MHD modeling of CME-driven magnetosphere and prediction of Space Weather

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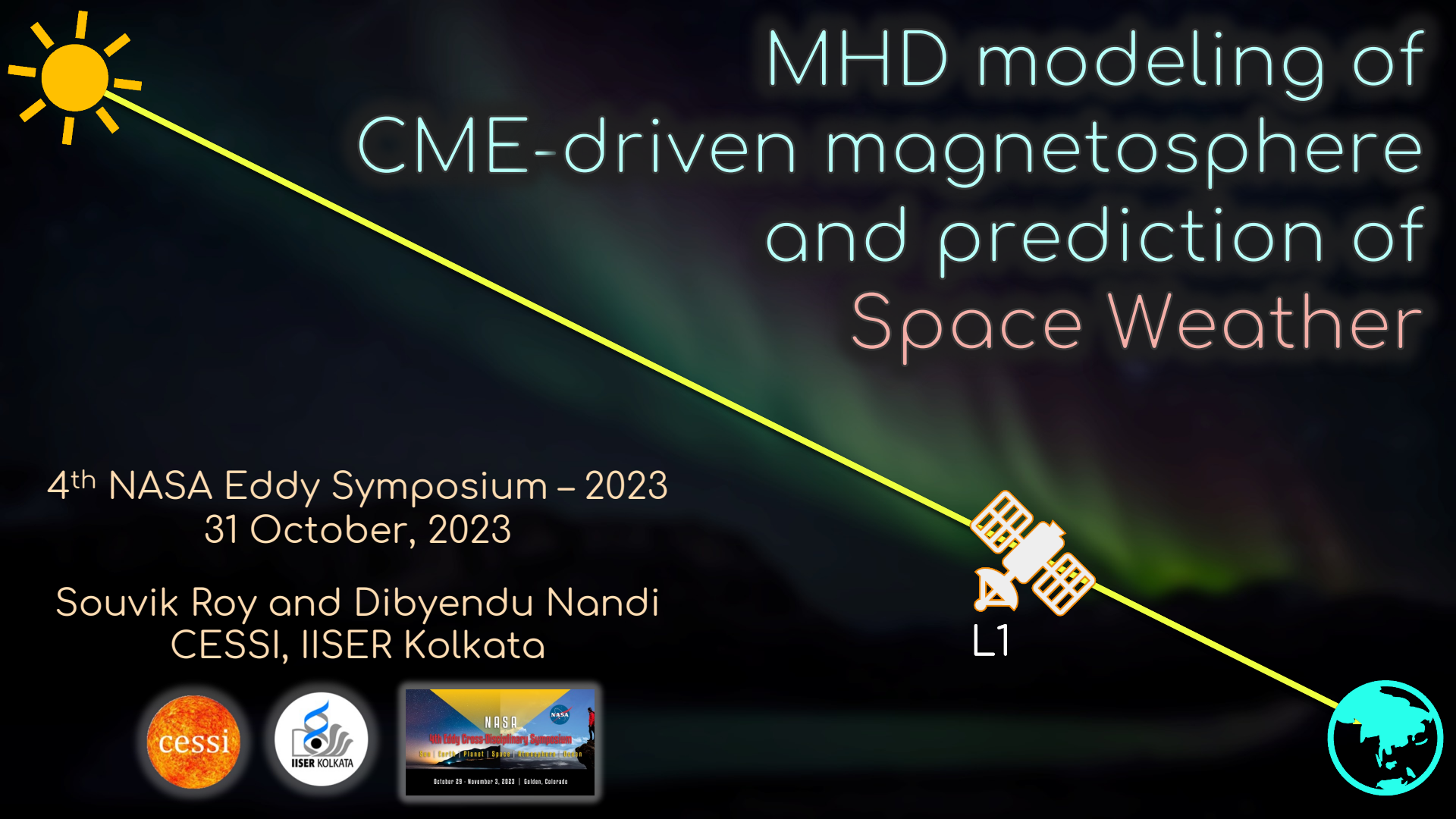
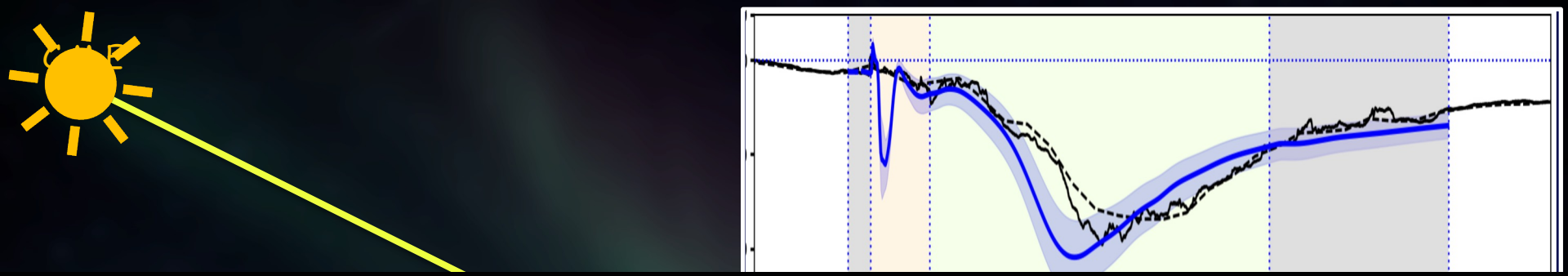


