SO/PHI data request form

Quiet Sun atmospheric heating through flux cancellations

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Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

Magnetic flux cancellation is one of the most important processes observed in the quiet Sun. It is responsible for a significant fraction of the total internetwork flux that is removed from the solar surface, 25% according to Gosic et al. 2016 (based on Hinode/NFI measurements) and even 41% according to Anusha et al. 2017 (based on SUNRISE/IMaX observations). Cancellations have been associated with localized brightenings and jets in chromospheric and transition region lines (Guglielmino et al. 2010; Ortiz et al. 2014, 2016).

Magnetic flux cancellation is believed to be the signature of magnetic reconnection in high layers, but the actual field topology and the height of energy release are not well known. Interestingly, this process may help explain the chromospheric heating of quiet Sun internetwork regions. Using SST and IRIS observations, Gosic et al. (2018) recently showed that the cancellation of internetwork fields also gives rise to strong small-scale brightenings in Ca II 8542 and SJI 2796/1400 A. Local temperature enhancements of up to 2000 K were detected in some cases in the temperature minimum region/low chromospherer by means of inversions. It was concluded that these events can explain the observed heating locally, but not globally because of too few cancellations. However, there is the possibility that many cancellation events were not detected in the internetwork due to insufficient polarimetric sensitivity.

Thus, the goals of this observing program are: (1) determine the rate of flux cancellation events in the quiet Sun internetwork at unprecedented sensitivity; (2) assess the influence of these events in the upper layers, focusing on their contribution to the chromospheric heating of the quiet Sun; and (3) resolve the azimuth ambiguity to distinguish Omega or U-loop magnetic configurations and understand the physical mechanism behind cancellations.

We will use the high polarimetric sensitivity of PHI to detect much weaker signals than has been possible until now. Also, the large field of view of PHI will allow us to cover several supergranular cells and increase the statistics. By combining the PHI observations with simultaneous EUI measurements at similar spatial resolution and cadence we will be able to cover the whole atmosphere seamlessly. Coordination with IRIS will reveal the chromospheric/transition region counterparts of these cancellation events, at the highest spatial resolution achievable nowadays. In summary, the dataset to be acquired will be unique in terms of its long duration, stability, and full coverage of the layers involved in magnetic cancellation events. All these are critical aspects to study the challenging quiet Sun internetwork.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Quiet Sun
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): Vector B, v_LOS, I_c
- Total length of observation: 1 hour
- Cadence (maximum 1 dataset/min): 1 dataset/min
- Pointing needs (disc centre, limb, active region location, particular μ): Disk center (tracking on)
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): Observations within perihelion window, for highest spatial resolution, angle to Earth between, say, 20 and 50 deg.
- Total number of datasets: 60 full datasets
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: 2k x 2k
- Full resolution or 2x2, 4x4 binned data: Full resolution
- noise level (default 10^{-3}): 10^{-3}
- Co-observations with other instruments: EUI observations, plus IRIS measurements, for seamless coverage of atmosphere. Hinode/SP or ground-based telescope (SST, DKIST) required for azimuth ambiguity resolution.
- Possible datasets: 2022-03-22T09:40-T10:40 and 2022-03-17T00:00-T00:30 (second one a bit too short)

SO/PHI data request form

Flux sources and sinks of the magnetic network

Luis Bellot Rubio[1], Milan Gošić[2]

[1]Instituto de Astrofísica de Andalucía-CSIC

[2]Lockheed Martin Solar and Astrophysics Lab

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

The network contains about 85% of the total quiet Sun magnetic flux (e.g., Gosic et al. 2014). What is the origin of this flux? Until recently, it was believed that ephemeral regions (ERs) are the main source of flux for the network. Martin (1990) reported that 90% of the network flux comes from ERs, while Hagenaar et al. (2003) found that the entire network flux can be replaced by ERs in only 8-19 hours.

However, using long-duration, high-cadence Hinode NFI magnetograms, Gosic et al. (2014) discovered that the internetwork transfers to the network as much flux as the network contains in only 14 hours. Indeed, the IN would contribute 1.6 x 10^{24} Mx day^{-1} to the network over the entire solar surface.

This is an enormous amount of flux. Since the network flux does not increase indefinitely, there must be a way to get rid of the flux supplied by the internetwork. We still do not know the exact mechanisms, but the network must be a place where flux cancellation/flux disappearance occurs continually.

The goals of this observing campaign are the following: (1) study the evolution of the magnetic network over the lifetime of supergranular cells; (2) determine the sources and sinks of network flux; (3) assess the contribution of internetwork fields to the network; (4) Study surface processes occurring in the network and their influence in upper layers.

To achieve these goals we propose to carry out a dedicated campaign to follow the evolution of several network cells from birth to death, at high cadence, high spatial resolution, high sensitivity, and with full Stokes polarimetry, including the linear signals that could not be observed with the Hinode NFI. A mimimum duration of 24 hours is required, with a goal of 48 hours. The observations should be complemented with simultaneous high-resolution EUI measurements over the same FOV and IRIS spectroscopic and imaging measurements, to obtain seamless coverage of the atmosphere. The IRIS data span a range of heights and are useful even with vantage points differing by 40 degrees. An apppropriate time to carry out the coordinated observations is the beginning of the perihelion window in the third orbit (April 5, 2023).

The proposed observations can solve an important problem in solar physics, namely the origin and fate of the network flux. They are truly unique, since no other existing or planned space asset has the sufficient sensitivity or FOV to provide the required measurements. This science problem cannot be tackled using observations from the ground because of their too short durations and small FOVs.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Quiet Sun
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): Vector B, v_LOS, I_c
- Total length of observation: 48 hours (minimum 24 h) -> third orbit with IRIS or second orbit without IRIS
- Cadence (maximum 1 dataset/min): 1 dataset/min
- Pointing needs (disc centre, limb, active region location, particular μ): Disk center (tracking on)
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): Observations within perihelion window for highest spatial resolution and partial co-rotation
- Total number of datasets: 2880 (minimum 1440, **equivalent to 360 full datasets** because of partial FOV)
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: 1k x 1k
- Full resolution or 2x2, 4x4 binned data: Full resolution
- noise level (default 10^{-3}): 10^{-3}
- Co-observations with other instruments: EUI observations at same spatial resolution and cadence, plus IRIS spectroscopic and imaging measurements, to study effects of network evolution in high atmospheric layers (first priority) . Low cadence SPICE maps to complement atmospheric coverage (second priority).

SO/PHI data request form

(first science orbit; SO/PHI-Team internal version)

Title
Solar Polar Faculae

Name of proposer
Julián Blanco Rodríguez

Affiliations
UV

Science case (stay on one slide):

please also state, why is PHI needed; why is the science unique?

- The topic of this proposal are Polar Faculae. Polar Faculae (PFe) are bright small scale magnetic features with kilo-Gauss fields found around the solar poles. Together with bright points are the clearest proxy of magnetic flux tubes, and contribute to global irradiance and magnetic field. PFe present an activity cycle in anti-phase with sunspots, i.e. appearing in higher numbers and at lower latitudes when the solar magnetic field is in poloidal configuration. Thus, PFe are key elements and tracers of the polar and global fields.
- The aim of the work is to study the magnetic field and topology of PFe from two vantage points simultaneously. PHI can provide very high resolution data and combine it with near-Earth observatories, revealing PFe minute structure and tube configurations and helping to constrain projection models. Moreover, following the solar rotation, PHI can observe the structures for longer periods of time and with more direct line of sight. Studying PFe magnetic field vector this way will grant new information into their distribution, characteristics, and contribution to the polar and global fields. The study of PFe evolution will also contribute to the polar dynamics understanding. And combined with EUI and SPICE, it will supply simultaneous observations at different heights for long time periods, providing evolution analyses of the PFe magnetic footpoints and their relation to the higher layer phenomena, giving support to studies of structure development from surface to outer solar layers.
- PFe observations at both maximum and minimum latitudes with polar pointing and coordinated observations with Earth of I_c + vector B are asked, together with raw data when possible. To be performed at particular windows: i) short series of 1-2 minutes cadence for short evolution; ii) series of few hours observations with 30-60 min cadence for mid-long evolution. FDT observations can provide larger context and statistics at lower resolution (possible PD enhancement of raw data) while still observed from two LOS.

Requirements/data (use additional slide if needed)

- Type of solar feature: **Polar Faculae**
- HRT or FDT: **mainly HRT, some context FDT**
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): **raw data; I_c + vector B**
- Total length of observation: **at specific windows: i) 60 min; ii) 24 hours**
- Cadence (maximum 1 dataset/min): **for the above specific windows: i) 1 min, maximum of 2 min between datasets; ii) 30 min, maximum of 60 min**
- Pointing needs (disc centre, limb, : **Poles**
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): **high latitudes**
- Total number of datasets: **minimum of i) 30-60 datasets, ii) 24-48 datasets**
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: **Full frame (in HRT), full disc FDT**
- Full resolution or 2x2, 4x4 binned data: **Full resolution**
- noise level (default 10^{-3}): **default**
- Co-observations with other instruments: **Hinode, ground based (e.g. SST)**
- Special requests: **program to be performed especially at maximum/minimum latitude windows**

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Heating of coronal loops: magnetic footpoint dynamics

Cosima Breu & MPS EUV team

MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- Numerical models of a coronal loop show the complex magnetic interaction from the photospheric levels into the coronal parts of the loop. In some cases internal rotation of the magnetic footpoints can be shown to be related to bright strands within the loop. Through a combination of high-resolution observations with EUI/HRI/174 and PHI/HRT we aim to study how the evolution of the photospheric magnetic field can govern the structure of strands forming a (bundle of) coronal loop(s). Based on experience from Hi-C we can expect EUI/HRT/174 to reveal some sub-structure within active region coronal loops. At matching resolution PHI will provide the evolution of the magnetic footpoints. Certainly, PHI should be able to isolate the relative dynamics between individual magnetic patches at the loop footpoints, and with some luck PHI might even reveal the internal motions within these magnetic patches. This would provide insight into the location of the generation of the energy flux into the loop.
- This is linked to “Loop brightenings: what is happening at the footpoints?”

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: **active region**
- HRT or FDT: **HRT**
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): **B_los, I_c**
- Total length of observation: **1 hour**
- Cadence (maximum 1 dataset/min): **1 min**
- Pointing needs (disc centre, limb, active region location, particular μ): **active region, best inside μ=0.5**
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): **inside 0.5 AU (resolution)**
- Total number of datasets: **60**
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: **full frame (to maximize FOV)**
- Full resolution or 2x2, 4x4 binned data: **full resolution**
- noise level (default 10^{-3}): ???
- Co-observations with other instruments: EUI/HRI/174; EUI/HRI/Lya; SPICE (for thermal context of diffuse corona)
- Special requests:

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Stereoscopic reconstruction of 2D photospheric velocity flows

D. Calchetti, G. Valori, J. S. Castellanos Duran

MPS

Science case (stay on one slide):

- Line-of-sight (LoS) velocity at photospheric heights has been measured for decades, while horizontal velocity is currently inferred using tracking algorithms applied to time series of magnetograms (LoS and vector) or continuum images. Combining PHI with HMI we will have the first possibility to measure LoS velocity from two vantage points, and this information can be used to observationally reconstruct two components of the 3D velocity vector.
- While the determination of the velocity vector will still be incomplete, the observations of particular phenomena on the Sun may allow to reconstruct the full velocity vector in particular cases. For instance, granular motions are mostly radial; similarly, the emergence of bipoles within a forming active region mainly occurs along the conjunction line between the forming sunspots. Such particular phenomena have a (approximate) symmetry that, combined with a favorable observation geometry, can be exploited for the full determination of the velocity vector with only two vantage points.
- Combined observations with PHI and HMI can be used to measure the proper horizontal motions of several features on the solar photosphere. If successful, we would use such measurements to constrain and validate widely used tracking algorithms applied to magnetic regions. Simulations are needed to validate the reconstruction algorithm and to properly treat systematic errors.

