Summery and Discussion from the WG3 (Simulation Working Group)

Fang Shen (Sigma Group @ NSSC)

Jeju, Republic of Korea, 18 - 22 September 2017

1. Scientific Objective

(1) Provide global context for all CME events investigated by the ISEST team:

a. Make comparison among the popular numerical models, and the observations for these CME events;

b. Try to improve the numerical prediction ability

(2) Investigate processes of the CME initiation, heliospheric propagation, and CMEs interaction

(3) Develop tools to assist collaboration of numerical modelers, theoreticians, and observers

- **2. Presentations in WG3**

(1) Theme-setting talk by Christina Verbeke:

"Progress of MHD Simulations for the Interplanetary Propagation of Coronal Mass Ejections"

(2) Contributions by:

a. Bernard Jackson:

"Iterative 3-D MHD ENLIL Modeling Using Interplanetary Scintillation (IPS) Observations"

b. Mark Cheung

"Data-driven evolving models of the solar corona"

c. Kyung-Sun Park

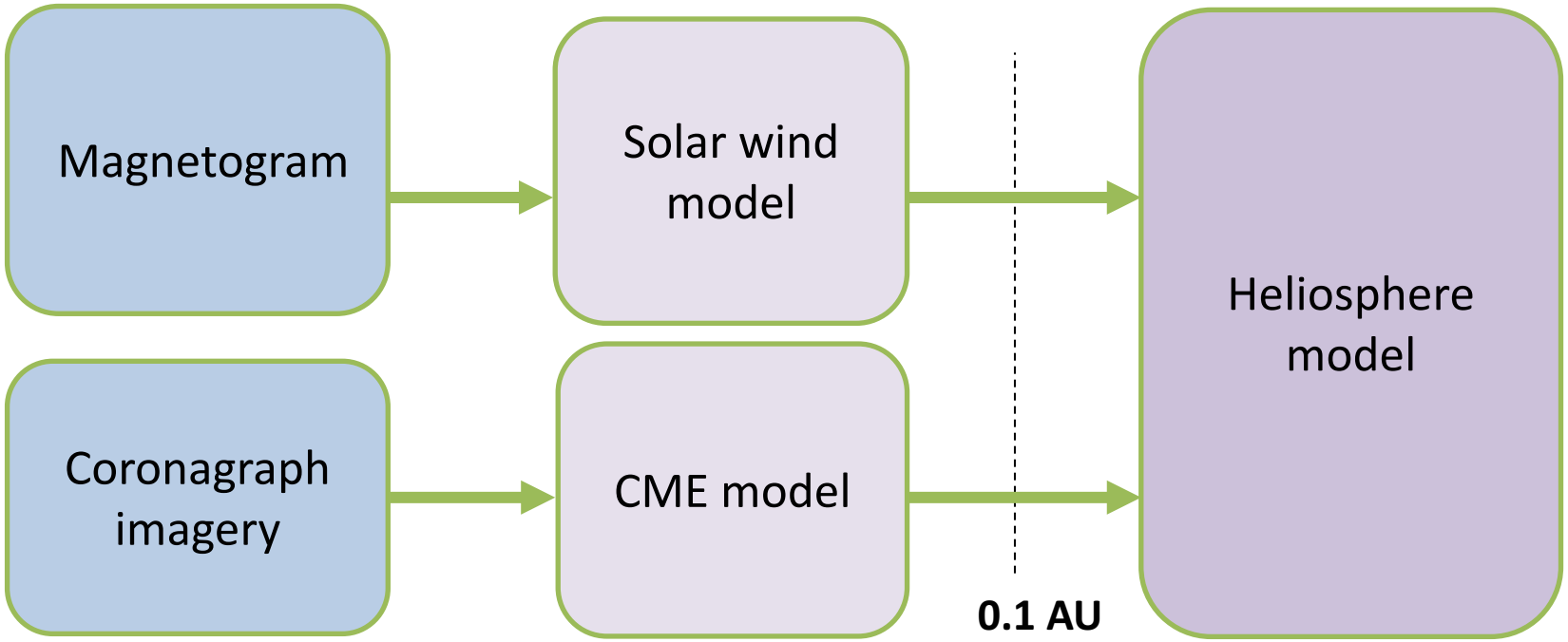
"Response of the Earth's magnetosphere and ionosphere to the small-scale magnetic flux rope in solar wind by the global MHD simulation "

Progress of MHD Simulations for the Interplanetary Propagation of CMEs

- Constraining CME model parameters
- Interaction with ambient solar wind and CMEs
- MHD-Simulations
  - Heliospheric modeling
    - ENLIL
    - SUSANOO-CME
    - EUHFORIA

(see talk by C. Verbeke)

