Contemporary Astronomy Homework
Assignment 1 – PR

1. Our solar system is only about 4.5 billion years old, whereas the Milky Way galaxy is at least 10-12 billion years old. Open clusters of stars are about 50 million years old. Extremely large stars can only last a few million years, yet we see them shining. What does this prove?
   • Stars did not form all at once and that the process of star formation is a continuous process that is still occurring.

2. What are the types of nebula and their characterizing features?
   • Emission nebulae – a hot gas cloud whose atoms emit light. The star(s) that is(are) imbedded within the cloud that are responsible for the heating may or may not be visible.
   • Dark nebulae – a gas and dust cloud so dense that it extinguishes the light sources beyond it.
   • Reflection nebula – a gas and dust cloud that reflects starlight; principally blue light is scattered toward the observer.
   • Supernovae nebulae – an expanding shell of gas and dust that is expanding outward from a supernova.
   • Planetary nebulae – an expanding shell of gas and dust that is expanding outward from a star is shedding mass in the late stages of its evolutionary lifetime.

3. What is the source of 21cm radio wavelength radiation in space?
   • Neutral atomic Hydrogen.

4. What are HII regions of space and what are the types of radiation that are emitted there?
   • Regions of gas and dust where Hydrogen is in an ionized condition.
   • Emitted light is principally red due to the Hydrogen-alpha line transition. (level 3→2)

5. What portion of the electromagnetic spectrum is used to map the location and distribution of interstellar gas and dust?
   • Radio waves, principally 21 cm radiation from atomic Hydrogen but with contributions by other organic molecules such as Carbon Monoxide (CO).
   • Visible light principally red light from atomic hydrogen.

6. What information about interstellar gas and dust can be gleaned from absorption spectra of starlight that passes through it?
   • Chemical composition
   • Temperature
   • Velocity
   • Density

7. What is reddening?
   • Starlight that has become relatively more red due to the relatively higher rate of scattering of short wavelength light (blue light) versus long wavelength light (red light).

8. What is extinction?
   • The complete dimming of starlight due to the presence of gas and dust.

9. What is the most likely reason that a particular area of space is dark?
   • Gas and dust have completely extinguished background light.

10. Match the particular portions of the electromagnetic spectrum (type of radiation) that can be used to map the following sources: gases, stars, very hot gasses, regions of electron-positron annihilation?
    • Gases – visible, radio
    • Stars – visible, infrared
    • Very hot gases – x-ray
    • Electron/Positron annihilation regions – gamma rays

11. What is the basic structure of the Milky Way Galaxy?
    • A flattened disk with spiral arms.
    • A central nuclear bulge.
12. How is the mass of the Milky Way Galaxy determined?
   • By applying Kepler’s laws and the law of gravity for the Sun the mass contained within the Sun’s orbit can be calculated.
   • By applying Kepler’s laws and the law of gravity to the motions of nearby galaxies.

13. What determines how long the Milky Way galaxy will be luminous?
   • The rate of formation of stars. Eventually all the gas and dust that can form stars will have done so.

14. What are the characteristics of Population I stars in the Milky Way Galaxy?
   • Their spectra show the presence of heavier elements.
   • They are found in the disk plane of the galaxy.
   • They are young stars.

15. What are the characteristics of Population II stars in the Milky Way Galaxy?
   • Their spectra show the absence of heavier elements.
   • They are found in the halo and bulge areas of the galaxy.
   • They are old stars.

16. A star forming region is dominated by the presence of which type of stars?
   • Type O and B.
   • Large, hot stars.

17. Where in a galaxy is one likely to find open clusters?
   • In the disk region, particularly within the spiral arms.

18. Where in a galaxy is one likely to find globular clusters?
   • In the halo and bulge region.

19. Where should one look in the sky to look in the direction of the center of the Milky Way Galaxy?
   • In the direction of the constellation of Sagittarius.

20. What evidence supports the existence of a black hole at the center of the Milky Way Galaxy?
   • The orbits of nearby objects indicate a central mass of 2-4 million solar masses.
   • The volume within which this large mass is located is very small.
   • The center region does not itself emit light.

