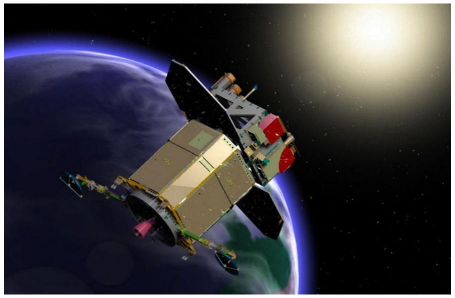


The Helioseismic & Magnetic Imager on the Solar Dynamics Observatory

The HMI Team – Stanford University, LMSAL, HAO, ++

ABSTRACT

The HMI investigation will study the origin of solar variability and will characterize and understand the Sun's interior and the various components of magnetic activity. The HMI instrument is part of the Solar Dynamics Observatory (SDO) mission scheduled for launch in 2009. HMI makes measurements of the motion of the solar photosphere to study solar oscillations and measurements of the polarization to study the Sun's vector magnetic field. HMI will help establish the relationships between the internal dynamics and magnetic activity in order to understand solar variability and its effects, leading to reliable predictive capability, one of the key elements of the Living With a Star (LWS) program.

The Michelson Doppler Imager (MDI) instrument has made helioseismic and magnetic field observation of the Sun for all of solar cycle 23. HMI will continue these important measurements from space into the next solar cycle. The HMI instrument is an evolution of the successful MDI design with key improvements in resolution, image cadence and vector magnetic field measurement capabilities. Measurements of the Fe I spectral line at 617.3 nm with the HMI tunable narrow band filter determine motions of the solar photosphere to study solar oscillations. Measurements of the polarization in this same spectral line enable determination of all three components of the photospheric magnetic field.

See: **http://hmi.stanford.edu** for more information.

Parameter	Requirement
Central wavelength	6173.3 Å ± 0.1 Å (Fe I line)
Filter bandwidth	76 mÅ ± 10 mÅ fwhm
Filter tuning range	680 mÅ ± 68 mÅ
Central wavelength drift	< 10 mÅ during any 1 hour period
Field of view	> 2000 arc-seconds
Angular resolution	better than 1.5 arc-seconds
Detector resolution	0.50 ± 0.01 arc-second / pixel
Focus adjustment range	± 4 depths of focus
Pointing jitter reduction factor	> 40 db with servo bandwidth > 30 Hz
Image stabilization offset range	> ± 14 arc-seconds in pitch and yaw
Pointing adjustment range	> ± 200 arc-seconds in pitch and yaw
Dopplergram cadence	< 50 seconds
Image cadence for each camera	< 4 seconds
Timing	< 1 μs stability, < 100 ms absolute
Science telemetry allocation	< 55 Mbits/s
Instrument design lifetime	> 5.3 years

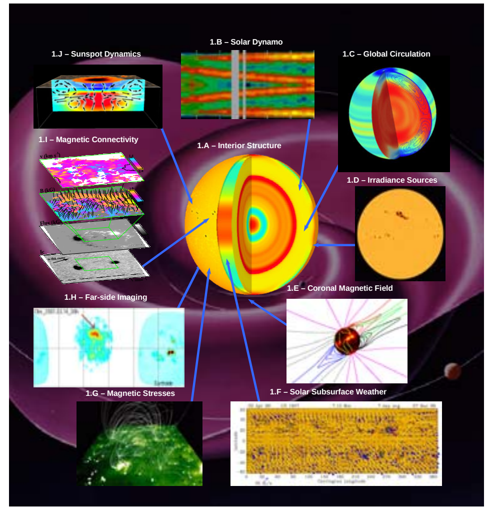
HMI Major Science Objectives

The primary goal of the Helioseismic and Magnetic Imager (HMI) investigation is to study the origin of solar variability and to characterize and understand the Sun's interior and the various components of magnetic activity. The HMI investigation is based on measurements obtained with the HMI instrument as part of the Solar Dynamics Observatory (SDO) mission. HMI makes measurements of the motion of the solar photosphere to study solar oscillations and measurements of the polarization in a spectral line to study all three components of the photospheric magnetic field. HMI produces data to determine the interior sources and mechanisms of solar variability and how the physical processes inside the Sun are related to surface magnetic field and activity. It also produces data to enable estimates of the coronal magnetic field for studies of variability in the extended solar atmosphere. HMI observations will enable establishing the relationships between the internal dynamics and magnetic activity in order to understand solar variability and its effects, leading to reliable predictive capability, one of the key elements of the Living With a Star (LWS) program.

