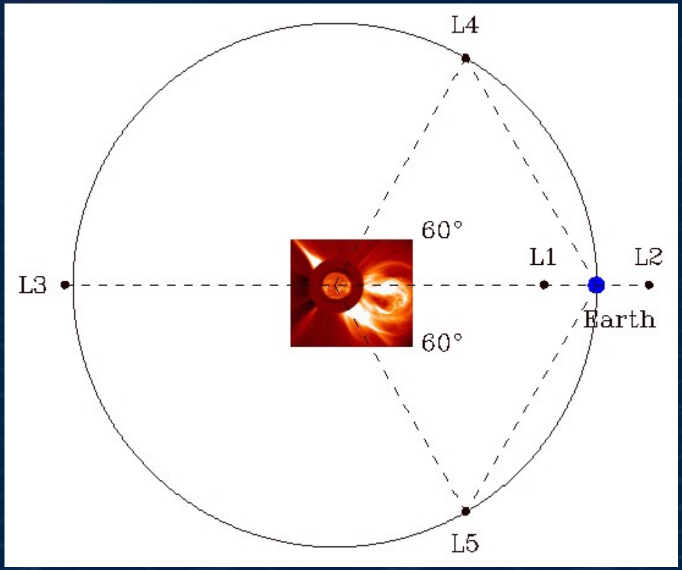
An L5 Mission Concept for Compelling New Space Weather Science

RESCO (China)
REal-time Sun-earth Connections Observatory

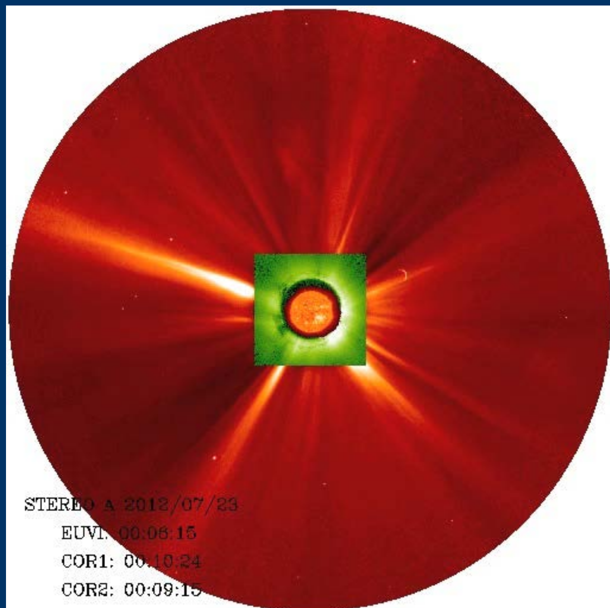
INSTANT (Europe)
INvestigation of Solar-Terrestrial Associated Natural Threats

Ying Liu
(National Space Science Center, CAS)

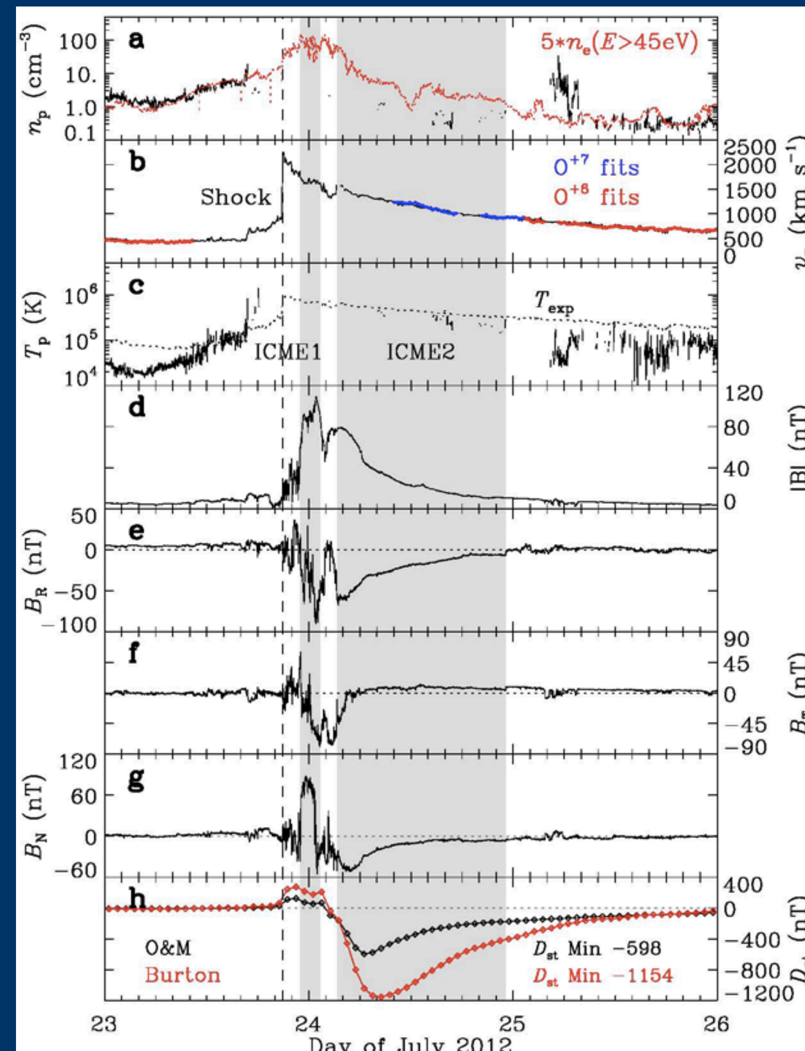
Benoit Lavraud, Richard Harrison, Jackie Davies, William Liu, Yong Liu, Milan Maksimovic, Jean-Claude Vial, Frederic Auchere, Nat Gopalswamy, Stuart Bale, George Parks



