Opening EPREM: Progress toward an open-source coupling-agnostic model

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2024 NASA CCMC Workshop

Model Overview

EPREM

The Energetic Particle Radiation Environment Model

Solves the focused transport equation on linked nodes that move with the frame of the solar-wind plasma.

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$$\left[1-\frac{\left(\vec{V}\cdot\hat{b}\right)v\mu}{c^2}\right]\frac{df_s}{dt} \qquad \text{(convection)}$$

$$+v\mu\hat{b}\cdot\nabla f_s \qquad \text{(streaming)}$$

$$+\frac{\left(1-\mu^2\right)}{2}\left[-v\hat{b}\cdot\nabla\ln B-\frac{2}{v}\hat{b}\cdot\frac{d\vec{V}}{dt}+\mu\frac{d\ln\left(n^2/B^3\right)}{dt}\right]\frac{\partial f_s}{\partial\mu} \qquad \text{(adiabatic focusing)}$$

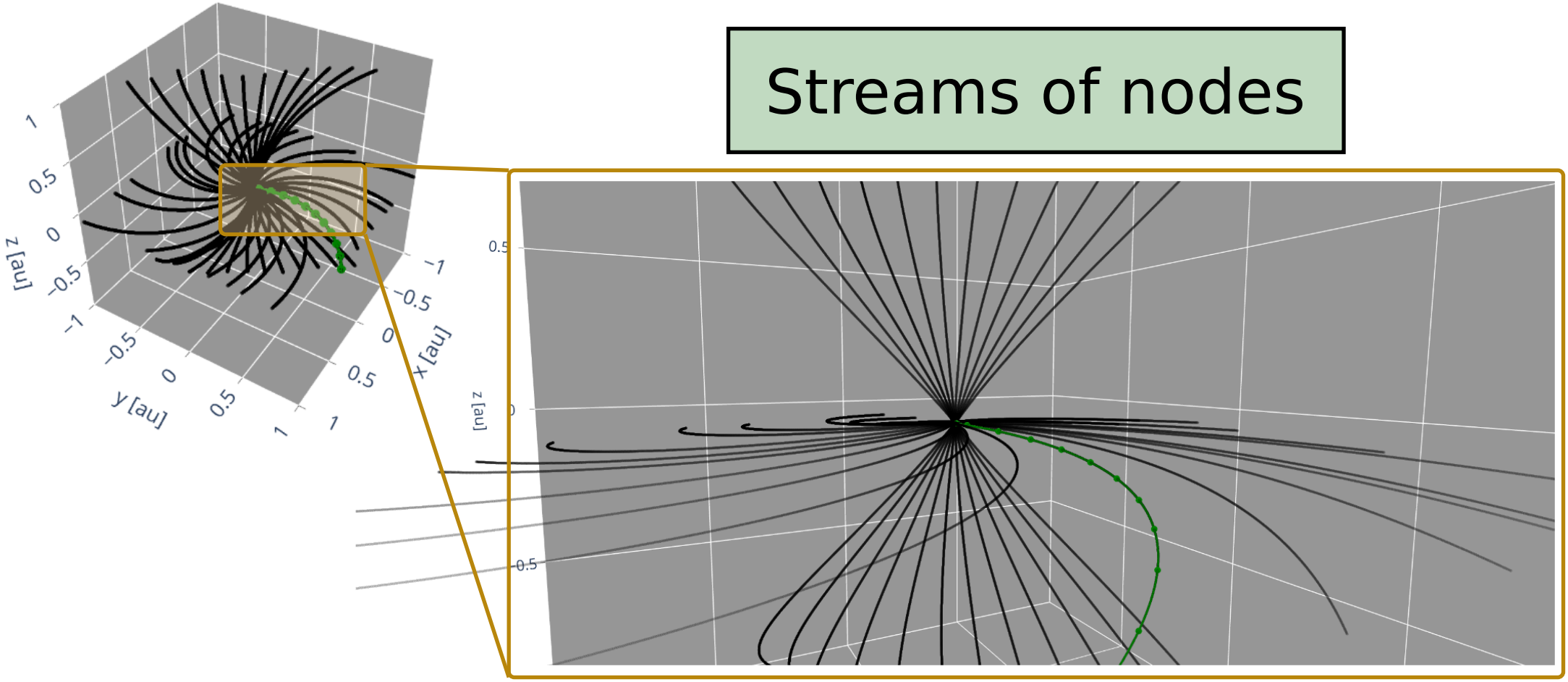
$$+\left[-\frac{\mu}{v}\hat{b}\cdot\frac{d\vec{V}}{dt}+\mu^2\frac{d\ln\left(n/B\right)}{dt}+\frac{\left(1-\mu^2\right)}{2}\frac{d\ln B}{dt}\right]\frac{\partial f_s}{\partial\ln p} \qquad \text{(cooling)}$$

$$=\frac{\partial}{\partial\mu}\left(\frac{D_{\mu\mu}}{2}\frac{\partial f_s}{\partial\mu}\right)+q\left(\vec{r},p,t\right) \qquad \text{(pitch-angle scattering and injection)}$$

EPREM

The Energetic Particle Radiation Environment Model

Solves the focused transport equation on linked nodes that move with the frame of the solar-wind plasma.



EPREM

The Energetic Particle Radiation Environment Model

Solves the focused transport equation on linked nodes that move with the frame of the solar-wind plasma.

