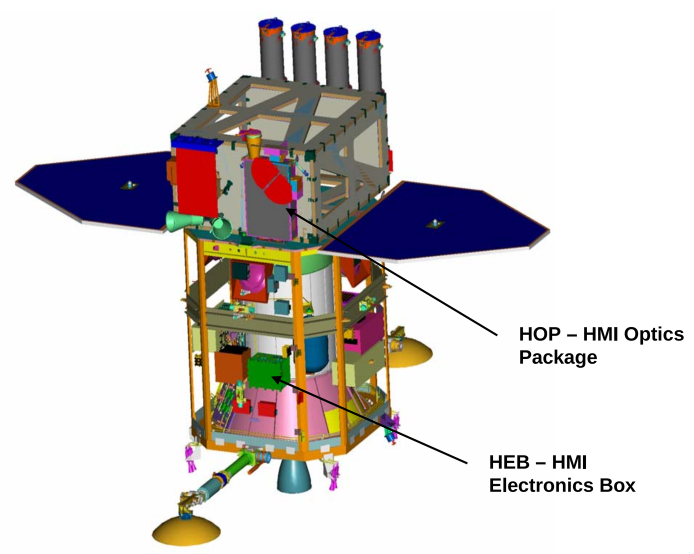
Helioseismic and Magnetic Imager for Solar Dynamics Observatory

Philip Scherrer and HMI Team

ABSTRACT

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. Here we will give an overview of the HMI science goals, the HMI instrument and its expected performance, the science products produced and the ways in which the science community and public will be able to utilize HMI data.

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



The Solar Dynamics Observatory will be placed into an inclined Geosynchronous orbit to maximize sunlit hours while providing high bandwidth telemetry. Launch in late summer 2008.

