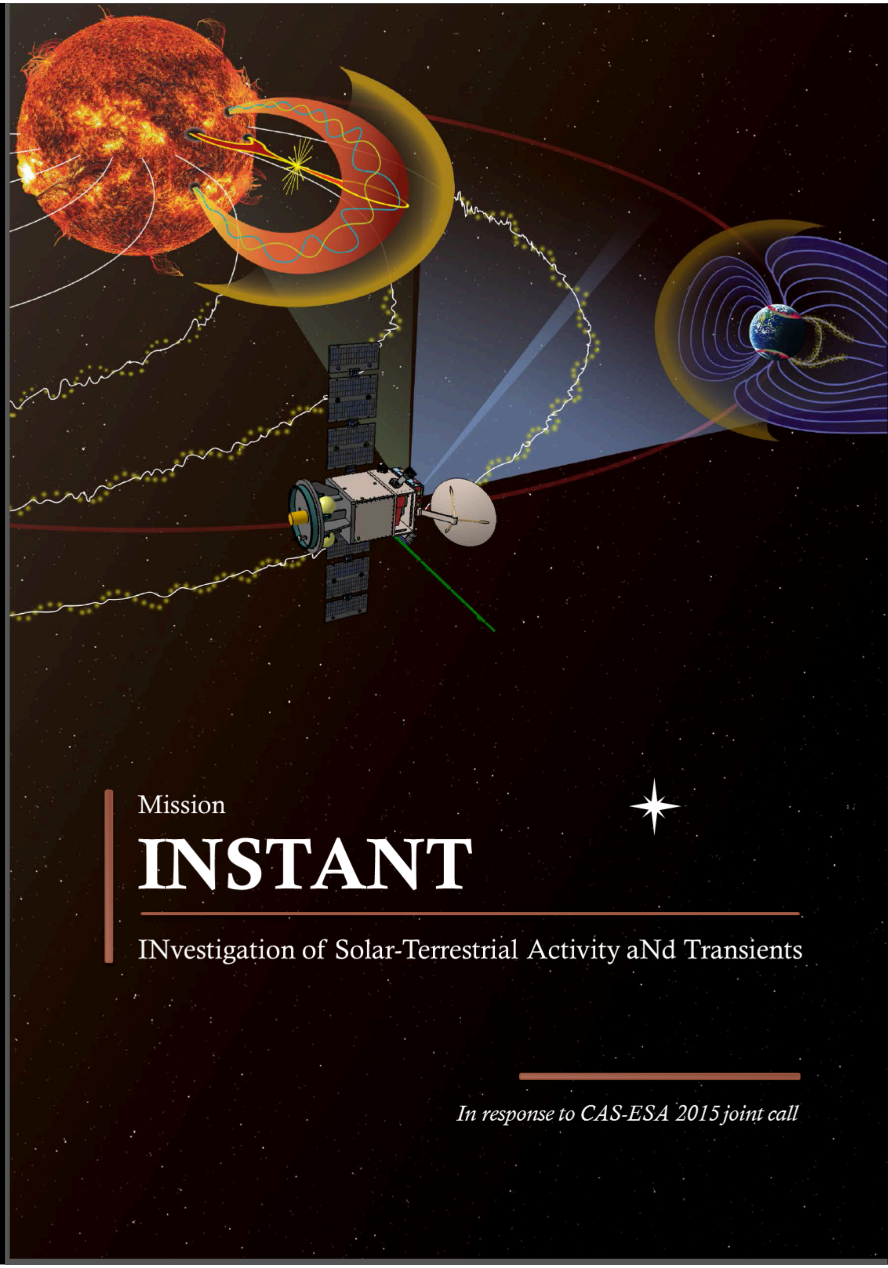
