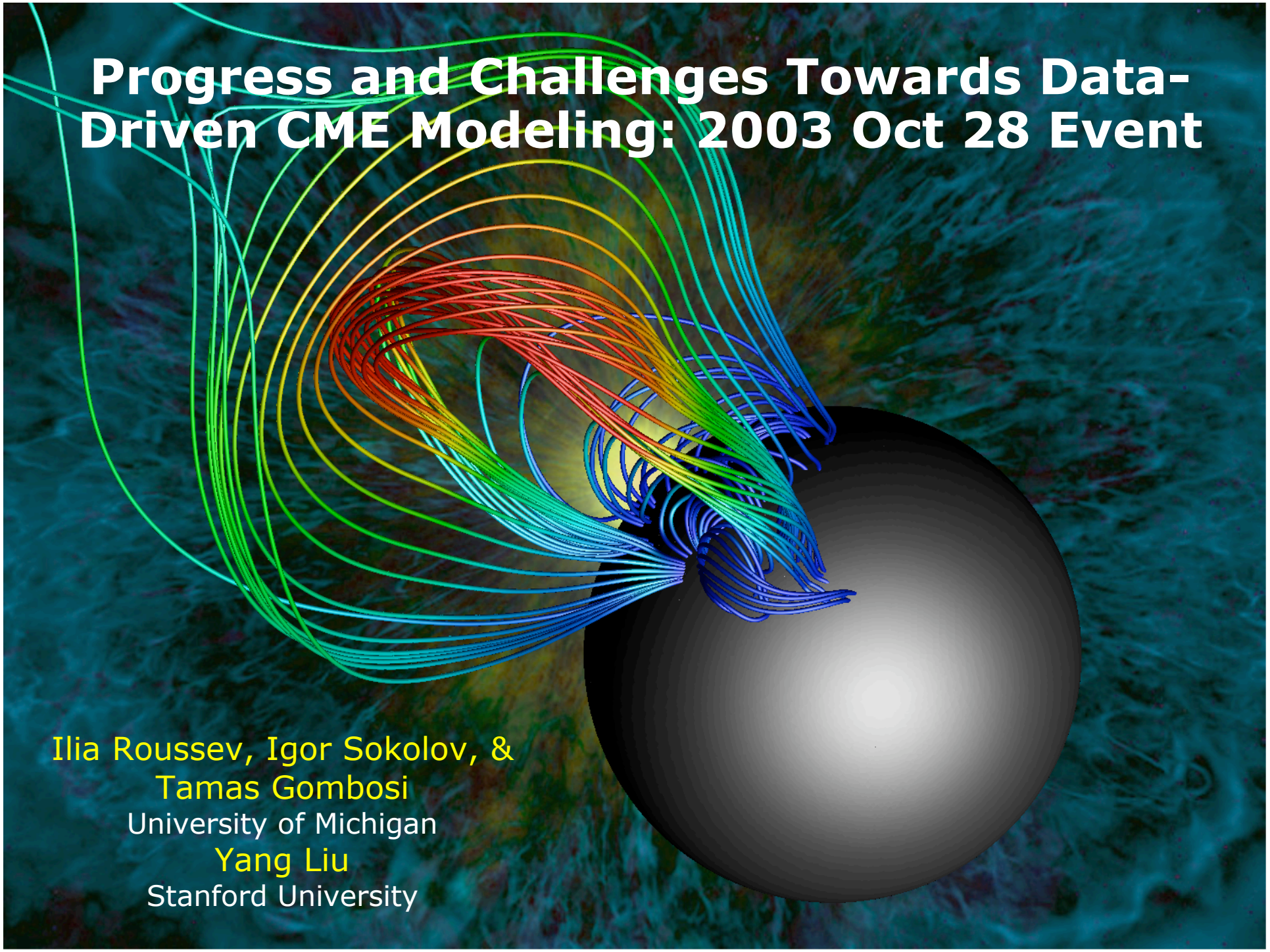
Progress and Challenges Towards Data-Driven CME Modeling: 2003 Oct 28 Event



Ilia Roussev, Igor Sokolov, &
Tamas Gombosi
University of Michigan
Yang Liu
Stanford University

CME Event on 2003 Oct 28

Summary of Observations:

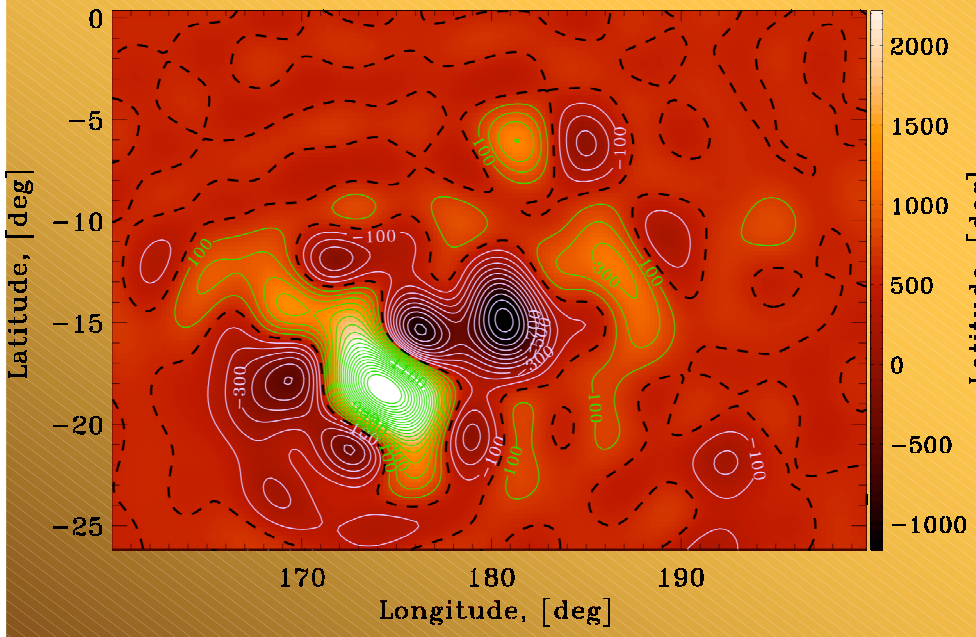
- Eruption occurred in AR10486 classified as a δ-type magnetic configuration.
- The CME was associated with an X17.2-class flare observed by EIT between 10:36-12:01UT, centered at S16E08, with peak emission at 11:12UT.
- GOES satellites observed the flare from AR10486 between 09:51-11:24UT (peak emission at 11:10UT).
- Large prominence (inverse "S" shape!) has been seen erupting prior to the flare, and the prominence material (1.4-2.1x10^{16}g) was clearly visible in EIT and LASCO images.
- LASCO data indicated a strong acceleration of the CME below $5R_S$.
- Height-time profile above $5R_S$ was moderately linear and the derived mean plane-of-sky speed was 2,459km/s.
- Estimated bulk kinetic energy of the CME was between 4.2-6.4x10^{32}ergs.
- GOES-11 satellite recorded a peak in the 100 MeV proton flux of about 33,600 pfu – the strongest proton event for Solar Cycle 23!
- ICME shock arrived at the Earth after 19 hours on Oct 29 at about 06:00 UT.

