Radiation mediated shocks in gamma-ray bursts
(and other things)

IAP high-energy group meeting, 2022 01 20

Filip Samuelsson, Christoffer Lundman, & Felix Ryde

Other works

Ultra-high-energy cosmic rays

The Astrophysical Journal, 902:148 (15pp), 2020 October 20
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Constraining Low-luminosity Gamma-Ray Bursts as Ultra-high-energy Cosmic Ray Sources Using GRB 060218 as a Proxy

Filip Samuelsson[1], Damien Bégué[2], Felix Ryde[1], Asaf Pe'er[3], and Kohta Murase[4,5,6,7]

The Astrophysical Journal, 876:93 (17pp), 2019 May 10
https://doi.org/10.3847/1538-4357/ab153c

The Limited Contribution of Low- and High-luminosity Gamma-Ray Bursts to Ultra-high-energy Cosmic Rays

Filip Samuelsson[1,2], Damien Bégué[3], Felix Ryde[1,2], and Asaf Pe'er[4,5]

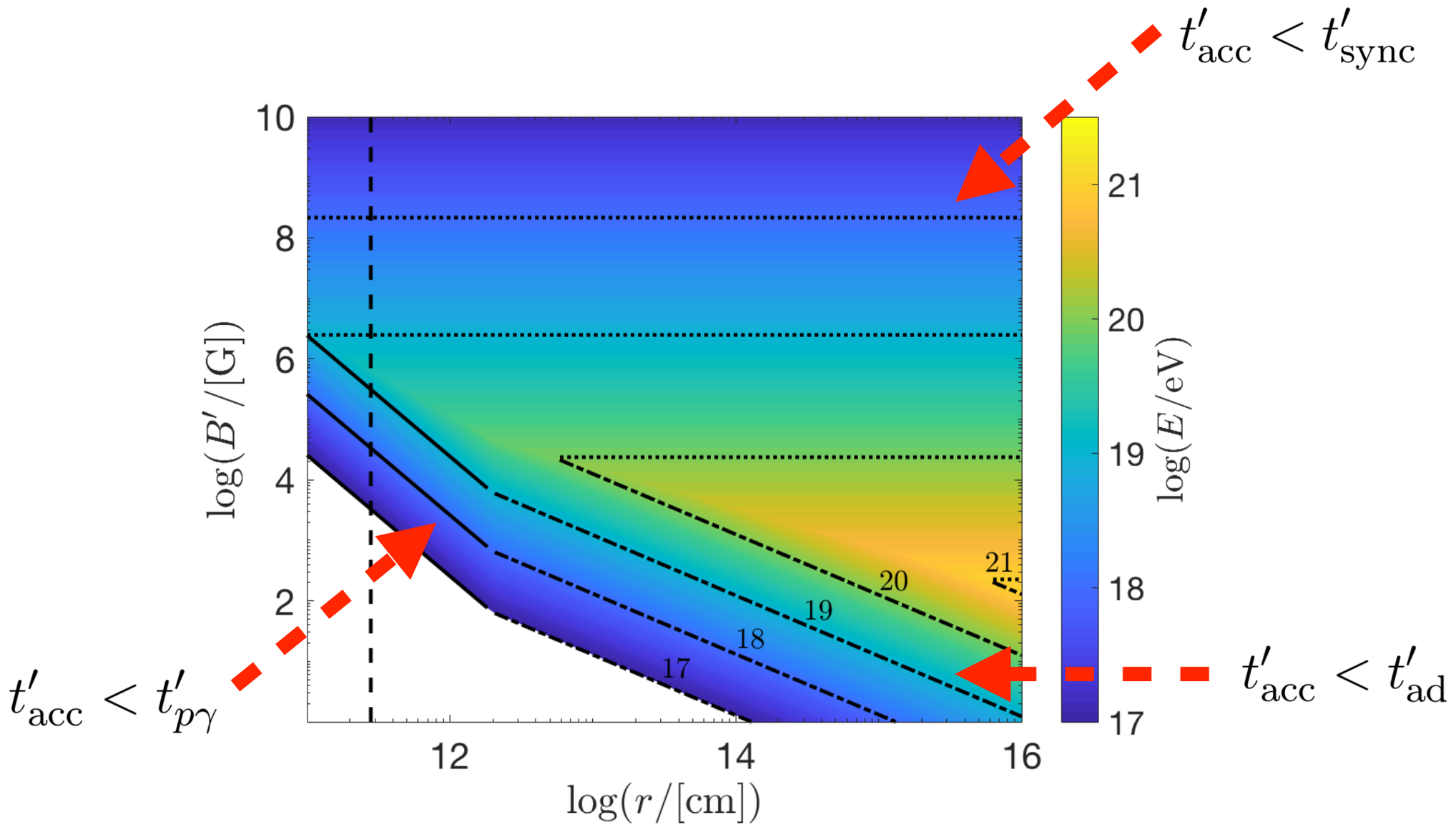
Idea

- If cosmic-rays are accelerated, so are electrons
- Electrons in magnetic fields radiate
- Is this radiation compatible with observations?

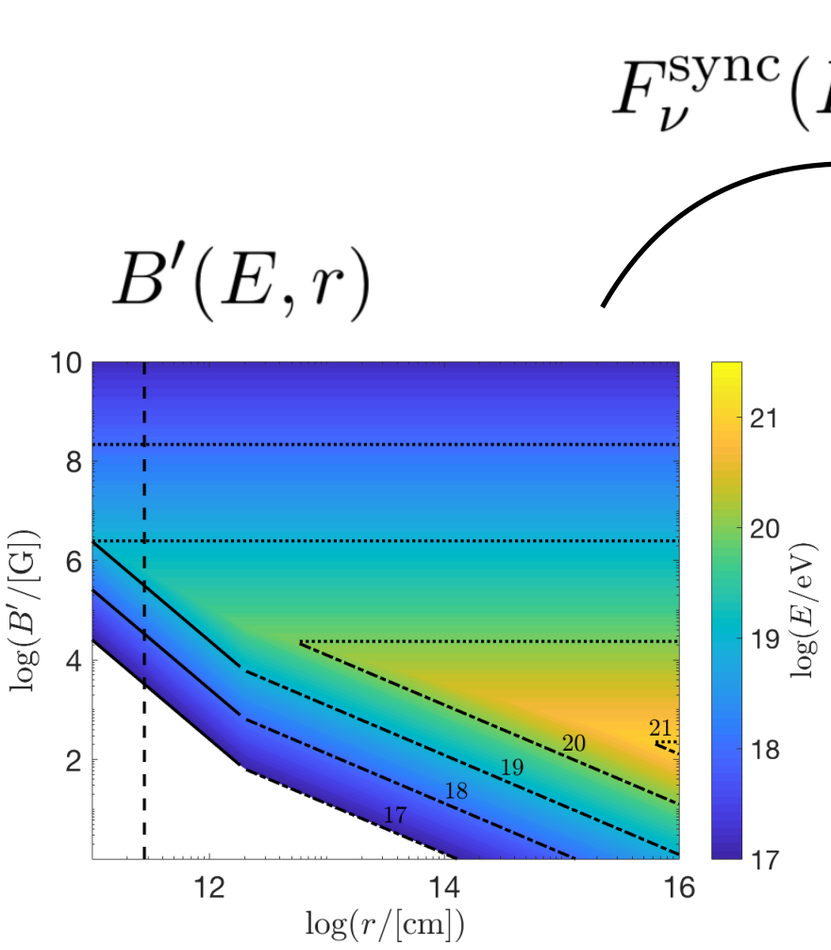
Magnetic field (prompt phase)

