Fitting a radiation mediated shock model to prompt gamma-ray burst data

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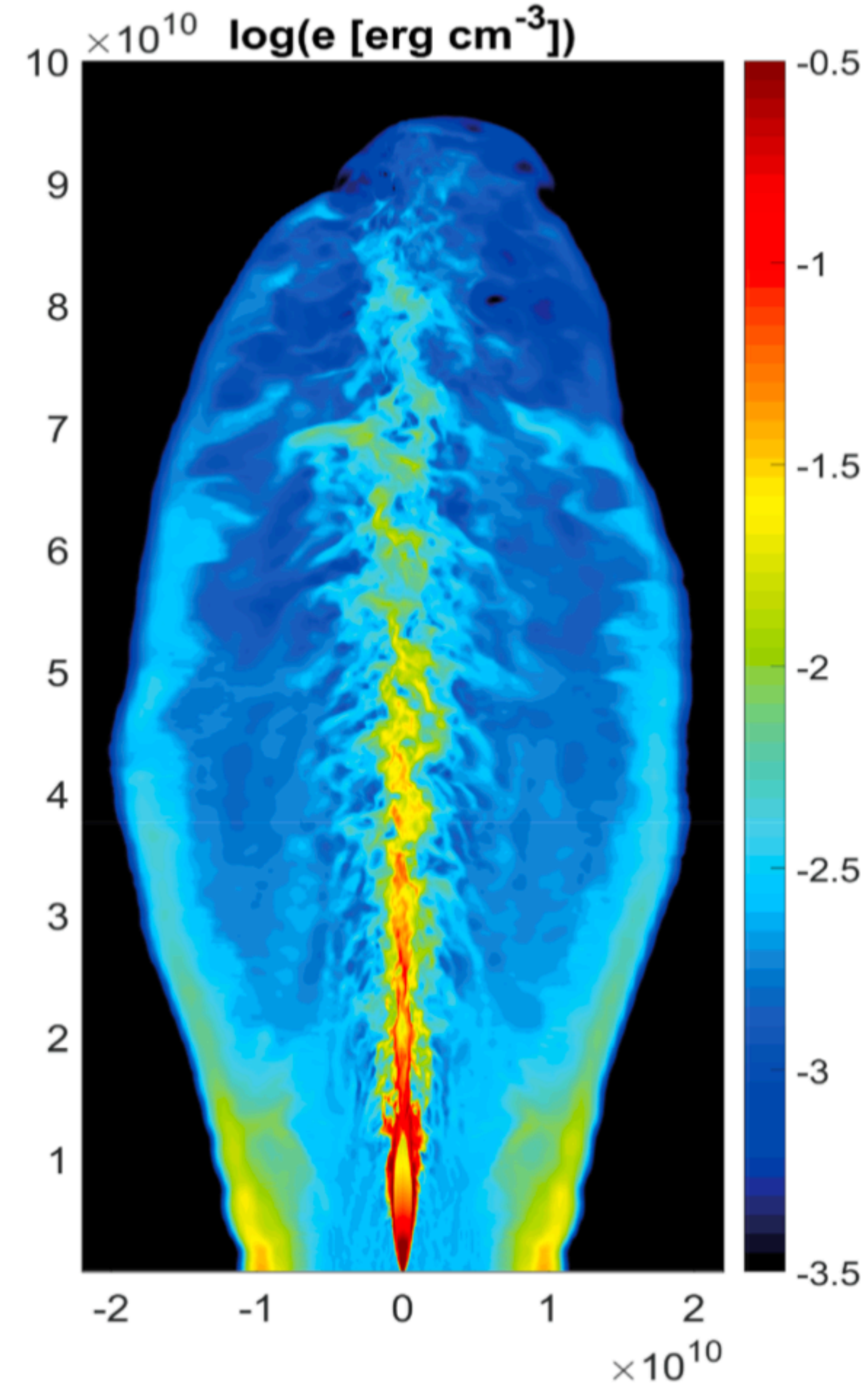
The motivation

Gamma-ray burst prompt emission

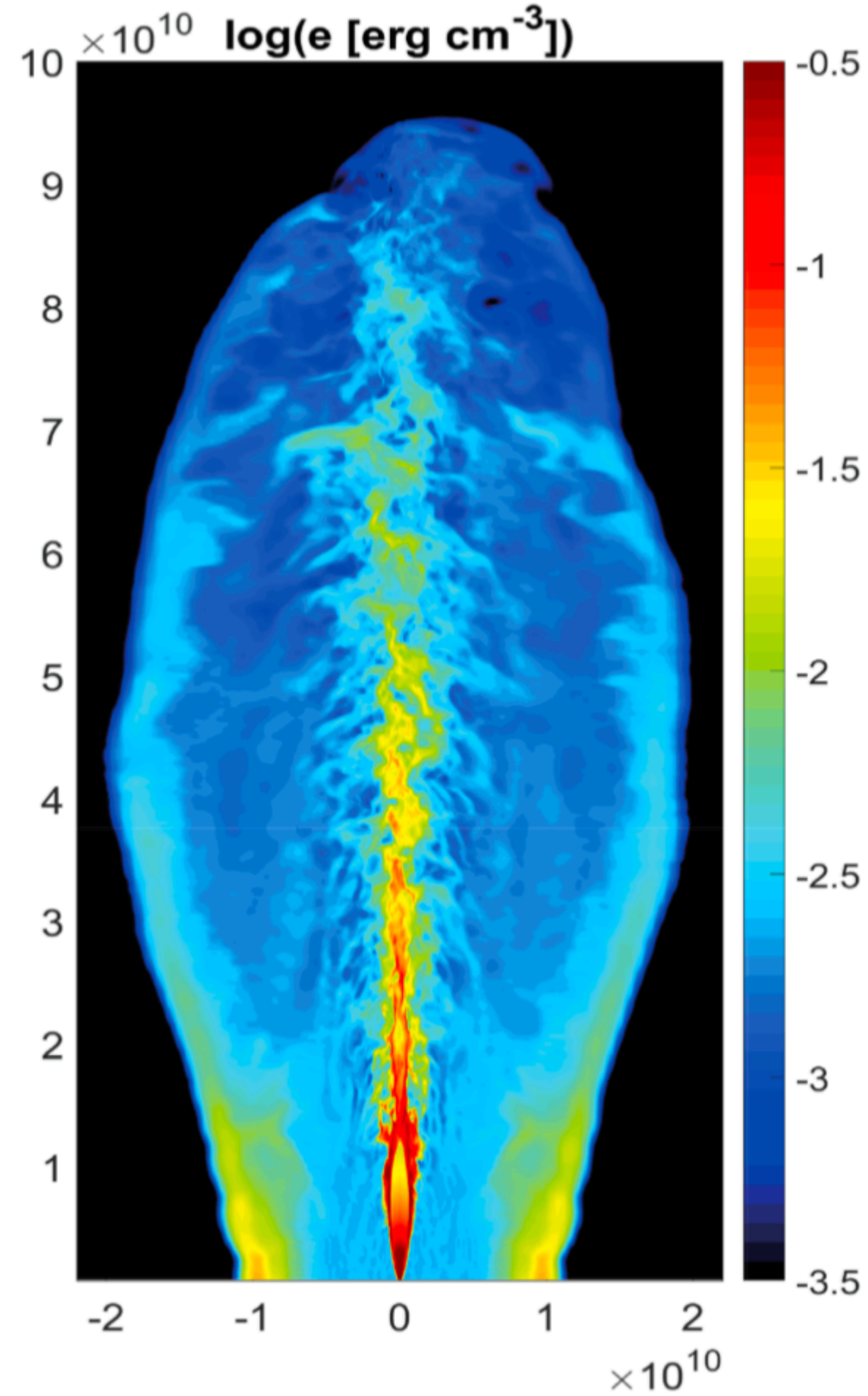
- The prompt emission mechanism in GRBs remains unknown
- Photospheric emission promising candidate
- Thermal spectra too narrow —> requires some dissipation
- Radiation mediated shocks (RMSs)



