WG5 Report

Spiros Patsourakos & Jie Zhang

ISEST 2018 WORKSHOP
24-28 September 2018, Hvar, Croatia

The Bs challenge: Statement of the WG

(from ISEST description)

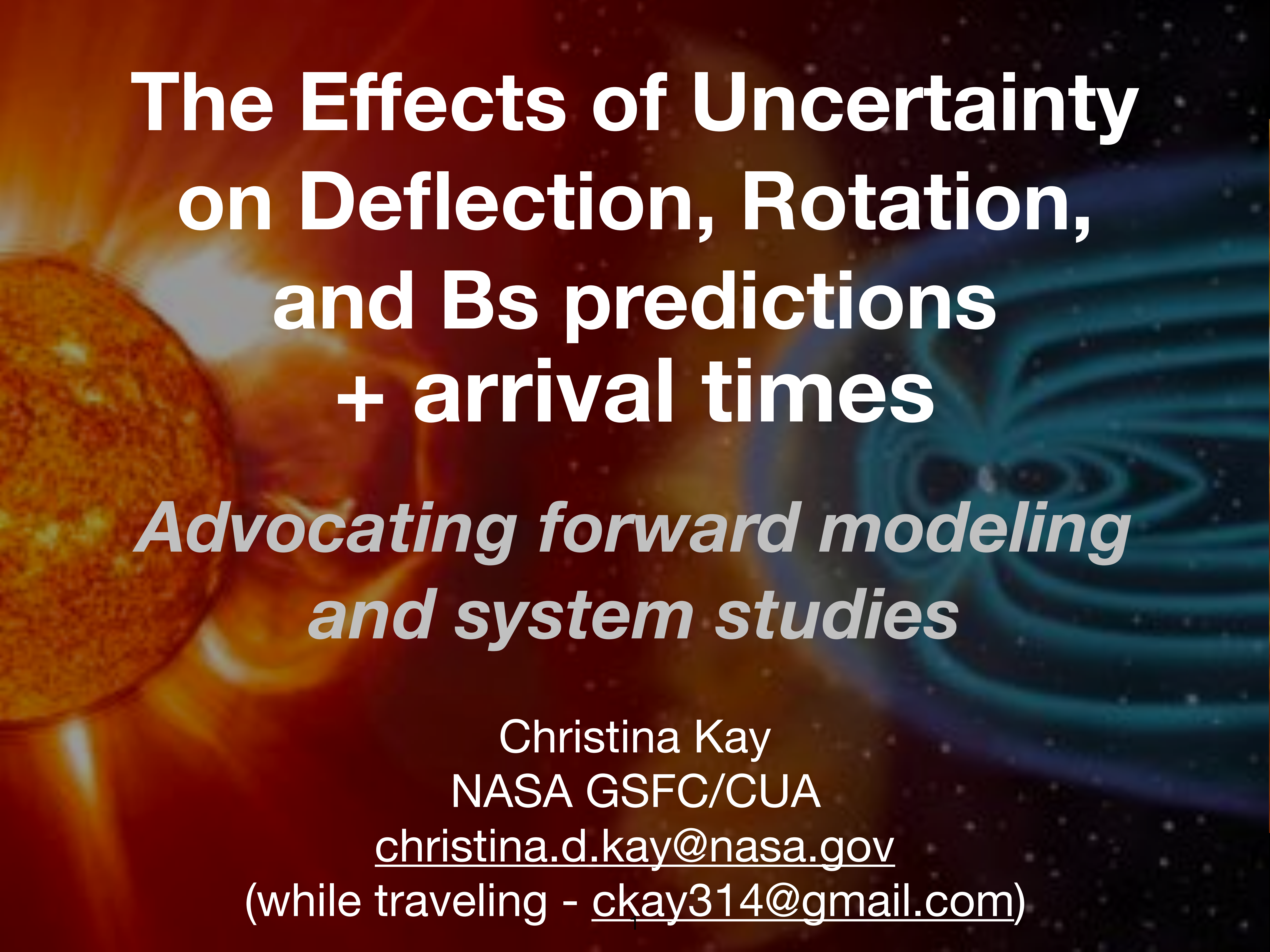
The presence of **southward** magnetic fields in ICMEs are the most important factor in producing **geomagnetic storms**.

WG5 aims to understand and reconstruct the possible flux rope **magnetic structure** of CMEs/ICMEs from observations and models. It also aims to **predict** the **intensity** and the duration of the **Bs** in ICMEs **upon arriving at the Earth**.

DIFFICULTIES ….

Summary of Talks

- Invitation talks by
  1. C. Kay on deflection , rotation and Bs prediction
  2. C. Scolini on EUHFORIA
- Seven other talks on various issues



The Effects of Uncertainty on Deflection, Rotation, and Bs predictions + arrival times