Requirements/data(use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: emerging AR (if possible, otherwise QS)
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): vector_B, v_LOS and I_c
- Total length of observation: at least 2h
- Cadence (maximum 1 dataset/min): less than 90s
- Pointing needs (disc center, limb, active region location, particular μ): active region location
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): 20-60 degrees to Sun-Earth line
- Total number of datasets: at least 80
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: best: full frame; needed: AR size
- Full resolution or 2x2, 4x4 binned data: full resolution
- noise level (default 10^{-3}): 10^-3
- Co-observations with other instruments: HMI
- Special requests: Angle to the Earth

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Longitudinal and transversal oscillations with stereo observations

Daniele Calchetti

MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- Oscillations in magnetic elements and in sunspots have been studied for decades. Only few studies (e.g. Stangalini et al 2013 for magnetic elements) tried to investigate the interaction between longitudinal and transversal waves by using tracking algorithm to measure the horizontal displacements.
- With PHI we will be able to study for the very first time this oscillations from a different vantage point. This opportunity must be exploited by performing stereo observations in order to detect velocity and magnetic signals of the same region observed from the Earth.
- This observation can reveal the interactions between different wave modes and any relation to magnetic field oscillations or inclination in small magnetic elements and in active regions. Multi-line observation could also be used to study the propagation through the atmosphere of these waves.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: QS, Sunspot if available
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): I_c, Vlos, Bvect (raw data if possible)
- Total length of observation: at least 1 hour (best: > 2h)
- Cadence (maximum 1 dataset/min): 60 s
- Pointing needs (disc centre, limb, active region location, particular μ): Depending on the angle to the Earth
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): Angle to the Earth ~20-60 degrees
- Total number of datasets: at least 60
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: min: .5k x .5k, best: full frame
- Full resolution or 2x2, 4x4 binned data: Full resolution
- noise level (default 10^{-3}): 10^-3
- Co-observations with other instruments: best: High resolution telescope and instruments with spectropolarimetric capability at high cadence and high sensitivity (CRISP, IBIS, GRIS, GFPI, HELLRIDE, HINODE SOT, ...); min: HMI
- Special requests: Possible off-pointing for stereo observation. If the requirements cannot be satisfied, I would be happy to have this observation during the second orbit.

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Constraining mode conversion with stereo observations

Calchetti (PI), Schunker, Roth, Strecker

MPS, UoN, KIS, IAA

Science case (stay on one slide):
Please also state, why is PHI needed; why is the science unique?

- Helioseismic waves are perturbed non-linearly by strong surface magnetic fields such as sunspots. This makes it challenging to infer the subsurface structure of sunspots and active regions.
- It has been suggested that sound waves are converted to magneto-acoustic waves in strong magnetic fields. These waves should be observed as a slow acoustic wave propagating along the direction of the magnetic field, and Alfvenic oscillations of the magnetic field itself.
- So far, it has only been possible to measure the line-of-sight velocity and the magnetic vector field from one direction to test this. Combining SO/PHI observations with SDO will give us the unique and essential “stereo” observations of the velocity vector and magnetic field vector to unambiguously observe these oscillations.
- Fully constraining perturbations to the helioseismic waves, may make it possible to better infer the subsurface structure of sunspots using helioseismology.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: active region / sunspot
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): vector B, v_LOS, I_c
- Total length of observation: 6 hours < t < 24 hours
- Cadence (maximum 1 dataset/min): 60 seconds (vector B could be 1/hour)
- Pointing needs (disc centre, limb, active region location, particular μ): active region location
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): angle to Earth, but common observation with SDO e.g. 20-50 degrees
- Total number of datasets: t/dt (1440 would be nice)
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: full frame
- Full resolution or 2x2, 4x4 binned data: 2x2 bin (resolution ~HMI could be fine if TM is low)
- noise level (default 10^{-3}): N/A
- Co-observations with other instruments: SDO
- Special requests: Potentially also interesting with full-disk observations if there is a big sunspot

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Validating photospheric tracking algorithms

D. Calchetti, B. Löptien

MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- Tracking horizontal displacements on the solar surface is used in many applications in solar physics. Several techniques exist, as LCT, FLCT, ILCT, YAFTA, CST, DAVE, and comparisons have been made between them (e.g. Welsch et al. 2008). Despite the systematic errors and limitations of these algorithm, they are valuable tool in modern solar physics.

- We aim to test the results obtained by tracking algorithms in comparison with transversal velocity obtained by stereoscopic observations provided by Earth observatories and PHI, and measuring the effect of other systematic errors, as the CLV.

- This will be the very first time that such a test will be done by directly measuring the transversal velocity of the photosphere, and by observing the same region of the Sun from different vantage points.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Quiet Sun
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): min: (I_c, V_LOS, B_LOS); best: raw data
- Total length of observation: min: 2 hour; best: more than 8 hours
- Cadence (maximum 1 dataset/min): 1 minute
- Pointing needs (disc centre, limb, active region location, particular μ): Depending on the angle to the Earth
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): angle to the Earth ~30 – 60 deg
- Total number of datasets: at least 120
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: min: 512x512, best: full frame
- Full resolution or 2x2, 4x4 binned data: full resolution
- noise level (default 10^{-3}): 10^-3
- Co-observations with other instruments: HMI, ground facilities if possible
- Special requests: Stereoscopic observation (possible off-pointing). At least 8 hours of observation at HiRes and HiCad is needed for granulation tracking. If the requirements cannot be satisfied, we would be happy to have this observation during the second orbit.

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Relationship between the Ca II K brightness and the magnetic field strength using SO/PHI in combination with Rome/PSPT

T. Chatzistergos, N. Krivova, S.K. Solanki (MPS)

I. Ermolli (INAF OAR)

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- Close relationship between Ca II K brightness and the magnetic field strength is known, but the exact form differs among the various studies and is particularly uncertain at higher B/μ.
- Such a relationship is important for, e.g., recovering the evolution of the solar magnetic field on decadal-centennial time scales from historical Ca II photographs, which is, in turn, important for solar irradiance reconstructions, understanding solar influence on climate and understanding brightness variability of Sun-like stars.
- Observing simultaneously the same regions on the Sun from different viewing angles, SO/PHI and Rome PSPT (also using magnetograms from SDO/HMI) offer a unique opportunity to better constrain this relationship.

Requirements/data

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: faculae/network/QS
- HRT or FDT: FDT and HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): B_LOS, I_c
- Total length of observation: 5-10 minutes daily or every few days throughout the whole window
- Cadence (maximum 1 dataset/min): 1 dataset/min
- Pointing needs (disc centre, limb, active region location, particular μ): SW+PW: around disc center, NW: westward of disc centre (has to see parts of the Sun that would be seen by PSPT close to limb)
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): SW + PW more important; if available, data from the cruise phase would also be helpful
- Total number of datasets: ~ 1 set/min x (5-10 min/day) x (10-30 days) ≈ 50 – 300 sets
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: full frame
- Full resolution or 2x2, 4x4 binned data: full
- noise level (default 10^{-3}): default
- Co-observations with other instruments: Rome PSPT (Kanzelhöhe can be used as a back-up in case of bad weather)
- Special requests: (1) see pointing needs; (2) SO/PHI data taken CET mornings (e.g. 08:30-14:30 UT) are preferrable

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Magnetic footpoints of active region loops

Lakshmi Pradeep Chitta

Max Planck Institute for Solar System Research

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- Using Sunrise high-resolution observations, we identified cancellation of mixed-polarity magnetic field patches at the footpoints of loops in active regions. This cancellation process and associated reconnection could heat the overlying corona. SO/PHI will be able to provide longer time sequence covering a larger field of view than Sunrise. With the proposed observing sequence, we would address the issue of prevalence of magnetic flux cancellation/emergence at the footpoints of coronal loops in active regions.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: **Active region or prominent magnetic bipoles closer to the disk center.**
- HRT or FDT: **HRT**
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): **B_LOS**
- Total length of observation: **4 hours**
- Cadence (maximum 1 dataset/min): **1 minute**
- Pointing needs (disc centre, limb, active region location, particular μ): **active region / bipoles near disk center**
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft):
- Total number of datasets: **4**
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: **Full frame**
- Full resolution or 2x2, 4x4 binned data: **Full resolution**
- noise level (default 10^{-3}): **Default**
- Co-observations with other instruments: **SO/EUI**
- Special requests:

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Evolution and stability of magnetic network

Lakshmi Pradeep Chitta and Jonathan Nölke (PhD Student)

Max Planck Institute for Solar System Research

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- The larger field of view of SO/PHI and its ability to observe magnetic fields at high spatial resolution for longer duration enables us to better probe the evolution and stability of magnetic network structure of the quiet Sun. With the proposed observations, we will address how network forms and decays by investigating collective behaviour of its magnetic elements on longer timescales of hours.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: **Quiet-Sun magnetic network**
- HRT or FDT: **HRT**
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): **B_LOS**
- Total length of observation: **24 hours (longer if possible)**
- Cadence (maximum 1 dataset/min): **2 minute**
- Pointing needs (disc centre, limb, active region location, particular μ): **disc center**
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft):
- Total number of datasets: **2**
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: **Full frame**
- Full resolution or 2x2, 4x4 binned data: **Full resolution**
- noise level (default 10^{-3}): **Default**
- Co-observations with other instruments: **SO/EUI to study impact on the upper atmosphere**
- Special requests:

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Magnetoconvection in unipolar plages

Lakshmi Pradeep Chitta

Max Planck Institute for Solar System Research

Science case (stay on one slide):
Please also state, why is PHI needed; why is the science unique?

- Active regions harbour extended unipolar plages. Recently, using SST observations we studied granular-scale magnetic dynamics in a decaying plage region. We found signatures of transient flux emergence/cancellation within unipolar regions. This provides clues on the nature of magnetoconvection in plages. However, SST observations were seeing-limited and were not of long duration. This limited our ability to extract statistical properties of magnetic transients in plages. Such transients could be important in transferring heat to the overlying coronal moss or plumes (densely packed coronal loops rooted in plages). We propose to observe plages with So/PHI in order to gain better insights into how unipolar areas in active regions evolve.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: **Active region plage closer to the disk center.**
- HRT or FDT: **HRT**
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): **vector B**
- Total length of observation: **4 hours**
- Cadence (maximum 1 dataset/min): **1 minute**
- Pointing needs (disc centre, limb, active region location, particular μ): **active region closer to disk center**
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft):
- Total number of datasets: **4**
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: **Full frame**
- Full resolution or 2x2, 4x4 binned data: **Full resolution**
- noise level (default 10^{-3}): **Default**
- Co-observations with other instruments: **SO/EUI**
- Special requests:

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Multi-angle view of fast horizontal flows in photospheric granulation

Catherine Fischer, Nikola Vitas, Luis Bellot Rubio

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Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

Simulations show supersonic horizontal flows within granules covering 3%–4% of the solar surface at any time (Stein & Nordlund 1998) with shocks forming near intergranular lanes at the deceleration sites of the horizontal flows (Cattaneo + 1990).

In observations horizontal flows can only be detected directly when observing towards the limb as they are seen then as projected line-of-sight velocities. This is at the cost of significant loss of spatial resolution. Therefore other indicators at disk center were taken as proxies to detect fast horizontal flows and associated shocks, such as the excess in line width at intergranular lanes interpreted as a sign of turbulence introduced by the shocks (Nesis+ 1992). Utilizing high spatial resolution Hinode SP observations taken at low mu-angle Bellot Rubio (2009) showed that as a lower limit 0.3% of pixels in the Field of view harbour fast horizontal flows with maximum blueshifts at the border of the granule in the direction to the disk center/towards the observer.

We now have the unique opportunity by combining SO/PHI and EUI data together with satellite (Hinode SP) or ground-based data to observe these features stereoscopically. We will thereby be able to detect the fast horizontal flows, pinpoint their location, study the granulation pattern without foreshortening, and analyze effects on the upper solar atmosphere.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature*: quiet Sun*
- HRT or FDT: *HRT*
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): *preferably raw data (else nominal HRT: B vector, vlos, Ic)*
- Total length of observation: *20 minutes*
- Cadence (maximum 1 dataset/min): *1 dataset/min*
- Pointing needs (disc centre, limb, active region location, particular µ): *disc centre*
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): *high spatial resolution, angle to Earth between 40 degrees and 70 degrees*
- Total number of datasets: *20 data sets*
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: *FOV can be reduced to 1k x 1k or even 0.5k x 0.5k in case of telemetry restrictions*
- Full resolution or 2x2, 4x4 binned data: *Full resolution*
- noise level (default 10^{-3}): *default*
- Co-observations with other instruments: *EUI*
- Special requests: *This science case needs to be run with Hinode/SP or comparable spectropolarimeter or spectroscopy instrument with similar spectral resolution .*

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Photospheric response to flares

Catherine Fischer, Lyndsay Fletcher, Sebastián Castellanos Durán

Leibniz-Institute for Solar Physics (KIS), University of Glasgow,
Max Planck Institute for Solar System Research

Science case (stay on one slide):

We are interested in studying the impact on the lower solar atmosphere during the large energy release associated with a flare. We have found short-lived and localized (5 arcsec) photospheric asymmetric Stokes V profiles at locations of chromospheric hard X-ray sources during an X-class flare (Fischer+2012). These patches show a subresolution fine structure and indicating either fast opposing mass flows within the resolution element (possible triggers for sunquakes) or localized heating affecting the line shape (indicating chromospheric back warming (Kerr+ 2014)).

