An L5 mission concept for innovative solar and heliospheric science

INSTANT (Europe)
Investigation of Solar – Terrestrial Associated Natural Threats

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

1st Workshop – Planning for a joint scientific space mission
Chinese Academy of Sciences (CAS) - European Space Agency (ESA)
Chengdu, China, 25-26 February 2014

Team

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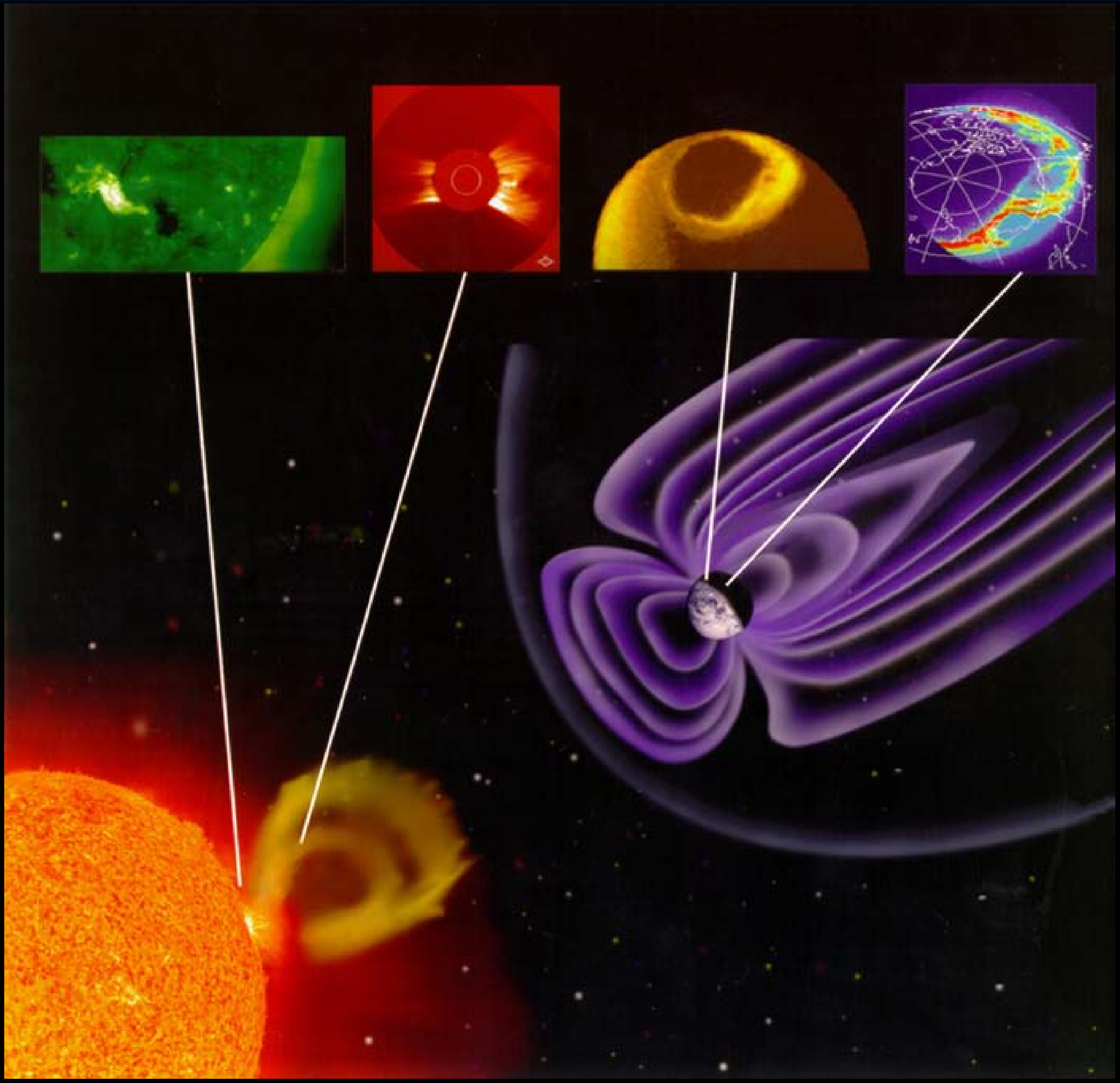
Motivation: the science of Sun-Earth connection

