

## **AST 301 – Introduction to Astronomy**

Unique ID: 47005

Spring 2022

MWF 2:00 PM – 2:50 PM

**Location:** Welch Hall 3.502

**Class Zoom Link:** <https://utexas.zoom.us/j/92718691699>

**Instructor:** Prof. John Chisholm

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**Help Hours:** Monday's 11-12 (or by appointment)

**Teach Assistant:** Malvika Badrinarayanan

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**Help Hours:** MWF 12-1 PM

**Teach Assistant:** Alicia Montecinos

**Email:** [alicia.montecinos@utexas.edu](mailto:alicia.montecinos@utexas.edu)

**Help Hours:** M/T/TH 4-5PM

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### **Desired Learning Outcomes**

If you have ever looked up at the night sky from a dark spot you will immediately see why astronomy is the oldest science. The sense of wonder about the origin of those twinkling lights have inspired civilizations across the globe and time to wonder “What am I seeing?” and “How did the Universe unfold to lead to me?” These questions have driven humans to explore both physically and mentally what fundamentally shapes the Universe. To understand our origin story.

In this class, we will explore what we know about the origin of the solar system, stars, galaxies, and the Universe as a whole through the lens of exploration and scientific discovery. We will study the physical understanding that collective humanity has developed to comprehend the Universe around us, but we will pay close attention to, and demystify, the actual discovery process. You will explore for yourself the mysteries of the Universe and discover our current paradigm of the Universe.

This course is divided into four parts

1. History of Astronomy and foundations to understand the Universe
2. The Solar System and other planets
3. The Sun and other stars
4. Galaxies, the building blocks of the large-scale Universe, and the Big Bang

Each part aims to get you to reveal the mysteries of the Universe for yourself.

## **COURSE DETAILS**

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### **Meeting Information**

We will meet Mondays, Wednesdays, and Fridays from 2-2:50PM on zoom for the first two weeks with the possibility of also being in Welch Hall 3.502 after that.

The on-going (never-ending?) pandemic makes much of our in-person scheduling challenging to project. Per the current, University guidelines, we will be constantly monitoring our modality guidelines. This means that we could offer in-person instruction after the 31<sup>st</sup> of January. For the entire semester, I envision having some component of the class simulcast onto Zoom. Even if we do return to Welch, I will have a component on Zoom. This means that you should never feel like you are pressured to attend in-person. Also, if you are not feeling well, please attend the lecture on Zoom. However, if the University guidelines change, I will update my modality expectations.

Will this simulcasting work perfectly? Probably not. When we do return to a dual-modality, the Teach Assistants and I will do our best to also accommodate students on Zoom, but there will naturally be a tendency to prioritize those that are in class. As such, please come to in-person class if you are healthy and feel comfortable to do so, but we will do our best to also remotely guide you in your pursuit of the mysteries of the Universe.

### **Canvas Course**

Canvas is going to be your main resource for this course. Every announcement, homework and reading assignment, deadline, and grading will be done through the canvas environment. You will access your homeworks and tests through there as well. This is also where you should ask questions to your fellow classmates. Check it often for announcements and familiarize yourself with how to use it. There is also a portal to the MasteringAstronomy course through Canvas, which is your gateway to using your text book.

### **Canvas Message Board**

If you have a course-related question (not a personal question), please post first in the Canvas message board. One of your classmates or teaching assistants might see it and respond with the solution. Have a conversation with them! Figure out the problem together. If after 6 hours no one has responded to your canvas message, please send me an email and I will happily help you. There are over 150 students in the class and it becomes prohibitively challenging to answer all questions, but I am here for any questions that cannot be answered.

### **Student Help Hours**

If you have questions about material or want to better understand a particular subject, come to our help hours! We are here to help you on your journey to understand the cosmos.

## **Course Materials**

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This course requires three different materials

1. *The Cosmic Perspective*, Edition 9; Bennett, Donahue, Schneider and Voit
2. MasteringAstronomy
3. Stellarium

### **The Cosmic Perspective**

*The Cosmic Perspective* is in its ninth edition and contains a wealth of beautiful figures and diagrams. It has a ton of updated information and many practice problems.

Each lecture is paired with 5-20 pages of reading from *The Cosmic Perspective* and listed (1) at the end of this syllabus, (2) link on the Canvas Course page, and (3) in the MasteringAstronomy calendar. You will greatly benefit if you do this reading **before** lecture. That way you will be able to come to class ready to discuss the content we cover.