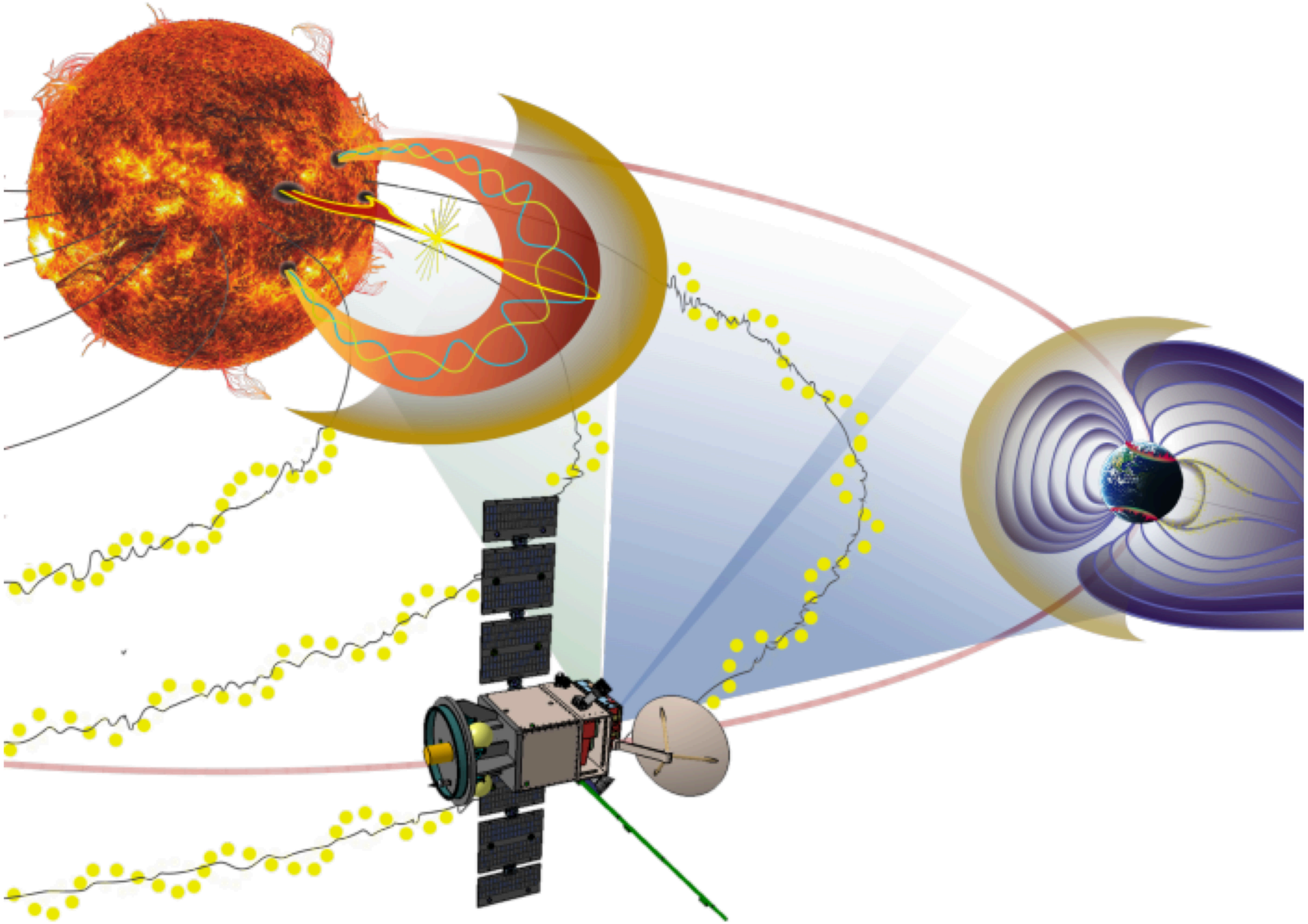
INSTANT



