L5 *in-situ* MEASUREMENTS

POTENTIAL IMPROVEMENTS FOR SPACE WEATHER FORECASTING AND SCIENCE

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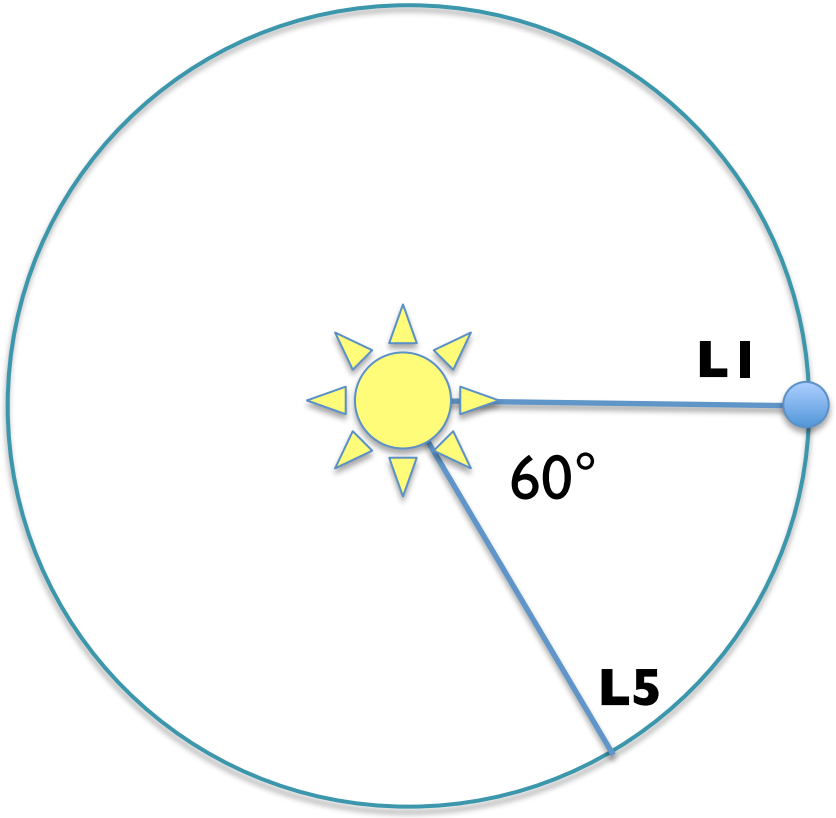
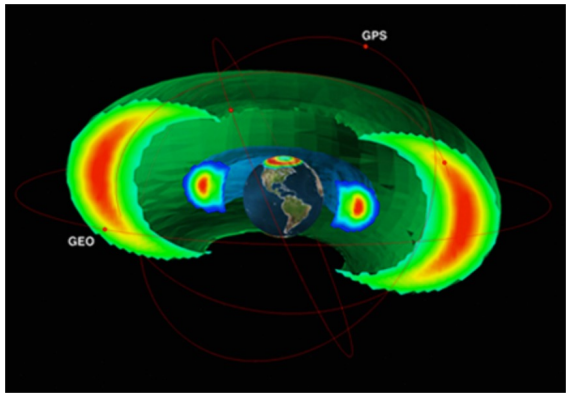
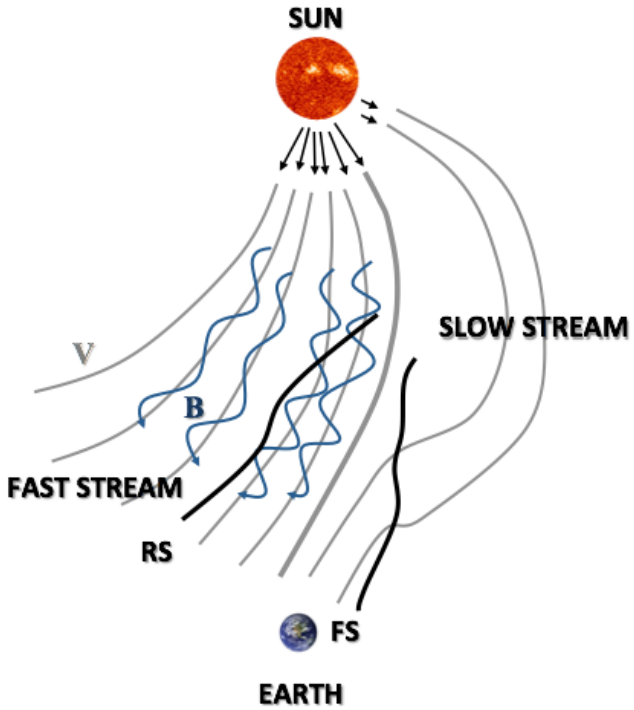


