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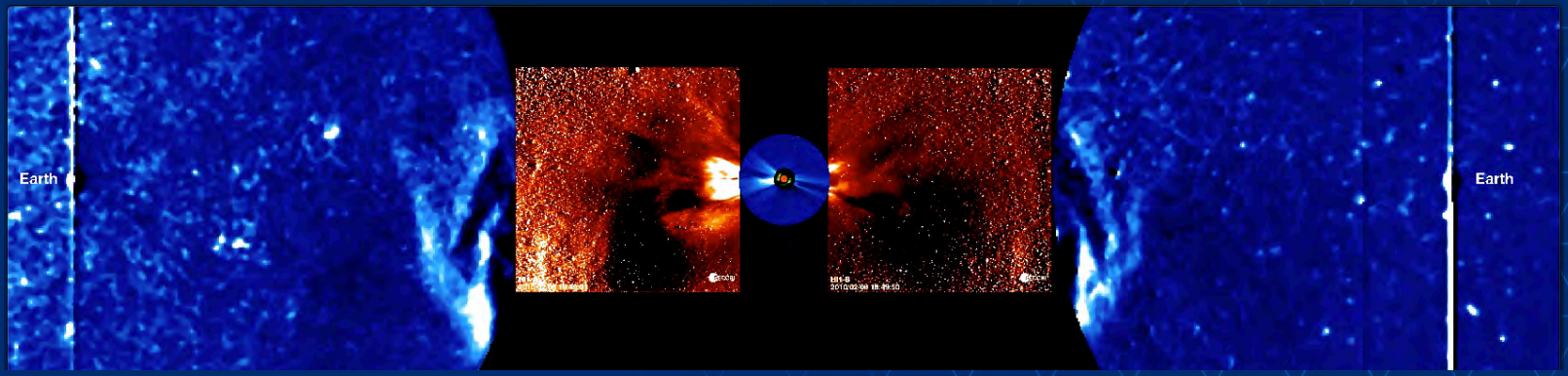


# Imaging the Solar Wind From Space

## Where do we stand?

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# Covered Topics

- **What have CORs & HIs done for Heliophysics?**
  - 'paradigm' shifts in understanding solar activity and the solar driving of the heliosphere

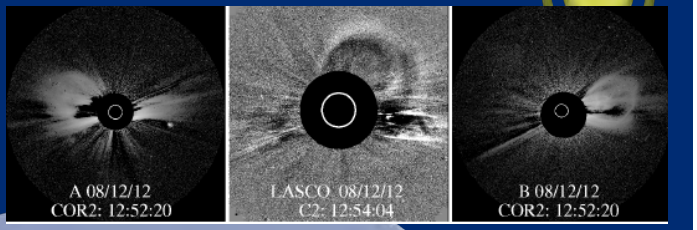
- **What is still missing?**
  - Key knowledge gaps

- **What are the 'lessons learned'?**
  - Where and how to observe with COR/HI telescopes

- **Where do we go next?**
  - The next frontier(s)

# ‘Paradigm Shift’: Coronal Mass Ejections

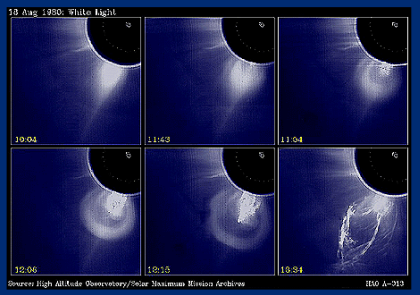
COR imaging remains the main ‘means’ of CME observations



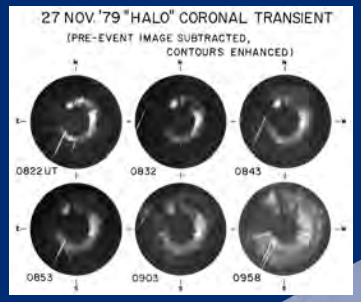

2007- : CMEs in 3D

1996- : CMEs across 2 cycles & over the full corona

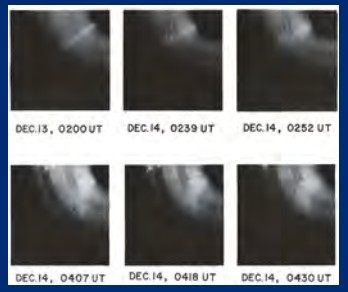

1980s: CMEs in the inner corona



1980s: Halo CMEs




1971: Discovery!



