Institute of Astronomy, National Central University

PHD QUALIFYING EXAMINATION — GALACTIC AND EXTRAGALACTIC ASTROPHYSICS

27th May, 2004

(1) (15 points)
   (a) (10 points) Derive the Eddington luminosity.
   (b) (5 points) It was found that the X-ray binary sources in Magellanic Clouds are in general more luminous than those in the Milky Way. Please try to give a possible explanation for this phenomenon. [Hint: consider the formula of the Eddington luminosity.]

(2) (20 points)
   The current cosmic black body radiation has a temperature $T = 2.7$ K, and the current matter density is $\rho_{\rm m0} = 3 \times 10^{-31}$ g cm^{-3}.
   (a) (10 points) If the recombination temperature of the proton and electron is 3,000 K, what is the redshift of the recombination epoch?
   (b) (10 points) What is the redshift when the Universe transferred from radiation-dominated to matter-dominated?
   (The radiation constant $a = 7.565 \times 10^{-15}$ erg cm^{-3} deg^{-4}.)

(3) (15 points)
   Suppose that the stellar density profile in a spherical elliptical galaxy falls as $n_* \sim r^{-\alpha}$. Show that the density profile of the isothermal interstellar gas in the galaxy will vary as $n \sim r^{-\alpha\beta}$, where β is the ratio of the average kinetic energy of a star to the thermal energy of an isothermal gas particle.
   [Hint: assume that each component of the galaxy is in hydrostatic equilibrium with the gravitational potential.]

(4) (20 points)
   In the 20th century, there have been 3 famous examples of "distance determination" to certain celestial objects. Please describe the key person (people) involved, the observational methodologies used in the determination of distance, and the most important physical significance of these objects inferred from the observations in the 3 cases.
   (i) The 1st one was in the 1920's, about the distances to the many "nebulae". There was an important debate held in 1920 regarding the nature and distances to these nebulae. Who were involved in the debate? Whose discovery of what gave an answer to this debate? What was the observational methodology (and the celestial objects) involved?
   (ii) The 2nd one was in the 1960's, about the distance to quasi-stellar objects (QSOs). What was the key mystery regarding the observed spectrum? Who solved the mystery and how? How is this related to the interpretation of the physical nature of QSOs?
   (iii) The 3rd one was in the 1990's, about the distances to the "Gamma-Ray Bursts" (GRBs). In 1995 there was an important debate regarding the nature and distances to these bursts. Who were involved in the debate and what were their points of view? What can we infer from the all-sky monitoring of GRB's conducted by the "Compton Gamma-Ray Observatory"?

(5) (15 points)

What can we infer from the "flat" galactic rotational curves? Tully-Fisher relation states that the luminosity of a galaxy is proportional to the 4th power of its maximum rotation speed, $V_{\rm max}$. If we take this maximum speed as the flat portion of the rotation curve, please derive the relation. During the derivation, one has to use the idea of "mass-to-light" ratio. Please describe the physical meaning of "mass-to-light" ratio. How does the estimated "mass-to-light ratio" vary from solar neighborhood to spiral arms, to galaxy, to galaxy clusters, and to the Universe?

(6) (15 points)

What are the observational signatures of "BL Lac Objects"? How do we determine the distances to these objects? What mechanism(s) are thought to be responsible for the fast varying brightness of these objects? How are these objects related to the more "traditional" quasars? Superluminal motion is sometimes thought to be related to these objects. Please describe why we could see "superluminal motion".