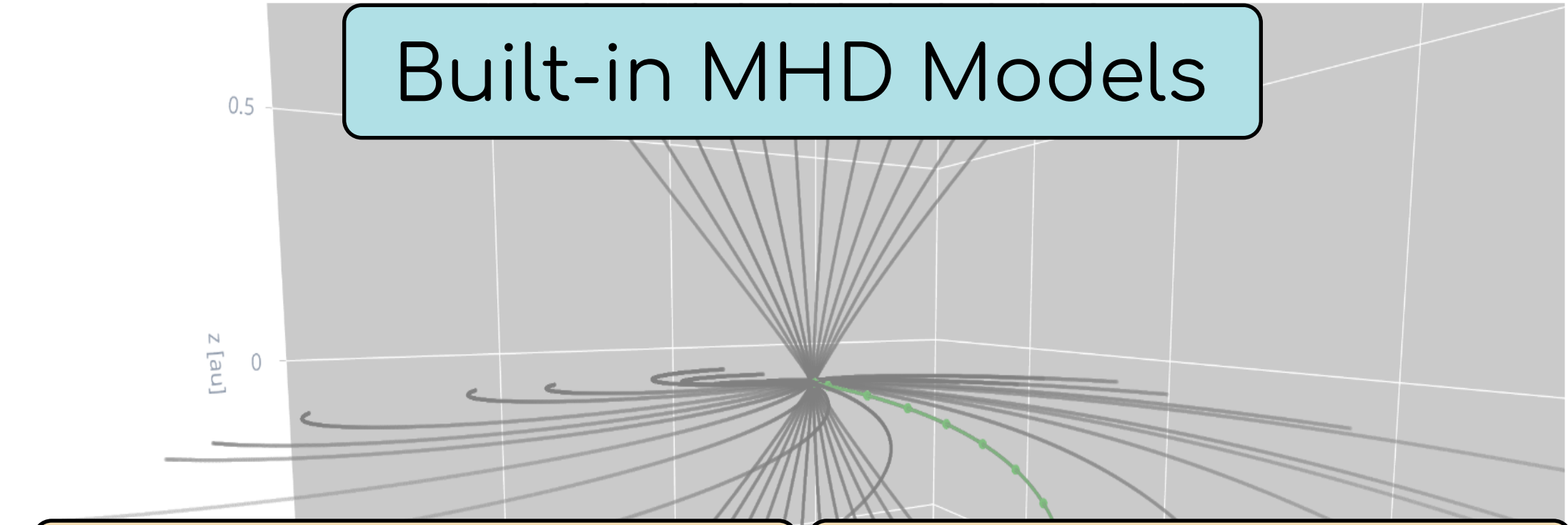
Requires knowledge of

- magnetic field ($\mathbf{B}$)
- velocity field ($\mathbf{V}$)
- density (n)

EPREM

The Energetic Particle Radiation Environment Model

Built-in MHD Models



Wind

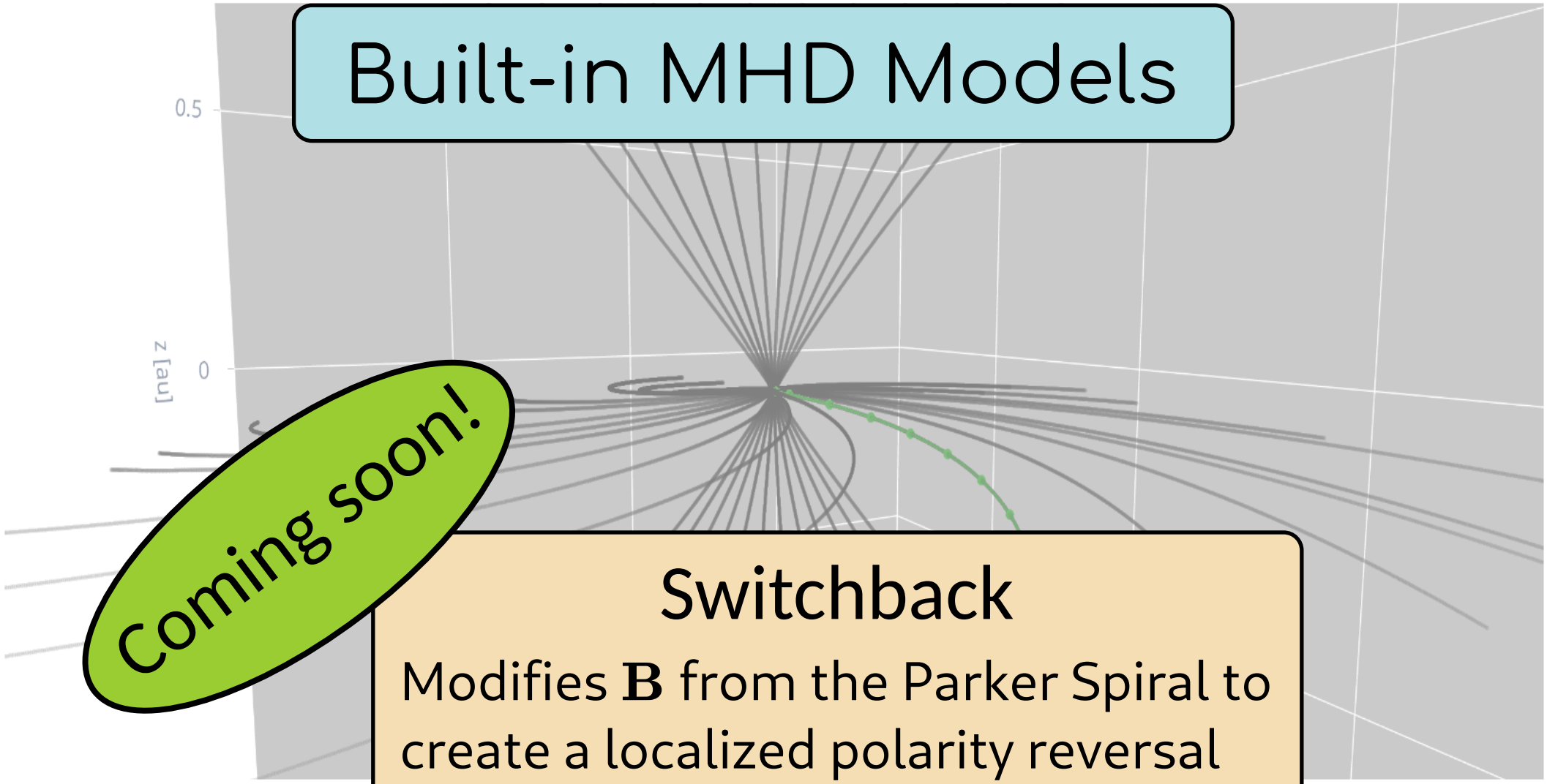
Applies $\mathbf{B}$, $\mathbf{V}$, and n consistent with a Parker spiral