We plan to analyze the possible physical processes behind magnetic field transients that show up as opposite polarity intrusions in flaring sunspots, and link them with the responses of other layers in the solar atmosphere. Studying such transient as well as permanent magnetic field changes (cf. Kleint 2017; Castellanos Duran+2020) can provide valuable input to the flare dynamics and for flare models.

From the PHI instruments we will obtain high spatial resolution, high cadence magnetic field and velocity information, which will pinpoint the impacted photospheric region and would allow to resolve the previously mentioned fine structure of the loop foot points and their connection with sunquakes (if present).

In addition, EUI data allows to study the loop connectivity, to identify post-flare loops, and Lyman-alpha kernels of the flare, whereas plasma composition as well as loop density and temperatures are derived with SPICE. With STIX we perform X-ray imaging and spectra analysis, locate the hard X-ray sources (impact locations), and identify soft X-ray loop tops to gain further information on magnetic field topology and energy release.

WHY PHI: SO is currently the only observatory to deliver magnetic field information together with X-ray imaging The large FOV of PHI as a imaging spectropolarimeter makes it possible to cover the whole flare arcade and its footpoints at the same time. Combined with the chromospheric and transition region information Solar Orbiter is the only observatory which can collect all the necessary data for this science case.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature*: Flaring active region*
- HRT or FDT: *HRT*
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): *PHI HRT nominal mode: v_LOS, I_c, B_vector, (preferably if possible raw data)*
- Total length of observation: *2h*
- Cadence (maximum 1 dataset/min): *1 dataset/1min*
- Pointing needs (disc centre, limb, active region location, particular μ): *Sunspot*
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): *high spatial resolution (close to the Sun)*
- Total number of datasets: *120 datasets*
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: *Full frame if restricted due to telemetry also 1kx1k acceptable*
- Full resolution or 2x2, 4x4 binned data: *Full resolution*
- noise level (default 10^{-3}): *default*
- Co-observations with other instruments: *STIX,EUI,SPICE*
- Special requests: *no special request*

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Magnetic field flux evolution and H-alpha filament formation

Ricardo Gafeira, David Orozco Suarez

University of Coimbra, Instituto de Astrofisica de Andalucía

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

It is well-known that magnetic fields support and surround the cool and dense plasma of filaments above the visible solar surface (photosphere) and several configurations have been proposed for them.

Although their detailed configuration is under debate, these magnetic fields are rooted in the underlying photosphere and stay rooted there for a long period of time, until the filaments vanish or get ejected.

The imprint on the magnetic field at the photospheric layers are relevant for understanding the whole filament formation and evolution process.

The photospheric counterpart of the filaments magnetic skeleton can actually be seen even before the filaments are visible. Hence, it is important to follow the evolution of magnetic fields under filaments.

Hence, we propose to study the emergence and cancelation rates of the photospheric magnetic field along the solar surface just where the filament sits.

With this information we expect to identify regions where the emerging and canceling rates will be different from the quiet Sun surroundings or even specific of filament appearance

Ultimately, if precursors for the H-alpha filament appearance and formation were identified using PHI data, the locations where filaments will appear could be predicted before we can observe it from the Earth. In this case, this result will strongly depend for the future observations on the gap between the PHI observation of the target and the time that will be possible to observe from the earth.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: emerging H-alpha filaments
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): vector B, v_LOS, I_C
- Total length of observation: 3/6 hours
- Cadence (maximum 1 dataset/min: 10 min or less (I based that values on the nano flare programs)
- Pointing needs (disc centre, limb, active region location, particular μ): N/D
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): Preferentially an SO-Sun-Earth angle lower than 60 degrees
- Total number of datasets: 36/72
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: Full frame
- Full resolution or 2x2, 4x4 binned data: Full resolution
- noise level (default 10^{-3}): Default
- Co-observations with other instruments: any ground telescope that observes H-alpha
- Special requests:

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Small-scale internetwork magnetic structure and the diffuse QS corona

Jamie Gorman & MPS EUV team

MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- In the quiet Sun, the corona as seen in EUI/HRT/174 shows not only small-scale brightenings, the campfires, but also comparably large regions with very smooth appearance. In analogy to the background seen in active regions, this could be termed diffuse corona. Organized in patches of a few to several 10 Mm in size it is unclear how these unstructured features are driven energetically. One possibility could be the (interaction of) network and internetwork fields or emergence and braiding of the flux within the internetwork. Comparing extrapolations of the magnetic field with the spatial distribution of the diffuse corona will reveal some first hints on the magnetic connectivity. The combination of EUI and PHI is a key: the high resolution of EUI is needed to distinguish small isolated brightenings from the diffuse corona and with matching resolution PHI will then reveal the magnetic structure below. Following the evolution of the magnetic patches at the surface level should give insight into how the magnetic dynamics could drive these diffuse coronal features.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: **quiet Sun**
- HRT or FDT: **HRT**
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): **B_los, I_c**
- Total length of observation: **1 hour**
- Cadence (maximum 1 dataset/min): **1 min**
- Pointing needs (disc centre, limb, active region location, particular μ): **QS @ disk center**
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): **0.3 AU (resolution)**
- Total number of datasets: **60**
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: **full frame (to maximize FOV)**
- Full resolution or 2x2, 4x4 binned data: **full resolution**
- noise level (default 10^{-3}): ???
- Co-observations with other instruments: EUI/HRI/174; EUI/HRI/Lya; SPICE (for thermal context of diffuse corona)
- Special requests:

SO/PHI Data Request Form

Magnetic Nature of Campfires Seen in EUI/HRI

Fatima Kahil*, Pradeep Chitta*, Sudip Mandal*

*Max Planck Institute for Solar System Research, Göttingen, Germany

Science case (stay on one slide):
Please also state, why is PHI needed; why is the science unique?

Quiet-Sun observations with SO/EUI/HRI have recently uncovered the ubiquitous presence of small-scale brightenings (campfires) that are typically of few Mm2 in size and last only for few tens of seconds. In addition to that, uni and bi-directional plasma jets have also been identified using the high cadence EUI observations. It is conjectured that the mechanism that drives these brightenings is possibly the small-scale magnetic reconnection. Given the spatial extents of these bright features, SO/PHI HRT observations are best suitable for an investigation of the underlying field at this high spatial resolution. We propose to provide SO/PHI HRT time series of a quiet-Sun region at disc center at maximum cadence recorded co-spatially and co-temporally with EUI HRI time series. Apart from a quiet-Sun region, it would also be interesting to investigate a more active patch such a moss region and compare the field configurations. This would facilitate us towards a better understanding of the physical conditions that lead to a reconnection event.

The PHI B_LOS maps in the first place will allow us to distinguish between scenarios such as emergence or cancellation, wherein magnetic field extrapolations will help us understand the different field configuration types such as forking vs crossing, and to compare with theoretical models of these small-scale transient events.

Such required time series are best recorded around perihelion, at highest spatial resolution. However, there are also advantages in recording a set of observations at inferior conjunction with Earth during the first orbit. The spatial resolution will be only roughly half as high, but it will allow making additional use of Earth-orbiting resources, in particular IRIS, but also AIA and partly Hinode. Observations at intermediate angles between these two extremes will allow determining the heights of the campfires when combining EUI and AIA observations. This will be of considerable value when applying extrapolation techniques to the observed magnetic maps in order to get the magnetic structure at the height of the campfires.

Requirements/data
Besides best guess requirements, you may also list minimum requirements on the data

Type of Solar Feature: Quiet Sun, Active region moss

HRT or FDT: HRT

Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): raw data, B_Los

Total length of observation: 1 hour

Cadence (maximum 1 dataset/min): 1 min

Pointing needs (disc centre, limb, active region location, particular μ): disc center

Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): perihelion, Inferior Earth conjunction

Total number of datasets: 60 datasets

Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: 2k x 2k

Full resolution or 2x2, 4x4 binned data: full

noise level (default 10-3): default

Co-observations with other instruments: EUI/EUV HRI and EUI/ Lya HRI and SPICE, AIA, IRIS

Special requests: none

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Continuum intensity perturbation due to solar oscillations

Nadiia Kostogryz, Damien Fournier, Laurent Gizon, Jesper Schou

MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- Solar continuum intensity is often used as one of the observables in helioseismic measurements. These measurements show a centre-to-limb systematic effect (Zhao et al.2012). This appears due to some physical, such as the interaction between p-modes and granulation (Baldner& Schou , 2012, Schou &Birch 2020) as well as radiative transfer effects in the perturbed atmosphere (Kostogryz et al. 2021), and instrumental effects (Liang et al. 2018, Gizon et al. 2020).
- Solving radiative transfer in the perturbed atmosphere due to oscillations is not a trivial problem (Kostogryz 2021), however, it allows us to understand the physical reason of the centre-to-limb variation of the observed oscillations. Recently, we solved this problem and described behaviour of different modes from the centre to the limb.
- Observing from two angles should allow us to check the calculations. As we observe the same position from different angles we will measure the intensity with the maximum contribution of the different sources to the intensity at different heights. This will cause the phase shift and the amplitude difference between the two measurements and closer to the limb this phase shift and amplitude will be larger. A good understanding of these effects will lead to a better understanding of the mode physics near the solar surface and also it will lead to reducing some of the systematic errors in helioseismic measurements.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Full disk.
- HRT or FDT: FDT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): I_c
- Total length of observation: At least 24 hours.
- Cadence (maximum 1 dataset/min): 1/min
- Pointing needs (disc centre, limb, active region location, particular μ): N/A (full disk)
- Orbit needs: Large overlap with Earth view. At least ~15 degrees off Earth-Sun angle.
- Total number of datasets: At least 24 hours (1440 datasets)
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: Full disk.
- Full resolution or 2x2, 4x4 binned data: Resulting solar diameter of at least 500 pixels
- noise level (default 10^{-3}): Default should be fine, no polarimetry
- Co-observations with other instruments: HMI. Should preferably avoid eclipse seasons.
- Special requests: This is intended to be covered with the 2021 and 2022 HS runs.

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Understanding solar UV variability using SO/PHI in combination with Aditya/SUIT

N. Krivova, K.L. Yeo, S.K. Solanki, T. Chatzistergos

MPS

Science case (stay on one slide):
Please also state, why is PHI needed; why is the science unique?

- Variability of the solar UV (200-400 nm) irradiance is critical for understanding solar influence on climate but is poorly constrained:
  - in UV irradiance measurements due to insufficient stability of the instruments;
  - in irradiance models due to uncertainties in the facular Contrast(B, λ, μ).
- Facular Contrast(B, λ, μ):
  - Observations: difficult, single λ and μ, B is usually not available;
  - Models: mostly 1D (poor closer to the limb) with no direct link to B; 3D models start appearing (observational validation needed).
- Aditya-L1/SUIT: will provide full disc images in 3 broad-band filters between 200 and 400 nm and a number of narrow ones (e.g. Ca II, Mg II) with the resolution of 1.4".
- SUIT will give Contrast(λ, μ). SDO/HMI can provide B/μ (thus high uncertainty closer to the limb). By observing regions, that are close to limb in SUIT images, at the disc centre (or close to it) SO/PHI can provide B directly without foreshortening, which is unique.

Requirements/data

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: faculae/network/QS
- HRT or FDT: Ideally HRT. As a minimum requirement: at perihelion, FDT would do as well; further away – HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): B_LOS, I_c
- Total length of observation: 5-10 minutes every few days throughout the whole window (minimum: 5 min on 5 days during SW and PW)
- Cadence (maximum 1 dataset/min): 1 dataset/min
- Pointing needs (disc centre, limb, active region location, particular μ): SW+PW: around disc center, NW: westward of disc centre (has to see parts of the Sun that would be seen by SUIT from L1 close to limb)
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): SW + PW more important
- Total number of datasets: ~ 1 set/min x (5-10 min/day) x (5-10 days) ≈ 25 – 100 sets
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: full frame
- Full resolution or 2x2, 4x4 binned data: full
- noise level (default 10^{-3}): default
- Co-observations with other instruments: Aditya-L1/SUIT (also SDO/HMI but this should be available)
- Special requests: see pointing needs

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

CLV of the facular contrast using SO/PHI in combination with SDO/HMI

N. Krivova, K.L. Yeo, S.K. Solanki, F. Kahil

MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- Uncertainties in the facular contrast, in particular its dependence on B and μ, limit the reliability of the spectral irradiance models. This has consequences for our understanding of solar influence on climate.
- Current issues with the available facular contrasts(B, μ):
  - Observations: B is usually not available; observations close to the limb are uncertain;
  - Models: mostly 1D (poor closer to the limb) with no direct link to B; 3D models start appearing (observational validation needed).
- By observing the same regions on the Sun from different viewing angles, SO/PHI and SDO/HMI can provide B directly without foreshortening, which offers a unique opportunity to constrain the facular contrast close to the solar limb.

