SPACE SCIENCES LABORATORY
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WHPI First Workshop
September 13–17, 2021

Using planetary missions to identify and follow transient structures in the solar wind

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Complementing observations from heliophysics missions

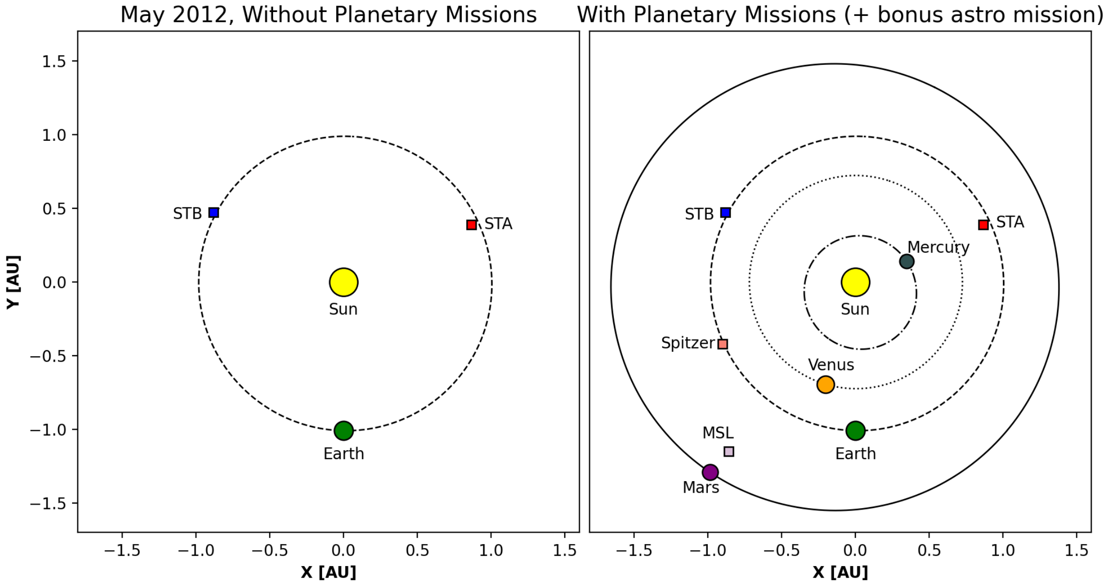
Heliophysics is now truly a "whole heliospheric" field → we are no longer focussed uniquely on the Sun–Earth line

We have had a bunch of heliophysics missions launched in the past few decades through the inner heliosphere

- Some examples: 1970s: Helios, 1990s: Ulysses, 2000s: STEREO, 2010s: PSP, 2020s: SolO…

…but what if these data are NOT ENOUGH??? If we want to understand the complex processes happening everywhere in the heliosphere, **we need to get as many data points as we can**

PLANETARY MISSIONS *are often extremely useful in providing extra observations and "expanding our horizons" throughout the inner heliosphere*



Examples as to how we can use non-heliophysics missions to our advantage in relation to the May 2012 events are shown in Palmerio et al. 2021, Space Weather, doi:10.1029/2020SW002654

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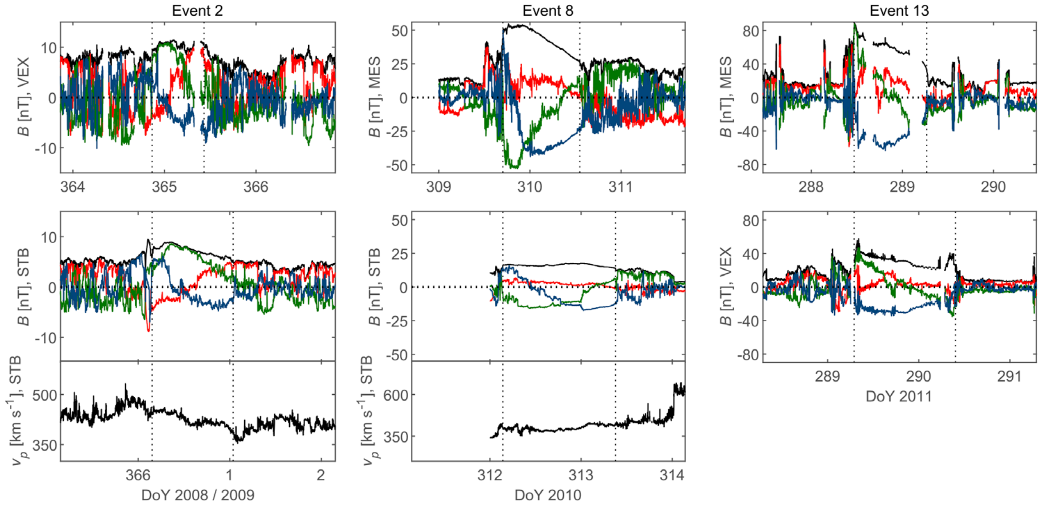
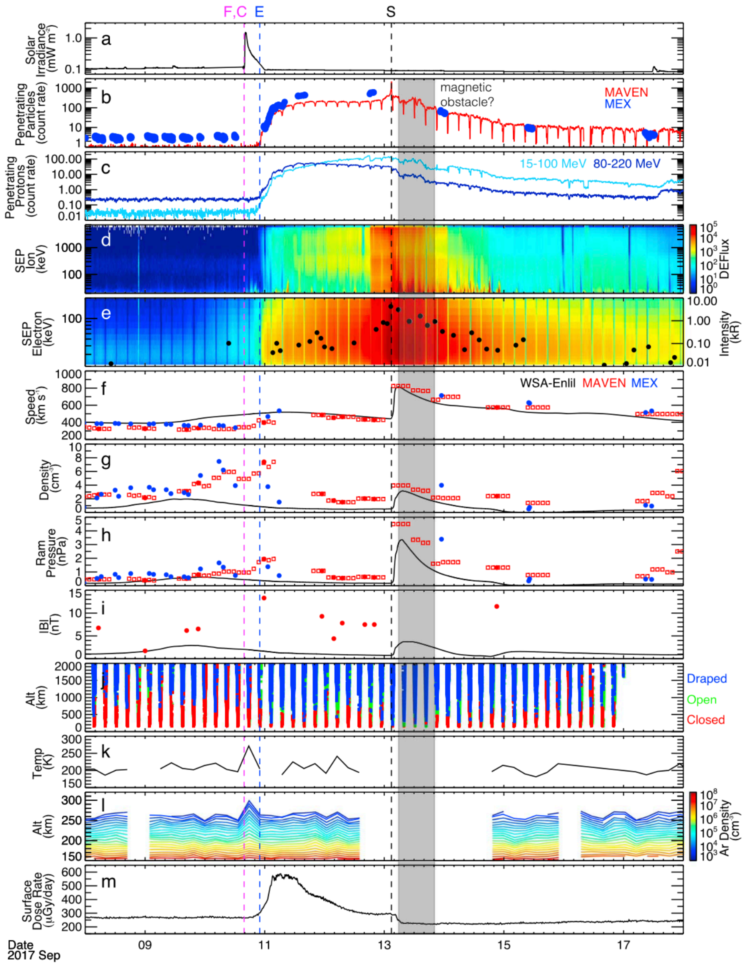
Adding the extra data point(s): What can we learn from planetary missions?

