NASA Mission Management Updates to the *Hinode* Science Working Group

September 2016

On behalf of the US instrument teams
Focused Mode Coordination

- Status: Operable
  - No major issues reported from the teams.
  - Plans for QS conditions not completely resolved

- Reminder for Focused Mode HOPs sent to community via SolarNews.
  - (released Sept 1, 2016)

- Focused Mode coordination
  - Focused Mode Liaison not used since last SWG
    - Relying on weekly instrument team meetings for communication

- Priority list circulating with weekly meetings
  - Active Region evolution (flux emergence, waves in sunspots, flare monitoring)
  - Coronal Holes
  - Prominence / Filament
  - Disk-center (long baseline synoptic scans)
  - Polar magnetic network
Focused Mode Coordination

- Flare WatchDog
  - Yumi Bamba-san has been filling this position very well. Has now graduated, but still working with the mission.
  - Talk on
  - Suggestions for successor for uptick in activity...eventually? Continue with a graduate student?

![Procedure for flare watch decision](image)
November 23rd is Thanksgiving week (less US support already). FM during Dec/Jan holidays.

*** Hi-C II launch in July? ***; Other launches / campaigns?
**HOPs**


**Guidance for Hinode scientific operations**

July 27, 2015

**HOP PROPOSAL FORM**

- Message to accepted HOP proposers: Hinode Ground-based coordination protocol (updated on Dec. 22, 2009)
- New policy regarding major flare watches, target of opportunity HOPs, and synoptic/long-term study HOPs (updated on July 31, 2010)
- Prioritization of Flag observations for Hinode (updated on December 20, 2011)
- Prioritization of IRIS-Hinode Operations Plans (HOPs) (updated on June 18, 2015)

**Submission Form:** [https://docs.google.com/forms/d/1mvUqVsIIEZ0ta4hbzkVqKKv_kW8x6lHI584lkvaOzX8/viewform](https://docs.google.com/forms/d/1mvUqVsIIEZ0ta4hbzkVqKKv_kW8x6lHI584lkvaOzX8/viewform)

**NASA HOP information site:** [http://hinode.msfc.nasa.gov/hops.html](http://hinode.msfc.nasa.gov/hops.html)
HOPs

SSC planning site: http://hinode.msfc.nasa.gov/submitted_hops.html

**Recent/Coming Submissions -- SSC Planning**

HOP 313 Jets/Usos: ToO: 40 x 1 hour sequences
HOP 315 GREGOR/Vernia: Sept 10-30; 8:30-10:30 & 14:30-17:00 UT
HOP 317 COMP/Tok: ToO: 18:00 UT
HOP 315 MMS/Hiroshi: Aug 25-31; 17-23 UT
HOP 320 SmallScales/L: Aug 19-21; 15-23 UT
HOP 321 Unclosed/Un: Aug 19-Sept 1; 08:10 UT
HOP 322 Filament/Lu: Aug 9-20 (5 days); 04 UT (2 hrs)
HOP 323 SST/Torbell: Sept 23-Oct 8; 11-15 UT
HOP 324 HOP29/Su: Sept 1-8; 17-21 UT

**NEW UPDATED SUBMISSIONS**

HOP 206 -- North Poles Map/Shimojo: September; Once every 3 days for 6 hours (SAA-free)
Submitted HOP #1: Moore/MiXSS: TBD

Ongoing HOP # 206/81:

Title: Peter Panorama Map for understanding Polar Reversals in Cycle 24

ToO: No

Proposal: Shimojo, Tsuruta, Shiotani, Ike, Argall

Dates: March

Times: Every 3 days for 6 hours

Target/Pointing: North Pole

Comments: Shimojo in the month for the North poles, and we need to schedule runs of HOP# (6 days) and HOP 206 (every 2-3 days for a month). You may recall that he made the standing request at the SAA time 6-7 hours of SAA free time per run.

**Hinode Operation Plans Submissions -- SSC Planning**

**HOP # 1**

Title: Coordinated Observations with the MiXSS Cubeset for Cross Calibration and DEM Analysis

Main Objective: Perform XRT cross-calibration with the MiXSS cubeset spectra and use EIS spectra to create full sun DEM map for comparison to MiXSS measurements.