Requirements/data

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: faculae/network/QS
- HRT or FDT: FDT; if possible also HRT at a few orbital positions, especially when further away from the Sun
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): B_LOS, I_c
- Total length of observation: 5-10 minutes daily or every few days throughout the whole window
- Cadence (maximum 1 dataset/min): 1 dataset/min
- Pointing needs (disc centre, limb, active region location, particular μ): For HRT: SW+PW - around disc center, NW - westward of disc centre
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): SW + PW more important; if available, data from the cruise phase would also be helpful
- Total number of datasets: ~ 1 set/min x (5-10 min/day) x (10-30 days) ≈ 50 – 300 sets
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: full frame
- Full resolution or 2x2, 4x4 binned data: full
- noise level (default 10^{-3}): default
- Co-observations with other instruments: SDO/HMI (should be available)
- Special requests: For FDT: see pointing needs

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

The center-to-limb variations in the helioseismic travel-time measurements from the PHI observations

Zhi-Chao Liang

MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- PHI provides us an opportunity to observe the meridional flow in the polar regions. To measure the meridional flow using time-distance helioseismology, one needs to remove a major systematic error in the travel-time measurements, the center-to-limb variations (CLV).
- Previously I found that the magnitude of HMI's CLV depend on SDO's orbital motion. So the CLV obtained from PHI could be different from that of HMI due to different orbital motions, even they both measure the same spectral line.
- As a first step toward the measurement of the meridional flow in the polar regions, I would like to determine the CLV from PHI and compare with that from HMI.
- To investigate the CLV in a different aspect, I would also like to measure the time lag between the Doppler signals viewed by the two instruments, which is expected to be consistent with the CLV obtained from the travel-time measurements.
- The result of this work will be used to determine the meridional flow in the polar regions if possible. This work will also provide useful information for the mode physics where the CLV may come into play in the measurement of the phase shift between the Doppler signals viewed from different vantage points.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: quiet sun, full solar disk
- HRT or FDT: full-disk images
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): v_los
- Total length of observation: ideally 10 days (if not possible, I would combine multiple observation windows)
- Cadence (maximum 1 dataset/min): 60 sec
- Pointing needs (disc centre, limb, active region location, particular μ): disk center
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): overlap with HMI (80%~90%)
- Total number of datasets:
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: full solar disk
- Full resolution or 2x2, 4x4 binned data: the resulting solar diameter of at least 500 pixels
- noise level (default 10^{-3}):
- Co-observations with other instruments: HMI
- Special requests:

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Multi-View Synoptic Maps with HMI and PHI

Philipp Löschl, Johann Hirzberger, Sami Solanki, Jesper Schou

MPS

Contact: loeschl@mps.mpg.de

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- We combine SO/PHI with SDO/HMI full disk magnetograms (vector & LoS) to produce multi-view synoptic maps.
- The heliocentric orbit of Solar Orbiter gives SO/PHI a unique line of sight that will be used for co-observation with SDO/HMI.
- Combining simultaneous observation of the near and far side of the Sun will reduce the observation time of the solar surface by up to 50% for favourable orbital orientations, thus strongly limiting the solar evolution that is usually encountered during a full Carrington rotation.
- The application of such rapid synoptic charts will allow us to:
    1. check for distortions in the distribution of the surface magnetic flux in classically produced synoptic charts from a single vantage point
    2. check for differences in the magnetic field extrapolated into the heliosphere

Requirements/Data	Optimal	Minimal
Type of solar feature	Full Sun	Full Sun
HRT or FDT	FDT	FDT
Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data):	Vector B	B_LOS
Total length of observation:	synoptic	synoptic
Cadence (maximum 1 dataset/min):	1 dataset / 1h	1 dataset / 12h
Pointing needs (disc centre, limb, active region location, particular μ):	disc centre	disc centre
Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft):	Any	Any
Total number of datasets:	synoptic	synoptic
Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5:	Full frame	Full frame
Full resolution or 2x2, 4x4 binned data:	Full resolution	Full resolution
noise level (default 10^{-3}):	default	default
Co-observations with other instruments:	SDO/HMI	SDO/HMI
Special requests:	no	no

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Testing far side imaging based on GONG data

Valentin Martínez Pillet, Kiran Jain, David Orozco Suarez, Hanna Strecker, Alejandro Moreno Vargas

National Astronomical Observatory (NSO-USA), Instituto de Astrofísica de Andalucía

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

Far side imaging is a technique able to grasp the magnetic activity of the far side of the Sun, not visible from Earth. The inference method relies on the analysis of sound wave travel times, which is used to predict the location of accumulations of magnetic flux on the far side of the Sun (González Hernández, I.; Hill, F.; Lindsey, C., 2007, ApJ, 669, 1382). Using time series of solar surface velocity data, inferred from instruments like GONG, far side imaging of the Sun is currently being available in a daily basis. So far, far side imaging has been successful to some extent. It is able to predict the appearance of large active regions. This was tested with different methods, e.g., active regions rotating from the far side of the Sun into the field of view from Earth, and likewise, dissipating when rotating out of the field of view. However, a proper calibration of the detected magnetic fluxes require the direct observations of active regions located on the far side. Solar Orbiter PHI is the only instrument capable of providing such observations.

Here we request data for cross-calibrating the far side images provided in a daily basis by GONG. The underlying idea is to first, cross-calibrate PHI with GONG using front side data and then cross-calibrate GONG far side predictions with PHI far side observations. This will allow GONG to not only qualitatively forecast the far side magnetic activity but also to provide flux calibrated far side information.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Front side and Far side FDT (or HRT) observations
- HRT or FDT: FDT (although HRT is also usable)
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): raw data
- Total length of observation: several days; at least one week
- Cadence (maximum 1 dataset/min): 1 per day
- Pointing needs (disc centre, limb, active region location, particular μ): from front side and far side (conjunction) FDT maps
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): N/A
- Total number of datasets: minimum 7 datasets, covering, at least, a week of Earth and far side (near conjunction) would be necessary
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: Full frame
- Full resolution or 2x2, 4x4 binned data: Full resolution
- noise level (default 10^{-3}): Default
- Co-observations with other instruments: GONG
- Special requests: First calibration steps are doable using cruise phase PHI data

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Coronal bright points, their structure and possible eruption

Nikolina Milanovic & MPS EUV team

MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- With its improved spatial resolution EUI will show increased detail of coronal bright points, bundles of compact loops reaching a million Kelvin that are associated with small magnetic patches of opposite polarity lasting for one to several hours. Essentially, this is similar to a miniature version of an active region. Preliminary results of the emission measure with SPICE shows that the effects are strongest at low temperatures around and below 0.1 MK, thus suggesting that these bright points are predominantly heated from below. Besides EUI/HRI/174, the observations should also include EUI/HRI/Ly-a and SPICE to ensure good co-alignment and to study the thermal structure of the bright points. The combination of following the coronal evolution at unprecedented resolution and an investigation of the magnetic structure at matching resolution with PHI will shed new light on our understanding of coronal bright points.
- Related to “Flux emergences directly related to coronal bright points”.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: **quiet Sun and coronal hole (i.e. two campaigns should be a coronal hole be available)**
- HRT or FDT: **HRT**
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): **B_los, I_c**
- Total length of observation: **3 hours**
- Cadence (maximum 1 dataset/min): **5 min or 10 min**
- Pointing needs (disc centre, limb, active region location, particular μ): **QS @ disk center, CH wherever it is**
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): **below 0.5 AU (resolution)**
- Total number of datasets: **36 (for two campaigns, QS and if available CH)**
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: **full frame (to maximize FOV)**
- Full resolution or 2x2, 4x4 binned data: **full resolution**
- noise level (default 10^{-3}): ???
- Co-observations with other instruments: EUI/HRI/174; EUI/HRI/Lya; SPICE
- Special requests:

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Flux emergences directly related to coronal bright points

Nikolina Milanovic & MPS EUV team

MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- Coronal bright points typically exist for one to several hours, with a fast flux emergence phase in the beginning. Capturing the early phase of the formation of the bright point will be of high interest because, in particular, to understand the formation of the bipolar magnetic field concentration using PHI. Naturally, this is closely linked to a more general study on the structure of coronal bright points, but here the focus should be on the initial phase. In particular, when relating the coronal dynamics in EUI/HRI/174 observations to the interaction with the pre-existing magnetic flux (through magnetic field extrapolations) this should provide valuable information on the energisation of coronal bright points. One central question would be the role of energy dissipation at low height (e.g. through chromospheric reconnection) to energisation with an overlying magnetic field (seen through loop-dominated heating).
- Related to “Coronal bright points, their structure and possible eruption”.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: **quiet Sun**
- HRT or FDT: **HRT**
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): **B_los, I_c**
- Total length of observation: **1 hour (or longer to capture more flux emergence events)**
- Cadence (maximum 1 dataset/min): **1 min**
- Pointing needs (disc centre, limb, active region location, particular μ): **QS @ disk center**
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): **below 0.5 AU (resolution)**
- Total number of datasets: **60**
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: **full frame (to maximize FOV)**
- Full resolution or 2x2, 4x4 binned data: **full resolution**
- noise level (default 10^{-3}): ???
- Co-observations with other instruments: EUI/HRI/174; EUI/HRI/Lya; SPICE
- Special requests:

SO/PHI data request form
(first science orbit; SO/PHI-Team internal version)

Looking for photospheric counterparts of SPICE/EUI/coronal blue-shifted events

Moreno Vacas , A. [1], Harra, L. [2][3], Schwanitz, C. [2][3], Orozco Suárez, D. [1], del Toro Iniesta, J.C. [1]

[1] Instituto de Astrofísica de Andalucía-CSIC (IAA-CSIC)

[2] Eidgenössische Technische Hochschule Zürich (ETH)

[3] Physikalisch-Meteorologisches Observatorium Davos/World Radiation Center (PMOD/WRC)

Science case:

please also state, why is PHI needed; why is the science unique?

- Recent observations combining Hinode(EIS) and SDO(AIA&HMI) showed relationship between magnetic cancellations in the photosphere and coronal strong blue-shifts close to coronal hole boundaries.
- Observation of solar structures in network regions with PHI, EUI and SPICE to study their similarities/differences in order to understand the consequences of photospheric magnetic evolution in quiet coronal features.

- Solar Orbiter will provide simultaneous, same point of view and same resolution (high resolution) data with PHI and EUI and spectroscopic data from SPICE.

- We want to study the same phenomena in photosphere and chromosphere in order to stablish a relationship between solar structures in both layers. We will need a great number of events to have good statistics.

Requirements/data

- Type of solar feature: Network regions close to coronal holes boundaries
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): vector B, v_LOS, I_c
- Total length of observation: 1 hour
- Cadence (maximum 1 dataset/min): 1 min
- Pointing needs (disk center, limb, …): Coronal holes boundaries at center
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): Perihelion
- Total number of datasets: 60
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: 2kx2k
- Full resolution or 2x2, 4x4 binned data: Full Resolution
- noise level (default 10^{-3}): 10^{-3}
- Co-observations with other instruments: EUI & SPICE + AIA(SDO) & EIS(HINODE) when available
- Special requests: Coordination with EUI & SPICE

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Ring-Diagram analysis of SO/PHI data

Kaori Nagashima

Max Planck Institute for Solar System Research

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- Systematic variations of the "flow signals" with the disk position are reported in various helioseismology studies; they are generally larger than the subsurface meridional flow signals. (Zhao et al. 2012, Komm et al. 2013, 2015)
- Systematic variations depend on the observables/instruments.
- Physical causes of the systematics are still unclear.
  - due to the formation height difference with the position? (Baldner and Schou 2012)
- Simultaneous observations of the areas on the Sun from different angles with SO/PHI and SDO/HMI (or ground-based instruments, e.g., GONG) would be the unique opportunity to improve our interpretation of the center-to-limb variation, and hence, to improve the helioseismology technique in general.
- We would like to do the ring-diagram helioseismology analysis using the full disc SO/PHI data, especially the overlapped areas with SDO/HMI.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: ***full disc***
- HRT or FDT: ***FDT***
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): ***v_LOS (if possible I_c as well)***
- Total length of observation: ***>24hr***
- Cadence (maximum 1 dataset/min): ***1 dataset/min***
- Pointing needs (disc centre, limb, active region location, particular µ): ***disc centre***
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): ***Need a significant field-of-view and temporal overlap with SDO/HMI (or ground-based telescopes).***
- Total number of datasets: ***> 1440***
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: **1kx1k or smaller, *as long as (almost) full solar disc is covered***
- Full resolution or 2x2, 4x4 binned data*: **full resolution (solar diameter > 500 pixels)***
- noise level (default 10^{-3}): ***default is ok***
- Co-observations with other instruments: ***SDO/HMI (or ground-based telescopes, e.g., GONG)***
- Special requests: ***We would like to use the data obtained during the helioseismology runs in January 2022 for this analysis.***

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

EUV-dark CH-like structures adjacent to an active region

Jonathan Nölke, Johann Hirzberger, Hardi Peter

Affiliations(s): MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

Equatorial CHs are often associated with decaying ARs. Therefore, we want to study EUV-dark areas CH-like structures adjacent to an AR in detail to determine their nature.

