PHYS4000 Introduction to Astrophysics HW #3 Due 3 Mar 2017

(1) Maoz, Problem 4.1.

(2) Maoz, Problem 4.3.

(3) A burst of neutrinos from SN 1987A was observed by the KamkokaNDE-II detector in Japan on 23 Feb 1987, coinciding with the optical supernova signal from the Large Magellanic Cloud (LMC). (See also Maoz, Problem 4.3, i.e. Problem 2 above.) This was first reported in the article Hirata, et al., Phys.Rev.Lett.58(1987)1490. Eleven neutrino events were observed, and their arrival times and energies are reported in the article.

Show that the spread Δt in arrival times from the spread ΔE in energies is

$$\Delta t = \left|\frac{dt}{dE}\right| \Delta E \qquad \text{where} \qquad \frac{dt}{dE} = -\frac{d}{c}\frac{(mc^2)^2}{E^3}$$

where d is the distance to the LMC, mc^2 is the neutrino mass and $E \gg mc^2$. Use this result, the data from Hirata, et al., and the distance to the LMC to estimate an upper bound on the neutrino mass.

(4) Maoz, Problem 4.4. *Hint: For (a), it may be helpful for you to review your solution to Problem 3.3.*

I will point out to you that this analysis has far reaching consequences for cosmology. Type-IA supernovae are the most important "standard candles" for measuring distance on a cosmological scale. This problem emphasizes that their brightness does indeed come from a standard, and well understood, process, namely collapse of a white dwarf with mass just over the Chandrasekhar Mass.

(5) Find a journal article that reports the discovery of the highest mass neutron star observed. Discuss **briefly** how the mass was measured, and why this large mass is a challenge for our understanding of nuclear forces. *Hint: See the journal Nature in October 2010 for an article accompanied by an introductory article.*