

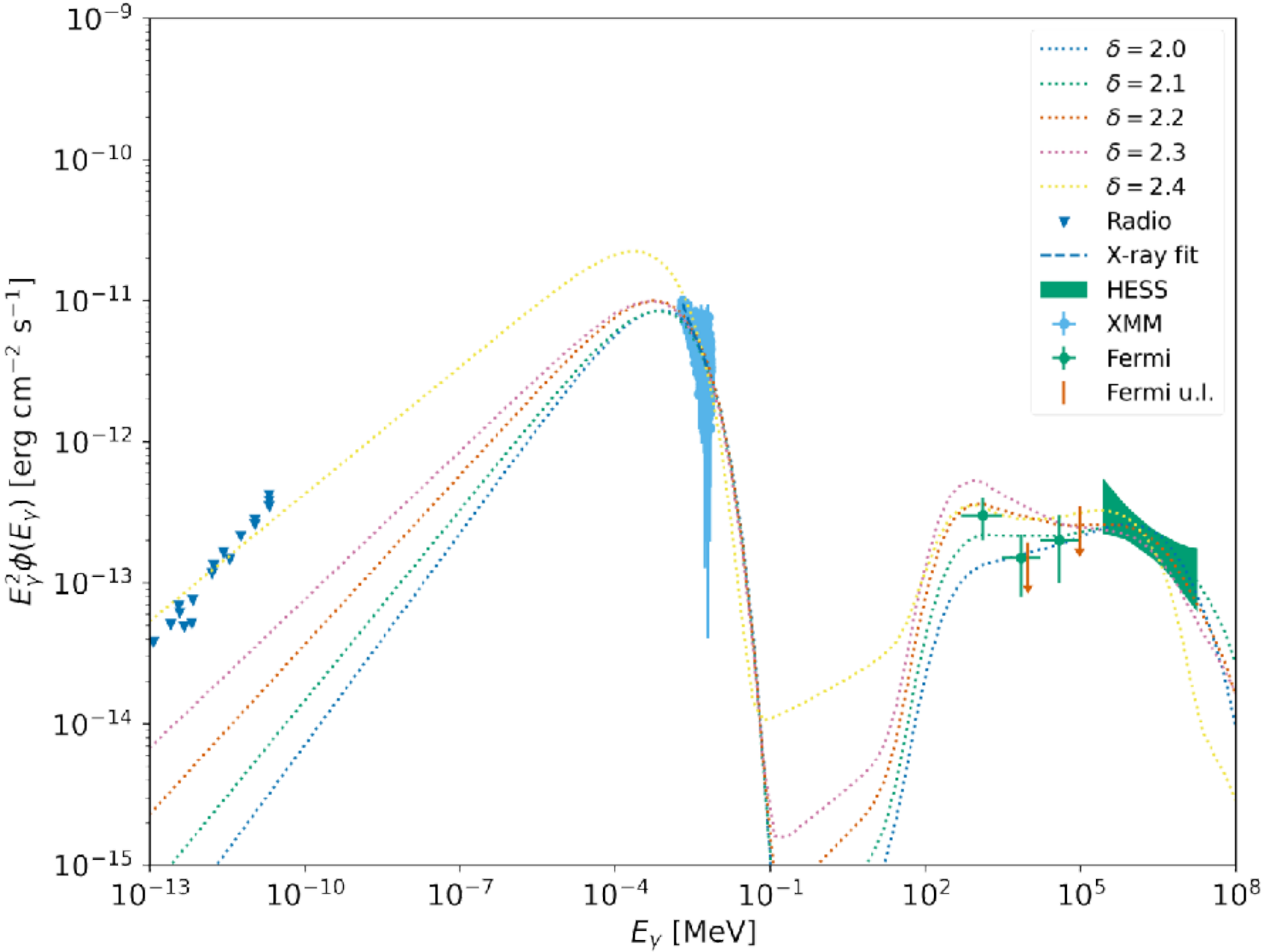
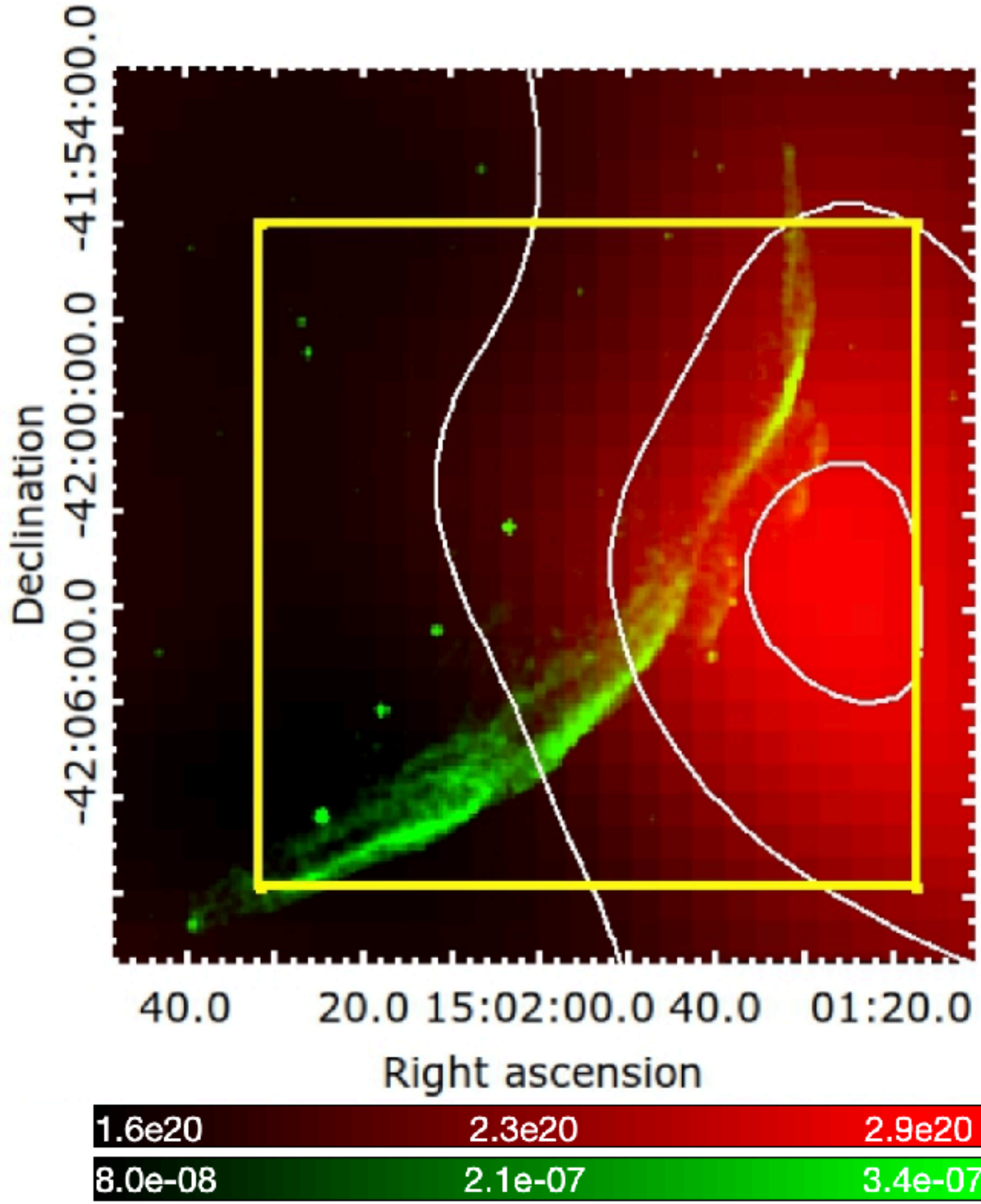
Transient gamma rays from the 2021 outburst of RS Ophiuchi

Vo Hong Minh Phan

Observatoire de Paris and Sorbonne University

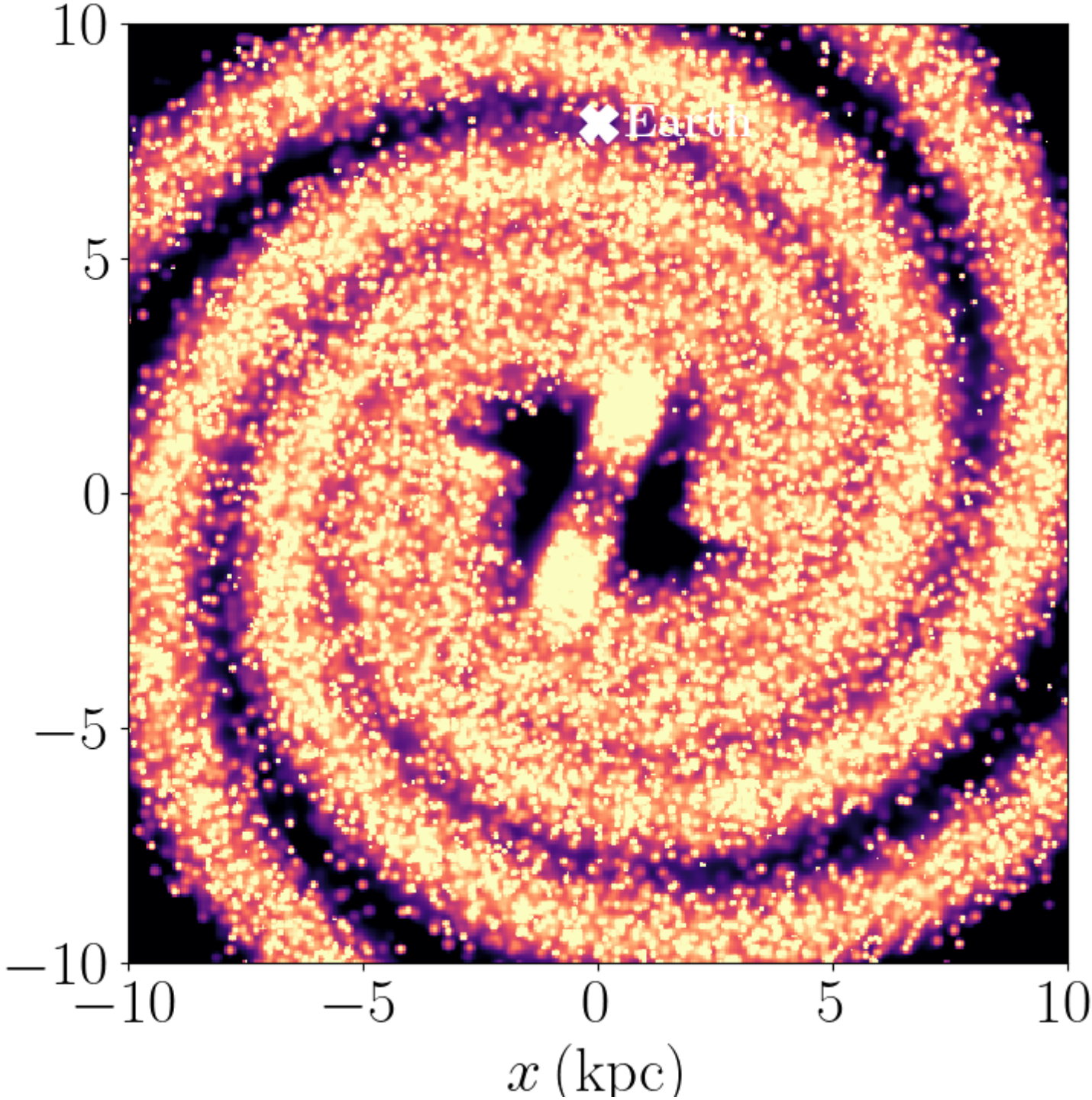
with Enrico Peretti, Pierre Cristofari, Vincent Tatischeff and Andrea Ciardi