### **MasteringAstronomy**

MasteringAstronomy pairs *The Cosmic Perspective* with Canvas. It allows the class to be done completely online. MasteringAstronomy is your portal to find reading assignments, homework and group work, and tests. You can also access the eText version of *The Cosmic Perspective* through MasteringAstronomy. It is a crucial component to the class.

Make sure that you sign up for MasteringAstronomy immediately.

You can set up your MasteringAstronomy by going to the “MyLab and Mastering” section of our Canvas Course. If you click on “Open MyLab & Mastering” it will bring you to the course home page. You will need to create an account if you are new to MyLab and Mastering. Once you create an account you will be able to select an available access option and access our Course. If you ever need a course number it is **chisholm32544**.

There should be a free two-week trial period for MasteringAstronomy, that will enable you to access the course content immediately if you are waiting for financial aid. Again, please make sure that you sign up for MasteringAstronomy immediately.

### **Stellarium**

Stellarium is a *free* virtual planetarium software that we will pair with MasteringAstronomy to do group labs. You can download the free version of the software [here](#). I recommend downloading the software onto your computer because the web-based verison does not have all of the functionality.

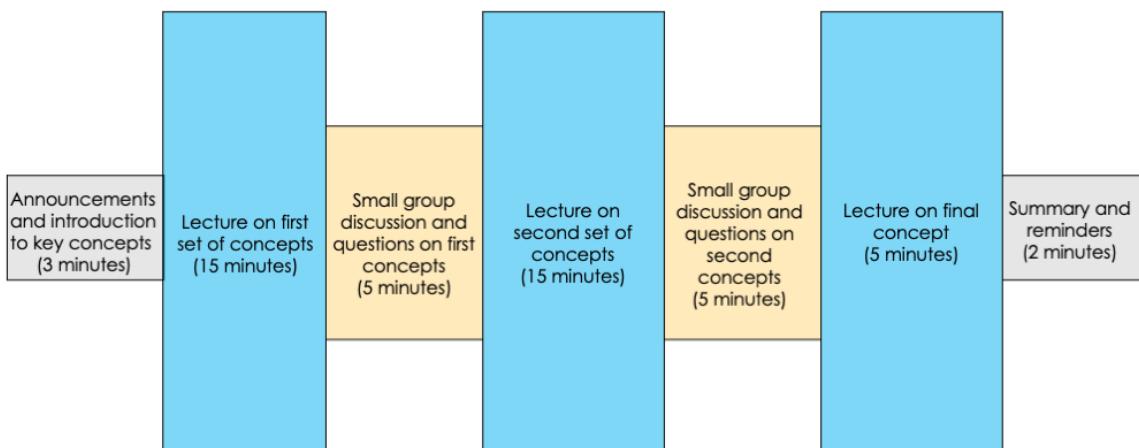
We will have a walk through of some of the functionality of Stellarium on the first day that we use it, but I encourage you to explore the many good YouTube videos available that show some of Stellarium's functionality.

### **Course Structure**

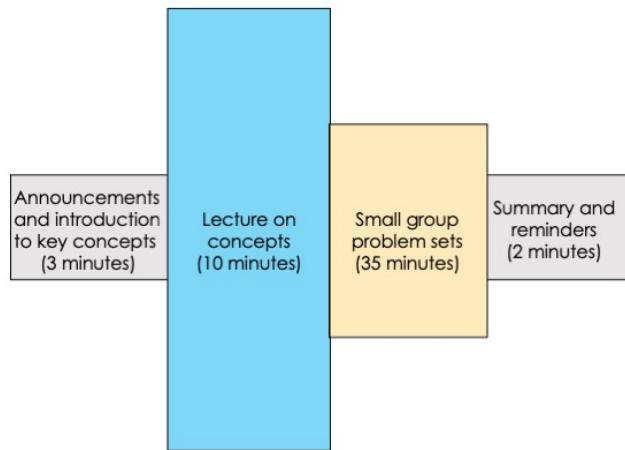
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We will have two distinct different types of lectures. Both structures aim to get you taking ownership over your exploration of Astronomy. There will be substantial amount of class time where you are talking about the mysteries of the Universe with your classmates, the Teaching Assistants, and me!

