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SUNRISE: High resolution UV/VIS observations of the sun from the stratosphere

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Abstract

SUNRISE is an international project for the development, construction and operation of a balloon-borne solar telescope with an aperture of 1 m, working in the UV/VIS spectral domain. The main scientific goal of SUNRISE is to understand the structure and dynamics of the magnetic field in the atmosphere of the Sun. SUNRISE will provide near diffraction-limited images of the photosphere and chromosphere with an unprecedented resolution down to 35 km on the solar surface at wavelengths around 220 nm. Active in-flight alignment and image stabilization techniques are used. The focal-plane instrumentation consists of a polarization sensitive spectrograph, a Fabry–Perot filter magnetograph and a phase-diverse filter imager working in the near UV. The first stratospheric long-duration balloon flight of SUNRISE is planned in summer 2009 from the Swedish ESRANGE station. SUNRISE is a joint project of the German Max-Planck-Institut für Sonnensystemforschung (MPS), Katlenburg-Lindau, with the Kiepenheuer-Institut für Sonnenphysik (KIS), Freiburg, Germany, the High-Altitude Observatory (HAO), Boulder, USA, the Lockheed-Martin Solar and Astrophysics Laboratory (LMSAL), Palo Alto, USA, and the Spanish IMaX consortium. This paper will give an overview about the mission and a description of its scientific and technological aspects.

Keywords: Solar; Telescope; Balloon; Magnetic field; Photosphere

1. Introduction: science with SUNRISE

The solar atmosphere is pervaded by magnetic fields which are at the root of the many fascinating phenomena grouped together under the name solar activity. The magnetic processes that govern solar activity locally determine 'space weather' as well as being potentially significant drivers of terrestrial climate variability on a time scale of decades to centuries. If we are to understand these fundamental processes, we must learn how the magnetic field interacts with the solar plasma and have to uncover the conversion of energy between its mechanical, magnetic, radiative and thermal forms. The solar photosphere represents the key interaction region. Thermal, kinetic and magnetic energy all are of the same order of magnitude and transform easily from one form into another. The interaction between convection, radiation and magnetic field in the electrically conducting solar plasma leads to the creation of a rich variety of magnetic structure, from huge sunspots down to intense magnetic field concentrations on length scales down to a few tens of kilometers. The fine scale structure is illustrated in Fig. 1.

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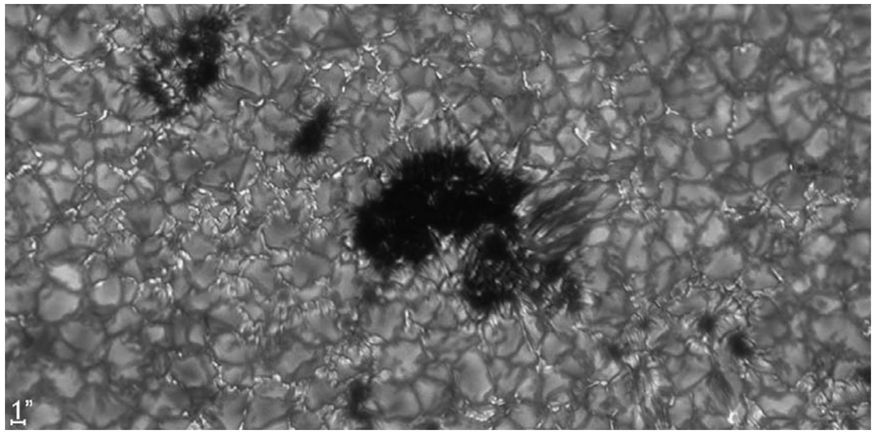

Fig. 1. High resolution image of a magnetic solar region observed in the light of the so-called G-band, an absorption band of the CH molecule at 430.5 nm. In this wavelength band the small scale manifestations of solar magnetism can be seen as bright features with high intensity contrast (image taken by V. Zakharov at the Swedish Solar Telescope on La Palma, Spain).

1.1. Science requirements

SUNRISE shall provide images of the magnetic structure and measurements of the magnetic field, the flow velocity and thermodynamic properties of the plasma...

