An L5 mission concept for small mission opportunities

INSTANT

INvestigation of Solar-Terrestrial Activity aNd Transients

Outline

- Motivations
- Limitations of current missions
- Scientific objectives
- Requirements
- Mission profile
- Model payload
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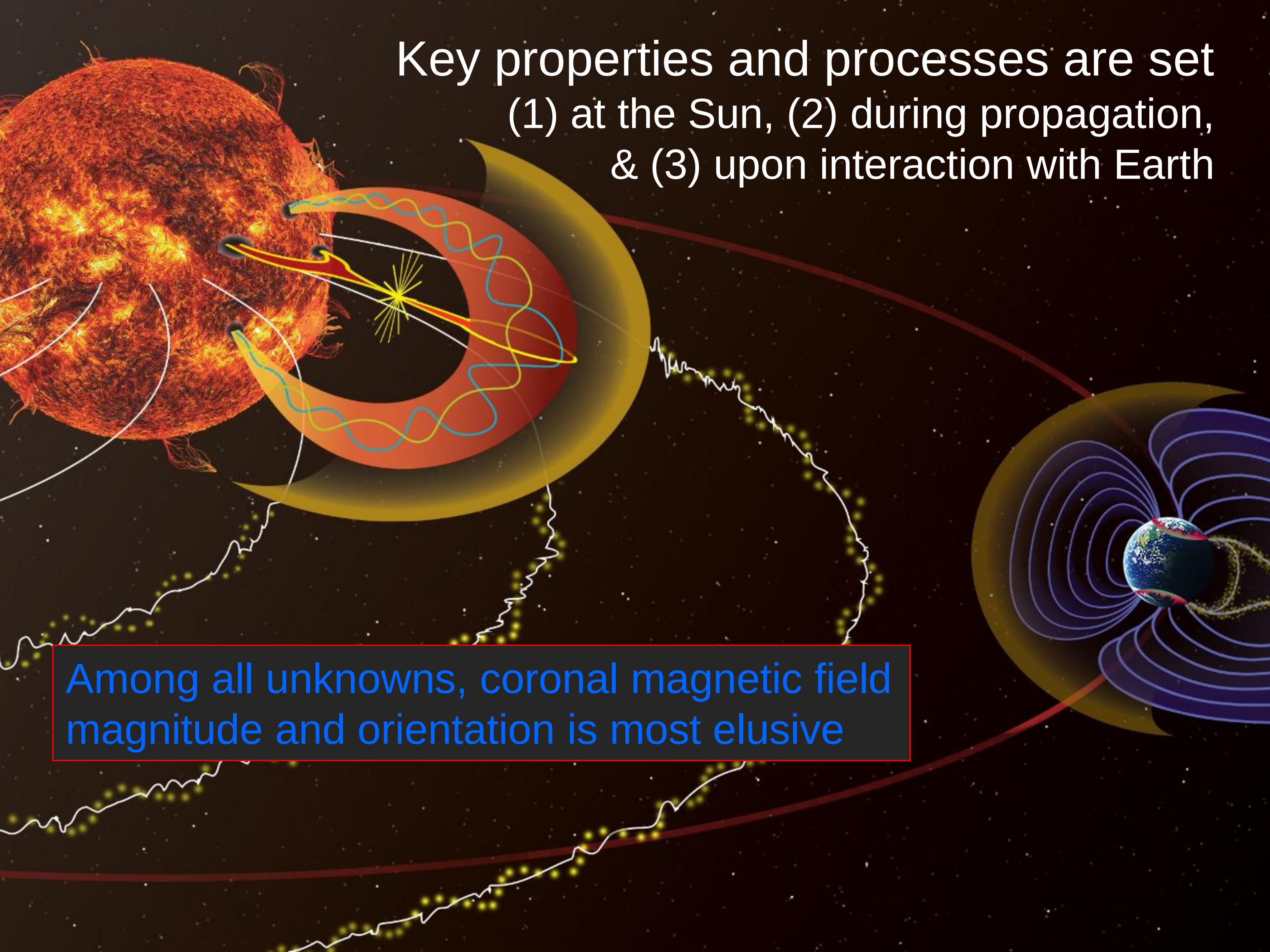
Key properties and processes are set
(1) at the Sun, (2) during propagation,
& (3) upon interaction with Earth
Among all unknowns, coronal magnetic field
magnitude and orientation is most elusive

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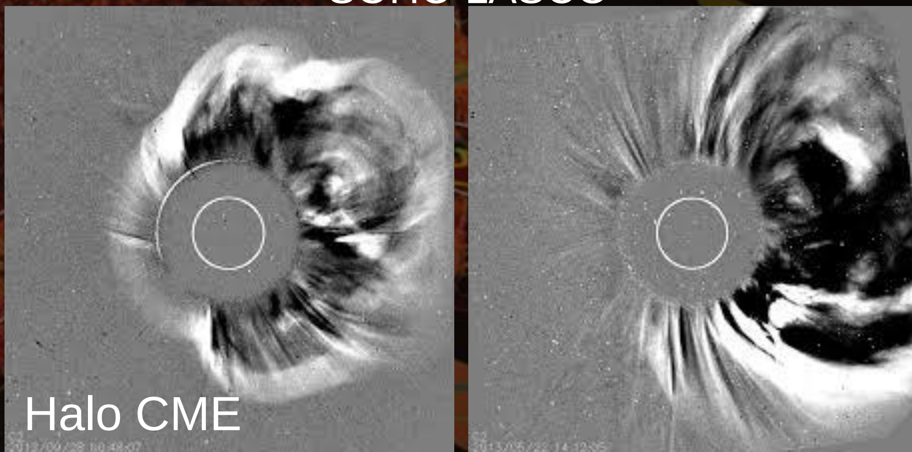
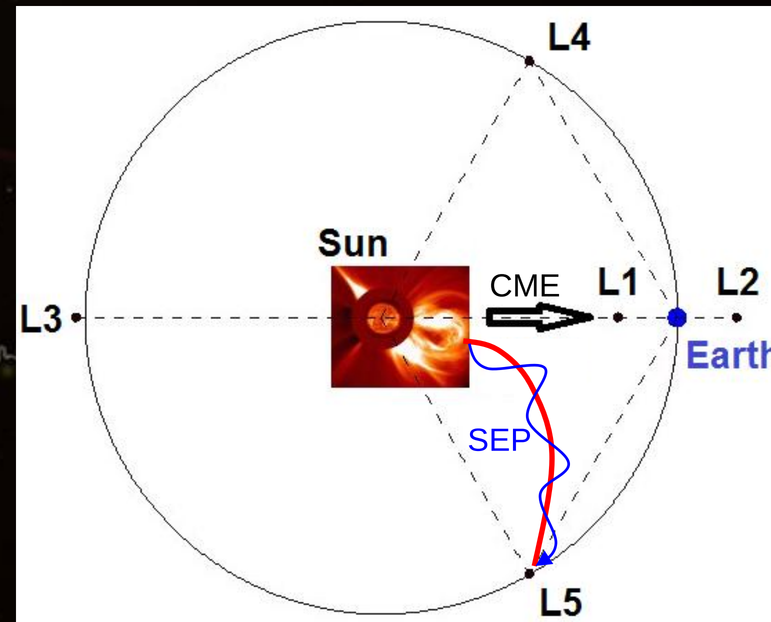
Limitations of Lagrangian L1 point observations

