Simulation of an electron-positron plasma in the context of the IGC paradigm

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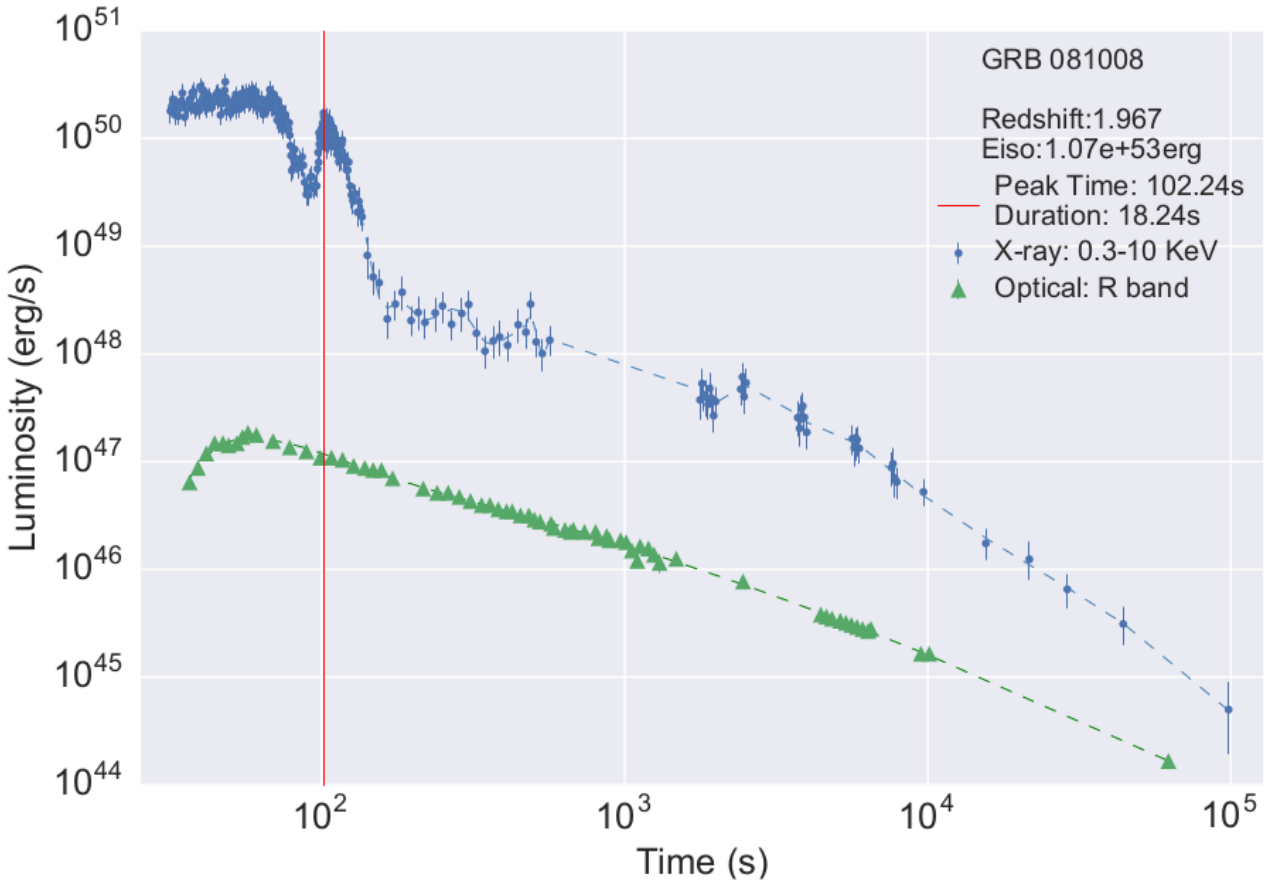
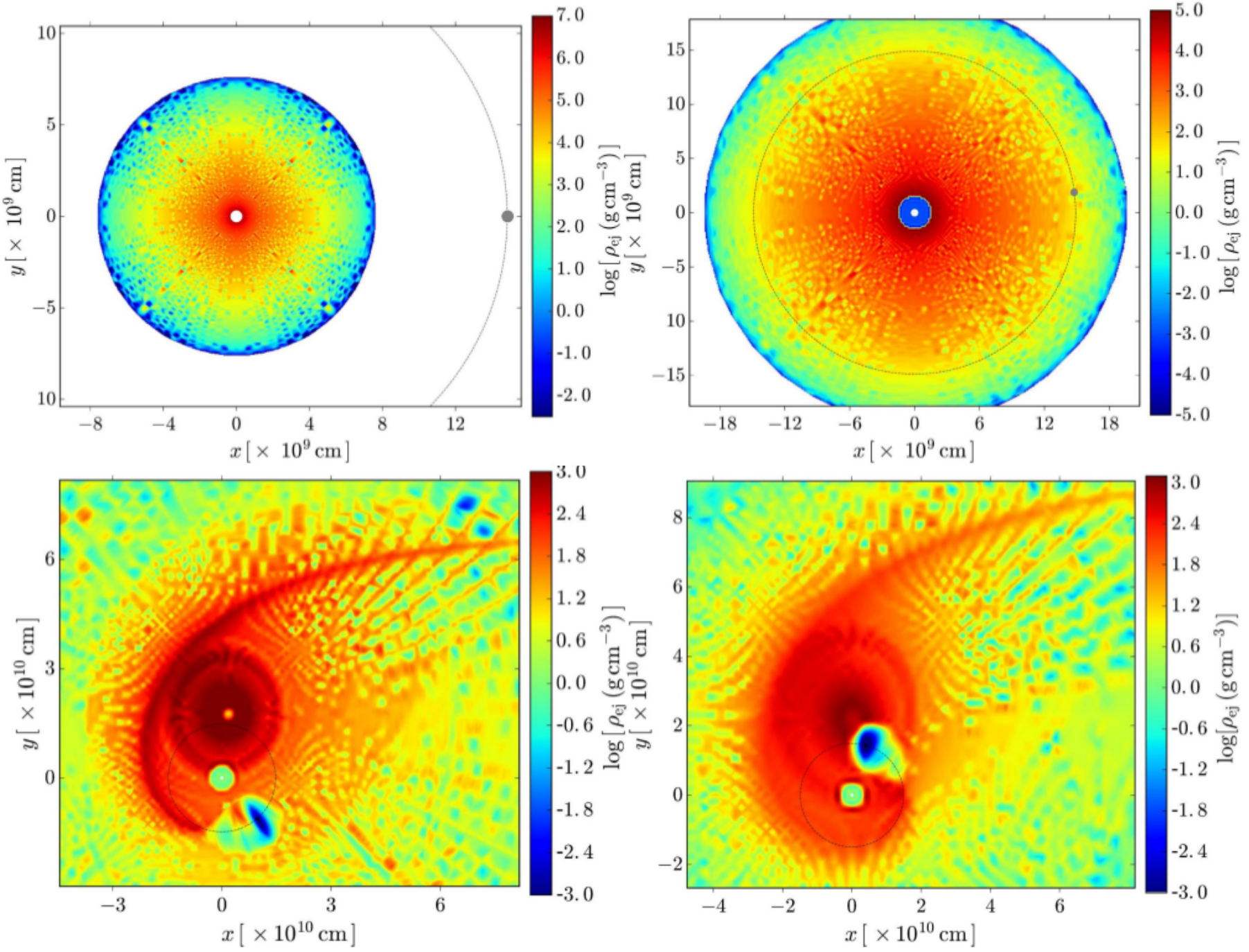
- *BDHNe and the IGC paradigm*
- *Numerical schemes*
- *Simulations*
- *Conclusions and future work*

Outline of the problem: *Gamma Ray-Bursts and X-ray flares*



- **SN-GRB connection** (see e.g. Woosley & Bloom 2006; Della Valle 2011; Hjorth & Bloom 2012).
- Observation of **X-ray flares** with measured Lorentz factors **Γ up to $\sim$4**, following the usual prompt emission with **$\Gamma \sim 10^2$-10^3** (R. Ruffini, Y. Wang et al., 2017, arXiv:1704.03821).

Outline of the problem: *The IGC paradigm for GRBs*



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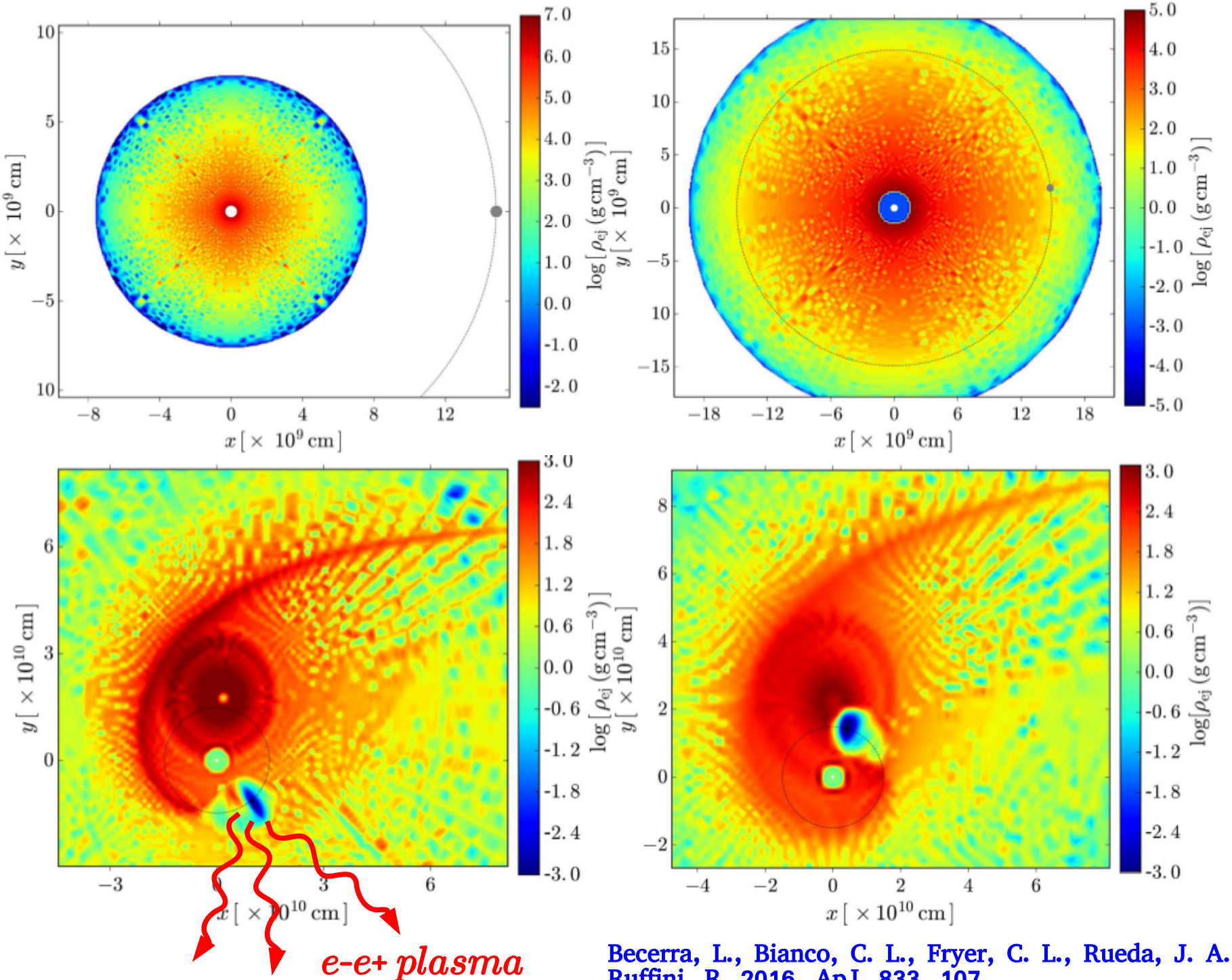