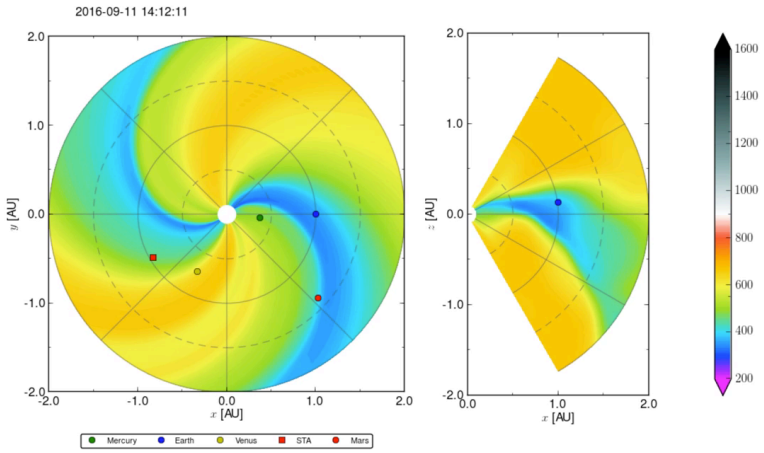
EUHFORIA



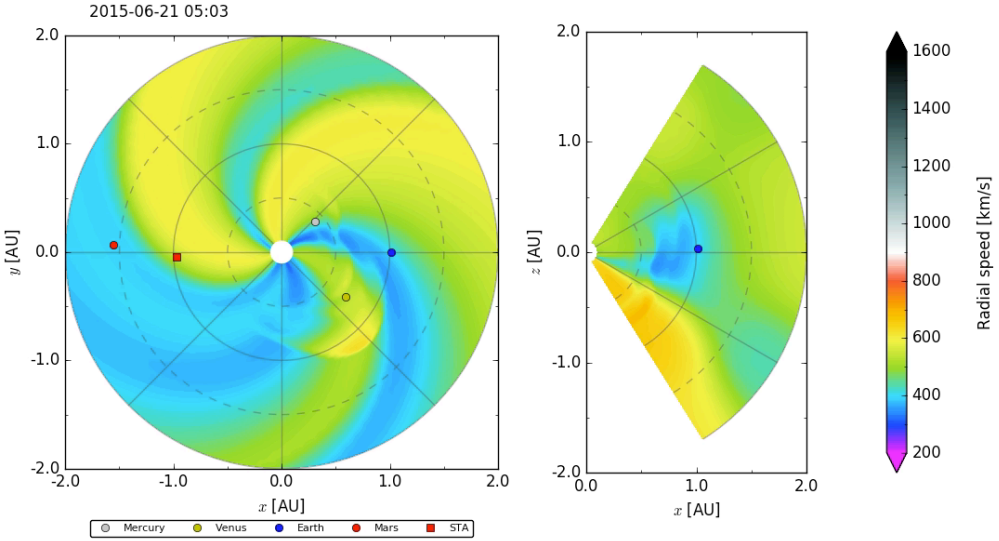
(see talk by C. Verbeke)