PHI observations will yield information on the strength and unipolarity of the underlying magnetic flux. The sensitivity and stability of PHI allow recording an uninterrupted time series over a longer period and co-observations with high-resolution EUI observations are crucial to understand the coupling of photospheric magnetic fields and the corona, in particular concerning small coronal structures. SPICE will provide information on the initial acceleration of the wind.

Additionally, co-observations with AIA on SDO would provide further information on how the properties of these areas, e.g. darkness and size, depend on temperature.

The evolution of the magnetic flux in these EUV-dark areas CH-like structures adjacent to an AR should be followed over a timescale comparable to the lifetime of a supergranule. This implies an observing sequence of about one day, at moderate cadence. To investigate the often rapid changes of their boundaries due to impact of flux emergence and cancellation and to transient activity one should also include a shorter stretch of data at high cadence of about one minute to capture this process.

Finally, the obtained data can also be used to extrapolate the magnetic field, determining if locally the field is open or closed and how far it is dominated by the adjacent AR. If a regular coronal hole is available, either at low latitudes or near the poles, these data can be compared to the well-studied regular CHs, but through the same instrumentation as EUV-dark CH-like structures adjacent to an AR.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: EUV-dark CH-like structures adjacent to an AR
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): B_LOS, Inclination
- Total length of observation: 10 min – 1h (1 min cadence), 1 day (30 min cadence), 6h (10 min cadence)
- Cadence (maximum 1 dataset/min): 1 min for 10 min – 1h, 30 min for 1 day, 10 min for 6h
- Pointing needs (disc centre, limb, active region location, particular μ): near AR
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): Co-observations with AIA on SDO would be useful to see how the properties (darkness, size, etc.) of these areas depend on temperature; spatial resolution: 116km/pixel @ 0.32AU
- Total number of datasets: > 90
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: full frame
- Full resolution or 2x2, 4x4 binned data: full resolution
- noise level (default 10^{-3}): default
- Co-observations with other instruments: EUI, SPICE, AIA
- Special requests:

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Mini coronal holes or super-quiet Sun: studying the magnetic field beneath areas in the corona which appear dark in EUV images to determine their nature

Jonathan Nölke, Johann Hirzberger, Hardi Peter

Affiliations(s): MPS

Science case (stay on one slide):
Please also state, why is PHI needed; why is the science unique?

Small areas in the quiet corona appearing dark in EUV images (which we will call mini coronal holes, mini-CHs) can be the result of different magnetic structuring in the photosphere. For one, they could overlie unipolar fields or they could simply be areas of super-quiet Sun, with lower level of magnetic flux than the average QS.

PHI observations will yield information on how strong and how unipolar the magnetic flux is, providing the means to distinguish between the two hypotheses. The sensitivity and stability of PHI allow recording an uninterrupted time series over a longer period and co-observations with high-resolution EUI observations is crucial to understand the coupling of photospheric magnetic fields and the corona, in particular concerning small coronal structures.

The evolution of the magnetic flux in the mini-CHs should be followed over a timescale comparable to the lifetime of a supergranule. This implies an observing sequence of about one day, at moderate cadence. To investigate the possible impact of flux emergence and cancellation one should also include a shorter stretch of data at high cadence of about one minute to capture this process.

Additionally, the obtained data can also be used to extrapolate the magnetic field, determining if locally the field is open or closed. With these a further differentiation between the hypotheses is possible. If a regular coronal hole is available, either at low latitudes or near the poles, these data from mini CHs embedded in the quiet Sun can be compared to the well-studied regular CHs, but through the same instrumentation as the mini CHs. The same applies for EUV-dark CH-like structures adjacent to an active region.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: mini coronal holes, areas in the corona appearing dark in EUV images
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): B_LOS, Inclination
- Total length of observation: 10 min – 1h (1 min cadence), 1 day (30 min cadence), 6h (10 min cadence)
- Cadence (maximum 1 dataset/min): 1 min for 10 min – 1h, 30 min for 1 day, 10 min for 6h
- Pointing needs (disc centre, limb, active region location, particular μ): disc centre or anywhere on disc not too close to limb, possible is also an AR
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): Co-observations with AIA on SDO would be useful to see how the properties (darkness, size, etc.) of the mini CH depends on temperature
- Total number of datasets: > 90
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: full frame
- Full resolution or 2x2, 4x4 binned data: full resolution
- noise level (default 10^{-3}): default
- Co-observations with other instruments: EUI, SPICE, AIA
- Special requests:

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

polar coronal holes and boundary evolution

Jonathan Nölke, Johann Hirzberger, Hardi Peter

Affiliations(s): MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

Polar coronal holes (CH) are regions where one magnetic polarity dominates and the magnetic field lines are open to space. PHI observations provide the means to study the magnetic field under the CHs and at the boundary from polar CH to QS as well as to follow the evolution of this boundary (with EUI and SPICE), in particular the impact changes in magnetic flux have on the boundary itself.

The sensitivity and stability of PHI allow recording an uninterrupted time series over a longer period and co-observations with high-resolution EUI observations are crucial to understand the coupling of photospheric magnetic fields and the corona, in particular concerning small coronal structures . SPICE will provide information on the initial acceleration of the wind.

To follow the evolution of the CH boundary and the corresponding magnetic flux an observing sequence of about a day at a moderate cadence should be carried out. An additional short-term sequence at the highest cadence needs to be included to investigate the anticipated impact of flux emergence and cancellation on the CH boundary evolution.

Additionally, the obtained data can be used to extrapolate the magnetic field.

Provided raw data can be made available it would also be possible to study the shape and changes thereof of absorption line profiles at the CH boundaries.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: polar CHs
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): B_LOS, Inclination, optionally raw data (for observations of CH boundaries)
- Total length of observation: : 10 min – 1h (1 min cadence), 1 day (10 min cadence)
- Cadence (maximum 1 dataset/min): 1 min for 10 min – 1h (long enough to see the impact of flux emergence and cancellation), 10 min for 1 day (ideally)
- Pointing needs (disc centre, limb, active region location, particular μ): polar region
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): AIA, 116 km/pixel at 0.32 AU
- Total number of datasets: > 150
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: full frame
- Full resolution or 2x2, 4x4 binned data: full resolution
- noise level (default 10^{-3}): default
- Co-observations with other instruments: EUI, SPICE, SWA
- Special requests:

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Sunspots and pores height measurements using stereoscopic observations

Amanda Romero Avila, Bernd Inhester, Johann Hirzberger

MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

SO/PHI in combination with other observatories provides the unique possibility to measure the heights of the undulating solar surface using stereoscopic methods.

Solar surface stereoscopy represents the first method measuring the photospheric heights in a direct manner. This allows to, e.g., obtain the Wilson depression in sunspots and pores on a geometrical scale, i.e. avoiding the transformation between optical and geometrical depth.

This science case provides therefore an independent method to evaluate the results obtained from alternative methods (based only on radiative transfer) to obtain geometrical heights of photospheric structures, more specifically sunspots, pores and granules. In addition, it will give a better understanding of the 3D structure of these solar surface structures.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Active Regions (sunspots and pores)
- HRT or FDT: HRT and FDT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): mainly I_C (B_LOS and/or B_vector is helpful); raw Stokes profiles to compare with alternative methods
- Total length of observation: single snapshots
- Cadence (maximum 1 dataset/min): -
- Pointing needs (disc centre, limb, active region location, particular μ): various μ angles to test the efficiency of the method
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): Angle to Earth < 90 deg; various solar distances and separation angles to be tested
- Total number of datasets: single snapshots
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: HRT: Full frame, FDT: full disk
- Full resolution or 2x2, 4x4 binned data: Full resolution
- noise level (default 10^{-3}): Default; SNR>500 for I_C
- Co-observations with other instruments: SDO/HMI ; (Hinode/SOT and hi-res ground-based observations to be tested)

Special requests: As co-alignment needs to be precise; geometrical models of the instruments are needed

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Deep Probing Helioseismology

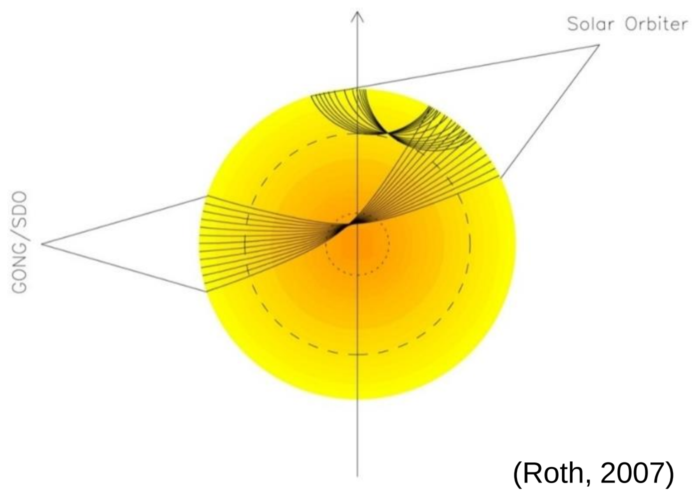
Markus Roth, Matthias Waidele

KIS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- Large-scale flows (differential rotation, meridional flow) in the solar interior are considered relevant for the generation of the Sun's variable magnetic field.
- Currently probing the deep solar interior is limited, as only part of the solar surface can be observed.
- On the long-term: the combination of data from multiple venture points will help improving the helioseismic capabilities (Roth et al. 2016).
- This requires PHI as it is the only instrument that allows views on the Sun that are off the Earth-Sun line.
- The objective is
  - to start the preparations of combining data from PHI and SDO/GONG for helioseismology
  - based on the combined data, estimating the improvements in flow detection with global helioseismology (Schad et al. 2011, 2012, 2013; Schad & Roth 2020) by studying the so-called leakage matrix
  - Improving the capabilities of the helioseismic Fourier-Legendre analysis (Braun & Fan 1998, Roth et al. 2016) that can be made by extending the field of view, i.e. studying effects on systematics.



(Roth, 2007)

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: full Sun
- HRT or FDT: FDT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): v_LOS
- Total length of observation: minimum 4 days
- Cadence (maximum 1 dataset/min): 1 dataset/min
- Pointing needs (disc centre, limb, active region location, particular μ): disc centre
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): angle to Earth between 30° and 330°
- Total number of datasets: >5760
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: crop to cover the full solar disk
- Full resolution or 2x2, 4x4 binned data: 2x2 binning is possible as long as 200 pixels cover the solar diameter
- noise level (default 10^{-3}): 10^{-3}
- Co-observations with other instruments: SDO or GONG
- Special requests: None

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Flows around active regions

Roth (PI), Strecker, Calchetti, Schunker, Waidele

KIS, IAA, MPS, UoN, KIS

Science case (stay on one slide):
Please also state, why is PHI needed; why is the science unique?

