

WHOLE HELIOSPHERE & Planetary Interactions

Don Kolinski¹, Robert Allen², Giuliana de Toma¹, Sarah Gibson¹, Ian Hewins¹, Liying Qian¹, Barbara Thompson³
 1. High Altitude Observatory, National Center for Atmospheric Research; 2. Applied Physics Laboratory, Johns Hopkins University; 3. NASA Goddard Space Flight Center

MAIN SCIENCE OBJECTIVES

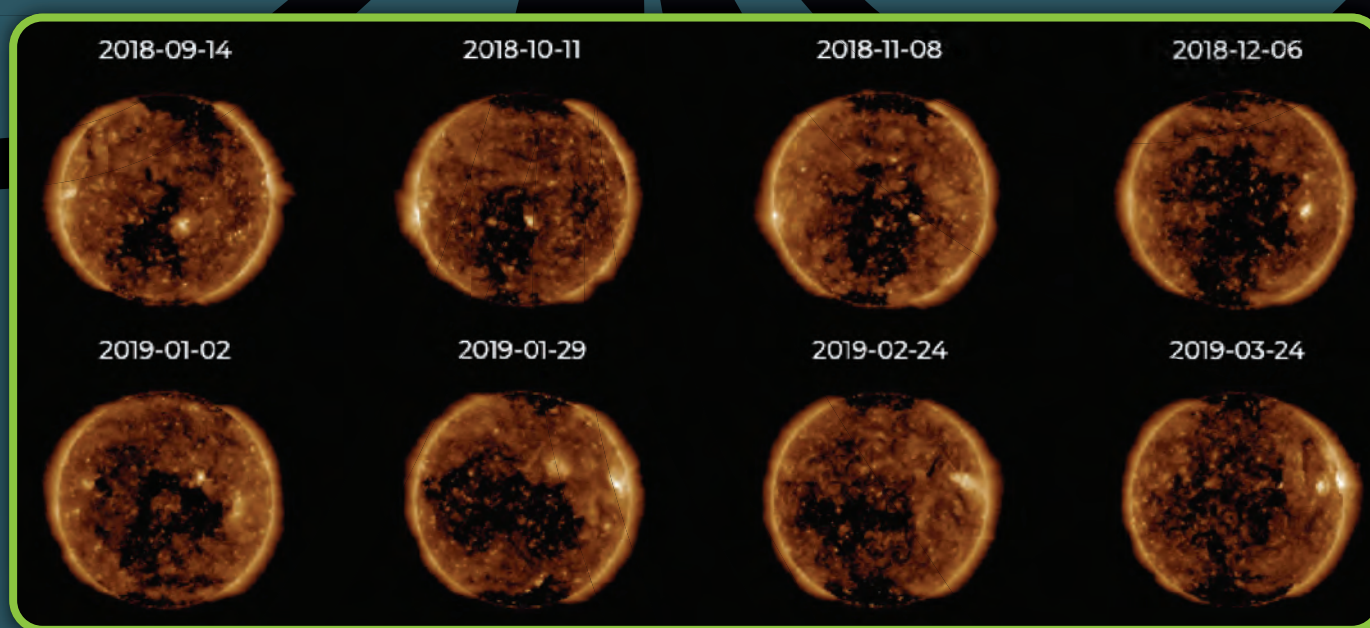
- Characterize the 3D magnetic structure of the Sun and Heliosphere during the solar activity minimum.
- Follow the evolution and effects of the Sun's radiative output, magnetic field and outflowing solar wind plasma as they interact with the background heliosphere and with the magnetospheres and atmospheres of the Earth and other Planets.
- Compare the current minimum with previous solar minima and investigate how periods of extremely low solar activity affect the geospace and other planetary space environments.
- Embrace latest advances in data collection, management, analysis, and communication and set the stage for the next generation of collaborative Heliophysics System Observatory research.