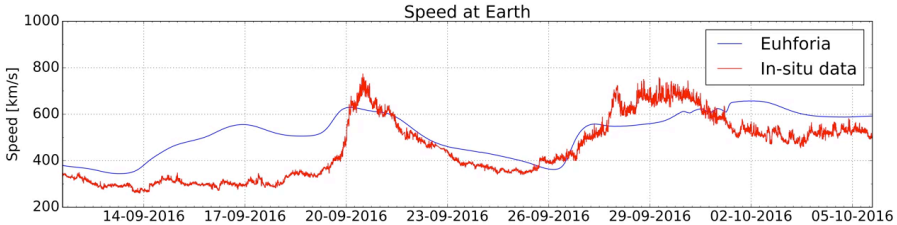
EUHFORIA

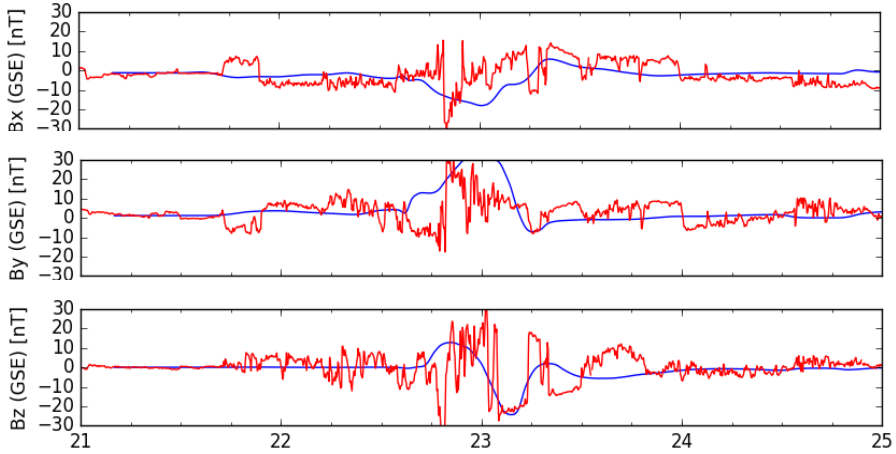
Solar wind model run



June 2015 event: Flux rope



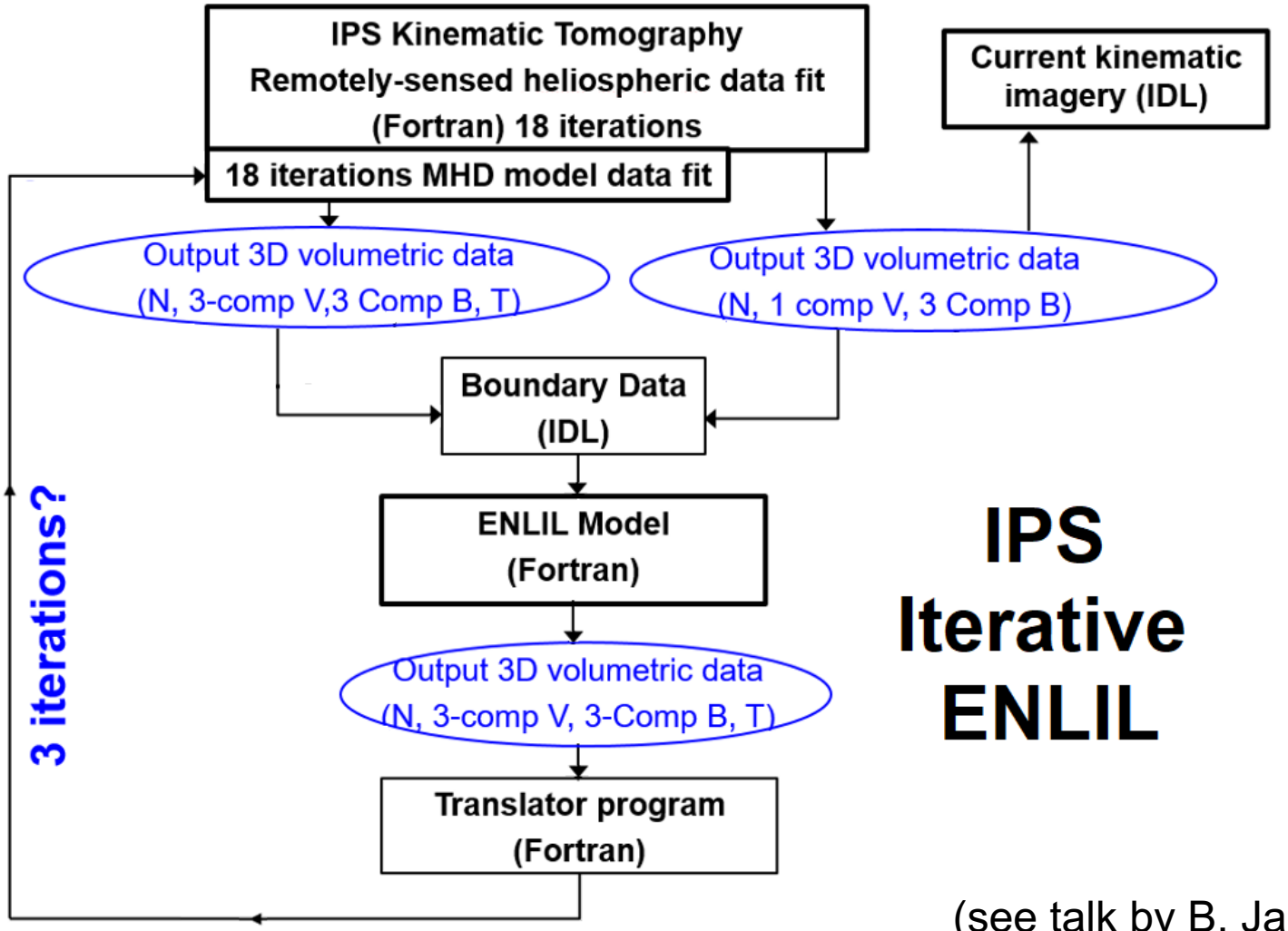




(see talk by C. Verbeke)

Iterative 3D MHD ENLIL Moding Using IPS

Iterative process with the ENLIL 3-D MHD model



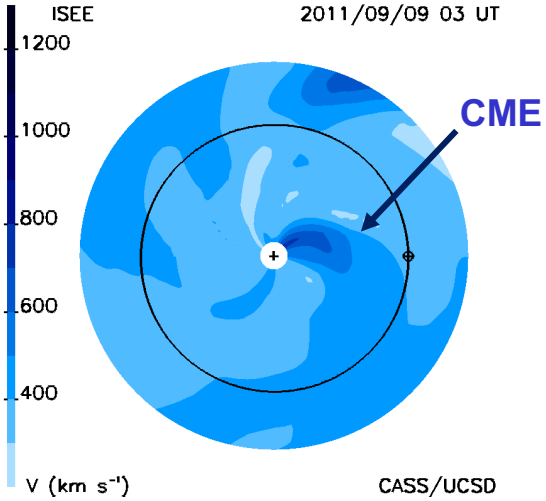
(see talk by B. Jackson)

