez, A. Chevalier, H. Roth, "In-flight performance of the VIRGO solar irradiance instruments on SOHO", Solar Physics, Vol. 175, pp 267-286, 1997.

M. Anklin, C. Fröhlich, W. Finsterle, D. Crommelynck, S. Dewitte, "Assessment of the degradation of VIRGO radiometers onboard SOHO", Metrologia, 1998.

D. Crommelynck, S. Dewitte, "Metrology of total solar irradiance monitoring", Adv. Space Res., Vol. 24, No. 2, pp. 195-204, 1999.

L. Dame, M. Herse, G. Thuillier, T. Appourchaux, D. Crommelynck, S. Dewitte, A. Joukoff, C. Froehlich, F. Laclare, C. Delmas, P. Boumier, "PICARD: Simulataneous measurements of the solar diameter, differential rotation, solar constant and their variations", Adv. in Space Research, Vol. 24, No. 2, pp. 205-214, 1999

S. Dewitte, A. Joukoff, D. Crommelynck, R. B. Lee III, R. Helizon, R. S. Wilson, "Contribution of the SOLCON program to the long term total solar irradiance observation", Journal of Geophysical Research, Vol. 106, No. A8, pp 759-766, 2001

Vicente Domingo

Born 13 April 1934 in Valencia, Spain

First University degree, Chemistry, University of Valencia, 1956
Ph.D. in Physics, Thesis on “Fisión Ternaria del U^{235}”, University of Madrid, Spain, 1960

I have devoted most of my career to basic science research and basic science research development and promotion.

On particle detection and Cosmic Rays:

- 1960-61 Research on Particle detection techniques, development of a new solid state detector for cosmic rays, at the Centre d’Études Nucléaires, Saclay, France with a fellowship of the International Atomic Energy Agency.
- 1961-62 I developed a system for detection of environmental radioactivity for the city of Valencia, and taught “Techniques for nuclear radiation detection” at the University of Valencia. (lecturer)
- 1962-65 Research on Cosmic Rays at Chacaltaya Laboratory, of the University of La Paz, Bolivia, as part of a team lead by scientists from Tokyo University and the MIT. Studied the energy spectrum and composition of galactic cosmic rays with energy between 10^{14} and 10^{17} eV (3 years at University of La Paz, and 3 months at MIT, Massachusetts).

On Elementary Particles:

- 1965-67 Mainly research on high energy physics on experimental particle interactions at the Department of Physics and Astrophysics, University of Colorado, Boulder, Colorado. The subject was the study of the interaction proton-antiproton at moderate energy. I also developed a preliminary study for a Cosmic Rays observatory at Mount Evans.
- 1967-70 Continuation of the research on high-energy particle interactions, at Centre Européen de Recherche Nucléaire (CERN), in Geneva, Switzerland.

On Space Science:

- 1970-99 Research and project scientist at the Space Science Department (SSD) of the European Space Agency (ESA). Most of this time was spent at the European Space Research and Technology Center (ESTEC), Noordwijk, The Netherlands, with the exception of three years, from 1995 through 1998, when I worked at NASA’s Goddard Space Flight Center (GSFC), Greenbelt, Maryland.
- Between 1970 and 1985 I carried out basic research of the Earth magnetosphere and of the interplanetary medium and solar wind by the analysis and interpretation of energetic particle measurements carried out by ESA and NASA scientific satellites. I produced significant contributions to the understanding penetration of solar energetic particles into the earth environment, and to the acceleration and propagation of energetic particles in the solar wind.
- My experience in project work has included conducting studies for satellites on cosmic rays, on climatology, and particularly on solar science. From 1978 through 1982, after participating in the study for a Climatology satellite, I promoted the study of the solar irradiance in Europe that is so important for the understanding of the Earth’s climate and of the Sun itself. This activity has led to the flourishing of a number of research groups that have flown instruments to that end in several ESA and NASA missions. From the mid 1980’s I became increasingly involved in, and eventually took charge of the scientific co-ordination for the development of the ESA/NASA Solar and Heliospheric Observatory, SOHO. I was the project scientist of the observatory during its development until 1995, from ESTEC, in the Netherlands, and later of its operation, from 1995 through 1998 at NASA/GSFC, in Maryland. In 1998 I returned to ESTEC, to re-engage with research with data obtained with SOHO, before retiring from ESA in 1999.
- 1999-to date, I reside in Valencia, Spain. I conduct some solar physics research at

the Grupo de Astronomía y Ciencias del Espacio (GACE), of the University of Valencia, where I am also promoting the participation of the group in the construction of a solar magnetograph, to be flown in a NASA long duration balloon in collaboration with other groups. I also have a contract with the University of Barcelona, where I commute regularly to do some collaborative research on Solar Physics and Space Weather. I also supervise the PhD thesis of a student who analyses SOHO data.

Publications:
I have published, as main author or co-author, more than 140 articles of which 50 in refereed journals

Bernhard Fleck

SOHO Project Scientist
ESA Research and Scientific Support Department, NASA/GSFC

Education:
- Ph.D., Physics, 1991, University of Würzburg, Germany. Thesis: *Untersuchungen zur Dynamik oszillatorischer Vorgänge in der Sonnenatmosphäre*
- Diploma, Physics, 1987, University of Würzburg, Germany

Professional History:
- SOHO Project Scientist, ESA Research and Scientific Support Department, 1998-
- SOHO Deputy Project Scientist, ESA Space Science Department, 1993-1998
- Research Scientist, University of Würzburg, 1991-1993

Other Relevant Experience:
- Study Scientist, Solar Orbiter
- Co-I SOVIM (Solar Variability and Irradiance Monitor, to be flown on the ISS)

Memberships:
IAU, SPD, Astronomische Gesellschaft, Board Solar Physics Section of the European Astronomical Society and European Physical Society, Board Joint Astrophysics Division of EAS and EPS

Selected Recent Publications:

Fleck, B.: 2001, Highlights from SOHO and Future Space Missions, in "The Dynamic Sun", Proc. 1999 Kanzelhoehe Summerschool, eds. A. Hanslmeier, M. Messerotti & A. Veronig, Kluwer, p. 1-41

Fleck, B., Brekke, P., Haugan, S., Sanchez Duarte, L., Domingo, V., Gurman, J.B., Poland, A.I.: 2000, Four Years of SOHO Discoveries - Some Highlights, ESA Bull. 102, 68-86

Fleck, B., Keller, C.U.: 2002, Solar Observing Facilities, in "The Dynamic Sun", ed. B.N. Dwivedi, Cambridge University Press, in press

Fleck, B., and the Solar Orbiter Study Team: 2001, Solar Orbiter - A High Resolution Mission to the Sun and Inner Heliosphere, SPIE Proc. Series, Vol. 4498, p. 1-16

O'Shea, E., Banerjee, D., Doyle, J.G., Fleck, B., Murtagh, F.: 2001, Active Region Oscillations, A&A 368, 1095-1107

Straus, Th., Severino, G., Deubner, F.-L., Fleck, B., Jefferies, S.M., Tarbell, T.: 1999, Observational constraints on models of the solar background spectrum, ApJ 516, 939-945

Claus Fröhlich

Education:
Diploma in physics from Federal Institute of Technology at Zürich (ETHZ) 1961, Dr.sc.nat in solid state physics from ETHZ 1969 (medal for Ph.D.Thesis).

Background:
Professional: 1961-69: Research assistant at Laboratorium für Festkörperphysik, ETHZ; 1969-71: Research assistant at PMOD; 1971 Head of World Radiation Center and 1975-1999 Director of PMOD/WRC; since August 1999 Senior Scientist at PMOD/WRC; 1988-92: President of Swiss National Climate Programme, ProClim, of the Swiss Academy of Natural Sciences; Member of Academia Europaea, International Academy of Astronautics, International Astronomical Union, European Astronomical Society (founding member), European Geophysical Society, American Geophysical Union.

Lecturer ETHZ: “Radiation and Climate”, “Space Science: Exploration of the Solar System and Astronomy” until 2001

Commissions: 1980-2001: Member of the Commission for Space Research of the Swiss Academy of Natural Sciences; 1987-: Member and Co-Leader of Solar Electromagnetic Radiation Study for Solar Cycle 22 (SOLERS22), and follow-up programs of SCOSTEP/ICSU; 1987-91: Member of the Solar System Working Group of European Space Agency (ESA); 2000-: Member of the “Commission de Programme Scientifique” of CNES, France.

Space Experiments: Co-Investigator SOVA Experiment (Solar Variability) on EURECA (flown Aug.1992-May 1993), Principal Investigator IPHIR experiment (Interplanetary Helioseismology by Irradiance measurements) on the USSR mission PHOBOS to Mars and its satellite Phobos (flown July 1988 - March 1989); Principal Investigator VIRGO (Variability of Solar Irradiance and Gravity Oscillations) Experiment on SOHO (launched Dec 2 1995), Principle Investigator of SOVIM to be flown on ESA Express Pallet SOLAR on ISS; Co-Investigator PICARD/CNES; Science-Team Member of ESA Phase A studies DISCO, SOHO and PRISMA.

VIRGO II-plus Research Interests and Investigation Role:
Solar irradiance and variability, Low frequency helioseismology and flux budget. Science and H/W implementation expert as PI of VIRGO/SOHO.

