Forward modeling of coronal mass ejection flux ropes in the inner heliosphere with 3DCORE

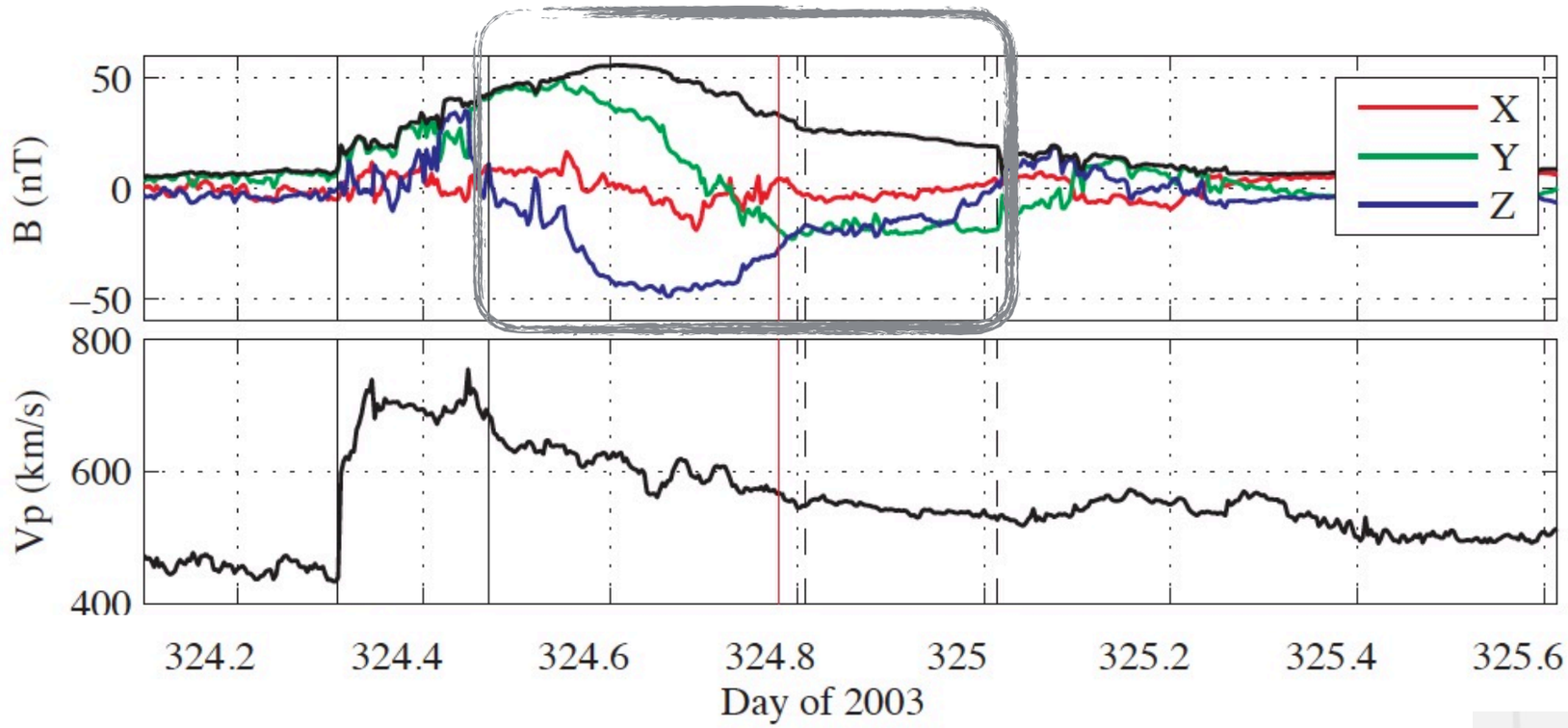
Christian Möstl, Tanja Amerstorfer, Erika Palmerio, Alexey Isavnin, Charles J. Farrugia, Chris Lowder, Reka Winslow, Julia M. Donnerer, Emilia Kilpua, and Peter D. Boakes

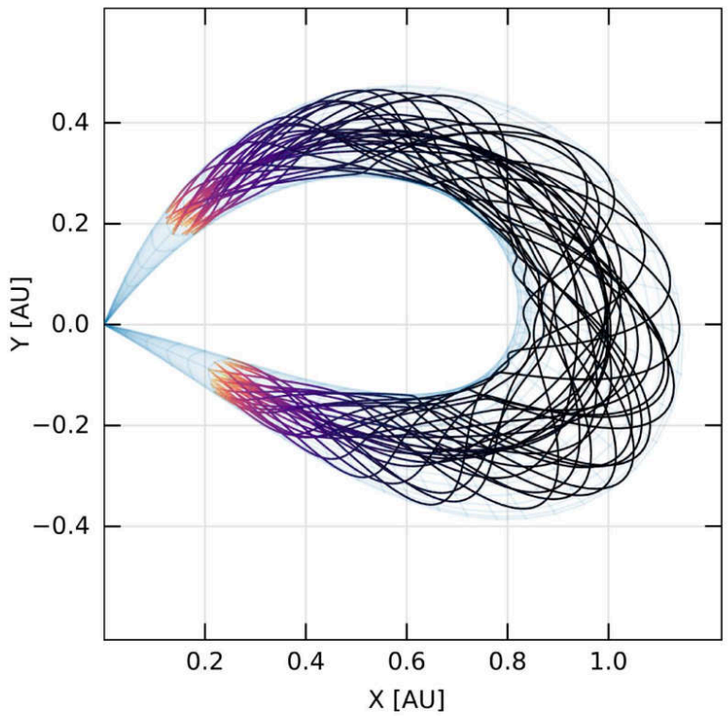
christian.moestl@oeaw.ac.at

ÖAW ÖSTERREICHISCHE AKADEMIE DER WISSENSCHAFTEN

IWF INSTITUT FÜR WELTRAUMFORSCHUNG

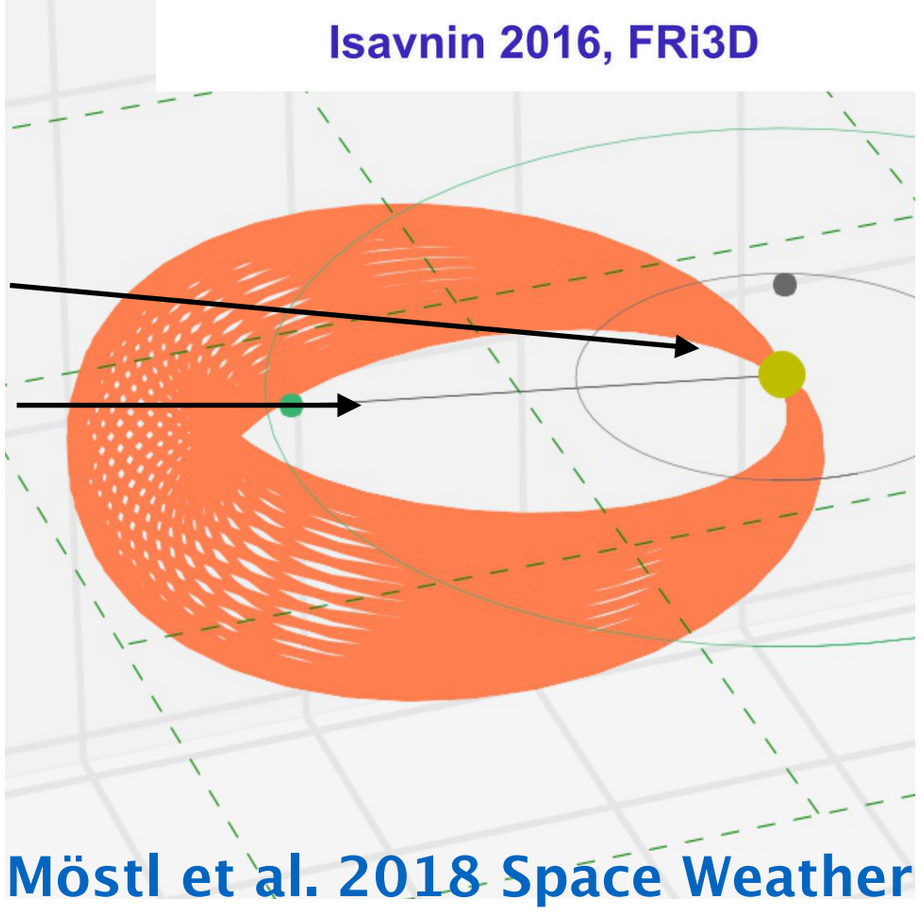
Bz problem





Semi empirical CME flux rope models:

- able to make magnetic field predictions
- 3D trajectory effects
- very quick computation times
- start with outer coronagraph field of view



