

Astronomy 1304: Solar System
Spring 2022 Syllabus

Lecture

Meeting Times: — Location: Web

Instructor: Anirban Bhattacharjee

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Course Description:

ASTRO 1304 is an introductory course for non-science majors. It provides a broad introduction to Astronomy including: (1) daily, monthly and yearly patterns in the sky; (2) basic physics of gravity, light, and atoms; (3) stars and stellar evolution; (4) formation of the solar system; (5) Planets and exoplanets; and (6) the fundamental tenets of science and the scientific process. The goal of this course is to cover most of the areas of modern astronomy at a level which requires only basic mathematics.

Resources:

Required:

Astronomy Notes (AN) by Nick Strobel (<http://www.astronomynotes.com>)

<https://openstax.org/details/books/astronomy>

– Online textbook for pedagogical development of concepts

Occasionally, you will need a calculator in class. A basic scientific calculator will work well.

Various Wikipedia Articles (WA)

– Supplemental reading for additional declarative knowledge

Loose-leaf paper – for in-class assignments

Optional:

”Universe” (w/ Starry Night Enthusiast CD-ROM) (UN) by Roger Freedman & William Kaufmann III, 8th ed.(9th edition is ok too)

Course Objectives:

We will follow the guidelines set forth by the American Astronomical Society, the National Science Education Standards, the American Association for the Advancement of Science, and the in-class survey. The goals for this class are as follows:

- Appreciate the scientific process, how it works, the notion that physical laws are universal, the elements of scientific theories, what they do and do not tell us.
- Develop familiarity with the night sky and how its appearance changes with time and position on Earth.
- Describe how data is collected from astronomical objects, and what quantities can be measured/inferred.
- Understand basic - yet crucial - physical laws, and the processes that govern astronomical quantities.
- Integrate concepts from related subjects to explain relationships (e.g., physics and math) between astronomical quantities.
- Infer the nature, structure and evolution of the Universe, and objects therein.

Instructional Philosophy of the Course:

The overarching goals of this course are for you to understand the nature of science through the eyes of astronomy; to understand the big ideas in astronomy; and to develop a lifelong interest in astronomy and current events surrounding astronomy. To meet these three goals, the course instructors have carefully designed a sequence of learning tasks and assessment procedures as outlined below.

– – *To get the best out of this course, if you are having problems with understanding the course material, is by emailing me or texting me through a free messenger service called WhatsApp or iMessage if you have an iPhone. My phone number that you will need to add in your contact list is +13073997657. PLEASE DO NOT TEXT ME DIRECTLY, I WONT BE ABLE TO RESPOND OR MIGHT NOT EVEN RECEIVE YOUR MESSAGE*

-Carefully studying the text is REQUIRED. The course mini-lectures are designed to focus on the really difficult aspects of astronomy or to provide structure for your out-of-class study. You are accountable for all material, concepts, and interrelationships presented in the mini-lectures and the text. Reading assignments should be completed BEFORE the date listed. Otherwise, the mini-lectures and tutorials will be less useful in helping you develop a deep understanding of the course topics. It is important to remember that the exams or questionnaires will cover material from the text readings that may or may not be discussed in class.

Assessment and Grading:

In order to promote an active and collaborative learning environment, there will be no curve to assess grades. Each student will only be competing against themselves, and will be responsible for gaining the declarative knowledge and conceptual understanding for performance. This is a three credit class with three credits in the primary lecture section (§1) and one credit from the accompanying lab section. The portion of the grade in the lecture section will come from four sources: (1) midterm exams, (2) the final exam, (3) group project /term paper, (4) Zoom Attendance, and (5) HWs and Quizzes . Midterm exams will account for 25% of the final grade. There will be three midterm exams. The top two will count toward the grade (12.5% each) and **the lowest score will be dropped**. There will be no make ups for the midterm exams. The final exam is **mandatory** and will be **comprehensive**. The final exam will contribute 25% of the final grade. All of the exams (midterms and final) will be multiple choice, and will be 100 points each (weighted according to how much they contribute to the final grade).

The exams will test your understanding of key concepts in astronomy. A list of these concepts can be found in this syllabus. Along with each exam, we will also ask for opinions regarding what you like, dislike, and ask for suggestions for improving the class.