Gottlieb+ (2019); MNRAS, 488, 1416

Gap between theory and observation

- So far, no RMS model has been fit to GRB data
- Current simulations are too expensive
- We aim to bridge this gap



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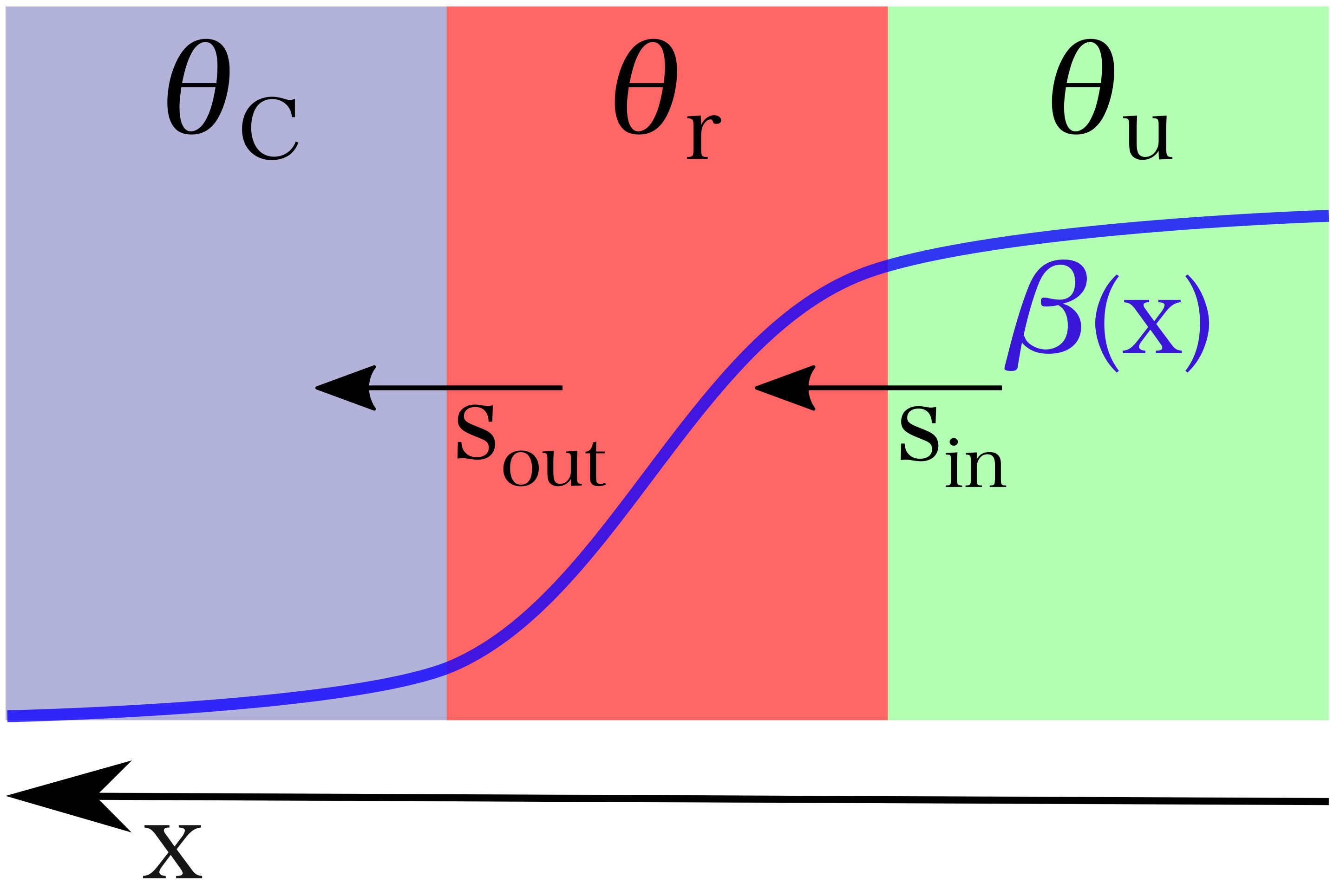
The approximation

The Kompaneets RMS approximation

- Fermi acceleration of in RMS converging flow ≈ repeated scatterings with hot electrons

- The Kompaneets RMS approximation (KRA)



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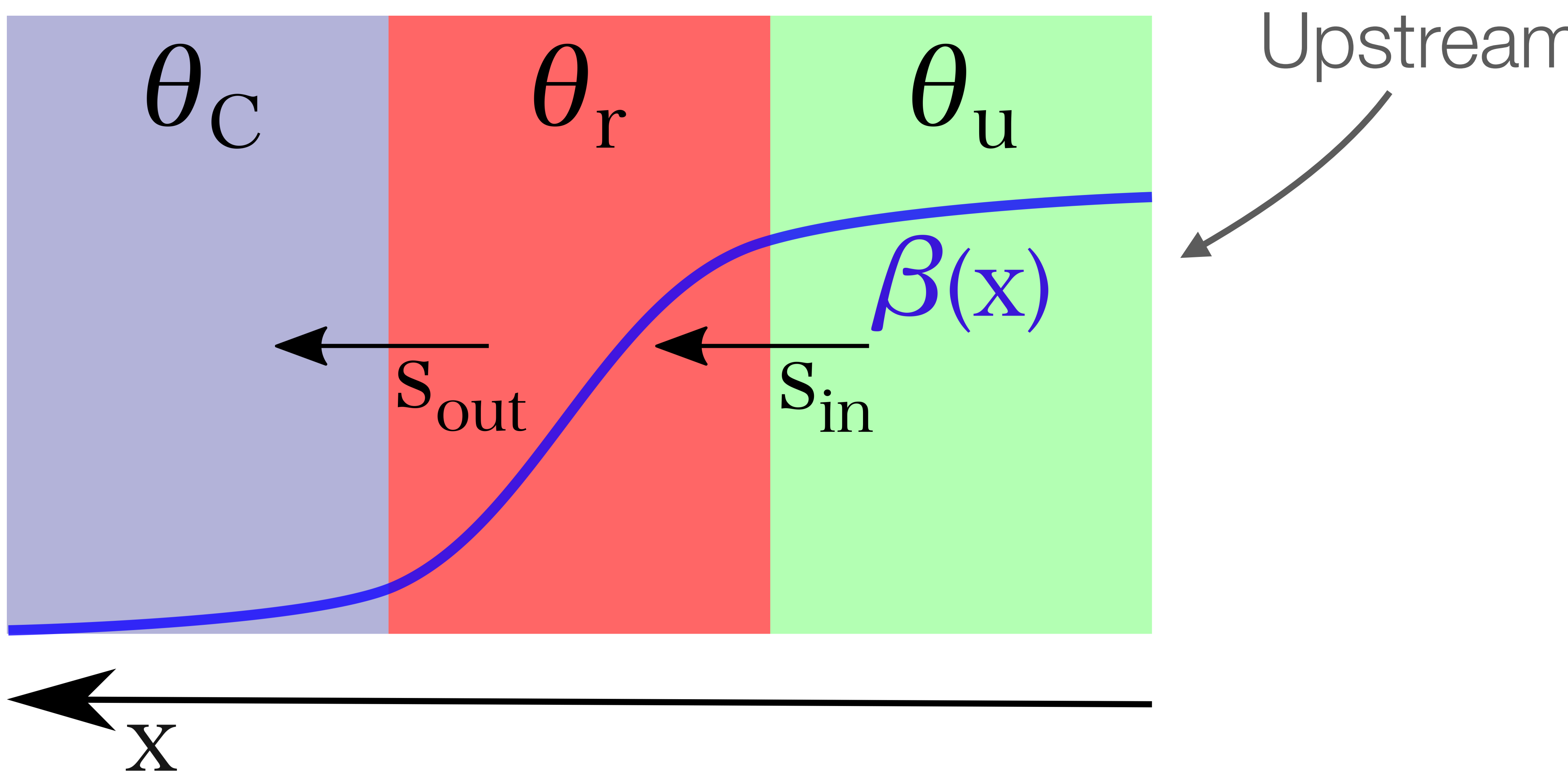