1. Context

2. Approach

3. Results

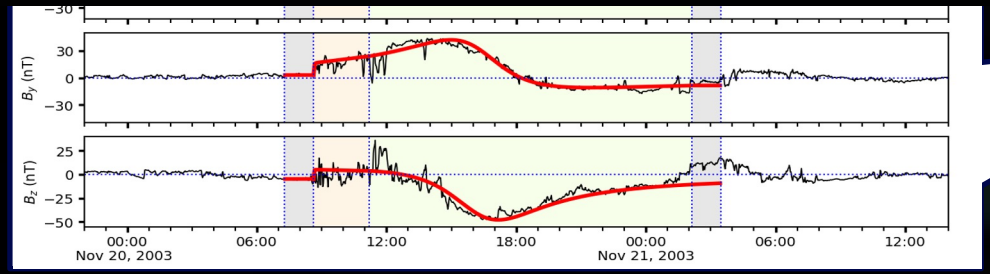
4. Ultimate Goal

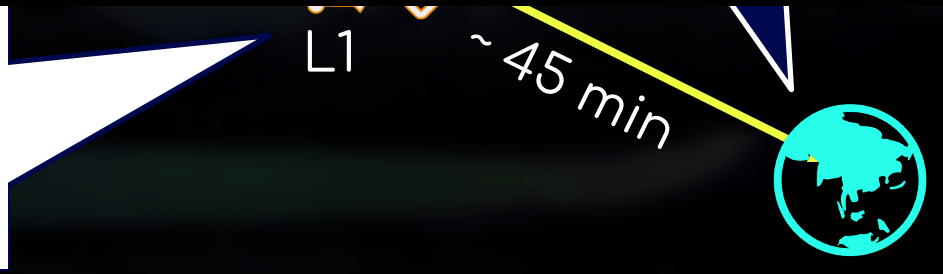


CESSI – STORM Interaction Module

aka

STORMI





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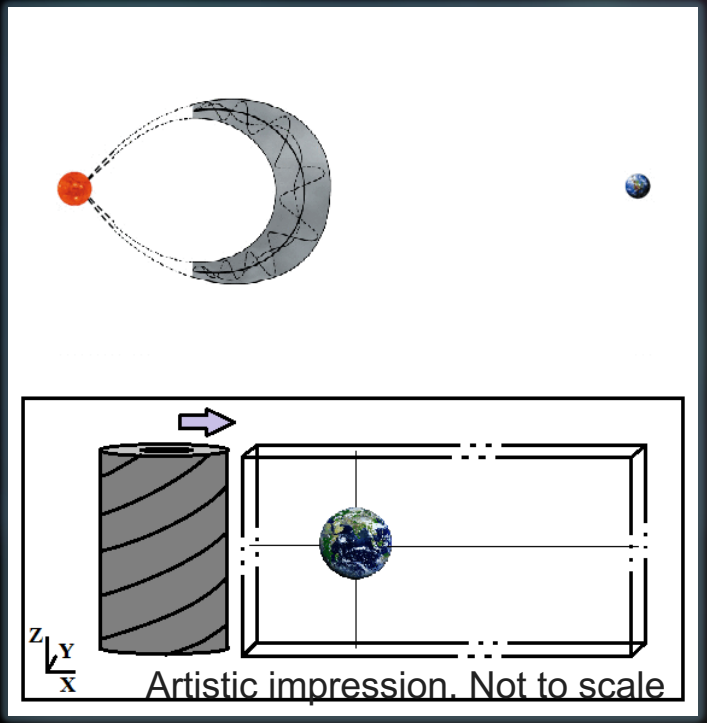
What is inside of STORMI?



