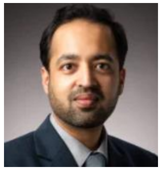
The effect of the electron's size on the observed light from astrophysical shocks.

How does an energy dependent electron-photon interaction probability, change our understanding of the light we observe from GRBs?

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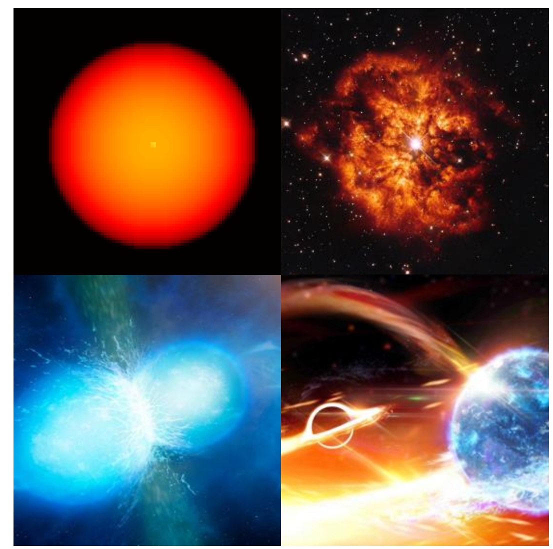
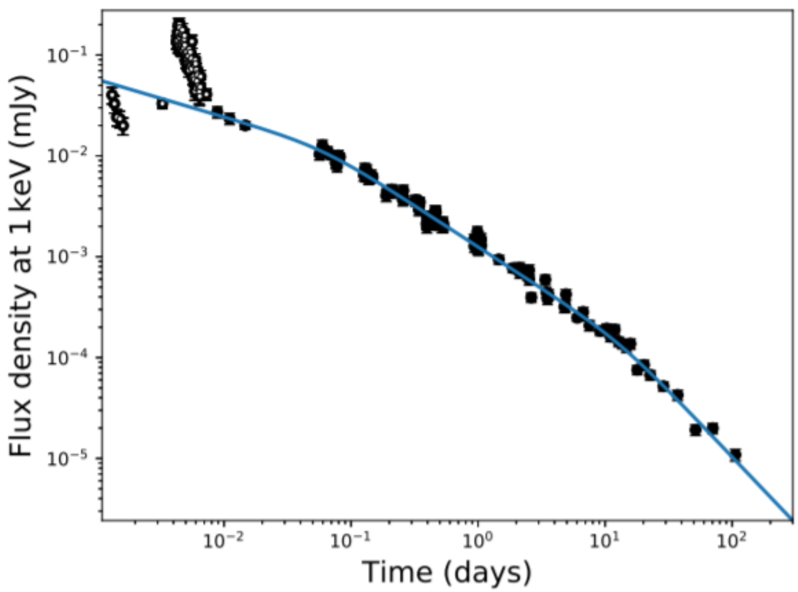
Gamma-ray bursts (GRBs) are the most powerful emission events in the known universe, in which a typical burst releases as much energy in a few seconds as the Sun will emit in its entire lifetime.
Left: artist's impression of a GRB.

First observed in 1967 by a Vela satellite, an American satellite looking for signs of illegal nuclear weapon detonation in space, we still don't know exactly which objects (the progenitors) violently explode to result in gamma-ray bursts.
Right: (top-to-bottom across) possible GRB progenitors: red supergiant star, Wolf-Rayet star, neutron star merger, black hole-neutron star merger.

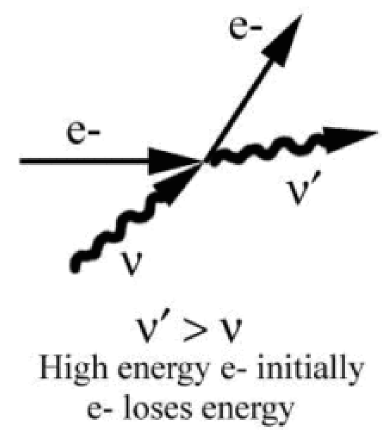


To deduce which progenitor resulted in a GRB we need to know the properties of the burst (total energy, density, magnetic field energy etc.) We find these properties by fitting the predictions of theoretical models to observational data.



Left: the observed X-ray brightness against time for GRB 161219B. Observed data points are in black, the blue curve is the output of a synchrotron-shock model with parameters for the magnetic field energy, density etc. chosen such that the model light curve fits the data well.