Advocating forward modeling and system studies

Christina Kay
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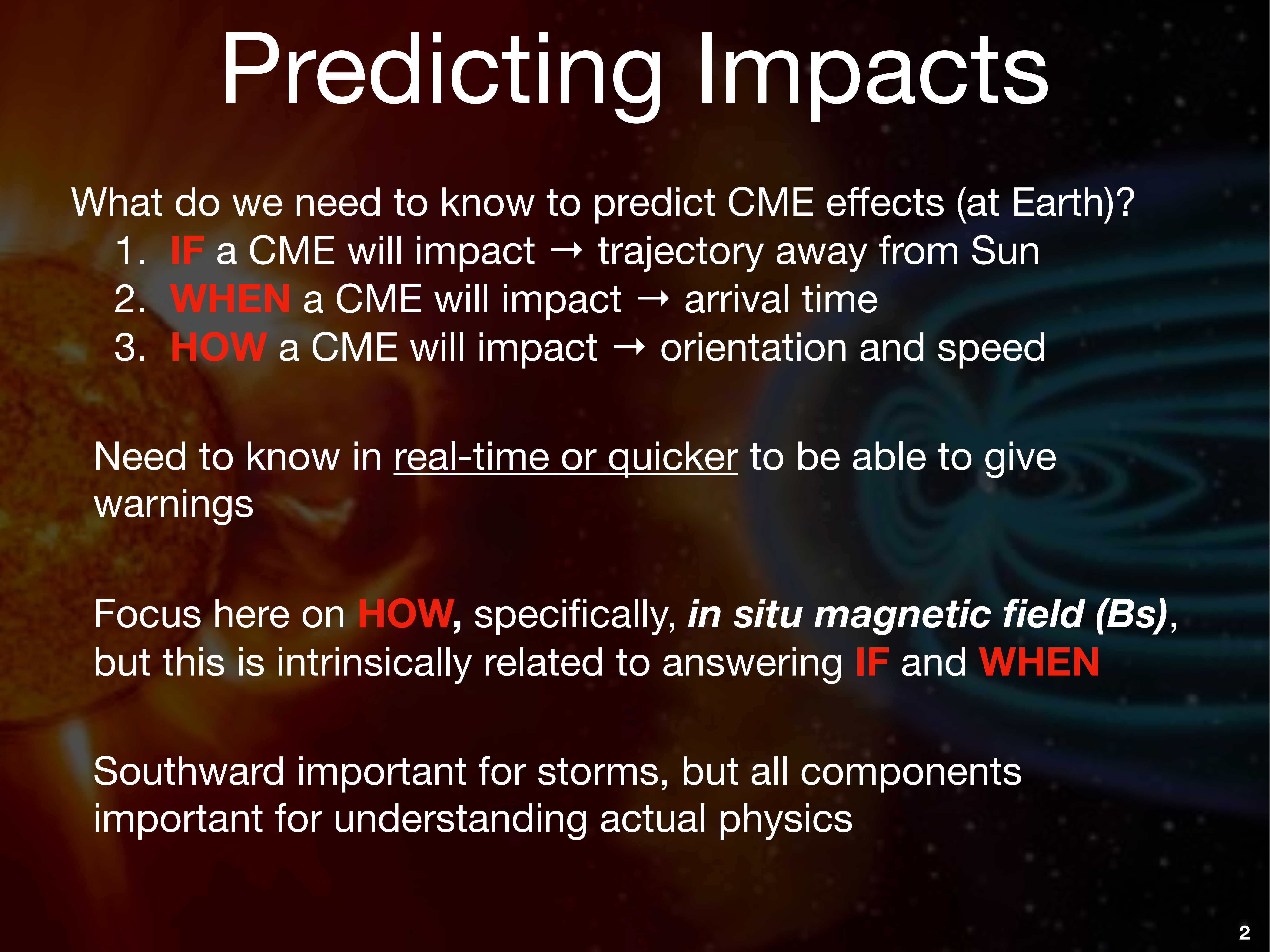
(while traveling - ckay314@gmail.com)

Predicting Impacts



What do we need to know to predict CME effects (at Earth)?

1. **IF** a CME will impact → trajectory away from Sun
2. **WHEN** a CME will impact → arrival time
3. **HOW** a CME will impact → orientation and speed

Need to know in <u>real-time or quicker</u> to be able to give warnings

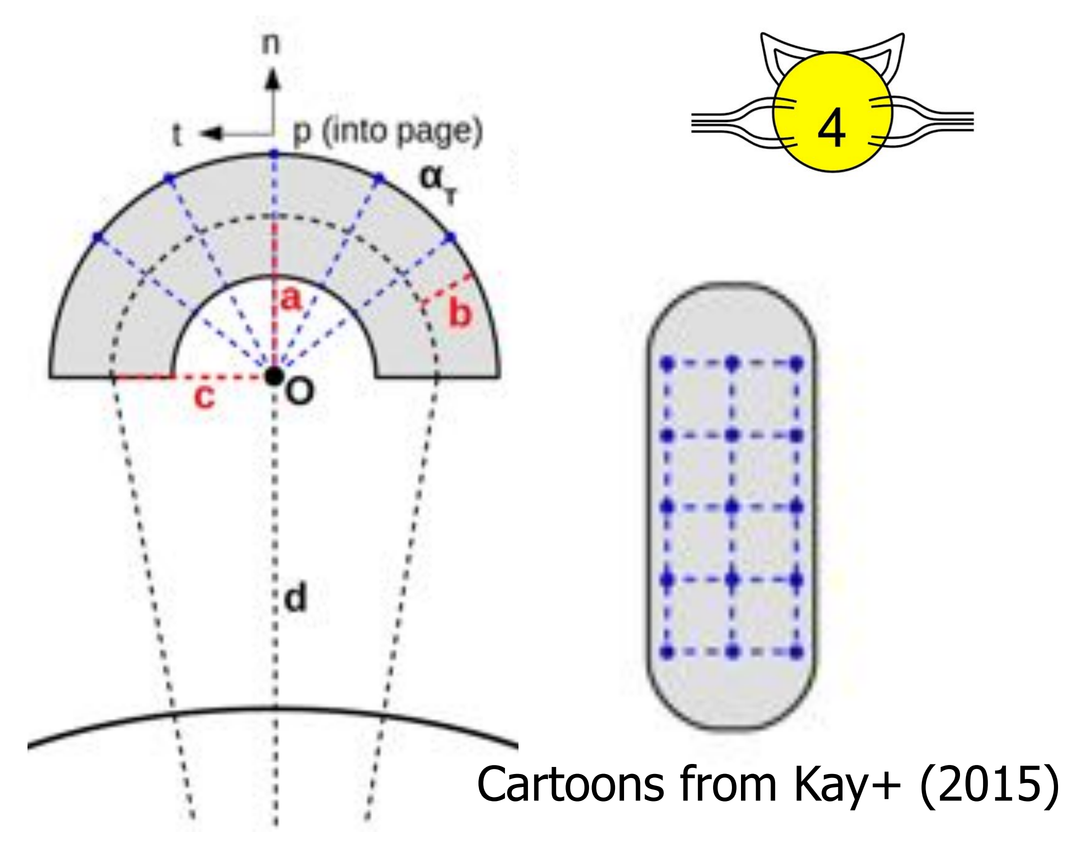
Focus here on **HOW**, specifically, ***in situ magnetic field (Bs)***, but this is intrinsically related to answering **IF** and **WHEN**

Southward important for storms, but all components important for understanding actual physics

ForeCAT Model

Forecasting a CME's Altered Trajectory

- Simple analytic model for CME deflection and rotation from JxB of external solar background (Kay+2015 - 3D version)
  - Rigid torus shape
  - Only external forces
  - Highly computationally efficient
- CME expansion and radial propagation from empirical models constrained by observations



Cartoons from Kay+ (2015)