PI: Benoit Lavraud (IRAP)
and Ying Liu (NSSC, CAS)



2.1 Science objectives

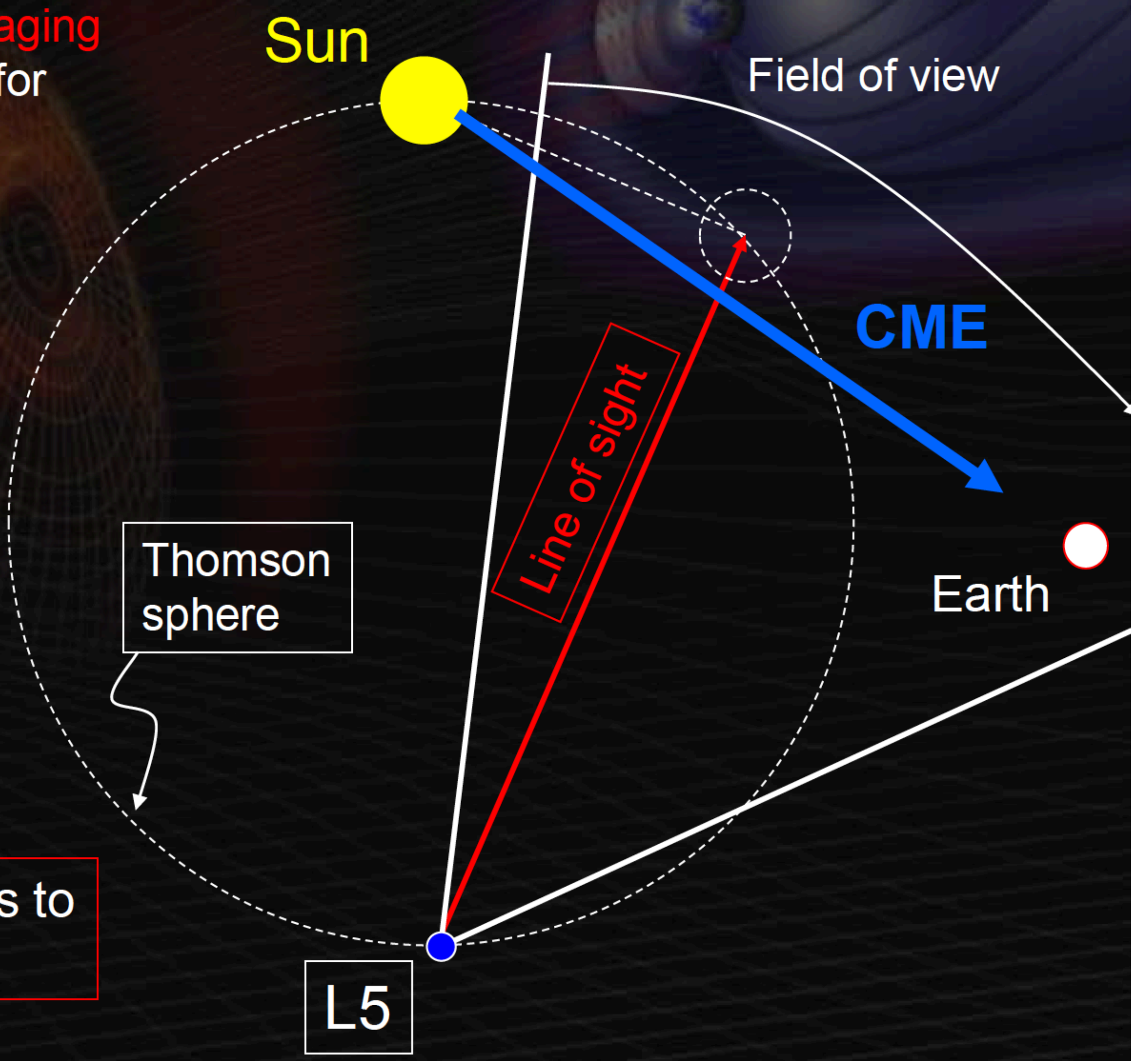
Solar perturbations, and in particular CMEs, are the most energetic transients affecting the heliosphere. Their impact on Earth's environment is often dramatic, and potentially highly damaging to our increasingly vulnerable technology-based society. Yet, it is striking that, to date, the physics underlying CME formation, eruption and propagation in the heliosphere is still poorly understood. Our understanding is poor owing to the elusive nature of a few key properties, in particular the magnetic structure of the corona, accurate CME kinematics, coronal shock strength and location, and knowledge of the background solar wind. Lack of knowledge of these key parameters also inhibits the modeling of CME behavior with sufficient detail for accurate prediction of their near-Earth characteristics. INSTANT is designed to open new windows in solar-terrestrial relations, and answer compelling questions in solar, heliospheric and space weather sciences:

1. What is the coronal magnetic field configuration before and during CME eruptions?
2. What controls CME acceleration and subsequent propagation in the inner heliosphere?
3. Where do CME-driven shocks form and how do their properties affect particle acceleration?
4. How do INSTANT observations at L5 increase our space weather prediction capabilities?

SCIENCE QUESTIONS	SUB-TOPICS
1. What is the coronal magnetic field configuration before and during CME eruptions?	Determining the magnetic field configuration of the corona
	Measuring the coronal structure associated with CME initiation processes
2. What controls CME acceleration and subsequent propagation in the inner heliosphere?	Connecting coronal magnetic field restructuring with early CME dynamics
	Disentangling CME Sun-to-Earth kinematics from projection and geometric effects
	Comparing CME remote-sensing characteristics with in-situ measurements
3. Where do CME-driven shocks form and how do their properties affect particle acceleration?	Determining shock formation and properties
	Measuring energetic particle spectra in relation to shock properties
4. How do INSTANT observations at L5 increase our space weather prediction capabilities?	Advance determination of CME arrival, geo-effective Bz, co-rotating interaction regions (CIRs) and solar energetic particles (SEPs)

→ How do CMEs accelerate and interact in the interplanetary medium?

- High cadence white light imaging in low corona (1.15 – 4 Rs) for CME acceleration
- Wide angle heliospheric imagers to track CME/CIR interactions in heliosphere
- Polarization information for accurate trajectory
- Off-Sun-Earth line location for tracking of <u>Earth-bound CMEs</u>