Shock

Solves the Rankine-Hugoniot equations for $\mathbf{B}$, $\mathbf{V}$, and n

EPREM

The Energetic Particle Radiation Environment Model



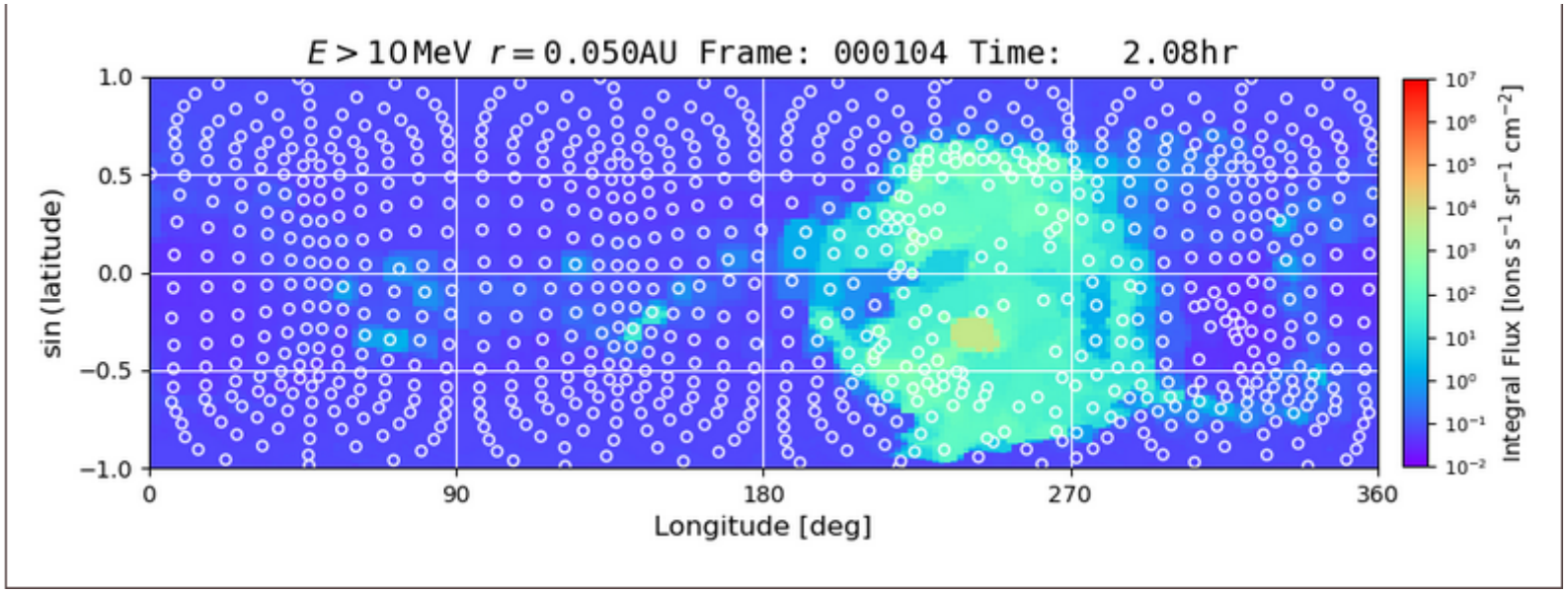
Built-in MHD Models

Coming soon!

Switchback

Modifies $\mathbf{B}$ from the Parker Spiral to create a localized polarity reversal

