Imaging the Solar Wind From Space: Where do we stand?

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November 15, 2022

Abstract

Next year marks the 50th anniversary of the detection of Coronal Mass Ejections from space. The discovery and subsequent observations of thousands of events from a stream of coronagraph telescopes marked a paradigm shift of our view of the corona, from a physical system changing gradually over a solar cycle, to a system marked with explosive transient activity on timescales from seconds to days to months. Thanks to coronagraphs, and more recently EUV imagers, Space Weather forecasting and research have become strong research areas within the Heliophysics discipline. adding to that, the transients and even the more quiescent background wind can now be imaged directly in the inner heliosphere thanks to the advent of heliospheric imaging since the mid-2000s. The recent deployment of the Parker Solar Probe and Solar Orbiter missions ushers a new era of coronal/heliospheric imaging from widely varying vantage points along with future missions, such as PUNCH, and operational mission at the L1 and L5 point. It is, therefore, an appropriate time to take stock of the lessons learned from the decades of imaging of the solar wind, both quiescent and transient. In this talk, I review those lessons/learned and discuss where to go next.

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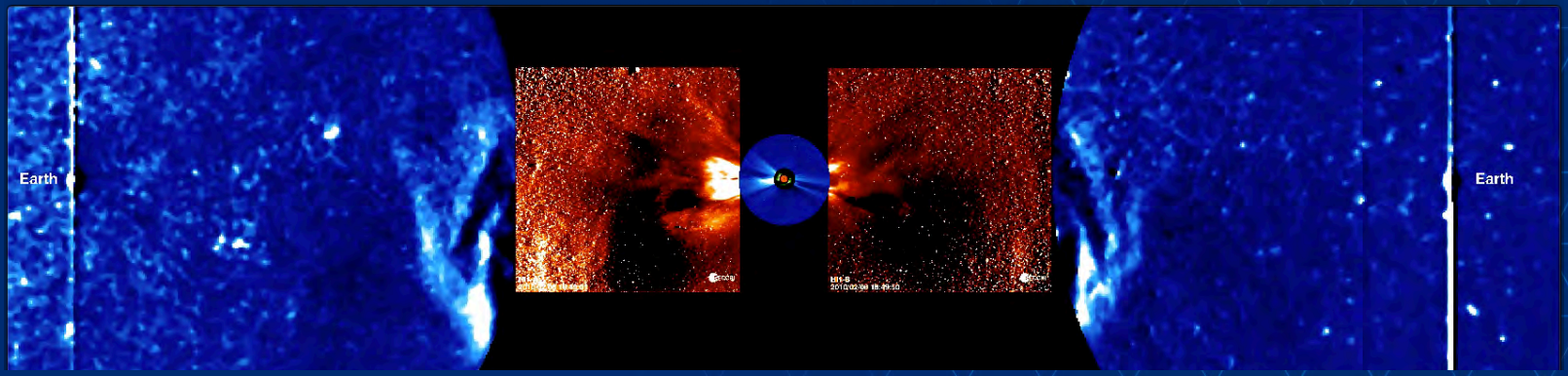

Imaging the Solar Wind From Space

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

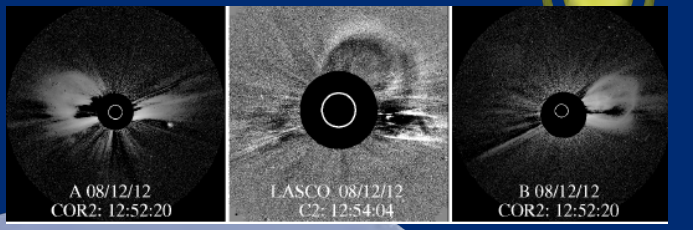
- **What is still missing?**
  - Key knowledge gaps

- **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

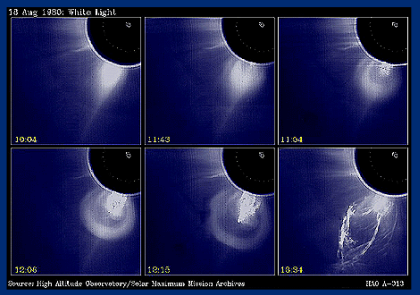
COR imaging remains the main ‘means’ of CME observations