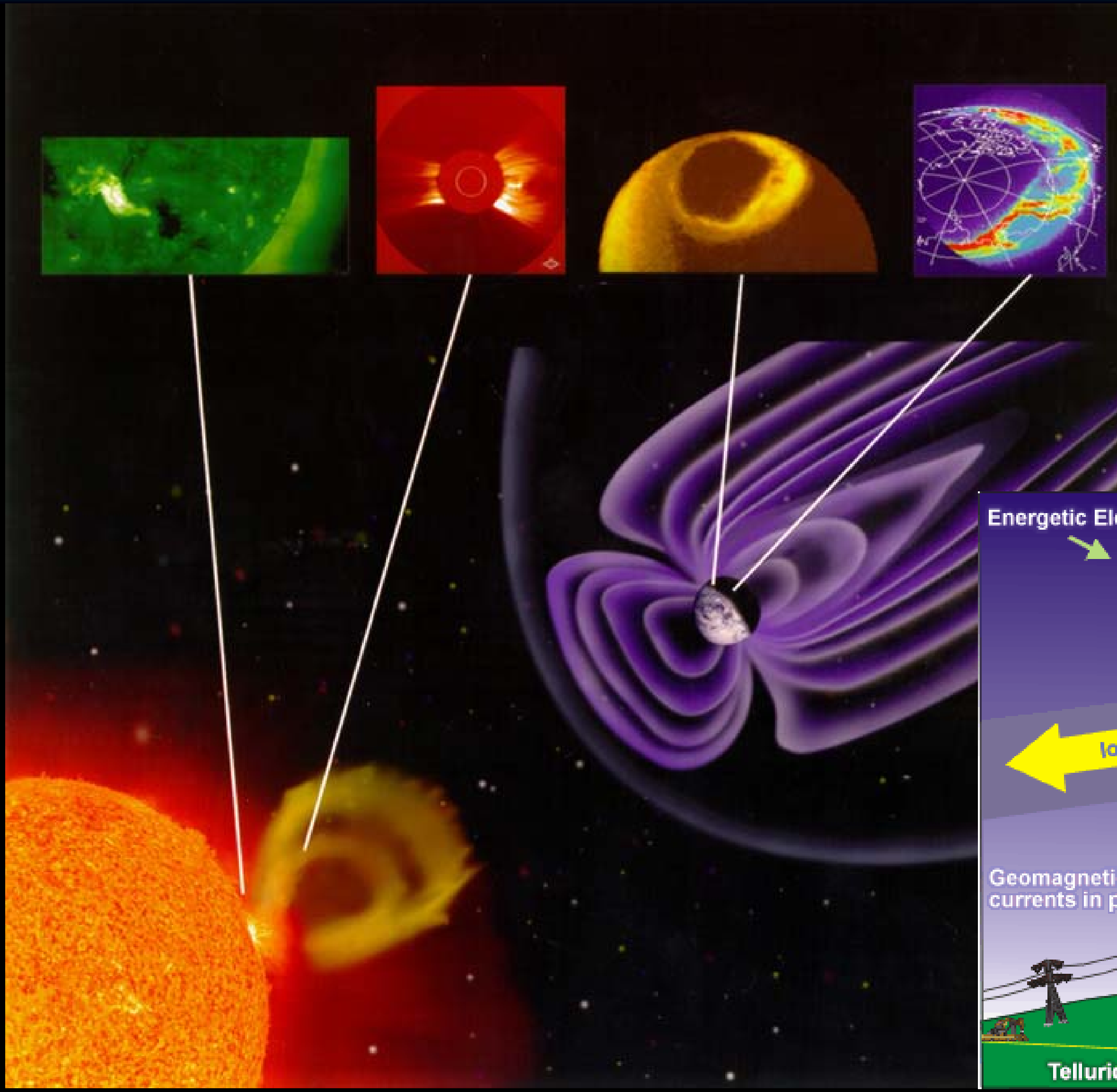


A chain of fundamental processes

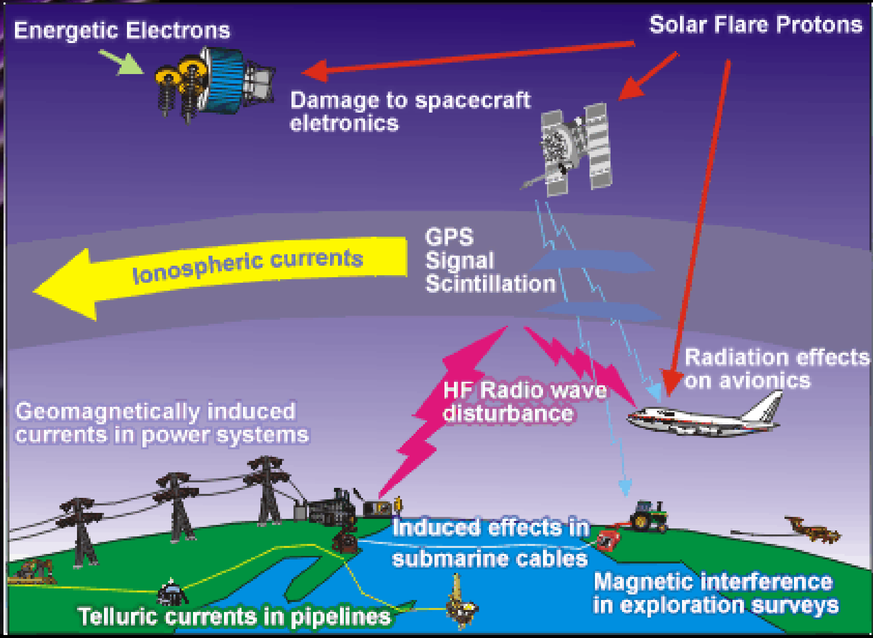
- Dynamo processes;
- Corona magnetic structure;
- Solar wind acceleration;
- Initiation of CMEs;
- Propagation and impact of perturbations (CME)
- Shocks, turbulence, magnetic reconnexion;
- Geomagnetic storms…