Mondays and Fridays we will have a somewhat typical lecture format. I will start each lecture with announcements and an introduction to our key concepts. The core of the lecture will include three different “blocks” where I elaborate on the concepts that you read about before the lecture, and two blocks where you discuss these concepts in small groups of 3-4 classmates. The Teaching Assistants and I will jump between Zoom break out rooms or walk around to the people in person to help answer questions during the discussion blocks. The lectures will then conclude with a summary and any reminders. The flow should look something like this:



Wednesdays will be less focused on lecturing and more focused on group problem sets and online labs where you will explore the Universe for yourself. The structure of those classes will look like



Every day will include some problem sets that you will discuss in a break out room and answer in MasteringAstronomy. Answering these questions will be most of your grade. Why is discussing with your classmates a majority of your grade? That is because science is meant to discuss and solve together. It is a collective and social pursuit.

### **Required reading**

A crucial component of this class structure is that you must be ready to discuss with your classmates. Coming prepared for the discussion and group work in class is crucial. Doing the pre-class reading is the only way to prepare. The required reading is listed in the schedule below, linked on Canvas, and posted on the MasteringAstronomy calendar. The required reading is typically between 5-20 pages and usually contains helpful diagrams.

### **In Class Participation**

The mysteries of the cosmos are everyone's to pursue and understand. I truly believe that the best way to achieve this is to actively participate with your fellow human. This is exactly the mysteries of the Universe have been uncovered in the past. There will be three types of interaction that you should come prepared to actively participate in class with

1. **Questions During Lecture** In my lecture blocks, I will ask you questions. I want you to answer those questions. When we are in person that means responding verbally with answers. When we are on Zoom, that means placing your responses in the chat, raising your hand when polled, or annotating the screen when I tell you to (sidebar: please don't annotate the screen when I don't tell you to!). Have fun with this and keep yourself engaged in what we are doing.
2. **Group Discussions and Problem Sets** Between lecture blocks there will be 3-10 minutes for you to talk with people in the class to work through a couple homework problems. On Wednesdays you will have larger

breakout sections to do labs. Take advantage of these times. Talk through the problems and help each other understand the problems. Make sure that **everyone** in your breakout session understands the problem. You will find that you do not truly understand the Universe until you have to teach someone else about it (teaching you about planetary atmospheres is the only way I will learn about them!). As such, helping someone understand the problem will do just as much to help you understand the problem. Give it a try.

3. **Canvas Message Board** If you have a question outside class, ask it on the Canvas Message Board. If you see a question on the Canvas Message Board that you know the answer to, help someone out and explain it to them. You will be amazed at how much you learn when you teach someone.

### Grading Breakdown

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Your total grade for this class will be a combination of three components:

70% Homework Assignments (2% per assignment)

30% Four take-home, open book tests (7.5% each test)

Letter grades will be assigned as

<b>A:</b> 94.00 – 100%	<b>B–:</b> 79.00 – 82.99%	<b>D+:</b> 67.00 – 70.99%
<b>A–:</b> 91.00 – 93.99%	<b>C+:</b> 76.00 – 78.99%	<b>D:</b> 63.00 – 66.99%
<b>B+:</b> 87.00 – 90.99%	<b>C:</b> 73.00 – 75.99%	<b>D–:</b> 60.00 – 62.99%
<b>B:</b> 83.00 – 86.99%	<b>C–:</b> 70.00 – 72.99%	<b>F:</b> 0.00 – 59.99%

Everything will be rounded to the nearest hundredth (0.01%). This means that a 90.993% will receive a B+ and a 90.996% will receive a A-.

### Homework Assignments

There will be 36 homework assignments, each worth 2% of your final grade, that will be posted on MasteringAstronomy. Assignments will be due at the **start** of **every** class **except test days and the days after tests**. The homework assignments are listed in this syllabus and will be clearly marked a week ahead of time in MasteringAstronomy. Homework submission closes at **1:59 PM** on the due date (the day the assignment is listed on the schedule below). Late homeworks will **not** be accepted for any reason. None at all. However, to receive full homework credit you only need to submit 35 homework assignments. This means that you can miss 1 homework assignment and still receive full credit. If you do all 36 homework assignments, and turn them in on time, you will receive up to **2%** extra credit (depending on your individual homework scores).

The homework assignments, and how much you will have to do outside of class, will largely vary on the day:

- **Homeworks that are due on Mondays** will be a combination of take home problems and problems that you do in-class on Friday.