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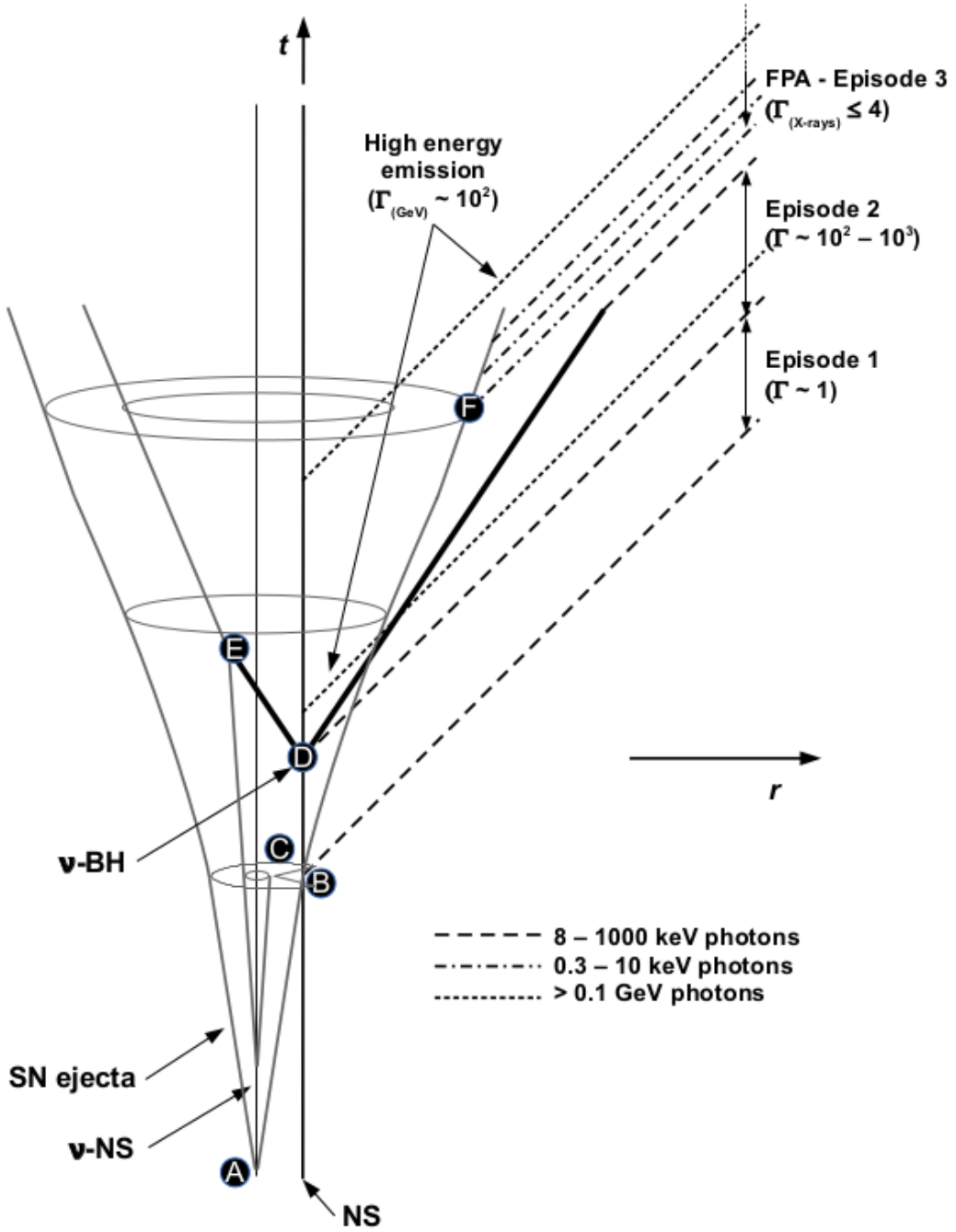

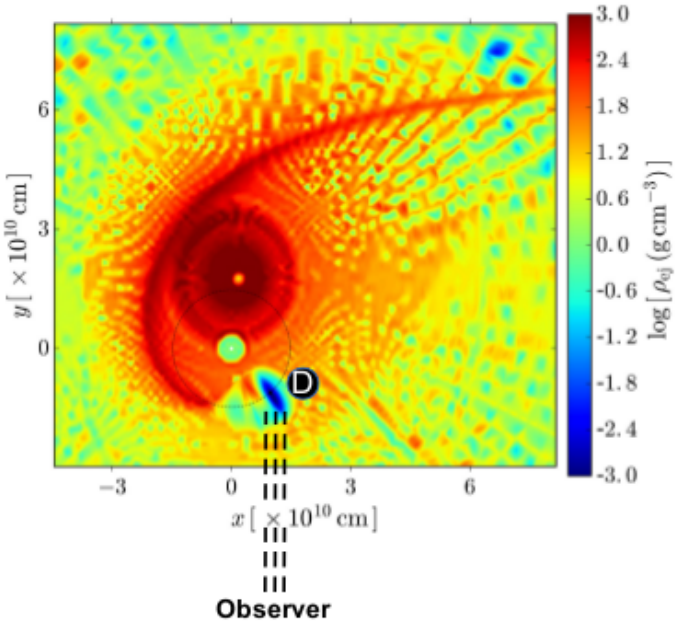

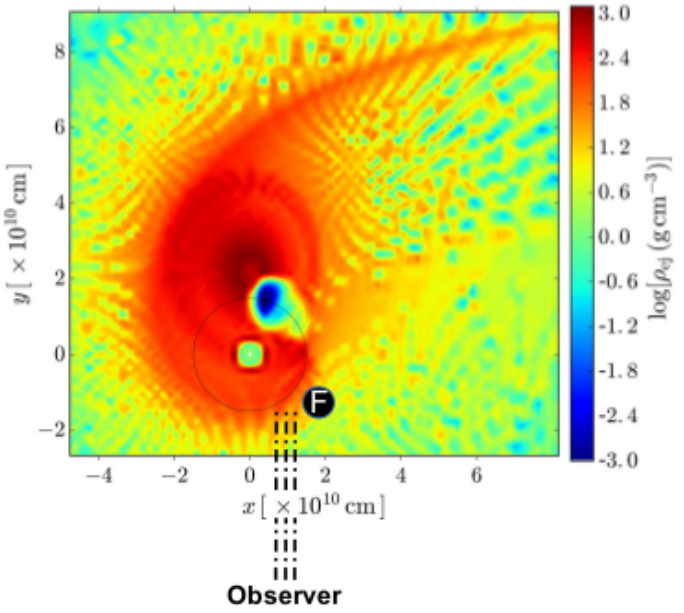

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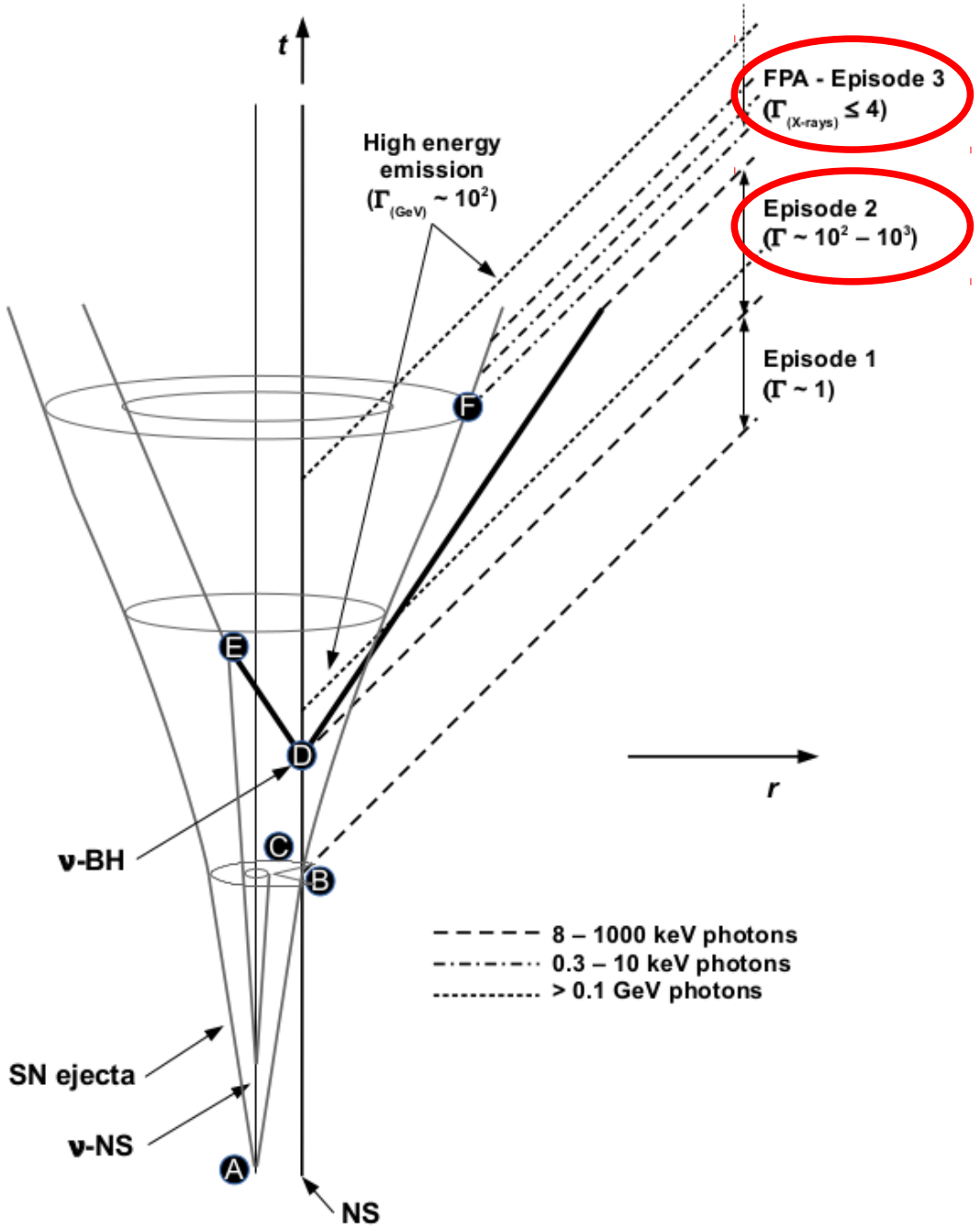

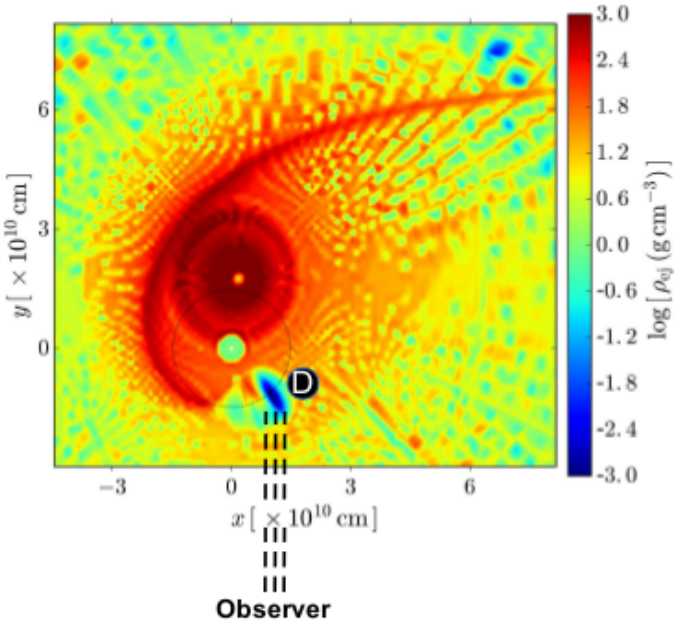

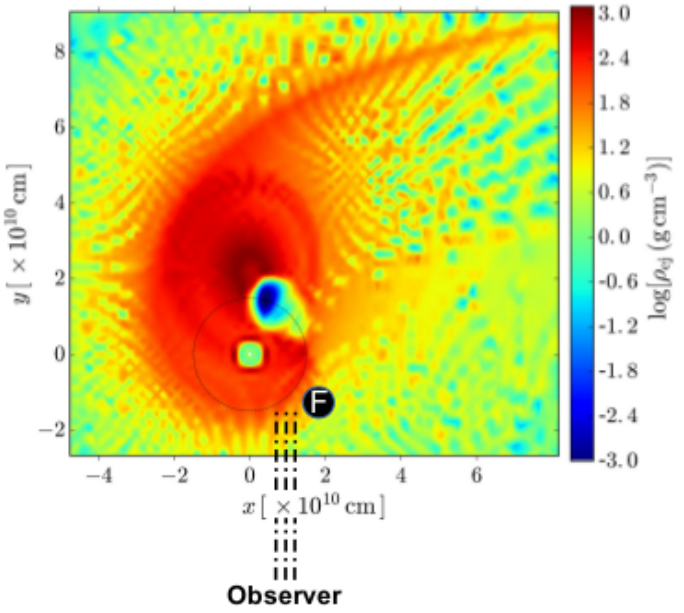

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Numerical Schemes

Baryon load

$$B = M_B c^2 / E_{e^+e^-}$$

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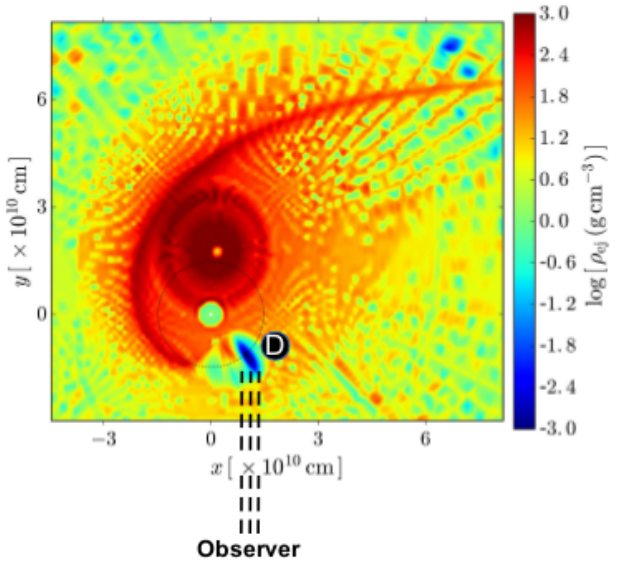