SOHO LASCO



L1 (i.e, Earth) **coronagraph** observations



Imaging: only **very rough** idea of CME shape, trajectory, speed & strength
In situ: optimal knowledge of geo-effective parameters, **but late…**

→ Position off-Sun-Earth line is essential

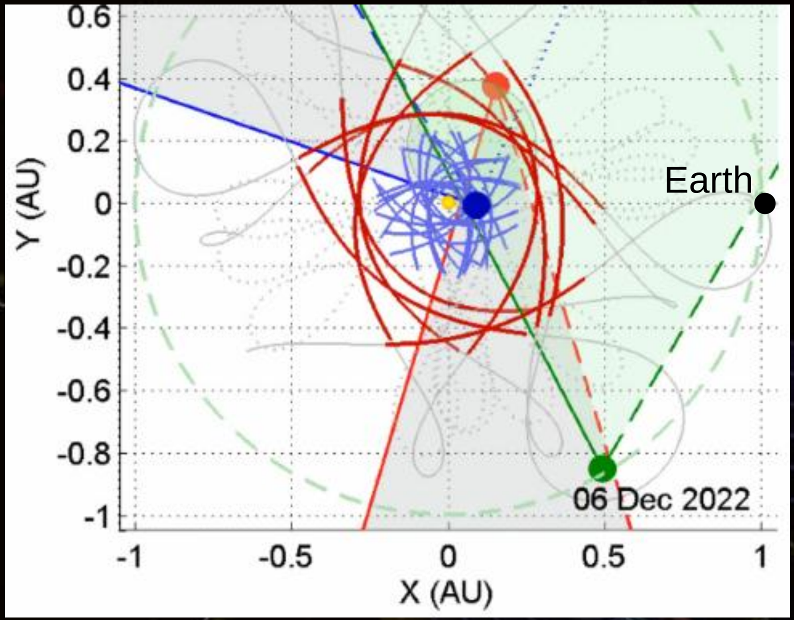
Early properties of Earth-directed CMEs, continuous tracking, multi-point and SEP measurements, & impact at Earth

Limitations of past and future off-Sun-Earth line missions

Limitations of STEREO:
- During solar minimum (low CME statistics)
- Drifted through L5: no continuous "Sun-Earth" vantage point

Limitations of Solar Orbiter and Solar Probe +:
- Solar Orbiter imagers off at aphelion
- No broader context – orbits rarely in proper location for study of Sun-Earth connections

Solar Orbiter Solar Probe+ INSTANT



INSTANT provides:

→ <u>Novel</u> coronal/heliospheric imaging and *in situ* data, during solar maximum, **at a key off-Sun-earth line vantage point**

→ Invaluable synergy with observations at Earth and inner heliosphere missions (Solar Orbiter, Solar Probe + and Bepi-Colombo)

→ Unprecedented space weather capabilities as bonus

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Science objectives

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?

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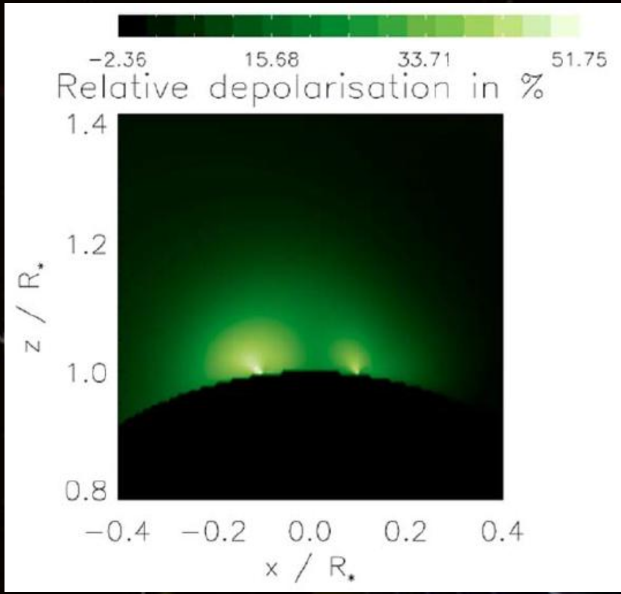
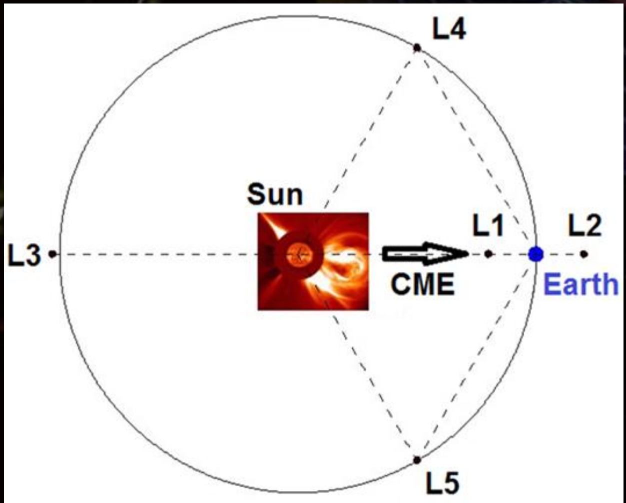
Requirements for objectives 1

→ What is the coronal magnetic field configuration before and during CME eruptions?