- with a spatial resolution down to ~35 km on the Sun,
- on a sufficiently large field of view, to cover the magnetic connectivity in the solar atmosphere (~30 Mm),
- over a sufficiently long time, to follow the evolution of magnetically active regions (i.e., several days),
- with a high cadence (⩽5 s) to resolve the fast, small scale interaction processes,
- simultaneously in different heights of the solar atmosphere.

This leads to the concept of a diffraction-limited operation of a telescope of 1 m aperture in the visible and UV spectral ranges (down to ~220 nm), featuring active in-flight alignment and image stabilization, equipped with a filter imager, a polarimetric spectrograph and an imaging magnetograph, that will be described below.

2. Mission concept

Ground based observations of the Sun are suffering from several limitations. The Earth's atmosphere does not allow access to the interesting solar UV radiation between 220 and 370 nm. In addition, atmospheric turbulence is usually creating image blur, so that high resolution imaging is possible only occasionally. Long term and high resolution observations especially in the UV are therefore conducted from space-borne instruments.

Avoiding the high costs associated with space missions, but taking the advantages of being above 99% of the Earth's atmosphere, SUNRISE shall be flown as a balloon-borne stratospheric solar observatory in the framework of NASA's LDB (Long Duration Balloon) program. A zero-pressure helium balloon with an inflated volume of 835,000 m^3 and 130 m diameter will lift the ~1800 kg science payload to float altitudes of 35–40 km.

NASA LDB missions have been launched mainly from Williams Field near McMurdo, Antarctica (77.86°S, 167.13°E), with a launch window from December to January. NASA recently expanded their launch capabilities by cooperating with ESRANGE (67.89°N, 21.10°E) near Kiruna, Sweden, allowing missions to be launched during the northern summer period as well. Relatively stable wind systems at float altitude take the balloon and instrument on circum-polar trajectories with flight durations of 9–2 days per revolution.

Launching balloons during solstice conditions close to the polar circle offers uninterrupted solar observations without day/night cycles at stratospheric altitudes. Permanent sunlight and only small elevation changes of the Sun form ideal conditions, so that undisturbed observation and power generation for the instruments are guaranteed. Furthermore, thermal conditions do not vary significantly and the balloon floats at nearly constant altitude.

The preferred launch site for the first SUNRISE mission is ESRANGE, although the flight duration currently is limited to 4–5 days due to the lack of Russian overflight permissions for NASA balloons. ESRANGE provides excellent infrastructure and is accessible with much lower logistical effort compared to McMurdo.

SUNRISE is designed for about two weeks autonomous operations. Instrument control, commanding and housekeeping acquisition is provided throughout the mission via a low bandwidth ARGOS/TDRSS based telemetry. During commissioning and the initial phase of operation direct contact to the instrument is highly desirable. A high speed communication system (E-Link, developed by ESRANGE) will be used by SUNRISE on rental basis. It acts as transparent ethernet connection with up to 2 Mbit/s up- and downlink over a distance of up to 500 km. Additional mobile ground stations along the trajectory would allow extended line-of-sight communication.

The processes to be studied by SUNRISE are generating highly variable structures like sunspots or emerging and decaying active regions. Due to their intrinsic nature these phenomena cannot be predicted in time and location. Parallel observations with ground based solar telescopes as the Swedish Solar Telescope/La Palma, VTT and GREGOR/Tenerife will be performed to support the target selection for SUNRISE. Additional coordinated measurements are planned with SOLAR-B/HINODE.

3. Instrument description

3.1. Gondola

High resolution imaging requires a stable platform. This is one of the main tasks for the gondola, situated about 100 m below the balloon at the end of the flight train. The gondola core is designed as an Aluminum/Steel framework structure (see Fig. 2), being relatively lightweight but providing the required stiffness and protection to the sensitive optical instrument. The telescope and instrumentation need to be precision pointed toward the Sun. Azimuthal control of the whole payload is performed via a momentum transfer unit at the top of the gondola, the elevation of the telescope is adjusted by a two stage linear drive in a range of 0–45 deg. Control loops, fed by signals from a high precision Sun sensor, shall keep the pointing constant within 7.5 arcsec rms.