Overview: CMEs and space weather



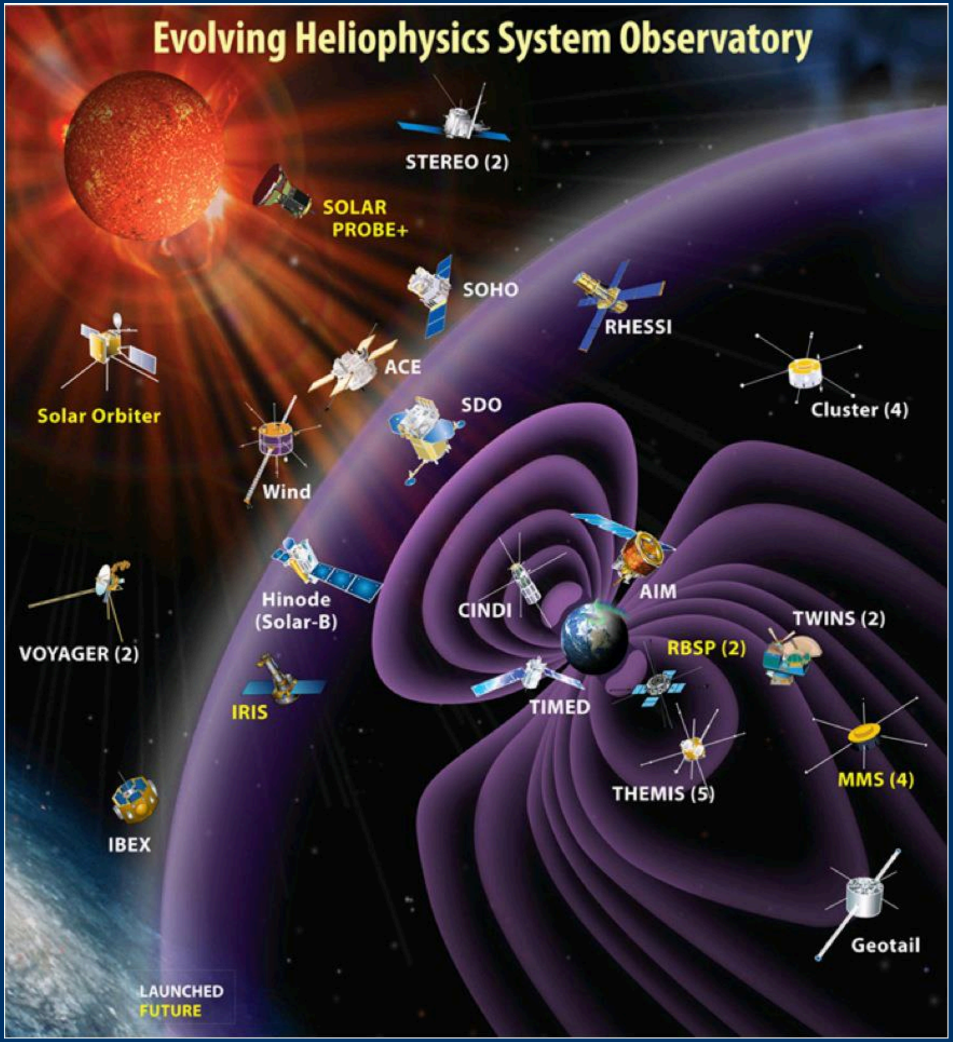
Liu et al., Nature Comm., 2014



• Coronal mass ejections (CMEs) are large expulsions of plasma and magnetic field from the solar corona and drivers of major space weather effects;

• Estimated cost of an extreme CME could reach up to a trillion dollars with a potential recovery time of 4 - 10 years.

