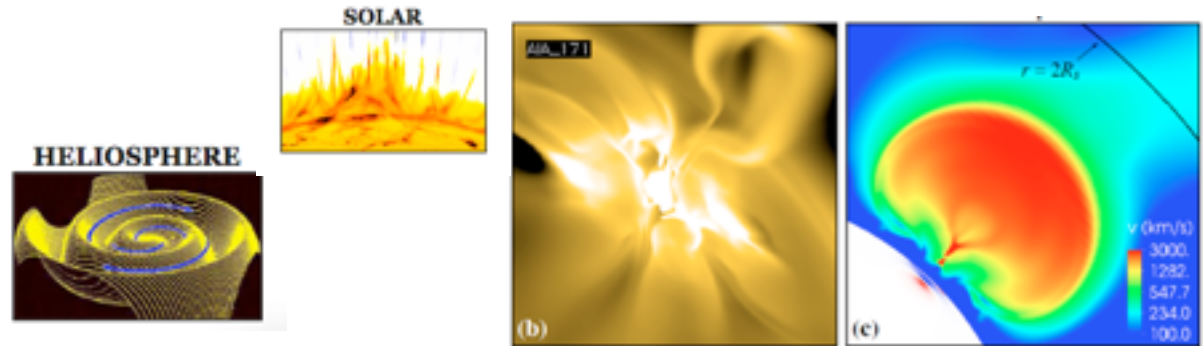


LWS and the CCMC: Fostering Community Modeling in the Next 10 Years



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Outline: LWS and the CCMC

1. Introduction: LWS science, space weather, & modeling/simulation
2. Where have we been?
3. Where are we now?
4. Where are we going?

I will draw on examples from Solar & Heliospheric Physics, as that is what I'm most familiar with.

Much of what I say I believe also applies to Geospace

We will hear more about the Geospace perspective in the upcoming Panel

Introduction

- Living With a Star, having completed ~10 years, now embarks on another 10 years
- Much has been accomplished
- However, much remains to be done if we are to fulfill the promises of this program
- In my charge for this talk, I was asked to:
 - Envision the role of LWS and the CCMC in supporting modeling/simulation the next 10 years
 - Discuss how we balance science needs versus space weather needs in these programs

Fundamental Science and Space Weather: Not really an either/or proposition

Fundamental Questions:

What are the underlying mechanisms of the solar cycle?

What causes massive magnetic eruptions (CMEs/flares)?

What heats the corona and accelerates the solar wind?

How are energetic particles accelerated and transported?

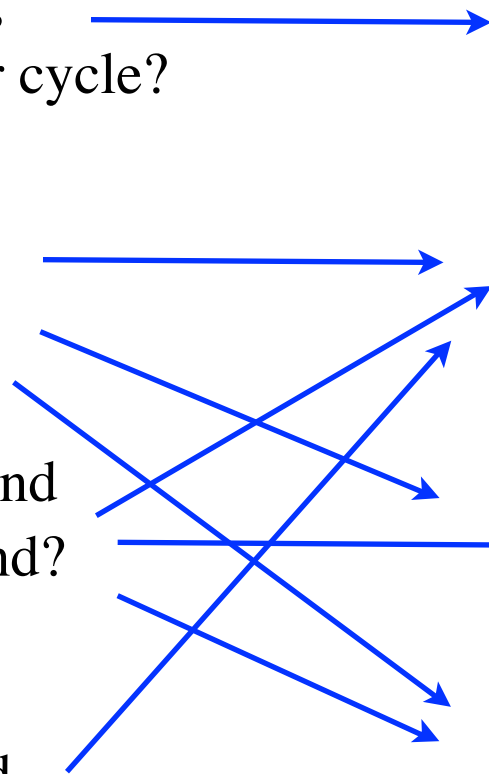
Space Weather Challenges:

Space Climate/long term variations

Radiation in the space and aviation environments

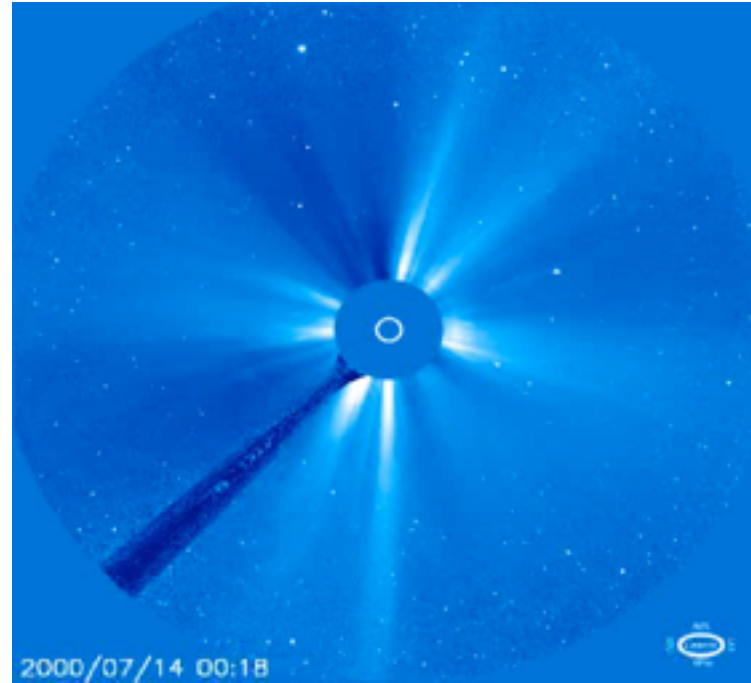
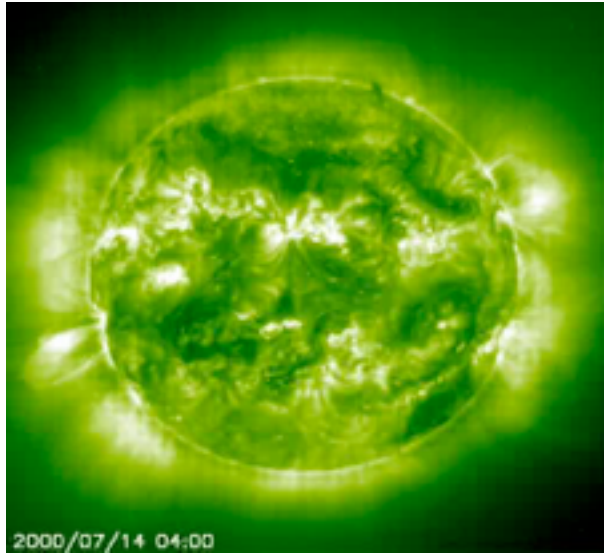
Electric Power Grids