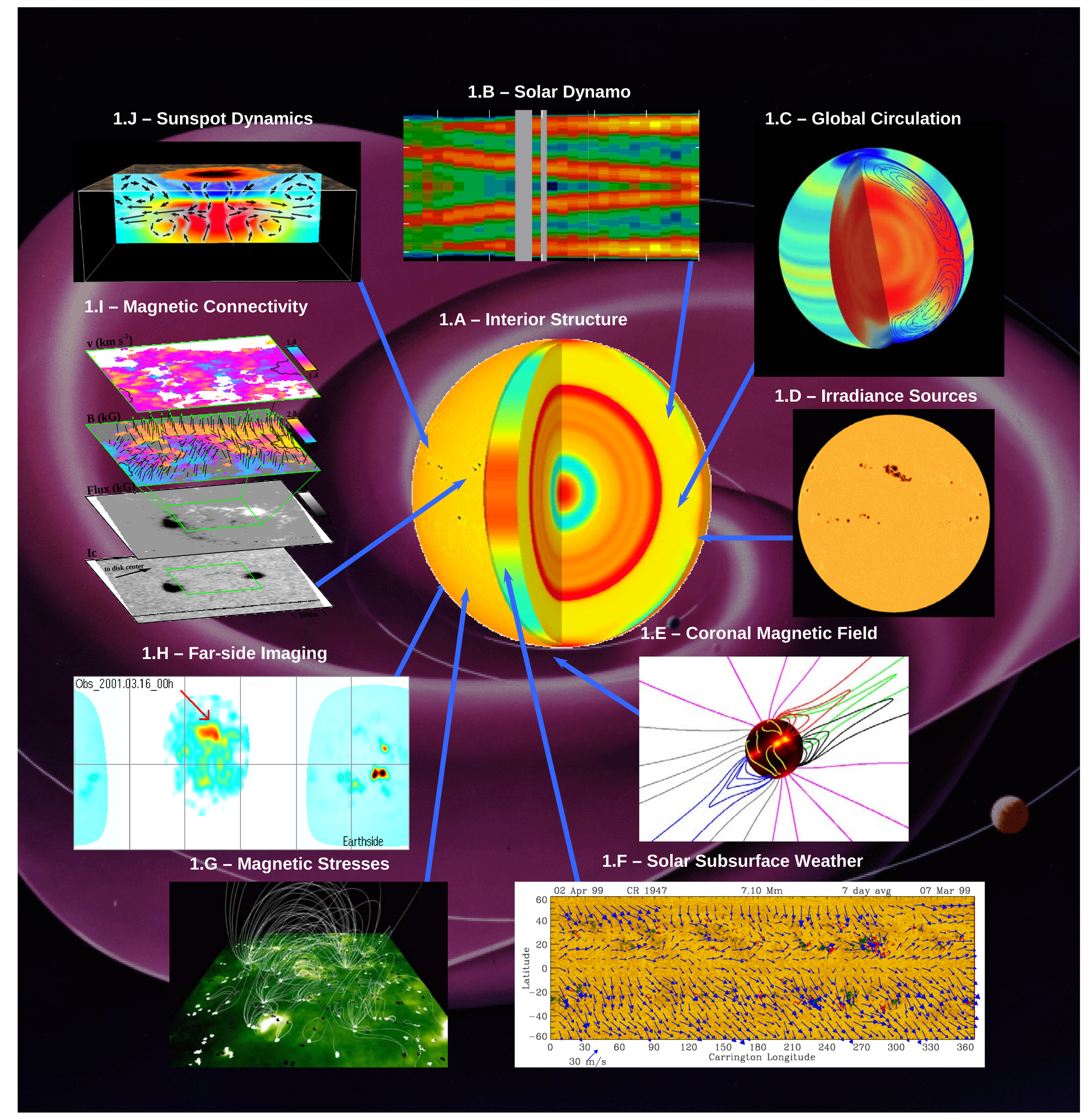
HMI Major Science Objectives

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 and 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) Active 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.

HMI Science Team

HMI is a joint project of the Stanford University Hansen Experimental Physics Laboratory and Lockheed-Martin Solar and Astrophysics Laboratory with key contributions from the High Altitude Observatory, and the HMI Science Team. All HMI data is available to all investigators as well as those in the initial team.

Name	Role	Institution	Phase B,C,D	Phase-E
Philip H. Scherrer	PI	Stanford University	HMI Investigation	Solar Science
John G. Beck	A-I	Stanford University	E/PO Science Liaison	Surface Flows
Richard S. Bogart	Co-I	Stanford University	Data Pipeline and Access	Near Surface Flows
Rock I. Bush	Co-I	Stanford University	Program Manager	Irradiance and Shape
Thomas L. Duvall, Jr.	Co-I	NASA Goddard Space Flight Center	Time-Distance Code	Helioseismology
Alexander G. Kosovichev	Co-I	Stanford University	Inversion Code	Helioseismology
Yang Liu	A-I	Stanford University	Vector Field Observable Code	Active Region Fields
Jesper Schou	Co-I	Stanford University	Instrument Scientist	Helioseismology
Xue Pu Zhao	Co-I	Stanford University	Coronal Code	Coronal Field Models
Alan M. Title	Co-I	LMSAL	HMI Instrument	Solar Science
Thomas Berger	A-I	LMSAL	* Vector Field Calibration	Active Region Science
Thomas R. Metcalf	Co-I	LMSAL	* Vector Field Calibration	Active Region Science
Carolus J. Schrijver	Co-I	LMSAL	AIA Liaison	Active Region Science
Theodore D. Tarbell	Co-I	LMSAL	HMI Calibration	Active Region Science
Bruce W. Lites	A-I	High Altitude Observatory	* Vector Field Inversions	Active Region Science
Steven Tomczyk	Co-I	High Altitude Observatory	* Vector Field Inversions	Active Region Science
Sarbani Basu	Co-I	Yale University	* Ring Analysis Code	Helioseismology
Douglas C. Braun	Co I	Colorado Research Associates	* Farside Imaging Code	Helioseismology
Philip R. Goode	Co-I	NJIT, Big Bear Solar Observatory	* Magnetic and Helioseismic Code	Fields & Helioseismology
Frank Hill	Co-I	National Solar Observatory	* Ring Analysis Code	Helioseismology
Rachel Howe	Co-I	National Solar Observatory	* Internal Rotation Inversion Code	Helioseismology
Jeffrey R. Kuhn	Co-I	University of Hawaii	* Limb and Irradiance Code	Irradiance and Shape
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Jon A. Linker	Co-I	Science Applications Intnl. Corp.	* Coronal MHD Model Code	Coronal Physics
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Juri Toomre	Co-I	JILA, Univ. of Colorado	* Sub-Surface-Weather Code	Helioseismology
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Bernhard Fleck	Co-I	European Space Agency	ILWS Coordination	Atmospheric Dynamics
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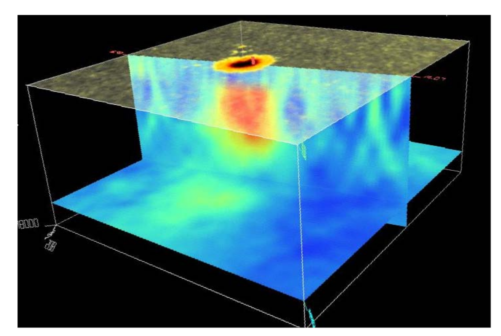
Sami K. Solanki	Co-I	Max-Planck-Institut für Aeronomie, DE		AR Science
Michael J. Thompson	Co-I	Imperial College, UK		Helioseismology
		HMI Science Team		* Phase D only