OBSERVING CAMPAIGNS

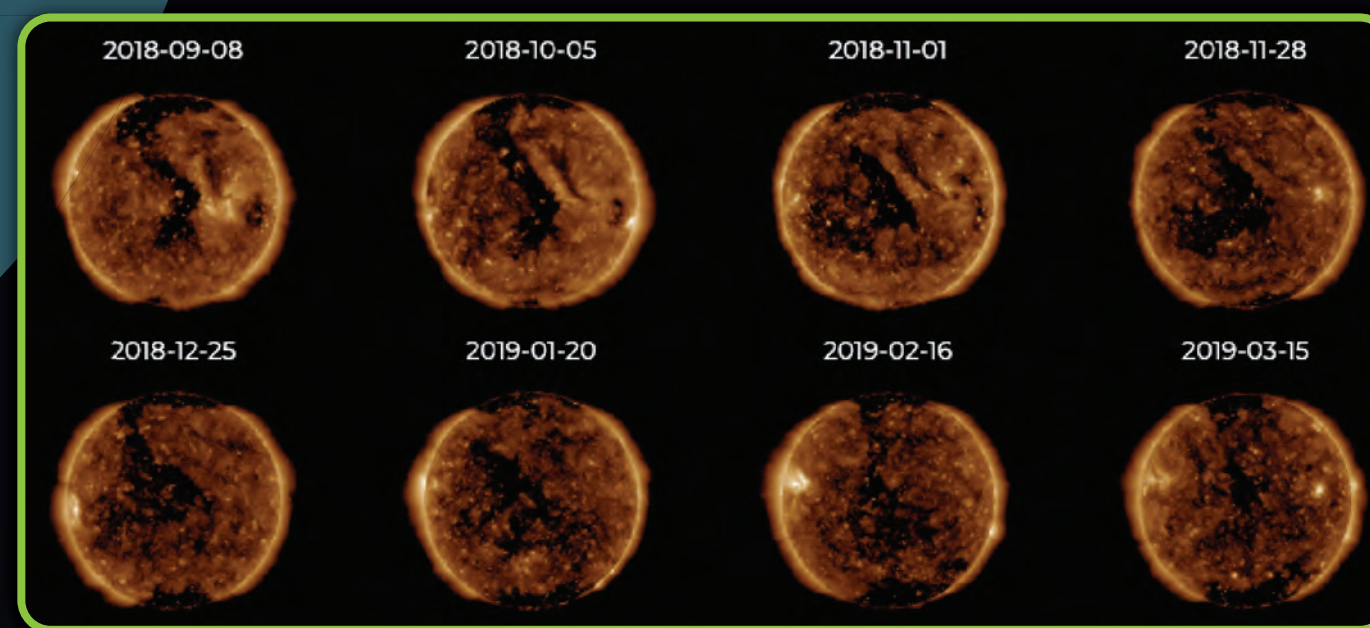
For the purpose of coordinating targeted observations, we have identified a few focus "campaign" time periods that take advantage of solar-heliosphere-planetary synergies including, for example, PSP perihelia.

Recurrent Coronal Holes/ High Speed Solar Wind Streams: Mar 12 - Apr 8, 2019

This campaign was focused on low-latitude coronal holes that become prevalent during the descending and minimum phase of the cycle and are sources of recurrent high-speed streams in the solar wind. The targets were two long-lived, low-latitude coronal holes that have been visible on the Sun for many rotations. (image inspiration: Janet Kozyra)



