Open Problems in Modern Astrophysics – Problem set 3. Autumn 2021

The answers should be returned by ***Friday (15.10) 4pm (16.00) in Moodle****, link through the official course homepage. The answers to the problem set will be discussed on Tuesday (19.10) at 12.15-14.00 in Room D123, Exactum.*

This problem set will contain **General** questions and questions based on the two papers: Piro, L., Troja, E., Gendre, B. et al., 2014, ApJL, 790, 15: "A Hot Cocoon in the Ultra-long GRB 130925A: Hints of a POPIII-like Progenitor in a Low-Density Wind Environment"(**Paper 1**)
Greiner, J., Mazzali, P.A., Kann, D.A. et al., 2015, Nature, 523, 189:"A very luminous magnetar-powered supernova associated with an ultra-long γ-ray burst" (**Paper 2**)

1. **General question 1**

   (a) Gamma-ray bursts can be classified into two basic categories, what are these? What type of progenitors are believed to give rise to the two basic GRB types? How can radio observations be used to estimate the size of the emitting region in a GRB?

   (b) Describe the typical spectral energy distribution for a GRB. Where does the SED peak and what is the shape of it? What is causing the observed emission in the GRB afterglow and why do we need to account for relativistic beaming?

   (c) What is Swift and how can it be used for detected GRBs? Using the internet check how many GRBs Swift have detected to date and how they are distributed in the two main GRB classes. What is the highest confirmed redshift for a GRB?

2. **General question 2**

   (a) In what type of host galaxies are long GRBs usually found? How is the long GRB detection rate correlated with the metallicity of the host galaxy. Explain physically why you expect to see a correlation with metallicity for long GRBs.

   (b) Describe briefly the typical host galaxy of short GRBs. How can we deduce from their observed host galaxies that the triggering mechanism for long and short GRBs is different? How are short GRBs related to type Ia supernovae?

   (c) For the central GRB engine. Describe briefly the role of rotation, neutrinos and magnetic fields? What is a GRMHD code and why should such a code be used for simulating GRBs?

3. Based on **Paper 1** answer the following questions:

   (a) The authors have observed an ultra-long GRB. How does ultra-long GRBs differ from the more common long GRBs? What type of progenitor is expected for ultra-long GRBs, as opposed to long GRBs? How can one estimate the size of the GRB progenitor object from the duration of the GRB?

   (b) The authors fit the observed data with a two-component model, what are the two components and what do the authors believe is their emission mechanisms? Give also values for the estimated energies in the two components. Are the estimated energies consistent with the explanation for the ultra-long GRB progenitors.

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(c) Finally, the authors discuss the relationship of their detection with Pop III stars. What is a Pop III stars and where would you normally observe them? Has any Pop III stars been unambiguously detected so far? Would it be possible to observe Pop III stars at lower redshifts as well?

4. Based on **Paper 2** answer the following questions:

(a) In this paper the authors claim to have a detected a new class of ultra-long GRBs. What type of object is the progenitor candidate in this case and why cannot the progenitor be a type Ic supernovae?

(b) The spectra of the GRB is studied in the paper, what is unusual about the spectral features? What is the estimated photospheric outflow velocity and how does it compare with more typical long GRBs? Are there any indications for radioactivally decaying material in the afterglow and are any expected?

(c) Explain briefly what is the energy source believed to be powering this GRB? What level of collimation is required in order to reconcile the observed luminosity with the energy available from the central engine. Finally, what do the authors conclude about GRBs. Can all GRBs be described by one model or is a host of different progenitor objects required?