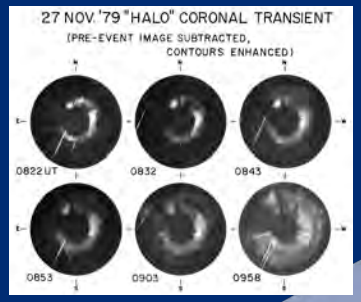
2007- : CMEs in 3D

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

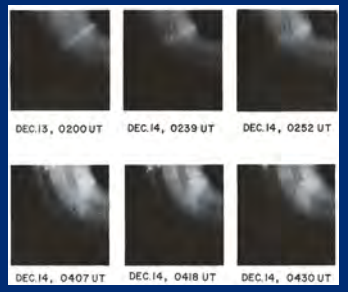
1980s: CMEs in the inner corona



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.

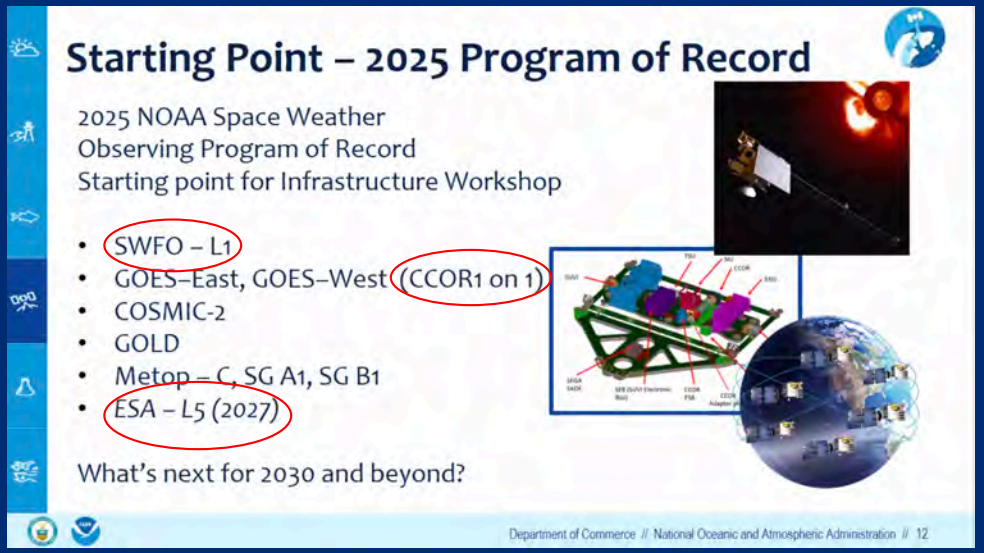
The following two actions are priorities to sustain current operational observing capabilities:

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

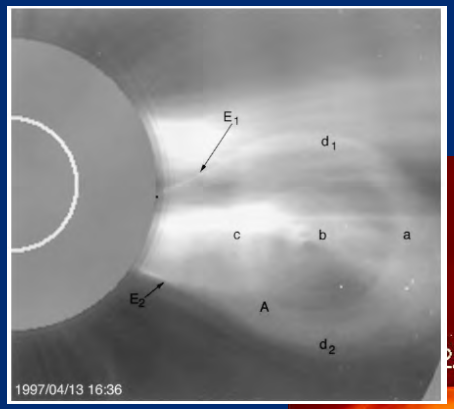
From 2015 SpW Action Plan



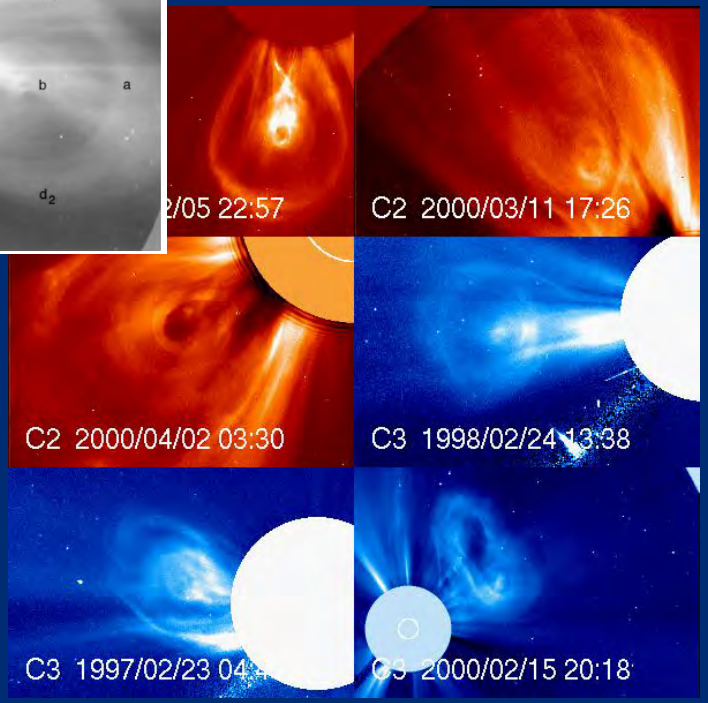
From E. Talaat’s presentation at NAS on 9/9/20

‘Paradigm Shift’: CME Structure

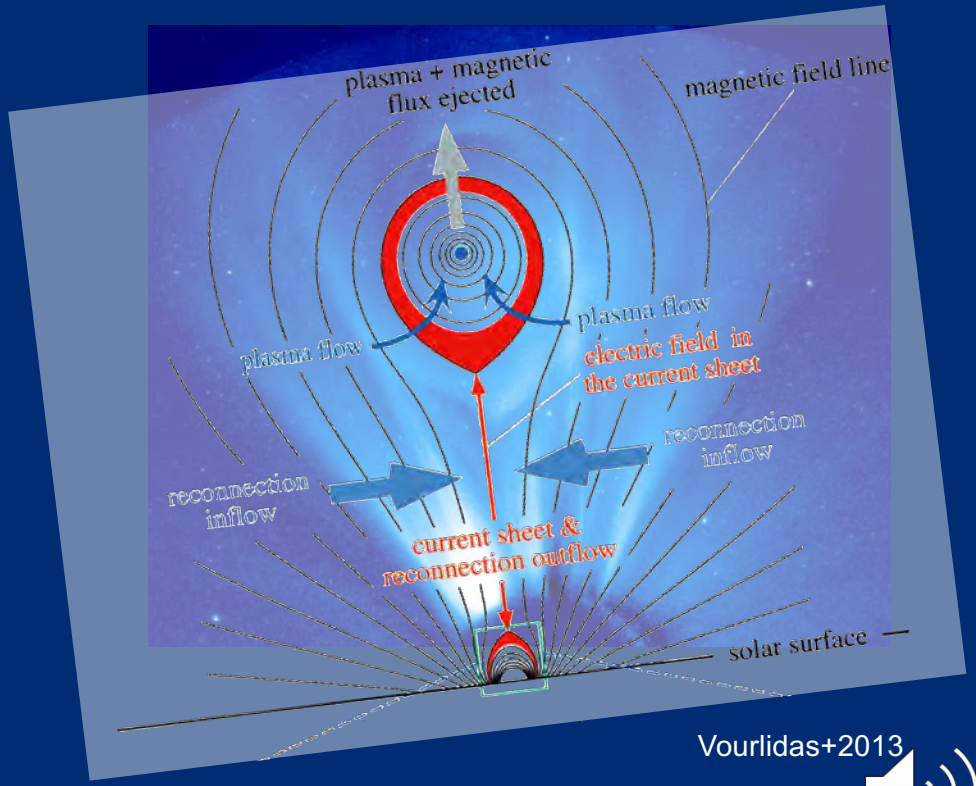
CMEs contain Magnetic Flux Ropes (as theory predicts)