Coronal Hole #1



Coronal Hole #2

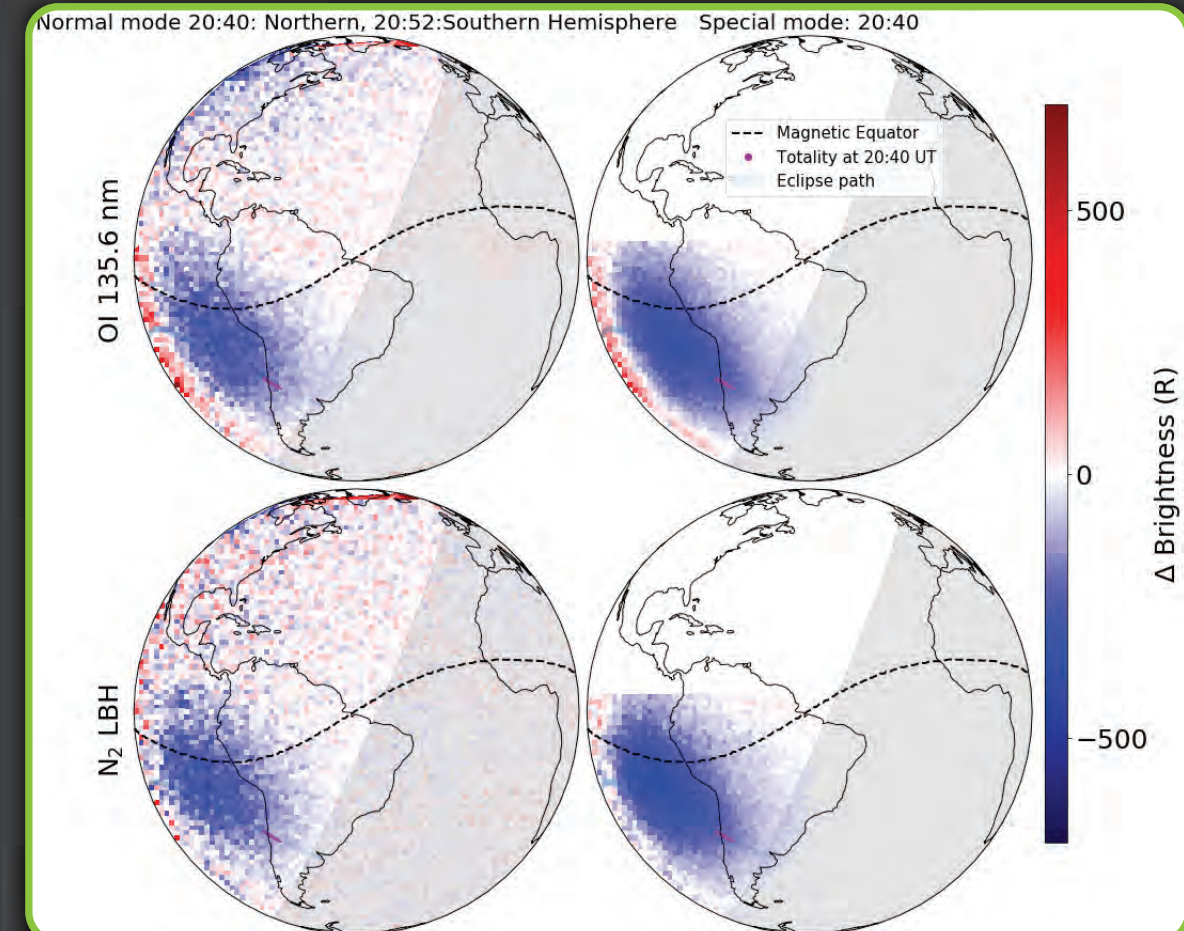
Total Solar Eclipse: Jun 29 - Jul 26, 2019

This campaign focused on the July 2, 2019 total solar eclipse visible across the South Pacific and southern South America. Total Solar eclipses are events that offer unique science opportunities. For example, observing the lower corona of the Sun with optimal conditions that cannot be achieved with coronagraphs; investigating how the Earth's atmosphere responds to the Sun's output; and measuring cosmic rays without the Sun as the source.