- **L5** *in-situ* observations: Benefits for near-real time space weather forecasting
- **L5** *in-situ* observations: Science

L5 *in-situ* Benefits for Space Weather Forecasting: Van Allen Belts

- **Fast streams** are key drivers of Van Allen belt electron flux enhancements
- L5 *in-situ* observations could give a few days ahead warning before a fast stream arrives at the Earth
- Information on fast stream key characteristics
  - interaction region structure, leading shock
  - peak velocity, density, Alfvénicity of fast streams





NOAA: warning when GOES electron fluxes at GEO exceed 10^3 e/(cm^2 s sr)

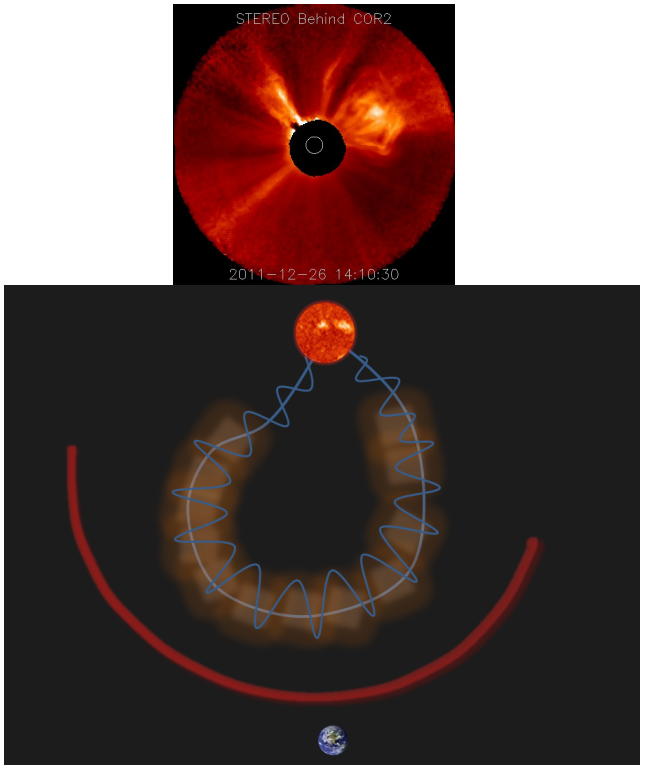
Kilpua et al., GRL, 2015

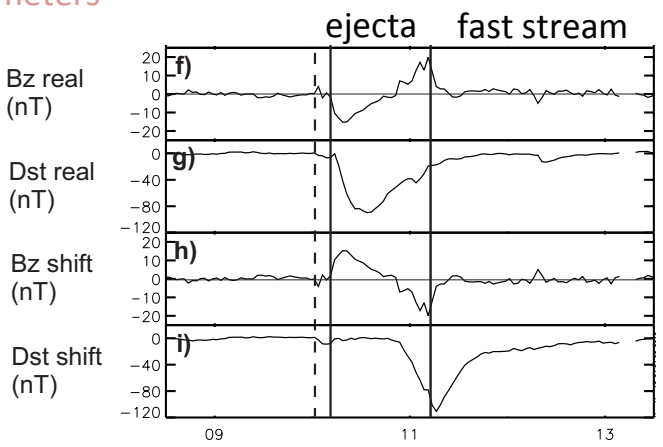
Storm driver	Warning
CME sheath	8%
CME ejecta + slow wind	2%
CME ejecta + fast wind	57%
interaction region + faster stream	58%

Kilpua et al., 2015: http://onlinelibrary.wiley.com/doi/10.1002/2015GL063542/full

L5 *in-situ* Benefits for Space Weather Forecasts: Ambient Solar Wind

- L5 *in-situ* observations could help to forecast the properties of the solar wind into which CMEs are launched
- Ambient solar wind may affect strongly CME propagation and its ability to drive space weather storms
- How fast CMEs will arrive? (deceleration/acceleration)
- Impact details (CME deflection, e.g. Isavnin et al., 2014)
  - CME followed by a faster wind: deflects west
  - CME blocked by a slower wind: deflects east
- Compression by a fast stream
  - prevents expansion (higher V, n_p, B ← all key CME parameters enhanced!
    ➔ stronger storm)
  - in particular for NS- and S-type CMEs compresses southward fields
    e.g., Kilpua et al., 2012