Chen+1997



Vourlidas+2000

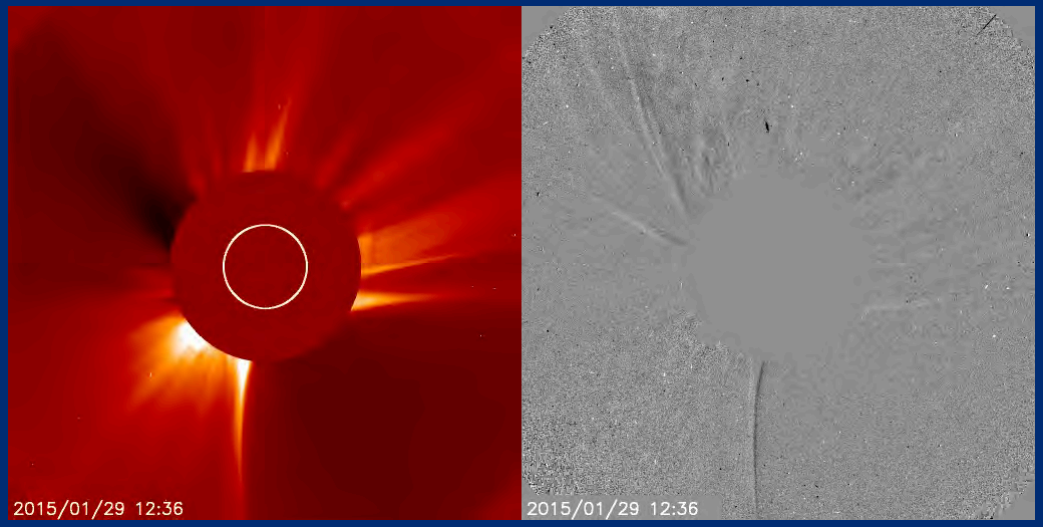


Vourlidas+2013

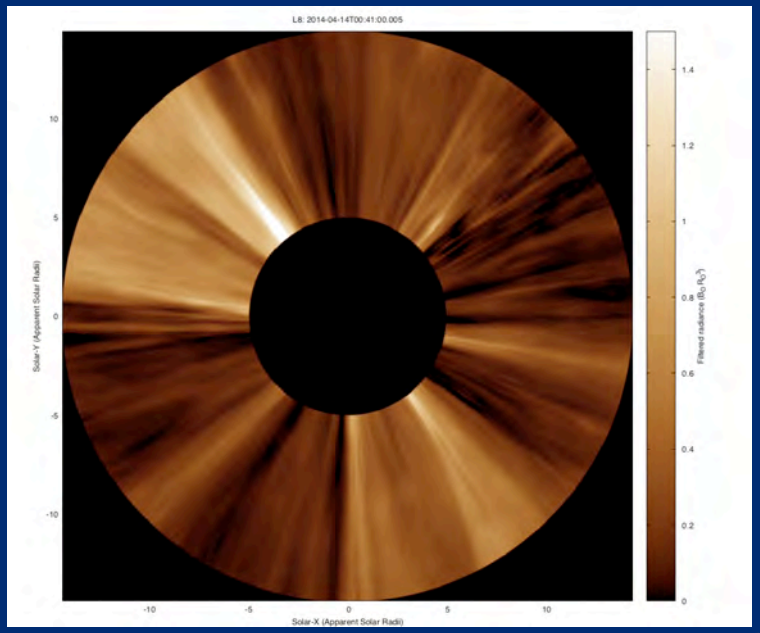
‘Paradigm Shift’: Dynamic Corona

CMEs, Jets, Waves, Blobs…

LASCO revealed an unexpected level of variability



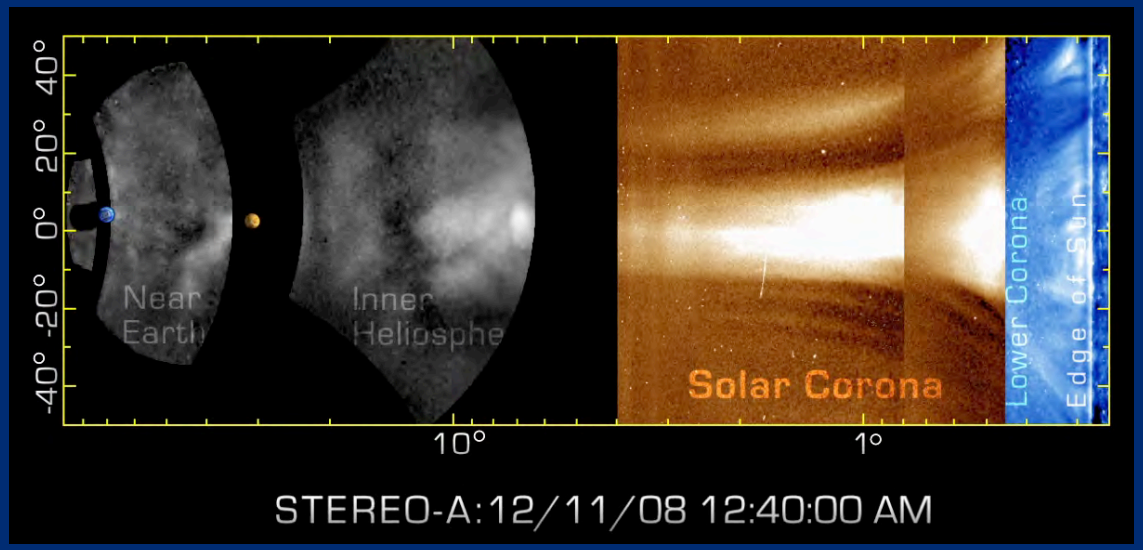
…that remains obvious even at 5-min cadence



