SDO/AIA FOV
PROBA2/SWAP FOV

Exploring the Transition Corona with the Coronal Spectrographic Imager in the EUV (COSIE)


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And the COSIE Team
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The Middle Corona: A Region in Transition

❖ Between the chromosphere-corona transition region and the nominal source surface **at ~ 2.5 solar radii there is another transition region**.

❖ Emission from the low corona is dominated by magnetically closed regions, while the outer corona has a mostly radial structure.

❖ The **transition corona** ("TC") is a dynamic portion of the atmosphere where the plasma β changes from low (β<<1) back to high (β>1), **the inverse of the lower transition region**.

❖ The topology of this region allows **solar wind and energetic particles to escape**. Mosaics of this full region with sufficient sensitivity take up to an hour to obtain.

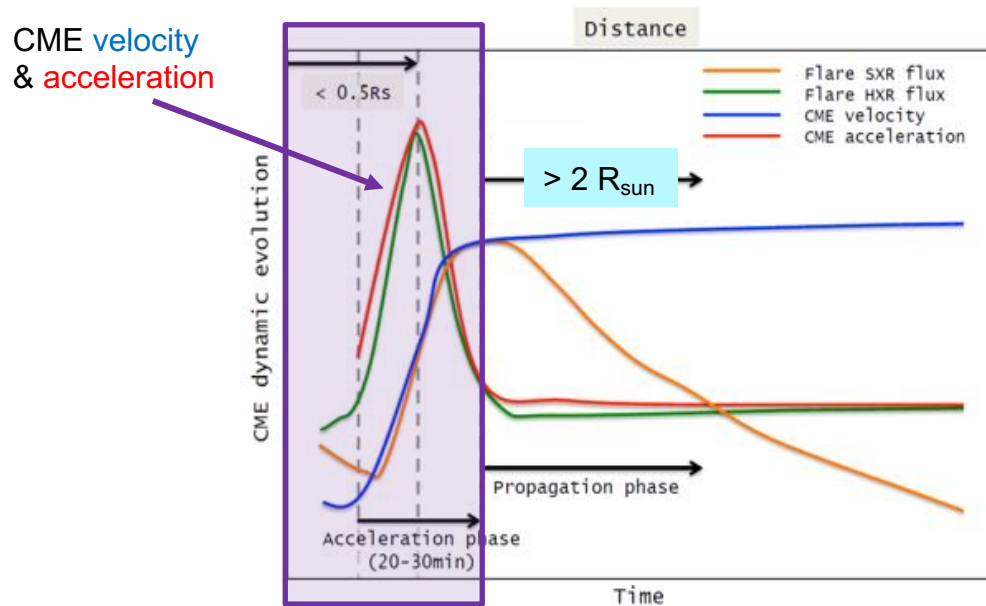AIA off-point mosaic from 2014 Nov 12.
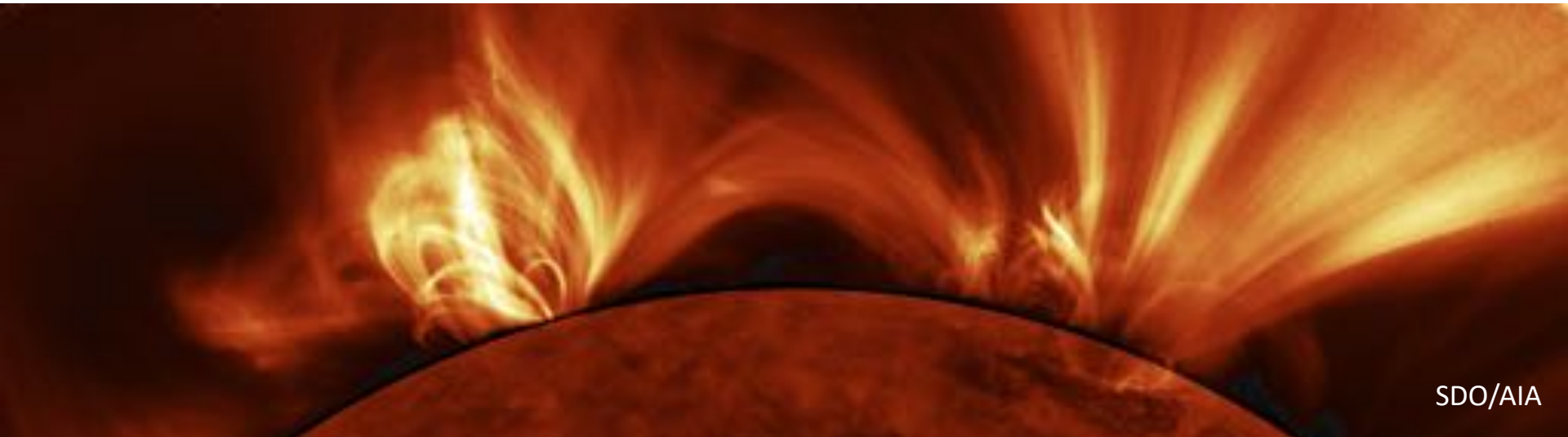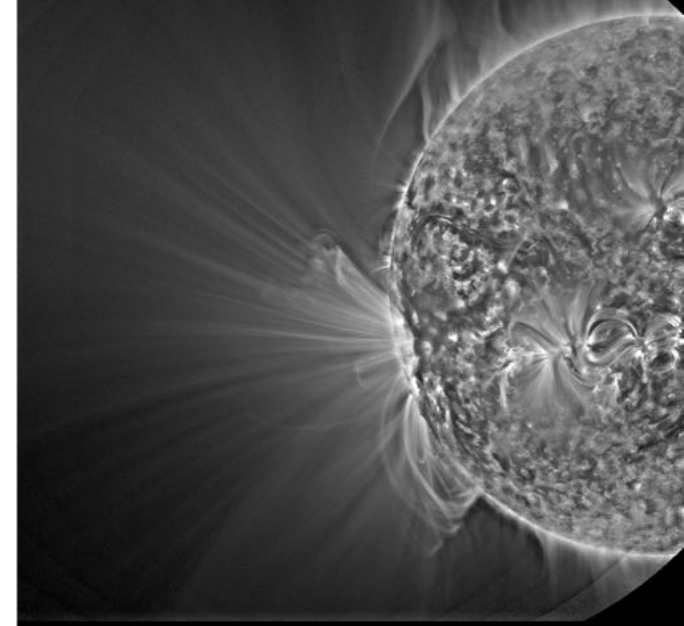
SDO/AIA

Science of the "Middle Corona"

Spaceweather events are significantly influenced by the magnetic connectivity through the middle corona:

- Acceleration, deflection, and expansion of solar wind, streamer plasmoids, and coronal mass ejections (CMEs)
- Reconnection outflows, current sheets, and the growth of post flare arcades

Kinematical properties of CMEs
(Temmer et al. 2016)