Global Communications



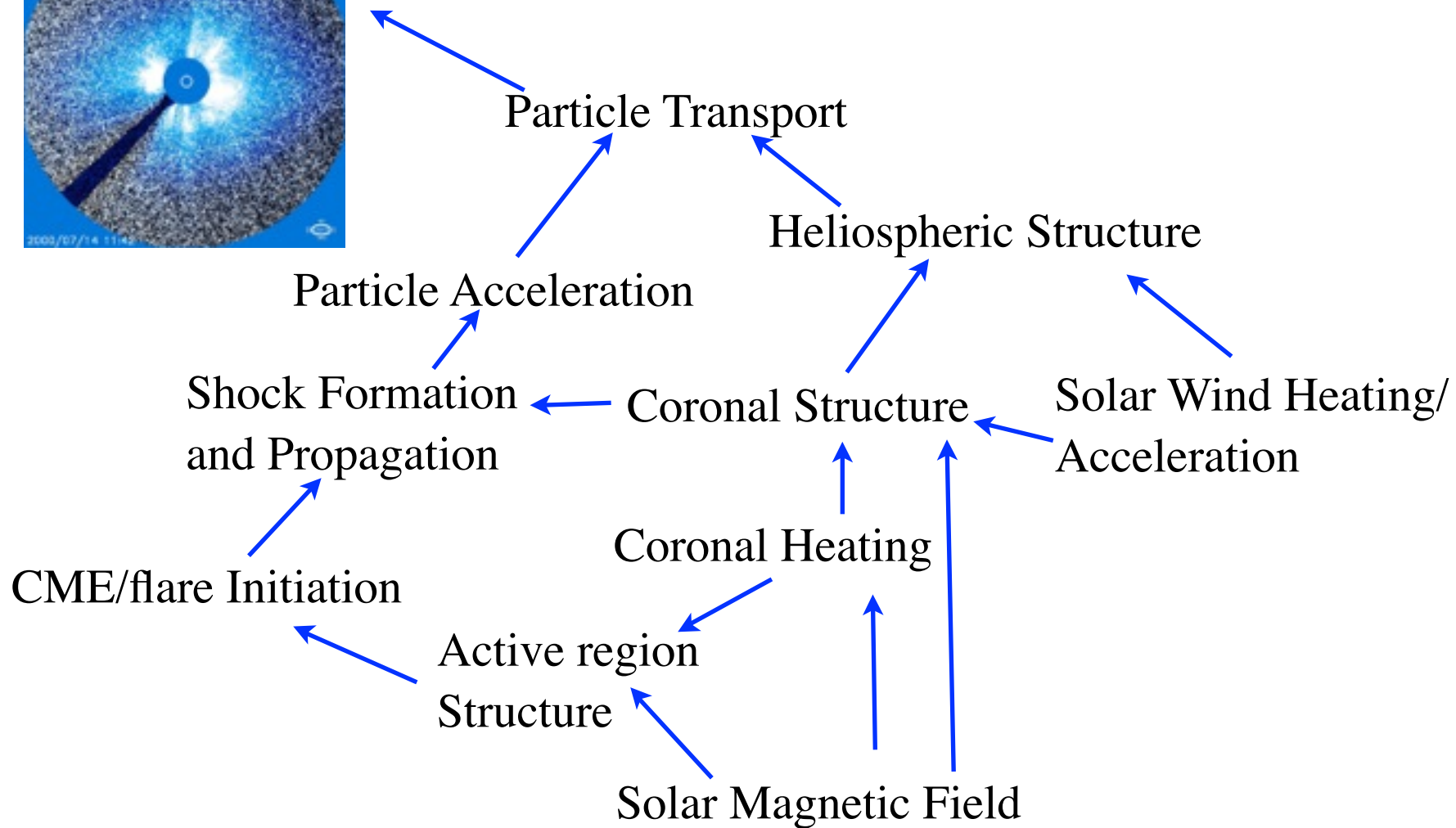
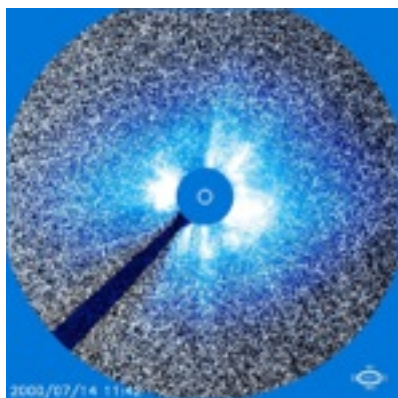
Example:

Radiation from SEPs, a Grand-Challenge Problem

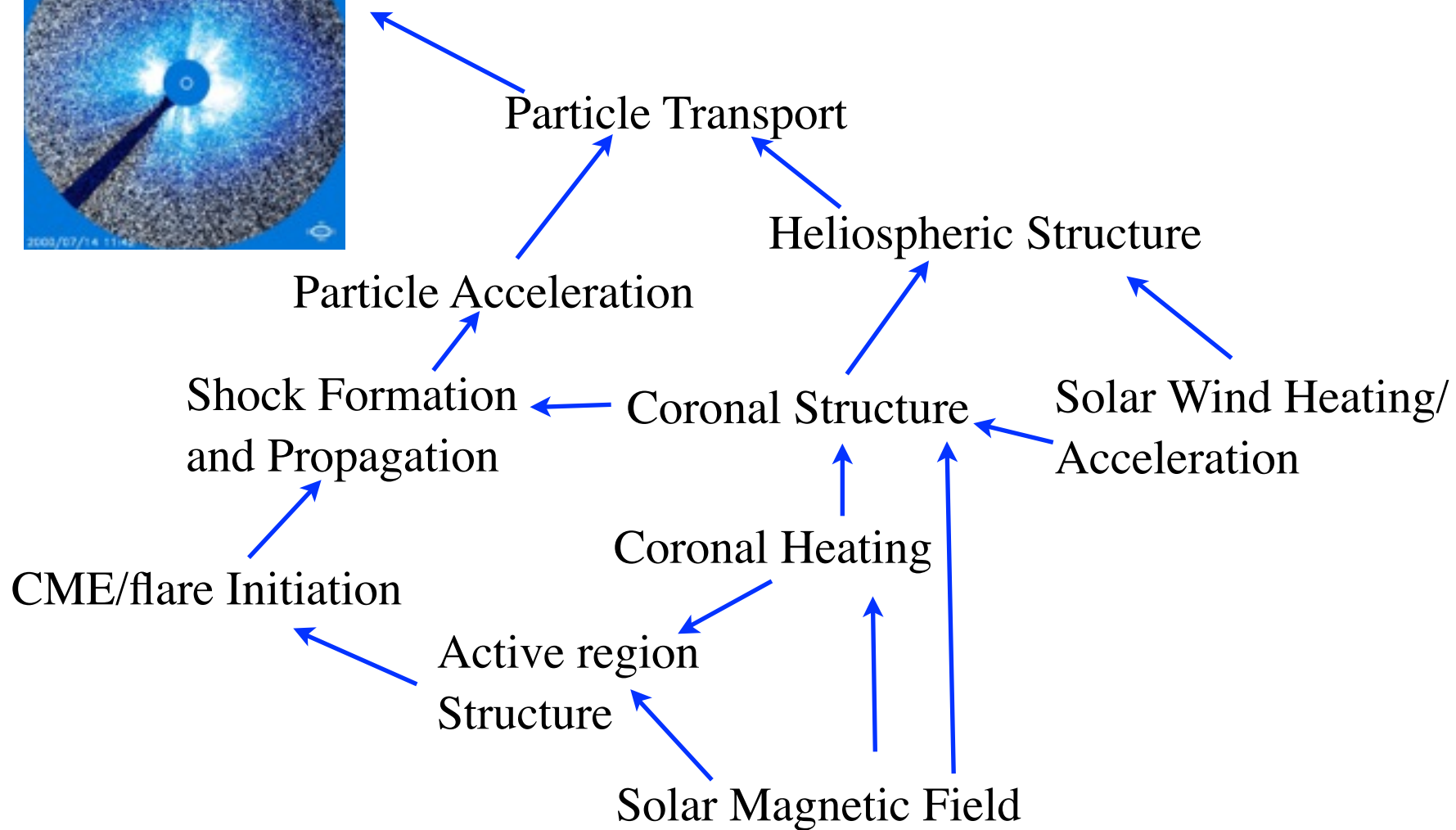
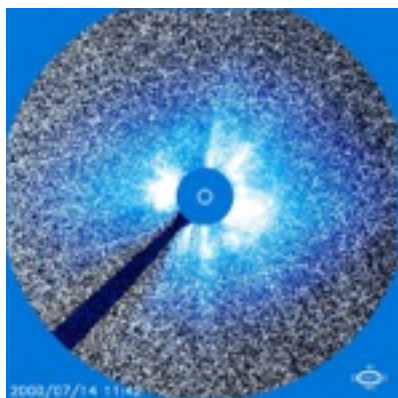


- Bastille Day Flare/CME: July 14, 2000
- X5.7 flare, 1800km/s CME, particles (hitting the LASCO detector) arrived in minutes after the initial eruption

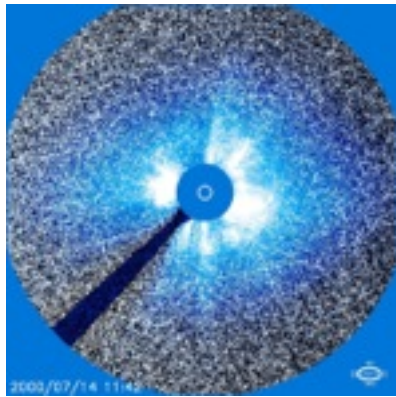
What Would it take to Predict Quantitatively Arrival time, Intensity?



