



Long-Term Data Archiving and Services at NASA's Heliophysics Digital Resource Library (HDRL)

Lan Jian

NASA Goddard Space Flight Center

National Academies Space Weather Roundtable

Summer Meeting

July 9, 2024



HDRL Organizational Chart

HP Data and Model Consortium / HDMC

**Brian Thomas (PS),
Tressa Helvey-Kasulke (PM)**

Overall management of the HDRL.

Registries, Metadata and DOIs for all digital resources; SPASE Data Model.

Heliophysics Data Portal (HDP)

Python and other software integration (PyHC).

Analysis and visualization services ((Py)SPEDAS, Autoplot).

Data upgrades and related services.

HelioCloud initiative with data and software from all groups.

All activities within
the various HDRL
components are
interrelated.

Solar Data Analysis Center / SDAC

Jack Ireland (PS)

Final Active Archive of solar data for Solar Dynamics Observatory (SDO)
and other NASA missions.

Virtual Solar Observatory (VSO) data access.

Helioviewer. SolarSoft. SunPy.

High Performance Computing for NASA HP.



Space Physics Data Facility / SPDF

Robert Candey (PS), Lan Jian (DPS)

Final Active Archive of non-solar data for NASA HP (and other related) missions.
Coordinated Data Analysis Web (CDAWeb) data browsing & access; Web Service access.

OMNIWeb data production and service.

SSCWeb and 4-D spacecraft orbit viewer.

Common Data Format (CDF). ISTP metadata standards.

Key Collaborators

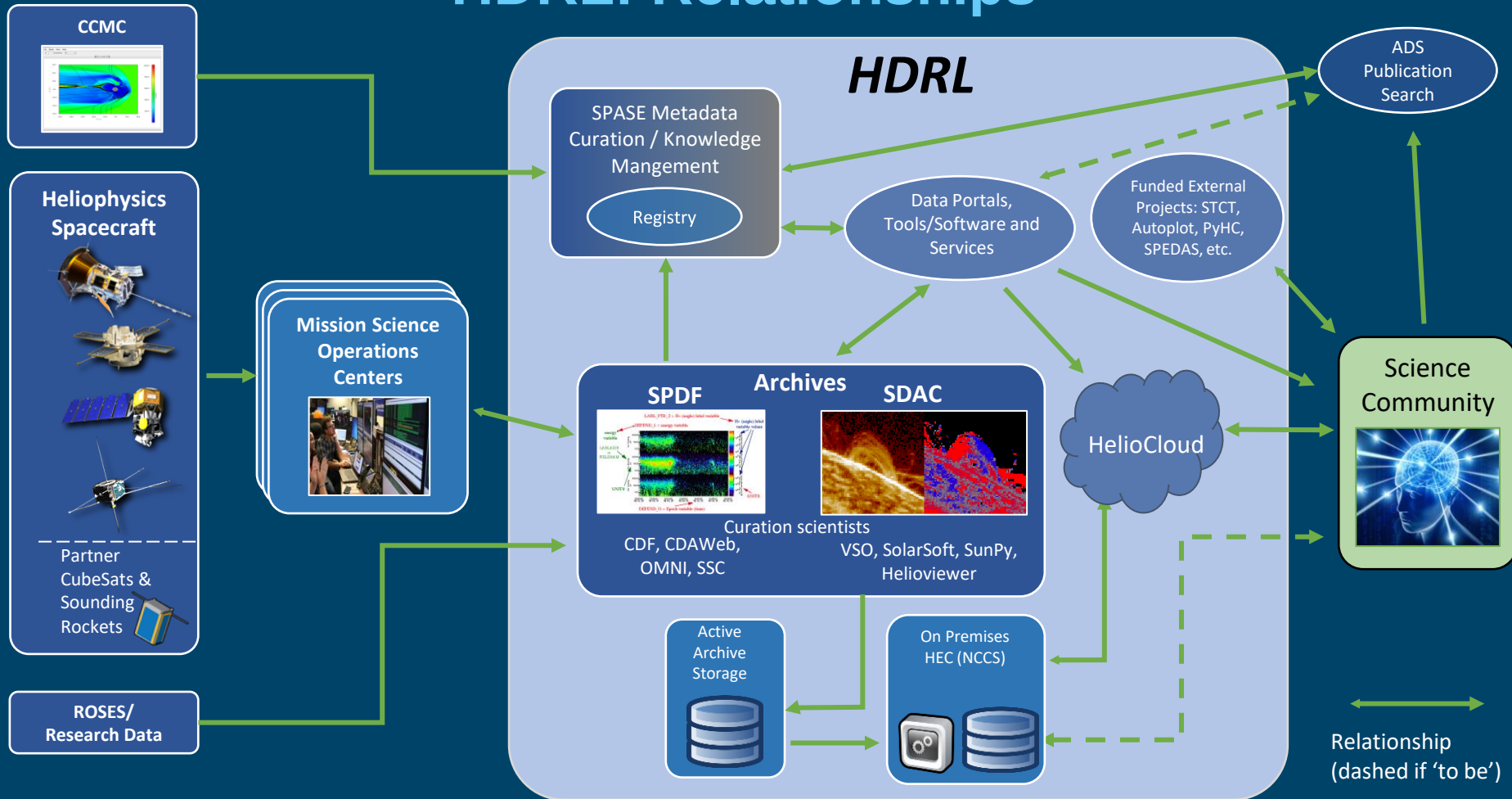
Center for HelioAnalytics

AI/ML and Adv Analytics Development, Mission-Enabling Tech, Community Resources, User Testing.