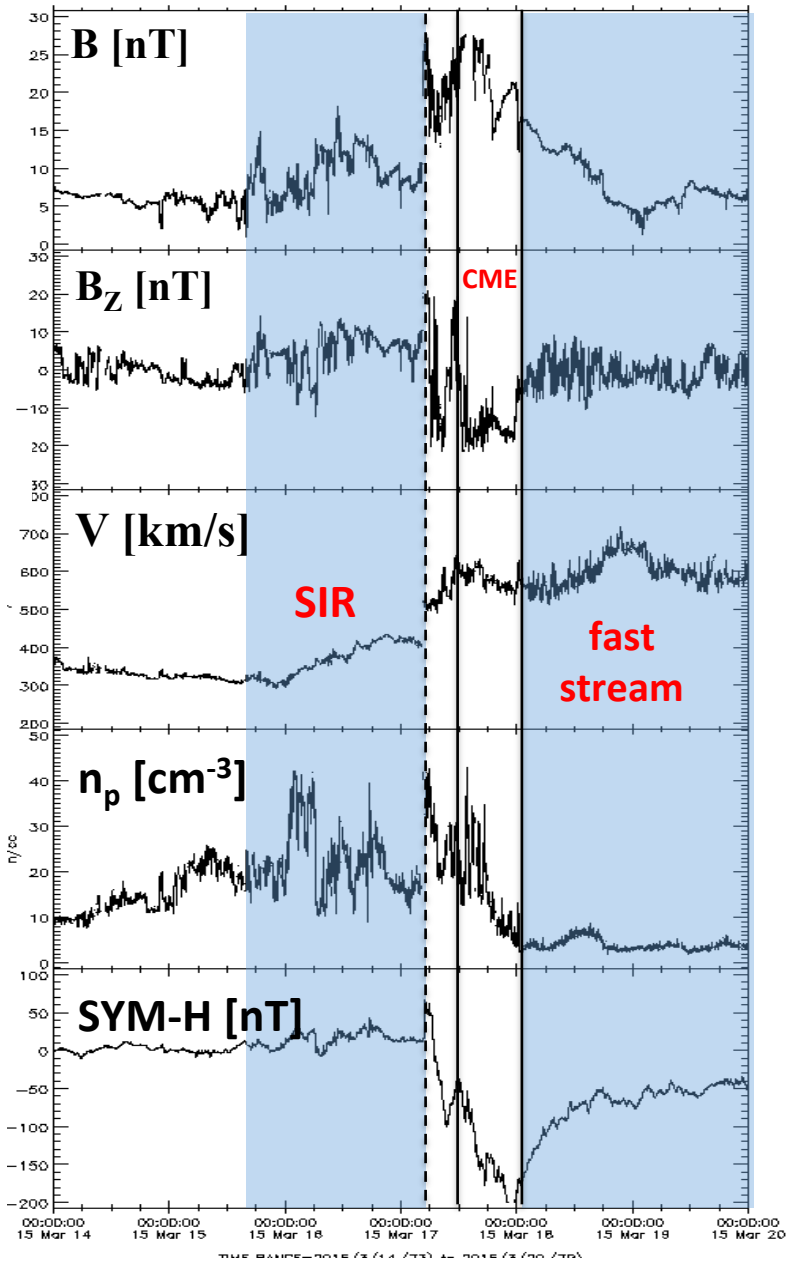


Isavnin et al., 2014: http://adsabs.harvard.edu/abs/2014SoPh..289.2141I
Kilpua et al., 2012: http://www.ann-geophys.net/30/1037/2012/