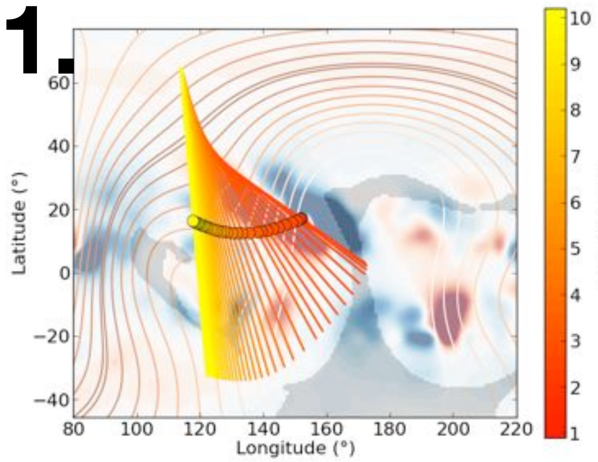
FIDO Model

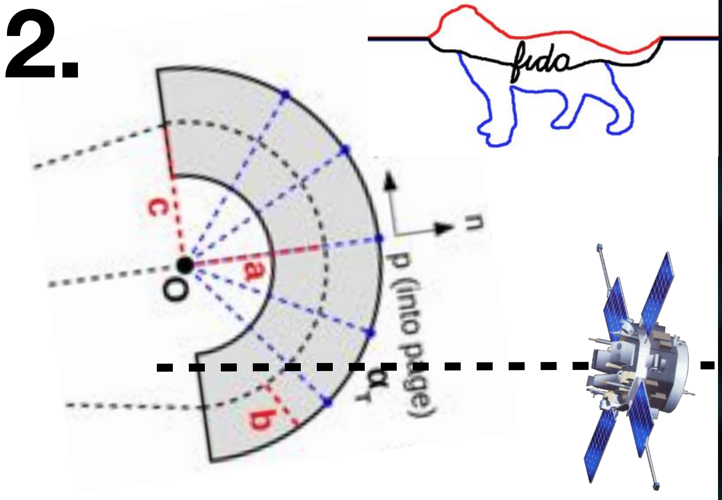
ForeCAT In situ Data Observer

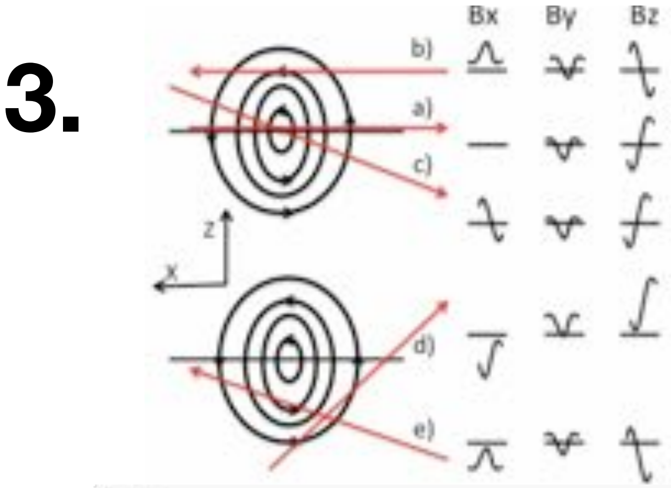
1. Take ForeCAT results for latitude, longitude, and tilt
2. Pass torus over spacecraft to get distance from torus axis
3. Apply simple flux rope model

- Aiming for ~hourly averages
- Total magnitude B_0 free parameter/automatically scaled

code available github.com/ckay314/FIDO

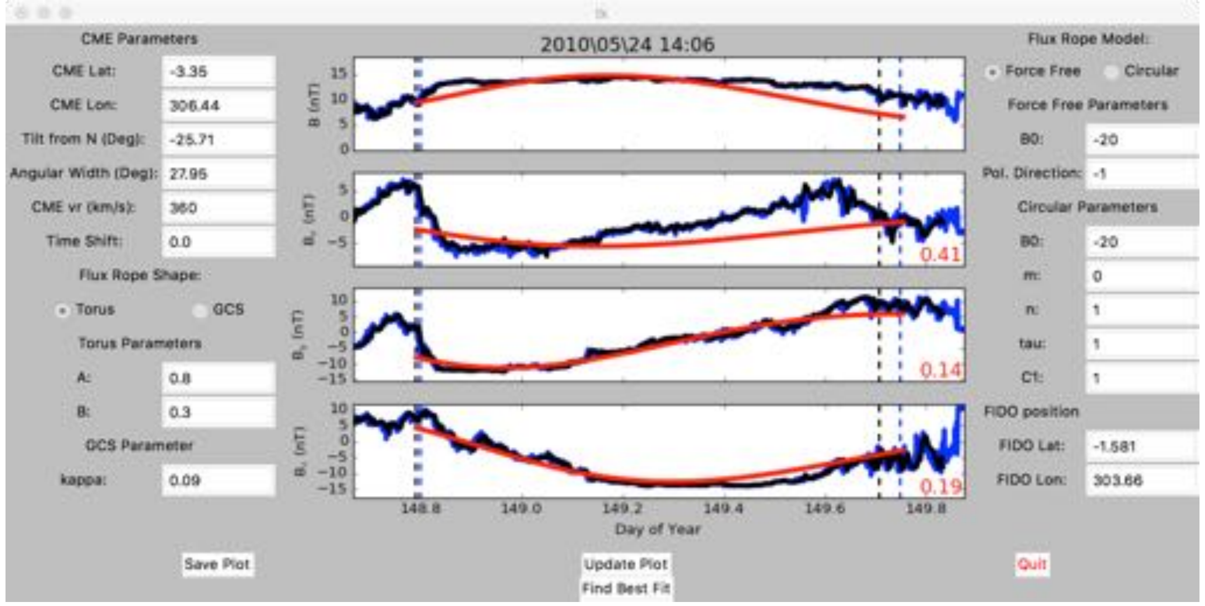






$$B_t = B_0 J_0 \left(\frac{2.4 d_t}{R_{CME}} \right)$$

$$B_p = B_0 H J_1 \left(\frac{2.4 d_t}{R_{CME}} \right)$$



CME Parameters

CME Lat: -3.35

CME Lon: 306.44

Tilt from N (Deg): -25.71

Angular Width (Deg): 27.95

CME vr (km/s): 360

Time Shift: 0.0

Flux Rope Shape:

● Torus ○ GCS

Torus Parameters

A: 0.8

B: 0.3

GCS Parameter

kappa: 0.09

Flux Rope Model:

● Force Free ○ Circular

Force Free Parameters

B0: -20

Pol. Direction: -1

Circular Parameters

B0: -20

m: 0

n: 1

tau: 1

C1: 1

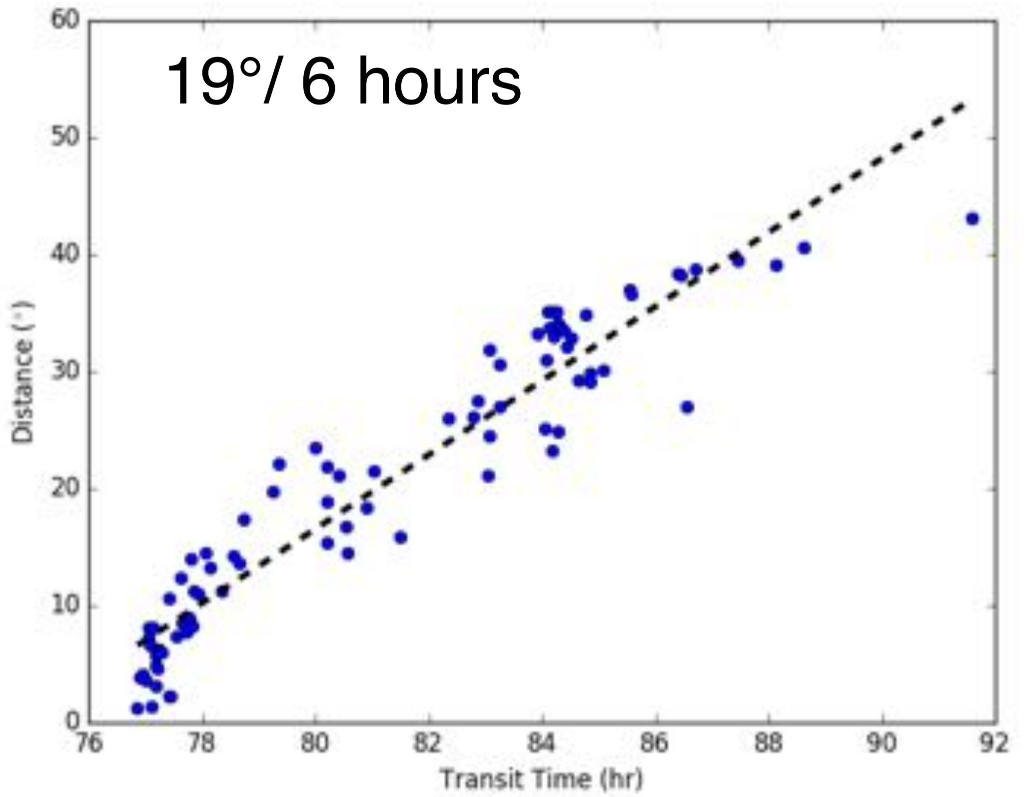
FIDO position

FIDO Lat: -1.581

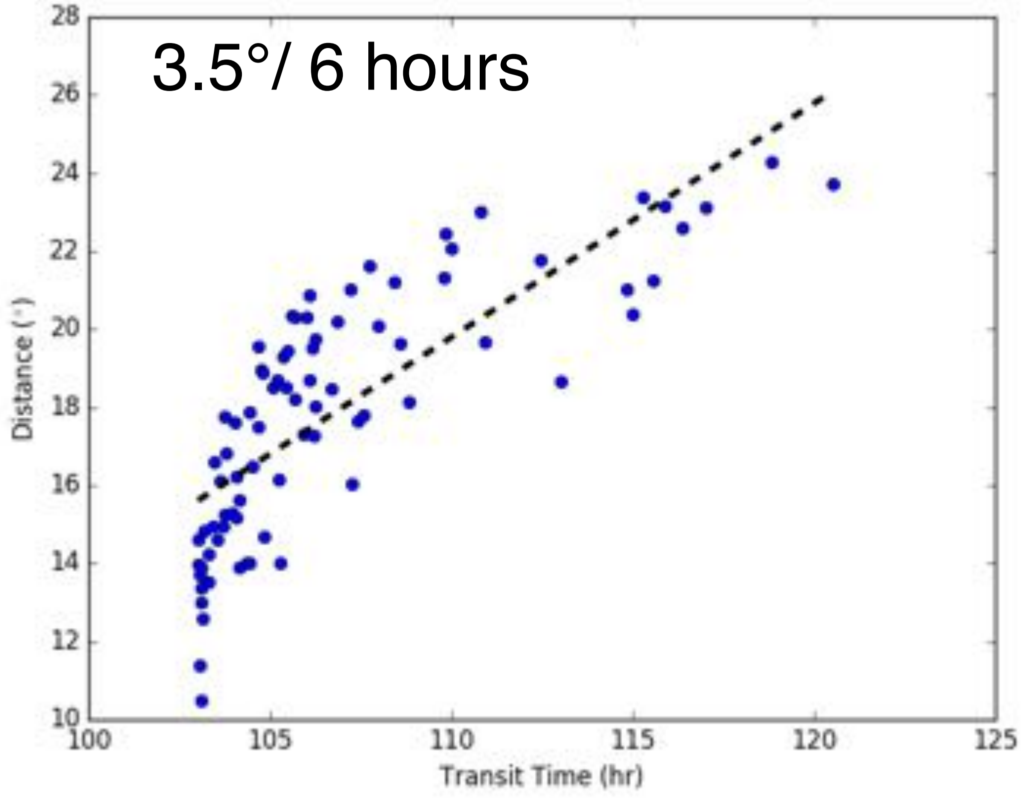
FIDO Lon: 303.66

Deriving Sensitivity

- Want to quantify *how accurately* CME position must be known for accurate arrival times
  - Determine change in CME position that corresponds to change of six hours (~average best-case error in field)



- Rate varies from case to case (0.5° to 19°)
  - Less sensitive near CME nose



- On average, 6 hours corresponds to about 8°
  - Very limited sample, not entirely linear, → order of magnitude estimate!

Summary

- Big picture studies can provide more insight than simply considering a small portion of a CME’s evolution
    - Combination of distances and observations + modeling
- Forward modeling can yield useful information about in situ magnetic field and arrival time
- Uncertainty in initial parameters can have large effects on results
    - Shown for model-driven forward modeling, certainly holds for (GCS) reconstruction-driven results
- In the future, using distribution of ensemble results will allow for assigning probability to predictions

Observation-based Sun-to-Earth simulations of geo-effective CMEs with EUHFORIA

Camilla Scolini[1,2]

and

F. P. Zuccarello[1], L. Rodriguez[2], S. Poedts[1], C. Verbeke[1], E. Palmerio[3],
M. Mierla[2], J. Pomoell[3]

[1]KU Leuven, Belgium
[2]Royal Observatory of Belgium, Belgium
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Motivation & outline