The HMI E/PO program is implemented as part of the Stanford SOLAR Center at Stanford University. **http://solar-center.stanford.edu**

HMI Education/Public Outreach Partnerships

Institution * For AIA	*Student Involvement*	*K-14 Curriculum Development*	*Teacher Workshops*	*Assessment Support*	*Multimedia Development*	*Distance Learning Support*	*Distribution of Materials*	*Access to Undeserved*	*Public/ infomal education*
Stanford	X	X	X	X	X	X	X	X	X
LMSAL	X	X			X		X	X	X
Stanford-Haas	X			X	X			X	X
MSU*	X	X	X	X	X	X	X	X	X
SAO*	X	X	X	X	X	X	X	X	X
The Tech Museum	X		X				X	X	X
Chabot SSC	X		X				X	X	X
Morrison Planetarium /CA Academy of Sciences	X		X				X		X
Lawrence Hall of Science		X	X	X			X	X	
IIISE		X					X		
NASA-CORE							X		

LWS / SDO "Poster Picture" shows HMI goal



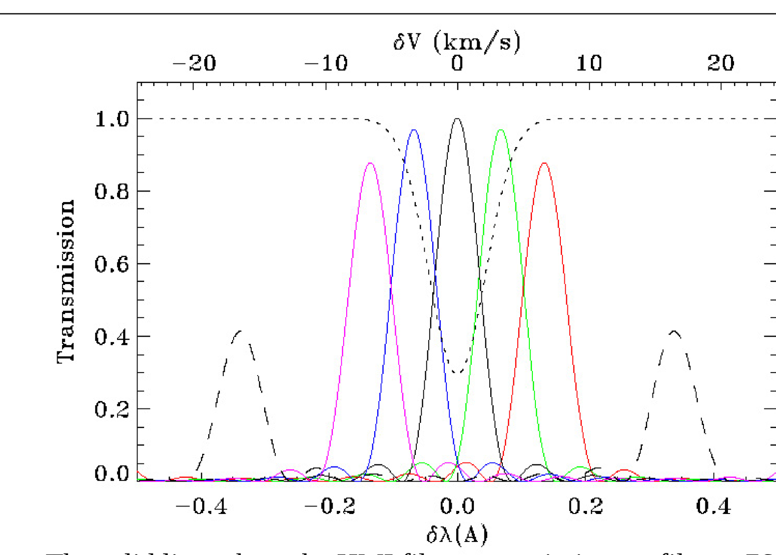
Sound-speed beneath a sunspot (+, red, and -, blue perturbations) from SOHO/MDI high-resolution data.