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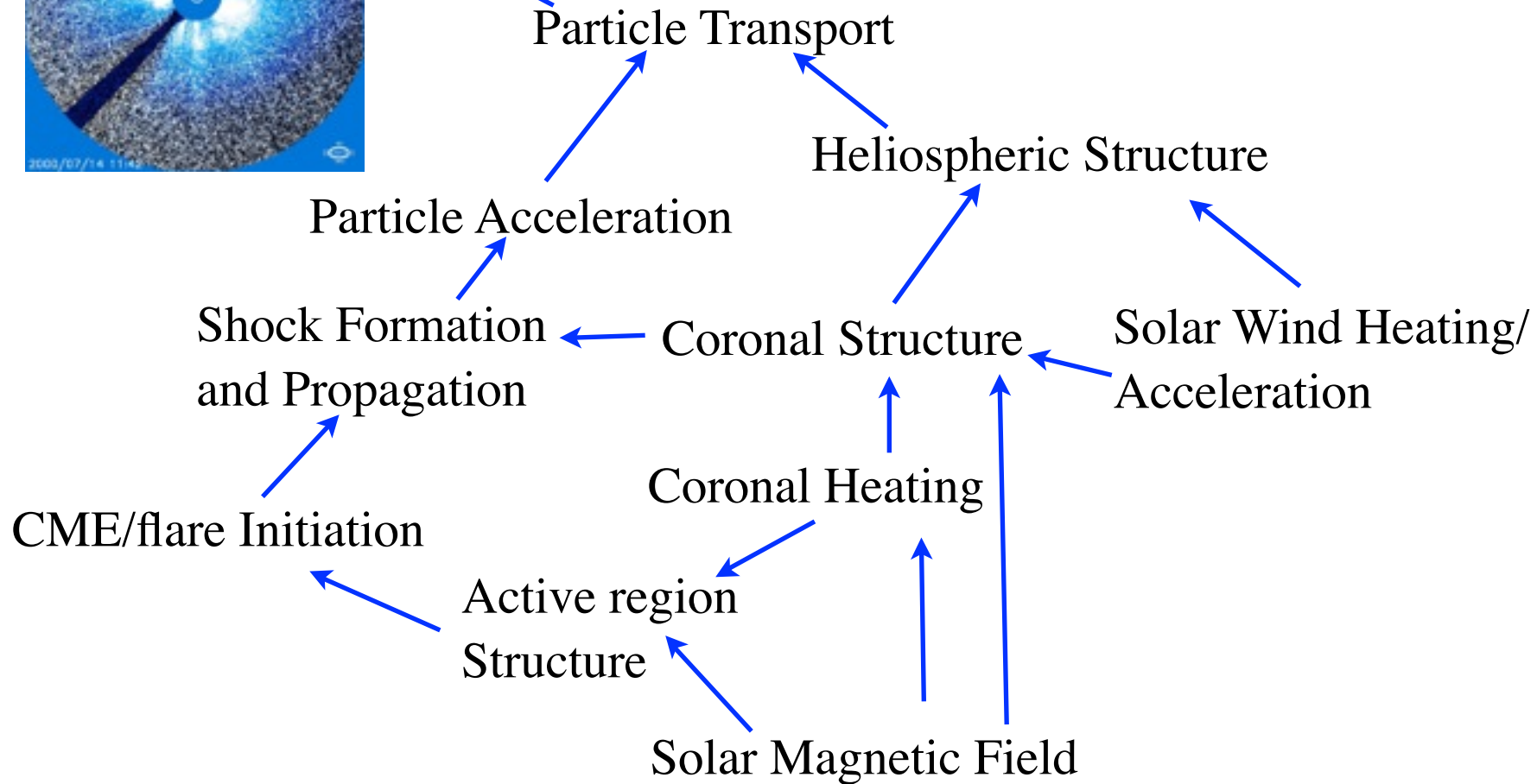


What Would it take to Predict Quantitatively Arrival time, Intensity?



14 years ago: This seemed impossible

Now: Many of the elements exist, some coupled



Where Have We Been?

A Look Back at the First CCMC Workshop (2001)

- I had recently been appointed chair of SHINE
- SHINE was fairly new - upcoming in 2002 was the first true stand-alone SHINE workshop (Banff)
- First SHINE grant competition was underway
- I was asked to speak at the CCMC workshop on the SHINE perspective, as well as my own thoughts as a code developer

Where Have We Been?

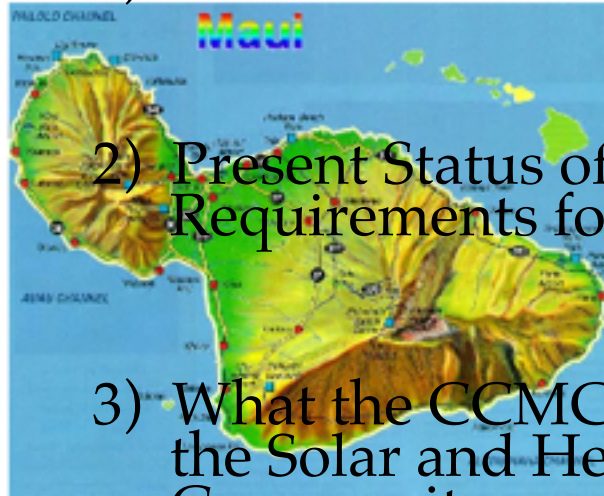
A Look Back at the First CCMC Workshop (2001)

- The first write workshop was on Maui
- The concept of SHINE Community modeling soon started to really arrived yet
- It was clearly necessary

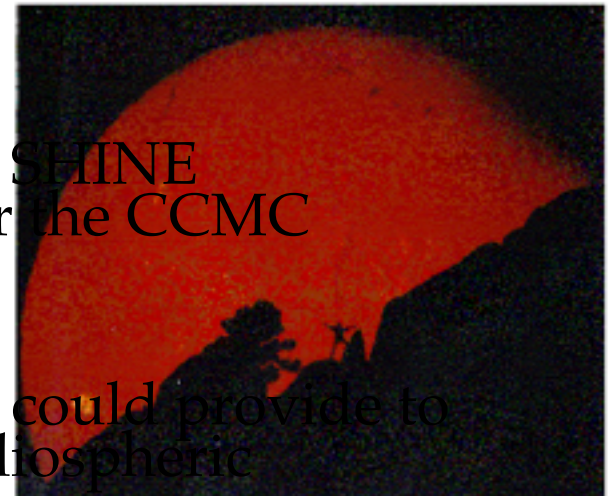
SHINE REQUIREMENTS FOR THE Community

CCMC: PRESENT STATUS Coordinated Modeling Center

1) What is SHINE?



