

chapter 31 study guide answers galaxies and the universe

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Chapter 31 Study Guide Answers: Galaxies and the Universe

Welcome to your comprehensive study guide for Chapter 31, which explores the vast, dynamic, and awe inspiring realm of galaxies and the broader universe. Whether you're a high school student tackling the final exam, a college freshman preparing for a midterm, or an enthusiastic lifelong learner, this guide is designed to help you master the concepts, answer practice questions confidently, and deepen your appreciation for the cosmos.

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Overview of Chapter /31

Chapter 31 delves into the structure, composition, and evolution of galaxies, while also situating them within the larger context of the universe. The chapter covers:

1. The classification of galaxies (spiral, elliptical, irregular, lenticular).
2. Key components of galaxies: stars, gas, dust, dark matter, and supermassive black holes.
3. The cosmic distance ladder and methods for measuring galactic distances.
4. The large scale structure of the universe: clusters, filaments, voids.
5. Cosmological models and the expanding universe.
6. Future prospects in galactic astronomy and cosmology.

By the end of this chapter, you should understand how astronomers observe and interpret the physical properties of galaxies, and how these observations inform our models of the universe's past, present, and future.

Key Concepts

1. Galactic Morphology

Galaxies are broadly categorized based on their appearance:

- Spiral Galaxies – characterized by a flat, rotating disk with spiral arms and a central bulge. The Milky Way is a classic example.
- Elliptical Galaxies – range from nearly spherical to highly elongated shapes, lacking prominent disks or spiral arms.
- Irregular Galaxies – lack a distinct shape, often chaotic due to gravitational interactions.
- Lenticular Galaxies – intermediate type with a disk but no significant spiral structure.

2. Stellar Populations and Star Formation

Star formation rates differ across galaxy types. Spiral arms are rich in cold molecular clouds, fueling ongoing star formation, whereas elliptical galaxies have largely exhausted their gas and show little new star birth. The **initial mass function (IMF)** describes the distribution of stellar masses at birth and is a cornerstone for modeling galactic evolution.

3. Galactic Dynamics

Rotational curves—plots of orbital velocity versus radius—reveal the presence of unseen mass. Flat rotation curves imply a dark matter halo enveloping galaxies. The interplay between visible baryonic matter and dark matter shapes galaxy stability and evolution.

4. Cosmic Distance Ladder

Accurate distance measurements are essential for determining intrinsic properties like luminosity and size. The ladder involves several rungs:

1. Parallax for nearby stars.
2. Variable stars (Cepheids, RR Lyrae) for intermediate distances.
3. Type Ia supernovae for far away galaxies.
4. Redshift distance relation (Hubble's Law) for cosmological scales.

5. Large Scale Structure

Galaxies cluster into groups, clusters, superclusters, and filaments, with vast voids between them. This cosmic web is a result of gravitational instability acting on primordial density fluctuations.

6. Cosmology and the Expanding Universe

The Friedmann equations, derived from General Relativity, describe how the universe's scale factor evolves over time. Key parameters include the Hubble constant (H_0), matter density (ρ_m), dark energy density (ρ_Λ), and curvature (k). Observations of the cosmic microwave background (CMB), baryon acoustic oscillations (BAO), and supernovae constrain these values.

Important Terms and Definitions

Conceptual Questions

Below are a selection of conceptual questions that test your understanding of Chapter 31. Answers follow each question.

1. Why do spiral galaxies exhibit flat rotation curves, and what does this imply about their mass distribution?
2. Explain how the cosmic distance ladder is constructed and why multiple rungs are necessary.
3. Compare and contrast the star formation rates in spiral and elliptical galaxies.
4. Discuss the significance of the Hubble constant in cosmology.
5. How does the large scale structure of the universe inform our understanding of dark matter?

Practice Problems with Answers

These practice problems are designed to reinforce the concepts covered in Chapter 31. Each problem includes a detailed answer to aid in self assessment.

Problem 1: Rotational Curve Analysis

Observations of the Andromeda Galaxy (M31) reveal that stars at a radius of 20 kpc orbit at 250 km s⁻¹, while the

inner disk (5 kpc) rotates at 200 km s^{-1} . Calculate the mass enclosed within 20 kpc assuming a circular orbit and compare it to the mass within 5 kpc. What does this suggest about the distribution of dark matter?