- Approximate code, **constant thickness**,
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  - 1D

  - Constant thickness approximation

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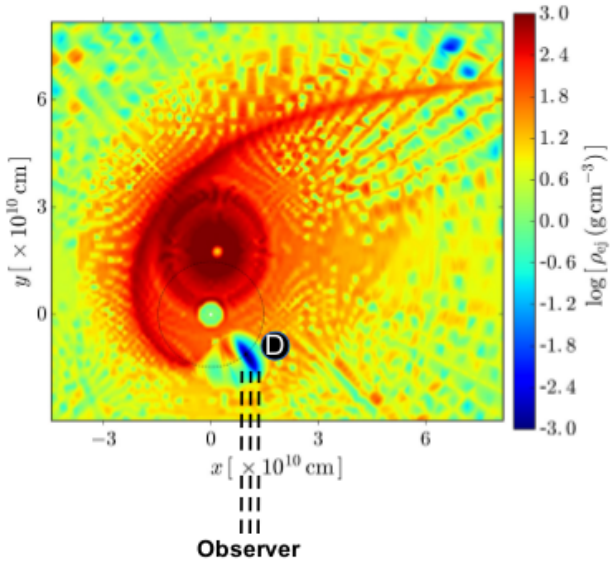

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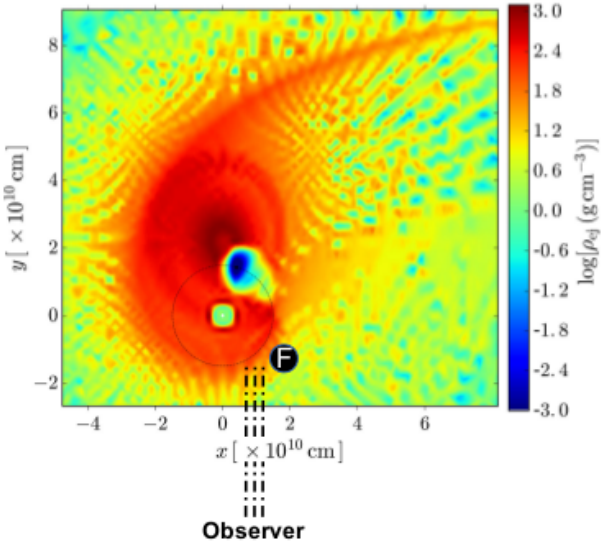

- Approximate code, **constant thickness**, Ruffini, Xue, Bianco, ICRANet,1999.

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- Nowadays: using **PLUTO** code (Mignone, 2007) to solve the **RHD** equations.

  - 1D, 2D, 3D.

  - Works with several Godunov-type solvers (Lax-Friedrichs, HLL, etc). Shock-capturing schemes.

Numerical Schemes

- RHD equations (1D, spherical symmetry) in conservation form:

$$\frac{\partial(\rho\Gamma)}{\partial t} + \nabla.\,(\rho\Gamma\mathbf{v}) = 0 \qquad \textit{Mass}$$

$$\frac{\partial m_r}{\partial t} + \nabla.\,(m_r\mathbf{v}) + \frac{\partial p}{\partial r} = 0 \qquad \textit{Momentum}$$

$$\frac{\partial \mathcal{E}}{\partial t} + \nabla.\,(\mathbf{m} - \rho\Gamma\mathbf{v}) = 0 \qquad \textit{Energy}$$

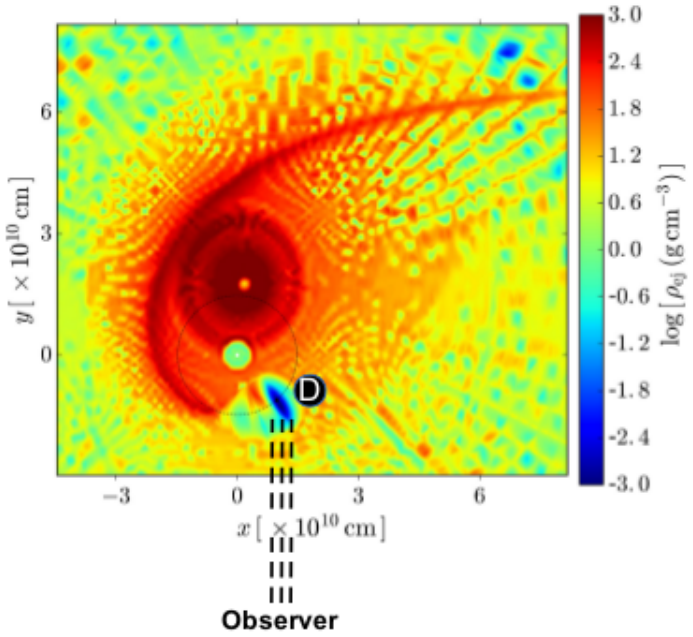
- Closure: Equation of State

$$h = \rho + \frac{\gamma p}{\gamma - 1}$$

Constant γ index = 4/3 ***(verified)***

- Assumption of **local thermodynamic equilibrium**

Results in 1D*, low density*



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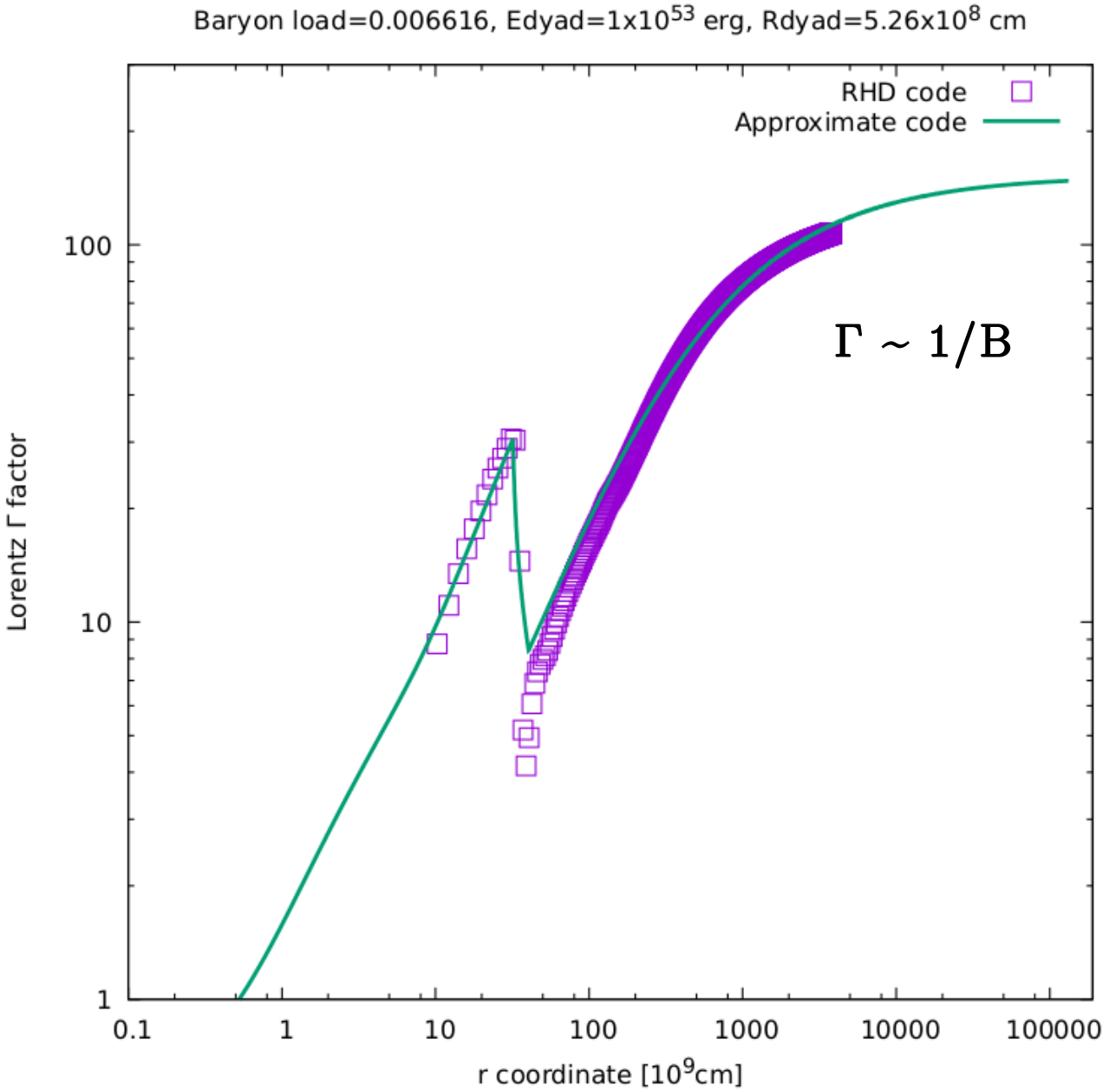
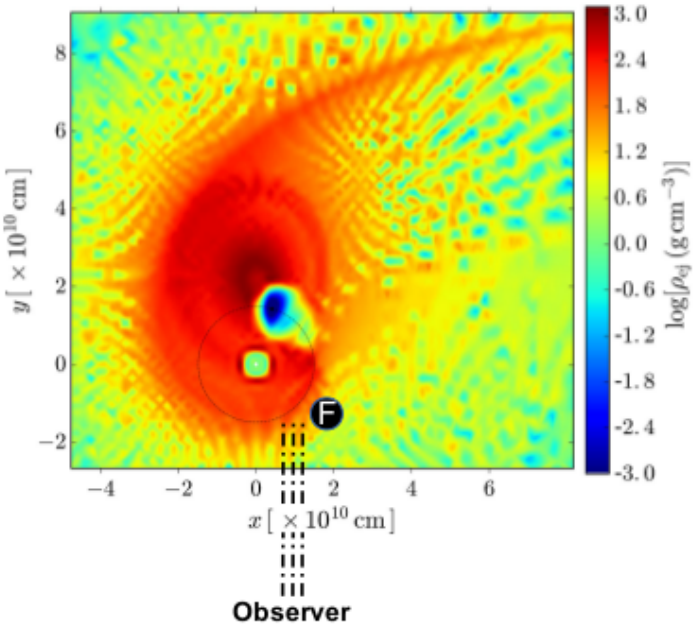
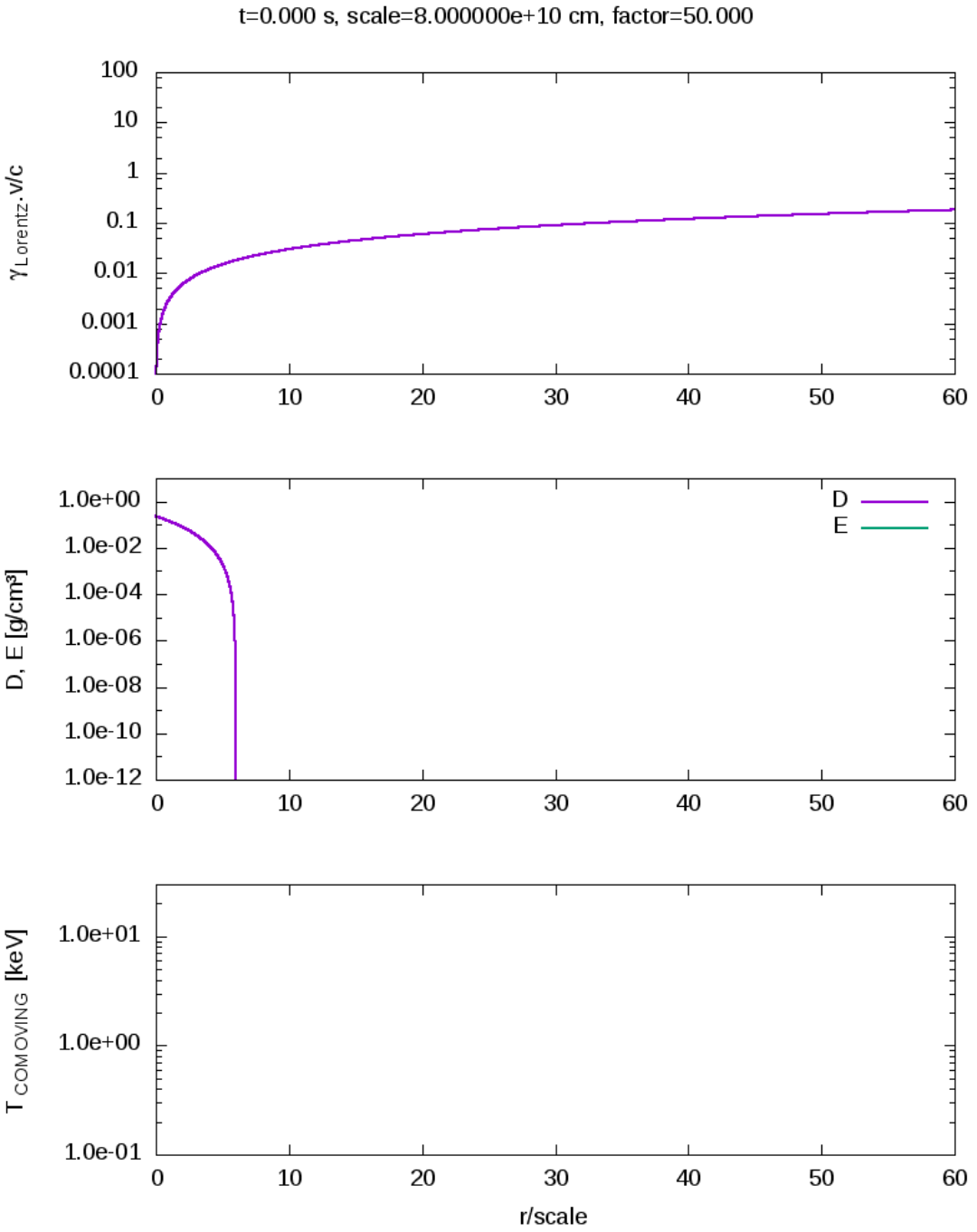