The final portion of the grade from the lecture section will come from attendance and class participation. As mentioned above in the **Instructional Philosophy of the Course** section, we will periodically ask you to write a short paragraph. The topic may be related to the assigned reading, to a current event in astronomy, or to a key concept covered in that class period. I will also assigning regular HW and quizzes. These will be collected and perused by the instructors. Answers demonstrating a command of the assigned reading or concepts will be given full credit. These will contribute to 20% of the grade for the class. In cases of university-sanctioned excused absences (e.g., ROTC, university athletics, religious holidays), it is up to you to inform the me of the absence **well in advance of the date**, supplying both the dates and your name. If have done so and there are exams on those dates, you will not be penalized for missing them and accommodation will be arranged 10% of the grade will be based on group projects/ term paper which is assigned in the syllabus and will be discussed in detail during the first two weeks of class. Final 20% of the grade will be towards the final project.

		Grading Scheme	
Total points		Total Points	Grade
	$0.25 \times (\text{Final Exam})$	85–100	A
	$+0.25 \times (\text{Midterm Total})$	75–84.999...	B
	$+0.20 \times (\# \text{ HW and quizzes})$	65–74.999...	C
	$+0.10 \times (\text{ZoomAttendance})$	55–64.999...	D
	$+0.20 \times (\text{Term Paper / Project})$	below 54.999...	F

From the total points, letter grades will be assigned according to the table on the right. There will be no plus or minus grades assigned.

My favorite color is lavender blue.

Students with disabilities: If you require any special accommodations to participate in the class or complete assignments, please contact the instructor as soon as possible.

Academic Honesty:

University Student Conduct and Discipline defines Academic Dishonesty:

"The University expects all students to engage in all academic pursuits in a manner that is beyond reproach and to maintain complete honesty and integrity in the academic experiences both in and out of their classroom. The University may initiate disciplinary proceedings against a student accused of any form of academic dishonesty, including but not limited to, cheating on an examination or other academic work, plagiarism, collusion, and the abuse of resource materials. 1. Cheating includes:

- a. Copying from another students test paper, laboratory report, other report, or computer files, data listings, and/or programs, or allowing another student to copy from same.
- b. Using, during a test, materials not authorized by the person giving the test.
- c. Collaborating, without authorization, with another person during an examination or in preparing academic work.
- d. Knowingly, and without authorization, using, buying, selling, stealing, transporting, soliciting, copying, or possessing, in whole or in part, the contents of an unadministered test.
- e. Substituting for another student; permitting any other person, or otherwise assisting any other person to substitute for oneself or for another student in the taking of an examination or test or the preparation of academic work to be submitted for academic credit.
- f. Bribing another person to obtain an unadministered test or information about an unadministered test.
- g. Purchasing, or otherwise acquiring and submitting as ones own work any research paper or other writing assignment prepared by an individual or firm. This section does not apply to the typing of the rough and/or final versions of an assignment by a professional typist.
- h. "Plagiarism" means the appropriation and the unacknowledged incorporation of anothers work or idea in ones own written work offered for credit.
- i. "Collusion" means the unauthorized collaboration with another person in preparing written work offered for credit.
- j. "Abuse of resource materials" means the mutilation, destruction, concealment, theft or alteration of materials provided to assist students in the mastery of course materials.

- k. "Academic work" means the preparation of an essay, dissertation, thesis, report, problem, assignment, or other project that the student submits as a course requirement or for a grade.
- l. "Falsification of Data" means the representation, claim, or use of research, data, statistics, records, files, results, or information that is falsified, fabricated, fraudulently altered, or otherwise misappropriated or misrepresented.

Procedures for discipline due to academic dishonesty shall be the same as in other disciplinary actions, except that all academic dishonesty cases shall be first considered and reviewed by the faculty member. If, after reviewing the case, the faculty member believes that disciplinary action is necessary, he/she may recommend a penalty but must notify the student of his/her right to appeal to the academic department chair and, eventually, to the dean before imposition of the penalty. If the student does not accept the decision of the academic department chair or dean, the student may then follow the normal disciplinary procedures. No disciplinary action shall become effective against the student until the student has received substantive and procedural due process except as provided under Interim Disciplinary Action.