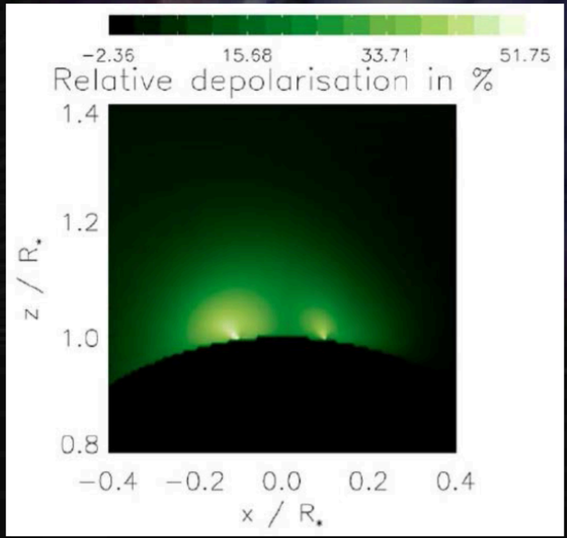


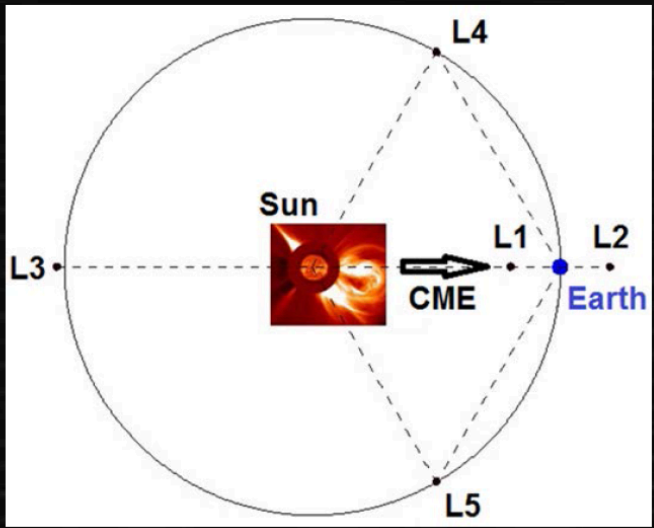
→ Also key measurements to address objectives 4, 5, 7

→ What is the magnetic field magnitude and topology in the corona?
→ How does the magnetic field reconfigure itself during CME eruptions?

- Novel Lyman-α measurements to determine line-of-sight magnetic field through the **<u>Hanle</u>** effect
- Measurement in low corona (1.15 – 4 Rs) for reconstruction of magnetic field topology
- Off-Sun-Earth line location for early determination of magnetic structure of <u>Earth-bound CME</u> and comparison with <u>*in situ* data</u> in heliosphere

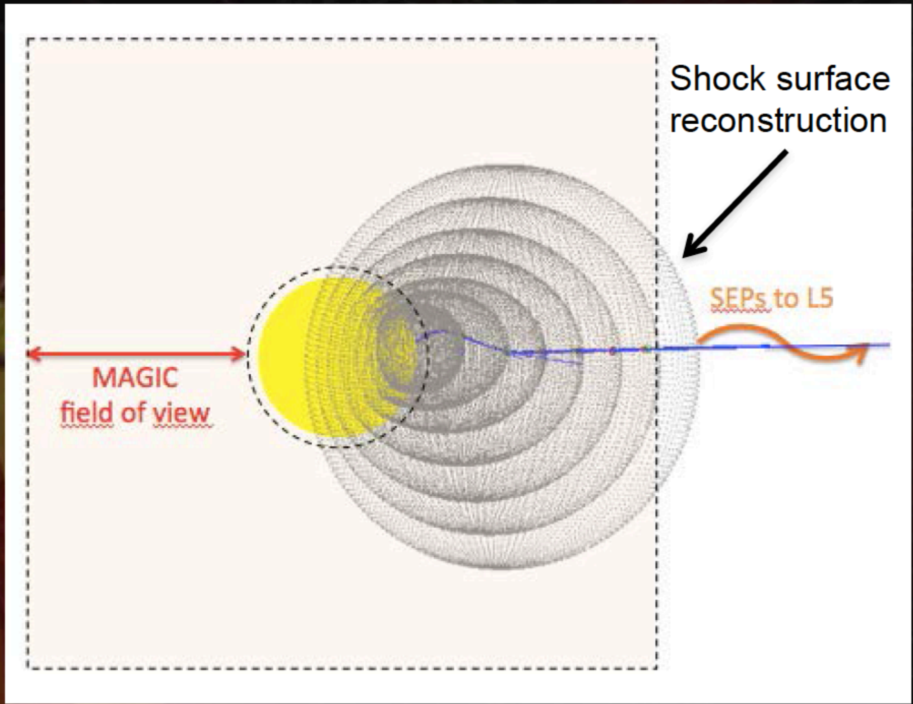
→ Also key measurements to address objectives 3, 5, 7, 9

