

EPREM:

Recent results, current status, and the path to version 1.0

Matt Young (he/him)
Bala Poduval
Nathan Schwadron



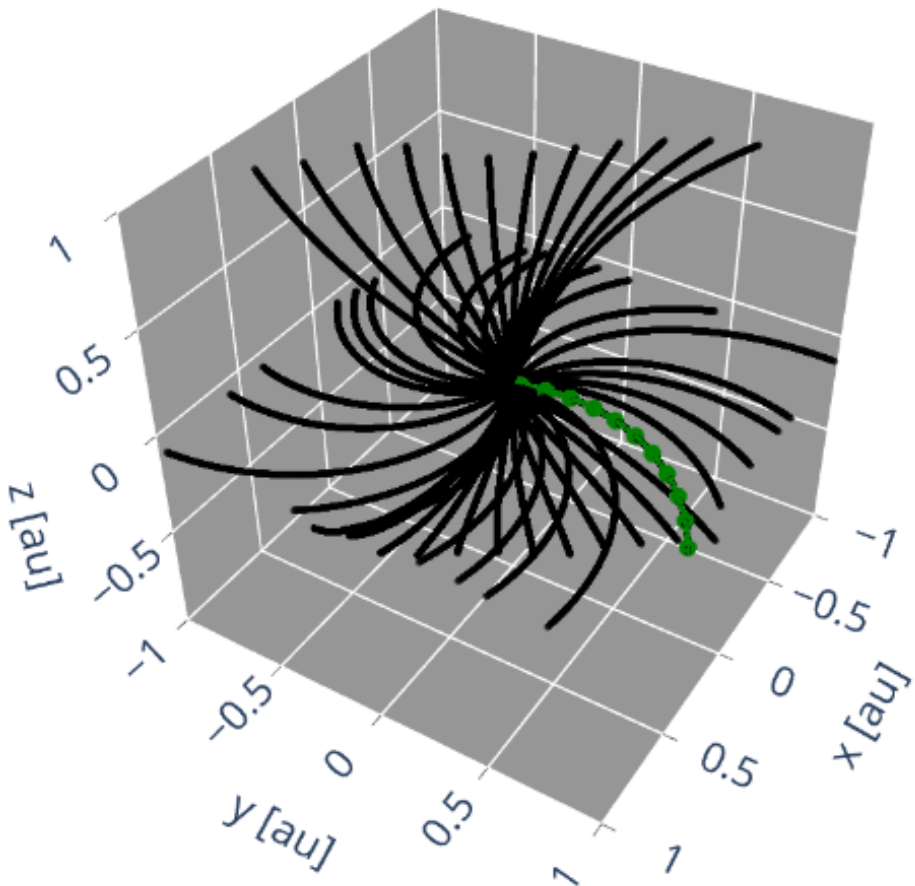
Ron Caplan
Jon Linker



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.



Particle Phenomena

convection

streaming

cooling

adiabatic focusing

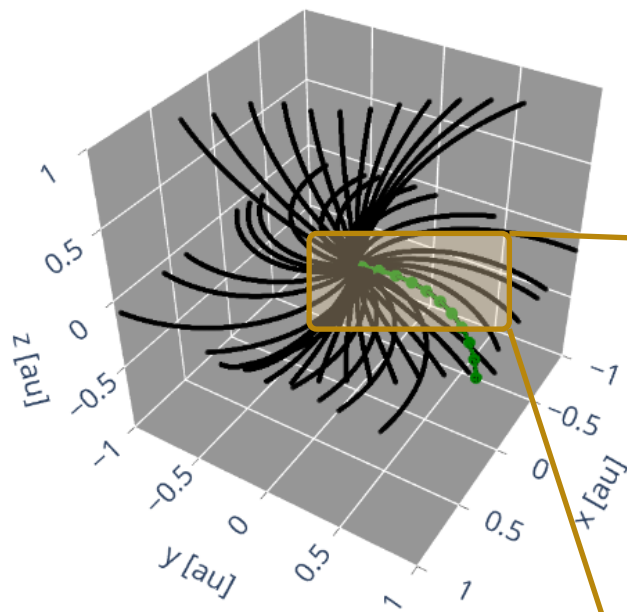
pitch-angle scattering

injection

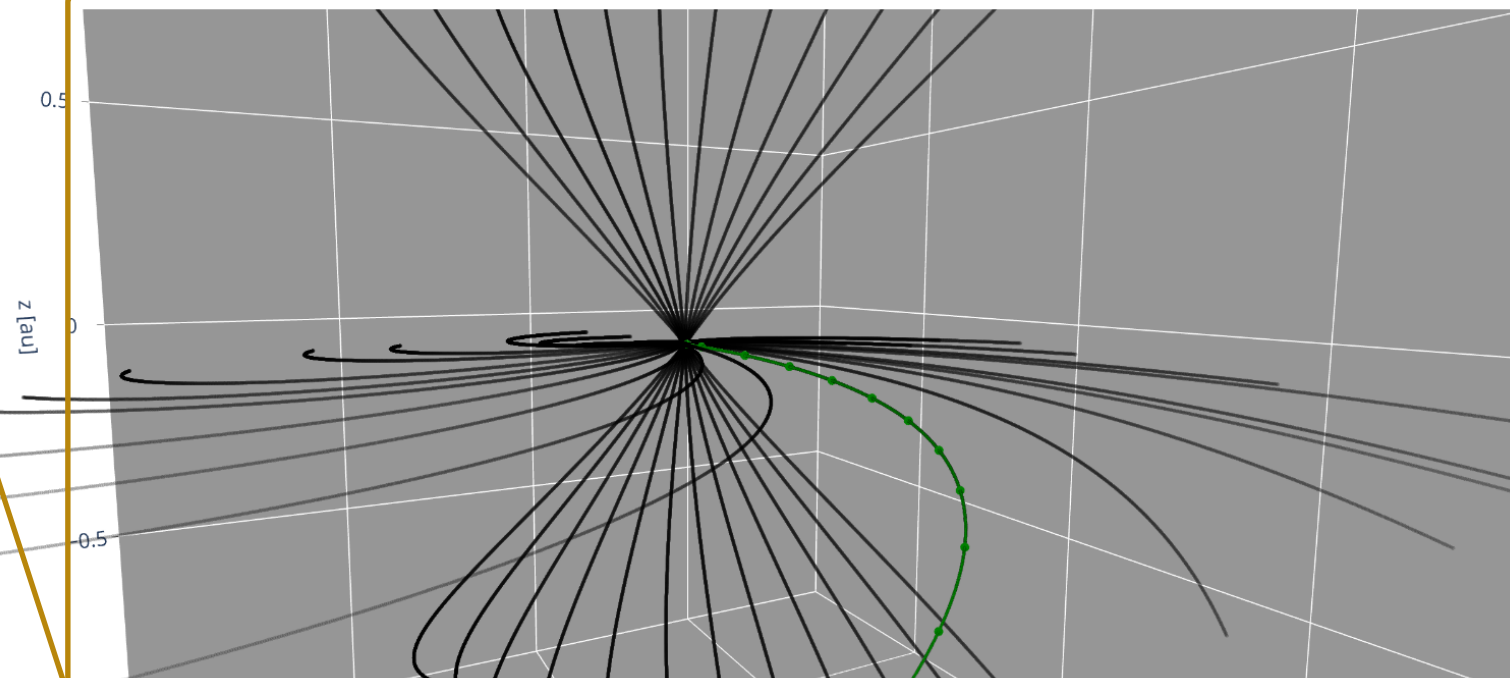
EPREM

The Energetic Particle Radiation Environment Model

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



Streams of nodes



Focused Transport Equation

describes acceleration and transport in the solar-wind frame

...

$$\begin{aligned}
 & \left[1 - \frac{(\vec{V} \cdot \hat{b}) v \mu}{c^2} \right] \frac{df_s}{dt} && \text{(convection)} \\
 & + v \mu \hat{b} \cdot \nabla f_s && \text{(streaming)} \\
 + \frac{(1 - \mu^2)}{2} & \left[-v \hat{b} \cdot \nabla \ln B - \frac{2}{v} \hat{b} \cdot \frac{d\vec{V}}{dt} + \mu \frac{d \ln (n^2 / B^3)}{dt} \right] \frac{\partial f_s}{\partial \mu} && \text{(adiabatic focusing)} \\
 + & \left[-\frac{\mu}{v} \hat{b} \cdot \frac{d\vec{V}}{dt} + \mu^2 \frac{d \ln (n / B)}{dt} + \frac{(1 - \mu^2)}{2} \frac{d \ln B}{dt} \right] \frac{\partial f_s}{\partial \ln p} && \text{(cooling)} \\
 & = \frac{\partial}{\partial \mu} \left(\frac{D_{\mu\mu}}{2} \frac{\partial f_s}{\partial \mu} \right) + q(\vec{r}, p, t) && \text{(pitch-angle scattering and injection)}
 \end{aligned}$$

Kóta, et al. (2005); Ruffalo (1995); Skilling (1971)

Focused Transport Equation

describes acceleration and transport in the solar-wind frame
of a distribution of charged particles

...