"Direct" measurements: Some spacecraft are equipped with magnetometers, plasma, and/or particle instruments

- Magnetic field and plasma instruments can directly sample the solar wind during cruise phase and during the apoapsis portion of an orbit, particle data are usually valuable for heliophysics purposes at nearly all times
- Examples: Magnetometers on Venus Express & MESSENGER, magnetic field, plasma, and particle instruments on MAVEN, particle instrument on BepiColombo…



Study of the flux rope structure of CMEs for radially aligned events between Mercury, Venus, and 1 AU: Good et al. 2019, JGR: Space Physics, doi:10.1029/ 2019JA026475

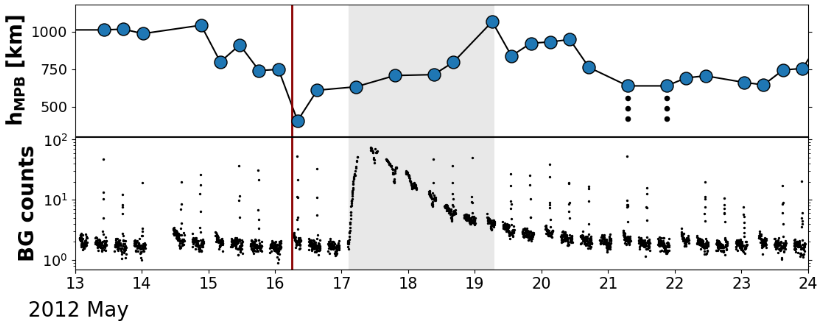


Solar wind & particle measurements for the Sep 2017 CME+SEP event at Mars: Lee et al. 2018, Geophysical Research Letters, doi:10.1029/2018GL079162

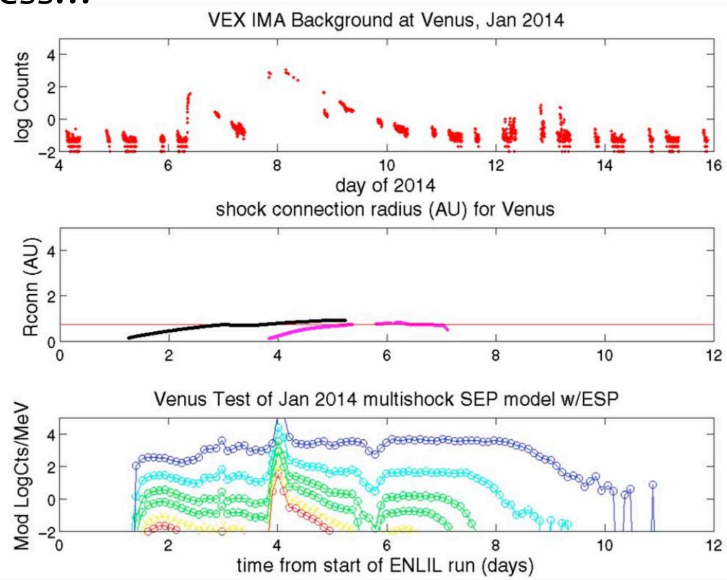
Adding the extra data point(s): What can we learn from planetary missions?

“Indirect” measurements: Some spacecraft and instruments provide measurements that are less “usual” for heliophysics, but extremely valuable

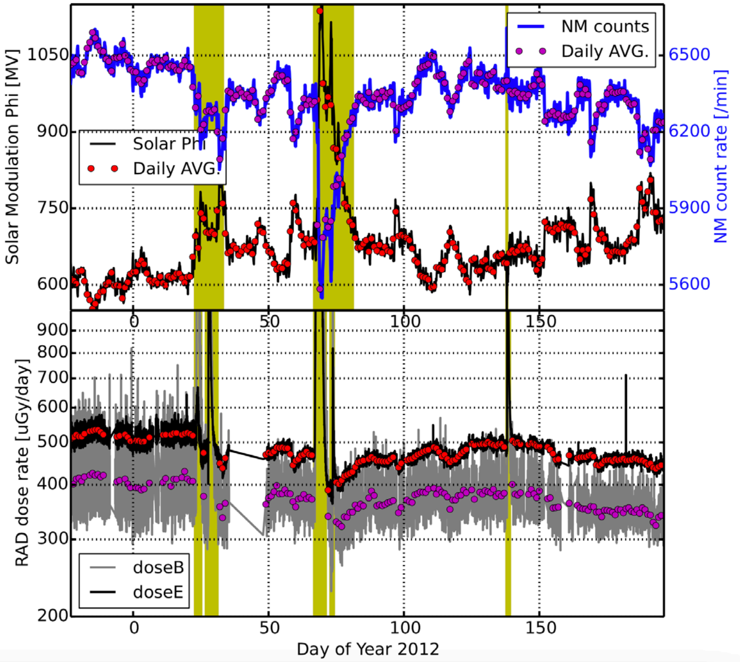
- These data can be used to infer the occurrence of space weather events such as the passage of a CME or SIR, as well as the arrival of SEPs or Forbush decreases
- Examples: Dose rate measurements on Curiosity, background counts on Venus & Mars Express, ionospheric sounding radar on Mars Express…



Altitude of the Martian magnetic pileup boundary for successive MEX orbits, indicating the passage of a CME (top) and MEX background counts indicating SEPs from a second eruption (bottom): Palmerio et al. 2021, Space Weather, doi:10.1029/2020SW002654



VEX background counts used for SEP model–data comparison at Venus: Luhmann et al. 2017, Space Weather, doi:10.1002/2017SW001617