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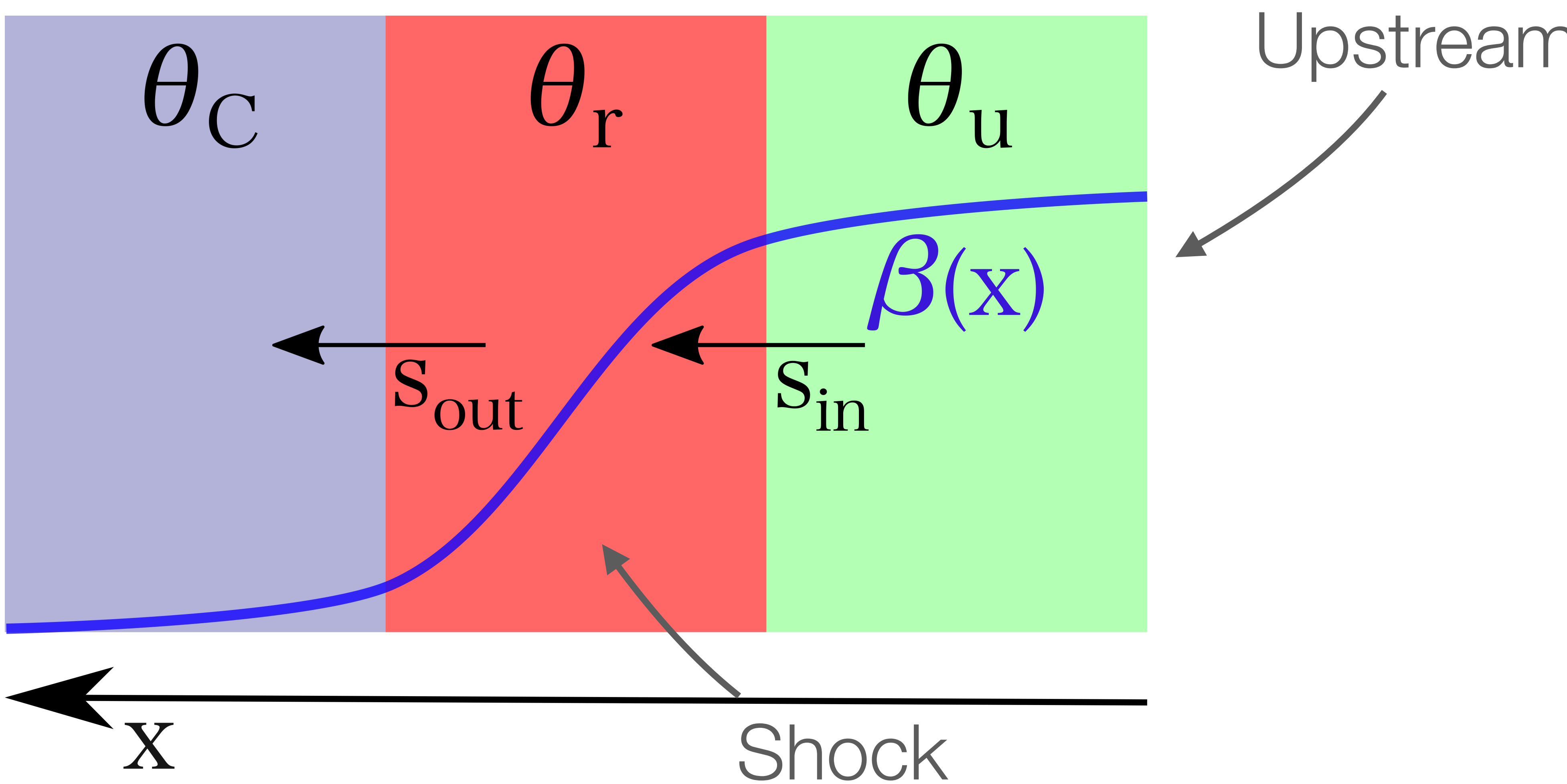