In addition, during the course of the semester, each student will be asked to carry out exercises in collaboration with other students. To nurture such an environment, we will consider any disruptive or disrespectful acts (such talking on a cell phone, or texting during class) to be a form of cheating. We consider academic dishonesty to be a serious offense and the maximum punishments allowed will be pursued in all scenarios. This includes completing any quizzes, or scantron forms with the help of another student or for scantron forms completed by another student who is not you. If similar work is submitted, all parties involved will receive a zero for their assignment. Make your work your own, be original. Good luck and enjoy your semester!

Key Concepts:

Ideas related to gravity:

- Gravity is the force that keeps planets in orbit around the Sun and governs the rest of the motion in the Solar System. Gravity alone holds us to the Earth's surface
- Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and inversely proportional to the square of the distance between them.

Ideas related to electromagnetic radiation:

- Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object—emitted by or scattered from it—must enter the eye.
- Electromagnetic waves result when a charged object is accelerated or decelerated. Electromagnetic waves include the electromagnetic spectrum from radio waves to gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength.
- Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance.

Ideas related to fusion:

- Stars produce energy from nuclear reactions, primarily the fusion of hydrogen to form helium. These and other processes in stars have led to the formation of all the other elements.
- Fusion is the joining of two nuclei at extremely high temperature and pressure, and is the process responsible for the energy of the sun and other stars.

The evolution of the universe

- The origin of the universe remains one of the greatest questions in science. The “big bang” theory places the origin between 10 and 20 billion years ago, when the universe began in a hot dense state; according to this theory, the universe has been expanding ever since.
- Early in the history of the universe, matter, primarily the light atoms hydrogen and helium, clumped together by gravitational attraction to form countless trillions of stars.

Stars and stellar evolution

- Billions of galaxies, each of which is a gravitationally bound cluster of billions of stars, now form most of the visible mass in the universe.

The evolution and structure of the solar system

- The sun, the earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. The early earth was very different from the planet we live on today.
- The Earth is the third planet from the Sun in a system that includes the Moon, the Sun, other planets and their moons, and smaller objects, such as asteroids and comets. The Sun, an average star, is the central and largest body in the Solar System.

The Sun and Earth's seasons

- The Sun provides the light and heat necessary to maintain the temperature of the Earth.
- The Sun is the major source of energy for phenomena on the Earth's surface. Seasons result from variations in the amount of the Sun's energy hitting the surface due to the tilt of the Earth's rotation on its axis and the length of the day.

Yearly patterns, daily patterns and moon phases

- The Sun, Moon, stars, clouds, birds, and airplanes all have properties, locations, and movements that can be observed and described.
- Objects in the sky have patterns of movement. The Sun, for example, appears to move across the sky in the same way every day, but its path changes slowly over the seasons. The Moon moves across the sky on a daily basis much like the Sun. The observable shape of the Moon changes from day to day in a cycle that lasts about a month.
- Most objects in the Solar System are in regular and predictable motion. Those motions explain such phenomena as the day, the year, the phases of the Moon, and eclipses.

SEMESTER OBSERVING PROJECT

I. Objective

Over the course of the semester, you will have the opportunity to observe many things, thereby imitating astronomers throughout history. Although contemporary astronomy is largely an indoor science, visual and telescopic observations are fundamental. Everything we know about the universe is either supported by observations or hinges on the support of future observations. Most of the observations you will make this semester will be similar to those that have been made by countless numbers of astronomers throughout history. However, they will be unique to you, and give you the opportunity to discover the nature of the universe for yourself.

Students often ask, “What is a good observation?” or “What should I draw?” Frustrated Astronomy instructors typically respond, “Draw what you see.” The lesson is clear. An observation will depend on an observer's eyesight or other equipment used to make the observation, and one's

ability to sketch in the dark. Even with this element of uncertainty, however, everyone's sketch of a Full Moon should be circular, the Andromeda Galaxy should not look like Jupiter, and the North Star should always be drawn roughly North. You should strive to record what you see as accurately as possible, but only in as much detail needed to clearly distinguish your object from another. You need not draw every star in Orion to obtain the general shape, for example.