Related Publications:
C. Fröhlich, et al., “VIRGO: Experiment for Helioseismology and Solar Irradiance Monitoring,” Sol. Phys., 162, 101-128, 1995

C. Fröhlich, et al., “First Results from VIRGO, the Experiment for Helioseismology and Solar Irradiance Monitoring on SOHO,” Sol. Phys., 170, 1-25, 1997

C. Fröhlich and Lean, J., The sun’s total irradiance: Cycles and trends in the past two decades and associated climate change uncertainties, Geophys. Res. Let. 25, 4377–4380, 1998

C. Fröhlich, Observations of Irradiance Variability, *Space Science Rev* 94, 15-24, 2000

Douglas O. Gough

National Academy of Sciences Senior Postdoctoral
1941 Born 8 February, Stourport, Worcestershire, England

Education:
- 1952-66 Hackney Downs School, London; St John's College,
- 1962 Mathematical Tripos (Wrangler), B.A., University of Cambridge
- 1966 M.A., Ph.D., University of Cambridge

Employment:
- 1966-67 Research Associate, JILA, University of Colorado
- 1967-69 National Academy of Sciences Senior Research Associate, New York
- 1969-73 Graduate Staff Member, Institute of Theoretical Astronomy, Univ. Cambridge
- 1973-85 Lecturer in Astronomy and Applied Mathematics, Institute of Astronomy and Department of Applied Mathematics and Theoretical Physics, University of Cambridge
- 1985-93 Reader in Astrophysics, University of Cambridge
- 1993- Professor of Theoretical Astrophysics, University of Cambridge
- 1999- Director, Institute of Astronomy, Univ. Cambridge (Deputy Director, 1993--99)

Fellowships, associate appointments:
- 1965 NSF Summer Fellow, Woods Hole Oceanographic Institution
- 1965 National Science Foundation Summer Fellow, Woods Hole Oceanographic Institution
- 1967-69 Visiting Member, Courant Institute of Mathematical Sciences, NYU
- 1972- Fellow of Churchill College, Cambridge
- 1977 Astronome Titulaire Associé des Observatoires de France
- 1978-83 Science Research Council Senior Fellow
- 1984-85 Professeur Associé de l'Université de Toulouse
- 1986- Honorary Professor of Astronomy, QMW, University of London
- 1986- Fellow Adjoint, JILA, Colorado
- 1990 Scientific Coordinator, ITP, University of California, Santa Barbara
- 1994 Visiting Scholar, School of Mathematics and Statistics, University of Sydney
- 1996- Visiting Professor, Department of Physics, Stanford University

Lectureships:
- 1988 Sir Joseph Larmor Lecturer, Cambridge Philosophical Society
- 1991 Wernher von Braun Lecturer, National Aeronautics and Space Administration
- 1993 Morris Loeb Lecturer in Physics, Harvard University
- 1996 BBV Lecturer, Instituto de Astrofisica de Canarias
- 1996 Bishop Lecturer, Columbia University
- 1996 Halley Lecturer, University of Oxford
- 2000 R J Tayler Memorial Lecturer, Royal Astronomical Society

Prizes:
- 1973 Gravity Research Foundation Prize (shared with F.W.W. Dilke)
- 1982 James Arthur Prize, Harvard University
- 1984 William Hopkins Prize, Cambridge Philosophical Society
- 1994 George Ellery Hale Prize, American Astronomical Society
- 2002 Eddington Medal, Royal Astronomical Society

Honour:
- 2001 Mousquetaire d'Armagnac

Professional Societies:
- Royal Astronomical Society: Fellow (1966-)
- American Astronomical Society: Member (1964-73), Member of Solar Physics Division (1990-)
- International Astonomical Union: Member (1970-)
- Astronomical Society of India: Member (1993-)

- Royal Society: Fellow (1997-)
- Institute of Physics: Fellow (1997-)
- Royal Danish Academy of Sciences and Letters: Foreign Member (1998-)

Editorial Boards:
- Solar Physics (1983-)
- Fundamentals of Cosmic Physics (1985-93)
- Inverse Problems (1997-)
- Encyclopedia of Astronomy and Astrophysics, IoP (1997-2000)

Publications:
About 300 papers in scientific journals and conference proceedings, mainly Mon. Not. Roy. Astron. Soc., Solar Phys., Astrophys. J. and Nature
Edited four conference proceedings

National and international consulting, committees, etc:
- ESA Consultant (DISCO: 1981-83; SOHO: 1983-85; PRISMA: 1991-93; STARS: 1993-96)
- NASA Mission Consultant (1983-86)
- IAU Organising Committee, Commission 35 (1984-90)
- EPS Organising Committee, Solar Physics Division (1988-91)
- SERC Space Science Programme Board (1986-89)
- SERC Theory Panel (later, Theory and Computation Panel; 1986-90; Chairman, 1987-88)
- SERC APS Grants Committee (later, Ground-Based Programme Committee; 1987-90)
- PPARC Theory Research Assessment Panel (1994-96), various ad hoc assessment committees
- PPARC Long-term Science Review (Solar-system Chairman, 1999)
- CoI on SOI, VIRGO and GOLF on ESA-NASA SOHO mission (1986-)
- Inversions Research Team Leader for GONG observatories (1986-)
- Scientific Executive Committee of the IRIS solar observatories (1989-)
- Principal Investigator, Danish space mission Rømer/MONS (1999-)

Antonio Jiménez

Education:
1984 B Sc Physics, 1985 Degree on Physics, 1989 Phd on Physics (Astrophysics) at Universidad de La Laguna, Tenerife, Spain.

Background:
Professional: 1985-1987 Astrophysic Resident at Instituto de Astrofísica de Canarias (IAC). 1987-1994 Postdoctoral position at IAC jointed to SOHO project. 1995 on, Permanent position at IAC as Principal Investigator. Member of the International Astronomy Union and the Spanish Astronomical Society. 1984-1989, responsible of the SLOT (Solar Luminosity Oscillation telescope, European Space Agency) instruments at Observatorio del Teide (Tenerife) and San Pedro Martir (Baja California). Responsible of the LOI/VIRGO(SOHO) prototype and enginiering model at Observatorio del Teide. 1987 on, Spanish representative of the Spanish contribution to VIRGO/SOHO, power supply, Electrical and Ground Support Equipment (EGSE). Responsible of all the Helioseismic installations at observatorio del Teide (Tenerife, Canary Islands) which include the following Internationals Netwoks: GONG, BISON, IRIS, TON, ECHO.
1993 on, Director of the VIRGO Data Center (VDC) held at IAC.

Related fields: Helioseismology from ground and space. Asteroseismology. Irradiance variations.

Space Experiments: Co-I of VIRGO (Variability of Solar Irradiance and Gravity Oscillations) Experiment on SOHO (launched Dec 2 1995).

Publications:
30 in refereed scientific journals
53 in contributions to symposia

Andrew R. Jones

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Extensive experience in design and development of very high reliability instrumentation for space and ground-based scientific measurements, including electronic, mechanical and optical specifications. Development of data reduction techniques, image processing and display algorithms. Scientific expert to European Space Agency for asteroseismology and high precision photometry, and member of NASA peer review system for UV proposals.

Job Title:
Senior Engineer, Kyocera Solar Inc. Scottsdale, AZ

Education:
- B.Sc BioPhysics, University of York: (1981–1983). Including medical physics and imaging, electron microscopy, ultra-high resolution spectroscopy.
- Ph.D. Experimental Physics, Birmingham: (1983–1986). Developed very high resolution spectrometers for detecting solar/stellar oscillations, and extra-solar planets. Developed a tunable laser heterodyne spectrometer for basic atomic physics measurements.

Professional, Research and Teaching Experience:
- Kyocera Solar Inc. (Scottsdale, AZ): Senior Engineer (2001 – present)
- ETA Engineering Inc. (Tempe, AZ): Systems and Product developer (2000–present)
- University of Southern California: Senior Research Scientist (1996–present)
- Amundsen-Scott South Pole station: Research Scientist (1994–1996)
- Bartol Research Institute: Research Scientist (1994)
- Universities of Aarhus (DK) and Groningen(NL): Research Scientist (1991–1993)
- Institute D'Astrophysique Spatiale (France): Research Scientist (1991)
- Instituto de Astrofisica de Canarias (Spain): Research Scientist (1989–1990)
- European Space Agency - ESTEC (Netherlands): Research Scientist (1986–1989,1991)

Current and Pending Support:
- Total award amount: not disclosed
- VIRGO II$^+$: unfunded
  Person-weeks per year committed to the project: 2 weeks

Alexandre Joukoff

Education:
Diploma in Physics from Université libre de Bruxelles (ULB) 1968, Dr. sc. on Solar wind angular distribution using HEOS-1 satellite data (experiment S58) from ULB 1974.

Background:
Professional: 1968-1974: Research assistant at the Institute for Astronomy and Astrophysics of ULB; Working at the Royal Meteorological Institute of Belgium (RMIB) since 1974, first at the air pollution division, later (1985) at the Radiometry section, Head of the Radiometry section since 1987, this section has been renamed as Remote Sensing from Space since 1999.

Commissions: member of the Commission for Climatology (WMO), Belgian representative to EUMETSAT STG, member of the EUMETSAT Steering Group for the Satellite Application Facility on Climate Monitoring, member of the GERB Program Steering Group, associated member of the National Belgian commission of Geodesy and Geophysics of the Royal Academy of Belgium.

Space Experiments: Scientist of the HEOS-1 S58 experiment on solar wind (launched in Dec. 1968); Successor to Dr. D. Crommelynck for solar constant program at RMIB: Principal Investigator SOLCON (NASA Space Shuttle flights), Co-Investigator VIRGO (Variability of Solar Irradiance and Gravity Oscillations) experiment on SoHO (launched Dec 2 1995), Co-Investigator of PICARD (CNRS/CNES microsatellite) with SOVAP experiment.

SDO Research Interests and Investigation Role:
Solar irradiance and variability monitoring for climate variations studies. Responsibility for the DIARAD radiometer of the VIRGO II^{+} Experiment on SDO.

Selected Publications:

Maintenance of a long term total solar irradiance data series (in coll. with S. Dewitte et D. Crommelynck), Proc. 31st ESLAB Symp. « Correlated Phenomena at the Sun, in the Heliosphere and in Geospace », ESTEC, Noordwijk, The Netherlands 22-25 September 1997 (ESA SP-415, December 1997), pp243-250, 1997.

Retrieval of aerosol parameters from surface radiometric measurements (in coll. with S. Dewitte), Österreichchische Beiträge zu Meteorologie und Geophysik, Nr. 19, 1998.

PICARD: Simultaneous measurements of the solar diameter, differential rotation, solar constant and their variations (in coll. with L. Damé et al.), Adv. In Space Research, 24, 1999.

The contribution of the SOLCON instrument to the long-term total solar irradiance observation (in coll. with S. Dewitte et D. Crommelynck), NASA SSPPO Symposium, September 1999.

Contribution of the Solar Constant (SOLCON) program to the long-term total solar irradiance observations (in coll. with S. Dewitte, D. Crommelynck, R. B. Lee III, R. Helizon et R. S. Wilson), JGR, 106, NO. A8, 15 759-15 765, 2001.