Electrical power is provided to the instruments and electronics via large solar panels, attached left and right at the front of the gondola framework structure, see Fig. 3. They benefit from the precision pointing toward the Sun, assuring nearly constant output of more than 1.5 kW. On the rear side of the gondola, shaded by the solar panels from direct Sun illumination, the instrument control electronics is located on two racks. The racks are inclined with respect to the structure due to thermal considerations. This orientation minimizes radiative input from the Earth and the hot solar panels onto the electronics, and maximizes the dissipation of generated heat to the cold sky above the instrument.

A commanding and communication package provided by CSBF (Columbia Science Ballooning Facility, a branch of NASA) is located underneath the gondola structure. It has separate solar panels at all four sides of the gondola to stay operational even in case of pointing loss. The package allows commanding and housekeeping downlink via TDRS and Inmarsat satellites along the complete trajec-

Fig. 2. The assembled core of the SUNRISE gondola framework, formed by aluminum side trusses and steel-welded upper and lower bridges. The azimuth drive or momentum transfer unit is installed at the top of the structure. Photograph courtesy by HAO.

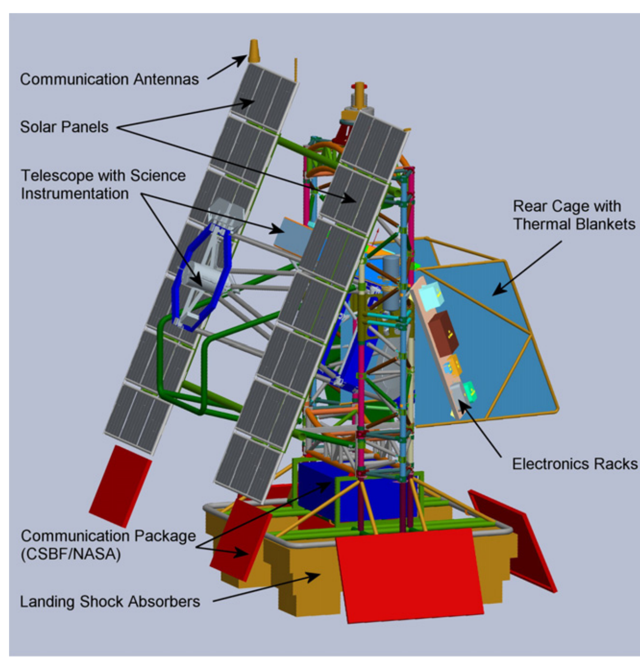

Fig. 3. Sketch of the assembled gondola with solar panels, electronics racks, landing shock absorbers, and NASA provided communication package with individual solar panels (below). The telescope and science instrumentation are visible only partly. The rear part of the gondola is formed like a cage to protect the sensitive telescope and instrumentation. It is covered with thermal control blankets.

tory. Shock absorbing crash pads at the very lower end of the gondola shall reduce mechanical loads during touch down and landing, thus enabling SUNRISE to be reflown with hopefully minimal refurbishment effort. The complete payload has dimensions of 5.5 m in width and length and is about 6.6 m high.

The gondola structure, the power and pointing systems are provided by the High Altitude Observatory (HAO), NCAR, Boulder, USA.

3.2. Telescope

The SUNRISE telescope is a light-weight Gregory-type reflector with 1000 mm clear aperture, 324 mm central obscuration, and 25 m effective focal length. Its Serrurier structure is built-up with a steel central frame. Front and rear rings as well as connecting struts are made of carbon fiber based composite materials for high stiffness and low thermal expansion. Details are shown in Fig. 4.

The parabolic main mirror with 1010 mm outer diameter and a focal length of 2.5 m is an extremely light-weighted Zerodur mirror currently being manufactured by SAGEM in France. At the primary focus a heat rejection wedge with a central hole acts as field stop. The hole defines the useable field-of-view of 3.4 arcmin, corresponding to about 148,000 km on the solar surface. The field stop is loaded with ca. 1 kW solar radiation and reflects 99% of the incoming light out of the telescope. This reduces the heat load on the science instrumentation to only about 10 W. Dedicated radiators connected by heat pipes keep the field stop temperature moderate to avoid Schlieren build-up.