CME velocity & acceleration

Distance

< 0.5Rs

> 2 R$_{sun}$

Flare SXR flux
Flare HXR flux
CME velocity
CME acceleration

CME dynamic evolution

Propagation phase

Acceleration phase
(20-30min)

Time

Observing eruptions from the source region through the middle corona is critical to studying their evolution.
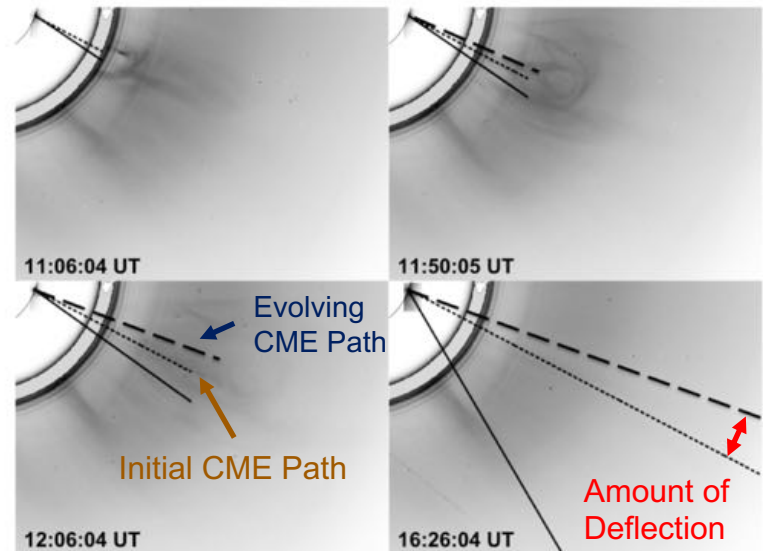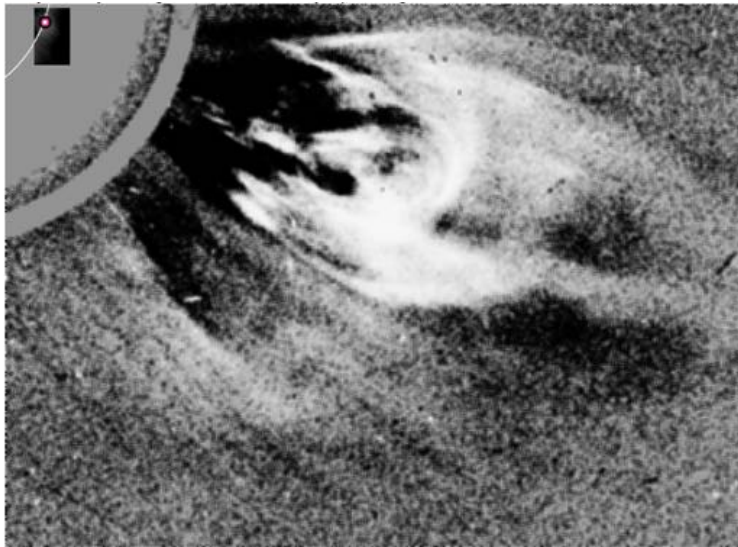
Acceleration primarily occurs within 1 R$_{sun}$.

Science of the "Middle Corona"

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2008 April 9 "Cartwheel CME" Event
Flows tracked from the Hinode/XRT field of view
out through LASCO-C2 (~2.5-6 R_{sun}).

11:06:04 UT   11:50:05 UT

Evolving CME Path

Initial CME Path

12:06:04 UT   16:26:04 UT

Amount of Deflection

Deflection from the global magnetic field topology and rotation begins between the source region and the outer corona (within 2 R_{sun}).

Savage et al. 2010

Science of the "Middle Corona"

Spaceweather events are significantly influenced by the magnetic connectivity through the middle corona:

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Science of the "Middle Corona"