# ‘Paradigm Shift’: Space Weather

## COR/HI Imaging raised Space Weather to the center of Research and Society

### 5.3 Establish and Sustain a Baseline Observational Capability for Space-Weather Operations

To ensure that an extreme space-weather event is detected before it affects Earth, and to enable future improvements while maintaining current levels of products and services, the United States must establish and sustain a set of baseline space- and ground-based observations. These platforms must meet reliability standards to ensure the observing systems reliably deliver the data and data-derived products. The associated data reception, relay, processing, assimilation, and archiving infrastructure required to utilize space-weather observations must also be included in the baseline.

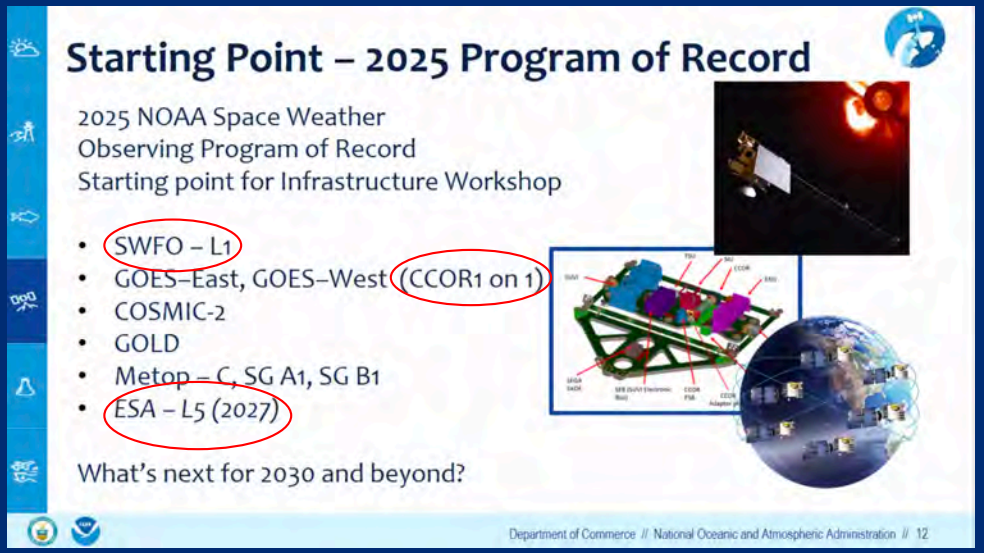
The following two actions are priorities to sustain current operational observing capabilities:

5.3.1 DOC, NASA, and NSF will develop a strategy for: (1) the continuous operation of the Solar and Heliospheric Observatory/Large Angle and Spectrometric Coronagraph (SOHO/LASCO) for as long as the satellite continues to deliver quality observations; and (2) prioritizing the reception of LASCO data in anticipation of extreme space-weather events.