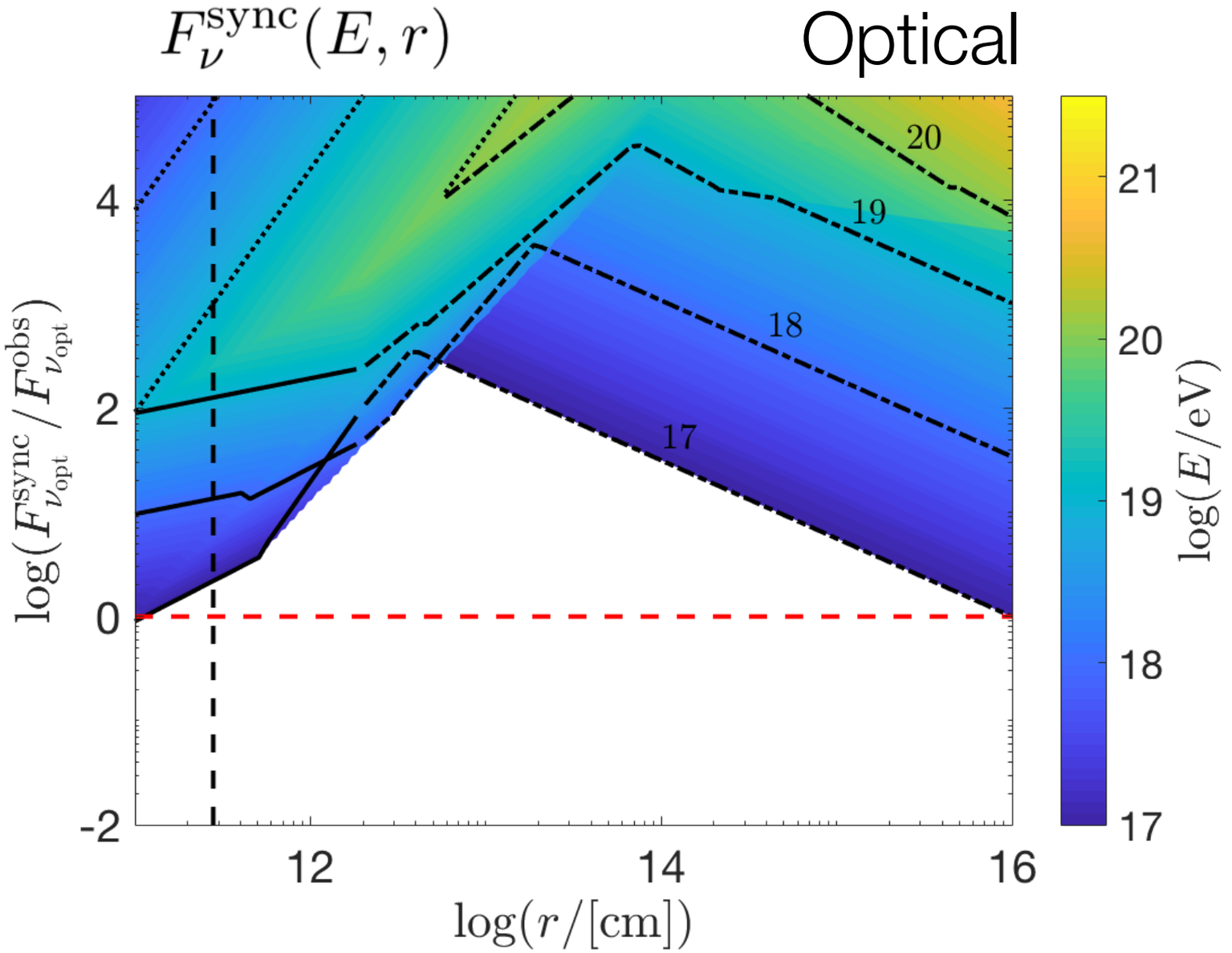
- Acceleration time scale shorter than cooling time scales

$$t'_{\rm acc} < \min[t'_{\rm sync}, t'_{\rm ad}, t'_{p\gamma}]$$



Synchrotron flux (prompt phase)





Possible collaboration?

- UHECR, neutrinos
- Electron synchrotron
- Shock acceleration
- Low-luminosity GRBs
- Thermal electrons

Proton synchrotron

Bethe-Heitler signature in proton synchrotron models for gamma-ray bursts

D. Bégué [1], F. Samuelsson [2] and A. Pe'er [1]

Idea

- Synchrotron fits suggests marginally fast cooling, which suggests proton synchrotron (Ghisellini+ 2020)

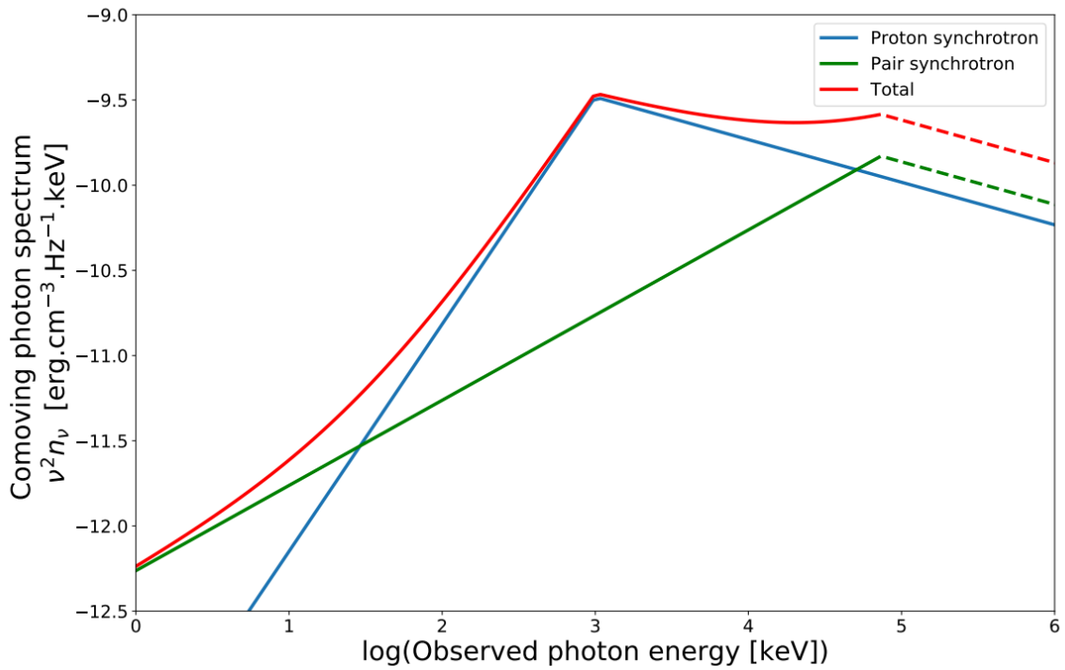
- High-energy protons can create Bethe-Heitler pairs

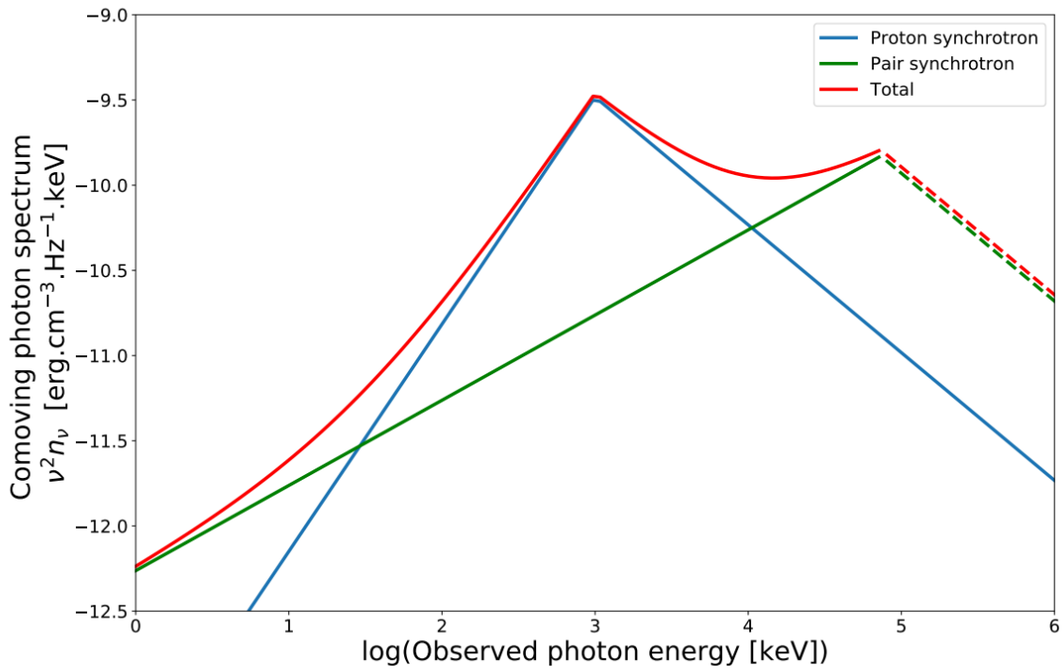
- Bethe-Heitler pair production (pe)

$$p + \gamma \rightarrow e^+ + e^-.$$

- What is the emission from these pairs?