- Active regions often exhibit flows in their surroundings. The moat flow around a sunspot is a prominent example. These flows might play a relevant role in the physics of the formation, stability, and evolution of active regions.
- Less is known about the sub-surface structure of these flows. Measuring the advection of acoustic waves by the flow will allow to conclude on the structure of such flows below the surface with helioseismic methods.
- Observations with PHI provide stable observation conditions with higher spatial resolution to resolve the spatial dependence of the flows, which are not available for a long time on the ground or from another instrument in space.
- In case co-observations from the ground with other lines are available, the height dependence of the flows could be further investigated.
- *If not possible in the first orbit, we would be happy to have these observations in the second orbit (North window in November 2022)*

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Sunspot
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): v_LOS, vector B, I_c
- Total length of observation: minimum 12 hours (if possible 24 hours)
- Cadence (maximum 1 dataset/min): 1 dataset/min
- Pointing needs (disc centre, limb, active region location, particular μ): active region location
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): if possible angle to Earth, then co-observations from ground could be possible. If not, still important science can be done.
  Resolution needs at least 250km/pix at a large FOV of minimum 300 Mm.
  These conditions are probably achieved in the second orbit, too.
- Total number of datasets: 720 - 1440
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: full frame
- Full resolution or 2x2, 4x4 binned data: full resolution
- noise level (default 10^{-3}): 10^{-3}
- Co-observations with other instruments: if angle to Earth is available then co-observations with VTT HELLRIDE and/or SST CRISP should be arranged.
- Special requests: None

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Mode Excitation

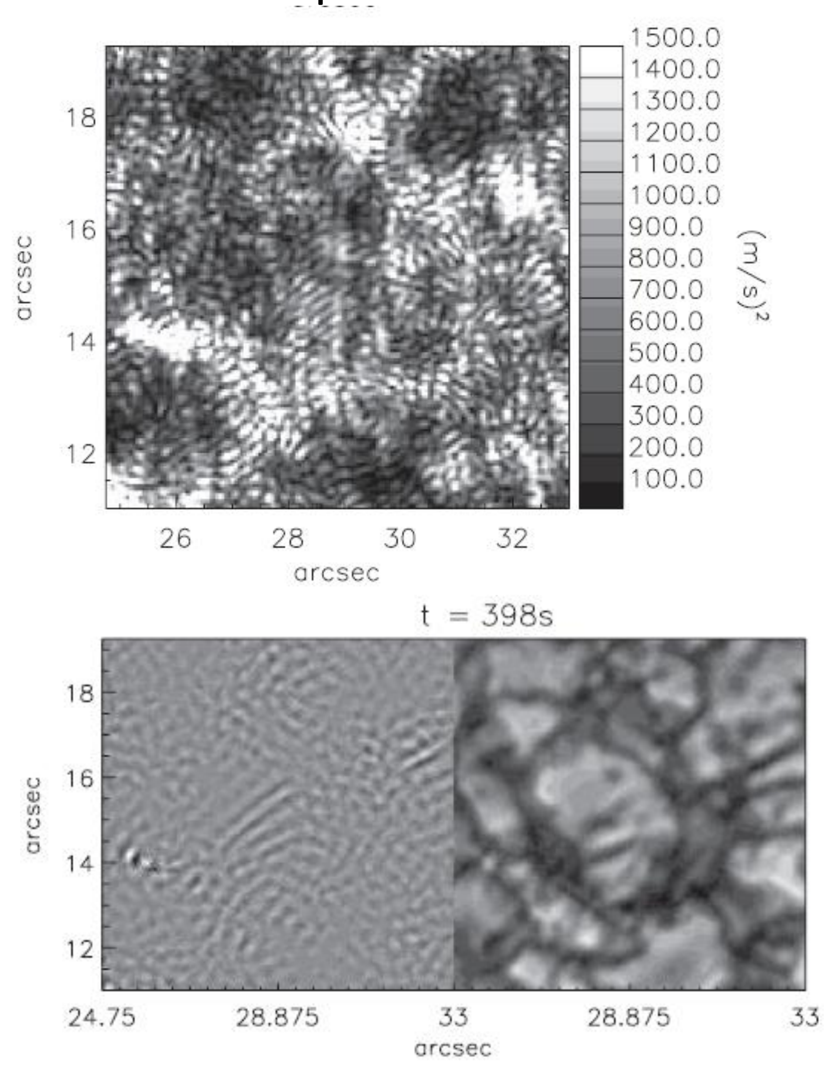
Markus Roth

KIS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- The excitation mechanism of solar oscillations is mostly not understood
- Knowledge on the source mechanism is an important ingredient for
  - Various helioseismic techniques:
    - Local helioseismology needs it for a proper calculation of the kernel functions, i.e. mode sensitivities. This requires to know the statistical properties of the mode excitation (source function)
    - Global helioseismology needs it for the eigenfunction perturbation analysis as relevant information about the vertical-to-horizontal displacement ratio, i.e. velocity vector.
  - The behaviour of the eigenfunction (amplitude, energy dissipation) in the atmosphere depends on the source function, therefore it affects the estimates on the energy transfer from the interior to the photosphere – chromosphere – corona acoustic waves.
- The high spatial resolution of PHI is needed to resolve the intergranular lanes without the perturbing effect of the Earth's atmosphere
- HMI has not the required resolution.



(Sunrise observations, Roth et al. 2010)

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Granulation
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): v_LOS, (vector B if activity is in the field of view), I_c
- Total length of observation: minimum 2 hours
- Cadence (maximum 1 dataset/min): 1 dataset/min
- Pointing needs (disc centre, limb, active region location, particular μ): disc centre
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft):
  spatial resolution between 116 km/pixel – 130 km/pixel
- Total number of datasets: 120
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: minimum 1kx1k; ideally full frame
- Full resolution or 2x2, 4x4 binned data: full resolution
- noise level (default 10^{-3}): 10^{-3}
- Co-observations with other instruments: none
- Special requests: None

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

The horizontal to vertical displacement ratio of solar oscillations

Jesper Schou

MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- One of the basic quantities that has never been directly measured in helioseismology is the (complex) ratio of the horizontal to vertical displacement of the p- and f-modes. Indirect measurements have been made by Schou & Bogart (1998), Rhodes et al. (2001) and others. Unfortunately the measurements are model dependent and with data from a single vantage point only, the inferred ratio is entangled with the height dependence, leaving significant uncertainties.
- Observations with PHI will allow us to make a direct measurement and to cleanly disentangle these two effects.
- With a good understanding of these effects we will improve our understanding of an important part of the mode physics near the solar surface. Also it will hopefully allow us to reduce some of the systematic errors currently plaguing helioseismic measurements.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Full disk.
- HRT or FDT: FDT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): V_LOS, ideally also I_c
- Total length of observation: At least 24 hours.
- Cadence (maximum 1 dataset/min): 1/min
- Pointing needs (disc centre, limb, active region location, particular μ): N/A (full disk)
- Orbit needs: Large overlap with Earth view. At least ~15 degrees off Earth-Sun line.
- Total number of datasets: At least 24 hours (1440 datasets)
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: Full disk. Slight limb cutoff acceptable.
- Full resolution or 2x2, 4x4 binned data: Resulting solar diameter of at least 500 pixels
- noise level (default 10^{-3}): Default should be fine, no polarimetry
- Co-observations with other instruments: HMI. Should preferably avoid eclipse seasons.
- Special requests: This is intended to be covered with the 2021 and 2022 HS runs.

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Effects of granulation on the visibility of solar oscillations

Jesper Schou

MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- The interactions of solar oscillations with the surface granulation are very difficult to model. One of the directly observable effects is the dependence of the complex mode amplitude on the position in the granulation, as described in Schou (2015, A&A, 580, L11), who used HMI observations.
- Due to the modest resolution, the contrast of the granulation as observed by HMI is very small which makes using HMI data very challenging.
- The superior spatial resolution of PHI, combined with a very good stability, means that the granulation can be substantially better resolved, thereby improving our ability to infer details of the interactions.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Quiet Sun
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): V_LOS, and I_c
- Total length of observation: 6 hours. Tradeoff can be made with extract size.
- Cadence (maximum 1 dataset/min): 1/min
- Pointing needs (disc centre, limb, active region location, particular μ): Disk center. Ideally also 45-60 degrees.
- Orbit needs: Significantly better resolution than HMI. Say 200km/pixel or inside 0.55AU.
- Total number of datasets: 360.
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: Sim. done with 48Mm patch, so 256^2, 384^2 or strips should do.
- Full resolution or 2x2, 4x4 binned data: Full resolution.
- noise level (default 10^{-3}): Default should be fine, no polarimetry
- Co-observations with other instruments: None.
- Special requests: Smaller datasets and/or different FOV/duration may be possible.

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

True CLV of Magnetic Flux and the Mystery of the Missing Open Flux

J. Sinjan, J.Hirzberger

MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

There is a mismatch in the amount of magnetic flux measured in situ in the heliosphere and the open flux at the solar surface. One reason for this could be that the magnetic flux measured at the solar poles (i.e. close to the limb) is underestimated.

Particularly for small scale magnetic structures the measurement of the transversal magnetic flux is limited and assumptions, e.g. vertical fields and that no other effect leads to a drop of flux near the limb, have to me made. This leads to the science case:

- Test these assumptions and find the True CLV of the magnetic flux
- Requires two different viewpoints at the same location of the Sun are required, one provided by PHI, the other from a similar polarimeter from the Earth-Sun Line (HMI etc.)
- Such an investigation is unique as it has not been possible before: no instrument with SO/PHI's capability has moved out of the Earth-Sun Line

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Active Region/Network and Plage
- HRT or FDT: Both (HRT preferred, FDT at close distance)
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): I_c+B-vector; raw data will provide higher accuracy
- Total length of observation: snapshots at various μ values (HRT); snapshots at close distance (FDT); short time series will give augmented science (evolution of flux)
- Cadence (maximum 1 dataset/min): 1-5 min
- Pointing needs (disc centre, limb, active region location, particular μ): various μ values
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): Earth visibility; 0-90 degrees
- Total number of datasets: 10-50
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: 2k x 2k (smaller fields possible – co-alignment with NEO required)
- Full resolution or 2x2, 4x4 binned data: Full resolution
- noise level (default 10^{-3}): 10^{-3}
- Co-observations with other instruments: Hinode and/or HMI; Ground based instruments: tbd (if co-alignment is possible)
- Special requests: none

SO/PHI data request form
(Cruise phase + first science orbit; SO/PHI-Team internal version)

Understanding the 3D velocity structure of sunspot penumbrae

Azaymi L. Siu Tapia[1], Sebastián Castellanos Durán[2], Björn Löptien[2], Nazaret Bello González[3]

1. Instituto de Astrofísica de Andalucía (IAA-CSIC)
2. Max Planck Institute for Solar System Research (MPS)
3. Leibniz-Institut for Solar Physics (KIS)

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

We propose to perform stereoscopic observations of a sunspot from two different vantage points using PHI and instruments from Earth. Stereoscopic observations provide two components of the velocity vector, allowing tighter constraints on the geometry of flows within the penumbra. Such data will help improving our understanding of the Evershed flow and potentially allow distinguishing between the two models for the origin of this flow (siphon flow or magnetoconvection). Similarly, the flow geometry within individual penumbral filaments could be derived. A similar kind of analysis can also be applied to orphan penumbrae. This science case is unique to PHI, since stereoscopic observations are not possible with current instrumentation. Ideally, both PHI and the instrument on Earth will utilize the same spectral line and observe the sunspot at a similar heliocentric angle in order to achieve a similar formation height.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Sunspot / orphan penumbra
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): inverted parameters
- Total length of observation: 120 min
- Cadence (maximum 1 dataset/min): 1 min
- Pointing needs (disc centre, limb, active region location, particular μ): Active region location
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): If possible, PHI should be looking at the sunspot from a similar angle as from Earth in order to sample similar heights with PHI and CRISP instruments, but from a different point in order to have stereoscopy.
- Total number of datasets: 120
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: Full frame
- Full resolution or 2x2, 4x4 binned data: Full resolution
- noise level (default 10^{-3}): Default

Co-observations with other instruments : CRISP at SST (Fe 6173 A and other spectral lines to get information from higher layers), Hinode SOT/NFI, Hinode SOT/SP, SDO/AIA, SDO/HMI, and SO/EUI HRI observations in Ly-alpha and 174 nm as context on the overall topology of the active region in the high layers, e.g., presence of pre-exisiting magnetic fields above the penumbra blocking the rising of new emerged flux.

- Special requests:

SO/PHI data request form
(Cruise phase + first science orbit; SO/PHI-Team internal version)

Differences between limb-side and center-side penumbra

Azaymi L. Siu Tapia[1], Ricardo Gafeira[1,2], Sami K. Solanki[3], and Luis Bellot Rubio[1]

1. Instituto de Astrofísica de Andalucía (IAA-CSIC)
2. University of Coimbra (UC)
3. Max Planck Institute for Solar System Research

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

We aim to study the differences between limb-side and center-side penumbra by performing stereoscopic observations using PHI and instruments from Earth.

This is the first time that the penumbra will be observed from two different vantage points, so one half of the penumbra will be seen as the limb-side penumbra from Solar Orbiter and, simultaneously, as the center-side penumbra from the Earth, allowing a direct comparison of the different morphology and physical properties due solely to projection effects. This will allow us to determine which differences arise due to intrinsic asymmetries in the penumbra and which ones are due to projection effects. Two approaches are necessary:

1) Stereoscopic observations of the full Stokes vector in the different parts of the penumbra to analyze the different shifts and shapes of the line bisectors (e.g., Rimmele 1995; Westendorp Plaza et al. 2001), as well as different magnitudes and signs of the net circular polarization (e.g., Martinez Pillet 2000). This should best be done when the spot is roughly at the same mu from Earth and from SO.