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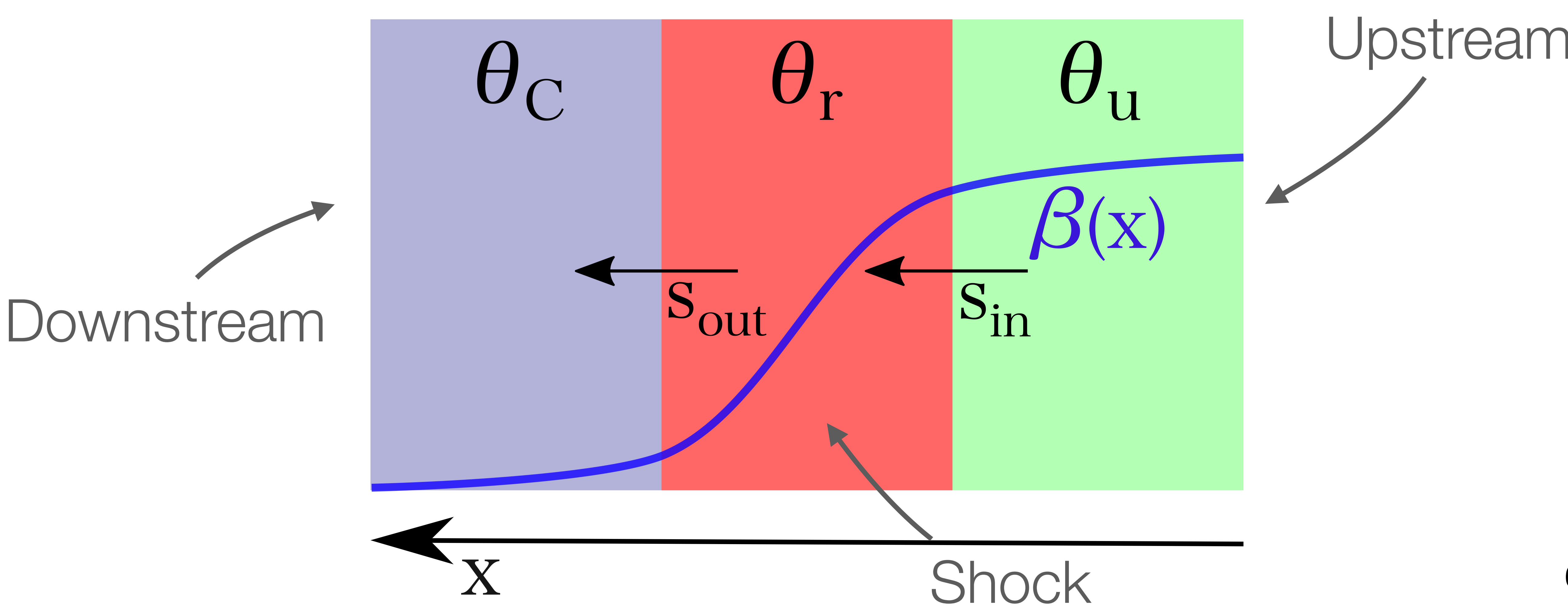
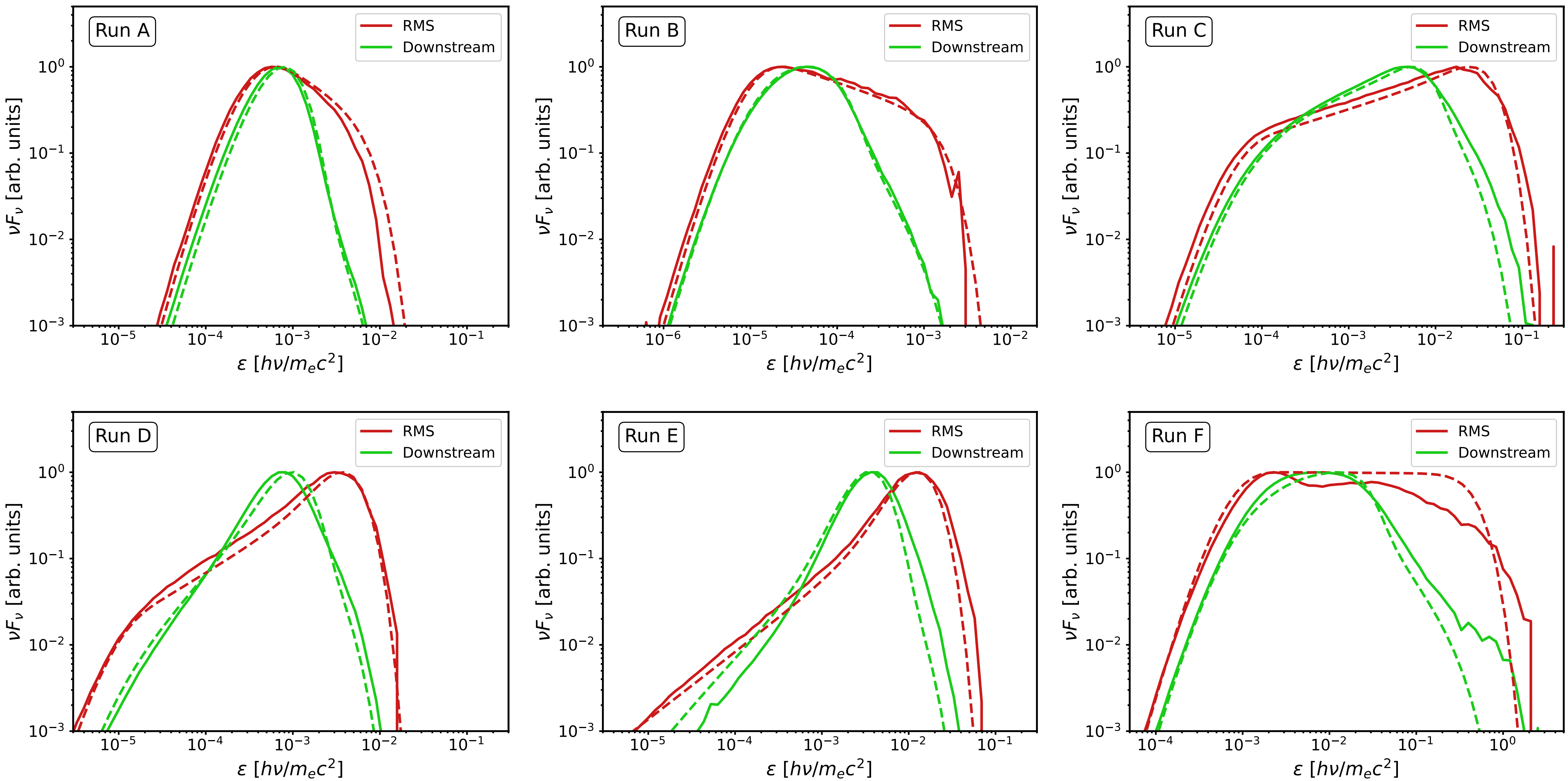


