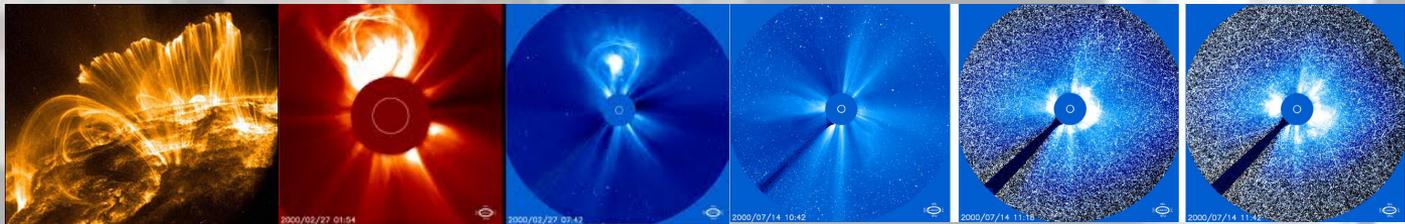


Coronal-Solar Wind Energetic Particle Acceleration Modules (C-SWEPA)

N. A. Schwadron, K. Kozarev, N. Lugaz, J. Linker, M. Gorby, Pete Riley, Z. Mikic, R. Lionello, T. Torok, V. Titov, B. Chandran, J. Cooper, M. Desai, K. Germaschewki, J. Giacalone, P. Isenberg, J. Kasper, K. Korreck, M. Lee, P. MacNeice, H. Spence, S. Smith, M. Stevens, P. Quinn, C. Joyce, R. Winslow, J. Chen, F. Rahmanifard

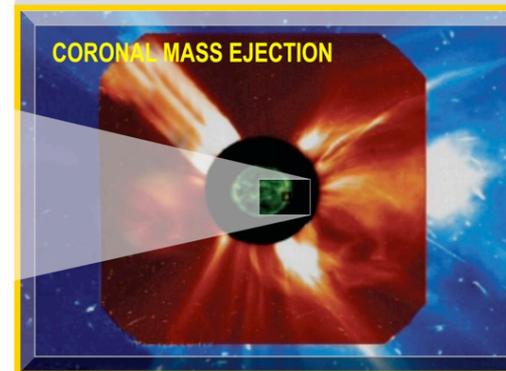
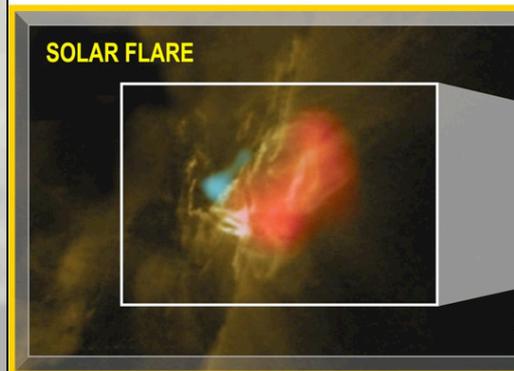
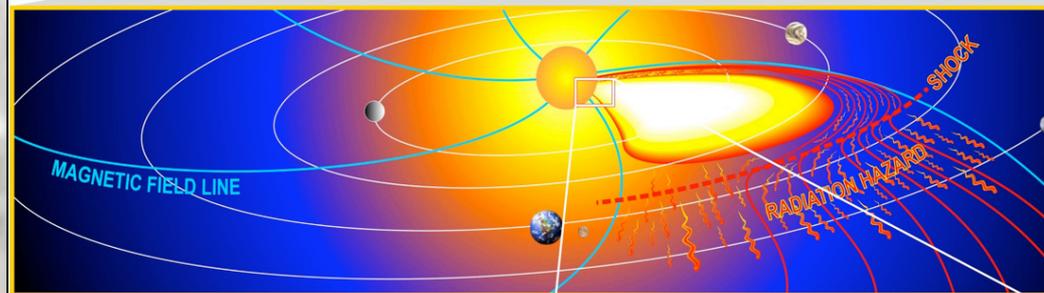
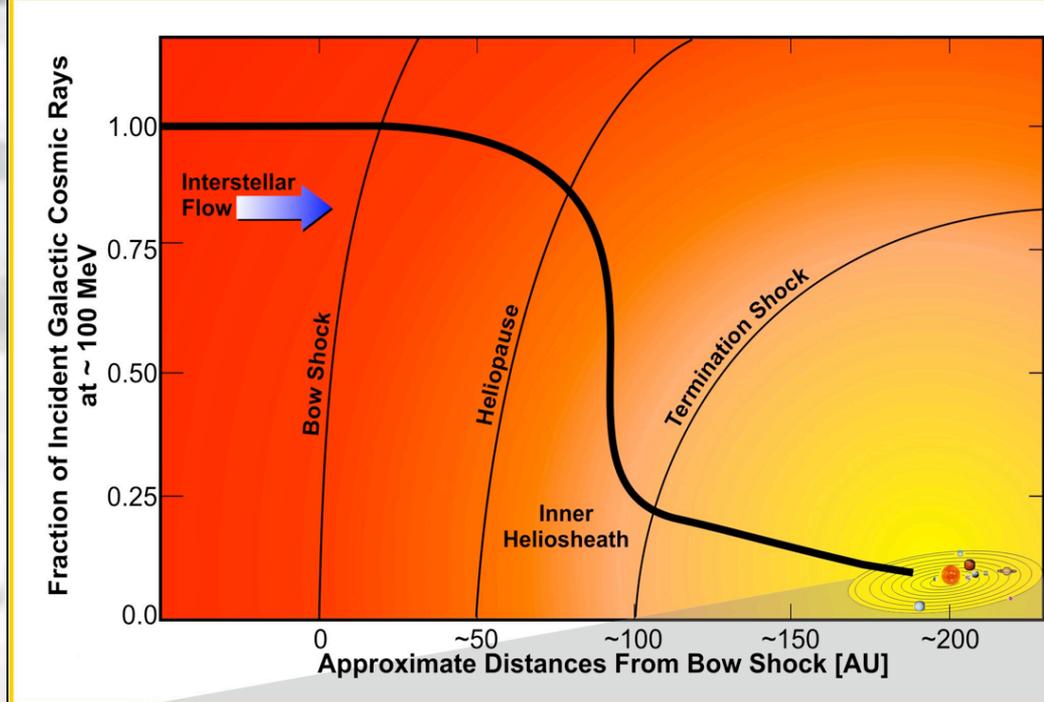