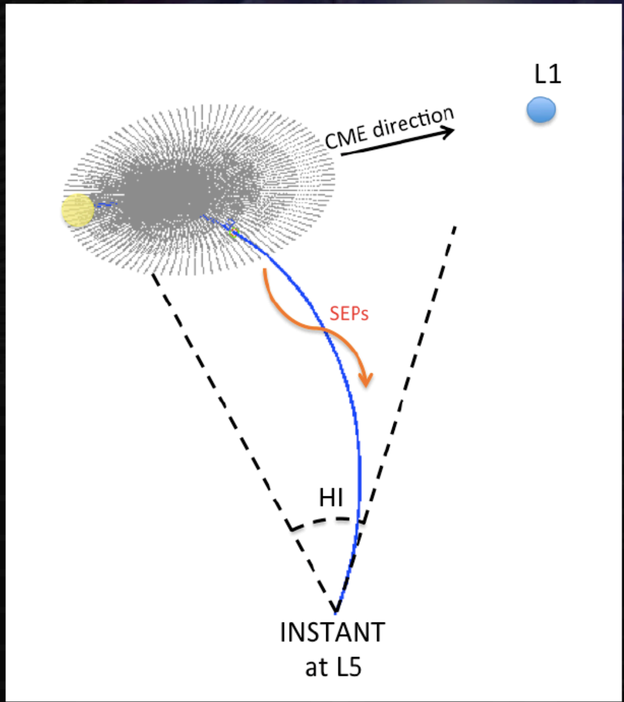




Requirements for objective 5

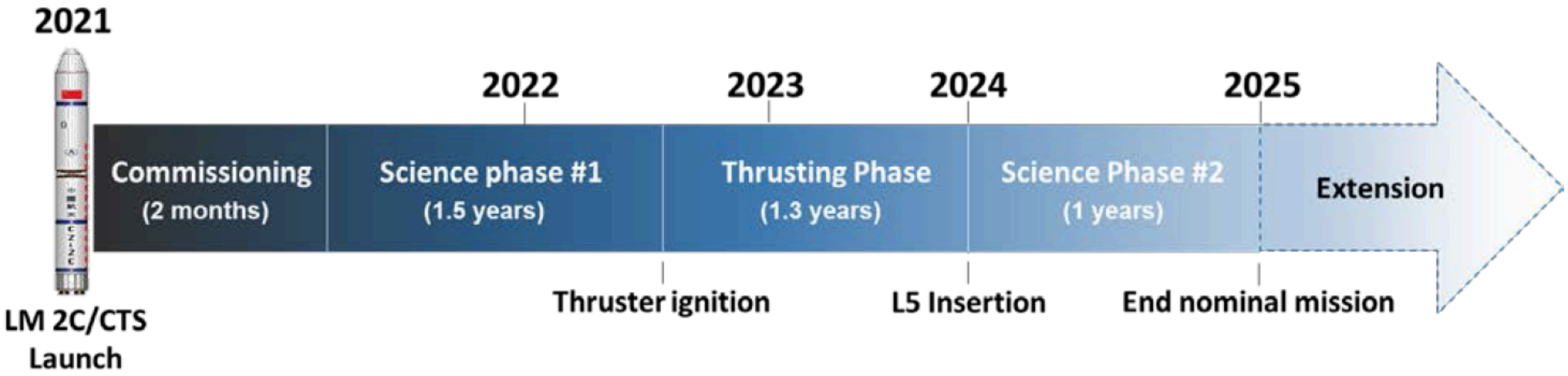
→ What are the sources and links between the slow and fast solar winds?





- Early imaging of shock formation in low corona (up to 4 Rs)
- Magnetic field and density imaging for shock properties
- Multipoint, off-Sun-Earth line measurement of energetic particles

→ Key measurements to address objectives 3, 4, 5, 6, 8


2021
2022
2023
2024
2025
Commissioning
(2 months)
Science phase #1
(1.5 years)
Thrusting Phase
(1.3 years)
Science Phase #2
(1 years)
Extension
LM 2C/CTS
Launch
Thruster ignition
L5 Insertion
End nominal mission