Iterative 3D MHD ENLIL Moding Using IPS

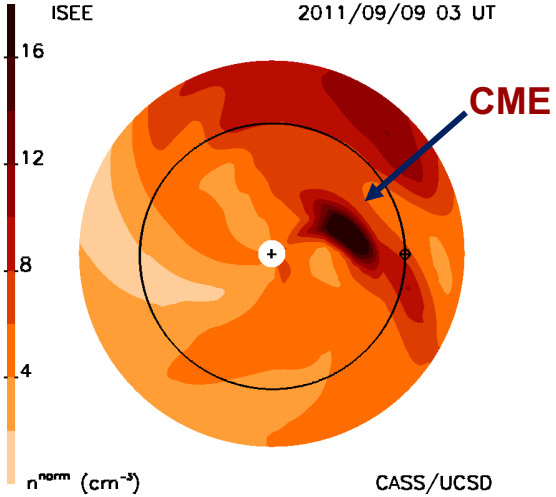
From Yu *et al.*, 2015, Solar Phys., 290, 2519

CME on 2011/09/09 03 UT

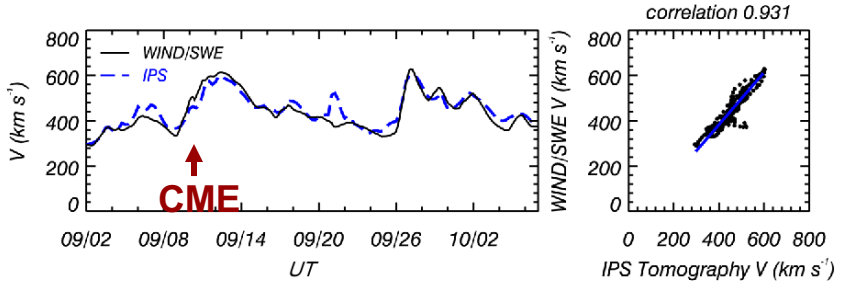
(a well-studied event using the kinematic IPS, ENLIL, and IPS-driven ENLIL)