2011/08/28 00:00
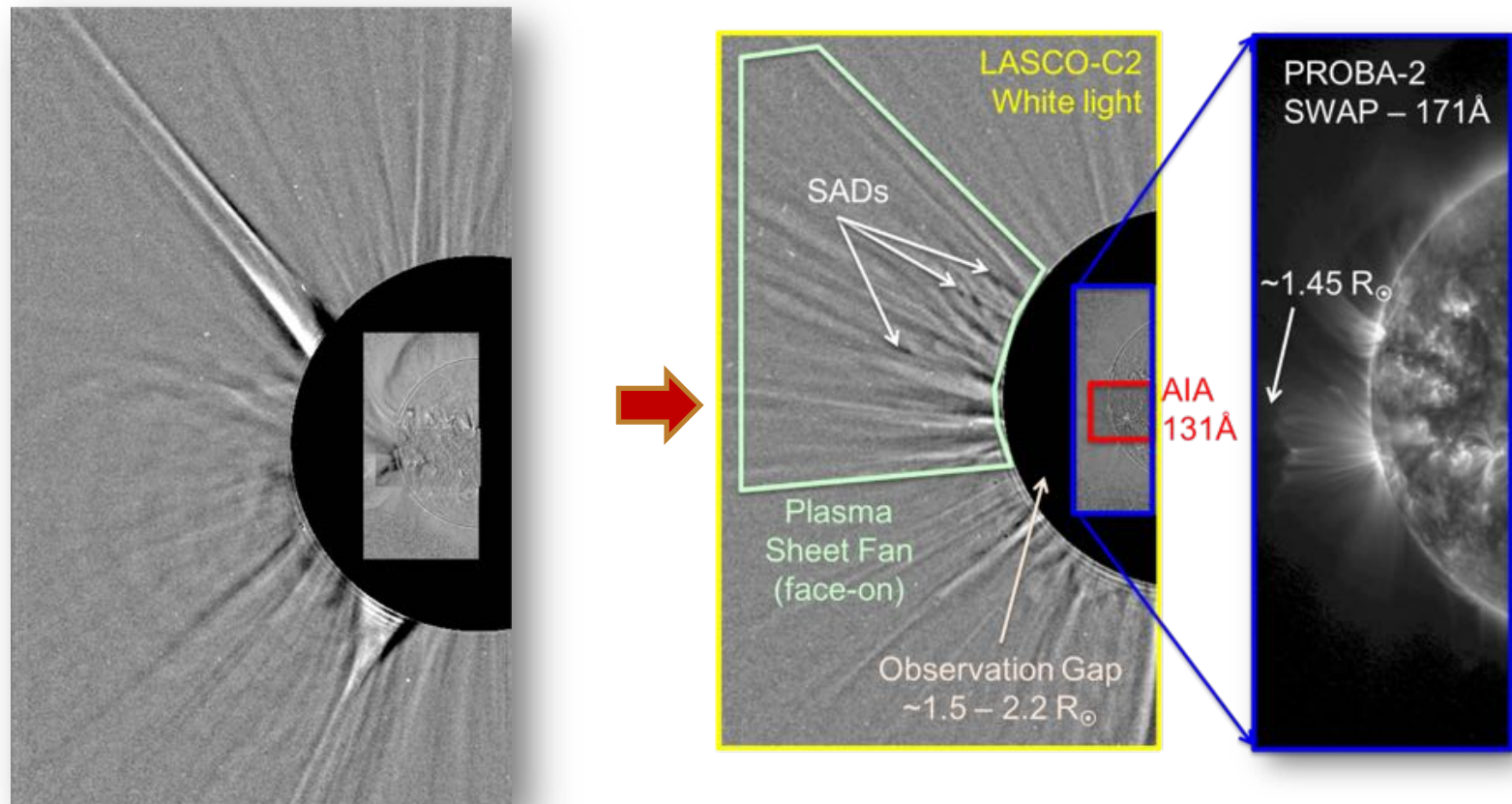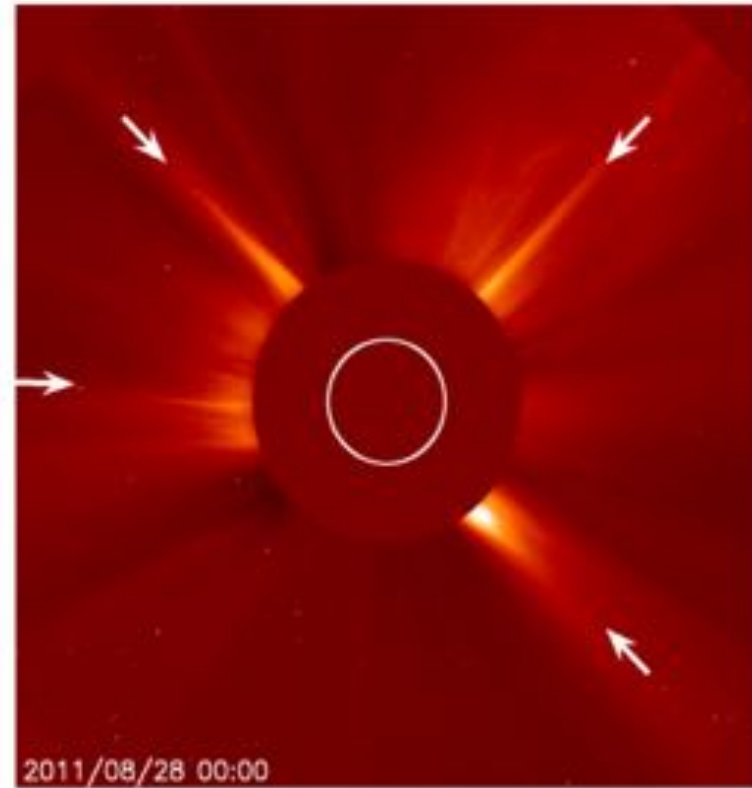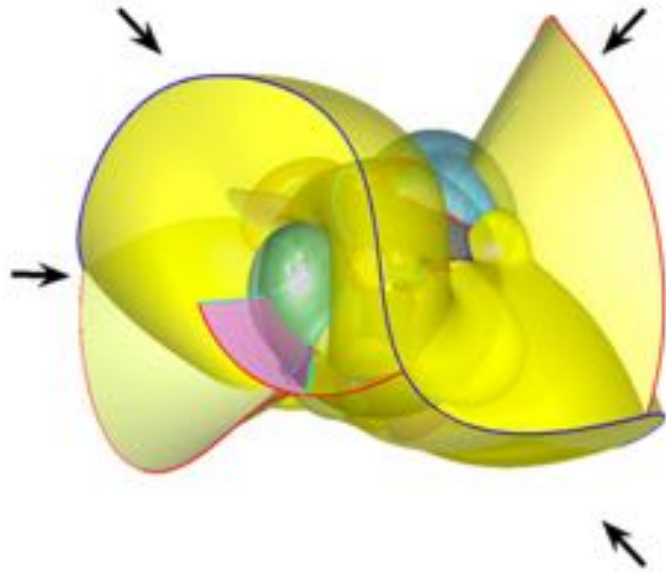
Topological modeling using a potential field source surface (PFSS) model constrained by photospheric magnetic field measurements, low coronal observations, and Large Angle Spectrometric Coronagraph (LASCO) C2 images.

EUV observations between 1.3 and 2.5 R0 will allow us to improve these models, particularly through the lower corona (DeRosa 2016; Masson et al. 2014).

Images courtesy of M. DeRosa (LMSAL).

COSIE – Targeting the Middle Corona

COSIE consists of a **wide-field extreme ultraviolet (EUV) Coronagraph** (**COSIE-C**) and a **slitless EUV Spectrograph** (**COSIE-S**), constructed to operate on the ISS. The **non-occulting design** is motivated by the need for diagnostics of space weather related activity in the low corona, **from source regions on the disk out to beyond 2.5R$_\odot$ in one single image**. Our field of view includes the critical dynamic region that controls:

SDO/AIA 171+193+211

- the location of both the fast and slow solar wind,
- the extended magnetic structures that can deflect coronal mass ejections (CMEs),
- the region where CMEs are heated and accelerated
- active regions, filaments, coronal holes, and polar plumes.

COSIE observations address how the coronal fields open and reclose in the solar atmosphere, how active regions interact with the global field, and how CMEs evolve as they accelerate through the solar atmosphere.
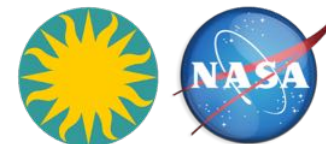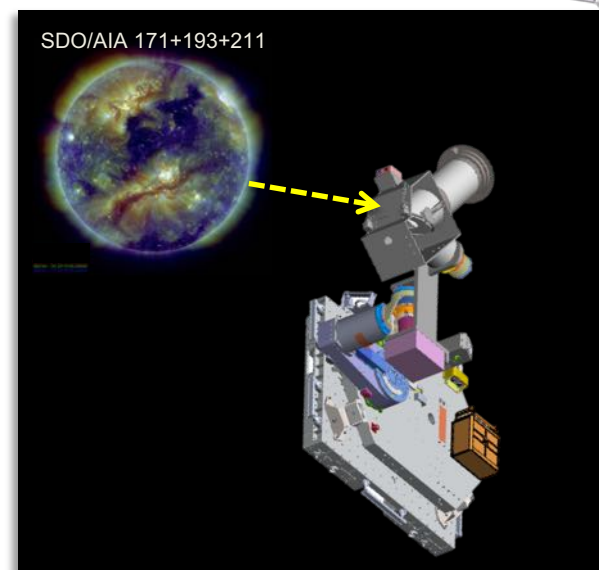
COSIE's mission goal is to understand the dynamics of the hot, magnetized solar coronal plasma. COSIE's high-cadence wide-field EUV imager (providing unprecedented imaging sensitivity) combined with full-disk spectroscopic imaging (targeting coronal and flare temperatures) enables the following **Science Objectives**:

1. Understand the processes that govern the transition between closed and open magnetic structures in the outer corona,
2. Understand the physical processes that control the evolution of CMEs in the low corona.

