### Update on NASA's Heliophysics/LWS Program

Solve <u>fundamental</u> mysteries of Heliophysics Understand the nature of our <u>home</u> in space Build the knowledge to forecast space <u>weather</u> throughout the heliosphere

> Madhulika Guhathakurta Lead Scientist, Living with a Star Heliophysics Division, NASA HQ

> > 9<sup>th</sup> July 2013 Bozeman, MT

A/ SPD Meeting a set of

### Heliophysics Recent Accomplishments (since last SPD meeting)

- NRC Release of Decadal Survey August 15, 2012
- RBSP launch on August 30, 2012. Renamed to "Van Allen Probes" after successful commissioning.
- Explorer full mission & MoO (ITM) selection announcement on 12<sup>th</sup> April.
- Congressional Testimony on November 28, 2012 to the House Subcommittee on Space and Aeronautics - National Priorities for Solar and Space Physics Research and Applications for Space Weather Prediction -<u>http://science.house.gov/hearing/subcommittee-space-and-aeronautics-national-priorities-solar-and-space-physics-research-and</u>
- Senate Commerce, Science and Transportation Subcommittee on Science and Space Holds Hearing on Assessing Space Threats which included space weather (March 20, 2013).
- Release of NRC Workshop Report: The Effects of Solar Variability on Earth's Climate -<u>http://www.nap.edu/catalog.php?record\_id=13519</u>
- NASA / NSF collaboration on space weather modeling
- Introduction to Heliophysics (science of space weather) in a dedicated session at AMS, 2013.
- International Living With a Star; engagement of the international community year anniversary at UNCOPUOS, 02/14/2013)
- Space Weather as a permanent agendesiter Data UNGO, PLKQS.
- Space Weather Enterprise Forum, 6/4/2013



# Excerpts from the Heliophysics Testimony

### From acting chair Mr. Palazzo

.....Our hearing today will focus on the incredible work being accomplished by NASA's Heliophysics Division and on the important operational aspect this research has for space weather prediction at NOAA.

NASA has developed and launched a broad network of spacecraft that allow researchers to better understand the Earth-Sun system. Their findings are used daily to help preserve our technological infrastructure by allowing system operators to better react to variations of the Sun. Building our knowledge in this field is essential for maintaining our way of life on Earth as well as for improving the capability of enabling human exploration beyond the protection of Earth's atmosphere and magnetosphere.

Together with a ground-based infrastructure of solar telescopes managed by the National Science Foundation, NASA and NOAA coordinate critical measurements into useable models that predict how space weather will affect our satellites, electric power grid, airline operators, and more.....

### From member Ms. Edwards

.....And Mr. Chairman, I'd be remiss if I didn't mention the budgetary challenges for this research and a crunched budget environment, there are significant implications for our society if we don't continue and expand research in this area. We need to protect these R&D investment, our assets, our quality of life, and our economic strength as a nation depend on this research.....

### Living With a Star (LWS) Program

### Provide a predictive understanding of the system and, specifically, of the space weather conditions at Earth and the interplanetary medium.

- 1. Understand solar variability and its effects on the space and Earth environments with an ultimate goal of a reliable predictive capability of solar variability and response.
- Obtain scientific knowledge relevant to mitigation or accommodation of undesirable effects of solar variability on humans and human technology on the ground and in space.
- 3. Understand how solar variability affects hardware performance and operations in space.

LWS Program Plan: Update in work for PIR in Sept/Oct. time frame

LWS PCA: Updated 6/13/12

9th July 2013

### Components:

- Science Missions
- Science (Targeted Research and Technology)
- Space Environment Testbeds (SET)

### **Implementation of Science Missions:**

GSFC or APL

### **Program Implementation:** GSFC

# LWS Program Components

Living With a Star (LWS) Program			
	Component Type		Phase
Program Components	7120.8	7120.5	
Science Missions			
SDO		*	Ops
Van Allen Probes		*	Ops
SARREL	*		impi
Solar Orbiter Collaboration		8	Devel
Solar Probe Plus		*	Form
Science	3		impi
Applications			
Space Environments Testbed		*	impi

### **Solar Orbiter Collaboration**

#### THE MISSION TO UNDERSTAND HOW THE SUN CREATES AND CONTROLS THE HELIOSPHERE

Project Category: 2

Classification: C

#### Solar Orbiter Science Objectives

### • Determine how and where solar wind plasma and magnetic field originate in the corona;

- Determine how solar transients drive heliospheric variability;
- Determine how solar eruptions produce energetic particle radiation that fills the heliosphere; and,
- Determine how the solar dynamo works and drives connections between the Sun and the heliosphere.