21. What is Sagittarius A?
   • An incredibly small radio source less than 10 AU in diameter at the center of the Milky Way galaxy that is believed to contain an enormous black hole.

22. Surrounding the center of the Milky Way Galaxy is an irregular disk of molecular clouds in the shape of a donut-shaped ring surrounding a void that lacks dust and gas. This ring starts about 5-7 ly from the center of the galaxy and is about 15 ly thick. What could be responsible for the lack of dust or cold gas between the donut-shaped ring and the center of the Milky Way Galaxy?
   • An extremely energetic event, perhaps a supernova blast.

23. What is the estimated radius of the black hole speculated to be at the center of the Milky Way Galaxy?
   • 2-3 AU

24. There is something missing from the radiation expected from the region immediately surrounding the center of the Milky Way Galaxy that does not support the theory that there is a black hole there. What is missing?
   • An extremely strong X-ray source.

25. A graph of stellar orbital speeds versus distances from the center of the Milky Way Galaxy (often referred to as a velocity distribution curve or rotation curve) is “flatter” than expected. What does this mean?
   • Stars are moving faster than would be indicated by the luminous mass in the galaxy.

26. What is the primary reason for postulating the existence of Dark Matter in galaxies?
• The stellar velocity distributions as a function of distance from the galactic nuclei (as indicated by stellar rotation curves) are essentially constant and shouldn’t be based on the luminous mass.

27. **Is all dark matter thought to be unusual or mysterious?**
   • The only thing unusual about a portion of the matter is that it is not radiantly visible. It is still baryonic (normal) matter.
   • The remaining portion is very mysterious in that it does not radiate or interact with radiation yet still has mass and interacts gravitationally.

28. **Distinguish between MACHO’s and WIMP’s.**
   • MACHO’s are thought to be normal baryonic matter in the form of planetesimal-sized bodies, extremely low mass cool stars, dead white dwarfs or neutron stars, black holes, or sub-atomic baryonic particles such as neutrinos.
   • WIMP’s are thought to be a new type of sub-nuclear matter that does not radiate or interact with radiation but still has mass and interacts gravitationally.

29. **What is a gravitational lens?**
   • Mass changes space-time in such a way that it changes the path of light, resulting in a deflection in the direction of the mass. This deflection can produce images, similar to the way images are formed by the deflection of light passing through a lens.

30. **What type of dark matter in the Milky Way Galaxy would cause gravitational lensing?**
   • Large massive bodies such as stars, galaxies, and clusters of galaxies.

31. **What are the desirable characteristics of a standard candle?**
   • An object whose luminosity or size is large.
   • Variations in luminosity or size are small.
   • The object is common.

32. **How was the distance to the Andromeda Galaxy determined?**
   • The periodicity-luminosity relationship for Cepheid variable stars.

33. **What is the Hubble law?**
   • The cosmological red-shifts of all galaxies other than those in the Local Group are directly proportional to the distances of the galaxies.

34. **Why does the Hubble law imply an expanding universe?**
   • All galaxies in all directions are moving away from each other.
   • The distance between a galaxy and every other galaxy increases with time.
   • This is only consistent with a universe in which space itself is expanding.

35. **What is the Hubble Constant?**
   • The slope of the graph of recessional velocity versus distance.
   • The rate at which the universe is expanding.

36. **What is the importance of the Hubble Constant?**
   • It implies the existence of an expanding universe created by a Big Bang.
   • It sets a limit on the age and size of the observable universe.

37. **Distinguish between reddening and red-shifting of light from a star?**
   • Reddening occurs when the scattering of light from a star differentially removes more blue light than red light leaving the remaining light redder.
   • Red-shifts refer to the proportional lengthening of all the wavelengths emanating from a source due to both the recessional velocity of the source and the mass of the source. It is not restricted to visible wavelengths of radiation and does not make the source appear red.

38. **What are the basic types of galaxies?**
   • Spiral
   • Elliptical
   • Irregular
39. What is the basic hypothesis of Hubble (known to be incorrect) in developing his galaxy tuning-fork diagram?
   • That the tuning-fork diagram is also an evolutionary pathway that explains the progression of a galaxy, in its life-cycle, through the various types of shapes.

