Course: AST 301: INTRODUCTION TO ASTRONOMY

Semester: Fall 2022

Unique No.: 47925

Hours: T, Th 2:00 – 3:30 p.m.

Location: Online (via zoom) (until further notice, subject to Covid status + future UT policy); Otherwise, WEL 3.502 (for 4 in-person exams + possible additional in-person activities TBD, announced in advance)

Textbook: (Required) Bennett, J., Donahue, M., Schneider, N., Voit, M. *The Cosmic Perspective* (9th Edition, 2020) (Pearson)

Exams: There will be four exams during the semester and no final exam. Exams are in-person, socially-distanced, and all are strongly encouraged to be masked and vaccinated. Tentative Exam Dates: Sept. 15, Oct. 11, Nov. 1, Dec. 1.

Homework: There will be required reading assignments. Problem sets will be assigned regularly and must be turned in, submitted online as .pdf file uploads via Canvas. HW is due by 11:59 PM on the due date. Late HW is discouraged but will be accepted with a maximum possible score of 80% of on-time HW, if turned in by the *start* of the next Help Session following the due date. Since HW solutions will be discussed at that Help Session, no later HW will be accepted.

Daily Questions:

Class lectures are essential to this course. Students must engage actively with them in order to learn, by regular attendance and note-taking and by asking and answering questions during class. Most classes (except exam days) will include a Daily Question, with answers collected and graded (using Canvas/zoom poll during class).

Grading: The course grade will be based on the weighted average of the scores on the exams (40%), homework (40%), and Daily Questions (20%). We drop your lowest exam score before computing the final average exam score, drop your lowest two HW grades before computing your final average HW grade, and drop your lowest two Daily Question grades before computing your final average Daily Question grade.

Quantitative Reasoning Flag:

This course carries the Quantitative Reasoning flag. Quantitative Reasoning courses are designed to equip you with skills that are necessary for understanding the types of quantitative arguments you will regularly encounter in your adult and professional life. You should therefore expect a substantial portion of your grade to come from your use of quantitative skills to analyze real-world problems.

Course Materials: ***Sharing of course materials is prohibited.***

No materials used in this class, including, but not limited to, lecture hand-outs, videos, assessments (quizzes, exams, papers, projects, and homework assignments), in-class materials, review sheets, and problem sets, may be shared online or with anyone outside class without the professor's explicit, written permission. Unauthorized sharing promotes cheating. It violates the University's Student Honor Code and is an act of academic dishonesty. Materials found online that are associated with a student, or any suspected unauthorized sharing of materials, will be reported to Student Conduct and Academic Integrity in the Office of the Dean of Students, which may result in sanctions, including failure in the course.

Class Recordings: Class recordings are reserved only for students in this class for educational purposes and are protected under FERPA. ***These recordings should not be shared outside of the class in any form.*** Violation of this restriction by a student could lead to Student Misconduct proceedings.

Instructor: Prof. Paul Shapiro
Office:
Phone:
email:
Office Hours: Immediately following class or by appointment (online via Zoom)

T.A.: Neha Akode
Office:
Cell Phone:
email:
Office Hours: Tu, Th 6:30 – 7:30 p.m. (online via Zoom)

T.A.: Chen-Kai Fan
Office:
Cell Phone:
email:
Office Hours: F 1 – 2 p.m. (online via Zoom)

Grader: Chun-Tao Tsao
Cell Phone:
email:
Office Hours: M 5 – 6 p.m. (online via Zoom)

Bi-Weekly Help/Review Sessions: M, W 6:30 – 7:30 p.m. (online via Zoom)

Covid and Possible Changes to this Class:

As Covid or UT rules and policies related to it evolve, we may have to adjust some of the details described above, accordingly.

Classroom Safety and COVID-19

For any illness, students should stay home if they are sick or contagious, not only to stop the spread, but also to promote their personal wellness.
The university will continue to provide rapid antigen self-test kits at distribution sites throughout campus. Students can receive up to four tests at a time.
The university will provide symptomatic COVID-19 testing on campus for all students, faculty and staff.
UHS maintains up-to-date resources on COVID, which can be found here:

COVID-19 Information and Resources

COVID-19 Exposure Action Chart

Diversity, Equity, and Inclusion

It is our intent that students from all diverse backgrounds and perspectives be well served by this course, that students' learning needs be addressed, and that the diversity that students bring to this class can be comfortably expressed and be viewed as a resource, strength and benefit to all students. Please come to us at any time with any concerns.

Statement of Learning Success

Your success in this class is important to us. We all learn differently, and everyone struggles sometimes. You are not, ever, the only one having difficulty! If there are aspects of this course that prevent you from learning or exclude you, please let us know as soon as possible. Together we will develop strategies to meet both your needs and the requirements of the course. We also encourage you to reach out to the student resources available through UT and are ready to help connect you with a person or Center if the need arises.