HMI Implementation

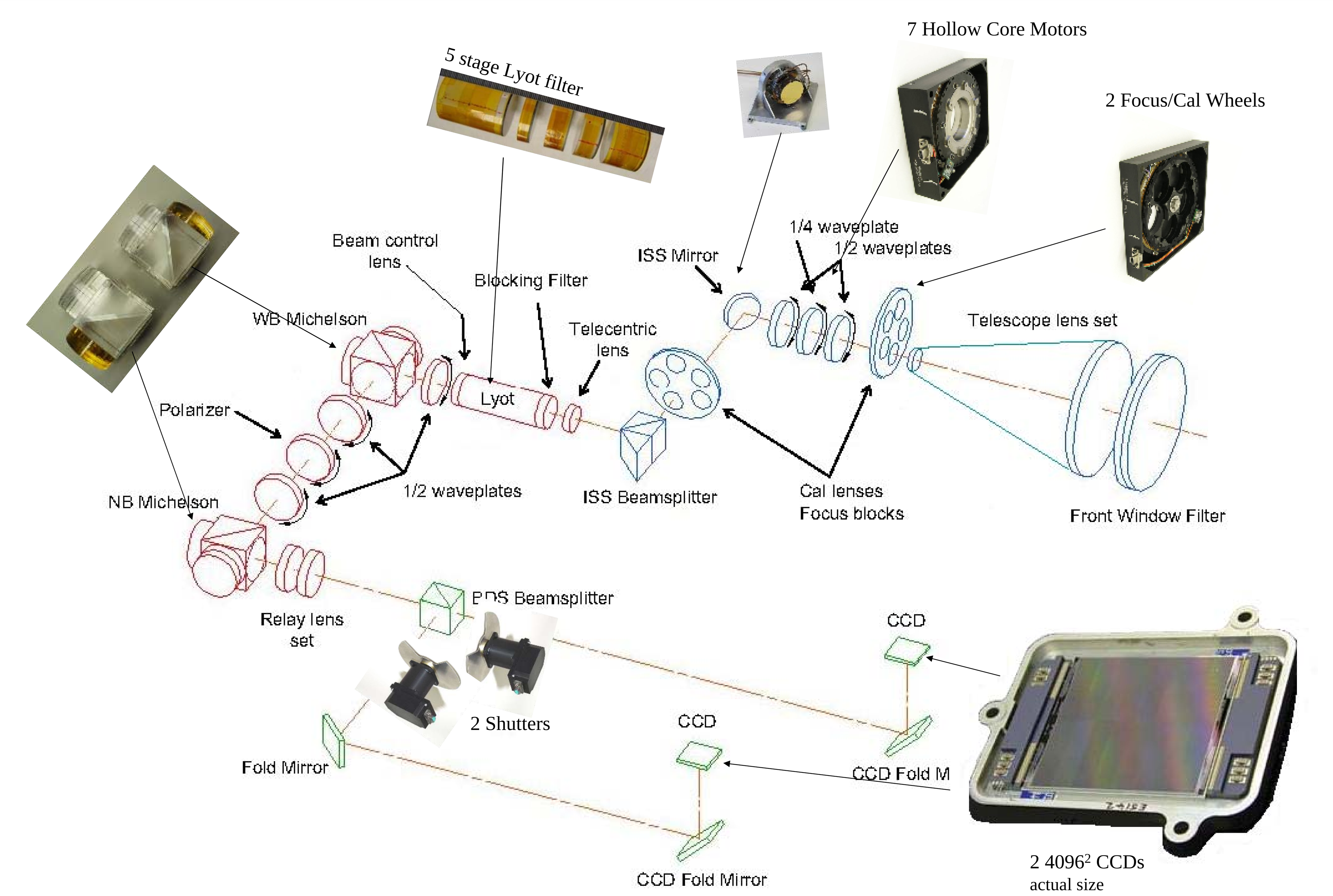
The HMI instrument design and observing strategy are based on the highly successful MDI instrument, with several important improvements. HMI will observe the full solar disk in the Fe I absorption line at 6173Å with a resolution of 1 arc-second. HMI consists of a refracting telescope, a polarization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