Verification of the approximation



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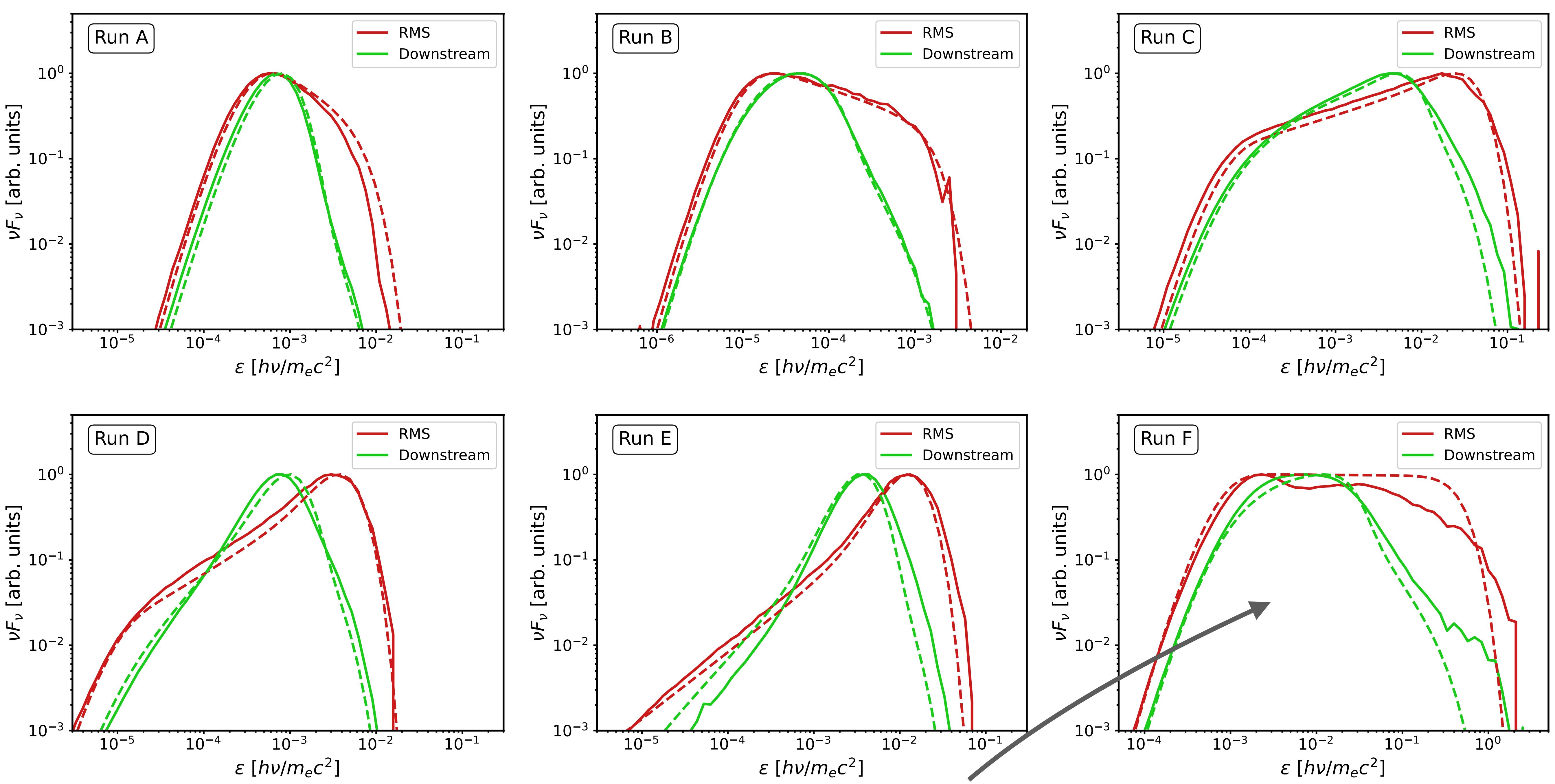
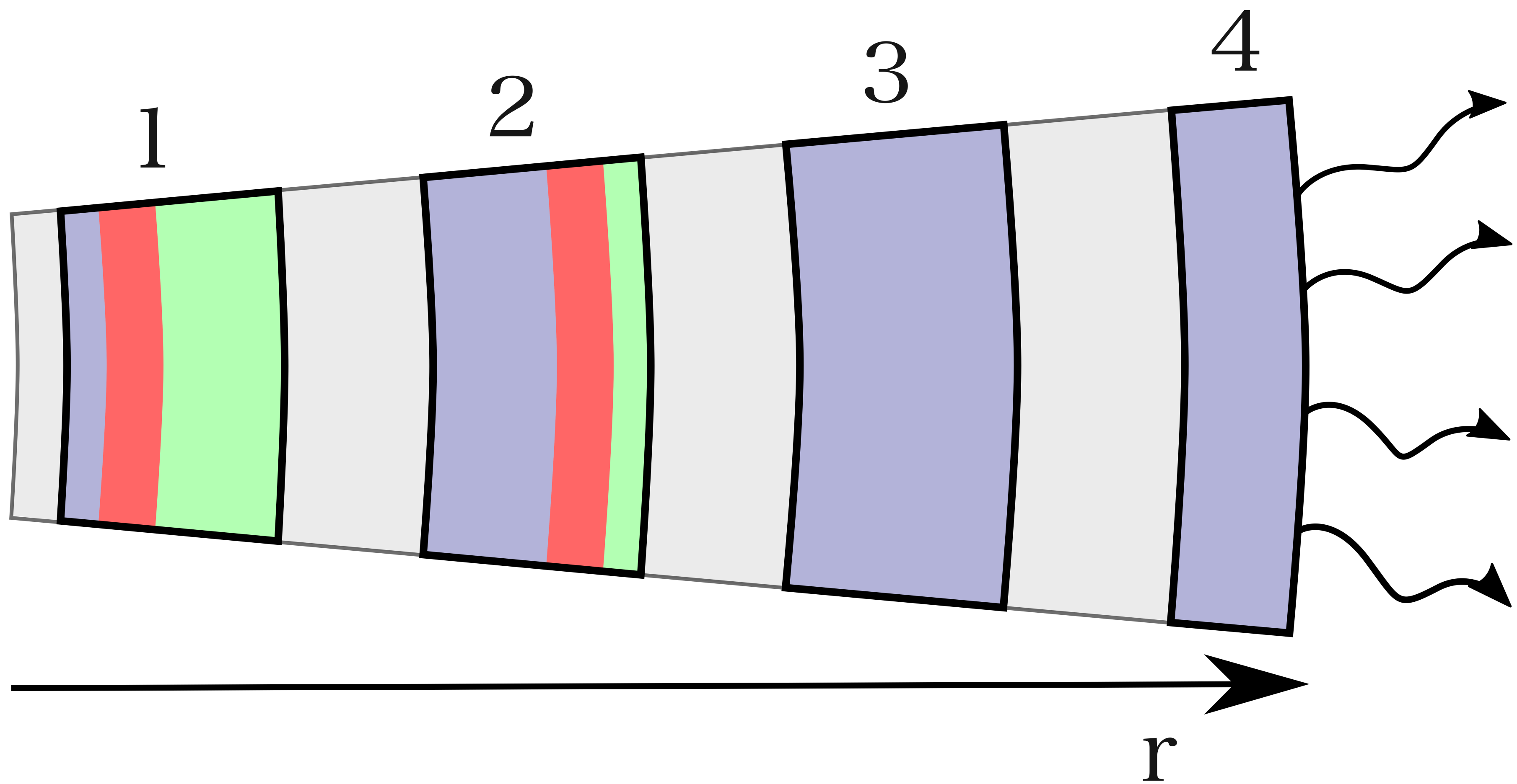