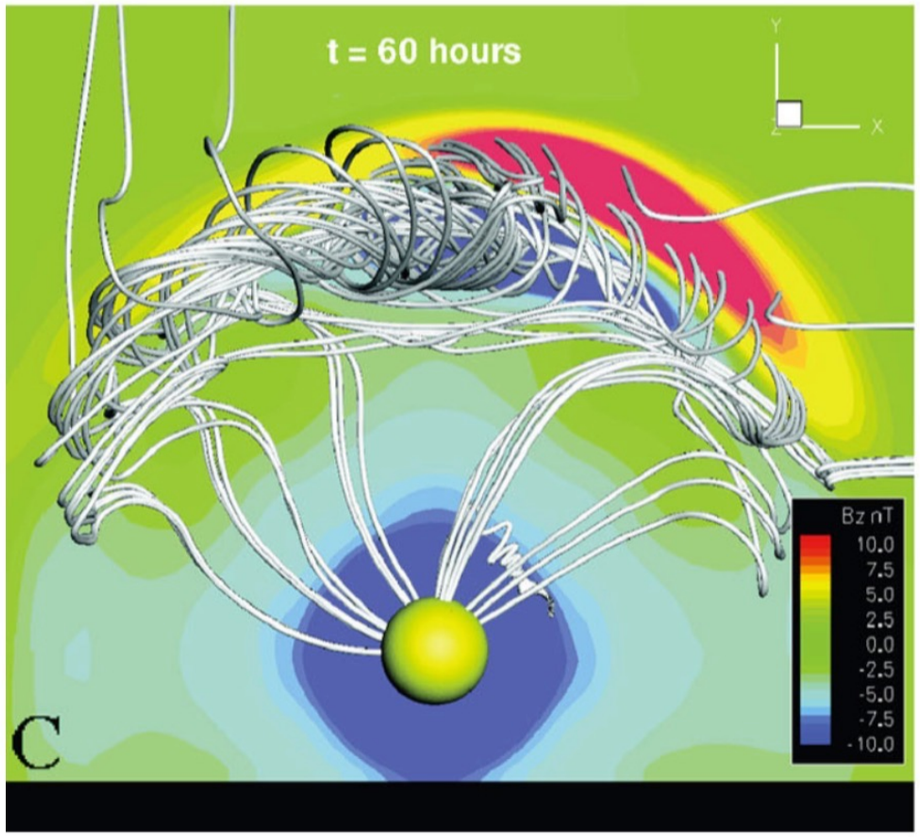
ICME physics

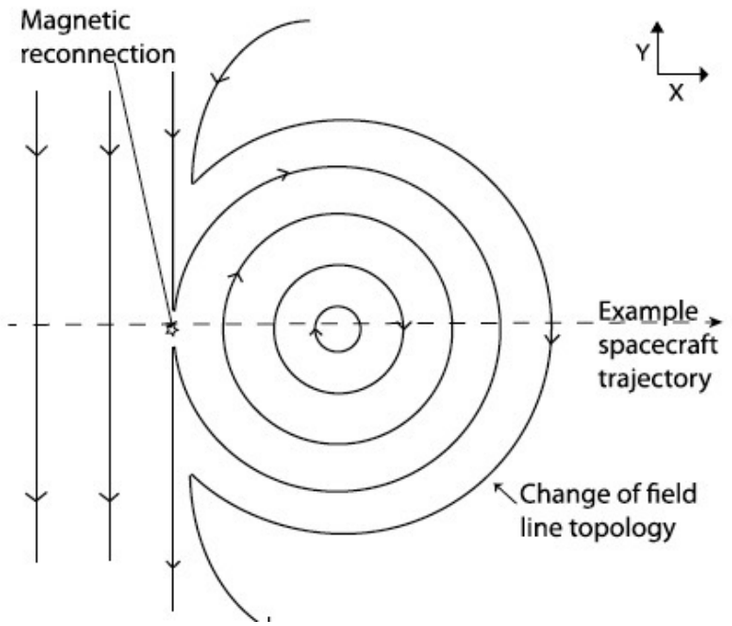
- **Included:**
- **Deflection, channeling in the corona (IP unclear)**
- **Rotation in the corona (IP unclear)**
- **Expansion, decline of magnetic field**
- **Solar wind drag**
- **Pre-conditioning of solar wind**

Not included:

- **Flattening (next step)**
- **Flux rope erosion**
- **CME-CME interaction, CME-CIR interaction**

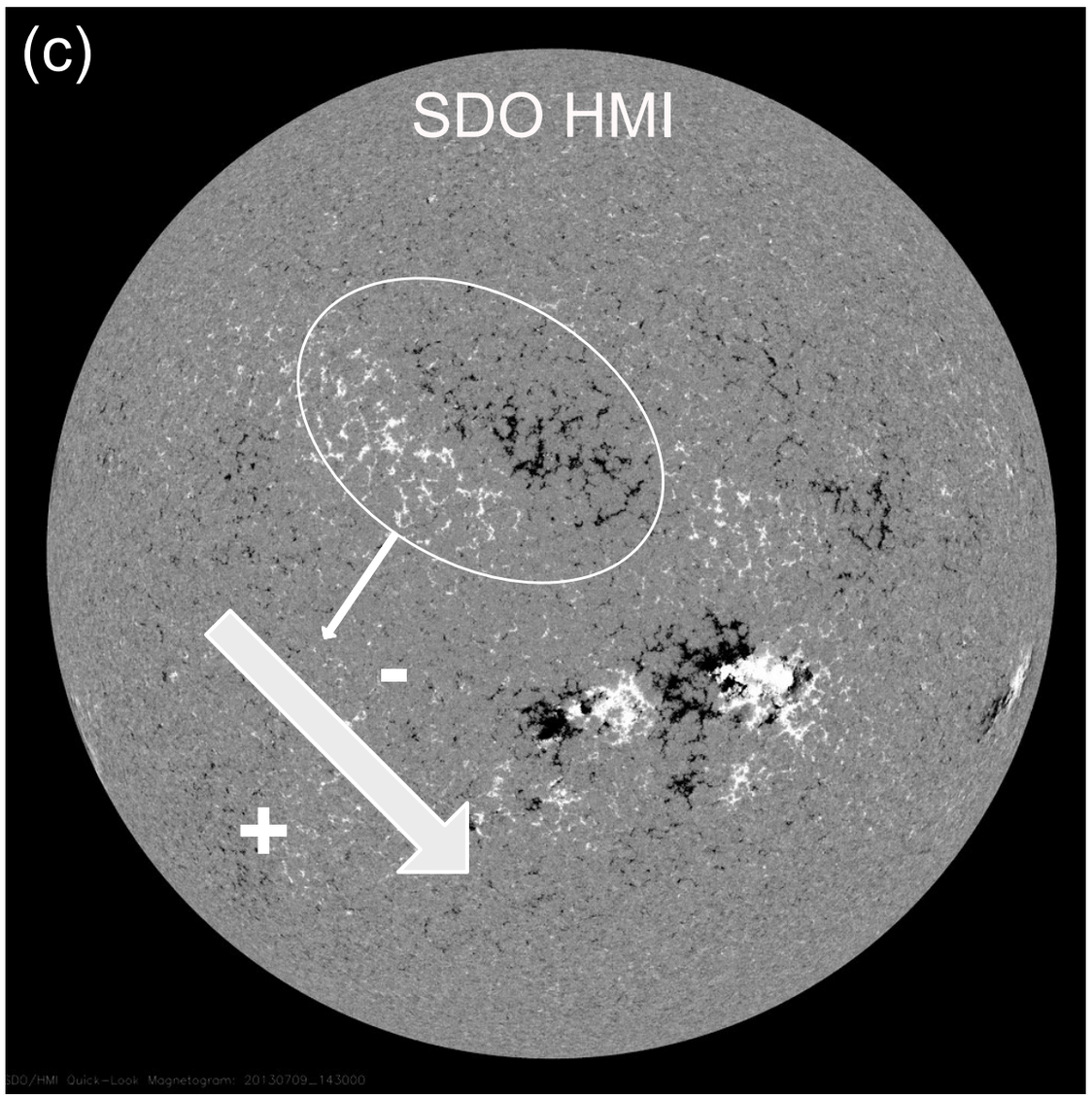
- **Manchester, Kilpua, Liu, Lugaz, Riley, Török, Vrsnak 2017 Space Sci. Rev.**