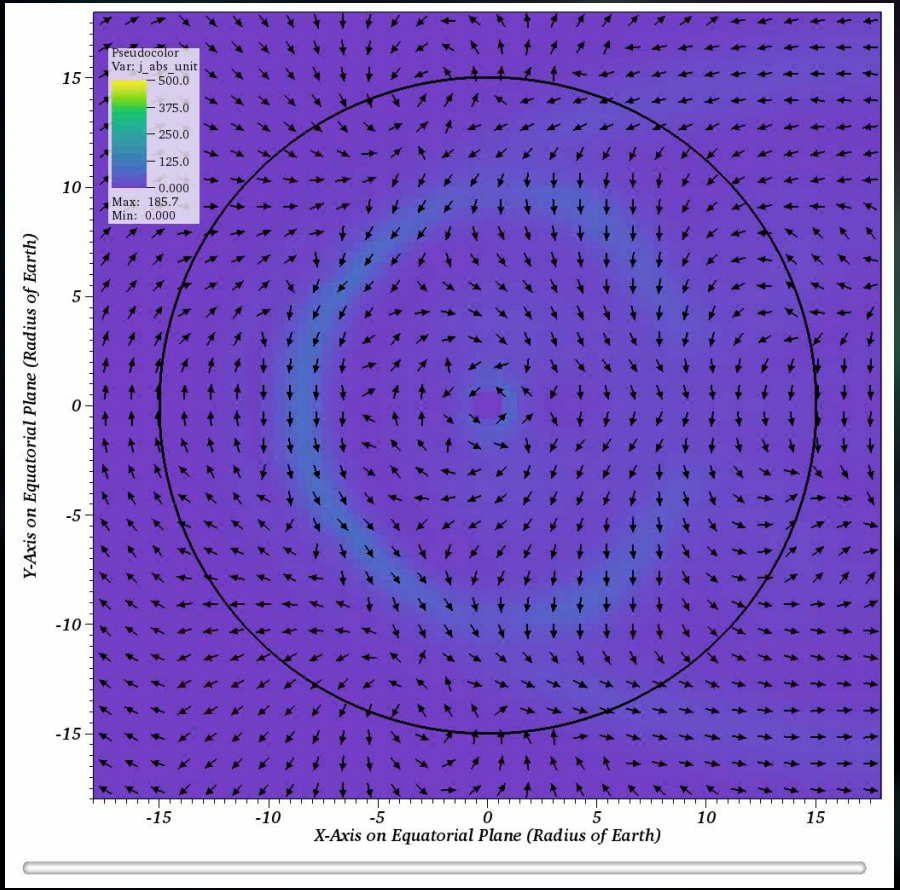
3D Magnetohydrodynamic simulation using

PLUTO architecture

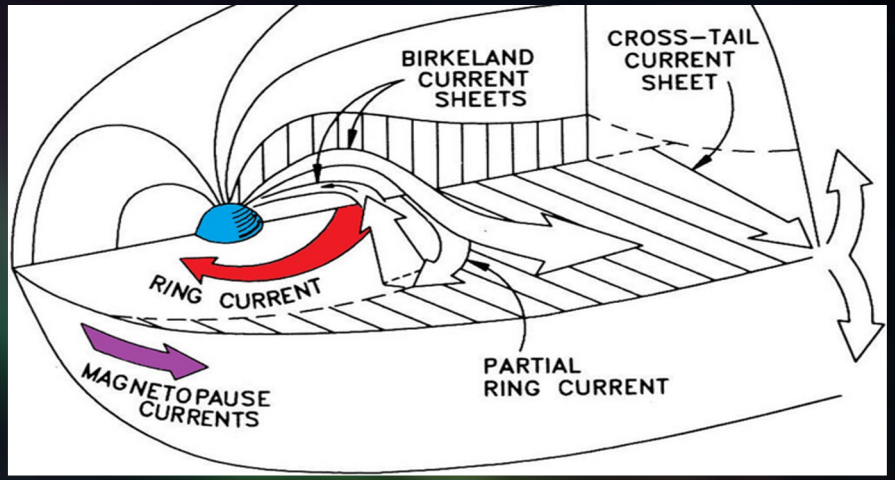
Assumptions:

- "Far out" earth-like planet
- Intrinsic dipolar planetary magnetic field
- Stellar wind as magnetised shock
- Non-relativistic, compressible, Adiabatic fluid Gamma = 5/3
- High Magnetic Reynolds number
- Lundquist or Gold-Hoyle type flux rope with no axial curvature
- expansion is assumed negligible during computation

Induced Currents!!

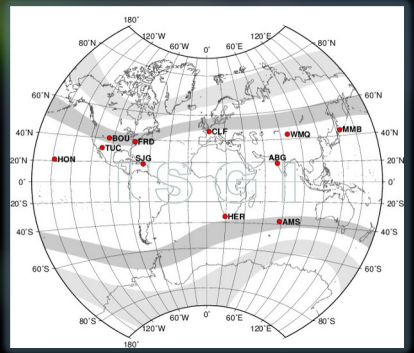


Magnetospheric current



Biot–Savart law

$$\vec{B}(r) = \frac{1}{c}\int_{v'} \frac{\vec{J}(r') \times \vec{r}}{r'^3} dv'.$$