Motivation

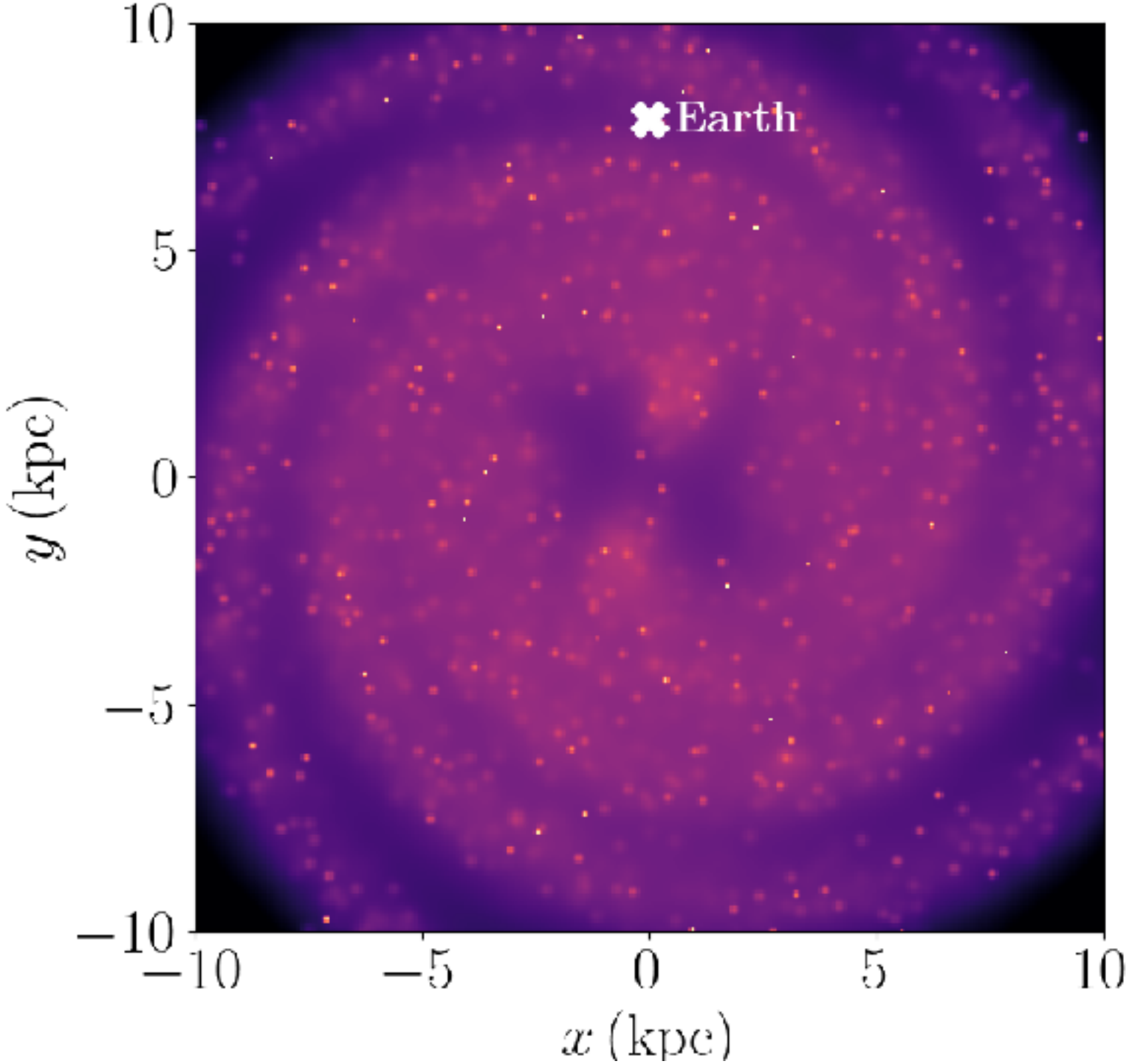


Motivation

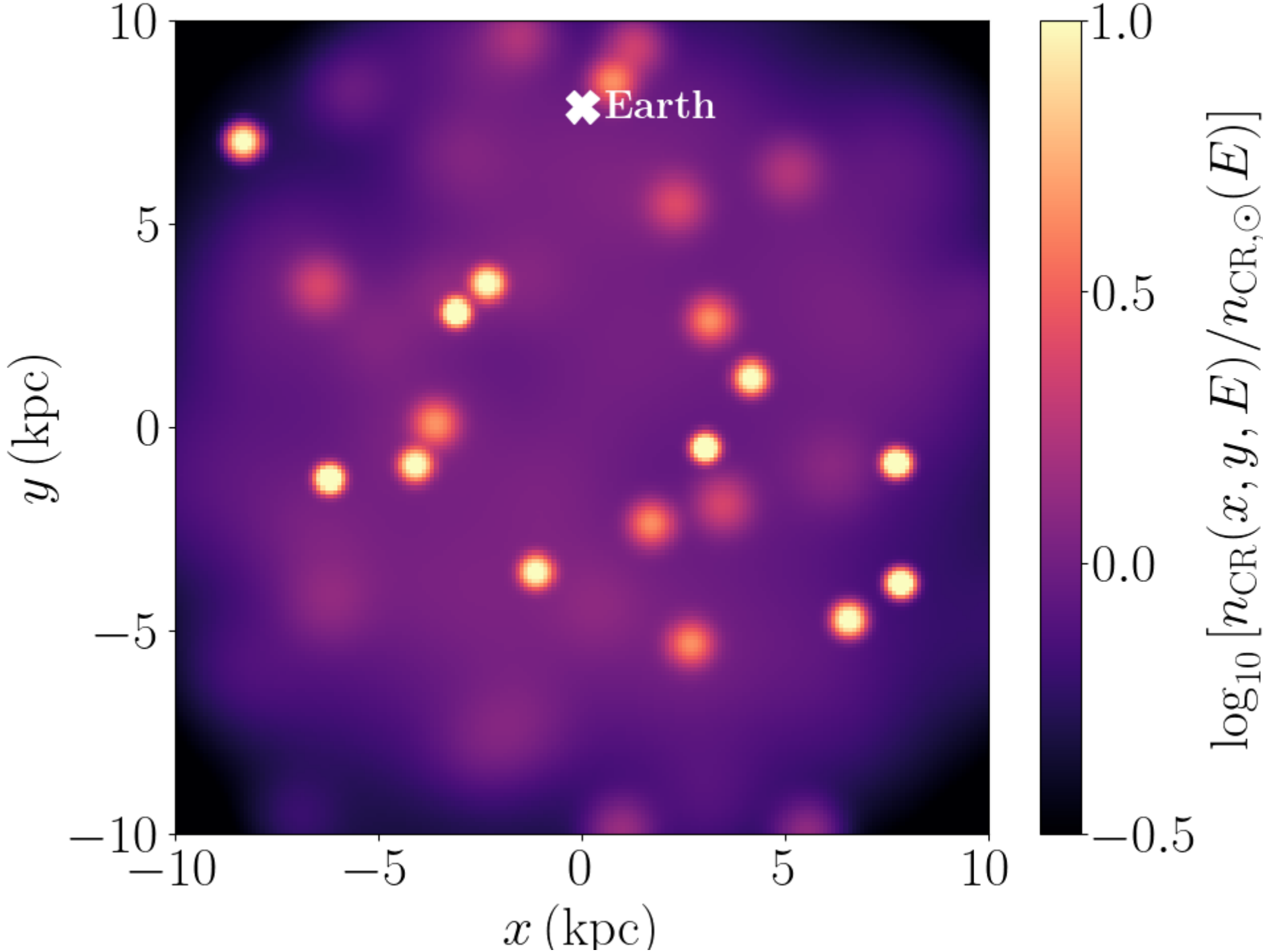
10 MeV



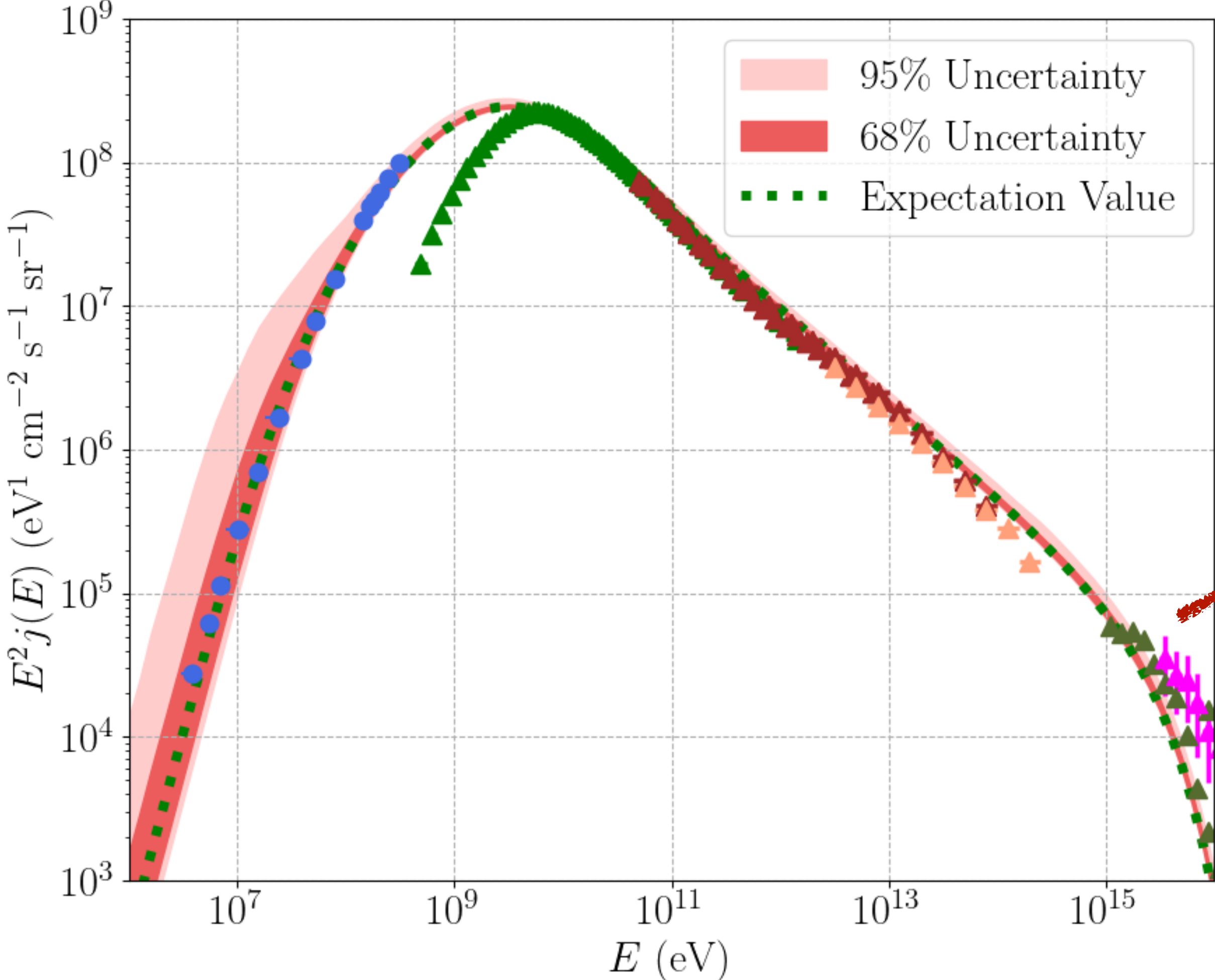
30 GeV



1 PeV



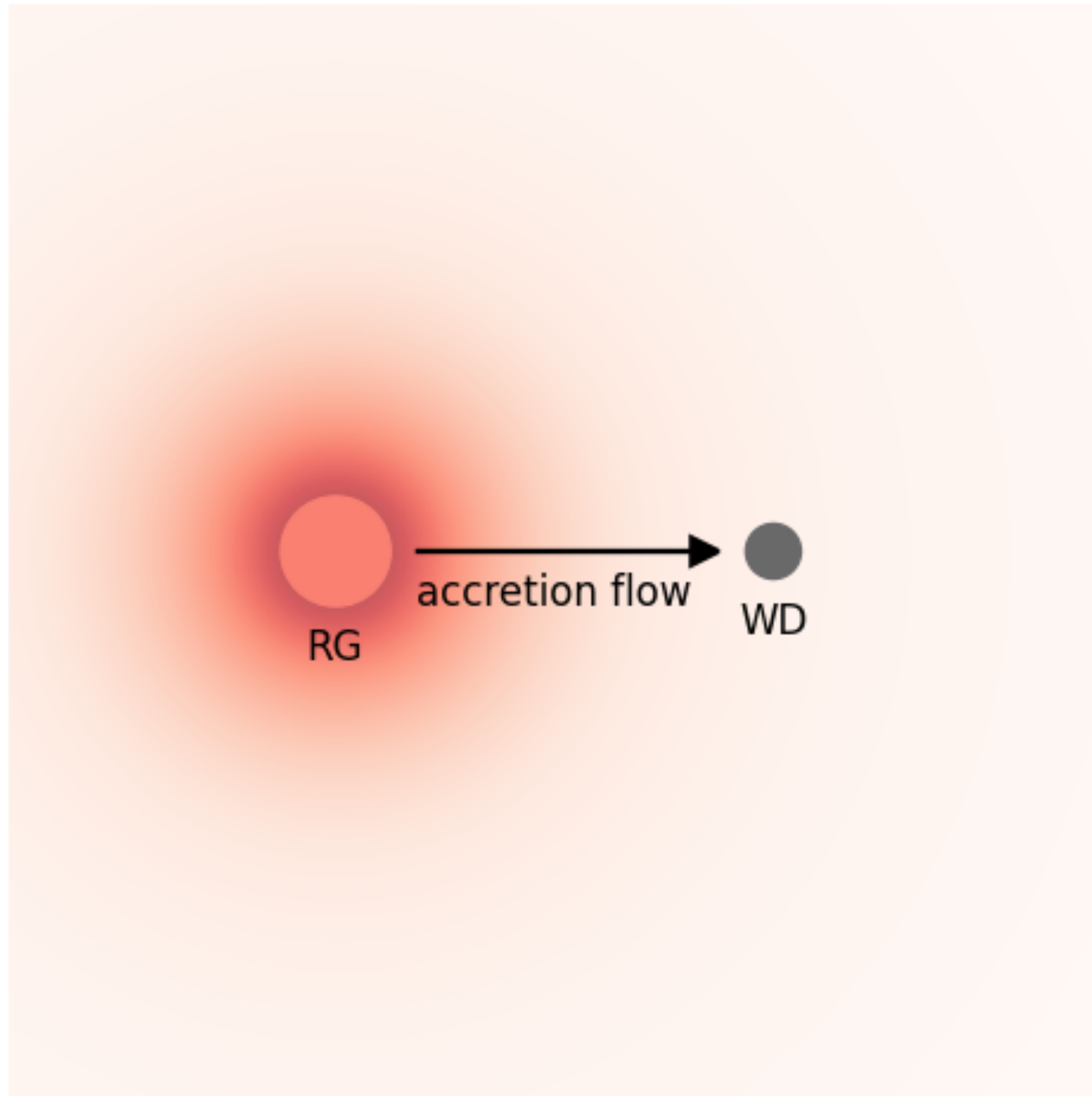
Motivation



$$E_{\text{max}} \sim 3 \text{ PeV}$$

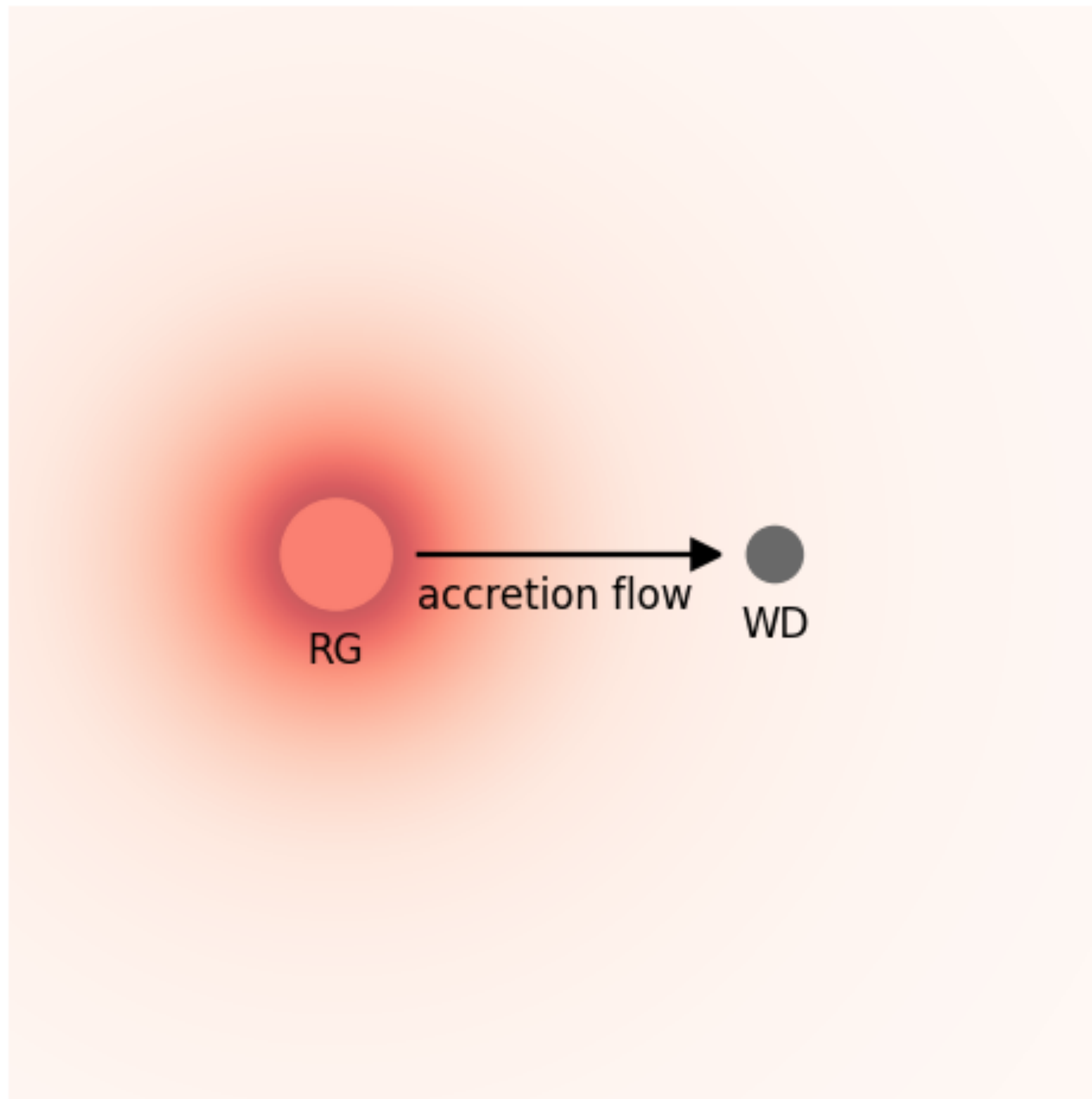
Alternatives to study
cosmic particle acceleration?

Schematic view of RS Ophiuchi



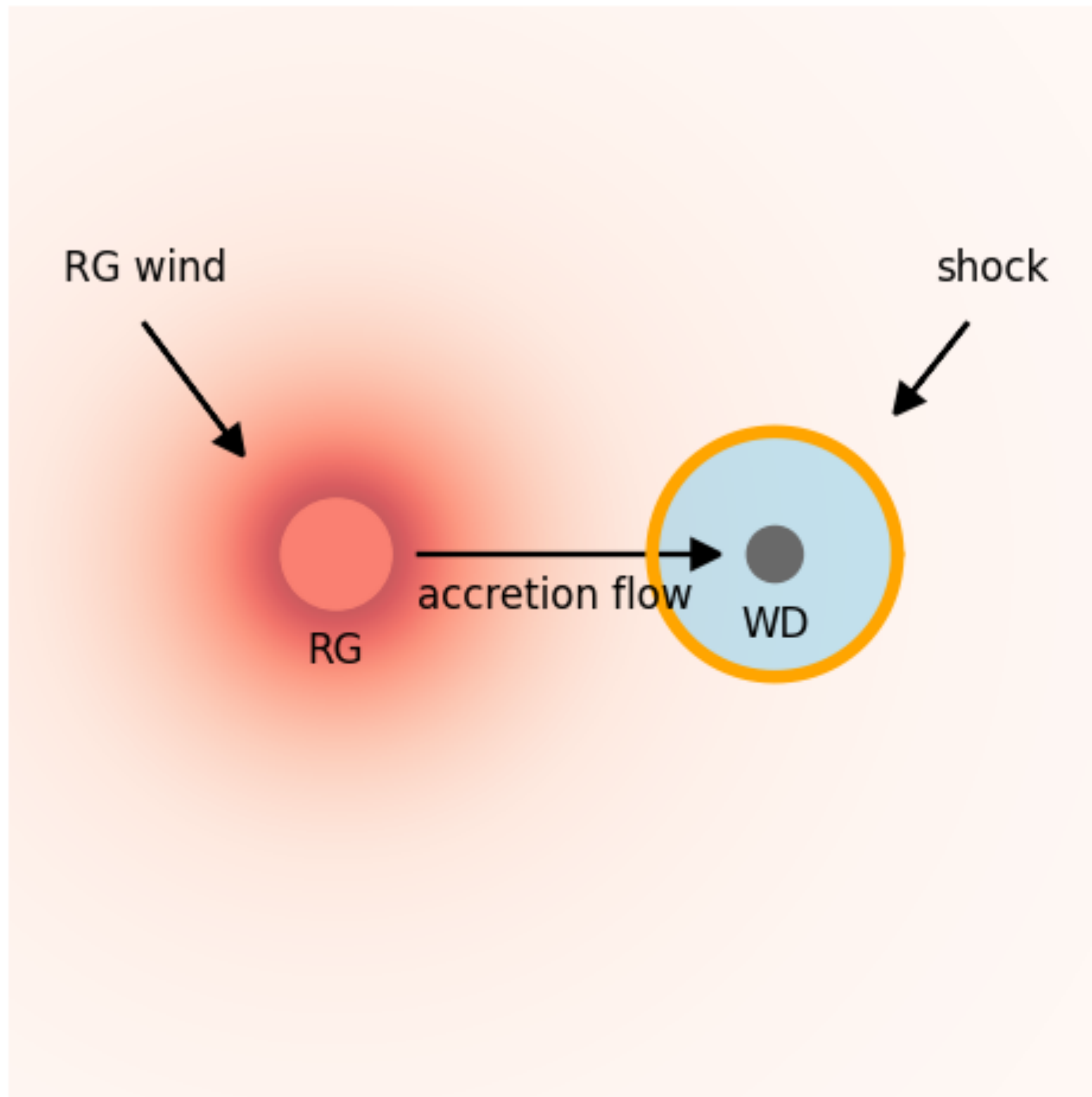
- White dwarf embedded in red giant wind.

Schematic view of RS Ophiuchi



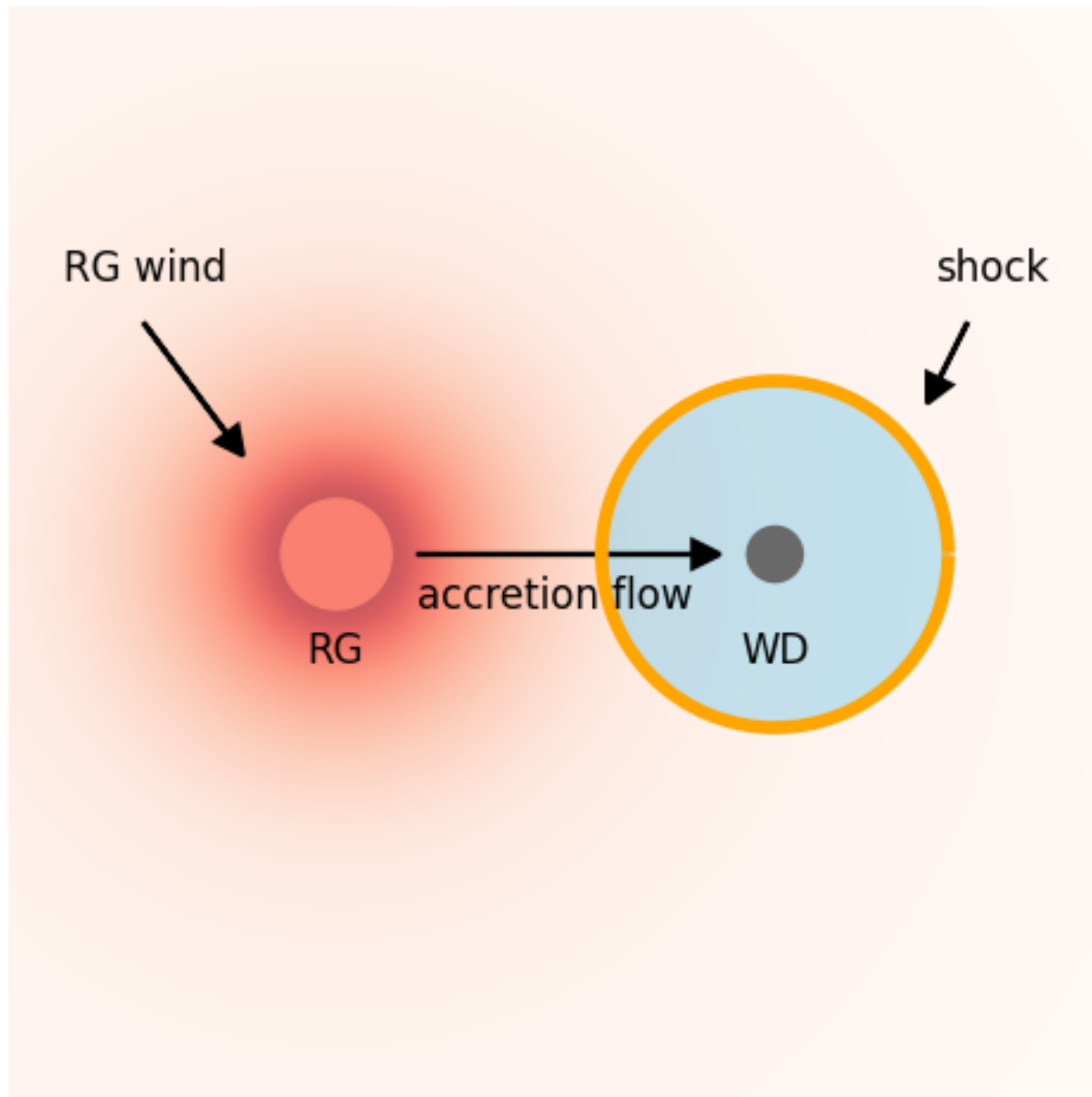
- White dwarf embedded in red giant wind.
- Distance to Earth ~ 1.5 kpc or 2.5 kpc ?
- Size of the system ~ 1.5 au.
- B-field close to red giant ~ 1 G to 10 G.
- Gas density close to red giant $\sim 10^8$ cm $^{-3}$.