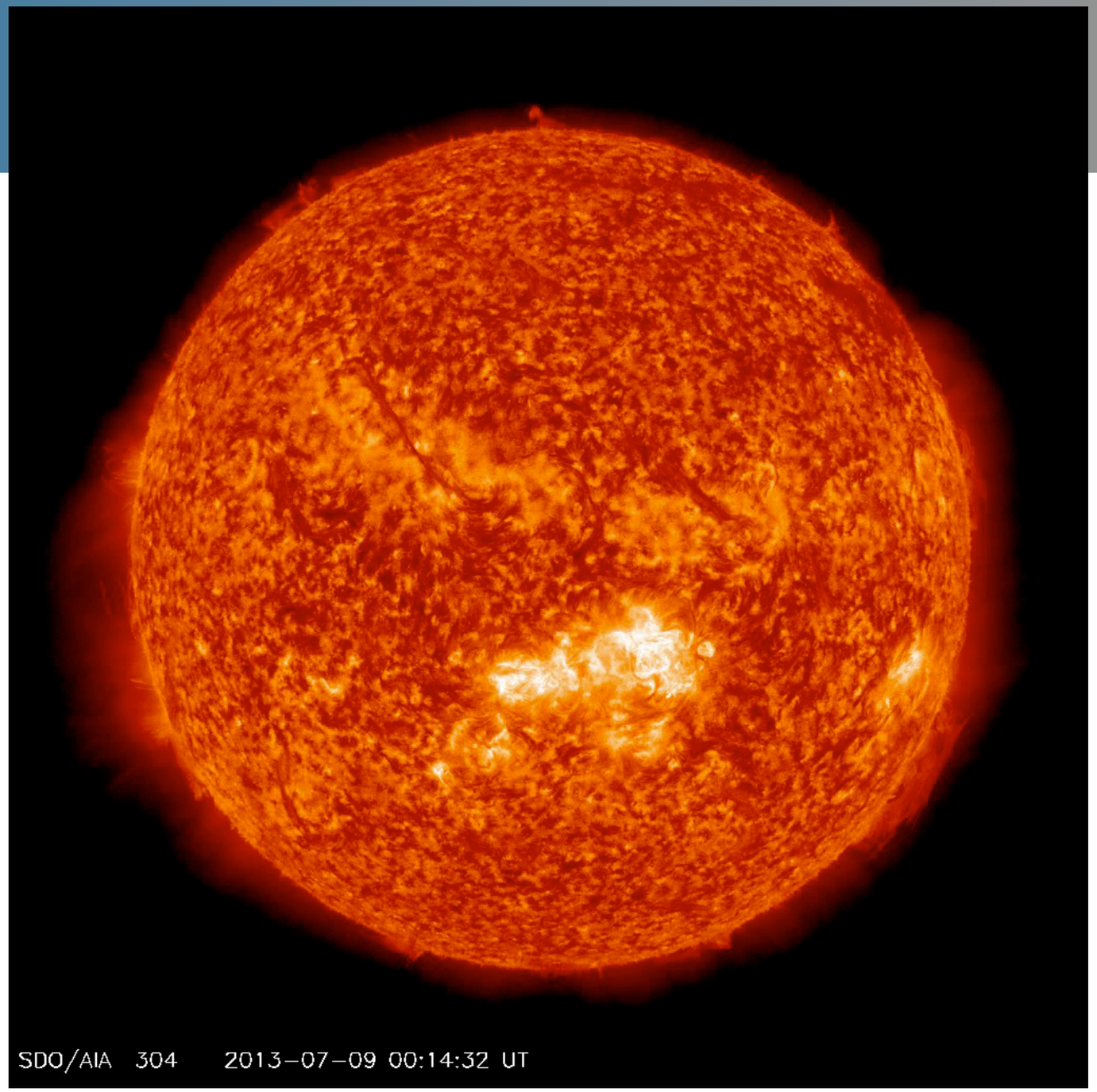




Solar Source

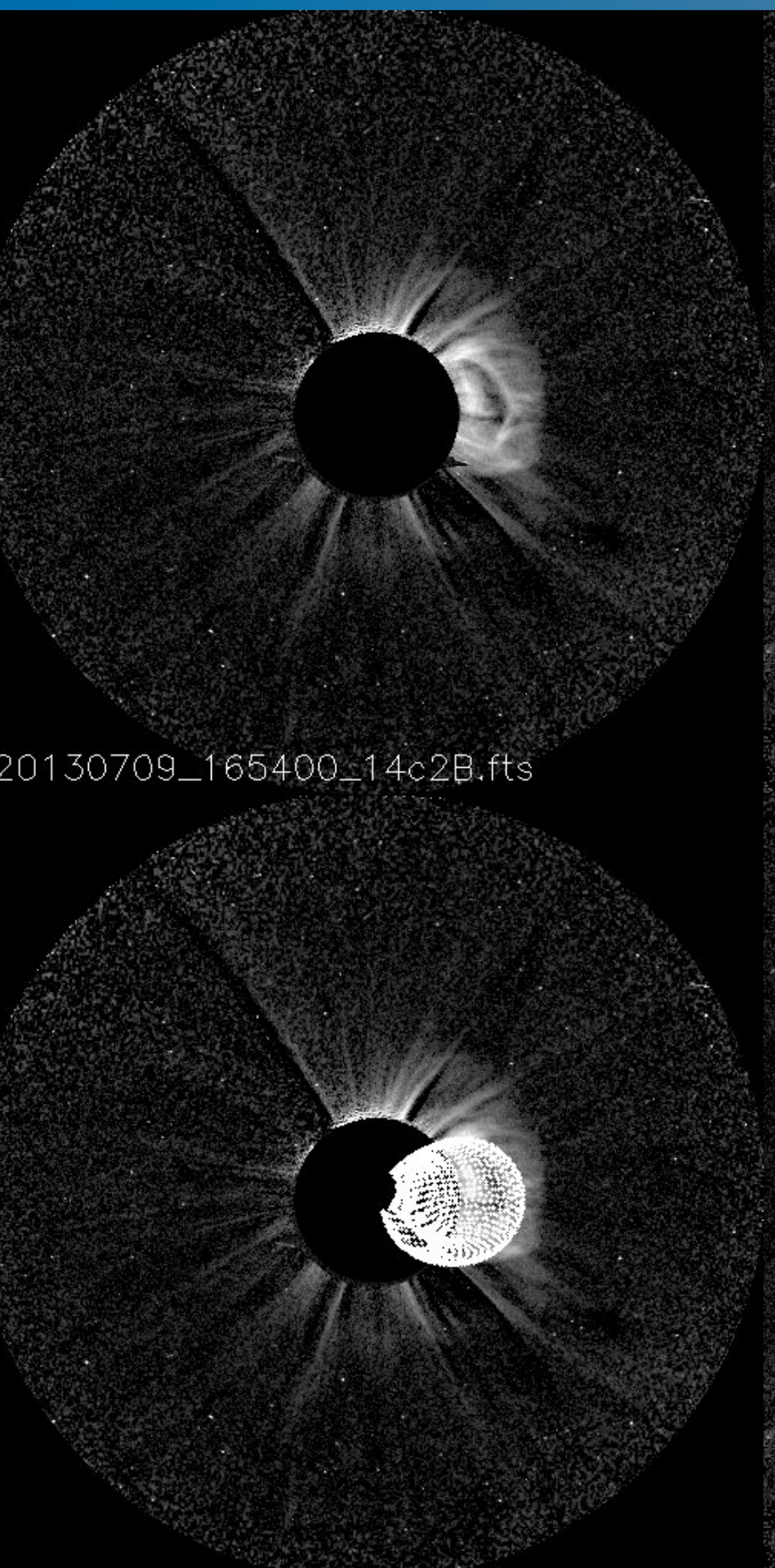
- CME event July 9–13 2013
- **Möstl et al. 2018, Space Weather, open access/arXiv**





- **Palmerio et al. 2018 Space Weather/arXiv**
- magnetic structure, left handed, axial field to southwest
  (follows northern hemisphere rule)