Fundamental plasma physic processes at hand

Motivation: the impacts of Sun-Earth connection

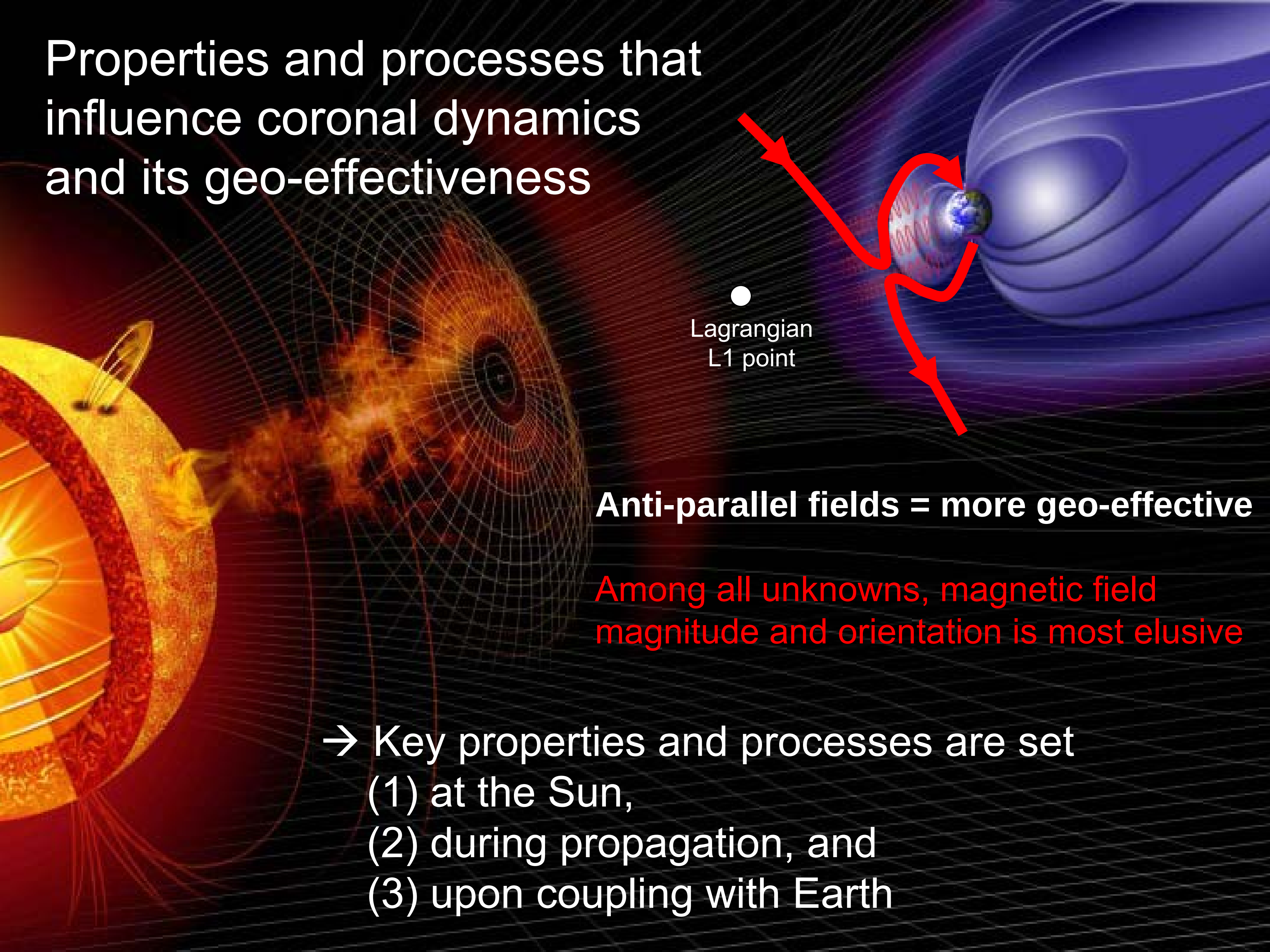


A chain of fundamental processes



Strong economic and societal impact: SPACE WEATHER!

Properties and processes that influence coronal dynamics and its geo-effectiveness



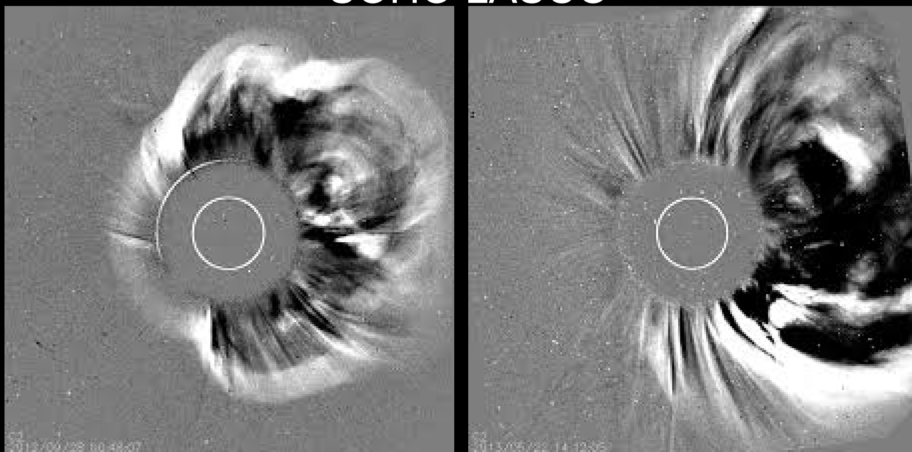
Anti-parallel fields = more geo-effective