Community Coordinated Modeling Center / CCMC

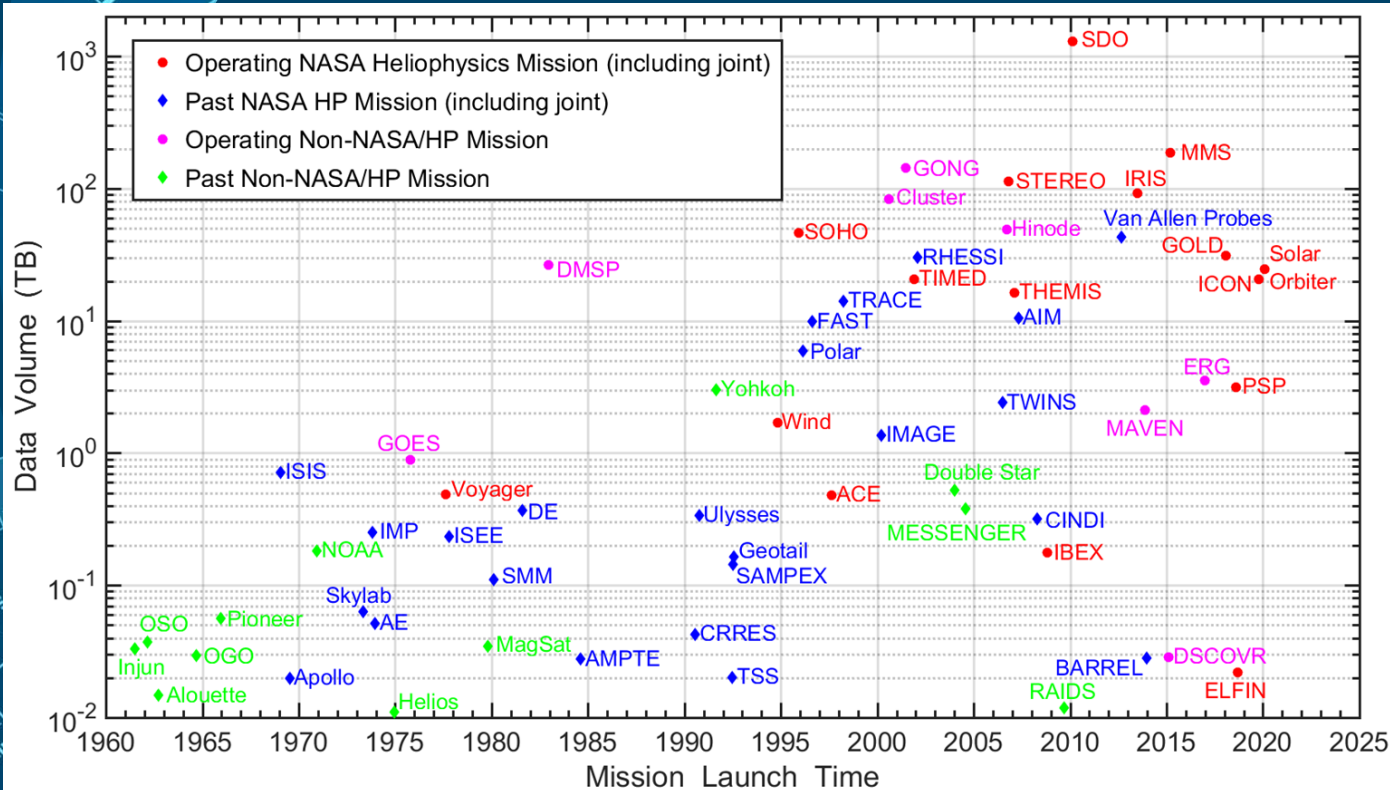
Data-model comparisons; Registry of models and output; “Kamodo” enabled visualization.

HDRL: Relationships



The Mission Never Ends for HDRL

Covering from the Sun to the Local Interstellar Medium



HDRL Combo Stats

- 100+ missions (30+ in operation)
- 8000+ datasets
- ~300 million files
- Current total volume: ~2.5 PB
- Projected Data: SDO 20 PB by 2030!