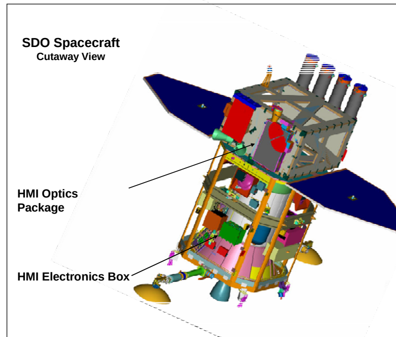
The broad goals described above will be addressed in a coordinated investigation in a number of parallel studies. These segments of the HMI investigation are to observe and understand these interlinked processes:

- **Convection-zone dynamics and the solar dynamo;**
- **Origin and evolution of sunspots, active regions and complexes of activity;**
- **Sources and drivers of solar activity and disturbances;**
- **Links between the internal processes and dynamics of the corona & heliosphere;**
- **Precursors of solar disturbances for space-weather forecasts.**

These goals address long-standing problems that can be studied by a number of immediate tasks. The description of these tasks reflects our current level of understanding and will obviously evolve in the course of the investigation.



1.A Sound speed variations relative to a standard solar model.
1.B Solar cycle variations in the sub-photospheric rotation rate.
1.C Solar meridional circulation and differential rotation.
1.D Sunspots and plage contribute to solar irradiance variation.
1.E MHD model of the magnetic structure of the corona.
1.F Synoptic map of the subsurface flows at a depth of 7 Mm.
1.G EIT image and magnetic field lines computed from the photospheric field.
1.H A ctive regions on the far side of the sun detected with helioseismology.
1.I Vector field image showing the magnetic connectivity in sunspots.
1.J Sound speed variations and flows in an emerging active region.



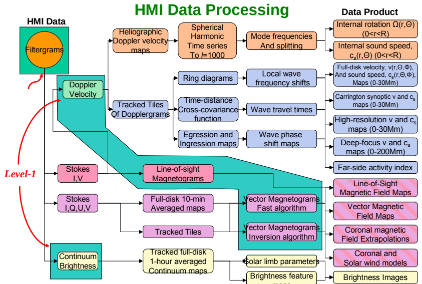
The Solar Dynamics Observatory will be placed into an inclined geosynchronous orbit to maximize sunlit hours while providing high bandwidth telemetry. Launch is scheduled for fall 2009.

HMI Observables

Doppler Velocity	
Cadence	45 s
Precision	13 m/s
Zero point accuracy	0.05 m/s
Dynamic range	±6.5 km/s
Line-of-Sight Magnetic Flux	
Cadence	45 s
Precision	10 G
Zero point accuracy	0.05 G
Dynamic range	± 4 kG
Continuum Intensity	
Cadence	45 s
Precision	0.3%
Accuracy pixel to pixel	0.1%

Vector Magnetic Field	
Cadence	90 s
Precision:	
Polarization	0.22%
Sunspots (1kG<|B|<4kG) *	
|B|	18G
Azimuth	0.6°
Inclination	1.4°
Quiet Sun (0.1kG<|B|<2kG) *	
|B|	220 G
Total flux density	35 G
Azimuth	15°
Inclination	18°

HMI Data Processing



HMI Data Analysis Pipeline

HMI Recent Progress & Current HMI Activities
(as of June 2009)

•The HMI instrument is complete, integrated onto SDO, tested, ready for launch.

•The first 30 days after launch will be used for CCD decontamination.

•First Light will be after 30 days, followed by 30-60 days of science commissioning.