GCS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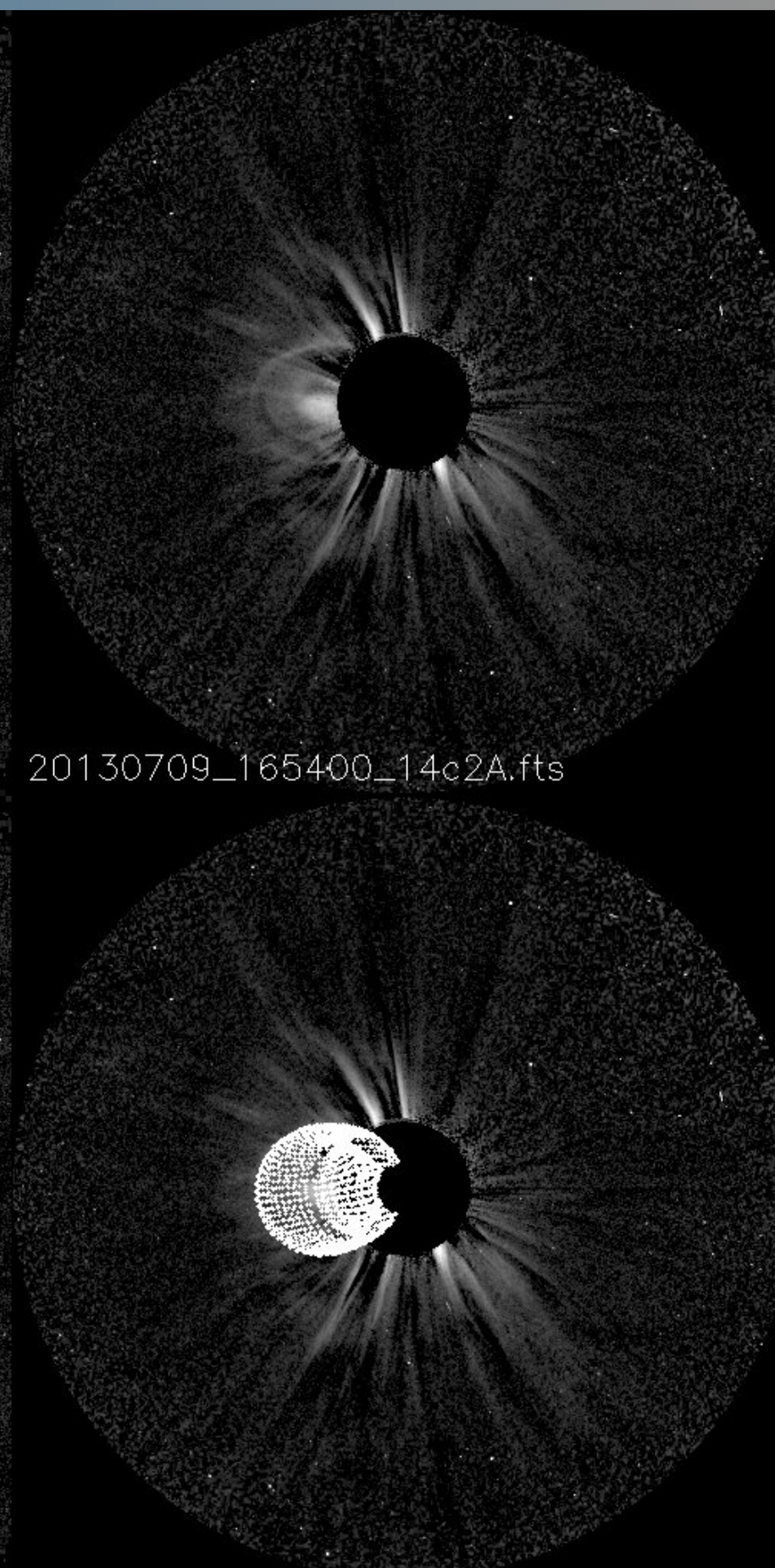
LASCO C2: 2013/07/09 16:58:41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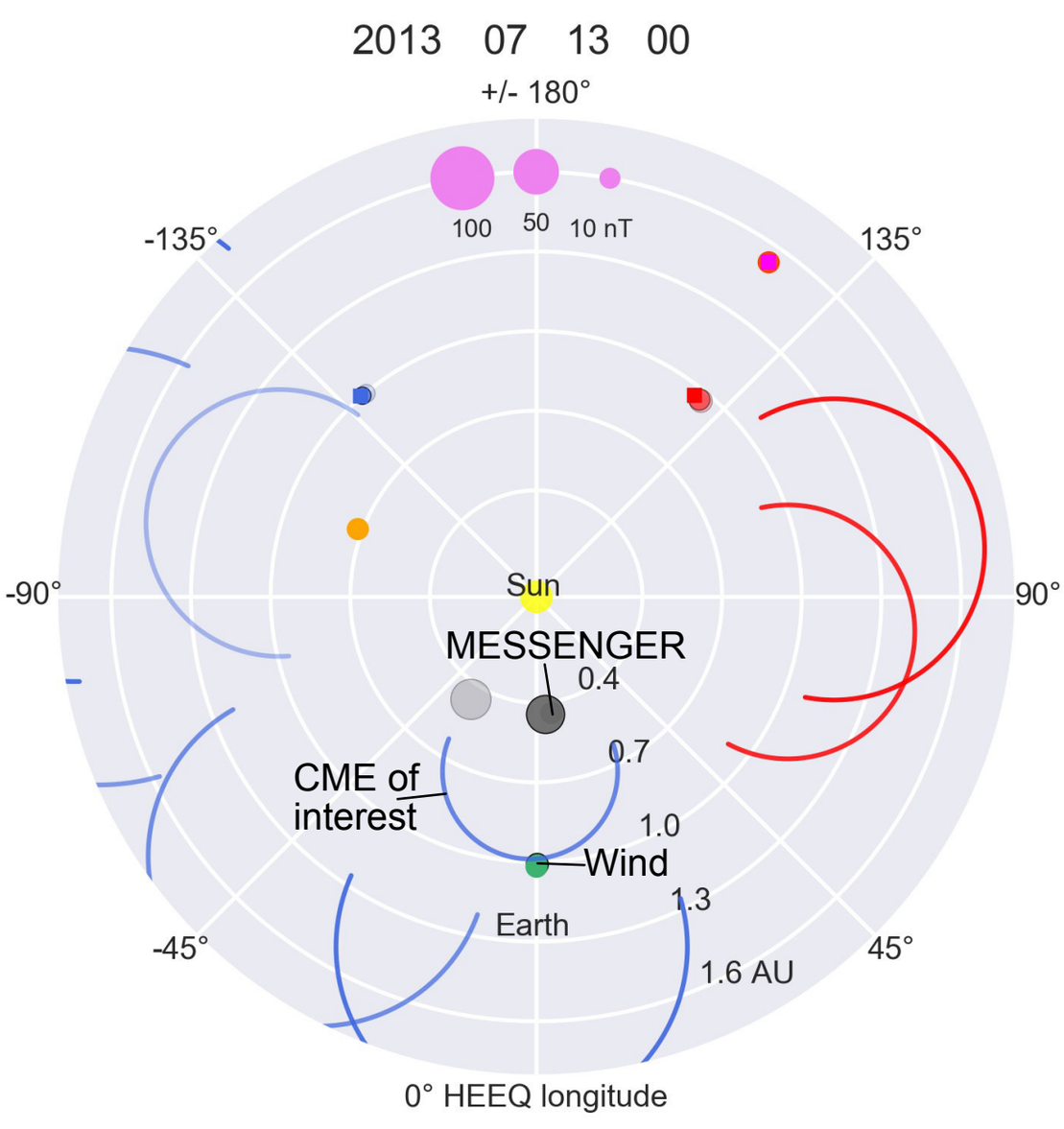
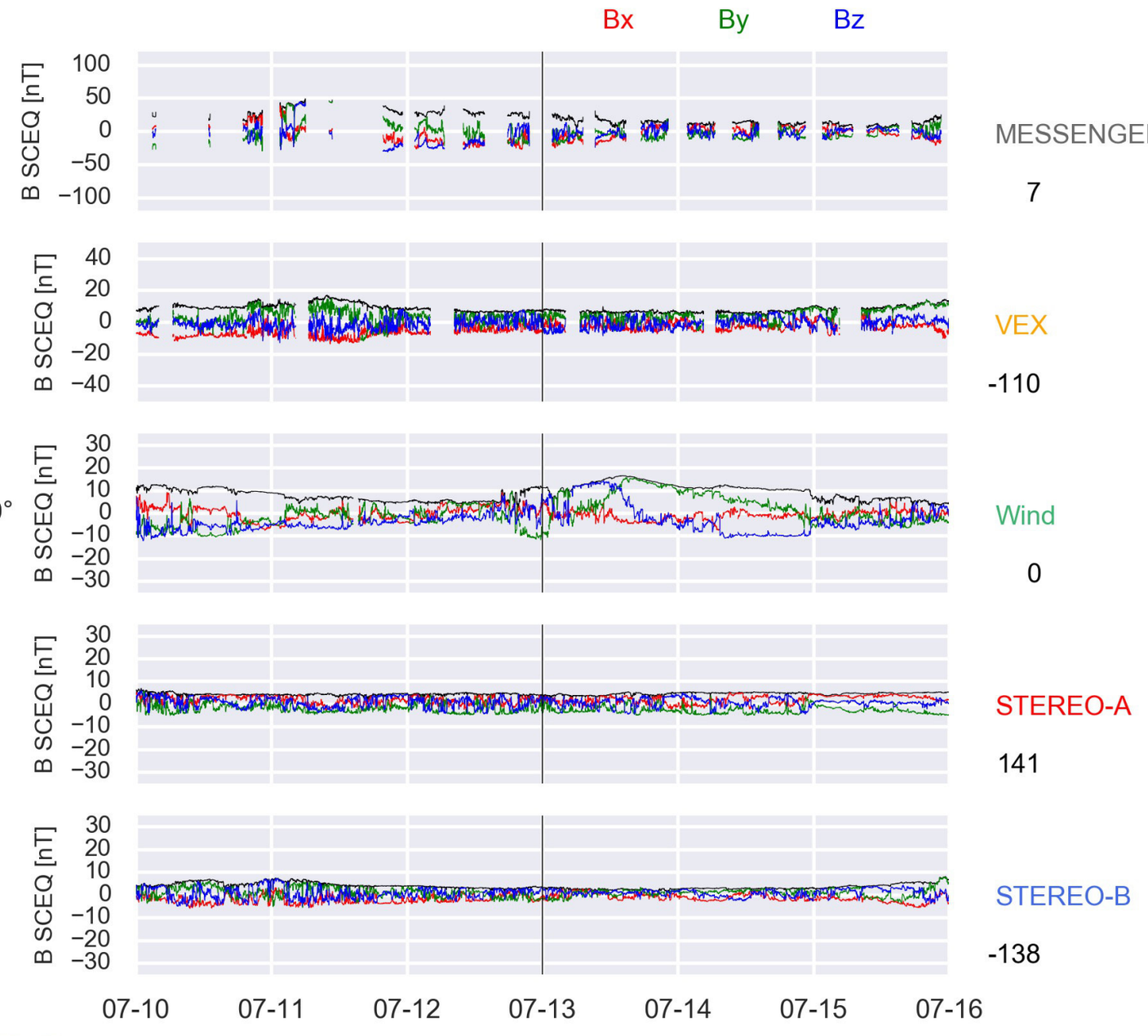
Heliosphere