Among all unknowns, magnetic field magnitude and orientation is most elusive

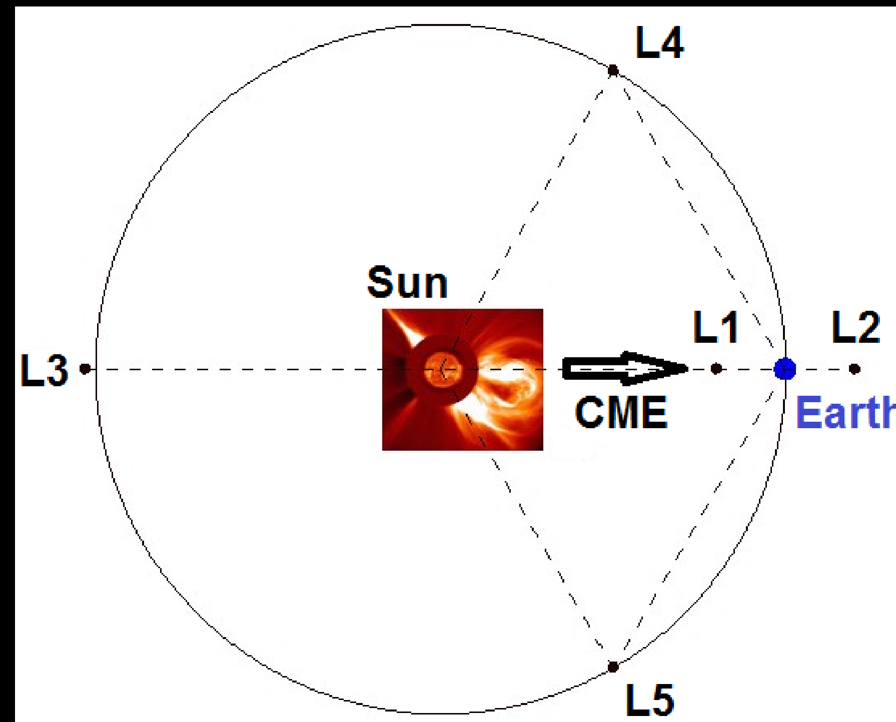
→ Key properties and processes are set
(1) at the Sun,
(2) during propagation, and
(3) upon coupling with Earth

Limitations of L1 solar observations

SOHO LASCO



L1 observations with **coronograph**:
If Halo = Earth-directed



However, from L1 point:

Imaging: only **very rough** idea of trajectory, speed & strength

In situ: optimal knowledge of geo-effective parameters, **but late…**

→ <u>Positions off the Sun-Earth line</u> have the UNIQUE potential for determining magnetic properties of Earth-directed eruptions, and continuous tracking to Earth

INSTANT/RESCO
Science objectives

The proposed mission will tackle the following key objectives:

1. What is the magnetic field magnitude and topology in the corona?
2. How does the magnetic field reconfigure itself during CME eruptions?
3. How do CMEs accelerate and interact in the interplanetary medium?
4. What are the sources and links between the slow and fast solar winds?

It will further provide the following crucial space weather capabilities:

5. Three-days advance knowledge of CIR properties that reach Earth
6. Twelve hours to 2 days advance warning of Earth-directed CMEs
7. ***First-ever capability*** of determining the magnetic field magnitude and orientation of Earth-directed CMEs using Lyman-α observations