Deliverable: Complete strategy to sustain SOHO/LASCO operations

Timeline: Within 1 year of the publication of this Action Plan

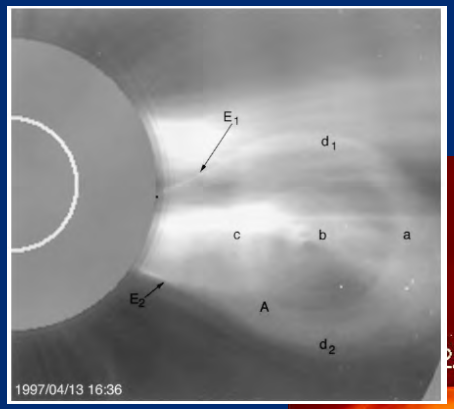
From 2015 SpW Action Plan



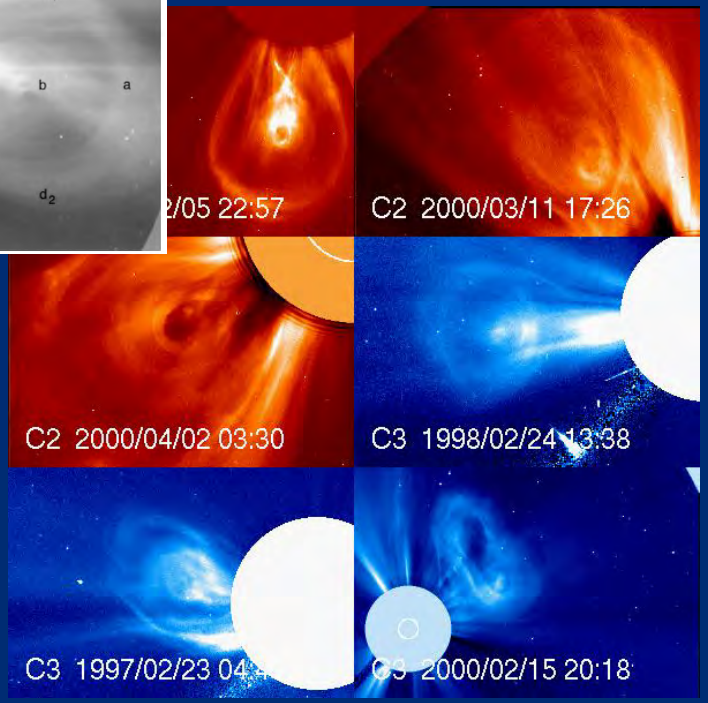

From E. Talaat’s presentation at NAS on 9/9/20

# ‘Paradigm Shift’: CME Structure

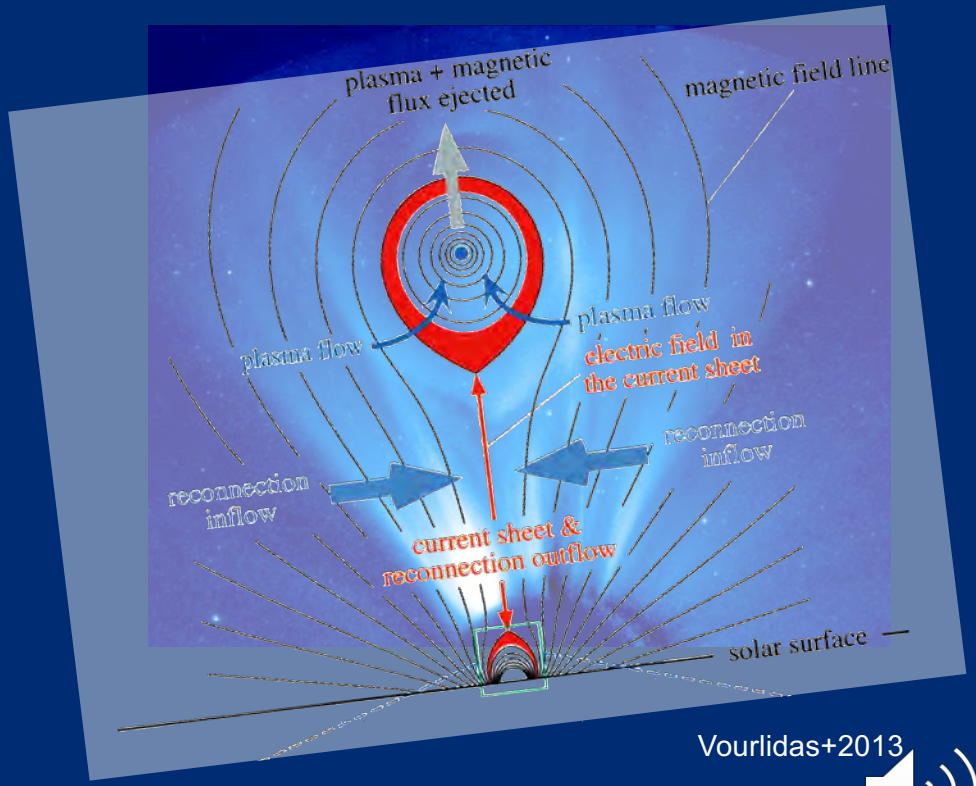
## CMEs contain Magnetic Flux Ropes (as theory predicts)