Neutron monitor data (on Earth) compared with dose rate measurements by the Mars Science Laboratory (i.e. Curiosity) during cruise phase: Guo et al. 2015, Astronomy & Astrophysics, doi:10.1051/0004-6361/201525680

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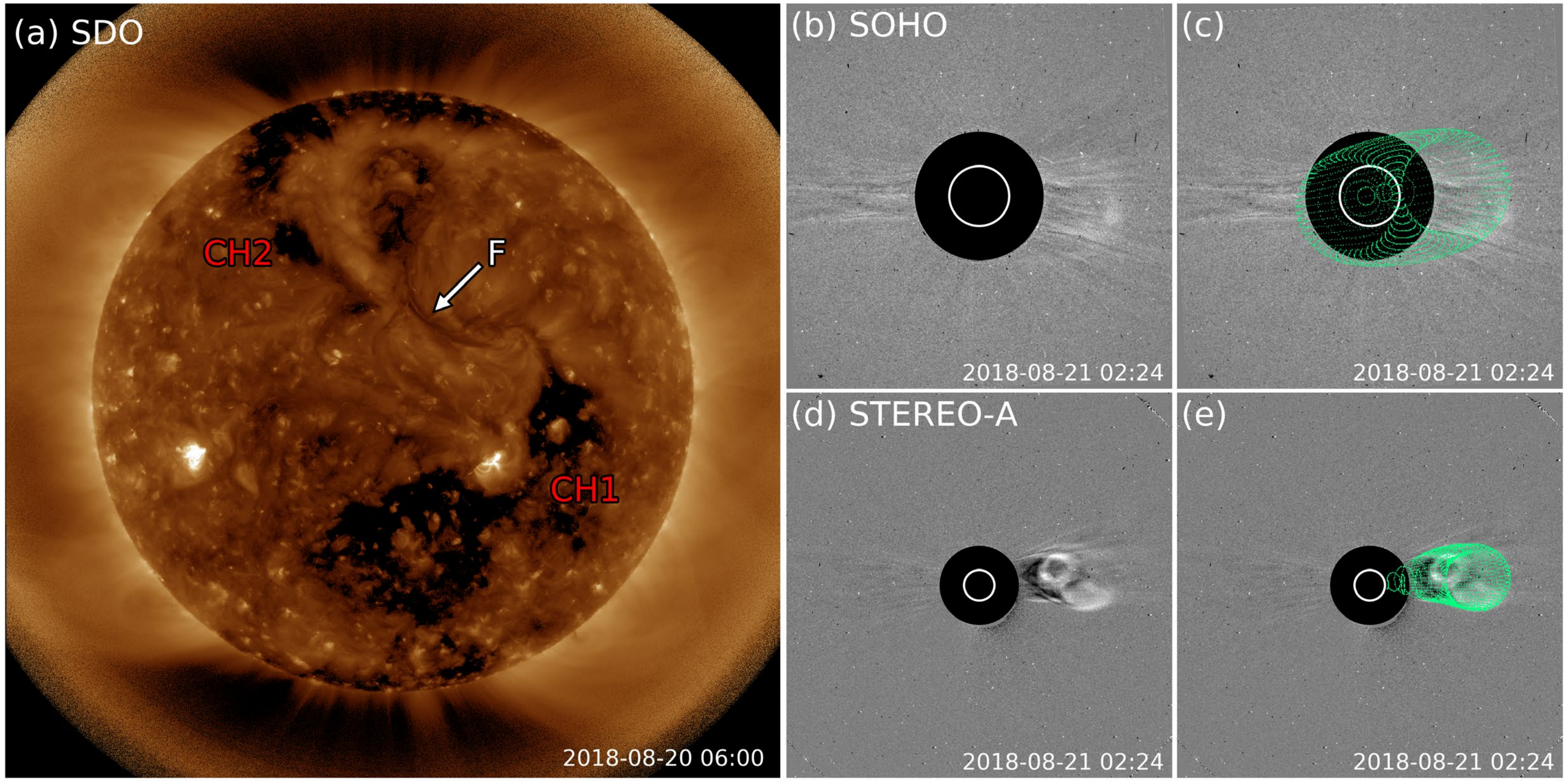
Aug 2018: Tracking a CME+HSS interaction between Earth and Mars

Solar observations



Slow eruption from a filament (F) in the northern hemisphere on 2018 Aug 20

As it propagates through interplanetary space, the CME is followed by a HSS from a coronal hole (CH2)

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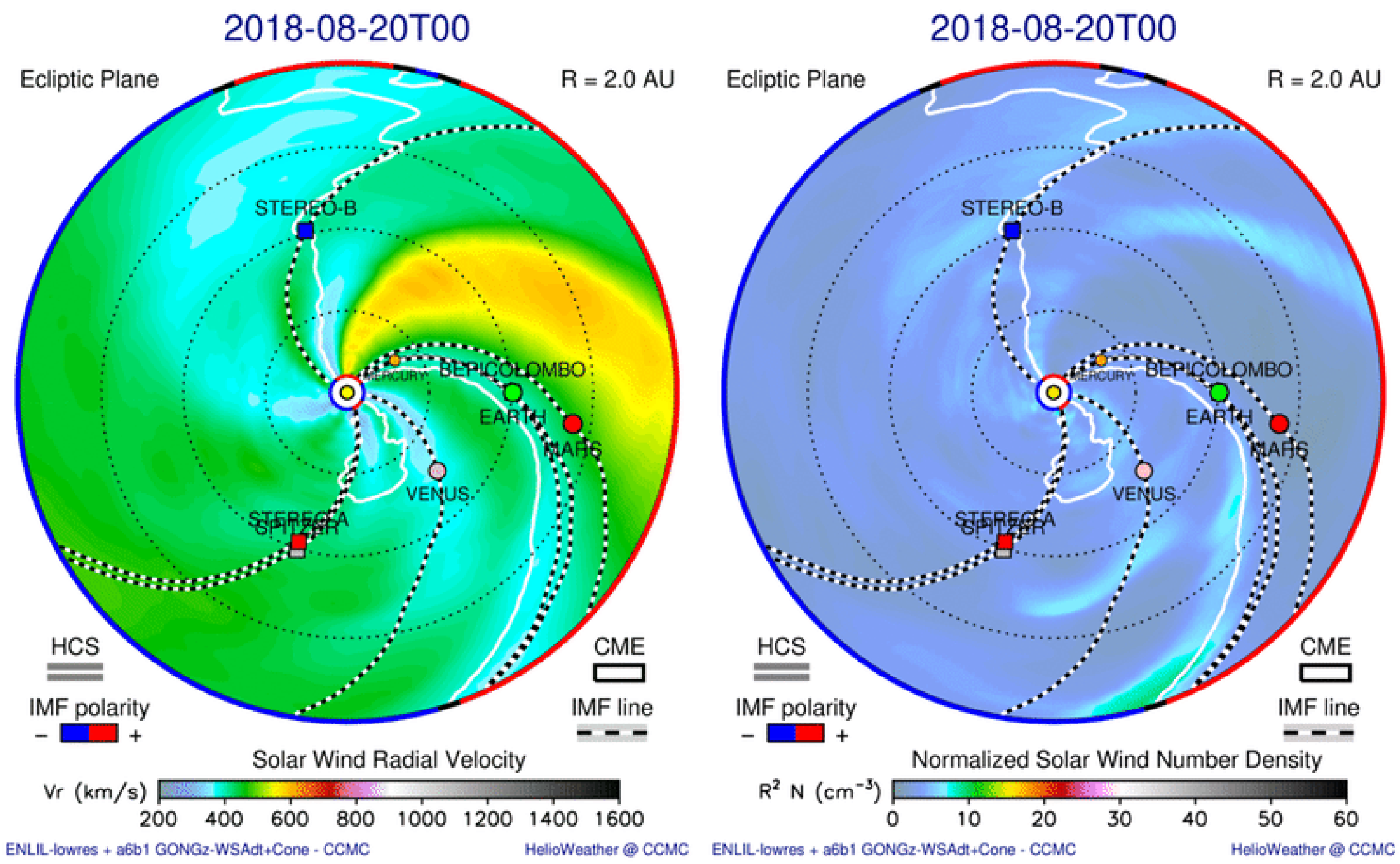
Aug 2018: Tracking a CME+HSS interaction between Earth and Mars