Schematic view of RS Ophiuchi



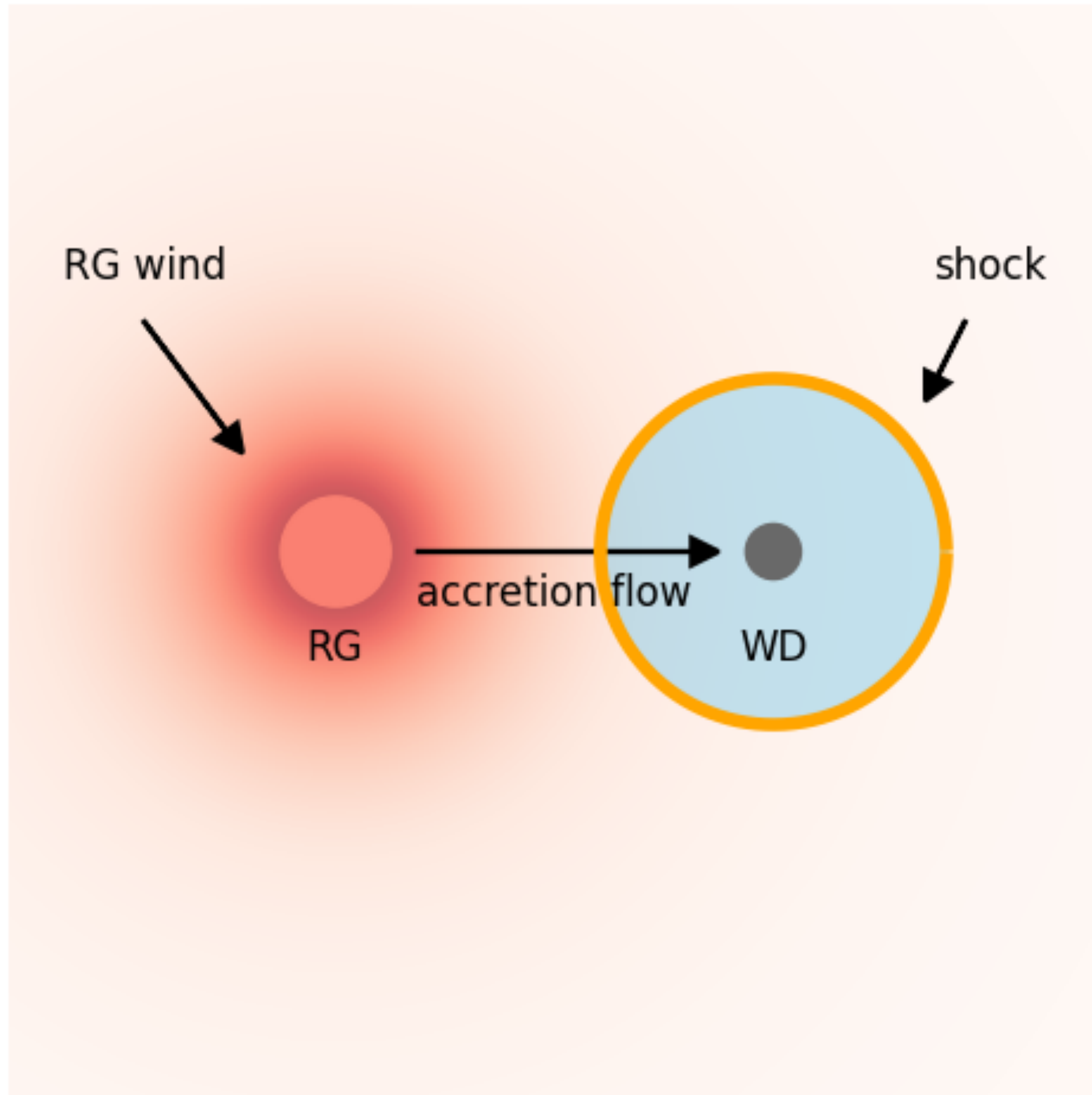
- White dwarf embedded in red giant wind.
- Distance to Earth ~ 1.5 kpc or 2.5 kpc ?
- Size of the system ~ 1.5 au.
- B-field close to red giant ~ 1 G to 10 G.
- Gas density close to red giant $\sim 10^8$ cm $^{-3}$.
- Explode every 10 or 15 years.

Schematic view of RS Ophiuchi

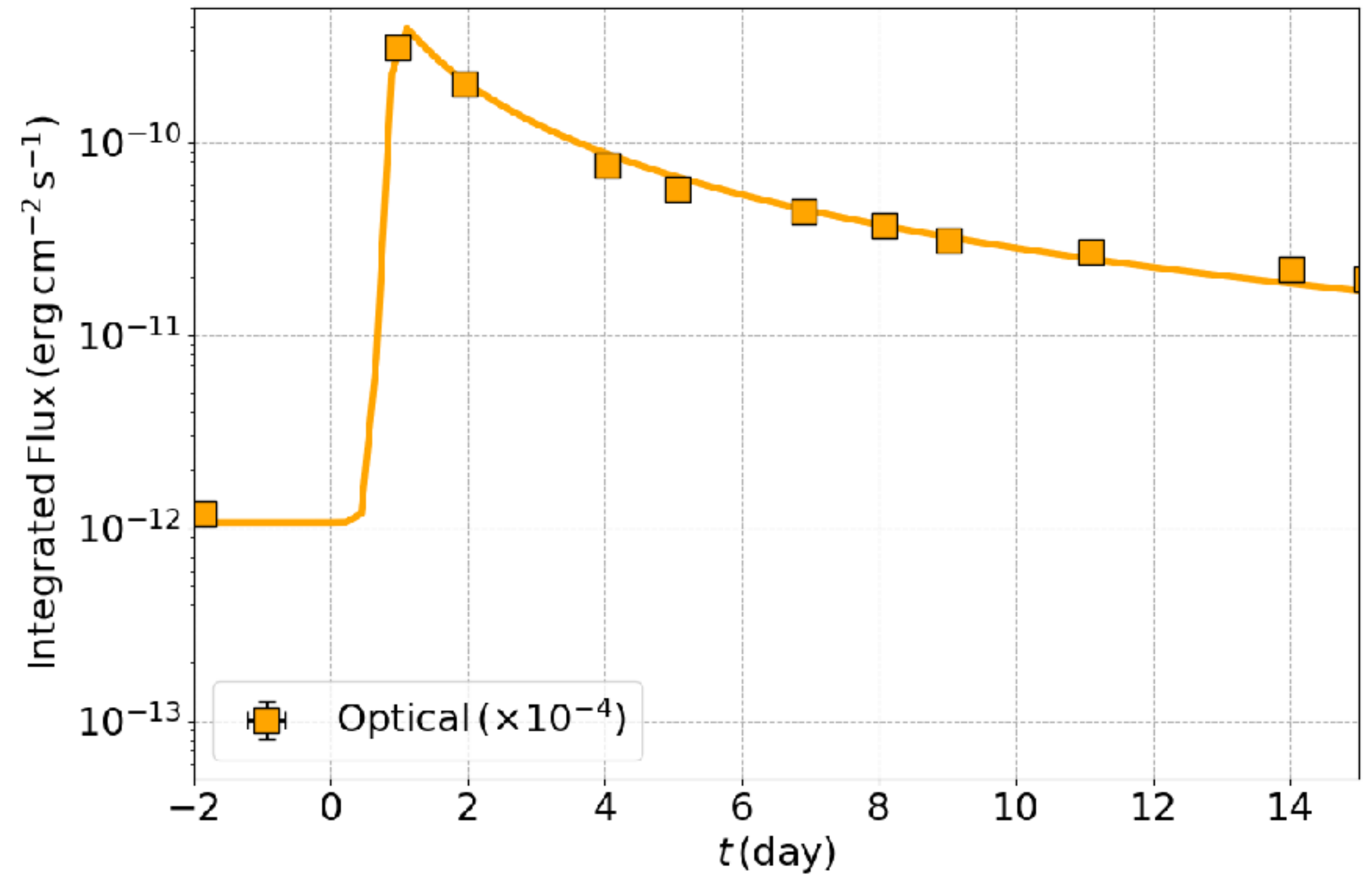


- White dwarf embedded in red giant wind.
- Distance to Earth ~ 1.5 kpc or 2.5 kpc ?
- Size of the system ~ 1.5 au.
- B-field close to red giant ~ 1 G to 10 G.
- Gas density close to red giant $\sim 10^8 \text{ cm}^{-3}$.
- Explode every 10 or 15 years.

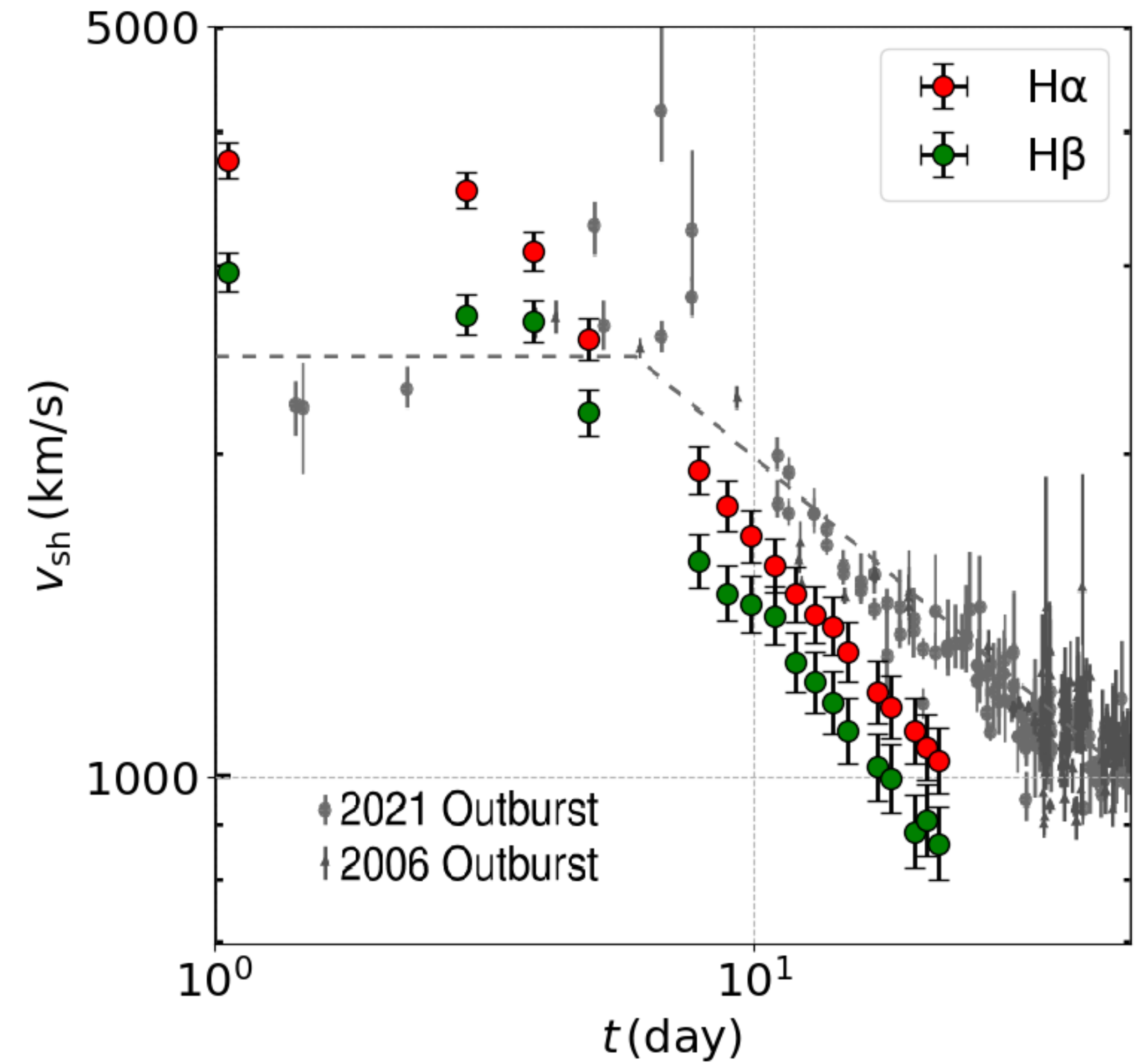
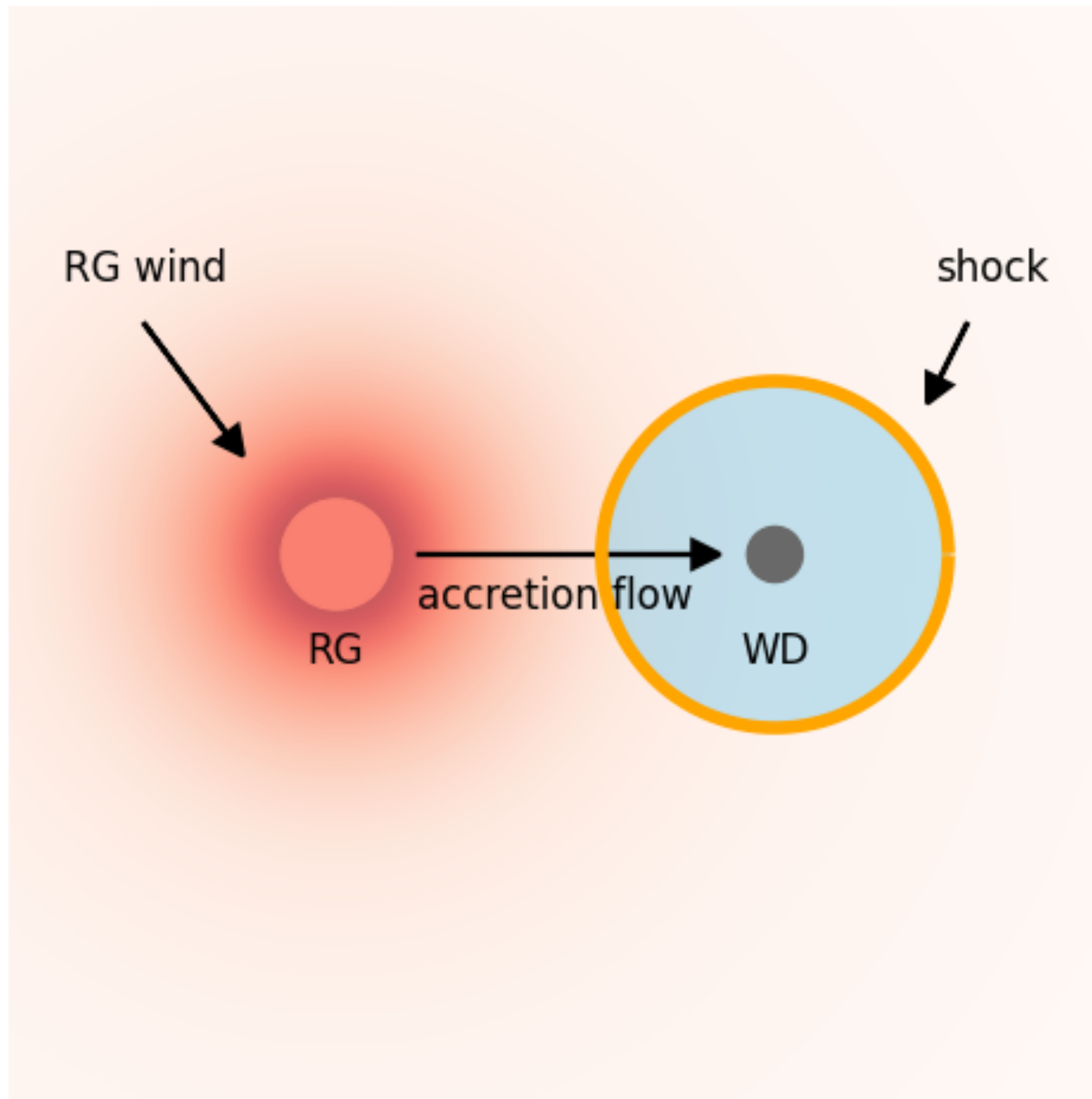
Optical light curve