Motivation:

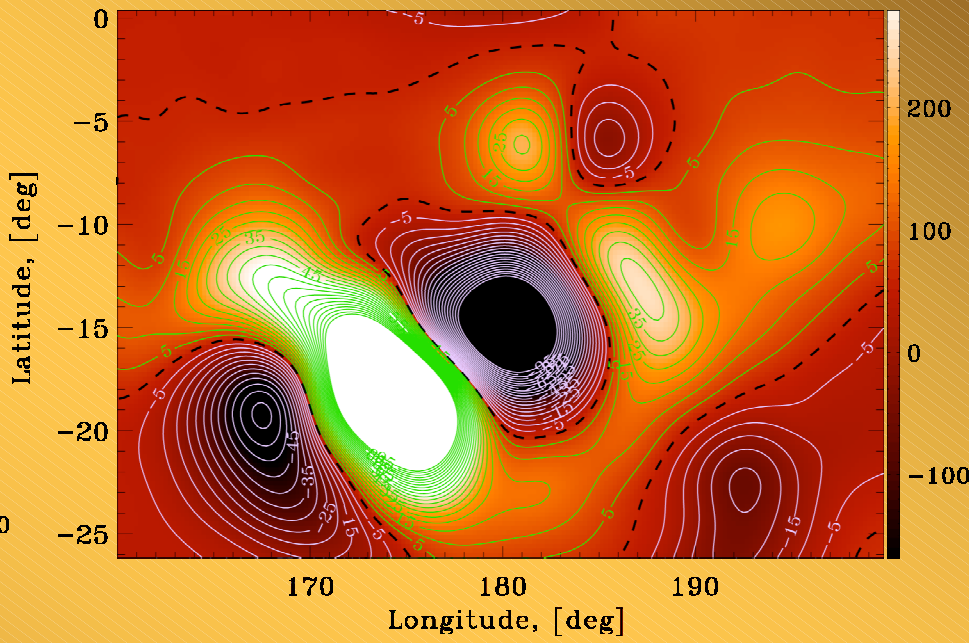
- Model the solar eruption on 2003 Oct 28 using magnetic data from MDI.

MDI Magnetograms

Map of B_R at R=1.00R_S



Map of B_R at R=1.05R_S

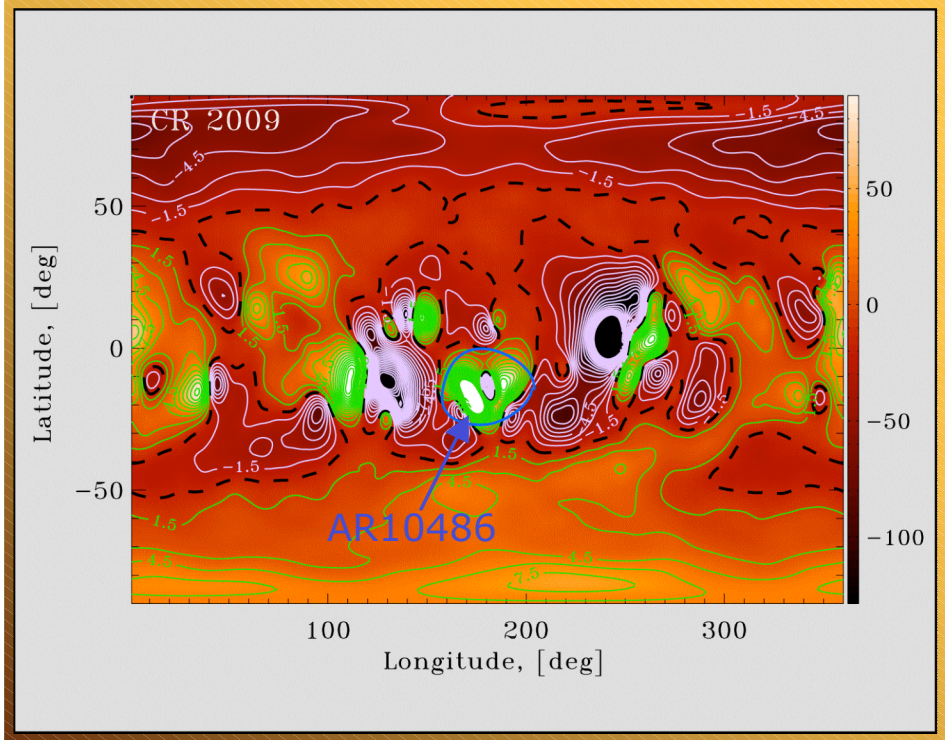


Where do we set the boundary: R=1.0R_S, 1.05R_S, or elsewhere?