L5 *in-situ* Benefits for Space Weather Forecasts: Ambient Solar Wind

Unexpected storm on March 17-18, 2015

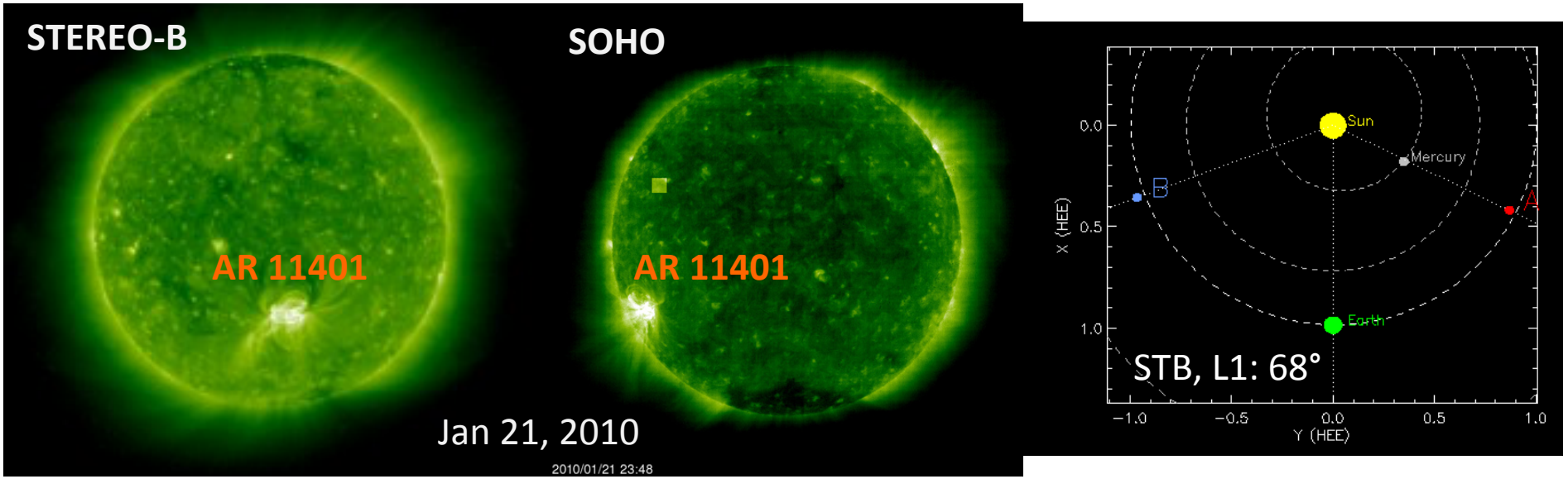
- CME on March 15 left relatively close to the limb and was associated with a small (C-class) flare
- largest storm of solar cycle 24. (Dst < -200 nT)
- Geoeffectiveness of the CME was significantly enhanced due to its interaction with the ambient solar wind
- impact with a dense and slow solar wind ahead (part of the stream interaction region)
- compression by the trailing fast wind (no expansion)
- high density ➔ larger ring current
- shock amplification of pre-existing fields



event analyzed in:
Kataoka et al., 2015, submitted to GRL

L5 *in-situ* benefits for Space Weather forecasts: CME properties

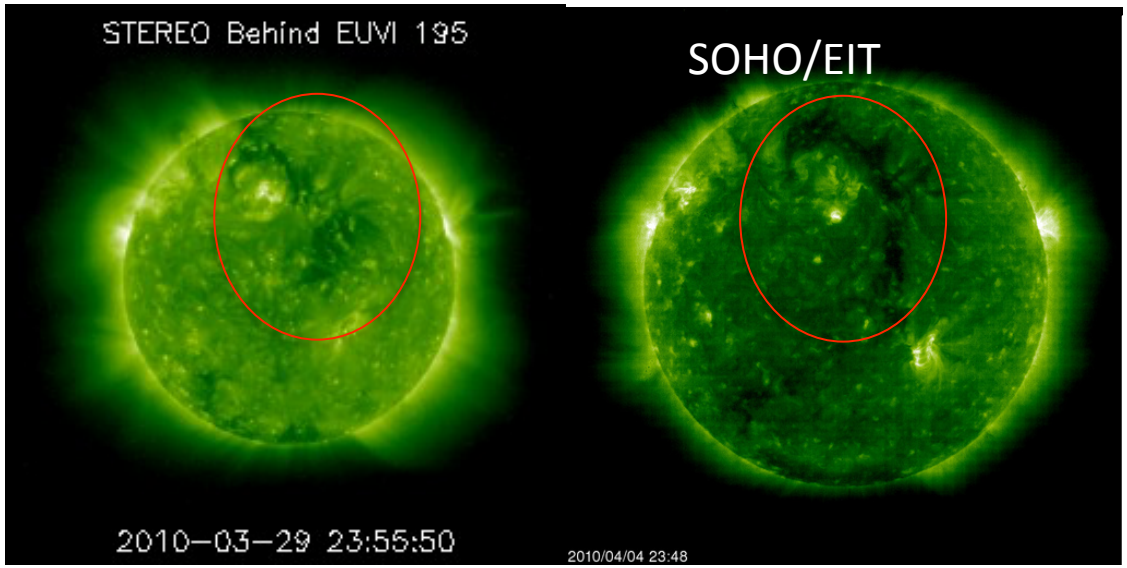
- Track CME properties from CME producing ARs before they become Earth-directed
- Is there a pattern in helicity/axis orientation/speeds/magnetic field magnitude of CMEs coming from the same AR? (related work in Liu et al., 2006, but more analysis needed)
- L5 *in-situ* observations of possible previous CMEs might help to forecast properties (even magnetic field characteristics!) of Earth-impacting CMEs