Results in 1D*, high density*





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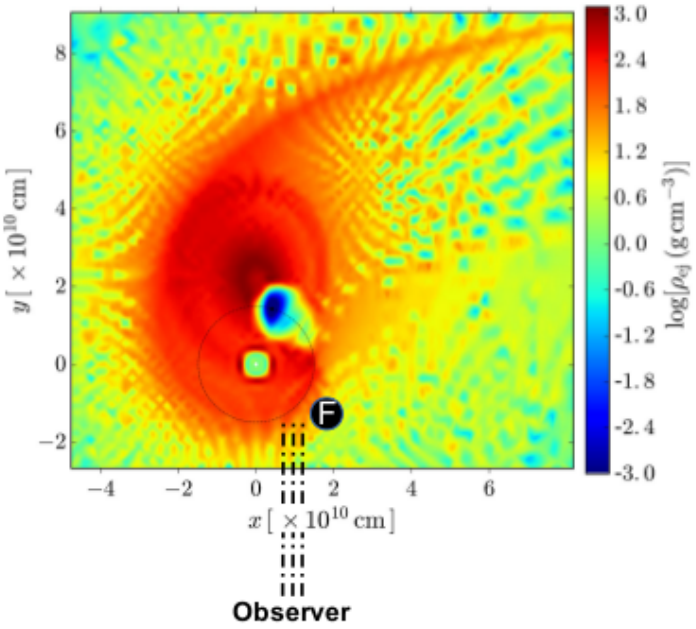

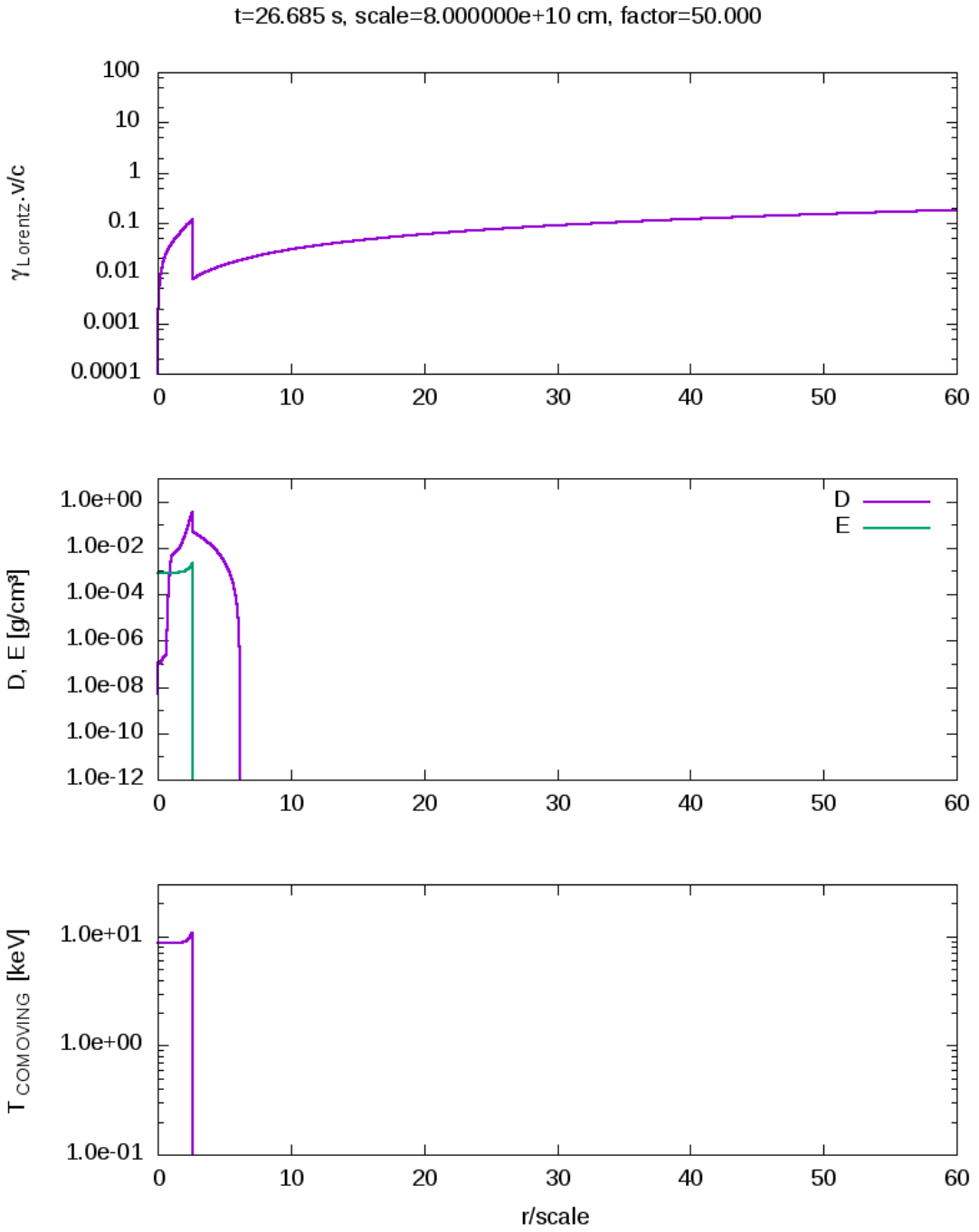

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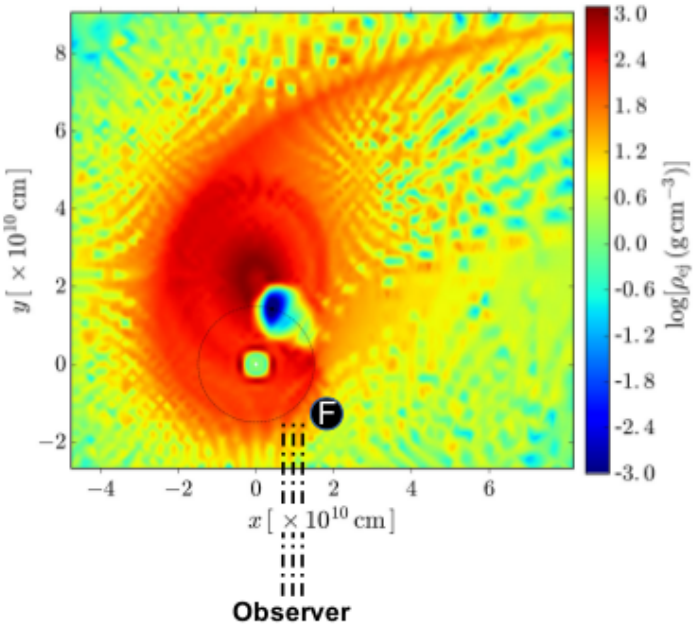

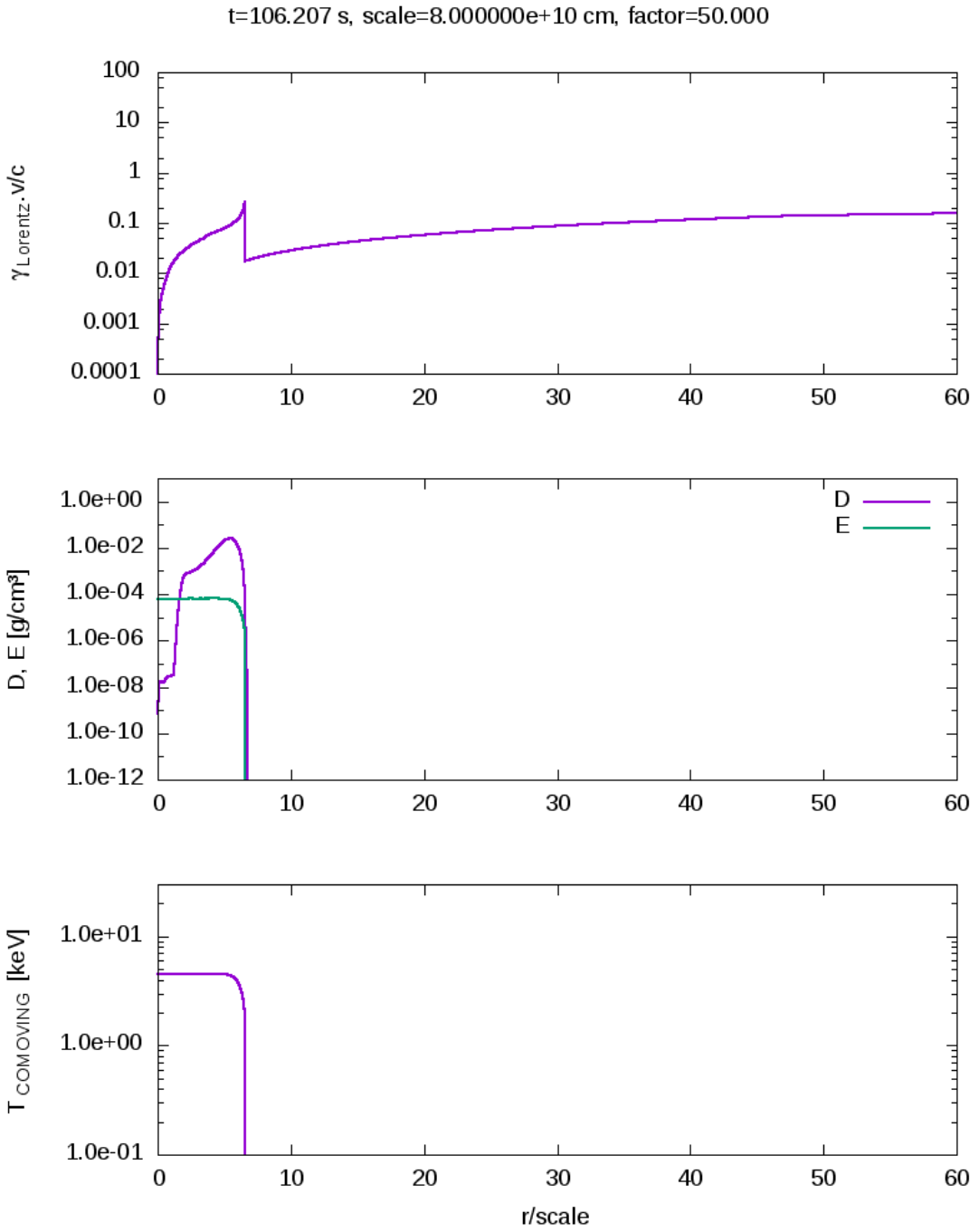

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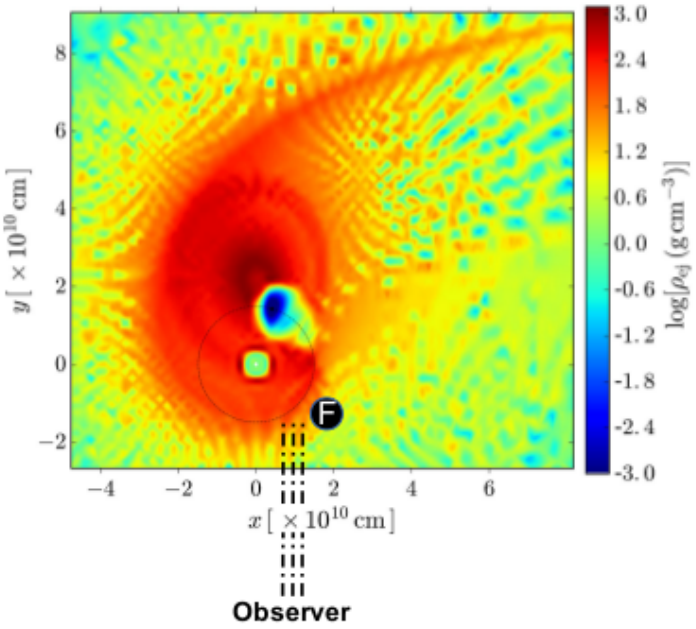