Chen+1997




Vourlidas+2000

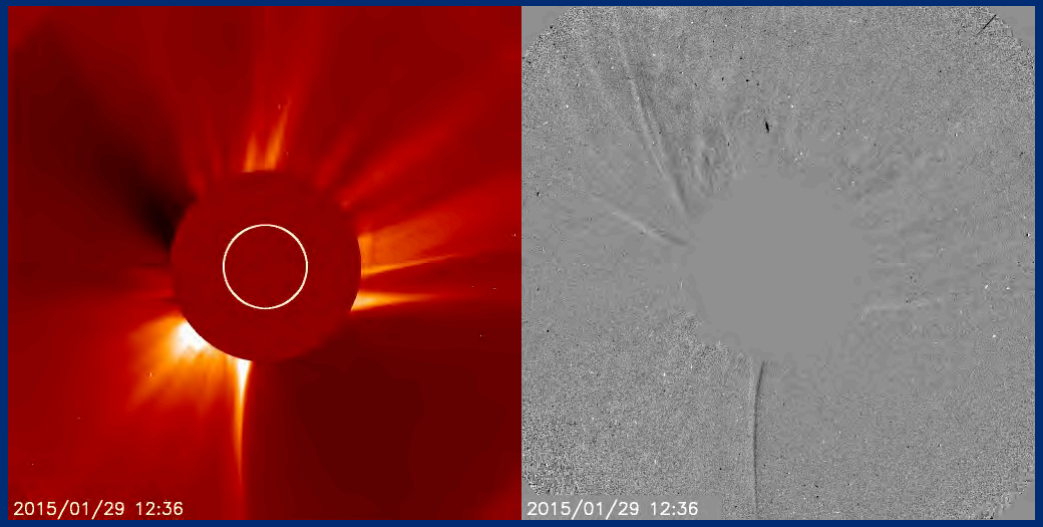



Vourlidas+2013

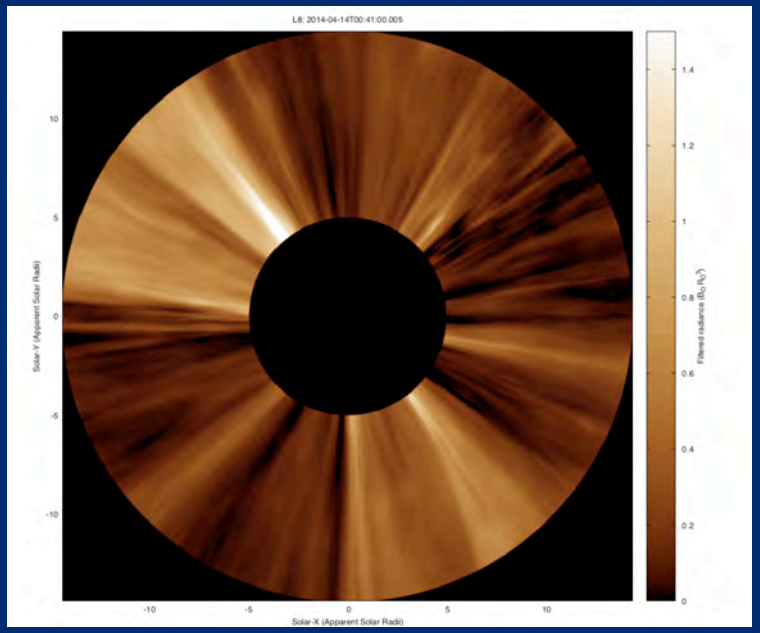
# ‘Paradigm Shift’: Dynamic Corona

## CMEs, Jets, Waves, Blobs…

LASCO revealed an unexpected level of variability



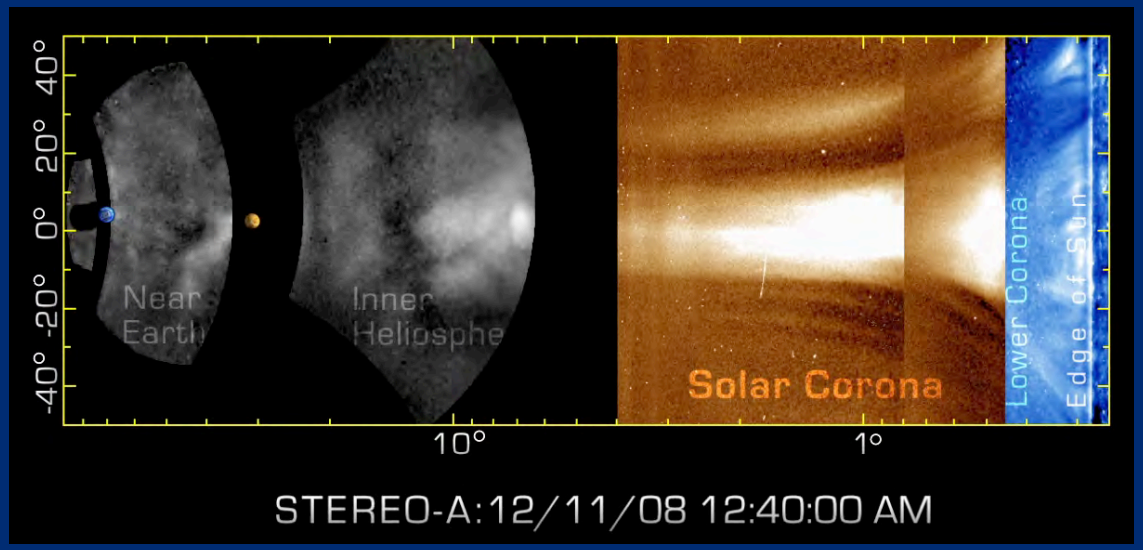

…that remains obvious even at 5-min cadence



DeForest+ 2018

# ‘Paradigm Shift’: Imaging the Solar Wind

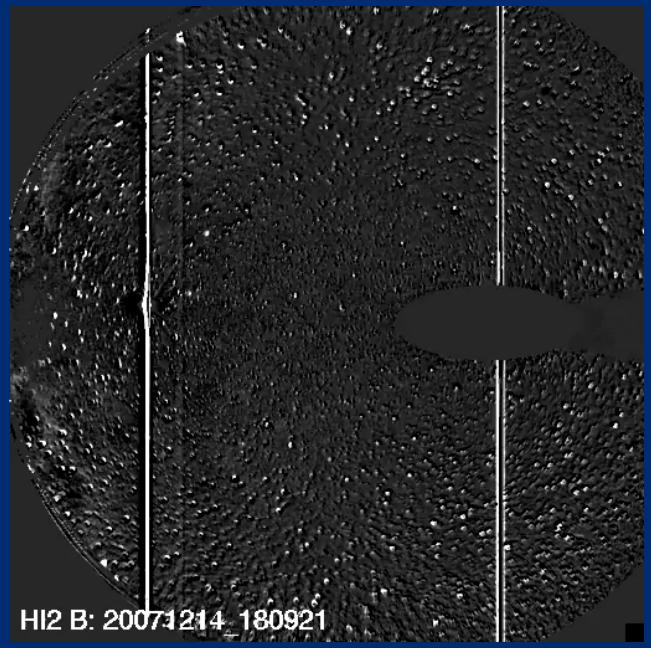