Heliospheric propagation



Simulation performed at NASA's CCMC

WSA–Enlil+Cone model

Earth and Mars were separated by 8° in longitude and 2° in latitude
→ almost radial alignment

In addition to the "main" CME, we also model a minor, preceding CME from earlier on the same day

According to 3D heliospheric simulation results using the WSA–Enlil+cone model, the CME(s) impact Earth directly, but just graze Mars

A ~500 km/s HSS follows the CME(s) in the simulation

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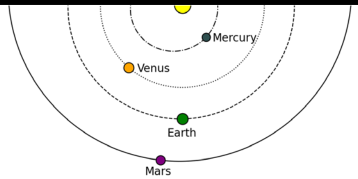
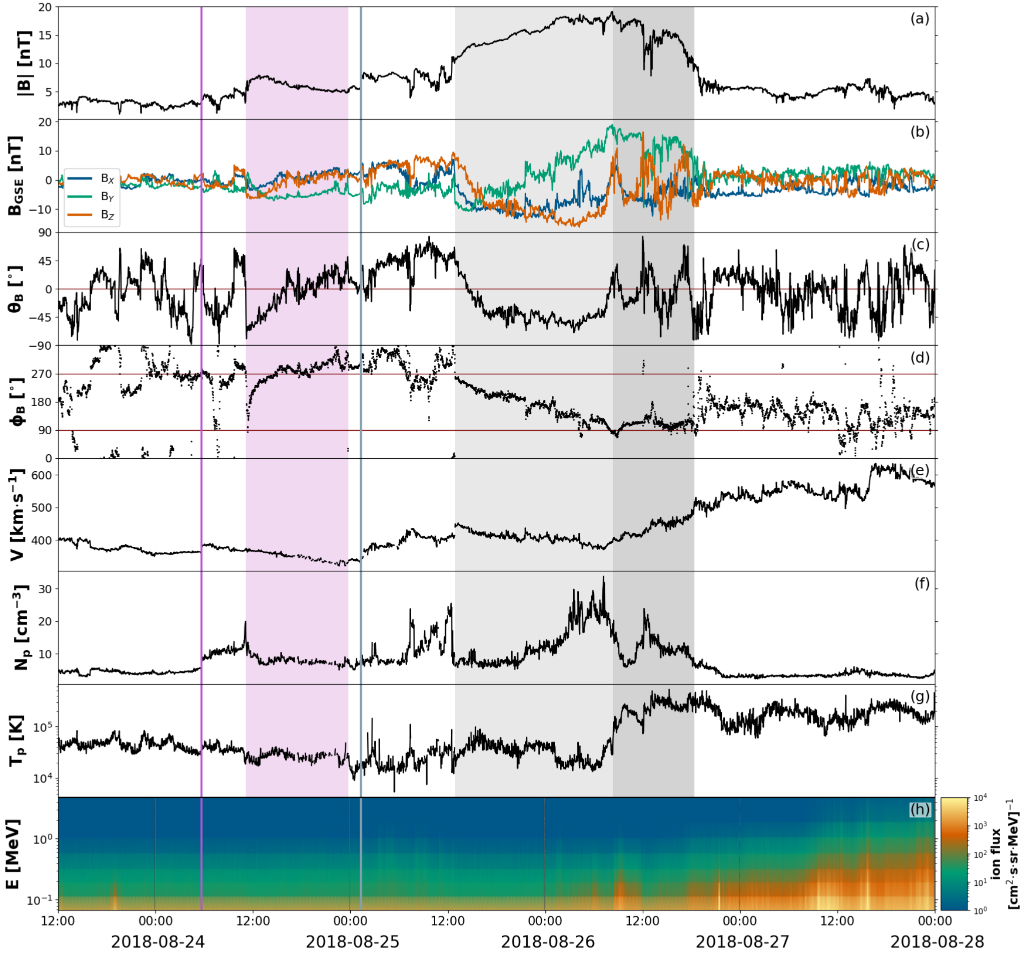