- Novel Lyman-α measurements to determine line-of-sight magnetic field through the **Hanle** 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 Earth-bound CME and comparison with *in situ* data in heliosphere

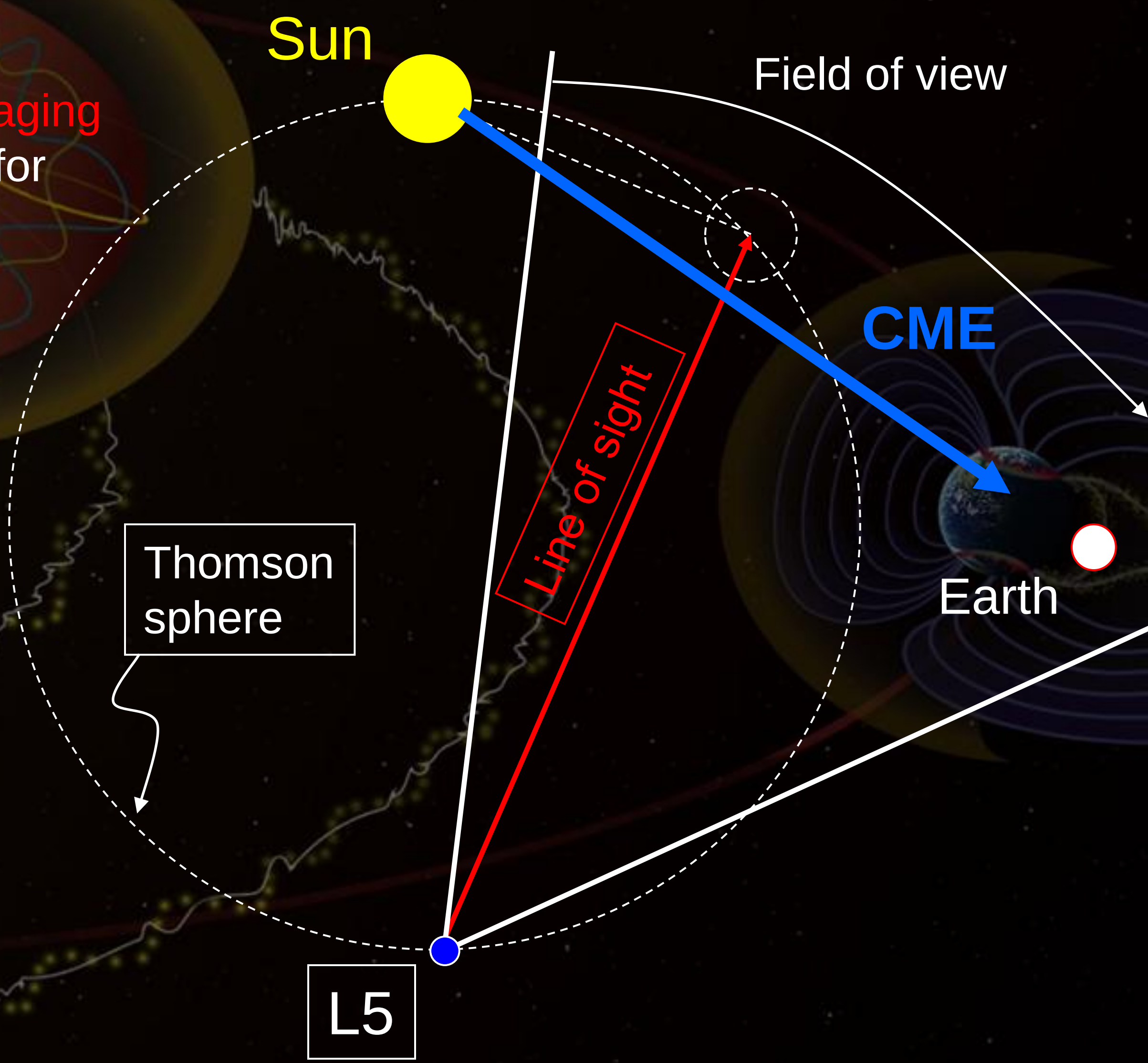




Requirements for objective 2

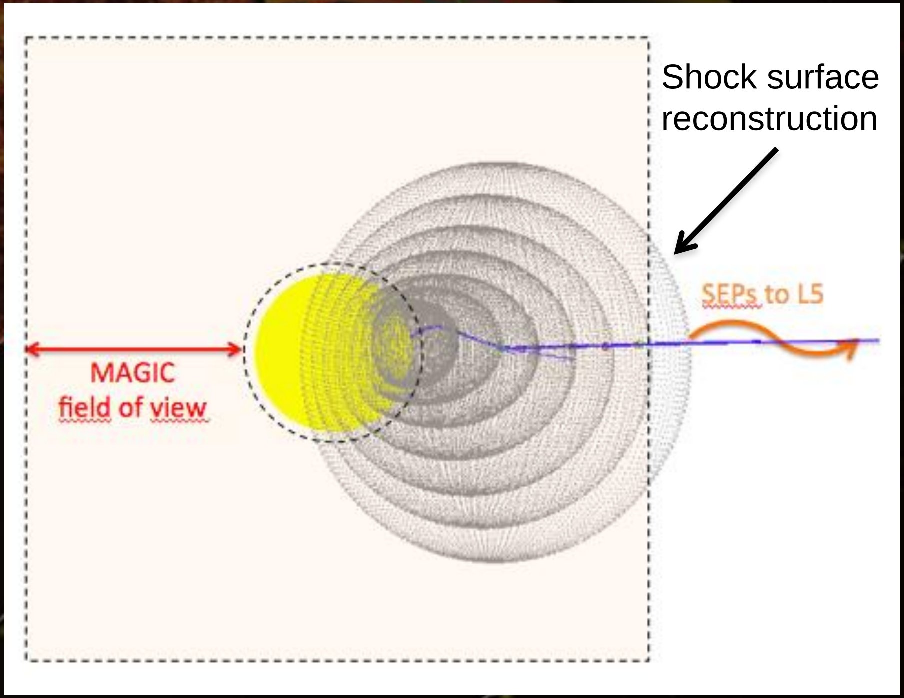
→ What controls CME acceleration and subsequent propagation in the inner heliosphere?