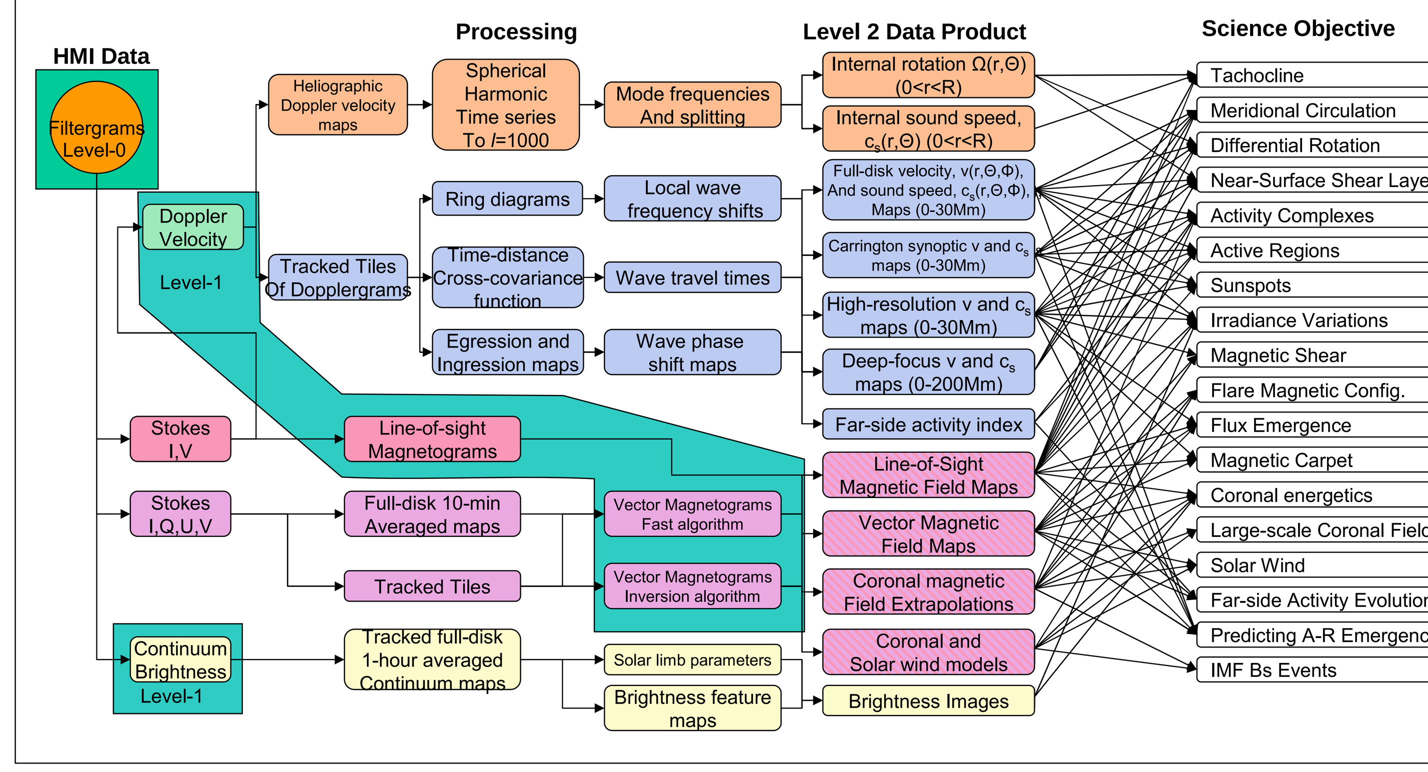
Images are made in a sequence of tuning and polarizations at a 4-second cadence for each camera. One camera is dedicated to a 45s Doppler and line-of-sight field sequence while the other to a 90s vector field sequence. All of the images are downlinked for processing at the HMI/AIA Joint Science Operations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