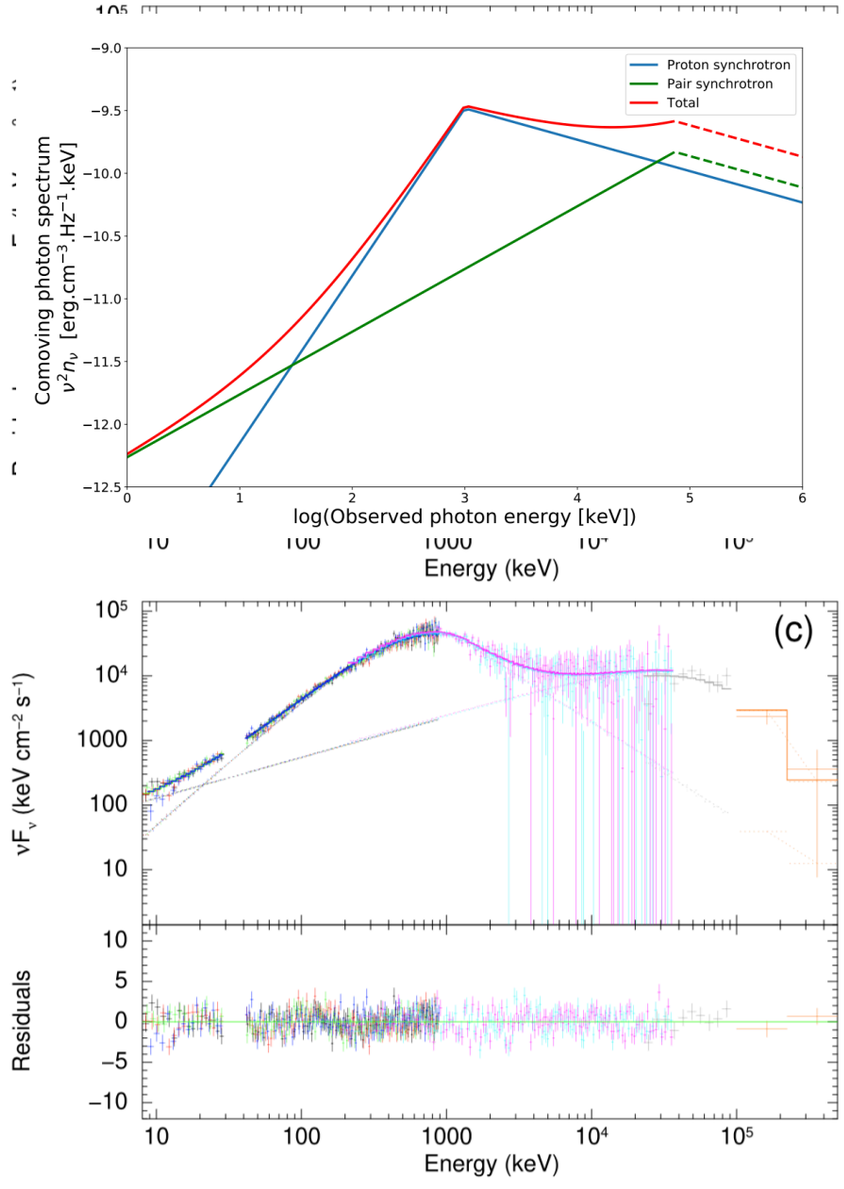
Joint spectrum

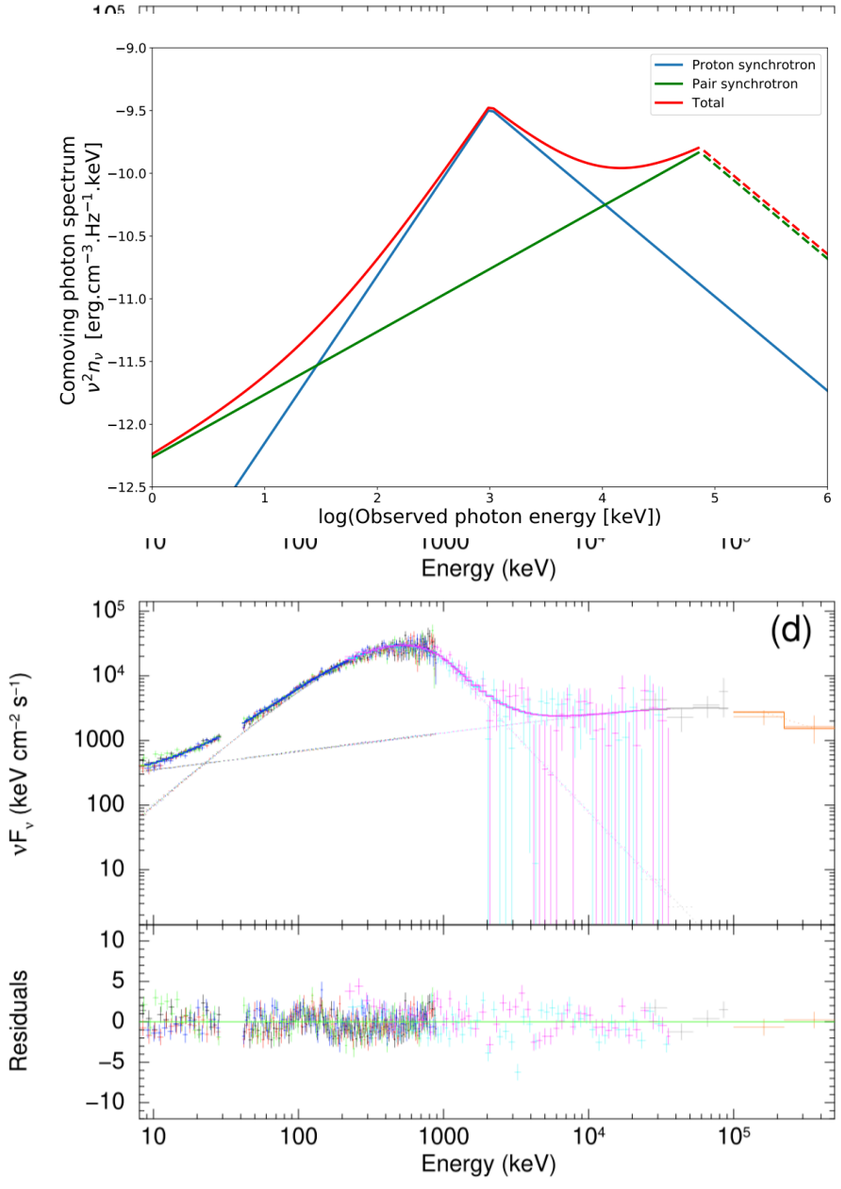




$r_{14} = 1,\ \Gamma_2 = 1,\ \nu_{\rm MeV} = 1,\ L_{52} = 10,\ \xi = 1$ and $p = 2.5$ (left) or $p = 3.5$ (right)

MAGICal GRB 190114C





Chand+ (2020), ApJ, 903

Possible collaboration?