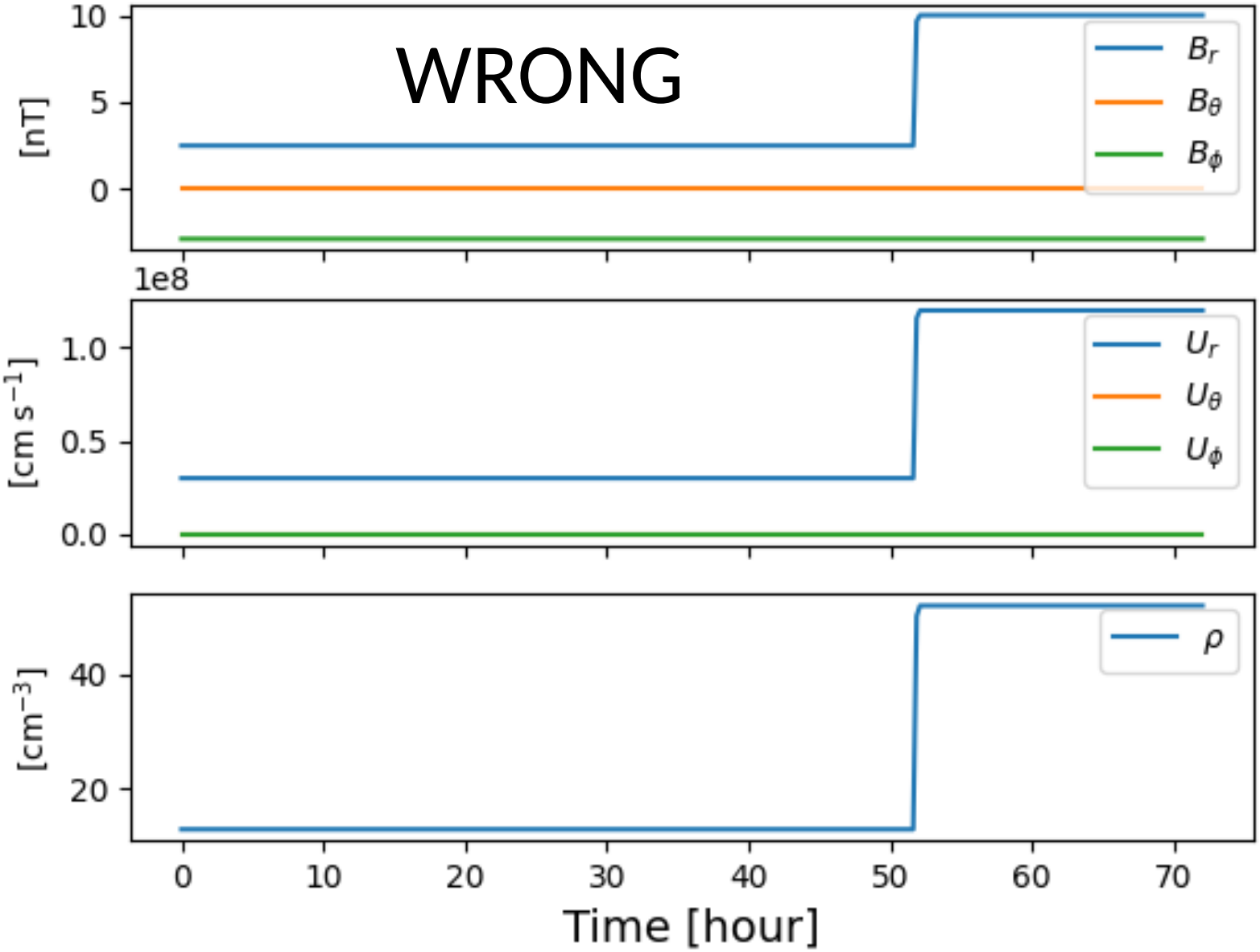
EPREM and STAT



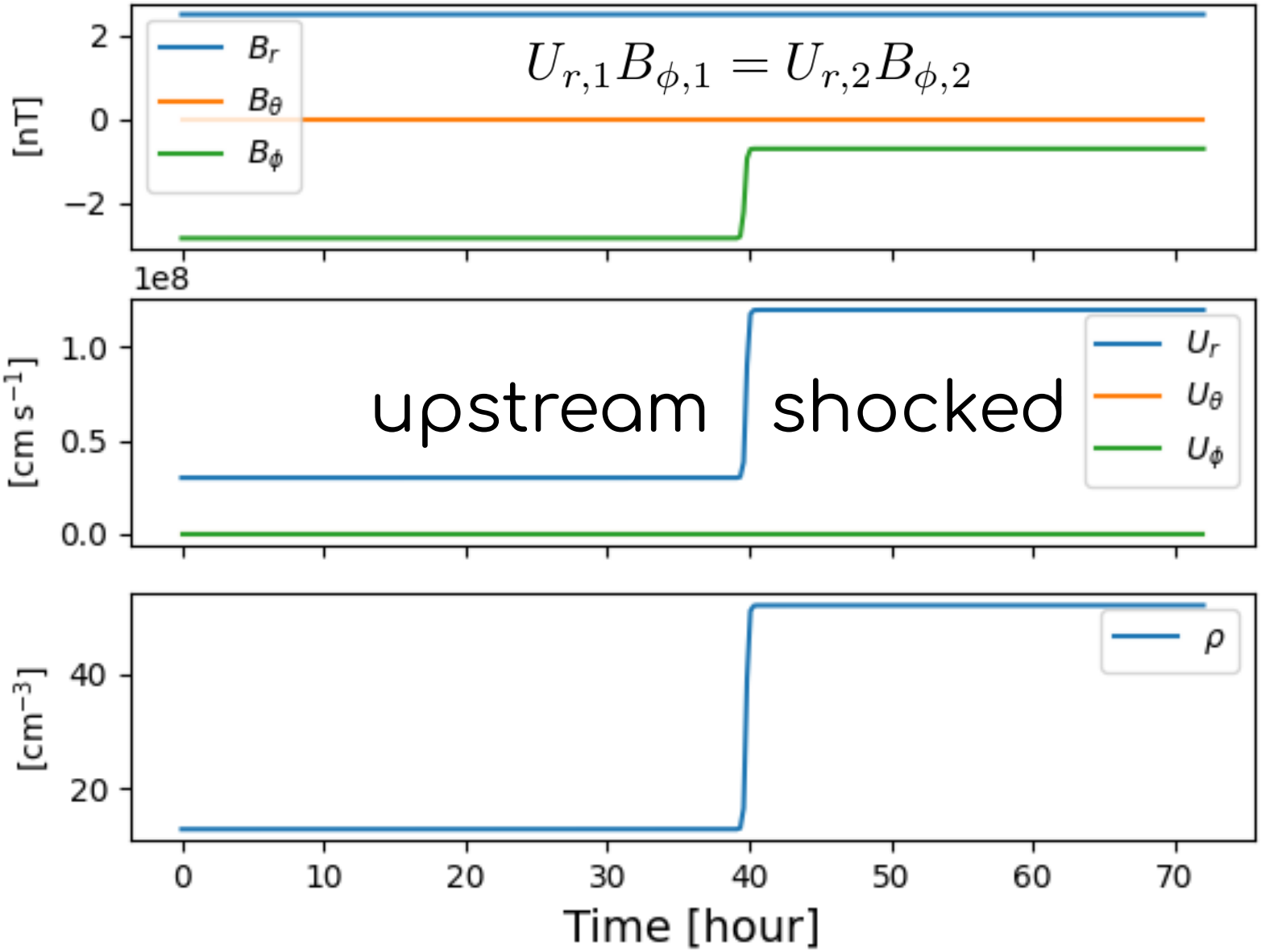
- The SPE Threat Assesment Tool (STAT) was jointly developed by UNH and PSI.
- STAT results are available through CCMC.
- STAT drives EPREM using B, V, and n from PSI's MAS simulation within the CORHEL framework.
- EPREM within STAT is intrinsically coupled to MAS/CORHEL but is functionally the same as open-source EPREM.