Natalie A. Krivova

Date and Place of Birth: December 24, 1969; Pavlograd, USSR

Citizenship: Russian
Profession: Astronomer

Position:
Post-doc (Max Planck Institute for Aeronomy, Katlenburg-Lindau, Germany);
Research Staff Member (Astronomical Institute, St. Petersburg University)

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Education and Degrees:
- 1998, Ph.D., Astrophysics and Radioastronomy, St. Petersburg University
- 1992, M.Sc., Astronomy and Mathematics, St. Petersburg University

Positions Held:
- Research Staff Member, 1998--: Astronomical Institute, St. Petersburg University (Russia);
- Junior Research Staff Member, 1997--1998: Astronomical Institute, St. Petersburg University (Russia);
- Guest Scientist, 1996: Institute of Astronomy, N. Copernicus University, Torun (Poland)

Scientific Interests:
Solar variability and Sun-Earth connection; Circumstellar environments of pre-main- and main-sequence stars; Optical properties of dust particles

Publications:
18 papers

Jeffrey R. Kuhn

Born: November 1, 1957: Columbus, Ohio

Address:
Institute for Astronomy,
2680 Woodlawn Dr, Honolulu, HI, 96822
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Telephone: 808-956-8968

Education:

- Ph.D. (Physics) Princeton - January 1981
- M.S. (Physics) Princeton - June 1979
- B.A. (Physics and Mathematics) Kalamazoo College - June 1977

Awards and Honors:

- Alfred P. Sloan Fellowship (1986)
- Shenstone Prize (1980, from Princeton for "outstanding work in experimental physics")
- Hornbeck Prize (1977, from Kalamazoo for "outstanding Senior Thesis")

Experience:

- Astronomer, Institute for Astronomy, University of Hawaii (Aug. 1998 - present)
- Astronomer, NOAO/National Solar Observatory, (Jan. 1993 - July 1998)
- Professor, Physics and Astronomy, Mich. State Univ. (Sept. 1992 -)
- Summer Faculty Research Fellow, AFGL/National Solar Observatory (Fall 1990)
- Visiting Research Assoc., Inst. Theor. Physics, Santa Barbara (Spring 1990)
- Associate Professor with tenure, Physics and Astronomy, Mich. State Univ. (Sept. 1986 - 92)
- Assistant Professor, Physics, Princeton University (Sept. 1982 - Aug. 1986)
- Instructor, Physics, Princeton University (Sept. 1981 - Sept. 1982)
- Lecturer, Physics, Princeton University (Jan. 1981 - Sept. 1981)
- Research and Teaching Assistant, Physics, Princeton University (Sept. 1977 - Jan. 1981)

Associated Publications:

APT: An astrometric and photometric telescope, J. R. Kuhn, R. Bush, R. Coulter, C. Frohlich, D-H Gwo, A. Jones, J. Pap, P. Scherrer, S. Sofia, R. Ulrich*, SPIE '98 Missions to the Sun II, San Diego, CA, C. Korendyke, ed.* 203 (1998).

Some Astronomical Performance Advantages of Off-Axis Telescope, J.R. Kuhn, S. L. Hawley*, Publ. Astron. Soc. Pac.* 111**,** 601-621 (1999).

The Near Infrared Coronal Spectrum, Kuhn, J.R., Penn, M.J. and Mann, I., *Ap. J. Letts.* 456, 67 (1996).

The Sun's Shape and Brightness, J.R. Kuhn, Bush, R., Scheick, X. and Scherrer, P., *Nature* 392, 155-157 (1998).

Flat Field Calibration of Image Array Data Without a Flat Field, J.R. Kuhn, H. Lin, and D. Loranz, *Publ. Ast. Soc. Pac.* 103, 1097 (1991).

One Solar Cycle Later: Reflections and Speculations on Directions in Helio- and Asteroseismology in a New Millenium, GONG 2000, SoHO X Conference, P. Palle, ed. (European Space Agency: Noordwijk), SP-464, 7 (2001)

On the constancy of the solar diameter, M. Emilio, J.R. Kuhn, R.I. Bush, and P. Scherrer, Ap. J., 543, 1007 (2000)

Rossby waves on the Sun as revealed by solar 'hills'?, J.R. Kuhn, Armstrong, J.D., Bush, R.I., and Scherrer, P. Nature, 405 , 544 (2000).

Using precise solar limb shape measurements to study the solar cycle, J.R. Kuhn, C. Frolich, and J.M. Pap, Space Science Reviews 94, 169 (2000)

Interpreting the Solar Limb Shape Distortions, J.D. Armstrong and J.R. Kuhn, Ap. J., 525, 533-538 (1999)

Table G1-1. Current and Pending Support of Jeff Kuhn.

Project Title (Grant/Contract Number)	Agency	Total Award	Award Period	% Effort to Project
Current Support:				
(1) High Resolution Coude Spectrograph for the Advanced Electo-Optical System (AEOS) Telescope [F29601-96-C-0125]	AFOSR	$3'400'000	9/21/96 - 12/31/02	1%
(2) Solar Limb Shape, Radius and Oscillation Studies Using SOHO/MDI [NAG5-8002]	NASA	$362'429	1/15/99 - 1/14/03	8%
(3) Solar C: Scatter-free Observatory for Limb Active Regions and Coronae [NAG5-8330]	NASA	$506'785	5/01/99 - 4/30/03	8%
(4) AEOS Haleakala Atmospheric Characterization - Operations, Sustaining Engineering and Maintenance [F29601-98-K-0149]	AFOSR Phillips Lab	$2'351'036	1/01/00 - 12/31/02	5%
(5) Understanding Magnetic Eruptions on the Sun and their Interplanetary Consequences [AFOSR F49620-01-1-0360]	AFOSR Univ of Cal Berkeley	$425'000	5/01/01 - 4/30/04	8%
Pending Support:				
(1) Near-IR Imaging Spectroscopy for Space Weather Forecasting	AFOSR	$454'000	04/01/02 - 03/31/04	1%
(2) Observational Investigation of Solar Magnetosphere	NASA	$1'320'000	06/01/02 - 05/31/05	8%
(3) Polarimetric Infrared Circumstellar Imaging	NSF	$217'000	7/1/02 - 6/30/04	8%
(4) Near Infrared Study of Solar Magnetism	NSF	$429'113	06/01/02 - 05/31/05	2%
(5) Development of a High Dynamic Range Imager	NSF	$698'805	8/1/02 - 7/31/05	10%
(6) Helioseismic and Magnetic Imager for the Solar Dynamics Observatory	NASA Stanford Univ		5/1/03 - 4/30/07	2%
(7) Advanced Technology Solar Telescope Design and Development	NSF NSO	$259'939	2/1/02 - 1/31/06	4%
(8) Virgo II Plus	NASA PMOD / WRC	$80'419	10/1/02 - 9/30/12	2%

Torben Leifsen

Address:
Institute of Theoretical Astrophysics
University of Oslo
P.O. Box 1029, Blindern, 0315 OSLO
NORWAY

Birth date- and place: 17 December 1961 in Drammen, Norway

Education:

- 1980-1983: Cand mag. degree in astrophysics from University of Oslo.
- 1984-1988: Cand. Scient degree in astrophysics from Institute of Theoretical Astrophysics, University of Oslo with Professor Per Maltby as supervisor. Thesis title: "Development of a new photometer and application of it in helioseismology and in measurement of relative radiation-flux in sunspots". (Norwegian language).
- 1990-1993: Dr. Scient study in astrophysics at Institute of Theoretical Astrophysics with Professor Per Maltby as supervisor. Remains to be completed.

Employment:

- September 1983 - December 1986: Observational assistant (50% position) at Oslo Solar Observatory. Main working field: Observations, development of software and instrumentation.
- 1987: Research assistant (50% position) at Institute of Theoretical Astrophysics. Main working field: Software development and implementation of MIDAS image processing software to local hardware.
- 1990 - 1993: Junior Research Scientist (100% position) at Institute of Theoretical Astrophysics. Main work: Helioseismology (Dr. scient thesis), colloquia in celestial mechanics (entry level) and system manager on local VAX/VMS and UNIX computers.
- 1994 - 1998: System manager (senior executive officer) with responsibility for the computer system at Institute of Theoretical Astrophysics. Part time research work in helioseismology with the SOHO/VIRGO team.
- 1998 - current date: Chief Engineer at Institute of Theoretical Astrophysics. Part time research work in helioseismology with the SOHO/VIRGO team.

Judit M. Pap

Title and Affiliation:
Senior Research Scientist, Goddard Earth Sciences and Technology Center, University of Maryland, Baltimore County, Phone: 301-286-7511, Fax: 301-286-1753, E-mail: papj@marta.gsfc.nasa.gov

Education:
- B.S and M.S: 1978, Eötvös University, Budapest, Hungary. Major in Physics and Astronomy. Minor in Mathematics.
- Ph.D.: 1986, Eötvös University, Budapest, Hungary, in Astrophysics.

Research Interest and Ongoing Research Efforts:
Analysis of solar irradiance variations (both bolometric and at various wavelengths); study of solar images based on pattern recognition and machine learning techniques; study of solar radius variations and global solar properties reprocessing and validating the UARS/ ACRIM II total irradiance data to improve the long-term composite time series used for climate research; study the effect of irradiance variations on the Earth's atmosphere and climate.

Experiences:
Judit Pap is Principal Investigator of various NASA grants; Co-Investigator on the SOHO/VIRGO experiment and Guest Investigator on SOHO/MDI; Co-Investigator on the French PICARD experiment for measuring total and UV irradiance and solar radius. J. Pap was a member of the science team writing the SOHO Senior Review for NASA in 1997; served as a member of NASA OSS review panels in 1993, 1994, and 1997; served as a Committee Member of Climate Change Panel, World Public Affairs Conference, April 19 -- 20, 2000, Boulder, CO. She has organized several international meetings: IAU Colloquium No. 143, “The Sun as a Variable Star: Solar and Stellar Irradiance Variations", Boulder, Colorado, June 20-25, 1993; 17th NSO/Sacramento Peak Summer Workshop - SOLERS22 1996 Workshop, June 17 - 21, 1996, Sunspot, NM; and “ISCS 2001 Symposium: Solar Variability, Climate and Space Weather", June 13 -- 16, 2001, Longmont, CO. She was a member of the Organizing Committee of the NASA Workshop on “Solar Influences on Climate", March 5-7, 2000, Tucson, AZ and she is the Main Organizer of the forthcoming “Solar Variability and Climate Change" special meeting of the COSPAR 2002 General Assembly, Houston, TX, October 2002.