Linking SPDF Services with Missions

https://spdf.gsfc.nasa.gov/data_orbits.html

Linking SPDF Services with Missions

Click an **SPDF service name** to check mark (✓) the spacecraft whose data are available.

Click a **spacecraft name** to check mark (✓) the SPDF services with its data.

See [Info for New Users](#) for more information about these data services.

~160 missions

 = Go to Service's Home Page  = Show Source Info * = Orbit/Trajectory Data Only					
DATA SERVICES: ✓ CDAWeb  High-resolution, current space physics data with graphics and listings from many missions. ✓ OMNIWeb Plus  Hourly-averaged solar wind magnetic field and plasma, etc. ✓ GIFWalk  Browse pregenerated data and orbit plots ✓ SPDF FTPS Site  Read FTP to FTPS information. ✓ SPDF HTTPS Site 	SOURCE SPACECRAFT:		ELFIN	Juno	San Marco
	ACE		Endurance	Kepler	SCATHA*
	Active*		Equator-S	KPLO (Danuri)	SDO
	Aerocube		Explorer	Landsat	SET-1/DSX
	Aeros		FAST	LANL	SMILE
	AIM		FIREBIRD*	LRO	SNOE
	Akebono*		Formosat	LUNA	SOHO
	Alouette1		Freja*	Magsat	Solar Orbiter
	Alouette2		Galileo*	MAP	SORCE
	AMPTE		Gateway*	Mariner 10	Spartan-A
ORBIT/ TRAJECTORY SERVICES:	APEX-MAIN*		GCOM W1	Mars	Spitzer
	Apollo		Genesis	MAVEN	SPORT
	Aqua		Geotail	MESSANGER	Sputnik 1
	Ariel-4		Giotto*	MGS	STEREO
	Arase (ERG)		GOCE	Microlab 1	Suisei
	ARCAD		GOES	Mir*	Swarm
	ARTEMIS		GOLD	MMS	Tatiana
	ASTRID II*		GPS	MRO	THEMIS
	AE		GMS 3	MSL	TIMED
	Aura		GRACE*	MSX*	TRACE
	Aureol2		Granat	Munin	TSS-1R
	BARREL		Hawkeye	New Horizons	TWINS

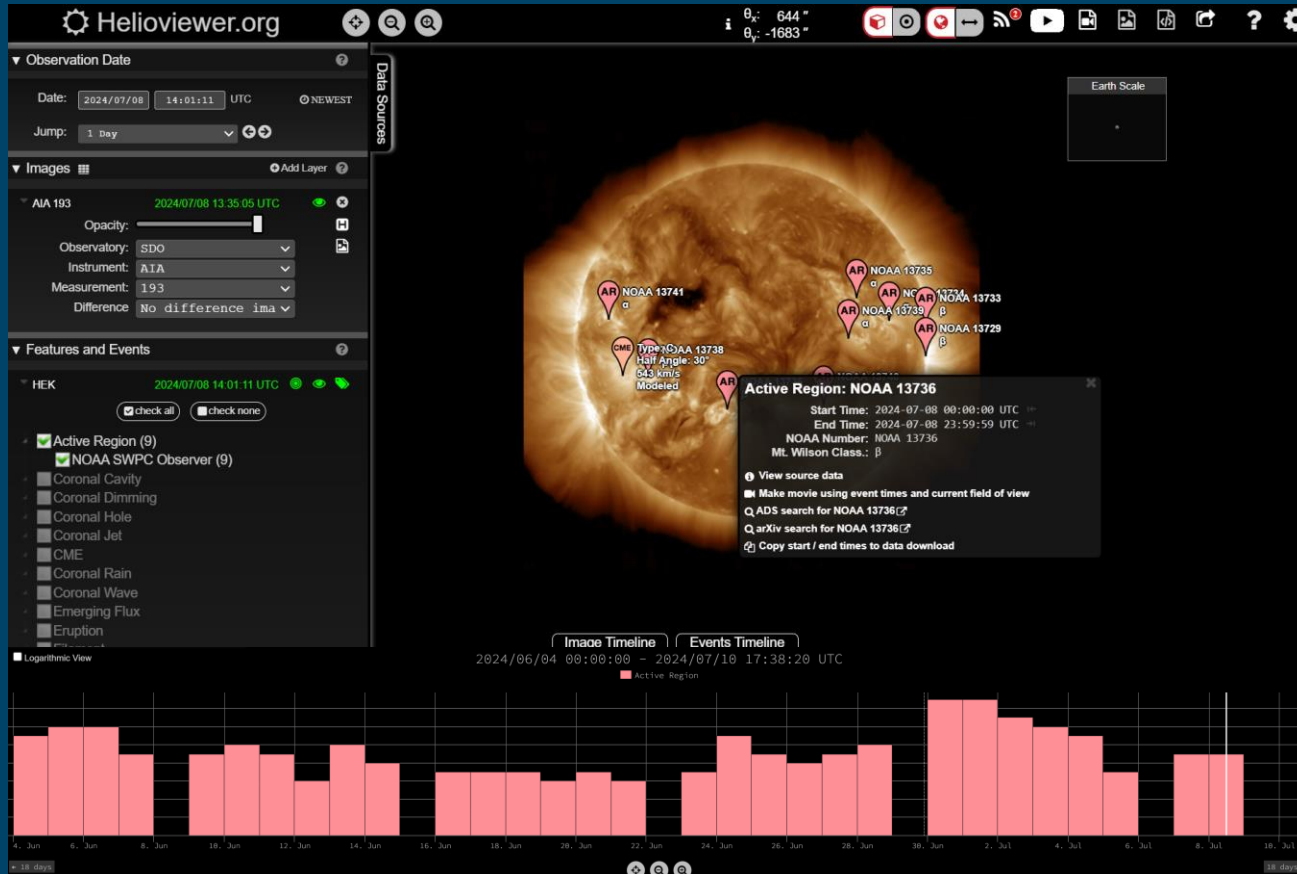
OTHER DATA SOURCES:

Planet & Comet Positions

Ground-based

Activity Indices

Helioviewer



Supports **near real-time** data from SDO, SOHO, GOES-R, GONG, Hinode, PROBA2

Created by users

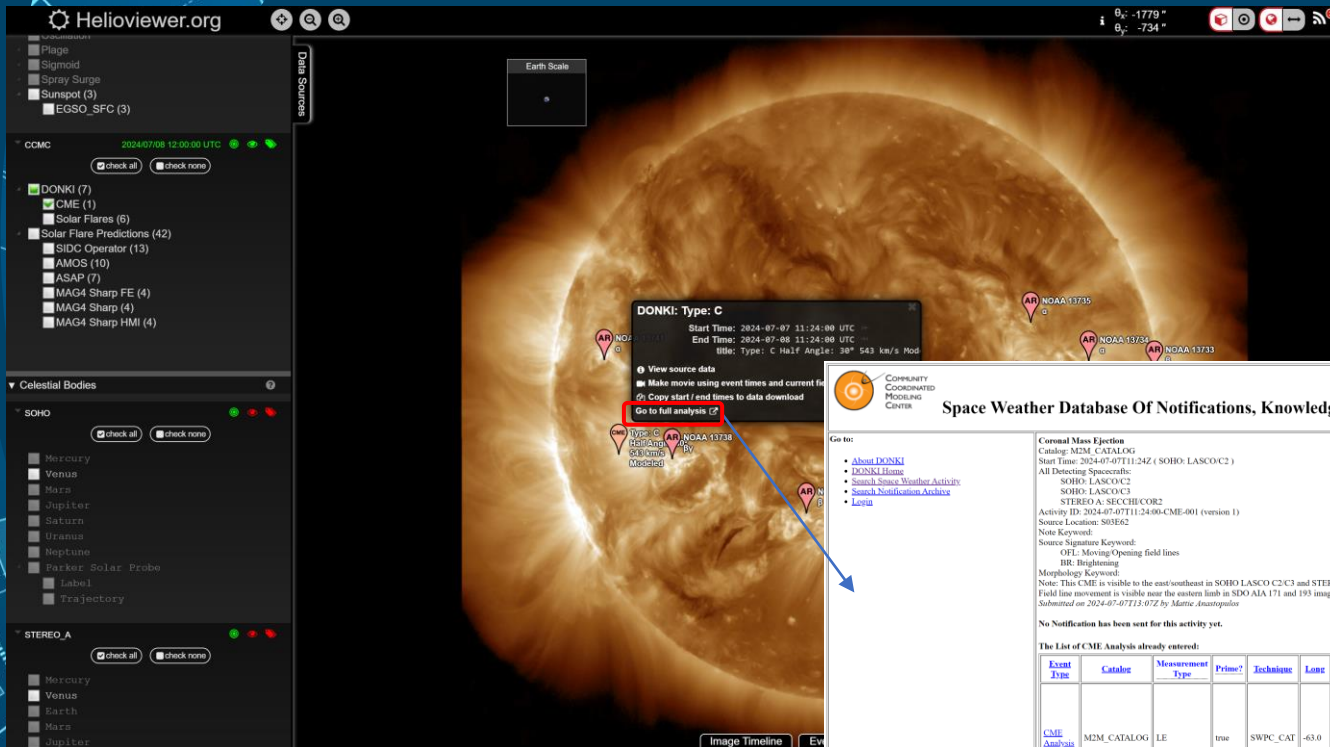
> 35 million screenshots

> 2.8 million movies

International community buy-in

- NOAA, National Solar Observatory (NSO), CCMC, Harvard-Smithsonian
- ESA, IAS (France), ROB (Belgium)

Helioviewer (Cont.)



