Towards a New Formation Flying Solar Coronagraph

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Abstract. We briefly describe an investigation aiming at the development of a giant solar coronagraph instrument onboard of two satellites, separated by about 150 m in formation flight for the detailed observation of the solar coronal plasma. The European Space Agency (ESA) has selected this instrument as the only payload onboard the Proba 3 satellites which will be launched in 2013. The Greek team is developing the command control board of the coronagraph.

1. Formation Flying

The ultimate performance of a large class of astronomical instruments, such as telescopes, interferometers, coronagraphs, etc, depends on their size. On the other hand, progress requires larger and larger instruments, while those presently in space are limited by the launchers capacity. Hence, currently the implementation in space of advanced, high performance instruments, such as large telescopes, large base interferometers, large base stellar and solar coronagraphs is prohibitive. Then, in order to circumvent such constraints, a new concept has emerged based on the idea to distribute such instruments over a cluster of spacecrafts in a formation flying (FF) configuration. Thus, FF is considered to be the most promising and effective approach to deploy...
the forthcoming generation of very large instruments in space. ESA is taking a leading role in this technology and has proposed an ambitious program starting with the demonstration mission PROBA-3 (PRoject for On-board Autonomy). PROBA-3 with its coronagraphic payload will pave the way for other more demanding FF applications, culminating with the Darwin mission to study exoplanets orbiting nearby stars within their habitable zone. Needless to say that there exists a strong demand from the wider astrophysical community for the FF capability of deploying very large instruments in space. The metrology methods developed for FF could be applicable to large-scale rigid structures to be deployed in space in the future. And, the development of compact telescopes with large apertures and low level of stray light is of wide interest not only in astronomy but also in remote sensing applications.

2. ESA Startiger project, “Toward a New Generation of Formation Flying Solar Coronagraph: First Demonstration and Future Challenges”

The ESA-funded Startiger project "Toward a New Generation of Formation Flying Solar Coronagraph: First Demonstration and Future Challenges" started in Sept. 2009, after a successful proposal submitted in the beginning of 2009 and selected in the framework of the ESA Startiger program of technology demonstration. This investigation is performed by a consortium of scientific institutes and industrial partners, all having extensive experience in space systems and instrumentation. It is led by the Laboratoire d’Astrophysique de Marseille (LAM), and includes the following partnering organizations: Centre Spatial de Liège, INAF-Osservatorio Astronomico Torino, University of Athens, and the Rutherford Appleton Laboratory. Other participating organisations are the LATMOS (Laboratoire Atmosphére, Milieux, Observations Spatiales) in France, the University of Padova, the University of Firenze and the National Observatory of Athens (Institute of Space Applications and Remote Sensing). The core-team consists of scientists from the five participating Institutes, co-located at the coordinated Institute in Marseille, France (LAM). The program ends in March 2010. This first investigation focuses on the development of the instrument metrology systems capable of controlling two satellites in formation flight forming a giant solar coronagraph, and of enhanced science capabilities for future in-depth physical characterization of the solar coronal plasma. The main outcome of the study is to develop a demonstrator validating the FF performances, such as the absolute pointing (± 20 milliarcsec off-pointing i.e. lateral displacements of the shadow as low as 15 μ) and the relative pointing /alignment (0.3 arcsec, i.e. ± 1.5 μ in the lateral direction and ± 10 cm in the longitudinal direction for the 150 m baseline).

3. ASPIICS Coronagraph

The "Association de Satellites Pour l’Imagerie et l’Interferometrie de la Couronne Solaire" (ASPIICS) investigation was proposed in Sept. 2009 in response to the Announcement of Opportunity for the provision of a solar coronagraph to be flown on the PROBA 3 Technology mission issued by the European Space Agency (ESA) on July 7, 2009 under reference D/SRE/DJS/PhE/og/25728. ASPIICS heralds the next generation of coronagraph for solar research, exploiting formation flying to gain access to the inner corona under eclipse-like conditions for long periods of time, the outcome of a long quest since Bernard Lyot invented the coronagraph in 1931. ASPIICS will make a giant
step in our knowledge of the solar corona by providing observations that will lead to the insights necessary for understanding key physical processes and for the prediction of space weather in the Sun-Earth system. ASPIICS is conceived to permanently reproduce the conditions of a total eclipse of the Sun in space ("artificial eclipse) capable of observing the inner corona from close to the solar limb to 3 solar Rsun in different modes:

1. high spatial resolution imaging of the continuum K+F corona in photometric and polarimetric modes,
2. high spatial resolution imaging of the E-corona in two coronal emission lines (CEL): Fe XIV and He I D3, and
3. two-dimensional spectrophotometry of the Fe XIV emission line.

ASPIICS further has the capability to independently control the pointing and alignment of the two satellites and to provide the initial and regular calibrations of the formation control system of the satellites, thanks to its Shadow Position Sensor (SPS) and Occulter Position Sensor (OPS).

The main Greek technological participation is on the construction of the Coronagraph electronics (Coronagraph Control Box), a collaboration of the Departments of Physics, Informatics and Telecommunications of the Un. of Athens and Greek Industry. The ASPIICS investigation is proposed by an international consortium consisting of 44 Co-Investigators and 41 Associated Scientists from Europe, the USA and Russia under the responsibility of the Principal Investigator, Philippe Lamy (LAM, France). The large number of participants in the ASPIICS proposal, with a mixing of senior and
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junior scientists, testifies to the vitality of the solar community particularly in Europe. ASPIICS will open a new window in coronal investigations by addressing multiple questions in coronal physics via the analysis of a large amount of expected data.

4. Objectives of the ASPIICS Coronagraph

Although solar physics missions have probed the corona in several temperatures and heights, the region within the sonic point where the solar wind and Coronal Mass Ejections (CMEs) are born indeed remains extremely difficult to observe with sufficient spatial resolution and sensitivity to understand these phenomena. Progress on this front requires eclipse-like conditions for long periods of time and that is precisely what is being offered by the PROBA 3 mission and the proposed ASPIICS payload. ASPIICS will have the capability to:

- characterize the morphology, dynamics and mass distribution of coronal structures, and their relation to the coronal magnetic field;
- identify the sources of the slow wind via extensive high resolution observations, in space and time, of active region expansion, streamer formation and evolution;
- identify and characterize the waves that contribute most to the heating of the corona;
- study the velocity fields, temperature and composition of the solar atmospheric plasma at unprecedented high spatial and temporal resolution in order to eventually resolve the nature of the processes of energy deposition and dissipation;
- determine the connection of coronal mass ejections (CMEs) with their low corona manifestations and establish their kinematics properties (e.g., impulsive acceleration).

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