- Proton synchrotron
- Bethe-Heitler

Radiation mediated shocks (RMSs)

An efficient method for fitting radiation-mediated shocks to gamma-ray burst data: The Kompaneets RMS approximation

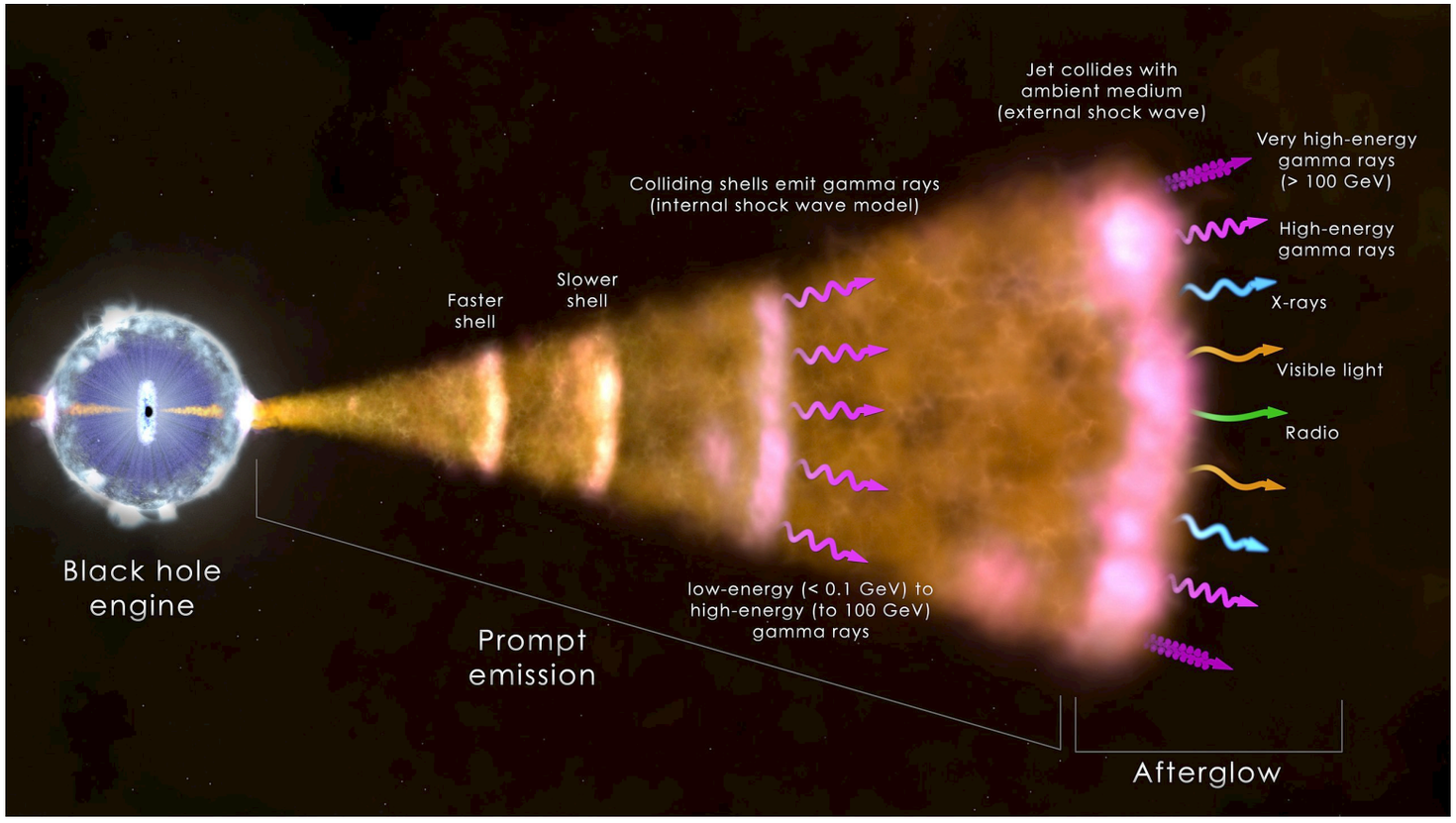
Filip Samuelsson,[1] Christoffer Lundman,[2] and Felix Ryde[1]

The motivation

Prompt emission unknown

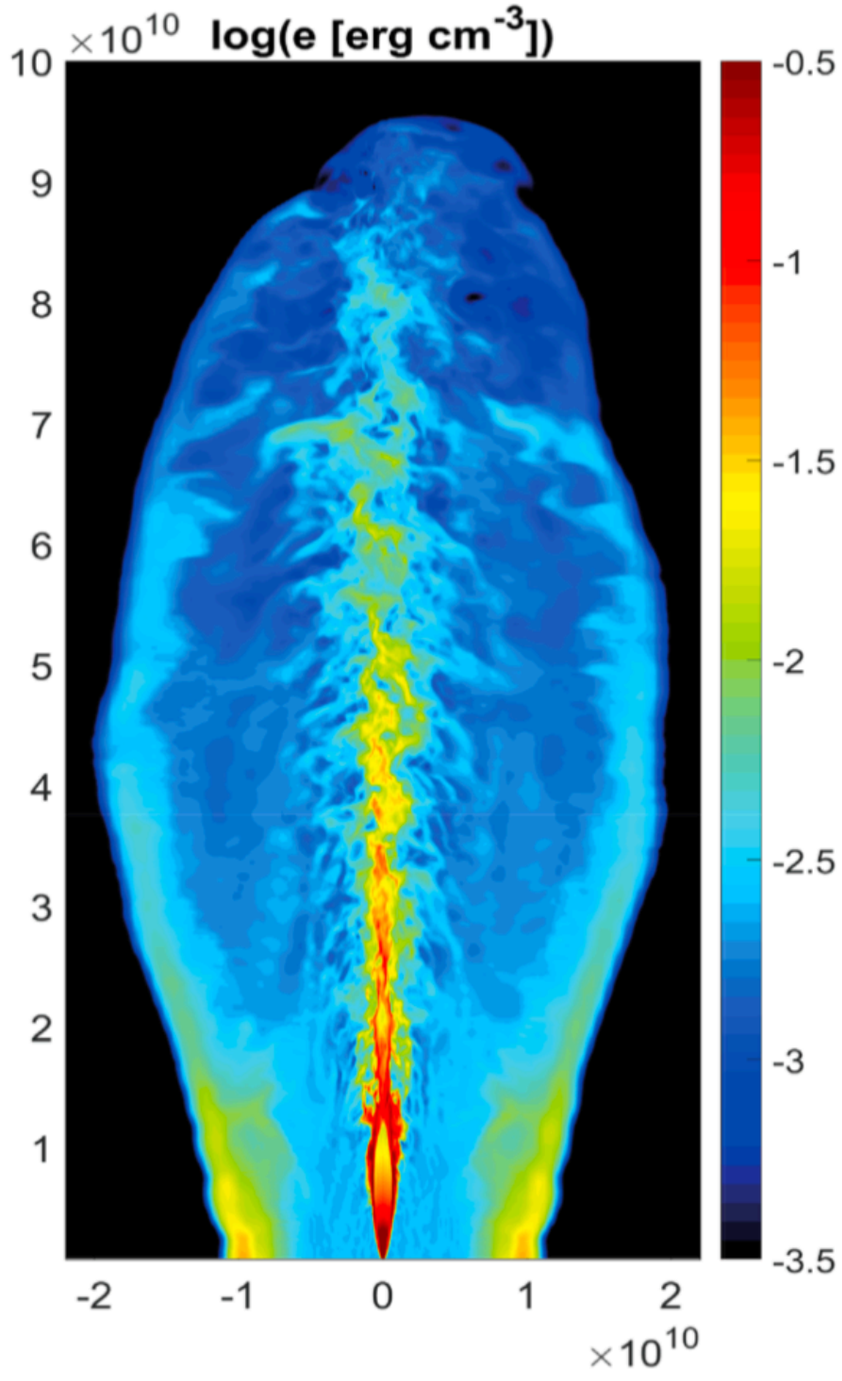
- Early studies suggested photospheric emission to be a black-body (Paczyński 1986, Goodman 1986)