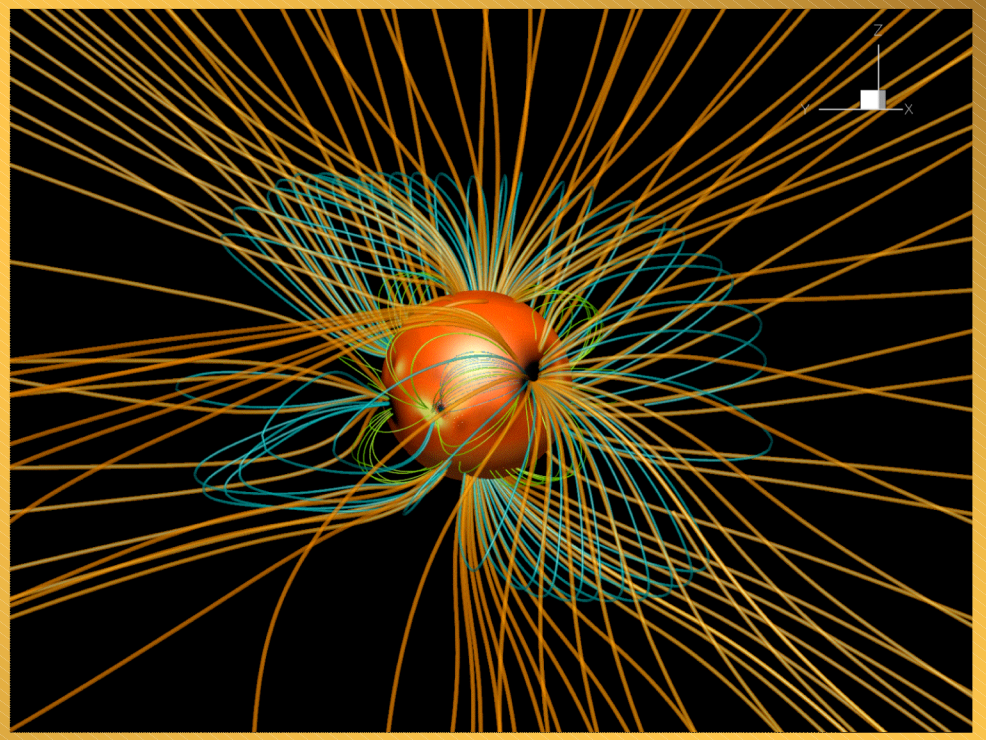
In this study we choose R=1.10R_S

Full-disk MDI Magnetograms Drive MHD Simulations

Map of B_R (potential field) at $R=1.10R_S$ on Oct 27 (order of harmonics n=90)



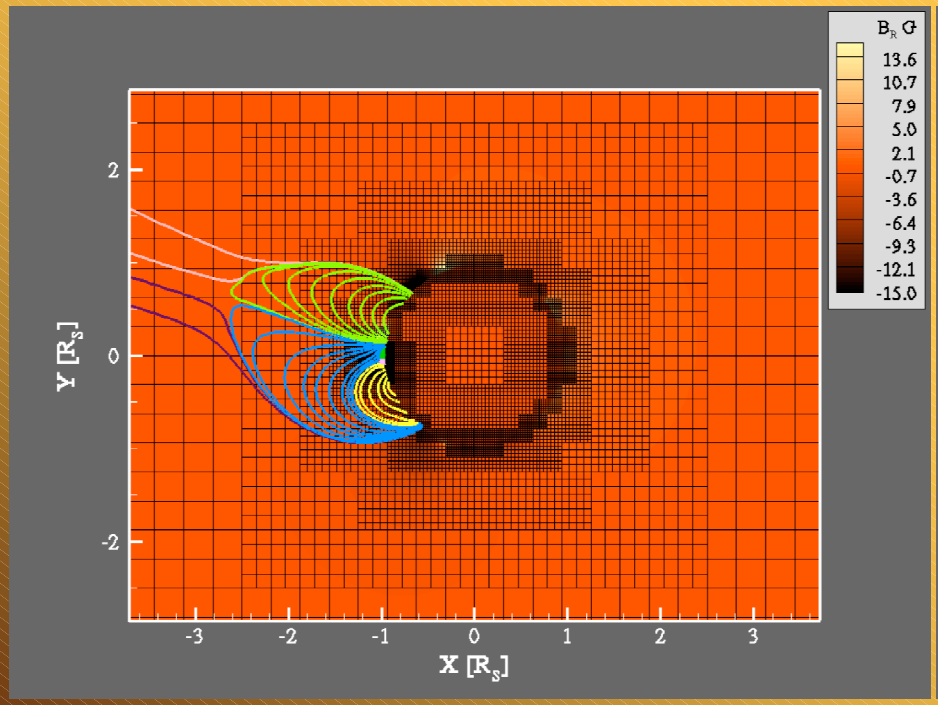
Computed coronal magnetic field (non-potential) at steady-state with solar wind