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

Kóta, et al. (2005); Ruffalo (1995); Skilling (1971)

Focused Transport Equation

describes acceleration and transport in the solar-wind frame
of a distribution of charged particles
as a function of time, position, momentum, and pitch angle

$$\begin{aligned}
 & \left[1 - \frac{(\vec{V} \cdot \hat{b}) v \mu}{c^2} \right] \frac{df_s}{dt} && \text{(convection)} \\
 & + v \mu \hat{b} \cdot \nabla f_s && \text{(streaming)} \\
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 \end{aligned}$$

Kóta, et al. (2005); Ruffalo (1995); Skilling (1971)

Focused Transport Equation

requires knowledge of solar-wind MHD quantities:
magnetic field (\mathbf{B}), velocity field (\mathbf{V}), and density (n)

$$\begin{aligned}
 & \left[1 - \frac{(\vec{V} \cdot \hat{b}) v \mu}{c^2} \right] \frac{df_s}{dt} && \text{(convection)} \\
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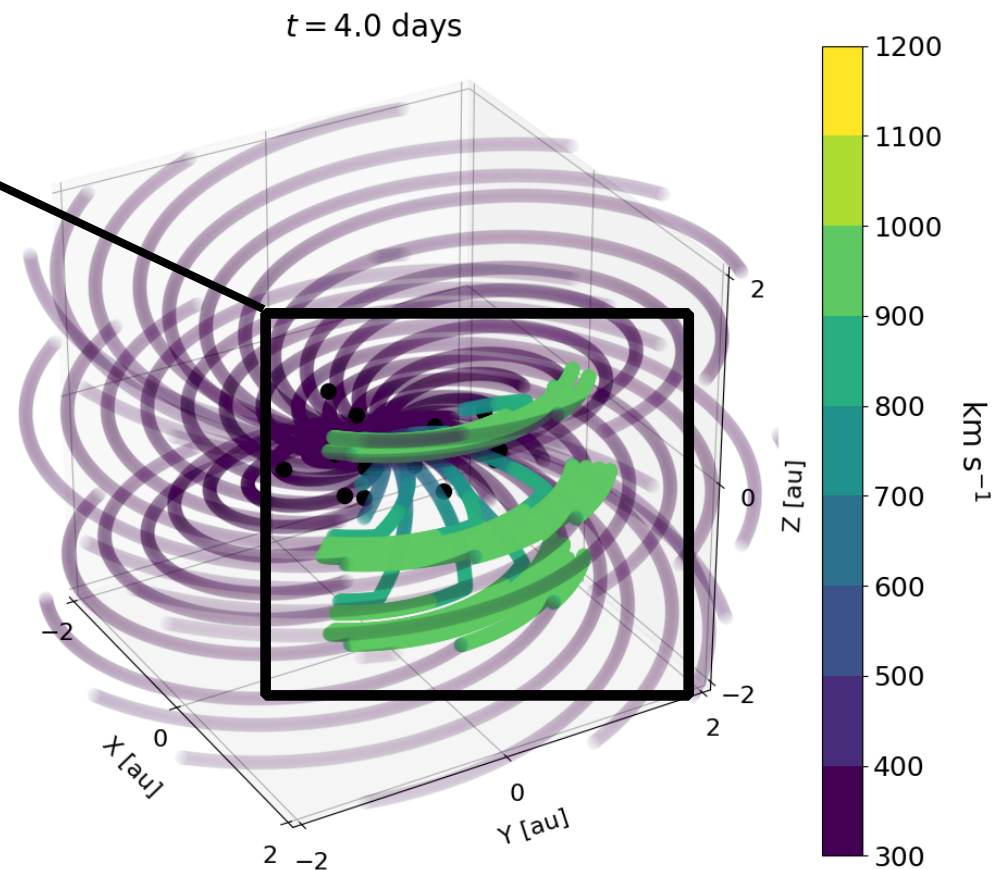
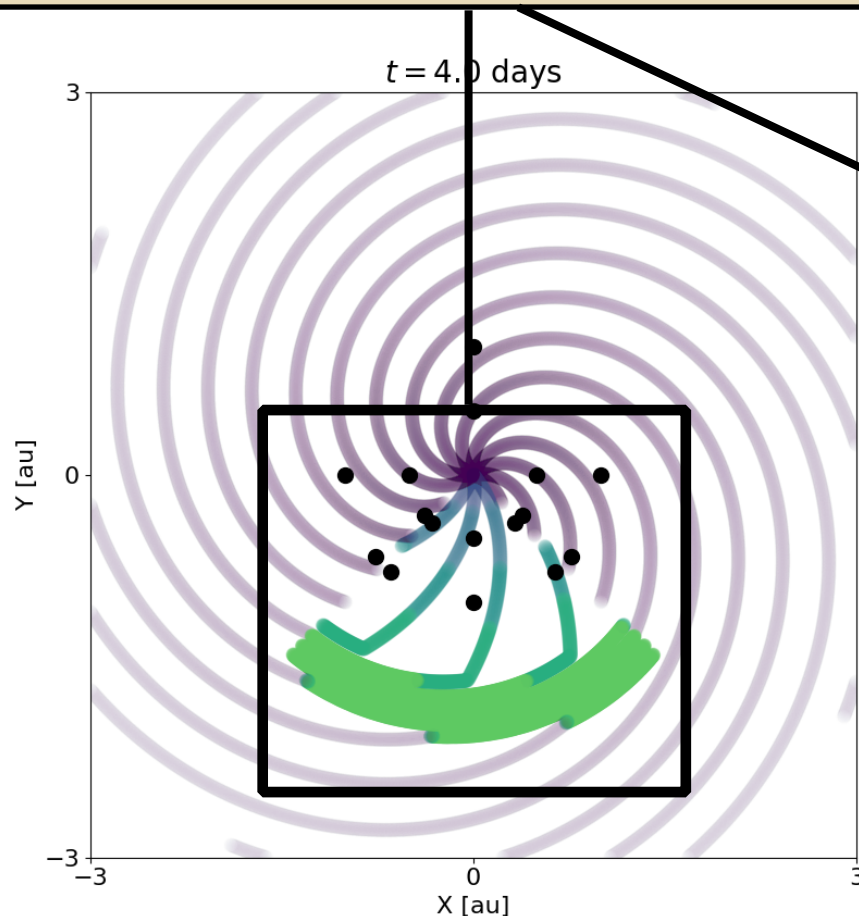
EPREM's Built-in Shock Model

Inside the cone

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

Outside the cone

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



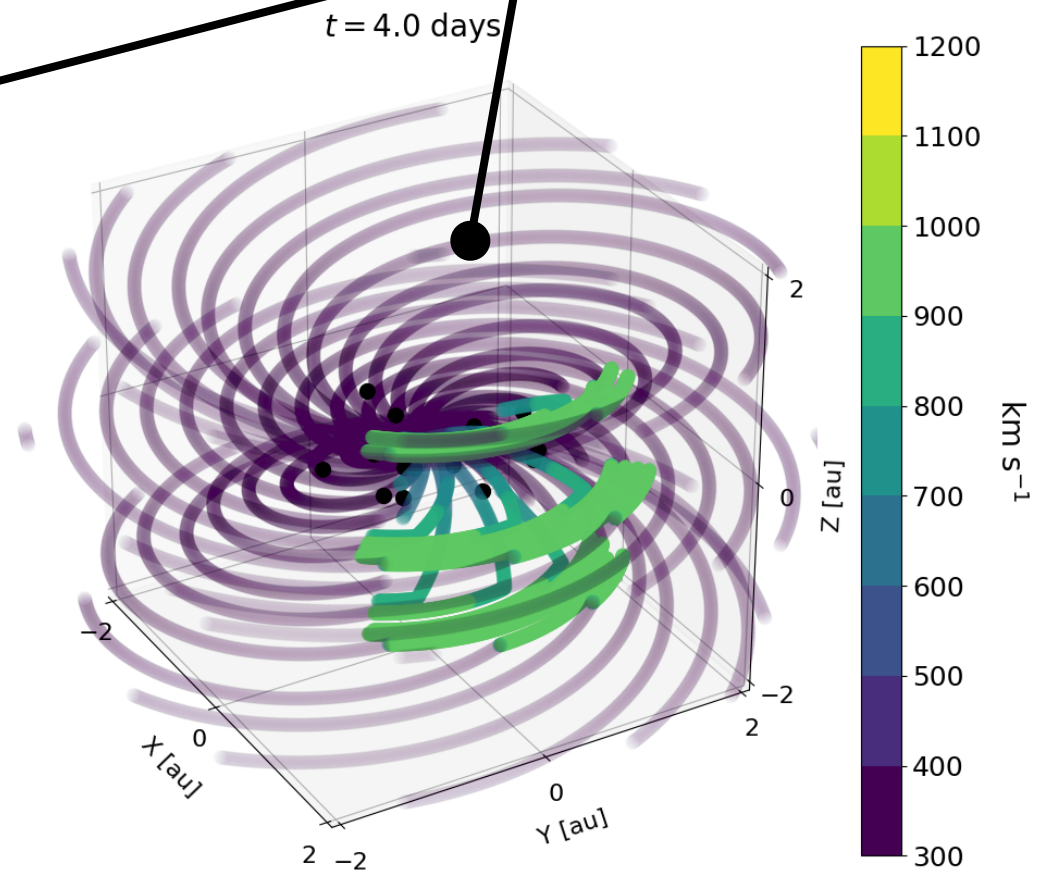
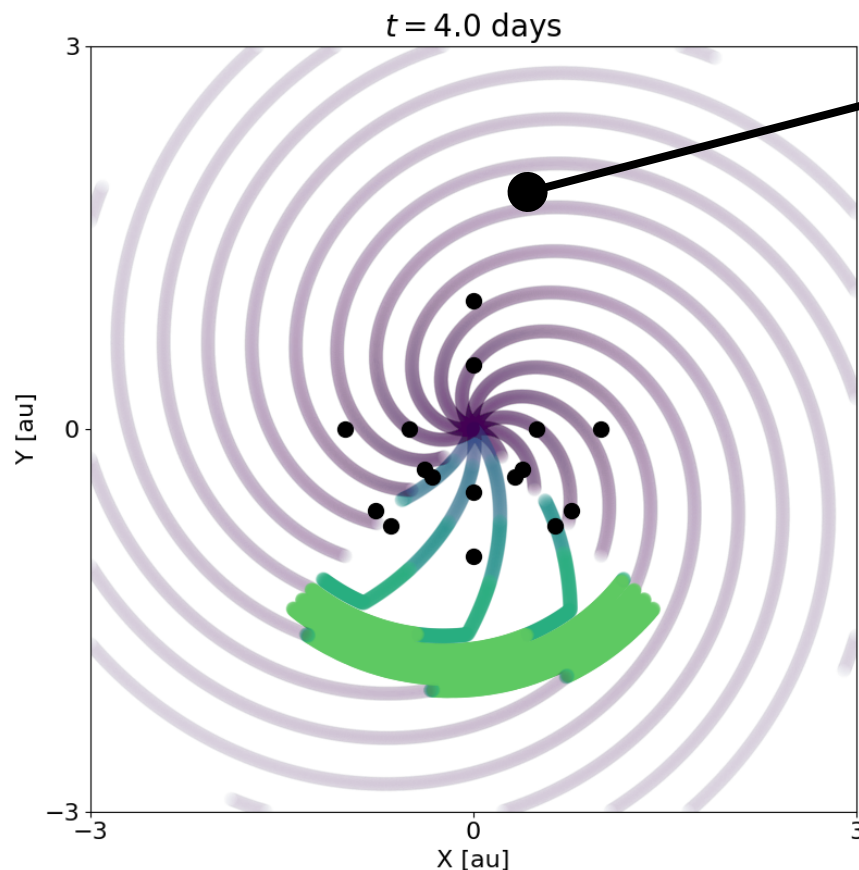
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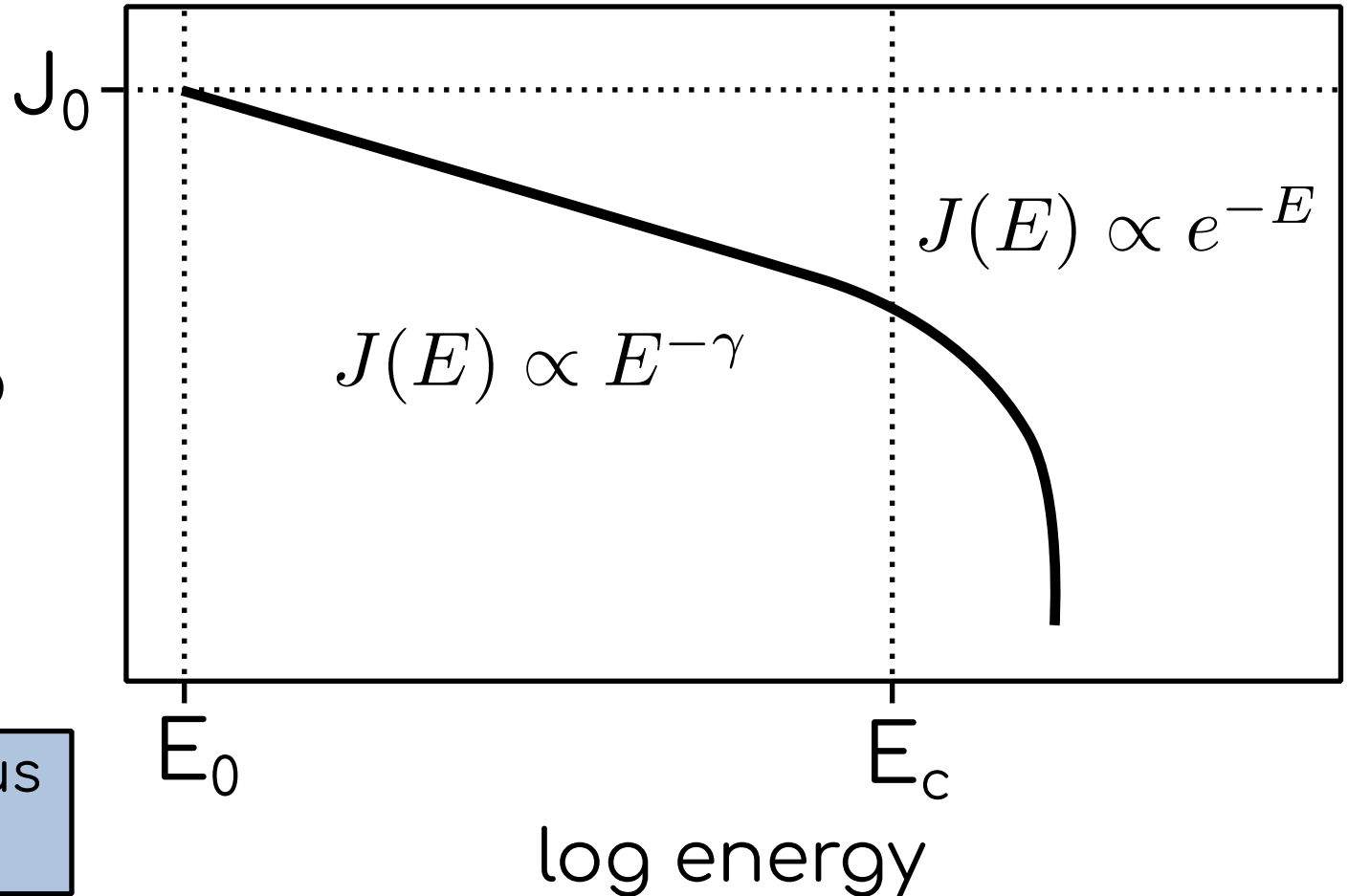