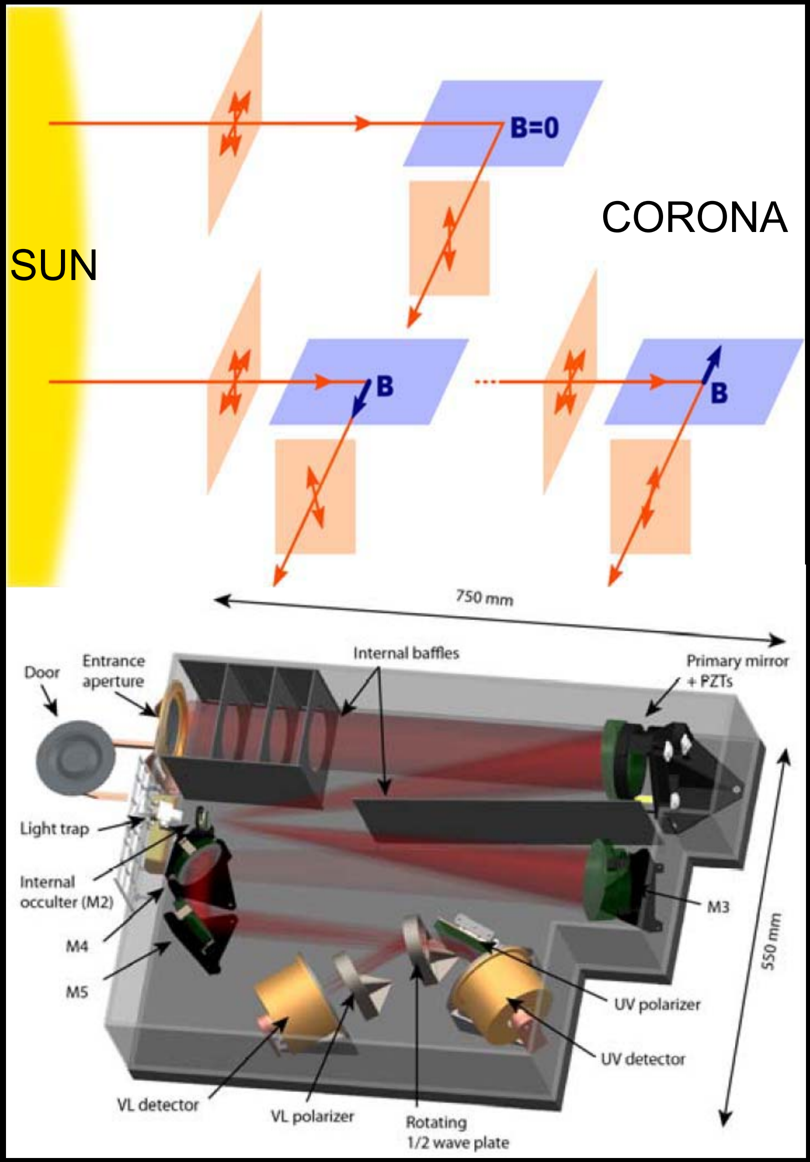
Requirement 1

Off-Sun-Earth line Lyman-α observation of coronal magnetic fields

Novel Lyman-α measurements to determine the magnetic field magnitude and orientation through the **Hanle** effect

Reconstruction of magnetic field structure during CME eruption

→ L5 location ideal for early determination of magnetic structure of Earth-directed CME



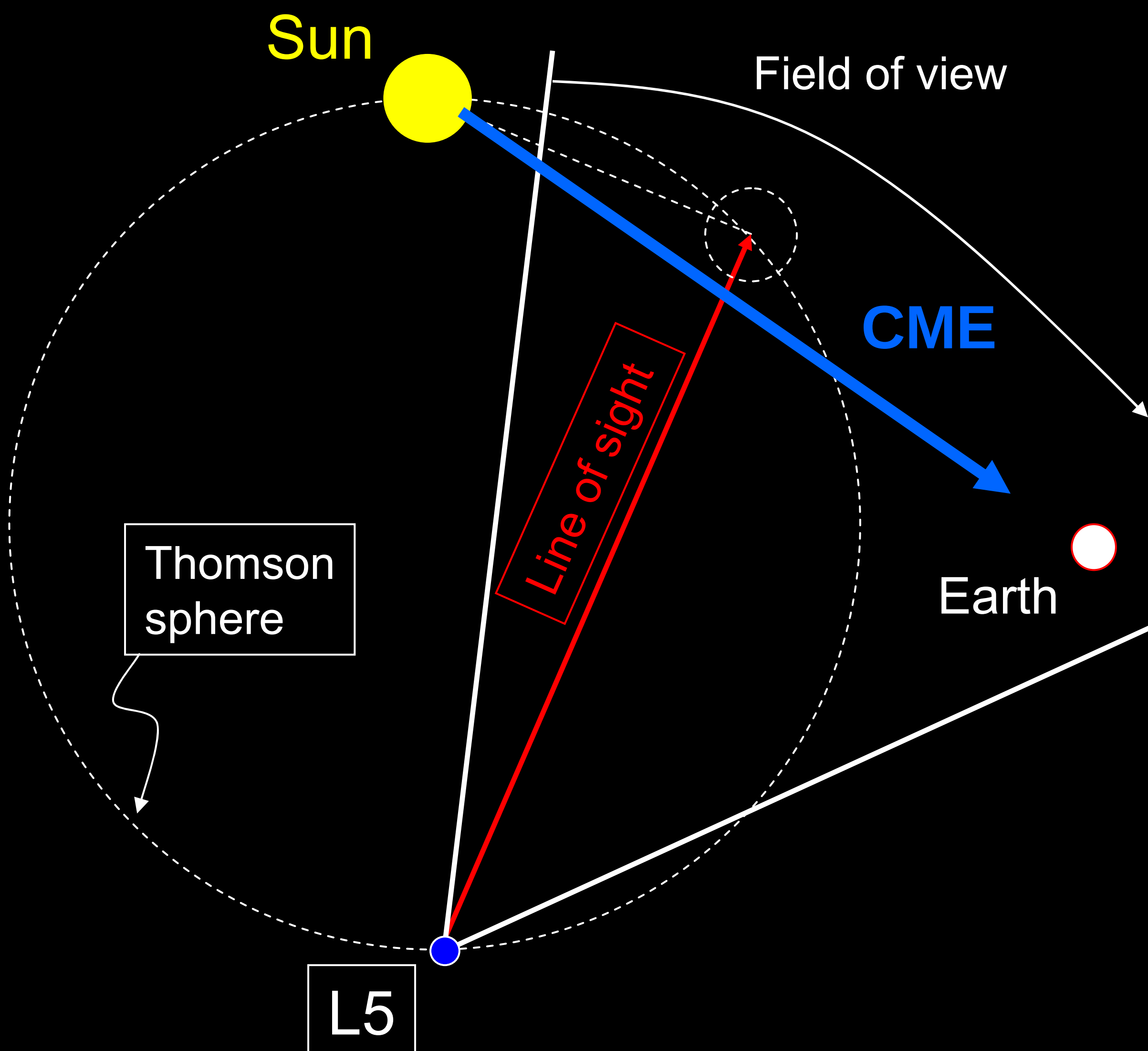
Requirement 2

Off-Sun-Earth line tracking with Heliospheric Imagers

White light emitted from Sun is subject to Thomson scattering by *in situ* electrons