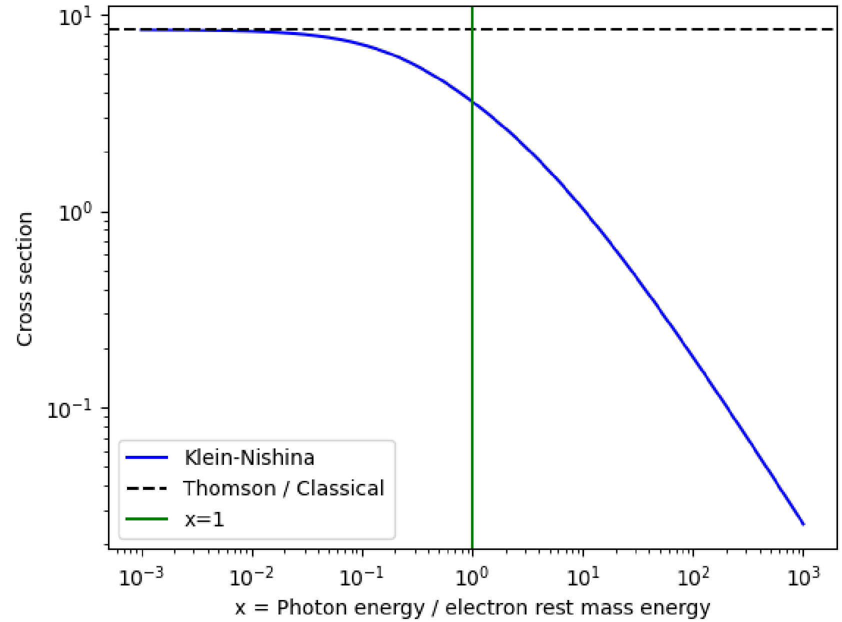
For the burst properties we derive to be accurate, we need to include the correct physics of the burst in our model. One important process which contributes to the light observed from the GRB is the synchrotron-self Compton (SSC) process. This process is often over simplified by models currently used in the GRB literature.

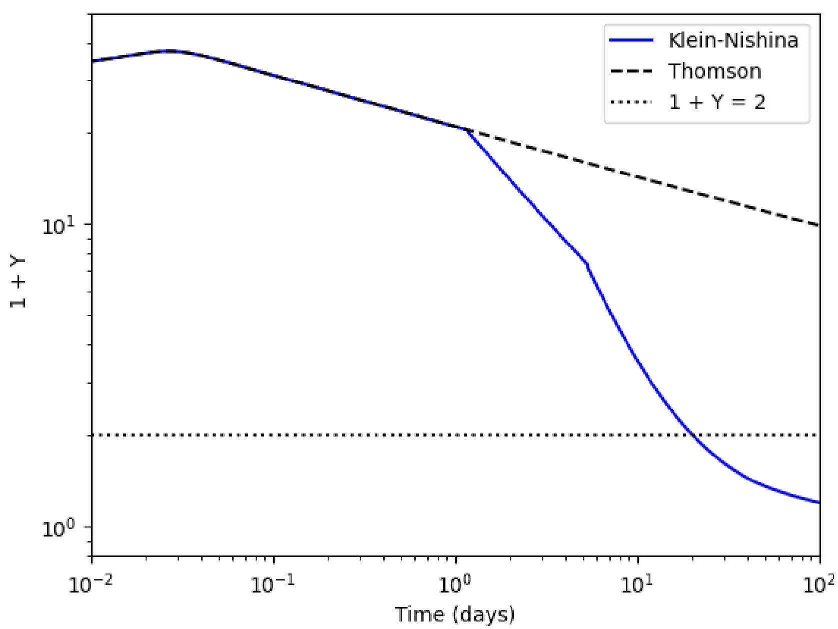


Right: SSC scattering involves a photon being up-scattered by a highly energetic electron, resulting in a much lower energy electron and higher energy up-scattered photon.