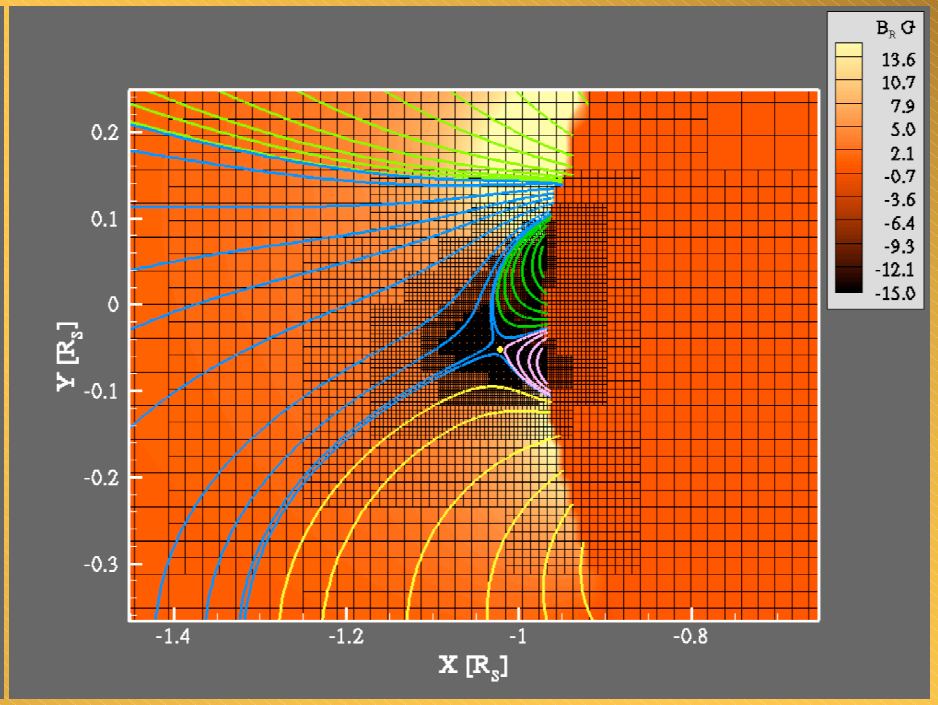


3D View of Solar Magnetic Fields on Oct 27, 2003

Grid Structure in Simulations

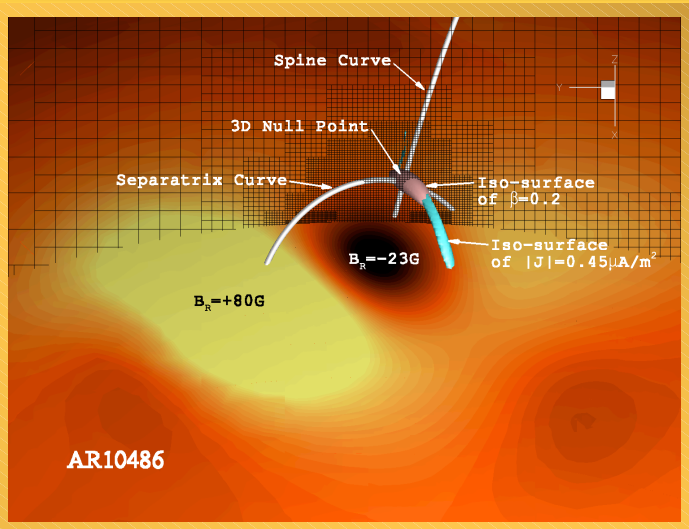
Largest cells are of size 1.25R_S (away from the Sun), whereas the finest ones are 1024 smaller (in vicinity of AR10486 and null point)!



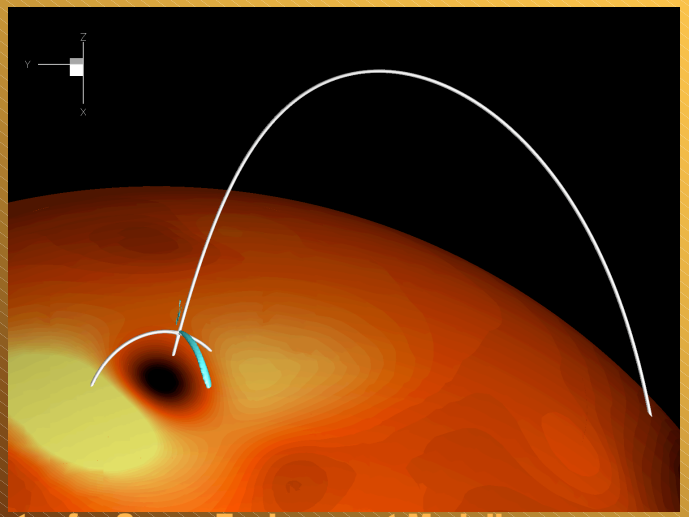


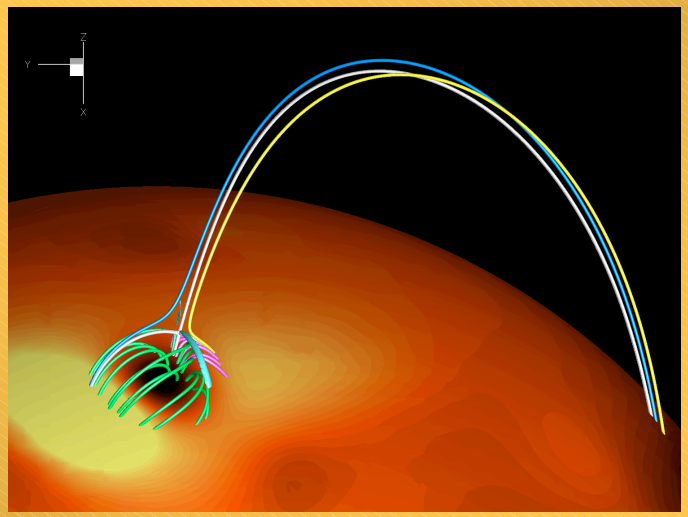
Close View of Active Region 10486 on Oct 27 at 1:35UT

3D images show specific features of the magnetic field topology of AR10486. Field lines with different colors represent the four distinct flux systems.

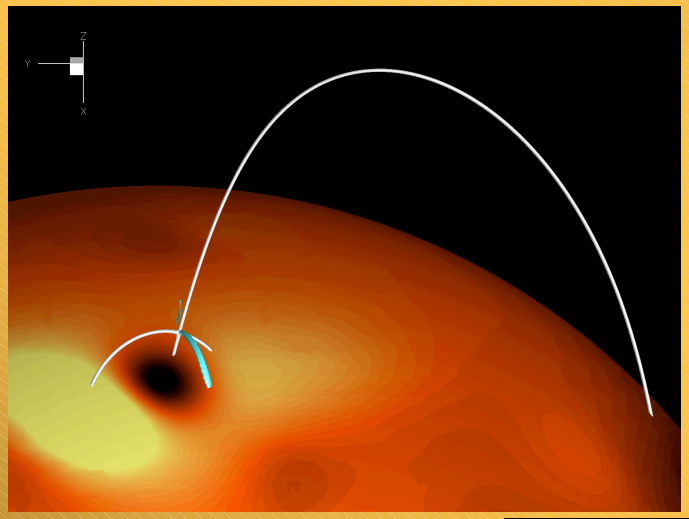


What happens as AR10488 continues to emerge on this day?