DeForest+ 2018

‘Paradigm Shift’: Imaging the Solar Wind

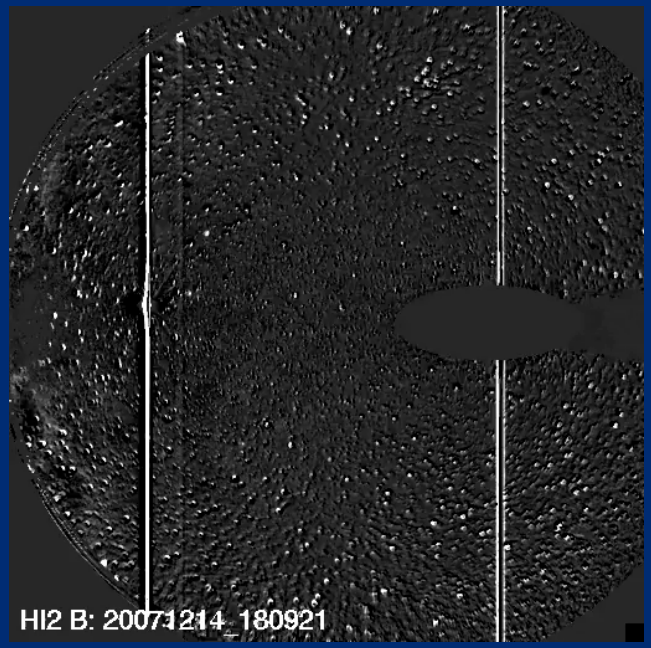
Heliospheric imaging offers a new way to study the inner heliosphere



Tracking solar wind from Sun to 1 AU

DeForest+2012

First Imaging of SIRs



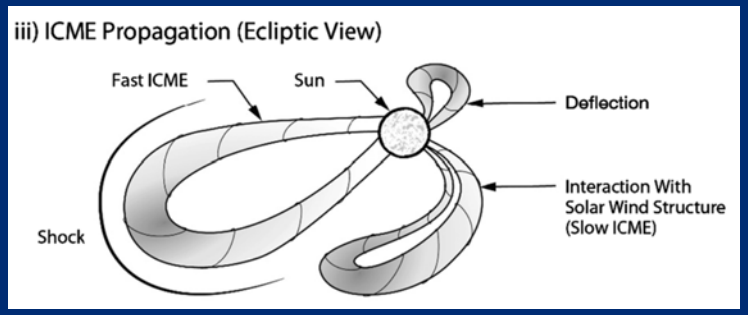
Sheeley+ 2008

What are we missing?