COSIE – Investigation Overview

The two channels, COSIE-C (coronagraph) and COSIE-S (spectrograph), which are selected by flipping a feed mirror.
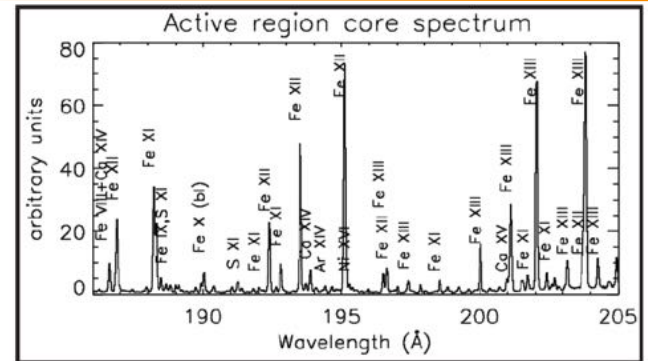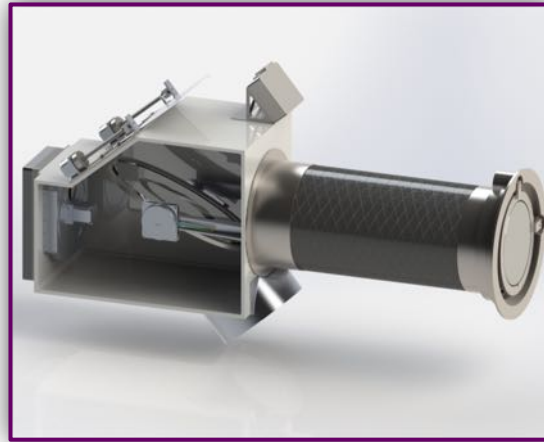
COSIE active region core spectrum (Del Zanna et al., 2018).
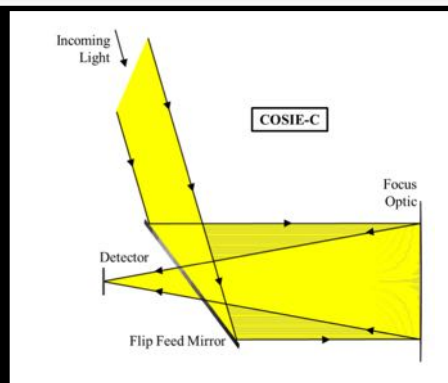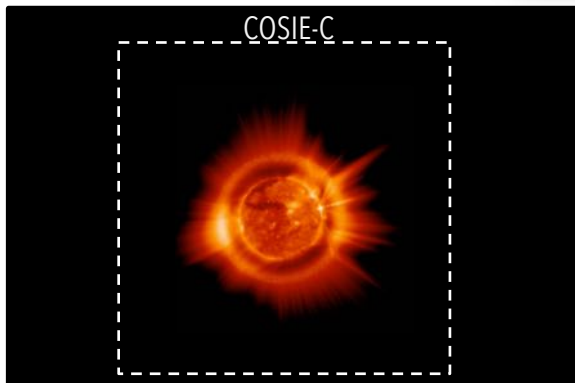
COSIE-C is not a typical "coronagraph". Rather than occulting the solar disk, the disk emission is reduced via an step filter. The **broadband filter** increases the sensitivity to hot coronal plasma by 500x over operating EUV imagers. **The result is unique wide-field imaging of the solar disk combined with the corona out to beyond 2.5 $R_\odot$.**
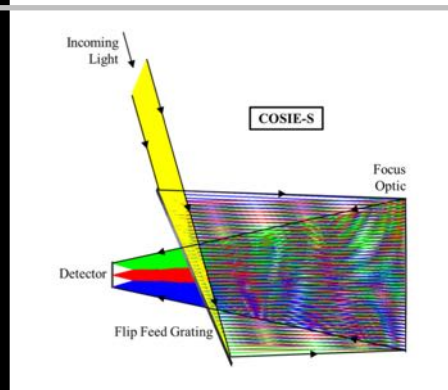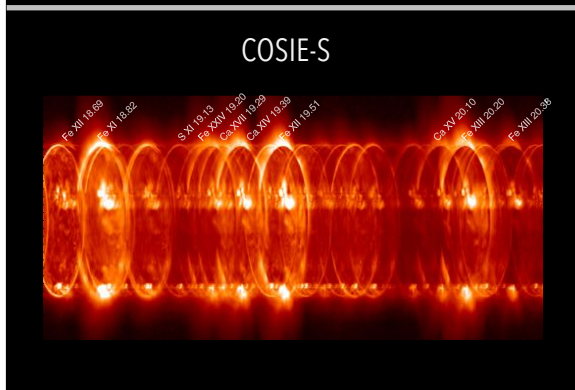
The COSIE-S channel disperses the incoming light across the passband, providing full-Sun images at many different wavelengths. Full disk density, temperature, and velocity maps can then be reduced from this data via novel de-convolution analysis software.

COSIE – Why?

Why COSIE? COSIE's **500x increase in EUV sensitivity** and improved spatio-temporal coverage compared to available coronal EUV instrumentation will answer major outstanding questions of solar wind origin, and lead to improved forecasting of geo-effective CMEs.
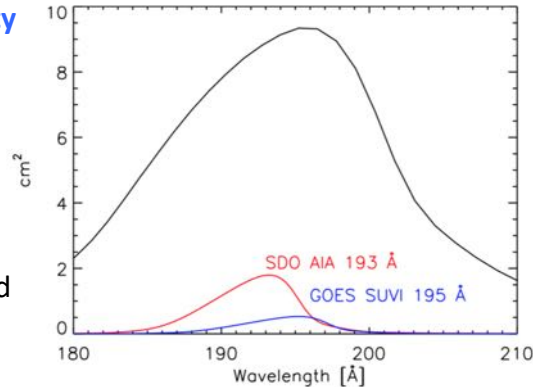

COSIE fills this gap
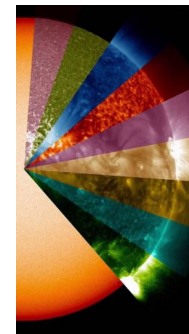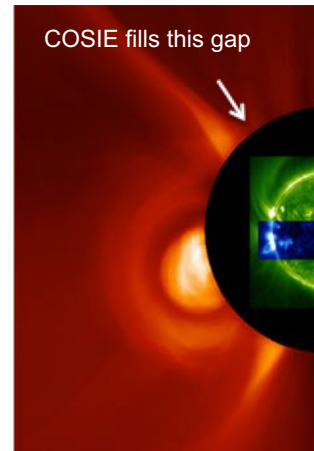
SDO/AIA
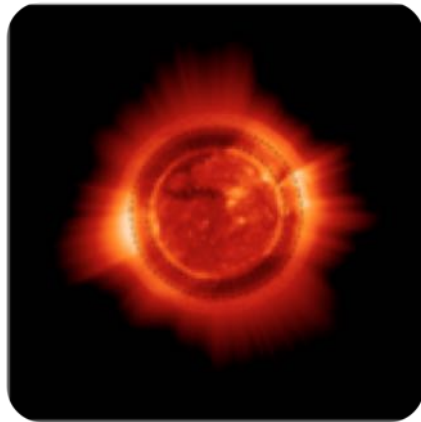Wavelength /
Phenomena Ranges