Mildly relativistic shock: $(\beta\gamma)_{\mathrm{u}} = 3$

The jet

A minimal jet model

- Implementing the KRA in a minimal jet scenario
- All zones account for adiabatic cooling and thermalization

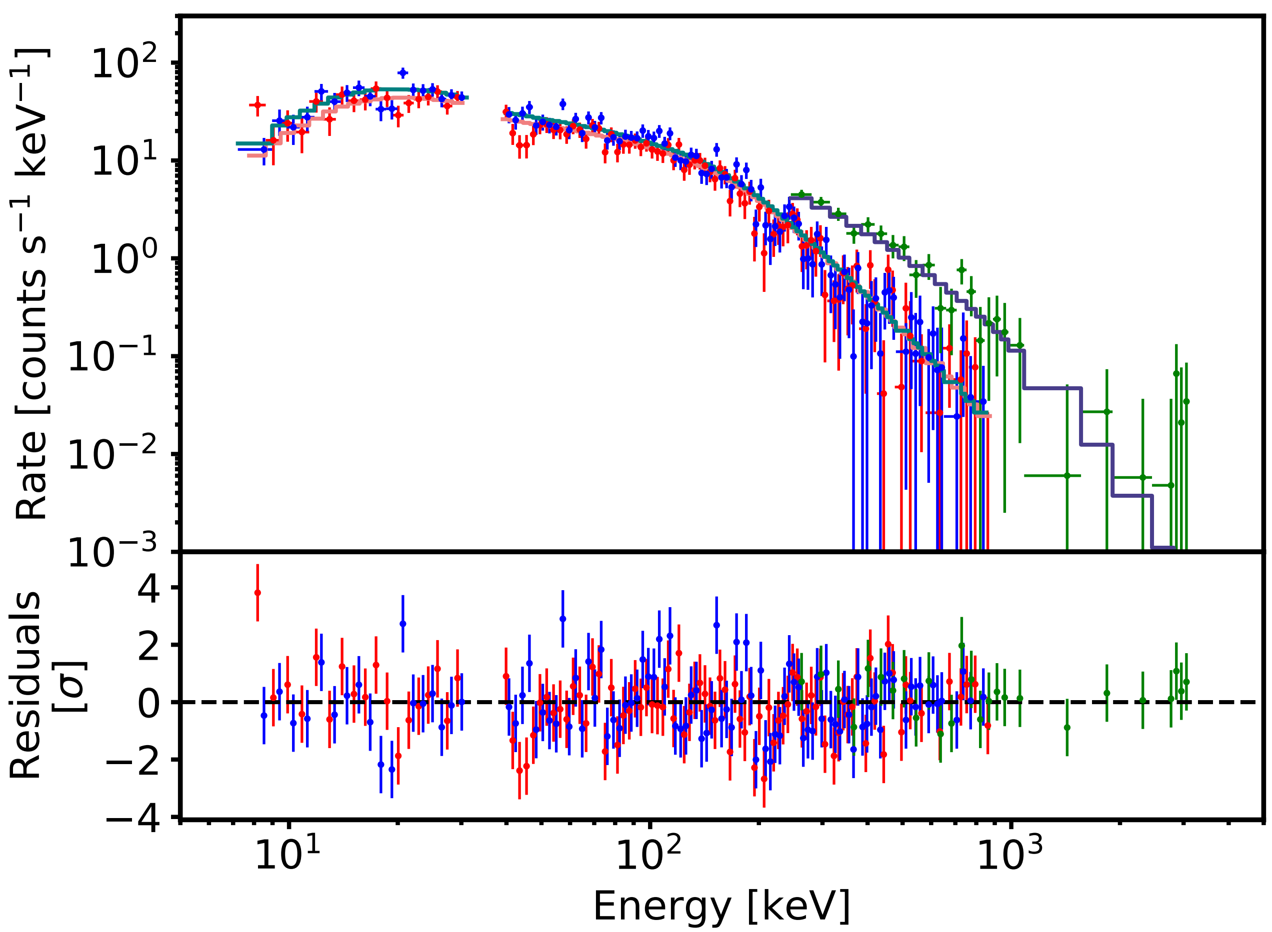


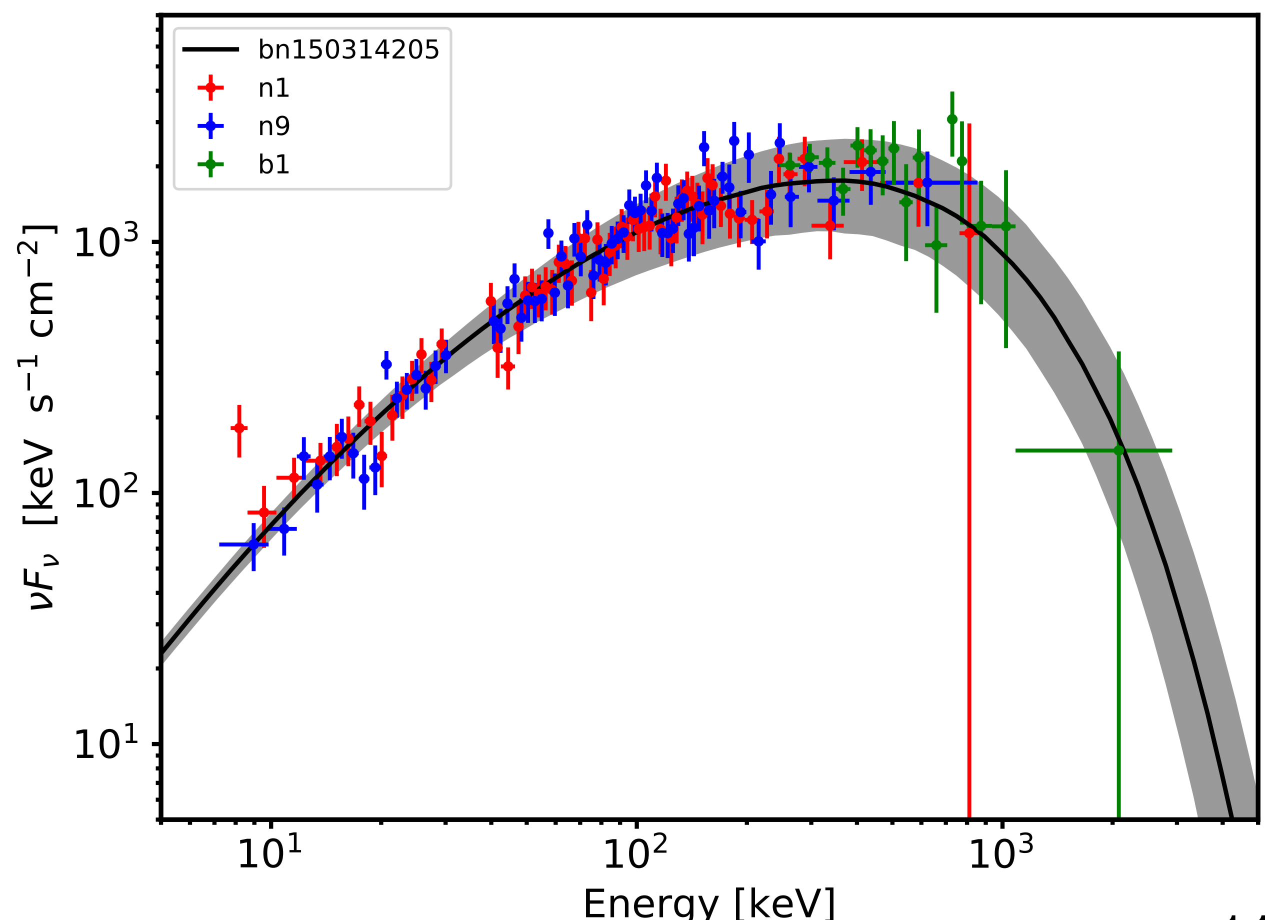
The fit

Time resolved spectrum GRB 150314A

- Assuming $\Gamma = 300$ one gets

$$(\beta\gamma)_{\rm u} = 1.89, \quad \theta_{\rm u} = 8.8 \times 10^{-5}, \quad \frac{n_\gamma}{n} = 2.0 \times 10^5$$





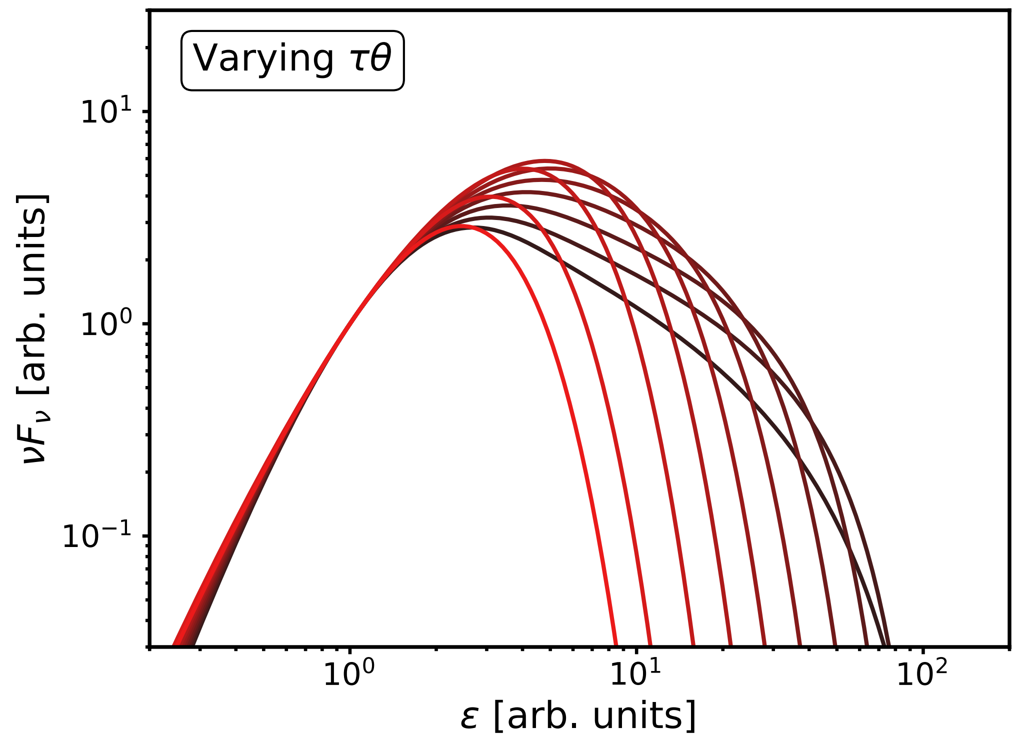
Summary

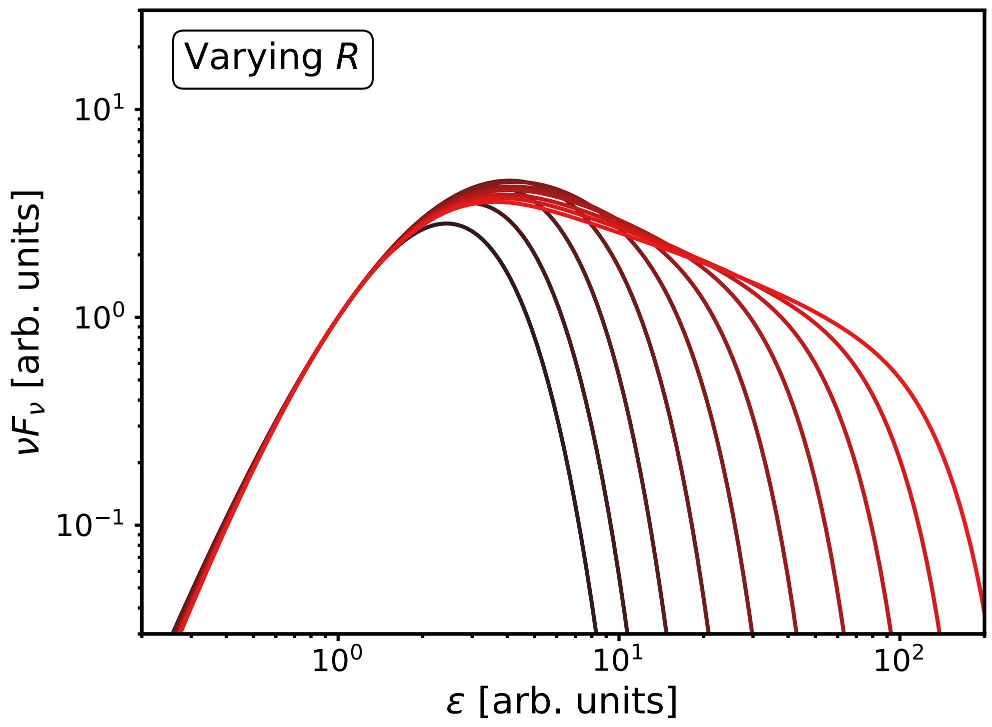
- RMSs may play an important role in GRB prompt emission, but so far, no such model has been fit to data
- We develop an approximation based on the similarities between bulk Compton scattering in an RMS and thermal Comptonization by hot electrons
- The approximation works well and is fast enough that we can fit an RMS model against data for the first time
- Now it is time to use the model for physics!