Getting Help with Technology

Students needing help with technology can contact the ITS Service Desk
For help with Canvas, students can try the "Help" link when they login to UT Canvas.
However, students can also ask our TA's for help, too.

Prof. Shapiro AST 301

Course Outline

Unit #	Topic
0.	Overview: The Scale of the Cosmos and Mathematical Preliminaries
1.	The Changing Sky
2.	Surveying the Stars
3.	Light and Telescopes
4.	Radiation and Matter
5.	Weighing and Measuring the Stars
6.	Stellar Structure
7.	Stellar Evolution: The Birth, Life and Death of Stars
8.	Our Milky Way Galaxy
9.	Galaxies
10.	Cosmology

UNIT #1
THE CHANGING SKY
Outline

(1) Apparent changes due to Earth's rotation and orbit around the Sun
   (a) Sidereal Day versus Solar Day
   (b) Celestial Sphere
   (c) Seasons

(2) The Moon and its orbit around the Earth
   (a) Synodic versus Sidereal Period
   (b) Phases

(3) Planets and their orbit around the Sun

UNIT #2
SURVEYING THE STARS
Outline

(1) Motivation: To answer the question, "What are the stars?" first answer the question, "*where* are the stars?"

(2) Heliocentric vs. Geocentric Theory of Solar System

(3) Stellar Parallax and the distances to Stars
   (a) Small Angle Formula
   (b) Parsec Definition
   (c) Parallax formula

(4) Inverse Square Law of Brightness and distances to celestial objects
   (a) Luminosity definition
   (b) Brightness, or Flux, definition
   (c) Inverse Square Law formula
   (d) Apparent Brightness vs. Absolute Luminosity

(5) Proper Motions of Stars
   (a) Velocity Vectors
   (b) Proper Motion formula

(6) Survey of the stars in the Solar Neighborhood and their motions

UNIT #3
LIGHT AND TELESCOPES
Outline

(1) Light: Wave-Particle Duality

(2) Waves
  (a) Periodic waves: wavelength, frequency, speed, period
    • relationship between λ, f, and v
  (b) light waves and the speed of light vs. wavelength and frequency
  (c) light as electromagnetic waves (radiation)
  (d) the spectrum of light

(3) Measuring the speed of light
  (a) Ole Roemer and the moons of Jupiter
  (b) James Bradley and Aberration of Starlight

(4) Telescopes and Optics
  (a) reflection
  (b) refraction
  (c) diffraction
  (d) resolving power
  (e) modern telescopes
  (f) spectrographs

(5) The Doppler Effect and Measuring Radial Velocity

UNIT #4
RADIATION AND MATTER:
LIGHT, ATOMS AND SPECTRA
Outline

(1) Temperature
  (a) Kelvin Scale
  (b) Absolute Zero

(2) Absorption and Radiation
  - Color of Opaque Objects

(3) Thermal Radiation

(4) Blackbody Radiation Laws
  (a) Ideal, equilibrium state of matter
  (b) Blackbody emission spectrum and radiation curves
    (i) Intensity I(λ) versus λ
    (ii) Wien's Law
    (iii) Stefan-Boltzmann Law
  (c) Using the Radiation Laws to Observe Stars

(5) Quantum Nature of Light
  (a) Planck Spectrum and Quantum Hypothesis
  (b) Planck formula: E = hf
  (c) Photons

(6) Line and Continuous Spectra: Kirchoff's Laws

(7) Atoms
  (a) Atoms, elements, nucleus, protons, electrons
  (b) Energy Levels and Origin of spectral lines
  (c) Hydrogen Atom and Spectrum

(8) Stellar Spectra
  (a) The Spectral Sequence
  (b) Stellar Composition: Most Abundant Elements

UNIT #5
GRAVITY AND MOTION:
WEIGHING AND MEASURING THE STARS
Outline

(1) Mass

(2) Velocity vs. acceleration

(3) Inertia

(4) Newton's Laws of Motion

(5) Circular Motion and Centripetal Acceleration

(6) Gravitation
- (a) Acceleration at Earth's surface measured by Galileo: "g"
- (b) Newton and the Moon
- (c) The Universal Law of Gravity
  - (i) "inverse square law"
  - (ii) mass dependence?
  - (iii) relation of force law to "g"

(7) Kepler's Laws of Planetary Motion

(8) Mutual Orbits and Center of Mass

(9) Generalized Kepler's Third Law

(10) Angular Momentum Conservation

(11) Binary Stars

(12) Masses of Stars Measured from Binary Orbits

(13) Sizes of Stars Measured from Binary Eclipses

UNIT #6: STELLAR STRUCTURE
or
"WHAT IS A STAR?"