#### NASA Contributions

- SoloHI NRL, Washington DC
- HIS SwRI San Antonio, Texas
- NASA LSP Launch services

#### Partners 8 1

- ESA Mission management, other scientific instruments, integration of instruments, mission operations, and overall science operations.
  - ASTRIUM Spacecraft bus
  - CSL (Belgium) SoloHI Instrument Calibration
  - University of Bern (Switzerland) HIS Instrument Calibration
  - ASI (Italy) SWA/HIS Data Processing Unit
  - CNES (France) HIS Instrument Subsystem

#### **Overall Status**

**Project Opinion: Green** 



# Solar Probe Plus (SPP)



#### Overview

Using in-situ measurements made closer to the Sun than by any previous spacecraft, SPP will determine the mechanisms that produce the fast and slow solar winds, coronal heating, and the transport of energetic particles.

Solar Probe Plus will fly to less than 10 solar radii (Rs) of the Sun, having "walked in" from 35 Rs over 24 orbits.

- Sponsor: NASA/GSFC LWS
- LWS Program Manager Nick Chrissotimos GSFC
- LWS Deputy Program Manager Mark Goans, GSFC
- Project Manager Andy Driesman, APL
- Project Scientist Nicky Fox, APL
- Mission Scientist Adam Szabo, <u>GSFC</u>
- Spacecraft Development/Operations APL
- Investigations selected by AO:
  - FIELDS University of California
  - ISIS Southwest Research Institute
  - SWEAP Smithsonian Astrophysical Obs
  - WISPR Naval Research Laboratory
  - HelioOrigins Jet Propulsion Laboratory

#### Milestones

Pre-Phase A:	07/2008 - 11/2009
Phase A:	12/2009 - 01/2012
Phase B:	02/2012 - 03/2014
Phase C/D:	03/2014 - 08/2018
LRD:	31 July 2018
Phase E:	09/2018 - 09/2025

Formulation Range: \$1233M - \$1439MCategory 1, Risk Classification B7

9th July 2013

## LWS Science (TR&T): Proposals and Awards 2012



23 proposals, 6 funded, average \$132 K

Workshops

4 proposals, 3 funded, average \$19 K

9th July 2013

AAS/SPD Meeting, Lika G.

8

### Living With a Star/NSF Partnership for Collaborative Space Weather Modeling

PI	Institution	Title	Objective
Bob Schunk	Utah State	Physical Processes Governing Energy and Momentum Flows on Multiple Scales in Near-Earth Space Using a First-Principles-Based Data Assimilation System for the Global Ionosphere-Thermosphere- Electrodynamics	Ionosphere- Thermosphere modeling, forecast
Spiro Antiochos	GSFC	A Modular Capability for Community Modeling of Flares, CMEs and their Interplanetary Impacts	CME impacts
Nathan Schwadron	New Hampshire	Corona-Solar Wind Energetic Particle Acceleration (C-SWEPA) Modules	SEPs
Dusan Odstrcil	George Mason	Integrated Real-Time Modeling System for Heliospheric Space Weather Forecasting	ENLIL MHD propagation from Sun to Earth – operations
George Fisher	UC Berkeley	The Coronal Global Evolutionary Model	Coronal Modeling, CME formation
Tony Mannucci	JPL	Medium Range Thermosphere Ionosphere Storm Forecasts	Sun-to-mud modeling, ionosphere
Nagi Mansour	Ames	Integrated Global-Sun Model of Magnetic Flux Emergence and Transport	Solar subsurface modelling; prediction, forecasting
<sup>9th</sup> A. JBhattacharjee	Princeton	Integration of Extended MHD and Kinetic Effects in Global Magnetosphere Models	MHD modeling ofg magnetosphere

## LWS Science (TR&T): Proposals and Awards 2012



SDO Science Data Analysis. 56 proposals
 Workshops & Infrastructure. 9 proposals

We are on schedule for selections to be made in time for funds to be released at the start of FY14, October 2013.