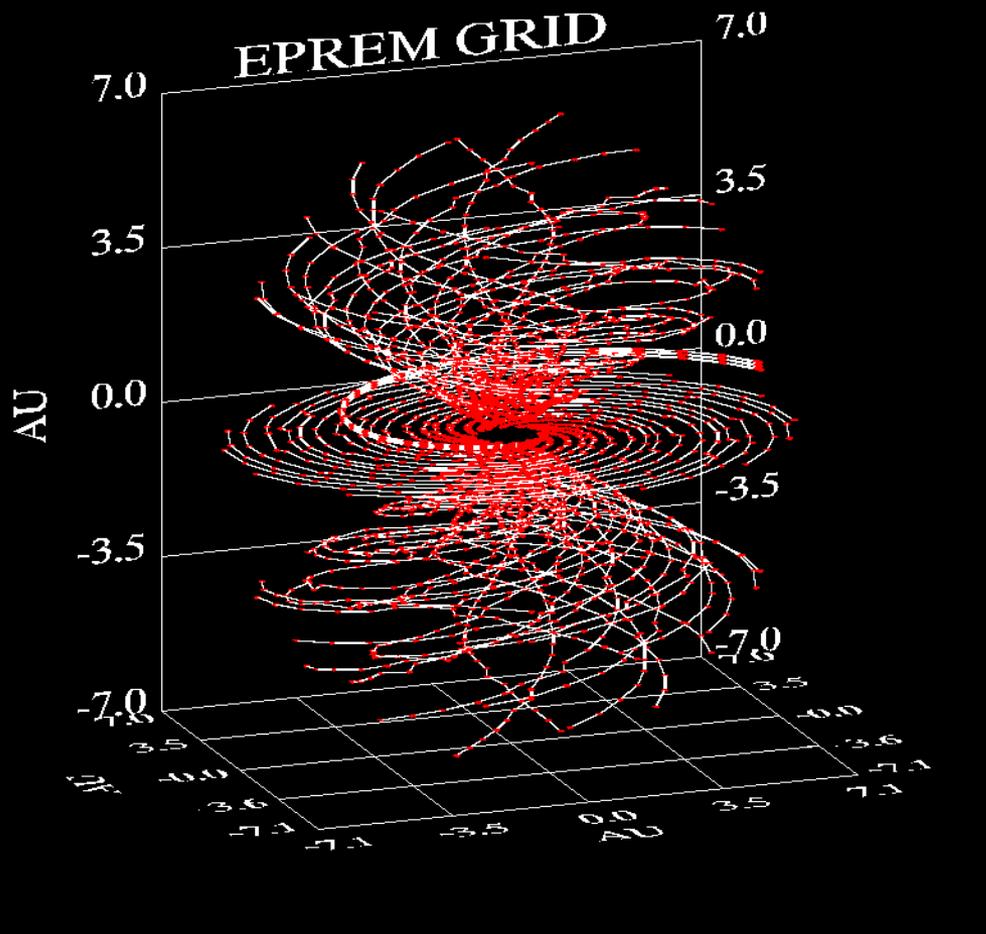
Institutions

- UNH
 - Energetic Particles Acceleration/EMMREM
 - Corona, CMEs and ICMEs
- PSI
 - Corona, CMEs and ICMEs
- SwRI
 - Seed particles
- Goddard & CCMC
 - Energetic particle acceleration
 - Community access

Radiation Hazards

- Galactic Cosmic Rays (GCRs)
 - Steady Background
 - Career limit in ~ 3 years
- Solar Energetic Particles (SEPs)
 - Acute Sources
 - ESPs versus impulsive component
 - Time-dependent response

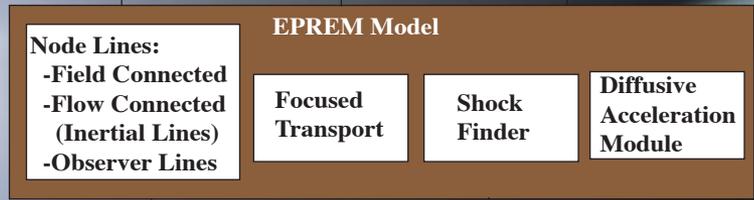




Seed Particles
S/C SEP data

MHD Data

Observer Data:
SPICE Kernels



Node line histories

Observer Output:
B, v, n, Pickup Ion & Energetic Particle Dist.,
Elsasser variables, subscale quantities

Input
Models
Output
Validation

BRYNTRN

HZETRN:
Planetary Atmosphere Transport

Free space dose,
Lunar dose rates, LET

Dose, Dose Rates
