

Institute of Astronomy, National Central University

PHD QUALIFYING EXAMINATION — GALACTIC AND EXTRAGALACTIC ASTROPHYSICS

9:00–13:00, 21st May, 2014

(1) (30 points) **Mass of galaxies and cluster of galaxies**

- (a) (5 points) How can we determine the mass of a spiral galaxy and a elliptical galaxy?
- (b) (15 points) Please explain what is Virial theorem. When we consider gravity and electromagnetic force cases ($U \sim r^{-1}$ case), please proof $2\langle K \rangle + \langle U \rangle = 0$. Here K and U are kinetic and potential energy, $\langle X \rangle$ is the long-term time average of quantity “ X ”. Please explain how to estimate the mass of a cluster of galaxies from observations using Virial theorem.
- (c) (10 points) For a cluster of galaxies with X-ray emission from intra-cluster hot gas, we can determine the mass of the cluster by assuming a pressure equilibrium between the gravity of the cluster and the thermal pressure of the hot gas. Show that the mass within a radius r of the cluster center is

$$M_r = - \frac{r^2 k_B T}{G \mu m_p} \left(\frac{1}{n} \frac{\partial n}{\partial r} + \frac{1}{T} \frac{\partial T}{\partial r} \right),$$

where k_B is the Boltzmann constant, m_p is the mass of proton, μ is the mean molecular weight, T is the temperature of the hot gas, and n is number density of hot gas.

(2) (10 points) **Active galaxies**

- (a) (5 points) What are the characteristics of active galactic nuclei (AGNs), i.e., in what situations will you call your source an AGN instead of a normal galaxy?
- (b) (5 points) What is the unification model of AGNs?

(3) (15 points) **Molecular gas**

- (a) (5 points) To determine the mass of a molecular cloud, we usually have to observe CO rotational emission lines using millimeter and sub-millimeter telescope, such as ALMA. Why don't or can't we observe the H₂ directly?
- (b) (5 points) Are there H₂ vibration transitions? If yes, what is the problem for people to observe the H₂ vibration lines to determine the mass of the molecular clouds?
- (c) (5 points) It is also known that CO rotational lines are usually optically thick. How and why can we determine the mass of a single molecular cloud and the total molecular mass of a galaxy using the optical thick CO lines?

(4) (18 points) **Distances**

- (a) (3 points) List at least three different methods in measuring distances to astronomical sources.
- (b) (5 points) Please explain and compare the meaning of the luminosity distance and the angular-diameter distance of a high-redshift galaxy.
- (c) (5 points) If a high-redshift galaxy has a diameter of 20 kpc, what is the smallest angular size of this galaxy we can observe in a matter-dominated universe?
- (d) (5 points) What is the redshift of the galaxy when it appears to have the smallest angular size?

(5) (15 points) **Dark energy**

The 2011 Nobel Prize of Physics was given to the discovery of dark energy.

- (a) (5 points) Please explain how did they discover it.
- (b) (10 points) Two strategic surveys, Dark Energy Survey (DES) and Hyper-Suprime-Cam have just started. The main aim of these surveys is dark energy. How they are going to studies with these strategic observations?

(6) (12 points) **Emission mechanisms and metallicity**

- (a) (5 points) Major emission mechanisms of astronomical objects can be divided into thermal, non-thermal and line emissions. Please describe all these mechanisms. Please list astronomical objects for each emission mechanism.
- (b) (7 points) Metallicity is one of the key physical parameters to study chemical evolution of galaxies. To express metallicity, astronomers use the solar abundance. Why we need to use it? Why metallicity is important to understand cosmic and galaxy evolution? Please describe the detail.