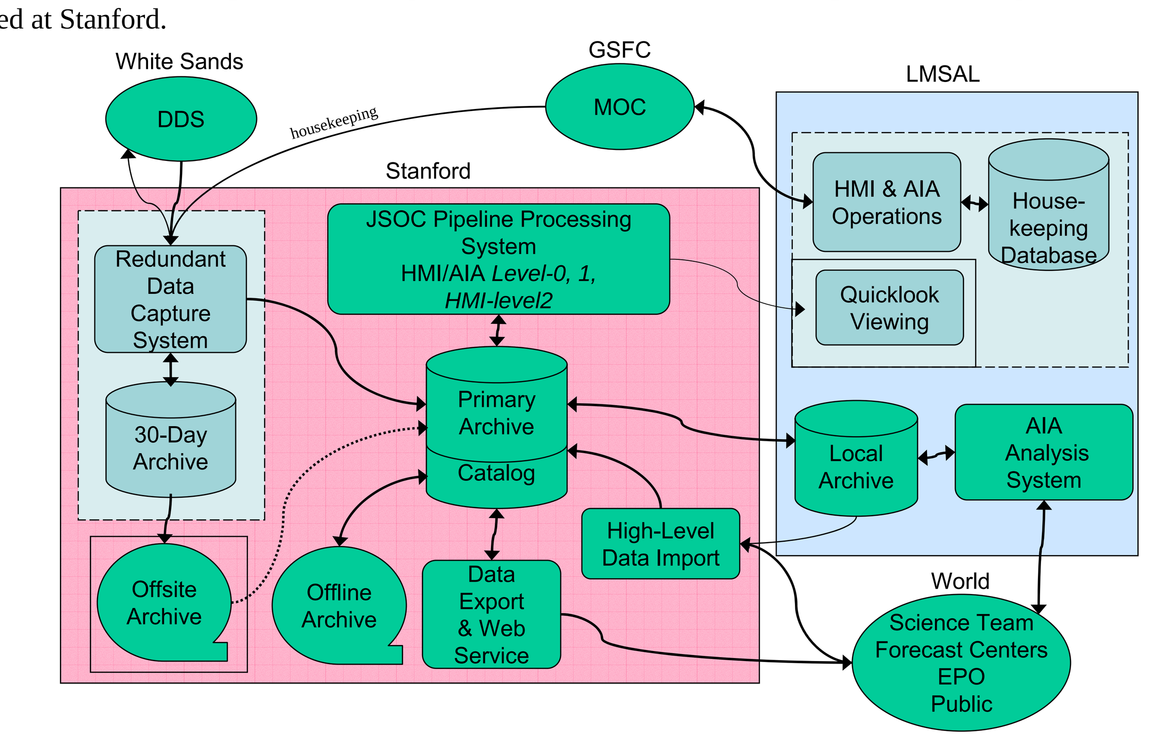


HMI Processing Pipeline and Standard Data Products



HMI and AIA Joint Science Operations Center (JSOC)

The Science Data Processing (SDP) for HMI and AIA will be done at Stanford and LMSAL. The Joint Operations Center (JOC) will be at LMSAL. For the SDP the Capture, pipeline processing, archive, and Distribution will be located at Stanford. The higher level AIA products will be at LMSAL. The higher level HMI products will be computed at Stanford.

