

**Graduate Institute of Astronomy, National Central University**  
**PHD QUALIFYING EXAMINATION 2023 — Galactic and Extragalactic Astrophysics**

1. Distance measurement of galaxies is always challenging in astronomy. **(a)** Please describe in detail how we could use the rotational velocity of disk galaxies to measure their distances. (10 points) **(b)** For those galaxies with little or negligible rotation (such as elliptical galaxies), please describe the alternatives (except for the supernovae or cepheids) that we could use to measure their distances. (10 points)
2. **(a)** Please explain the physical mechanism of producing X-ray emission in galaxy clusters and why the galaxy clusters are bright sources in X-ray. (15 points) **(b)** Please explain the Sunyaev-Zeldovich (S-Z) effect and show that how we can use the S-Z effect to detect the galaxy clusters from observations. (15 points)
3. Please show that the escape velocity  $v_e$  for a star in a globular clusters of  $N$  stars, is twice the typical random velocity  $v$  ( $v_e = 2v$ ) (10 points). What is the size of the cluster if  $N=10^6$  and assuming that the typical star mass  $m = 0.5$  solar mass, and  $v = 20$  km/sec? (10 points) (One solar mass =  $2 \times 10^{33}$  g and the gravitational constant  $G = 6.67 \times 10^{-8}$  cm<sup>3</sup>s<sup>-2</sup>g<sup>-1</sup>.)
4. In some VLBI observations of AGNs, we can observe some phenomena showing apparently fast-than-light motion, which is called “superluminal motion”. How do you explain this phenomenon? (10 points). On the other hand, following the Hubble’s law, we should derive that the velocity of a very distant galaxy is greater than the speed of light. How do you explain this using the Hubble’s law? (10 points).
5. Please explain what are luminous distance and angular-diameter distance. (5 points) What is difference of these two distances for a galaxy at redshift  $z=7$ ? (5 points)