Qualification Examination—Galactic and Extragalactic Astronomy
May, 2012

1. Motion of the Galaxy:

(a) How do we know the sun is moving with respect to the nearby stars, i.e., how do we know the motion of the sun relative to the Local Standard of Rest (LSR)? (5 point)

(b) How can you determine the rotating velocity of the LSR rotating about the Galactic center? and what is the meaning of the Oort's constants? (10 points)

(c) How can you determine the distance to the Galactic center? (5 points)

2. Atomic and molecular gas:

(a) There are neutral (atomic) gas and molecular gas in the interstellar medium of galaxies. Describe the methods we use to detect them. (5 points)

(b) Why don't we detect the hydrogen molecular gas H_2 directly? (5 points)

3. Rotation curve of spiral galaxies:

(a) Draw a typical rotation curve (velocity verse radius) of a spiral galaxy. (5 points)

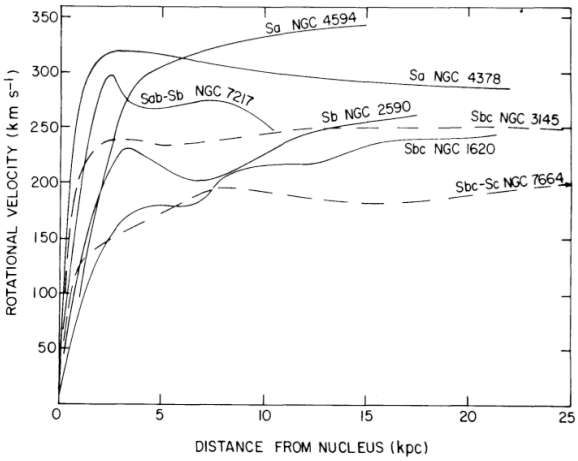
(b) How do you explain this type of rotation curve and what is its implication? (5 points)

4. Dark Energy:

The 2011 Nobel Prize of Physics was given to the discovery of dark energy. If your friends or your neighbors heard about this news and ask you about how you astronomers know that there is dark energy in the universe? and why the discovery deserves the Nobel prize? How would you answer their questions as a professional? (10 points)

Note : Please answer the following questions in English, because questions are written in English.

5. The right figure shows the rotation curve of spiral galaxies. Around the central part of galaxies, the curve shows the rigid body rotation. When we consider the spherical symmetry mass density distribution (p(r)=p_0= constant), please prove the rotation curve becomes the rigid body rotation. [3 points]



We also consider the rotation curve at r> 10 kpc. This radius is significantly larger than the size of galaxies. With this condition, the total mass of galaxies is expressed with M_G(r). Please derive the expected rotation velocity. [5 points]

The actual rotation curves of the galaxies are totally different with above assumption. The major reason is the existence of "Dark Matter". To explain the actual rotation curve, what kind of conditions (e.g. mass density profiles) are required? [5 points]

The origin of Dark Matter is totally unknown. To explain the observational results, Could dark Matter is required. Please describe four requirements. [8 points]

6. Three Professors (Prof. Saul Perlmutter, Prof. Brian P. Schmidt, and Prof Adam G. Riess) were awarded the Nobel Prize in Physics 2011. What was their major discovery? [5 points]

Please also describe their method to achieve this discovery. Please don't mention just the type of object. Please describe the background physics and/or instrumental improvements etc. [5 points]

7. The current Universe is believed to start from "Big Bang". There are three observational evidences. These are (a) the Hubble's law, (b) the abundance of light element, and (c) Cosmic Microwave Background (CMB). Please describe the details. Please also don't forget to describe why these observational results are evidences of "Big Bang". If you need, please also use some equations and figures. [9 points]

8. To find out large-scale structure, astrophysicists made the CfA survey, SDSS survey and so on (so-called galaxy survey or redshift survey).

(4-1) For these surveys, we needed to estimate redshift. Please describe how to measure redshifts for galaxies. Please also mention the physical backgrounds of the emissions (line, continuum, absorption etc) for the measurements. [5 points]
(4-2) Cluster of galaxies is one of the large scale structure in the Universe. Bottom figure shows X-ray (left) and optical (right) images for one of cluster fields with same spatial size. Please explain why there are significant differences. Please also mention the differences between plasma and neutral gas if you want to use plasma as the differences. [5 points]