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ScienceDirect
Advances in Space Research 42 (2008) 106–109
ADVANCES IN SPACE RESEARCH
(a COSPAR publication)
www.elsevier.com/locate/asr

The coronal dynamics imagers for the KuaFu mission

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Received 20 December 2006; received in revised form 23 November 2007; accepted 26 November 2007

Abstract

The Space Weather Explorer – KuaFu mission will provide simultaneous, long-term, and synoptic observations of the complete chain of disturbances from the solar atmosphere to the geospace. KuaFu-A (located at the L1 liberation point) includes Coronal Dynamics Imagers composed of a Lyman-α coronagraph (from 1.15 to 2.7 solar radii) and a white light coronagraph (out to 15 solar radii), in order to identify the initial sources of Coronal Mass Ejections (CMEs) and their acceleration profiles. The difficulty of observing the lower corona should not be underestimated since instrumental stray light remains a critical issue in the visible because of the low contrast of the corona with respect to the Sun. Observing the corona in the Lyman-α line is a valid alternative to white light observations. This approach takes advantage of both the intrinsic higher contrast of the corona with respect to the solar disk in this line compared to the visible, and the absence of F-corona at 121.6 nm. Furthermore, it has been convincingly shown that the coronal structures seen in Lyman-α correspond to those seen in the visible and which result from Thomson scattering of the coronal ionized gas. This is because the plasma is still collisional in the lower corona so that the hydrogen neutral atoms are coupled to the protons. A classical, all-reflecting internally-occulted Lyot coronagraph is required so as to preserve the image quality down to the inner limit of the field-of-view. A narrow band interference filter located in a collimated beam allows isolating the Lyman-α line. The visible coronagraph will adopt the approach of a single instrument having a large field-of-view extending from 2.5 to 15 solar radii. Such a design is based on refractive externally-occulted coronagraphs built for recent past missions, essentially the LASCO-C2 and C3 instruments and the SECCHI/COR 2 of the STEREO mission, which is itself a combination of the C2 and C3 instruments.

Keywords: Coronagraph; Solar corona; KuaFu; Space Weather

1. Introduction

The Space Weather Explorer – KuaFu mission will provide simultaneous, long-term, and synoptic observations of the complete chain of disturbances from the solar atmosphere to the geospace. The KuaFu mission may start at the next solar activity maximum (a possible launch by 2012), with an initial mission lifetime of 2–3 years that would hopefully be extended post-launch.

The KuaFu mission presents both a unique and most appropriate opportunity for coronagraphs. They will enjoy long and continuous observation periods (2–3 years) from the best suited L1 libration point between Sun and Earth. They will also be associated with a complete set of instruments observing together and continuously all events occurring on the solar disk, its atmosphere and out to the interplanetary medium upstream of the Earth.

In this context, we propose the Coronal Dynamics Imagers (CDI) which is composed of a Ly-α coronagraph called *LYCO* (from 1.15 to 2.7 $R_\odot$) and a white light coronagraph called *VICO* (from 2.5 to 15 $R_\odot$).

2. LYCO: LYman-α COronagraph

2.1. Rationale

We propose that the KuaFu payload includes a Ly-α internally-occulted coronagraph to observe the inner corona from 1.15 to 2.7 $R_\odot$ so as to bridge the gap between

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0273-1177/$34.00 © 2008 Published by Elsevier Ltd on behalf of COSPAR.
doi:10.1016/j.asr.2007.11.032

the solar disk imagers to the externally-occulted coronagraph whose inner edge is limited to $2.5R_{\odot}$. The solar corona was first observed in this line from a rocket flown during the total eclipse of 1970 (Gabriel, 1971). In spite of the low density of the hydrogen atoms present in the corona, the strength of the Ly-α line (121.6 nm) makes the corona quite bright. It has been convincingly shown that the coronal structures seen in Ly-α correspond to those seen in the visible and which result from Thomson scattering of the coronal ionized gas (Gabriel, 1971). This is because the plasma is still collisional in the lower corona so that the hydrogen neutral atoms are coupled to the protons. This insures the validity of all diagnostics as extensively demonstrated by the UVCS spectrometer aboard SOHO (Kohl et al., 1995). In particular, the radiance of the Ly-α emission line is an excellent diagnostic of the distribution of the coronal density, that is the mass of the gas (it can be further noted that the strength of this line is weakly dependent upon the temperature, contrary to most other emission lines in the UV and EUV).