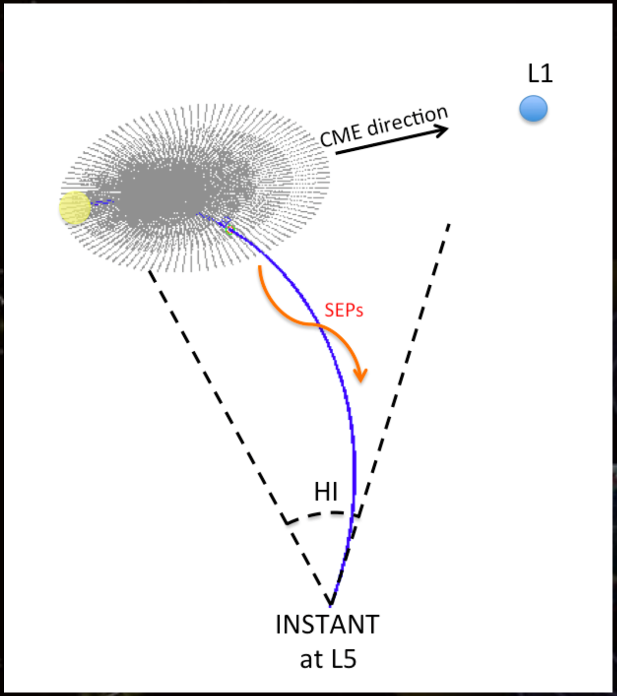
- High cadence white light imaging in low corona (1.15 – 4 Rs) for CME acceleration
- Wide angle heliospheric imagers to track CME/CIR interactions in heliosphere
- Polarization information for accurate trajectory
- Off-Sun-Earth line location for tracking of Earth-bound CMEs



Requirements for objective 3

→ Where do CME-driven shocks form and how do their properties affect particle acceleration?





- 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

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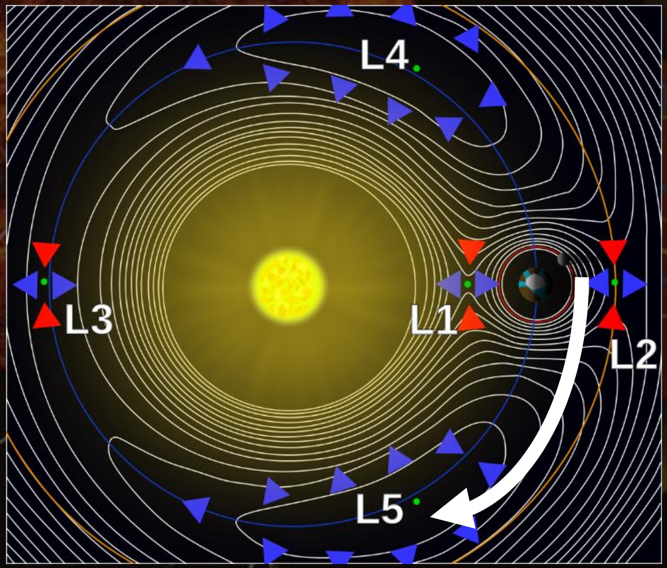
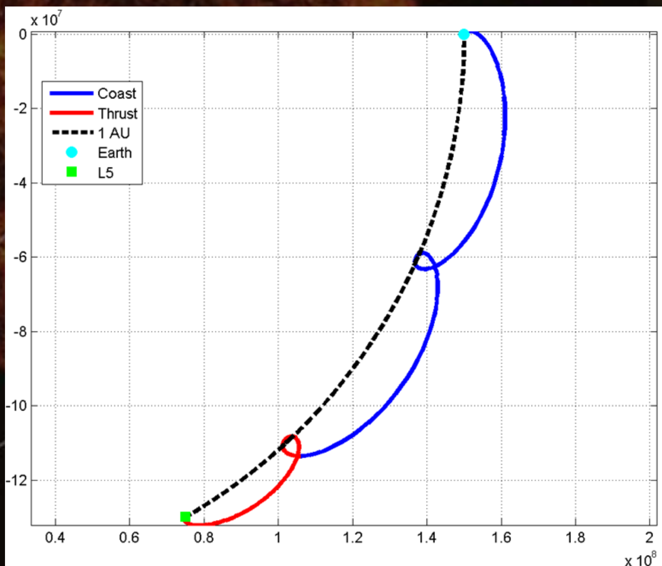
Mission profile: orbital requirements



- Observation off-Sun-Earth line is a key for innovative science of Earth-directed CMEs
- Towards L5 rather than L4 (CIRs and SEPs)
- Science operations start after commissioning (~few months)
- Earth-directed CMEs can be studied after S/C has drifted by ~ 20° towards L5
- L5 insertion after ~2 years operation

Mission profile for the ESA-China S2 call



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- L5 insertion after ~2 years operation

3 years operation sufficient to address key science objectives

Best if synergy with Solar Orb., SP+ and Bepi-C …

Mission profile for the ESA-China S2 call

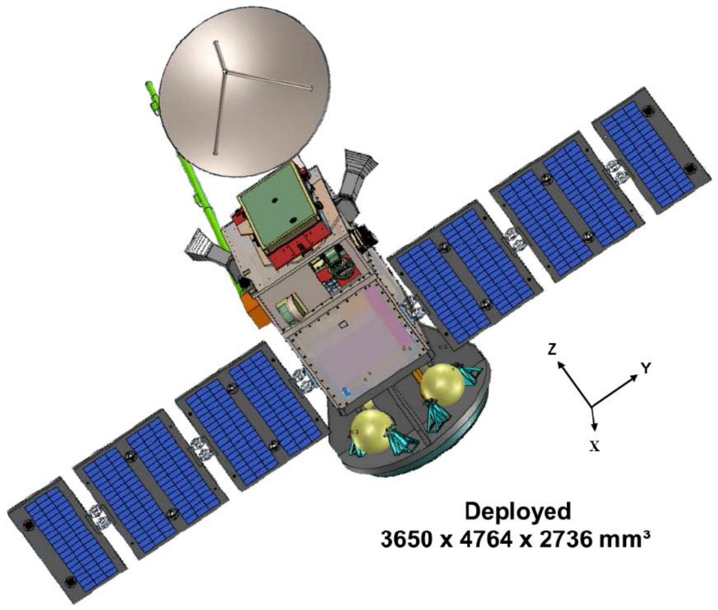
- Launcher that allows exit to L5

Long-March 2 CTS with upper stage

Long March 2C

Launch Service Provider	CGWIC
Company Headquarters	China
Manufacturer	SAST
Mass, kg (lb)	233,000 (513,677)
Length, m (ft)	41-42 (134.5-137.8)
Diameter, m (ft)	3.4 (11.2)
Year of First Launch	LM-2C: 1975, LM-2D: 1992
Number of Launches	LM-2C: 32, LM-2D: 11
Reliability	LM-2C: 100%, LM-2D: 100%
Launch Sites	Jiuquan Taiyuan Xichang
GTO Capacity, kg (lb)	1,250 (2,756)
LEO Capacity, kg (lb)	3,850 (8,488)
SSO Capacity, kg (lb)	1,300-1,900 (2,866-4,189)

