Joint Scientific Space Mission CAS – ESA: First workshop, Chengdu 24-26 February 2014

The WATCHER Heliospheric and Spaceweather Mission

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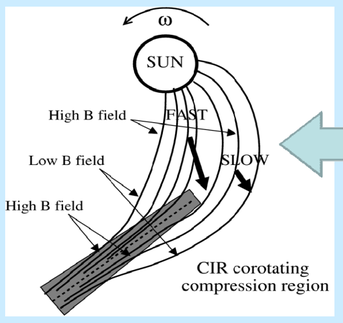
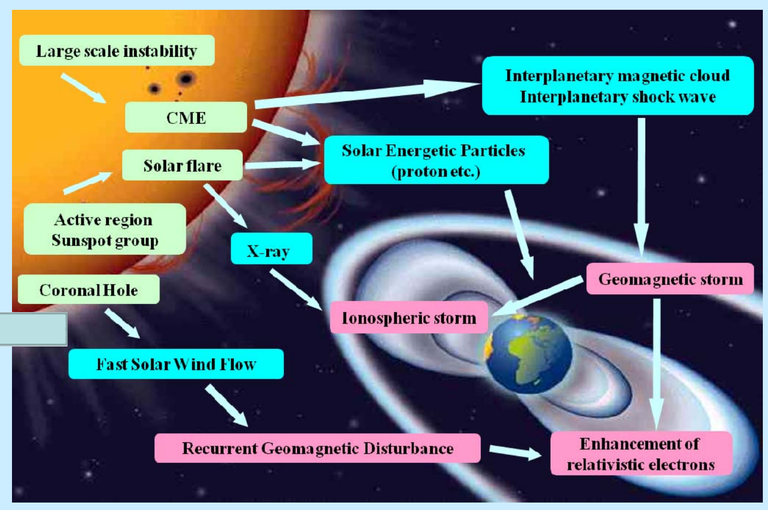
OVERVIEW. Coronal mass ejections (CMEs) and their interplanetary counterparts ICMEs and corotating interaction region (CIRs) are the main disturbances of solar origin that impact Earth's magnetosphere resulting in geomagnetic storms. In addition, CMEs can drive shock starting very close to the Sun then can therefore hit the Earth contrary to CIRs shocks which form beyond 1 AU. When viewed from the L1 Lagrange point where SOHO is located, the LASCO coronagraphs detect Earth-directed CMEs as halo CMEs partly obstructed by their occulters, propagating ambiguously forward or backward with poorly determined velocities thus making the prediction of their arrival time at Earth rather uncertain. Satellites at L1 or in Earth orbit detect CIRs only when they are about to hit the Earth. The twin STEREO spacecrafts have demonstrated the advantage of observing these disturbances from a different geometry and have opened a new window with the heliospheric imagers which can trace ICMEs beyond the field of view of coronagraphs up to 1 AU and detect CIRs remotely before they hit the Earth. However, the viewing angle of STEREO is constantly changing precluding permanent optimal viewing conditions. We present the WATCHER mission with the dual purpose of providing key scientific data on the two primary sources of space weather and directly serving the very purposes of space weather forecast. This will be achieved by placing a satellite on the Earth-L5 (Lagrangian point) arc at an offset angle of 30-60° from Earth and an adequate payload combining remote and in situ capabilities. From this ideal position and overlooking the region extending from the Sun to 1 AU, it will act as a CME/ICME and CIR watcher and sample the local solar wind. WATCHER will be able to provide advanced warning of solar eruptions, CMEs, CIRs and shocks well before their detection by Earth-based or L1 space-based observatories.

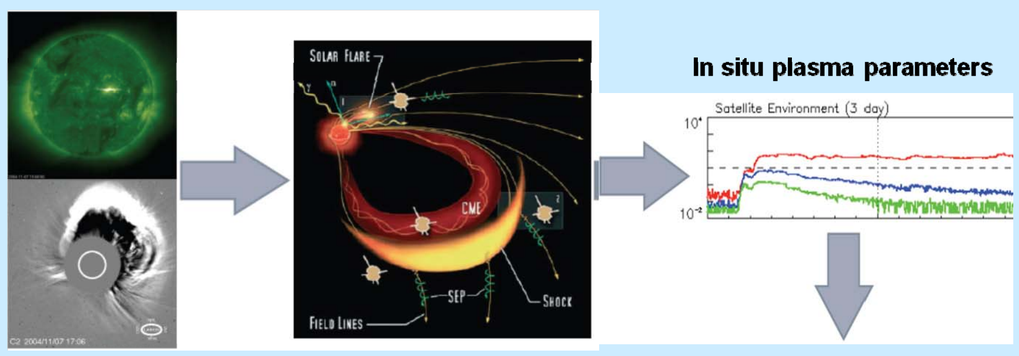
Keywords: Sun, corona, interplanetary medium, space plasma**,** heliosphere, space weather.