Through Atmospheres

Direct Dose, Dose Rate, LET Obs.,
e.g., LRO/CRA TER

Observations at Earth, Mars and Thru Atmosphere

Solar Wind, SEP, Pickup Ion, Plasma & Fields Comparison to in situ observations

Focused Transport in Lagrangian Frame (Kota, 2005)

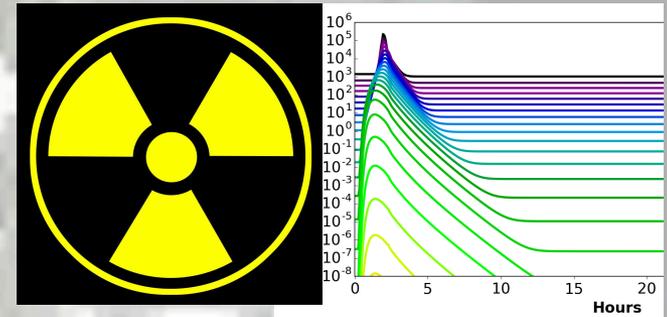
$$\left(1 - \frac{(\vec{u} \cdot \vec{e}_b)v\mu}{c^2}\right) \frac{df}{dt} + v\mu \frac{\partial f}{\partial z} + \frac{(1-\mu^2)}{2} \left[v \frac{\partial \ln B}{\partial z} - \frac{2}{v} \vec{e}_b \cdot \frac{d\vec{u}}{dt} + \mu \frac{d \ln(n^2/B^3)}{dt} \right] \frac{\partial f}{\partial \mu} + \left[-\frac{\mu \vec{e}_b \cdot d\vec{u}}{v dt} + \mu^2 \frac{d \ln(n/B)}{dt} + \frac{(1-\mu^2)}{2} \frac{d \ln B}{dt} \right] \frac{\partial f}{\partial \ln p} = \frac{\partial}{\partial \mu} \left(\frac{D_{\mu\mu}}{2} \frac{\partial f}{\partial \mu} \right) + S$$