J. Pap was the head of the Solar Electromagnetic Radiation Study for Solar Cycle 22 (SOLERS22) international research program (1995-1997) of SCOSTEP, Committee Member of the Solar Terrestrial Energy Program (STEP) Working Group 1, “The Sun as a Source of Energy and Disturbance" until December 31, 1997, and currently she is chairing Working Group 1 “Solar Energy Flux Study: From The Interior To The Outer Layer" of the “International Solar Cycle Studies (ISCS)" international research project of SCOSTEP.

She edited three Conference Proceedings and she is the lead editor of AGU Monograph “Solar Variability and its Effect on the Earth's Atmosphere and Climate". She is a full member of the International Astronomical Union, American Astronomical Society, Solar Physics Division of AAS, American Geophysical Union and founding member of the European Astronomical Society.

Selected Publications:
Fröhlich and Pap, J.: Multispectral analysis of total solar irradiance variations, A&A 220, (1989) 272.

Pap, J., Vigouroux, A., and Delache, P.: Study of the distribution of daily fluctuations in observed solar irradiances and other full-disk indices solar activity, Solar Physics 167, (1996) 125.

Vigouroux, A., Pap, J., and Delache, Ph.: Estimating long-term solar irradiance variability: a new approach, Solar Physics 176, (1997), p. 1.

Pap, J.: Long-term solar irradiance variability, In Sounding Solar and Stellar Interiors, (eds. J. Provost, F.-X. Schmider), Kluwer Academic Publishers, (1997), p. 235.

Pap, J.: Total solar irradiance variability: A review, In Past and Present Variability of the Solar-Terrestrial System: Measurement, Data Analysis and Theoretical Models, (eds. G.C. Castagnoli and A. Provenzale), International School of Physics "Enrico Fermi" Course CXXXIII, IOS Press, Amsterdam, (1997), p. 1.

Pap, J. and Fröhlich, C.: Total irradiance variations, Journal of Atmospheric and Solar Terr. Phys. 61, (1998), 15.

Pap, J., Anklin, M., Fröhlich, C., Wehrli, Ch., Varadi, F., and Floyd, L.: Variations in total solar and spectral irradiance as measured by the VIRGO experiment on SOHO, Adv. Space Res., (1999), p. 215

Varadi, F., Pap, J., Ulrich, R., Bertello, L., and Henney, C.: Searching for signal in noise by random lag singular spectrum analysis, in ApJ 526, 1052 (1999).

Pap, J., Rozelot, J.P., Godier, S. and Varadi, F.: On the relation between total irradiance and radius, Astronomy and Astrophysics 372, 1005 (2001).

Turmon, M., Pap, J., and Mukhtar, S.: Statistical pattern recognition for labeling solar active regions: Application to SOHO/MDI imagery, Astrophysical Journal 568, 396 (2002).

Pap, J., Fröhlich, C., Kuhn J., Sofia, S., and Ulrich, R.: The necessity of studying global solar properties, Adv. Space Res., (2002), in press.

Pap, J., M. Turmon, L. Floyd, Fröhlich, C., and Wehrli, Ch.: Total solar and spectral irradiance record, {\it Adv Space Res.}, in press (2002).

Pap, J.: Variations in solar total and spectral irradiance and climate impact of solar variability, in "Lecture Notes in Astrophysics", Ed.: J.P. Rozelot, proceedings of The 5th Summer School on Solar Astrophysics: "The Variable Shape of the Sun Astrophysical Consequences", in press (2002).

Current and Pending Support:

Current Support:

- NASA Earth Science Enterprise Grant NAG5-1160, "Analysis and Validation of the UARS/ACRIM II Total Irradiance"
  Total award amount: $36,981
  Total award period covered:
  1/15/02-1/14/03
  Effort: 25%
- NASA Earth Science Enterprise Grant NAG5-11326, "Variations in the Solar Energy Output on Time Scales of Years and the Solar Cycle"
  Total award amount: $40,451
  Total Award period covered:
  9/15/01-2/14/03
  Effort: 25%
- NASA Office of Space Science Grant NAG5-11624, "Variations in Total Solar and Spectral Irradiance Related to Solar magnetic Activity"
  Total award amount: $275,447, subcontracted to JPL $85'000
  Total Award period covered:
  2/1/02-1/31/05
  Effort: 35%

Pending Support:

- NASA Office of Space Science, "Study of the Terrestrial Effects of Solar Irradiance Variations from EUV to Infrared: A New Approach"
  Total award amount: $66,614
  Total Award period covered:
  5/1/02-4/30/03
  Effort: 35%
- NASA Office of Space Science, "VIRGO II^{+} (this proposal).
  Total award amount: $395,754
  Total Award period covered:
  9/1/02-9/30/13
  Effort: 50% for 9/1/07-8/31/09
  25% for 9/1/09-9/30/13

Janine Provost

Date and place of birth: 24 May 1942 at Auch (Gers)

Familial situation: married, 2 children

Nationality: French

Address:
Observatoire de la Côte d'Azur, Laboratoire Cassini
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Professional education:
- Agregation of Physics, 1968
- Thesis (Doctorat d'Etat) - Nice 1975: "Contribution à l'étude de la dynamique de l'atmosphère solaire".

Positions:
- Stagiaire de Recherche CNRS - Oct. 1968
- Attachée de Recherche CNRS - Oct. 1969
- Chargée de Recherche CNRS - Oct. 1977
- Directeur de Recherche CNRS - Oct. 1997

Area of expertise and research interest:
- Stellar oscillations: Helio/asteroseismology
- Solar and stellar structure and evolution
- 50 publications in referred journals,
- 50 publications in conference proceedings}

International collaborations
- Member of GONG collaboration (Global Oscillation Network Group)
- Member of IRIS (International Research on the Interior of the Sun)
- Co-investigator of VIRGO experiment on board of SoHO (Variability of Solar Irradiance and Gravity Oscillations)
- Co-investigator of the CNES microsatellite project PICARD
- Associated scientist of GOLF (Global Oscillations at Low Frequencies)
- Associated scientist of COROT (COnvection, ROtation and planetary Transits)
- Joint collaborator for the CEFIPRA Indo-french project "Dynamics of solar and stellar interiors"

Teodoro Roca Cortés

Born: 21st November 1951. Fuliola (Lleida). SPAIN.

Academic Degrees:
- 1973 Licenciado (BsC) en Físicas. Univ. Central de Barcelona.
- 1974 Licenciado con Grado (Ms.C.). Univ. Central de Barcelona.
- 1979 Doctor en Ciencias (Ph.D.). Univ. de La Laguna.

Main Research Lines:
- Solar Spectroscopy: Measurement and interpretation of line assymetries.
- Helioseismology: Leader of the Solar and stellar oscillations group at IAC.
- Velocity measurements using resonant scattering spectroscopy. CoI on the international earth-based networks and projects: IRIS, GONG, TON.
- Irradiance variations measurements as luminosity fluctuation. CoI on the international earth-based networks and projects: SLOE, LOI/VIRGO
- Asteroseismology: photometric and spectrometric measurements. CoI on the international earth-based networks and projects: STEPHI, STACC and PI on the CEE network ANTENA.
- Space helioseismology. Co I in the projects GOLF and VIRGO on SOHO.
- Space asteroseismology. Member of the Ass.Study and Phase A study Teams of the ESA M3 project: STARS

Publications:
- Scientific publications with referee: 70
- International Meeting, Symposia, etc..: 90
- National Meetings, Symposia, etc..: 18
- Scientific publications for outreach: 12

Teaching at Universities:
- 1977-1985: Ayudante and Titular de "General Physics", "Nuclear Physics" and "Astrophysics" at the Univ. of La Laguna.
- 1985- now: Professor of Astrophysics and Solar Physics at the U. of La Laguna.

Academic Posts and Membership in Scientific Associations:
- 1985-1989, Director of "Astrophysics Department" at the University of La Laguna.
- 1985-1989, Chairman of Postgraduate Teaching at the I.A.C.
- 1990-1992, ViceDean at the Faculty of Physics (U. La Laguna).
- 2000-now, Vicechancellor at U. La Laguna
- Member of the IAU, EAS, SEA

Hansjörg Roth

born December 06, 1947 in Degersheim SG, citizen of Switzerland

Education: Diploma from Zurich University of Applied Sciences Winterthur (ZHW) 1972.

Background:
Professional: since 1972: Electronic Engineer and Head of Electronic Department at PMOD/WRC, since 1985 Deputy Director PMOD/WRC

Commissions: 1980-2002: Expert for electronic apprenticeship Graubünden Switzerland

Space Experiments: Experiment Manager on several Sounding Rocket Flights (JPL/NASA), on IPHIR experiment (Interplanetary Helioseismology by Irradiance measurements), Experiment Manager on the USSR mission PHOBOS to Mars and its satellite Phobos (flown July1988 - March 1989), Experiment Manager on SOVA Experiment (Solar Variability) on EURECA (flown Aug.1992-May 1993) and Experiment Manager on VIRGO (Variability of Solar Irradiance and Gravity Oscillations) Experiment on SoHO (launched Dec 2 1995).