Mission profile for the ESA-China S2 call



- Launcher that allows exit to L5

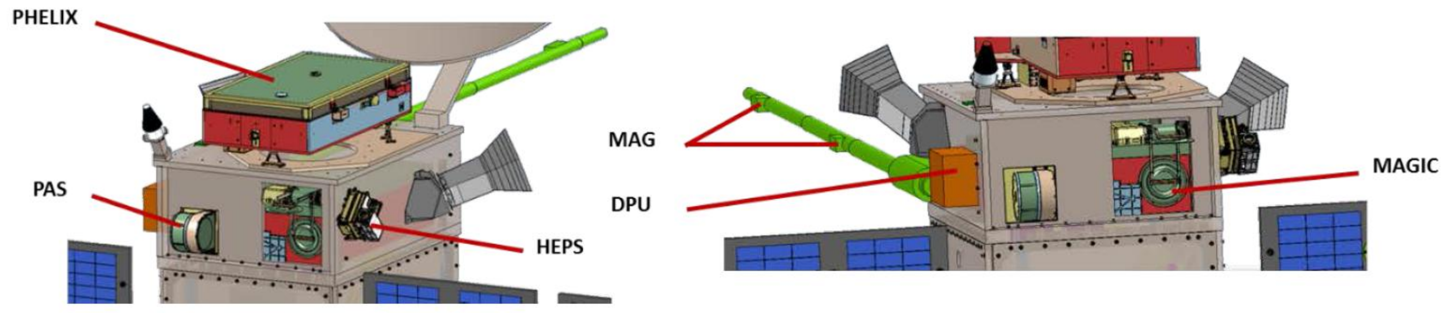
Long-March 2 CTS with upper stage

- Spacecraft mass max. 300 kg as per boundary conditions

Proba-type European platform

- Additional propulsion module for insertion at L5

Electric propulsion with required dV



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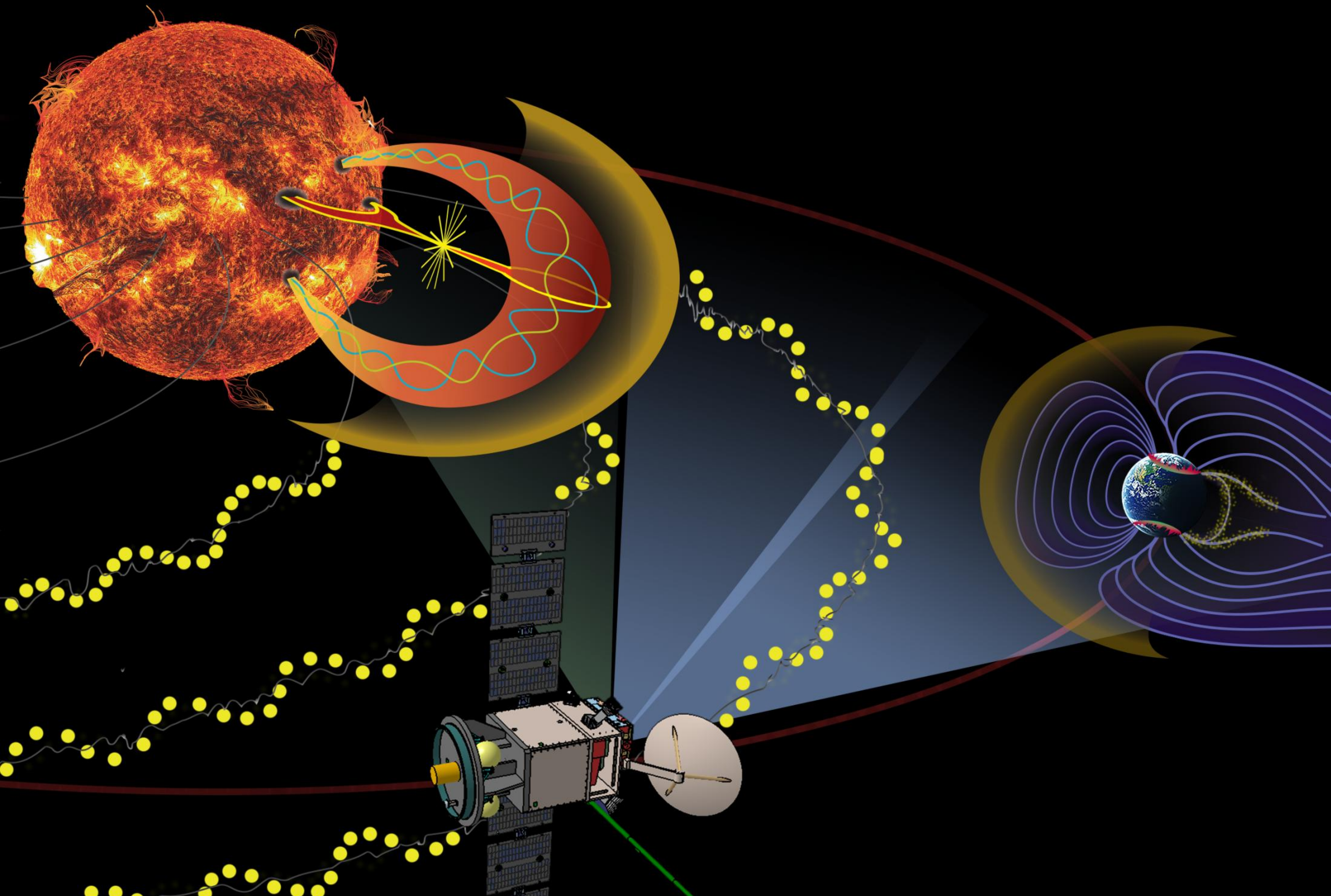
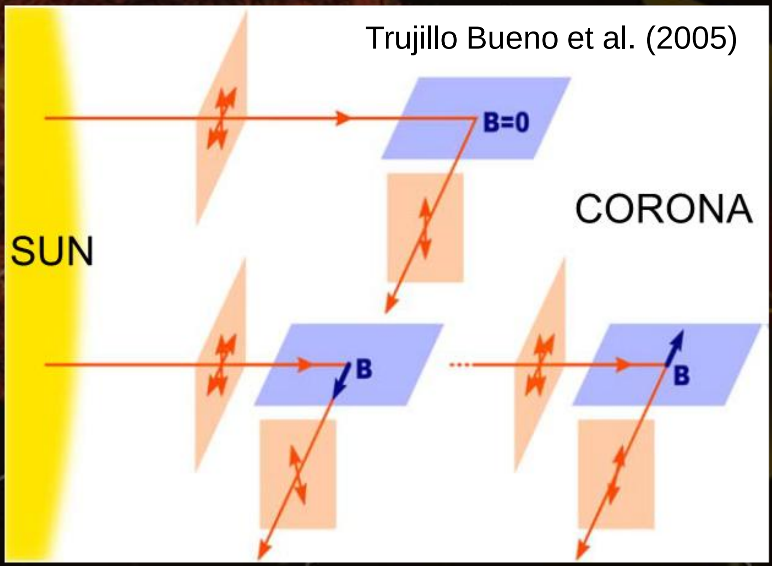
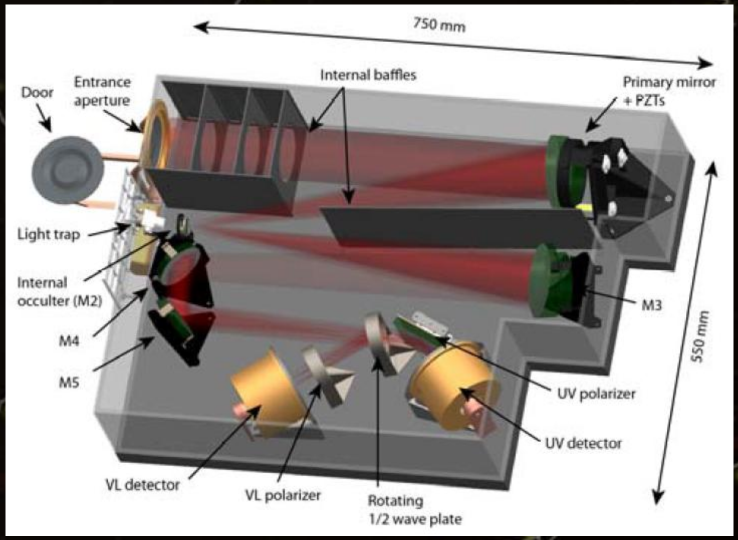
Payload fields of view