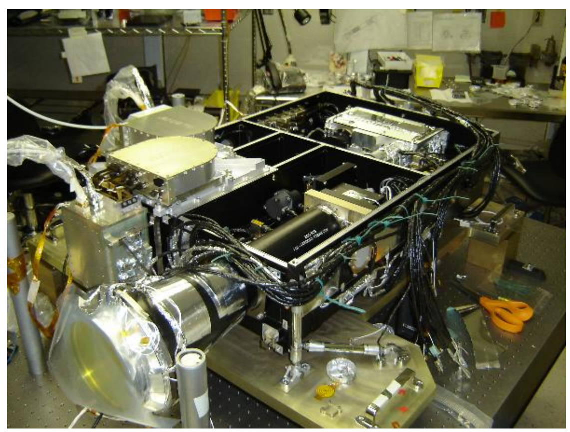
•Normal continual science observations will begin 60-90 days after launch.

•Launch is likely before the end of 2010.

•There will be about 6 months of overlap with SOHO/MDI for cross-calibrations.

•All HMI data will be available within a day or so after observation.

•Access to HMI data will be via the HMI/AIA JSOC (see box on far right).



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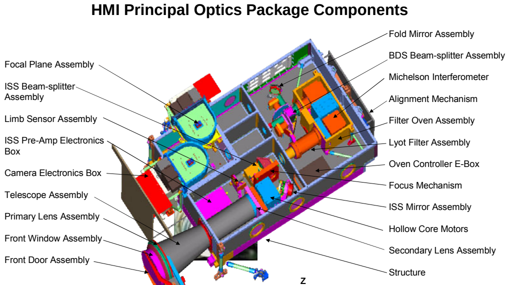
HMI/AIA JSOC (Joint Science & Operations Center)

•Data Capture from SDO ground system
•Archive of telemetry and processed data
•Distribution to team and exports to all users
•HMI and AIA processing to "level-1"
•HMI higher level science data products

•Expect to archive ~ 1000TB/yr
•Metadata stored in PostgreSQL database
•Image data is stored online and on tape (LTO-4)
•"Pipeline" processing system to generate standard products
•Special products computed automatically "on demand"

http://jsoc.stanford.edu

HMI Principal Optics Package Components



Optical Characteristics:
Effective Focal Length: 495 cm
Telescope Clear Aperture: 14 cm

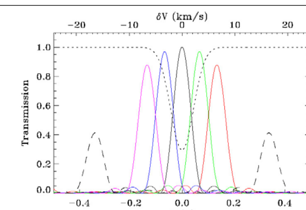
Mechanical Characteristics:
Box: 0.84 × 0.55 × 0.16 m
Over All: 1.19 × 0.83 × 0.30 m
Mass: 44.0 kg
First Mode: 73 Hz

HMI Implementation

The HMI instrument design and observing strategy are based on the highly successful MDI instrument, with several important improvements. HMI will observe the full solar disk in the Fe I absorption line at 6173Å with a resolution of 1 arc-second. HMI consists of a refracting telescope, a polarization selector, an image stabilization system, a narrow band tunable filter and two 4096² pixel CCD cameras with mechanical shutters and control electronics. The continuous data rate is 55Mbits/s.

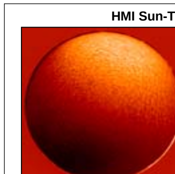
The polarization selector, a set of rotating waveplates, enables measurement of Stokes I, Q, U and V with high polarimetric efficiency. The tunable filter, a Lyot filter with one tunable element and two tunable Michelson interferometers, has a tuning range of 600 mÅ and a FWHM filter profile of 76 mÅ.

Images are made in a sequence of tuning and polarizations at a 4-second cadence for each camera. One camera is dedicated to a 45s Doppler and line-of-sight field sequence while the other to a 90s vector field sequence. All of the images are downlinked for processing at the HMI/AIA Joint Science Operations Center at Stanford University.

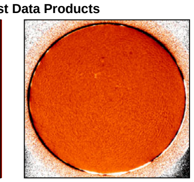


The solid lines show the HMI filter transmission profiles at 76 mÅ spacing. The black dashed line is the profile used for the continuum filtergram. The dotted line shows the Fe I line profile.

HMI Sun-Test Data Products



First Dopplergram



First Magnetogram