Aug 2018: Tracking a CME+HSS interaction between Earth and Mars

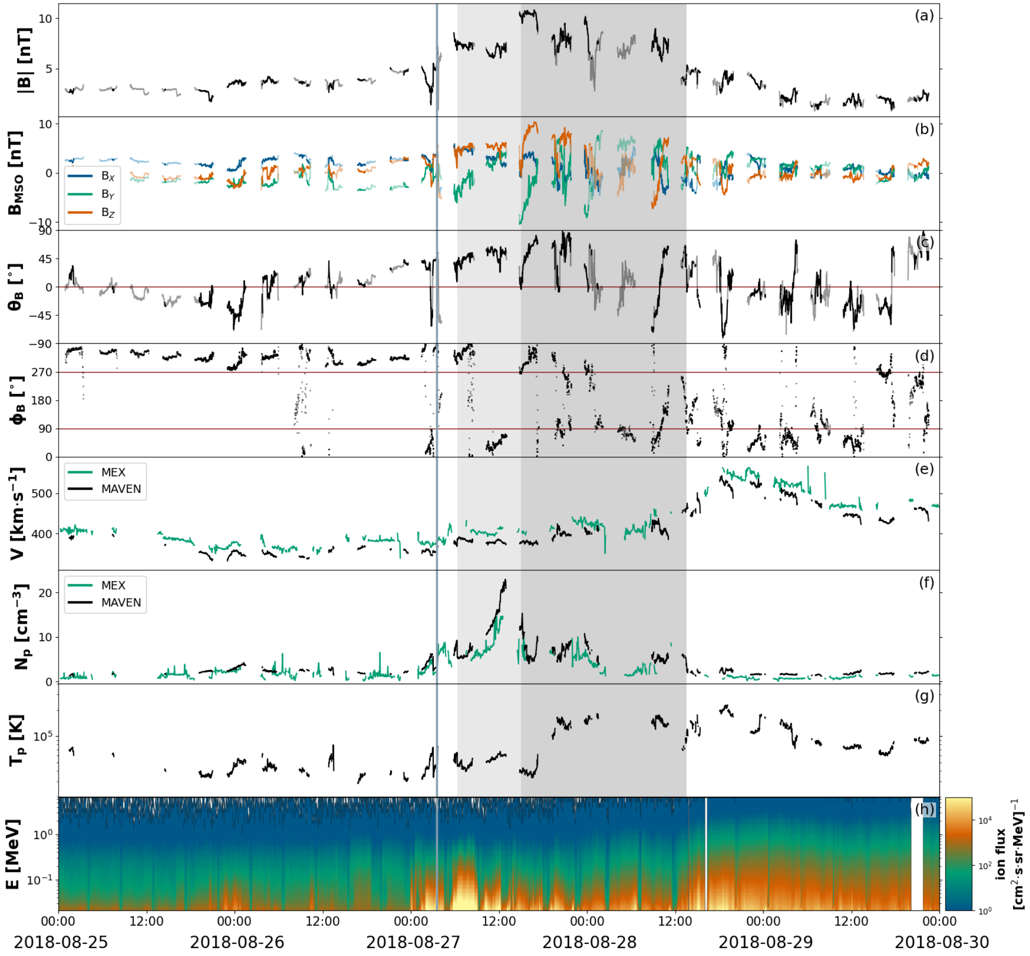
In-situ measurements

Earth



Clear CME+HSS interaction at Earth, more complicated situation at Mars

Mars



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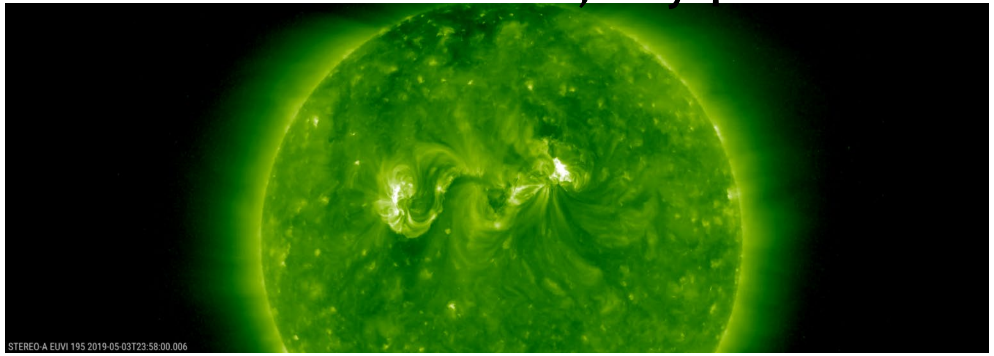
May 2019: Following CMEs during a WHPI month of interest

Overview

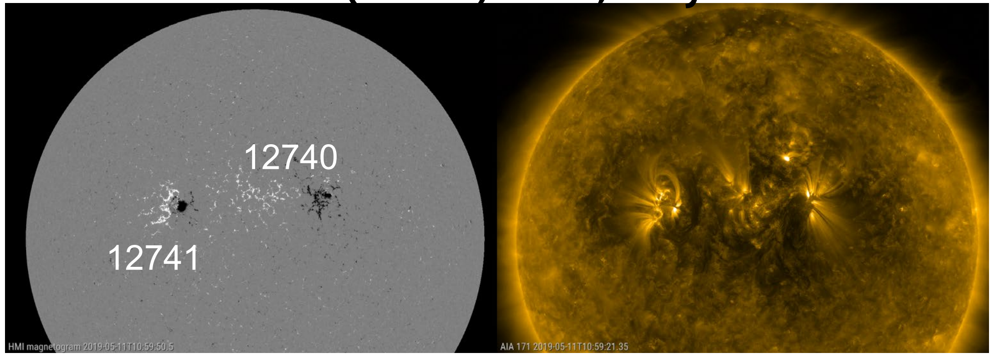
“Star” of the month: The couple of ARs 12740 & 12741

Group of large and rather eruptive ARs in the midst of a solar-min Sun

STEREO-A view, May 4



SDO (Earth) view, May 11



Major eruptions (detected in situ)

- CME1: 2019-05-03 (12741)
- CME2: 2019-05-03 (12740)
- CME3: 2019-05-07 (12740)
- CME4: 2019-05-07 (12741)
- CME5: 2019-05-10 (12740)

\+

- CME6: 2019-05-22 (stealthy)