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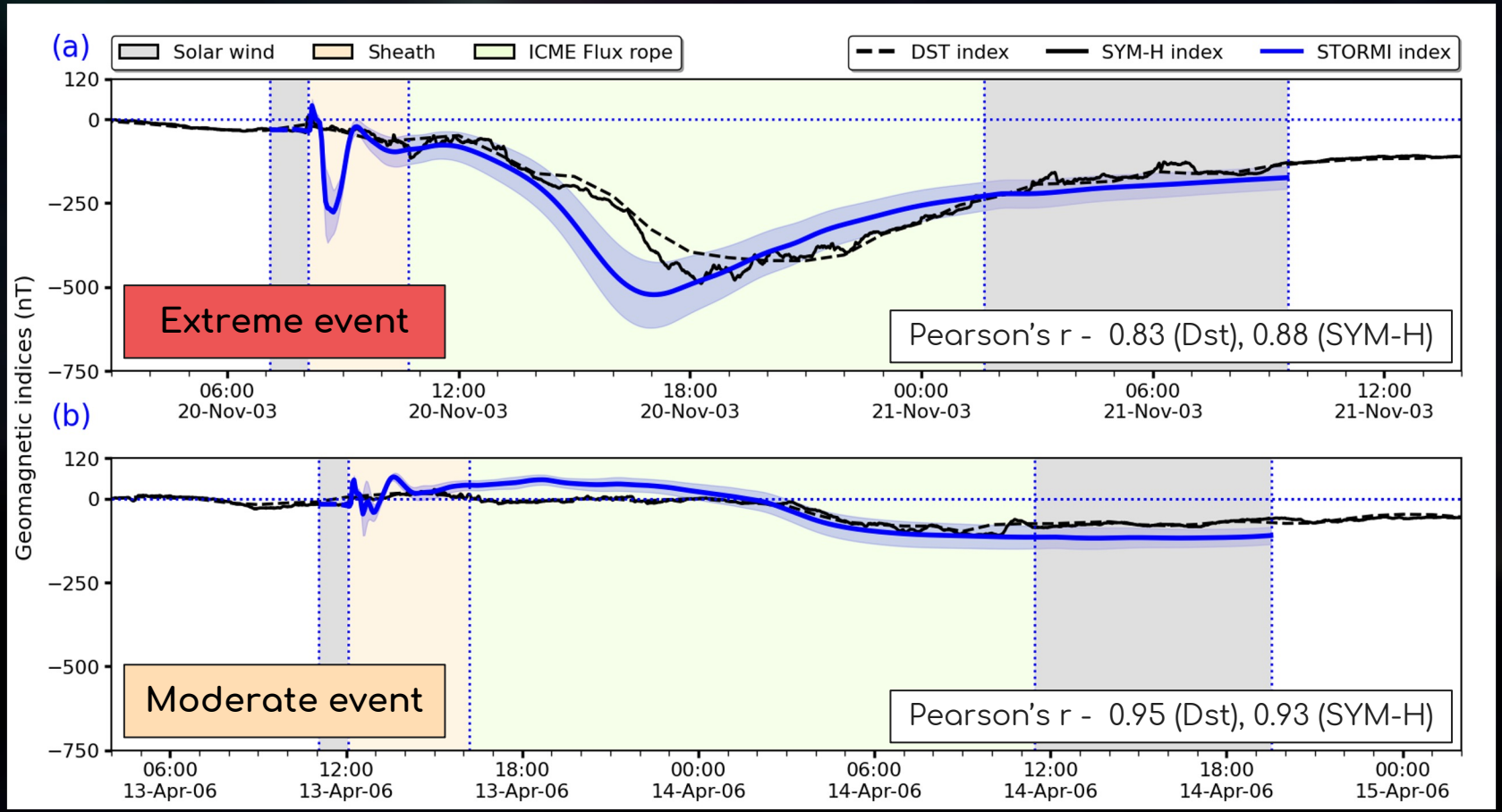