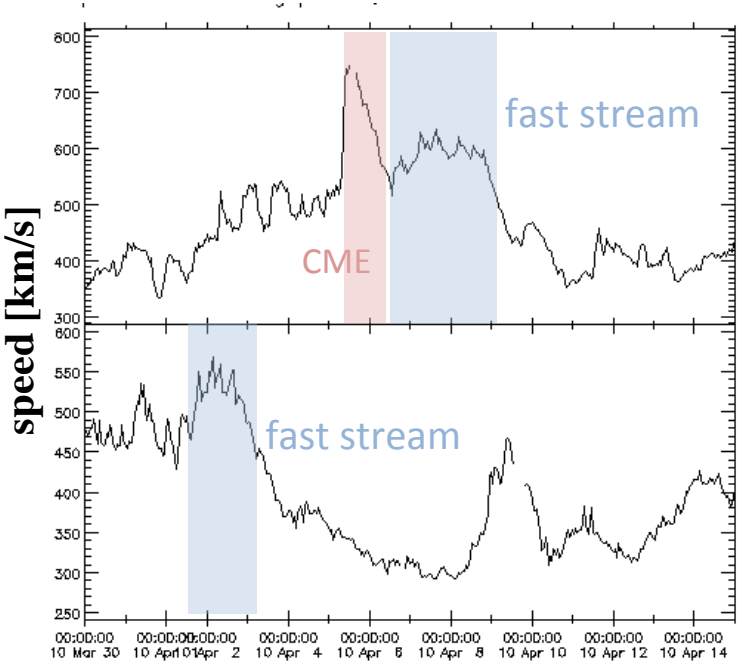


Liu et al., 2006: http://sun.stanford.edu/~yliu/papers/Liu_arcmesmc.pdf

L5 *in-situ* Space Weather Science Benefits: Heliosphere, larger view

- Measurements from L5 would significantly increase statistics of interplanetary CMEs, shocks and SIRs (important e.g. for capturing solar cycle variations)
- Increases chances to capture interesting in-situ events. E.g. July 2012 super-CME was not detected at L1, but was seen by a widely separated STEREO-A
- Recording how solar wind, and CME properties change in time and space (AR related flows, coronal holes evolution, fast stream properties etc.)





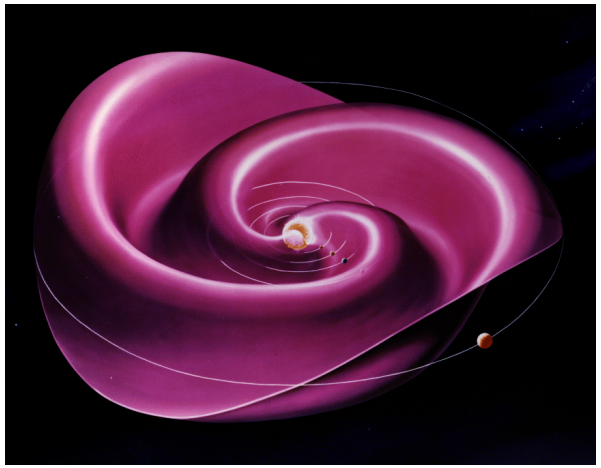
L5 *in-situ* Space Weather Science Benefits: Multi-Point Studies

- Multipoint analysis of **slow-fast stream interaction regions (SIRs) and following fast streams**

- SIRs and fast streams are key drivers of Van Allen Belt enhancements and weak to moderate level space weather storms and continuous auroral activity. Important also for the acceleration of solar energetic particles (SEPs)

- How does the structure of SIRs and fast streams vary in space and in time?
  - how parameters important for space weather evolve
  - how integer SIRs are and what is the contribution from intermittent release of plasma "blobs" (transient part of the solar wind)