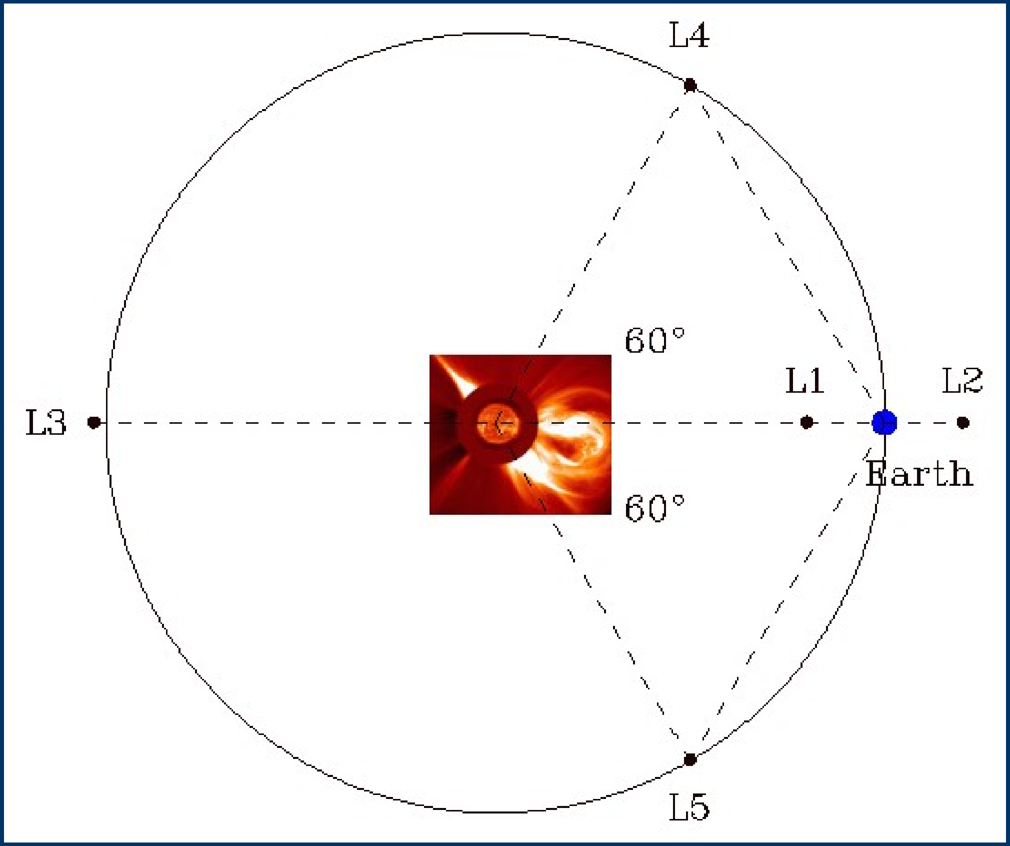
Overview: Motivation



- A number of spacecraft making routine remote-sensing and in-situ observations (such as SOHO, Wind and ACE) are already at L1, and are expected to operate there in the next 5-10 (or more) years;
- SDO, although not at L1, has a function similar to SOHO, and its extraordinary capability cannot be exceeded by a similar spacecraft near Earth;
- We must go away from the Sun-Earth line to cover the whole Sun-Earth space (STEREO).

Mission concept: RESCO

REal-time Sun-earth Connections Observatory



Liu et al., ApJ, 2010b

◆ A dedicated spacecraft at L5 to make combined remote-sensing and in-situ observations of the whole Sun-Earth space.

◆ Primary objective:

Understand nature and Sun-to-Earth propagation of solar wind transients.