The Background Spectrum in EPREM

$$J_s(E, r) = \alpha_s J_0 \left(\frac{r}{r_0} \right)^{-\beta} \left(\frac{E}{E_0} \right)^{-\gamma} \exp \left(-\frac{E}{E_c} \right)$$

abundance
(relative to H^+)

log flux



r_0 is a reference radius
(typically 1.0 au)

Mean Free Path in EPREM

EPREM allows the user to choose one of two mean-free-path profiles:

$$\lambda_{\parallel}(r) = \lambda_{\parallel 0} \left(\frac{\mathcal{R}}{\mathcal{R}_0} \right)^{\chi} \left(\frac{r}{r_0} \right)^{\beta} \quad (\text{radial})$$

$$\lambda_{\parallel}(|\vec{B}|) = \lambda_{\parallel 0} \left(\frac{\mathcal{R}}{\mathcal{R}_0} \right)^{\chi} \left(\frac{|\vec{B}|}{|\vec{B}_0|} \right)^{-\beta/2} \quad (\text{inverse-B})$$

particle rigidity: $\mathcal{R} = \frac{pc}{q} \text{ [cgs]}$

Recent Results

THE ASTROPHYSICAL JOURNAL, 1002:107 (24pp), 2026 May 1

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OPEN ACCESS

<https://doi.org/10.3847/1538-4357/ae5818>



Quantifying the Effects of Parameters in Widespread Solar Energetic Particle Events with EPREM

Matthew A. Young  and Bala Poduval 

University of New Hampshire, Durham, NH 03824, USA; Matthew.Young@unh.edu

Received 2025 October 1; revised 2026 March 16; accepted 2026 March 18; published 2026 April 29

- Parametric study of a generic widespread SEP event with uncoupled EPREM



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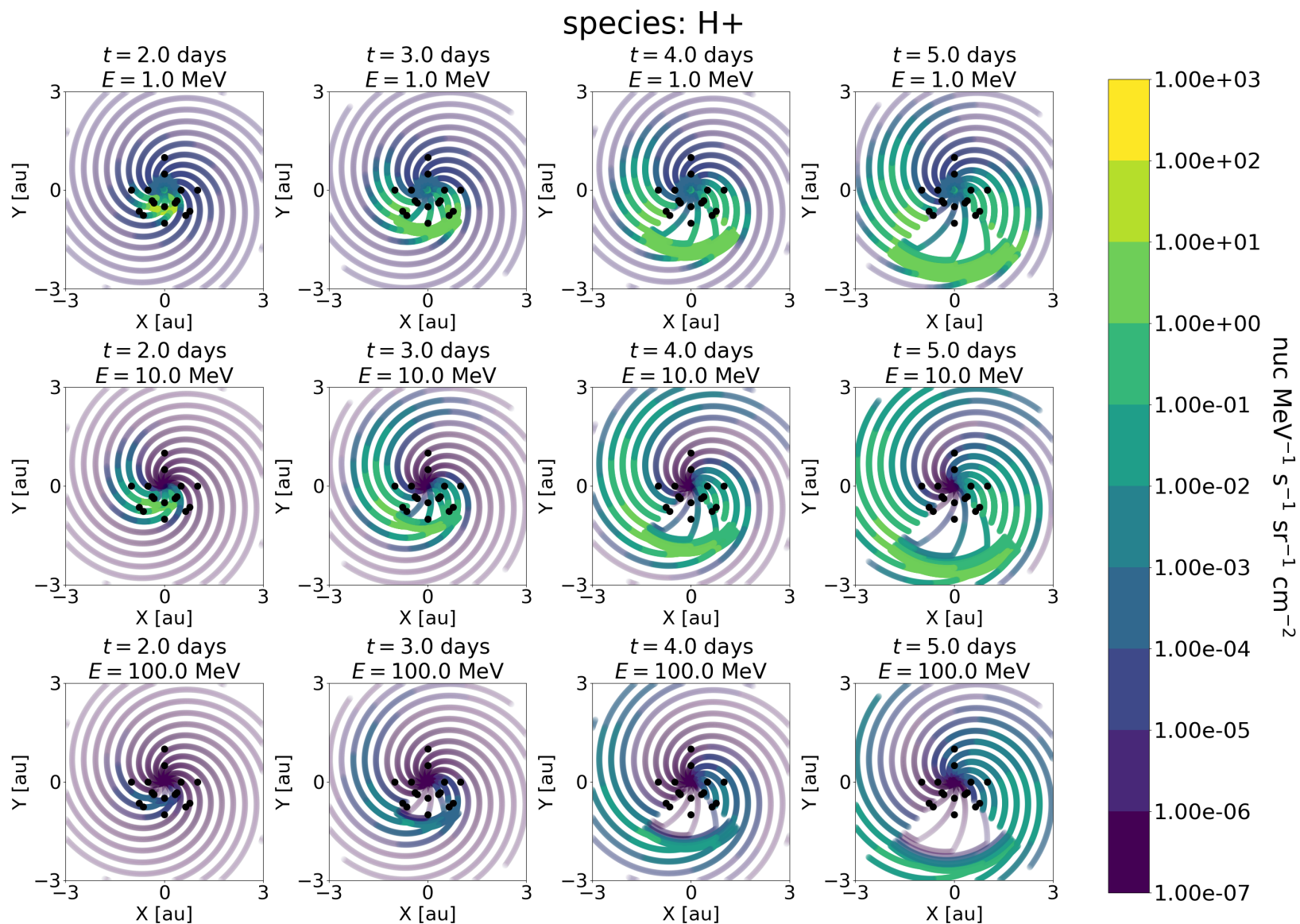
Received 2025 October 1; revised 2026 March 16; accepted 2026 March 18; published 2026 April 29

- Parametric study of a generic widespread SEP event with uncoupled EPREM
- Demonstrated effects of SEP acceleration and transport in the presence of a simple cone shock
- Appendices provide updated descriptions of EPREM structure and features