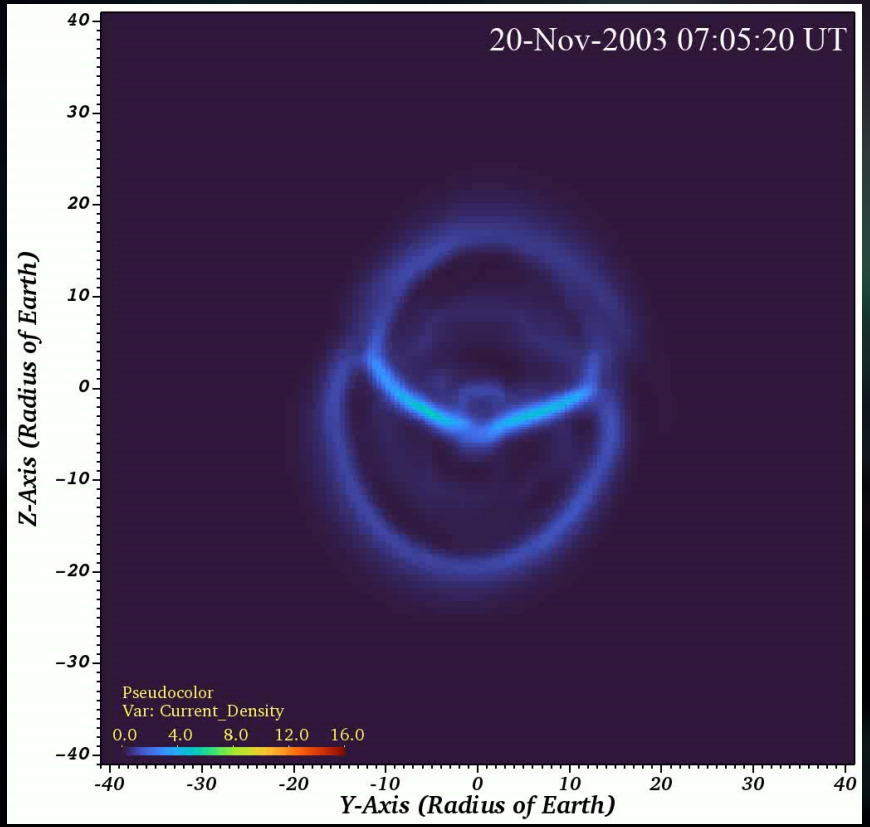
Prediction of Space Weather