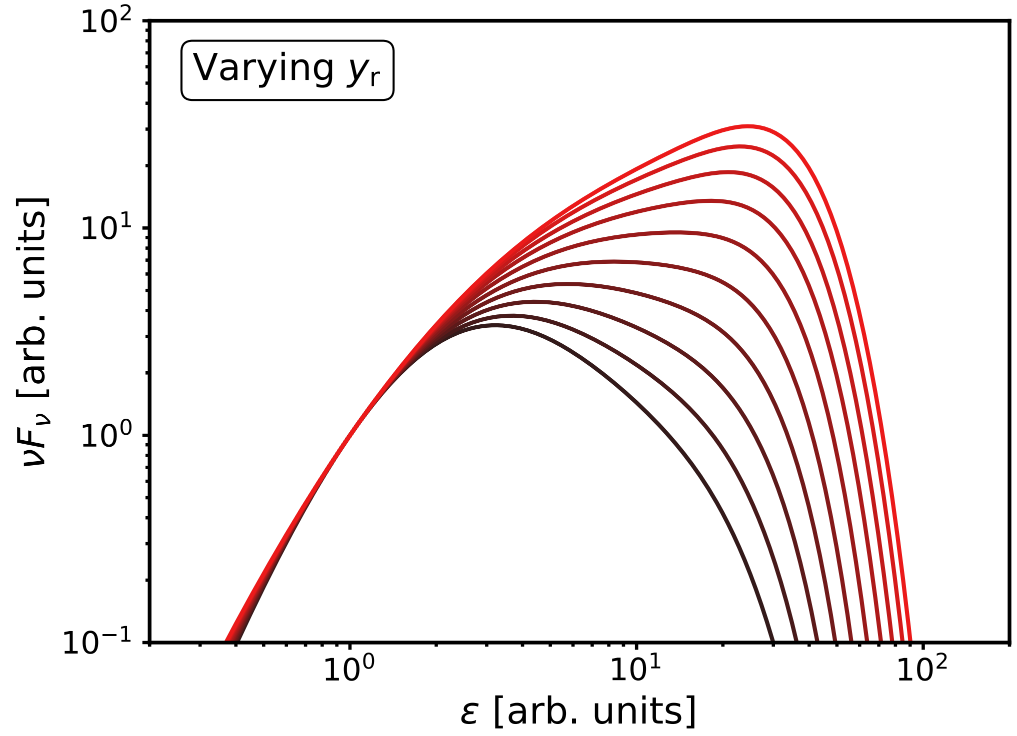
The backup slides

Parameters

- Three parameters for the shape





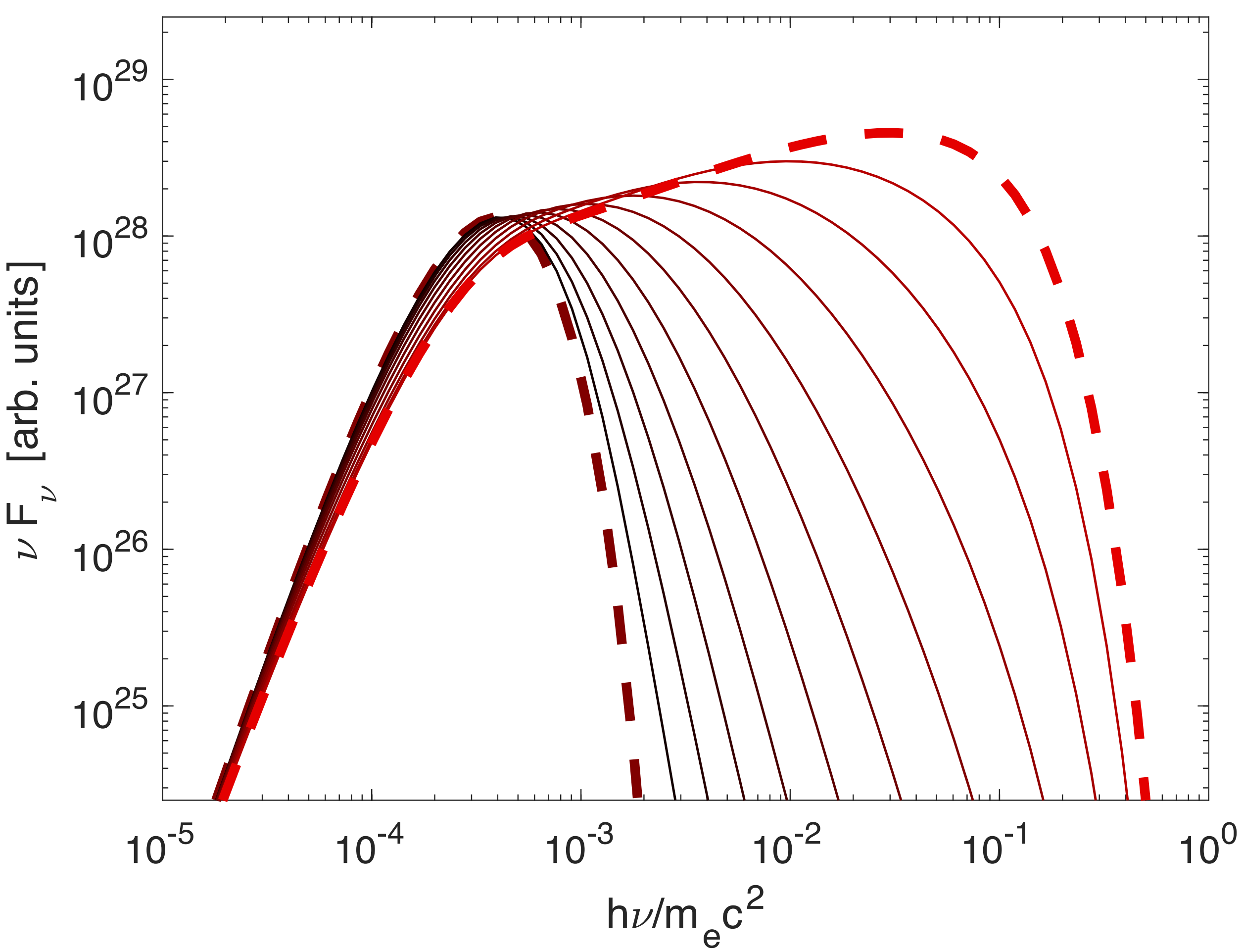


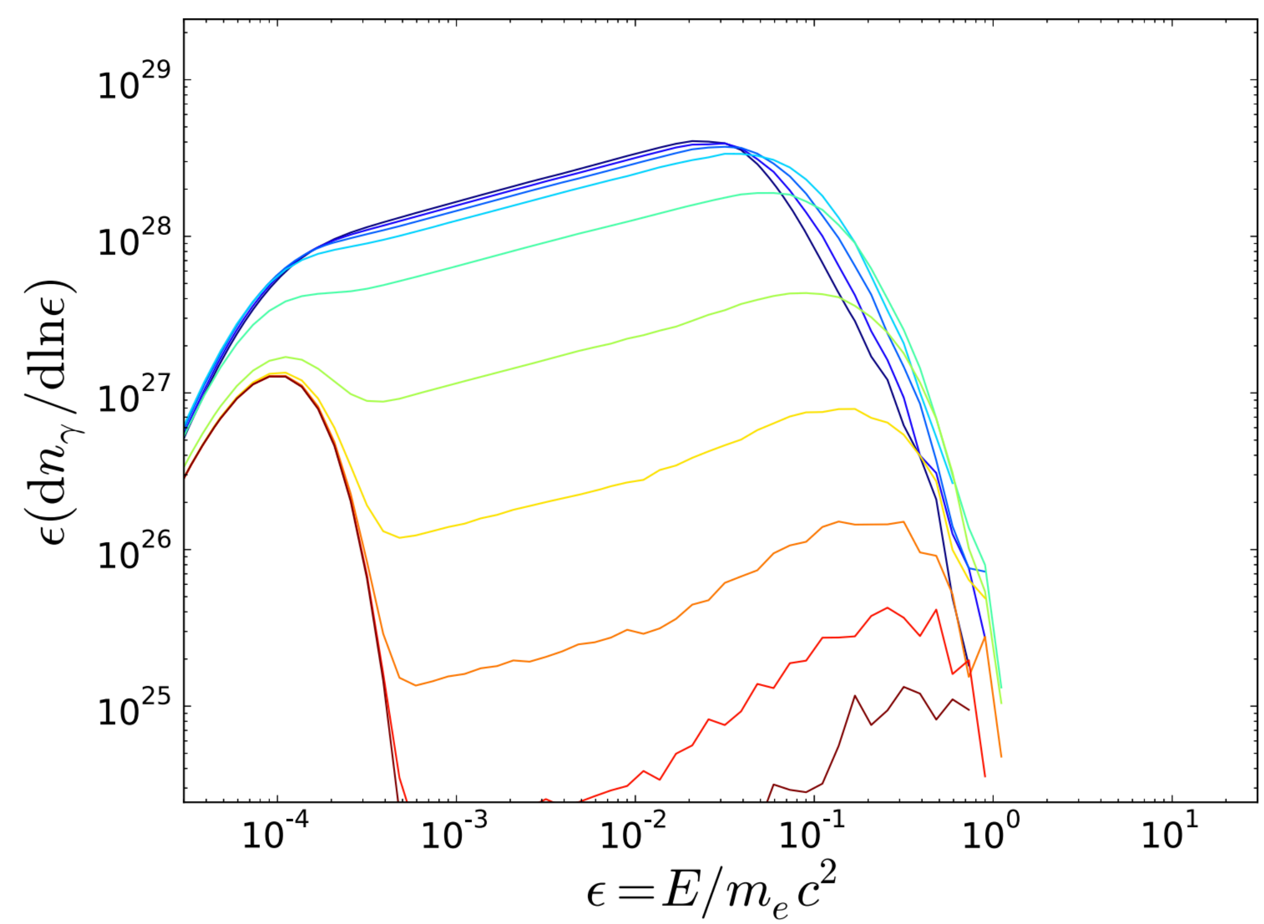
Kompaneet’s equation

- Repeated scatterings of non-relativistic thermal electrons

$$\frac{\partial}{\partial \bar{r}}\left(\bar{r}^2 n\right) = \frac{1}{\epsilon^2}\frac{\partial}{\partial \epsilon}\left[\frac{\epsilon^4}{\bar{r}^2}\left(\theta\frac{\partial(\bar{r}^2 n)}{\partial \epsilon} + (\bar{r}^2 n)\right) + \frac{2}{3}\frac{\epsilon^3(\bar{r}^2 n)}{\bar{r}}\right] + s$$