- **Homeworks that are due on Wednesdays** will completely be problems that we do together in-class and submitted through MasteringAstronomy. If you are not able to complete the assignments with your group during class on Monday, you still have until the start of class on Wednesday to complete and submit the assignment.
- **Homeworks that are due on Fridays** will be the lab-based group work that we do on Wednesdays. If you are not able to complete the assignments with your group on Wednesday, or you are not available to attend lecture, you will have until the start of class on Friday to complete and submit the assignment.

For all homework assignments you will have two chances to submit the correct answer. If you initially submit the wrong answer, MasteringAstronomy will give you a hint and allow you to change your answer. Try to learn from this and do not just guess.

To summarize: if you attend each class, you should only have take-home homework **due on Mondays at 1:59 PM**. If you miss a class and group work, for any reason, you can still get full credit for the homework by doing the homework on your own time and submitting it by 1:59 PM on the due date. No homework will be due on test days or the class after tests. You can miss 1 homework assignment and still receive full credit. If you do every homework assignment, you will receive 2% extra credit to your final grade.

## **Exams**

All exams will be open note and will be taken within MasteringAstronomy. Each exam will be worth 7.5% of your total grade. It will be timed so that you will have 50 minutes to take each exam. The exam will open immediately after the class that we review the material and will stay open until the start of the class (1:59 PM) after the class designated for the test. This means that you will have at least 5 days to take the test (Spring Break actually means you will have longer for one test). To accommodate your busy schedules, we will **NOT** have class on test days. This gives you the option of when to take the test: during our normal class time or any other 50 minutes during the 5 days that the test is open.

**You are expected to do tests by yourself and not in groups.** This means that there should be no collaborative work on tests and each individual should take their own test.

Exam questions will be similar in content and spirit to homework and group work questions. If you review and understand the problems that we did for homework, you will do great on the tests.

## **Extra Credit**

Yes! If you do all of the homework you will receive up to 2% extra credit.

## **Expected behavior**

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Our pursuit of the understanding of the Universe is a timeless and age-old question. This is a pursuit that everyone should feel comfortable to explore. This means that we inspire to create an environment that is free from bullying, harassment, and microaggressions. As such, there will be a **zero-tolerance** policy for harassment and discrimination. This is especially true during our group work and discussions. If there is ever an issue please do not hesitate to bring it to my or the Teaching Assistants attention and we will pursue it to the fullest extent of University policies. The bottom line: Everyone deserves respect and I expect you to treat everyone with respect.

While much of this class involves group work, tests are a personal experience. Any indication about academic dishonesty will result in an automatic zero on the assignment. Depending on the situation, I reserve the right to pursue any act of academic dishonesty to the furthest extent of University policy, including but not limited to failure of the class and being reported to Student Judicial Services in the Dean of Students Office. In this case, Judicial services will determine the final penalty.

## **Mental Health Resources**

The past two years (and counting) have been extremely stressful and trying times. Extreme isolation, illness, and loss of family and friends have caused many of us to revisit the important impacts that mental health can have on our learning and well-being. Your teaching assistants and I are here to help you with any aspect of your exploration of the Universe, so please come to us if you are having mental health issues and we will listen. However, we are not trained counselors. The University does provide mental health support through the Counseling and Mental Health Center. They have a website (<https://cmhc.utexas.edu/>) where you can access confidential virtual counseling services free of charge. There is also a 24-hour crisis hotline (512-471-2255) where you will immediately be put into contact with someone. You have people in your corner that are always here to support you

## **Questions**

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### **"How do I do well in this class?"**

Inevitably you are interested in doing well in this course. The best advice I have for you is give in to your curiosity and let yourself dive into the subject. Too vague? 70% (well, 72% if you do the extra credit) of your grade is homework and group work. If you show up every day to class ready to discuss the mysteries of the Universe, you are 75% of the way to getting an A. The next 25% comes from tests. The best way to prepare for tests is to review the material we covered for homework and group work. This will prepare you for the tests because most of

the test problem will be drawn from similar activities. If you are comfortable with what we did, you will be prepared for the tests. If you have questions about the homework assignments, come to Help Hours and ask questions.

#### **"Will the lectures be recorded and posted online?"**

I will post the lecture PDFs after class. The recorded lectures will not be distributed except for special circumstances. Please, send me an email or come to Help Hours if you would like to discuss recordings. No small group discussions will ever be recorded.