Related Publications:
Fröhlich C., Romero J., Roth H., Wehrli C., Andersen B. N., Appourchaux T., Domingo V., Telljohann U., Berthomieu G., Delache P., Provost J., Toutain T., Crommelynck D. A., Chevalier A., Fichot A., Dappen W., Gough D., Hoeksema T., Jimenez A., Gomez M. F., Herreros J. M., Roca Cortes T., Jones A. R., Pap J. M., Willson R. C.: 1995, VIRGO: Experiment for Helioseismology and Solar Irradiance Monitoring, Solar Phys. 162, 101

Fröhlich C., Andersen B., Appourchaux T., Berthomieu G., Crommelynck D. A., Domingo V.; Fichot A., Finsterle W., Gomez M. F., Gough D., Jimenez A., Leifsen T., Lombaerts M., Pap J. M., Provost J., Roca Cortes T., Romero J., Roth H., Sekii T., Telljohann U., Toutain T., Wehrli C.: 1997, First Results from VIRGO, the Experiment for Helioseismology and Solar Irradiance Monitoring on SOHO, Solar Phys. SoPh. 170, 1

Fröhlich, C., Crommelynck, D., Wehrli, C., Anklin, M., Dewitte, S., Fichot, A., Finsterle, W., Jimenez, A., Chevalier, A., Roth, H.: 1997, In-Flight Performance of the Virgo Solar Irradiance Instruments on SOHO, Solar Phys. 175, 267F

Fröhlich C., Andersen B. N., Appourchaux T., Berthomieu G., Crommelynck D. A., Domingo, V., Fichot A., Finsterle W., Gómez M. F., Gough D., Jiménez A., Leifsen T., Lombaerts M., Pap J. M., Provost J., Roca Cortés T., Romero J., Roth H.-J., Sekii T., Telljohann U., Toutain T., Wehrli C.: 1997, First results from VIRGO on SoHO, in IAU Symp. 181, 67

Schmutz W., Fröhlich C., Rüedi I., Roth H., Wehrli Ch., Wyss J.: 2001, SIM3D: Solar Irradiance Monitor-3D-View. in '*Solar Encounter: The First Solar Orbiter Workshop*', ESA SP--493, p. 447 -- 450.

Eugene V. Rozanov

Born: 12 March 1955 in Leningrad, USSR
Married to Dr. Tatiana Egorova, atmospheric scientist
One child: Roman
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7260, Davos Dorf, Switzerland
Phone: +41 081 4175100 ;
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E-mail: e.rozanov@pmodwrc.ch
Profession: Atmospheric Physicist, ETH and PMOD/WRC research associate, project manager

Education and scientific background:

- 1972-1979: Study of physics, S. Petersburg State University. MS, February 1979, MS Thesis: " The influence of trace gases on radiation regime of the Atmosphere in the infrared spectral region"
- 1979-1986: Research scientist in Main Geophysical Observatory, S. Petersburg, Russia
- 1986: Ph.D. from Main Geophysical Observatory, S. Petersburg, Russia. Ph.D. Thesis: " The assessment of climate feedback mechanisms with 1-D Radiative - convective model".
- 1986-1997: Senior research scientist in Main Geophysical Observatory, S. Petersburg, Russia
- 1988-1989: Visiting scientist, New York University, USA
- 1994-1995: Visiting Scientist, Max-Planck-Institute for Chemistry, Air Chemistry Department, Mainz, Germany
- 1997-2000: Research Assistant Professor, University of Illinois at Urbana-Champaign, USA
- 2001 – 2002: ETH and PMOD/WRC research associate, project manager

Publications:

Author or coauthor of 2 books and 57 papers in refereed scientific journals on climate, atmospheric radiation, photochemistry and dynamics.

Isabelle Rüedi

Born: 2 March 1967
Nationality: Swiss
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Fax: +41 81 417 5100
E-mail: i.ruedi@pmodwrc.ch

Education:

- 1986 – 1991 Studies of physics at the ETH-Zürich, Master thesis in Physics at the ETH-Zürich on "Measurements of Solar Magnetic Fields with Infrared Lines
- 1991 – 1992 Assistant at the Observatoire Cantonal de Neuchâtel working on the miniaturization of Rb atomic clocks
- 1992 – 1996 PhD in Physics at the ETH-Zürich on "Infrared Measurements of Sunspot Magnetic Fields"
- 1996 – 1999 Postdoc at the ETH-Zürich Working with data from different SOHO instruments (SUMER, CDS, MDI, EIT)
- 2000 – present Scientific Collaborator at the Observatory Davos Responsible for the maintenance of the World Standard Group.

Space Experiments:
Co-I on VIRGO, SOVIM and PREMOS(PICARD)

Related Publications:

Rüedi I., Fröhlich C., Schmutz W., Wehrli Ch., 2000, IOM Report No. 74 (WMO/TD-No. 1028), p. 64 – 67. Report on the International Pyrheliometer Comparisons - The Maintenance and Dissemination of the World Radiometric Reference.

Damé L., Cugnet D., Hersé D., Crommelynck D., Dewitte S., Joukoff A., Rüedi I., Schmutz W., Wehrli C., Delmas C., Laclare F., Rozelot J.-P.: 2000, in "The Solar Cycle and Terrestrial Climate", ESA SP--463, p. 223 -- 229, PICARD: Solar Diameter, Irradiance and Climate

Schmutz W., Fröhlich C., Rüedi I., Roth H., Wehrli Ch., Wyss J.: 2001, SIM3D: Solar Irradiance Monitor-3D-View. in *'Solar Encounter: The First Solar Orbiter Workshop*', ESA SP--493, p. 447 -- 450.

Michael E. Schlesinger

Born: February 23rd 1943, Los Angeles, California.

Professor of Atmospheric Sciences
Department of Atmospheric Sciences
University of Illinois at Urbana-Champaign
105 S. Gregory Ave.; Urbana, IL 61801;
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Education:
- B.S. (1965) - Engineering, University of California, Los Angeles
- M.S. (1970) - Engineering (Fluid Mechanics), University of California, Los Angeles
- Ph.D. (1976) - Meteorology, University of California, Los Angeles.

Professional Positions:
- 1964: Engineer, U.S. Naval Ordinance Test Station, China Lake, CA.
- 1965: Engineer, N.V. Philips, Eindhoven, Netherlands.
- 1965-1966: Engineer, Ralph M. Parsons Company, Los Angeles, CA.
- 1966-69: Research Assistant, UCLA, School of Engineering and Applied Sciences.
- 1971-1974: Research Assistant, UCLA, Department of Meteorology.
- 1973-1976: Resident Consultant, Climate Dynamics Program, Rand Corporation
- 1976-1982: Assistant Professor, Department of Atmospheric Sciences, Oregon State University
- 1982-1989: Associate Professor, Department of Atmospheric Sciences, Oregon State University
- 1989-: Professor, Dept. of Atmospheric Sciences, University of Illinois, Urbana-Champaign

Publications for 2001-2002:

Assessment of the Effect of the Montreal Protocol on Atmospheric Ozone, Geophys. Res. Lett., 28:12, 2389-2392, 2001 (Egorova, Tatiana A., Eugene V. Rozanov, Michael E. Schlesinger, Natalia G. Andronova, Sergey L. Malyshev, Igor L. Karol, Vladimir A. Zubov)

Identification and Separation of Mount Pinatubo and El Nino-Southern Oscillation Land Surface Temperature Anomalies. J. Geophys. Res., 106, 14,757-14770, 2001 (Yang, F. and M. E. Schlesinger).

Climate-change strategy needs to be robust, Nature, 412, 375, 2001 (R. J. Lempert and M. E. Schlesinger).

Objective Estimation of the Probability Distribution for Climate Sensitivity, J. Geophys. Res., 106, D19, 22,605-22,612, 2001 (Andronova, N, and M. E. Schlesinger).

The Climate Impacts of Sulfate Aerosols, Integrated Assessment, 2, 111–122, 2001 (Robert Mendelsohn, Michael Schlesinger, and Larry Williams).

Changes in Near-Surface Temperature and Sea Level for the Post-SRES CO2-Stabilization Scenarios. Integrated Assessment, 2(3), 95-199, 2001 (Schlesinger, M. E. and S. Malyshev).

Climate Sensitivity, Encyclopedia of Global Environmental Change, Vol. 1, 301-308, John Wiley & Sons Ltd., 2001 (Schlesinger, M. E. and N. G. Andronova).

JGR authors set the record straight, Science, 295 (5554), 441-442, 2002 (M. E. Schlesinger and N. G. Andronova.).

The University of Illinois, Urbana-Champaign Three-dimensional Stratosphere-Troposphere General Circulation Model with Interactive Ozone Photochemistry: Fifteen-year Control Run Climatology, J. Geophys. Res., 106, D21, 27,233-27,254, 2002 (Rozanov, E., M. E. Schlesinger, V. A. Zubov).

On the surface and atmospheric temperature changes following the 1991 Pinatubo volcanic eruption: A GCM study, J. Geophys. Res., 107(0), 10.1029/2001JD000373, 2002. (F. Yang and M. E. Schlesinger).

Adaptive Decision Strategies. In Innovative Energy Strategies for CO2 Stabilization, R. G. Watts (Ed.), Cambridge University Press (in press), (R. J. Lempert and M. E. Schlesinger).

The Economic Geography of Climate Change, J. Econ. Geography (in press) (Yohe, G., and M. E. Schlesinger).

Cloud Feedbacks. In Frontiers in the Science of Climate Modeling, J. T. Kiehl and V. Ramanathan (Eds.), Cambridge University Press (in press) (D. A. Randall, M. E. Schlesinger, V. Galin, V. Meleshko, J.-J. Morcrette, R. Wetherald).

Contextual Determinants of Malaria. Workshop Summary and Discussion. In Contextual Determinants of Malaria, E. Casman and H. Dowlatabadi (Editors). Resources for the Future Press, Washington, D. C. (in press) (Basher, R., Beljaev, A., Birley, M. Bos, R., Bouma, M., Bradley, D., Casman, E., Cox, J., Desowitz, D., Devlin, D. Dowlatabadi, H., Fischhoff, B., Flannery, B., Focks, D., Gubler, D., Gusmao, R., Kidson, C., Kondrachine, A., Kovats, S., Lave, L., Lindsay, S., Litsios, S., Longstreth, J., Lutz, W., Martens, P., McMichael, A., Morgan, M. G., Mouchet, J., Reiter, P., Roberts, D., Sabatinelli, G., Schapira, A., Schlesinger, M. Sharma, V. P., Strzepek, K., Tang, L.-H., Wilson, M.).

Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet, Science (submitted) (Hoffert, M. I., K. Caldeira, G. Benford, D. R. Criswell, C. Green, L. D. D. Harvey, H. Herzog, J. Katzenberger, H. S. Kheshgi, K. S. Lackner, J. S. Lewis, H. D. Lightfoot, W. Manheimer, J. Mankins, G. Marland, M. E. Mauel, L. J. Perkins, M. E. Schlesinger, T. Volk, T. M. L. Wigley).