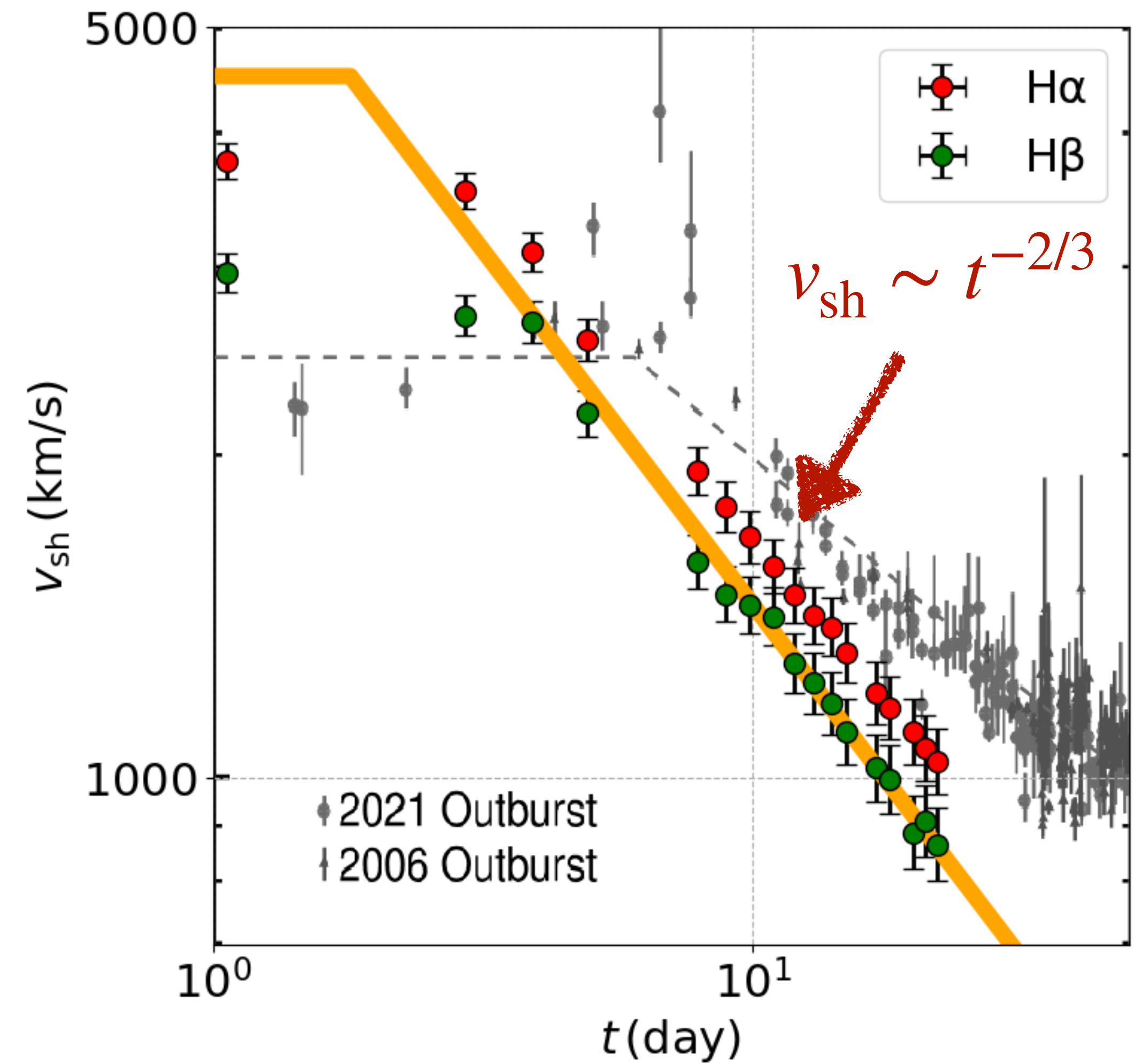
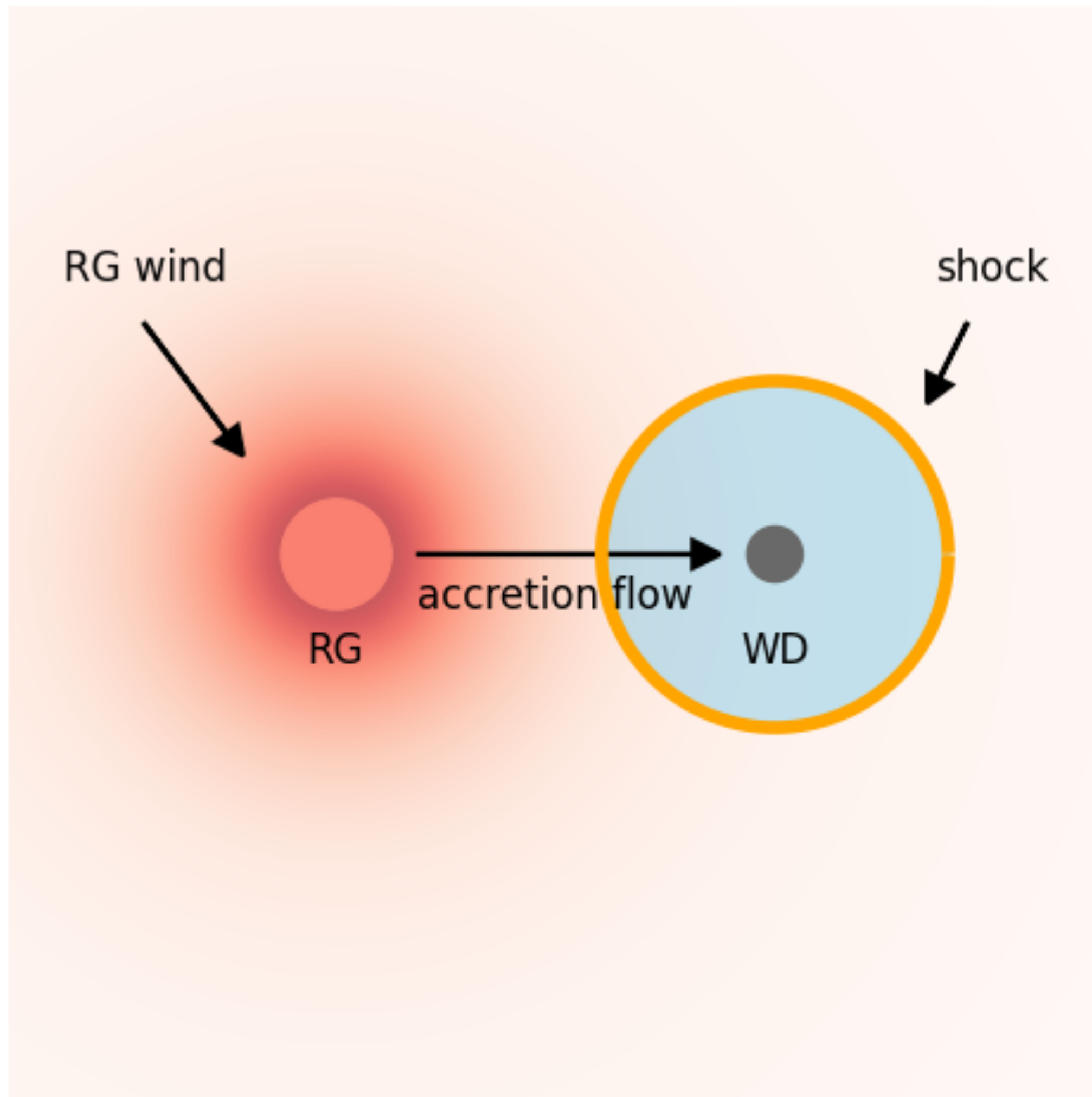
$t = 0$ day at 2021 August 8.25 in Coordinated Universal Time



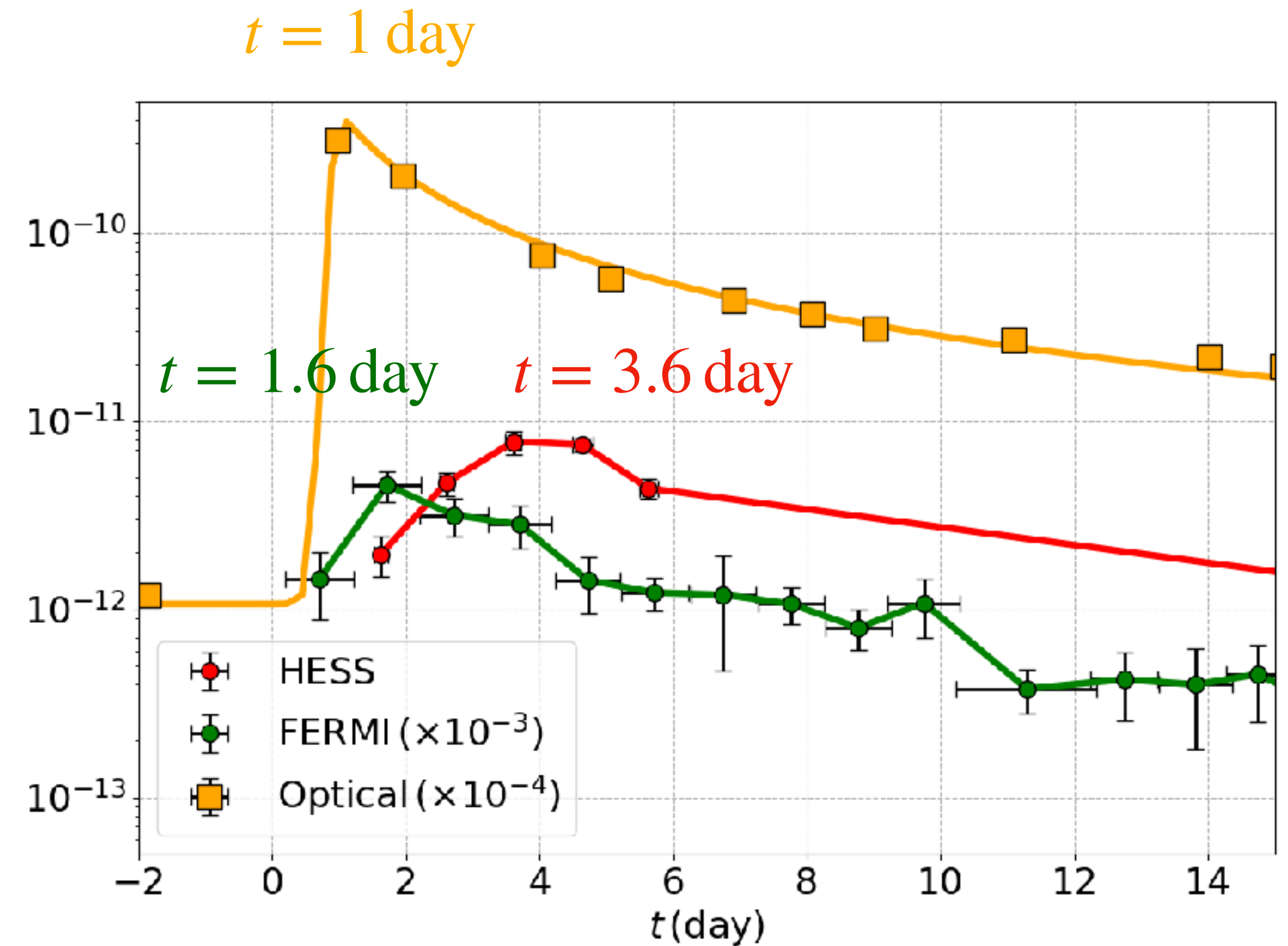
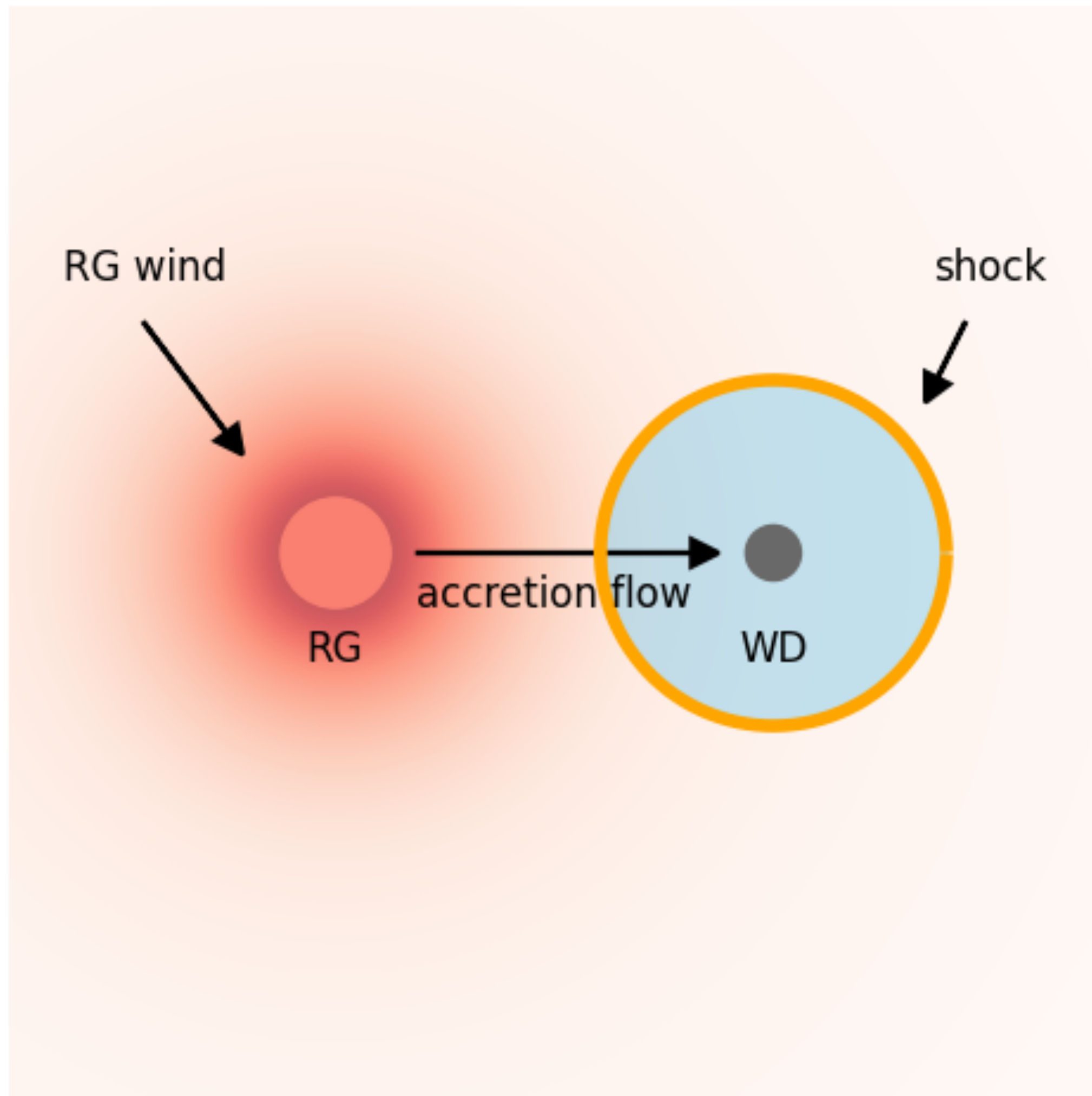
Shock dynamics