The light passing through the field stop is reflected off the elliptical secondary mirror M2 and folded back by two flat mirrors M3 and M4 to feed the focal-plane package. The latter is mounted piggy-back on the telescope structure and described in the following chapters.

The optical system of the SUNRISE telescope is semi-active to maintain the highest performance throughout the flight. A wavefront sensor located in the Postfocus Instrumentation is constantly monitoring the alignment status, generating control signals for mirror re-positioning. The M2 lateral and axial position is fine adjustable to keep the relative M1/M2 alignment even under varying telescope elevation and thermal loads. Fine focusing is performed by moving M3 and M4 accordingly.

Thermal control of the primary mirror is essential for the performance of the telescope. About 80 W solar radiation are absorbed in the coating. Dedicated baffles behind the mirror with reflective front sides increase the view factor to the cold sky and in parallel shade the mirror against Earth radiation and albedo reflected sunlight.

A retractable curtain in the plane of the central frame can close the rear compartment of the telescope in case of pointing loss, acting as an aperture door. The energy density in the primary focus is high enough to seriously damage structural parts in case of uncontrolled beam wandering.

The telescope is built by Kayser–Threde (Munich) under contract of the Max-Planck-Institut für Sonnensystemforschung, Katlenburg-Lindau, Germany.

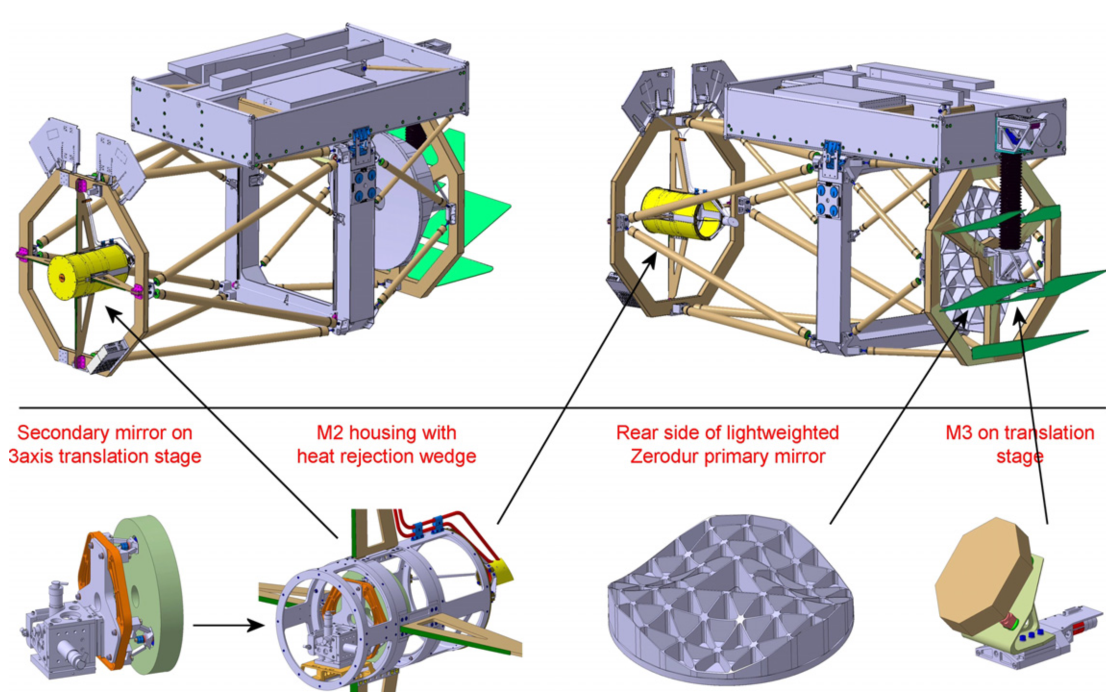

Fig. 4. Sketch of the SUNRISE telescope in front and rear side view. The instrument platform is attached at the top of the telescope central frame. The front ring carries the radiators of the heat rejection wedge, at the rear three louver-type blades are installed for thermal control of the primary mirror. The lower row shows some component details.