CORE PAYLOAD TEAM

MAGIC

(PI) Frédéric Auchère – IAS – France
(Co-PI) Pierre Rochus – CSL – Belgium
(Co-I) Hardi Peter – MPG – Germany
(Co-I) Alberto A. Herrero – INTA – Spain
(Co-I) Stefaan Poedts – KU Leuven – Belgium
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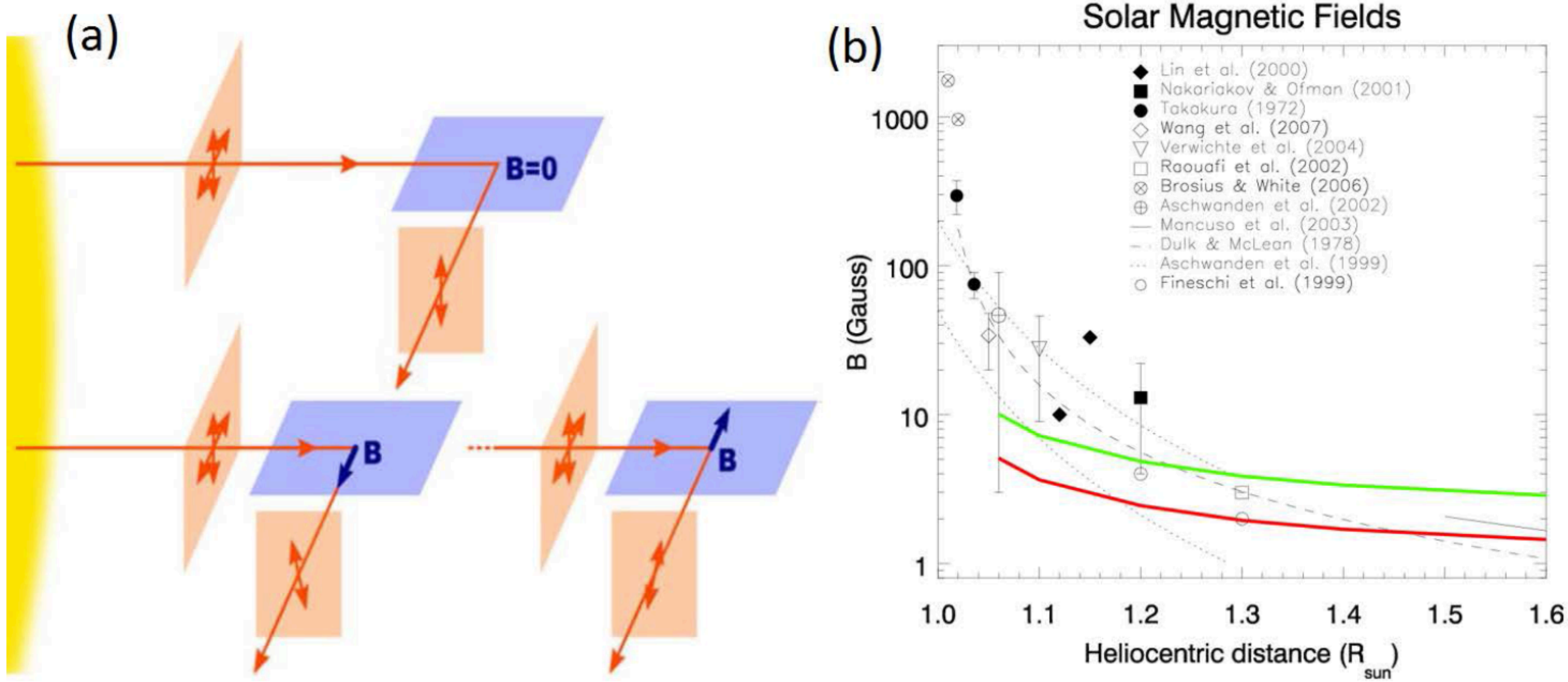
MAG

(PI) Jindong Wang – NSSC – China

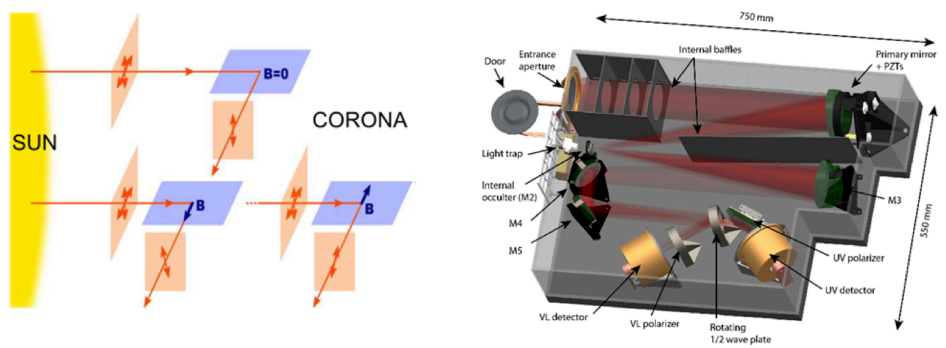


(a)
B=0
B
B
(b)
Solar Magnetic Fields
Lin et al. (2000)
Nakariakov & Ofman (2001)
Takakura (1972)
Wang et al. (2007)
Verwichte et al. (2004)
Raouafi et al. (2002)
Brosius & White (2006)
Aschwanden et al. (2002)
Mancuso et al. (2003)
Dulk & McLean (1978)
Aschwanden et al. (1999)
Fineschi et al. (1999)
B (Gauss)
1000
100
10
1
1.0
1.1
1.2
1.3
1.4
1.5
1.6
Heliocentric distance (R_{sun})

CoMP is an imaging coronagraph polarimeter with a tunable birefringent filter capable of detecting the Fe xiii 1074.7 nm and 1079.8 nm lines as well as the He I 1083 nm line. The new CoMP observations provide, for the first time, daily full-Sun observations of the magnetic field in the corona. The primary observables of CoMP are the four Stokes parameters (I , Q , U , V).

MAGIC: MAGnetic Imaging Coronagraph

The MAGIC coronagraph images the solar corona in Lyman-α (UV) and white-light (WL) bandwidths from 1.15 to 3 R_S (with a possible extension to 4 R_S) from Sun centre with a resolution of 1.87 arcsec per pixel. It is an **innovative instrument** that will for the first time permit the measurement of the coronal magnetic field using observations in the **Lyman-α line from space**. MAGIC will perform **polarization measurements** to determine the plane of polarization of the light scattered by protons in the corona.



