Examination. High Energy Astrophysics Dec. 12 2005

The exam should be handed in not later than Wednesday at 16.00 to Ulla Engberg. The exam is supposed to be solved independently, and without copying of the book or notes. To pass you need approximately half of the items correct (assuming you have done the home work problems). If you have questions you may call me (55 37 85 17) or better send an email (claes@astro.su.se) and I will call you, or come to my room, I will be in Copenhagen on Wednesday.

Problems

No special order in terms of difficulty!

1. A pulsar has a period of 2 milli-seconds and a slow-down rate of 10^{-19} s/s.
   (a) Estimate the age of the neutron star.
   (b) Estimate the magnetic field of the neutron star.

2. An active galaxy has a central black hole mass of 10^7 $M_\odot$ and accretes in a disk at a rate of 0.1 $M_\odot$ yr^{-1}.
   (a) Assume that the black hole is non-rotating. What is the radius of the last stable orbit?
   (b) Suppose the disk extends to this radius and that no energy is released inside this radius. What is the total luminosity of the disk?
   (c) What fraction of the Eddington luminosity of the black hole is this?
   (d) Estimate the maximum temperature of the disk, assuming it radiates like a black-body.

3. A supernova remnant has a radius of 4.1 pc and an age 400 years. The density of the interstellar medium in this direction is 1 cm^{-3}
   (a) Estimate the total energy in the explosion.
   (b) Calculate the temperature behind the shock.

(c) Assume that the magnetic energy is 10 % of the thermal energy behind the shock. What is the magnetic field?

(d) Calculate the frequency where synchrotron losses cause a break in the spectrum.

4. A cluster of galaxies has an X-ray luminosity of 10^{43} erg s^{-1} and a gas temperature of 10^8 K. The radius of the X-ray emitting region is 0.2 Mpc. Estimate the density and mass of the hot gas in the cluster, assuming that the density and temperature are roughly constant.

Theory

Max 1 A4 page per item (and preferably less!). Be concise without loosing content.

5. Give an argument why there is an upper limit to the mass of a degenerate star (without nuclear burning), i.e. the Chandrasekhar mass. Preferably refer to formulae.

6. Discuss briefly the collapse and the explosion of the core of a massive star, emphasizing the physics involved. Do not forget the energy aspect.

7. Which two types of gamma-ray bursts are there, what characterize them and describe briefly the main ingredients of the most popular models for these? What observational evidence is there which speaks in favor of these models?

8. The inner regions of an accreting disk has usually a high enough temperature that the opacity is dominated by electron scattering and the pressure by radiation pressure. Therefore, $\kappa = \kappa_T = \sigma_T/m_p = 0.4\ \mathrm{cm}^2\mathrm{g}^{-1}$ is the Thompson opacity, and $p = \sigma T^4/3c$.

   (a) Show from the disk equations that the thickness of the disk is given by

$$H = \frac{3\dot{m}\sigma_T}{8\pi c m_p}[1 - \left(\frac{r_s}{r}\right)^{1/2}].$$

   (b) By writing the accretion rate in terms of the total luminosity of the disk show that

$$\frac{H}{r_s} = \frac{3L}{L_{Edd}}[1 - \left(\frac{r_s}{r}\right)^{1/2}].$$

where L_{Edd} is the Eddington luminosity. A disk radiating close to the Eddington luminosity can therefore in the inner parts no longer be considered as thin.

1 pc $= 3.09 \times 10^{18}$ cm, 1 erg $= 10^{-7}$ W, $\kappa_T = 0.4$ cm^2 g^{-1}

Good luck!
Claes