Payload: innovative coronal imaging





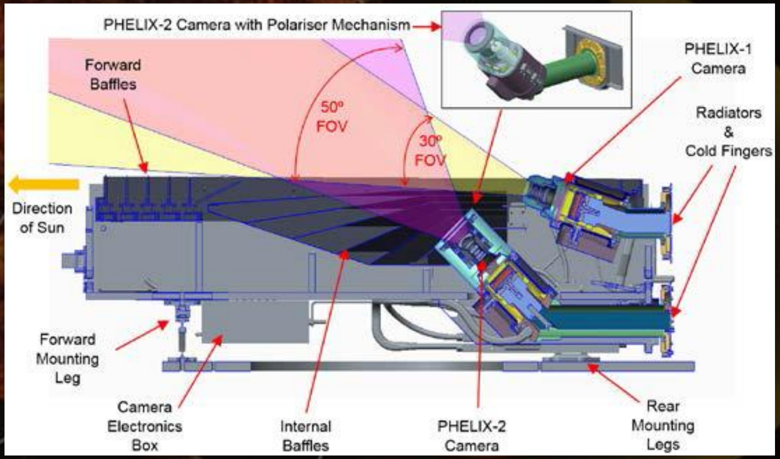
MAGIC: MAGnetic Imaging Coronagraph

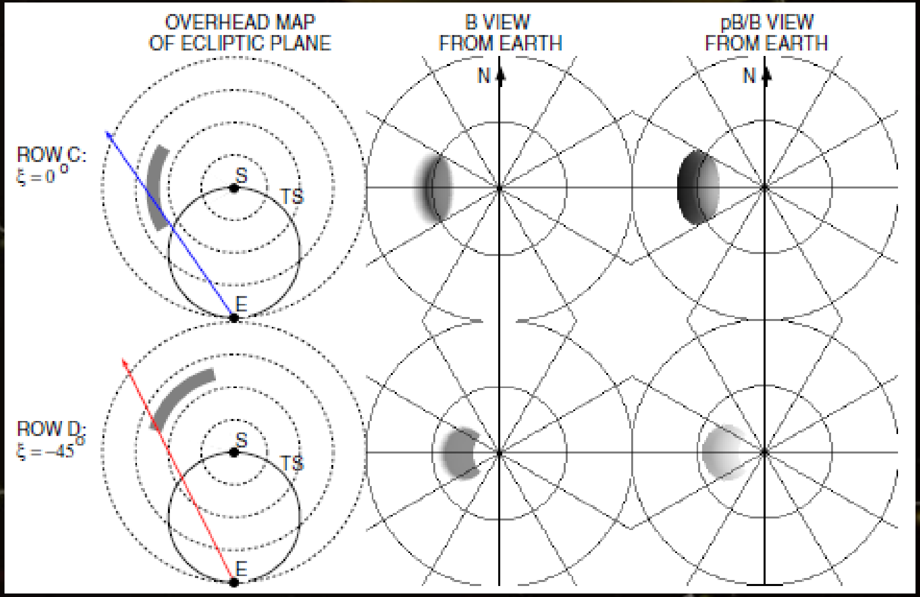
- Novel Lyman-α measurements to determine line-of-sight magnetic field component through the **Hanle** effect
- High cadence (5-7 min) measurement in low corona (1.15–4 Rs) for reconstruction of magnetic field topology
- White light for electron density estimates
- Off-Sun-Earth line for early determination of magnetic structure of Earth-bound CME and comparison with *in situ* data