As illustrated in the left-hand side Figure above, the magnetic field magnitude and orientation (in the plane parallel to the solar limb) can then be determined through **the Hanle effect**.

Parameter	Values
Mass	25 kg
Power	23 W
Volume	75 x 55 x 20 cm
Angular resolution	1.87 arcsec
Pointing accuracy	2 arcsec
Pointing stability	3.6’’ per 120 s exposure time
Bandwidth	1216 Å (Lyman-α) & 5600 Å (White-light)
Field-of-view	1.15 – 3 R_S
Cadence	Phase 1/2: 5 and 30 minutes
Data product	Phase 1: 3072×3072; Phase 2: 1024×1024 or lower
TM rate	Phase 1: 95.4 kbps ; Phase 2: 11.4 kbps
TRL	6

When the local magnetic field is at the Van Vleck angle of roughly 54. 7◦ with respect to solar radial, the light becomes unpolarized, and the strength of L (strength of the total linear polarisation) goes to zero.

Rachmeler et al. (2013) argue that it is possible to distinguish between cylindrical flux ropes, Spheromak flux ropes, and sheared arcades using coronal polarization measurements.

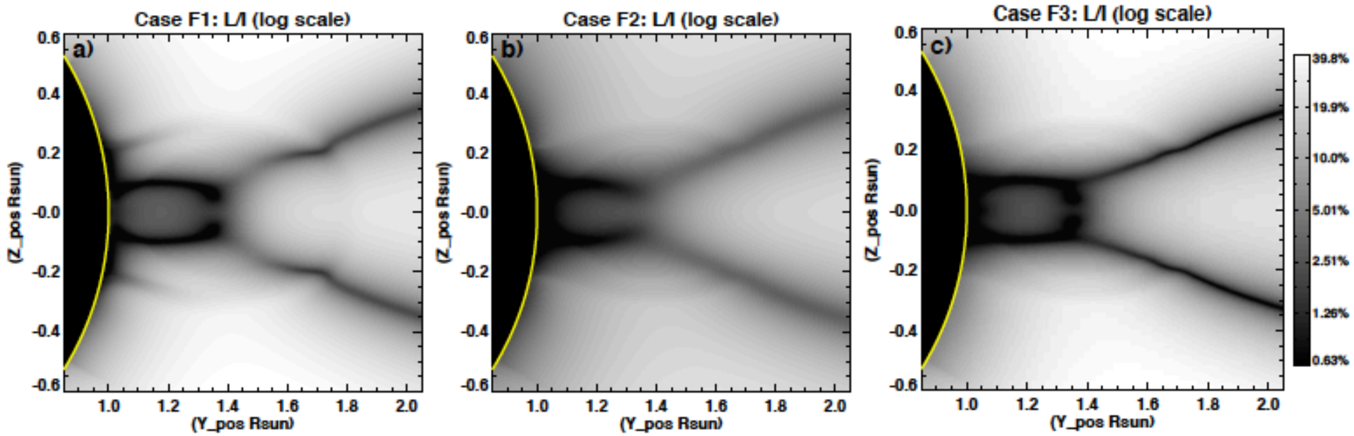
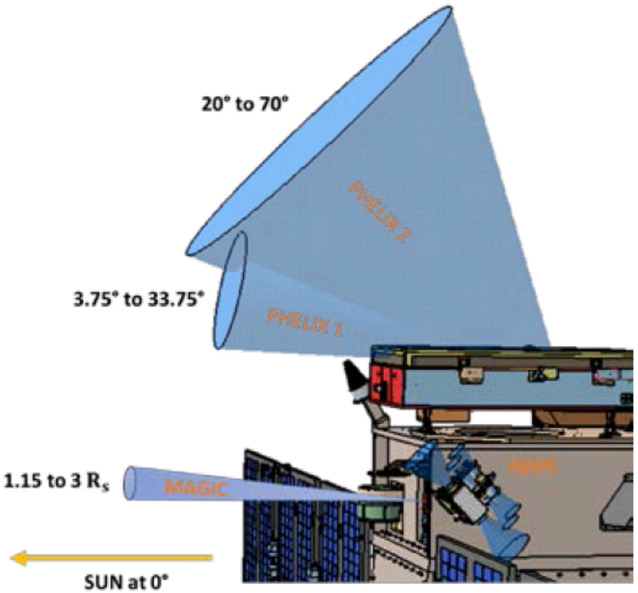


Figure 6. Comparison of the relative linear polarization for the three cases of the cylindrical flux rope. All three images use the same scale.