Helioviewer.org

Earth Scale

CCMC 2024/07/08 12:00:00 UTC

DONKI (7)

- ☒ CME (1)
- ☐ Solar Flares (6)

Solar Flare Predictions (42)

SIDC Operator (13)

AMOS (10)

ASAP (7)

MAG4 Sharp FE (4)

MAG4 Sharp (4)

MAG4 Sharp HMI (4)

CELESTIAL BODIES

SOHO

STEREO_A

DONKI: Type: C

Start Time: 2024-07-07 11:24:00 UTC

End Time: 2024-07-08 11:24:00 UTC

Title: Type: C Half Angle: 38° S43 km/s Mod

View source data

Make movie using event times and current frame

Copy start / end times to data download

Go to full analysis (P)

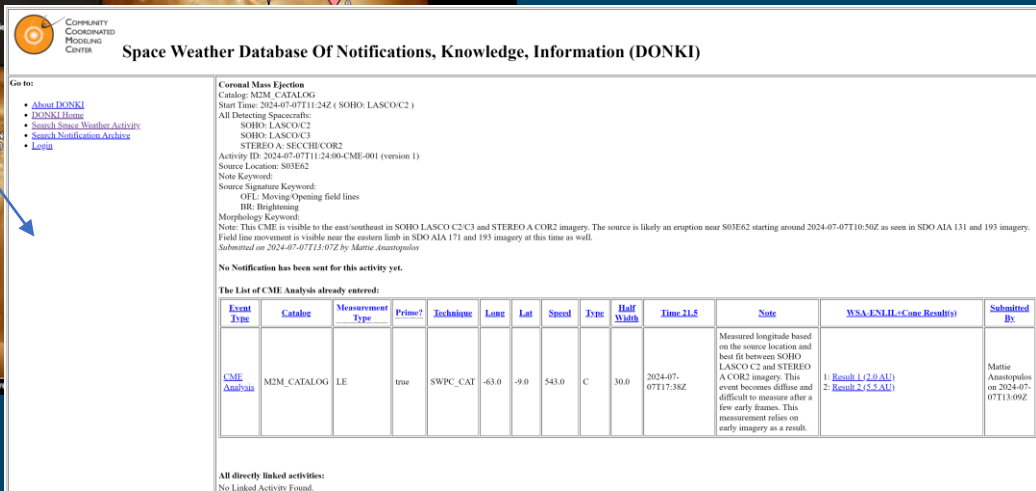
NOAA 13735

NOAA 13735

NOAA 13733

NOAA 13733

Image Timeline



Space Weather Database Of Notifications, Knowledge, Information (DONKI)

Go to:

- [About DONKI](#)
- [DONKI Home](#)
- [Search Space Weather Activity](#)
- [Search Notification Archive](#)
- [Login](#)

Coronal Mass Ejection

Catalog: M2M_CATALOG

Start Time: 2024-07-07T11:24Z (SOHO: LASCO C2)

All Detecting Spacecrafts:

- SOHO: LASCO C2
- SOHO: LASCO C3
- STEREO A: SECCHI COR2

Activity ID: 2024-07-07T11:24:00-CME-001 (version 1)

Source Location: S03E62

Note Keyword:

Source Signature Keyword:

OFL: Moving/Opening field lines

BR: Brightening

Morphology Keyword:

Note: This CME is visible to the east/southeast in SOHO LASCO C2/C3 and STEREO A COR2 imagery. The source is likely an eruption near S03E62 starting around 2024-07-07T10:50Z as seen in SDO AIA 131 and 193 imagery. Field line movement is visible near the eastern limb in SDO AIA 171 and 193 imagery at this time as well.

Submitted on: 2024-07-07T13:07Z by: [Mariusz Anasagulis](#)

No Notification has been sent for this activity yet.

The List of CME Analysis already entered:

Event Type	Catalog	Measurement Type	Prime?	Technique	Long	Lat	Speed	Type	Half Width	Time 21.5	Note	WSA-ENLIL+Conc Result(s)	Submitted By
CME Analysis	M2M_CATALOG	LE	true	SWPC_CAT	-63.0	-9.0	543.0	C	30.0	2024-07-07T17:38Z	Measured longitude based on the source location and best fit between SOHO LASCO C2 and STEREO A COR2 imagery. This event becomes diffuse and difficult to measure after a few early frames. This measurement relies on early imagery as a result.	1: Result 1 (2.0 AU) 2: Result 2 (5.5 AU)	Mariusz Anasagulis on 2024-07-07T13:09Z