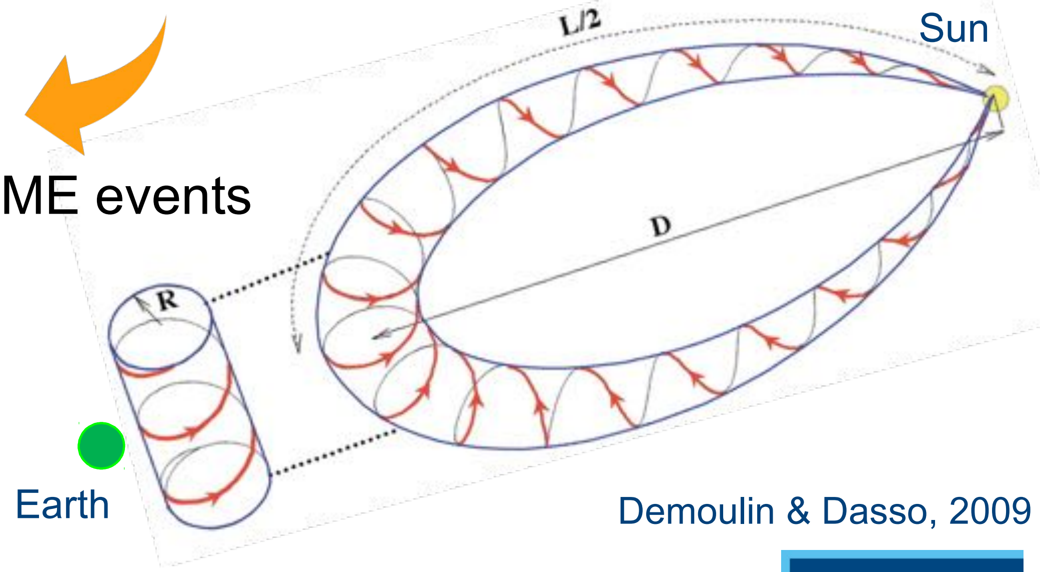
1) EUHFORIA: newly developed solar wind and CME propagation model designed for space weather purposes (Pomoell & Poedts 2018)

- ○ **Flux-rope CME models** (spheromak and Gibson-Low) recently implemented (Verbeke et al 2018, in prep)

→ Goal of **this study:** assessing the predictive capability of the new flux-rope models at Earth (ICME and ICME geoeffectiveness), based on CME observations at the Sun

2) ISEST WG4 campaign events:
textbook (T) and problematic (P) CME events

- ○ July 12, 2012 (T)
- ○ March 15, 2013 (T?)
- ○ September 9-10, 2014 (P)