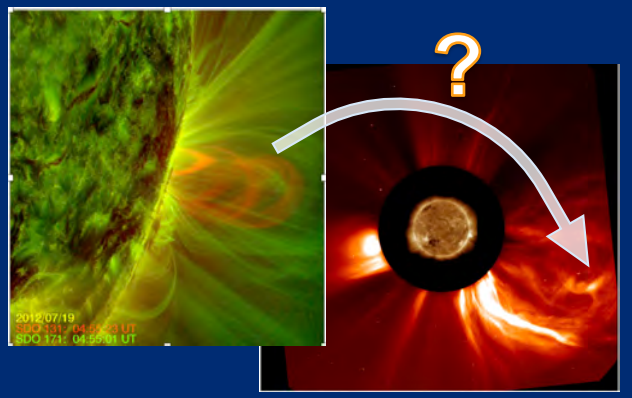
Top-level knowledge gaps in 2020

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

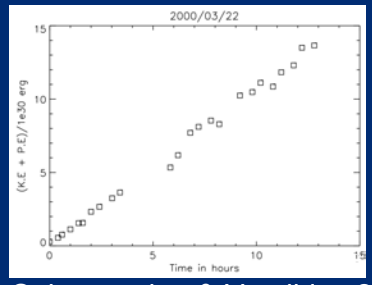
Luhmann+2020



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



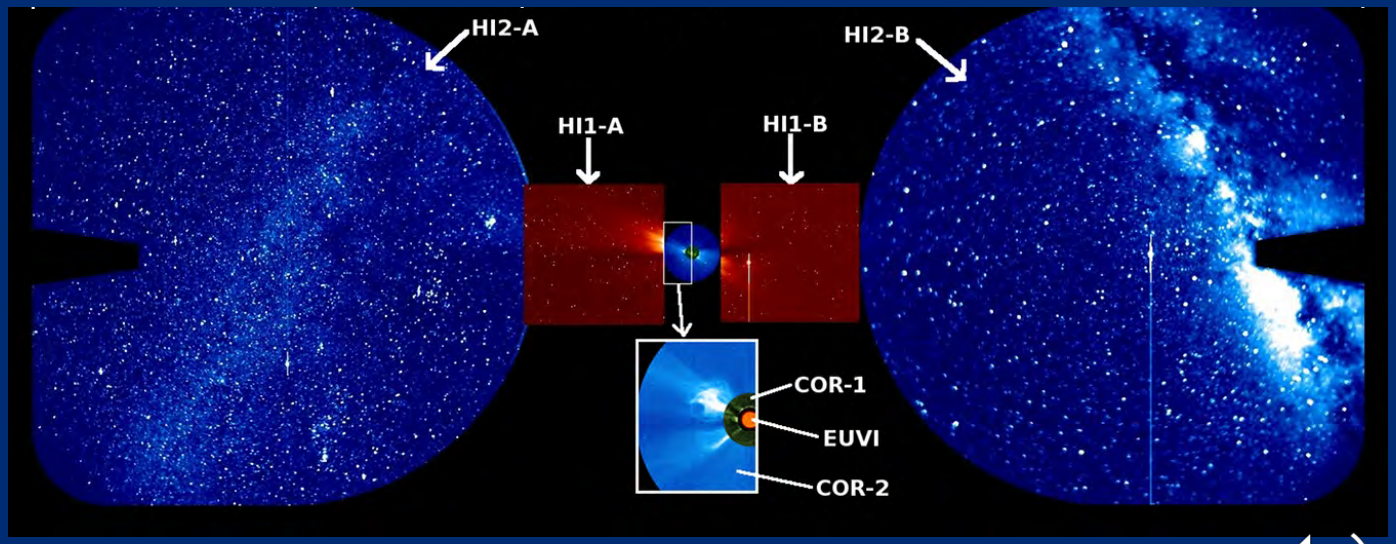
- **The physics challenge**
  - Energy budgets and force-balance



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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