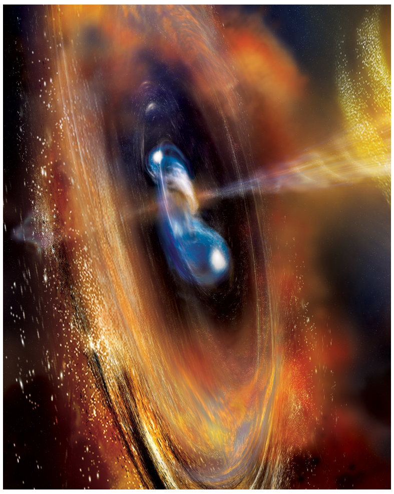
An investigation of the electron synchrotron cooling scenario for GRB 211211A

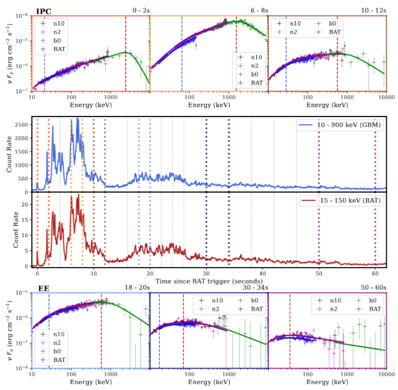
MARIA PETROPOULOU & APOSTOLOS MASTICHIADIS



Gamma-Ray Bursts (GRBs) are extragalactic transient sources of γ-ray radiation produced in relativistic jets that are launched after a catastrophic event, such as a binary neutron star merger or the collapse of a massive star. Despite numerous observations, the question of how γ-rays are produced remains unanswered. The leading scenario is still that of electron synchrotron radiation. GRB 211211A, a minute-long burst associated with a kilonova at a distance of 350 Mpc, offers a unique case study of prompt GRB emission. Swift/BAT and Fermi/GBM data reveal structured light curves and strong spectral evolution over the course of 1 min. This METEOR project includes (i) theoretical investigation of synchrotron-cooled electron distributions in variable source conditions (e.g. decaying magnetic field), and (ii) application of results to observations of GRB 211211A. (Image credit: A. Simonnet (Sonoma State U.), NASA GSFC)

Theory

The evolution of particles that lose energy (i.e. cool) due to radiative processes, like synchrotron radiation, is generally described by a partial differential equation (PDE): $\partial_t N(\gamma,t)+\partial_\gamma\left[b(\gamma,t)N(\gamma,t)\right]+N(\gamma,t)/t_{esc}(\gamma,t) = Q(\gamma,t)$. Here, γ is the particle Lorentz factor, $N(\gamma,t)$ is the number of particles inside the source at time t with Lorentz factors between γ and $\gamma+d\gamma$, $b(\gamma,t)$ is a function that describes the energy loss rate of a particle with Lorentz factor γ, $t_{esc}(\gamma,t)$ is the escape timescale from the source, and $Q(\gamma,t)$ is the rate at which particles are injected into the source. By solving the PDE for physically motivated choices for b and t_{esc} one can study the effects of time-dependent magnetic fields $B(t)$ on the particle distribution function, and the resulting photon spectrum.



Evolution of prompt emission spectra (upper/lower panels) and light curves (middle row) from GRB 211211A. Adopted from **[1]**.

Applications

1. The student will solve (analytically or numerically) the electron PDE for different case studies: (i) constant magnetic field and escape, (ii) decaying magnetic field $B \propto t^{-m}$ and constant escape **(see e.g. [2])**, and (iii) $B \propto t^{-m}$ with $t_{esc}(B)$. He/she will compute the synchrotron photon spectrum and study the spectral evolution over time for each case.
2. The student will use the results of the theoretical investigation to explain the spectral evolution observed in GRB 211211A (see figure). Time provided, the student may attempt to model numerically the spectra and light curve of GRB 211211A using an in-house radiative transfer code.

References

[1] Gompertz B. P., Ravasio M. E., Nicholl M., et al., 2023, NatAs, 7, 67.
[2] Uhm Z. L., Zhang B., 2014, NatPh, 10, 351.

Contact

☎ +302107276894 (supervisor)
✉ mpetropo@phys.uoa.gr