Proposal: No

Proposers: Christopher Moore, Tom Woods, Amir Dasi, Henry Warrer, Ignacio Ugarte-Urra

Previous Submissions:

Moore
Woods
Casas
Warrer
Ugarte-Urra

Dates: Due to two sets of XRT observations on two subsequent days and one set of EIS observations, on a specified day and time most appropriate for Hinode set via communication between the Proposal P1 and the Hinode Team (see agreements)

Times: TBD (see comments)

Target/Pointing: XRT Observations: Full sun images at solar center. No other targets of interest. EIS Observations: See HOP #300

Comments: Desired measurement order:

Measurements on the agreed upon start date (first available opening in the Hinode Operation Plan) and when MiXSS is the only target. Use HOP #206/81 for the new EIS observations.

**Hinode Operation Plans Submissions -- SSC Planning**

**HOP # 2**

Title: Coordinated Observations with the MiXSS Cubeset for Cross Calibration and DEM Analysis

Main Objective: Perform XRT cross-calibration with the MiXSS cubeset spectra and use EIS spectra to create full sun DEM map for comparison to MiXSS measurements.

Scientific Justification:

The first MiniSun X-ray Solar Spectrometer (MiXSS) cubeset was deployed on May 16, 2016, had been in normal science operations since June 5, 2016, and is providing spectroscopically resolved X-ray measurements. Simultaneous observations with Hinode XRT filters will be used to cross-calibrate the two instruments. Combined MiXSS and Hinode XRT data will be used to explore short-term active region evolution (days to weeks). Long term solar X-ray variability (months to years) may be investigated by the potential presence of flares. (X > 0.5) chromosphere (EM < 1067 cm-3) plasmas in active regions and coronal abundances variations.

These proposed XRT measurements will help constrain the relationship between the MiXSS spectra and XRT filters, and will serve as a baseline for future solar X-ray studies. EIS capability of spectrally and spatially resolved UV measurements to create full sun raster mosaic images are essential for full sun DEM estimates. These EIS UV derived DEMs can be used to synthesize the solar emissions at other wavelengths like EUV.

Finally, the EIS 477 full sun raster mosaic data at ~3.5 resolution will provide unique images of relatively well-resolved spectral lines. These special line images allow for direct assessment of the coronal structure at different temperatures, elements and ionization stages. These EIS mosaic and XRT images will be used in analyzing the validity of different coronal heating mechanisms in numerical simulations.

Conduct XRT and MiXSS measurements will supply a wealth of data to address numerous questions about the physics and current conditions of the corona.

In summary our objectives are:

1. Cross-calibrate XRT with the MiXSS cubeset.
2. Conduct EIS UV derived DEMs for comparison to bin X-ray observations.
3. Perform a short term active region (to half sun) solar predictive evolution study via X-rays.
4. Use EIS spatial light mosaic and XRT images to test the validity of coronal heating models in

**Hinode Operation Plans Submissions -- SSC Planning**

**HOP # 3**

Title: Coordinated Observations with the MiXSS Cubeset for Cross Calibration and DEM Analysis

Main Objective: Perform XRT cross-calibration with the MiXSS cubeset spectra and use EIS spectra to create full sun DEM map for comparison to MiXSS measurements.

Proposal: No

Proposers: Christopher Moore, Tom Woods, Amir Dasi, Henry Warrer, Ignacio Ugarte-Urra

Previous Submissions:

Moore
Woods
Casas
Warrer
Ugarte-Urra

Dates: Due to two sets of XRT observations on two subsequent days and one set of EIS observations, on a specified day and time most appropriate for Hinode set via communication between the Proposal P1 and the Hinode Team (see agreements)

Times: TBD (see comments)

Target/Pointing: XRT Observations: Full sun images at solar center. No other targets of interest. EIS Observations: See HOP #300

Comments: Desired measurement order:

Measurements on the agreed upon start date (first available opening in the Hinode Operation Plan) and when MiXSS is the only target. Use HOP #206/81 for the new EIS observations.

**Hinode Operation Plans Submissions -- SSC Planning**

**HOP # 4**

Title: Coordinated Observations with the MiXSS Cubeset for Cross Calibration and DEM Analysis

Main Objective: Perform XRT cross-calibration with the MiXSS cubeset spectra and use EIS spectra to create full sun DEM map for comparison to MiXSS measurements.