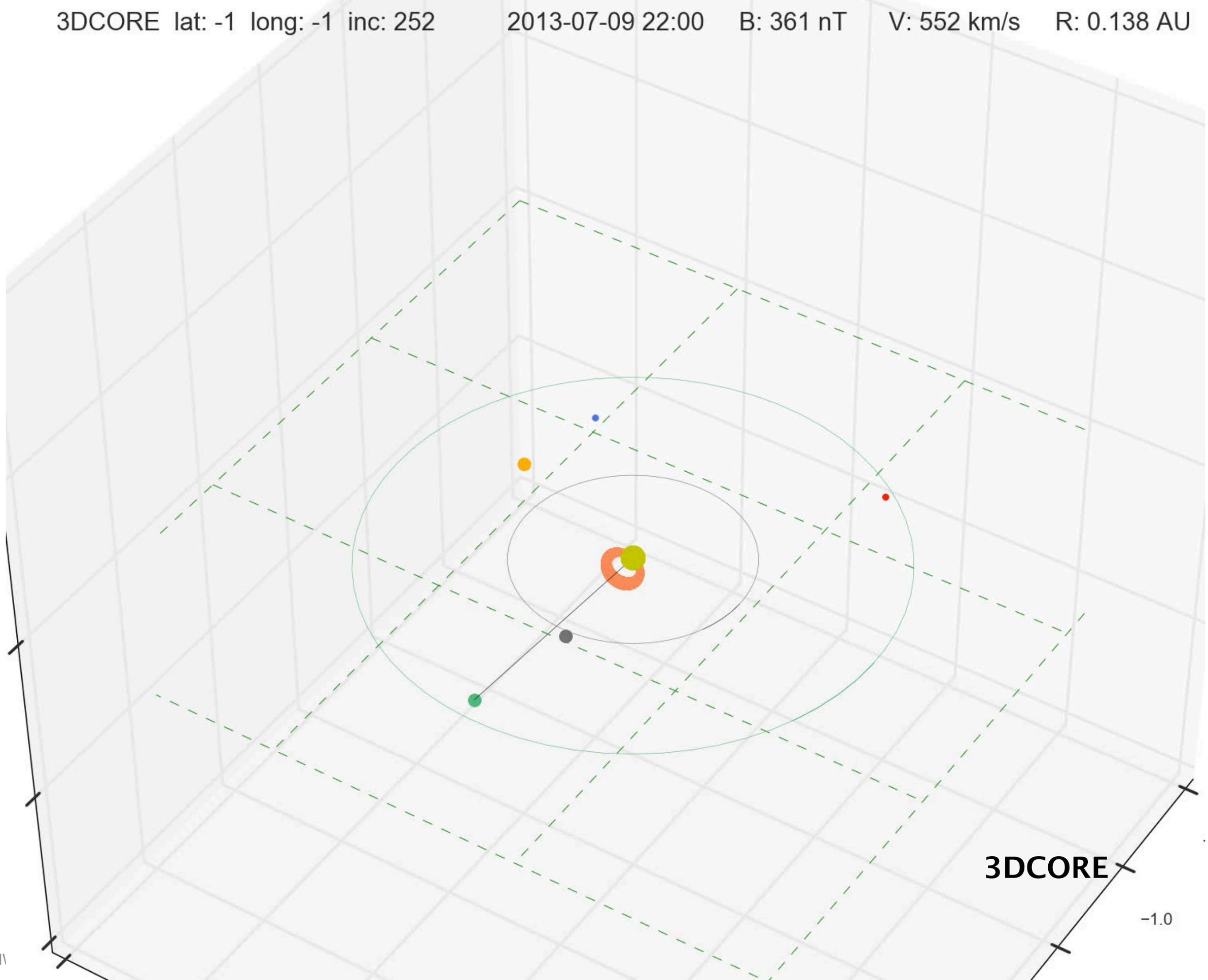




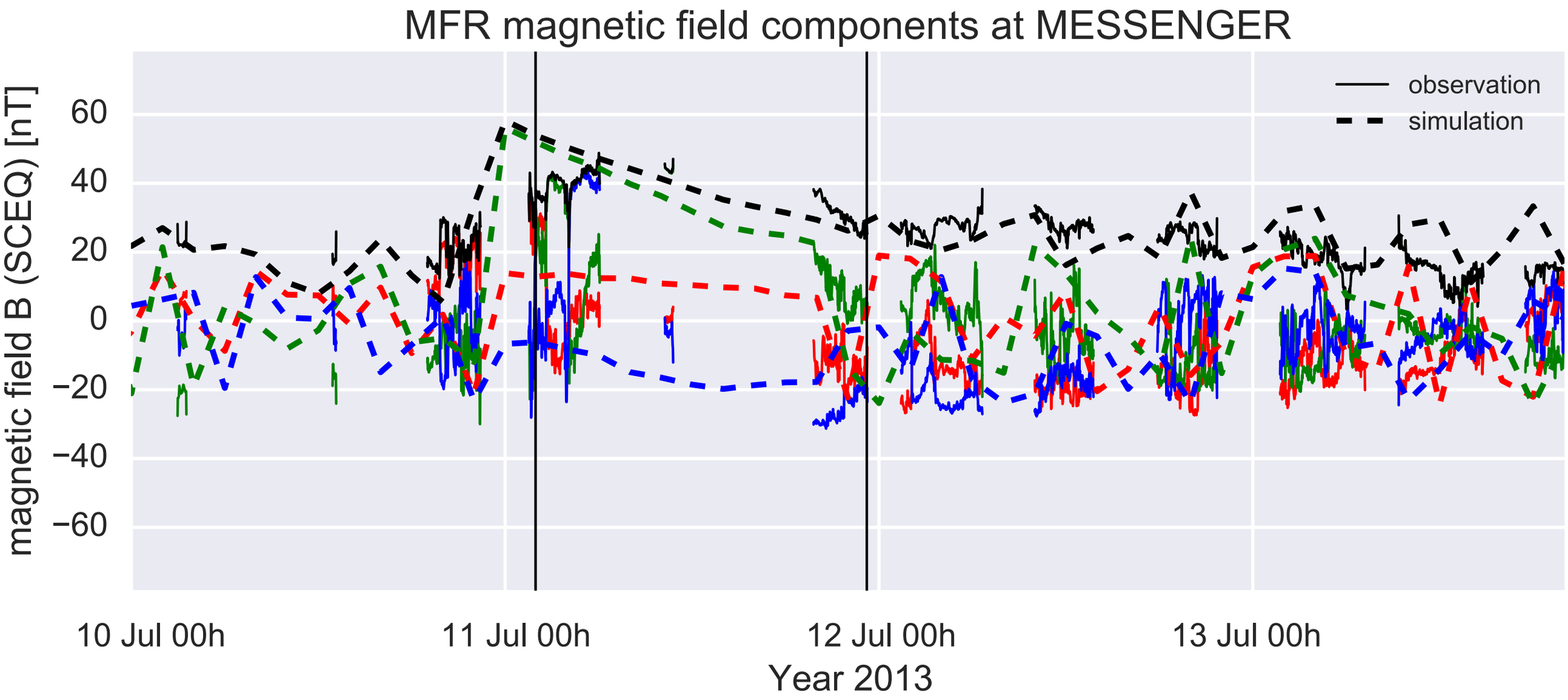
MESSENGER Venus STEREO-A STEREO-B Earth Mars MSL Maven Ulysses Rosetta

C. Möstl

3DCORE lat: -1 long: -1 inc: 252 2013-07-09 22:00 B: 361 nT V: 552 km/s R: 0.138 AU