2) Stereoscopic observations of the sunspot penumbra during the passage of the sunspot across the solar disc to compare the two penumbral sides at different heliocentric angles.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Sunspot penumbra
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): 1) Raw data: full Stokes vector; 2) vector B, v_LOS, I_c
- Total length of observation: 1) 30 min; 2) 30 min per day during the sunspot passage across the solar disc
- Cadence (maximum 1 dataset/min): 1 min
- Pointing needs (disc centre, limb, active region location, particular μ): 1) active region location; 2) active region location + particular μ (at different heliocentric angles)
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): Near perihelion to secure the highest spatial resolution. 1). When the sunspot is located at a similar mu angle from Earth and from PHI.
- Total number of datasets: 1) 30; 2) 30 per day
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: Full frame, or partial frame if sunspot is small and fits the 0.5kx0.5k FOV.
- Full resolution or 2x2, 4x4 binned data: Full resolution
- noise level (default 10^{-3}): Default
- Co-observations with other instruments: 1) CRISP/SST (Fe 6173 across same wavelength range as PHI); 2) HMI and Hinode SOT
- Special requests:

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Moving magnetic features, their structure and connection to sunspots

Hanna Strecker, David Orozco Suarez

Instituto de Astrofísica de Andalucía

Science case (stay on one slide):
Please also state, why is PHI needed; why is the science unique?

Moving magnetic features (MMFs), small magnetic patches in the moat region around sunspots, have been proposed to be responsible for the removal of magnetic flux from sunspots. However, this has never been confirmed due to contradictory results in the ratio of the flux loss from the spot and the flux transfer from the MMFs (e.g., Martínez Pillet 2002, Kubo et al. 2007). The contribution of MMFs to the flux loss from a sunspot is assumed to depend on the physical mechanisms to which they are associated. However, their classification into different classes could be restricted by the temporal and spatial resolution of the observation. MMFs are associated with the magnetic canopy (Zuccarello et al. 2009, Rempel 2015) and with brightenings and jet-like events in the transition region (Tiwari et al 2018). Flux cancellation processes between MMFs could affect both, the structure of the sunspot canopy and, adjunctly, the stability of the sunspot.

PHI’s HRT provides observations of a large FOV, covering an entire sunspot, the surrounding moat region, and attached network, at highest spatial and temporal resolution. Combined with the high magnetic sensitivity, these attributes are ideal to study the topology of MMFs, their field strength and magnetic flux and how they evolve in time, over the entire region from within the sunspot to the network. The performance of PHI, combined with the stability of the measurements over the entire duration of the observation, can not be achieved with any other telescope. Furthermore, in combination with EUI and SPICE, the relation of flux cancellation events of MMFs to the transition region can be studied. This will provide a better understanding of the configuration of MMFs and their connection to the sunspot over multiple heights in the solar atmosphere.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Active region, sunspot (if not available a pore would also be fine)
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): vector B, v_LOS, I_C
- Total length of observation: 3 hours at least to track MMFs, 5 hours would be better
- Cadence (maximum 1 dataset/min): 5 min (minimum), higher is preferred
- Pointing needs (disc centre, limb, active region location, particular μ): active region location
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): Highest possible spatial resolution to study MMFs, close to perihelion
- Total number of datasets: Depends on total length of observation and cadence: minimum 36 datasets (5 min cadence, 3 hours), 150 datasets (2 minute cadence, 5 hours)
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: Full frame
- Full resolution or 2x2, 4x4 binned data: Full resolution
- noise level (default 10^{-3}): Default
- Co-observations with other instruments: EUI and SPICE, to relate structure and dynamics of MMFs and their response to transition region
- Special requests:

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Magnetic flux evolution of sunspots

Hanna Strecker, Luis Bellot Rubio

Instituto de Astrofísica de Andalucía

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

Sunspot evolution and decay has generally been studied by a change of the total magnetic flux and area evolution (e.g., Martinez Pillet 2002). However, the processes driving sunspot evolution and decay are not understood. Studies of simulated sunspots suggest that the decay process of sunspots starts below the surface, while the area and magnetic flux seen at the surface is constant (Strecker et al. 2021). The evolution of the inner structure of a sunspot, i.e., the umbra-penumbra ratio and the development of light bridges, could be indicators of this hidden initial decay process. During the further evolution sunspot decay must be accompanied by a loss of flux from the sunspot. Therein, moving magnetic features might have a key role. Therefore, the amount of magnetic flux in the surrounding of a sunspot contributed by different types of magnetic features is important to study in greater detail, especially, over a long time period in relation to the flux evolution of the sunspot.

PHI observations at the highest spatial resolution, extending over several days, are necessary to study the flux evolution of an active. The large FOV will show the entire active region, at best a sunspot, the surrounding moat region, and opposite polarity. The combination of continuous observation over several days, a large FOV and high spatial resolution provided by PHI cannot be provided by any other satellite or earth bound telescope. The height extension of magnetic loops connecting different polarities of the active region and their evolution, in interaction with the photospheric evolution, e.g., flux cancellation events, can be studied by making use of support by EUI and SPICE observations.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Active region, sunspot (if not available a pore would also be fine)
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): vector B, v_LOS, I_c
- Total length of observation: several days of tracking an active region
- Cadence (maximum 1 dataset/min): 30 minutes; higher is preferred
- Pointing needs (disc centre, limb, active region location, particular μ): active region location
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): Close to perihelion
- Total number of datasets: based on the SOOP "R_SMALL_MRES_MCAD_AR-Long-Term" 186 datasets for a duration of 3days and 21 hours
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: Full frame
- Full resolution or 2x2, 4x4 binned data: Full resolution
- noise level (default 10^{-3}): Default
- Co-observations with other instruments: EUI and SPICE, relate structure and dynamics of MMFs and their response to transition region, extend tracking duration of active region/sunspot by making use of Earthbound telescopes, e.g., SST, GREGOR, DKIST or Hinode
- Special requests:

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Studying active regions from flux emergence until flux dispersal

Hanna Strecker, Alejandro Moreno Vacas, David Orozco Suarez

Instituto de Astrofísica de Andalucía

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

The study of the evolution of active regions has been limited in time, both by solar rotation and by the inability to observe the far side solar photosphere from Earth. However, active regions generally have a longer lifetime, from their emergence to the full dispersal of their magnetic flux, than can be observed from Earth or satellites placed in its vicinity. Extending the observation period will improve our understanding of the evolution of active regions. Studies that can be performed include the latitudinal change or the evolution of magnetic flux over the lifetime of an active region. Therefore, we combine SDO/HMI measurements with SO/PHI observations taken during conjunction, with PHI observing the far side of the Sun. The continuous observations of HMI allow us to track any active region, visible from PHI on the Sun’s far side during conjunction, in its earlier and later evolution.

We will start the analysis with the conjunction dataset taken in February 2021, which has a variable cadence, the longest being about one day. We propose to continue this study during later orbits by also using synoptics and HRT data when an active region is tracked.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Active region
- HRT or FDT: FDT and/or HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): vector B, v_LOS, I_c; raw data (if telemetry allows)
- Total length of observation: 10 to 15 days to cover a full disk passage of an active region
- Cadence (maximum 1 dataset/min): 6 hours – 4 datasets per day (minimum); higher is preferred
- Pointing needs (disc centre, limb, active region location, particular μ): Disc centre (FDT); active region location (HRT)
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): Around solar far side conjunction
- Total number of datasets: 40 datasets (minimum), depending on cadence and days - As stated in the science case we will start our analysis with the conjunction dataset acquired in February 2021, however, we would like to extend the analysis during later orbits. For the later orbits also synoptics and HRT data of tracked active regions can be used.
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: For FDT cropping, to still have the full disk in the FOV, is possible; for HRT the full frame is necessary to obtain the full active region
- Full resolution or 2x2, 4x4 binned data: Full resolution
- noise level (default 10^{-3}): Default
- Co-observations with other instruments:
- Special requests: We will make use of HMI data to obtain information about the active regions in the time before and after its visibility on the solar far side.

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Title

Relation between explosive events and campfires

(L. Teriaca, Z. Huang)

MPS

Science case: Relation between Explosive Events and Campfires

- EUI sees small localized brightenings ubiquitous of quiet Sun regions, the campfires
- They have length scales between 400 and 4000 km and last between 10 and 200 s
- Occur at heights between 1 and 5 Mm and seem to be mostly coronal.
- They are mostly located along the network boundaries, suggesting relation to magnetic field concentrations.
- The location and relatively low height opens the question of the possible relation with the transition region explosive events: high velocity bidirectional jets with typical spectroscopic signature.
- In March 2022 SolO will cross the Sun-Earth line while at 0.5 AU distance from the Sun. Combined IRIS, EUI and SPICE observations are foreseen for that period.
- PHI data would be of high importance in determining the magnetic structure associated to these events and to understand the nature of these two types of events and how they are (or not) related to each other.

Requirements/data

- Type of solar feature: Quiet Sun
- HRT or FDT: HRT
- Physical parameters needed: B_los
- Total length of observation: at least 10 min
- Cadence (maximum 1 dataset/min): 1 min
- Pointing needs (disc center, limb, active region location, particular μ): Disk center
- Orbit needs: angle to Earth as small as possible
- Total number of datasets: 10
- Full frame: 2k x 2k
- Full resolution or 2x2, 4x4 binned data: Full resolution
- noise level (default 10^{-3}): default
- Co-observations with other instruments: EUI, SPICE, IRIS
- Special requests: None

SO/PHI data request form
(Cruise phase + first science orbit; SO/PHI-Team internal version)

Long-term evolution of AR with FDT (a.k.a. synoptic+)

Valori G. [1], Wiegelmann T.[1]

Affiliations(s)

[1] MPS

Science case

The evolution of the magnetic field in active regions (ARs) is key to the understanding of coronal mass ejections (CMEs) and flares. The build-up of large-scale currents, mostly in the emergence phase (lasting days to weeks [1]), results in increased magnetic (free) energy and helicity. This, in turn, is at the core of storage-and-release models that are currently used to interpret CMEs. In particular, magnetic helicity can be used to characterized the storage-and-release models in a general way that is independent of the details in which CMEs are triggered, and has been recently considered as a potential forecasting tool. The validation of such studies requires a continuous monitoring of individual ARs.

Continuous monitoring of ARs was so far limited to a few days (vector observations beyond the +/-40 heliographic degrees are often consider to be too noisy for some coronal model techniques). This means that the full process of emergence and activity, let alone decay, of individual ARs was never continuously observed. On the other hand, in such type of studies, the numerical effort required by modeling (e.g. a full 3D NLFFF extrapolation for every considered time snapshot) is still significant, and re-binning of high-resolution observations is often employed (e.g.,in [2] HMI magntograms covering 4 days mostly at 1-hour cadence are re-binned to 2" prior to extrapolation).

SO/PHI, in coordination with HMI, offers the unique possibility of following an AR for a much longer span of time than done so far. While this project could benefit from high-resolution magnetograms, the observing constraints of regular cadence and long coverage may be easier accommodated for FDT than for HRT. The on-disc FDT resolution during, e.g., the Perihelion and Northern windows of NMP1 will always be smaller then 1030 km, which is slightly better than the 2" (re-binned) HMI resolution employed in [2]. Hence, combining SDO/HMI and PHI/FDT a coherent modelling of AR evolution with a ~2" spatial resolution and 1-hours cadence over ~200 heliospheric degrees is possible in principle, which will demonstrate for the first time the potential for long-term AR monitoring by SO/PHI, and offer a unique application for helicity studies. The required observation cadence will depend on the evolution phase in which the AR will be, typically 1 hour for an emergence phase (which will be technically unfeasible), to 6 -or possibly even longer- hours in the late decaying phase. Both these options are presented as optimal and minimal, respectively, for best adaptation.