3.3. Postfocus Instrumentation

The SUNRISE Postfocus Instrumentation (PFI) sits piggy-back ontop the telescope. Similar to the telescope, carbon fiber based composites and honeycomb structures are used for the mechanical frame, providing high stiffness and low thermal expansion, paired with reduced weight.

Besides the supporting structure, the PFI consists of five individual instrument modules, three out of which are science instruments, the other two are "service" modules for Image Stabilization and Light Distribution (ISLiD) and for Correlation tracking and Wavefront Sensing (CWS). The science instrumentation consists of the SUNRISE Filter Imager (SUFI), the SUNRISE Polarimetric Spectrograph (SUPOS) and the Imaging Magnetograph eXperiment (IMaX), a vector magnetograph based upon a tunable narrowband filter. Basic design parameters for the instrumentation are listed in Table 1.

The instruments require to have some electronic units closeby. The mechanism controllers for SUFI and SUPOS as well as the proximity electronics for the CWS are located inside some of the PFI compartments, see Fig. 5.

The Postfocus Instrumentation is responsibility of MPS, unless otherwise noted.

3.4. Image Stabilization and Light Distribution System: ISLiD

The SUNRISE science requirements demand precision fine pointing and simultaneous observations of all three science instruments. This is ensured by ISLiD. ISLiD is a complex panchromatic reimager based on dichroic beam-

Table 1
Design parameters of the Postfocus Instrumentation

Telescope	Gregory configuration	
	Primary focal length	2.5 m
	Effective focal length	25 m
	Image scale	8.25 arcsec/mm
CWS, Correlating Wavefront Sensor	Wavefront sensor	64×64 pixel^2, CCD
	Pointing accuracy	$\leqslant$0.05 arcsec
	Dynamic range	70 Hz minimum
	Number of subapertures	7
	No. of Zernike terms	5
SUFI, SUNRISE Filter Imager	Phase diversity imager	
CCD camera	Format	2048×2048 pixel^2
	Pixel size	12×12 μm^2
	FOV (3 pixel sampling)	20×40 arcsec^2
Phase diversity	Beamsplitter, 1 CCD	
Double filter wheel	5 Filter positions	220 nm (continuum)
		279.6 nm (Mg II k)
		300 nm (continuum)
		313 nm (OH molecular band)
		388 nm (CN molecular band)
IMaX, Imaging Magnetograph eXperiment	Polarimetric narrowband imager	
Filter unit	Prefilter	Narrowband interference filter
	Main filter	$LiNbO_3$ Fabry–Perot etalon in double pass
	Spectral resolution	4 pm
	Spectral line	525.06 nm (Fe I)
Polarimetry unit	Polarization modulator	2 Nematic liquid crystals, 15 Hz
Camera	2 CCDs	1024×1024 pixel^2
	Pixel size	12×12 μm^2
	FOV	50×50 arcsec^2
Phase diversity	2 Separate CCDs	
SUPOS, SUNRISE Polarimetric Spectrograph	Polarization sensitive spectrograph	
Scanning unit	Focal length	1000 mm
	Spectral line	854.2 nm (Ca II)
	Step width	0.05 arcsec
	Total range	±50 arcsec
Main disperser	Grating	158 grooves/mm
	Spectral resolution	2.7 pm (near 850 nm)
	Dispersion	12.6 pm/mm (near 850 nm)
Polarimetry unit	Dual beam system	Polarizing beam splitter
	Retarder	2 nematic liquid crystals, 16 Hz
Camera	CCD, Format	652×488 pixel^2
	Speed	16 frames/s
	Pixel size	12×12 μm^2
	CCD IFoV	65 arcsec $\times$ 0.26 nm