Code Updates

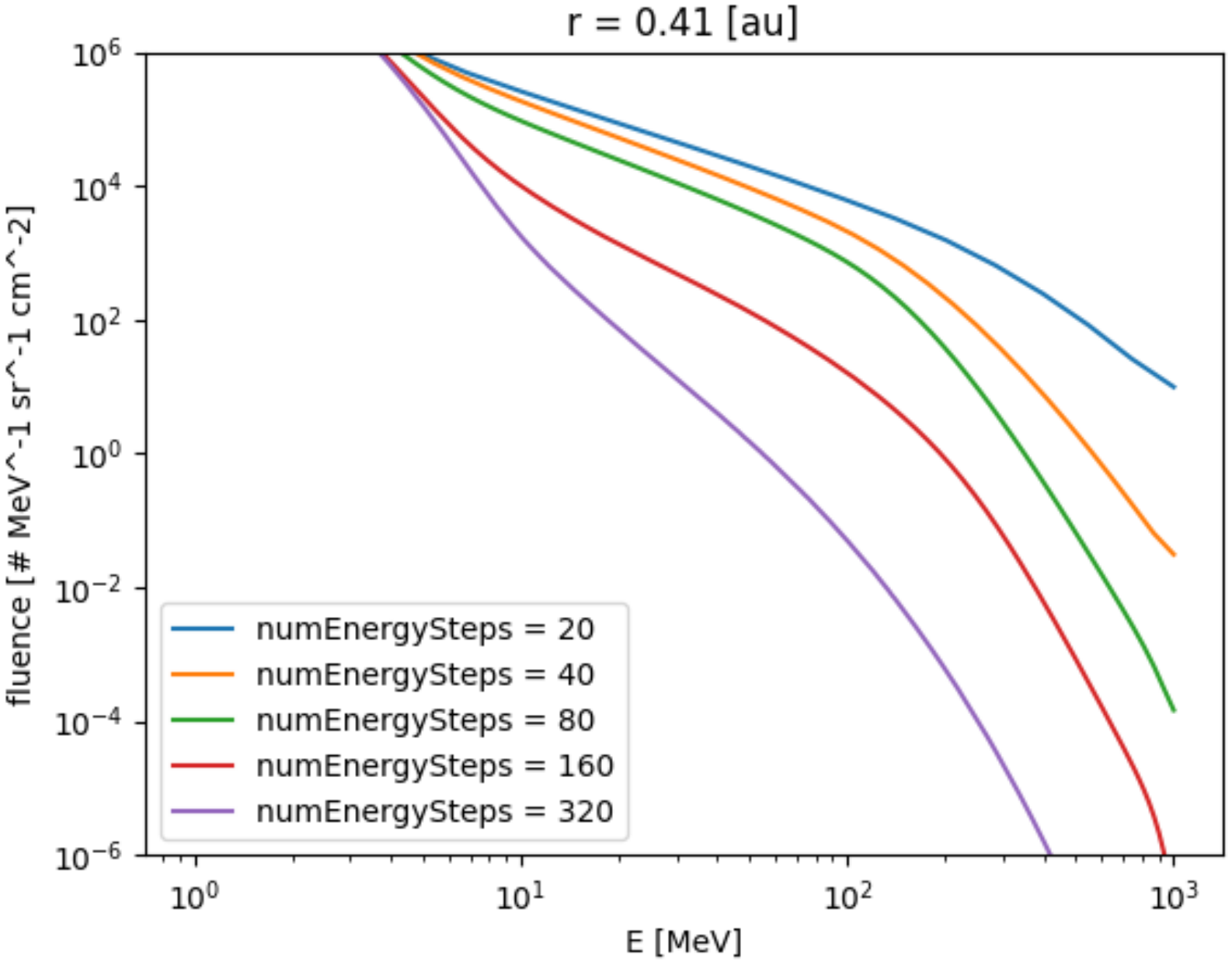
Ideal Shock MHD: Old version



Ideal Shock MHD: New version