Answer: For a circular orbit, $(v = \sqrt{GM/r})$. Rearranging gives $(M = v^2 r / G)$. Converting units: $(G = 4.302 \times 10^{-6}) / (\text{kpc} / M_{\odot}^{-1} / (\text{km} / \text{s})^2)$. For 20 kpc: $(M_{20} = (200^2 \times 20) / 4.302 \times 10^{-6} \approx 2.9 \times 10^{11} M_{\odot})$. For 5 kpc: $(M_5 = (200^2 \times 5) / 4.302 \times 10^{-6} \approx 4.6 \times 10^{10} M_{\odot})$. The mass increases roughly linearly with radius, indicating a substantial amount of mass beyond the luminous disk—consistent with a dark matter halo.

Problem 2: Distance Ladder Calculation

A Cepheid variable in a nearby galaxy has a period of 10 days and an apparent magnitude of 15. The period–luminosity relation for Cepheids is $(M = -2.76 \log_{10} P - 1.40)$. Calculate the distance modulus and the distance to the galaxy in parsecs.

Answer: First, compute absolute magnitude: $(M = -2.76 \log_{10}(10) - 1.40 = -2.76(1) - 1.40 = -4.16)$. Distance modulus $(\mu = m - M = 15 - (-4.16) = 19.16)$. Distance $(d = 10^{(\mu + 5)/5} = 10^{(19.16 + 5)/5} = 10^{4.832} \approx 6.8 \times 10^4) / \text{pc} \approx 68 \text{ kpc}$. This places the galaxy within the Local Group.

Problem 3: Hubble's Law Application

A galaxy has a measured redshift of 0.02. Assuming a Hubble constant of $70 \text{ km s}^{-1} \text{ Mpc}^{-1}$, estimate its recessional velocity and distance.

Answer: For small redshifts, $(v \approx cz = 3 \times 10^5 \times 0.02 = 6000) \text{ km s}^{-1}$. Using Hubble's Law: $(d = v / H_0 = 6000 / 70 \approx 85.7) / \text{Mpc}$. Therefore, the galaxy is approximately 86 Mpc away.

Problem 4: Dark Energy Density

Given that the critical density of the universe is $(\rho_c = 3H_0^2 / (8\pi G))$ and that the measured Hubble constant is $70 \text{ km s}^{-1} \text{ Mpc}^{-1}$, calculate (ρ_c) in units of $(10^{-29}) \text{ g cm}^{-3}$. If the dark energy density parameter (Ω_{Λ}) is 0.7, what is the actual dark energy density (ρ_{Λ}) in the same units?

Answer: Convert H_0 to s^{-1} : $(70) \text{ km s}^{-1} \text{ Mpc}^{-1} = (70 \times 10^3) \text{ m s}^{-1} / (3.086 \times 10^{22}) \text{ m} = (2.27 \times 10^{-18}) \text{ s}^{-1}$. Then $(\rho_c = 3(2.27 \times 10^{-18})^2 / (8\pi \times 6.674 \times 10^{-11})) \approx 9.2 \times 10^{-27} / \text{kg m}^{-3}$. Convert to g cm^{-3} : $(9.2 \times 10^{-27}) / \text{kg m}^{-3} = (9.2 \times 10^{-30}) / \text{g cm}^{-3}$. Thus $(\rho_c \approx 0.92 \times 10^{-29}) \text{ g cm}^{-3}$. Then $(\rho_{\Lambda} = \Omega_{\Lambda} \rho_c = 0.7 \times 0.92 \times 10^{-29} \approx 0.64 \times 10^{-29}) / \text{g cm}^{-3}$.

Problem 5: Galaxy Cluster Mass Estimation

A galaxy cluster exhibits a velocity dispersion of 800 km s^{-1} . Using the virial theorem, estimate the total mass of the cluster within a radius of 1 Mpc. Assume the virial theorem gives $(M = 3 \sigma^2 R / G)$.

Answer: Plugging in values: $(\sigma = 800) / \text{km s}^{-1}$, $(R = 1)$

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