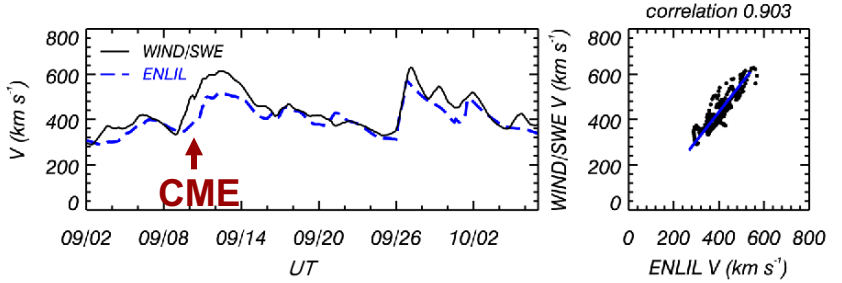
Velocity Meridional Cut



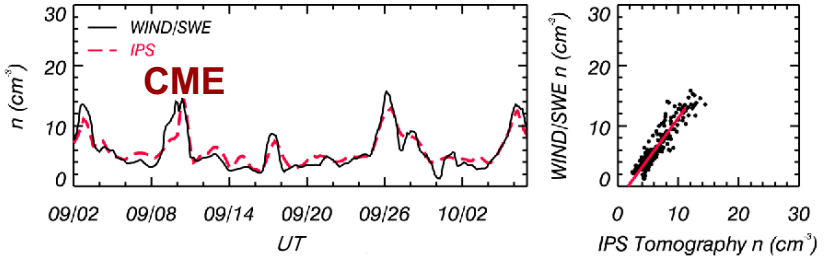
Density Meridional Cut



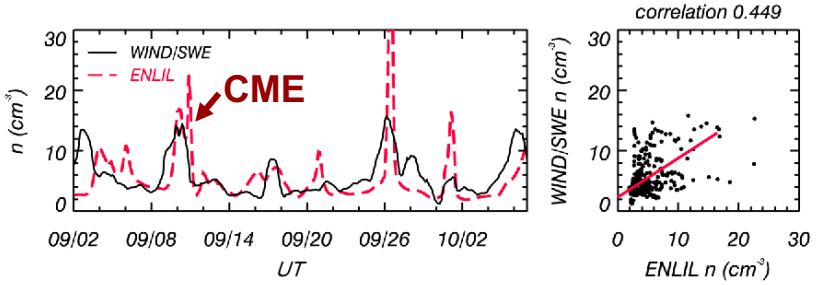
Kinematic Model Velocity Time Series



ENLIL IPS-driven Model Velocity Time Series



Kinematic Model Density Time Series



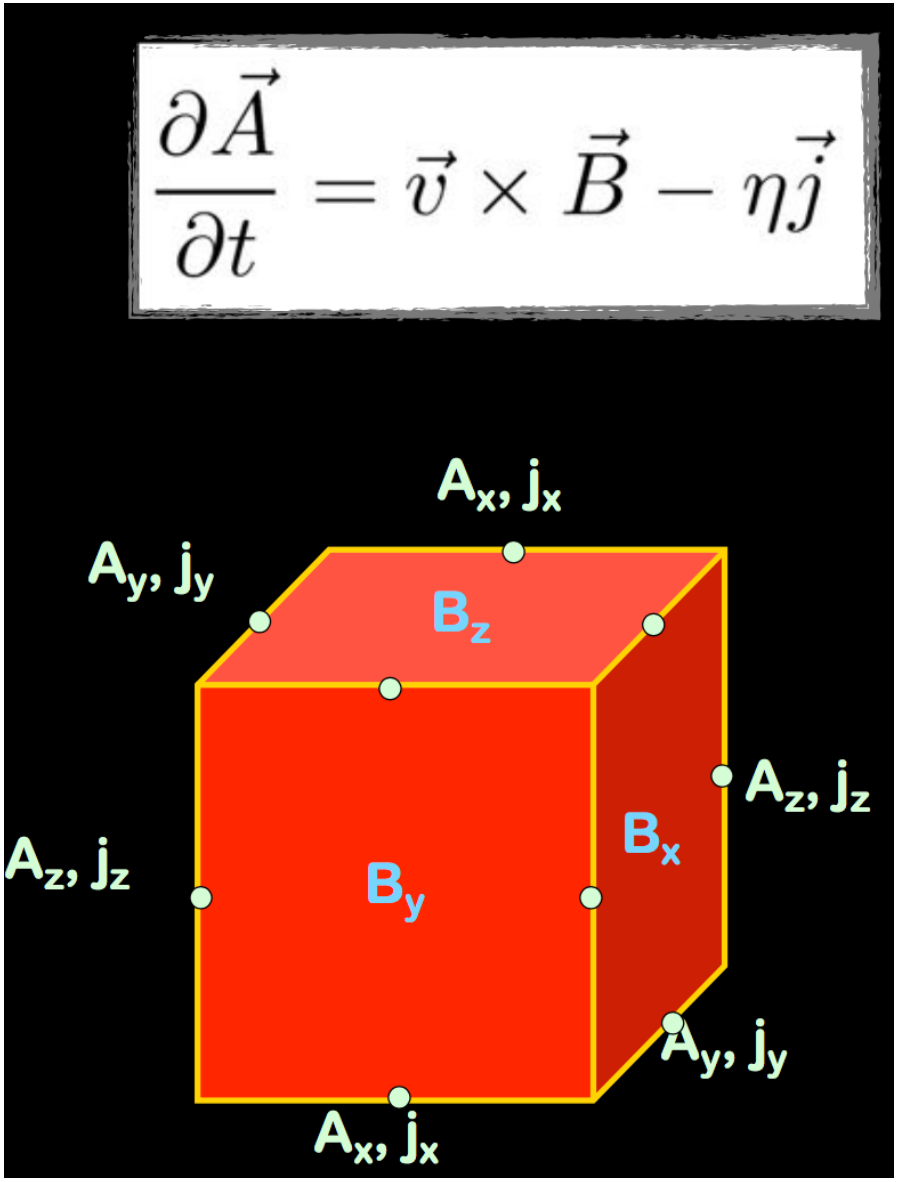
ENLIL IPS-driven Model Density Time Series

Data-driven evolving models of the solar corona

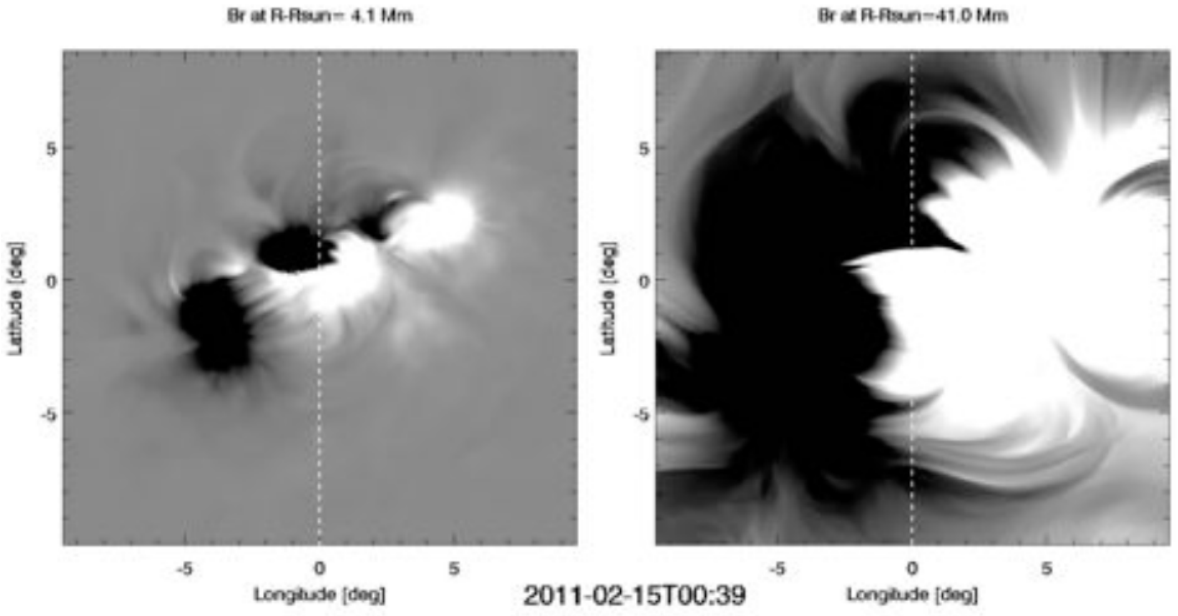
Magnetofriction: a data-driven model which allows us to track how the non-potential solar coronal field evolves over time-scales of hours to weeks.

