Satellite Missions and Observations

Heliophysics System Observatory

Geotail, 1992
- Study the processes through which solar wind energy, momentum, and particles must pass to enter the magnetosphere

VOYAGER, 1977
- Explore the interaction of the heliosphere with the local interstellar medium

Wind, 1994
- Define the large-scale structure of global interplanetary disturbances in the inner heliosphere

SOHO, 1995
- Define the large-scale structure of global interplanetary disturbances in the solar atmosphere

ACE, 1997
- Understand solar, interstellar, and galactic sources of energetic particles

TRACE, 1998
- Explore three-dimensional magnetic structures in the Sun's atmosphere

RHESSI, 2002
- Understand energy release in solar flares

AIM, 2007
- Discover the causes of polar mesospheric clouds and their relationship to climate change

CINDI Instrument on C/NOFS, 2008 (MO)
- Understand the dynamics of the Earth's ionosphere

THEMIS, 2007
- Understand the substorm instabilities that abruptly and explosively release solar wind energy stored within the Earth's magnetotail

TWINS Instruments on NRO, 2006/2008 (MO)
- Investigate the nature of sources, transport, and sinks of plasma populations

IBEX, 2008
- Explore the interstellar boundaries beyond the solar system

STEREO, 2006
- Characterize the propagation of CMEs through the heliosphere

Hinode, 2006
- Study the Sun's magnetic field and how energy stored in the field is released

Cooper Downs

SHINE Student Day 07/25/2010
This Talk

Overview of Spacecraft missions involved in Heliophysics research

Focus on some particular instruments that might be relevant to sessions at this year’s SHINE

Want to gain general idea of what people are likely to be talking about
Nasa Heliophysics Division
http://sec.nasa.gov/
Nasa Heliophysics Division
http://sec.nasa.gov/

- Great resource for overview of Missions in the field
- Check out the ‘Strategic Roadmap” for 2009-2030
- Great for Science, better for jargon!

Explore the Heliophysical system to understand the Sun and its effects on the Earth, the solar system, space environmental conditions that are experienced by human and robotic explorers, and enable technologies that enhance life and society.
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Heliophysics System Observatory

**Missions In Formulation/Development**

- **2023**
  - Solar Dynamics Observatory, 2009
  - Solar Orbiter, 2017 (Launch date under assessment by ESA)

- **2024**
  - Magnetospheric Multiscale, 2014
  - Solar Probe Plus, 2018

- **2025**
  - Ion-Neutral Coupling in the Atmosphere, 2025
  - Dynamic Geospace Coupling, 2023

- **2026**
  - Heliospheric Magnetics, 2026

**Future Priority Science**

- **2020**
  - Climate Impacts of Space Radiation, 2020
    - Understand our atmosphere’s response to auroral, radiation belt, and solar energetic particles, and the associated effects on nitric oxide and ozone

- **2025**
  - Ion-Neutral Coupling in the Atmosphere, 2025
    - Understand how neutral winds control ionospheric variability

- **2023**
  - Dynamic Geospace Coupling, 2023
    - Understand how magnetospheric dynamics provides energy into the coupled ionosphere-magnetosphere system

- **2021**
  - Solar Energetic Particle Acceleration and Transport, 2021
    - Understand how and where solar eruptions accelerate energetic particles that reach Earth

- **2018**
  - Origins of Near-Earth Plasma, 2018
    - Understand the origin and transport of terrestrial plasma from the Sun to the magnetosphere and solar wind
  
  - Magnetospheric Multiscale, 2014
    - Understand the microphysics of magnetic reconnection

- **2012**
  - Radiation Belt Storm Probes, 2012
    - Understand how populations for relativistic particles in space form or change in response to inputs from the Sun
# Nasa Heliophysics Division

## Overview of Missions

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<td>Geotail</td>
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<td>Hinode (Solar-B)</td>
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<td>SOHO</td>
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<td>STEREO</td>
<td>Polar</td>
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<td>Voyager</td>
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<td>Wind</td>
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## Nasa Heliophysics Division