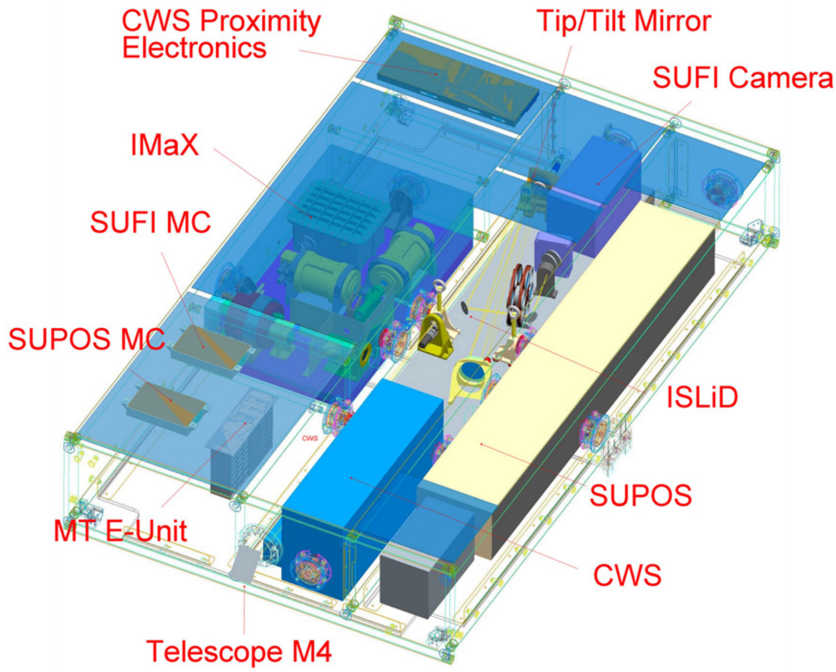

Fig. 5. Sketch of the Postfocus Instrumentation piggy-back on the telescope. The central compartment houses ISLiD with the tip-tilt mirror and SUFI with a double filter wheel and CCD camera. IMaX with its two cameras is seen on the left. SUPOS is housed in the right compartment. Light from the main telescope enters from the lower left via telescope mirror M4. Mechanism controllers (MC) for SUFI, SUPOS and other supporting electronics are shown, blue areas indicate radiator surfaces.

splitters, which guide the different wavelength bands to the individual science branches with maximum photon flux. Reimaging is achieved with a two mirror arrangement (for SUFI) and additional refractive optics for SUPOS and IMaX. Part of the light, which is not used for scientific analysis, is fed to the CWS, the second service module. Providing high image quality in the UV creates stringent surface quality requirements on at least some of the optical elements. The beamsplitter coatings in addition are critical in terms of polarization requirements.

ISLiD contains a fast piezo-driven tip-tilt mirror at a pupil plane of the optical system. A field lens in the telescope secondary focus projects the aperture stop of the primary mirror onto the tip-tilt mirror. In order to allow for the UV part of the solar spectrum to be transmitted, the field lens is made from fused silica and uncoated.

The tip-tilt mirror is used to stabilize the image and compensate for residual image motion due to gondola shake or vibrations within the system. The control signals for the tip-tilt mirror are generated in the CWS. The closed-loop bandwidth of the image stabilization system is about 70 Hz. The system has a sensitivity of better than 0.003 arcsec and allows improving the fine pointing from 7.5 arcsec rms provided by the gondola to about 0.05 arcsec rms at the science instruments.

3.5. *Correlating Wavefront Sensor: CWS*

The CWS is a high speed camera system with a lenslet array in a pupil image, having a field-of-view of 12.5×12.5 arcsec^2. The CWS is used in two ways, for (high frequency) precision image stabilization and guiding, and to control the proper alignment of the telescope (low frequency). The lenslet array has seven subapertures (one center subaperture, six on a concentric ring), forming six independent images on the detector (central subaperture is blocked by the telescope central obscuration). The information derived from the six independently analyzed images of the same solar scene can be used to measure the local wavefront tilt per subaperture. The resolution is sufficient to determine the coefficients of a Zernike polynomial decomposition of the wavefront error up to the third radial degree. The coefficients for tip and tilt, defocus and Seidel coma are used as error signals. A control loop time-integrates these error signals and converts them into actuation signals which are used to drive and align the telescope secondary mirror, M2.

The fast read-out of the CWS camera (1 kHz) allows to detect any correlated image motion of the six separately generated images on the detector. Correlated image motion is created by residual uncompensated gondola movements and vibration as well as by the slow movement of high contrast features on the solar disk (rotation). Fast software routines convert correlation signals to actuator signals for the tip-tilt mirror performing the pointing correction, image stabilization and guiding.