Proton Flux v. Energy: Old version



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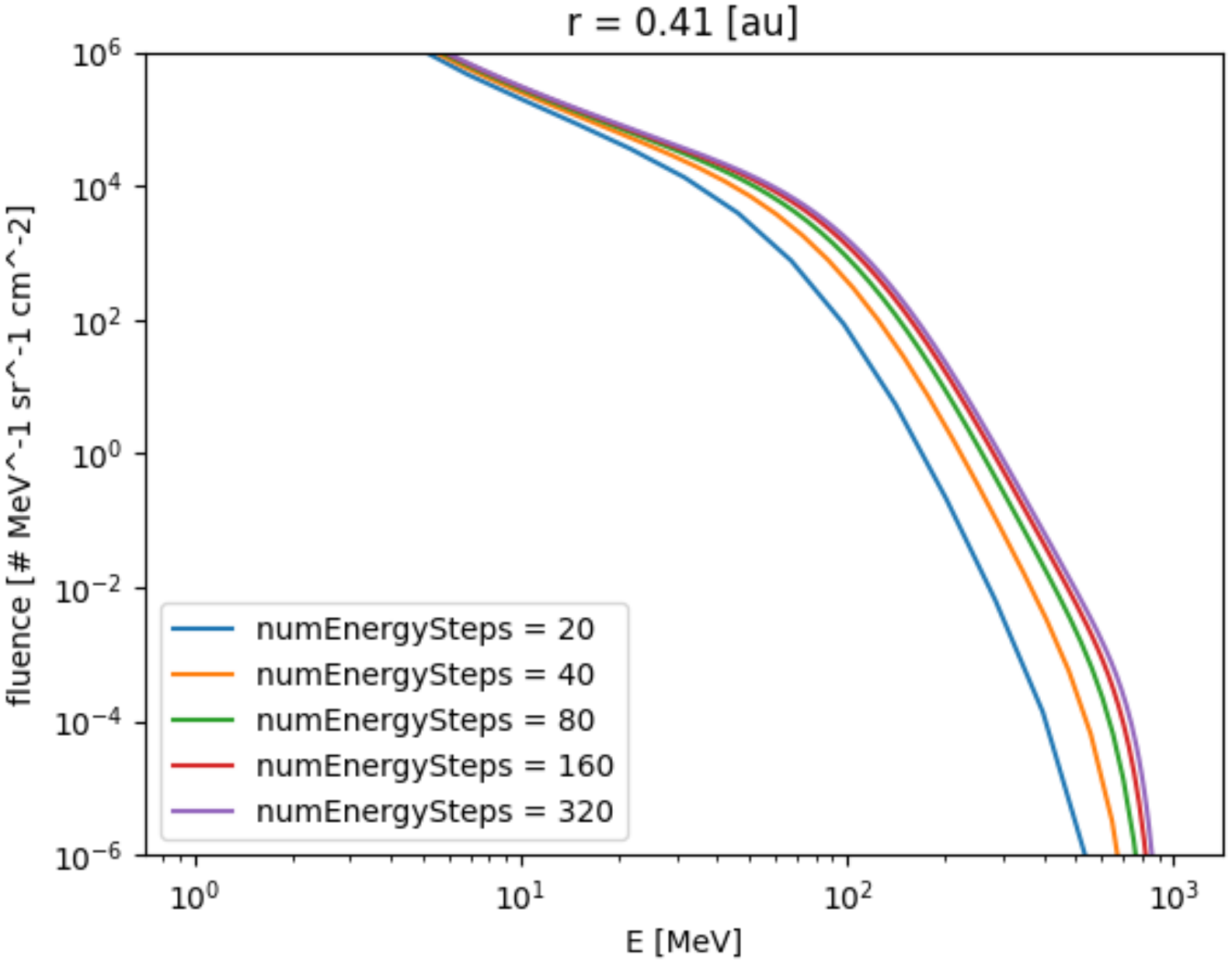
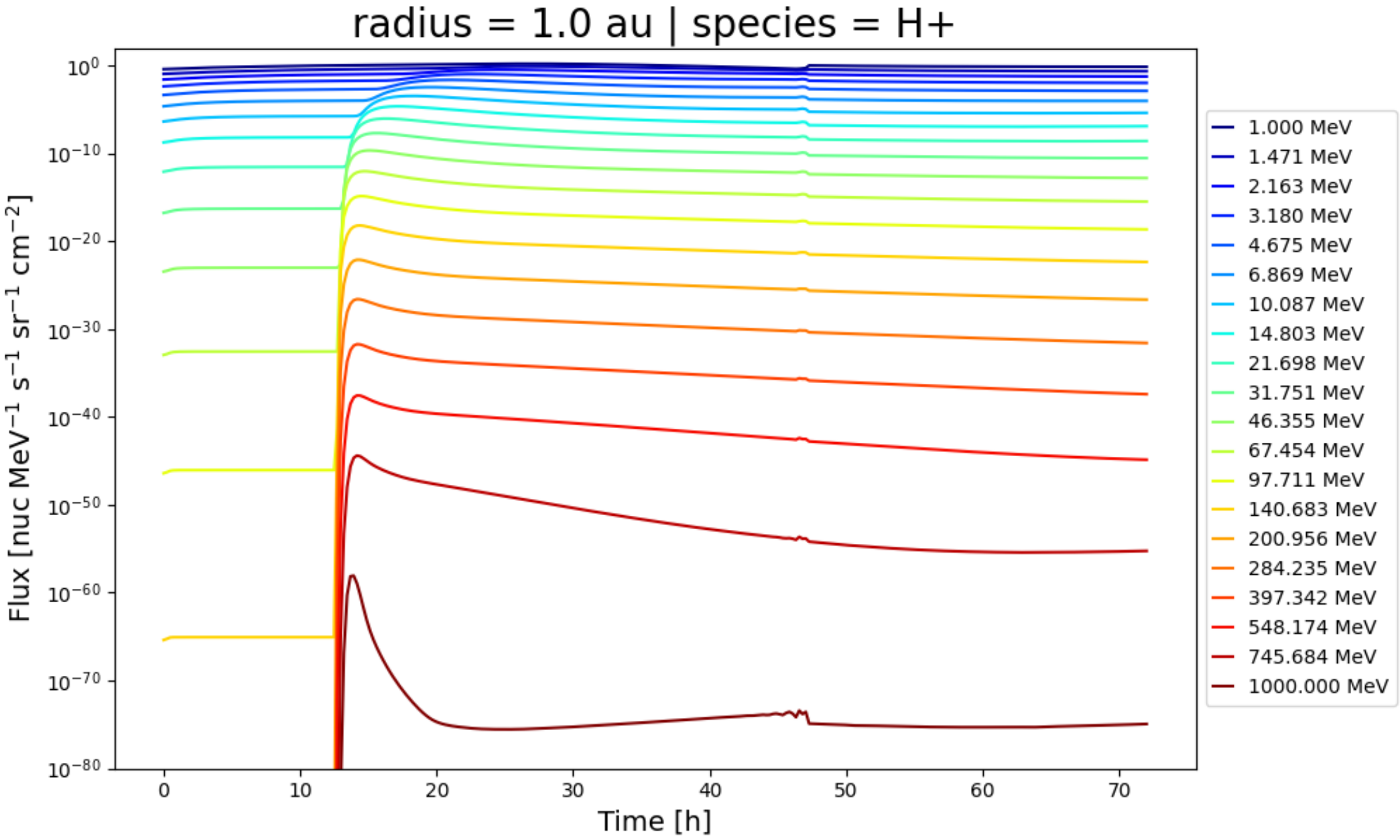
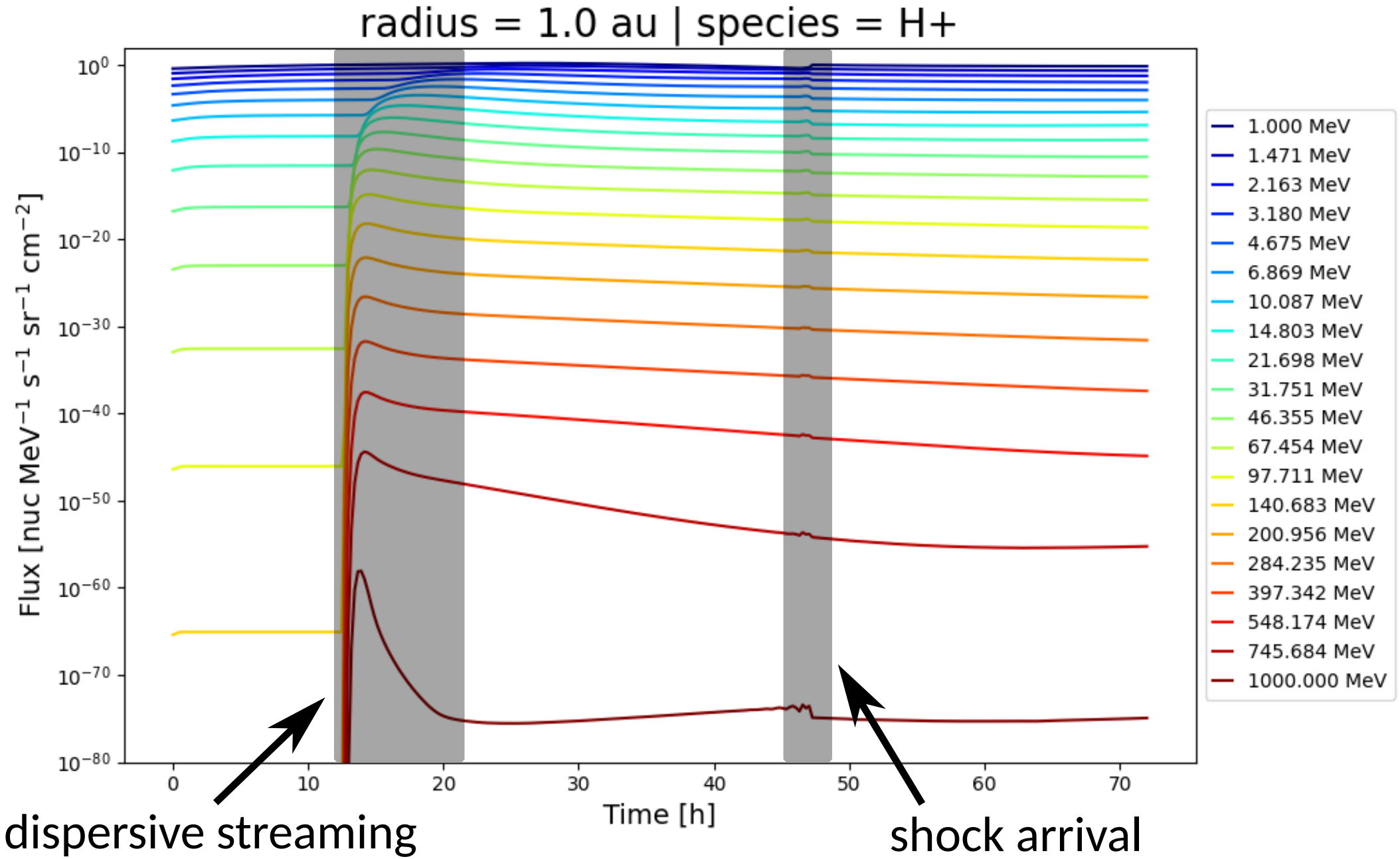