Heritage: R&T, SOHO, Solar Orb., ground, …

TRL 6+

Payload: new 'polarized' heliospheric imagers





Howard et al. [2013]

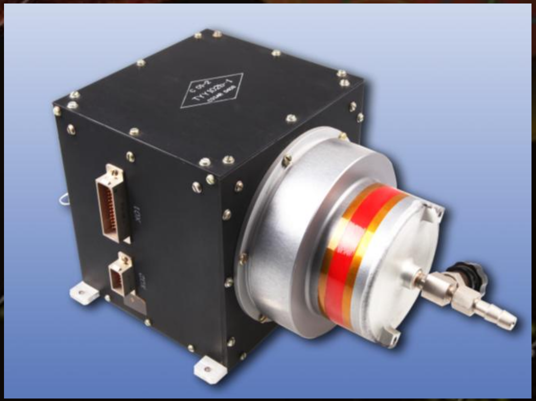
PHELIX: Heliospheric Imagers

- Wide angle (2.5 – 60°) white light imagers to track CME and CIR interactions in heliosphere
- Polarization measurements for accurate trajectory
- Off-Sun-Earth line for early determination of trajectory of Earth-bound CME and comparison with *in situ* data in heliosphere

Heritage: R&T, STEREO, SOHO

TRL 9

Payload: *in situ* instruments



- In situ, off-Sun-Earth line (towards L5) measurement of B-field and thermal protons for CMEs and corotating structures
- 1 AU (towards L5) measurement of energetic particles for direct detection and study of SEPs

MAG: Flux-gate Magnetometer

PAS: Proton and Alpha Sensor

HEPS: High energy Particle Sensors
(e-/p+ and heavies in 10s keV – 10s MeV)

Heritage: Cluster, Chang'E, Solar Orb…

TRLs 9

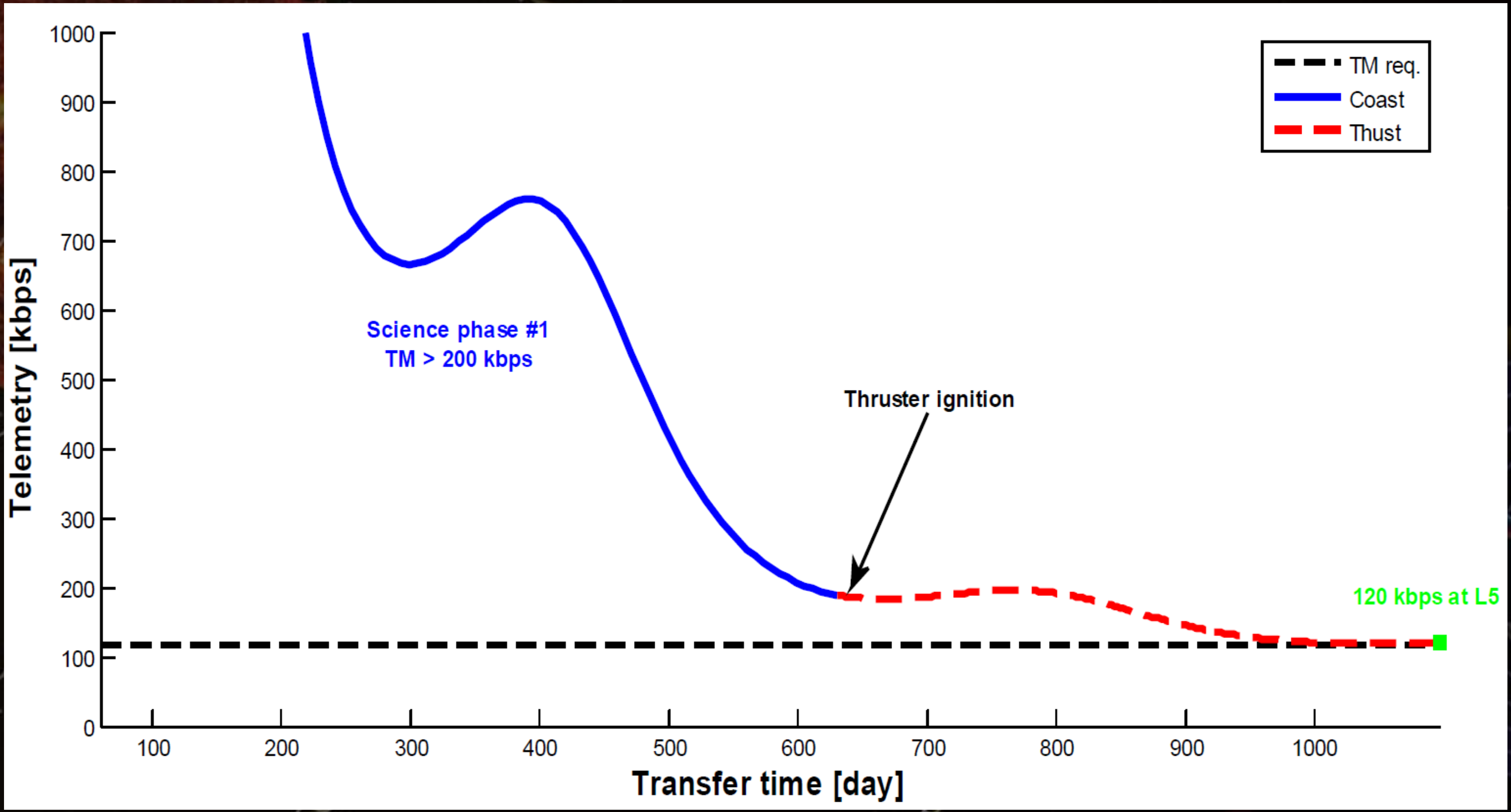
Payload budgets

All instruments have TRL >~ 6

Instrument	Mass (kg)	Power (W)	Dimensions (cm)	Telemetry (kbps)	TRL	Heritage
MAGIC	25	23	75 x 55 x 20	Phase 1/2: 95.4/11.4 Beacon: 0.6	6	Ground prototype and testing
PHELIX	20	20.2	84 x 56 x 22 (25 x 15 x 6)	Phase 1/2: 26/4 Beacon: 0.33	> 6	STEREO
PAS	3.5	6.5	14 x 11 x 15 (16 x 16 x 8)	Phase 1/2: 2/1 Beacon: 0.04	> 6	Chang'E-1/2
MAG	3	4	11 x 6 x 5 (24 x 18 x 5)	Phase 1/2: 2/1 Beacon: 0.005	> 6	FengYun-4 China-Russia YH-1
HEPS	2.5	5.5	13 x 17 x 14	Phase 1/2: 2/1 Beacon: 0.01	> 6	Solar Orbiter
IDPU	4	5.5	22 x 15 x 10	0.5	6	Shenzhou Shuangxing
TOTAL	**58**	**64.7**	-	**127.9 / 18.9** **Beacon: 1**	-	-