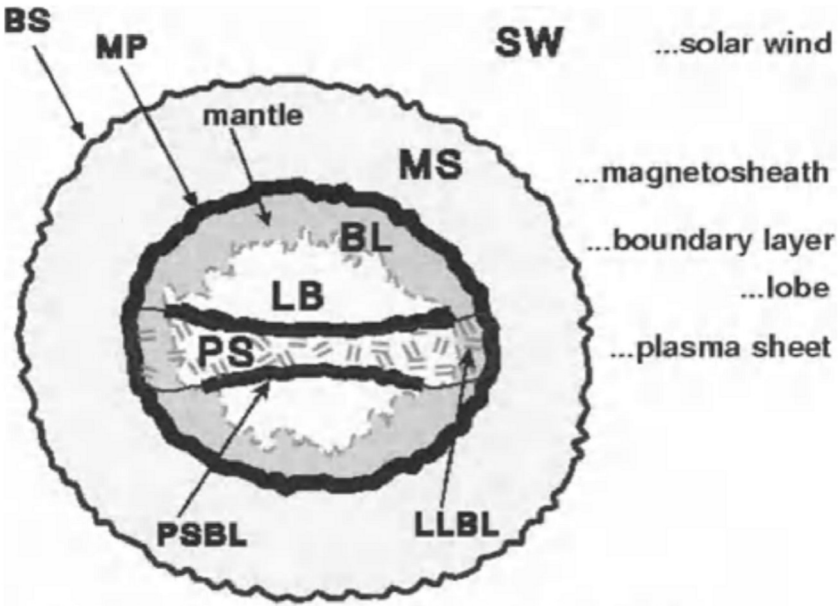
Can we solve the magnetospheric dynamics?