Since the Ly-α line is a valid alternative to white light observations, it is important to point out the potential advantages of the former approach. First the difficulty of observing the lower corona should not be underestimated and the SOHO/LASCO-C1 instrument (Brueckner et al., 1995) has shown that instrumental stray light remains a critical issue in the visible because of the low contrast of the corona with respect to the Sun. A white light instrument is part of the STEREO payload (Kaiser, 2005) and it will be of interest to see how it will perform. The potential superiority of the Ly-α approach stems from the intrinsic higher contrast of the corona with respect to the solar disk in this line compared to the visible (a typically a gain of a factor 1000). This is somewhat offset by the stray light level which is larger in the UV than in the visible. However progress in superpolishing mirrors ease this limitation and altogether a gain of a factor 50 is expected in the stray light performances of a Ly-α coronagraph over a visible instrument. A further advantage is the mere absence of F-corona at 121.6 nm thus alleviating the need to separate the K and F components via polarization measurements, a process which is a source of error.

2.2. Scientific objectives

By bridging the gap between the solar disk and the inner limit of $2.7R_{\odot}$ of the externally-occulted coronagraph, LYCO will allow to connect the coronal structures and trace the transient events (mostly Coronal Mass Ejections, CMEs) from their sources on the disk to the outer corona. The expected high spatial resolution images of all structures (loops, archs, streamers, coronal holes, reinforcements, . . .) will map the distribution of the coronal density (and therefore the mass) and will further give access to the topology of the magnetic field above the photosphere, at least up to $1\ R_{\odot}$ above the limb. CMEs will be detected in the low corona and easily connected to their source on the disk (flares, eruptive prominences). Their

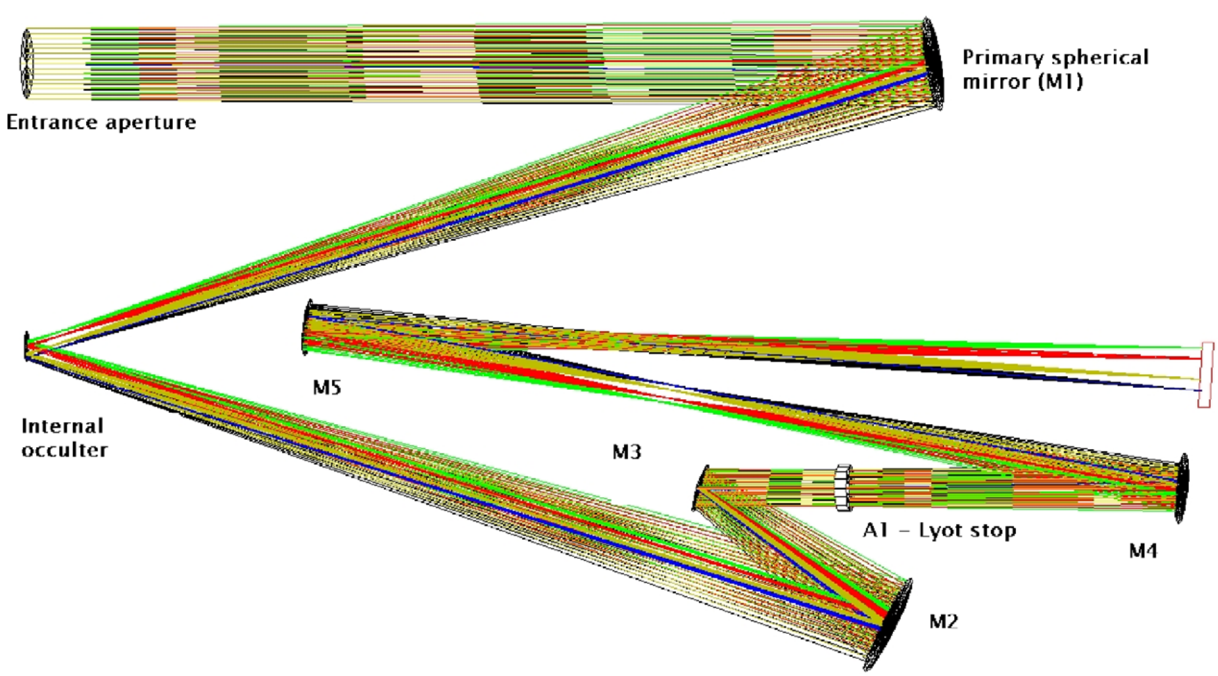

Fig. 1. LYCO optical layout. The primary off-axis superpolished spherical mirror forms a real image of both the Sun and the corona onto a flat mirror which acts as a field mirror. The solar disk image passes through a hole (equivalent radius $1.15\ R_{\odot}$) in the center of the field mirror and is dumped out. The coronal light is reflected from the field mirror on two off-axis spherical mirrors (M2 and M3). The combination of M1, M2, and M3 forms a collimated beam and produces a real image of the entrance aperture at the Lyot stop (A1) corrected for the first three Seidel aberrations (spherical aberration, coma, and astigmatism). The collimated beam is then focalized by an off-axis Gregorian telescope (M4 and M5) onto the detector. The Gregorian telescope creates a real image of the internal occulter.