Spectrum — Heating — Cooling — Ad. cooling — Sources



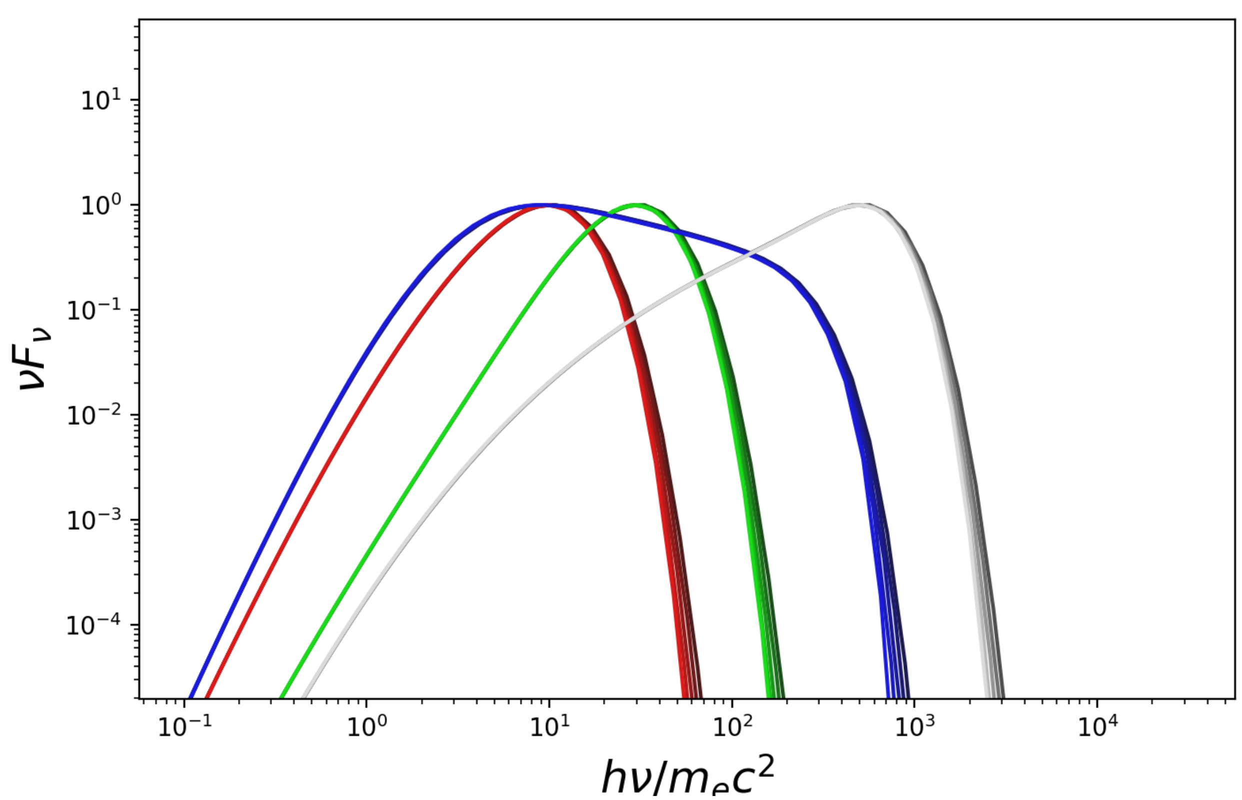


Lundman+ (2018); ApJ, 858:7

Degeneracy

- Old model parameters:
  tau, theta_U, theta_RMS, y_RMS

- New model parameter:
  tau*theta_RMS, R = theta_U/theta_RMS, y_RMS



Higher order effects at the photosphere

- We never observe a Planck or Wien spectrum
- High-latitude emission and fuzzy photosphere including angle dependent beaming and adiabatic cooling