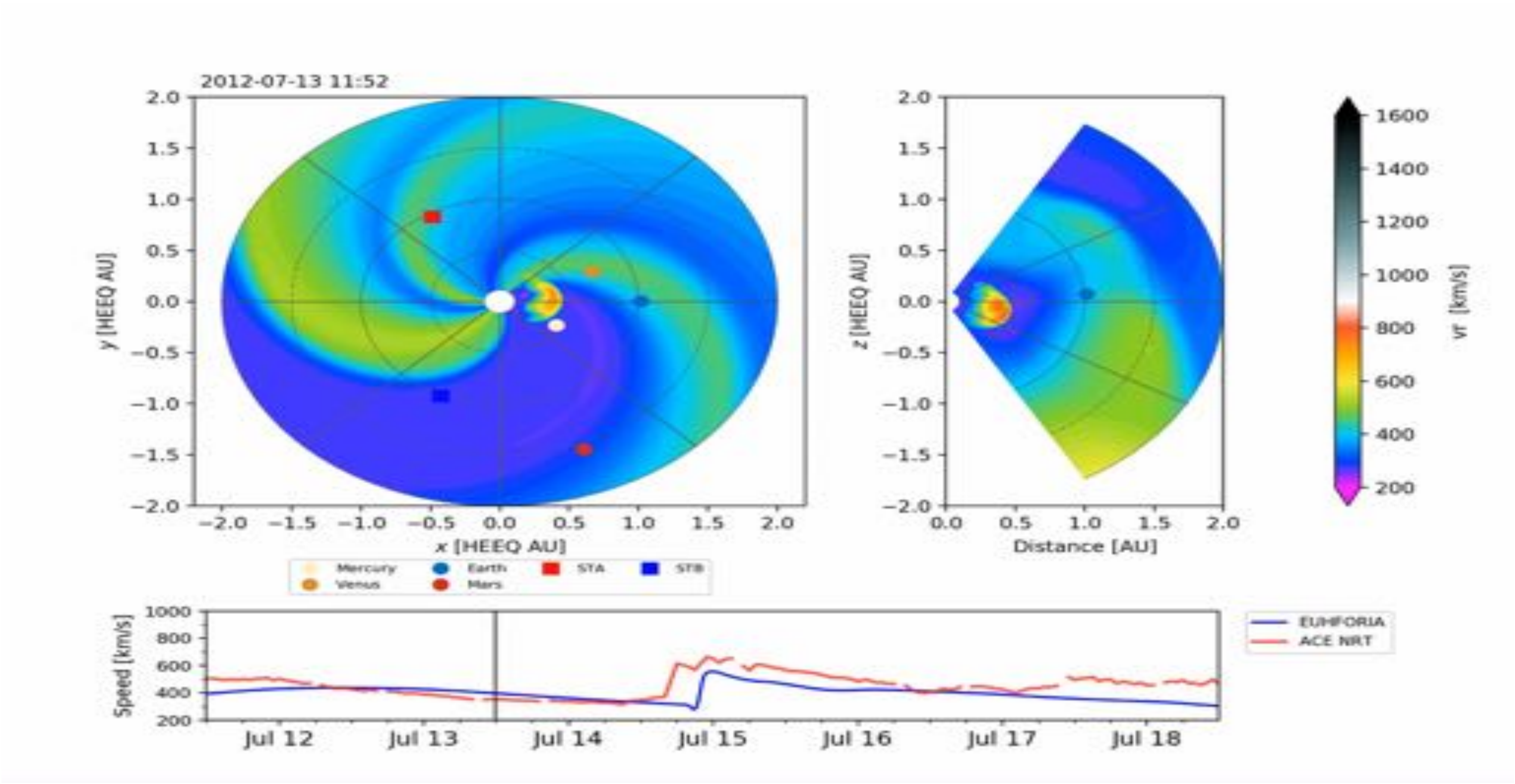


Demoulin & Dasso, 2009

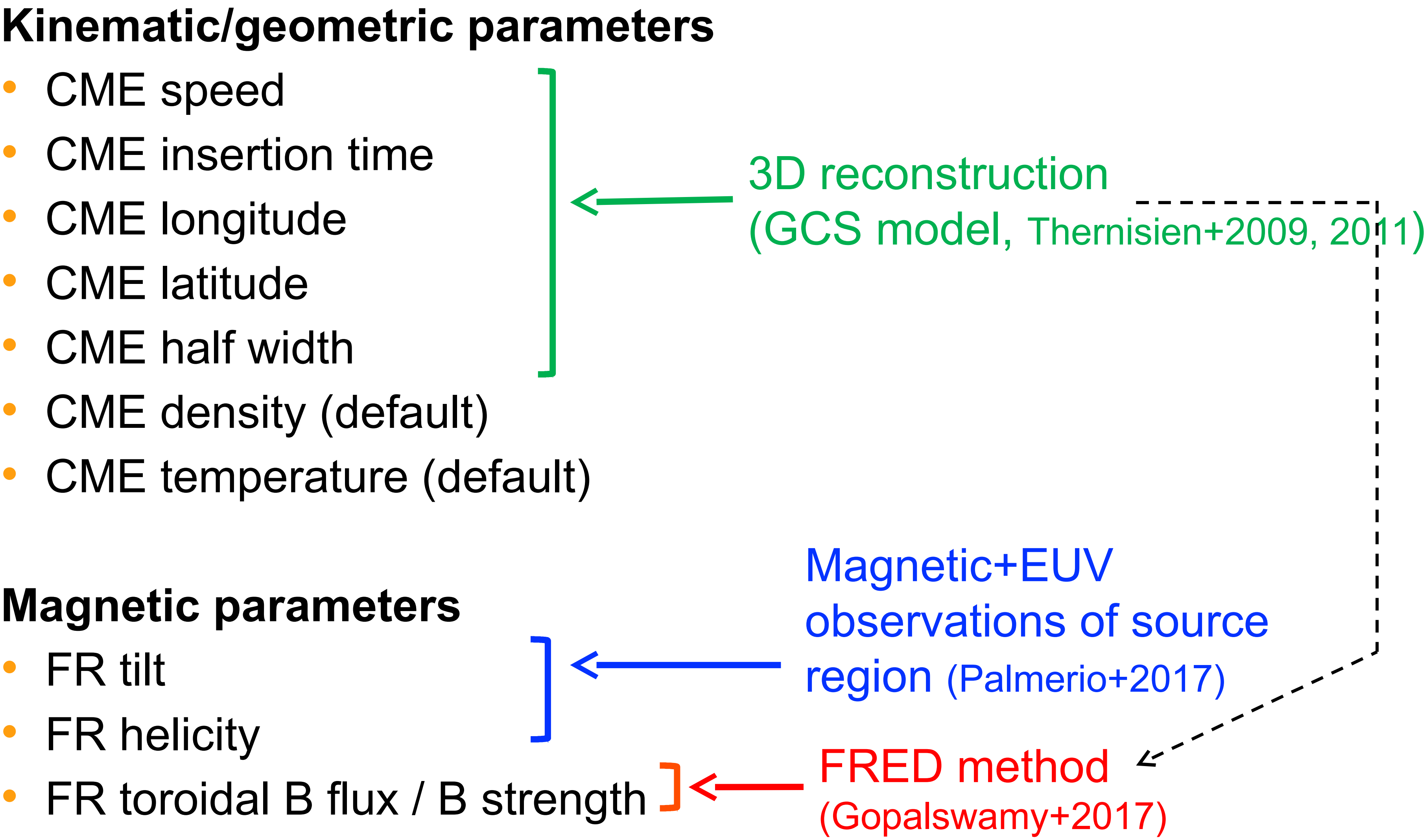
Pomoell & Poedts (2018, JSWSC)

EUHFORIA

- 3D coronal and heliospheric model
  - Corona (up to 0.1 AU): magnetogram + semi-empirical WSA model
  - Heliosphere (0.1 AU to 2.0 AU): time-dependent 3D MHD model
  - CME models: cone CMEs or **flux-rope CMEs**



CME parameters at 0.1 AU



Kinematic/geometric parameters

- CME speed
- CME insertion time
- CME longitude
- CME latitude
- CME half width
- CME density (default)
- CME temperature (default)

3D reconstruction
(GCS model, Thernisien+2009, 2011)

Magnetic parameters

- FR tilt
- FR helicity
- FR toroidal B flux / B strength

Magnetic+EUV observations of source region (Palmerio+2017)

FRED method
(Gopalswamy+2017)

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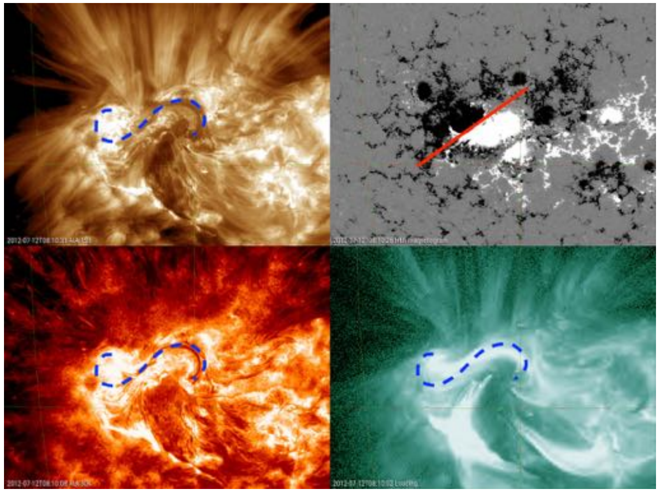
Magnetic parameters

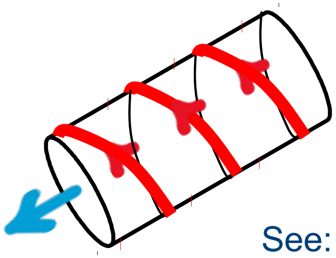
FR tilt and chirality

- EUV / X-ray sigmoid



→ Tilt/orientation: -135°

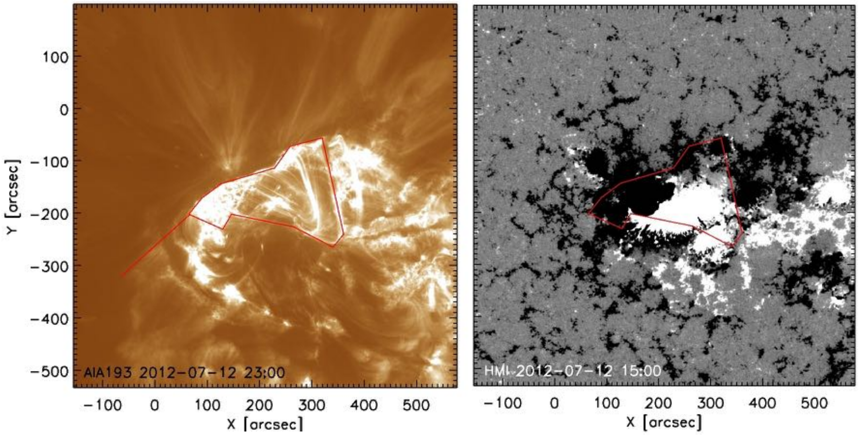
→ Helicity: +1 (right-handed)



See: Palmerio+2017, 2018

FR magnetic field strength (FRED method)

- Eruption near the solar disk center (small projection effects)
- Stable, long-lasting PEA



→ Toroidal B flux = 7 x10^{13} Wb

@ 14.6 R_s (±30% uncertainty; Pal+2017)

See: Gopalswamy+2017

CONCLUSIONS

First **observation-based** study of **magnetized CMEs** and their **impact on Earth** with EUHFORIA

Translating observations into a proper set of CME input parameters is non trivial

- Cone CMEs and flux-rope CMEs need to be initialized in different ways (separation between Vexp / Vrad needed)

How much do we improve using a flux-rope CME model?