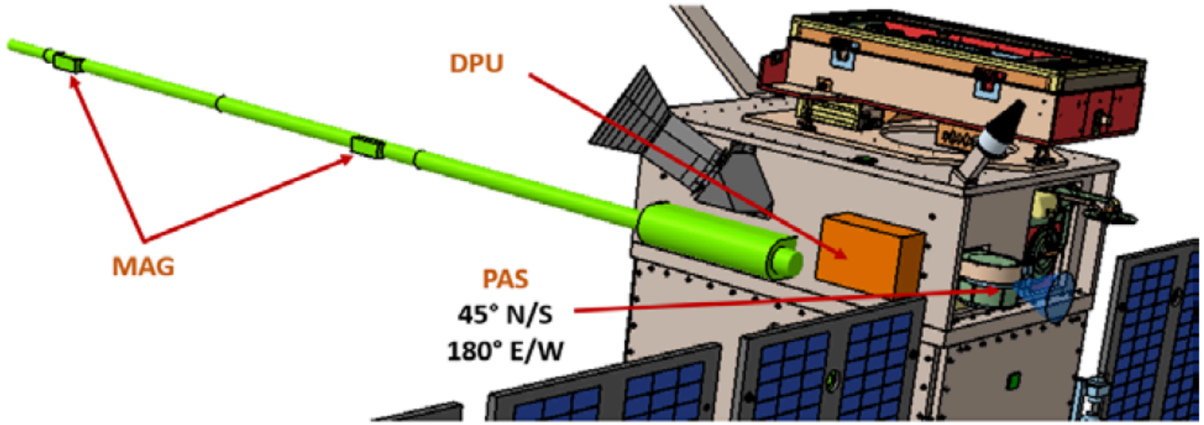


Figure 5.1. *Accommodation of the INSTANT payload, with FOVs. Cf. also* ***Figure 6.6****.*

Table 5.7. *PHELIX budgets and resources.*

Parameter	PHELIX-1	PHELIX-2
Field-of-view diameter	30°	50°
Elongation range (FOV)	3.75° – 33.75°	20° – 70°
Spectral bandpass	630 – 730 nm	400 – 1000 nm
Image bin size (1k x 1k binning)	1.75’	2.9’
Summed image cadence	Phase 1/2: 15/30 min	Phase 1/2: 20/60 min
Polarimetry capability	N/A	Polarized images at -60°, 0° and +60°
Brightness sensitivity	3 x 10^{-15} B_O	3 x 10^{-16} B_O
	Total Resource Requirements	
Mass (PHELIX / DPU)	16 kg / 4 kg (10% / 20% margins)	
Size (PHELIX / DPU)	840 x 550 x 260 mm / 250 x 150 x 60 mm	
Power	14.2 W / 6 W (10% / 20% margins)	
Pointing accuracy (3σ)	± 6’ for PHELIX pitch axis; ± 1° for yaw & roll axes	
Pointing stability (3σ / 30 min)	21” for PHELIX pitch & yaw axes; 37” for roll axis	
Accommodation	Minimize other spacecraft units above plane of baffles	
Data product	Polarized brightness images of K coronal activity	
Telemetry rate	Phase 1: 26 kbps (1024 x 1024 images) Phase 2: 4 kbps for 512 x 512 (15.5 kbps for 1024 x 1024: burst) Beacon: 330 bps for 256 x 256, 1 hr, total brightness only	
TRL	> 6 (9 for most sub-systems)	

Table 5.11. *HEPS budgets and resources.*

Parameter	Values
Mass	2.5 kg (10% margin)
Power	5.5 W (10% margin)
Volume	13 x 17 x 14 cm
Energy ranges	Electrons: 20 keV – 15 MeV Protons: 20 keV – 105 MeV Heavy ions: 19 – 210 MeV/nuc
Energy resolution	20 %
Angular resolution	20° opening angle
Cadence	1 min
Accommodation	FOV 45° both parallel and anti-parallel to Parker spiral
Data product	Fluxes, histograms, pulse-height data
TM rate	1 or 2 kbps function of phase (10 bps beacon)
TRL	> 6 (9 for most subsystems)

Table 5.12. *HEPS on-ground calibration plans.*

Parameter	Electrons	Protons	Ions
EPT at Univ. Kiel (CAU)	10 eV – 100 keV	20 – 400 keV	20 – 400 keV/q
EPT at NSSC	100 eV – 30 keV	Up to 10 MeV	0.2 – 30 keV/q
EPT et HIMAC			~10 MeV/nuc
HET at HIMAC		10 – 100s MeV	10s – 100s MeV/nuc
HET at NSSC	> 100 keV		
Radioactive sources (CAU)	Electrons & gammas		Alphas

Costing

- An industrial partner has estimated the cost of the proposed spacecraft to ESA at 43 M€. The proposed launch cost to CAS is estimated at 15 M€.

- Mission operations and ground segment are shared between the two agencies.

- The total cost at completion (CaC) is 52.8 M€ for ESA and 53.3 M€ for CAS.

Payloads are provided by national agencies.