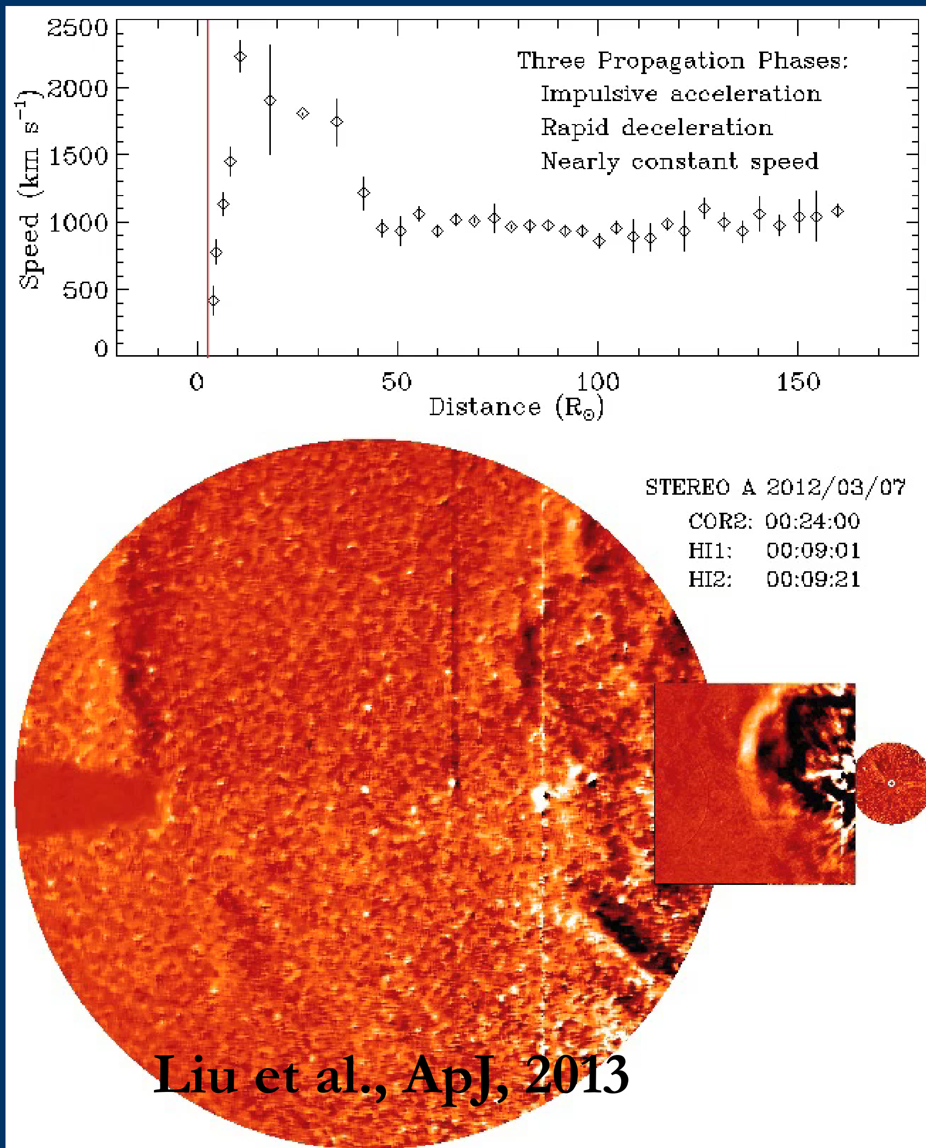
◆ Suggested payload:

- EUV imager (15 kg, optional);
- Coronagraph (20 kg);
- Heliospheric imager (15 kg);
- Magnetometer (3 kg);
- Solar wind plasma detector (5 kg).

Scientific objectives

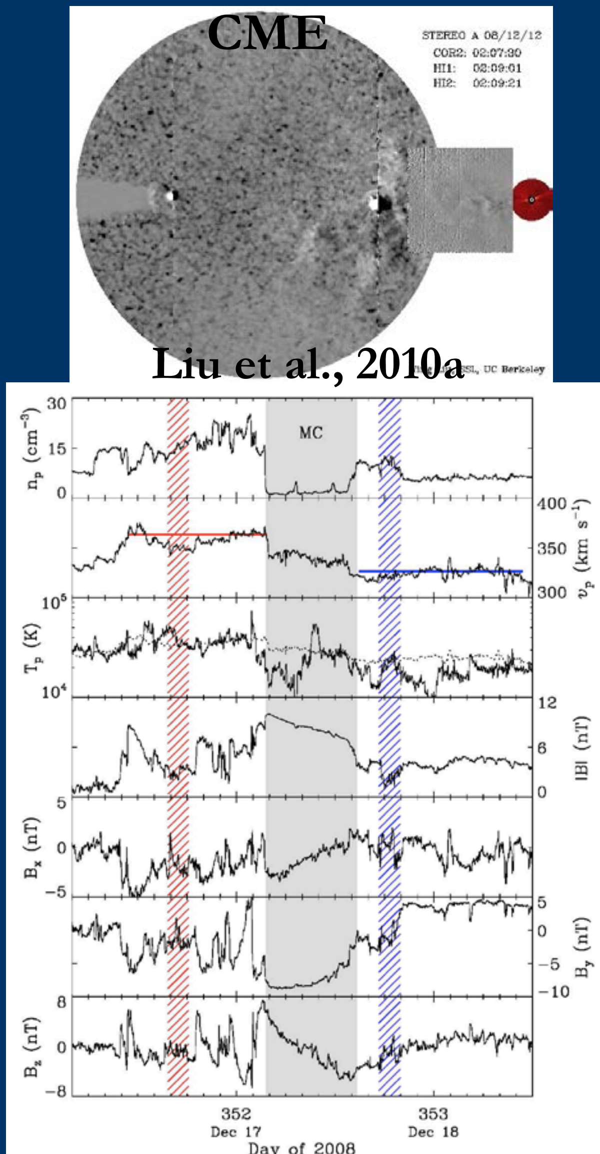
- Investigate the Sun-to-Earth propagation of solar wind transients (including CMEs and CIRs) with unprecedented high-cadence, wide-angle imaging observations;
- Understand the nature of solar wind transients by connecting imaging observations with in-situ measurements;
- Determine the magnetic field magnitude and orientation of Earth-directed CMEs for the first time;
- Explore the advantages for space weather forecasting provided by the L5/L4 vantage points.