- Up to +40%(min Bz)/+80%(min Dst) compared to cone model (2012-07-12)
- Modelling geoeffective sheaths beyond tested capabilities (2014-09-10)
- Flux-rope results vary significantly moving around Earth by just few degrees (2013-03-15)

Textbook events can be more complicated than expected (2013-03-15)

Uncertainty quantification needed to assess the quality of a prediction

- Uncertainty on observational parameters can be large (magnetic parameters)
- Parameter study to assess model sensitivity (work by C. Verbeke)

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What can we learn from coronal dimmings about the early evolution of Earth-directed CMEs?

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[3] Skolkovo Institute of Science and Technology, Russia

ISEST Workshop, Hvar, September 25, 2018

FWF Der Wissenschaftsfonds.

FFG

Summary

- performed statistical analysis on 62 dimming/flare/Earth-directed CME events
- If CMEs occur together with flares, coronal dimming statistically reflect properties of both phenomena
- The area of the total dimming, i.e. including both core and secondary dimmmings, its total brightness and the total unsigned magnetic flux show the highest correlations with the flare fluence (c>0.7) and the CME mass (c>0.6)
- Their corresponding time derivatives, describing the dimming dynamics, strongly correlate with the GOES flare class (c>0.6) and the maximum speed of the CME (c~0.6)
- balance between positive and negative magnetic flux within the dimming regions as well as the strong correlation between the flare reconnection fluxes → same amount of magnetic flux is added to the erupting structure that is reconnected during the associated flare (Lin et al. 2004)
- results confirm feedback relationship between flares and CMEs (Vršnak et al. 2008, 2016)

detection method: Dissauer et al. 2018a, arXiv:1802.03185

dimming-flare relationship: Dissauer et al. 2018b, arXiv:1807.05056

dimming-CME relationship: Dissauer et al. 2018c, submitted to ApJ

Clustering of Coronal Mass Ejections

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Cristina Cadavid and Michael Artinian

HelioResearch and
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ISEST Workshop, Hvar, Crovatia, September 2018

Conclusions

✓ The Max Spectrum defines two scaling exponents of extreme events: α (tail exponent) and θ (extremal index, $1/\theta$ is mean number of CME in a cluster)

✓ The cumulative distribution of fast CMEs speeds asymptotically follows a power law with $\alpha \approx$ 3.2-3.7 (Fréchet extremes). This exponent defines *the distribution of high speeds, i.e. a range of fast CMEs.*

✓ The fast CMEs (and extreme SEPs associated with them) come in clusters with $\langle\theta\rangle = 0.5$: If one fast CME occurs it is followed on average by one or two other fast CME in a relatively short time. The mean time between CMEs with speeds exceeding 1,000 km/s is 42 hrs.

✓There are indications that clusters of fast CMEs originate from the complex active regions (clusters of active regions).

XVIth Hvar Astrophysical Colloquium
International Study of Earth-affecting Solar Transients
ISEST 2018 Workshop
24 - 28 September 2018, Hvar, Croatia

Features of spectral-polarization dynamics of flare active regions by microwave observations

Tatiana Kaltman, Vladimir Bogod, Anton Storozhenko

Russian Academy of Sciences
Special
Astrophysical Observatory

Summary

- The RATAN-600 archive of daily solar observations starting from 1997 (9-13 UT in the range from 1.67 cm up to 32 cm with left and right circular polarization) is open for investigations.
- Several solar events based on regular observations with RATAN-600 radio telescope are presented.
- The spectral-polarization observations over a wide wavelength range reveal numerous intensity and polarization effects reflecting the characteristics of active regions at the pre-flare, flare and post-flare stages.
- The frequency range covers the gyroresonance emission from all the active regions, corresponding to the magnetic field strengths found in the corona (up to 2500 G), and other emission mechanisms, being able to indicate the preflare state and monitor the solar flare activity.

On the role of the magnetic cloud topology on galactic cosmic-ray Forbush decreases at energies above 70 MeV

Simone Benella[1], Catia Grimani[1], Monica Laurenza[2] and Giuseppe Consolini[2]

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Conclusions and future work

- Generally, the shock/sheat region and the magnetic cloud have comparable effects on the GCR modulation. Indeed LPF measured a 7% variation during the shock/sheat part and a 3% variation due to the magnetic cloud transit.
- In the numerical simulation the particle count variation along the LPF path is about 20% with an isotropic flux of particles entering the magnetic cloud from all directions with zero magnetic field outside.
- The profile of GCR variation observed on LPF is well reproduced by the simulation, this seem to be addressed by the magnetic configuration of the region explored by the s/c.

Statistical analysis of recurrent and sporadic Forbush decreases at different phases of solar ativity

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Pushkov Institute of Terrestrial Magnetism, the Ionosphere and Radio Wave Propagation Russian Academy of Science (IZMIRAN)

- Medians of FD magnitude are greater at high solar activity. Distributions of FD and SW parameters differ for recurrent and sporadic FDs.
- FDs in solar cycle 24 and in the minimum between cycles 23 and 24 are mainly caused by HSS from CHs, in the maximum of cycle 23 - by ICMEs.
- FD parameters are greater for sporadic FDs. This difference is larger in the maxima of cycles 23 and 24 than in the minimum between the cycles.
- IMF is greater for sporadic FDs in the maxima of cycles 23 and 24 and is practically the same for the two groups of events in the minimum. IMF for sporadic events is much smaller in cycle 24 than in cycle 23.
- SW velocity is in average larger for recurrent FDs. This velocity is greater for sporadic FDs at the maxima of cycles 23 and 24 and for recurrent FDs in the minimum between the cycles. The velocity is lower for both groups of FDs in recent cycle than in previous one.
- In the maximum of cycle 23, sporadic FDs develop much faster than recurrent ones; in the maximum of cycle 24 and in the minimum between the cycles, the duration of main phase is approximately the same for recurrent and sporadic FDs; this duration is shorter during the maxima of cycles 23 and 24 than during the minimum between the cycles for both groups of events.