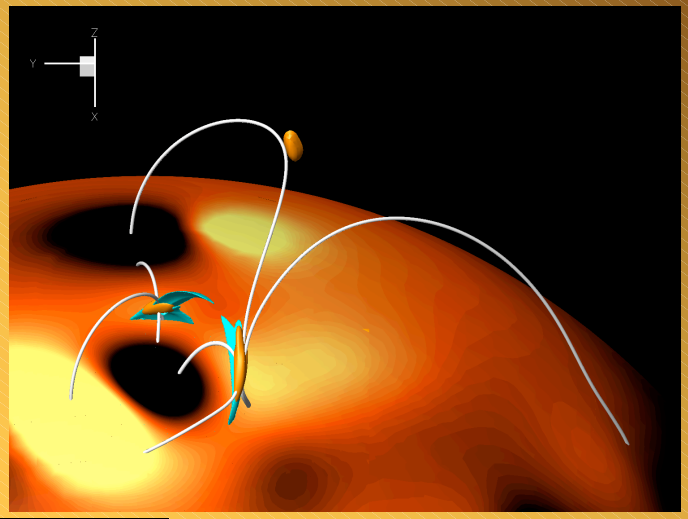


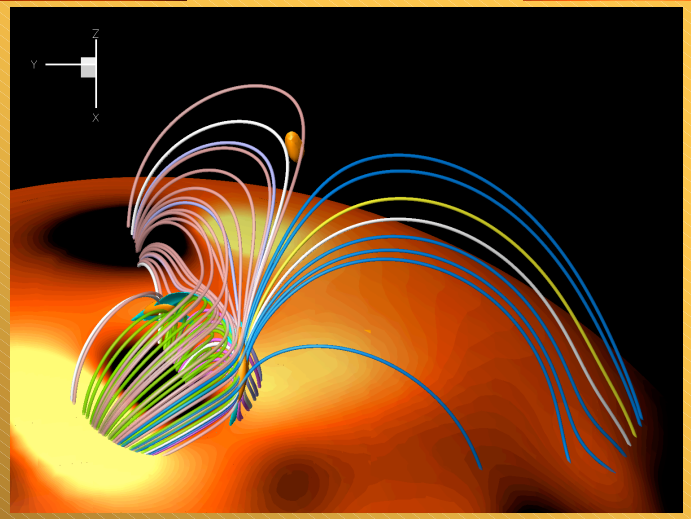


Close View of Active Region 10486 on Oct 28 at 9:35UT



32 hours later



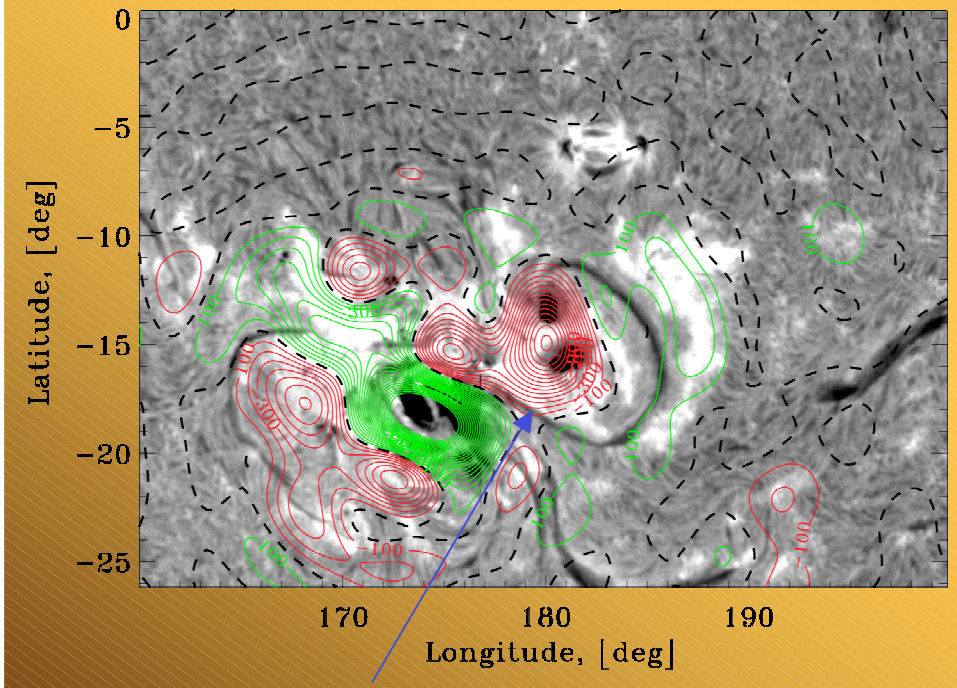


There are more magnetic flux systems of interest now, and therefore more colors…

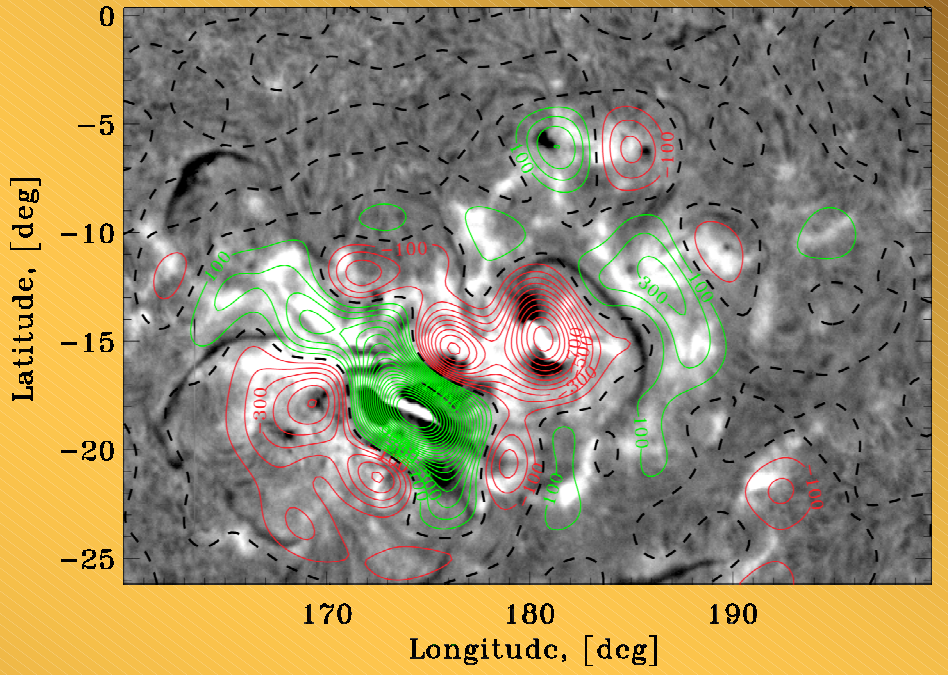
The emergence of AR10488 results in the appearance of more null points in the corona!