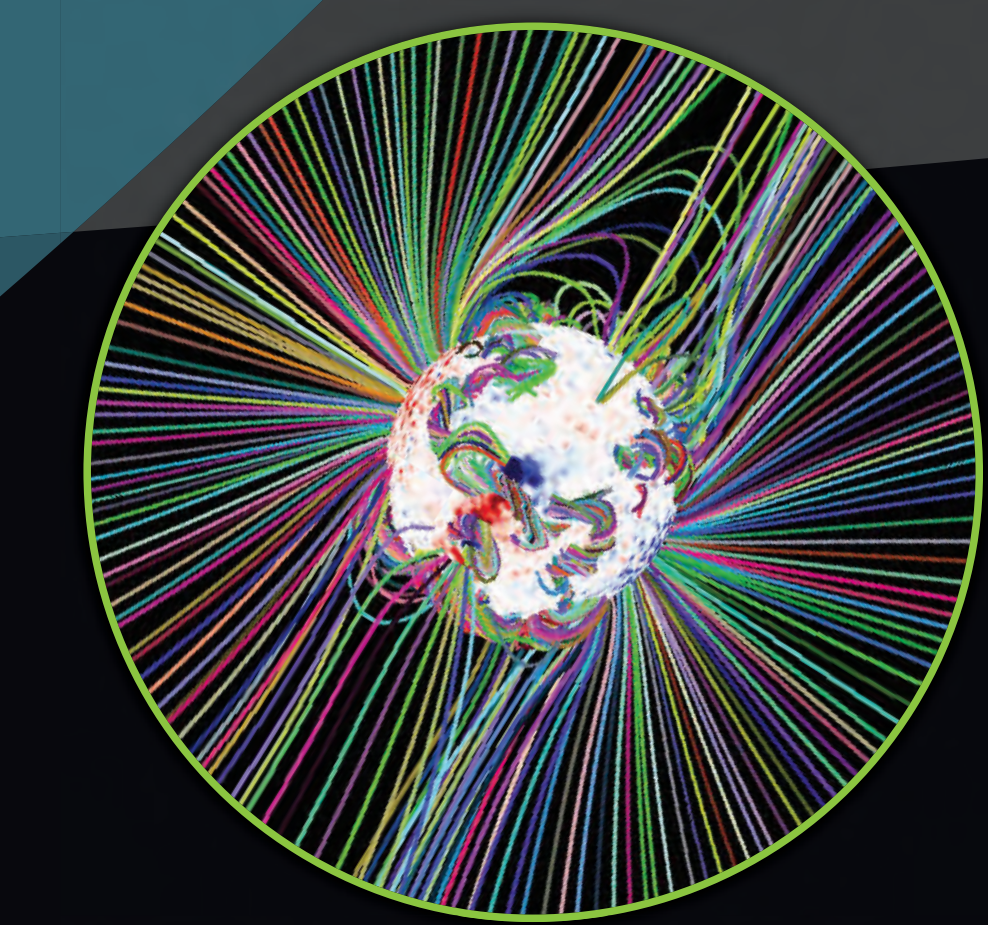


2 July, 2019 eclipse image taken at Cerro Tololo Inter-American Observatory (credit: NASA/Goddard/Rebecca Roth)

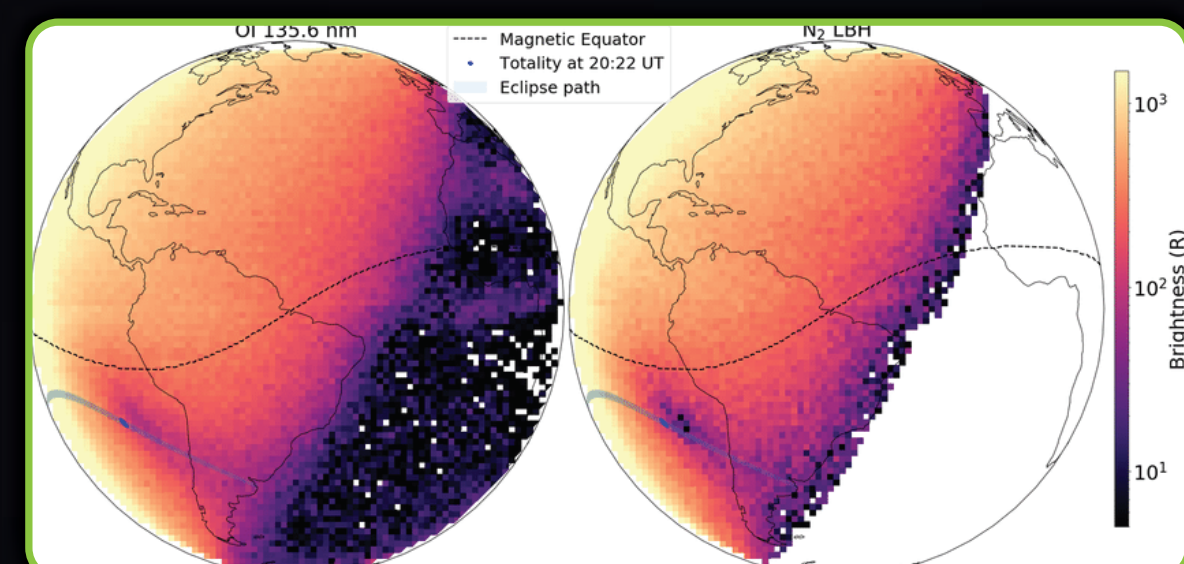
GOLD images solar eclipse effects in the thermosphere



GOLD Ch. A (left) and Ch. B (right) images of OI 135.6 nm (top) and N2 LBH (bottom) 20:40 UT July 2, 2019 brightness difference with June 30 baseline. (Saurav Aryal et al., 2020)



MHD model of the solar corona (Courtesy of Predictive Science Incorporated)