Scientific Justification:

The first MiniSun X-ray Solar Spectrometer (MiXSS) cubeset was deployed on May 16, 2016, and has been in normal science operations since June 5, 2016, and is providing spectroscopically resolved X-ray measurements. Simultaneous observations with Hinode XRT filters will be used to cross-calibrate the two instruments. Combined MiXSS and Hinode XRT data will be used to explore short-term active region evolution (days to weeks). Long-term solar X-ray variability (months to years) may be investigated by the potential presence of flares. (X > 0.5) chromosphere (EM < 1067 cm-3) plasmas in active regions and coronal abundances variations.

These proposed XRT measurements will help constrain the relationship between the MiXSS spectra and XRT filters, and will serve as a baseline for future solar X-ray studies. EIS capability of spectrally and spatially resolved UV measurements to create full sun raster mosaic images are essential for full sun DEM estimates. These EIS UV derived DEMs can be used to synthesize the solar emissions at other wavelengths like EUV.

Finally, the EIS 477 full sun raster mosaic data at ~3.5 resolution will provide unique images of relatively well-resolved spectral lines. These special line images allow for direct assessment of the coronal structure at different temperatures, elements and ionization stages. These EIS mosaic and XRT images will be used in analyzing the validity of different coronal heating mechanisms in numerical simulations.

Conduct XRT and MiXSS measurements will supply a wealth of data to address numerous questions about the physics and current conditions of the corona.

In summary our objectives are:

1. Cross-calibrate XRT with the MiXSS cubeset.
2. Conduct EIS UV derived DEMs for comparison to bin X-ray observations.
3. Perform a short term active region (to half sun) solar predictive evolution study via X-rays.
4. Use EIS spatial light mosaic and XRT images to test the validity of coronal heating models in

**Hinode Operation Plans Submissions -- SSC Planning**

**HOP # 5**

Title: Coordinated Observations with the MiXSS Cubeset for Cross Calibration and DEM Analysis

Main Objective: Perform XRT cross-calibration with the MiXSS cubeset spectra and use EIS spectra to create full sun DEM map for comparison to MiXSS measurements.

Proposal: No

Proposers: Christopher Moore, Tom Woods, Amir Dasi, Henry Warrer, Ignacio Ugarte-Urra

Previous Submissions:

Moore
Woods
Casas
Warrer
Ugarte-Urra

Dates: Due to two sets of XRT observations on two subsequent days and one set of EIS observations, on a specified day and time most appropriate for Hinode set via communication between the Proposal P1 and the Hinode Team (see agreements)

Times: TBD (see comments)

Target/Pointing: XRT Observations: Full sun images at solar center. No other targets of interest. EIS Observations: See HOP #300

Comments: Desired measurement order:

Measurements on the agreed upon start date (first available opening in the Hinode Operation Plan) and when MiXSS is the only target. Use HOP #206/81 for the new EIS observations.
Current report (as of Sept. 2, 2016):

91 HOPs reporting (~28% for HOPs 72-325 & 2 < 71)
251* Total Productivity Outputs
123 Refereed Publications
20 Non-refereed Publications [e.g., Conf. Proceedings]
46 EPO Activities
62 Other Outputs [e.g., Talks, Posters]

*Total slightly below last year’s report due to duplicated N-r pubs & EPO submissions discovered.
A. Kobelski put together a table characterizing the target study and coordination for each HOP (from 71).
I combine the study table with the product output information for each HOP (not just refereed papers!). Incomplete due to not having information for each HOP (e.g., eclipses, SRs) and needs some closer inspection per HOP, but it’s a decent first order proxy for assessing what Hinode has been most successful at observing thus far. Shows the richness of the campaigns.
Hinode regularly coordinates with both ground- and space-based observatories and complements several regularly scheduled data-collecting observatories(*) . Hinode also co-observes with sounding rocket and balloon technology development demonstrations. Much of the coordination is scheduled through the Hinode Operations Plan (HOP) program. Since 2008, partnering sites and instrumentation include (but not limited to):