The Sun-Earth Connection: a Chain of Processes



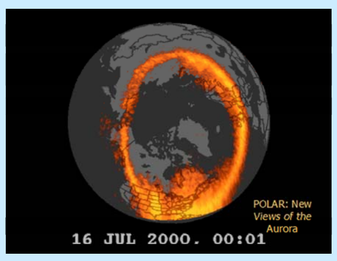


Discover, understand and model the connection between solar phenomena and interplanetary/geospace disturbances



Flare and CME

Propagation in interplanetary space: ICME



A Chain of Processes: an example

Aurora

A Chain of Processes: three main stages

- Solar source of the disturbances:
  - solar flares, CMEs, Energetic particles
- Transportation of the disturbances:
  - interplanetary clouds, radio waves, shock waves, solar energetic particles
- Geo-effectiveness:
  - aurora activities, sub-storms, magnetic storms

These three stages must be continuously monitored to understand the complete chain of actions/reactions from the solar atmosphere to geo-space and perform space weather forecast.

WATCHER: a Dual Purpose Mission

1. A science heliospheric mission:

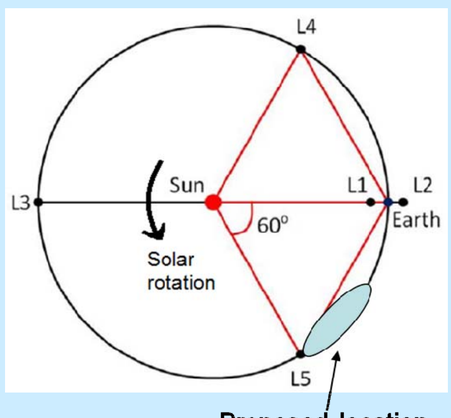
- Determine the magnetic conditions in the Sun interior and at its surface precursors of interplanetary disturbances terrestrial observations.
- Detect and track interplanetary disturbances (CMEs/ICMEs and CIRs) from their sources to Earth and determine their magnetic structure.
- Determine where shocks form and how they evolve.
- Understand the role of interactions affecting the propagation of disturbances (especially CMEs) and how they affect their arrival time at Earth.
- Study the Sun-Earth relations as a global, complex system.

2. A space weather mission:

- Advance warning of CIR which will reach Earth (typically 3 days)
- Advance warning of Earth-directed CMEs (12 hrs to 2 days)

Mission concept

The unique potential of space missions located at the equilateral Lagrangian points has already been highlighted by Akioka et al. (2005) and later, by Gopalswamy et al. (2011, EASCO mission). Later on, the HAGRID and INSTANT missions have been proposed respectively in the UK and in France. The proposed WATCHER mission will consist in a three-axis stabilized satellite to be placed on the L5 (Lagrangian point) arc at an offset angle of 30-60° from Earth. Preliminary orbital studies by CNES indicate that, because of planetary perturbations, the L5 point is not a deep gravitational well and that satellite keeping at any position on the Earth-L5 arc requires only a modest ΔV.



Payload

The WATCHER S/C will carry instruments to make both remote-sensing from the Sun to 1 AU and in-situ measurements.

A magnetic and Doppler imager

- Measure the photospheric magnetic field and acquire magnetograms allowing observing the source regions of CMEs before they rotate to Earth view.
- Measure velocity fields allowing performing stereo heliosismology in combination with other observatories probing the convection zone where the Sun acquires its magnetism.

A combined EUV disk and inner coronal imager

- Observe the solar source location of CMEs and their propagation to ≃3 Rs.
- Offer several diagnostics of eruptions and allow mapping coronal holes.
- Provide advanced warning of active regions that would be rotating on to the disk to face Earth and of HSS and CIRs.

A white light coronagraph

- Observe, characterize and track CMEs from ≃2 to ≃20 Rs.

A couple of heliospheric imagers

- Observe, characterize and track CMEs to 1 AU.

A solar wind plasma instrument and a magnetometer

- Make in-situ measurements of the solar wind providing information on CIRs that would arrive at Earth about 4 days after being detected in situ.

A low-frequency radiotelescope (optional)

An energetic particle detector (optional)

Collaboration

Building, launching, inserting and operating such a satellite is well within the present technical capabilities of Europe and China opening the way for a technical collaboration. Several Chinese laboratories have already been and are still involved in the definition and studies of solar/heliospheric missions such as KUAFU and SPORT and are already developing relevant instruments (e.g., coronagraphs, EUV imagers) in collaboration with European laboratories. These collaborative activities could be further expanded.

Heritage

Strong European participations in the SOHO and STEREO missions and in the forthcoming SOLAR ORBITER and SOLAR PROBE PLUS missions on the one hand, and past and on-going studies of coronal and heliospheric missions in China provide a very strong heritage. Most proposed instruments for the WATCHER mission can be readily constructed without new technical developments.