GOLD Ch. A images of OI 135.6 nm (left) and N2 LBH (right) brightnesses at 20:40 UT on July 2, 2019. The reduction in brightness is clear in both emissions very close to the totality. (Courtesy of Saurav Aryal and the GOLD Team)

GROUND-BASED SUPPORTING OBSERVATORIES

- | | |
|---------------------------------------------------|-------------------------------------------------|
| Advanced Modular Incoherent Scatter Radar (AMISR) | Jicamarca Radio Observatory (JRO) |
| Arecibo Observatory | Kanzelhöhe Observatory (KSO) |
| Baikal Astrophysical Observatory (BAO) | Kislovodsk Mountain Astronomical Station (KMAS) |
| Big Bear Solar Observatory (BBSO) | Latin American Giant Observatory/NEWRUS |
| Catania Astrophysical Observatory (INAF-OACT) | Lomnický Stit Observatory |
| Crimean Astrophysical Observatory (CrAO) | Long Wavelength Array (LWA) |
| Dunn Solar Telescope | Low-Frequency Array (LOFAR) |
| Expanded Owens Valley Solar Array (EOVSA) | Mauna Loa Solar Observatory (MLSO) |
| Expanded Very Large Array (EVLA) | Meudon Observatory |
| Félix Aguilar Observatory | MIT Haystack's Millstone Hill Geospace Facility |
| Fuxian Solar Observatory (FSO) | Nançay Decameter Array (NDA) |
| Global Oscillation Network Group (GONG) | Nobeyama Radioheliograph (NoRH) |
| GREGOR | Osservatorio Astronomico di Roma |
| Ground Magnetometers (USGS, SuperMAG Databases) | Pic du Midi Observatory |
| Hida Observatory | Sardinia Radio Telescope (SRT) |
| Huairou Solar Observing Station (HSOS) | Sayan Solar Observatory |
| Hvar Observatory | Siberian Radioheliograph (SRH) |
| Istituto Ricerche Solari Locarno (IRSOL) | SST |

SPACE MISSIONS RELEVANT TO WHPI

SOLAR	HELIOSPHERE	EARTH	PLANETS
PSP	ACE	AIM	MMS
Hinode	ARTEMIS	Geotail	THEMIS
Iris	IBEX	GOLD	TIMED
SDO	PSP	GRACE	Van Allen
SOHO	STEREO	ICON	
SORCE	WIND		

Whole Heliosphere and Planetary Interactions (WHPI) is an international initiative focused on the solar minimum period that aims to understand the interconnected sun-heliospheric-planetary system. The simpler magnetic configuration and infrequency of Coronal Mass Ejections (CMEs) makes solar minimum an ideal time to follow how the solar magnetic and radiative output propagates through the heliosphere and affects the Earth and planets' atmospheres and magnetospheres.

WHPI currently involves more than 600 solar, heliospheric, geospace, and planetary researchers, with monthly colloquia and show-and-tell tutorials, a special session at the Fall 2020 AGU, a workshop in 2021 with more than 200 registered participants, and multiple campaigns in support of Parker Solar Probe perihelia. A topical AGU Journals Special Issue is currently soliciting papers. These and other activities are coordinated via the WHPI web page.