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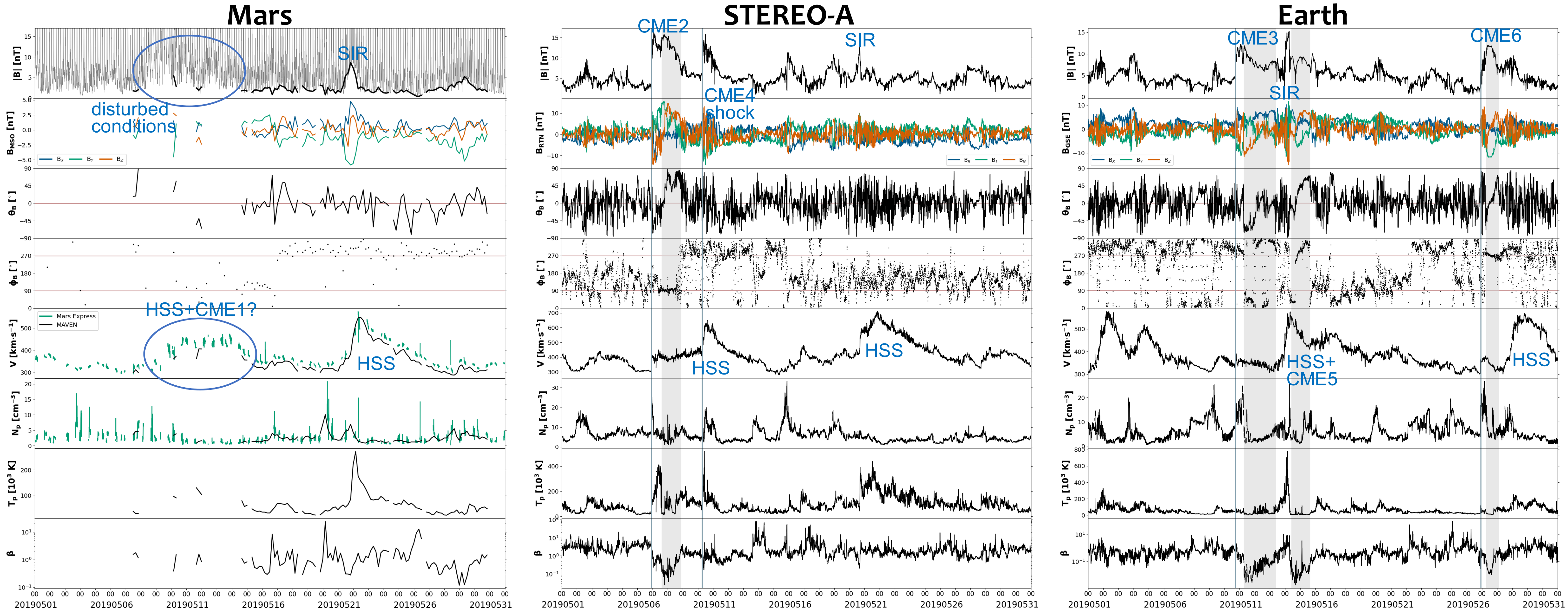
MAVEN upstream data: Jasper Halekas & Christina Lee

May 2019: Following CMEs during a WHPI month of interest

In-situ measurements



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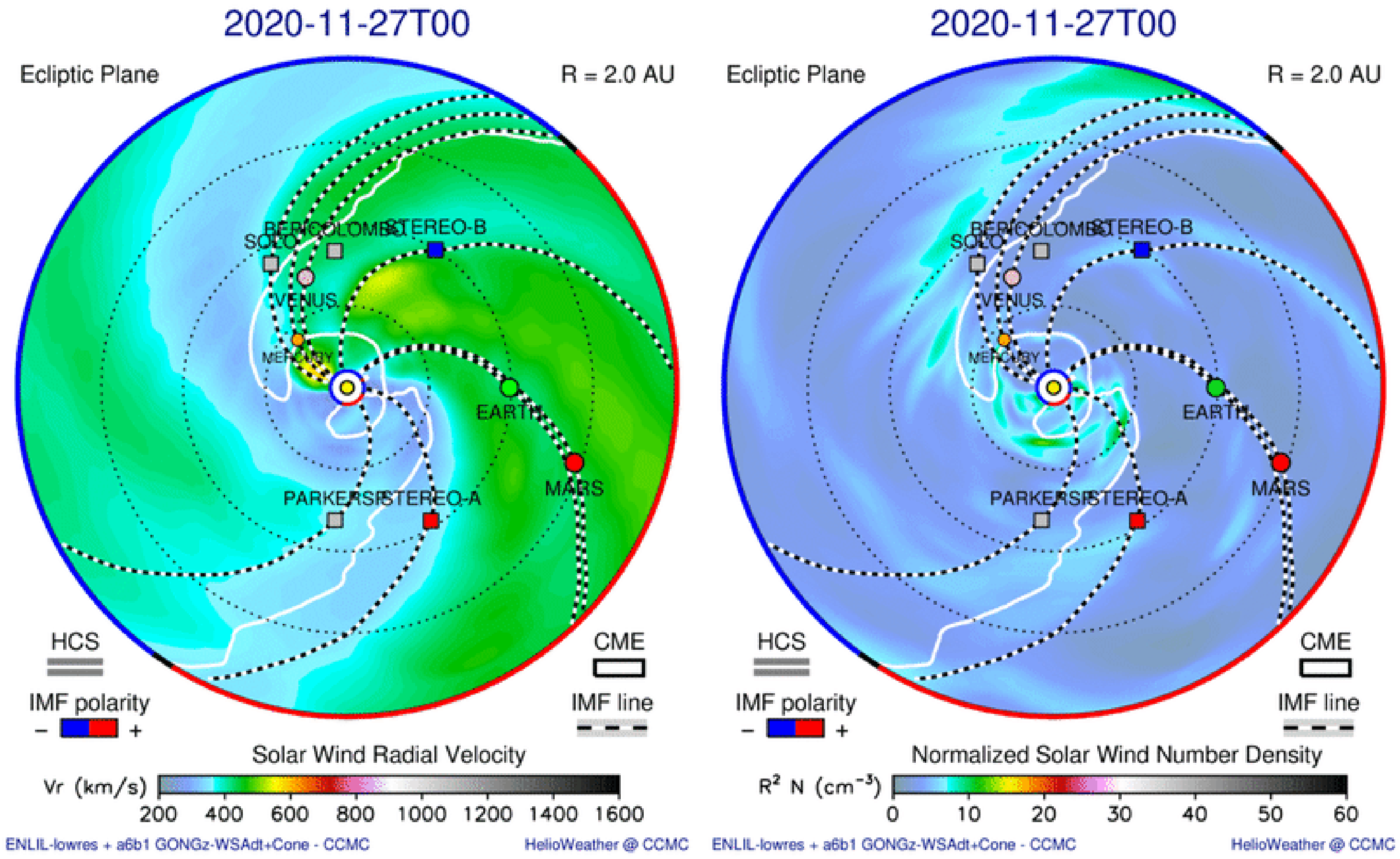
Nov–Dec 2020: Studying the spread of SEPs in the inner heliosphere

Overview of the eruptions



Simulation performed at NASA's CCMC

WSA–Enlil–SEPMOD model(s)