### Overview of Missions

**Operating:**
- ACE
- AIM
- CINDI
- Cluster
- Geotail
- Hinode (Solar-B)
- IBEX
- RHESSI
- SDO
- SOHO
- STEREO
- THEMIS
- TIMED
- TRACE
- TWINS
- Voyager
- Wind

**In Development:**
- IRIS
- MMS
- RBSP

**Under Study:**
- Solar Orbiter
- Solar Probe

**Past:**
- Equator-S
- FAST
- IMAGE
- IMP-8
- Polar
- Pioneer 10/11
- SAMPEX
- SPARTAN-201
- SNOE
- ST5
- Ulysses
- Yohkoh
In-Situ / Heliosphere
The Heliosphere: Voyager

Session 5: ENA’s Pickup Ions, ACRs

In-situ instruments that actually went to the edge of the solar wind!

Passed through termination shock in 2004 (v1) and 2007(v2)

Found this interface is not symmetric!
The Heliosphere: Ulysses

Sessions 2, 14

Did 3 polar orbits around the sun, 1990-2009

Long period orbits, observed solar min AND solar max conditions

Great for fast/slow wind comparisons

Often will see Ulysses plots when talking about fast solar wind and solar cycle variation
The Heliosphere: Wind / Ace / STEREO

Sessions 1, 2, 5, 6, 10

In-situ instruments in the near-earth / 1AU environment

Workhorse instruments for measuring the solar wind and energetic particle spectrum at 1AU

Due to their separation, different parts of CME’s pass STEREO A and B → more info

Session 10: CMEs → In-Situ
The Heliosphere: IBEX

Session 5: ENA’s, Pickup Ions, ACRs

- Interstellar Boundary Explorer: NASA Small Explorer mission (2008 launch, earth orbit)

- Heliosphere is the source of ENAs which IBEX measures

- Clever rotation pattern allows it to ‘look’ in all directions over 6 months

- Effectively maps the Termination shock and Heliosheath from home!
The Heliosphere: IBEX

Session 5: ENA’s, Pickup Ions, ACRs

Possible Sources of IBEX Ribbon [McComas et al., Science, 2009]

1) Max Pressure/Stagnation
   SW Flow → Max Pressure - Stagnation
   Extrosonal Confinement
   ENA

2) Primary ENAs from Compression
   Compressed ISM B-field
   ENA

3) Secondary ENAs
   Solar Wind ENAs
   ENAs from Inner Heliosheath
   Heliopause

4) ENAs from Magnetic Reconnection
   Magnetic Reconnection
   ENA

5) ENAs from Shock Accelerated PUIs
   SW B-field
   ENA

6) ENAs from HP Instabilities
   Instabilities RT or KH
   Motion away from nose
   ENA

To Sun (IBEX) → To ISM
The Heliosphere: IBEX
Session 5: ENA's Pickup Ions, ACRs
Want more?

- Visit Virtual Heliospheric Observatory (VHO)
- Centralized data distribution center: vho.nasa.gov
Remote Sensing of the Sun

SOHO: 1996-Present

STEREO: 2006-Present

Hinode (Solar-B): 2006-Present

SDO: 2010 – Present
Zeeman splitting of photospheric lines gives measure of Line-of-sight magnetic field.

Spectropolarimetric measurements can allow you to reconstruct vector magnetic field.

Crucial for studying magnetic evolution of the sun.