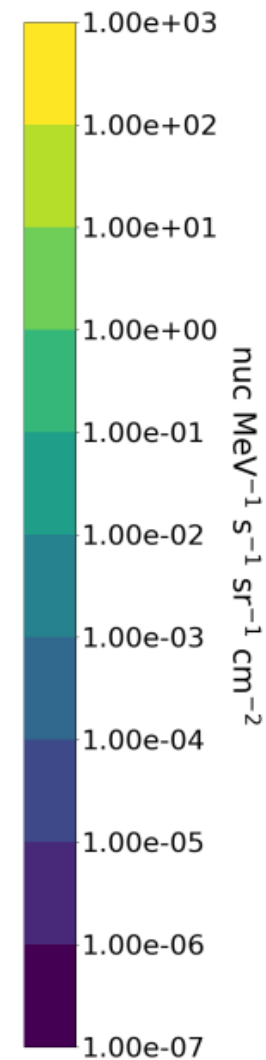
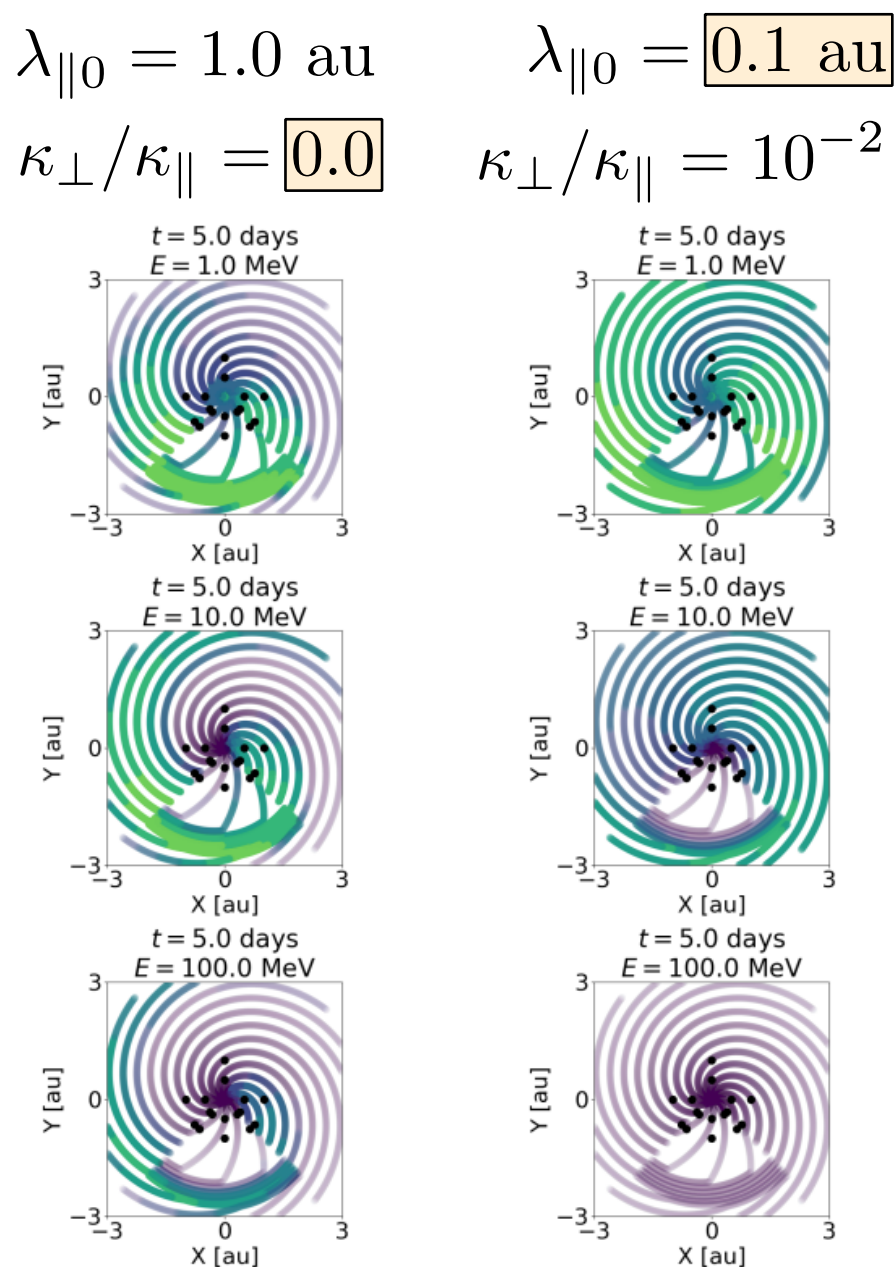
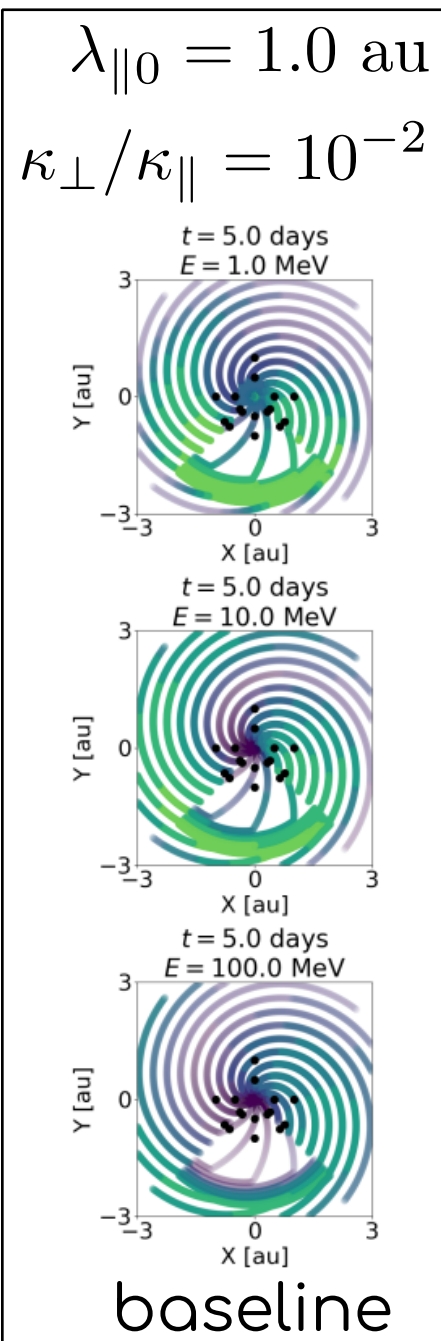


