Homework 1- Due Thursday Feb 21 2019

1. Black Body Spectrum 10 pts
A neutron star radiates as a black body with characteristic T = $3x10^6$K. Give an estimate of the characteristic wavelength of the radiation and the luminosity of the source (assume a radius of 10km). At a distance of 100pc what is its total flux?
Is the estimate of 10km for the emitting region reasonable/unreasonable?

2. Instrumentation question 15 pts
i) What sort of instrument (telescope, detector or combination) should one use to observe this neutron star and why (numbers please). In other words given the bandpass and effective area curves of modern x-ray observatories (Swift, XMM, Chandra, AstroSat etc) which one should you use and why(use the additional material on the class web site or the HEASARC web site for details on the satellites).
ii) Calculate (or use PIMMS (on the HEASARC web site) to estimate how far away Chandra can detect such a neutron star for a 10ks observation.– Is it this object detectable in the optical (3000-7000 A) band (Assume HST can reach 27^{th} mag in V)?

3. Bremmstrahlung 10 pts
The problem has 2 parts
1) assuming a uniform density gas, a size of 1 Mpc , that the emission mechanism is <u>only</u> thermal bremsstrahlung what is the density of gas required to produce 10^{44} ergs/sec in the 0.5-10 kev band from a plasma of temperature 4 keV.
2) The gas in clusters is not of uniform density: lets assume that at R<R(c) the gas density is constant and at R>R(c) it decreases as R^{-2} until the virial radius (R_{max}=2Mpc); what is the central gas density required to produce the same luminosity (assume that R(c)=200kpc.

4. What is high energy astrophysics ? (this is a short essay question) 15 pts
What sort of objects are in the purview of high energy astrophysics and why. For one of these objects/areas describe what could only be learned from high energy observations. Please keep answer to 2 paragraphs.

5. How Transparent is the universe to x-rays? 10 pts
An analytic expression for the cross section for absorption of photons is
$\sigma(E) = 2 \times 10^{-22}$ cm^2 (H atom)$^{-1}$(E/1keV)$^{-8/3}$
and the definition of mean free path of $r_{mfp}=1/(n_H\sigma)=1/\tau$ where n_H is the number density of hydrogen . Assume that the interstellar medium in our Galaxy contains an average density of 1 hydrogen atom per cubic centimeter.

a. Use the analytic expression above for a) UV photons of energy 20eV b) soft x-rays of 200 eV c) medium energy x-ray of 2 keV and hard x-rays of 20keV calculate the mean-free-path for a photon in the interstellar medium.
b) Considering a typical distance between stars of 1pc and the thickness of the galactic plane what is the reduction in flux of nearby stars and extragalactic objects at each of these energies; the flux that we detect, F(E), is related to the emittted flux, I(E) by F(E)=I(E)exp(–τ(E))

6) 15 pts

a) Why do we believe that the Crab nebulae emits primarily via synchrotron radiation across the entire electromagnetic spectrum from radio to GeV γ-rays?

b) What is the relative lifetime of the particles radiating at 1Gev, 10 keV and at 100 Mhz if they come from the same population of particles radiating in a magnetic field of 1 microgauss (See Rossweg and Bruggen eq 3.163 for the synchrotron cooling time: $\tau_{synch}=635\ B^{-2}E^{-1}$ sec where B is in Gauss and E is in ergs)

c) Are the values of magnetic field reasonable? Since the Crab is an extended source in the radio and x-ray should it be one in the γ-ray? (e.g. assume that the particles are being transported at some fraction of the speed of light into the nebulae).

You might be interested in looking at some of the recent papers on the high energy variability of the Crab (e.g. Wilson-Hodge et al. 2011, 2011ApJ...727L..40 and Rolf Buehler &Roger Blandford arxiv1309.7046.pdf) and comment on the observed and expected timescales for variability.