The period of late November to early December 2020 was characterised by a series of eruptions between two notable flares: M4.4 on 2020-11-29 and C7.4 on 2020-12-07

Modelling the whole inner heliosphere in terms of background solar wind, CMEs, and SEPs with WSA–Enlil–SEPMOD

6 total observers: Earth + 3 heliophysics missions (STEREO, PSP, SolO) + 2 planetary observers (spacecraft around Mars & BepiColombo)

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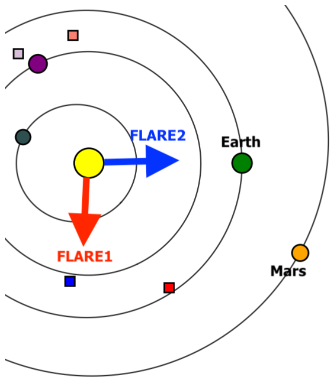
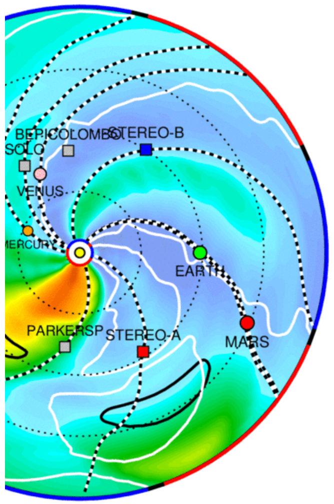
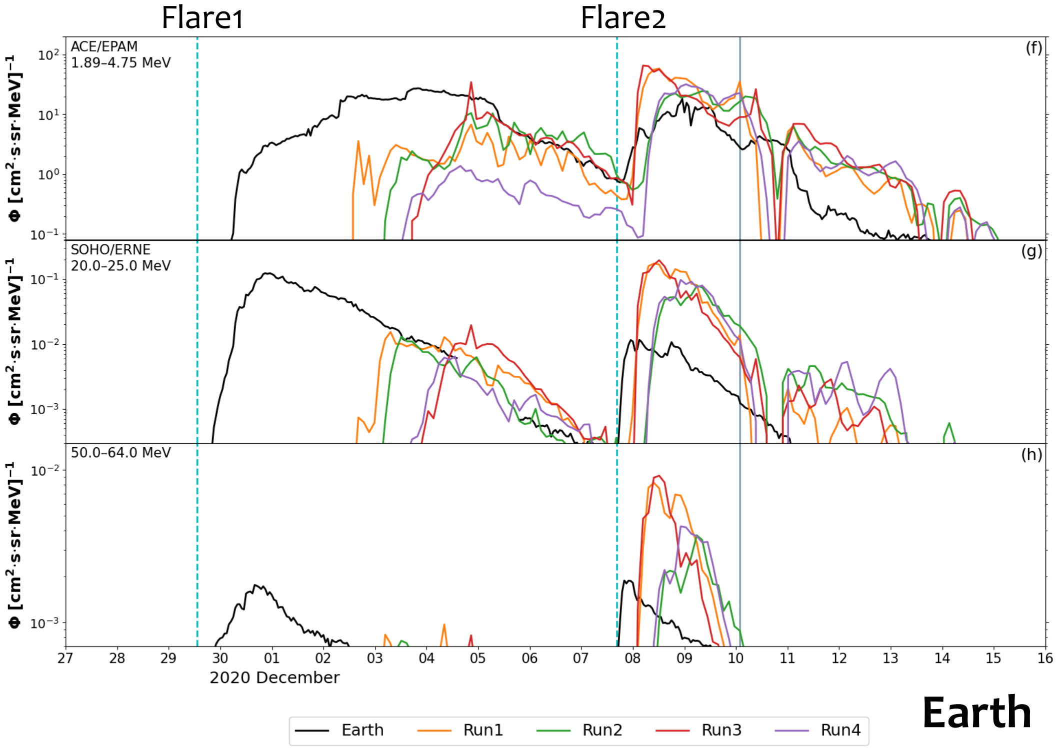
Nov–Dec 2020: Studying the spread of SEPs in the inner heliosphere

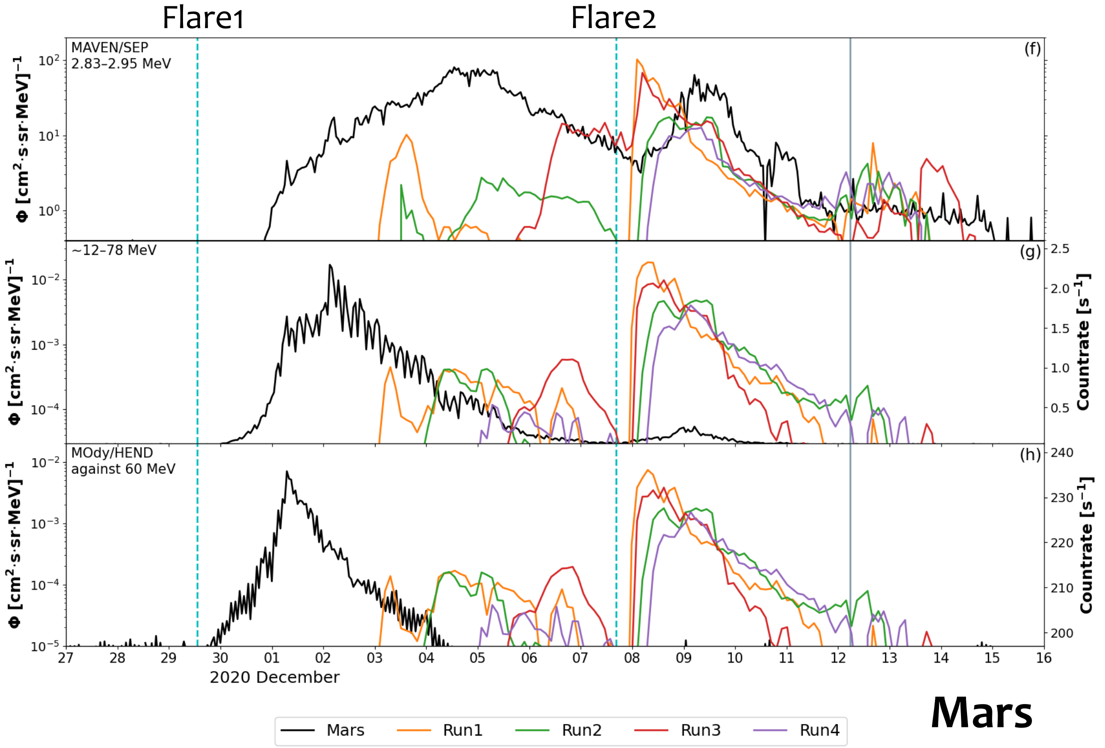
Earth versus Mars







Earth



Mars

Earth and Mars were basically along the same IMF line throughout the analysed period, according to Enlil results → expected to see very similar SEP profiles