## Heliospheric imaging offers a new way to study the inner heliosphere




Tracking solar wind from Sun to 1 AU

DeForest+2012

First Imaging of SIRs



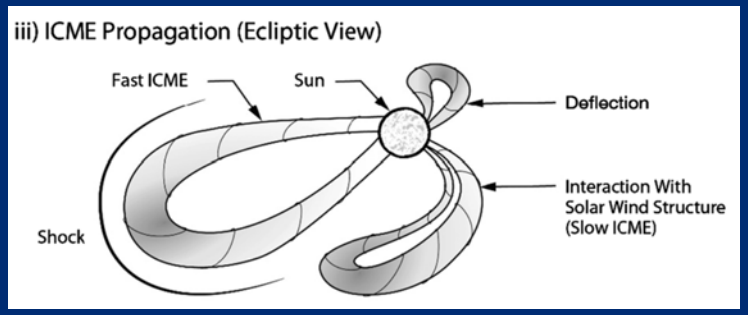

Sheeley+ 2008

# What are we missing?

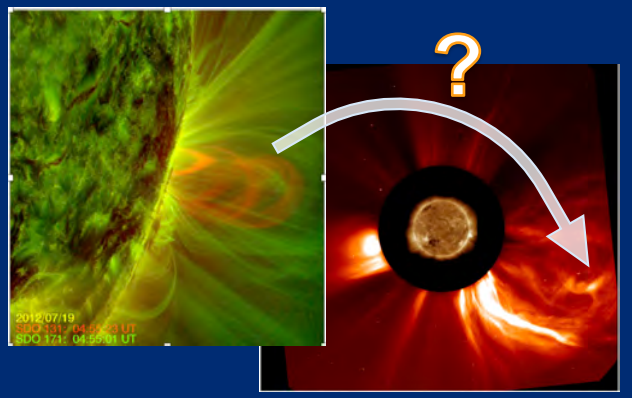
## Top-level knowledge gaps in 2020

- **The interaction challenge**
  - CME-CME
  - CME-Solar Wind
  - CME-Magnetic Field

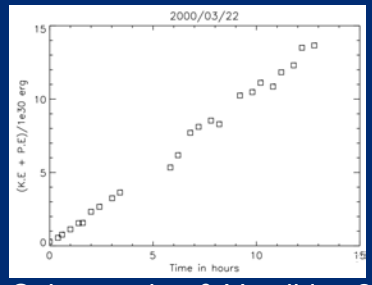
Luhmann+2020




- **The inner corona challenge**
  - What really happens between ~1.3 and 3-4 Rs?