Insanely difficult to measure B in the corona directly → extract from photospheric measurements.
Looking at the Sun: Magnetic Fields

**SOHO** Session 7: Magnetic Obs → Corona Models

- MDI experiment onboard SOHO
- Full disk LOS B measurements since 1996
- Common source for Potential Field extrapolations (which only need LOS B)
- Full coverage gives very consistent data set
Looking at the Sun: Magnetic Fields

HINODE Session 7: Magnetic Obs → Corona Models

- SOT/SP experiment onboard Hinode
- Targeted, high resolution vector magnetograms
- Study full dynamics of gas + magnetic field evolution in ARs
- Common source of NLFF extrapolation data
- Only complaint is that it's not full sun all the time

Schrijver et. al. 08
Looking at the Sun: Magnetic Fields

**SDO**
- Session 7: Magnetic Obs → Corona Models
- Session 9: SDO → Solar obs on ‘roids

- HMI experiment onboard SDO
- Full Disk Spectropolarimetry
- High Res + Continuous coverage!
Looking at the Sun: Magnetic Fields

SDO

Session 7: Magnetic Obs → Corona Models
Session 9: SDO → Solar obs on ‘roids
Looking at the Sun: The Chromosphere

HINODE  Session 11: Chromosphere -> Heliosphere?

- SOT has high cadence, high resolution ability to image chromospheric lines
- Insanely good for watching continuous dynamics of the Chromosphere
- Spicule observations → Coronal heating arguments
Looking at the Sun: Corona, Spectroscopy

HINODE

- EIS: EUV spectrograph

- Detailed spectrums = wealth of information

- Quantitatively measure temperatures and flows in the corona

- Huge for coronal heating studies
Looking at the Sun: Corona, Spectroscopy

HINODE Sessions 11+12
EVE experiment: measure TOTAL EUV irradiance in huge wavelength range (0.1 – 105nm)

- Huge for measuring total energy of flares as well as understanding sun-earth connection

- Rachel Hock will share some first results in the Splinter Session!
Looking at the Sun: Corona, Imaging

**SOHO**

- Corona is optically thin (mostly) → imaging projections through entire thing

- EIT imager 1k by 1k full sun observations of low corona (EUV regime)

- LASCO – white light imager, revolutionized study of CMEs
(LASCO team / NRL)
Looking at the Sun: Corona, Imaging

STEREO

- Identical pair with different ~1AU orbits
- EUVI imager 2k by 2k full sun,
- Like EIT except higher cadence
- Cor1 and Cor2: Coronagraphs similar to LASCO
- HI1 and HI2: Large FOV imagers
- Follow CME’s from sun to 1AU!
Looking at the Sun: Corona, Imaging

**SDO**

Sessions: too many to count

- AIA – EUV imager x 1000
- 4k by 4k
- 8 bands
- 10s cadence

- Temp sensitivity + cadence + full sun coverage give whole new perspective!
Looking at the Sun: Corona, Imaging

SDO
Looking at the Sun: Corona Imaging

**SDO**
- Fun Tidbit: AIA compared to other EUV imagers:

<table>
<thead>
<tr>
<th></th>
<th>SDO/AIA</th>
<th>STEREO/EUVI</th>
<th>SOHO/EIT</th>
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</thead>
<tbody>
<tr>
<td>Pixels</td>
<td>4k x 4k</td>
<td>2k x 2k</td>
<td>1k x 1k</td>
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<tr>
<td>Bands</td>
<td>8</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Max Cadence</td>
<td>10s</td>
<td>150s</td>
<td>600s</td>
</tr>
<tr>
<td>Relative to SDO</td>
<td>1 x 1 x 1</td>
<td>4 x 2 x 15</td>
<td>8 x 2 x 60</td>
</tr>
<tr>
<td>Relative Data Size</td>
<td>1</td>
<td>120</td>
<td>960</td>
</tr>
</tbody>
</table>
Main Point

- Satellite mission are integral to advancing our understanding of the Sun and Heliosphere

- New missions keyed by building upon successful missions with technological advances.

- New instruments continually redefine our understanding

- Poised for significant advances with the successful launch of SDO!
FIN?

- 2:00 Splinter Session: Spacecraft Missions and Data
- SDO early Observations (Rachel Hock)
- Data Access and Analysis (Cooper Downs)
- Introduction to DEMs and CHIANTI (Rachel Hock)
- Research Talk: Evidence for Surface Alfven Wave Damping from Differential Emission Measure Tomography
- Research Talk: IBEX (Christina Prested)