Outline

(1) The Sun: the reference star
(2) Stellar Masses, Sizes, and Densities
(3) Observability of Stars
(4) Luminosity Function in Solar Neighborhood
(5) Hertzsprung-Russell Diagram
(6) Mass-Luminosity Relation for Main Sequence Stars
(7) Lifetimes of Stars and Fuel Efficiency
(8) The Gas Laws
(9) Stellar Equilibria
    (a) Hydrostatic Equilibrium
    (b) Thermal Equilibrium
        (i) heat transfer
        (ii) opacity
(10) Explaining the Mass-Luminosity Relation
(11) Age of Sun
(12) Energy Source in Stars
(13) Mass and Energy in Special Relativity
(14) Nuclear Reactions: Fission vs. Fusion
(15) Stellar Fusion
    (a) Nucleosynthesis: H $\rightarrow$ Fe
    (b) energy release and fuel efficiency
    (c) rate of energy production
    (d) two chief routes for H to He fusion
        (i) Proton-Proton chain
        (ii) C-N Cycle
    (e) Solar Neutrino Problem

UNIT #7
STELLAR EVOLUTION:
THE BIRTH, LIFE AND DEATH OF THE STARS
Outline

(1) Stellar Structure: Model of a Star at One "Snapshot" in Time
  (a) 4 Equations of of Stellar Structure
  (b) Russell-Vogt Theorem
  (c) Explaining the Main Sequence

(2) Stellar Evolution: Following the Changes of a Star from One "Snapshot" in Time to the Next

(3) Origin and Infancy of Stars
  (a) Where are stars born?
    – The Clue: Young stars and interstellar clouds
  (b) Why do stars form?
    – Star formation and gravitational instability in interstellar clouds
  (c) How do stars form?
    – The stages of collapse of a protostar
  (d) Last stage of a protostar
    (i) Hayashi Track
    (ii) Hayashi Forbidden Zone

(4) Limits of Main Sequence
    – range of masses which form stars

(5) Life on Main Sequence
  (a) ZAMS: Stars of different mass, same composition
  (b) 2 classes: Population I and II
  (c) lifetimes
  (d) evolution
  (e) Ages of clusters
  (f) Leaving the Main Sequence

(6) The Red Giant Stage
  (a) He burning: "Triple Alpha" Process
  (b) Approaching the end: Carbon-Oxygen core, and beyond, up to Iron

(7) The Deaths of Stars
  (a) White Dwarfs
    (i) Degeneracy and Degeneracy Pressure
    (ii) Chandrasekhar Mass Limit

(b) Mass Loss
    (i) Planetary Nebulae
    (ii) Supernovae
    (iii) Heavy Element Enrichment of Interstellar Medium
(c) Mass Exchange in Binary Stars
    (i) Roche surface (or lobe, or limit)
    (ii) Age paradox in close binaries
    (iii) Novae: a binary with a white dwarf member

(8) Neutron Stars and Pulsars

(9) Black Holes

UNIT #8
THE MILKY WAY GALAXY
Outline

(1) General Overview of M–W galaxy
- size, shape, structure
  - – flattened disk
  - – spheroidal bulge
  - – halo
  - - nucleus
  - – globular clusters
  - – spiral arms
  - – solar location

(2) History
  (a) Galileo and telescope resolves M–W into stars
  (b) William Herschel and "star counts": M–W is a disk (but looks like we are at the center)
  (c) Harlow Shapley and globular clusters: RR Lyrae variable stars indicate distance to globular clusters
  ⇒ locates Galactic Center ("GC")
  ⇒ we are *NOT* at center of M–W

(3) Galactic Rotation
  (a) Jan Oort and stellar Doppler shifts: pattern of radial velocities shows that stars orbit the GC
  (b) Rotation Curve and Kepler's Third Law: The Mass of the Galaxy
  - explaining the rigid rotation of inner galaxy
  - measure mass interior to Sun's orbit around GC
  - Detect "dark matter": Flat rotation curve of outer galaxy shows that mass distribution continues out past the last starlight

(4) Spiral Arms
- Density Waves

(5) The Nucleus

(6) The Halo

(7) The Globular Clusters
- contrast of Globular vs. Open Clusters

(8) Two Stellar Populations: Pop I vs. Pop II

(9) The Interstellar Medium

UNIT #9
GALAXIES
Outline

(1) Shapley-Curtis Debate

(2) Hubble settles the Debate: The Cepheid Yardstick

(3) Distribution of Galaxies

(4) Clusters of Galaxies
  (a) Local Group
  (b) Galaxy Clusters
  (c) Superclusters

(5) Types of Galaxies
  (a) Spirals
  (b) Ellipticals
  (c) Others

(6) Active Galaxies: Quasars

(7) Hubble Law of Recession of Galaxies

UNIT #10
COSMOLOGY
Outline

(1) The Expanding Universe
  (a) Using Hubble's Law to estimate the age of the universe
  (b) Using Hubble's Law to estimate the size of the "observable" universe

(2) Big Bang Model

(3) Cosmic Microwave Radiation Background

(4) Mass and energy content of the universe
  (a) Ordinary matter
  (b) radiation
  (c) dark matter
  (d) other (e.g. cosmological constant)

(5) The Formation of Galaxies and Large-Scale Structure in the Universe