9th July 2013

AAS/SPD Meeting, Lika G.

10

# LWS Focus Topics (Updated)

2007	2008	2009	2010	2011/2012	2013
Magnetic Connection of Photosphere and Low Corona	Properties of the Solar Dynamo that affect Irradiance and Active Regions	Behavior of the Plasmasphere and its Influence on the Iono- /Magnetosphere	Jets in the Solar Atmosphere and their Effects in the Heliosphere	Interaction between the magnetotail and the inner magnetosphere and the impact of that interaction on the radiation belt environment	Thermospheric wind dynamics during geomagnetic storms and their influence on the coupled M-I-T system
Modulation of Galactic Cosmic Rays, due to Long-term Solar Activity	Use Inner Heliosphere Obs. to Better Constrain CME and SEP Models	Origin and Nature of the Slow Solar Wind, and its effect on Helio Structures, and SEP Transport	Factors that Control the Highly Variable Intensity and Evolution of Solar Particle Events	Atmosphere- Ionosphere Coupling During Stratospheric Sudden Warmings	Connection between Solar Interplanetary Structures and the response of Earth's radiation belts
Daily Variability in the Thermosphere and lonosphere	Integrate Non- MHD/Kinetic Effects into Global Models	Plasma-Neutral Gas Coupling	Incorporating Plasma Waves in Models of the Radiation Belts and Ring Current	Flare Dynamics in the Lower Solar Atmosphere	Magnetic Flux Ropes from the Sun to the Heliosphere
Combined Modelling of Loss, Acceleration, and Transport of Magnetospheric Electrons, Protons	Response of ITM Composition and Temperature due to Solar XUV and Energetic Particle Variation	Predict the Onset and Space Weather Impacts of Fast CMEs/Eruptive Flares	Low-To Mid- Latitude Ionospheric Irregularities and Turbulence		Short term solar/ atmospheric variability and climate
Prediction of the Interplanetary Magnetic Field Vector Bz at L1		The Sun-Climate Strategic Theme	The Sun-Climate Strategic Theme	The Sun-Climate Strategic Theme	

# **Steering Committee Members**

- Nathan Schawdran
- Tony Mannucci
- Amitava Bhattacharjee
- Spiro Antiochos
- Farzaad Kamlabadi
- Tony Mannucci
- Jon Linker
- Antti Pulkennin
- Paul Withers
- Daniel Weimer
- WV Kent Tobiska
- Nat Gopalswamy
- Peter Pilewiske
- Harlan Spence

Chair Co-Chair First Meeting of SC: July 15-17, Boulder, CO

Terry Onsager	NOAA
Rodney Vierick	NOAA
T. Morretto	NSF
Kent Miller	AFSO
Masha K.	CCMC
Ilia Roussev	NSF

LWS future viewed in the context of the past (one solar cycle...or so)

- TR&T SDT, 2003 and on-going (~250 M)
- Launched SDO, 2/2010
- Launched RBSP, 8/2012
- Developed curriculum and Heliophysics Text Books
- Established Eddy Fellowship for early career scientists
- Established Heliophysics Summer School
- Started ILWS an inter agency cooperation in 2003
- Space Weather is a regular agenda item at UNCOPUOS

# LWS Future: Short term

- Increasing emphasis on future FSTs on science focused on societal impacts including sunclimate.
- 4.2 M/year effort of strategic capability to fill gaps and develop end to end space weather models.
- Maximize scientific return from SDO & Van Allen Probes.
- Lead the UN effort on Space Weather
- More inter-agency and international partnership.
- More cross-directorate partnership within NASA.
- COSPAR/ILWS Space Weather Roadmap Study.

