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CCD cameras and Spacewire interfaces for HERSCHEL/SCORE suborbital mission.

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Abstract. The HERSCHEL/SCORE is a suborbital mission that will observe the solar corona in UV (H Lyα and HeII Lyα) and in the visible light for measurements of coronal polarization. The coronagraph for such observation is an Italian instrument and, in particular, the CCD camera detectors are developed at the XUVLab of the Department of Astronomy and Space Science of the University of Florence. Such detectors communicate with the on-board computer by means of a IEEE1355 Spacewire standard interface board (developed in our laboratories) and implement a lot of smart and custom procedures for imaging. The main innovation of SCORE coronagraph is the first use in space of a variable retarder plate based on liquid crystals and the optical design capable of simultaneous observation in UV and Visible light.

Key words. HERSCHEL, CCD cameras, Spacewire interface, Coronagraph, Solar corona, resonant scattering

1. Introduction

SCORE (Sounding CORona Experiment) has been included in the HERSCHEL (HElium Resonant Scattering in the Corona and HELiosphere) sounding rocket payload. HERSCHEL is conceived as a NASA Sounding Rocket Program providing new EUV/UV and visible-light coronal observations to directly measure and to characterize in detail the properties of the two most abundant elements, Hydrogen and Helium. In particular, HERSCHEL will be able to provide:

- The first global images of the HeII corona
- The first global EUV images of the corona for the two most abundant elements, H and He
- The first maps of He abundance in the corona
- The first global maps of the solar wind outflow (H and He+ outflow)
- Polarimetric measurement in the visible of the solar extended corona
- A proof-of-principle for the SCORE

The HERSCHEL payload consists of the HERSCHEL EUV Imaging Telescope (HEIT), similar to the SOHO/EIT instrument, the HERSCHEL EUV Coronagraph (HECOR) and the SCORE coronagraph. The latter is a reflecting coronagraph designed to get images of the full corona from 1.2 to 3 R$\odot$ in the HI Ly line at 121.6 nm, in the HeII Ly line at 30.4 nm and to measure polarimetric brightness in the visible spectral region. The coronagraph is externally occulted and its optical design is based on novel solutions to improve the stray light rejection and to use the same optical components to focus the radiation in the selected wavelength bands. In order to measure the coronal polarized radiation in the visible band, the SCORE coronagraph is equipped with a novel polarimetric group implementing an LC (Liquid Crystal) retarder plate. SCORE is under development and is ready for pre-flight characterization tests. These tests will provide information on the telescope multilayer mirrors, the stray light rejection, and the low noise CCD cameras.

The detectors for the SCORE coronagraph are two CCD cameras provided by the XUVLab team of the Dept. of Astronomy and Space Science of the University of Florence. The cameras were developed starting from the laboratory prototype which was used for ground applications, following the rocket specifications, and optimized to operate the selected sensor.

Each camera will operate at a pixel rate of 300 kHz and will satisfy requirements, such as very low readout noise, high quantum efficiency, wide dynamic range, good linearity and uniformity. Moreover, a good level of versatility is a desirable feature that allows:

- arbitrary pattern generation of the digital clock waveforms, to operate our camera with a variety of CCDs and to fine-tune the selected sensor
- satisfying the mission requirements like the data transfer protocols between the interface and the main computer, as well as limitations on weight, power, size: a customizable camera can be modified while a commercial camera is usually not
- generating an additional synchronous trigger to drive the polarimeter during the image acquisition.

Both the CCD cameras communicate through the Spacewire (SpW) interface an ESA/NASA standard protocol for data transmission in space applications. The SpW interfaces and CCD cameras have a high level of automation due to the small observing time (only $\sim$300 s); during such a short observational time is not possible to send commands from ground station, therefore the electronics must recognize errors and must recover them.

2. SCORE instrument

The SCORE coronagraph is an external occulted off-axis Gregorian telescope, capable of simultaneous images acquisition in the visible light (VL) and a UV narrowband (UVL). The SCORE coronagraph will observe in VL and H Lyα simultaneously using a MgF2 filter, then a mechanism will swap this filter with an Aluminum filter to observe only UVL (He II Lyα). Then the filters will be swapped again to acquire H and VL images once and again. The SCORE coronagraph detectors are two CCD cameras, one for VL images (VLD) and one for UVL images (UVD); both CCD cameras are provided by XUVLab. The VLD includes a polarimetric group to measure the polarized brightness of solar corona. The main innovation of this polarimeter is the liquid crystals variable retarder plate (LCVR).