- Observed spectra are generally much broader



Gap between theory and observations

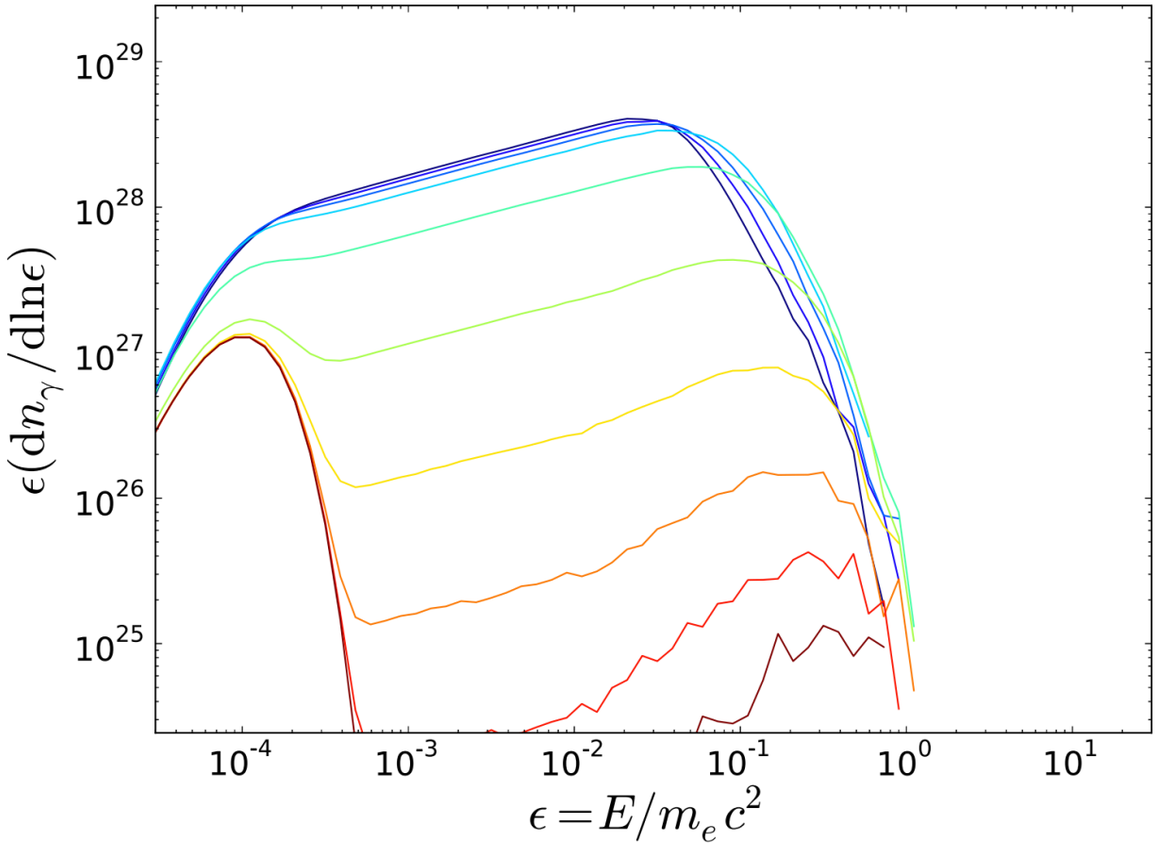
- Dissipation broadens the spectrum
- Shocks are radiation mediated
- So far, no RMS model has been fit to GRB data
- We aim to bridge that gap



Gottlieb+ (2019); MNRAS, 488, 1416

Radiation mediated shocks

- Photons interact on much larger scales: if they can mediate the shock, they will
- Photons scatter back and forth, dissipating energy
- Separation in scales makes simulations expensive
- Develop an approximative method