Recent Results

baseline simulation run

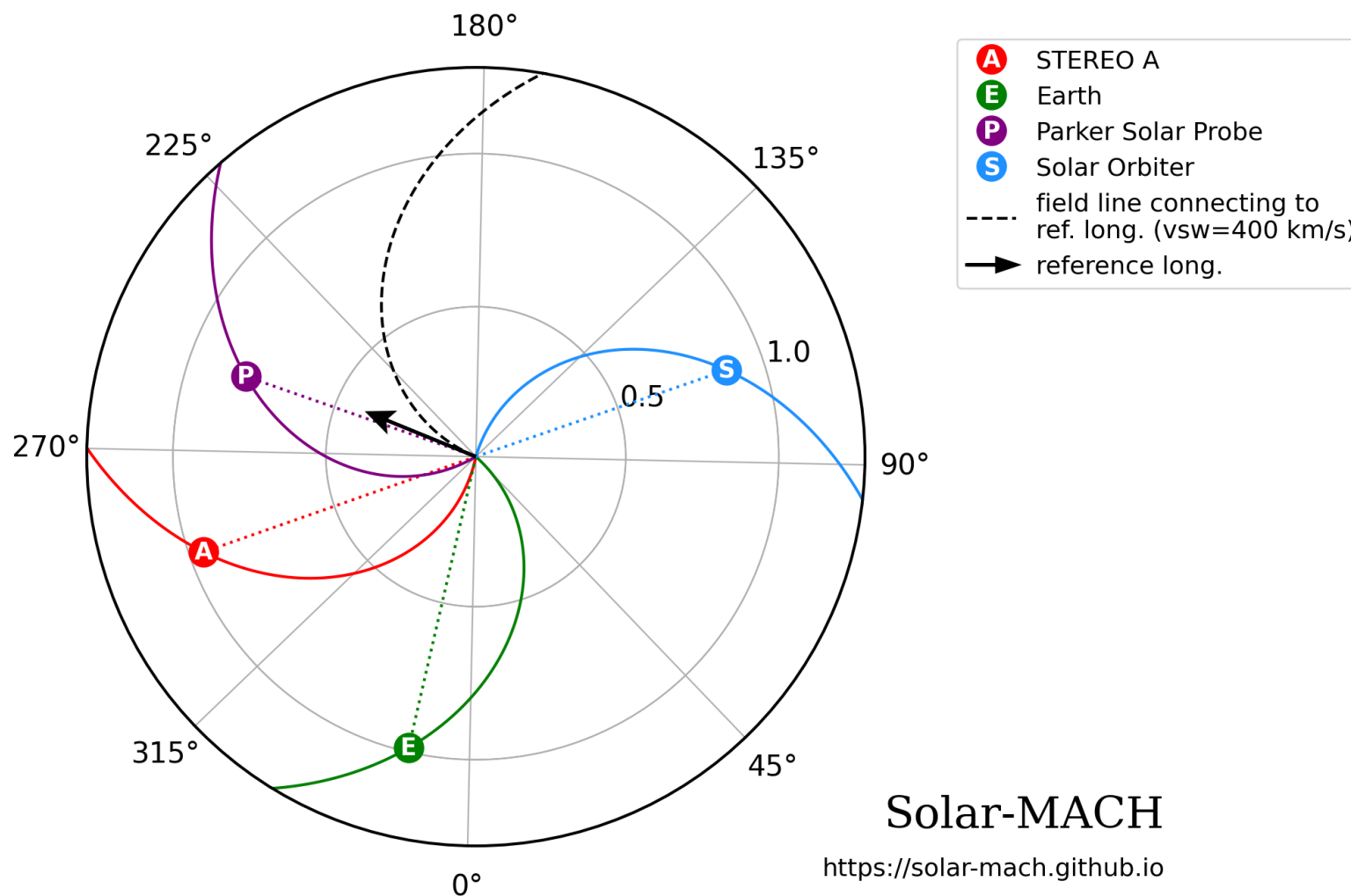


Recent Results



Recent Results

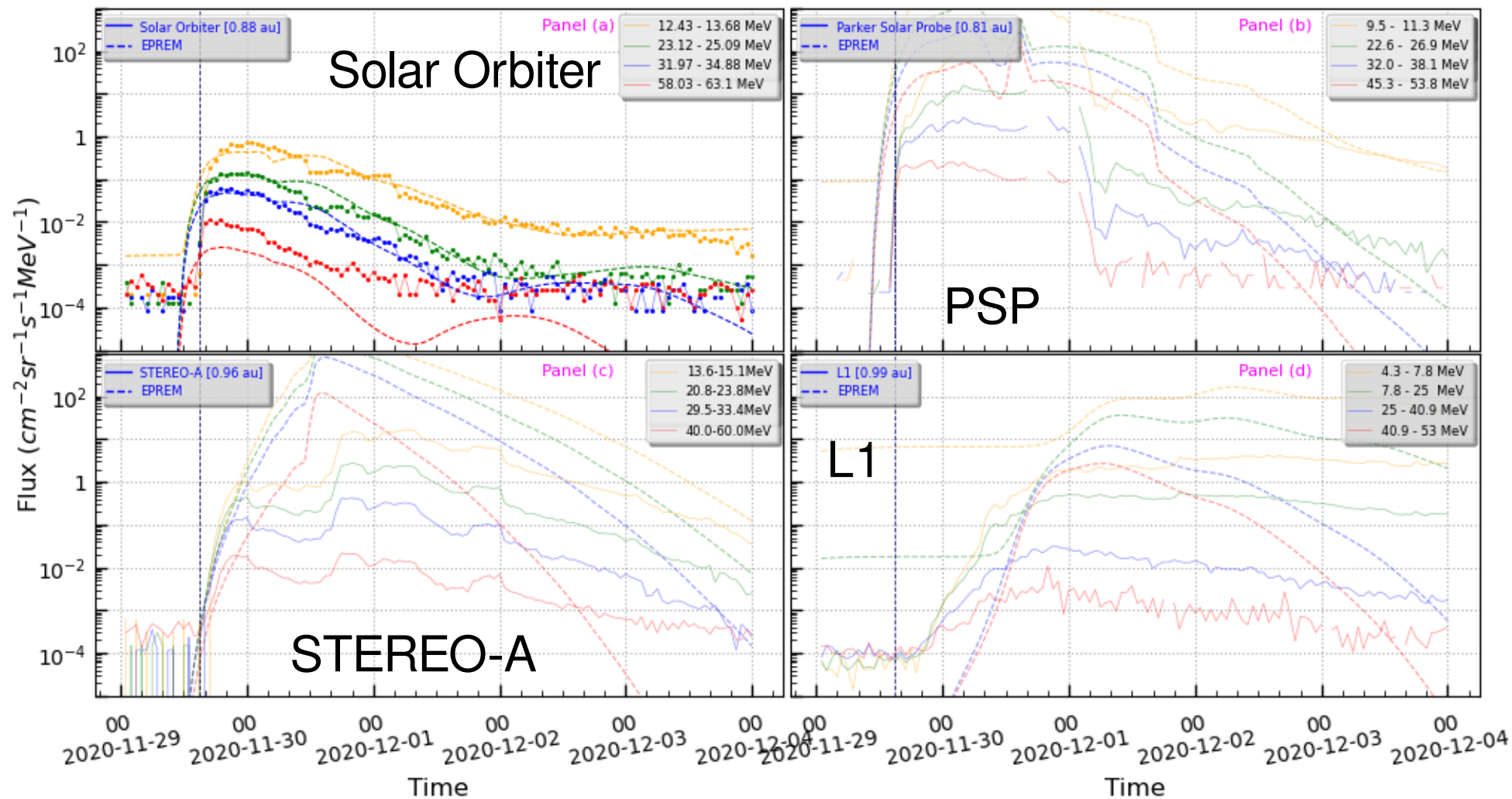
2020-11-29 12:00 (UTC)



29 November 2020 SEP Event

Recent Results

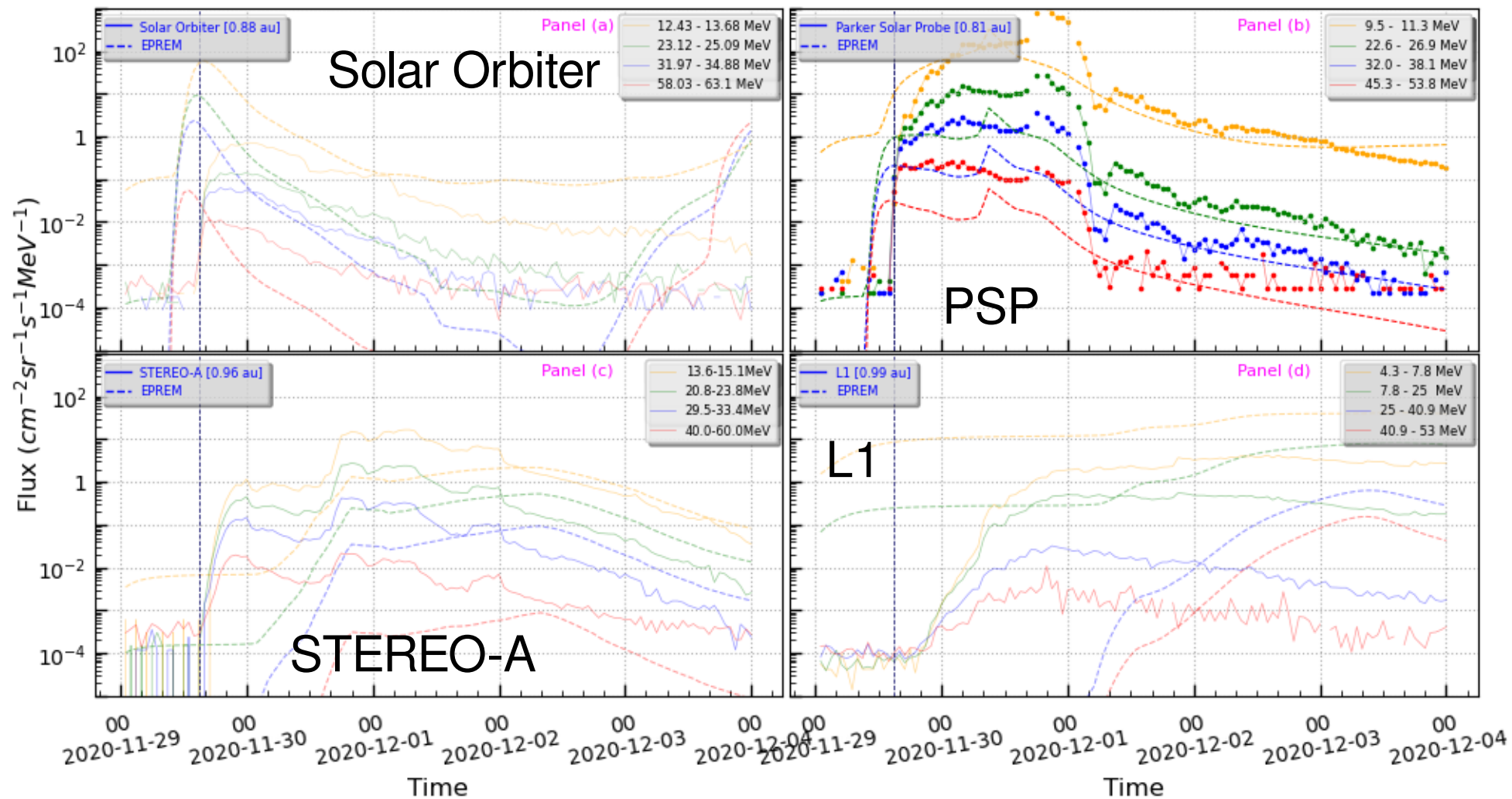
Poduval & Young (in prep.)



29 November 2020 SEP Event

Recent Results

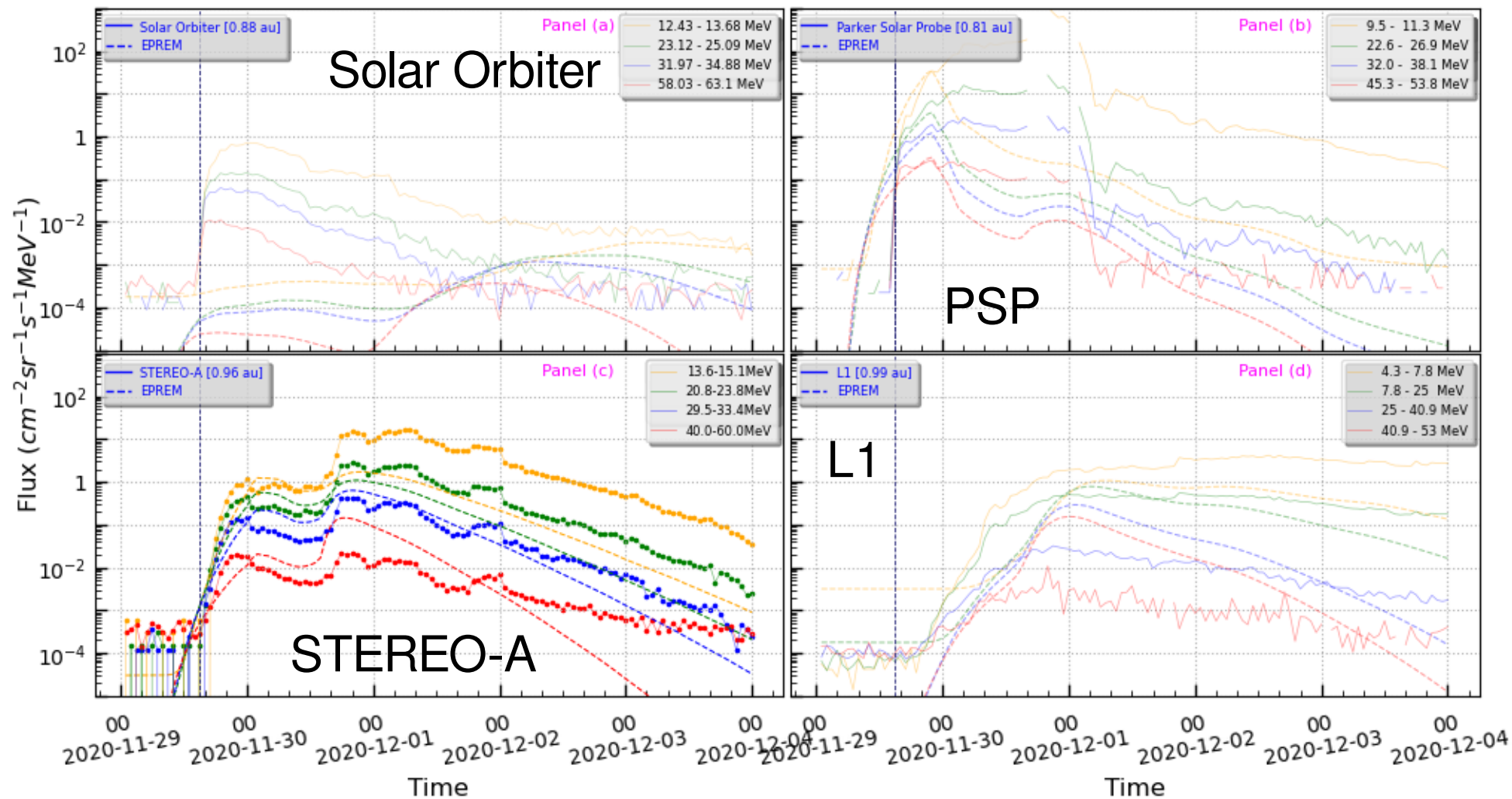
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29 November 2020 SEP Event