COSIE – Sensitivity & FOV

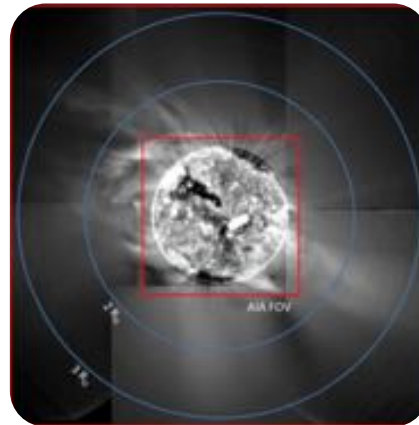**500x increase in sensitivity over an AIA EUV image due to effective area, throughput, and filter selection.**

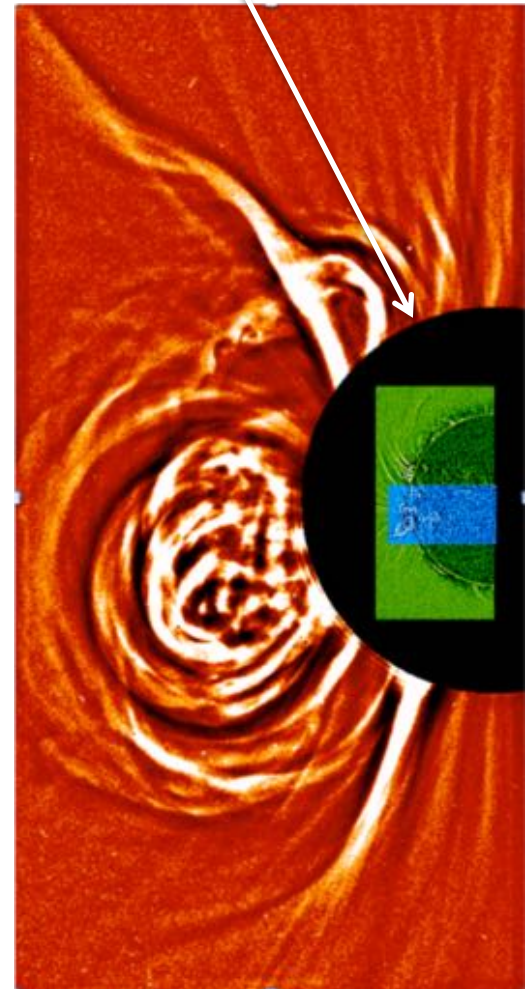COSIE-C off-disk effective area compared to SDO and GOES SUVI (Del Zanna et al., 2018).
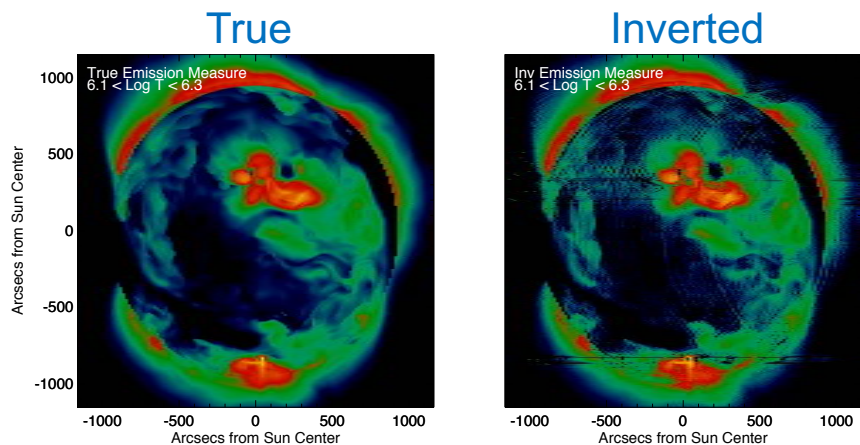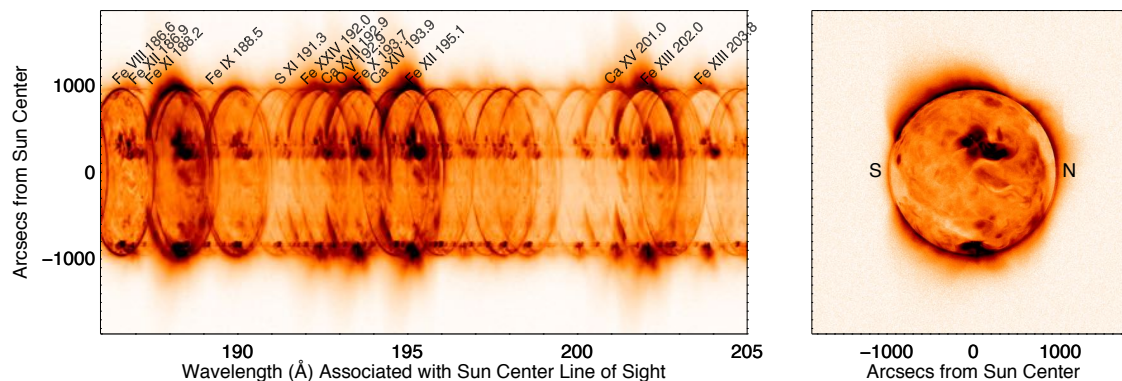

COSIE fills this gap (> 3 R_{sun} x 3 R_{sun}) with a single wavelength in a single image, meaning **UNAMBIGUOUS CONNECTIVITY.**

LASCO-C2+SWAP+AIA

COSIE – simulated, with attenuated disk

GOES mosaic – actual, less sensitivity
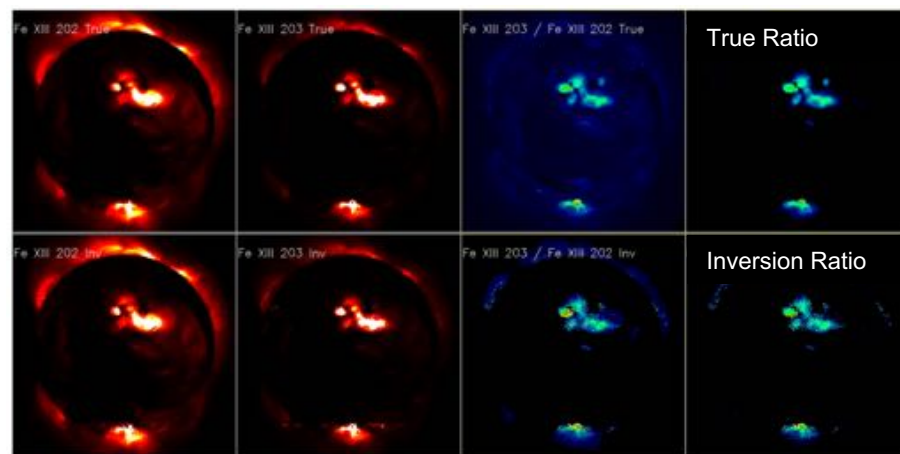
COSIE – De-convolution