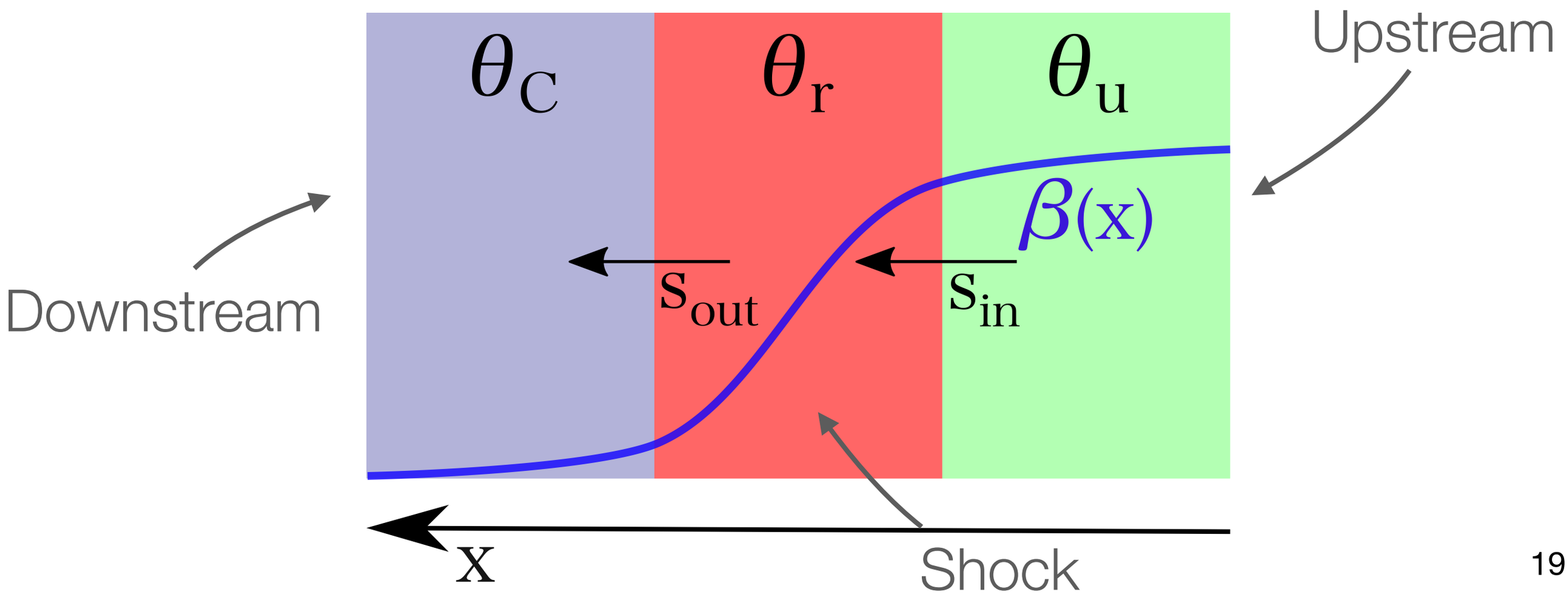
Lundman+ (2018); ApJ, 858:7

The approximation

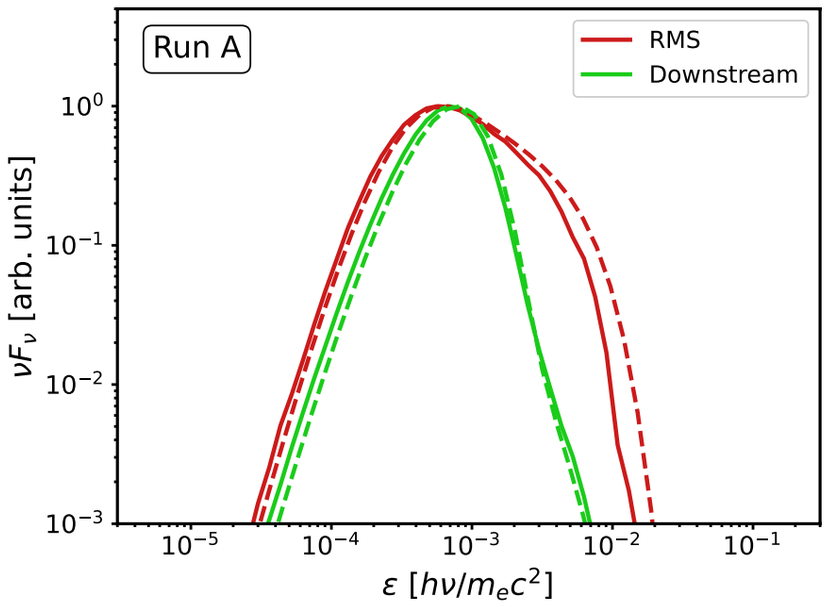
The Kompaneets RMS approximation

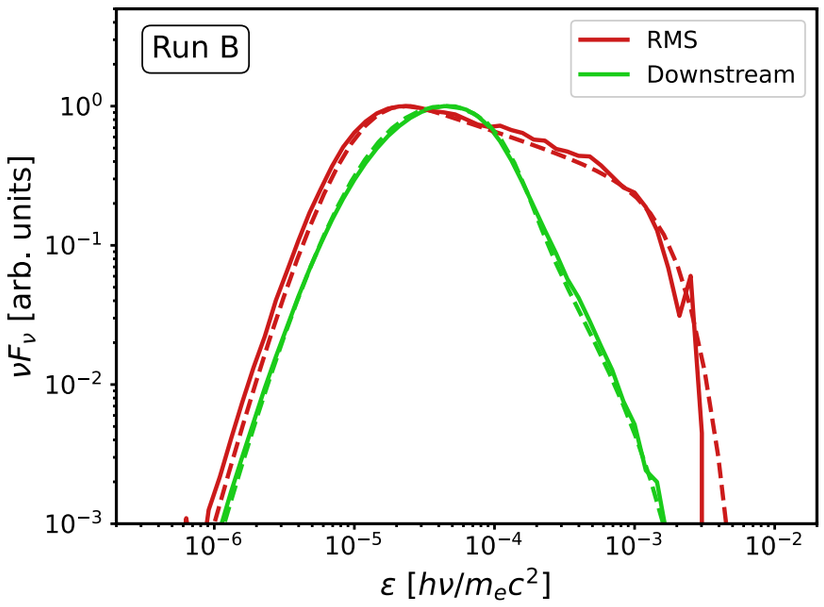
- Fermi acceleration of in RMS converging flow ≈ repeated scatterings with hot electrons

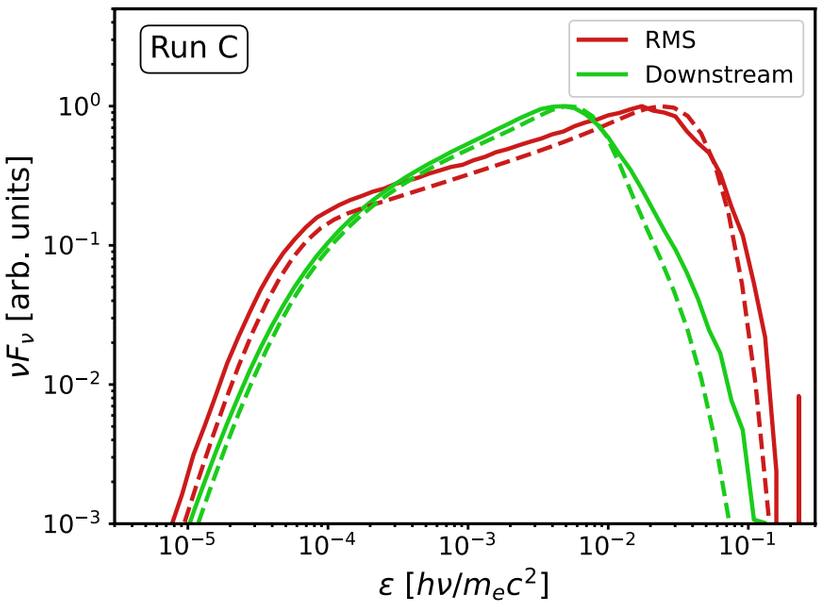
- The Kompaneets RMS approximation (KRA)

