

Astronomy 20

Homework # 4

Posted on the class webpage on November 5, 2004

Return to TA (!) by 5 pm on Friday, November 12, 2004

1. A handy unit of energy is 1 Gipper = the amount of energy released in a global thermonuclear war (let's say, 10,000 1-megaton warheads; one of them releases $\sim 4 \times 10^{22}$ erg if carelessly dropped).
 - (a) What is the solar energy generation rate, in Gippers/sec?
 - (b) What is the fuel consumption rate of the Sun, in tons of hydrogen per sec? Assume the net efficiency of ~ 7 MeV per nucleon.
 - (c) How long does it take for the Earth to intercept the amount of sunlight equal to 1 Gipper?
 - (d) Consider a neutron star with the mass of $1.4 M_{\odot}$ and the radius of 30 km. If you drop a professor ($M_{Prof} \approx 80$ kg) on it from a safely large distance (i.e., where the binding energy ≈ 0), what would be the amount of energy released upon the impact, assuming that it is all converted into radiation?
2. Consider a type Ia supernova, whose progenitor is a carbon-oxygen white dwarf of a mass $M_{wd} = 1.4 M_{\odot}$, and radius $R_{wd} = 1500$ km. In burning of C and O to produce Fe-group elements, 7.3×10^{17} ergs are produced per gram of fuel.
 - (a) Estimate the binding energy of the white dwarf.
 - (b) What fraction of its mass has to be converted into iron in order to blow it apart?
 - (c) Assuming that practically all of its mass is ejected with average speeds of 5000 km/s, how much more iron has to be produced in order to supply the necessary kinetic energy?
3. One hypothesis for the origin of γ -ray bursts (GRBs) is that they represent spiral-down collisions of two neutron stars, whereby some of the surplus binding energy is released in the form of γ -rays. Consider a neutron star binary, with each component having a mass of $M_{ns} = 1.4 M_{\odot}$ and a radius $R_{ns} = 30$ km.
 - (a) Estimate the binding energy for each star as if it were isolated. Ignore any relativistic effects.
 - (b) Assume that after the collision, about 1% of their total initial binding energy is released as γ -rays over the burst time of 1 second. Compute this L_{γ} .
 - (c) Given this L_{γ} , and assuming the linear scale (i.e., an "effective radius" R) of the emission region to be about 10 km, what is the effective blackbody temperature T_{eff} ?
 - (d) Assuming (incorrectly, but OK for the homework purposes) that the emission is thermal, what is the energy (in Mev) of individual photons corresponding to the peak of the Planck curve for this T_{eff} ? Does this make sense?

(more on the other side)

Ay 20, HW4, problem 3, continued...

- (e) Many GRB-detecting satellites have a burst detection limit of $F_{lim} = 10^{-7}$ erg/cm². How far could they detect such hypothetical merger events, in Mpc?
- (f) If a mean separation between average galaxies is 5 Mpc, estimate how many galaxies are thus observable by these satellites.
- (g) If the average supernova rate per galaxy is ~ 1 event per 100 years, how many supernovæ per day happen among the total number of galaxies you just computed in (f)? Does this provide an adequate neutron star supply rate, given that we detect about 1 burst per day?