Pinatubo Volcanic Eruption Effects in the UIUC Stratosphere/Troposphere GCM With Interactive Photochemistry. J. Geophys. Res. (submitted) (Rozanov, E., M. Schlesinger, S. Malyshev, N. Andronova,

Current and Pending Support:

- Current support:
  Title: Research on Greenhouse-Gas-Induced Climate Change
  Principal Investigator: Michael Schlesinger
  Funding Agency: NSF
  Period: 9/1/2000 to 8/31/2006
  Budget: $275k, $300k, $300k, $300k, $300k
- Pending Support:
  NSF: $28000
  NASA: VIRGO II+, $36591

Werner K. Schmutz

Born August 29, 1952 in Zürich, citizen of Switzerland

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Tel. +41 81 417 51 11
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Education:
- 1974 – 1979 Studies of physics at the ETH in Zürich with Diploma in Experimentalphysik
- 1979 – 1983 Ph.D. in astrophysics at the Institute of Astronomy, ETH Zürich

Experience:
- 1984/1985 Organization of an exhibition on popular astronomy for the government of Zürich
- 1985 – 1987 Wissenschaftlicher Mitarbeiter at the Institut für Theoretische Physik und Sternwarte der Universität Kiel, Germany
- 1988 – 1991 Research associate at JILA, University of Colorado and NBS, USA
- 1991 – 1998 Oberassistent at the Institute of Astronomy, ETH Zürich
- 1992 – now: Lecturer ETH Zürich and University of Zürich
- 1993 – 1997 Member of the Observing Program Committee of the European Southern Observatory
- 1993 – present Member of the Swiss Commission for Astronomy
- 1995 Habilitation and Venia Legendi, ETH Zürich
- 1995 Member of the IUE time allocation committee of the European Space Agency
- 1996 – 1999 Co-leader of the stellar physics group at IfA ETH Zürich
- 1998 – 2001 Member of the Users Committee of the European Southern Observatory
- 1999 – present: Director Physikalisch-Meteorologisches Observatorium Davos
- 2001 – present: Member of the Swiss Commission for Space Research

Space Experiments:
Co-I on SOVIM and PICARD (instrument-PI of PREMOS)

Publications:
- 63 papers in refereed journals
- citations: 930 (science citation index of the Web of Science, Institute for Scientific Information, UK, April. 2002)

Related Publications:
Rüedi I., Fröhlich C., Schmutz W., Wehrli Ch., 2000, IOM Report No. 74 (WMO/TD-No. 1028), p. 64 – 67. Report on the International Pyrheliometer Comparisons – The Maintenance and Dissemination of the World Radiometric Reference.

Damé L., Cugnet D., Hersé D., Crommelynck D., Dewitte S., Joukoff A., Rüedi I., Schmutz W., Wehrli C., Delmas C., Laclare F., Rozelot J.-P.: 2000, in "The Solar Cycle and Terrestrial Climate", ESA SP-463, p. 223 -- 229, PICARD: Solar Diameter, Irradiance and Climate

Schmutz W., Fröhlich C., Rüedi I., Roth H., Wehrli Ch., Wyss J.: 2001, SIM3D: Solar Irradiance Monitor 3D-View. in '*Solar Encounter: The First Solar Orbiter Workshop*', ESA SP-493, p. 447 – 450.

Sami K. Solanki

Institutional Address:
The Managing Director
Max-Planck-Institut für Aeronomie
Max-Planck-Str. 2,
37191 Katlenburg-Lindau, Germany
Tel. +49-5556-979-552,
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Education:
Eidgenössische Technische Hochschule Zürich, Ph.D., Natural Sciences, 1987.

Research Interests:
Observations and magnetohydrodynamic theory of solar and stellar magnetism and convection; solar variability and its influence on the Earth; structure of the solar atmosphere; solar wind acceleration; resonance polarisation and the Hanle effect; helio- and asteroseismology; stellar rotational evolution; protoplanetary discs and extrasolar planets.

Post-Degree Appointments:
- 2001 Appointed Honorary Professor of the ETH Zürich
- 1999-Present: Director at the Max-Planck-Institut für Aeronomie in Katlenburg-Lindau, Germany
- 1999 Minnaert Professor at the University of Utrecht, Holland
- 1998 Appointed Professor of Astronomy at the University of Oulu, Finland
- 1989-1999 Research scientist, lecturer and group leader at the Inst. of Astron., ETH Zürich
- 1987-1989 Postdoctoral research fellow at the University of St. Andrews, Scotland

Publications:
A total of 272 scientific publications, of which 133 are in refereed scientific journals.

Selected Relevant Publications:
Solanki S.K., Schüssler M., Fligge M. 2000 “Evolution of the Sun's Large-Scale Magnetic Field Since the Maunder Minimum”, *Nature*, 408, 445-447.
Fligge M., Solanki S.K., Unruh Y.C. 2000 “Modelling Short-Term Spectral Irradiance Variations”, *Space Sci. Rev.*, 94, 139-144.
Unruh Y.C., Solanki S.K., Fligge M. 2000 “Modelling Solar Irradiance Variations: Comparison with Observations, Including Line-Ratio Variations”, *Space Sci. Rev.,* 94, 145-152.
Fligge M., Solanki S.K. 2000 “The Solar Spectral Irradiance Since 1700”, *Geophys. Res. Lett.*, 27, 2157-2160.
Solanki S.K., Schüssler M., Fligge M. 2002 “Secular Variation of the Sun's Magnetic Flux”, *Astron. Astrophys.*, 383, 706-712.

Thierry Toutain

Born: August 8, 1961
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Universitetet i Oslo
Postboks 1029 Blindern
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e-mail: tierry.toutain@astro.uio.no

Professional career:

- since 1994: Scientist employed by the French national research council (CNRS) at the Observatoire de la Côte d'Azur, Nice, France. Helioseismology : analysis of data from space instruments
- 1999 and 2001 Visiting scientist at the Institute of Theoretical Astrophysics, University of Oslo. Development of numerical methods to detect solar g-modes
- 1992-94 ESTEC, Space Science Department, the Netherlands, ESA postdoctoral research fellow. Analysis of helioseismic data from ground-based instruments
- 1990-92 PMOD-WRC, Davos, Switzerland, ESA external postdoctoral research fellow. Development of numerical methods to study solar p-modes

Educational background:

- 1990 PhD - Physics, University of Paris VI, France
- 1985 D.E.A. - Plasma Physics, University of Paris VI, France
- 1984 Maitrise - Physics, University of Paris VI, France

Military service:

- 1985-86 Accomplished

Specialities:

Timeseries analysis, statistics, data analysis

Computer competences:

- Programming: Fortran, IDL
- Environments: UNIX, LINUX, VMS, WINDOWS, DOS

Christoph Wehrli

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Education:
Diploma from Federal Institute of Technology at Zürich (ETHZ) 1978.

Background:
Professional: 1978-88: research assistant, 1989-2001 senior scientist at PMOD/WRC; member of the Swiss Academy of Natural Sciences; member of the Optical Society of America.

Commissions: 1990-1997: Member of Solar Electromagnetic Radiation Study for Solar Cycle 22 (SOLERS22), a subprogramme of SCOSTEP/ICSU and Co-Leader of Working Group1 on Total and near-UV to Infrared spectral irradiance.

Space Experiments: Co-Investigator IPHIR experiment (Interplanetary Helioseismology by Irradiance measurements) on the USSR mission PHOBOS to Mars and its satellite Phobos (flown July1988 - March 1989);
Co-Investigator SOVA Experiment (Solar Variability) on EURECA (flown Aug.1992-May 1993);
Co-Investigator VIRGO (Variability of Solar Irradiance and Gravity Oscillations) Experiment on SoHO (launched Dec 2 1995).

Selected Publications:

Fröhlich, C., et al., “VIRGO: Experiment for Helioseismology and Solar Irradiance Monitoring,” *Sol. Phys*. 162, 101-128, 1995

Fröhlich, C., et al., “First Results from VIRGO, the Experiment for Helioseismology and Solar Irradiance Monitoring on SOHO,” *Sol. Phys*. 170, 1-25, 1997

Fröhlich, C., et al., “In-flight Performances of Virgo Solar Irradiance Instruments on SOHO”, *Sol. Phys*. 175, 267-286, 1997

Wehrli, Ch., T. Appourchaux, D. Crommelynck, W. Finsterle, C. Fröhlich, and J.M. Pap, “Solar Irradiance Variations and Active Regions Observed by VIRGO Experiment on SOHO”, in *Sounding Solar and Stellar Interiors*, eds: Provost, J., Schmider, F.X., Observatoire de la Cote d’Azur, Nice, 1997

Wehrli, Ch., C.Fröhlich, M.Anklin, M.Fligge, S.K.Solanki, and Y.Unruh, “Wavelength Dependence of Solar Irradiance Variability from VIRGO onboard SOHO”, in B.Fleck & a.Wilson Eds., *31 ESLAB Symposium: CorrelatedPhenomena at the Sun, in the Heliosphere andGeospace*, ESA SP415, Noordwijk, NL 1998

Fligge, M., S.K. Solanki, Y.C. Unruh, C. Fröhlich, and Ch. Wehrli, “A model of solar total and spectral irradiance variations”, *Astron. Astroph.* 335, pp. 709-718, 1998

Z. Eker, P.N.Brandt, A.Hanselmeier, W. Otruba and C. Wehrli: Deriving effective sunspot temperatures from SOHO/VIRGO irradiance measurements, submitted to A&A, Mar. 2002

G2. Statement of Commitment

This Appendix entails the Statements of Commitment from the following Co-investigators:

- Bo N. ANDERSEN
- Thierry APPOURCHAUX
- Pål Brekke
- Werner DÄPPEN
- Steven DEWITTE
- Vicente DOMINGO
- Bernhard FLECK
- Claus FRÖHLICH
- Douglas O. GOUGH
- Antonio JIMNEZ
- Andrew R. JONES
- Alexandre JOUKOFF
- Natalie A. KRIVOVA
- Jeffrey R. KUHN
- Torben LEIFSEN
- Judit M. PAP
- Janine PROVOST
- Teodoro ROCA CORTÉS
- Eugene V. ROZANOV
- Isabelle RÜEDI
- Michael E. SCHLESINGER
- Sami K. SOLANKI
- Thierry TOUTAIN
- Christoph WEHRLI