**Ground-based:**
- Atacama Large Millimeter/Submillimeter Array (ALMA) – Chile
- Bialkow Observatory – Poland
- Big Bear Solar Observatory (BBSO) [NST/FISS/IRIM] – New Jersey
- Dunn Solar Telescope (DST/NSO) [IBIS/ROSA/SHAZAM/FIRS] – New Mexico
- Dutch Open Telescope (DOT) – La Palma
- Fuxian Lake Solar Observatory [NVST] – China
- GREGOR Solar Telescope [GRIS] – Tenerife
- Haleakala Observatory – Hawaii
- Hida Observatory [DST] – Japan
- Iitate Radio Telescope (IPRT) – Tohoku University/Japan
- Kanzelhoe Solar Observatory (KSO) – Austria
- Lomnicky Peak Observatory [CoMP] – Czech Republic
- Mauna Loa Solar Observatory (MLSO) [CoMP] – Hawaii
- McMath-Pierce Telescope (NSO) – New Mexico
- Meudon Solar Tower – Paris
- Ondrejov Observatory – Czech Republic
- Pic du Midi Observatory – France
- Solar Magnetic Activity Research Telescope (SMART) – Japan
- Solar Terrestrial Laboratory [IPS] – Nagoya University/Japan
- Solar Tower Telescope of Nanjing University – China
- Swedish Solar Telescope (SST) [CRISP/TRIPPEL] – La Palma
- Synoptic Optical Long-term Investigations of the Sun (SOLIS/NSO) – New Mexico
- Vacuum Tower Telescope (VTT) – Tenerife
- Very Large Array (VLA)

(Note: Several High Schools and Science Museums in Japan)

**Space-based:**
- Active Cavity Radiometer Irradiance Monitor Satellite (ACRIM)
- *Advanced Composition Explorer (ACE)
- Akatsuki (Venus probe)
- Cassini (Saturn mission)
- Hubble Space Telescope (HST) [WFPC3]
- Interface Region Imaging Spectrograph (IRIS)
- Mercury Surface, Space Environment, Geochemistry, and Ranging (Mercury mission)
- Nuclear Spectroscopic Telescope Array (NuSTAR)
- Project for OnBoard Autonomy 2 (PROBA2) [SWAP]
- *Ramaty High Energy Solar Spectroscopic Imager (RHESSI)
- Solar and Heliospheric Observatory (SOHO) [SUMER/EIT/CDS/UVCS/MDI/LASCO]
- *Solar Dynamics Observatory (SDO) [AIA/EVE/HMI/MinXSS]
- Solar Radiation and Climate Experiment (SORCE) [TIM]
- *Solar Terrestrial Relations Observatory (STEREO) [EUVI]
- Telescopes for EUV Spectral Imaging of the Sun (TESIS) [CORONAS]
- Time History of Events and Macroscale Interactions during Substorms (THEMIS)
- Transient Region and Coronal Explorer (TRACE)
- *Wind: Comprehensive Solar Wind Laboratory for Long-Term Solar Wind Measurements

**Technology Demonstrations:**
- SUMI
- HIC (1, 2)
- VAULT
- RAISE
- FOXSI
- CLASP
- SUNRISE (Balloon)
- VERIS
- EUNIS
- MOSES (1 & 2)

52 Total Observatories/Rockets/Balloons; at least 69 instrument coordinations
Senior Review Upcoming (early this year to line up with NASA budget reviews)

Announcement of Opportunity expected within the next month
Presentation to Panel ~March 2017
Results ~May 2017

Need to:

Schedule US team meeting at Hinode 10.
Set Prioritized Science Goals for the next few years.
Determine sufficiency of response to previous PSGs.
Pull together impactful coordinated observations (IRIS, NuSTAR, ALMA).
Send out call for HOP outputs.
In response to the 2012 NRC Decadal Survey Science Challenges and 2014 Heliophysics Roadmap Research Focus Areas, the Hinode mission has set forth four Prioritized Science Goals (PSGs):

- Study the sources and evolution of highly energetic dynamic events.
- Characterize cross-scale magnetic field topology and stability.
- Trace mass and energy flow from the photosphere to the corona.
- Continue long term synoptic support to quantify cycle variability.

### Table 2: Prioritized Science Goals and required observations mapped to the 2014 Heliophysics Roadmap Research Focus Areas (RFA) and 2012 Decadal Survey Challenges (DSCs).