3. CCD cameras

The VLD is an E2V CCD47-20 1024x1024, frame transfer, operating in 2x2 binning mode. It has a 16-bit dynamic range and produces 4Mb images. The UVD is an intesified CCD. The CCD is the E2V CCD42-40. UVD will acquire both He and H images, by selecting different filter configurations in the telescope. The images acquired by both CCD are readout at 300 kpx/s and stored into an internal FIFO memory, one per each detector, in $\sim$1.7 s (VLD); then they are ready for download to the PC.

Each camera is controlled by its own electronics, which is able to provide all signals for the detector (bias voltages, clocks, signals for the polarizer), and to manage the acquisition sequence. SCORE CCD electronics consists of the following PCB boards:

1. Power Supplies & Bias Generator (PS)
2. Peltier Power Supplies (PPS) & shutter controller (VLD only)
3. Sequencer (SEQ) & Clock Driver
4. CCD & Preamplifier (PA)
5. Correlated Double Sampler (CDS & ADC)
6. SpaceWire interface (SpW)
7. LCVR (Liquid Crystal Variable Retarder) controller (LCVRC) (VLD only)

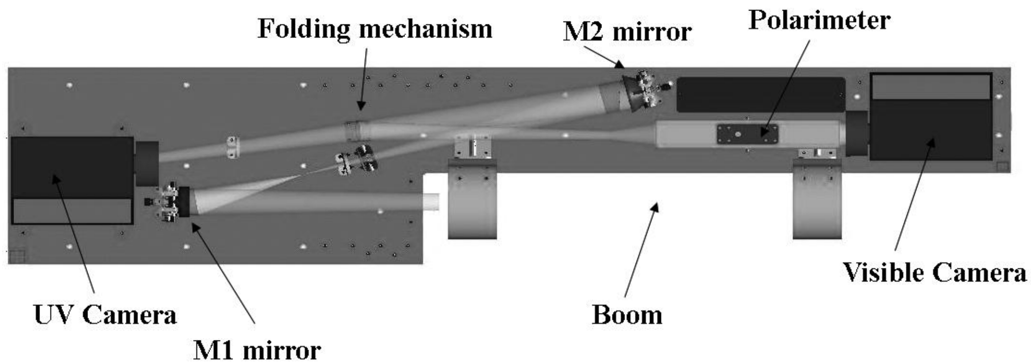

Fig. 1. figure 1: SCORE coronagraph

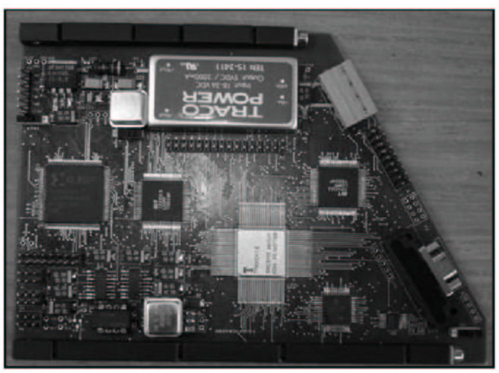

Fig. 2. figure 2: Spacewire board

Boards n 1÷6 are hosted inside the CCD camera case, while the LCVRC is a stand-alone board hosted in a case (Polarimeter Electronics Box - PEB) near the KPol polarimeter. SCORE has two observing modes:

1. UV HI + VL pB
2. UV HeII

A folding mirror, driven by a folding mirror mechanism (FMM), is used to switch between the two modes.

4. Spacewire interface

Spacewire is an ESA and NASA standard already selected for missions like Rosetta, Mars Express, SWIFT. It is planned for future mission like GAIA, Bepi Colombo MPO, JWST, and others. Spacewire is defined in the European Cooperation for Space Standardization ECSS-E50-12A standard. The CCD camera, the LCVR controller and the Peltier power supply need a link to the onboard computer. It sends commands to the cameras and LCVRC to power-up, to start acquisition, handshake, housekeeping of temperature and commands to manage recovery following failures. Since this kind of interface is still rare, the application is for space and the requirements for the interface are very specific, we developed a custom Spacewire interface. A fully compliance with SpaceWire (ECSS E-50-12A) is not required for the link; the revised IEEE-1355 DS/DE sub-standard with LVDS signalling, is implemented: this guarantees compatibility with SpaceWire standard. This is achieved by using the SMCSlite device. A buffer for an image of 4 Mb is required; the image is received from the ADC at 300 kHz and it is buffered in case the onboard computer is busy. An image is transmitted via the IEEE-1355 link packed with some additional information, placed in the header. Key components are:

- SMCSlite Communication Controller
- 4 Mb FIFO memory
- FIFO Controller
- Local Controller
- LVDS Driver/Receiver

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