HISTORY

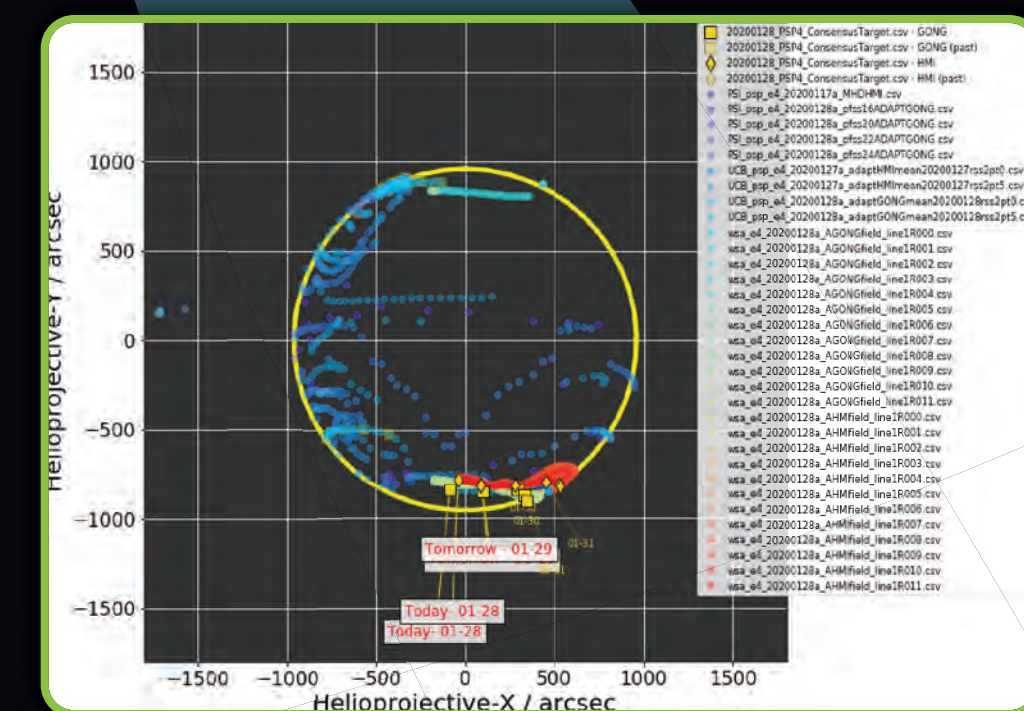
WHPI builds on the success of previous coordinated efforts to characterize the three-dimensional, interconnected solar-heliospheric systems during solar minimum: The international Whole Sun Month and Whole Heliosphere Interval. By focusing on particular solar rotations near solar minimum, specific structures and activity could be traced throughout the heliosphere and down into the Earth's space environment and upper atmosphere. The intervals have extended their discipline range with each iteration: from Sun-solar wind (WSM) to Sun-solar-wind-geospace (WHI). It is thus appropriate that WHPI will broaden the emphasis further to include planetary magnetospheres and atmospheres, and in particular, planetary space weather.

Parker Solar Probe Perihelion Observing Campaigns

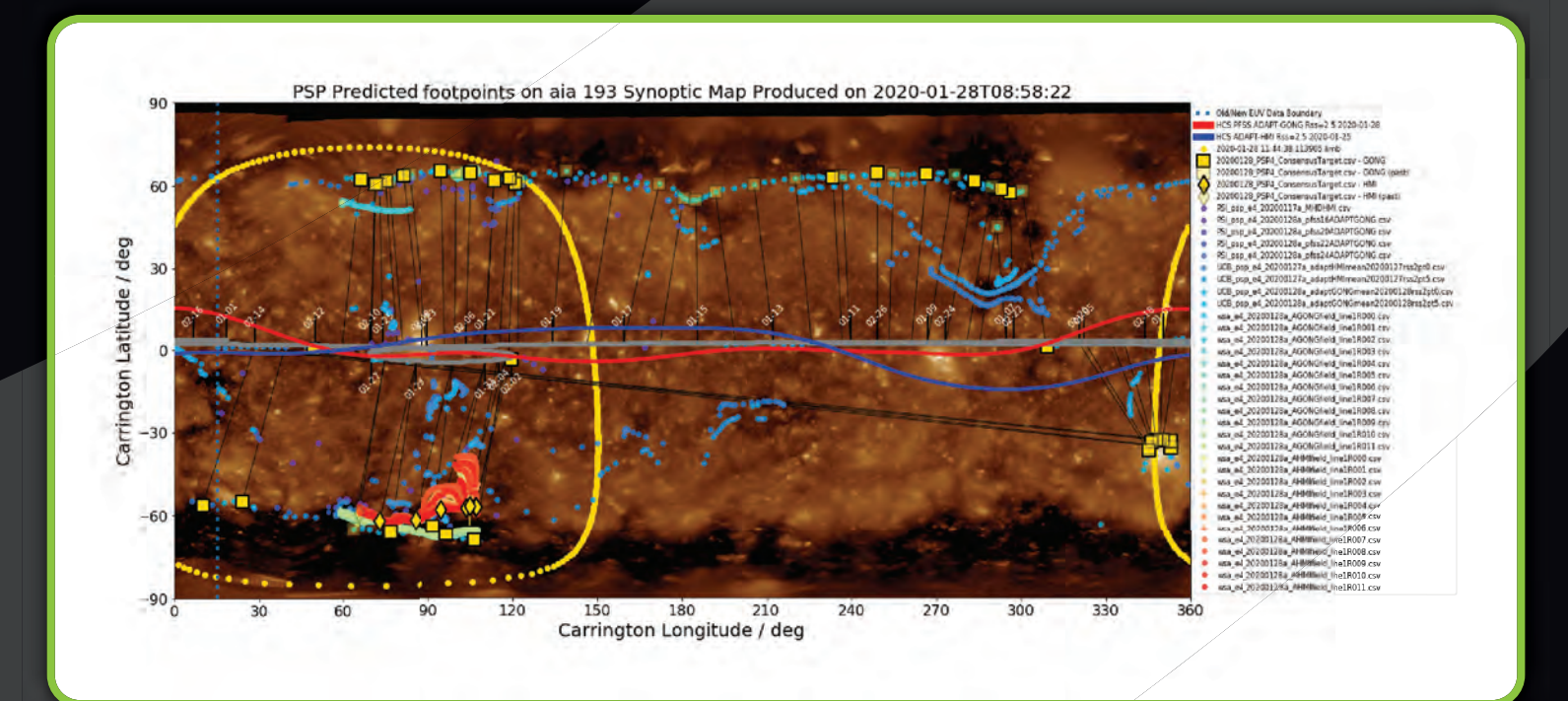
WHPI has completed four successful campaigns centered around PSP perihelions (4th perihelion, Jan 15 - Feb 11, 2020; 7th perihelion, Jan 12 - 23, 2021; 8th perihelion, Apr 28 - May 7, 2021; and 11th perihelion, Feb 18 - 28, 2022). Additionally, the coronal hole campaign overlapped with the PSP 2nd perihelion. Here we present the 4th perihelion campaign as an example of consensus target predictions and observations.