- Balance of Lorentz force and fictitious frictional force (Yang, Sturrock & Antiochos, 1986; Craig & Sneyd 1986)
  - Plasma velocity proportional to Lorentz force: $v = \nu^{-1}\, jxB$ where ν is the frictional coefficient
  - Evolve magnetic field according to Induction Equation.

(see talk by M. Cheung)

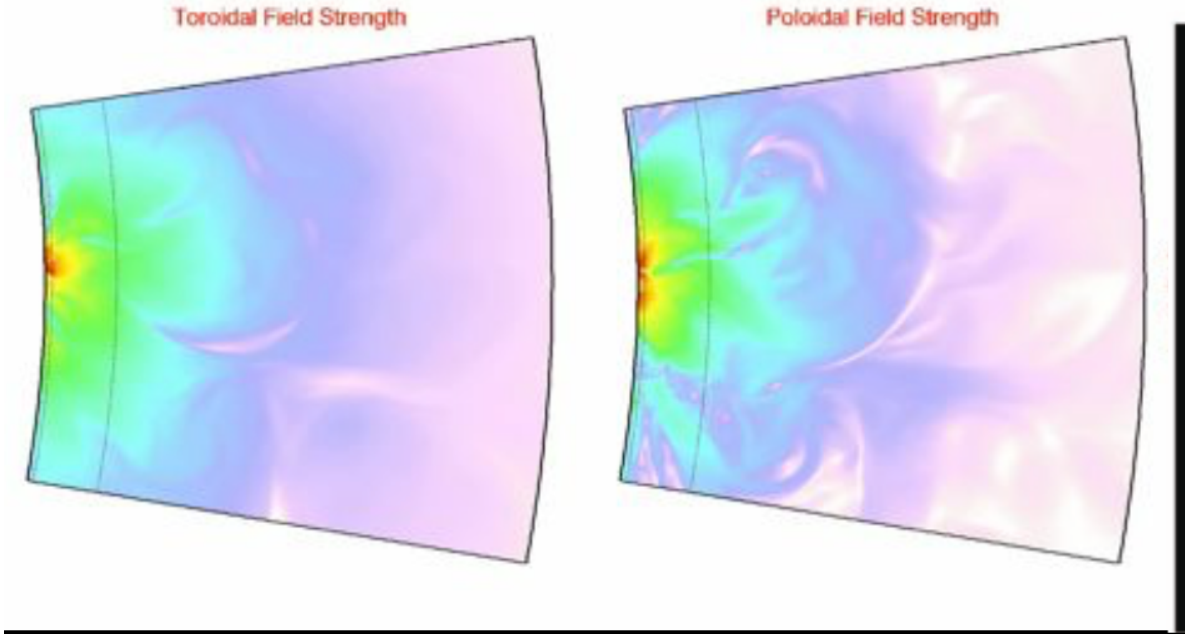


Data-driven evolving models of the solar corona

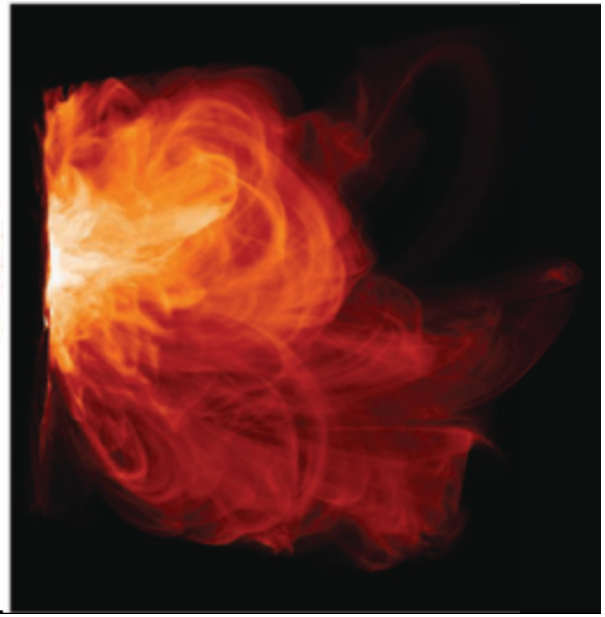


Data-Driven NOAA AR 11158 model in a spherical wedge

Orange ~ $\int_{los}\langle j^2\rangle dl$, where $\langle j^2\rangle$ is fieldline-averaged j^2