### Heliophysics/LWS Coordination with HEOMD, Earth, Planetary, and Astrophysics



- HEOMD to Helio MSL/RAD
- Earth to Helio SORCE, ACRIMSAT Helio to Earth – TIMED, AIM, SDO/EVE
- Helio to Planetary ARTEMIS
- Planetary to Helio Juno, MAVEN, Messenger, MSL, LADEE, LRO, Cassini

# Future: Medium Term

- Solar Probe Plus
- Solar Orbiter Collaboration
- Support Russia's Inter-Helio Probe and China's SPORT missions

These 3 missions will offer a truly unique epoch in heliospheric science. While each mission will achieve its own important science objectives, taken together these 3 spacecraft will be capable of doing the multi-point measurements required to address problems of CME initiation and propagation, including the large-scale topology and propagation dynamics. In particular, it may be possible to achieve many of the science objectives of previously envisioned multi-spacecraft heliospheric missions, such as NASA's 'Sentinels' concept. We would like to know more about IHP.

(ilwsonline.org/)

- In light of reduced budgetary environment develop appropriate small mission concepts to satisfy space weather model/observational needs.
- Implement a robust sun-climate program utilizing feedback from the NRC report.
- Strategic Capability emphasizing more societal impacts
- Next two text books from summer school on Interplanetary SWx & Societal Imapacts.
- Develop curriculum for 4 year degree colleges
- Establish the interdisciplinary science of "Interplanetary Space Weather"

16

# **Societal Needs**

- Power Grid
- Energetic Particles
- Particle Precipitation
- HF Communication
- Single-Frequency Navigation
- Dual-Frequency Navigation
- Safety of Human and Robotic Explorers in Space

### **Heliophysics Summer School**

Heliophysics Partine Physics of Heliophysics Heliophysi	
Since 2007, we have had:	
Total Students	190
<b>International Students</b>	82
U.S. Students	108
PhD Level	170
Masters Level	20

- Each year, approximately 35 graduate level students are appointed from 13-15 different countries.
- Starting in 2013, 3 to 5 physics teachers of upper division undergraduate classes will be invited to attend.

### 2013 Summer School Heliophysics of the Solar System

12-19 July, Boulder, CO

A select group of students and teachers will learn about the exciting science of heliophysics as a broad, coherent discipline that reaches in space from the Earth's troposphere to the depths of the Sun, and in time from the formation of the solar system to the distant future.

### **School Deans**

Dr. Karel Schrijver Lockheed Martin Advanced Technology Center

Prof. Jan Sojka Utah State University

Frances Bagenal University of Colorado/LASP/APS

Apply online at www.vsp.ucar.edu/Heliophysics

9th July 2013

# HELIOPHYSICS .

2013 Summer School Heliophysics of the Solar Systems, 12-19 July 2013 · Boulder, Colorado Application Deadline: 1 March

Special Opportunity for Physics Students & Physics Teachers

Applications are invited for the 2013 Heliophysics Summer School, which will be held in beauful Boulder, Colorado. We see evening students and undergraduate level teachers and instructors to join us this coming summer for a unique professional septeinner. Students and teachers will learn about the exciting science of heliophysics as a broad, coherent discipline that eachers in space from the Earth's troopedhere to the depthroit of the Sun, and in time from the formation of the solar system to the distant future. At the same time, a goal of the Summer School is for the group of instructors to develop materials from Heliophysics that can be applied in their classes.

The Heliophysics Summer School focuses on the physics of space weather events that start at the Sun and influence througheres, incorpolaters and magnetopheres throughout the solar system of these avoide variety of conditions under which the interaction of bodies with a plasma environment can be studied; there are planets with and whoth a large-scale magnetic fields and associated magnetopheres planetary atmospheres displanetary a variety of thicknesses and compositions; satellities of the giant planets reveal how interactions occur with subsonic and sub-Alfvéric flows whereas the solar valid interact with supersonal and super-Alfvéric impacts.