4th Perihelion campaign: Jan 15 - Feb 11 2020

During this PSP encounter with the Sun, the Earth and many space observatories were near-radially aligned with PSP, and STEREO A was near quadrature. This was an opportunity for coordinated targeted observations and modeling. Coordinated observations were made ahead of the campaign by 33 solar, 7 heliospheric, 15 geospace, and 3 planetary missions (see ground-based support and solar missions at bottom-left of this poster).



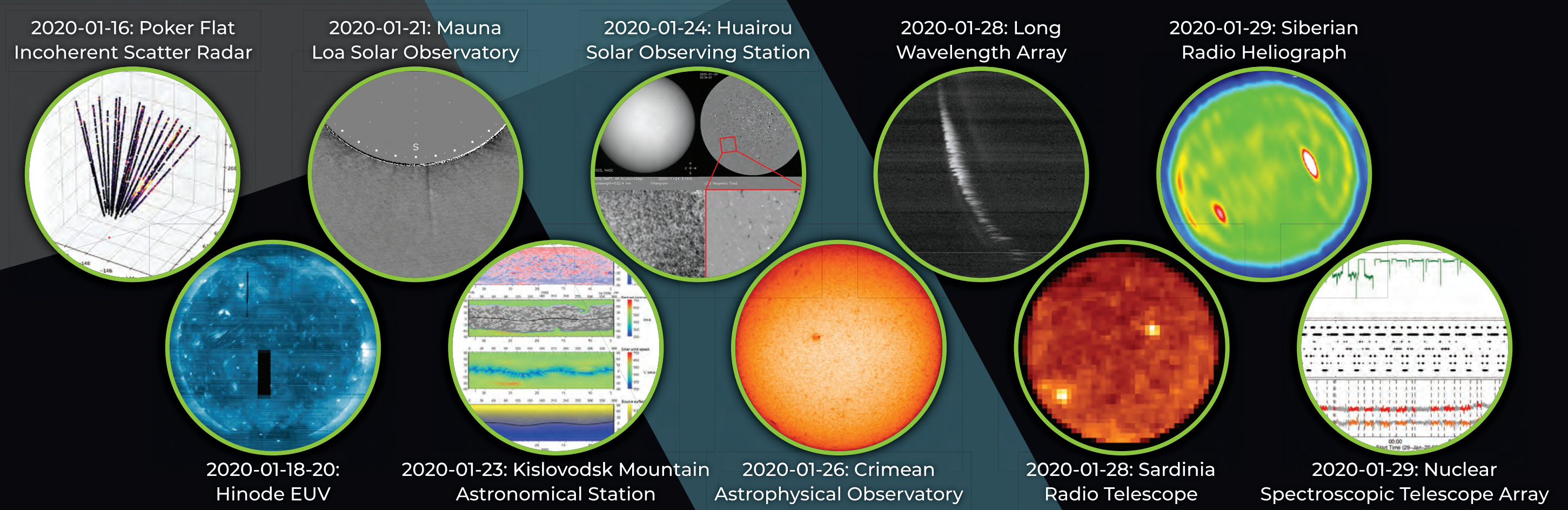
Helioprojective PSP predicted footprints: one footprint per day plotted on the solar disk. Colored dots show predictions from a range of models (Courtesy of Sam Badman).