The correlation tracker/wavefront sensor unit including the tip-tilt mirror and the control software is developed by the Kiepenheuer-Institut für Sonnenphysik, Freiburg, Germany.

3.6. SUNRISE Filter Imager: SUFI

SUFI samples the photosphere and chromosphere in distinct wavelength bands. The channel at 225 nm allows studies of the upper photosphere and lower chromosphere. At the same time, this wavelength is important for the stratospheric ozone formation. The OH-band at 313 nm and the CN-band at 388 nm provide high contrast, and thus sensitivity to thermal inhomogeneities in the photosphere. The Mg II k line (singly ionized magnesium) at 279.6 nm is an excellent thermometer for the chromospheric temperature structure.

SUFI is the instrument allowing for the highest angular resolution of down to 0.05 arcsec (~35 km on the Sun surface). This corresponds to diffraction limit of the 1 m mirror for a wavelength of 225 nm. In order to achieve near diffraction-limited imaging, a phase-diverse imaging technique is used by splitting the image in front of the CCD detector: half of the CCD area collects the focused image, while a special optical arrangement forms a second image of the same scene on the second half of the CCD, now with a defocus of one wave. Postfacto restoration of the image free from static aberrations of the optical path can be achieved.

The optical arrangement is a Schwarzschild system to magnify the telescope secondary focus by a factor of 5 onto the CCD. The sensor is a 2 k by 2 k UV enhanced fast read-out CCD. The field-of-view of the instrument is 20×40 arcsec^2. SUFI works in 5 distinct wavelength bands in the near UV between 220 and 390 nm, which are selected by "ion aided deposition" (IAD) coated interference filters sitting in a double filter wheel to ensure sufficient blocking against the strong visible and near infrared parts of the solar irradiance.

3.7. SUNRISE Polarimetric Spectrograph: SUPOS

The achievement of the main science goals of SUNRISE depends on quantitative and accurate measurements of the strength and orientation of the magnetic field with appropriate spatial, spectral and temporal resolution. SUPOS allows high resolution vector-polarimetry, simultaneously providing photospheric and chromospheric magnetic field measurements.

SUPOS has undergone a considerable design change and is now designed as a single spectral line high resolution grating spectrograph working at a wavelength around 854 nm. Here a chromospheric line of singly ionized Calcium (Ca II) allows for simultaneous magnetic field diagnostics due to its Zeeman splitting. The line is formed in different layers, spanning from the photosphere to the chromosphere. While the interpretation of the data is more demanding as compared to purely photospheric lines, the advantage of having access to chromospheric magnetism more than compensates for this. The full polarisation state of the spectral line will be detected using two nematic liquid crystal variable retarders followed by a polarizing beam splitter. The CCD camera is read-out synchronized with the electro-optical modulation in order to demodulate the polarization signal.

3.8. Imaging Magnetograph eXperiment: IMaX

IMaX is an imaging vector magnetograph, developed for observations of Doppler shifts and polarization in the Zeeman sensitive photospheric spectral line of Fe I (neutral iron) at 525.06 nm. Images will be taken in two to four narrow wavelength bands in either of the spectral line wings. The instrument will provide fast-cadence two-dimensional maps of the complete magnetic vector, the line-of-sight velocity and continuum frames with high spatial resolution. It has the largest field-of-view of all instruments, which is 50×50 arcsec.

A tunable $LiNbO_3$ solid state Fabry–Perot etalon is used in double pass. This configuration significantly saves mass and power and relaxes the demanding requirements on passband stability. Since the free spectral range of such a system is quite small, a narrowband interference filter (FWHM 0.1 nm) must be used. Both, prefilter and etalon must be thermally stabilized. Imaging is done with two synchronized CCD cameras for phase diversity reconstruction. Polarimetry is done with two nematic liquid crystal modulators. Four switching states are needed for full Stokes vector polarimetry. A two-state observing mode is foreseen for longitudinal magnetometry (only circular polarisation).

IMaX is being developed by a Spanish consortium led by the Instituto de Astrofísica de Canarias, La Laguna (Tenerife), in cooperation with the Instituto de Astrofísica de Andalucia, Granada, the Instituto Nacional de Tecnicas Aeroespaciales, Madrid, and the Grupo de Astronomia y Ciencias del Espacio, Valencia.