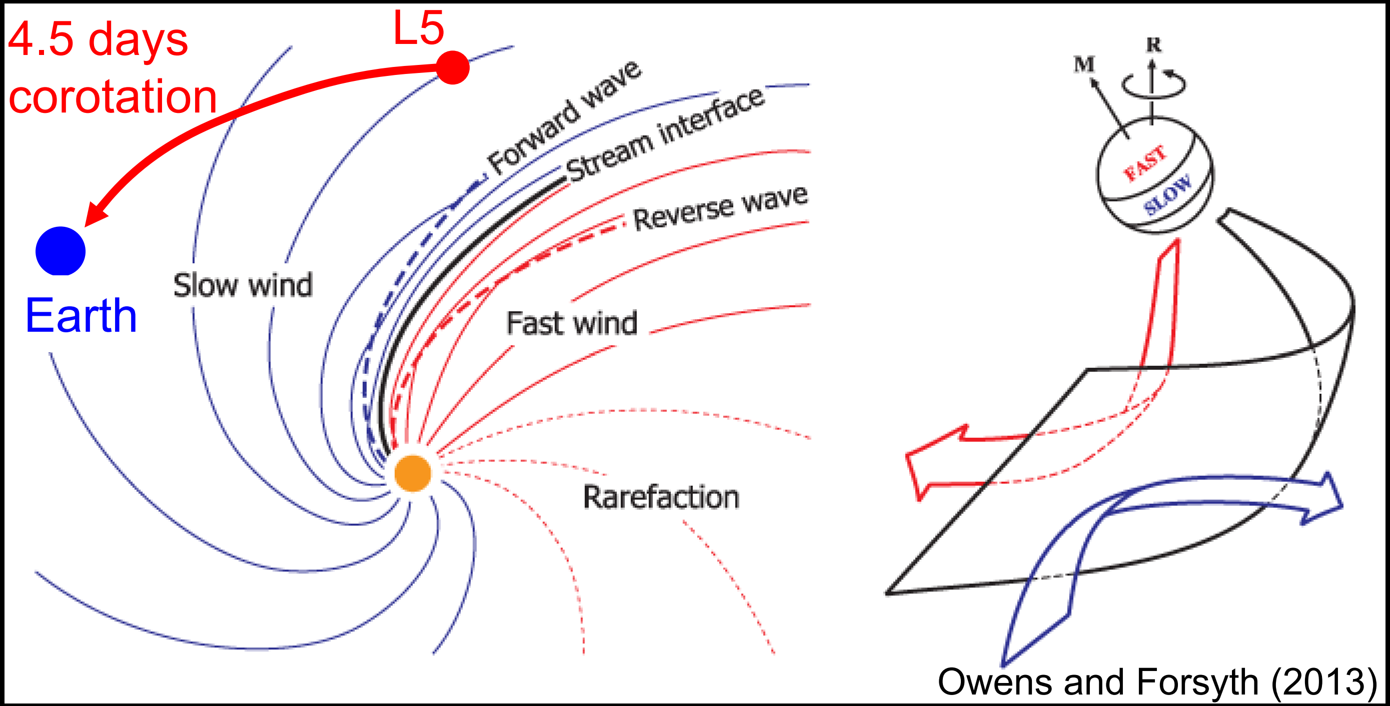
Locations of enhanced electron density scatter more light

→ L5 location ideal for tracking signatures of Earth-directed CME



Requirement 3

L5 early warning and multi-point tracking of solar wind origins



Owens and Forsyth (2013)

Owing to solar rotation, fast winds overtake slow winds in the ecliptic, forming ***geo-effective*** corotating interaction regions (CIR)

These can be tracked in heliospheric imagers and **measured in situ**

→ L5 location ideal for 4.5 day advance measurements of the key in situ properties (V, B) of Earth-bound corotating structures

INSTANT/RESCO

Requirements compatibility matrix and budgets

NAME	INSTRUMENT TYPE	MASS (kg)	POWER (W)	SCIENCE OBJECTIVE
MAGIC	Visible light and Lyman-α coronograph	26	20	1, 2, 3, 6, 7
HI	White light heliospheric imagers	20	19	3, 4, 6
MAG	Magnetometer	3	3	3, 4, 5
PAS	Ion sensor	4	4	3, 4, 5
TOTAL		**53**	**46**	

+ optional disk UV imager (cf. talk by Y. Liu)

The mission concept satisfies the technical constraints
(s/c mass ≤ 250 kg, payload mass ≤ 60 kg and power ~50 W)

It requires a propulsion module to station the spacecraft at L5

The launcher is envisaged as Long March 2 or Soyuz

CONCLUSIONS

Well-thought, innovative concept that tackles both compelling solar and heliospheric science objectives and Space Weather