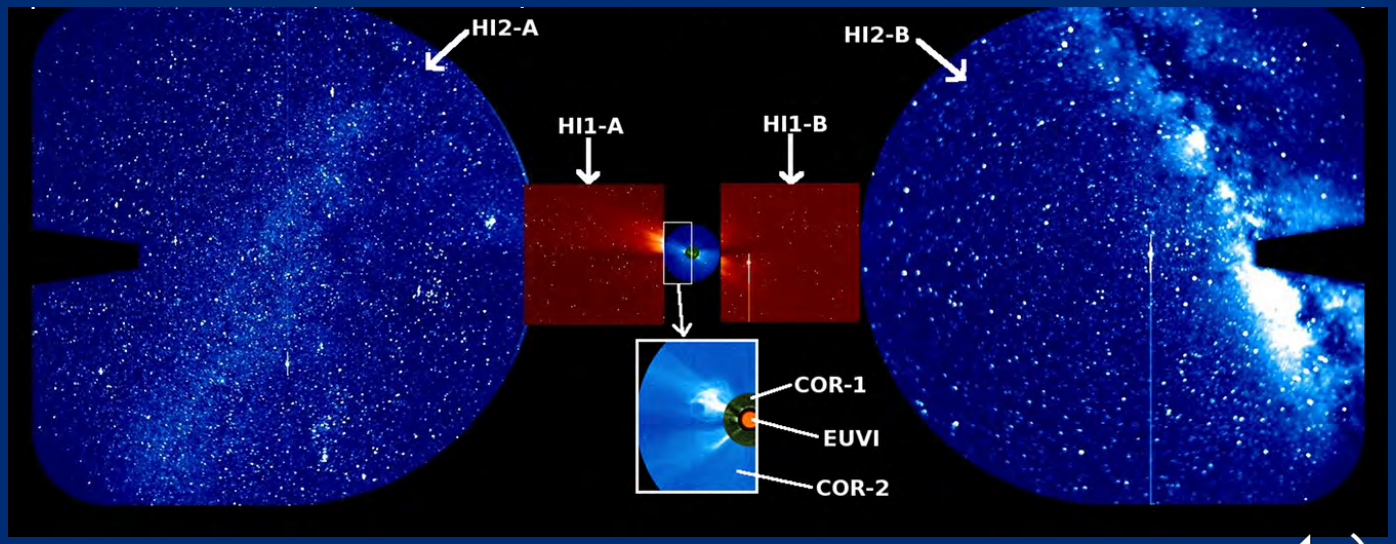

- **The physics challenge**
  - Energy budgets and force-balance




Subramanian & Vourlidas 2007

# 'Lessons—learned'

- **Viewpoint, Viewpoint, Viewpoint**
- **24x7 and synoptic observations are indispensable.**
- **Full view around the Sun**
  - CORs are better than His
- **Image beyond 15 Rs**
  - To ensure proper CME kinematics, morphology, shock formation



# Where do we go next?

## Expand beyond Visible, beyond imaging, beyond the ecliptic

- **The inner corona challenge**
  - What *really* happens between ~1.3 - 4 Rs?

→

- **Uninterrupted** imaging from surface to >4 Rs
  - EUV+COR or COR-only
- **Stereoscopic** imaging of the source regions
  - EUV

- **The interaction challenge**
  - CME-CME
  - CME-Solar Wind
  - CME-Magnetic Field

→

- **High SNR** HI imaging
  - At COR spatial res; from 2 viewpts, preferrable
- **Out-of-Ecliptic (>60°)** COR/HI imaging
  - To 0.5 AU
- **Multi-viewpoint** imaging < 3-4 Rs

- **The physics challenge**
  - Energy budgets and force-balance

→

- **off-limb** spectroscopy of inner corona
- **upper chromospheric** magnetic fields
- **Tighter integration** of models & observations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