2) Present Status of SHINE Requirements for the CCMC



3) What the CCMC could provide to the Solar and Heliospheric Community

Jon A. Linker

Science Applications International Corporation

4) My Own Thoughts as a Prospective Code Contributor

Slide Time Machine

Eight Years later: SHINE 2009

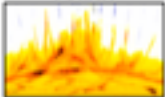
- 2nd year of Introduction to Community models session

Models:

Presenters	Model Name	Model Developers /Providers
B. Abbett	RADMHD	Abbett
B. Abbett/G. Fisher	ANMHD	Abbett
G. Fisher	FLCT	Fisher
B. Jackson	IPS Reconstruction	Jackson et al.
Y. Lee	PFSS	Luhmann et al.
B. Lynch	ARMS	Devore et al.
P. MacNeice	CCMC	CCMC
S. McGregor	WSA	Arge et al.
P. Riley/J. Linker	MAS/CORHEL	Mikic et al.
I. Sokolov	BATS R US/SWMF	Gombosi et al.

Slide Time Machine

Where Are We Now: Solar/Heliospheric models at the CCMC

	* CORHEL/MAS/WSA/ENLIL/	J. Linker, Z. Mikić, R. Lionello, P. Riley, N. Arge, D. Odstrčil	PSI, AFRL, U.Colorado	physics-base
	PFSS	J. Luhmann et al.	SSL/UC Berkeley	Potential Magn
	WSA/PF with CS	Nick Arge	AFRL	Potential S
	* SWMF/SC/THz	Bart van der Holst, Igor Sokolov, Ward Manchester, Gabor Toth, Darren DeZeeuw and Tamas Gombosi	CSEM	Physics-base
	* SWMF/SC/TH	Bart van der Holst, Igor Sokolov, Ward Manchester, Gabor Toth, Darren DeZeeuw and Tamas Gombosi	CSEM	Physics-base
	ANMHD	Bill Abbett, Dave Bereik, George Fisher, Yuhong Fan	UC Berkeley	physics-base
ASSA	Sangwoo Lee ² , Sanhak Hong ¹ , KiChang Yoon ¹ , Jaehun Kim ¹ , Yungkyu Kim ¹ , JeongDeok Lee ² , SeungJun Oh ² ¹ Korean Space Weather Center (KSWC), ² SELab Inc.	KSWC		
	* CORHEL/MAS/WSA/ENLIL/	J. Linker, Z. Mikić, R. Lionello, P. Riley, N. Arge, D. Odstrčil	PSI, AFRL, U.Colorado	physics-base
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	* SWMF/SC/TH	Bart van der Holst, Igor Sokolov, Ward Manchester, Gabor Toth, Darren DeZeeuw and Tamas Gombosi	CSEM	Physics-base
	ENLIL	D. Odstrčil	Univ. of Colorado at Boulder	Physics-base
	ENLIL with Cone Model	D. Odstrčil	Univ. of Colorado at Boulder	Physics-base
	Heliospheric Tomography with SMEI data	B. Jackson, P. Heck	CASS/UCSD (SMEI)	Data Assim
	Heliospheric Tomography with IPS data	B. Jackson, P. Heck	CASS/UCSD (SMEI or IPS)	Data Assim
	Exospheric Solar Wind	H.Lamy, V.Pierard	IASB-BIRA	Physics-base
	* EMMREM	N. Schwadron, H. Spence, L. Townsend, R. Squier, F. Cucinotta, M. H. Kim, K. Kozarev, R. Hatcher, M. FourAslan, M. A. Dayeh	U. of New Hampshire, U. Tenn, Southwest Research Institute (SwRI), NASA JSC	physics-based Lagrangian Primary Transport (E Radiation Environ Physics-based Secondary (EMMREM looping ve TraNsport BRYS
	* PREDICCs	Nathan Schwadron and Harlan Spence	U. of New Hampshire	physics-based Lagrangian Primary Transport (E Radiation Environ Physics-based Secondary (EMMREM looping ve TraNsport BRYS

* Received funding from Strategic Capabilities (LWS-NSF-AFOSR)

Where We Are Now

- Science model development has come a long way in 13 years
- LWS funding has played a key role in facilitating it
- The models are useful to the community, but challenges for the future lie ahead:
 - At this point, the WSA/Enlil with cone-model CMEs is the only solar/helio model space weather operations model at NCEP
 - More sophisticated models exist, elucidate more physics, and at times compare well with observations
 - These models have more currency in the scientific community, but are not space weather ready
 - Key physics is still missing in many of the models
 - In some sense, the “easy” part is over, and it’s starting to be “put up or shut up” time for the models

Where We Are Going: Getting Real

- There are many practical challenges to making models useful for operations
- Providing runs on demand forces a model to confront some of these practicalities
 - Non-expert use implies scaling down of the model, increasing robustness at the expense of fidelity
 - “Blind” processing of input data may lead to nonsensical models
 - Computing power more limited than for “ideal, one time uses”
- Data assimilative techniques need to be further developed - this is not a straightforward extension of atmospheric modeling techniques