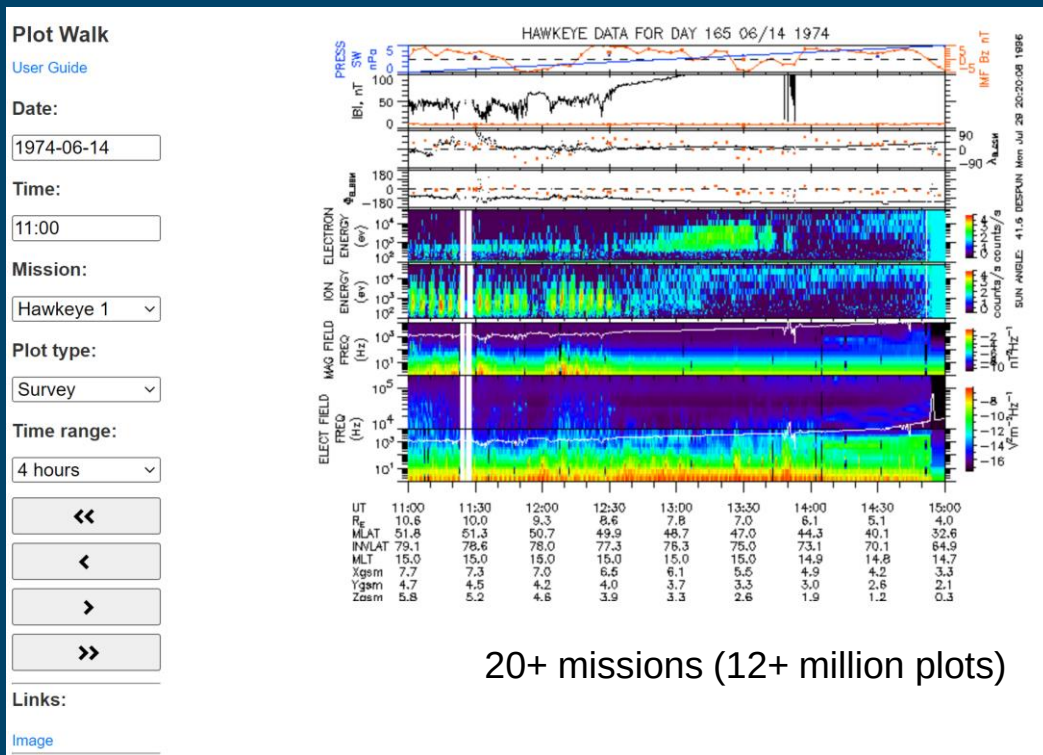
All directly linked activities:

No Linked Activity Found.

Restoration of Historical Data

- ❑ Standard data format
 - Flexible Image Transport System (FITS) for remote-sensing solar data
 - Common Data Format (CDF) and netCDF4-Classic for in-situ particle and field data
- ❑ Follow the recommended file and data collection naming practices and the FITS standards or International Solar-Terrestrial Physics (ISTP) metadata guidelines
- ❑ There are FITS and CDF file verification programs to check if the data meet the metadata standards
 - SPDF team can help the CDF data generation and validation if needed
- ❑ Some NASA ROSES programs (e.g., Heliophysics Data Environment Enhancements) support such efforts. The Open Science initiative requires archiving of research products

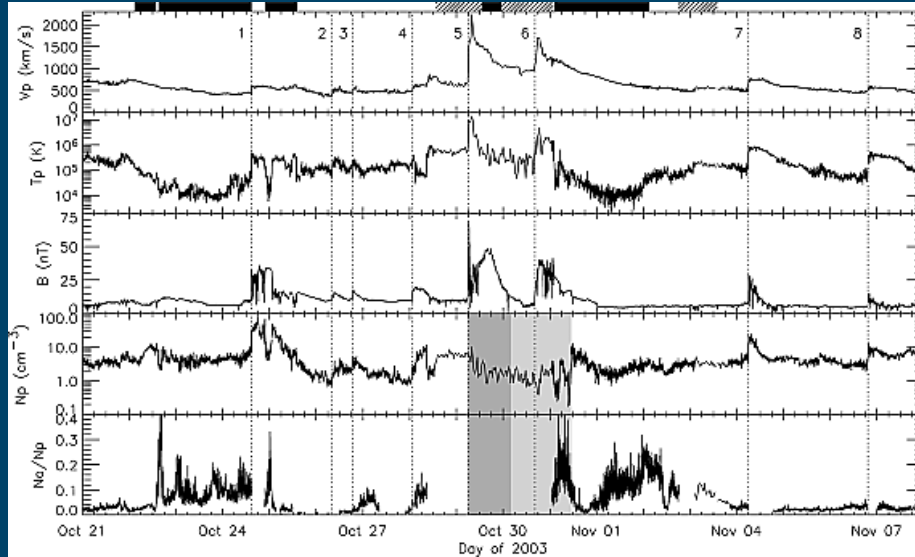
Archiving of Plots, Catalogs, & Documents



20+ missions (12+ million plots)