Recent Results

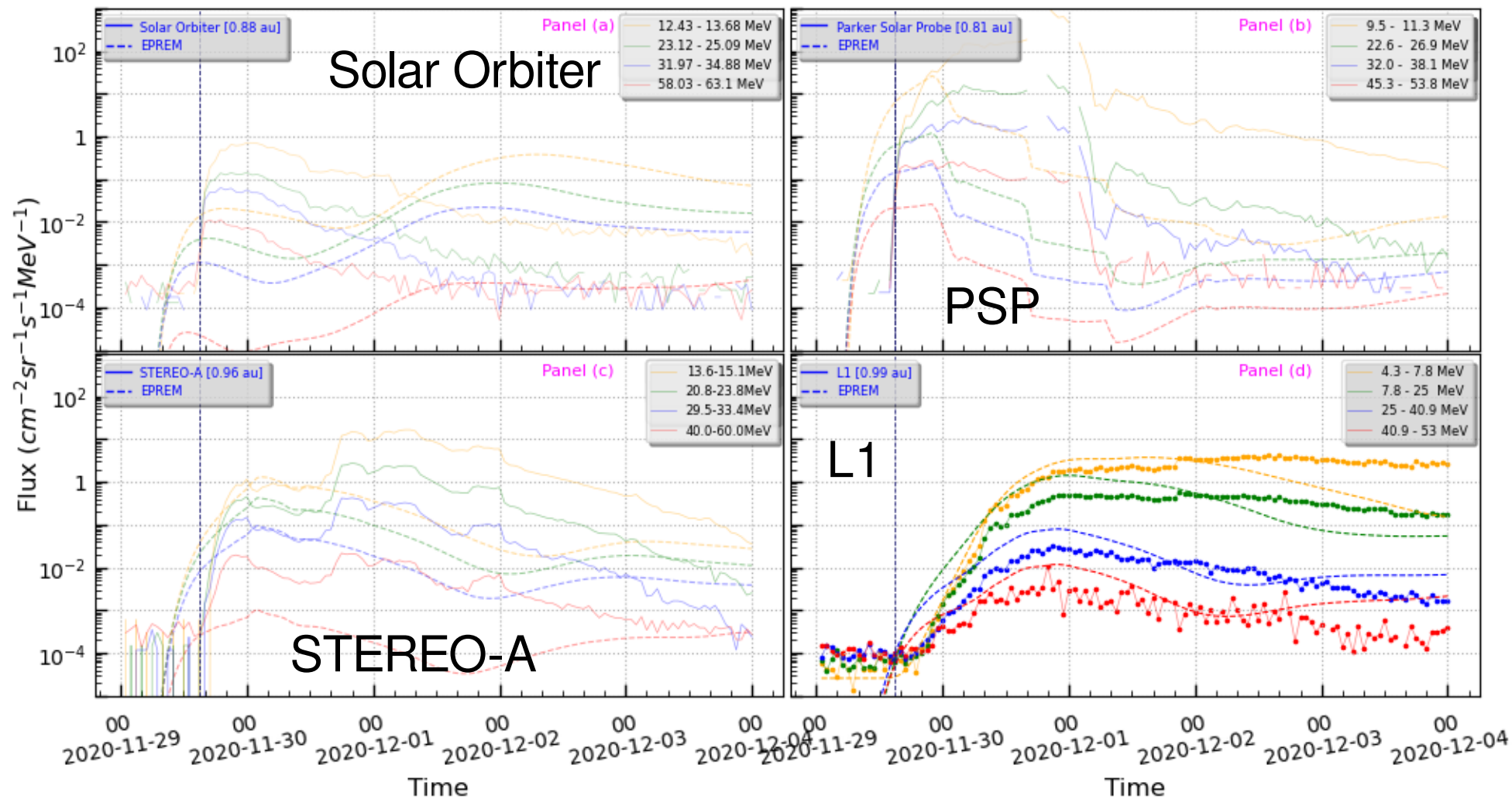
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29 November 2020 SEP Event

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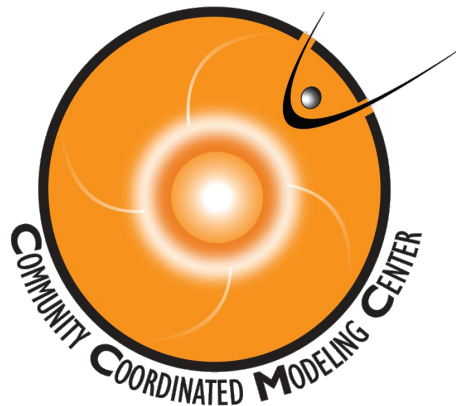
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29 November 2020 SEP Event

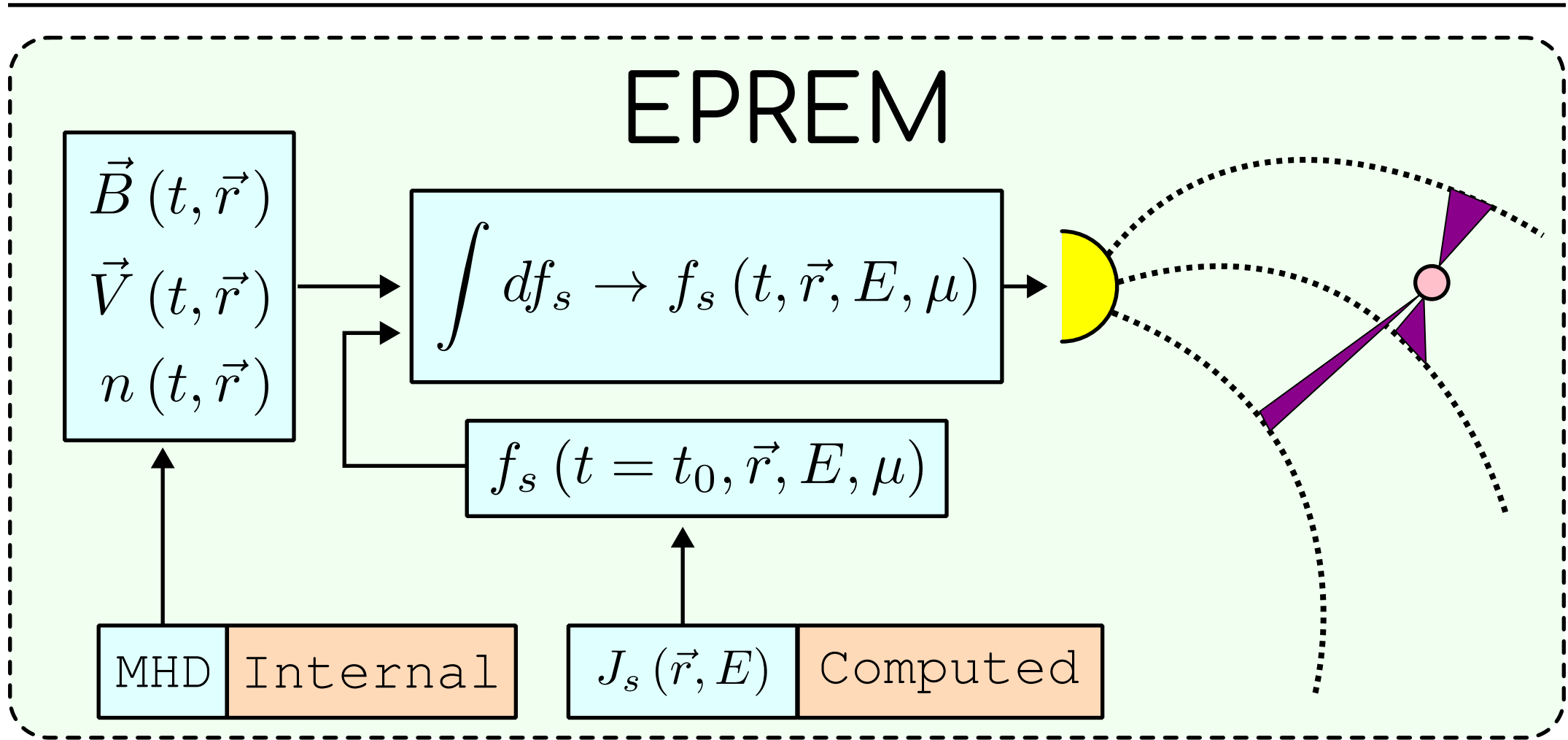
Current Status

- Developed on  **GitLab**
 - Latest updates on `main`
- Tags for at least every minor version
(most recent is `v0.15.0`)

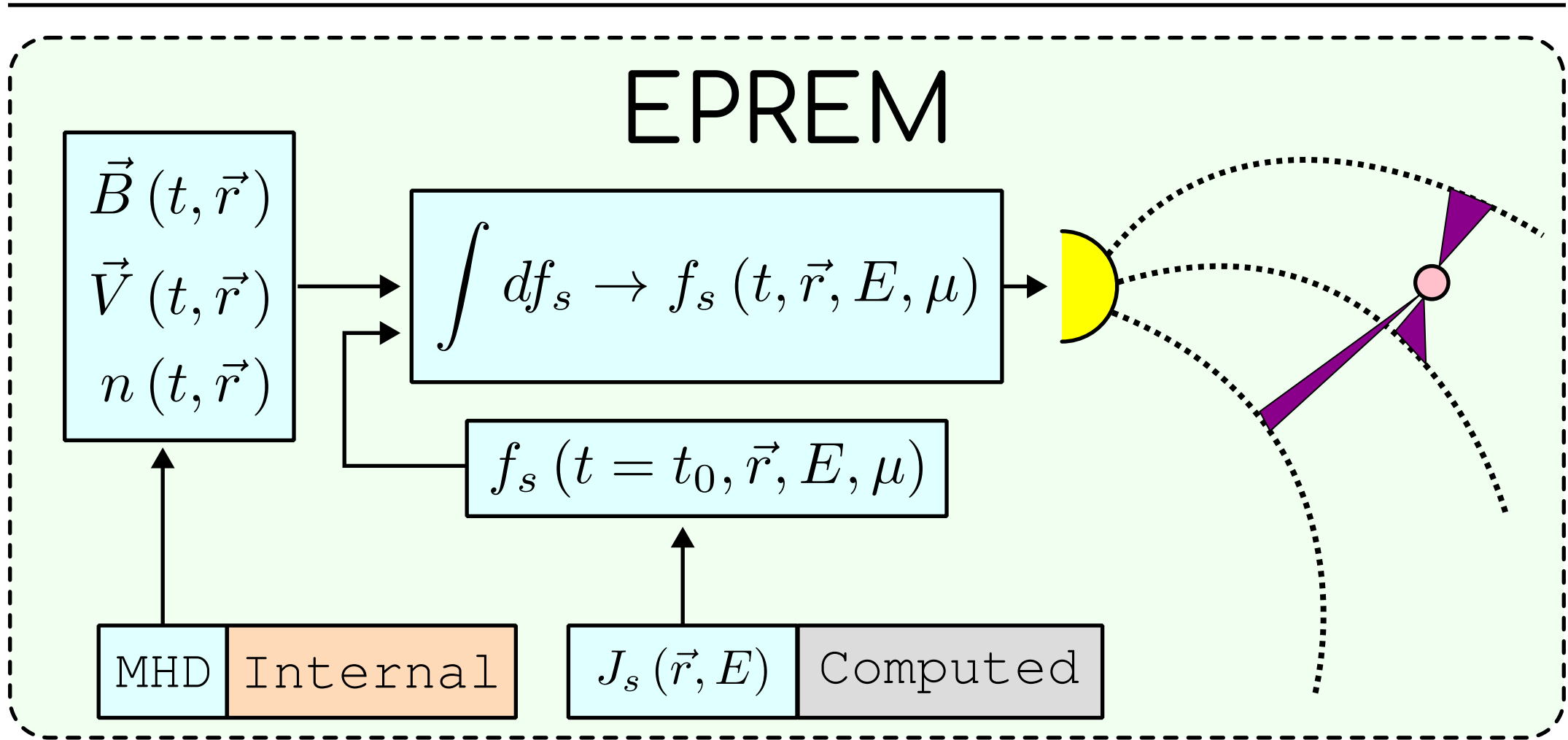


"v0" available for
Runs-on-Request (RoR)