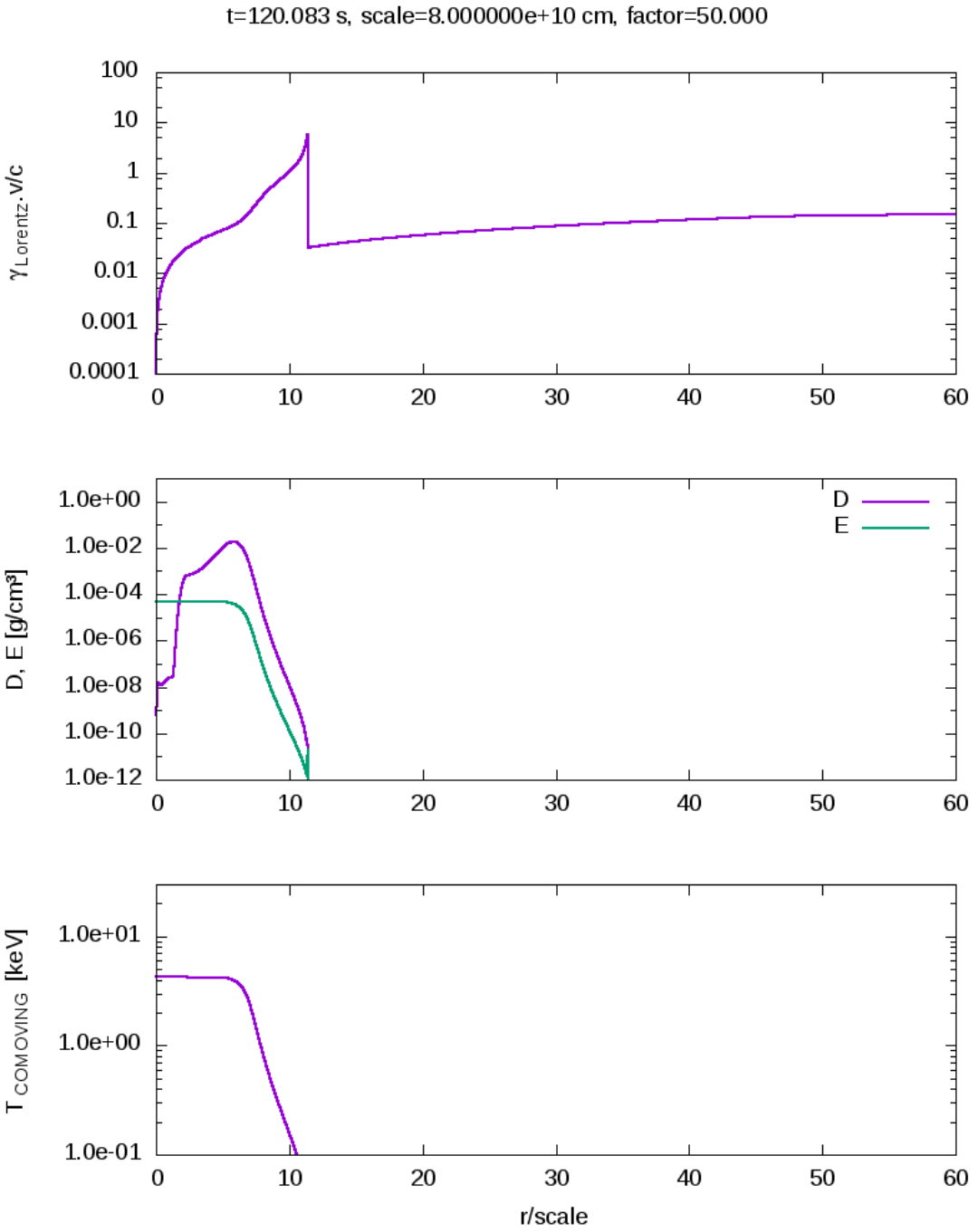

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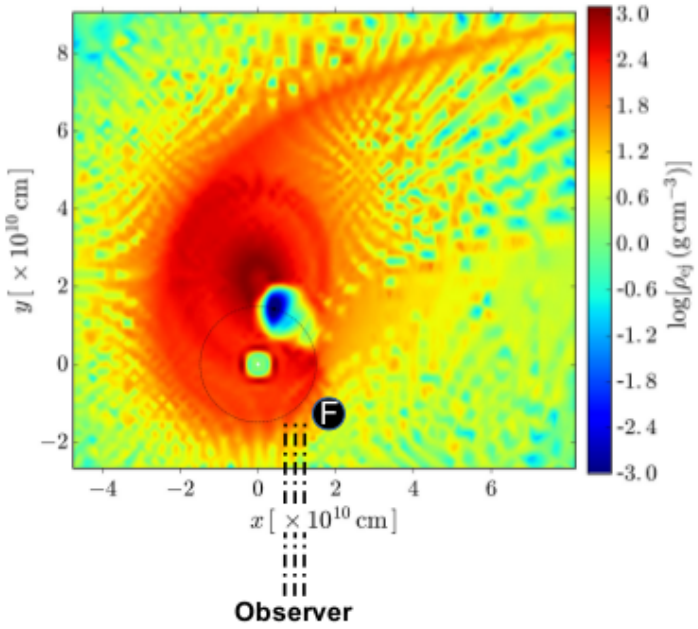