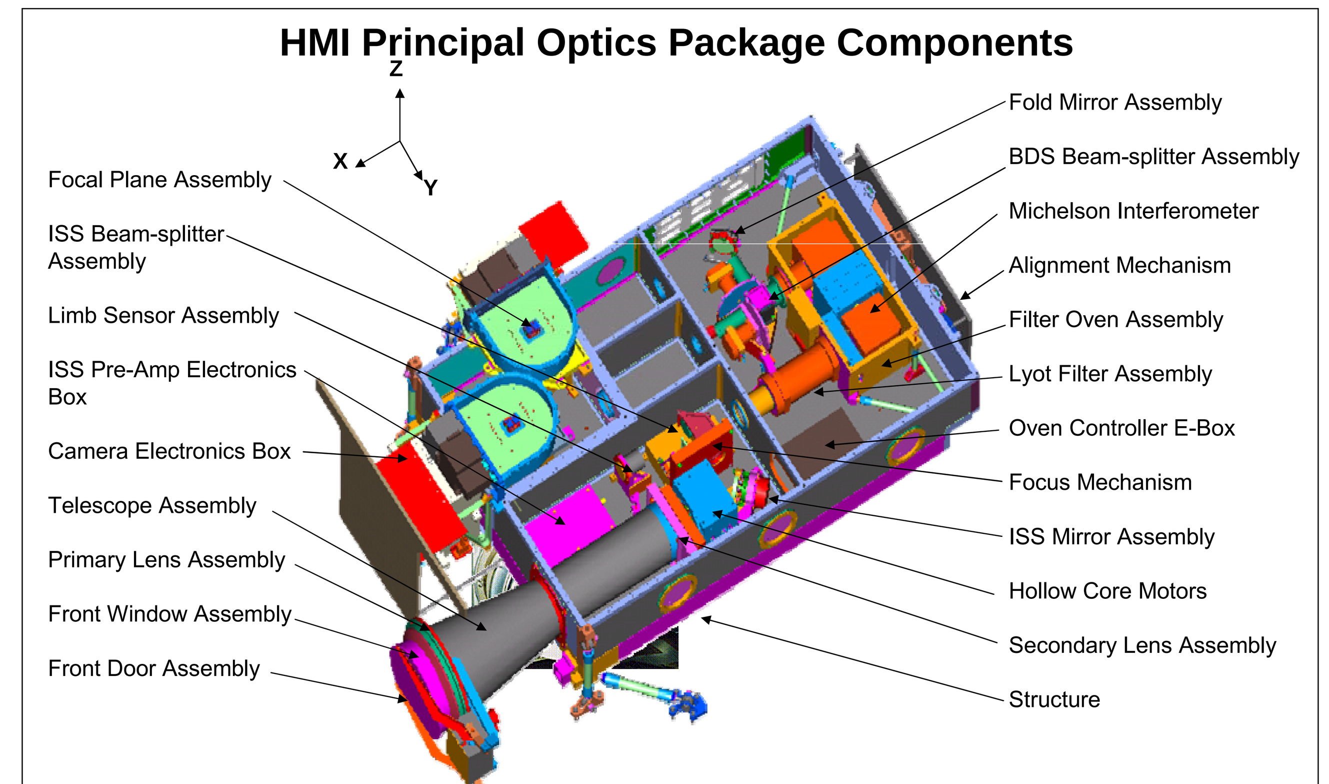


HMI Observables

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	0.6º
Inclination	1.4º
Quiet Sun (0.1kG<|B|<2kG) *	
|B|	220 G
Total flux density	35 G
Azimuth	15º
Inclination	18º

HMI Principal Optics Package Components



Optical Characteristics:
Effective Focal Length: 495 cm
Telescope Clear Aperture: 14 cm
Focal Ratio: *f*/35.4
Final Image Scale: 24 μm / arcsec
Re-imaging Lens Magnification: 2
Focus Adjustment Range: 16 steps of 1 mm

Filter Characteristics:
Central Wavelength: 617.3 nm
Reject 99% Solar Heat Load
Bandwidth: 0.0076 nm
Tunable Range: 0.05 nm
Free Spectral Range: 0.0688 nm

Mechanical Characteristics:
Box: 0.84 × 0.55 × 0.16 m
Over All: 1.19 × 0.83 × 0.30 m
Mass: 42.15 kg
First Mode: 73 Hz

Structure model HMI Optics Box (left)

Brassboard electronics box under test (right).