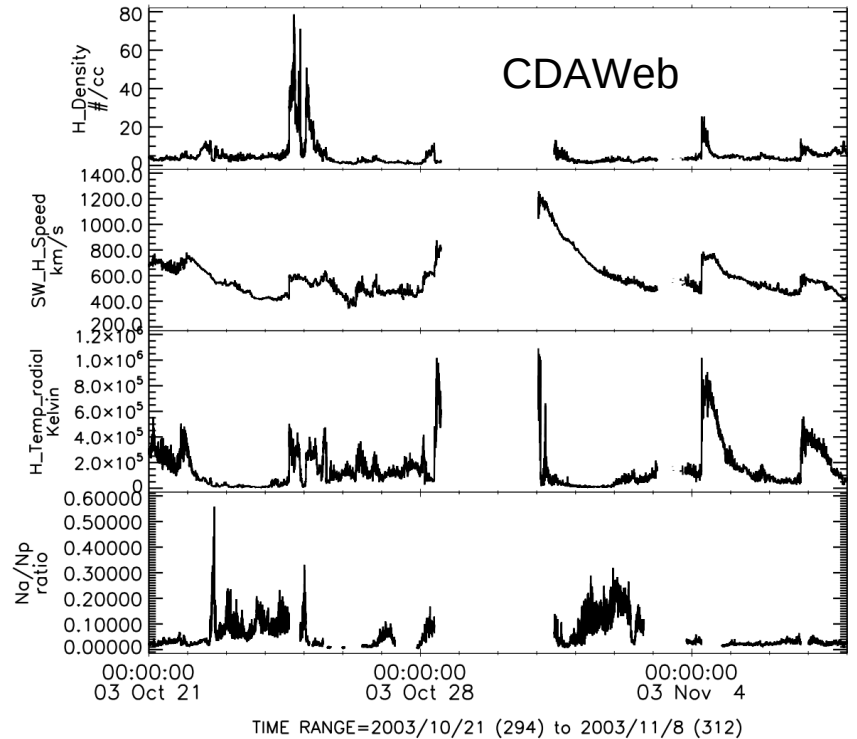
Documents: Project data management plan, user guide, senior review reports, calibration and measurement algorithms document (CMAD), etc.

ACE Data: Halloween Event in 2003



Skoug et al. (JGR 2004)

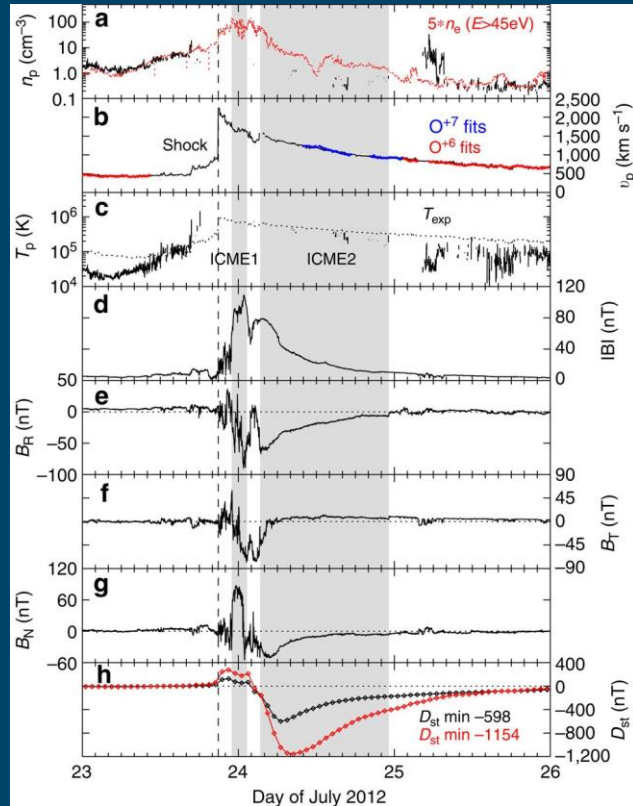
AC SWEP>ACE Solar Wind Electron Proton Alpha Monitor HO>64-sec Level 2 data



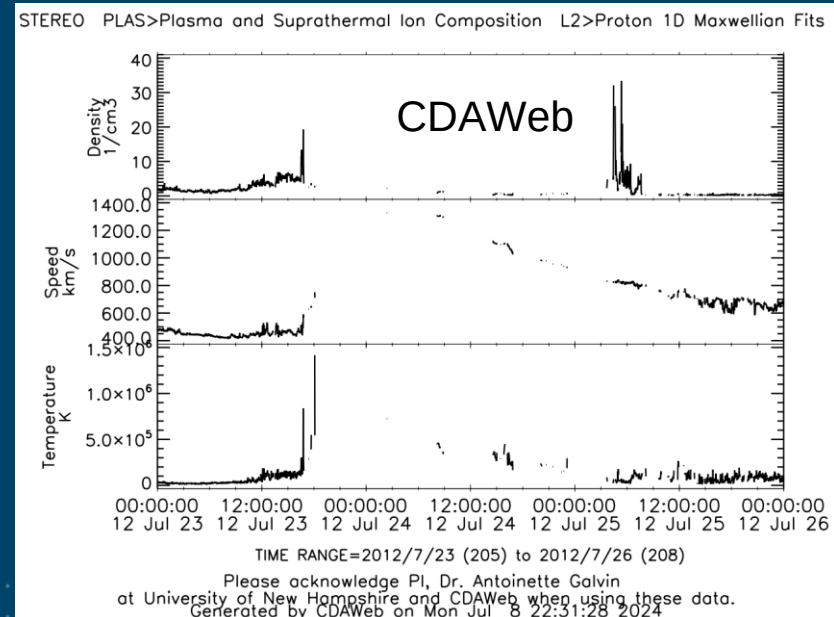
Please acknowledge PI, D. J. McComas at SWRI and CDAWeb when using these data.
Generated by CDAWeb on Mon Jul 8 22:34:42 2024