Sun-to-Earth propagation of transients

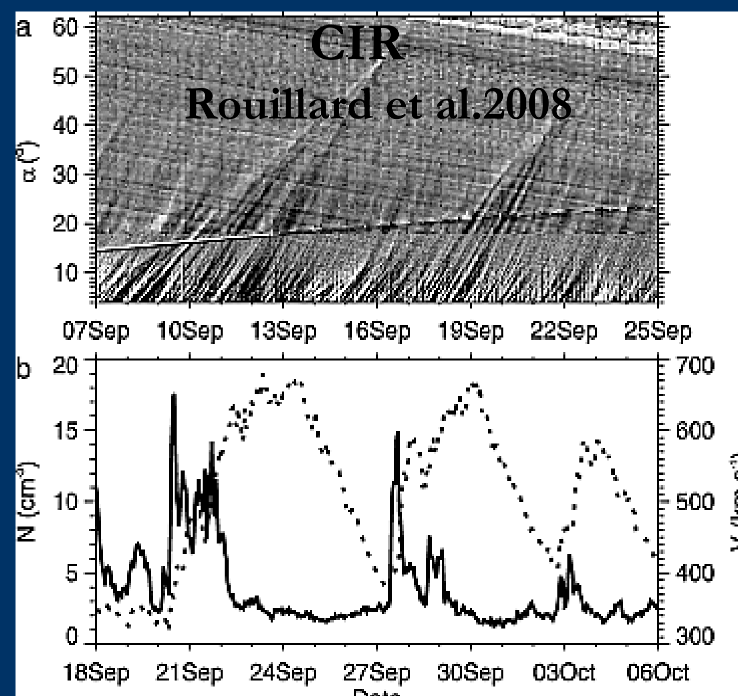


- Understand the physical mechanisms that govern the Sun-to-Earth propagation of solar wind transients;
- Understand how solar wind transients interact with the ambient corona and heliosphere;
- Understand how solar wind transients interact with other coronal and solar wind structures;
- Develop a practical capability for space weather forecasting.