Simulated COSIE-S and -C measurements used as input for the inversion code to derive **FULL-SUN** Emission Measure and Density Maps.
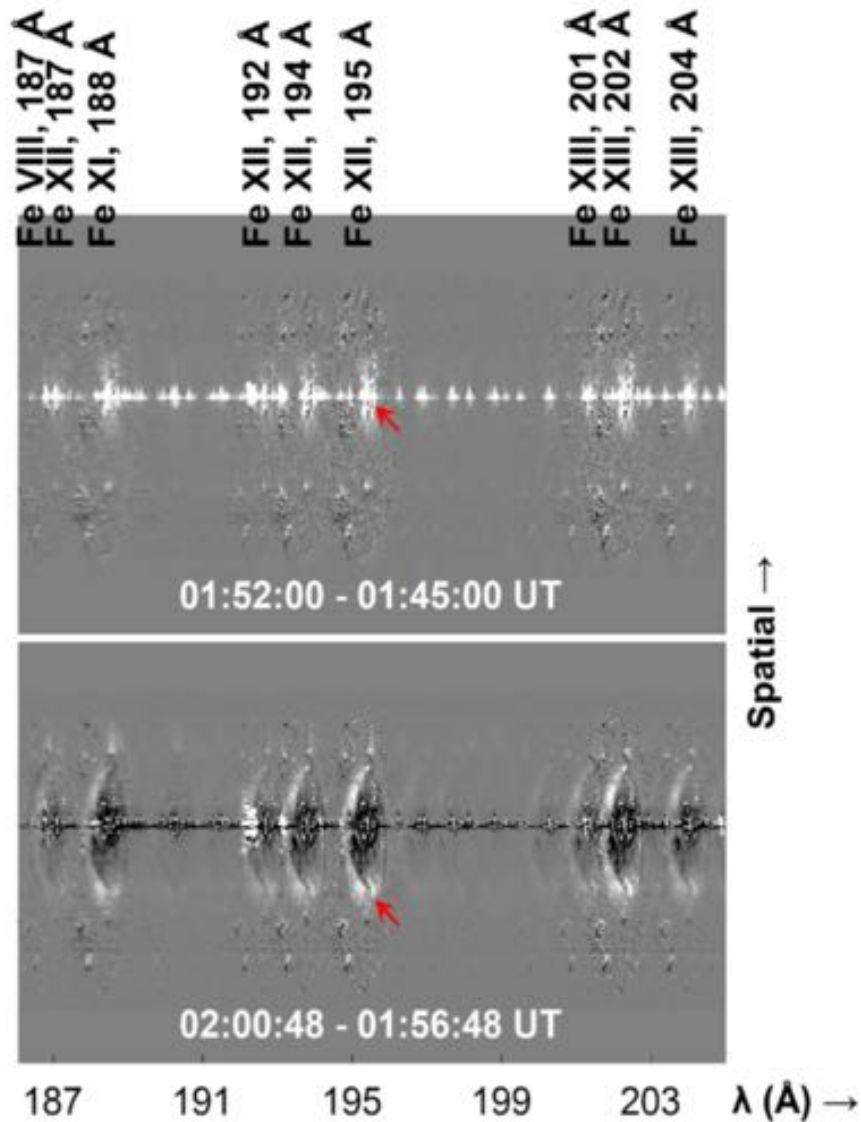

True   Inverted

True versus reconstructed (inverted) emission measure maps for temperatures of 1.2 – 2 MK.

An example of full-Sun intensity, line ratios, and densities.

Winebarger et al., 2018

COSIE-S – Full-disk Overlapping Spectral Diagnostics

Fe VIII, 187 Å
Fe XII, 187 Å
Fe XI, 188 Å

Fe XII, 192 Å
Fe XII, 194 Å
Fe XII, 195 Å

Fe XIII, 201 Å
Fe XIII, 202 Å
Fe XIII, 204 Å

01:52:00 - 01:45:00 UT

02:00:48 - 01:56:48 UT

Spatial →

187   191   195   199   203   λ (Å) →

Modeled COSIE-S observation of an EUV wave from the 2011-Feb-15 X-class flare and CME (Vanninathan et al. 2015).

***Flare* is seen as a bright or dark line** across the middle of each image.

The *wave* moves outward from the flare site, as shown by red arrow in the 195 A image.

Images courtesy of J. Samra (SAO).

COSIE – Why?

Why COSIE? COSIE's **500x increase in EUV sensitivity** and improved spatio-temporal coverage compared to available coronal EUV instrumentation will answer major outstanding questions of solar wind origin, and lead to improved forecasting of geo-effective CMEs.

Why EUV? The reduced dynamic range between the solar disk and the corona in the extreme ultraviolet (EUV) compared to white light **enables the effective use of a non-occulting step filter without the compromising effects of aperture diffraction.**

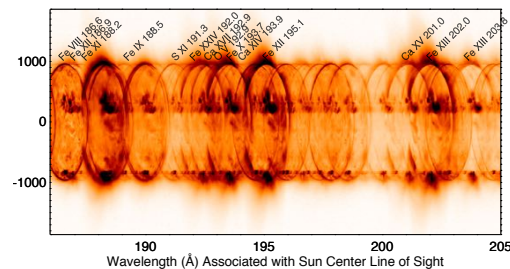

COSIE fills this gap with a consistent wavelength
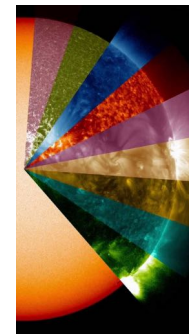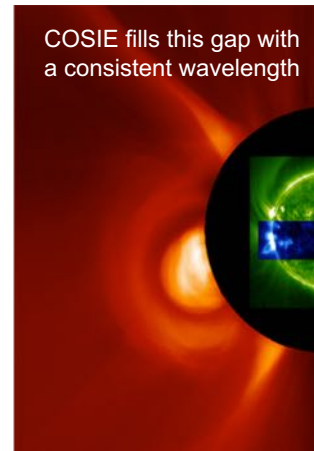
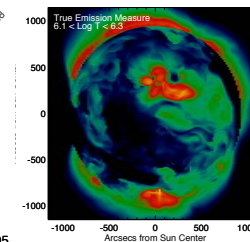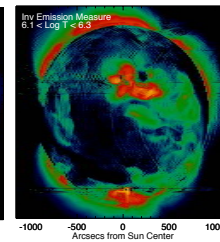SDO/AIA Wavelength / Phenomena Ranges
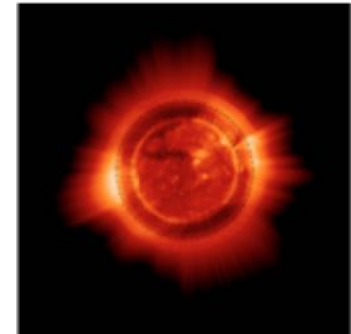
COSIE-C FOV