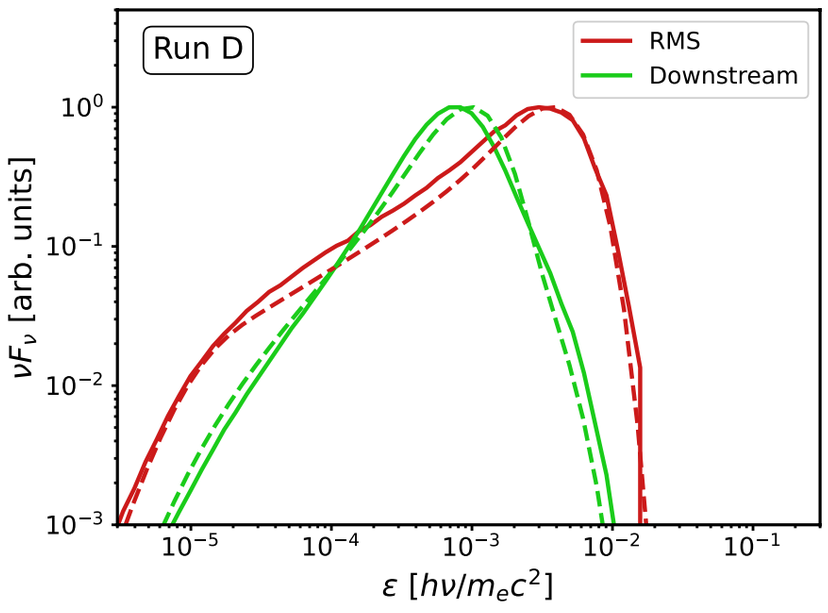


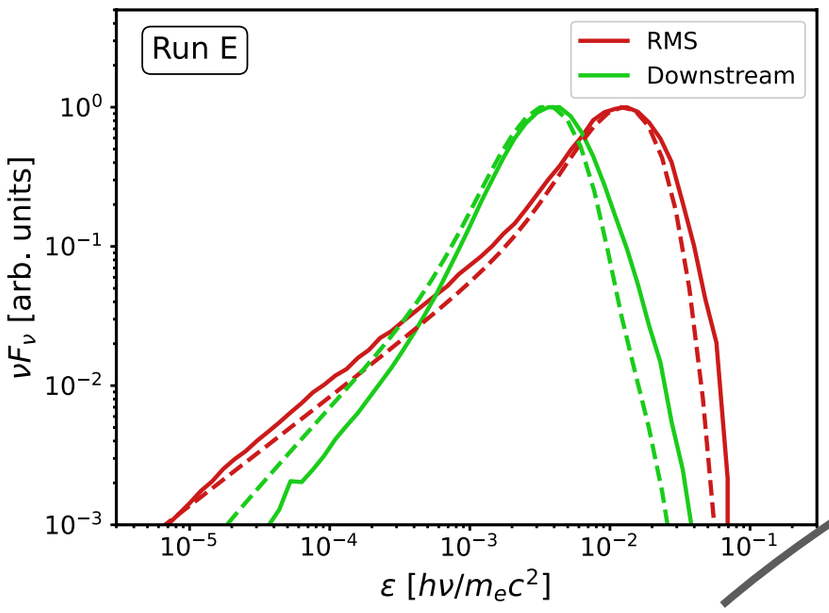
Verification of the approximation

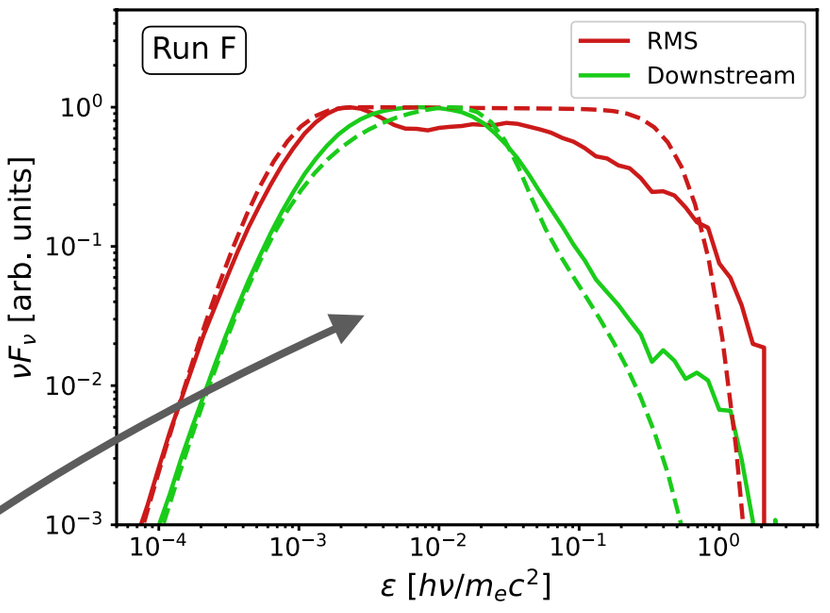










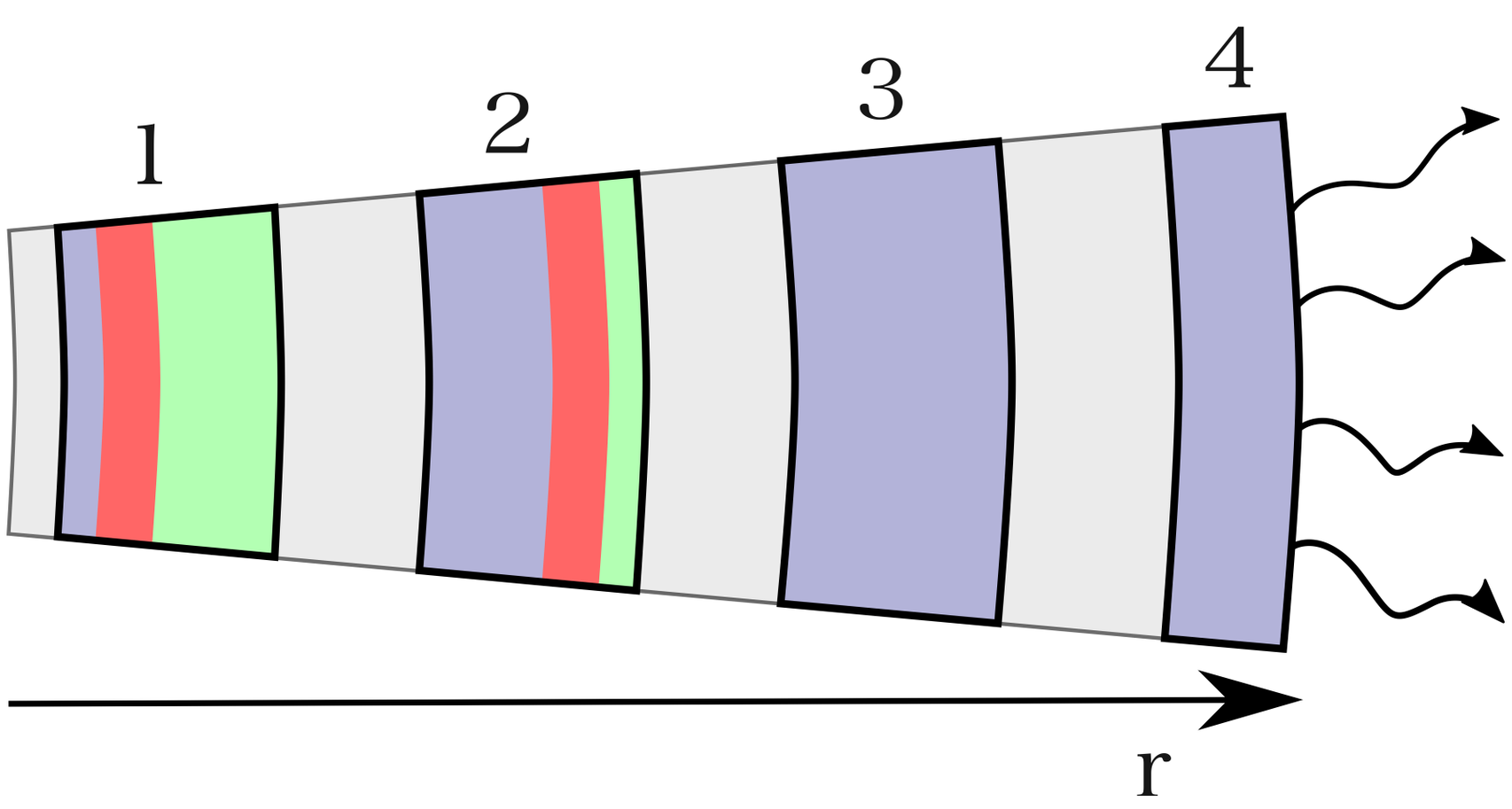


Mildly relativistic shock: $(\beta\gamma)_{\mathrm{u}} = 3$

The jet

A minimal jet model

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

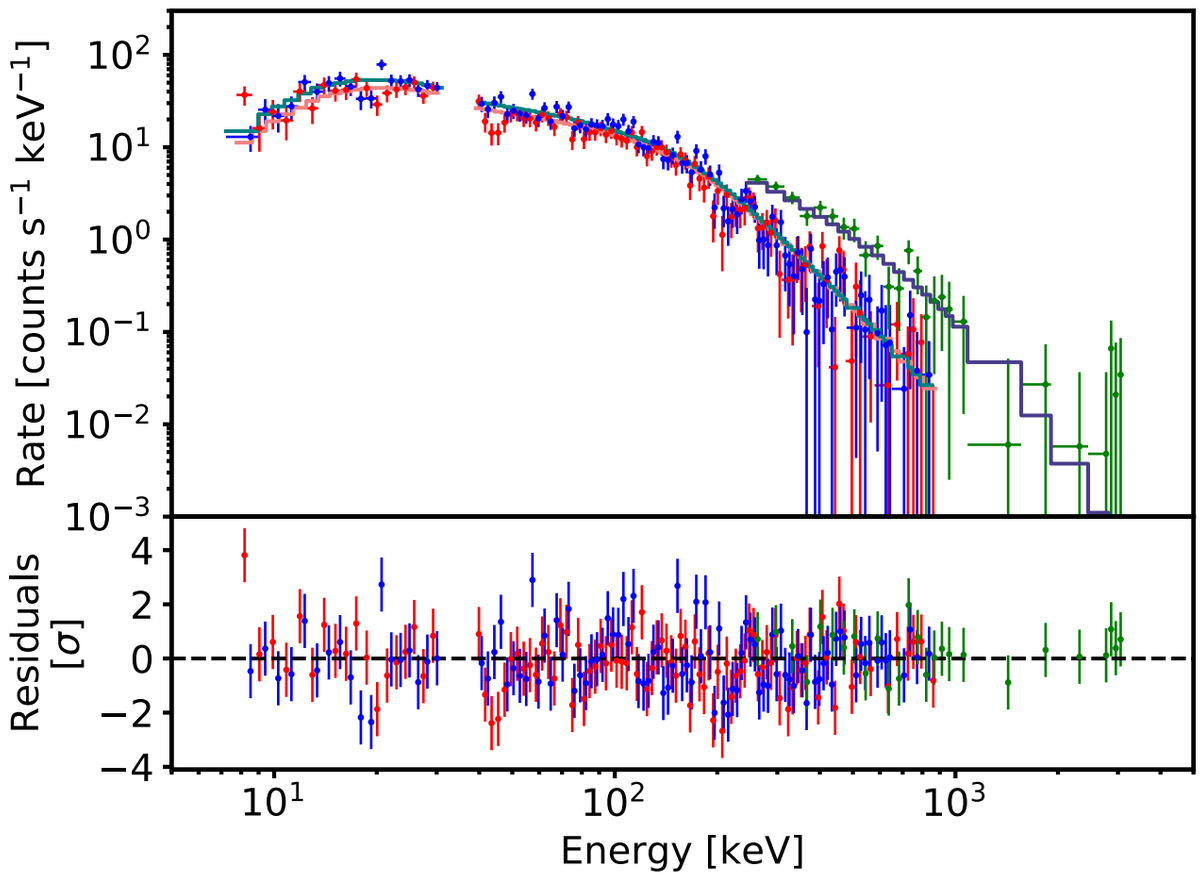


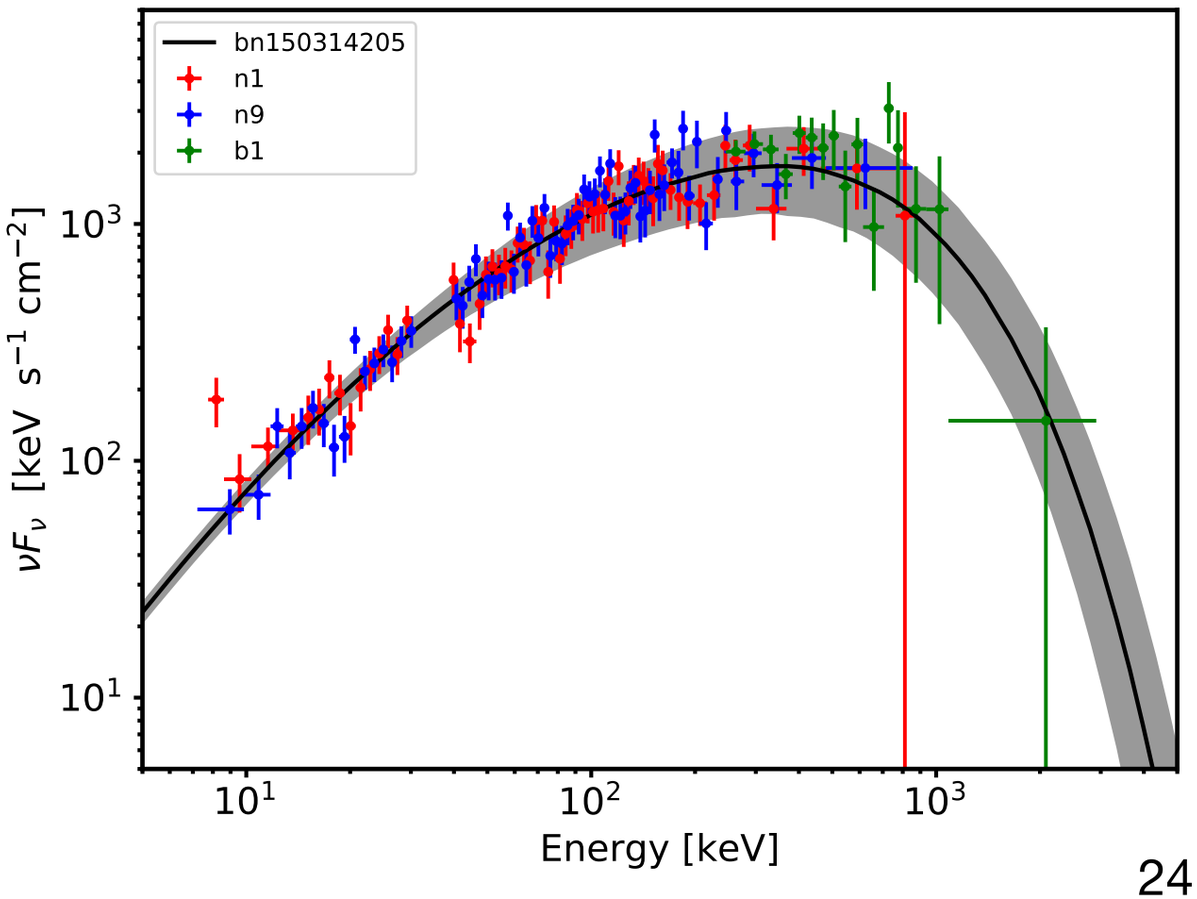
The fit