This holds true for Flare1, but Mars sees SEPs from Flare2 only at lower energies

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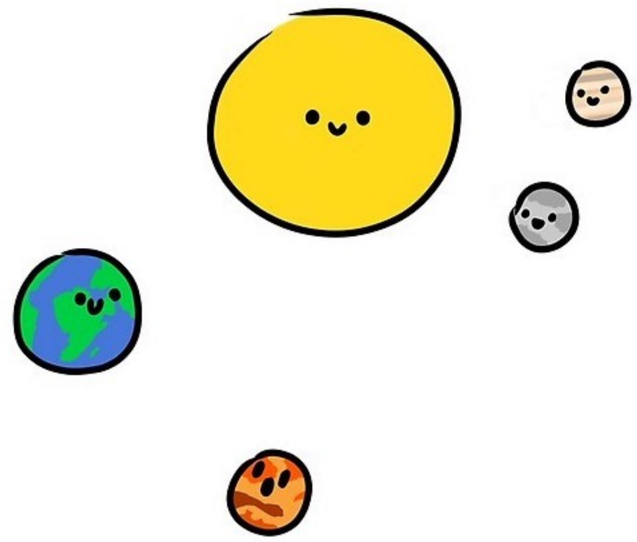
Take-home messages

Planetary missions have a lot to offer to the field of heliophysics!
→ They can complement and enhance the observations made with the "traditional" heliophysics missions, and thus facilitate a more holistic approach to the dynamic heliosphere

Following different solar transients (CMEs, SIRs, HSSs, SEPs) throughout as many locations as possible is valuable not only from an intrinsically observational viewpoint, but also for more comprehensive testing and refining of models

Coordinated efforts such as WHPI are excellent venues for bringing together different observations and expertises → loads of data to collect and to work on collectively!



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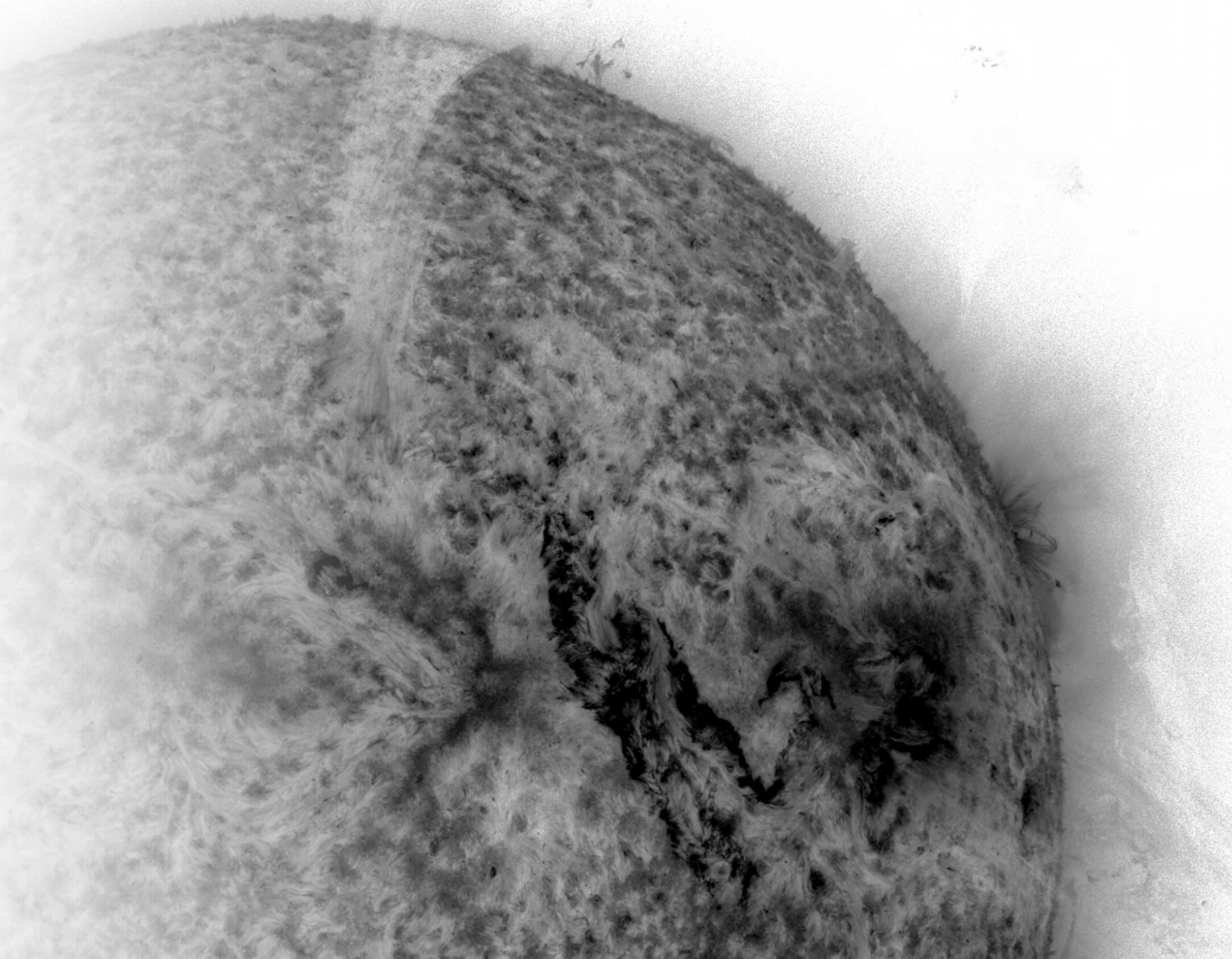
Thank you for your attention!

Special thanks to Christina Lee, Janet Luhmann, Leila Mays, and many other great collaborators



Erika Palmerio’s research is supported by the NASA Living With a Star Jack Eddy Postdoctoral Fellowship Program, administered by UCAR’s Cooperative Programs for the Advancement of Earth System Science (CPAESS) under award no. NNX16AK22G