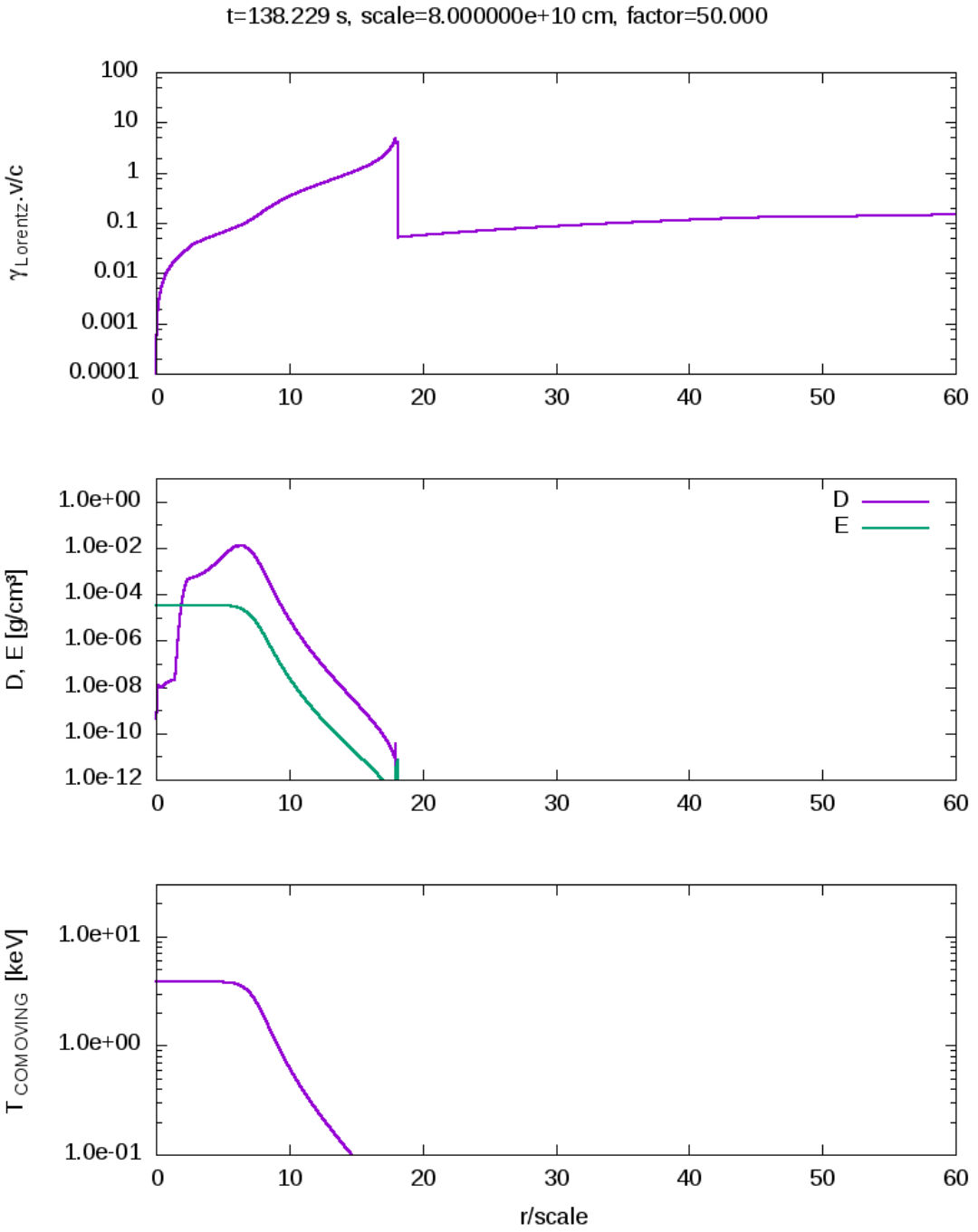

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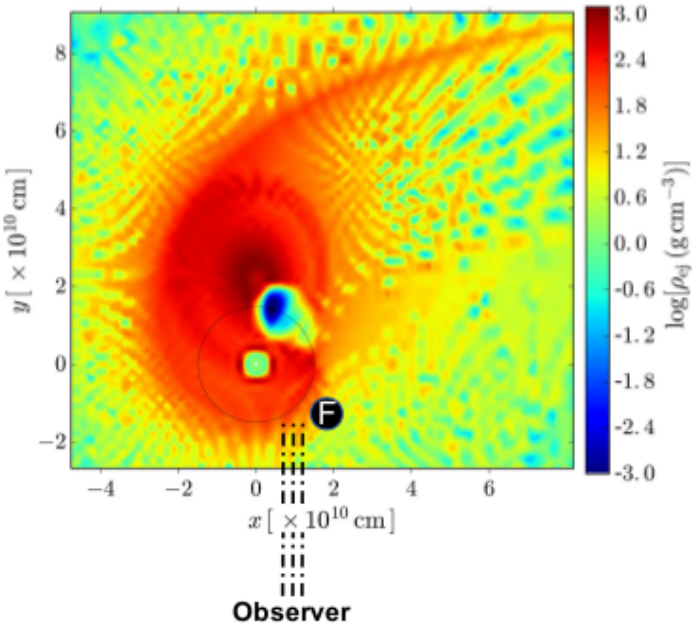
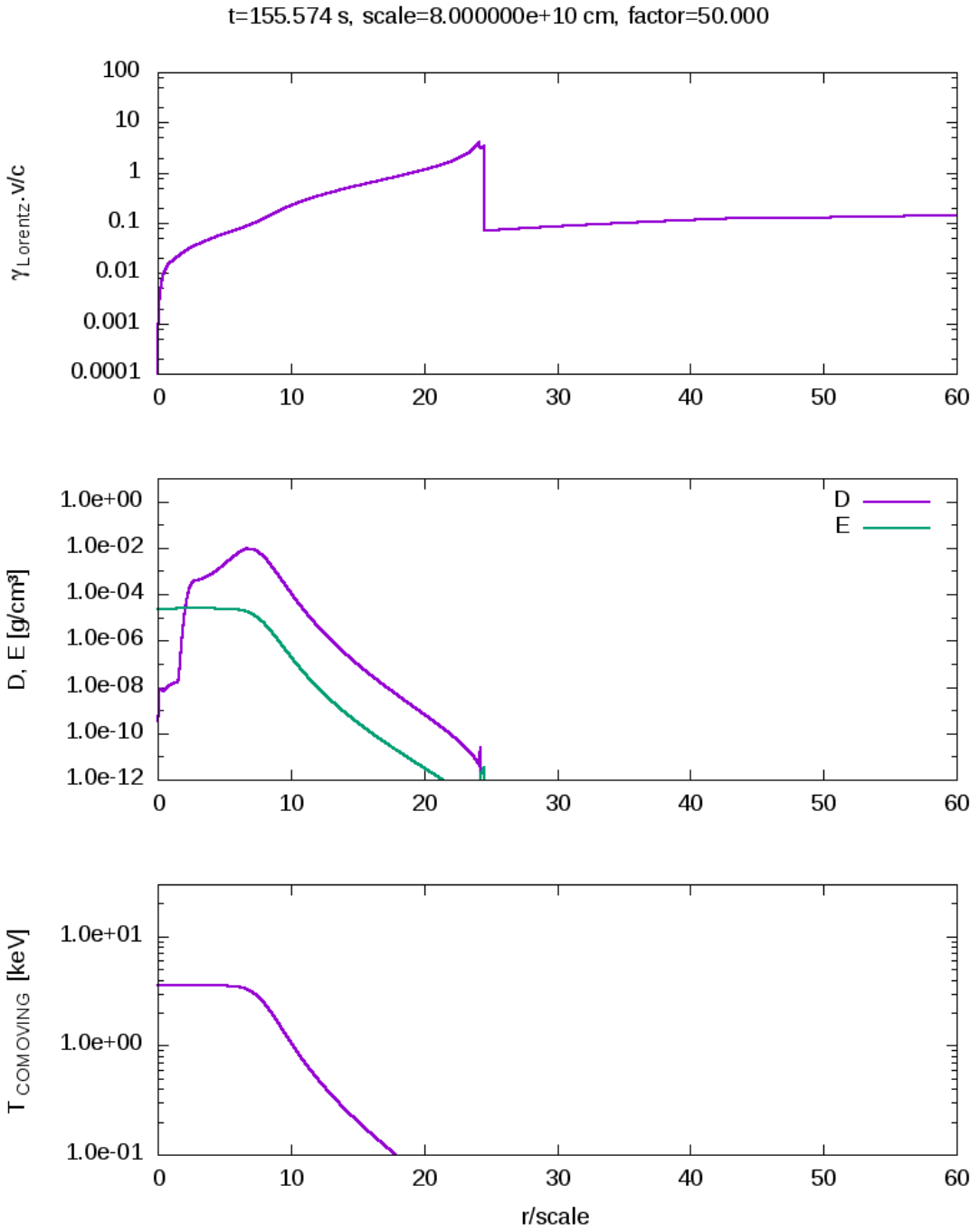
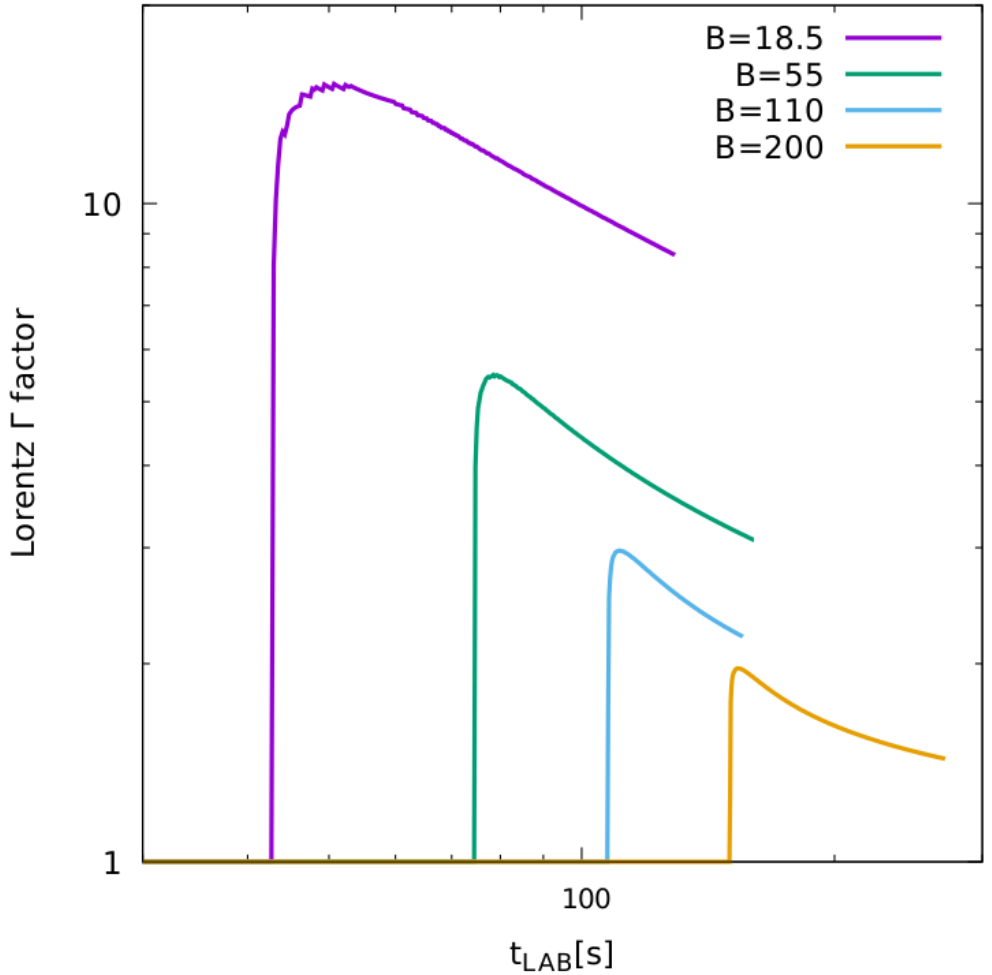




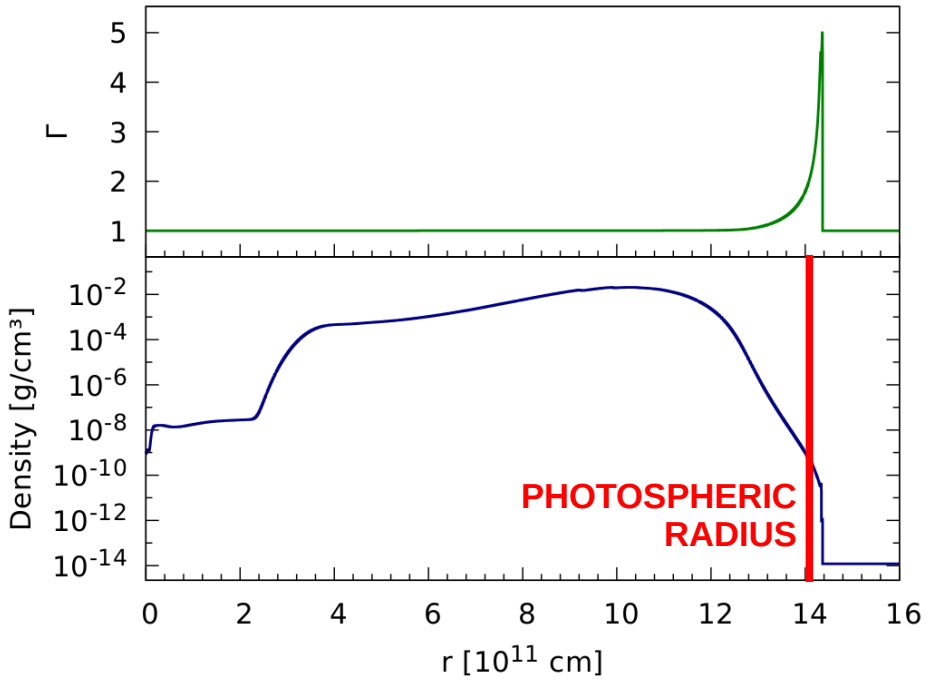
Results in 1D*, high density*

Lorentz Gamma at photospheric radius (τ=1)



Optical depth:

$$\tau = \int_{R_{ph}}^{\infty} \mathrm{d}r\, \sigma_T\, n_{e^-}(r)$$



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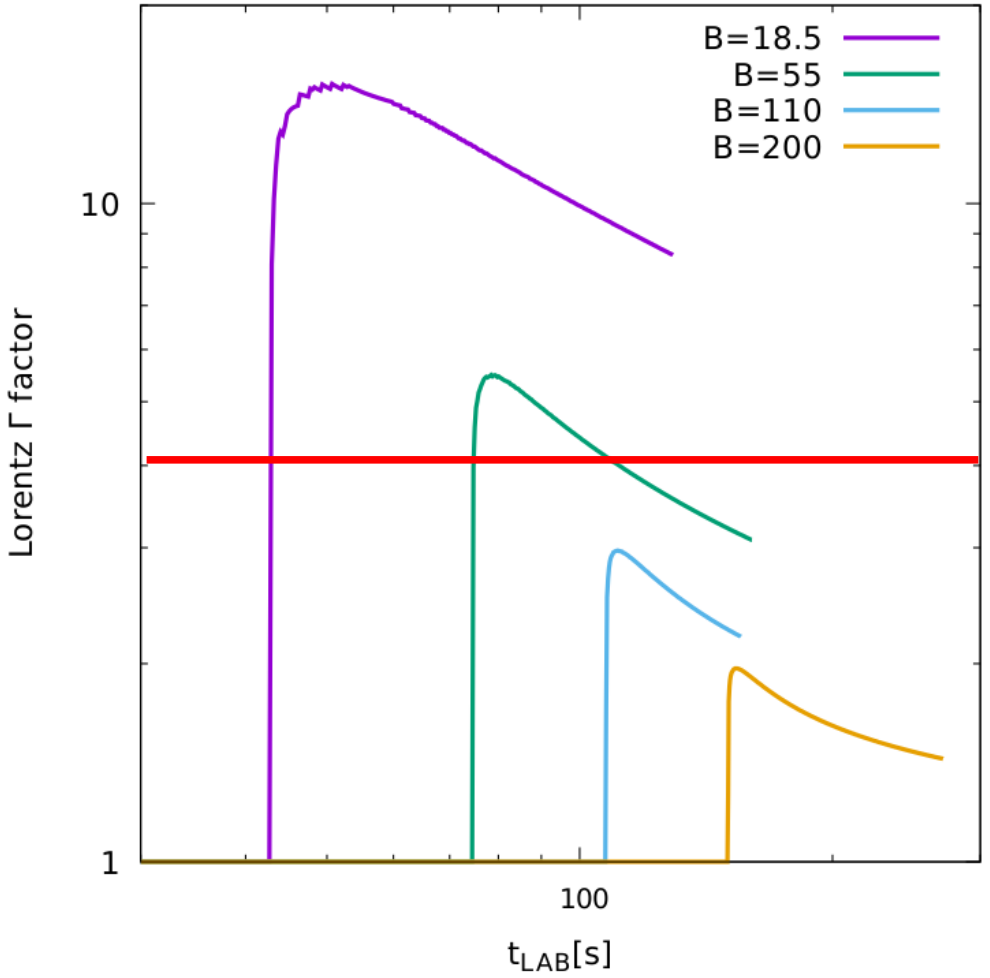

Γ<4 *for high enough baryon load*

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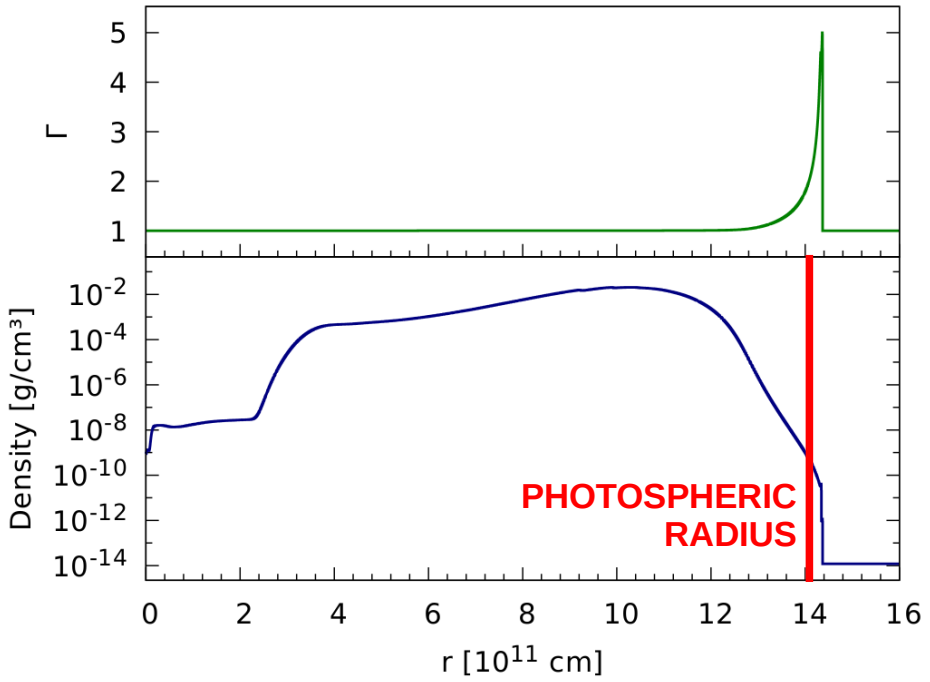
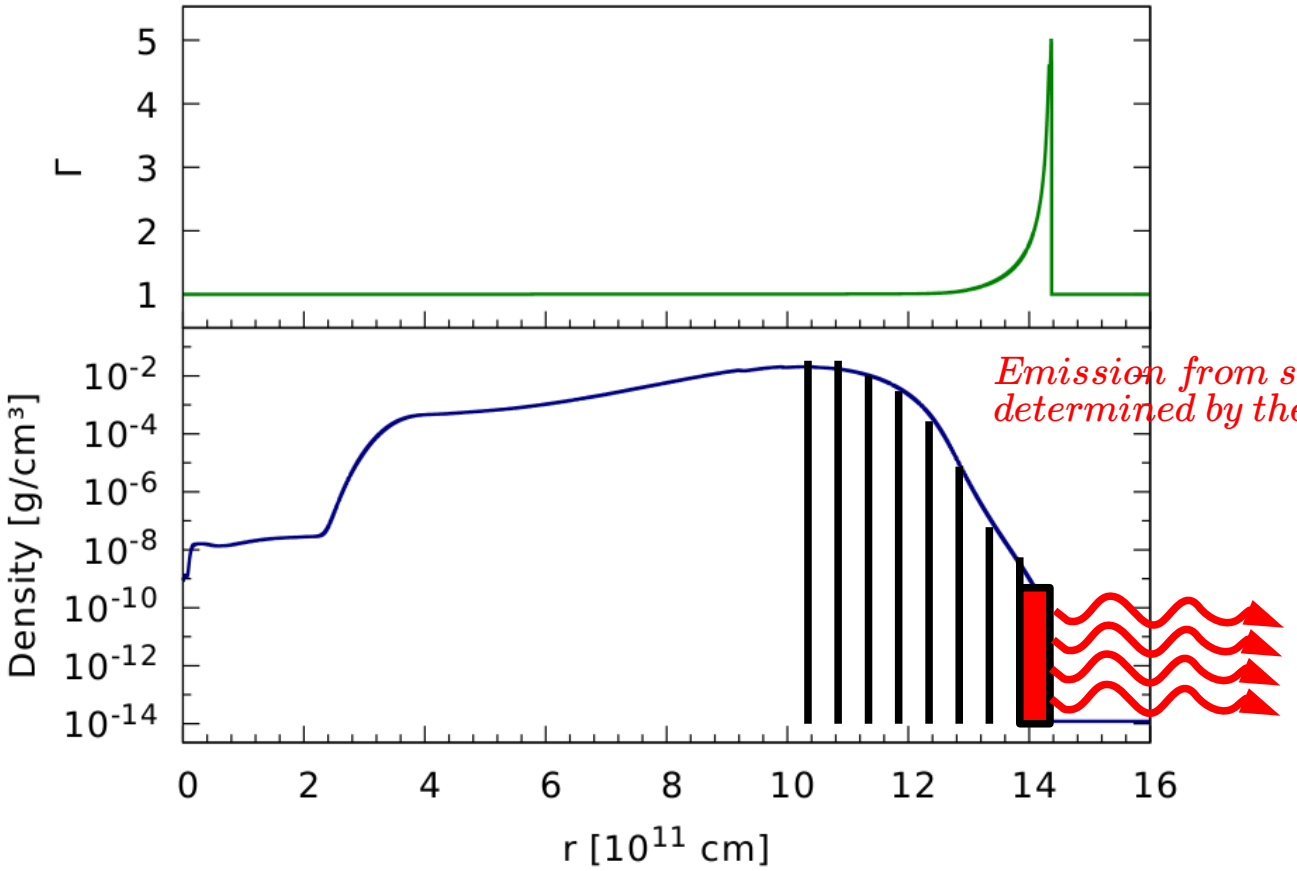