- Cross-field Diffusion
- Drift

Wargo Axiom

Science enables
Exploration and
Exploration enables
Science

*The Radiation
Environment affects
Human Systems*



*(Human-made)
Radiation
Instruments Probe
Radiation and Its
Effects*



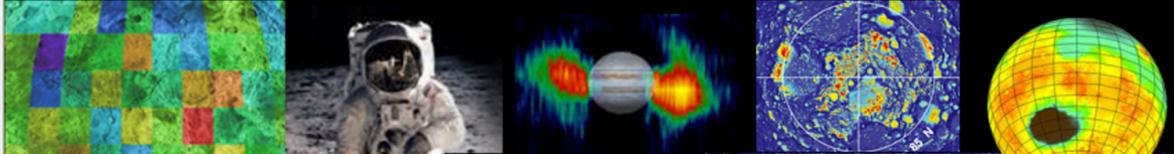
C-SWEPA Team Interactions

- LRO/CRaTER
- DREAM/DREAM2
- Sun-2-Ice
- SPP
- International Team on Radiation Interactions



INTERNATIONAL SPACE SCIENCE INSTITUTE

ISSI Research Team:
Radiation Interactions at Planetary Bodies



Abstract and Team Proposal | Team Members | Schedule & Meetings | Project Publications & Reports

The International Space Science Institute (ISSI) is an Institute of Advanced Study, bringing together scientists from all over the world meet in a multi- and interdisciplinary setting to advance the understanding of results from space missions, ground based observations and laboratory experiments.

The international research teams are set up in response to an Annual Call by ISSI. Their goal is to carry out a research project leading to publications in scientific journals.



Proposal Abstract

Radiation Interactions at Planetary Bodies

SINCE THE LAUNCH of the Lunar Reconnaissance Orbiter (LRO) in 2009, the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) has directly measured the Lunar radiation environment and mapped albedo protons (~100 MeV) coming from the Moon. Particle radiation has widespread effects on the lunar regolith ranging from chemical alteration of lunar volatiles to the formation of subsurface electric fields with the potential to cause dielectric breakdown that could modify the regolith in permanently shaded craters. LRO/CRaTER's direct measurements are transforming our understanding of the lunar radiation environment and its effects on the moon.

Similarly, the Radiation Assessment Detector (RAD) has been measuring the energetic particle radiation environment on the surface of Mars since the landing of the Curiosity rover in August 2012. The atmosphere is about 1% as thick as Earth's, and the majority of Solar Equivalent (related to radiation environment and temperature) is from the Sun.

Recent measurements on other planetary objects show how radiation interactions affect the environment.

This ISSI team will study the radiation environment on Mars. Read more... (proposal abstract)



International Space Science Institute | Radiation Interactions at Planetary Bodies

Goals

- **Goal 1:** Scientifically explore the [seed populations](#) and acceleration of energetic particles in the low corona, through interplanetary space, and over broad longitudinal regions
- **Goal 2:** [Couple the energetic particle acceleration model \(EPREM, the energetic particle radiation environment model\) with MHD models that describe the propagation of coronal mass ejections](#) from the low coronal plasma environment through the interplanetary medium.
- **Goal 3:** [Validate results the coupled EPREM and EMMREM models](#) with observations at distributed observers near 1 AU and out beyond Mars. Validation extends across our understanding of radiation induced hazards from solar energetic particles and galactic cosmic rays at Earth down to atmospheric levels, out into deep space and to Mars and beyond.
- **Goal 4:** [Extend key data sets](#) useful for the project: shock parameters at 1 AU, CME propagation data, and radiation environment data through the inner heliosphere.

