Exercises Stellar Transients

Useful numbers

These numbers may be useful when solving the exercises.

Solar mass	$M_\odot$	$1.99 \cdot 10^{33}\,\mathrm{g}$
Solar luminosity	$L_\odot$	$3.85 \cdot 10^{33}\,\mathrm{erg\,s^{-1}}$
Parsec	pc	$3.086 \cdot 10^{18}\,\mathrm{cm}$
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	$1.66 \cdot 10^{-24}\,\mathrm{g}$
Energy	1 eV	$1.602 \cdot 10^{-12}\,\mathrm{erg}$
	1 erg	10^{-7} Joule

Exercise 1: Etendue

The etendue of a telescope is the product of its field of view (usually expressed in square degrees) and mirror area (square meters). Assuming that the sensitivity of the telescope scales directly with the inverse of the mirror area, how many more Galactic sources will one detect when increasing the etendue with a factor of 2 and how many more cosmological sources?

Exercise 2: Transient rise time

The rise phase of a transient is the time when the instability is active, while the decay phase represents the mostly slower return to equilibrium.

a. There is a fundamental lower limit to the rise time. Can you think of what that is?

b. For the shortest transient events this is less than 1 ms. What does that suggest about the origin of these events?

Exercise 3: Stellar black holes

Most stellar black holes in our Galaxy are discovered in soft X-ray transients (15 of the 18 dynamically confirmed cases). On average the peak bolometric luminosity is approximately 10^{39} erg/s. In fact, most month-long transients with such a peak luminosity are black hole systems; there are only a handful exceptions. Most of the radiation (roughly 50% or more) is radiated in the classical X-ray band. The typical light curve consists of a fast rise and an exponential decay with an e-folding decay time of 30 days. Thus far, 37 such transients have been found in the Galaxy, 10 since 1996. The average recurrence time is thought to be of order 30 years.

a. What is the typical energy radiated by such a transient?

b. The radiation is powered by gravitational energy liberated by dumping the accretion disk on the compact object. How much mass is needed to provide the energy found in **a**, assuming that the material falls from infinity to a Schwarzschild radius of 10 km (for a non-spinning 3 solar mass black hole)?

c. What is approximate average mass transfer rate from the donor star?

d. Given the typical sensitivities of all-sky monitors, make an estimate of the limiting distance up to where these transients can be detected.

e. Make an order of magnitude estimate of the number of such systems in the Galaxy.

f. What would be the limiting distance if we were to use the Chandra telescope to search for such transients? Could we detect such transients in other galaxies? For a typical Chandra exposure, the sensitivity is 10^{-15} erg/s/cm2 in the classical X-ray band.