3.9. SUNRISE supporting electronics

SUNRISE is a complex system comparable to a spacecraft. A central on-board computer (Instrument Control Unit, ICU) is interfacing with dedicated instrument control computers and the pointing system computer via an ethernet based network. The largest part of the electronics is located on two racks mounted to the gondola structure, only proximity electronics like mechanism controllers or the voltage supply for the piezo-driven tip-tilt mirror are located close to the optical modules. Commercial-of-the-shelf products are used as far as possible. These products would typically not survive the environmental conditions of a balloon flight. Critical items need to be encapsulated in pressure vessels, modified and specifically qualified for this type of application.

The science data are stored on-board. Two units with 24 (100 GB) harddisks each (2×2.4 Terabyte) give about 3.6 Terabyte net capacity with RAID-5 functionality, corresponding to the expected data volume acquired in a 2 weeks mission. High data rates are achieved with Firewire connections. The two data storage containers are mounted within the gondola framework for maximum protection at mission termination and landing and for easy dismounting. A spring-based shock protection system shall ensure the mechanical integrity of the data storage containers. To avoid any oscillating masses and adverse effects on the pointing control loops, the data storage containers need to be rigidly clamped during the mission. A special release mechanism frees the containers at mission termination.

4. Programmatic and technological challenges

SUNRISE faces interesting programmatic and technological challenges. A balloon project is something "in-between". It is not regarded as a typical space mission but the instrument development definitely differs from ground based experiments. Funding is significantly lower, but the technological challenges unfortunately are comparable to space projects, especially in their combination of thermal, structural and optical constraints.

Heat exchange at float altitudes with pressure levels around 3 hPa is dominated by radiative interaction, similar to spacecrafts in orbit. Variable energy input from the Sun and via Earth's albedo together with high power dissipating commercial electronics requires detailed thermal modeling to predict component temperatures and to define appropriate surface treatments, coatings or insulation.

During ascent phase the balloon passes the extremely cold tropopause layer, where the air density is still high enough to severely chill-out exposed elements by convective coupling. This is especially a risk for gasket sealed pressurized vessels containing electronics and makes dedicated thermal-vacuum testing necessary.

"Off-nominal" conditions, i.e., pointing loss or off-pointing need special consideration during instrument thermal design.

Unlike a space-borne instrument, SUNRISE still is facing gravity during mission. Following the elevation changes of the Sun, the telescope and the science instruments piggy-back ontop will be subjected to a varying gravity vector. This fact in combination with the stringent pointing requirements asks for high structural stiffness. Detailed structural analyses have been made, also to verify instrument integrity during transport, ground handling and at mission termination (shock loads at parachute opening). Eigenfrequency decoupling of the various sub-assemblies is mandatory to avoid interaction with the gondola servo control loops providing the fine pointing.

SUNRISE has to meet high optical performance requirements to be able to compete with instruments like SOLAR-B. The advantage of having a larger aperture can only be used, if the overall wavefront error is small enough. The wavefront error of SUNRISE is mainly controlled by its largest element, the primary mirror. State-of-the-art technologies as ion beam figuring help to build the 1 m primary mirror with diffraction-limited performance under thermal and gravitational loads.

In addition SUNRISE will extend the wavelength range into the UV. This is relevant not just for SUFI as the only UV instrument, but as well for the telescope and ISLiD. Surface figure errors on optical components, coatings and material selection need to be tailored accordingly. Outgassing properties of all components close to the optics become important. Molecular contamination and polymerization due to the high UV flux could seriously degrade the optics.

5. Schedule

SUNRISE plans to conduct a continental US test flight with the gondola, main parts of the electronics and a dummy telescope in October 2007. The telescope delivery to MPS is expected in early 2008. Assembly, alignment and calibration of telescope and Postfocus Instrumentation, the system integration and testing with the refurbished gondola will take place at MPS in Germany until end of 2008/beginning of 2009. Mission preparation and shipping to ESRANGE will be in spring 2009, aiming at a launch during the May/June 2009 launch window.

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