Where We Are Going: Space Weather Test Beds

- There has been some controversy about the role of the CCMC in space weather “operations” (e.g. ISWA)
- The CCMC is not strictly “operational” - Our community should use this to our advantage
 - Our discipline does not have the resources to overcome “the valley of death” if we stick to traditional approaches
 - CCMC can provide more agility in testing different concepts than traditional operational agencies
 - New approaches can be tried out here more easily
 - This could be an avenue for small business (SBIR)
 - Yes, there is a space weather business: ACSWA (American Commercial Space Weather Association)

Where We Are Going: Physics

- Physics/modeling challenges:
 - Higher resolution to capture scales within a given paradigm (e.g. MHD)
 - Cross-scale coupling (e.g. kinetic & MHD)
 - Cross-region coupling (e.g. photosphere, chromosphere, transition region, corona)
- In many cases this requires the merging of “building blocks” already present or under development at the CCMC and elsewhere
- CCMC models provide many of the necessary building blocks
- The building blocks themselves need further refinement

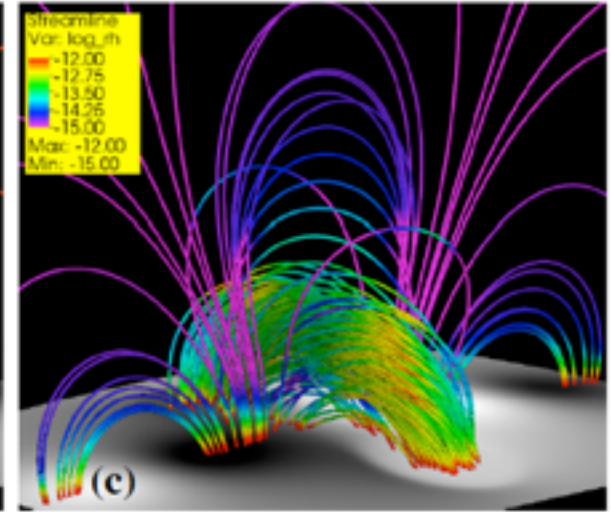
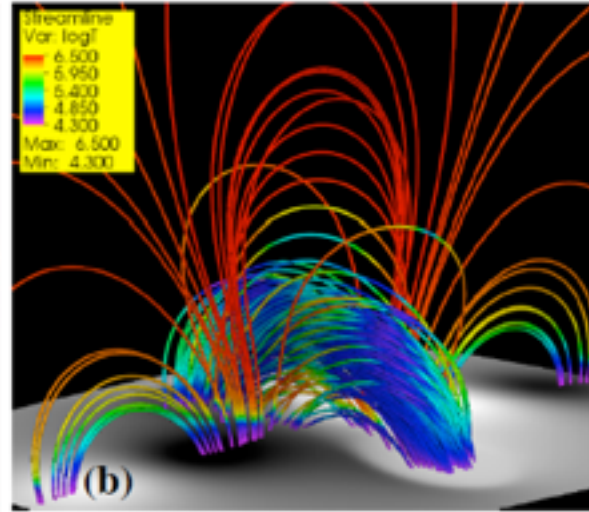
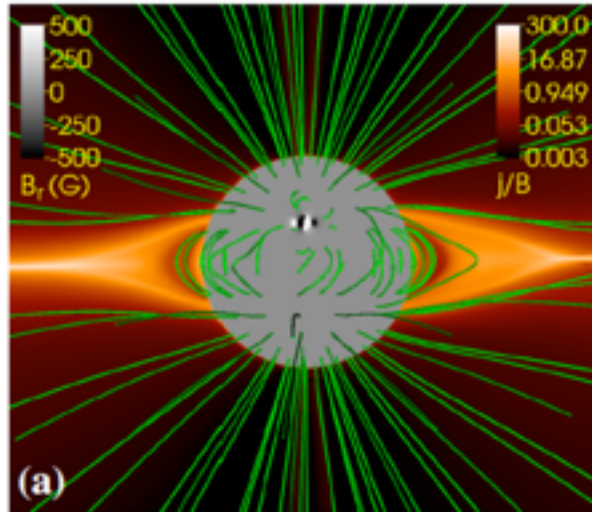
Example: Fast CME in Thermodynamic MHD

An Energized Flux Rope Equilibrium in a Global Thermodynamic Simulation

Equilibrium After Flux Rope Insertion

$\log_{10}(\text{Temperature})$ [K]

$\log_{10}(\text{Mass Density})$ [g/cm³]



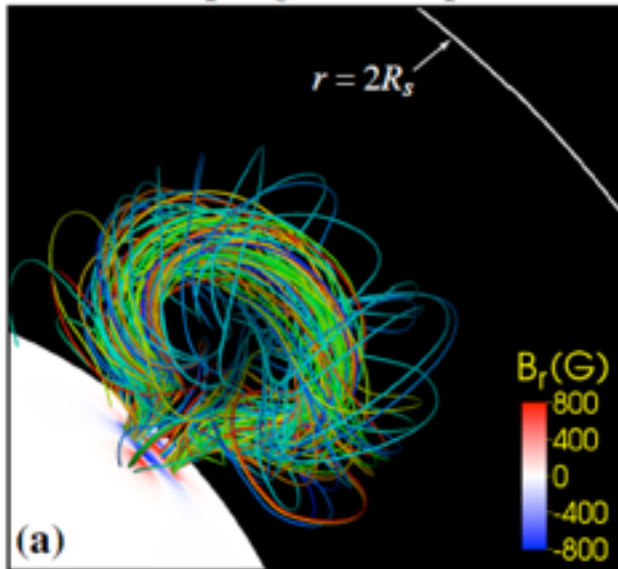
Idealized pre-eruptive configuration for a fast CME simulation. (a) The equilibrium after insertion of the flux rope. Magnetic field lines in the stable flux rope before eruption, colored by temperature (b) and mass density (c), showing that a cool and dense prominence has formed.

