Institute of Astronomy, National Central University

PHD QUALIFYING EXAMINATION — GALACTIC AND EXTRAGALACTIC ASTROPPHYSICS

30th May, 2006

Please answer 5 out of the following 6 problems.

(1) (20 points)

(a) (10 points) Show that the line of sight velocity of a material, which is located at distance R from the Galactic Center and at the direction $(l, b) = (l, 0)$, is given by

$$v_{\rm los}(l, R) = [\Omega(R) - \Omega(R_0)]R_0 \sin l,$$

where R_0 is the distance of the Sun from the Galactic Center, $\Omega(R)$ is the angular velocity at a distance R from the Galactic Center.

(b) (10 points) We set $R_A = 0.1R_0$, $R_B = 0.9R_0$ and $R_C = 1.5R_0$ and assume flat rotation curve, i.e., $v_0 = \Omega(R)R = \text{constant}$. We define $v_A(l) \equiv v_{\rm los}(l, R_A)$, $v_B(l) \equiv v_{\rm los}(l, R_B)$, and $v_C(l) \equiv v_{\rm los}(l, R_C)$. When $l = 0$, arrange $|\mathrm{d}v_A(l)/\mathrm{d}l|$, $|\mathrm{d}v_B(l)/\mathrm{d}l|$, and $|\mathrm{d}v_C(l)\mathrm{d}l|$ in descending order. Moreover, when $l = \pi/4$, what is the minimum value of R to make the material on the line of sight?

(2) (20 points)

(a) (5 points) Describe the concept of Dynamical Friction.

(b) (10 points) Due to the Dynamical Friction, a globular cluster of mass M at r would fall into the Galactic Center according to:

$$r\frac{\mathrm{d}r}{\mathrm{d}t} = -4.28\frac{GM}{v_c},$$

where r is the distance from the Galactic Center, and v_c is a constant for flat rotation curve. Assume Globular Cluster A has mass $10^6 M_\odot$ and is initially at $r(0) = 20$ kpc. How long will they take to reach the Galactic Center in unit of T_A years? Comment on your results.

(3) (20 points)

If one can observe the velocity distribution $v_c(r)$ of circular orbits of a spherically symmetric system, one can deduce the mass distribution $M(r)$ of the system.

(a) (5 points) Derive an appropriate formula relating the circular velocity $v_c(r)$ and the mass $M(r)$ enclosed inside r.

(b) (15 points) Please express v_c as function of r for (i) a point mass, (ii) a homogeneous sphere of radius a, and (iii) a sphere described by the Isochrone phtential:

$$\Phi(r) = -\frac{GM_0}{b + \sqrt{b^2 + r^2}}.$$

Sketch the three v_c distributions.

(4) (20 points)

(a) (10 points) What are the observational signatures of Quasi-stellar objects (QSOs)? Please describe these observational properties in terms of their "continuum emission" (e.g. shape of continuum across the entire electromagnetic spectrum), "line properties" (emission or absorption, narrow or broad), "variability" (in different wavelengthes from X-ray to radio), and "jet" (their morphology and the wavelength regions in which jets are observed).

(b) (10 points) Please describe the physical mechanisms responsible for the generation of their "continuum emission", "lines", "variability" (e.g. light traveling argument), and "jet" (including "superluminal motion").

(5) (20 points)

(a) (10 points) It is generally believed that Seyfert 1 galaxies are the lower-redshift counterparts of QSOs. However, Seyfert 2 galaxies have quite different observational properties from Seyfert 1's. Please describe the major differences between these two kinds of active galaxies. From the spectro-polarmetric observations performed in the mid-80's, astronomers claimed that at least some Seyfert 2's are "hidden Seyfert 1's". Please explain why.

(b) (10 points) The closest quasar 3C273 has an apparent visual magnitude of V = 12.8. If we adopt h = 0.5 (for a distance of 880 Mpc), please calculate the absolute magnitude (in V) of 3C273. If the absolute magnitude of the Sun is $M_{\odot} = +4.76$, please calculate the visual luminosity of 3C273.

[Note: 1 pc = 3×10^{18} cm]

(6) (20 points)

(a) (5 points) It is a general consensus now that there exists a "supermassive blackhole" (SMBH) in the center of our Galaxy. Please describe the two major dynamical evidences for this claim.

[Hint: one evidence comes from the gas in the vicinity of the core, while another evidence is from the stars close to the center observed by VLT in IR.]

(b) (5 points) A gas cloud 0.3 pc from the center of our Galaxy has a measured velocity of 260 km s^{-1}. If the cloud is in orbit of the center, please calculate the mass enclosed in the region which is responsible of this motion. What is the Schwarzschild radius of this "black hole" corresponding to this mass?

[Note: $M_{\odot} = 2 \times 10^{33}$ g, $R_{\odot} = 7 \times 10^{10}$ cm, AU $= 1.5 \times 10^{13}$cm, $G = 6.67 \times 10^{-8}$ dyne cm^2 g^{-2}, $c = 3 \times 10^{10}$ cm s^{-1}]

(c) (10 points) Various observations indicate that a UV luminosity of $10^7 L_{\odot}$ is required to generate the IR radiation detected near the center of our Galaxy. If we assume that the luminosity of the central continuum source is generated by the gravitational energy released from material falling toward the central "SMBH", with the mass you calculated in (b), please calculate how much mass per year ($\dot{M}$, in units of $M_{\odot}$ yr^{-1}) is needed to generate the observed UV luminosity.

[Hint: $E = \frac{1}{2}(GM_{\rm bh}M/r_f - GM_{\rm bh}M/r_i), L = {\rm d}E/{\rm d}t$]