Prominence Eruption on Oct 28

Contour map of B_R at R=1.0R_S and Hα image from BBSO on Oct 27



Contour map of B_R at R=1.0R_S and Hα image from BBSO on Oct 28



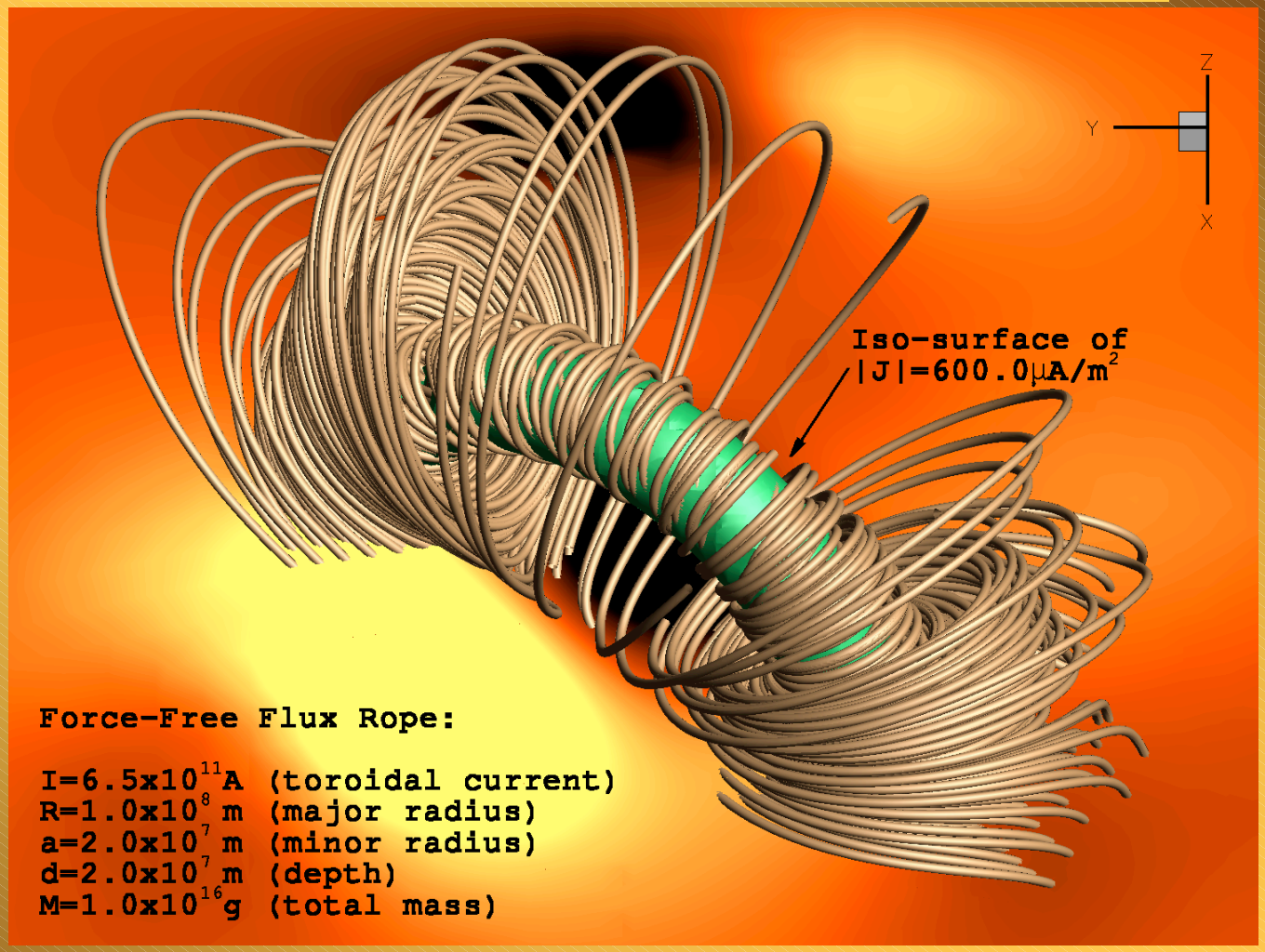
Next step: model the prominence eruption originating from AR10486 on Oct 28!

Step 1: What Analytical Solution for Flux Rope Would Resemble Observed CME?

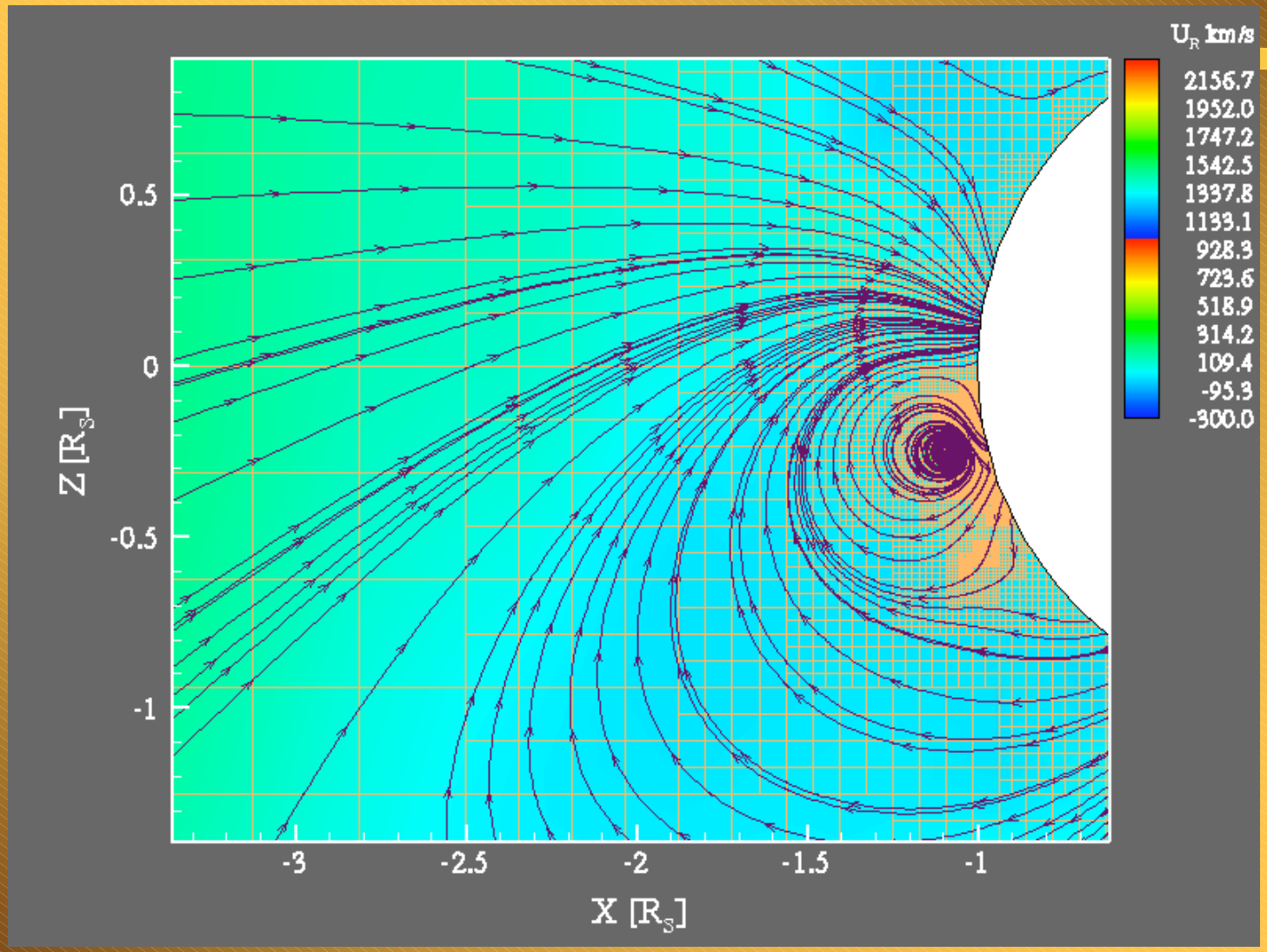
Image shows the superposition of a 3D force-free flux rope (Titov & Démoulin type) onto the background field taken from observations.