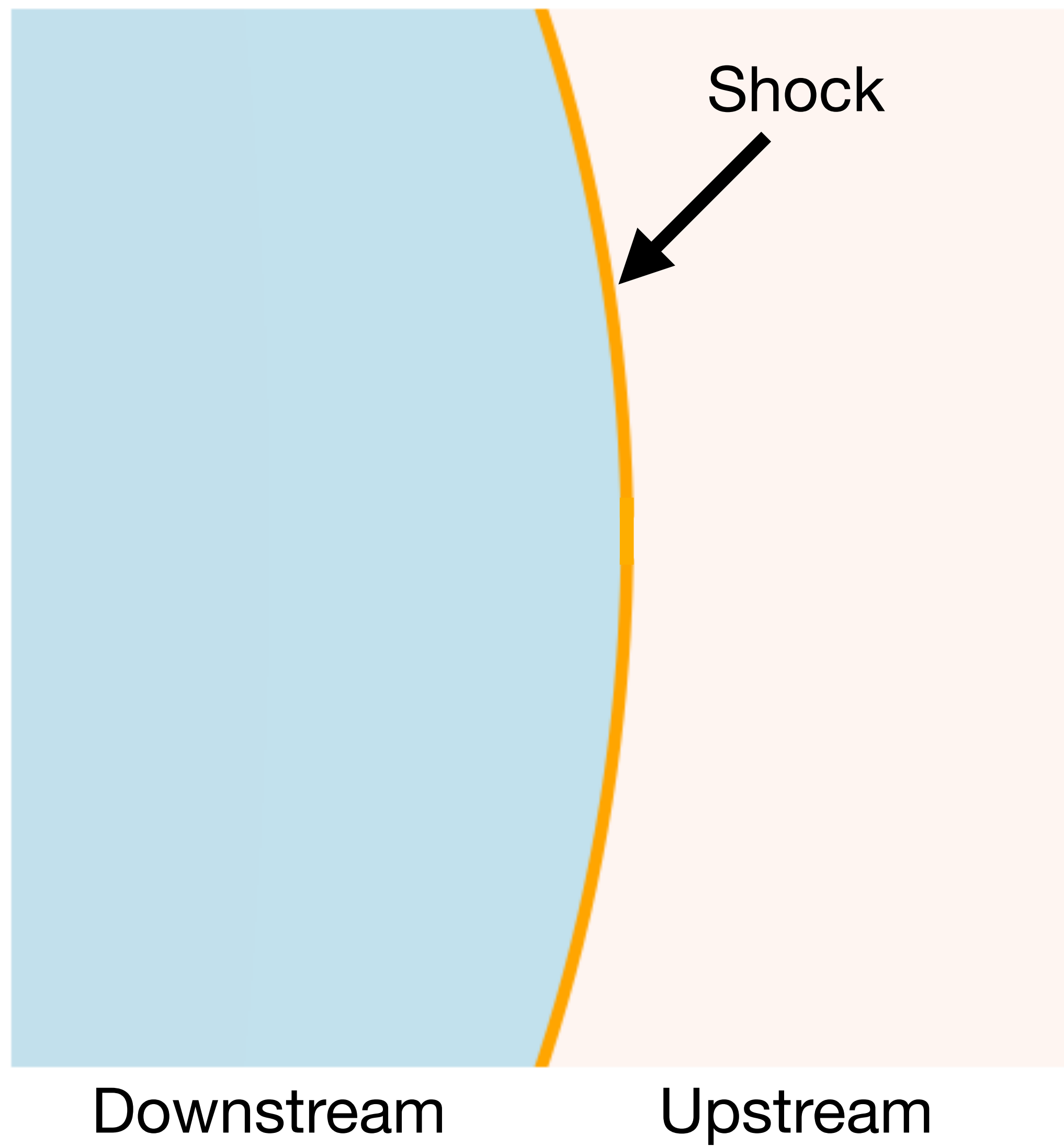
Shock dynamics



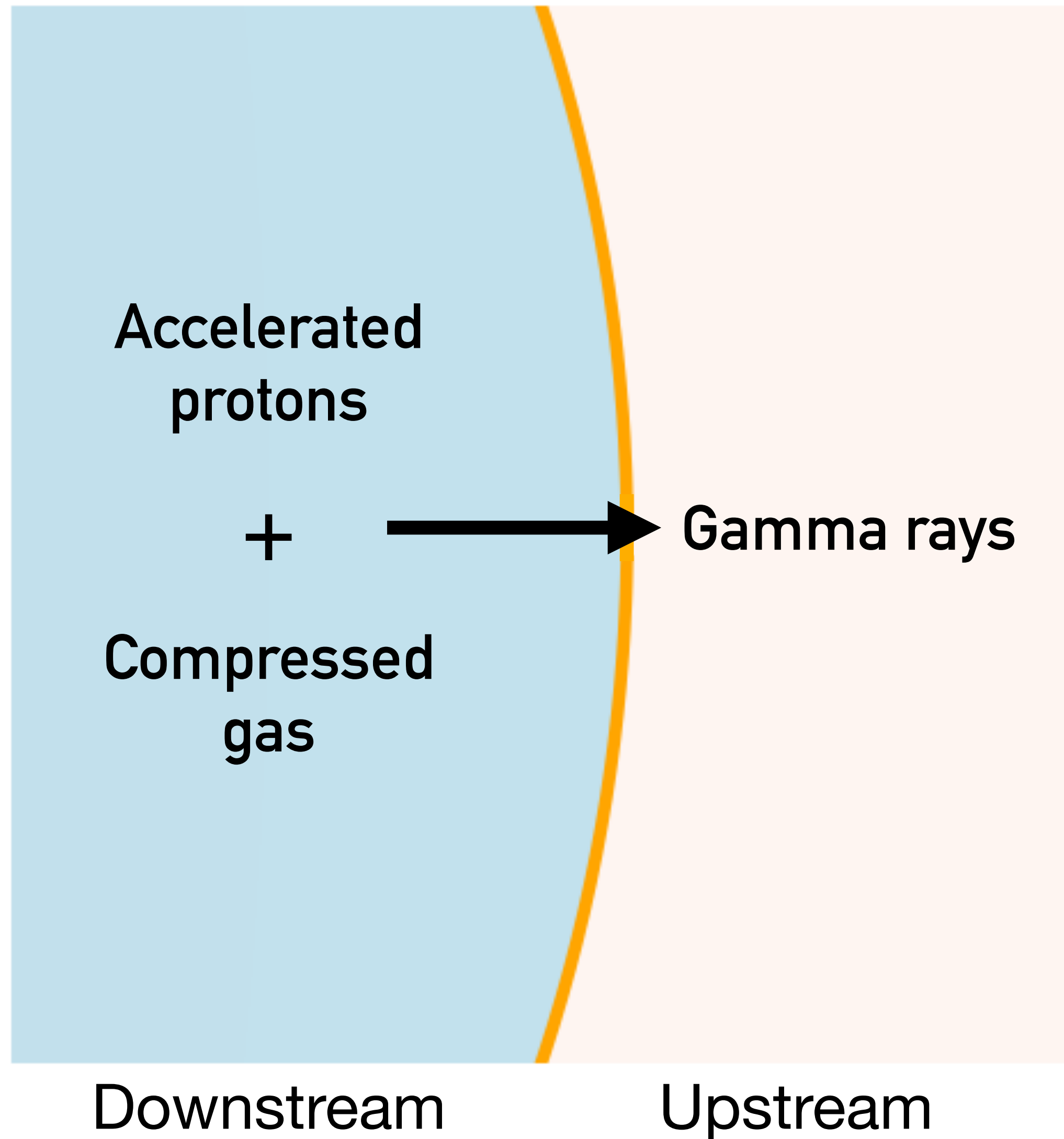
Gamma-ray light curves



Particle acceleration in nova shocks

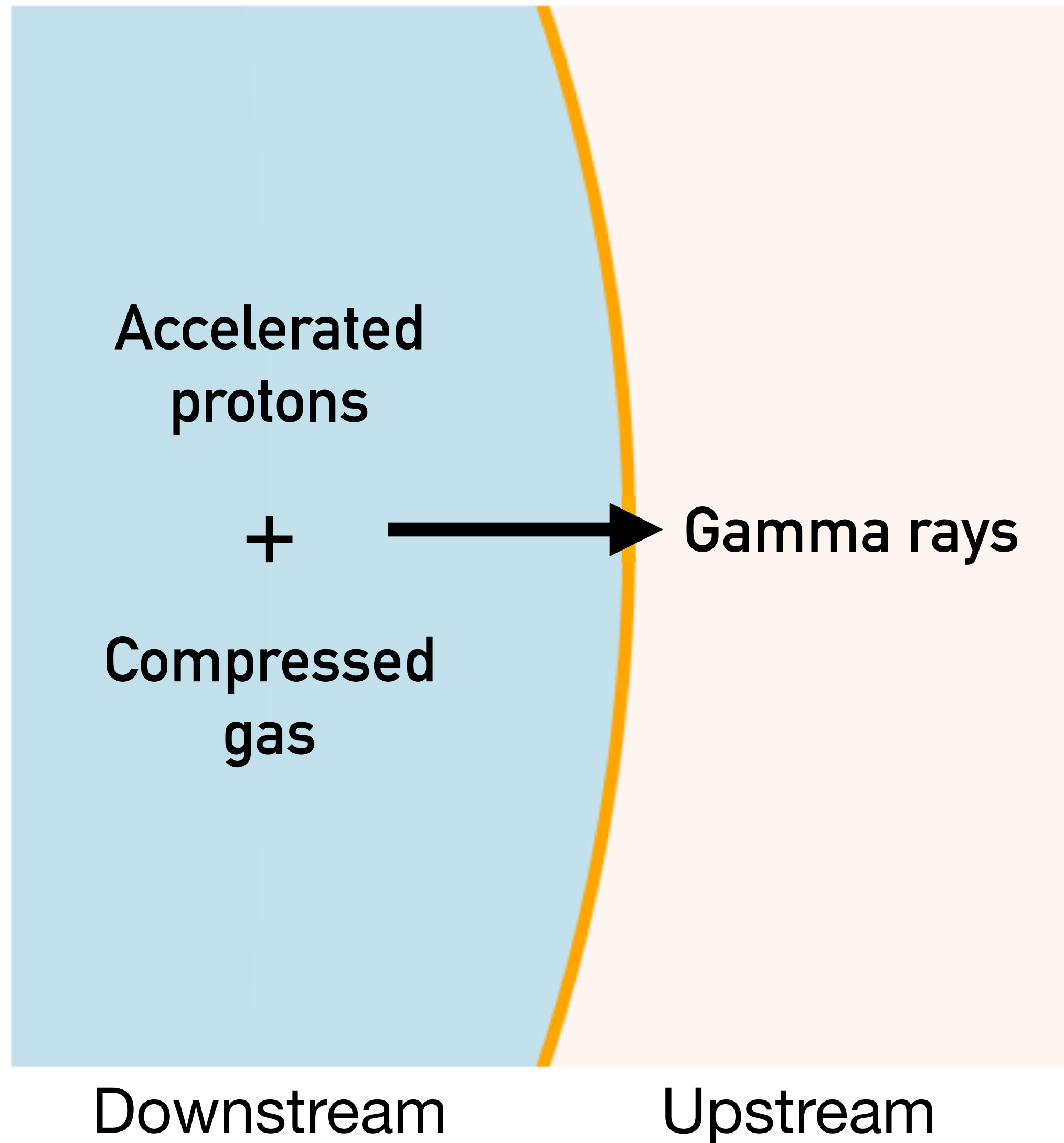


Particle acceleration in nova shocks



$$\frac{\partial N(E, t)}{\partial t} = \pi R_{\text{sh}}^2(t) v_{\text{sh}}(t) f_p(E, t),$$

Particle acceleration in nova shocks

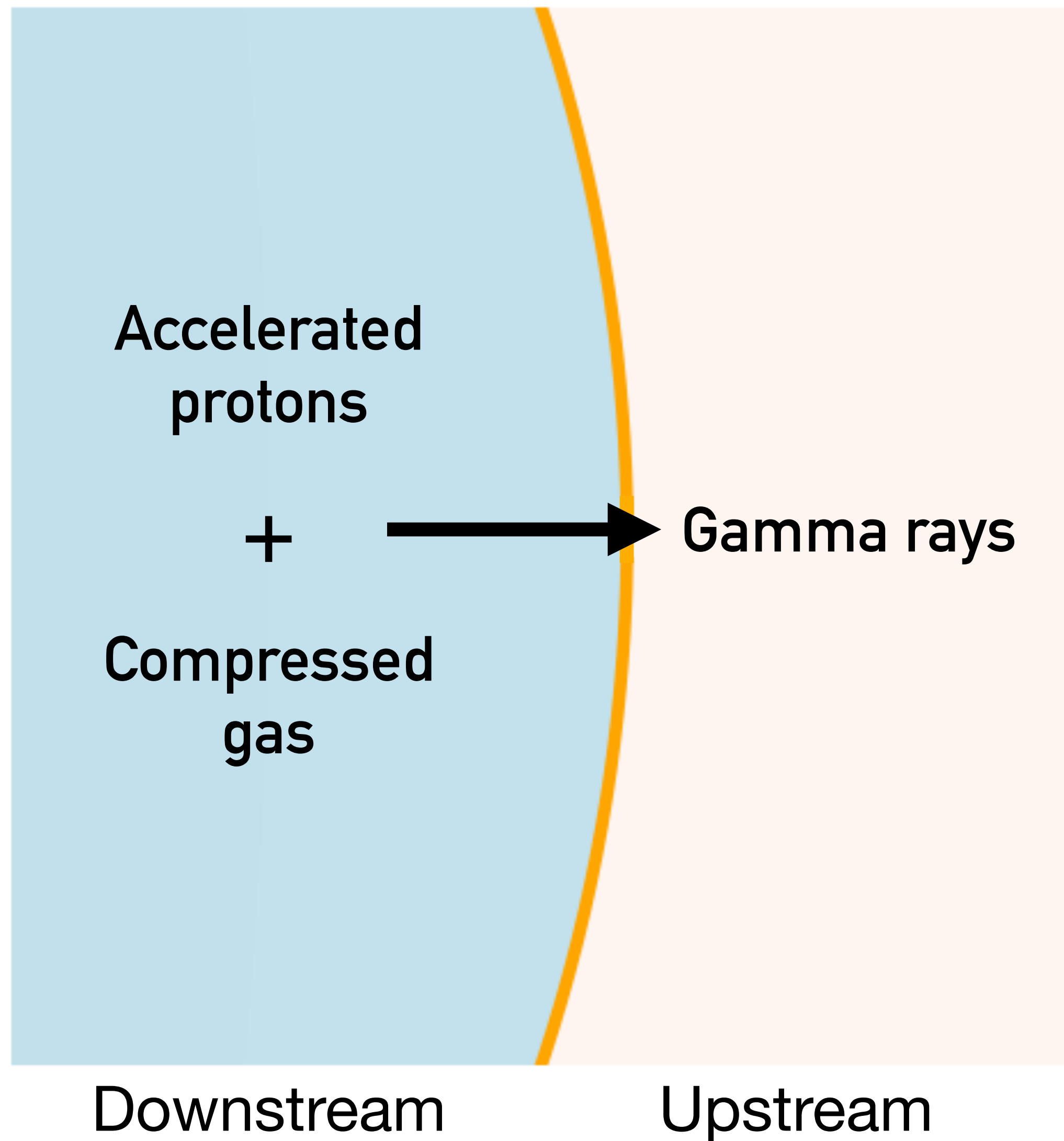


$$\frac{\partial N(E, t)}{\partial t} = \pi R_{\text{sh}}^2(t) v_{\text{sh}}(t) f_p(E, t),$$



Shock dynamics

Particle acceleration in nova shocks



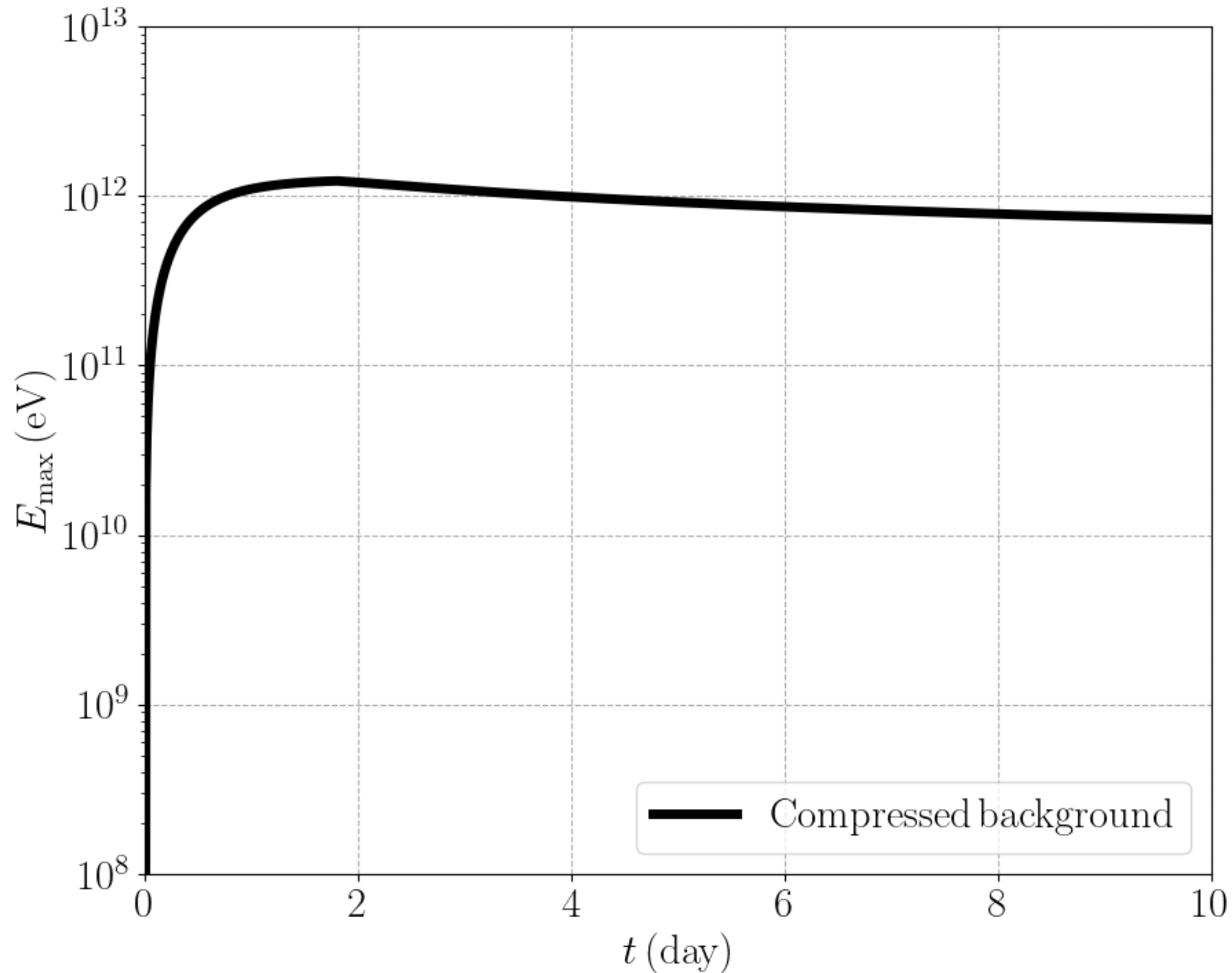
$$\frac{\partial N(E, t)}{\partial t} = \pi R_{\text{sh}}^2(t) v_{\text{sh}}(t) f_p(E, t),$$