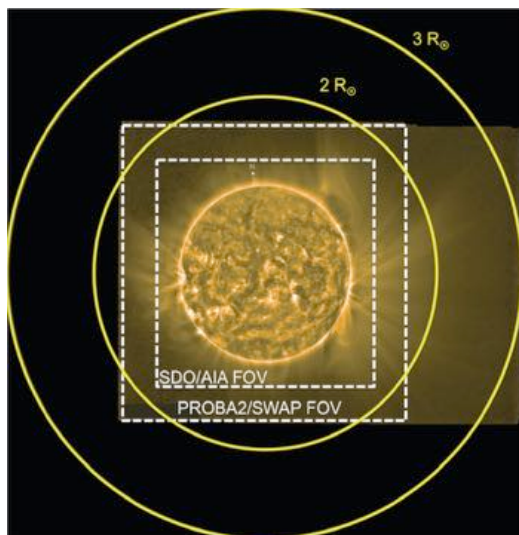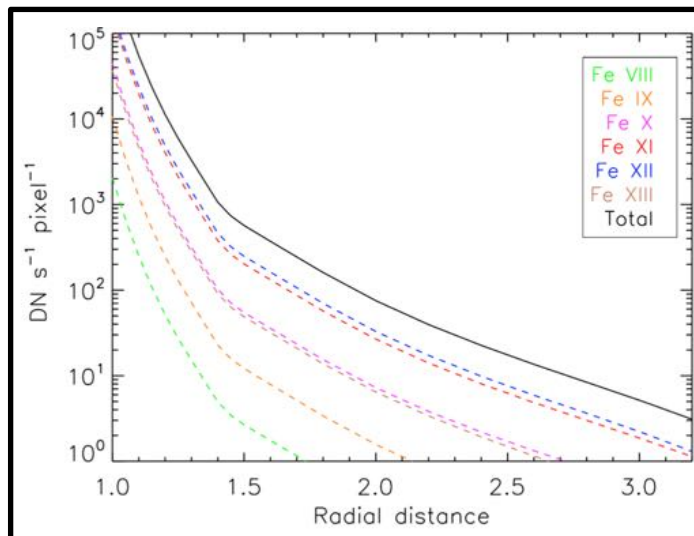COSIE-S Overlapogram

True   Inverted

The Extended EUV Corona

Observing the middle corona in EUV is scientifically attractive because the corona is **greatly extended** in this passband.

SWAP 174 mosaic. EUV streamer emission visible beyond 2 $R_\odot$ (c/o D. Seaton [CU/NOAA]).

Estimated Quiet Sun off-limb count rates for COSIE-C (Del Zanna et al., 2018).
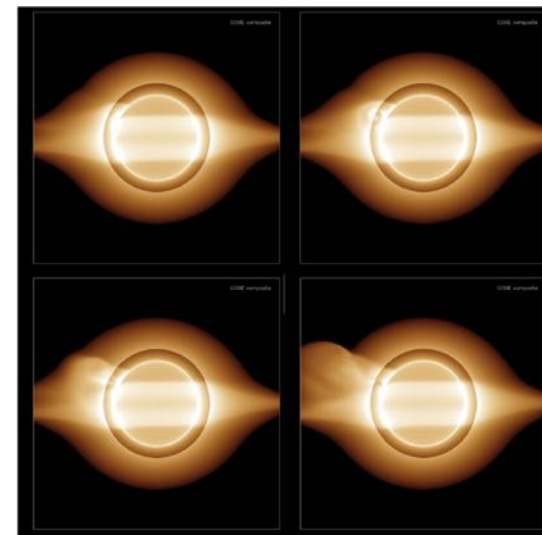
A simulation of coronal streamers and a CME folded through the COSIE-C response function (c/o K. Reeves [SAO]).

❖ The fall-off is less steep than in white light. **Disk/Coronal brightness varies by a small factor in the EUV** (vs. 10^6 in white light).

❖ EUV structures are highly dynamic and magnetically variable.

❖ **Dynamic events observed at all position angles around the limb**.

COSIE – Why?

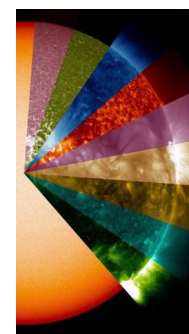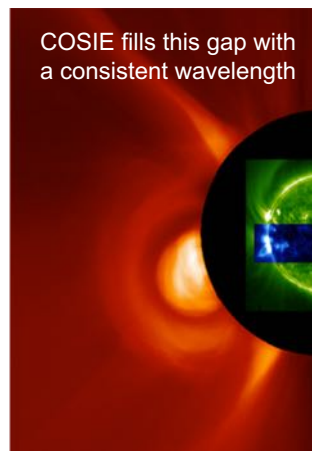**Why COSIE?** COSIE's **500x increase in EUV sensitivity** and improved spatio-temporal coverage compared to available coronal EUV instrumentation will answer major outstanding questions of solar wind origin, and lead to improved forecasting of geo-effective CMEs.
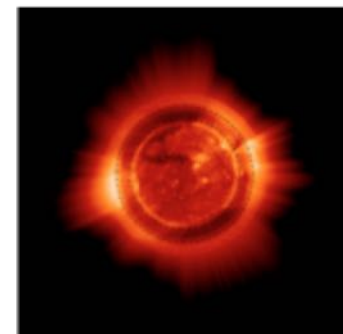
Why EUV? The reduced dynamic range between the solar disk and the corona in the extreme ultraviolet (EUV) compared to white light **enables the effective use of a non-occulting step filter without the compromising effects of aperture diffraction.**

Why now? Space weather forecasting is a high-priority national issue, and developing the **next generation of forecasting models** requires observations that fill the gap between the disk and the outer corona.