- Combines more realistic coronal energy physics (MAS/CORHEL) with CME initiation

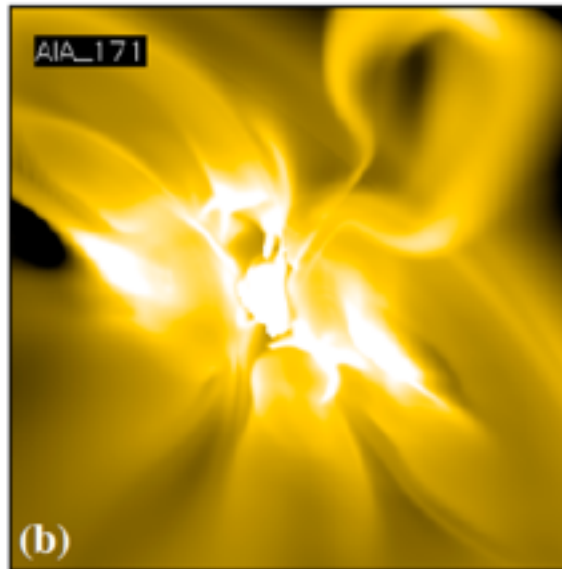
Example: Fast CME in Thermodynamic MHD

Simulation of a Fast CME in an Idealized Quadrupolar Field

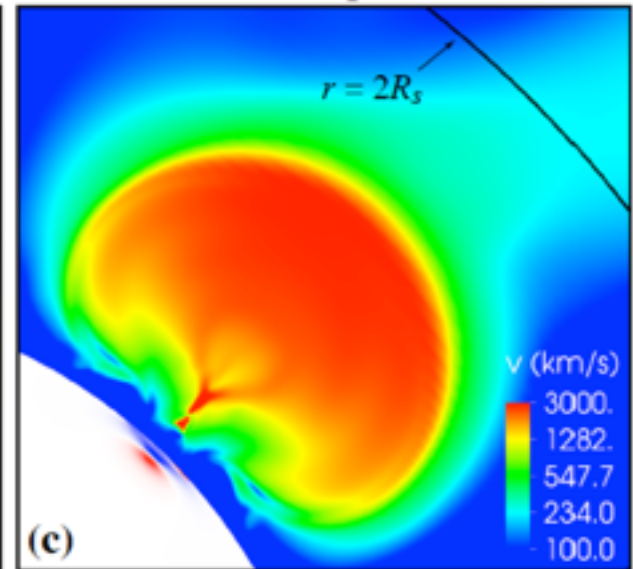
Erupting Flux Rope



Simulated AIA 171Å Emission

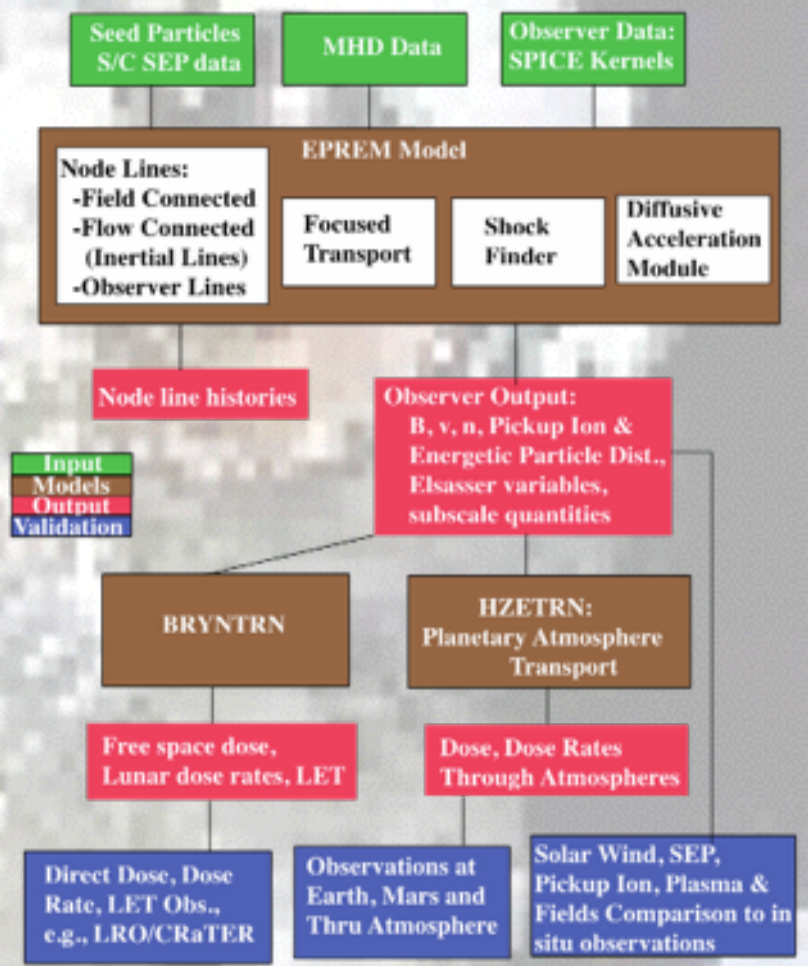
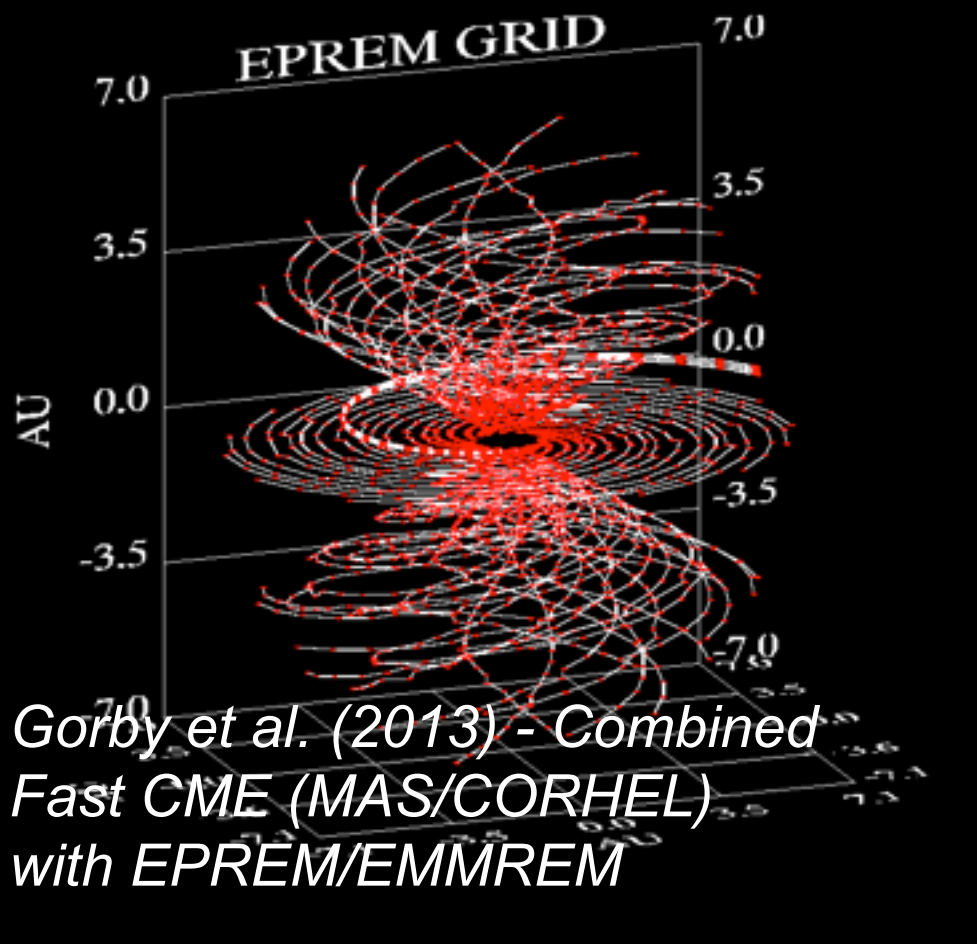