Flux rope in the ambient magnetic field is out of equilibrium (due to imbalanced hoop force) and it erupts, yielding the observed CME kinematics in the solar corona.

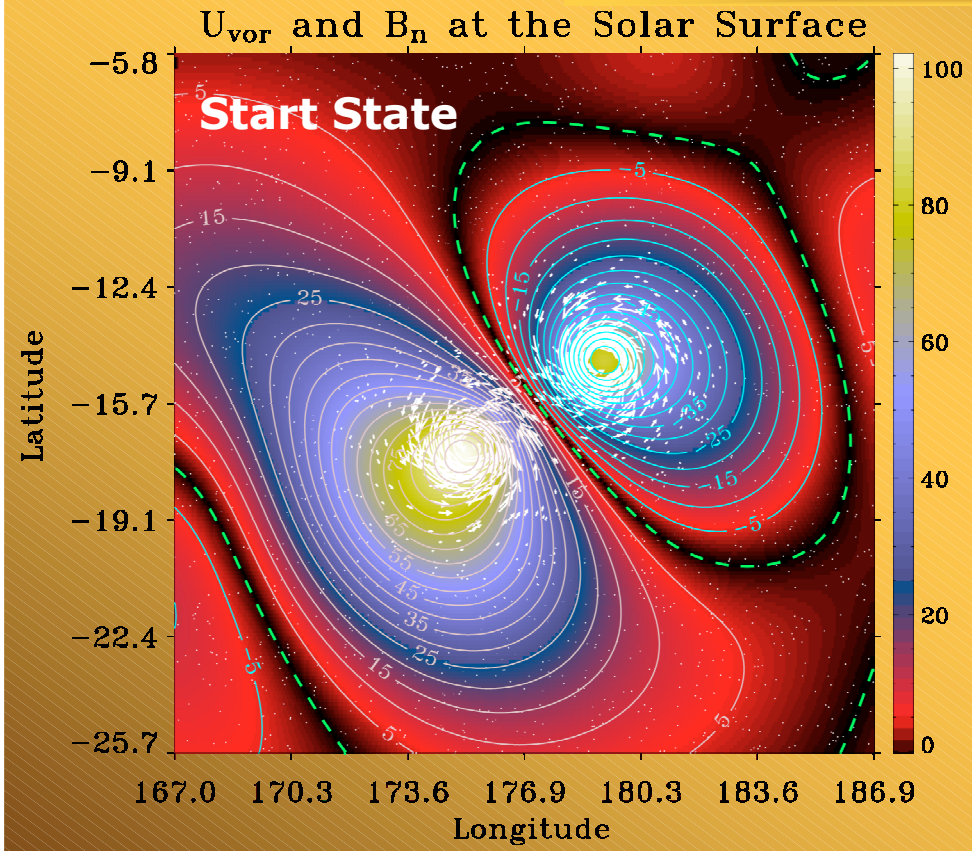
There is a logical gap here, which we will try to fill in over the course of our further simulations!



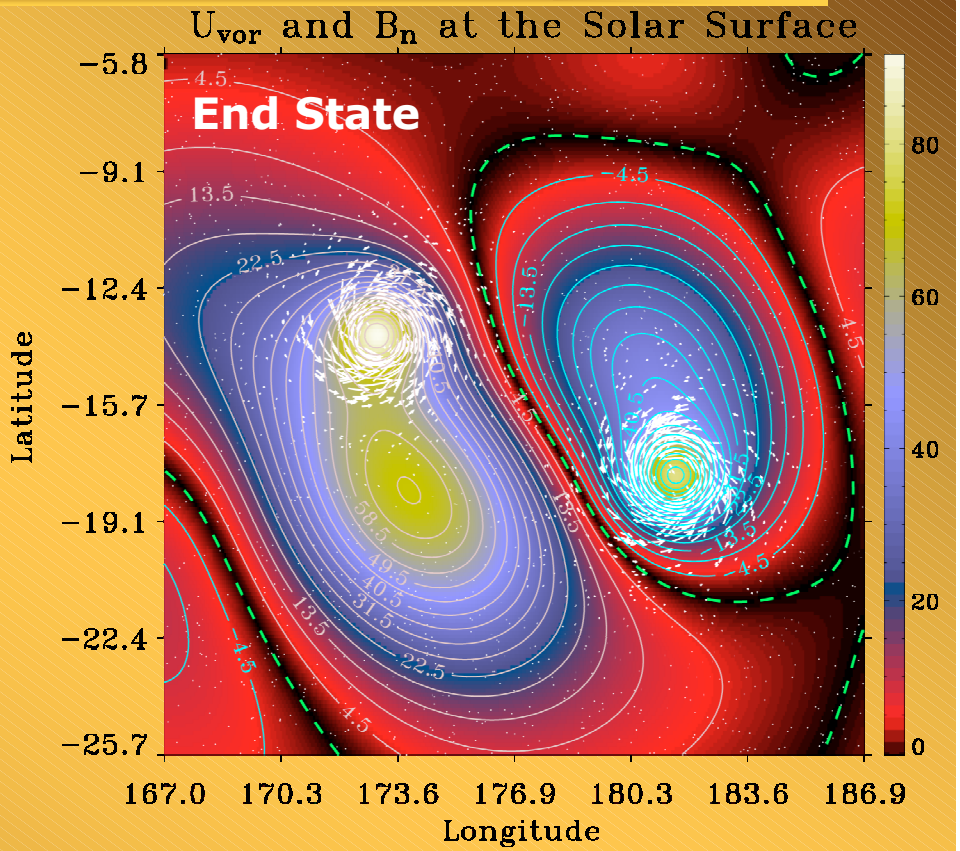
Dynamics of CME Eruption



Step 2: Try Something Better!