- Global structure of heliospheric plasma and current sheets



L5 *in-situ* Space Weather Science Benefits: Multi-Point Studies

- Multipoint analysis of **interplanetary coronal mass ejections and their shocks and sheath regions**

- Interplanetary CMEs rarely extend 60° in longitude
  (only a handful CMEs detected *in-situ* by well-separated spacecraft so every event is a plus)
  - Improved understanding of large-scale CME morphology

- CME shocks span typically much large longitudes than the ejecta
  (Helios: Roughly 50% of the shocks were observed by both spacecraft when they were separated by about 90°, Lucas et al., 2011)

- Analysis of shock and CME sheath properties at widely separated locations
  - Improved understanding of large-scale shock and sheath properties
  - SEP acceleration and analysis

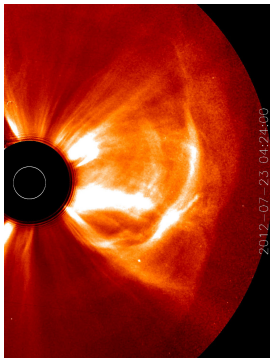
de Lucas et al. http://www.sciencedirect.com/science/article/pii/S1364682610004049

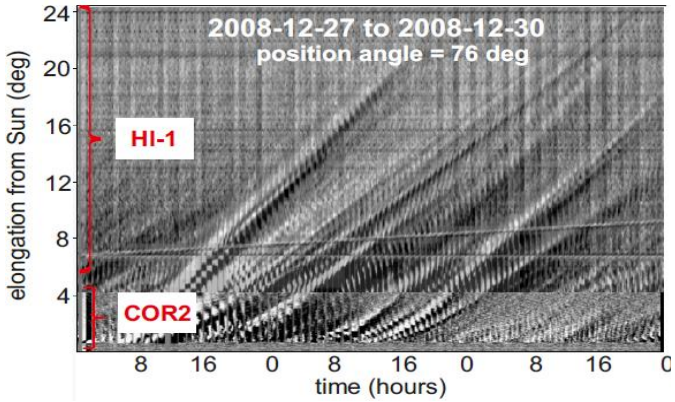
Linking *in-situ* and Remote-Sensing Observations: Science Benefits

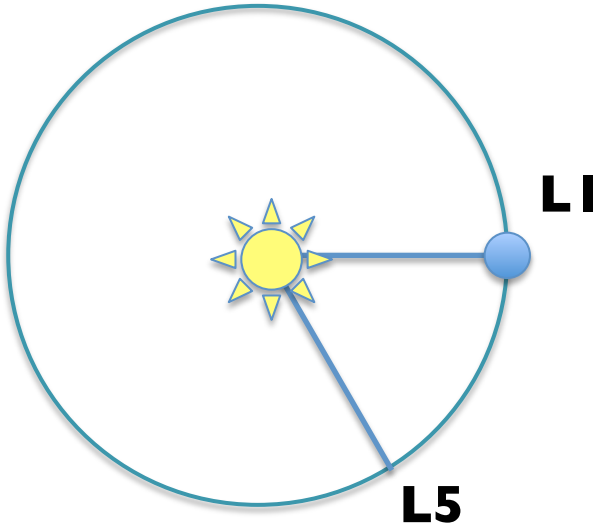
- L5 and L1 points allow effectively linking *in-situ* and remote sensing observations (minimal projection effects. Events directed to the spacecraft easily visible)

Sample of research topics relevant for space weather research

- CME and SIR kinematics and evolution from Sun to 1 AU
- Linking CME properties close to the Sun and at 1 AU (e.g., orientation)
- Linking CME morphology close to the Sun and at 1 AU (flux rope, sheath etc.)
- Tracking of even small coronal blobs (origin of the slow solar wind)







CONLUSIONS

- Main advantages of **L5** Space Weather mission lies in **L5 remote sensing** observations (e.g., early warnings of the CME eruption by track the evolution of the source AR), accurate knowledge of the CME key properties, monitoring the CME evolution from the Sun to the Earth)

However

- **L5** ***in-situ*** observations have also direct and important use for near real-time space weather forecasts
  - Properties and occurrence of fast solar wind streams (Van Allen belts)
  - Predicting the ambient plasma where the CMEs are launched
  - Tracking CMEs from CME-active ARs

- In addition, **L5** ***in-situ*** observations benefit several science research topics
  - global structure of SIRs, shocks, sheaths, heliospheric plasma and current sheets etc.
  - evolution of coronal structures and the solar wind