Simulated using STORMI



Observed by Geotail spacecraft

Ref: Christon et. al., Space Physics, 103, A10,1998

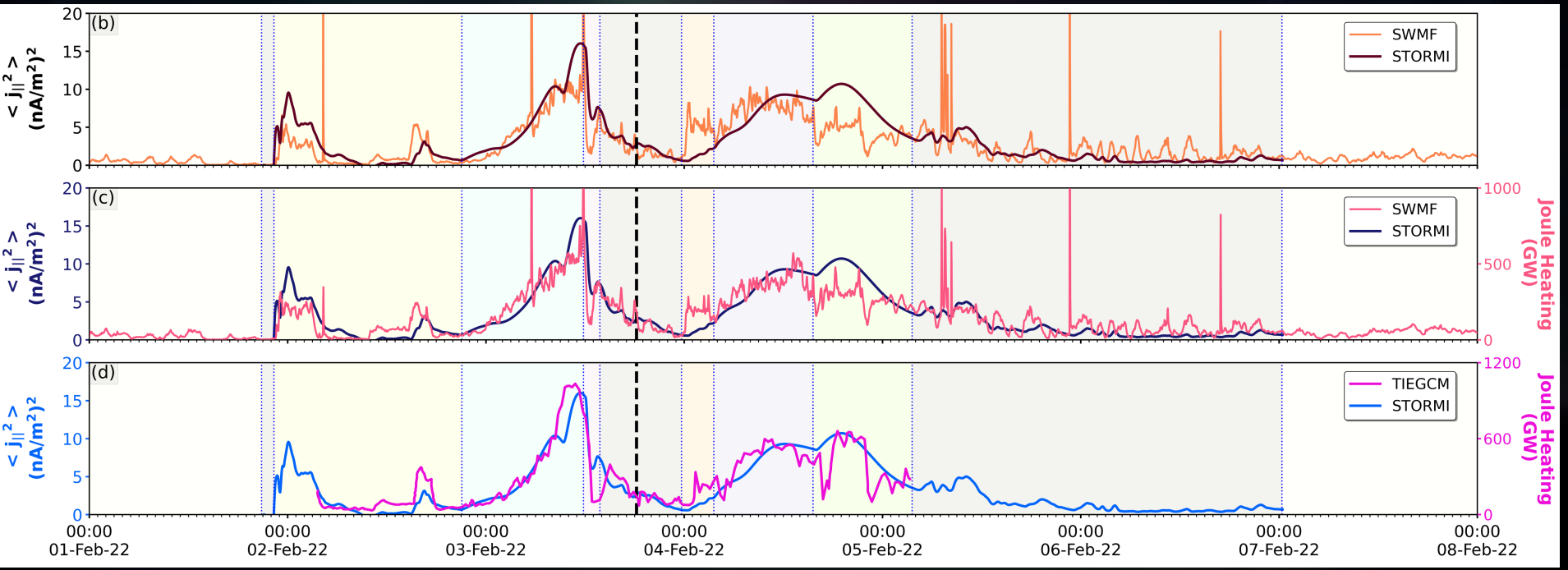


Magnetotail Plasma Regime Identification

Can we solve the magnetospheric dynamics?

The Joule heating leads to $\frac{dP}{dV} \propto j^2$

Averaged over a geocentric sphere of 8 R_E



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Are we predicting the Dst/SYM-H index?

Technically NO !!

Because we are not using particle definition of plasma or ring current physics

BUT

As a proxy of Dst/ SYM-H, our Index performs well in estimating the geoeffectiveness and temporal evolution of a storm.

AND

sacrificing intricate complexities, we focus on the development of a simple, time-efficient modelling framework with reasonably good prediction skills.

Can we predict geoeffectiveness in real time?

Unfortunately, NO !!

Because with our current computation power, it takes few hours to days to run a complete simulation.