S/C mass ≤ 300 kg, payload mass ≤ 60 kg and power ≤ 65 W

Payload telemetry



Two science phases related to location and telemetry:

- Phase #1: detailed solar and solar wind science
- Phase #2: Sun-earth connection and space weather science

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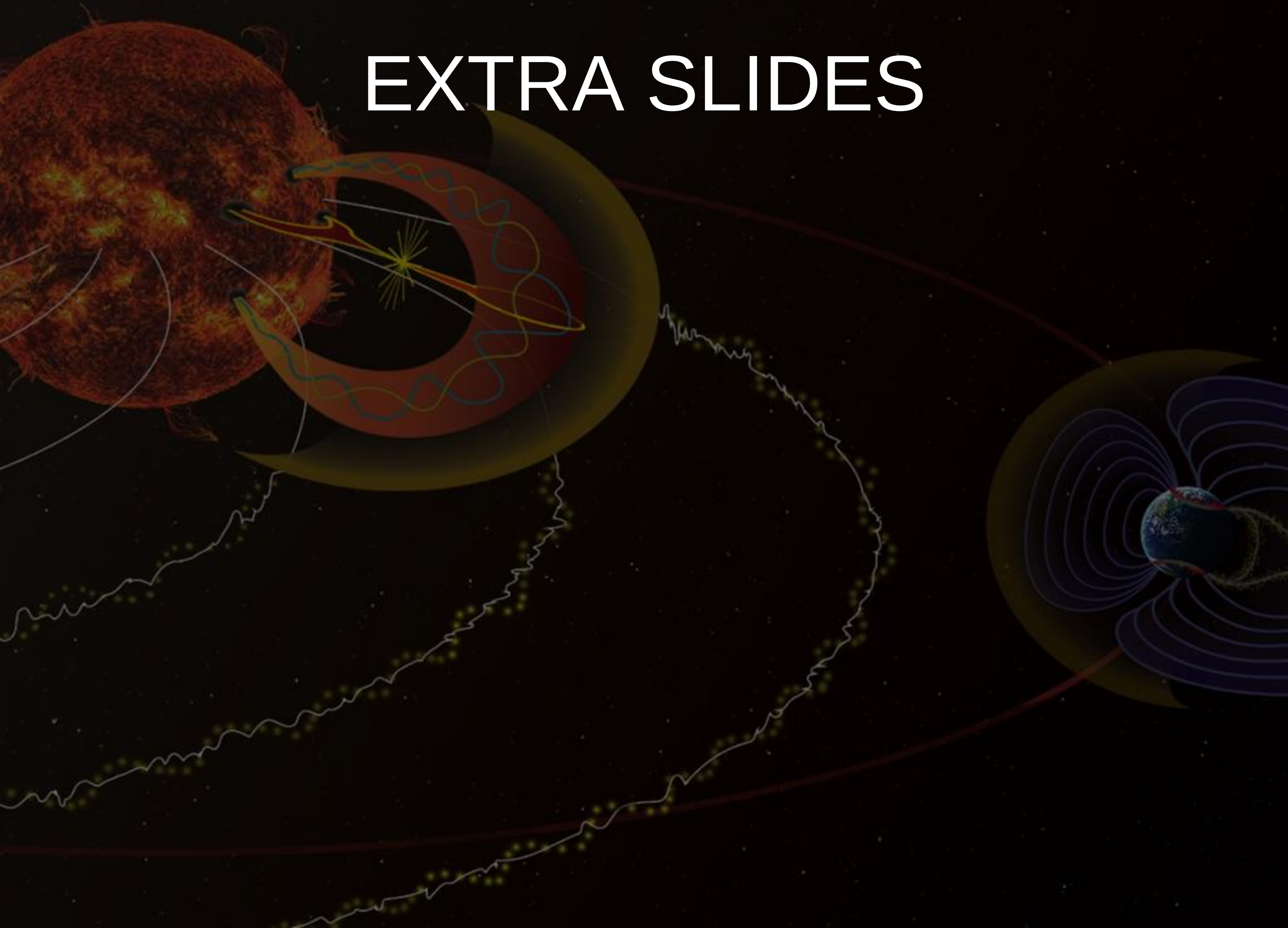
Innovative concept that tackles compelling solar and heliospheric science objectives, and space weather as bonus, through:

→ unique measurements: Lyman-α and polarized HI
→ view from L5 for system-wide science
→ launch at Solar Maximum (2021)
→ synergy/timeliness with SolO and SP+
→ large, supportive communities in EU – China (and US)

The mission proposed falls into S-class constraints

Although not selected in the ESA/China call, this concept ought to be revised and submitted in future small mission calls

EXTRA SLIDES



Summary of ESA-China S2 mission key elements

We place ourselves within the boundary conditions:

- S-class mission with 50 M€ ESA + equivalent by China
- Additional contribution to payload by national agencies
- Spacecraft mass 300 kg + possibly propulsion module
- 60 kg/65 W for payload

The proposed approach to shared contribution is:

- Launch by China (Long March)
- Platform by ESA (Myriad Evol., Proba, SSTL, …)
- Payload shared by ESA member states and China
- Ground segment shared by ESA and China

Timeline: 2015 — Selection; Development

2021 — Launch+Com.; Orbit drift

2023 — Insertion L5

2024 — End nominal mission

3-year nominal science (2021–2024)

Context

- S2: ESA S-class mission opportunity with China
- S-class mission with 50 M€ ESA + equivalent China
- Launch and payload costs may be additional
- Spacecraft mass ~300 kg + possibly propulsion module
- 60 kg/65 W for payload
- Launch in 2021

Timeline:

- First workshop in Chengdu in February 2014
- Second workshop in Copenhagen in September 2014
- Call will be issued mid-January 2015
- Proposals likely due mid-March 2015.