[1] see, eg. van Driel-Gesztelyi and Green Living Rev. Solar Phys. 12 (2015)

[2] Thalmann et al ApJ 887 (2019)

Requirements / data	Optimal	Minimal
Type of solar feature	Active region	Active region
HRT or FDT	FDT	FDT
Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data)	Vector B	Vector B
Total length of observation	12 days	12 days
Cadence (maximum 1 dataset/min)	1 hour	6 hours
Pointing needs	Disc centre	Disc centre
Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft)	NMP1: from late Perihelion (φ>60) to end of North Window	NMP1: From late Perihelion (φ>60) to end of North Window
Total number of datasets:	288	48
Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5:	Full frame	Full frame
Full resolution or 2x2, 4x4 binned data	Full resolution	Full resolution
noise level (default 10-3):	Default	Default
Co-observations with other instruments:	EUI (synoptic for context and validation)	EUI (synoptic for context and validation)
Special requests	None	None

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Stereoscopic disambiguation of vector magnetograms

Valori G. [1], Moreno A.[2], Loeschl P. [1], Hirzberger J.[1], Orozco D. [2], Del Toro Iniesta J.-C.[2]

Affiliations(s)

[1] MPS

[2] IAA

Science case

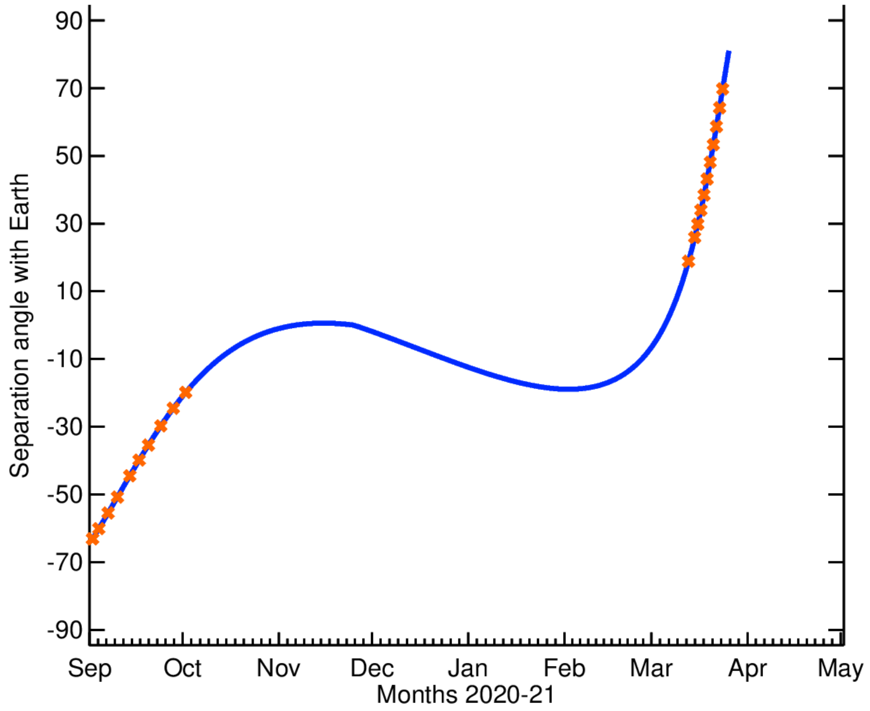
Remote observations of a same area on the Sun from different vantage points opens a novel possibility for removing the intrinsic ambiguity of the transverse component of the magnetic field. Differently from traditional single-view disambiguation methods, the equations for the stereoscopic disambiguation method (SDM hereafter) are exact for continuous magnetic fields.
The science case for the SDM is unique in providing the opportunity of the first observation-based resolution of the ambiguity in the transverse field. If successful, the SDM can be used to benchmark traditional single-view disambiguation methods, which are the run-of-the-mill of disambiguation (for PHI observation as well). To this goal, SO/PHI is mandatory as the only existing observatory providing magnetic field measurements away from the Earth-Sun line.

The accuracy of the SDM depends, among other factors, on the strength of the field and on the relative orientation of the field and of the two viewing points. An active region observed at high-resolution would offer the possibility of applications to physically relevant areas (umbra, penumbra, internal emerging areas, polarity inversion lines, pores, and, possibly, quiet sun) that differ for such requirements.
The minimal application of the SDM would require at least one observation within a favorable range of viewing angle (phi in +/-(40-50) deg). An additional observation at smaller separation (~20deg) would be relevant for minimizing the effect of different optical paths, but still possibly allowing for the stereoscopic view to solve the ambiguity. A more extensive exploration of the performances of the SDM would require a wider range of separation angles. In the same spirit, application to both cruise phase and NMP1 would offer a test for the accuracy of the SDM on different distances from the Sun. Therefore, in this data request, a minimal and an optimal set of parameters are proposed, which, depending on feasibility, can offer a more limited or a wider scope for testing and application.

Special requests

Irregular cadence.
Because of the varying orbital speed of SO, the observation cadence is irregular. For instance, obtaining the set of observations for separation angles at +/-(20,25,30,35,40,45,50,55,60,65,70) deg requires to take measurement at intervals varying from 2 to 4 days over 30 days in the cruise phase, and approximately every day over 11 days in the NMP1.

Therefore, depending on the mission phase (cruising or NMP1) and the set of parameters used (minimal or optimal), the variable cadence needs to be adjusted accordingly.



SO/PHI data request form
(Cruise phase + first science orbit; SO/PHI-Team internal version)

Flux rope formation
(new proposal)

Valori G. [1], David Orozco[2]

Affiliations(s)

[1] MPS

[2] IAA

Science case

Flux ropes are helical magnetic field structures that can support material against gravity. They are understood to constitute the core field that, loosing stability against the surrounding field, are ejected to form solar eruptions, carrying their load of material with them. The advances in theoretical interpretation of this mechanism has put forward a characteristic transition point during the process of formation of flux ropes where the helical structure is initially connected to the photosphere (the so-called bald patch -BP- configuration, with inverse crossing of the transverse component at polarity inversion line) to a fully detached flux rope (with an hyperbolic flux tube -HFT- separating it from the photosphere and a direct crossing of the transverse component at the PIL). Such a transition was indeed confirmed, albeit only indirectly, using photospheric vector magnetograms and head-on views of reconnection events as inferred from EUV observations. On the other hand, numerical modeling of such complex phenomena often relies on force-free extrapolations that rarely contain well-detached flux ropes, except for very few cases (see e.g. James et al ApJ 855L, 2018). Also, the head-on view of EUV events is always prone to uncertainties about the real height of the observed events, making often difficult to associate them to specific field line rearrangements in the 3D structure of the forming flux rope.

The unique opportunity offered by PHI and Solar Orbiter is to allow numerical modeling of an AR using high resolution PHI vector magnetograms and, at the same time, to combine EUI with the Earth view (eg from AIA) to provide a stereoscopic reconstruction of the emission height associated to reconnection events. We propose to exploit such an opportunity to study the formation of flux ropes in active regions, with particular emphasis on the BP-to-HFT transition and the associated formation of sigmoidal EUV structures that are formed by flux cancellation at the PIL. The topology of the forming flux rope, and the BP and HFT characterization in particular, would be obtained employing the quasi-separatrix layers method applied to a series of nonlinear force-free extrapolations. In the fortunate case that an eruption would occur during the observation time, this study can be easily extended to address mechanism behind the (eventual) slow rise phase preceding the eruption, and whether that is related to the HFT phase of the flux rope, and ultimately the instability reconnection mechanism triggering the eruption.

While the PHI cadence is not crucial, the observation should happen during the transition phase. The following data request is based on the assumption of such a lucky coincidence.

Requirements / data	
Type of solar feature	Active region
HRT or FDT	HRT
Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data)	Vector B
Total length of observation	3 days
Cadence (maximum 1 dataset/min)	1 hour
Pointing needs	Active region
Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft)	Angle to Earth: 40-60deg (for EUI/AIA sterescopy)
Total number of datasets:	84
Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5:	Full frame
Full resolution or 2x2, 4x4 binned data	Full resolution
noise level (default 10-3):	Default
Co-observations with other instruments:	EUI/HRT at highest possible cadence compatibly with full period of observation
Special requests	None

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Global coronal magnetic field modelling

Thomas Wiegelmann, Gherardo Valori,

Argiris Koumtzis

MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- We use synoptic vector magnetograms as boundary condition for reconstructing the solar coronal magnetic field with nonlinear force-free and stationary MHD-models.
- SO/Phi-data are used in combination with SDO/HMI measurements to create the synoptic vector magnetograms. Polar measurements from Phi and measurements from behind the Sun will provide much more powerfull synoptic maps as from HMI alone.
- The inner corona (up to about two solar radii) can be modelled with a nonlinear force-free model. Further outwards a stationary MHD-model is used.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: full sun
- HRT or FDT: FD to make synoptic vector maps
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): vector B
- Total length of observation: any, each snapshot treated separately
- Cadence (maximum 1 dataset/min): no special requirements
- Pointing needs (disc centre, limb, active region location, particular µ):
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft):
- Total number of datasets: any
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: 0.5kx0.5k
- Full resolution or 2x2, 4x4 binned data: 4x4 binned or even binned more
- noise level (default 10^{-3}): not specified
- Co-observations with other instruments: no
- Special requests: no

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Magneto-hydro-static modelling of the quiet Sun

Thomas Wiegelmann & Maria S. Madjarska

MPS

Science case (stay on one slide):

Please also state, why is PHI needed; why is the science unique?

- We request PHI/HRT data for the purpose of developing an automatic computational tool to extrapolate the photospheric magnetic field measured with SoLO/PHI/HRT into the chromosphere and corona.
- While the coronal magnetic field is force-free, we need to consider plasma forces (pressure gradient force and gravity force) in the photosphere and chromosphere by employing our magneto-hydro-static (MHS) model.
- PHI/HRT produces high resolution magnetic-field measurements that can help to resolve the thin (about 2 Mm) non-force-free layer between the photosphere and the corona. The vertical resolution of the MHS-model scales with the horizontal resolution of the measurements from Phi. The linear MHS-model uses the LOS magnetic field as a boundary condition.
- Free model parameters will be optimized using a Simplex-Downhill minimization by comparing the model magnetic field with observations from SoLO/EUI.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: Quiet Sun
- HRT or FDT: HRT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): B_LOS
- Total length of observation: Any, MHS-model treats each snapshot separately
- Cadence (maximum 1 dataset/min): Any
- Pointing needs (disc centre, limb, active region location, particular μ): not specified
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): not specified
- Total number of datasets: not specified
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: all for testing and comparing
- Full resolution or 2x2, 4x4 binned data: all for testing and comparing
- noise level (default 10^{-3}): default is ok
- Co-observations with other instruments: EUI
- Special requests: No

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Helioseismic far-side imaging: validation & calibration with SO/PHI

Dan Yang

Max Planck Institute for Solar System Research

Science case (stay on one slide):
Please also state, why is PHI needed; why is the science unique?

- Helioseismology has long been used to monitor active regions on the Sun's far-side (w.r.t Earth view), which is an important component for accurate space weather forecasting. The best way to validate this technique would be a direct comparison with magnetograms and continuum images from the far-side of the Sun. To-date, SO/PHI is the only instrument that allows such a validation.
- Direct SO/PHI observation of the Sun's far-side would enable an empirical relation between seismic images and magnetic field. Such a relation can be apply to all 25 years' data since SOHO mission. By combining this derived empirical magnetograms with front-side observations, we would have a clearer picture of the Sun's large scale magnetic field.

Requirements/data (use additional slide if needed)

Besides best guess requirements, you may also list minimum requirements on the data

- Type of solar feature: active regions/sunspots
- HRT or FDT: FDT
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): B_LOS, I_c
- Total length of observation: several days (or more) with large active regions on the far-side
- Cadence (maximum 1 dataset/min): 1 frame per day
- Pointing needs (disc centre, limb, active region location, particular μ): disc center
- Orbit needs (spatial resolution/co-rotation/angle to Earth/angle to other spacecraft): 45 degrees separation (or more) from Earth
- Total number of datasets: at least several frames (the more the better)
- Full frame 2k x 2k or partial frame 1kx1k, 0.5kx0.5: full solar disk
- Full resolution or 2x2, 4x4 binned data: solar diameter larger than 360 pixels
- noise level (default 10^{-3}):
- Co-observations with other instruments: SDO/HMI
- Special requests: None

SO/PHI data request form

(Cruise phase + first science orbit; SO/PHI-Team internal version)

Solar irradiance variability from the position of the SO spacecraft

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Science case

- The exact nature of solar irradiance variability is of interest for the relevance to the influence of the Sun on the Earth's climate and to the solar-stellar connection.
- Solar irradiance variability at rotational to cycle timescales is dominantly driven by its surface magnetism.
- At rotational timescales, solar irradiance fluctuates with the emergence and evolution of active regions and their passage across the solar disc with solar rotation.
- Based on this knowledge, sophisticated models have been developed at MPS to reconstruct solar irradiance variability from full solar disc magnetograms and continuum images, including that from SDO/HMI.
- Our objective is to incorporate SO/PHI full-disc magnetograms and continuum images into these models so to reconstruct solar irradiance variability as apparent from the spacecraft's unique orbit.
- The HMI-based and PHI-based reconstructions, representing solar irradiance variability as apparent from two different positions, will offer us an invaluable opportunity to examine the exact role played by active region evolution and by solar rotation in driving the rotational variability in solar irradiance.

Requirements/data

- Type of solar feature: Full solar disc.
- HRT or FDT: FDT.
- Physical parameters needed (available: B_LOS, vector B, v_LOS, I_c, raw data): B_LOS and I_c recorded at the same time or at least as close as possible.
- Total length of observation: Full duration of cruise phase and first orbit or at least as many 30-day sequences (i.e. solar rotation period) as practically possible.
- Cadence (maximum 1 dataset/min): 1 dataset/day.
- Total number of datasets: 1 dataset/day for as long as practically possible.
- Full frame or partial frame: Full frame.
- Full resolution or binned data: Full resolution.
- Noise level: Default.