The mission proposed falls into the S-class constraints

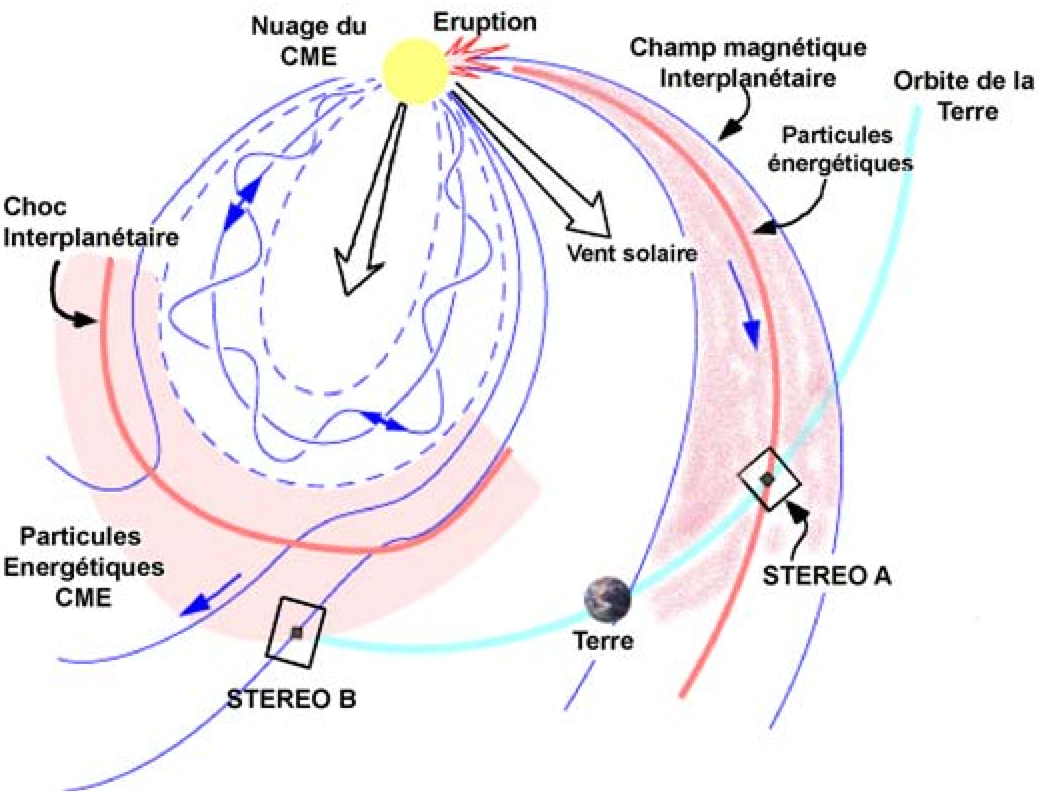
All countries/space agencies involved in space physics are currently designing and pushing for an L5 mission (INSTANT, RESCO, EASCO, HAGRID, 'KuaFu', etc.)

→ China/ESA can be first !

EXTRA SLIDES

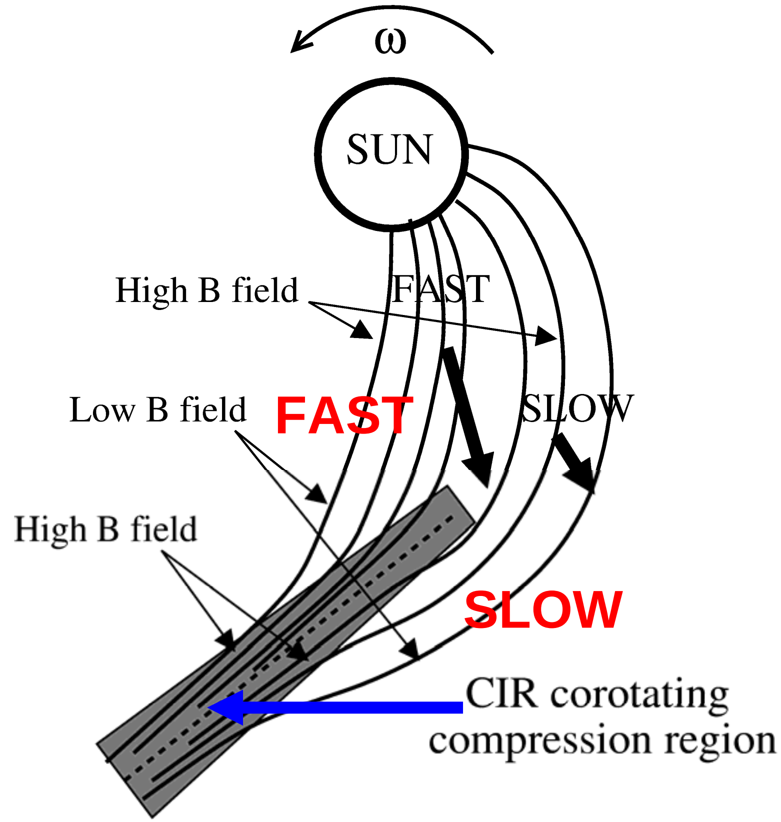
The main solar perturbations of interest