One note: You will see in class that the position and visibility of the stars depends greatly on when you are doing your observing. In order to be acceptable, every drawing MUST have the following information:

1. The date,
2. The time,
3. The direction you are facing and the directions to your left and right
4. A label of what you have drawn.

Without this information, you have only made a drawing, not an Observation that contains useful astronomical data!

II. Activities

The semester observing project will consist of three activities.

1. Naked eye observations of stars, constellations and planets
2. Telescopic observations using the telescopes outside town
3. Naked eye observations of the Moon and its phases

Each activity is described in more detail on the following pages, along with checklists to help you keep track of what you have and haven't done. All observations for all activities must be meticulously recorded in your observing book (the lab notebook) with all the above information. At least once per month, check your work with me to make sure that (1) adequate progress on the project is being made, (2) that the observations are satisfactorily complete and of reasonable quality.

Activity 1: Naked Eye Observations

All observations must be completed by semester's end. You only need to turn in one observation of each object, but you are encouraged to observe objects more than once until you feel that your sketch is a good one. Observations will be graded on completeness, accuracy, and clarity.

On the next page, there is a table of constellations and stars that you will need to observe for this part of the semester project. (Make sure you are looking under the correct semester.) Space has been left at the bottom as your instructor may suggest other objects, such as planets or comets, which are only visible at special times. Also note that the shapes of these constellations are subject to interpretation. The constellation of Ursa Major has been identified both as a large animal and a kitchen utensil. Which is it? Again, the best rule of thumb is to see for yourself. If you see a

teapot instead of an archer when observing Sagittarius then remember it as a teapot. When lying on its side, Orion may look to you like a giant bow tie rather than a hunter; feel free to use your imagination.

Your sketches for Activity 1 will be semicircular sketches of the sky as shown in the sample sketch on the following page. The semi-circle is used to depict the half of the sky that you are facing. The horizon is depicted by the flat portion of the semi-circle. Objects seen directly overhead should be drawn at the top of the frame. The corners of the semi-circle are reserved for objects seen on the horizon directly to your left and right. Since the sky you observe depends on date, time, direction, and observing locale, you must record this information near all sketches. You may include as many stars, constellations, and planets in one sketch as you wish without making the sketch incomprehensibly congested. All objects **MUST** be clearly labeled. Furthermore, parts of the horizon may be obscured by buildings, trees, etc. These should be clearly and accurately depicted and labeled in your sketch.

Star charts to help you find constellations are available online, e.g., at <http://www.heavens-above.com>. Please note that the projection of sky used in the star charts is not the same as the observations you will be making. In the star charts, the horizon is shown as the outside, circular border. They depict the entire sky, as if you are lying on your back. The observations that you will be recording require you to be standing, where you can only see half of the sky without contorting your body. The charts may be used as a guide to help you find the constellations. Observations that resemble star charts will be considered cheating.

Activity 1: Naked Eye Observations Checklist

Fall Semester	Spring Semester	
Ursa Major (Big Dipper)	Ursa Major (Big Dipper)	
Ursa Minor (Little Dipper) with <i>Polaris</i>	Ursa Minor (Little Dipper) with <i>Polaris</i>	
Auriga (the Charioteer) with <i>Capella</i>	Auriga (the Charioteer) with <i>Capella</i>	
Cepheus (the King)	Cepheus (the King)	
Cassiopeia (the Queen)	Cassiopeia (the Queen)	
Cygnus (the Swan) with <i>Deneb</i>	Cygnus (the Swan) with <i>Deneb</i>	
Boötes (the Herdsman) with <i>Arcturus</i>	Boötes (the Herdsman) with <i>Arcturus</i>	
Lyra (the Lyre) with <i>Vega</i>	Lyra (the Lyre) with <i>Vega</i>	
Pegasus (the Winged Horse) with <i>the Great Square</i>	Pegasus (the Winged Horse) with <i>the Great Square</i>	
Perseus (the Warrior)	Perseus (the Warrior)	
Taurus (the Bull) with <i>Aldebaran</i>	Taurus (the Bull) with <i>Aldebaran</i>	
Scorpius (the Scorpion) with <i>Antares</i>	Orion (the Hunter) with <i>Betelgeuse</i> and <i>Rigel</i>	
Sagittarius (the Archer)	The Pleiades (the Seven Sisters)	
Summer Triangle with <i>Deneb</i> , <i>Vega</i> , and <i>Altair</i>	Leo (the Lion) with <i>Regulus</i>	
Aquila (the Eagle) with <i>Altair</i>	Canis Major (the Big Dog) with <i>Sirius</i> (the brightest star in the night sky)	
Virgo (the Maiden) with <i>Spica</i>	Canis Minor (the Little Dog) with <i>Procyon</i>	
Hercules (the Strongman)	Gemini (the Twins) with <i>Castor</i> and <i>Pollux</i>	