STEREO A: 2012 July 23 CME

- Specially-processed data have appeared in publications for extreme space weather events, but some of them are still not available publicly
- Although they may not meet the high quality of standard validated science data, it is critical to have them archived



Liu et al. (NatCommun 2014)



Resource Registration & Discovery

- **Knowledge Management**

- Dictionaries/taxonomies for solar and space physics discovery
- Improved space physics resource discovery at Astrophysics Data System (ADS)



- **SPASE - Space Physics Archive Search and Extract**

- International standards for heliophysics resources
- Developing v3.0 to better include solar, refactoring for interoperability, and fine-tuning for discovery



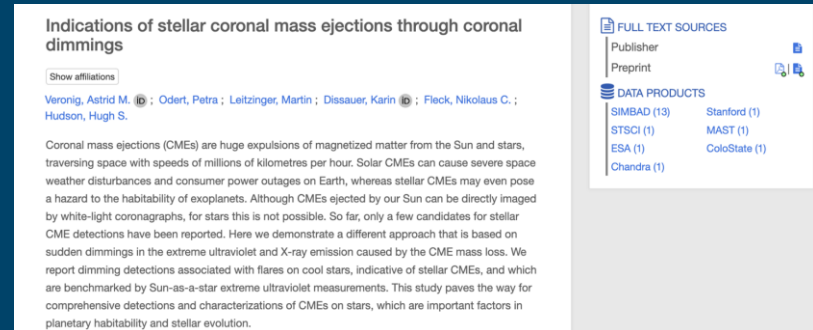
- **Registration Operations**

- Creation of SPASE records and Digital Object Identifiers (DOIs) for HDRL resources



- **Interlinking Resources**

- Interlinking HDRL datasets and services with ADS search
- Testing the application of **ChatGPT** for extracting data citations from science papers



Indications of stellar coronal mass ejections through coronal dimmings

Show affiliations

Veronig, Astrid M.  ; Odert, Petra ; Leitinger, Martin  ; Dissauer, Karin  ; Fleck, Nikolaus C. ; Hudson, Hugh S.

Coronal mass ejections (CMEs) are huge expulsions of magnetized matter from the Sun and stars, traversing space with speeds of millions of kilometres per hour. Solar CMEs can cause severe space weather disturbances and consumer power outages on Earth, whereas stellar CMEs may even pose a hazard to the habitability of exoplanets. Although CMEs ejected by our Sun can be directly imaged by white-light coronagraphs, for stars this is not possible. So far, only a few candidates for stellar CME detections have been reported. Here we demonstrate a different approach that is based on sudden dimmings in the extreme ultraviolet and X-ray emission caused by the CME mass loss. We report dimming detections associated with flares on cool stars, indicative of stellar CMEs, and which are benchmarked by Sun-as-a-star extreme ultraviolet measurements. This study paves the way for comprehensive detections and characterizations of CMEs on stars, which are important factors in planetary habitability and stellar evolution.

FULL TEXT SOURCES

Publisher

Preprint

DATA PRODUCTS

SIMBAD (13)	Stanford (1)
STSCI (1)	MAST (1)
ESA (1)	ColoState (1)
Chandra (1)	

Example Result at ADS linking to NASA datasets
(HDRL datasets will start appearing 4Q FY24)

Summary & Discussion

- ❑ HDRL is where the Heliophysics System Observatory comes together
 - Provisioning & curation of scientific big data from many sources
 - Development & maintenance of metadata standards
 - Support for data analysis and modeling in multiple computational environments
 - Design and implementation of a collaborative open science infrastructure
- ❑ Archiving of **real-time data**
 - Solar data are available via SDAC services (VSO, Helioviewer, websites)
 - SPDF archives some in-situ real-time data from ACE, STEREO, Solar Orbiter with some latency
 - Archiving of real-time data at SPDF needs to coordinate with missions, NOAA and other agencies
- ❑ Archiving of **historical science data**
 - Need to archive specially-processed data for extreme space weather events
 - SPDF team can assist the generation and test of CDF data
 - HDMC can help SPASE and DOI registration, then enable additional services