Long-term periodicities in the heliospheric magnetic flux density

Melinda Dósa and Géza Erdős

Wigner Research Centre for Physics
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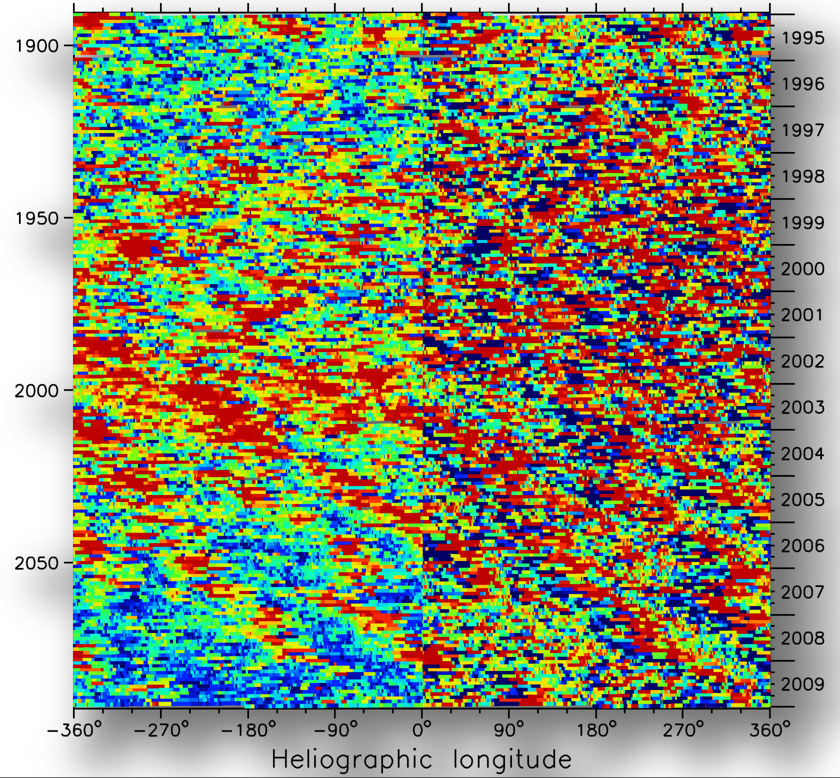
Hvar 2018, Croatia

Conclusions, further questions



Recurrent flux enhancements are associated with high speed solar wind (CIRs).

The recurrence rate of high speed streams and magnetic sectors in not the same

- Major reorganization of the solar magnetic field?
- Are there coronal hole pairs in northern and southern hemisphere on similar longitude?
- Are there active longitudes in the corona?

Solar Radio Imaging-Spectroscopy and Heliospheric Imager

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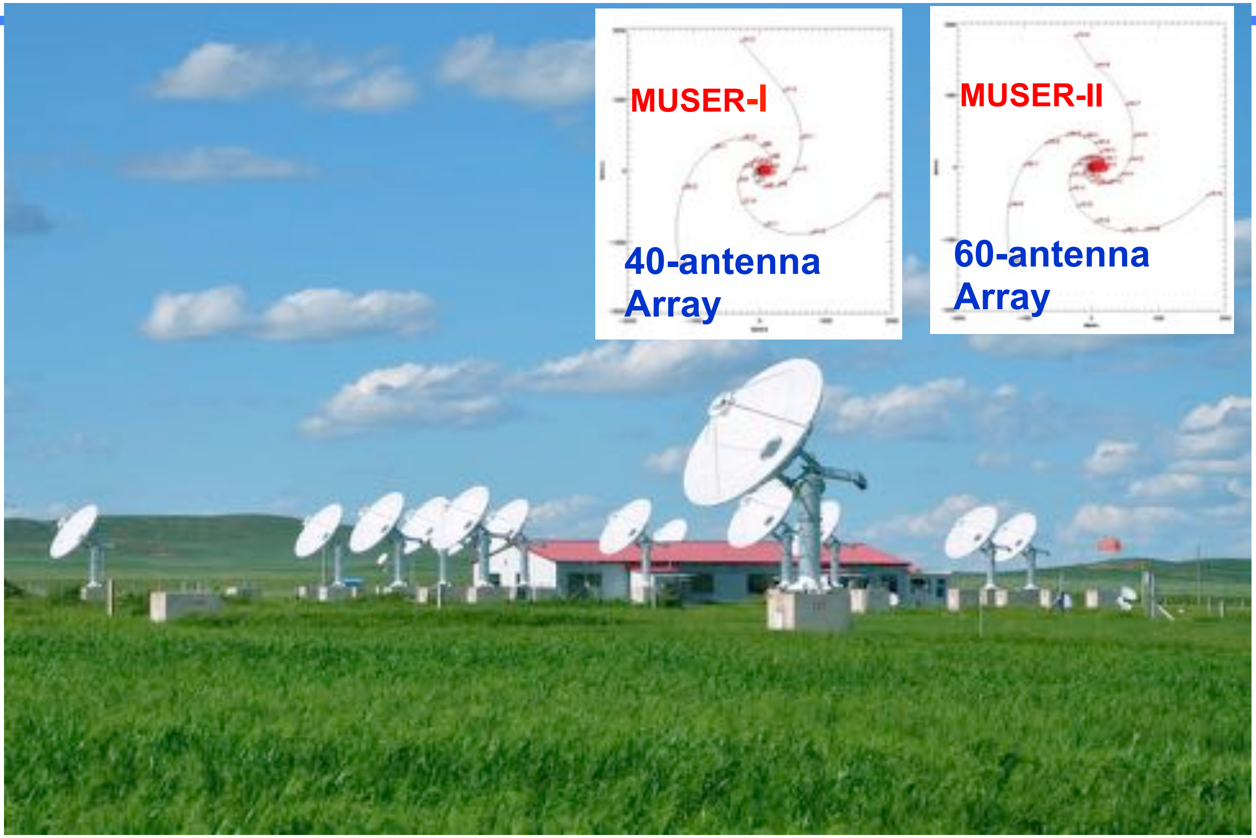
National Astronomical Observatories, CAS, Beijing, China
2) University of Chinese Academy of Sciences, Beijing, China

25 Sept 2018 XVIth HAC: ISEST 2018 Workshop, 24-28 Sept 2018, Hvar, Croatia

MUSER - Mingantu Spectral Radiheliograph



MUSER:

64 channels in 0.4-2.0 GHz & 520 channels in 2.0-15 GHz

space resolution: 1.3″-50″

time resolution: ~ 25 & ~200 ms

Meridian-II Project

National Science Infrastructure Project under “13th 5-year plan” program (2016-2020) has been approved.

Solar & Interplanetary Subsystem as a new part in Meridian-II:

- **Metric & decametric arrays in Tibetan Plateau (by NSSC) & Mingantu**
- **IPS telescope with 3 sites and 2 frequencies including major one at Mingantu**

Use 2 20 m antennas for MUSER-I Calibration

Add 2-3 ~15 m antennas for MUSER-II Calibration

Summary

- **Solar & Interplanetary sub-system has been included in Meridian-II project**
- **Solar Radio observing facilities will play important role in future space weather studies and monitors. Observations with PSP, Solar Orbiter**
- **A part of WIPSS**

The Workshop on Solar Radio and IPS Data Analysis, Tongliao, Inner Mongolia, China, 15-18 October 2018.
(http://wsrips2018.csp.escience.cn/dct/page/1)