G3. Letters of Endorsement

This Appendix entails the Letters of Endorsement from the organizations listed below:

Table G3-1. Instrument/Science

Organization Name	Co-Investigator Name
Physikalisch-Meteorologisches Observatorium Davos World Radiation Center (PMOD/WRC)	Claus FRÖHLICH Hansjörg ROTH Eugene V. ROZANOV Isabelle RÜEDI Christoph WEHRLI
European Space Agency (ESA) Research and Scientific Support Department	Thierry APPOURCHAUX
Royal Meteorological Institute of Belgium	Steven DEWITTE Alexandre JOUKOFF
Instituto de Astrofisica de Canarias	Antonio JIMENEZ Teodoro ROCA CORTÉS
Norwegian Space Centre	Bo N. ANDERSEN
University of Cambridge, Institute of Astronomy	Douglas O. GOUGH
University of Hawaii, Institute of Astronomy	Jeffrey R. KUHN
Goddard Earth Sciences and Technology Center University of Maryland Baltimore County	Judit M. PAP

Table G3-2. Educational/Public Outreach

Organization Name
Smithsonian National Air and Space Museum
Goddard Earth Sciences and Technology Center University of Maryland Baltimore County

G4. Statement of Work (SOW) and Funding Information

1. Introduction

This Statement of Work (SOW) defines the scope of work for the Variability, Irradiance and Gravity Oscillation (VIRGO II$^+$) experiment, to be performed by Physikalisch-Meteorologisches Observatorium Davos and World Radiation Center (PMOD/WRC) as the lead institution for the experiment. The VIRGO II$^+$ team will develop and operate the experiment and its instrumentation as a dedicated solar observatory to determine the fundamental physical mechanisms responsible for the variation of the solar luminosity and total irradiance measured at Earth.

2. Background

The VIRGO II$^+$ experiment is led by PD Dr. Werner Schmutz, the Principal Investigator (PI) at PMOD/WRC, Davos, Switzerland. The PI has appointed Hansjörg Roth (PMOD/WRC) as Project Manager (PM) with the authority and responsibility to perform programmatic and technical management of the investigation.

The primary institutional responsibilities will be as follows:

a. PMOD/WRC will design and manufacture the bi-directional mount of the package.

b. PMOD/WRC will acquire the electronic for the interface adapter from a Swiss industry. The additional electronic unit will be put on top of the existing power supply. It will cover the following functions:

- Motor drivers to operate the existing covers on VIRGO II$^+$, with an adjustable pulse length motor current;
- Clock generator to run VIRGO II$^+$ and to establish an accurate time basis for VIRGO II$^+$ (replacement of the 2048 Hz clock provided by SOHO).

c. NSC will develop the LOI$^+$ read-out- and pointing electronic. This electronic is located in the expanded box of the power supply.

d. ESA/RSSD will design and integrate a new detector for the LOI$^+$ providing a higher resolution with 1000 x 1000 pixels, integrate the detector and its associated electronics in the LOI$^+$ structure, and perform the LOI$^+$ testing.

e. ESA/RSSD will develop/refurbish the existing LOI$^+$ telescope.

f. PMOD/WRC will design and build the electronic box as a piggy back on the power supply;

g. PMOD/WRC will acquire H/W and S/W for the S/C-simulator;

h. PMOD/WRC will organize the environmental testing for the refurbished experiment.

i. RMIB in Brussels will contribute the refurbishment of the DIARAD radiometer;

j. IAC will contribute and refurbish the existing VIRGO DC/DC power supply by the original manufacturer CRISA Madrid;

k. IAC will update the existing VIRGO-EGSE S/W and contribute the hardware needed;

l. IAC VIRGO Data Center (VDC) will be upgraded to process, analyze and store the VIRGO II$^+$ data;

m. The scientific data will be made available to the science community from VDC, and the mission results will be published in scientific journals and meetings.

3. Scope

PMOD/WRC under the leadership of the PI Dr. Werner Schmutz takes full responsibility for all aspects of VIRGO II$^+$, including instrument definition, development, integration and test; ground system operations, science operations, data acquisition and distribution with the intention of allowing the PI the maximum flexibility to conduct the VIRGO II$^+$ investigation.

4. Tasks

4.1 Phase A-Concept Definition

PMOD/WRC, RMIB, NSC, RSSD of ESA, and IAC technical personnel, along with selected co-investigators, will develop detailed mission and cost plans during the six-month Phase A study. The following tasks shall be performed:

a. Mission Concept: The Mission Implementation Plan will be finalized and the roles of each institute (PMOD/WRC, RMIB, RSSD of ESA and IAC) defined.

Risk Management: Define a plan to be documented in the Phase A, that identifies high-risk items along with an associated risk mitigation plan.

b. Instrument Payloads

The design of the refurbished instruments will be refined and performance characteristics will be finalized. A major effort will be devoted to study the optical design of the new LOI$^+$ instrument and investigation to increase the performance of DIARAD.

c. Instrument/Subsystem Integration and Test

A preliminary plan for (re-)integration of the instruments and performance testing will be developed, including plans for calibration, contamination control, and transportation.

d. Mission Operations and Data Analysis

Science plans and data analysis techniques will be planned and documented.

e. Educational Outreach

A detailed plan for the E/PO efforts will be developed and documented.

f. Final Report

The results of the Phase A study will be documented in the Concept Study Report. This report will contain more details about:

- Science Objectives
- Instrument Definition
- Data Products and Analysis
- Educational Outreach Program
- Plans for Phase B/C/D/E
- Detailed Cost and Institutional Subcontracting Plan

4.2 Phase B-Preliminary Design

During Phase B (scheduled for 8 months between May 2003 and December 2003), the PI and the mission team shall provide the facilities, materials, services, and personnel necessary to perform the definition work for the VIRGO II$^+$ mission. The results of the phase B Study will be presented at the Design and Cost Review.

PMOD/WRC and the VIRGO II$^+$ Mission Team will start the final design and development for refurbishment of instruments and ground segment. The following key activities will be performed:

a. Define the detailed mission requirements including science, instrument, ground data system and mission operations;

b. Define the mission operation ground system specification and the overall ground data system concept and operations plan including the operation center;

c. Define the performance specification for the instrumentation; and finalize the design of LOI$^+$, instruments, EGSE and S/C-Simulator;

d. Develop a risk management and de-scope plan, to be documented in the Phase C/D/E Implementation Plan.

e. Order long lead parts or take other measures, as necessary, to reduce schedule risks;

h. Develop the Mission Assurance and Safety Plan and necessary supporting procedures.

4.3 Phase C/D - Detailed Design, Fabrication, and Integration

Starting from the SOW as defined during phase A and B, the task requirements of Phase C/D will be further developed and updated, using a Phase C/D/E implementation Plan for the design, development and operation of the VIRGO II$^+$, ground hardware/ software and data processing and distribution. During Phase C/D, the PI and the VIRGO II$^+$ mission team will provide the facilities, materials, services and personnel to design, fabricate, assemble, test and deliver VIRGO II$^+$ and the related GSE for AIV and launch activities. The following tasks needs to be performed:

a. Phase C-Detailed Design:

This phase takes place during 6 months between December 2003 to June 2004. the phase C will be terminated by the critical design review (CDR) where the final design will be frozen.

b. Phase D-Fabrication and Implementation will take place between July 2004 and July 2006, during which hardware manufacturing and refurbishment, flight-software development for the Interface adapter and the EGSE will be completed. In parallel the instruments' integration and test phase, as well as instrument calibration, will take place.

c. Launch and Early On-Orbit Operations: The VIRGO II$^+$ mission team will provide the personnel to support the AIV and mission pre-launch activities.

d. The VIRGO II$^+$ mission team will prepare technical and programmatic data for all mission and project reviews.

4.4 Phase E-Mission Operations and Data Analysis Phase

During the period of mission, the instrument-PI are responsible for their data product. They will, in cooperation with the Science Team, process the level 0 data, taking into account all known effects to produce level 1. These data will be continuously provided for the science community through the internet. The level-2 data will take some time to be produced as they are based on the detailed assessment of the long-term behavior of the instruments. The VIRGO II$^+$ mission team will implement a comprehensive plan for providing educational and public outreach opportunities within the mission.

4.5 Contributions by NASA-Funded American Individuals

Judit M. Pap, GEST/University of Maryland, Baltimore County: She will participate in the proposed SDO/VIRGO II$^+$ experiment as science Co-Investigator and she will lead the U.S. VIRGO II$^+$ E/PO activities. The VIRGO II$^+$ E/PO activities will be coordinated with the E/PO activity of the GSFC/LWS office.

During Phase A through D, Dr. Pap will provide pre-launch science support and will assist the PI and the VIRGO II$^+$ science team to clarify up-coming science questions and will participate in producing any documents and/or papers concerning the VIRGO II$^+$ activities. She will also work on science algorithm developments.

During Phase E, Dr. Pap will participate in data calibration, evaluation and validation (both irradiance time series and images). She will also analyze irradiance time series and compare the VIRGO II$^+$ irradiance time series with the LOI$^+$ images. She will concentrate on carrying out Research Tasks 5 "Solar Irradiance" and 6 "Energy and Entropy Transport". In this capacity she will analyze total and spectral irradiance variations, spectral distribution of total irradiance variations, and the relation of irradiance variations to magnetic activity. Judit Pap will also work on Research Tasks 1 "Solar Radius", 3 "Surface Brightness Dependence", and 4 "Local Brightness Dependence". She will participate in irradiance modeling and will work together with the climate researchers involved in the project. These research efforts will also be collaborative efforts with UMBC/GEST and JCET scientists.

Jeff R. Kuhn, University of Hawaii: He will define astrometric instrument performance specifications and advise the Principal Investigator and the LOI$^+$ instrument CoI on the instrument design and configuration. After launch, Dr. Kuhn will contribute analysis algorithms for astrometry and irradiance procedures.

Michael E. Schlesinger, University of Illinois: U.S. representative of climate community will participate in three meetings of the VIRGO II$^+$ scientific team, the first during 2002, the second during 2003 and the third during 2007. During each of these meetings he will provide a focus on the relevance of the VIRGO II$^+$ research on climate change, both past and future.