↓

Shock injection spectrum

$$f_p(E, t) \sim E^{-2.2} \exp\left(-\frac{E}{E_{\text{max}}(t)}\right)$$

Particle acceleration in nova shocks



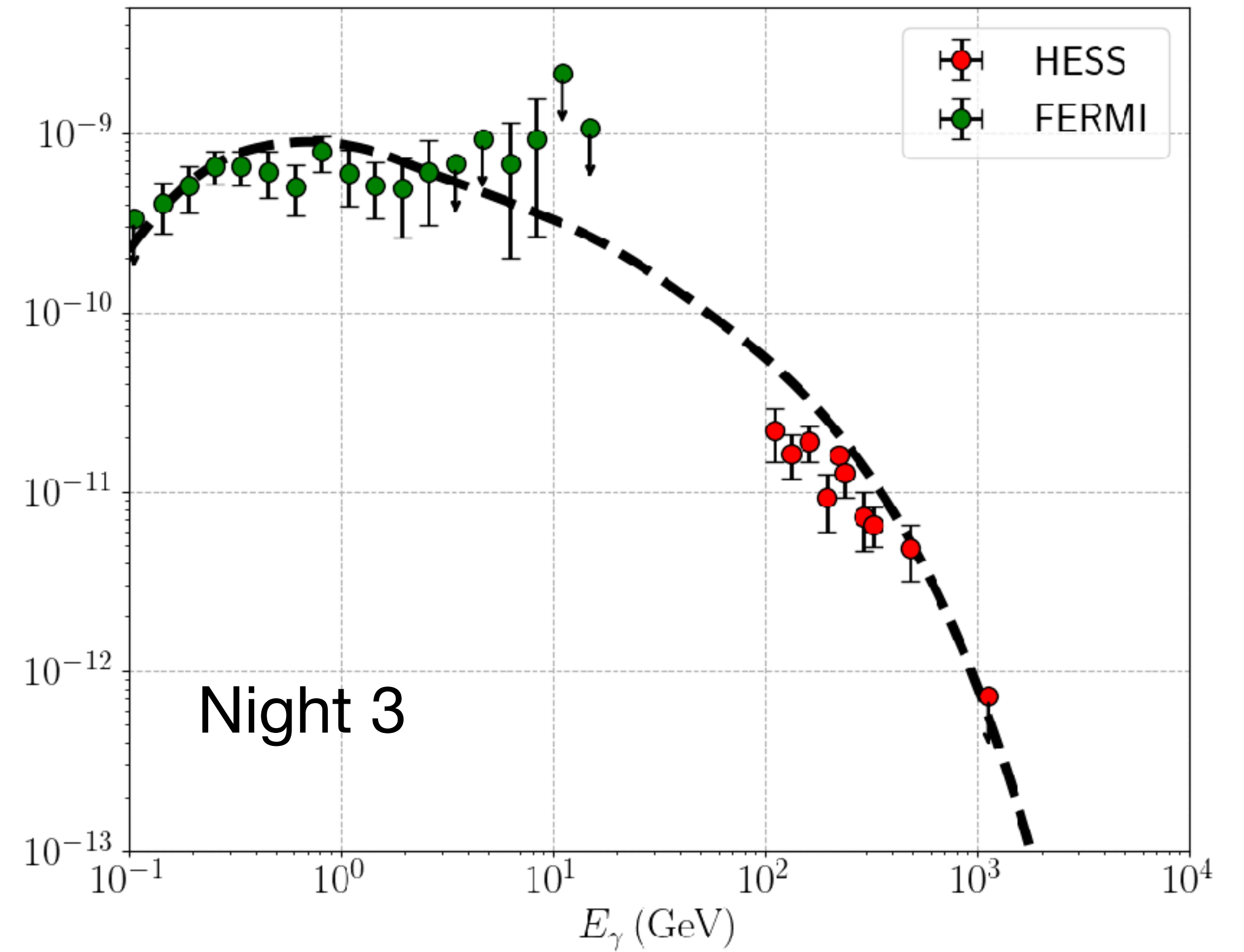
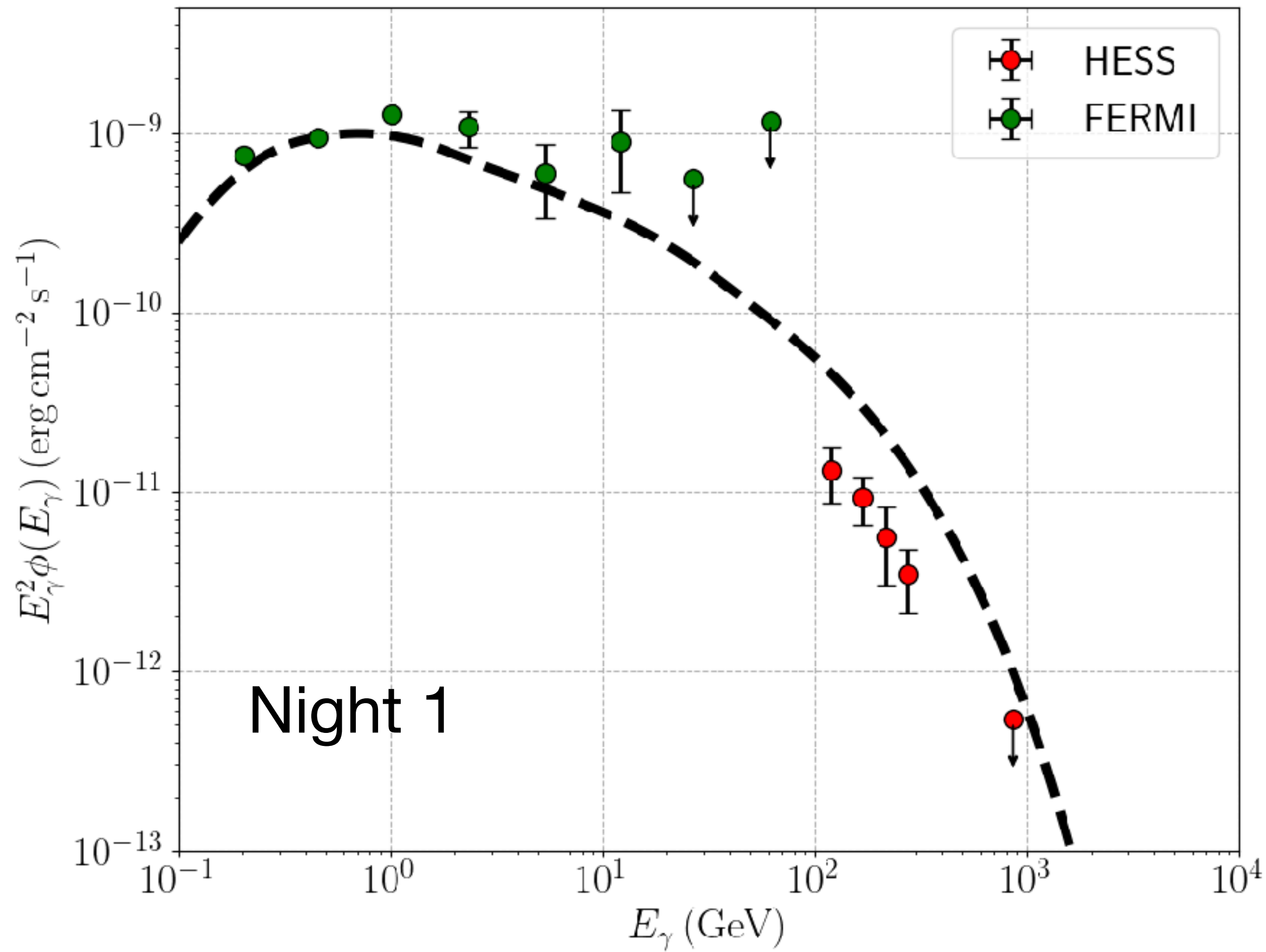
$$\frac{\partial N(E, t)}{\partial t} = \pi R_{\text{sh}}^2(t) v_{\text{sh}}(t) f_p(E, t),$$



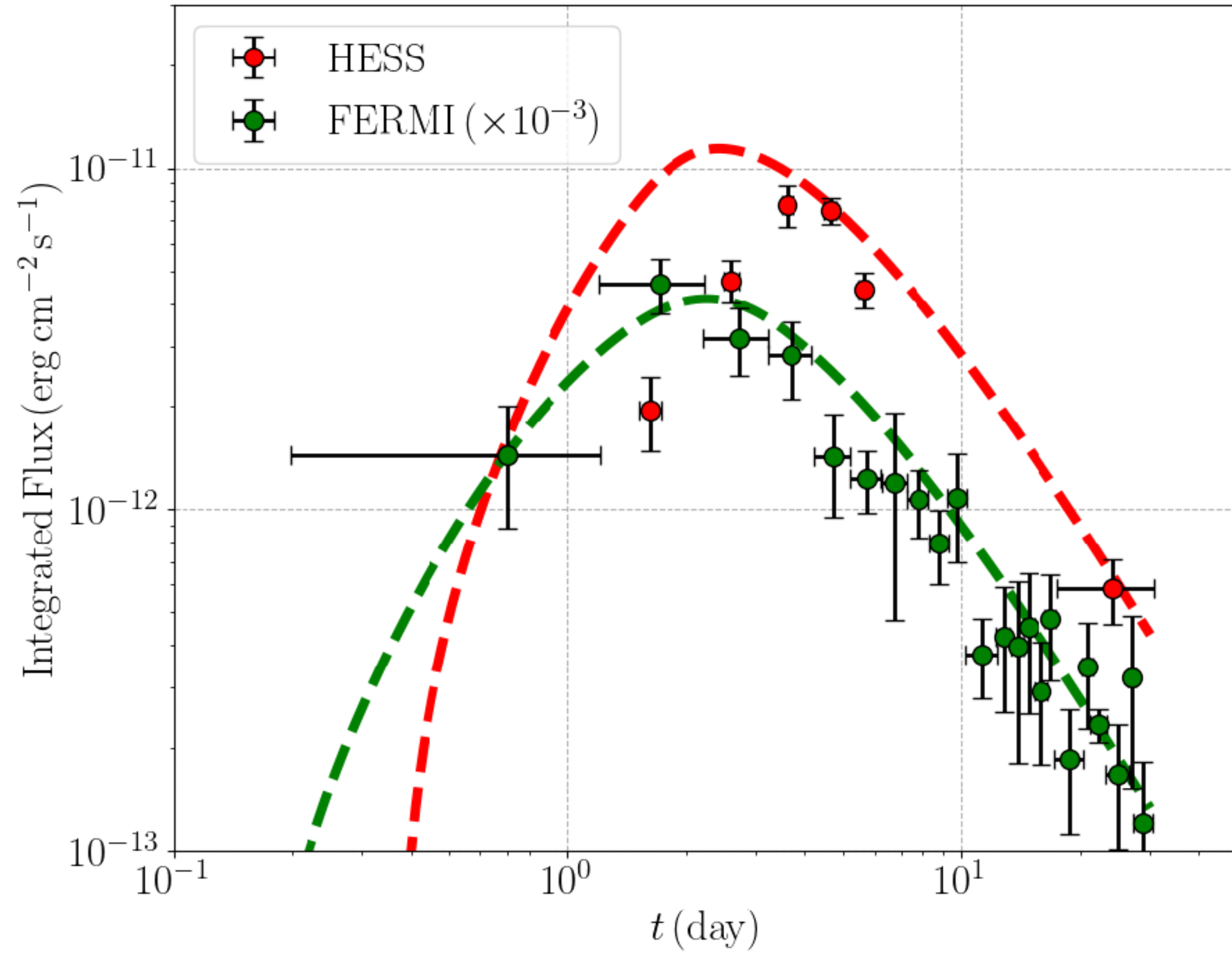
Shock injection spectrum

$$f_p(E, t) \sim E^{-2.2} \exp\left(-\frac{E}{E_{\max}(t)}\right)$$

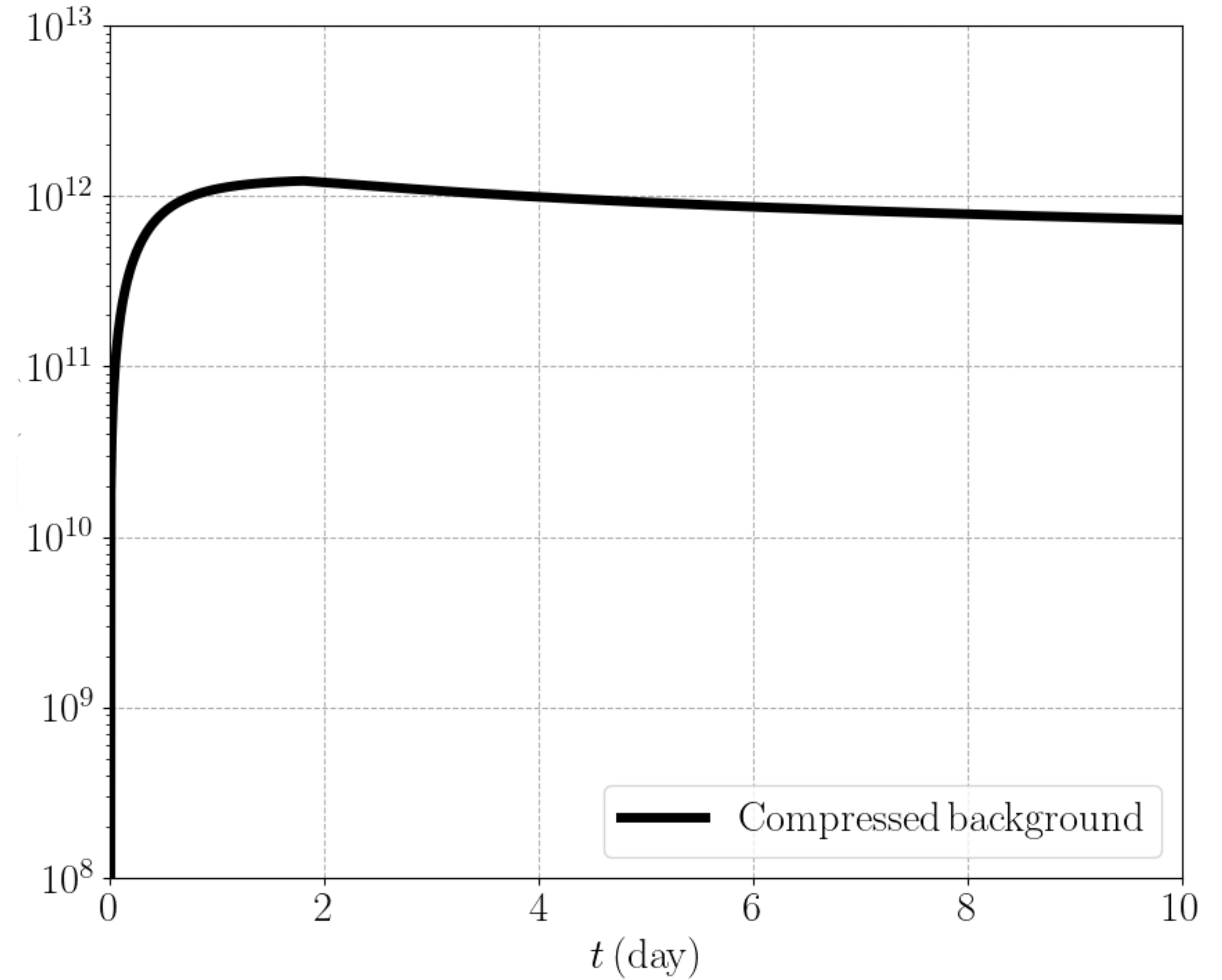
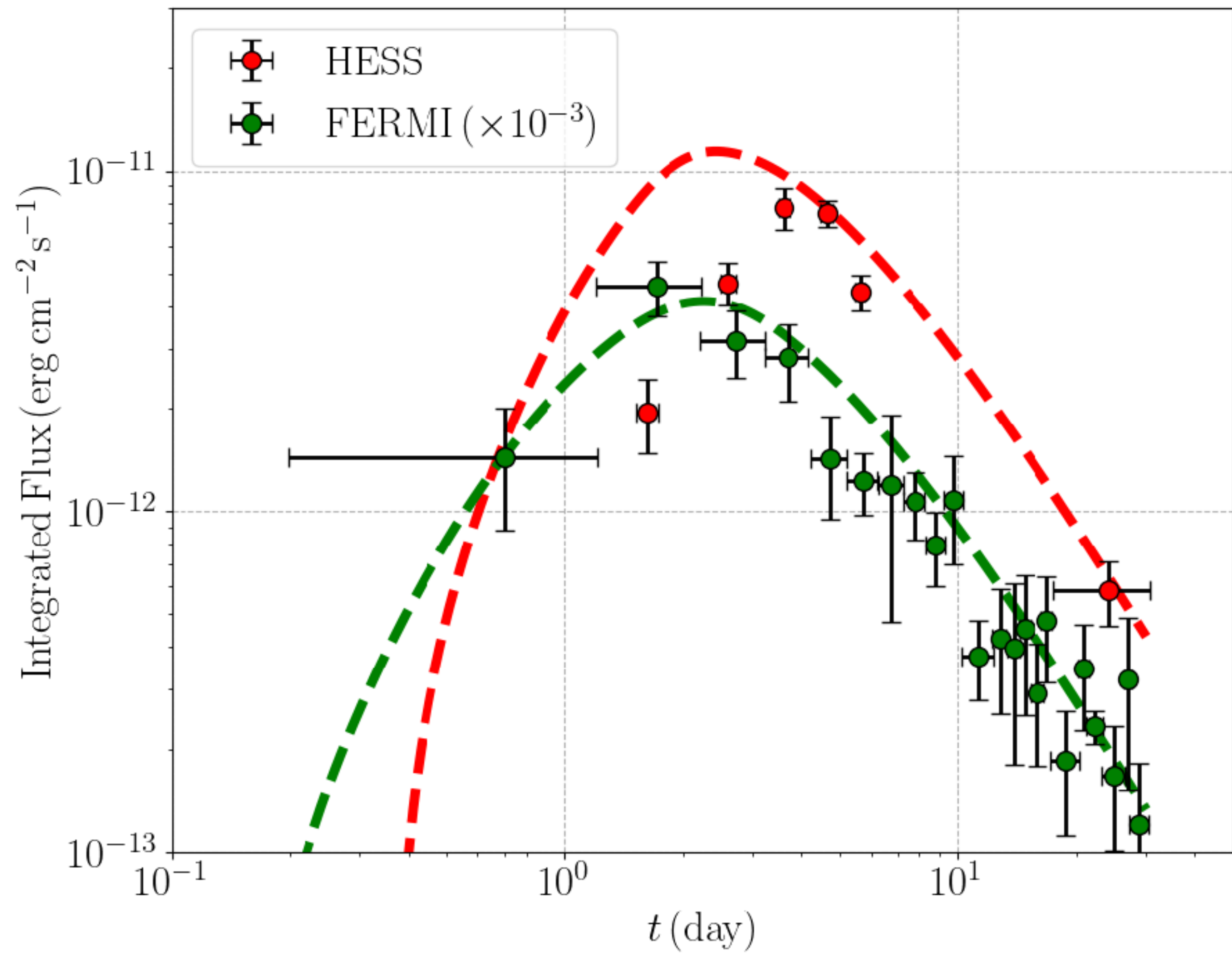
Gamma-ray emission



