**ASTR-1200-01: Stars & Galaxies (Spring 2019) . . . . . Study Guide for Midterm 3**

The third midterm exam for ASTR-1200 takes place in class on **Wednesday, April 17, 2019.** The exam covers the parts of Chapters S2, S3, 18.3–18.4, 19, 20, and 21 in *The Cosmic Perspective* that were assigned as readings. The exam draws on the readings, lecture material, clicker questions, and concepts in the homework. Please come to office hours, the Astronomy Help Room, and/or the extra pre-exam review sessions if you need assistance with this material.

The exam will consist mainly of multiple-choice questions, and a few (probably two) short-answer questions that require you to write a couple of sentences for each. The midterm exams are closed-book and closed-notes. You can bring a calculator, but you should not need one. Of course, no phones or laptops (or any device that connects to the outside world) are allowed.

Some of the questions will involve memorization, but these ought to be concepts that we have highlighted and/or repeated as being major topics. Other questions will involve you taking what you know and applying it in a slightly different way.

Below is a list of sources for study aids, followed by a "birds-eye-view" list of topics that we covered. If you review and understand every item in those lists (along with where they appear in the lecture-note PDFs), you should be in good shape for the exam.

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## SOURCES FOR STUDY ASSISTANCE

- **Textbook**
  - "Learning Goals" (start of every chapter)
  - "Big Picture" and "Summary of Key Concepts" (end of every chapter)
  - "Common Misconceptions" and "Think About It" boxes
- **Canvas**
  - All lectures notes are posted in PDF format
  - Review the clicker questions from lectures
  - Solutions to the homeworks will be posted
  - The first and second midterm exams (with answers) have been posted, too
  - Feel free to use the "Discussions" tab to chat online, post questions, find study partners, etc.
- **Study Groups**
  - You are encouraged to study with classmates, but be sure to take turns asking and answering questions. When done right, this can be one of the best ways to learn.
- **Office Hours & Help Sessions**
  - **Prof. office hours:** Tues. & Fri., 10:00-11:00 (Duane D111)
  - **TA office hours:** Mondays, 10:00-12:00 (Duane D232)
  - **TA pre-exam review session:** Tues., April 16 only, 11:00-1:00 (probably Duane D142)
  - **Astronomy Help Room:** Tues., Wed., & Thurs., 2:00-6:00 (Duane D142)

## TOPICS/CONCEPTS FOR MIDTERM EXAM 3

### Chapter S2: Special Relativity

- The Michelson-Morley experiment. It showed that light always travels at the same speed, no matter the motion of the source or observer ("$c = c = c$").
- Implications of special relativity: time dilation, length contraction, mass increase (perceived for something moving with respect to the observer). Nothing can go faster than $c$.

### Chapter S3: General Relativity

- Einstein's Equivalence Principle: the effects of gravity are indistinguishable from the effects of acceleration.
- We live in 4-dimensional spacetime, and gravity curves it ("rubber sheet model"). Objects want to travel along the straightest possible path.
- The paths of both matter and light beams can be curved by gravity. This produces effects like gravitational lensing, gravitational time dilation, and the precession of Mercury's orbit.

### Chapter 18: Black Holes & Gravitational Waves (sections 18.3, 18.4 only)

- What is a black hole? Know the role of escape velocity and the definition of the event horizon. How are objects "spaghettified" when they fall in?
- Do black holes really exist? Review the observational evidence (massive-star binary systems).
- Gravitational waves: what are they; what can generate them (NS-NS or BH-BH binary mergers); how has LIGO detected them? *(Too recent to be in the textbook... see lecture notes!)*

### Chapter 19: the Milky Way Galaxy (sections 19.1, 19.2, 19.3, 19.4)

- How did we determine the size & scale of the Milky Way? Where are we with respect to the center?
- General structure of the Milky Way: bulge, disk (with spiral arms), and halo (with globular clusters). How much gas/dust is in each region? What types of stars are in each region?
- How can we use our solar system's orbital motion to calculate the mass of our galaxy?
- Overview of star–gas–star cycle and the multiple "components" of the interstellar medium.
- Spiral arms are density-wave "traffic jams," not rotating spokes. Know about how new stars are formed as gas passes through the spiral arms, and why the star-forming regions are blue.
- Sagittarius A$^*$: How do we know there is a supermassive black hole at the galactic center? How did we determine its mass?

**Chapter 20: Other Galaxies & the Expanding Universe** (sections 20.1, 20.2, 20.3)

- Galaxy classification: spiral, elliptical, lenticular, irregular. Know basic properties of each type.
- Who are our neighbors in the "Local Group?"
- When plotting galaxies on an H-R diagram (luminosity vs. color), know what's going on with the blue cloud vs. the red sequence. Why are galaxies in the latter group called "red & dead?"
- The Cosmic Distance Ladder: how we measure distances from near to far...
  - Radar ranging and parallax
  - Standard candles: main-sequence fitting & the tip of the red-giant-branch
  - Cepheid variables: Leavitt's period–luminosity relation
  - White dwarf supernovae: the brightest standard candles of all
- Main contributions of Edwin Hubble: (1) classified galaxies with "tuning fork" diagram, (2) used Cepheids to measure distances to nearby galaxies, (3) discovered *Hubble's Law:* more distant galaxies are moving away from us faster.
- Know basics about Hubble's constant $H_0$ and how to estimate the age of the universe from it.
- Some effects of the expansion of the universe:
  - Cosmological redshift stretches out all distances over time
  - The total distance to the "cosmic horizon" can be huge (bigger than just light-travel-time over the age of the universe)
  - The Cosmological Principle says we should see the same expansion no matter where we are

**Chapter 21: Galaxy Evolution & Quasars** (sections 21.1, 21.2, 21.3)

- There is evidence that many galaxies evolved by undergoing collisions & mergers. In the early universe, galaxies were smaller & more irregular than they are now.
- The Milky Way will someday collide with the Andromeda Galaxy. First there will be a brief "starburst" phase, but then the gas will get used up. Eventually there will just be one big, merged elliptical galaxy with no more gas or star formation.
- Most galaxies have supermassive black holes (SMBHs) at their centers. More massive galaxies have more massive SMBHs.
- If a SMBH is swallowing lots of gas from a surrounding accretion disk, some of the gas will be converted to energy ($E = mc^2$) and make an Active Galactic Nucleus (AGN):
  - Most of the time, we see an AGN as a bright source called a *quasar.*
  - If we're looking directly down its narrow radio jet, we see an even brighter *blazar.*

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