Work in progress: *emission* (1D)

Luminosity estimation, photon diffusion



Emission from succesive layers, determined by the photon diffusion time

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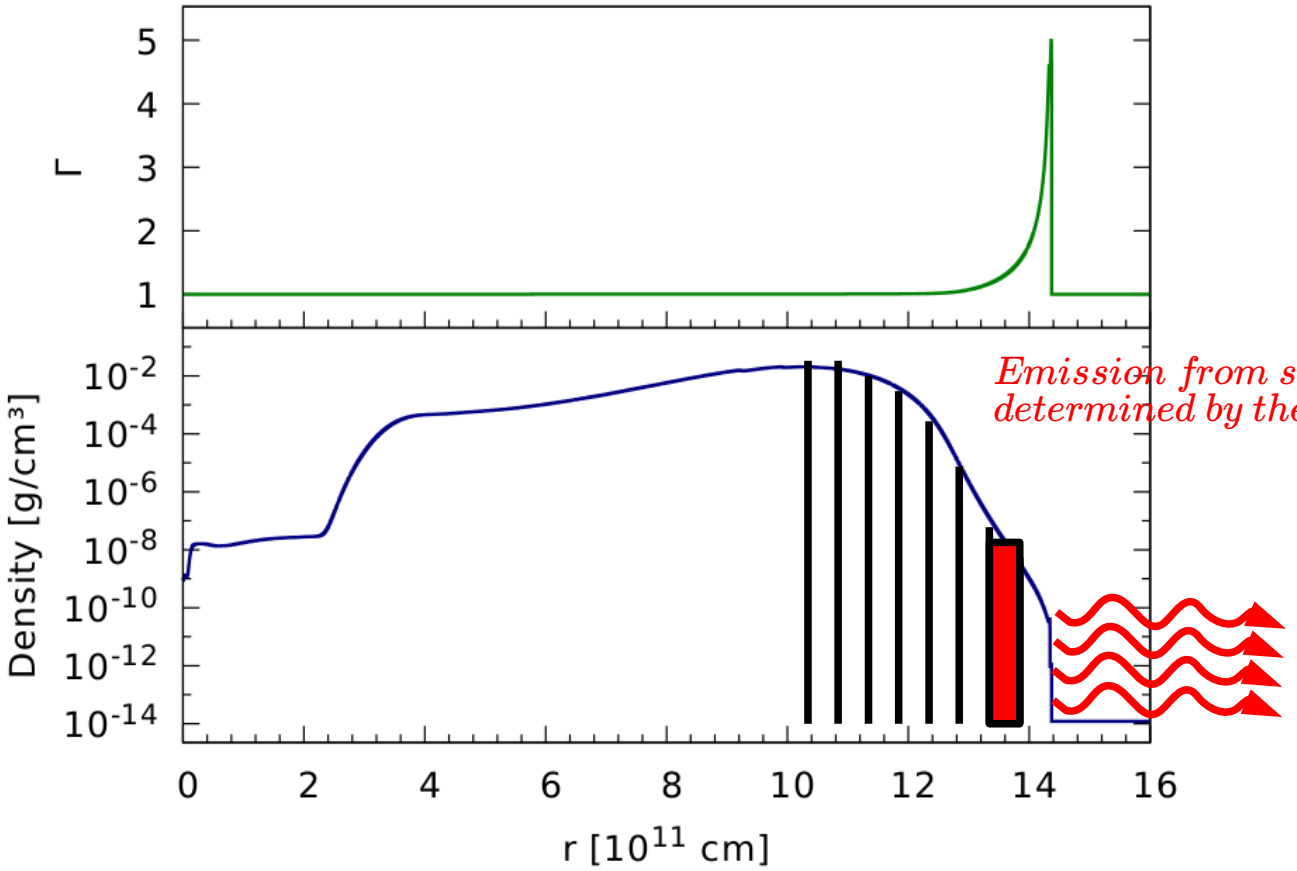

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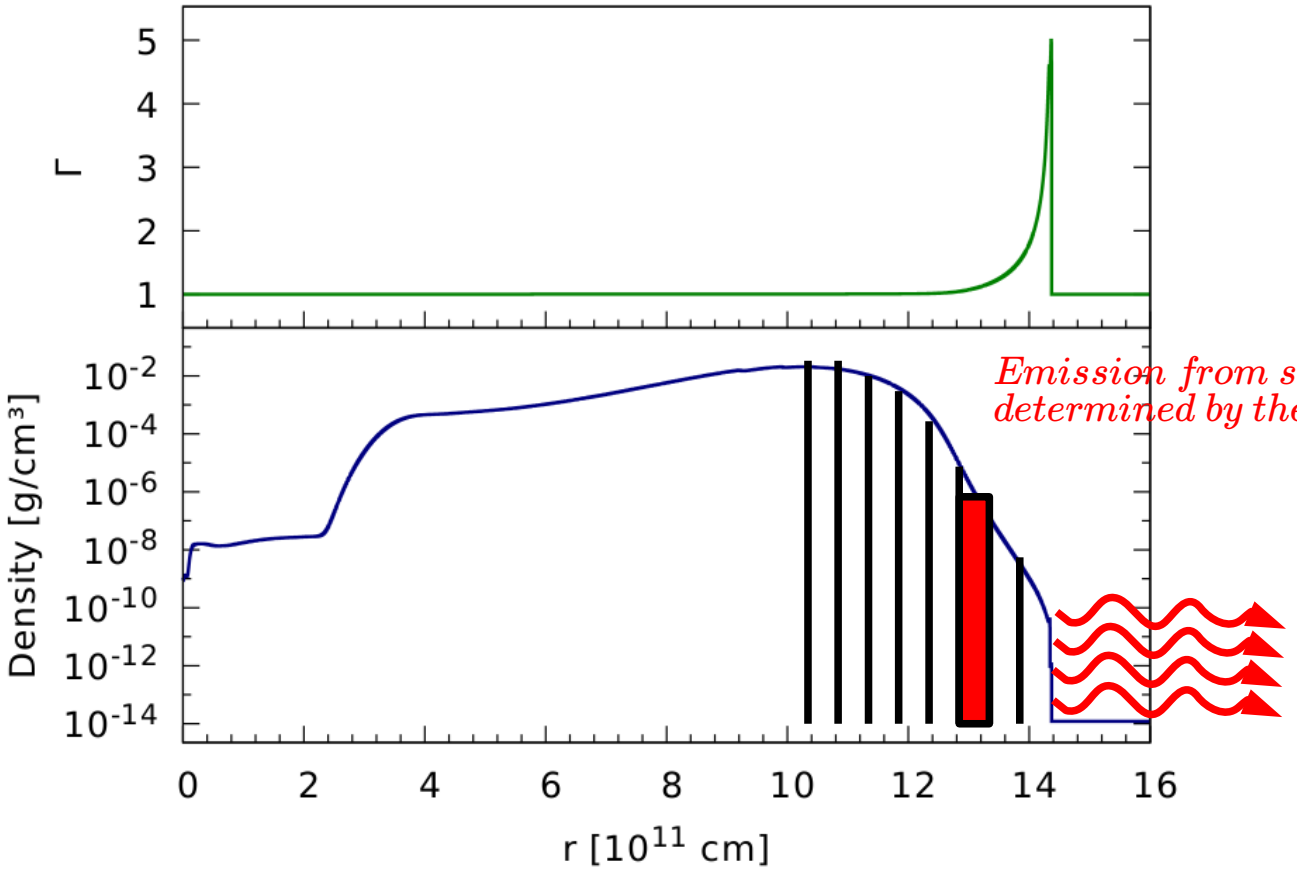

Emission from succesive layers, determined by the photon diffusion time

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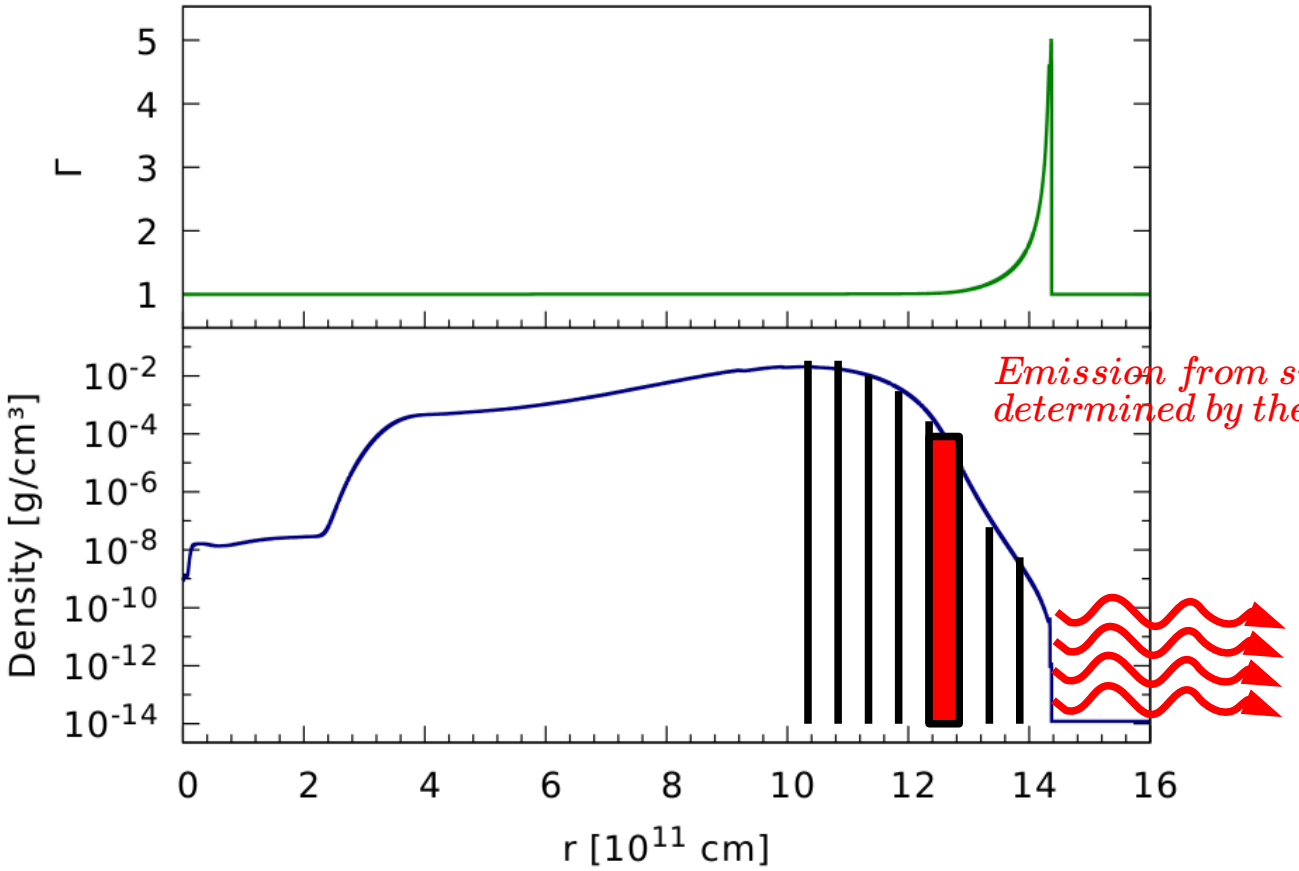