#### **"This class is heavy on technology, where can I find IT support?"**

It's true that that pandemic has caused much of this class to move to an online mode. Homeworks are assigned and collected online. Tests are taken all online. There is quite the heavy burden on being able to access and understand the electronic platform. However, the class grade is **not** supposed to be about exploring computer issues. We will be accommodating of reasonable technological issues. I especially understand and recognize that computers are not uniformly available for all UT students. Since you have the option of doing the homeworks and group work on your own, explore the option of computer labs on campus. If you have trouble accessing your MasteringAstronomy or Canvas passwords or usernames, there is not much I can do. Please contact either Mastering or Canvas directly. If you are having issues with software or accessing the electronic content of the class you have a couple options: (1) post on the Canvas message board, or (2) email the Teaching Assistants or me. Your fellow students and instructors will do their best to help you.

#### **"Will there be math?"**

Astronomy and physics are deeply rooted in math. It is our only way to know what we know about the Universe around us. However, this course is not intended to strongly stretch your math skills. There definitely will be **some** math, but it is all math that you have seen before in highschool. Very little algebra, no calculus. Don't worry about those. There are five types of math that we will be doing:

1. Interpreting equations and calculating values
2. Significant figures
3. Using units
4. Scientific Notation and understanding large numbers
5. Interpreting graphs

The first of these involves being familiar with putting numbers into equations. For instance if I tell you  $x = a + b$  and give you  $a$  and  $b$  you will be expected to

determine what  $x$  is. Similarly, if I ask you “if I increase  $a$ , and keep  $b$  constant, what will happen to  $x$ ?“ you should be able to answer it.

Significant figures are important when answering homework questions. What is a significant figure? A significant figure is a digit that can be accurately estimated. We will go over in class how you can determine which ones to use.

Units are important to understand the values we will be using. When you go to the doctor’s office and they tell you your height in feet and inches, that provides you a sense for how tall you are. Similarly, when we discuss that the nearest star outside our solar system is 4.26 light years away, you should be comfortable to convert that to meters by knowing that 1 light year is  $9.4 \times 10^{15}$  m. It is as simple as doing:

$$4.26 \cancel{\text{light years}} \times \frac{9.4 \times 10^{15} \text{m}}{1 \cancel{\text{light years}}} = 4 \times 10^{16} \text{m}$$

As that last part demonstrated, Astronomy deals with numbers that are beyond our normal, every-day understanding. As such, we will have to get used to scientific notation.  $10^3$  is the same as 1,000, but you wouldn’t be happy if I asked you to write out all the zeros in the distance to the nearest star ( $4 \times 10^{16}$  m). Scientific notation makes our pursuit of Astronomy way more accessible!

The fourth math topic involves looking at a graph and determining the relationship between two variables. This skill will help you understand how we can interpret the Universe around us, and is highly transferable to your daily life.

Our first few homework assignments will include summaries of these basic math ideas for you to refamiliarize yourself. You will not be asked to do heavy algebra or calculus, nor will you be asked to derive things. However, the above math skills are crucial to understand how science works and how we understand the Universe.

### Course Schedule

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CLASS NUMBER	DATE	TOPIC	HOMEWORK DUE PRECLASS THROUGH MASTERING ASTRONOMY	Preclass Reading
1	W Jan 19 <sup>th</sup>	Introduction	--	--