<table>
<thead>
<tr>
<th>RFA &amp; DSCs</th>
<th>SCIENCE OBJECTIVE</th>
<th>SAMPLE OBSERVATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>§ 3.1:</strong> PSG1 – Study the sources and evolution of highly energetic dynamic events.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RFA H1</td>
<td>3.1.1 Observe large-scale eruptive events from flare to particle acceleration.</td>
<td>- Coordinated radio, EUV, and X-ray observations of thermal &amp; non-thermal eruption processes.</td>
</tr>
<tr>
<td>RFA F2</td>
<td>3.1.2 Characterize the energetics of nanoflares and properties of non-thermal electrons.</td>
<td>- Nanoflare electron beam studies with NuSTAR.</td>
</tr>
<tr>
<td>RFA F1</td>
<td>3.1.3 Probe magnetic reconnection flux transfer and energy release during flaring events.</td>
<td>- Spectrally probing chromospheric evaporation/condensation in flare loops.</td>
</tr>
<tr>
<td>DSCs SH 2 &amp; 3</td>
<td><strong>Focused Mode opportunity:</strong> CME watch</td>
<td>Synergies: IRIS, ALMA, VLA, EOVSA, NuSTAR, SDO, RHESSI, STEREO</td>
</tr>
</tbody>
</table>

| **§ 3.2:** PSG2 – Characterize the cross-scale magnetic field topology and stability. |
| RFA H1 | 3.2.1 Study active region energy storage, topology, and evolution. | - Monitor the temperature stratification above ARs to potentially predict energy releases. |
| RFA F2 | 3.2.2 Determine the impact of small-scale magnetic fields on the solar atmosphere. | - Specifically-designed sequences for IRIS coordination to observe unresolved fine structure in the transition region. |
| 3.2.3 | Determine the impact of large-scale magnetic field variations on the heliosphere. | - Test S-web model predictions concerning magnetic field topology in the outer corona with deep, wide-field SXR imaging. |
| DSCs SH 2 & 3 | **Focused Mode opportunity:** AR evolution | Synergies: IRIS, SDO |

| **§ 3.3:** PSG3 – Trace mass and energy flow from the photosphere to the corona. |
| RFA H1 | 3.3.1 Isolate solar wind sources and measure their mass supply. | - New EIS observing modes scanning for slow solar wind sources. |
| RFA F5 | 3.3.2 Characterize the heating of the chromosphere. | - Link chromospheric heating diagnostic ion transport with Poynting flux estimates. |
| 3.3.3 | Quantify the generation, dissipation, and impact of magnetic waves. | - Vorticity measurements tracing chromospheric twist into the corona. |
| DSCs SH 2 & 3 | **Focused Mode opportunity:** EIS scans | Synergies: ACE, IRIS, SDO |

| **§ 3.4:** PSG4 – Continue long term synoptic support to quantify cycle variability. |
| RFA F4 | 3.4.1 Understand solar irradiance variations. | - Derive continuum contrast from SOT continuum bands and IRIS Mg II index. |
| RFA H1 | 3.4.2 Monitor solar cycle evolution and stability. | - Polar magnetic fields, X-ray bright points, and magnetic activity band progression as indicators of solar cycle evolution and activity. |
| 3.4.3 | Relate solar variability to stellar evolution. | - Application of “Sun-as-a-star” methods to synoptic data for stellar abundance profiles. |
| DSCs SH 1 & 3 | **Synergies:** IRIS, SDO |
On October 9, 2014 a coronal cavity was observed by Hinode and IRIS as part of IHOP 264.

The cavity structure is clearly in the EIS Fe XII, and Fe XIII raster scans, but the cavity wall is not visible in the EIS Fe XV line, indicating that the cavity defining structures are less than ~2MK.

The cavity is also visible in the XRT Thin-Be filter, though foreground and background loops are also visible.

Jibben, Reeves, & Su, *Frontiers in Astronomy and Space Sciences*, submitted
Hinode Highlights: Coronal Cavity Structure

Jibben, Reeves, & Su, *Frontiers in Astronomy and Space Sciences*, submitted

IRIS movie from the slit-jaw imager shows a disturbance that causes plasma to flow over and around the prominence, outlining the cavity structure.

A combination XRT/SOT movie shows that an incursion of hot plasma from the north is responsible for the disturbance. XRT data also indicates heating around the tip of the prominence.

Via the Hinode/XRT team through the Smithsonian Astrophysical Observatory.
Hinode Highlights: Coronal Cavity Structure

- IRIS observations show areas of decreased Si IV emission along the neutral line, indicating the presence of a “bald patch” magnetic configuration, where fields have a concave-up shape near the Sun’s surface.

- Modeling shows that a weakly twisted magnetic flux rope is consistent with the observations for this cavity, including the existence of a “bald patch” at the neutral line.