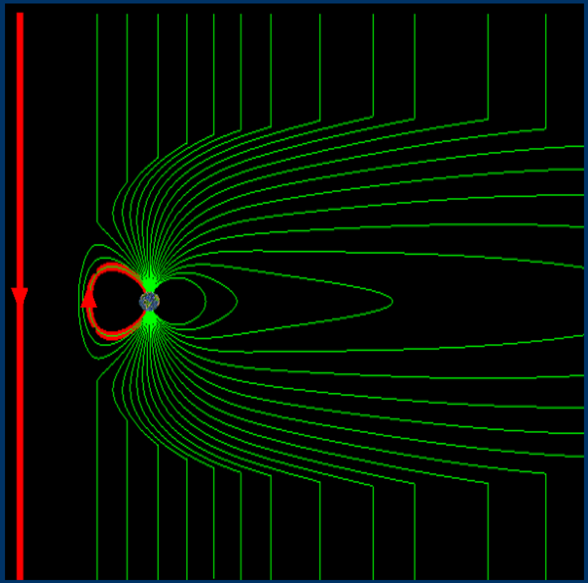
Nature of solar wind transients

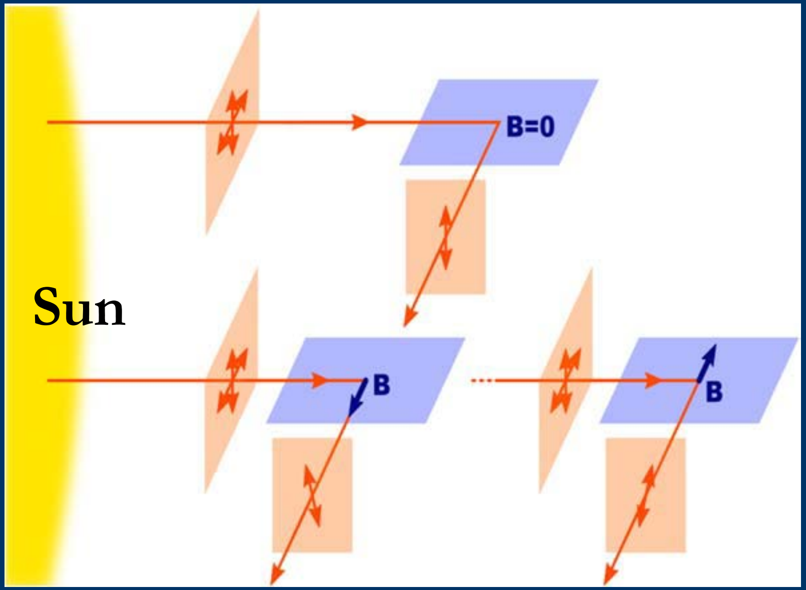


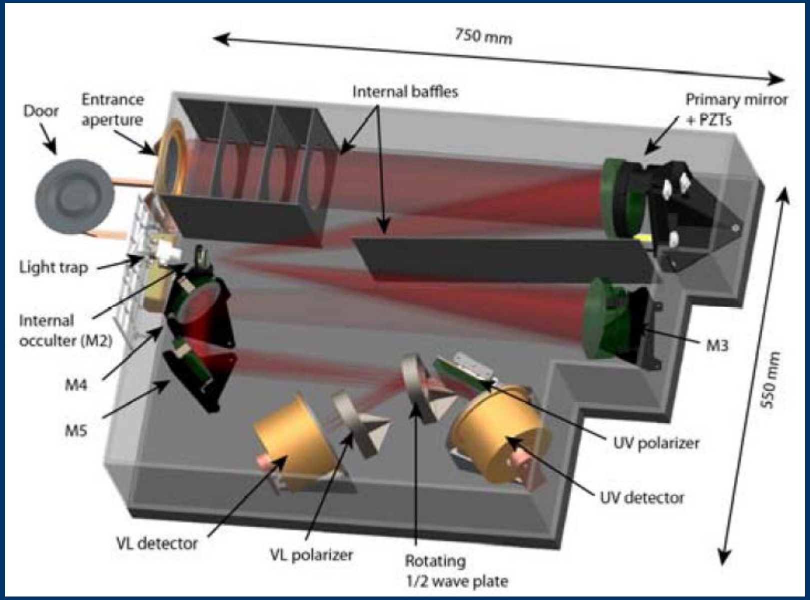
- Investigate how wide-angle imaging observations connect with in-situ signatures;
- Disentangle the structures of solar wind transients including CMEs and CIRs;
- Understand the physical nature of solar wind transients.



First ever capability of determining CME B field





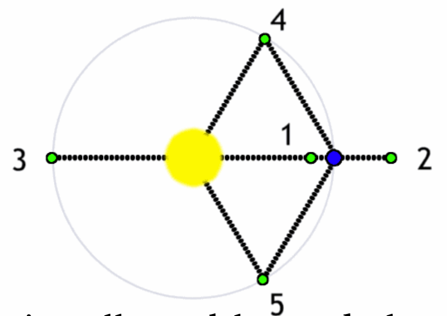


• CME magnetic field is a key element in space weather but so far elusive;

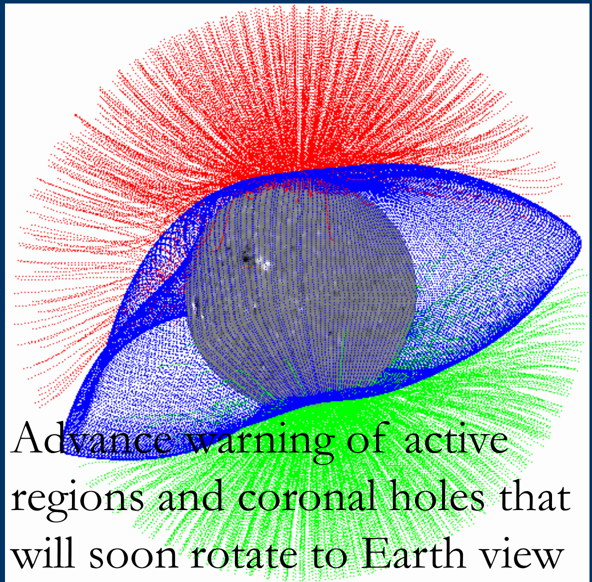
• Novel Lyman-alpha measurements to determine the magnetic field magnitude and orientation through the Hanle effect;

• The L5 location is ideal for early determination of magnetic structure of Earth-directed CMEs.