Time resolved spectrum GRB 150314A

- Assuming $\Gamma = 300$ one gets

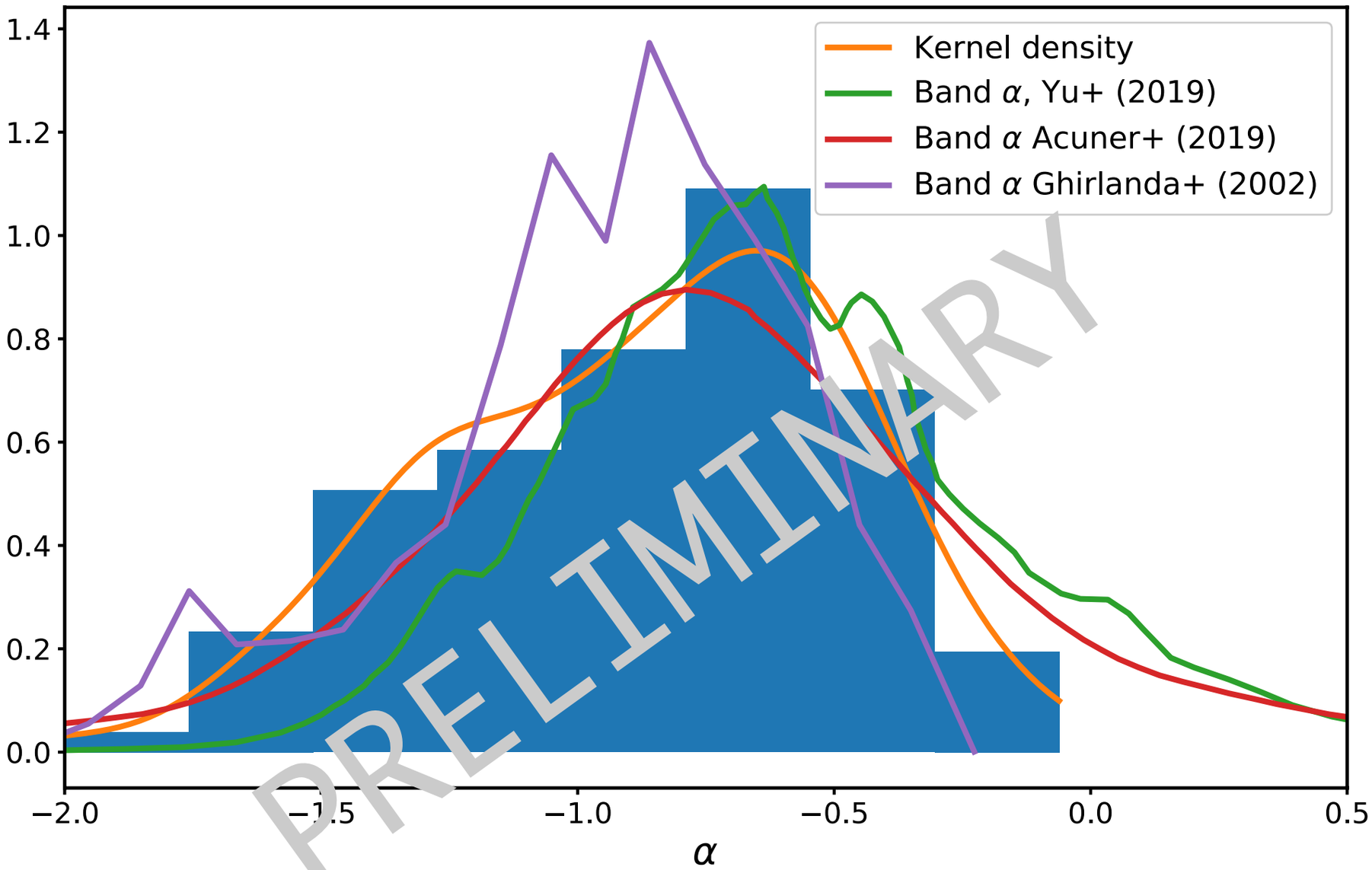
$$(\beta\gamma)_{\rm u} = 1.89, \quad \theta_{\rm u} = 8.8 \times 10^{-5}, \quad \frac{n_\gamma}{n} = 2.0 \times 10^5$$





Next work

Alpha distribution from RMS



Summary

- GRBs are unlikely accelerators of UHECRs
- Bethe-Heitler pair emission together with proton synchrotron may have been seen
- RMSs can create a wide variety of spectra behaviors in GRBs