Current Progress and Next Steps

Ideal Shock Proton Fluxes



Ideal Shock Proton Fluxes



Why Open EPREM?

Historically, there have been **multiple closed-source implementations** of EPREM with **high redundancy** and **model-specific** MHD-coupling logic.

Why Open EPREM?

Our goal is to develop a **single open-source implementation** of EPREM with **model-agnostic** MHD-coupling logic.

Why Open EPREM?

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done

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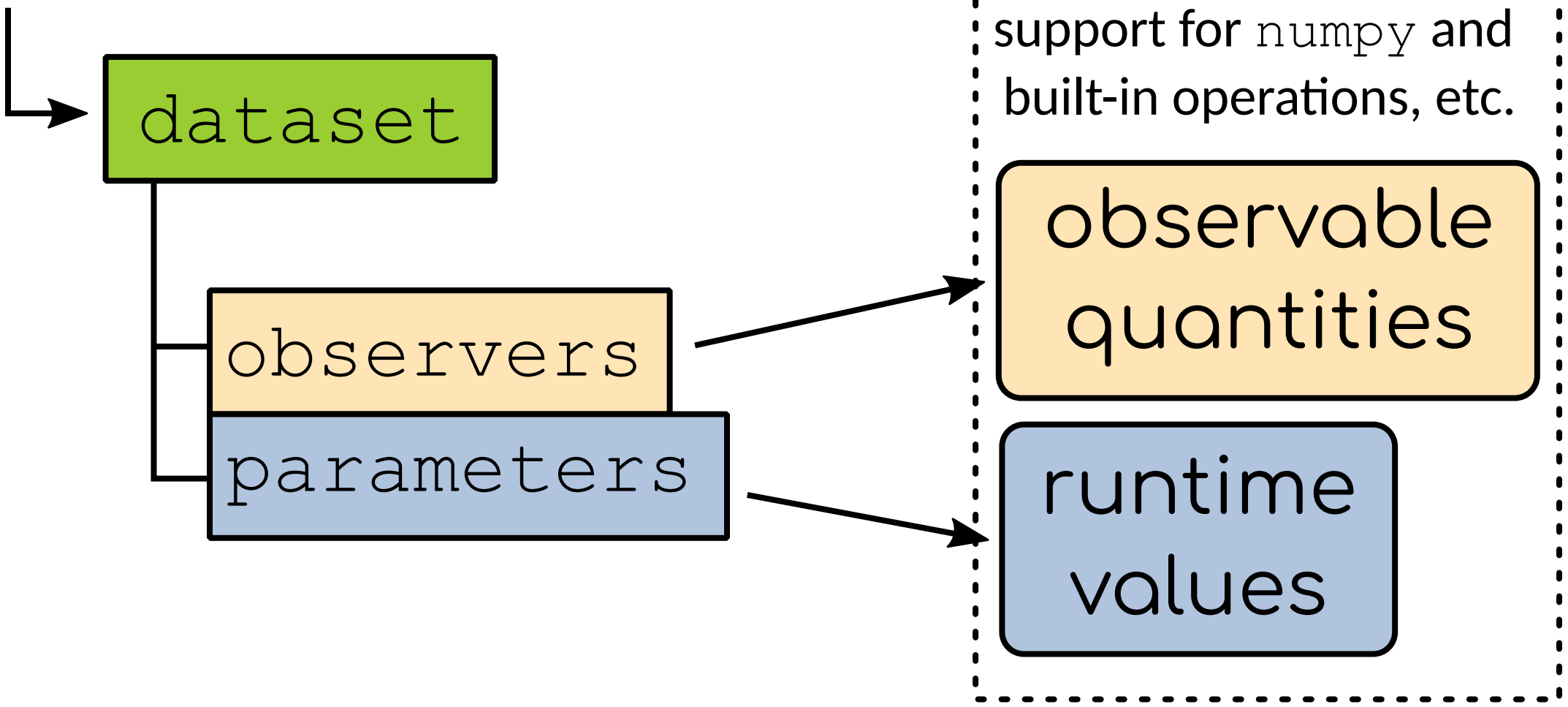
work in progress

EPREMpy

- path to EPREM output
- name of config file



Plans, Hopes, and Dreams

- Implement a magnetic switchback model
- Runs on Request: Coming Fall 2024
- Improve the ideal-shock model
- Support multiple forms of the seed spectrum
- Revive neglected EPREM features
- Develop a test framework

(not to mention library updates and bug fixes...)

Acknowledgements

NASA O2R

80NSSC20K0285

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NSF Solar-Terrestrial

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Thank You

Matthew.Young@unh.edu

https://gitlab.com/open-eprem/eprem

https://gitlab.com/open-eprem/eprempy

https://gitlab.com/open-eprem/eprem-analysis

```
pip install eprempy
```