Why ISS? The ISS provides a low cost **unique observing platform that offers an excellent option for testing cutting edge instrumentation** prior to investing into a free flying spacecraft. It offers high data rates and ample power **at an altitude compatible with high energy observations**. The orbital day/night cycles do not compromise COSIE science, as nearly all departing CMEs will be detected.
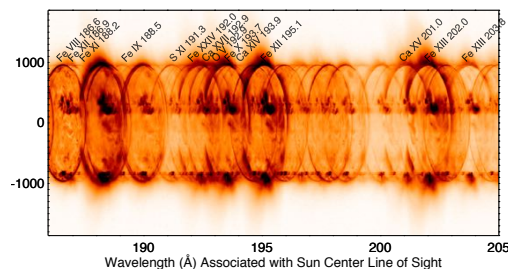

COSIE fills this gap with a consistent wavelength

SDO/AIA Wavelength / Phenomena Ranges

COSIE-C FOV

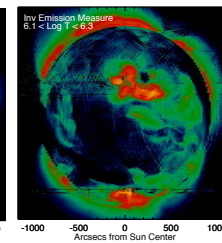### COSIE-S Overlapogram

Wavelength (Å) Associated with Sun Center Line of Sight

True   Inverted

Arcsecs from Sun Center
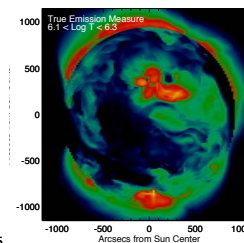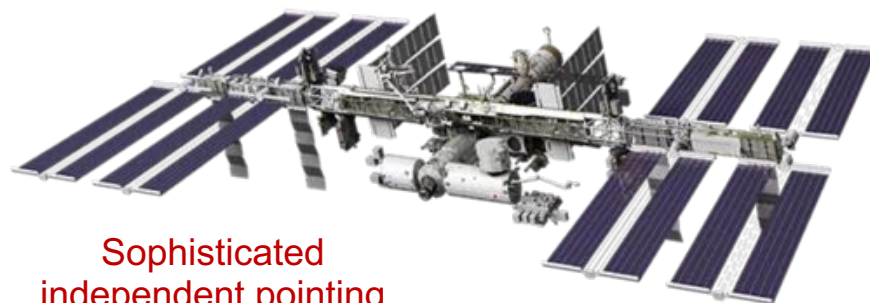
Sophisticated independent pointing system required!

COSIE – Capturing Events on the ISS

A comparison of TIMESCALES for COSIE (left) and Solar Targets (right).

Instrument	Target
	Active Longitudes (~2-3yr)
Nominal Mission Lifetime (2 yr)	
Minimum Mission Lifetime (6mos)	CH Evolution (2-6mo)
	Solar Rotation (27d)
	AR Evolution (3-12d)
	Emerging Flux (1-3d)
	CME Transit Time (0.6-8hrs)
Orbit (90m)	
	Flare Duration (10-60m)
Time on Target (10-40m)	
	Wave Periods (300s)
	AR Jets (30-300s)
	AR Transient Loop Brightening (10-60s)
Cadence (4-20s)	

Log(Time) [s]: 8, 7, 6, 5, 4, 3, 2, 1

Well-observed over multiple orbits on the ISS.

Well observed in a single orbit on the ISS.

Table courtesy of E. DeLuca (SAO).

COSIE – CME Detection Percentages

Dots show COSIE measurements made 30 seconds apart (CY 2011 data set).

CMEs taken from SAO filament eruption catalog: http://aia.cfa.harvard.edu/filament/ and CACTus.
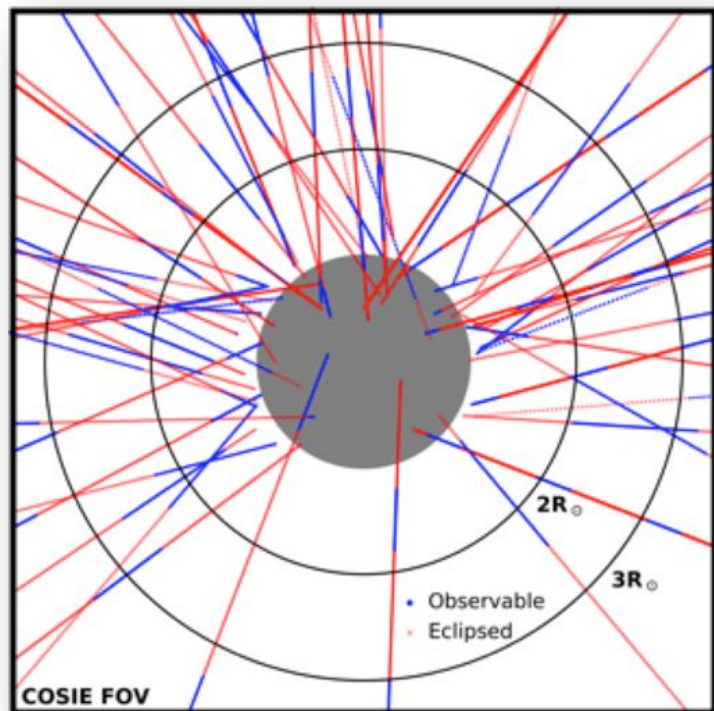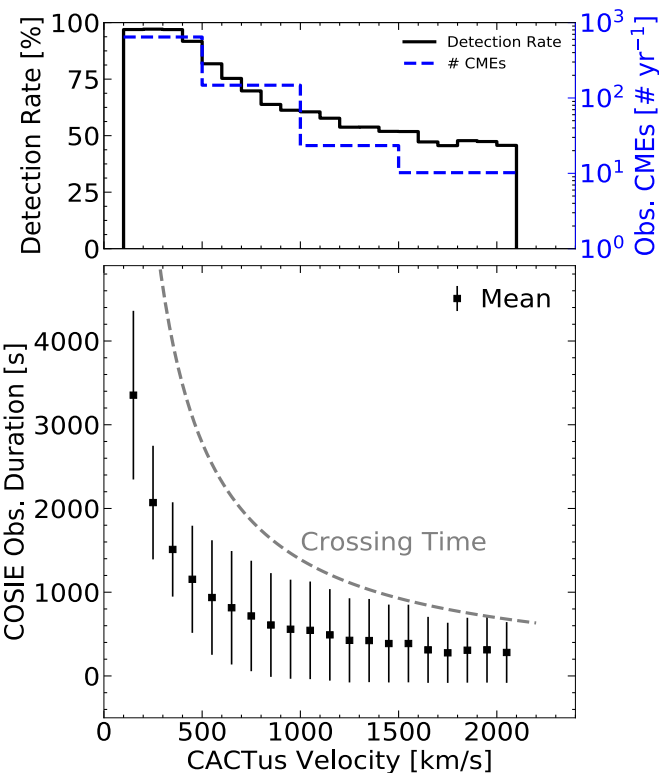

The COSIE mission will observe ~10 fast CMEs (>1000 km/s) within a third of a year of observing time and nearly all slow CMEs (<1000km/s). Within the COSIE field of view (FOV) at right are shown representative CME trajectories. Blue indicates observed periods. Red indicates when COSIE is eclipsed.

COSIE – Summary of Mission Goals | Now & Later

1. Determine the magnetic connectivity between the lower and outer corona where the transition between open and closed magnetic fields occur.

2. Characterize the magnetic topology and dynamic evolution of slow solar wind sources.

3. Trace the early evolution of coronal mass ejections and prominences as they propagate into the interplanetary medium and create space weather.

COSIE is a relatively compact instrument **suitable for providing full-disk, wide field context for hot plasmas in the corona to any complementary Explorer size mission**.

Excellent candidate for an L5 mission. L4 even better due to availability of magnetic history from Earth's line of sight? **Coupling with a white light coronagraph would increase scientific return**.

Thanks

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