CME Speed



The simulation of a fast CME in the quadrupolar field shown above using a thermodynamic MHD model. The view a few minutes after the onset of eruption: (a) Magnetic field lines showing the erupting flux rope, (b) simulated EUV emission, and (c) the plasma speed in the plane parallel to the initial flux rope axis.

- Combines more realistic coronal energy physics (MAS/CORHEL) with CME initiation



Focused Transport in Lagrangian Frame (Kota, 2005)

$$\left(1 - \frac{(\bar{u} \times e_b) \cdot \mu}{c^2}\right) \frac{df}{dt} + \mu \frac{\partial f}{\partial z} + \frac{(1 - \mu^2)}{2} \left[v \frac{\partial \ln B}{\partial z} - \frac{2}{v} e_b \times \frac{d\bar{u}}{dt} + \mu \frac{d \ln(n^2 / B^3)}{dt} \right] \frac{\partial f}{\partial \mu} +$$

$$\left[-\frac{\mu e_b}{v} \times \frac{d\bar{u}}{dt} + \mu^2 \frac{d \ln(n/B)}{dt} + \frac{(1 - \mu^2)}{2} \frac{d \ln B}{dt} \right] \frac{\partial f}{\partial \ln p} = \frac{\partial}{\partial \mu} \left(\frac{D_{\mu\mu}}{2} \frac{\partial f}{\partial \mu} \right) + S$$

Where We Are Going: Supercomputing

- The physics challenges drive us to seek more resolution and computer power
- This power is becoming available: million core supercomputers
- In massively parallel computing, it is all about scaling - how to efficiently increase the # of cores you use to solve a much larger problem
- This strategy works if you need to encompass many scales -and that is certainly one of our difficulties.
- We need to leverage these advances in computing to make breakthroughs in our science
- This strategy is not synonymous with squeezing the most computing out of modest supercomputers - which may be more relevant to space weather

Large-Scale Computations

- As multi-scale, coupled models begin to attack larger problems, the concept “of runs on demand” may lose meaning for such cases
 - Runs that take millions of core hours can’t be repeated frequently
- It may make sense to have these runs available for community investigation, with visualization and analysis tools provided as well
- Versions of these codes would still be available for smaller runs on demand

LWS/CCMC at an Interesting Crossroads

1. On the one hand, models need to become robust enough that they can eventually contribute to space weather operations
 - This may involve physics compromises, parameterization, etc.
 - Making models suitable for real data environments is time-consuming
2. On the other hand, space weather science has not reached the point of becoming an engineering problem
 - We have real physics challenges to solve, that presently limit the applicability of our science
 - It might be tempting to pursue (1) at the expense of (2)
 - In my opinion, this would be a mistake and possibly imperil the entire field
 - LWS/CCMC must continue to embrace both

Summary

- At least in Solar/Heliospheric Physics, the concept of community modeling has come a long way since the inception of the CCMC
- LWS (and other programs) have funded “building blocks” - many of which are sophisticated coupled models in there own right
- LWS and CCMC must strive to maximize the practical benefit from these models, while facilitating the larger endeavors we need to solve our most challenging questions

Extra Slides