G5. Reference list

Andersen, B. N.: 1996, A&A 312, 610-614.
Andronova, N. G., Schlesinger, M. E.: 2000, Geophys. Res. Lett. 27 (14), 2137.
Andronova, N. G., Schlesinger, M.E.: 2001, J. Geophys. Res., 106 (D19), 22, 605-22, 612.
Appourchaux, T., Andersen, B. N.: 1990, Sol. Phys. 128, 91.
Appourchaux, T., Fröhlich, C., Andersen, B., Berthomieu, G., Chaplin, W., Elsworth, Y., Finsterle, W., Gough, D.O., Hoeksema, T., Issak, G., Kosovichev, A.G., Provost, J., Scherrer, P., Sekii, T., Toutain, T.: 2000, ApJ 538, 401.
Armstrong, J.D., Kuhn, J.R.: 1999, ApJ 525, 533.
Brown, T.: 1987, in Solar Radiative Output Variation, ed. (P. Foukal), NCAR, Boulder.
Brusa, R. W., Fröhlich, C.: 1986, Appl. Opt. 25, 4173.
Chapman, G.: 1987, Ann. Rev. Astron. Astrophys. 25, 633.
Crommelynck, D.: 1982, NASA CP 2239, 3.
Crommelynck, D., Domingo, V.: 1984, Science 225, 180.
Crommelynck, D., Dewitte, S.: 1999, Adv. Space Res. 24, 195.
Crommelynck, D., Domingo, V., Fichot, A., Fröhlich, C., Penelle, B., Romero, J., Wehrli, Ch.: 1993, Metrologia 30, 375.
Crowley, T.J., Kim, K.-Y.: 1996, G. Res. L. 23(4), 359.
Dearborn, D.S.P., Blake, J.B.: 1980, ApJ 237, 616.
Delache, Ph., Laclare, F., Sadsaoud, H.: 1986, in Advance in Helio- and Asteroseismology, eds. (J. Christensen-Dalsgaard and S. Frandsen), IAU Press, p. 223.
Eddy, J.A.: 1988, BAAS 20, 949.
Fligge, M. and Solanki, S.: 1998, A&A 332, 1082.
Fligge, M., Solanki, S. K., Unruh, Y. C.: 2000a, Space Sci. Rev. 94,139.
Fligge, M., Solanki, S. K., Unruh, Y. C.: 2000b, A&A 353, 380.
Fox, P.: 2002, In Solar Variability and its Effect on the Earth's Atmosphere and Climate, AGU Monograph Series, eds. (J.M. Pap et al.), in press.
Fox, P., Sofia, S.: 1994, in The Sun as a Variable Star, eds. (J. Pap, C. Fröhlich, H.S. Hudson, S.K. Solanki), Cambridge Univ. Press., p. 280.
Friis-Christensen, E., Lassen, K.: 1991, Science, 254, 698.
Fröhlich, C., Anklin, M.: 2000, Metrologia 37, 387.
Fröhlich, C., Finsterle, W.: 2001, IAUSymp. 203, 105.
Fröhlich, C., Lean, J.: 1998, In Proceedings of the IAU Symposium 185, ed (F.L. Deubner), Kluwer Academic Publishers, p. 89.
Fröhlich, C., Pap, J.: 1989, A&A 220, 272.
Fröhlich, C. et al.: 1995, Solar Phys. 162, 101.
Fröhlich, C., Crommelynck, D., Wehrli, C., Anklin, M., Dewitte, S., Fichot, A., Finsterle, W., Jiménez, A., Chevalier, A., Roth, H. J. : 1997, Solar Phys. 175, 267.
Gilliland, R.L.: 1980, ApJ 248, 1144.
Gray, D.F., Livingston, W.C.: 1997, ApJ 474, 802.
Gough, D.: 1994, in The Sun as a Variable Star, eds. (J. Pap, C. Fröhlich, H.S. Hudson, S.K. Solanki), Cambridge Univ. Press, p. 252.
Hansen, J., Lacis, A., Ruedy, R., Sato, M., Wilson, H.: 1993, Natl. Geogr. Res. Explor. 9, 142.
Howe, R., Christensen-Dalsgaard, J., Hill, F., Komm, R. W., Larsen, R. M., Schou, J., Thompson, M. J., Toomre, J.: 2000, ApJL 533, L163.
Hoyt, D. V. and Kyle, H. L. and Hickey, J. R. and Maschhoff, R. H.: 1992, J. Geophys. Res. 97, 51.
Kuhn, J.: 1996, in Global Changes in the Sun, in the VI. Winter School at Instituto d'Astrophysica de Canarias, ed. (T. Roca Cortes), Cambridge Univ. Press, p. 231.
Kuhn, J. R., Stein, R. F.: 1996 ApJ 463, 117.
Kuhn, J.R., Libbrecht, K.G., Dicke, R.H.: 1985, ApJ 290, 758.
Kuhn, J.R., Lin, H., Loranz D.: 1991, Publ. Ast. Soc. Pac. 103,1097.
Kuhn, J., Bogart, R., Bush, R., Sa, L., Scherrer, P., Scheick, X.: 1997, in Sounding Solar and Stellar Interiors, eds. (J. Provost and F.-X. Schmieder), IAU 181, Nice, p. 103.

Kuhn, J.R., Bush, R., Scheick, X., Scherrer, P.: 1998, Nature 392, 155.
Kuhn, J.R., Armstrong, J.D., Bush, R.I., Scherrer, P.: 2000, Nature, 405, 544.
Kumar, P., Quataert, E.J., Bahcall, J.N.: 1996, ApJ. 458, L83.
Laclare, F., Delmas, C., Coin, J.P., Irbah, A.: 1996, Sol. Phys 166, 211.
Lawrence, G.M., Rottman, G., Harder, J., Woods T.: 2000, Metrologia, 37, 407.
Lean, J., Beer, J., Bradley, R.: 1995, Geophys. Res. Letters, Vol. 22. No. 23, 3195.
Lee III, R.B., Barkstrom, B.R., Cess, R.D.: 1987, Appl. Opt. 26, 3090.
Lockwood, G. W., Skiff, Brian A., Baliunas, Sallie L., Radick, R. R.: 1992, 1992, Nature 360, 653.
Lydon, T.J., Sofia, S.: 1995, ApJS 101, 357.
Lydon, T.J., Sofia, S.: 1996, Phys. Rev. Lett. 76, 177.
Lydon, T.J., Guenther, D.B., Sofia, S.: 1996, ApJL 456, L127.
Nesme-Ribes, E., Sokoloff, D., Sadourney, R.: 1994, in The Sun as a Variabile Star, eds. (J.M. Pap, C. Fröhlich, H.S. Hudson, and S.K. Solanki), Cambridge Univ. Press, p. 244.
Pap, J.: 1997, in Past and Present Variability of the Solar-Terrestrial System: Measurement, Data Analysis and Theoretical Models, eds. (C. Castagnoli and A. Provenzale), Enrico Fermi Summer Workshop, Italian Physical Society, p. 1.
Pap, J., Fröhlich, C.: 1999, J. Atmospheric and Terrestrial Physics 61, 15.
Pap, J., Rozelot, J. P., Godier, S., Varadi, F.: 2001, A&A 372, 1005.
Parker, E.N.: 1995, ApJ 440, 415.
Parkinson, J.H., Morrison, L.V., Stephenson, F.R.: 1980, Nature, 288, 548.
Radick, R.R.; Lockwood, G. W., Skiff, B. A., Baliunas, S. L.: 1998, ApJSS 118, 239
Reid, G.C.: 1991, J. Geophys. Res. 96, 2835.
Reid, G.C.: 1997, Climatic Change 37, 391.
Ribes,E., Mein, P., Mangeney, A.: 1985, Nature 318, 170.
Ribes, E., Beardsley, B., Brown, T.M., Delache, Ph., Laclare, F., Kuhn, J.R., Leister, N.V.: 1991, in The Sun in Time, eds. (C.P. Sonett, M.S. Giampapa, and M.S. Matthews), Arizona Univ. Press, p. 59.
Schlesinger, M. E., Ramankutty, N.: 1992, Nature, 360, 330.
Sofia, S., Heaps, W., Twigg, L.W.: 1994, ApJ 427, 1048.
Sofia, S.: 1998, in Solar Electromagnetic Radiation Study for Solar Cycle 22, eds. (J.M. Pap, C. Fröhlich and R.K. Ulrich), Kluwer Academic Publishers, p. 413.
Spruit, H.: 1982, A&A 108, 348.
Solanki, S. and Fligge, M.: 1998, Geophys. Res. Lett. 25, 341.
Solanki, S., Fligge, M.: 1999, Geophys Res Lett, 26, 2465.
Toner, C.G., Jefferies, S.M., Toutain, T.: 1999, ApJ, 518, L127
Ulrich, R., Bertello, E.: 1995, Nature 377, 214.
Wehrli, C., Appourchaux, T., Crommelynck, D., Finsterle, W., Fröhlich, C., Pap, J.: 1998, in Sounding Solar and Stellar Interiors, Poster Volume, eds. (J. Provost and F.X. Schmider), IAU Symposium 181, OCAN, Nice, p. 209.
White, W.B., Cayan, D.R., Lean, J., Dettinger, M.: 1997, J. Geophys. Res. 102, 3255.
Willson, R.C.: 1984, Space Sci. Rev. 38, 203.
Willson, R.C.: 1994, in The Sun as a Variable Star, Solar and Stellar Irradiance Variations, eds. (J. Pap, C. Fröhlich, H.S. Hudson, S. Solanki), Cambridge University Press, p54.
Willson, R.C.: 1997, Science 277, 1963.
Willson, R.C., Helizon, R.: 1999, Proc. SPIE 3970, p.233.
Willson, R.C., Hudson, H.S.: 1988, Nature 332, 810.
Wolff, C.L.: 1974, ApJ 194, 489.
Wolff, C.L.: 1998, ApJ 502, 961.
Woods, T., Rottman, G., Harder, J. Lawrence, G., McClintock, B., Kopp, G., Pankratz, C.: 2000, SPIE Proc., 4135, p. 192.
Zhang, Q., Soon, W., Baliunas, S., Lockwood, G.W., Skiff, B.A., and Radick, R.R.: 1994, ApJ 427, L111.