Flares & coronal Mass Ejections



Initial, potentially large V and Bz
+ compressions

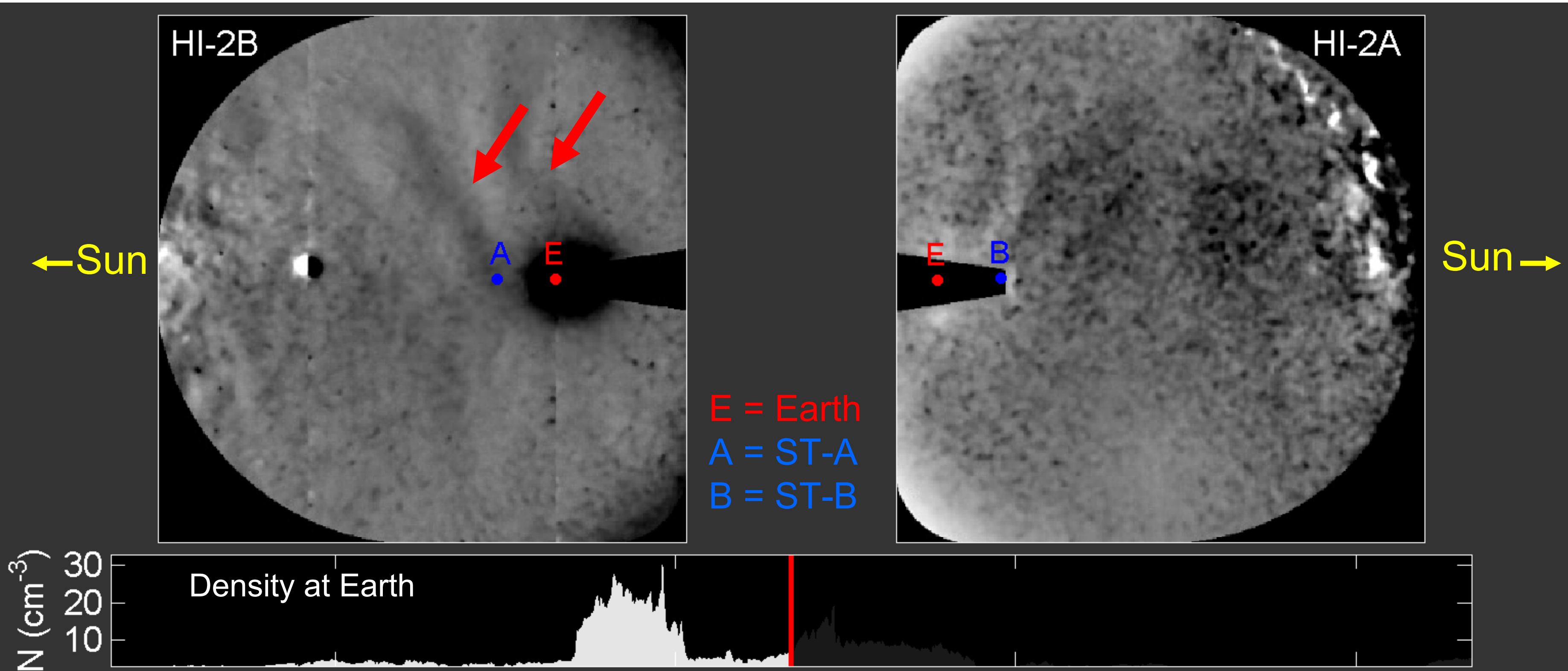
Corotating Interaction Regions



Enhanced V, and Bz
primarily from compression

→ All lead to enhanced coupling and geomagnetic storms

Interplanetary: observing entire CME propagation for first time



Difference images allow to track enhanced electron density

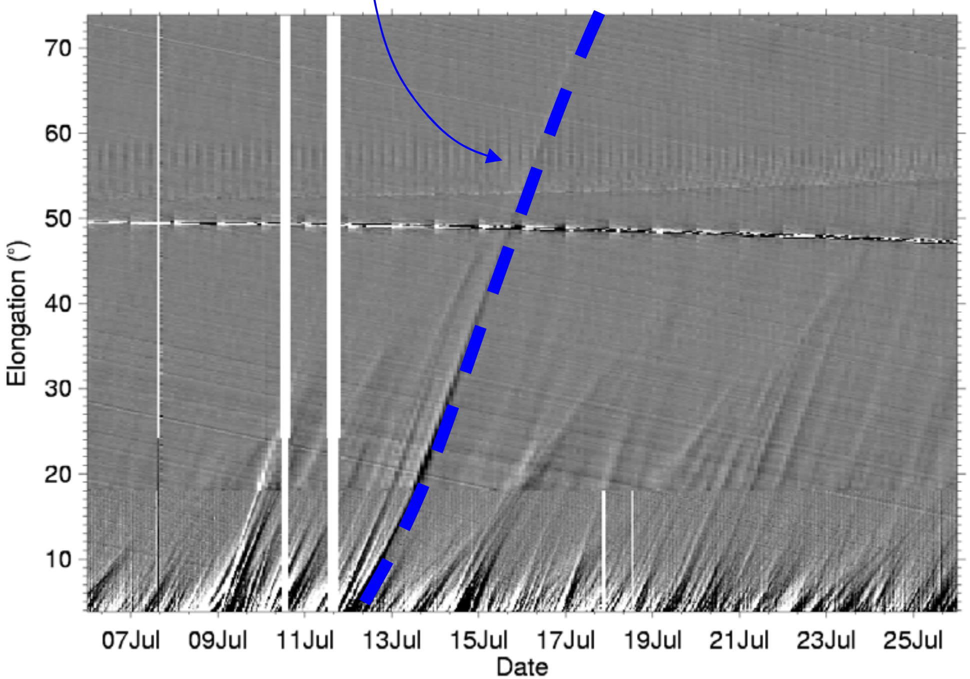
Combined use of remote (imaging) et *in situ* observations

Early determination of CME trajectory from ~L5

J-maps permit to track CMEs all the way from Sun to Earth

$$\alpha(t) = \arctan\left[\frac{vt\sin(\beta)}{H_o - vt\cos(\beta)}\right]$$

→ Trajectory β and speed v can be determined



Required minimum elongation range for proper trajectory determination ~30-40°

e.g., Davies et al. [2012]

→ ~8 hours required to determine Earthward impact of very fast CMEs (> 2000km/s like 23 July 2012)