LOS tangent to disk center in E/W direction

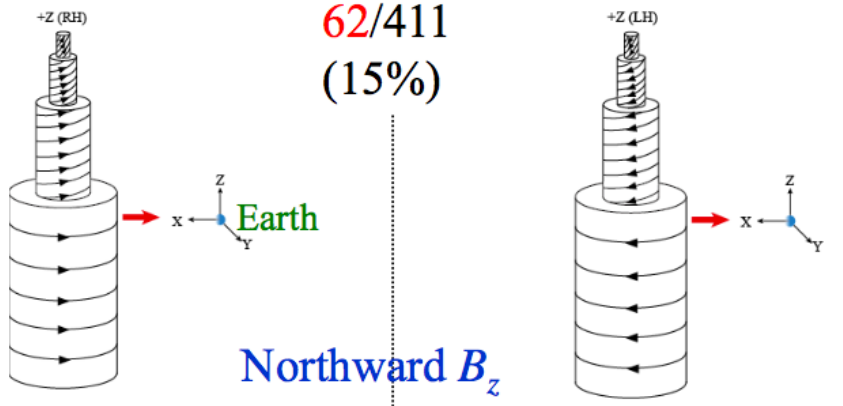


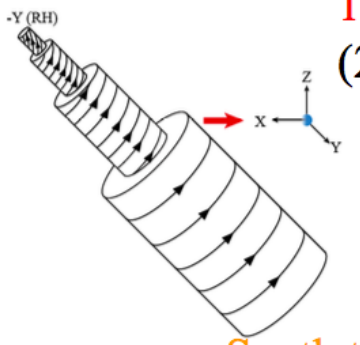
Response of the Earth's magnetosphere and ionosphere to the small-scale magnetic flux rope in solar wind by the global MHD simulation

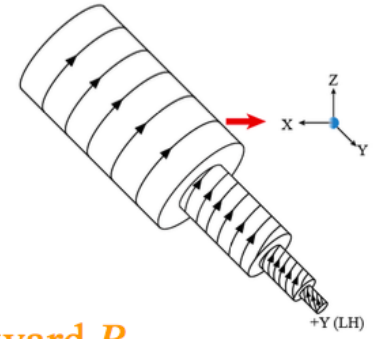
Magnetic flux rope distinguished by four types

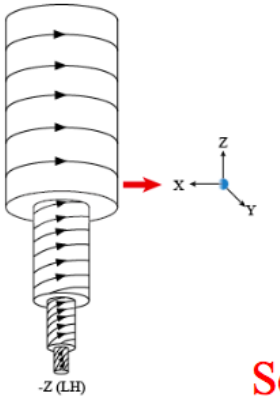
+Z Right –hand	+Z Left-hand	-Y Right –hand	+Y Left-hand
62/411 (15%)		120/411 (29.2%)	
Northward B_z		South to Northward B_z	

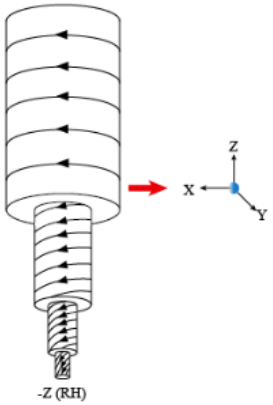
-Z Right –hand	-Z Left-hand	+Y Right –hand	-Y Left-hand
80/411 (19.5%)		149/411 (36.3%)	
Southward B_z		North to southward B_z	

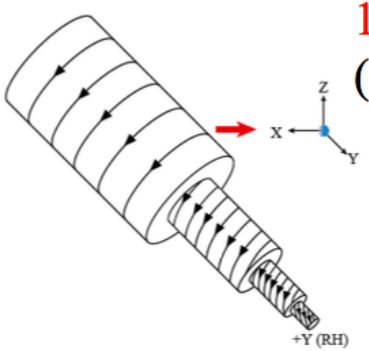


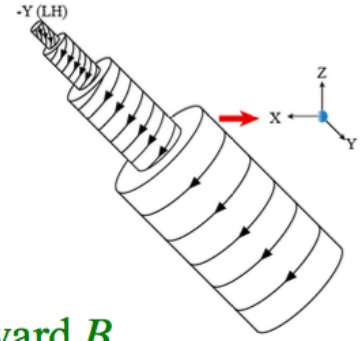












(see talk by K.- S. Park)