Superimpose a small magnetic dipole onto the background field. Over the course of a quasi-steady evolution, the two magnetic spots are expected to resemble the footprints of a flux rope.

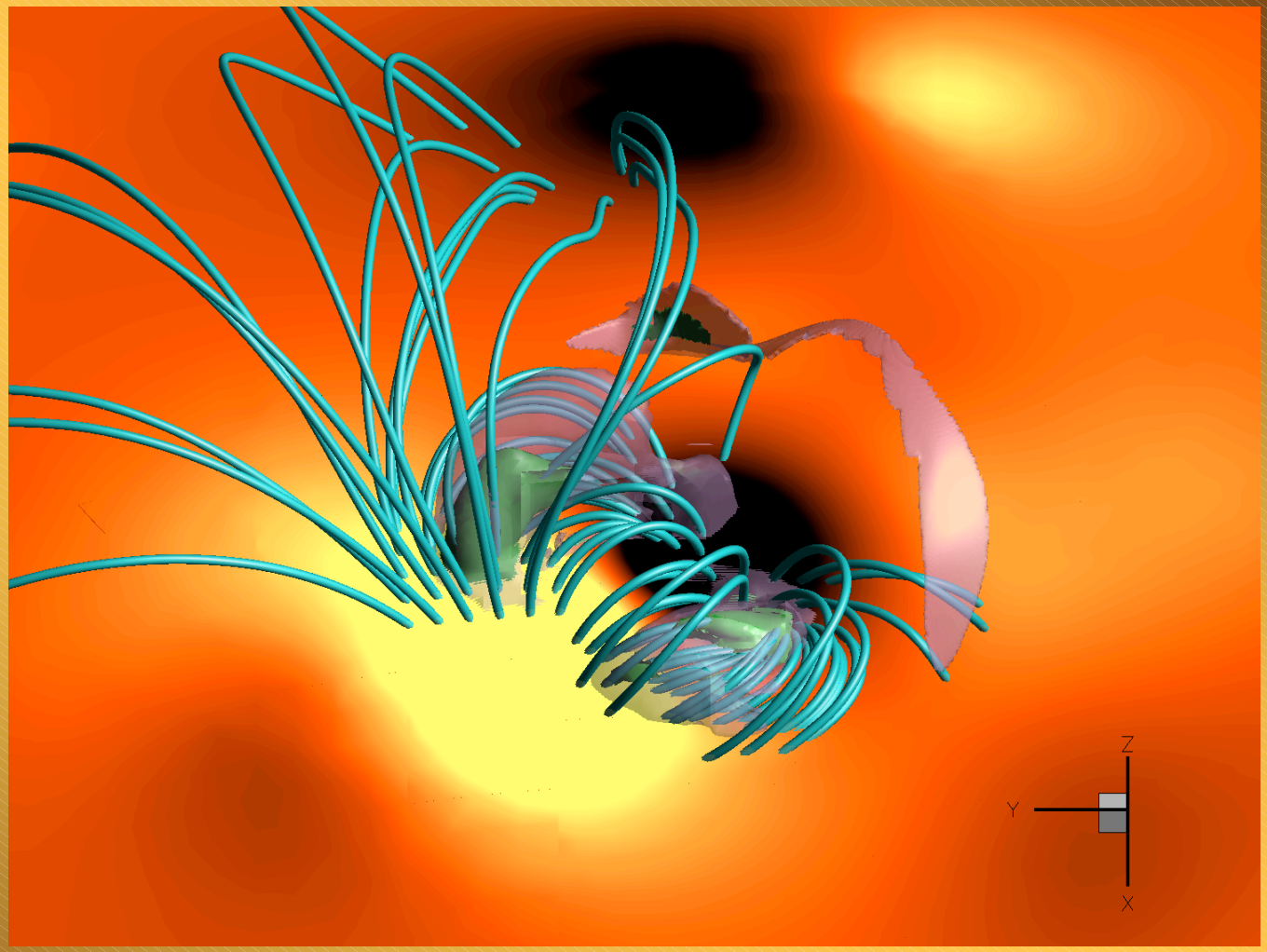


Imposed Evolution: Twist the magnetic field lines of the two spots (counterclockwise) while moving these spots apart.

Result: No Flux Rope Forms!

Image shows the end state of imposed evolution. No flux rope is present…

Work on this continues, stay tuned!



Summary of Results and Conclusions

Summary of Results:

- We incorporated magnetic data from MDI into a global MHD model of the solar corona, and we obtained a steady-state solar wind solution (with non-potential magnetic field) for CR2009 centered on Oct 27 and Oct 28.
- We prescribed a 3D force-free flux rope that resembles the observed properties (in terms of size, orientation, energetics, etc.) of the CME on 2003 Oct 28. The flux rope is out of equilibrium with the background field and it erupts, yielding a CME.
- We then tried to generate a flux rope by imposing electric field at the footprints of a magnetic dipole, hoping that a flux rope with desired properties would form over the course of a quasi-steady evolution of the field. The flux rope did not form…

Conclusions:

- Magnetic topology of AR10486 is very complex (no surprise), in fact way too complex. But, this should not discourage us from trying to understand the mechanism(s) that triggered the associated eruptions during the Halloween Epic.
- Is potential field extrapolation a good way to go, especially for active regions with enormous helicity contents like AR10486?

Future Work:

- Try to emerge a flux rope through the boundary by imposing a self-consistent evolution of the tangential electric field.
- We will keep experimenting, you stay tuned with us!

Acknowledgements

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Thank you!

Solicitation for Future Conference

http://dezeeuwg4.engin.umich.edu/~ilr/ISROSES/