Encompaised under a general title of comparative magnetospheres are processes occurring on a range of racitles from the solar wind interacting with comets to the interstellar medium interacting with the heliosphere. The school will address not only the physics of all these various environments but will also go into the technologies by which there various environments are being observed. The program is complemented with considerations of the societal impacts of space weather that affects stellites near at and elsewhere in the solar system.

The school will be based on lectures, laboratories, and recitations from world experts, and will draw material from the three textbooks. Heliophysics I-III, published by Cambridge University Press.

Several teachers along with about 35 students will be selected through a competitive process organized by the UCAR Visiting Scientist Programs. The school lasts for eight days, and each participant receives full travel support for airline tickets, logding and per dem costs.

#### Student Application Requirements

- Currently enrolled as a graduate student in any phase of training, or first or second year postdoctoral fellow. Major in physics with an emphasis on astrophysics, geophysics, plasma physics, and space physics, or experienced in at least one of these areas.
- Pursuing a career in heliophysics or astrophysics

#### Teacher Application Requirements

- At least three years of teaching experience. (Already having a connection with heliophysics is not a requirement.)
  Currently teaching physics (preferably electricity & magnetism), astronomy/planetary science, or Earth sciences at the upper division understanduus level.
- upper division undergraduate level. Willingness to provide feedback to the Summer School faculty and organizers on the comprehensibility and comprehensiveness of the overall set of lectures and supporting materials.



### Jack Eddy Postdoctoral Fellowship Program Application deadline 11 January 2013 www.vsp.ucar.edu/Heliophysics

- Established 2009 to train the next generation of researchers needed for the emerging field of heliophysics
- 9 postdoctoral fellows were awarded two-year appointments as of December 2012



Maria Spasojevic Stanford University





Jonathan Makela University of Illinois King-Fai Li



Ka-Kit Tung University of Washington

Andres Munoz-



Edward DeLuca Harvard-Smithsonian Center for Astrophysics

Kamen Kozarev



John Raymond Harvard-Smithsonian Center for Astrophysics

Ksenia Orlova



Yuri Shprits UCLA



Neel Savani

Angelos Vourlidas Naval Research Lab

Roger Varney



Stanley Solomon NCAR HAO

Liang Zhao



Sarah Gibson NCAR HAO 20



# 2013 Jack Eddy Postdoctoral Awards



**Stathis Ilonidis** Host Institution: Stanford University, Thomas Duvall

Project: Detection of Solar Active Regions Before They Emerge at the Surface and Improvement of Space Weather Forecasts





9th July 2013

**Bin Chen** Hosts Institution: New Jersey Institute of Technology, Dale Gary

Project: Coronal Magnetography: an Approach to Understanding Space Weather Drivers - Solar Flares and Coronal Mass Ejections

Antonia Savcheva Host Institution: Harvard-Smithsonian Center for Atmospherics, Katharine Reeves

♦ Project: Understanding Sigmoid Evolution and Eruption: From Formation to CME Propagation

**Thiago Brito** Host Institution: LASP/University of Colorado, Scot Elkington

Project: The effect of drift orbit bifurcations on radiation belt particles in time dependent fields

21

# Just When You Thought it was Safe to Predict the Solar Cycle....



22

AAS/SPD Meeting, Lika G.

As the solar cycle unfolds in an unexpected way, it is important to remember that Space Weather Swings Between Extreme Effects

Image: Guhathakurta, M. et al, "The Solar Cycle Turned Sideways," Space Weather, Wiley, doi: 10.1002/swe.20039

Solar La Niña (Iow sunspot numbei

extreme galactic cosmic rays

rapid accumulation of space junk

sharp contraction of the heliosphere

collapse of the upper atmosphere

total solar irradiance changes



Solar El Niño (high sunspot number)

super solar flares

extreme solar "cosmic rays" (energetic particles)

radio blackouts

extreme geomagnetic storms

melted power grid transformers – power blackouts

solar wind streams hit Earth

Illustration shows smoothed monthly sunspot counts from the past six solar cycles plotted horizontally instead of vertically. High sunspot numbers are in blue and on the left. Associated with each high and low sunspot numbers are different space weather impacts experienced at Earth (doi: 10.1002/swe.20039).

9th July 2013

# END