Investigator Highlights

- Matt Gorby, Jon Linker, Ron Caplan, Tibor Torok, Jon Linker, UNH, PSI
 - Fantastic work on development, coordination, coupling
 - Work with PSI and CCMC
- Leila Mays, CCMC
 - Excellent partner at the CCMC
 - Currently leading a C-SWEPA publication
 - Invited talks at AGU, EGU, on C-SWEPA coupling
- Colin Joyce wins UNH Graduate Research Award
 - Should graduate soon
 - 1 award given each year at University of New Hampshire competed across all graduate students
 - Authored or Co-authored 14 publications, first-authored 5 publications in incredibly diverse areas
- Reka Winslow
 - New PostDoc at UNH
 - Several new discoveries about the evolution of Coronal Mass Ejections through *conjunction* events from Messenger to ACE, STEREO and LRO
- Junhong Chen
 - Recently received PhD
 - Work on suprathermal ions and PUI acceleration
- Philip Quinn
 - Graduate student
 - Leading three papers on pickup ions, suprathermal ions and radiation through the inner heliosphere
- Fatemeh Rahmanifard
 - Studying evolution of the solar cycle, possible development of grand minimum and implications for radiation



Report/ Development	LWS	C-SWEPA	Science	Deliverable	Ref Papers/Prese ntations
Section 1: Radiation Environment Evolution	Radiation Hazards in Space and through atmospheres	Goal 3: Radiation interactions/vali dation	Deep Solar min (23-24), min 24 max, evolution into gran min?	PREDICCS	10 Refereed Papers 9 talks (7 invited)
Section 2: Radiation Interactions + Event Modeling	“	Goal 2: Model coupling & radiation events	Energetic Particle Acceleration	PREDICCS	4 Refereed Papers 4 talks
Section 3: Radiation Modeling Through Atmospheres	“	Goal 3: EMMREM Validation	Radiation Interactions	EMMREM + PREDICCS	4 Refereed Papers 3 talkw
Section 4: Pickup Ions + Seed Populations	SEPs/Seed populations	Goal 1: Seed populations + SEP acceleration	Suprathermal Tails, Pickup Ions	EPREM	2 Refereed Publications 2 talks
Section 5: Modeling SEPs	Energetic Particle Acceleration	Goal 2: Model Coupling + SEP acceleration	Energetic Particle Accleeration	EPREM EPREM+Cone EPREM+ENLIL EPREM+MAS	17 Refeed Papers 30 Presentations

Report/ Development	LWS	C-SWEPA	Science	Deliverable	Ref Papers/Prese ntations
Section 6: Observed SEP Spectral Properties	Energetic Particle Acceleration/Ra diation	Goal 4: Extend key datasets	SEP properties – tests models of SEP acceleration	Data Products & Sharing	10 Refereed Papers 18 talks (many invited)
Section 7: Progress on Deliverables	Radiation, SEP acceleration	Goal 3: Model coupling	Energetic Particle Acceleration + Radiation Interactions	EMMREM PREDICCS EPREM EPREM+Cone EPREM+ENLIL EPREM+MAS	5 Refereed Papers 7 talks (many invited)
Section 8: ICME Evolution + Magnetic Complexity	ICMEs, energetic particle propagation	Goal 4: Extend key datasets	ICME evolution	Data Products and Sharing	3 Refereed Publications 2 talks
Section 9: Active Regions + Superflares	Flares + Acute Radiation Hazarda	Goal 3: Energetic Particle Acceleration	Superflares	EPREM+MAS	1 Refereed Publication
Section 10: Data Products + Sharing	Radiation, Energetic Particles	Goal 4: Extend Key Datasets	Energetic Particles	Data Products	12 Talks

Overview of Deliverables

- *Deliverables outside CCMC*
 - **PREDICCS**: running in real-time radiation environment <http://prediccs.sr.unh.edu>
 - **EPREM – MAS**: model up and running, internal web interface working
- *Deliverables to the CCMC:*
 - **PREDICCS**: installed and running in real-time <http://ccmc.gsfc.nasa.gov/ccmc-swan/prediccs.php>
 - **EPREM**: installed, available for Runs on Request in work
 - **EPREM+cone**: installed available for Runs on Request in work
 - **Coupled WSA-ENLIL+EPREM**: installed, simulations are currently being tested, preliminary run results are listed at http://ccmc.gsfc.nasa.gov/community/LWS/lws_cswepa.php