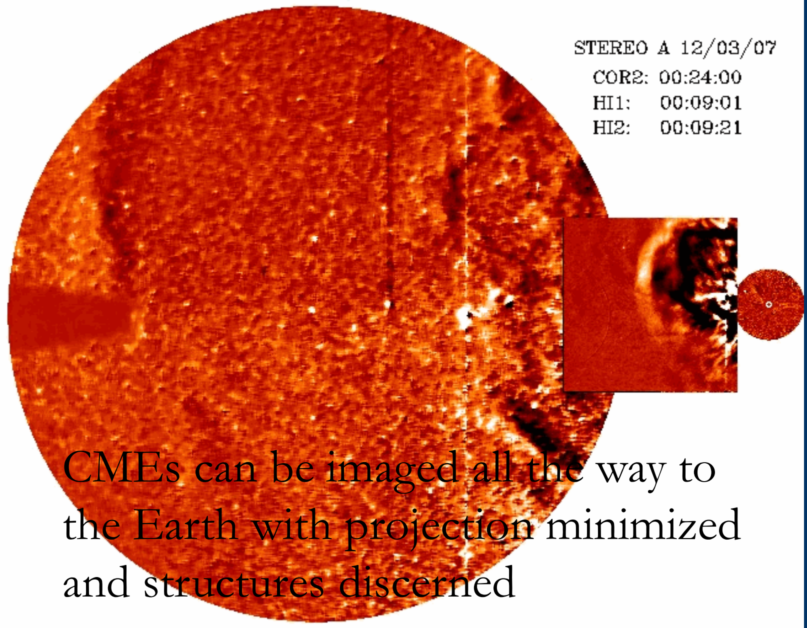
Space weather advantages at L5/L4



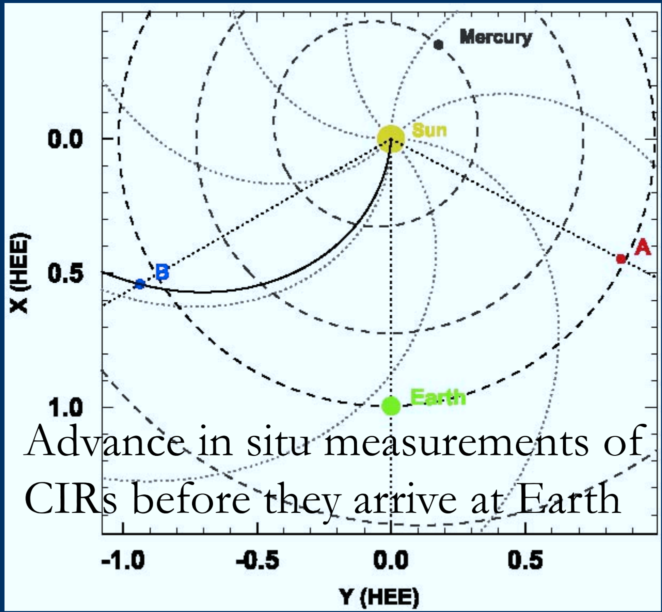
Gravitationally stable, and always able to monitor the Sun-Earth line



Advance warning of active regions and coronal holes that will soon rotate to Earth view



CMEs can be imaged all the way to the Earth with projection minimized and structures discerned



Advance in situ measurements of CIRs before they arrive at Earth

Suggested payload

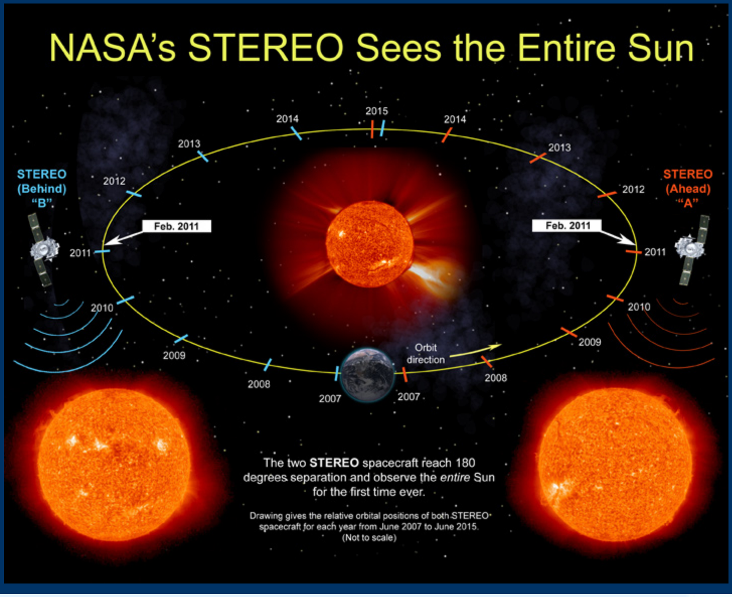
Science objective	Required measurements
Investigate the Sun-to-Earth propagation of solar wind transients	wide-angle white light, EUV (optional)
Understand the nature of solar wind transients by connecting imaging observations with in-situ measurements	wide-angle white light, in situ plasma and magnetic field
Determine the magnetic field magnitude and orientation of Earth-directed CMEs for the first time	Lyman-alpha polarization measurements
Explore the advantages for space weather forecasting provided by the L5/L4 vantage points	wide-angle white light, in situ plasma and magnetic field, EUV (optional)