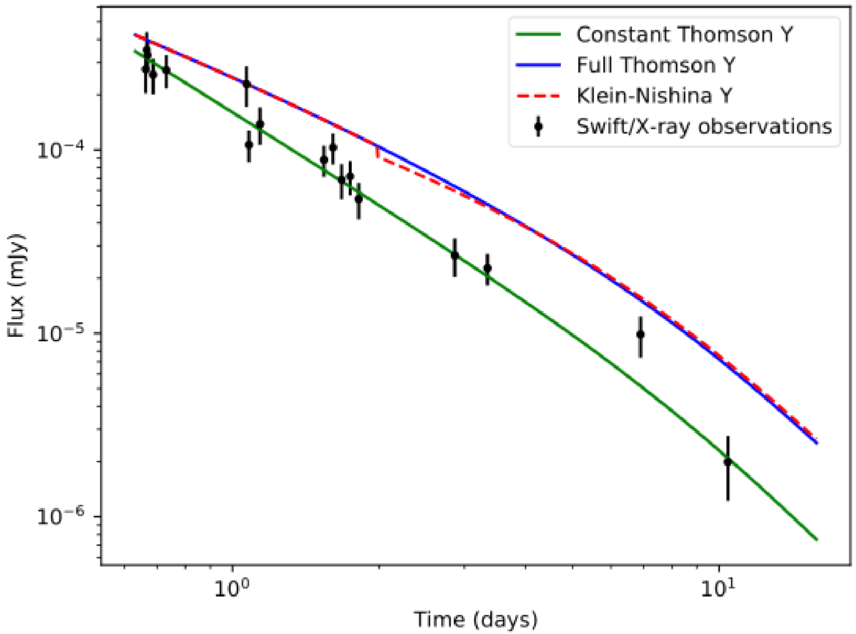
SSC scattering is often oversimplified by assuming a Thomson (classical) scattering probability. In reality the scattering probability changes with energy as described by the (quantum mechanical & relativistic) Klein-Nishina cross section.

Right: cross section (which is a proxy for the scattering probability) plotted against the ratio of photon energy to electron rest mass for a stationary electron. The Thomson (a.k.a classical) cross section approximates the cross section as being constant. This breaks down at high energies, where the correct Klein-Nishina cross section is much smaller.



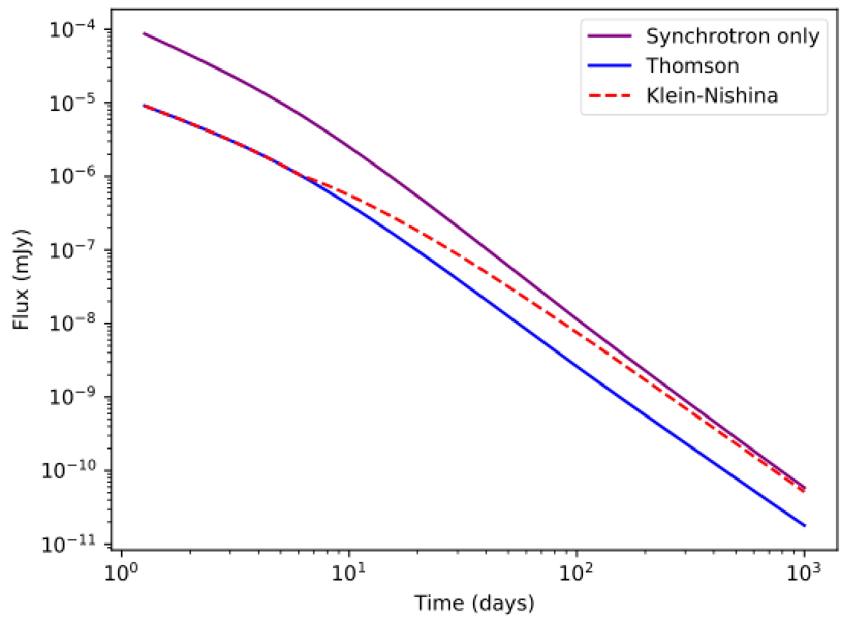


Left: Y parameter against time for a specific set of parameters. The Y parameter quantifies the amount that SSC scattering will change the light we see when we consider the entire electron population, instead of just a single electron as above. If we include a correct cross section (the Klein-Nishina cross section), as shown above, then we find the electrons' ability to cool is less than expected in the classical case. Below the black dotted line, the cooling by this up-scattering process is negligible.



Left: Brightness against time for GRB 090328A. Observed data points in black, coloured curves are model fits. By approximating Y as being constant, Cenko et al. 2011 chose parameters such that the green curve fit the data well. By using a more accurate description of Y which is time dependent (shown in blue) we can see that the light curve predicted by these parameters does not match the observed data. In this case the Klein-Nishina effect is not important and the KN corrected Y matches the full Thomson Y. This is one example in which an accurate description of the SSC scattering processes changes the predicted spectrum.

Right: a parameter set for which we expect Klein-Nishina effects to be important. In the coming weeks we will apply our corrections to more observational data to correct the derived parameters. The synchrotron only curve in purple is for Y = 0, when SSC effects are ignored entirely.



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