Qualification Examination --- Galactic and Extragalactic Astronomy
May 2019

1. X-ray photons are produced in a cloud of radius R at the uniform rate Γ (photons per unit volume per unit time). The cloud is a distance d away. Neglect absorption of these photons (optically thin medium). A detector at earth has an angular acceptance beam of half-angle $\Delta\theta$ and it has an effective area of ΔA.

[25 points]

A. Assume that the source is completely resolved. What is the observed intensity (photons per unit time per unit area per steradian) toward the center of the cloud. [5points]

B. Assume that the source is completely unresolved. What is the observed average intensity when the source is the beam of the detector? [5points]

C. X-ray interferometer satellites, if technically feasible (e.g. MAXIM/NASA), will offer the best spatial resolution. Assume the baseline of d = 20m, using X-rays with 12.4 keV (i.e. $1\,\text{Å}$). What is the expected spatial resolution? [2points]

D. Schwarzschild radius appears in the Schwarzschild metric, that is a solution of the Einstein equation. However, it coincides with the radius where the escape velocity become the light velocity in Newtonian mechanics. Please derive the radius using light speed c, blackhole mass of M, and gravitational constant G. [2points]

E. Assuming the distance to the blackhole d, please derive the apparent size of the black hole. [2points]

F. Is the X-ray interferometer sufficient enough to resolve the stellar mass black hole such as GRB1915+105? If needed, please use the distance of 9 kpc (pc=3×10^{16}m) and mass of 14 solar mass. (1 solar mass 2×10^{30} kg) [3points]

G. Using gravitational wave, a black hole merger was discovered. What is the importance of this discovery in terms of black hole astrophysics? [3points]

H. What is the detection mechanism (or physics) of gravitational wave? [5 points]

2. Large part of universe is plasma. [25points]

A. Please describe five differences between plasma and neutral gas. [2 points x 5 = 10 points]

B. Now we consider an isothermal spherical symmetry cluster of galaxies, which electron temperature of T_e and number density of electron ne. The n_e is described as

$$n_e(r) = \frac{n_0}{[1 + (r/r_c)^2]^{3/2}}$$

Here, r, r_c, and n_0 indicate distance from the center of cluster of galaxies, core radius, and electron number density at the center of cluster of galaxies, respectively. The redshift is extremely smaller than 1.

Please derive the formula of the total luminosity of thermal bremsstrahlung from the cluster of galaxies. The energy of thermal bremsstrahlung per unit time, unit volume, and unit frequency is expressed as

$$\epsilon_\nu = \alpha n_e^2 T_e^{-1/2} \exp\left(-\frac{h\nu}{kT_e}\right)$$

Here $\nu, h, k, and \alpha$ are frequency, Planck constant, Boltzmann constant and physical constant, respectively.

[5 points]

C. To find cluster of galaxies, X-ray observations are extremely powerful. Please explain the reason in terms of the emissivity. [5 points]

D. Radio observations (e.g. AMiBA, SMA, JCMT, ALMA as the Taiwanese resources) for cluster of galaxies are also important. Please describe the physical background of the observations. [5 points]

3. Distance [25 points]

A. How do we measure the distance to some nearby stars in the Milky Way? (Considering at least two methods) [5 points]

B. When we see a faint star, how do we know the faintness is caused by distance or by dust extinction? [5 points]

C. How do we measure the distance to the center of the Milky Way? (Considering at least two methods) [5 points]

D. What is the angular diameter distance? [5 points]

E. Is there a maximum angular diameter distance in the universe? If yes, what is it? [5 points]

4. Mass [15 points]

A. How do we measure the total mass of an elliptical galaxy? [5 points]

B. How do we measure the stellar mass of an elliptical galaxy? [5 points]

C. How do we measure the molecular mass of an elliptical galaxy? [5 points]

5. Dark Matter [10 points]

A. What is the evidence of dark matter? (considering at least three different evidences) [5 points]

B. Can stellar black holes be the major part of dark matter? If not, why? [5 points]