Activity 2: Telescopic Observations Checklist

Fall Semester	Spring Semester
Mizar and Alcor in Ursa Major (double star)	Mizar and Alcor in Ursa Major (double star)
Albireo in Cygnus (double star)	The Orion Nebula
M13 in Hercules (a globular cluster)	The Pleiades (an open star cluster)
The Andromeda Galaxy (M31)	M15 in Pegasus (a globular cluster)

Activity 2: Telescopic Observations

Occasionally during the semester, the lab instructors will provide opportunities for observing the objects listed in the above table. Again, space has been left intentionally blank for planets or other objects which may be visible at special times. Telescopic observations capture a very small portion of the sky, and thus should not be semicircular. Draw your observations within a circle that represents the edge of your field of view. The same rules for time, date, etc. apply.

Activity 3: Naked Eye Observations of the Phase of the Earth's Moon

For this activity you will sketch the shape, appearance, and position in the sky of the Moon on different dates. Your lab instructor will choose a two week time period over which to observe the Moon. During these two weeks, you must choose a time over which to observe the Moon **at the same time every single day/night**. (Confer with your lab instructor for suggestions of appropriate times in the given two week period.) For each observation within this two-week time period, make a naked-eye observation in the same manner as in Activity 1, facing South with due West to your right and due East to your left. If desired, these can be combined with observations for Activity 1. The instructors appreciate that sometimes “life” can get in the way of a project that takes two weeks to carry out. Hence, to receive full credit for this activity, you must make at least ten observations in the two week period.

Each observation of the Moon must include:

1. Date and time of the observation
2. Description of observation
3. Sky conditions
4. Compass directions
5. Sketch of the moon's location in the sky
6. Sketch of the “shape” of the moon. If the moon is only partially illuminated, make a careful note of which side, left or right, is lit.

As the Moon orbits the Earth once every month, we see the side of it that is illuminated by the sun from different angles. That is what causes the Moon to appear to go through phases. Each phase corresponds to a different angle between us (Earth), the Moon, and the Sun. For example,

Full is when the Earth sits between the Moon and the Sun; at that time, the illuminated half of the Moon is facing us. If the Moon, Earth, and Sun make a right angle, then we see only half of the side of the Moon illuminated by the Sun, and this is called first or third quarter phase (depending on which side of the Moon is lit).

Tentative Schedule of Topics, Assignments, and Exams

Date	Topic/Assignments
Week – Introductions	
	Introductions, Astronomy Survey, Pre-assessment, Office Hours, Tour of Universe Discussion of Syllabus, Popsicles, Day-to-day class structure Watch <i>Cosmic Voyage</i> : https://www.youtube.com/watch?v=qxXf7AJZ73A AN: Math Review, Section 3 — http://www.astronomynotes.com/mathrev/s3.htm AN: Chapter 1, all sections — http://www.astronomynotes.com/chapter1/ WA: http://en.wikipedia.org/wiki/Scientific_notation WA: http://en.wikipedia.org/wiki/Names_of_large_numbers LT: Sun size (105-107), Milky Way Scales (123-125)
Week 2 – Patterns in the Sky	
1/25	AN: Chapter 3, all sections EXCEPT Angles, Coordinates, Planetary Motions AN: — http://www.astronomynotes.com/nakedeye/chindex.htm WA: http://en.wikipedia.org/wiki/Celestial_sphere WA: http://en.wikipedia.org/wiki/Circumpolar_star LT: Position, Motion LT: Seasonal Stars
Week 3 – Patterns in the Sky	
2/1	WA: http://en.wikipedia.org/wiki/Sidereal_day (“Sidereal time and solar time” section only) LT: Solar vs. Sidereal Day, Ecliptic WA: http://en.wikipedia.org/wiki/Moon_phases LT: The Cause of Moon Phases, Predicting Moon Phases LT: Path of the Sun
Week 4 – Seasons, Gravity	
	WA: http://en.wikipedia.org/wiki/Seasons LT: Seasons AN: Chapter 4, section on Kepler’s Laws of Planetary Motion AN: — http://www.astronomynotes.com/history/s7.htm#A5 LT: Kepler’s Second Law LT: Kepler’s Third Law
Week 5 – Gravity, Midterm Exam	