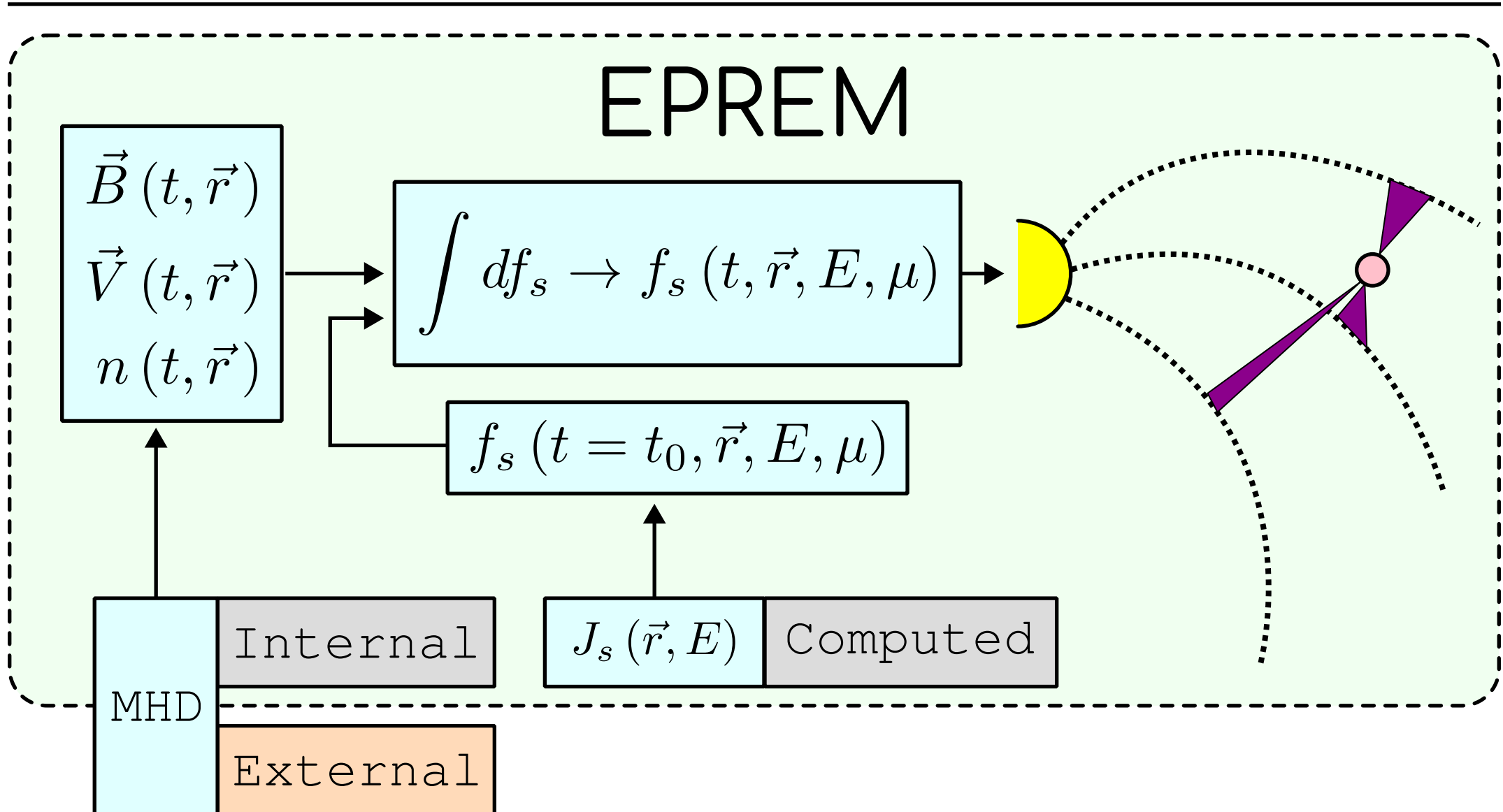
Current Status



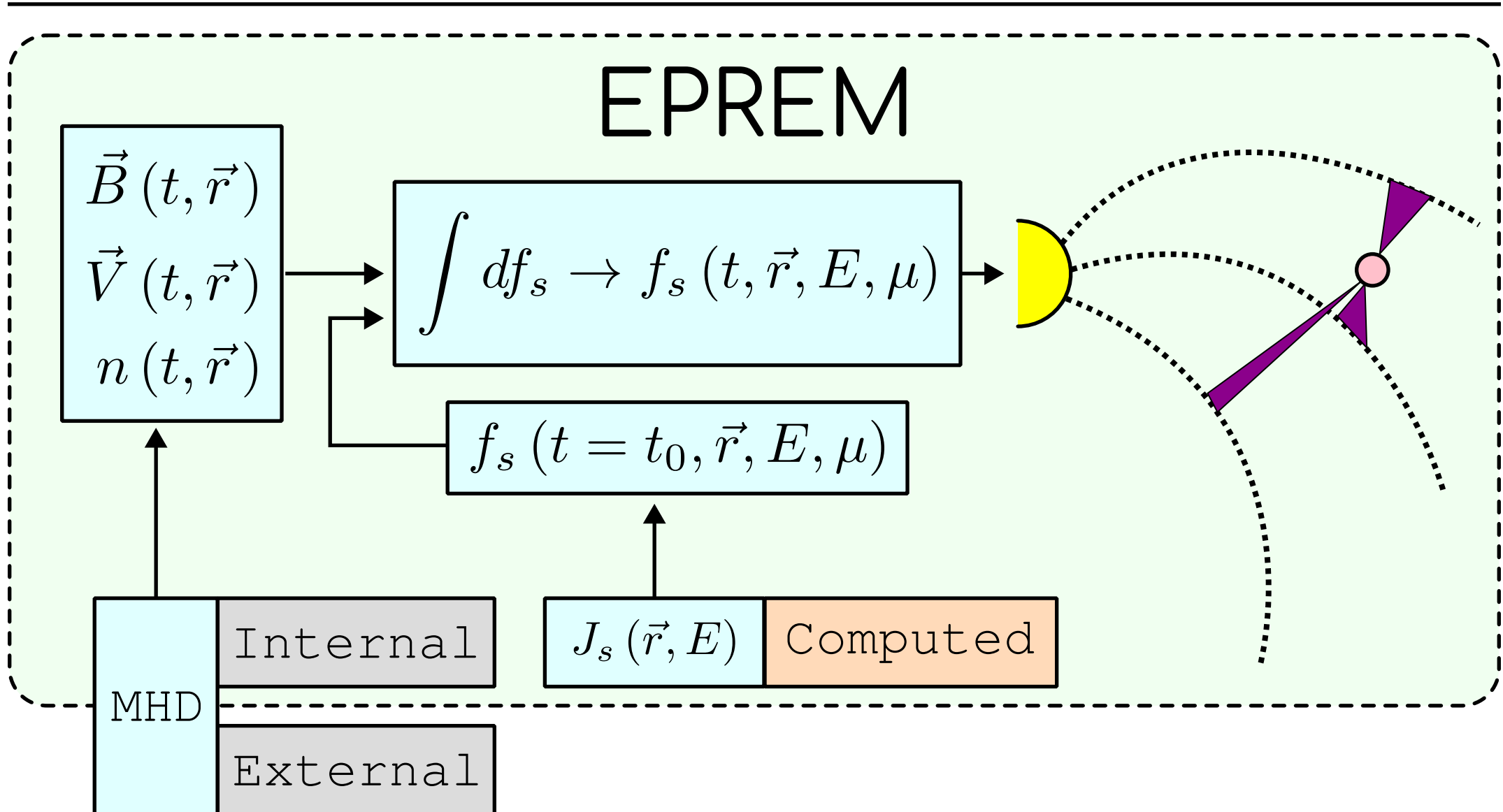
Planned Development: Internal MHD Models