Data Products - The CfA Interplanetary Shock Database

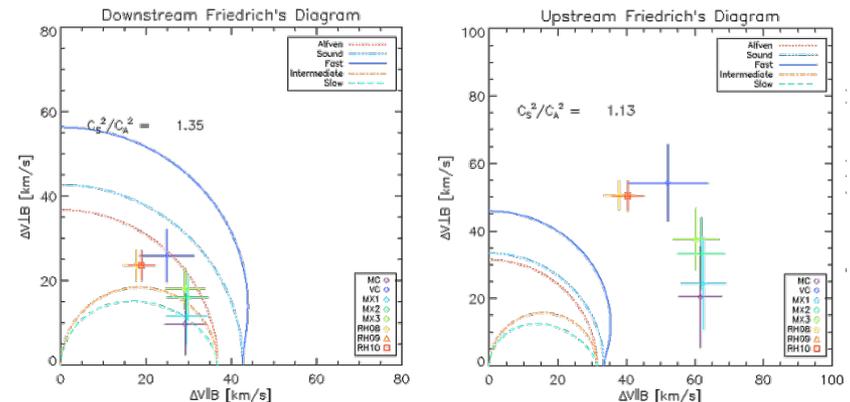
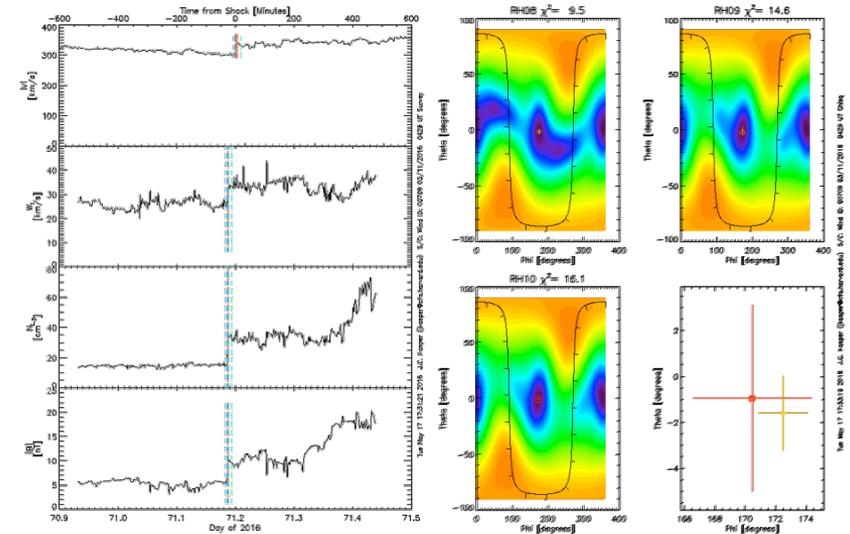
cfa.harvard.edu/shocks

- **Observational summaries and MHD solutions derived for 600+ IP shocks**
 - *Speed, orientation, morphology, type, magnitude*
- Integration with multiple spacecraft
 - **Wind** (1995-present)
 - **ACE** (through 2014)
 - **DSCOVR** (2015-present) pending lifting of data embargo
- Shock surface corrugation scaling
 - *James et al., 2015 (AAS)*
 - *Korreck et al. 2015 (AGU)*
- Scaling for minor ion heating
 - *Korreck et al. 2015 (AGU)*
- 1000+ page views per month, used by scientific, academic, and space weather communities

- Navigation
 - Previous event
 - Next event
 - Yearly list
- Select Spacecraft
 - Wind database
 - ACE database
- Analysis Description
- Publications
- News

CfA Interplanetary Shock Database - Individual Event Detail

Database: Wind Shock Analysis
 Event ID: 20160710429
 Observation time: 03/11/2016 71.18696 0429 [UT]



Data Sharing + Products (2/2)

- MESSENGER – 1 AU ICME Database
 - <http://spdf.gsfc.nasa.gov/pub/data/messenger/>
 - <http://cswepa.sr.unh.edu/icmecatalogatmercury.html>
- NASA's VEPO
 - <http://vepo.gsfc.nasa.gov>
- PREDICCS database
 - <http://prediccs.sr.unh.edu/data/goesPlots/archive/>

Agenda

- **Overview**
- Modeling Formation of Solar Transients from the Low Corona (Jon Linker)
- Energetic Particle Propagation and Acceleration from the Low Corona and through the Solar System (Nathan Schwadron)
- Particle Radiation at Earth and Through the Inner Solar System (Phil Quinn and Colin Joyce)
 - Source Populations (Phil Quinn)
 - Propagation of CMEs (Reka Winslow)
- CSWEPA Tools and Methodology (Matthew Gorby)