Date	Topic/Assignments
	AN: Chapter 5, all sections – http://www.astronomynotes.com/gravappl/chindex.htm (AN: Chapter 6, all sections – http://www.astronomynotes.com/relativity/chindex.htm) LT: Newton’s Laws and Gravity Review Session Midterm Exam 1 – Scales, Patterns in the Sky, Gravity
	Week 6 – Nature of Light
	AN: Chapter 11, section 4 only – http://www.astronomynotes.com/starprop/s4.htm WA: http://en.wikipedia.org/wiki/Magnitude_(astronomy) WA: http://en.wikipedia.org/wiki/Apparent_magnitude WA: http://en.wikipedia.org/wiki/Absolute_magnitude (Introduction and prologue to WA: Stars and Galaxies sections only) LT: Apparent and Absolute Magnitudes of Stars AN: Chapter 7, sections 1–3 – http://www.astronomynotes.com/light/chindex.htm LT: Electromagnetic Spectrum of Light LT: Telescopes and Earth’s Atmosphere
	Week 7 – Nature of Light
	AN: Chapter 7, section 4 – http://www.astronomynotes.com/light/s4.htm LT: Blackbody Radiation LT: Types of Spectra AN: Chapter 7, sections 7–10 – http://www.astronomynotes.com/light/chindex.htm LT: Light and Atoms
	Week 8 – Nature of Light, Evolution and Structure of the Solar System
	LT: Analyzing Spectra LT: Doppler Shift LT: Observing Retrograde Motion
	Week 9 – Evolution and Structure of the Solar System
	WA: http://en.wikipedia.org/wiki/Solar_system WA: http://en.wikipedia.org/wiki/Portal:Solar_System LT: Temperature and Formation of Our Solar System WA: http://en.wikipedia.org/wiki/Extrasolar_planets (esp. Detection Methods section) LT: Motion of Extrasolar Planets AN: Chapter 9, section 1-12 Watch “ <i>The Great Planet Debate</i> ” between Niel DeGrasse Tyson and Mark Sykes,

Date	Topic/Assignments
moderated by Ira Flato	
Week 10 – Exam, Stars	
Review Session Midterm Exam 2 – Nature of Light, Solar System AN: Chapter 11, sections 1–11 – http://www.astronomynotes.com/starprop/chindex.htm LT: Luminosity, Temperature, and Size	
Week 11 – Stellar Evolution	
AN: Chapter 11, sections 12–15 – http://www.astronomynotes.com/starprop/chindex.htm LT: H-R Diagram AN: Chapter 12, all sections – http://www.astronomynotes.com/starsun/chindex.htm LT: Star Formation and Lifetimes AN: Chapter 13, all sections – http://www.astronomynotes.com/evolutn/chindex.htm LT: Stellar Evolution	
Week 12 – Evolution of the Universe	
LT: Parallax and Distance AN: Chapter 15, all sections – http://www.astronomynotes.com/galaxy/chindex.htm LT: Galaxy Classification AN: Chapter 16, all sections – http://www.astronomynotes.com/cosmolgy/chindex.htm LT: Looking at Distance Objects	
Week 13 – Evolution of the Universe	
LT: Expansion of the Universe Big Bang Dark Matter and Dark Energy	
Week 14	
Presentation Week	
Week 15	
Midterm 3 Finals Week	