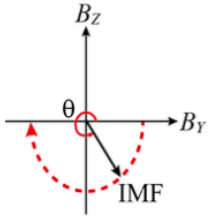
Response of the Earth's magnetosphere and ionosphere to the small-scale magnetic flux rope in solar wind by the global MHD simulation

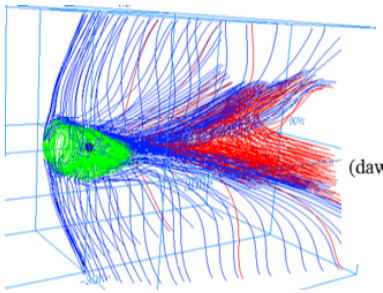
Simulation Results

Configuration of the magnetic field lines

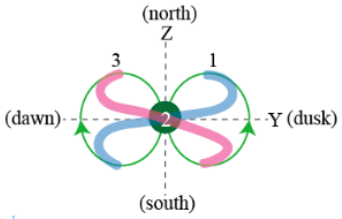
Green : closed field line
Blue : open field line
Red : reconnected field line

Case 1: -Z (RH)
Southward B_z

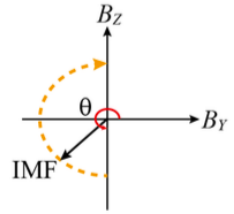


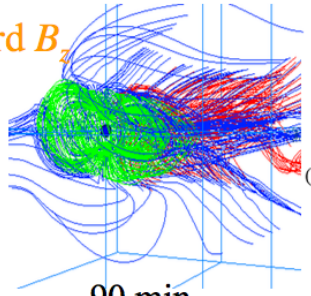


90 min



Case 3: -Y (RH)
South to Northward B_z





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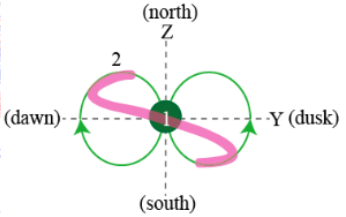
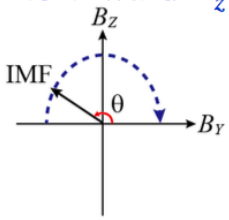
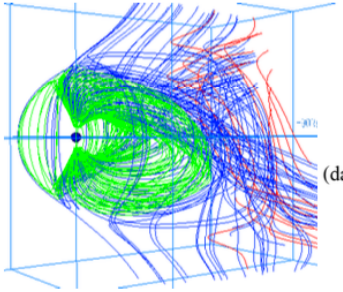


Dayside reconnection region

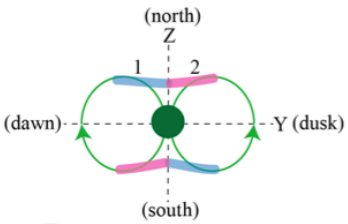
Dayside reconnection region

Case 2: +Z (RH)
Northward B_z

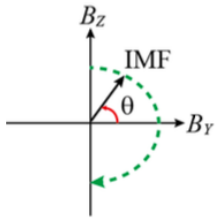


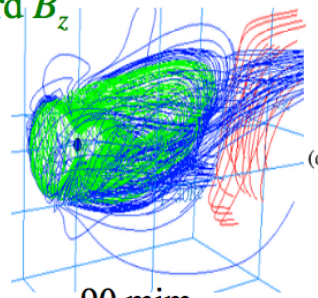


100 min



Case 4: +Y (RH)
North to southward B_z





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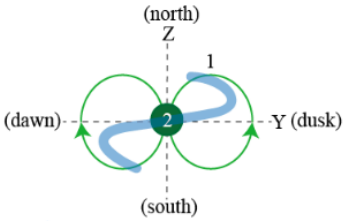

(see talk by K.- S. Park)

3. Conclusion---Future

- Simulations have really reached the point where very different simulations are used for different goals:
  - Real-time forecasting: ENLIL, EUHFORIA
  - Providing environment for analyses of real events: ENLIL, EUHFORIA, STELab, SWMF, AWSOM, H3DMHD, CESE, COIN, SUSANOO……
  - Understanding causes of eruption: complex initiation mechanism, as much realistic physics as possible — beyond ISEST goals?
  - CME-CME interaction: Most advanced domain where people are using simulations + data analysis (remote + in-situ) to learn new things.
- Is there something ISEST wants to focus on?
- Next year: individual progress can be expected: KU LEUVEN, STELab, NSSC, Michigan, LMSAL…

3. Conclusion---Future

- For coordinated work, 1-2 event(s) should be chosen - in coordination with other WGs (1 isolated, 1 multiple?). ISEST-simulation campaign events.
- 2013 March 15, 2015 March 15; 2017 SEP. 4-10?
- What is importance of solar initiation? What are the key model-input parameters for CME simulation? Direction? Speed? How to determine orientation at 0.1 AU?
- What are forecasting-performances of different empirical, analytical, and numerical models?
- How well models reproduce heliospheric kinematics of ICMEs?
- What can be done regarding the geomagnetic-activity forecasting?


Thanks