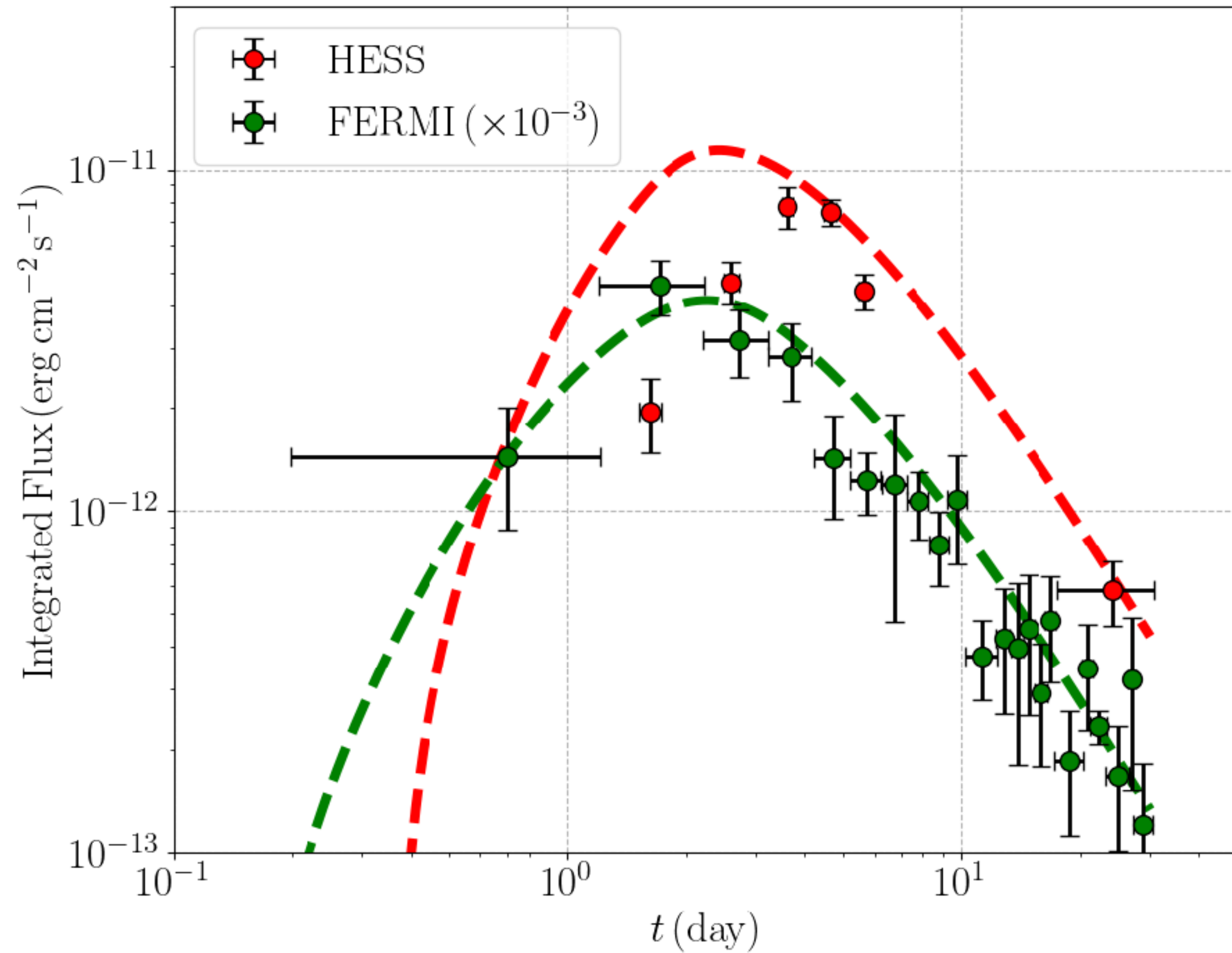
Gamma-ray emission



Gamma-ray emission

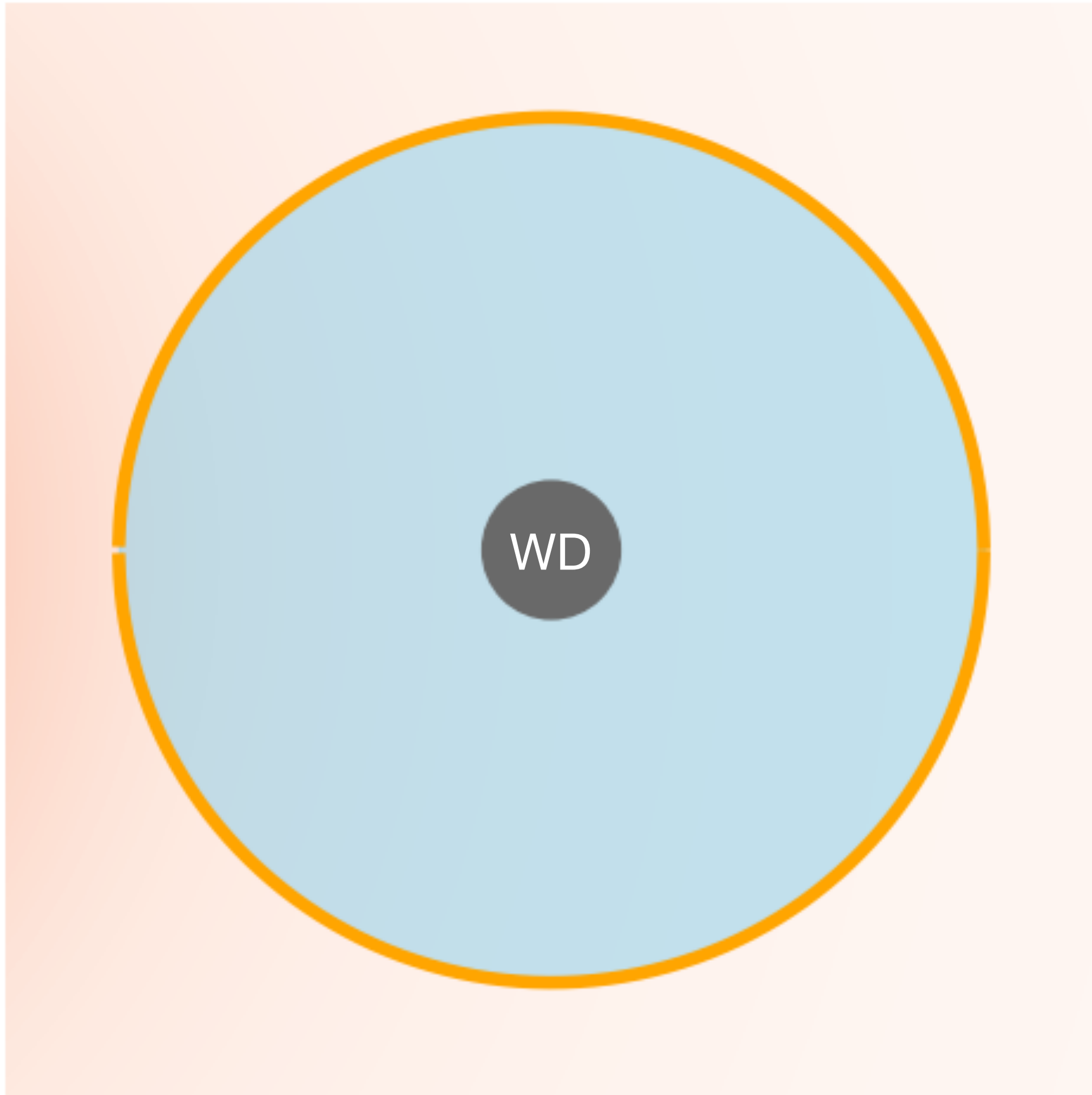


Gamma-ray emission

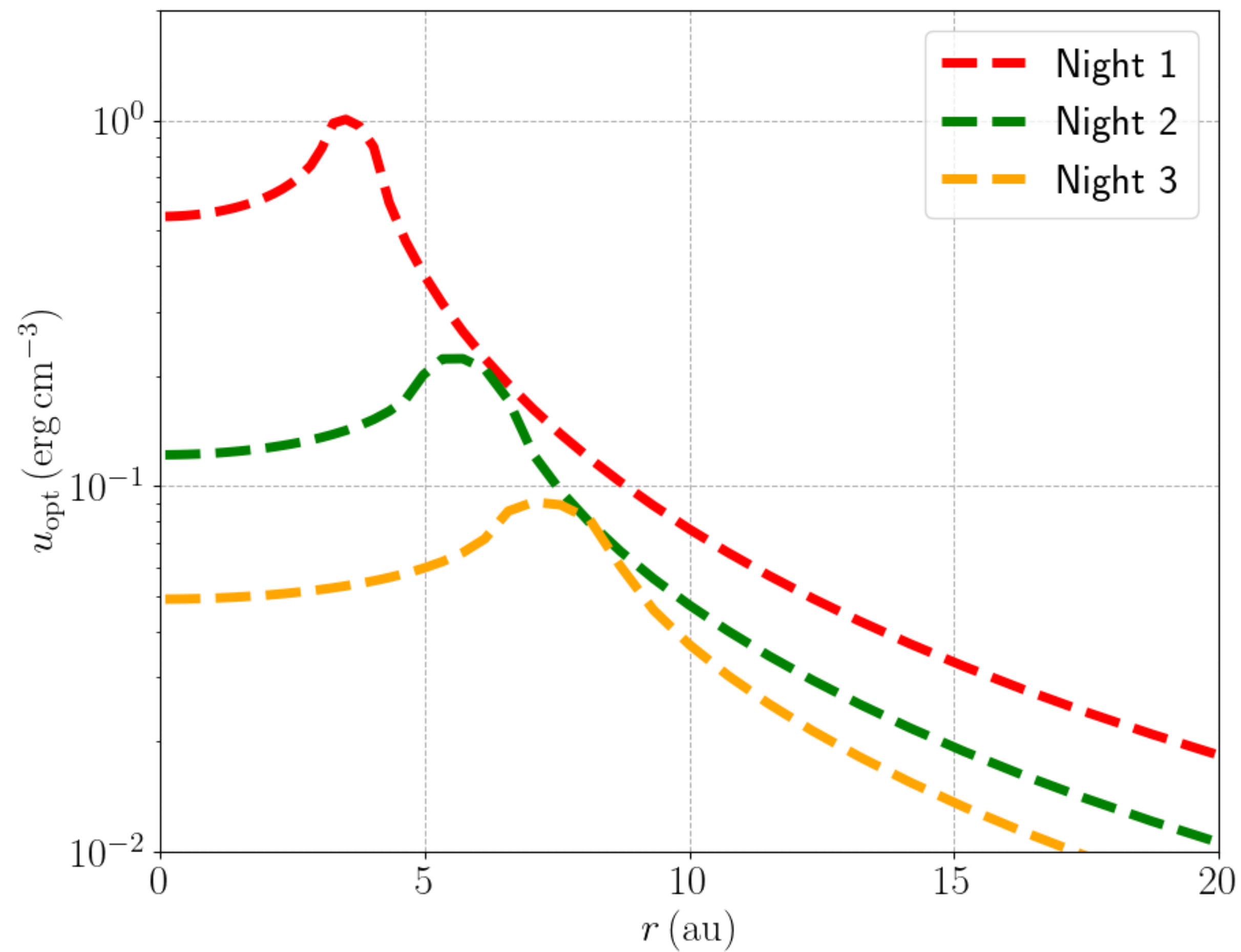
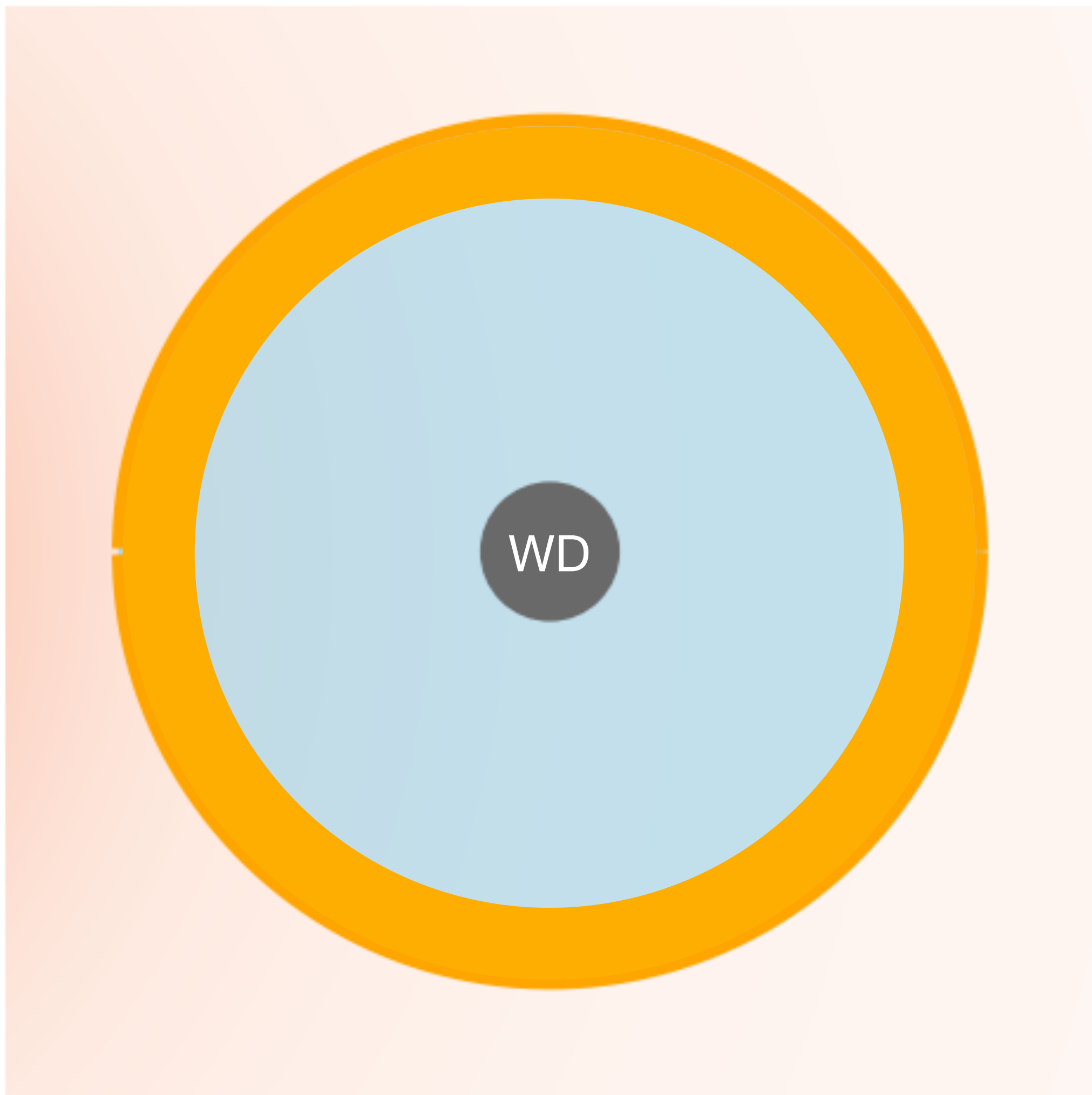


- Models proposed for this delay:
 - Changes in injection spectrum,
 - Multiple shocks,
 - Leptonic gamma rays,
 - ... ?