Heliographic Carrington footprints of PSP: the same data as in above-left figure but in Carrington coordinates (latitude-longitude) and with error bars in latitude and longitude for ensemble predictions. Also shown in this plot is the most recent GONG-ADAPT current sheet generated by the UCB model (red), and the date-stamped PSP trajectory in Carrington coordinates (grey) (Courtesy of Sam Badman; SDO/AIA 193A synoptic map produced)

4th Perihelion Observation Highlights

During the PSP 4th perihelion, our contributing observatories were taking observations. Here are some contributed highlights. Visit the campaign pages of our website to see more.



Other Parker Solar Probe Campaigns

- 4th PSP Perihelion: Jan 15 - Feb 11, 2020
 - 7th PSP Perihelion: Jan 12 - 23, 2021
 - 8th PSP Perihelion: Apr 28 - May 7, 2021
 - 11th PSP Perihelion: Feb 18 - 28, 2022
- Unique opportunity for coordinated observations. PSP nearly radially aligned with the Earth and several satellites (PI: Nour Raouafi).
- Focused on high resolution observations of coronal holes. Many large solar telescopes involved: GREGOR, SST, BBSO, DST, and many radio observatories (PI: Stefan Hofmeister).
- Coordinated observations with PSP

GET INVOLVED

WHPI Workshop

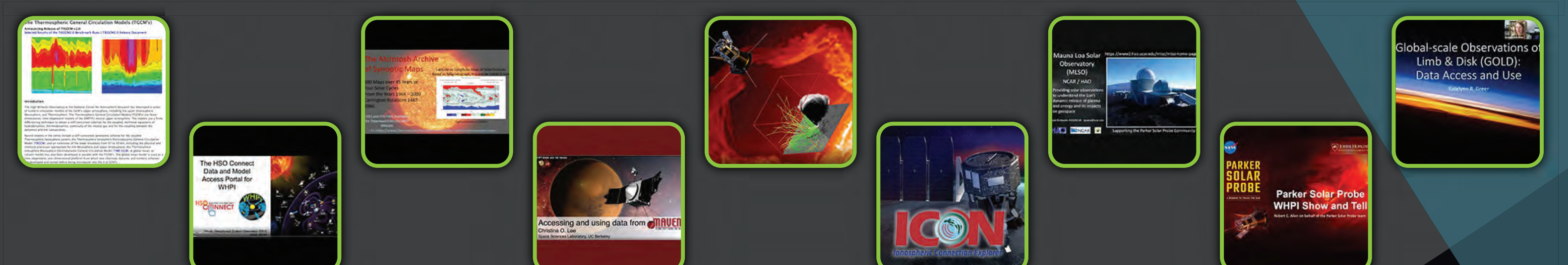
WHPI organized a successful virtual workshop from 13 - 17 September, 2020. We also had a presentation at COSPAR 2021 and a session at AGU 2020. Recording for these events can be found under 'Science' on our website.

WHPI Colloquia

To continue to promote discussion and collaborations across the various heliophysics and planetary disciplines, we host a series of WHPI Web Colloquia. Each colloquium will consist of two 20 min presentations + 5-10min for questions. Check our website for upcoming colloquia and recordings of past ones.

WHPI "Show & Tell" Days

WHPI regularly hosts presenters to offer tutorials of modeling and analysis techniques aimed at stimulating cross-disciplinary collaborations. These tutorials are prerecorded and are compiled in a library of tutorials on the WHPI website.



Examples of tutorials presented at "Show & Tell" days, which now reside in the WHPI website's library of tutorials



COMMUNITY COORDINATED MODELING CENTER

Link to website



<https://whpi.hao.ucar.edu>