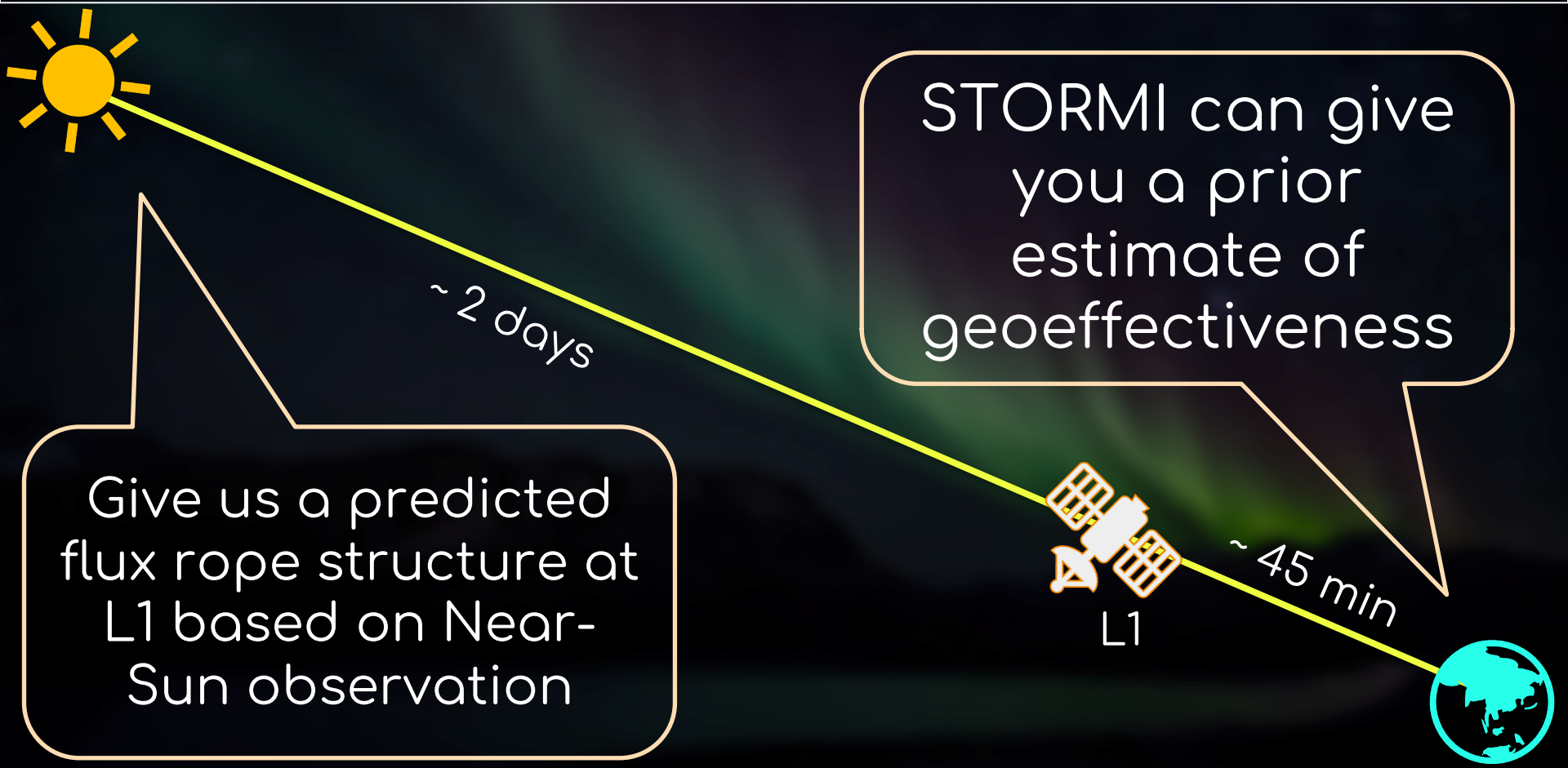
Whereas

It takes around 40 - 60 minutes for an ICME to reach from L1 point to Earth.

But

It is not completely impossible.

Can we predict geoeffectiveness in real time?



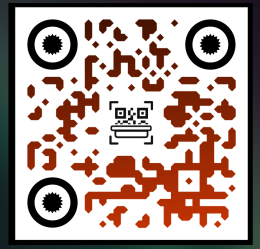
Possibilities!!!!

- ICME driven space weather for (exo)planetary bodies and validate observations.
- Incorporate ionospheric physics and and make it more robust.
- Incorporate multi-fluid MHD.
- Increase computational efficiency.
- Any thing you want to suggest!!

LOOKING FOR COLABS and POST-DOC OPPORTUNITIES.

Refer to:

Roy, S., & Nandy, D., 2023, APJL, 950, L11



For collaboration or further discussions:

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Thank You