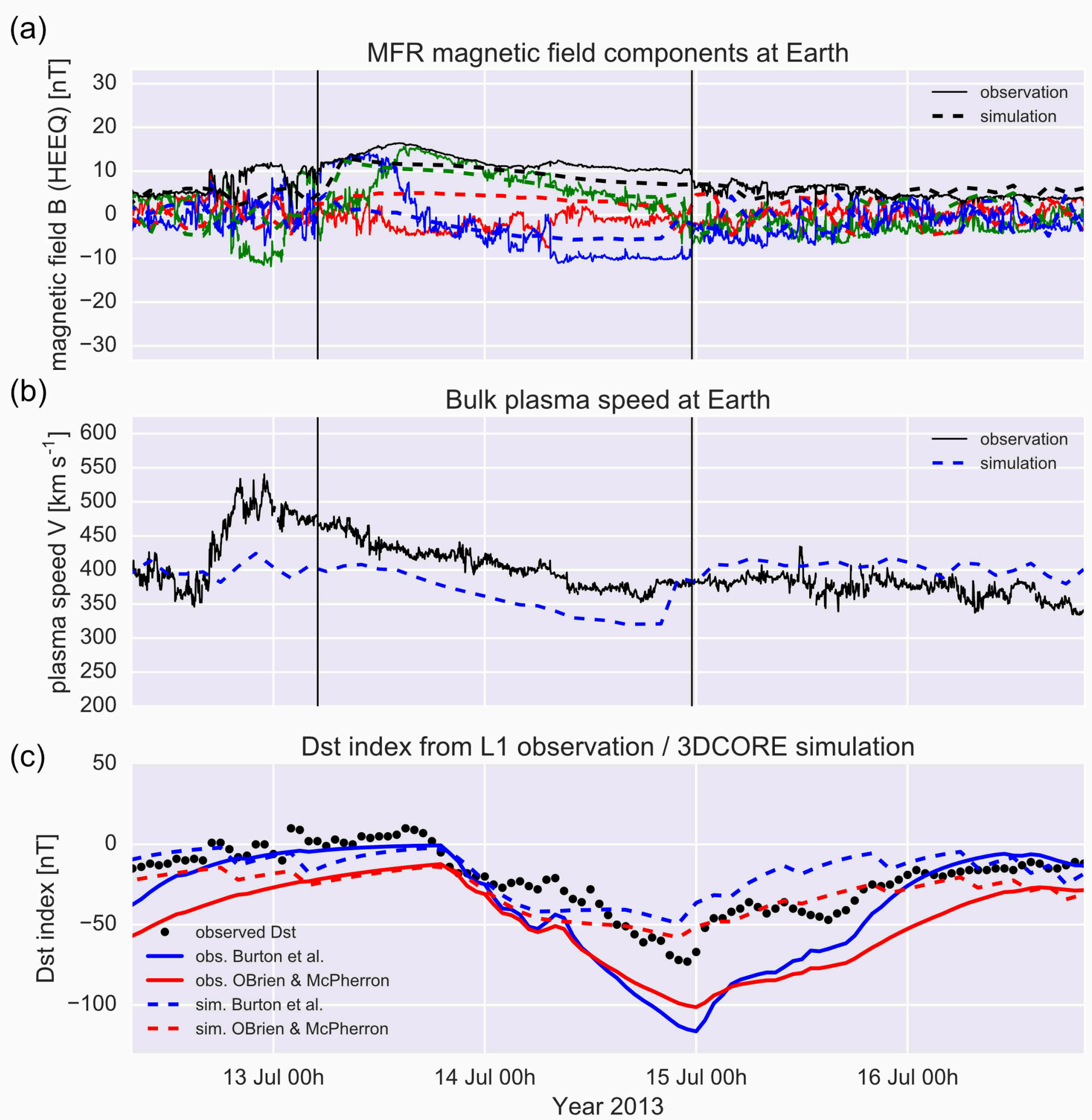
MESSENGER

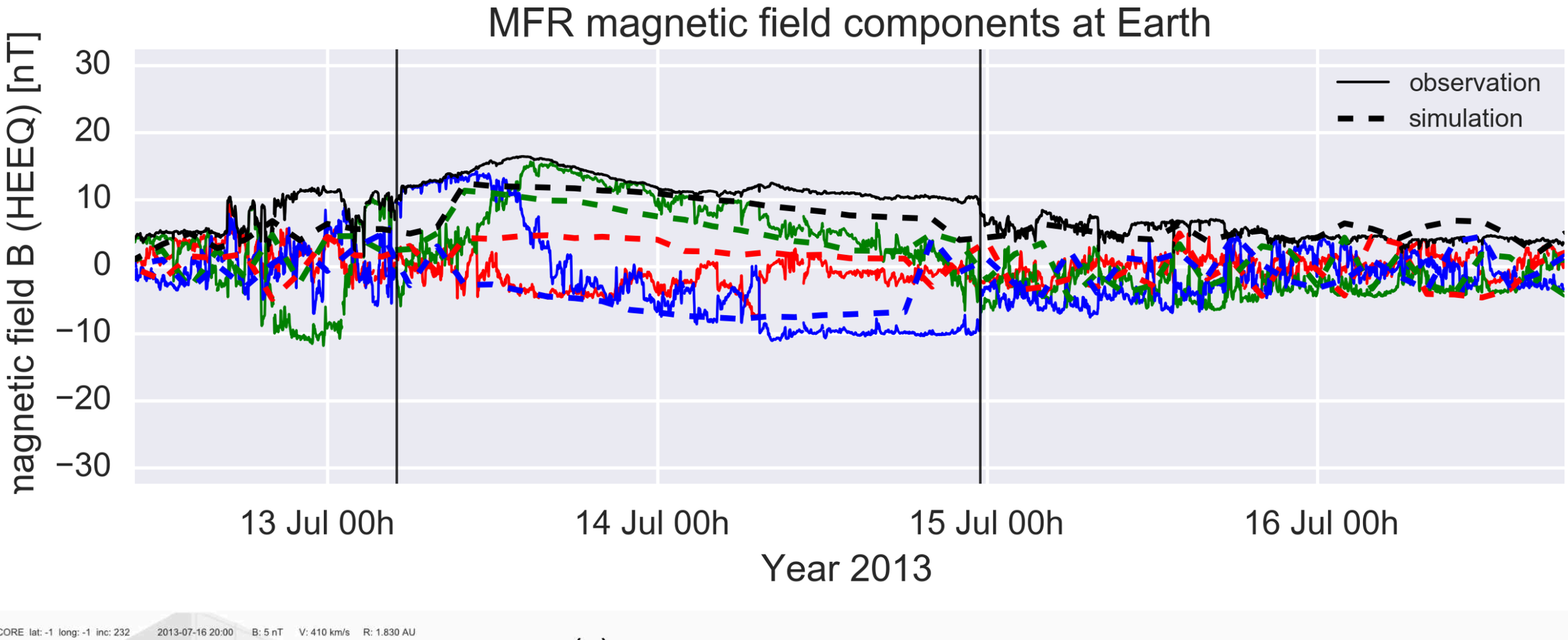


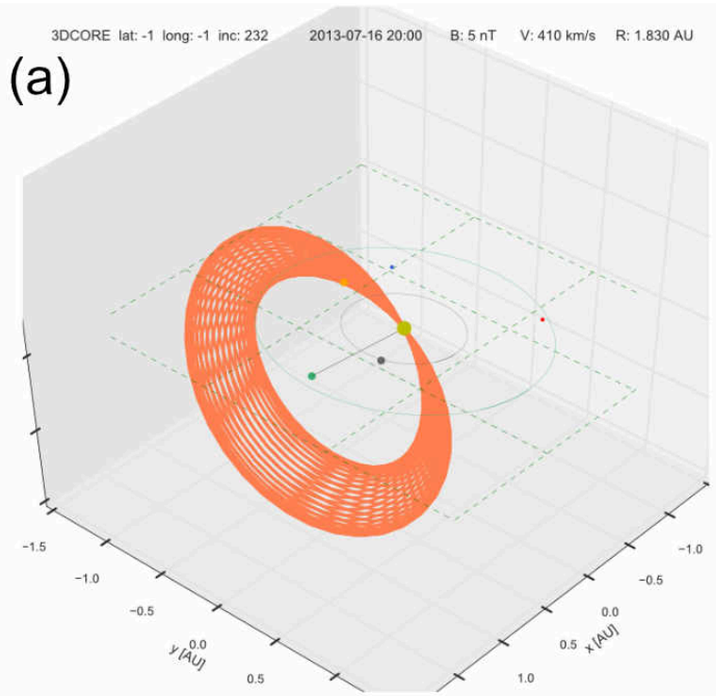
?? drag parameter, initial values: for axial field B0, diameter

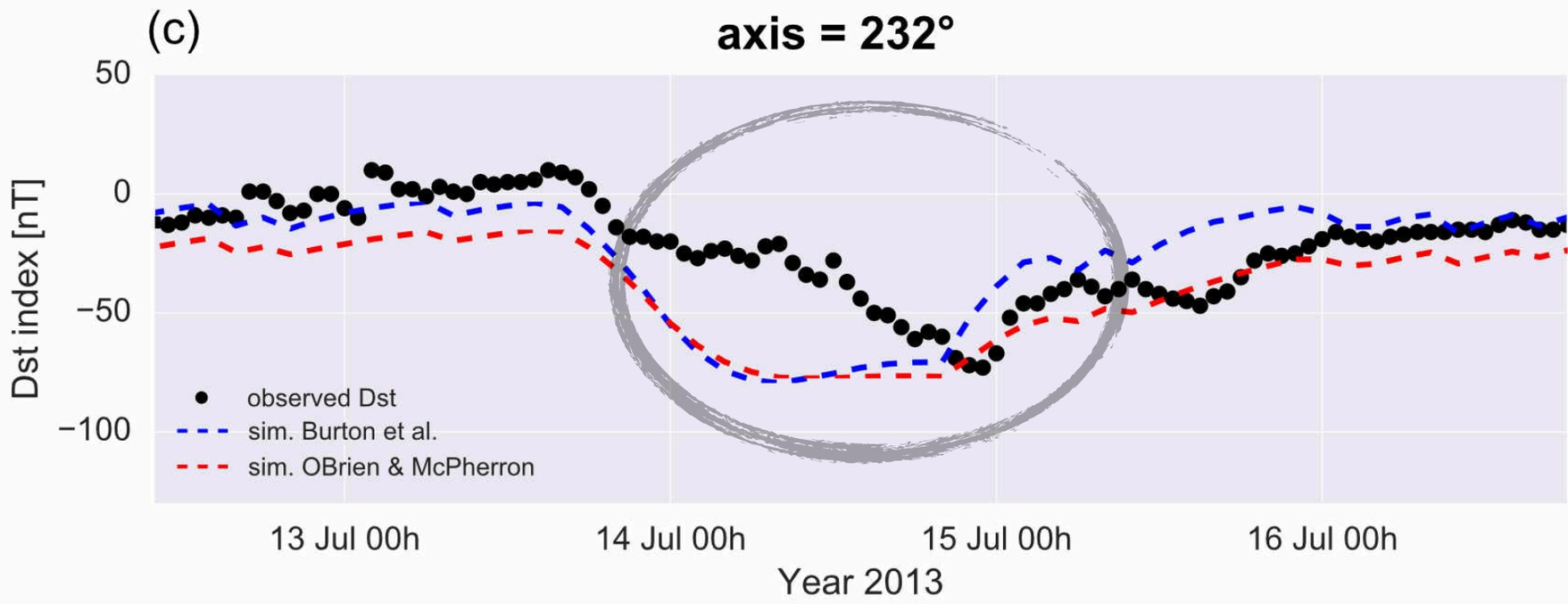
Wind at L1

input:
solar EUV,
magnetogram,
coronagraph GCS
modeling
MESSENGER rope
arrival time,
duration
and maximum
field

