Exercises Stellar Transients

Useful numbers

These numbers may be useful when solving the exercises.

Solar mass	$M_\odot$	$1.99 \cdot 10^{33}$ g
Solar luminosity	$L_\odot$	$3.85 \cdot 10^{33}\,\mathrm{erg\,s^{-1}}$
Parsec	pc	$3.086 \cdot 10^{18}$ cm
Speed of light	c	$2.998 \cdot 10^{10}\,\mathrm{cm\,s^{-1}}$
Gravitational constant	G	$6.673 \cdot 10^{-8}\,\mathrm{erg\,cm\,g^{-2}}$
Mass of proton	m_p	$1.66 \cdot 10^{-24}$ g
Energy	1 eV	$1.602 \cdot 10^{-12}$ erg
	1 erg	10^{-7} Joule

Exercise 15: Novae vs. X-ray bursts

Argue that in both novae and X-ray bursts the released energy through nuclear burning per gramme of burnt matter is of the same order. Estimate this quantity, and use it to explain why nova explosions eject most of the accreted matter and X-ray bursts do not.

Exercise 11: V/Vmax as a measure of GRB uniformity

In class we discussed the GRB logN-logP distribution which tests the uniformity of GRBs as a function of distance. This is a somewhat cumbersome diagnostic because one needs to assess the instrumental calibration. Maarten Schmidt introduced an alternative which he previously applied to quasars in the late 1960s: V/Vmax. V/Vmax is is the volume encompassed by the GRB divided by the maximum volume visible to the instrument at the time of the GRB (remember that the latter may change because of changing detection thresholds due to changing background levels).

a. If GRBs are uniformly distributed in space, what value would be expected for the average of V/Vmax?

b. If the actual $<$V/Vmax$>$ is smaller than that, what does that mean?

c. Why is V/Vmax easier to use than logN-logP?

Exercise 12: GRB afterglow

The afterglow decay of GRB 970508 has irregulaties in it (like a rebrightening after a day), but exhibits nowhere a clear break.

a. Can you think of reasons why an achromatic break was never detected for this burst?

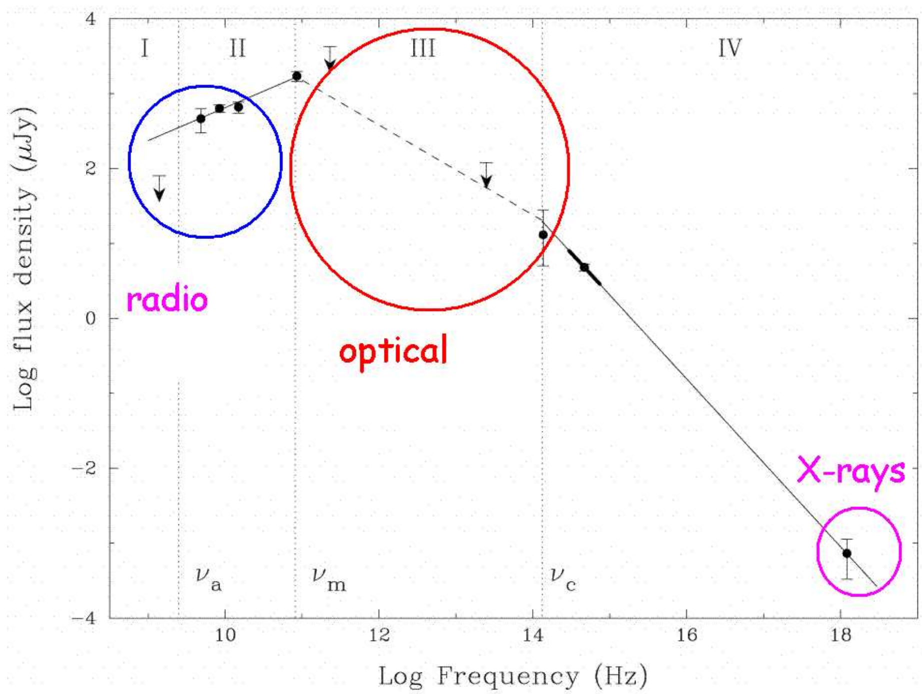
b. What radio observation provides a confirmation of one possible reason?

c. Working from the light curve in the lecture notes, estimate the decay index of the afterglow. Assume that the prompt emission ends and the afterglow emission starts at 70 s after the GRB start.

d. Estimate the X-ray radiative energy output of the prompt phase.

e. Estimate that of the afterglow up to 100 days after the burst (assuming it continues with the same power after the observations up to 100 days)

f. Assuming that the 'panchromatic' spectrum as depicted in the lecture notes applies throughout the 100 days, estimate the total energy output of the afterglow with an accuracy of a factor of a few and assess whether wavelength regimes other than X-rays are important to the energy budget of the afterglow.



Introduction to 4, 5 and 6

In the lecture we have seen that:

- electron-degenerate stars are white dwarfs
- white dwarfs cool to $T = 0$, and
- there is an upper limit to the mass of white dwarfs.

Here, we will investigate what happens if a white dwarf accretes mass such that it exceeds the upper mass limit (the Chandrasekhar mass). Note that this is not an academic question, but we know that this happens in the universe. Most white dwarfs are composed of a mixture of carbon and oxygen (roughly 50% each), and if one of them has a close binary companion, mass overflow onto the white dwarf may lead to a catastrophe...

Exercise 4

If we take a model of the sun and disturb it a little bit, i.e., we increase the central energy generation rate in the sun by a small amount, the following sequence of events happens in the model.

1. The increased nuclear energy generation will lead to a higher temperature in the center of the solar model.
2. The increased temperature will lead to an increased central pressure.
3. The force balance is disturbed, and the overpressure makes the core of the sun expand.
4. The expansion makes the temperature decrease.
5. As the nuclear fusion rate is a strongly increasing function of the temperature, the drop in temperature leads to a decrease of the nuclear energy generation rate.

The sun is stable against the applied disturbance.
Now, make the same gedankenexperiment with a white dwarf...