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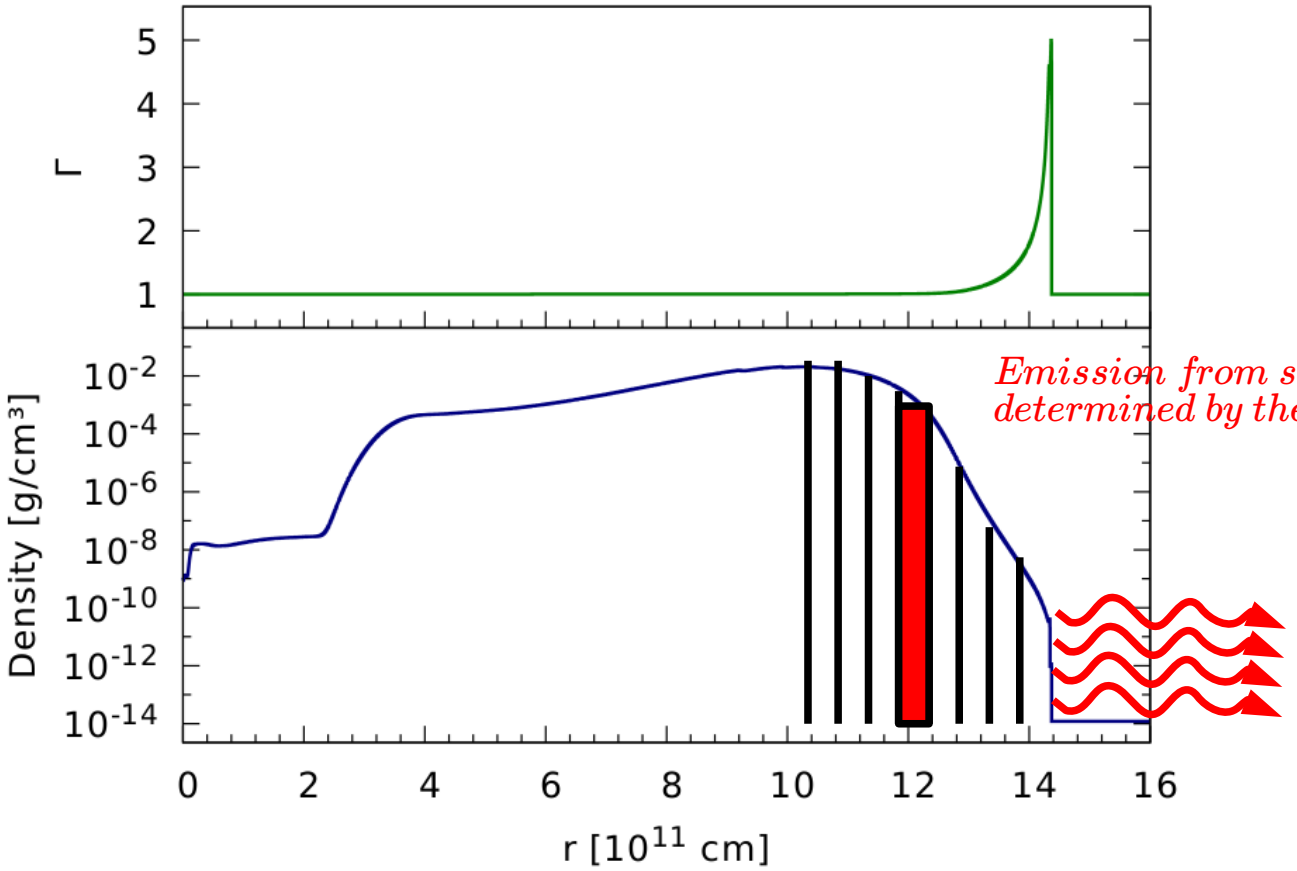

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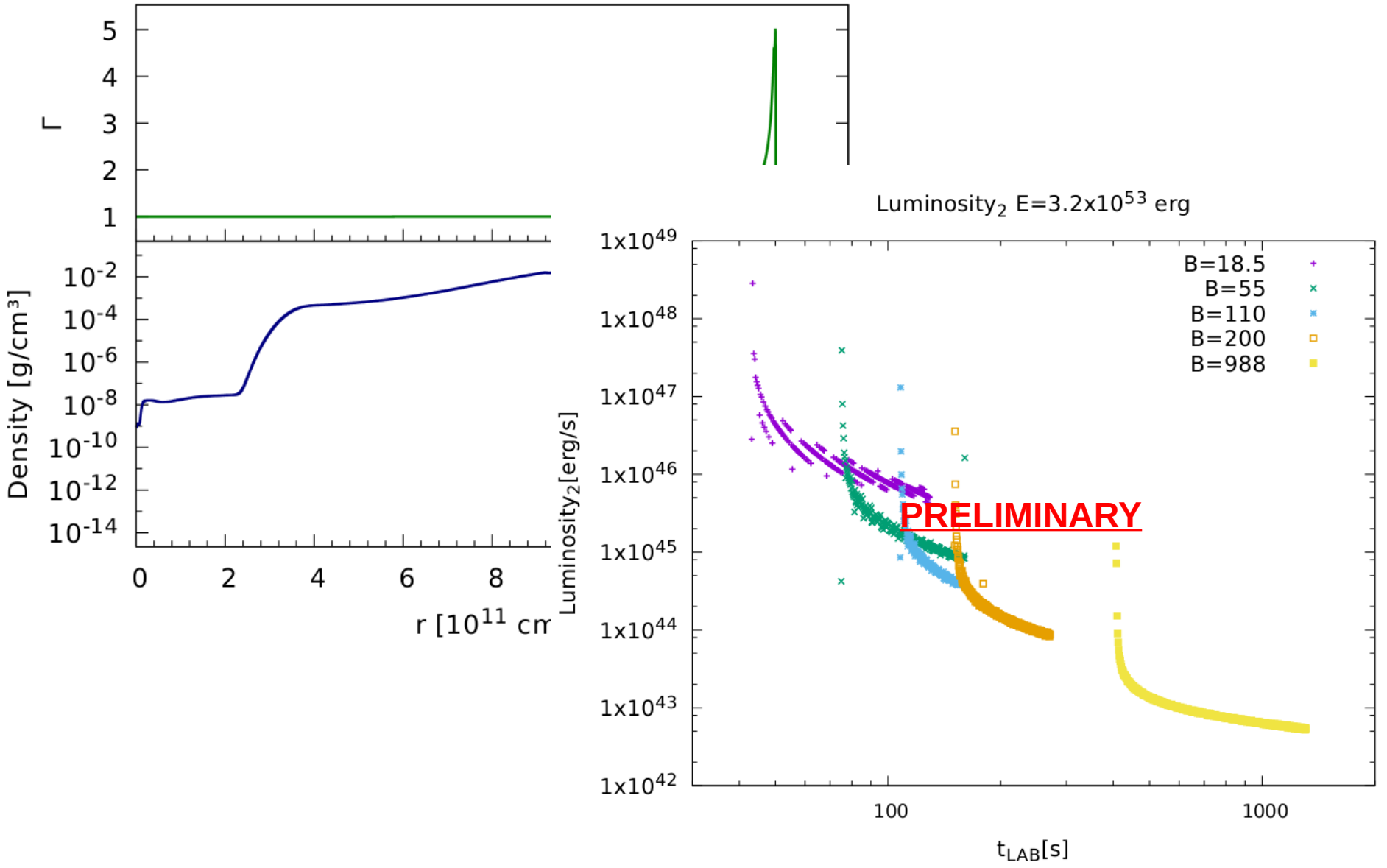
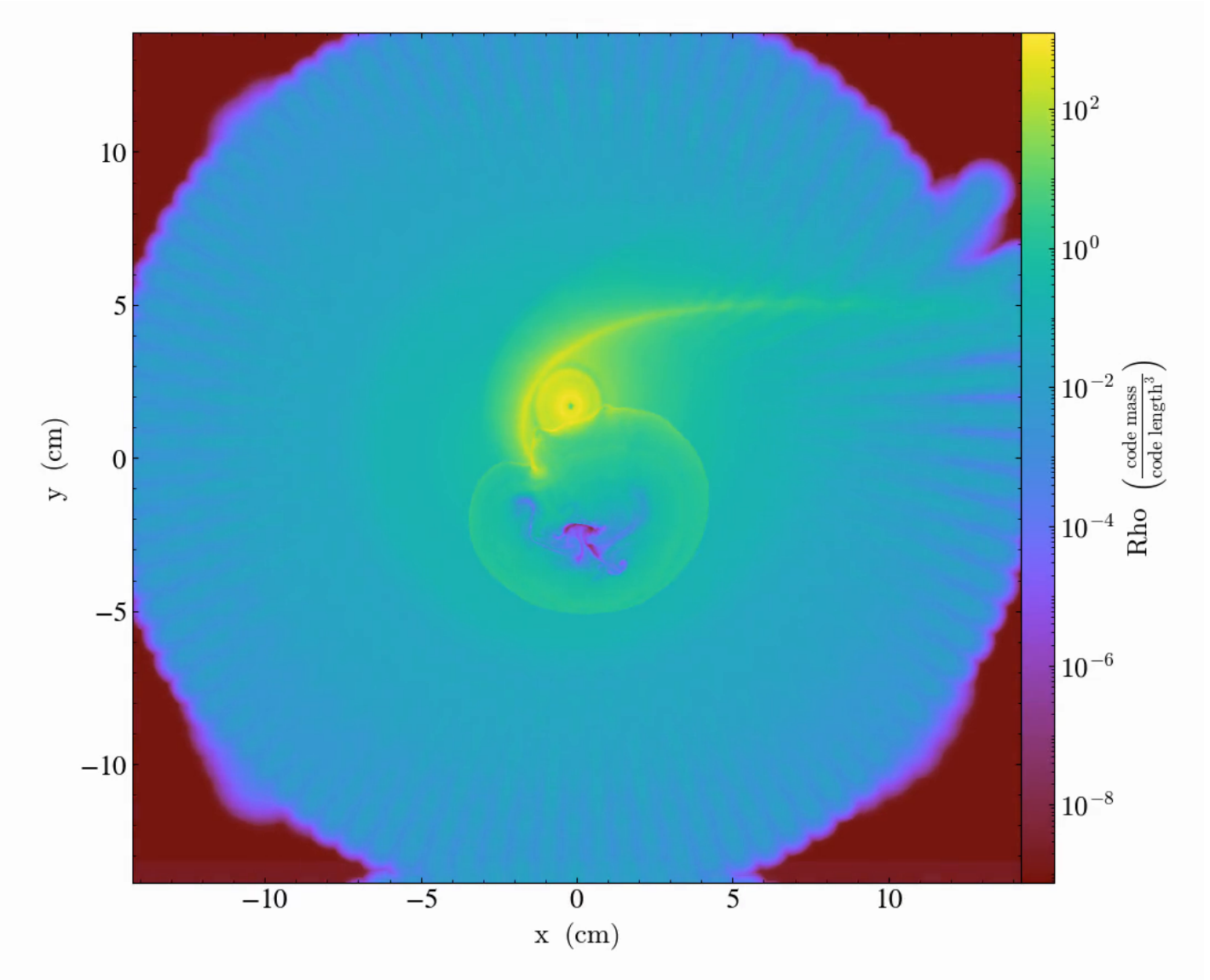


Work in progress: *dynamics in* 2D



PRELIMINARY

Conclusions and future work

- The dynamics of the considered positron-electron plasma is **well described by RHD** with a **constant polytropic index of 4/3, in the optically-thick regime**.

- 1D simulations show consistency with the observations of both **prompt emission ($\Gamma > 10^2$–10^3)** and **X-ray flares ($\Gamma < 4$)**.

- Lots of work to do! Dynamics and geometric dependence of the emission in **2D**, comparison with **real data**.

- Currently working on an improved calculation of the velocities and the luminosity curves. **RHD+radiation** (in collaboration with the PLUTO developing team).