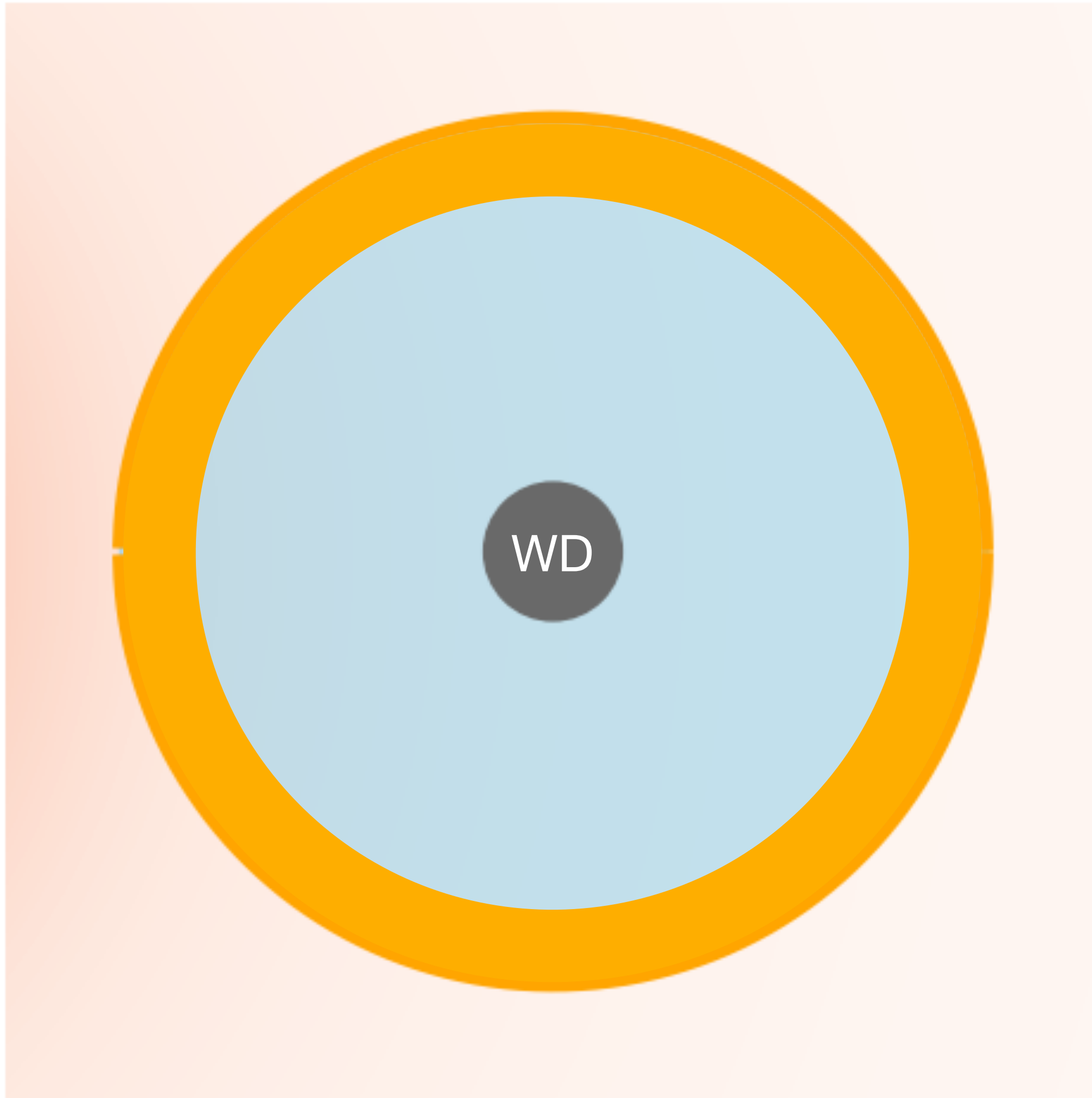
Gamma-ray absorption



Gamma-ray absorption



Gamma-ray absorption



- Gamma-ray flux with absorption

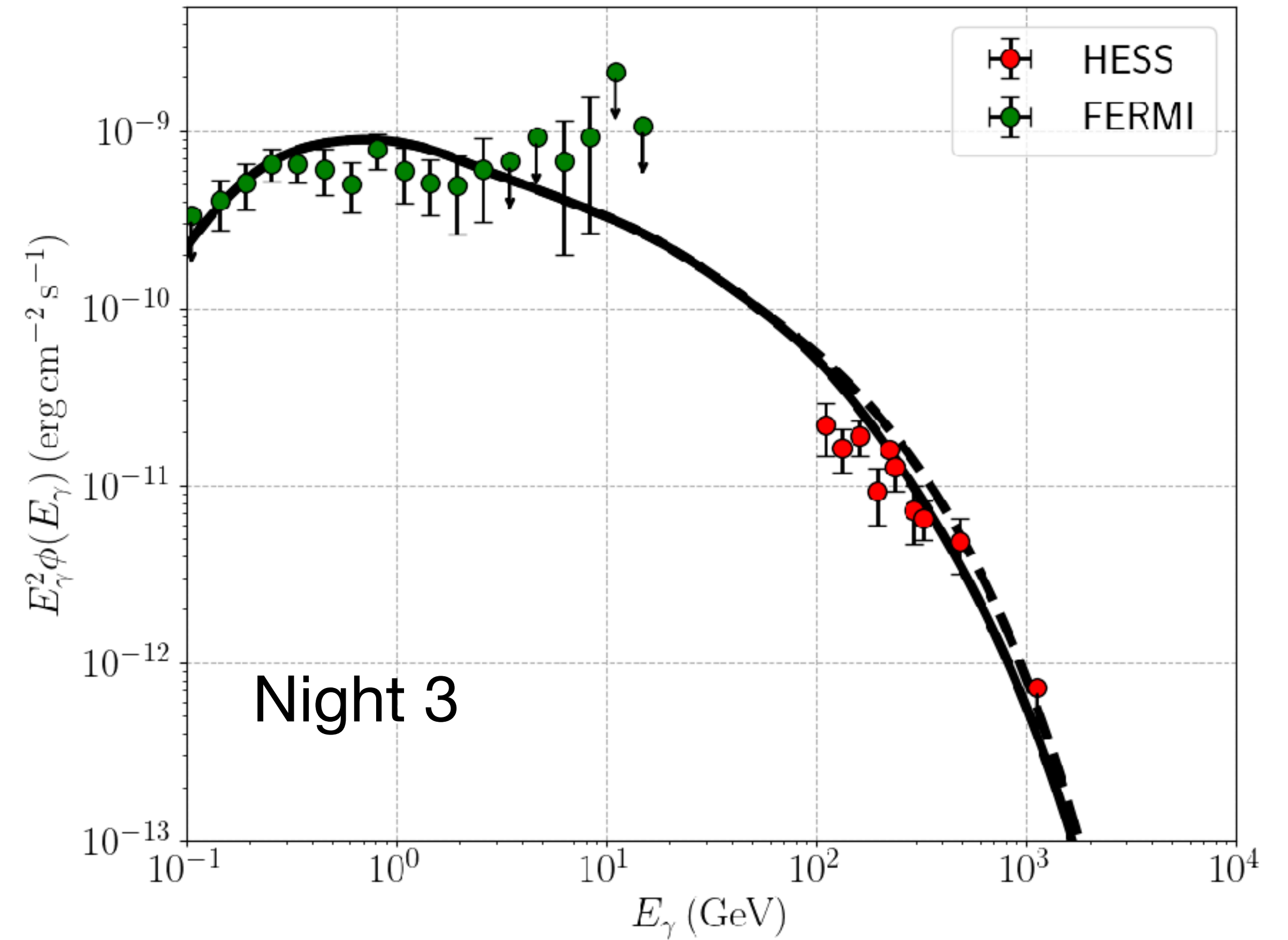
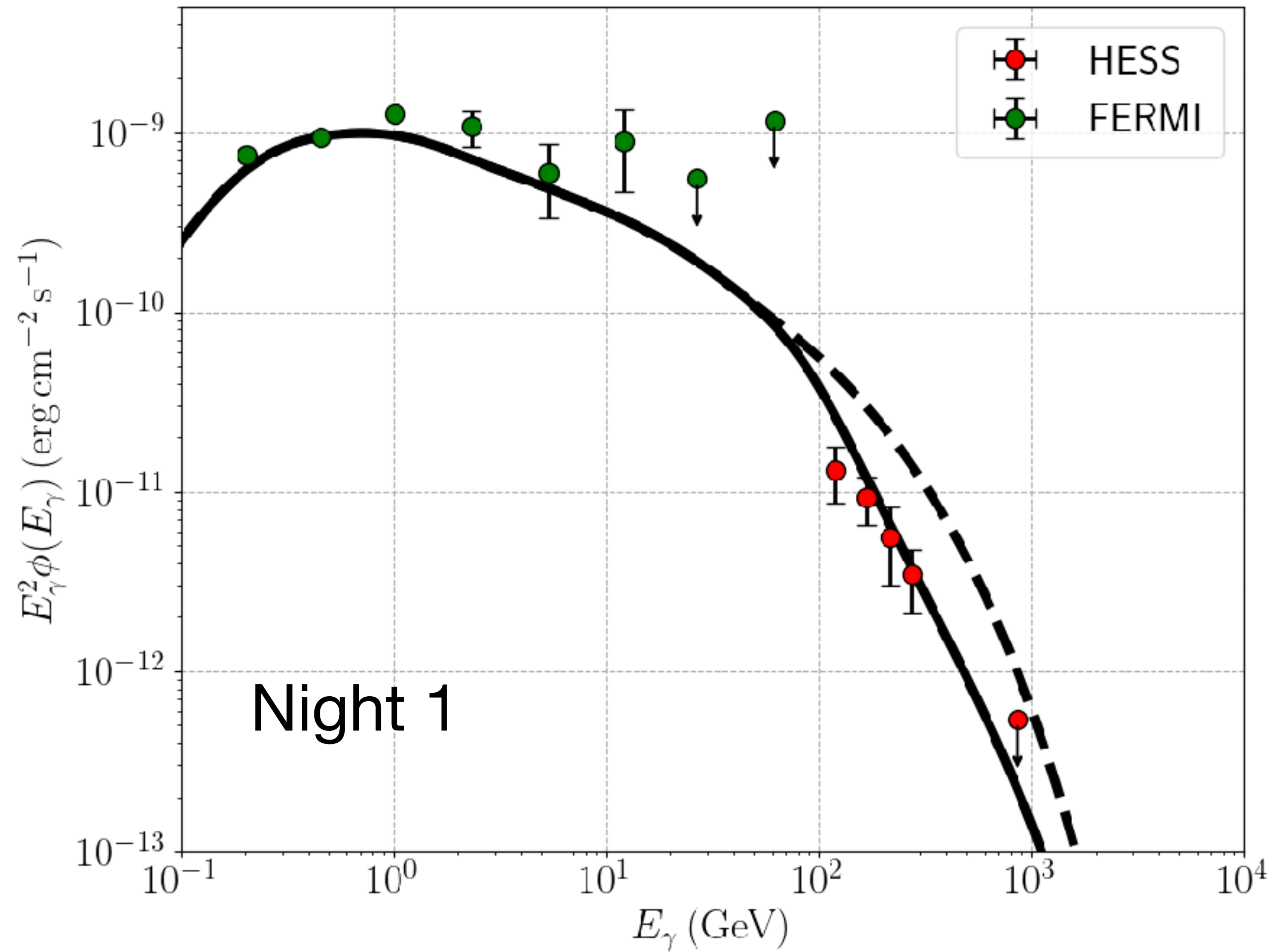
$$\phi(E_\gamma, t) \simeq \frac{\phi_0(E_\gamma, t)}{2} \left(e^{-\tau_1(E_\gamma, t)} + e^{-\tau_2(E_\gamma, t)} \right).$$

- Opacities from the two sides

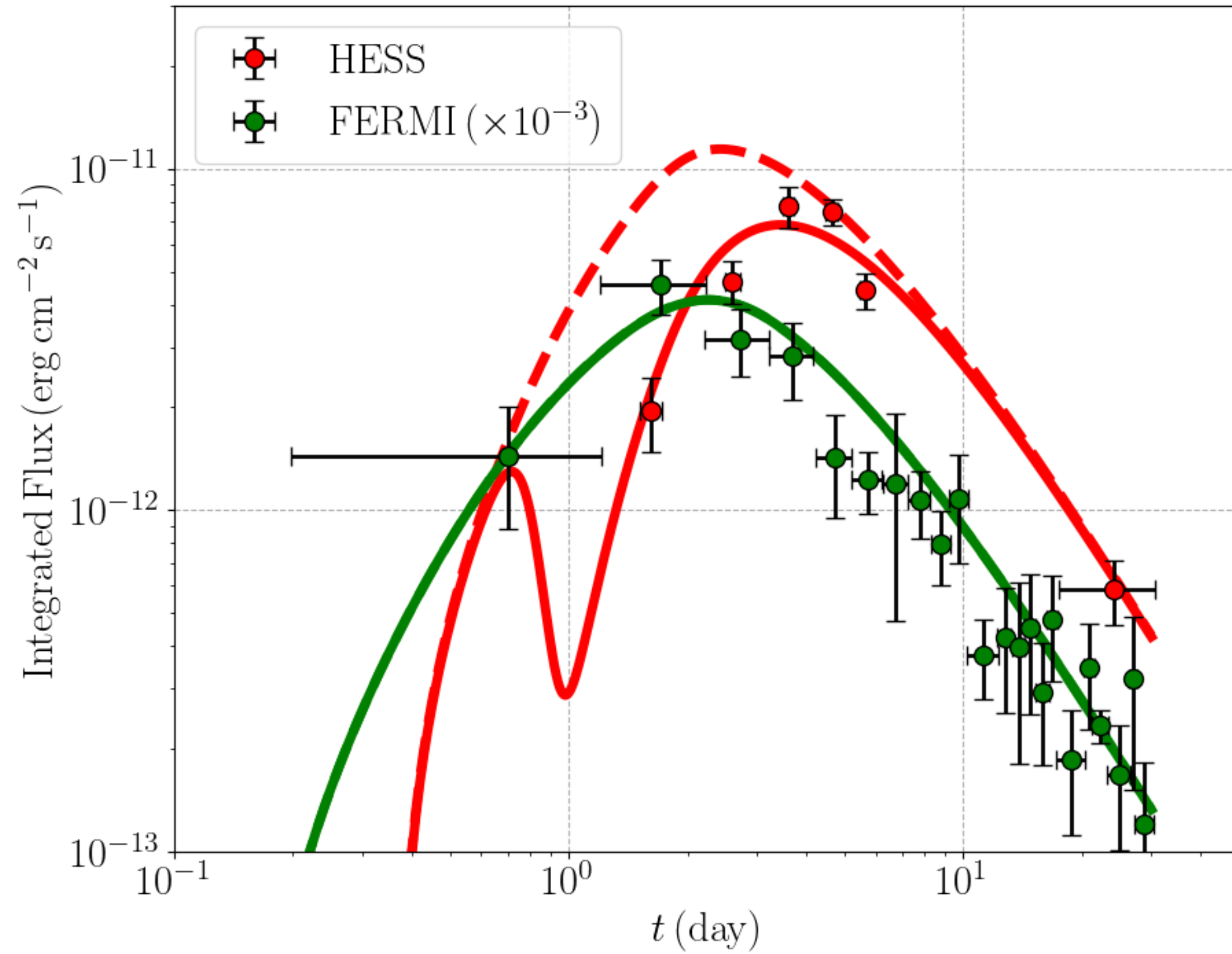
$$\tau_1(E_\gamma, t) = \int_{R_{\text{sh}}(t)}^{d_s} dr \int_0^\infty dE_{\text{ph}} f_{\text{opt}}(E_{\text{ph}}, r, t) \sigma_{\gamma\gamma}(E_\gamma, E_{\text{ph}}),$$

$$\tau_2(E_\gamma, t) = \tau_1(E_\gamma, t) + 2 \int_0^{R_{\text{sh}}(t)} dr \int_0^\infty dE_{\text{ph}} f_{\text{opt}}(E_{\text{ph}}, r, t) \sigma_{\gamma\gamma}(E_\gamma, E_{\text{ph}}).$$

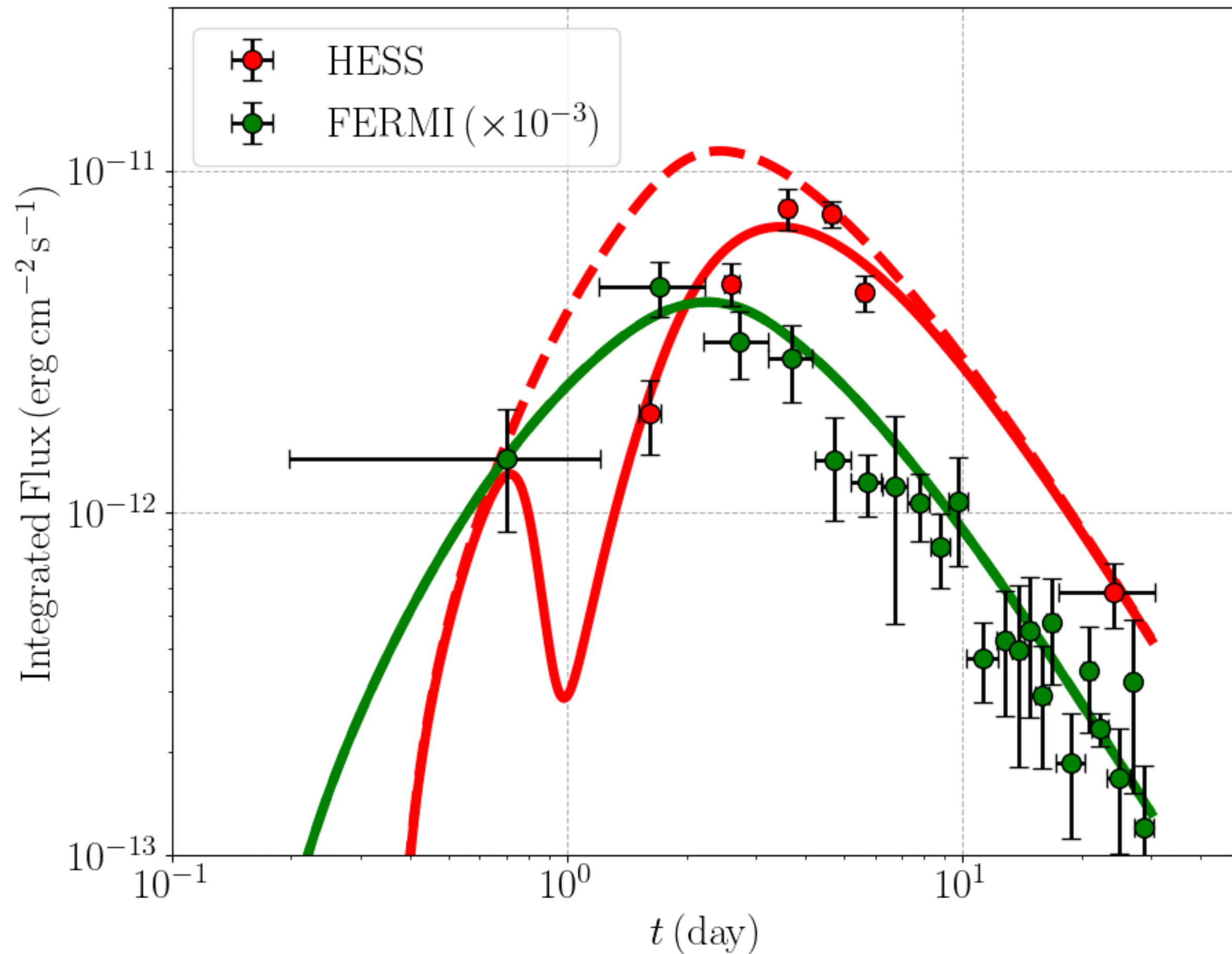
Preliminary results



Preliminary results








Conclusion and outlook



- Novae are ideal labs for particle acceleration.
- High-energy gamma rays from novae can be partially absorbed by optical photons in the first few days of the explosions.
- This can lead to a delay between GeV and TeV light curves.
- Maybe we can see neutrinos with future telescopes?

Search for sub-TeV Neutrino Emission from Novae with IceCube-DeepCore

R. Abbasi¹ , M. Ackermann² , J. Adams³, N. Aggarwal⁴, J. A. Aguilar⁵ , M. Ahlers⁶ ,
J. M. Alameddine⁷ , A. A. Alves Jr.⁸, N. M. Amin⁹, K. Andeen¹⁰ [Show full author list](#)

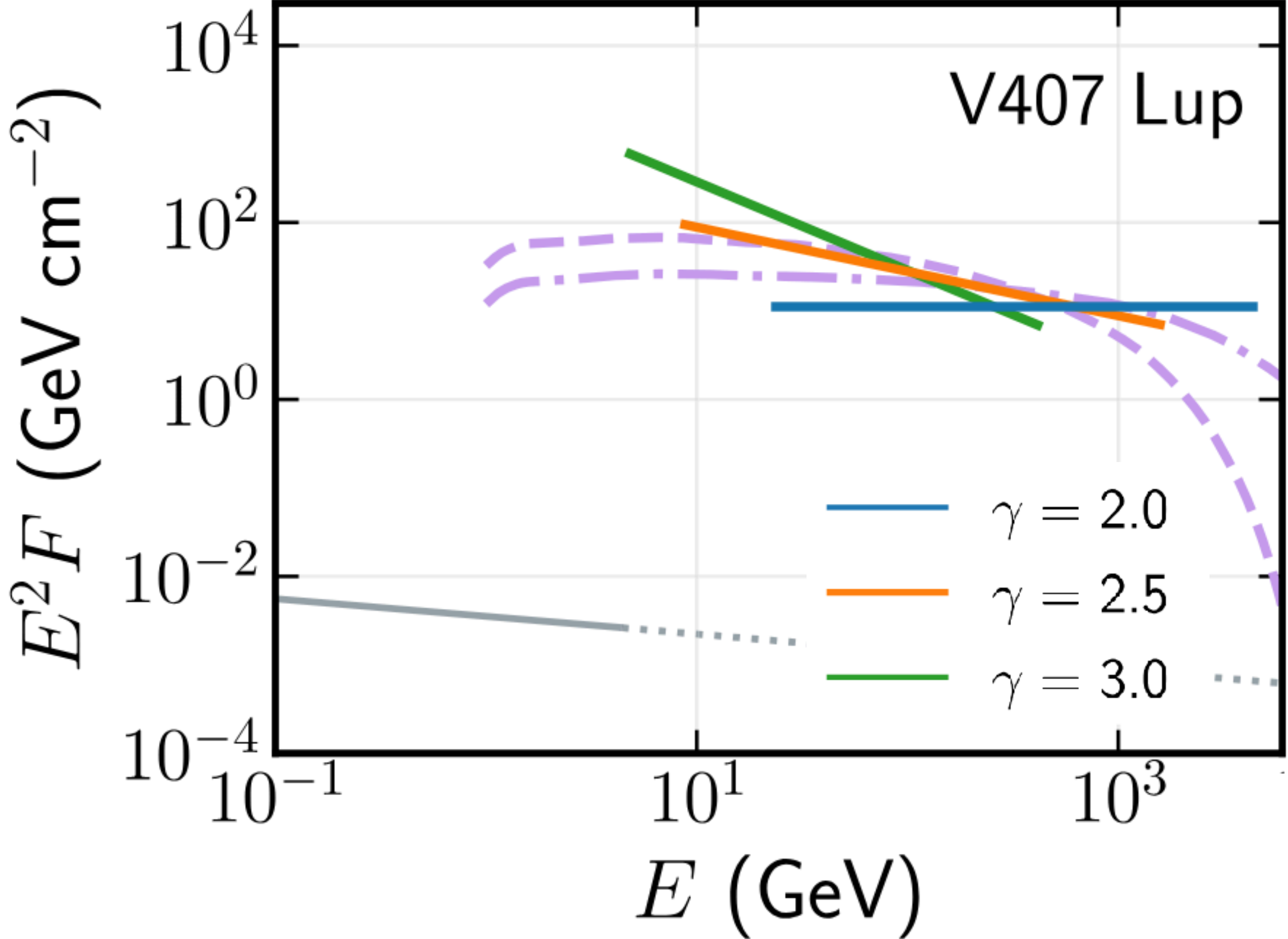
Published 2023 August 14 • © 2023. The Author(s). Published by the American Astronomical Society.

[The Astrophysical Journal](#), [Volume 953](#), [Number 2](#)

Citation R. Abbasi *et al* 2023 *ApJ* **953** 160

DOI 10.3847/1538-4357/acdc1b

Back up



Back up