Jibben, Reeves, & Su, *Frontiers in Astronomy and Space Sciences*, submitted
What determines the boundary between Umbra and Penumbra?
- Intensity? Flow field? Magnetic Field?

Prior to 2011, 103 years after Hale’s discovery of sunspot magnetic fields, no magnetic property for the boundary was found.
- A larger survey in 2015 has confirmed this and found a canonical value for $B_{\text{ver}}$ at the boundary.
- For $B_{\text{ver}} > 1860$ Gauss, the efficiency of convection is suppressed and dark umbra results, with intermittent convective umbral dots.
- For $B_{\text{ver}} < 1860$ Gauss, the unique mode of penumbral magneto-convection takes over: penumbral filaments with the same brightness and flow structure regardless of spot size.

Why did it take 100 years to find this?
- Measured magnetic fields depend on instrumental characteristics, especially seeing and stray light.
- Hinode Spectro-Polarimeter measures all sunspots in an identical way with uniform point spread function and pointing stability.
The canonical value of $B_{\text{ver}}$ is confirmed for spots of all shapes and sizes, as long as they have stable penumbra.

Sunspots from the Hinode SP Level-2 archive, showing the 1860 Gauss contour in $B_{\text{ver}}$ (Schlichenmaier, 2015)

Contributed by the Hinode/SOT team through the Lockheed Martin Solar Astrophysical Laboratory
Modern Computational Power Applied to Spectro-Polarimeter Data

- A clever new technique solves a massive spatially-coupled optimization problem to make best estimates for the atmospheric parameters (B, V, T, etc.) at each point, correcting for the blurring by diffraction. The maps show small-scale structures sharper than in the original data (van Noort, A&A 2013).

- Recent application by Tiwari et al (A&A 2015) not only derives the sharpest maps ever made of sunspot properties but also measures the depth dependence of temperature, velocity, and magnetic field strength, inclination and twist.

Contributed by the Hinode/SOT team through the Lockheed Martin Solar Astrophysical Laboratory

a) Temperature; b) Magnetic Field Strength; c) Magnetic inclination angle from vertical; d) Doppler velocity; all at \( \tau = 1 \) in the photosphere.
**Hinode Highlights: Chromospheric Evaporation During Flares**

*Chromospheric Evaporation Flows and Density Changes Deduced from Hinode/EIS During an M1.6 Flare*


- Observations of an M1.6 flare with Hinode/EIS, SDO/AIA, and RHESSI
- EIS Doppler shifts and electron densities are compared with the energy flux measured with RHESSI
- Spectroscopic results support explosive chromospheric evaporation and show the dependence of the upflow velocity on the steepness of the energy distribution

Contributed by the Hinode/EIS team through the Naval Research Laboratory
Hinode Highlights: Chromospheric Evaporation During Flares

Simultaneous Iris and Hinode/EIS Observations and Modeling Of The 2014 October 27 X2.0 Class Flare

- Observations of an X2 flare with Hinode/EIS+XRT, IRIS, SDO/AIA, and RHESSI
- High temperature line profiles in EIS generally show both a blue wing and stationary component but are completely blueshifted in IRIS, suggesting that evaporation is resolved with IRIS.
- Hydrodynamic simulations support an electron beam heating model.

Contributed by the Hinode/EIS team through the Naval Research Laboratory
Transit of Mercury – May 9, 2016

Hinode’s Solar Optical Telescope (SOT) captures images of magnetically driven structures on the solar surface with its high-resolution Spectro-Polarimeter (SP), which uses a slit to disperse light. SOT/SP images are created by either scanning a region with a slit (rastering mode) or by allowing a region to drift past the slit as the Sun rotates (sit and stare mode).

By scanning the slit across a region where Mercury was expected to traverse, SOT captured this beautiful image of the planet in front of solar granules (roughly the size of Texas) on the Sun’s surface. It took over 10 minutes to scan the full field of view with 512 vertical slits. Because Mercury moved while it was being scanning, the planet appears elliptical.