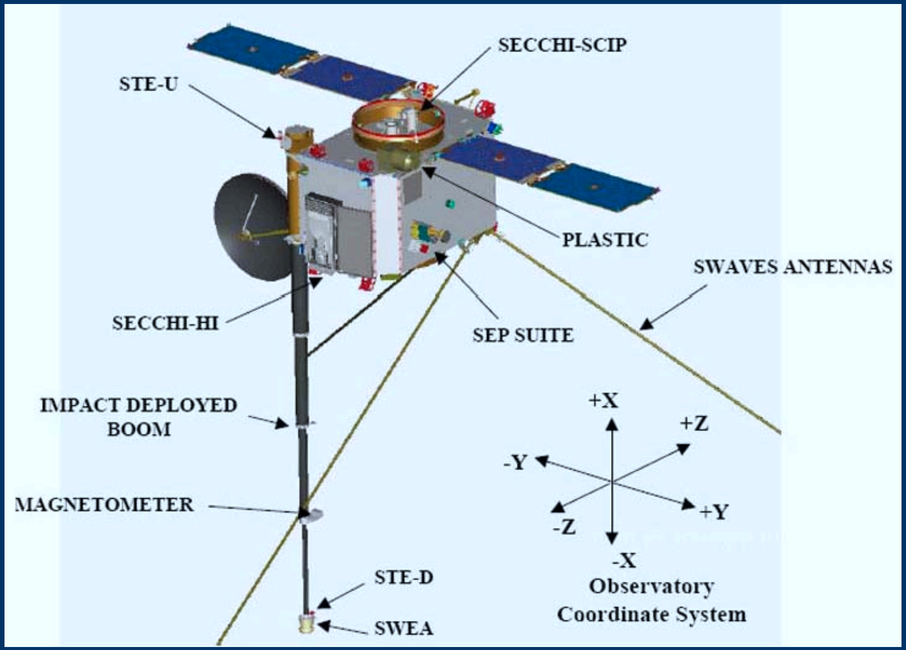
Suggested payload

Instrument	Mass (kg)	Power (W)
EUV Imager (optional)	15	15
Lyman-alpha Coronagraph	20	15
Heliospheric Imager	15	15
Solar Wind Plasma Detector	5	3
Fluxgate Magnetometer	3	2
Total	58	50

- This concept can satisfy the technical constraints (spacecraft mass $\leq$ 250 kg, payload mass $\leq$ 60 kg and power ~ 50 W);
- It requires a propulsion module to station the spacecraft at L5, and the launcher is envisaged as Long March 2 or Soyuz.

Strong heritage from STEREO





- STEREO, launched in Oct 26, 2006, is twin spacecraft off the Sun-Earth line.
- The two spacecraft drift away from Earth, so STEREO doesn't provide a fixed vantage point.
- We have been on the STEREO team for years and familiar with both the science and instrumentation.
- Four instrument packages:
  - SECCHI (image a CME from its birth in the corona all the way to the Earth);
  - IMPACT (measure in situ particles and magnetic field);
  - PLASTIC (measure in situ solar wind plasma and minor ions);
  - SWAVES (measure radio emissions).

Similar concepts in Europe and US

- An L5 mission is a key proposal in US Decadal Survey;
- The mission concept was studied at the Mission Design Laboratory, NASA GSFC;
- A straw man L5 mission was formulated, EASCO (Gopalswamy et al. 2011);
- Also see INSTANT poster by Benoit Lavraud.

Earth-Affecting Solar Causes Observatory (EASCO)

Instrument	Mass (kg)	Power (W)	Data Rate (kbps)
MADI	15	60	7
ICIE	10	8	30
WCOR	25	30	15
HI	10	15	5
HXI	6	5	2
UVOS	30	30	20
LRT	13	15	2
SWPI	10	5	3
MAG	3	3	3
EPD	16	23	3
Total	138	194	90

Summary

- L5 has various advantages, which can greatly advance space weather science and forecasting. Many countries are pushing for an L5 mission, and China/ESA can the first!

- The concept we propose will address compelling new science and develop practical space weather capabilities under the technical and programmatic constraints.

- As a crucial and popular idea, the L5 concept would allow wide collaborations between CAS and ESA on both science and instrumentation in solar physics, space physics and space weather.

Thank you!