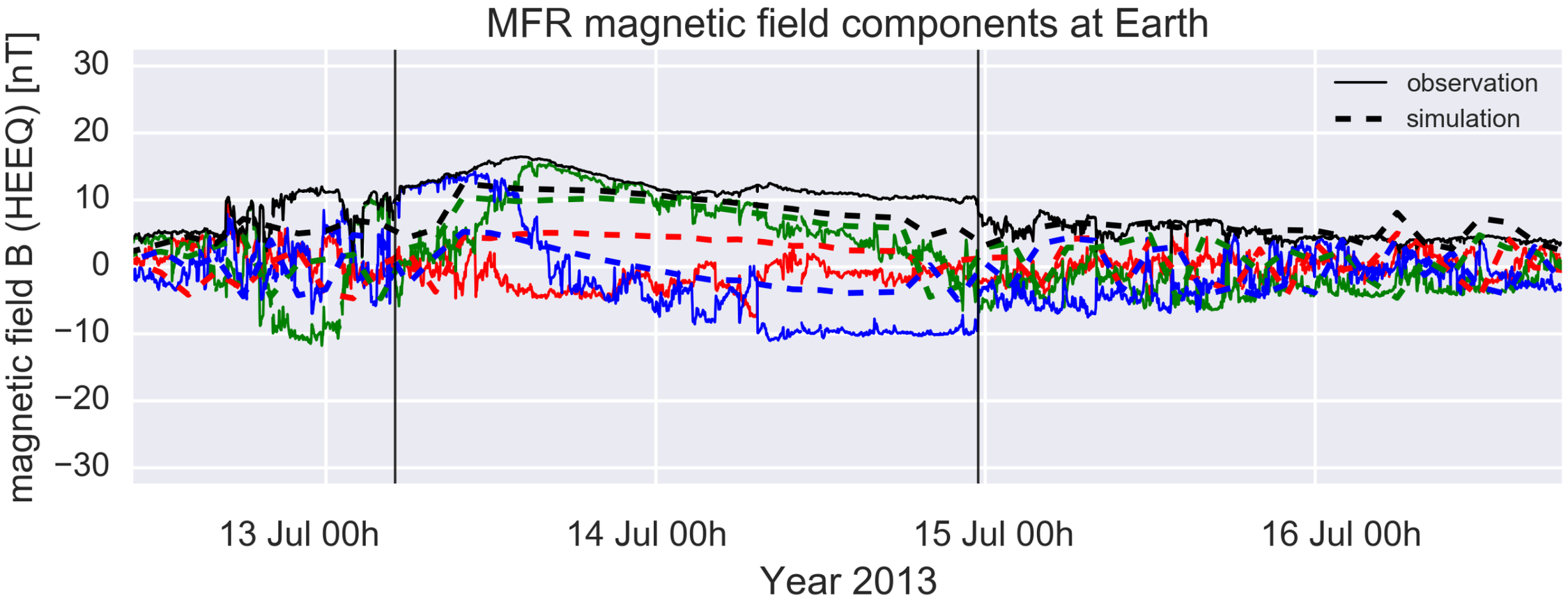


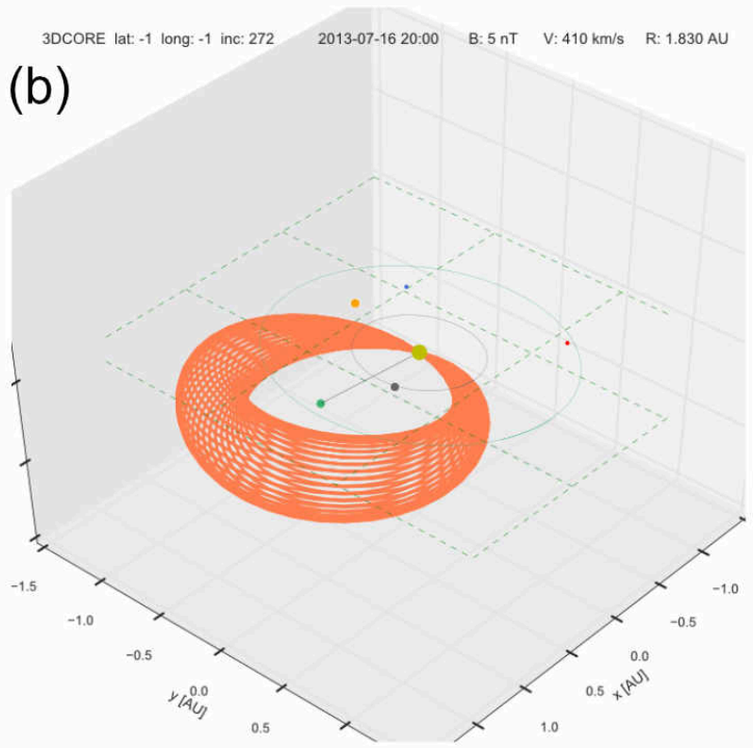


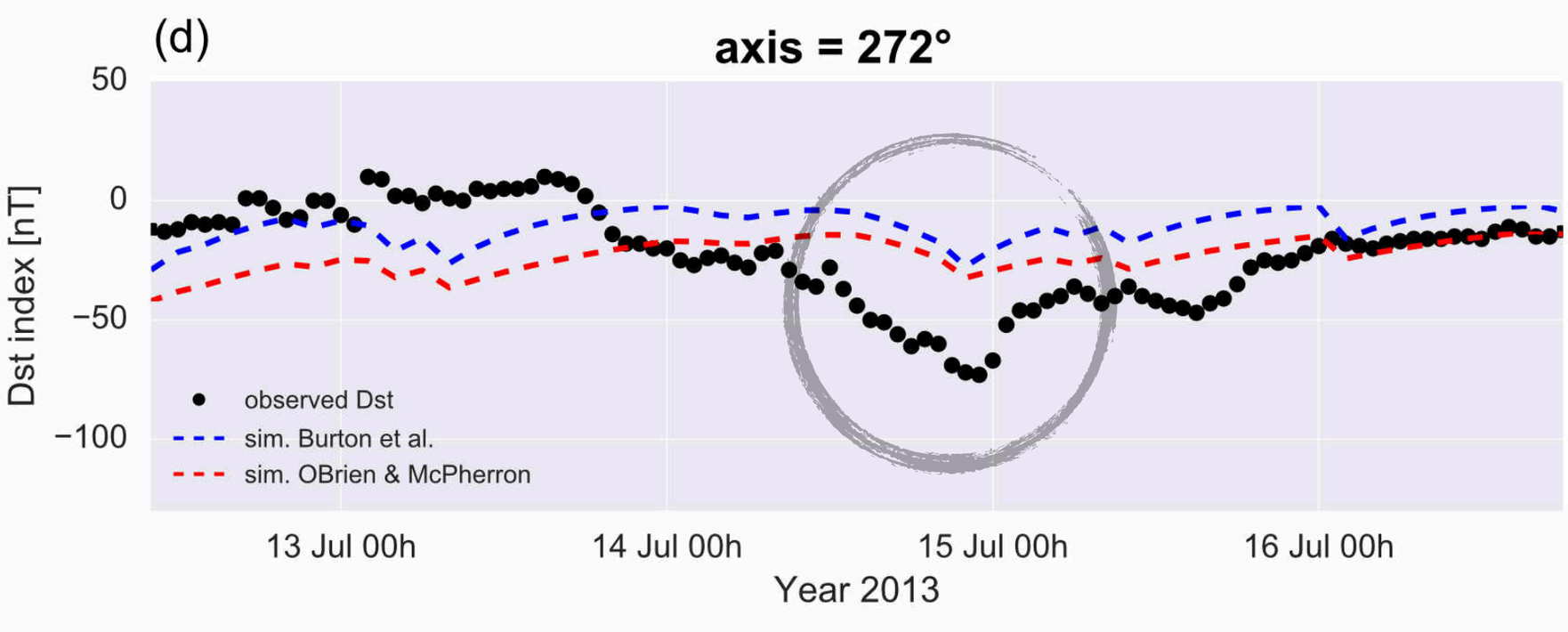




Möstl et al. 2018, Space Weather







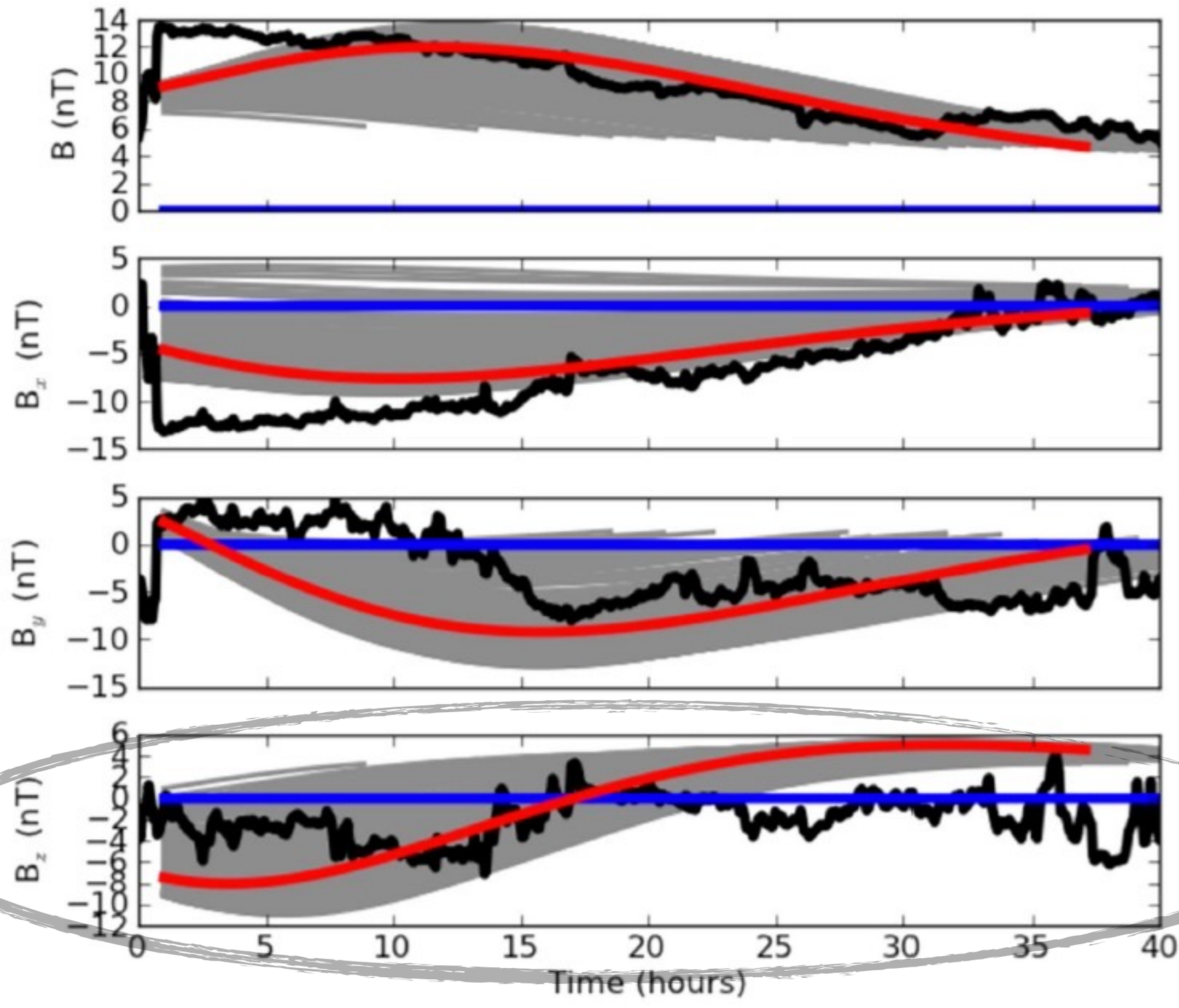
Möstl et al. 2018, Space Weather

FIDO

Kay et al. 2017 ApJ

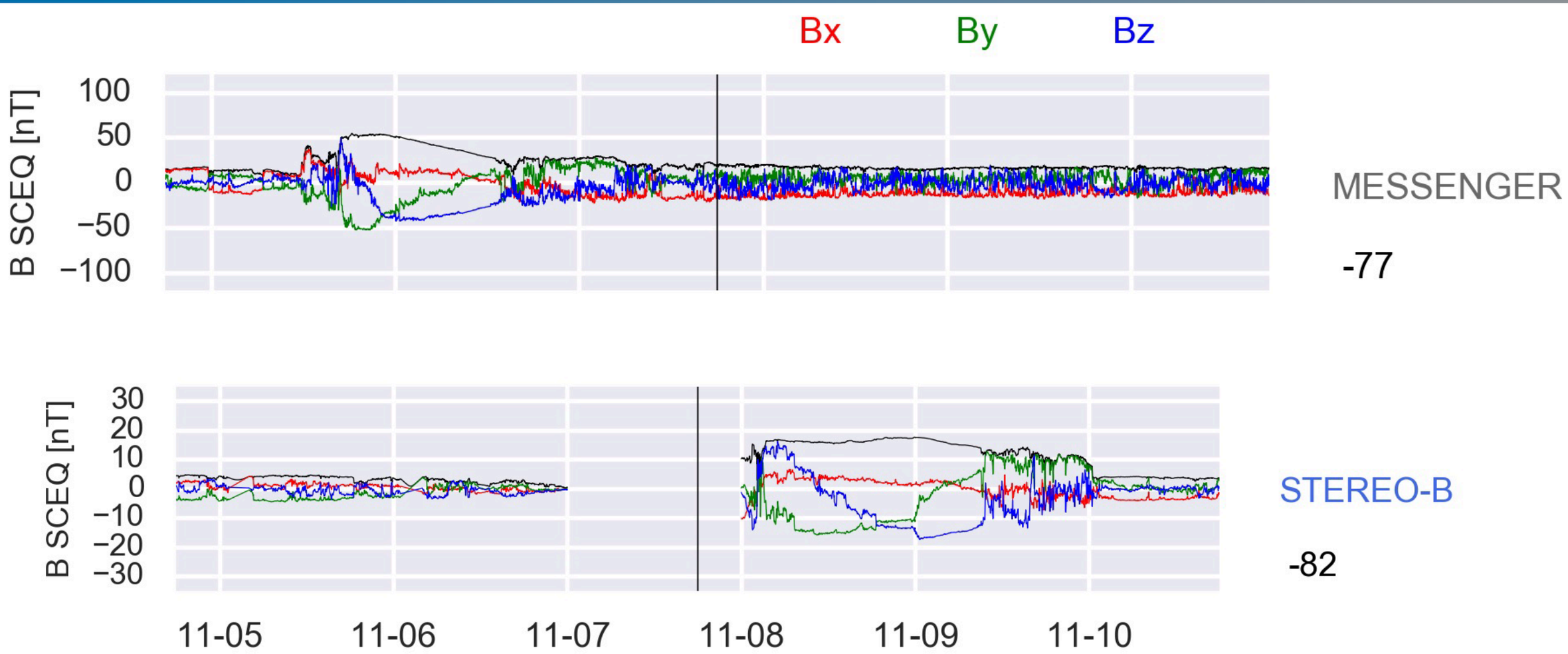
- **black**: ACE
- **red**: FIDO **and** rotation/ deflection
- **blue**: FIDO **no** rotation/ deflection
- **gray**: 150 simulations, variation:
  latitude ± 5°
  longitude ± 10°
  tilt ± 10°

- **CME flux rope field profile at L1 is highly sensitive to the CME initial parameters**



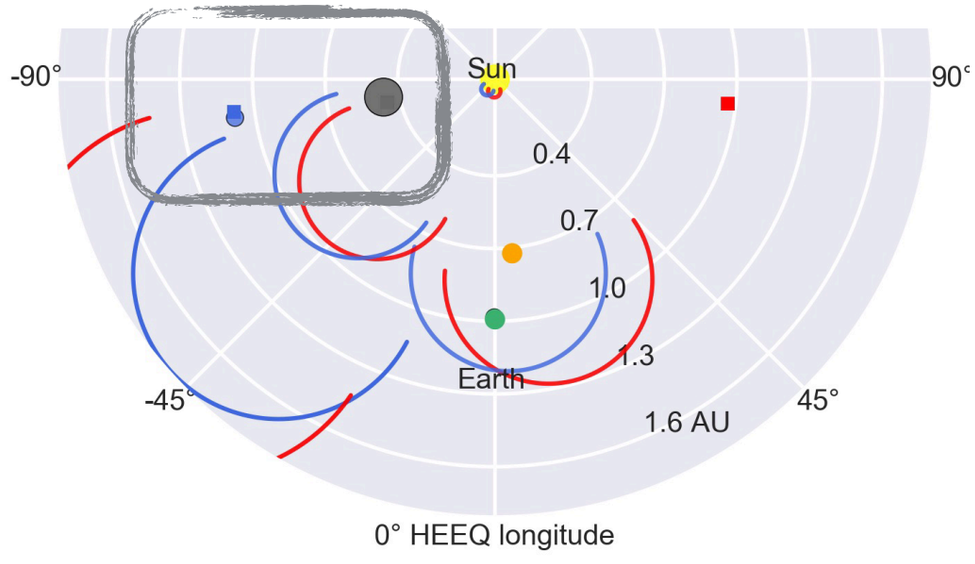
2011 February 15 CME

Future work: more events

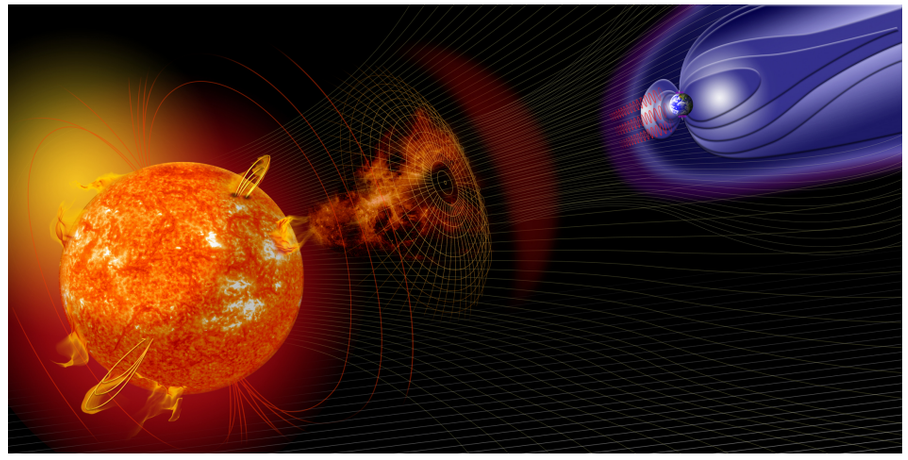


- 5 November 2010
  Good et al. 2018 Sol. Phys.,
  Amerstorfer et al. 2018 Space Weather (revised)

- Catalogs, movies all available on my **figshare** site and **helcats-fp7.eu**
- movies on youtube



3DCORE take-away



- **3DCORE is open source in python** figshare/github (**Möstl et al. 2018)**
- More events and sensitivity analyses needed (**Kay et al. 2017**)
- Find constraints on free parameters by combination with solar modeling, coronagraph/heliospheric imaging, ground based observations, in situ observations < 1 AU, …

  E.g. an **arrival time** e.g. at Mercury (**Orsini et al. 2018**) near Sun-Earth line is already a good **constraint on the kinematics** (**Kubicka et al. 2016**)
- Data from **Parker Solar Probe close** to the Sun may lead to breakthroughs on the 3D CME structure with the help of tools like 3DCORE