Image credit: JAXA/NASA/Lockheed Martin Solar and Astrophysics Laboratory (LMSAL)
For this stunning image, the slit was held in a fixed position while Mercury and the Sun drifted by over a period of 3.4 minutes. The image consists of 828 vertical strips, each one ~110 kilometers wide, that are stitched together. The background shows how the solar granules in the previous image change with time as convection causes material to flow up and down during the heating and cooling process.
Transit of Mercury – May 9, 2016

Hinode’s Extreme ultraviolet Imaging Spectrometer (EIS) also creates images by rastering with a slit, but it is optimized to observe the hotter temperature solar material in the Sun’s atmosphere. This image from EIS shows Mercury as it approaches the East limb of the Sun. The background solar image is centered on the Fe XII line (195 Å) and shows material that is over 1 million degrees Kelvin.

Image credit: JAXA/NASA/UKSA/Naval Research Laboratory (NRL)
Hinode’s third and final instrument, the X-Ray Telescope (XRT), is capable of taking full-Sun images of the hot solar atmosphere in soft X-rays.
Using its Al-poly filter, which captures the light from coronal material at millions of degrees, XRT tracked Mercury from limb to limb. The slight apparent wobble of Mercury’s path in front of the Sun is an optical effect called parallax caused by Hinode’s orbit around the Earth from pole to pole.
On October 27, 2014, an X2 flare was observed with SDO, IRIS and Hinode. IRIS was rolled by 90 degrees, so the IRIS and EIS fields of view overlapped.
Evidence for chromospheric evaporation: the EIS Fe XXIII line shows blueshifts of ~200 km/s. The IRIS Fe XXI line shows complete blueshifts (indicating flows are resolved), that decrease with time.


Via the Hinode/XRT team through the Smithsonian Astrophysical Observatory

Hinode Highlights: X2 flare on October 27, 2014
Hinode Highlights: X2 flare on October 27, 2014


- Temperatures from AIA and XRT show that hot emission (log(T[K]) > 7.2) is first concentrated at the footpoints before filling the loops.
- Density-sensitive lines from IRIS and EIS give estimates of electron number density of \( \geq 10^{12} \text{ cm}^{-3} \) in the transition region lines and \( 10^{10} \text{ cm}^{-3} \) in the coronal lines during the impulsive phase.

- Modeling indicates this data is consistent with an electron beam heating model rather than thermal conduction – key to distinguishing between flare heating sources.

Via the Hinode/XRT team through the Smithsonian Astrophysical Observatory.
Hinode Highlights: What is SOT doing now?

Since the Filtergraph camera failed in February, 2016, the Solar Optical Telescope’s science instrument is now the Spectro-Polarimeter (SP), which is working nominally. These slides show what data it collects, both ongoing observations for almost 10 years and new modes enabled by additional telemetry and IRIS coordination.

SP is a polarization-sensitive slit spectrometer. Its spectra are processed to make line profiles in two photospheric Fe I lines and Stokes images. Stokes QUV show the presence of magnetic fields in the atmosphere. Inversion of the line profiles makes maps of magnetic field vectors, Doppler shifts and other atmospheric thermal parameters.
Hinode Highlights: What is SOT doing now?

More telemetry is available now for SP and for XRT and EIS. As a result, SP can take more full-resolution spectra (0.16, not 0.32 arcsecond pixels). Few full resolution maps or time series have been made since the X-band failure in 2008, because the telemetry needed is 4x greater.

These full-resolution SP images show the mixed polarity region outside of a sunspot with the highest resolution and sensitivity available from any observatory. The bottom two images are derived by inversion of the Stokes spectra; the scattered noisy pixels are locations of very weak magnetic field where the inversion failed to converge.

Contributed by the Hinode/SOT team through the Lockheed Martin Solar Astrophysical Laboratory
Hinode Highlights: What is SOT doing now?

Many IRIS & Hinode science goals require sensitive magnetic field measurements with high cadence, covering the IRIS slit. New SP observing programs make repeated tall, skinny maps with 0.5 – 20 minute cadence. With careful planning, the IRIS and SP raster areas overlap to ~2 arcsecond accuracy in the narrow dimension.

Simultaneous SP magnetograms and IRIS Mg II spectrograph images of June 13. There is a vertical offset but alignment in the narrow horizontal dimension is good.

Both movies on this slide have 9 x 42 arcsecond FOV.

SP movies from a HOP 313 observation on June 13, 2016. This goal is to search for chromospheric manifestations of super-sonic downflows seen in the photosphere.

Full resolution SP movies from an IRIS & SOT study of explosive events in the mixed polarity outside of the sunspot on April 2, 2016.

Contributed by the Hinode/SOT team through the Lockheed Martin Solar Astrophysical Laboratory