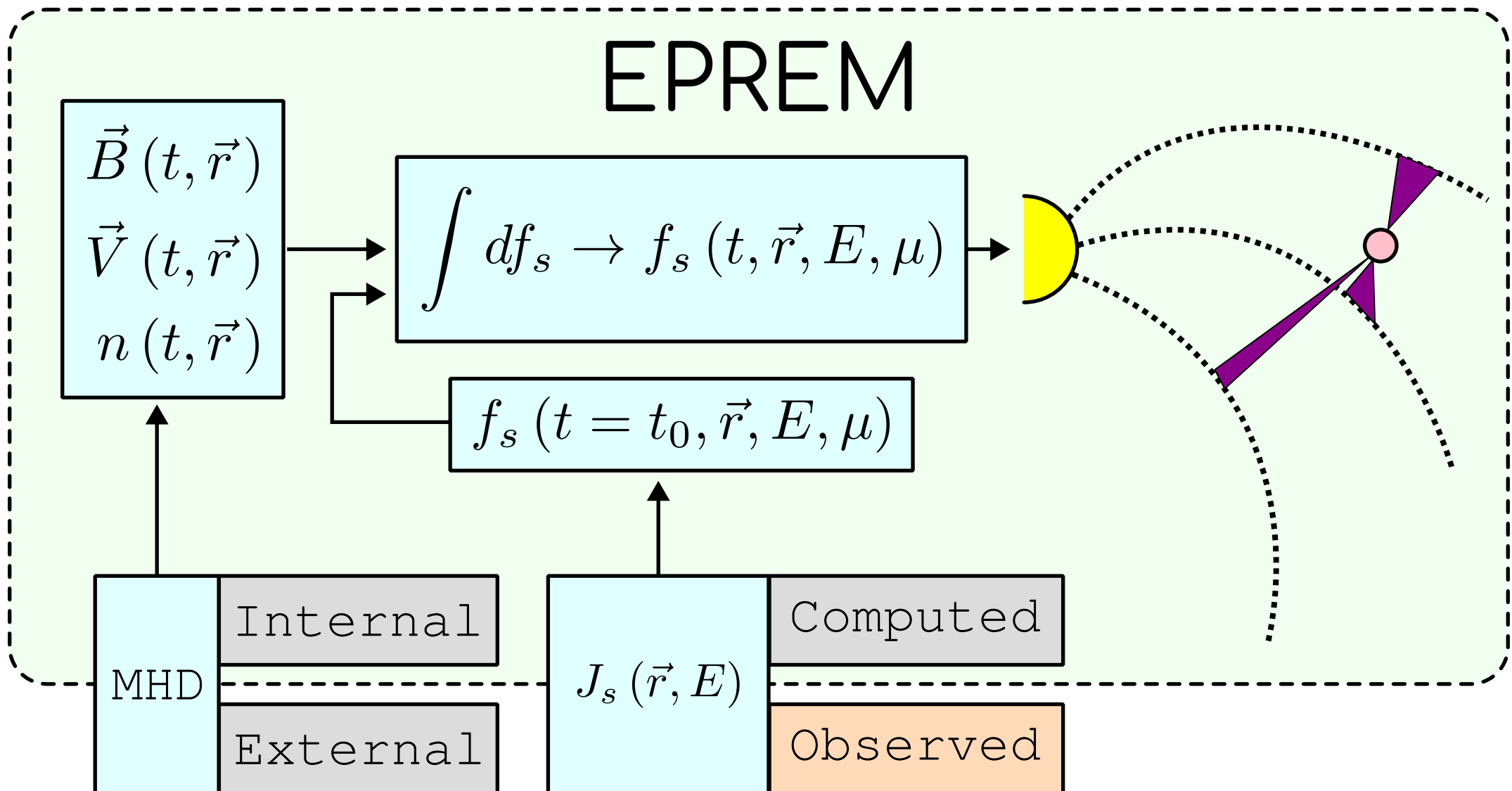
Planned Development: MHD Coupling



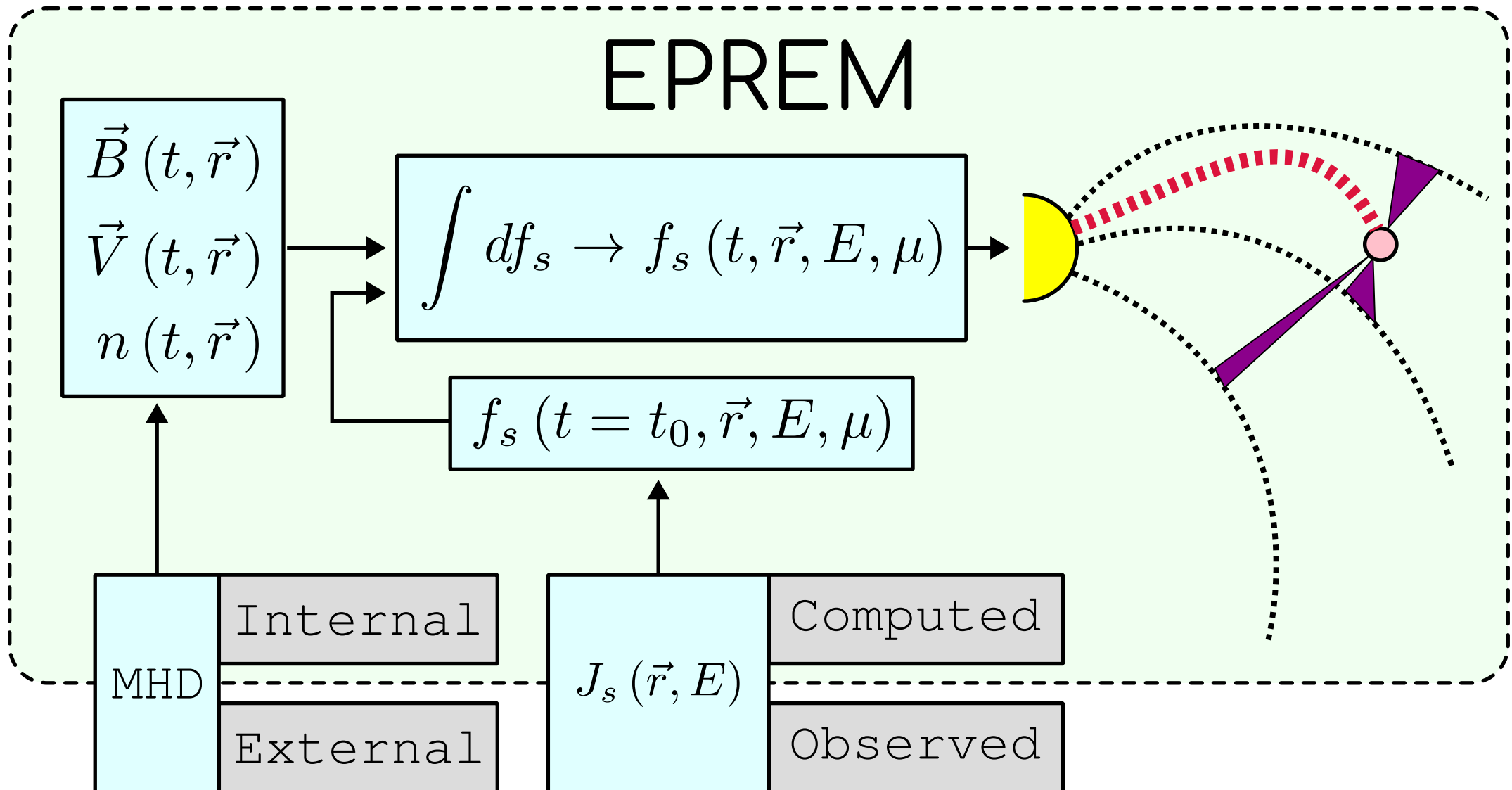
Planned Development: Initial Spectrum



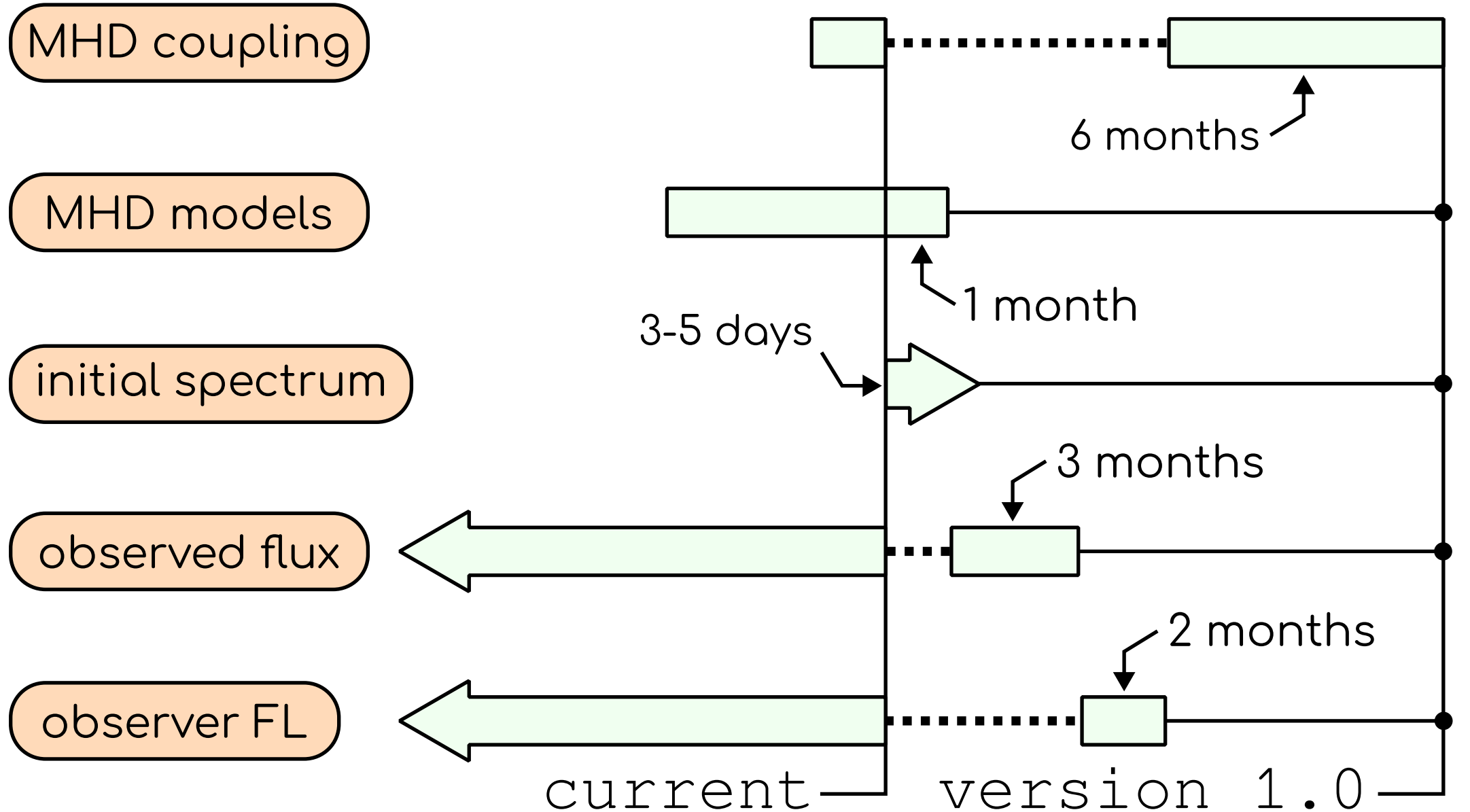
Planned Development: Observed Boundary Flux



Planned Development: Observer-Connected Field Line(s)



Planned Development: Roadmap and equivalent effort



Acknowledgements

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NSF 2325313

EPREM development was also supported by

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NASA LWS 80NSSC19K0067

Thank You!



view these slides



get the code

gitlab.com/open-eprem



stay in touch

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