40. What does “galactic cannibalism” refer to?
   • The interaction of a larger galaxy with a smaller galaxy and the subsequent merger of the two galaxies into one.

41. How does one know if a galaxy is young?
   • In reference to its age with respect to the Big Bang, the more distant the object the further back in time one is seeing the galaxy and therefore the younger it is.

42. If mergers are a mechanism for the production of larger galaxies and the production of elliptical galaxies, what would you expect to see in young galactic clusters?
   • A higher proportion of smaller galaxies
   • A higher density of galaxies
   • Evidence of interactions

43. What distinguishes an Active Galaxy from a “normal” galaxy?
   • The core region emits abnormally large amounts of energy.

44. What are the three basic types of Active galaxies and what are their characteristic features?
   • Radio galaxies – generally elliptical with bi-polar emission regions outside the core of the galaxy called radio lobes. The lobes are “fed” by electron jets emanating from the core of the galaxy that radiate synchrotron radiation.
   • Seyfert galaxies – spiral galaxies whose core is abnormally luminous and whose luminosity fluctuates with periods of several months or as short as several hours.
   • Quasars - extremely distant objects whose core regions are extremely small, extremely luminous, and whose luminosity varies in periods as short as several hours to periods as long as several months.

45. How is synchrotron radiation different from thermal radiation?
   • Synchrotron radiation is a form of radiation emitted by extremely fast moving charged particles interacting with magnetic fields.
   • Thermal radiation is radiation emitted by an object that is determined solely by the temperature of the object.

46. What type of radiation is most prominent in Active Galactic Nuclei?
   • Non-thermal radiation or “synchrotron” radiation.

47. What is a Quasar?
   • A quasi-stellar object with very high red-shift.
   • An active galactic nuclei with a very high red-shift.

48. What are the assumptions that lead to the interpretation that Quasars are extremely bright and extremely small?
   • Brightness - Their high red-shifts are assumed to follow the Hubble Law indicating that the objects are very far away and thus extraordinarily bright.
   • Size – Their relatively rapid variation in light intensity is limited by the speed of light and their size, thus they must be very small.

49. What is the basic idea behind the black hole-accretion disk model for Active Galactic Nuclei?
   • Extremely large black hole exists at the center of a galaxy accompanies by an extremely large accretion disk of matter swirling around them.
   • The radiation from the matter drawn into the black hole is the source of the extreme luminosity.
   • The dynamics of the rotating accretion disk material produces magnetic fields that direct escaping charges to form the jets and radio lobes associated with AGN’s (Active Galactic Nuclei).

50. What is the Local Group and how large is it?
   • A grouping of about 30 galaxies spanning about 5 million light years.
   • The larger members are three spirals, one of which is our Milky Way galaxy.
   • The remaining members are mostly small dwarf elliptical galaxies and a few irregular galaxies.
51. **What are the nearest Galactic clusters to our Local Group?**
   In order of distance:
   • The Canes Venaticorum Cluster
   • The Ursa Major Cluster
   • The Virgo Cluster (the largest)

52. **What is the size of the Local Supercluster to which the Local Group belong?**
   • It spans about 100 million light-years.

53. **What does the “Great Wall” refer to?**
   • An immense flattened cluster of superclusters lying approximately 330 million light-years away that spans a region of about 500 x 200 x 16 million light years.

54. **What does the “Great Attractor” refer to?**
   • An unseen source of gravitational attraction nearer than the “Great Wall” about which our Local Group (and other galaxies) is orbiting. It is thought to be an assemblage of superclusters about 130 million light-years away and about 260 million light-years in diameter.

55. **What are the differences between Rich and Poor galactic clusters?**
   • Poor clusters contain small numbers of galaxies that show little symmetry and tend to contain spiral galaxies.
   • Rich clusters contain thousands of primarily elliptical galaxies.

56. **What is the primary reason for postulating the existence of Dark Matter surrounding galactic clusters?**
   • The velocity curves (galaxy rotation curves) for the galaxies in the clusters are higher than can be accounted for by the luminous mass.

57. **What is the primary reason for postulating the existence of Dark Matter in the universe as a whole?**
   • We are not in a special spot in the universe.