2	F Jan 21 <sup>st</sup>	Scale of the universe and its timeline	<ul style="list-style-type: none"> <li>• Intro to Mastering Astronomy</li> <li>• Syllabus quiz</li> </ul>	<ul style="list-style-type: none"> <li>• Syllabus</li> <li>• Ch 1.1 &amp; 1.2</li> </ul>
3	M Jan 24 <sup>th</sup>	The motion of the Earth	<ul style="list-style-type: none"> <li>• Ch 1.1 &amp; 1.2</li> <li>• Powers of 10</li> </ul>	<ul style="list-style-type: none"> <li>• Ch 1.3 &amp; 1.4</li> </ul>
4	W Jan 26 <sup>th</sup>	The motion of the stars, causes of the seasons, and the moon	<ul style="list-style-type: none"> <li>• Ch 1.3 &amp; 1.4</li> <li>• Scientific notation</li> </ul>	<ul style="list-style-type: none"> <li>• Ch 2.1-2.3</li> </ul>
5	F Jan 28 <sup>th</sup>	The history and development of Astronomy	<ul style="list-style-type: none"> <li>• Ch 2.1-2.3</li> <li>• Units</li> </ul>	<ul style="list-style-type: none"> <li>• Ch 2.4-3.3</li> </ul>
6	M Jan 31 <sup>st</sup>	What is science? Describing motion and Newton's Laws	<ul style="list-style-type: none"> <li>• Ch 2.4-3.3</li> </ul>	<ul style="list-style-type: none"> <li>• Ch 3.4, 4.1, 4.2</li> </ul>
7	W Feb 2 <sup>nd</sup>	Conservation laws, gravity and orbits	<ul style="list-style-type: none"> <li>• Ch 3.4, 4.1, 4.2</li> </ul>	<ul style="list-style-type: none"> <li>• Ch 4.3-4.5</li> </ul>
8	F Feb 4 <sup>th</sup>	Properties of light	<ul style="list-style-type: none"> <li>• h 4.3-4.5</li> </ul>	<ul style="list-style-type: none"> <li>• Ch 5.1 &amp; 5.2</li> </ul>
9	M Feb 7 <sup>th</sup>	Using light to determine the properties of matter	<ul style="list-style-type: none"> <li>• Ch 5.1 &amp; 5.2</li> </ul>	<ul style="list-style-type: none"> <li>• Ch 5.3 &amp; 5.4</li> </ul>
10	W Feb 9 <sup>th</sup>	Exam Review	<ul style="list-style-type: none"> <li>• Ch 5.3 &amp; 5.4</li> <li>• Exam 1 goes live after class</li> </ul>	
11	F Feb 11 <sup>th</sup>	EXAM 1: Basics of the Universe, Ch 1-5	<ul style="list-style-type: none"> <li>• No class. Remember to take exam!</li> </ul>	
12	M Feb 14 <sup>th</sup>	An introduction to the Solar System	<ul style="list-style-type: none"> <li>• Exam 1 closes at start of class</li> </ul>	<ul style="list-style-type: none"> <li>• Ch 7.1-7.3</li> </ul>
13	W Feb 16 <sup>th</sup>	Formation of the Solar System	<ul style="list-style-type: none"> <li>• Ch 7.1-7.3</li> </ul>	<ul style="list-style-type: none"> <li>• Ch 8.1 &amp; 8.2</li> </ul>
14	F Feb 18 <sup>th</sup>	Basics of Planetary Geology, the	<ul style="list-style-type: none"> <li>• Ch 8.1-8.2</li> </ul>	<ul style="list-style-type: none"> <li>• Ch 9.1-9.3</li> </ul>

		Moon, and Mercury		
15	M Feb 21 <sup>st</sup>	Geology of Mars, Venus and the Earth	• Ch 9.1-9.3	• Ch 9.4 – 9.6
16	W Feb 23 <sup>rd</sup>	Planetary Atmosphere basics, the Moon and Mercury	• Ch 9.4 – 9.6	• Ch 10.1 & 10.2
17	F Feb 25 <sup>th</sup>	Atmospheres of the Moon, Mercury, Venus and Mars	• Ch 10.1 & 10.2	• Ch 10.3-10.5
18	M Feb 28 <sup>th</sup>	Earth's Atmosphere	• Ch 10.3-10.5	• Ch 10.6
19	W Mar 2 <sup>nd</sup>	Jupiter, Saturn, Uranus, and Neptune	• Ch 10.6	• Ch 11.1 & 11.2
20	F Mar 4 <sup>th</sup>	The moons and rings of the gas giants, Pluto and other dwarf planets	• Ch 11.1 & 11.2	• Ch 11.3, 12.1, 12.4
21	M Mar 7 <sup>th</sup>	Exoplanets	• Ch 11.3 12.1, 12.4	• Ch 13.1-13.4
22	W Mar 9 <sup>th</sup>	EXAM 2 REVIEW	• Ch 13.1-13.4 • Exam 2 goes live after class	• Review
23	F Mar 11 <sup>th</sup>	EXAM 2: Planets: Chapters 7-13	• No class. Remember to take exam!	• None
<b>Spring Break</b>				
24	M Mar 21st	The Sun as a star	• Exam 2 closes at start of class	• Ch 14.1-14.3
25	W Mar 23 <sup>rd</sup>	Different types of stars	• Ch 14.1-14.3	• Ch 15.1 &15.2

26	F Mar 25 <sup>th</sup>	Birth of stars	• Ch 15.1 & 15.2	• Ch 16.1-16.3
27	M Mar 28 <sup>th</sup>	The lives of stars	• Ch 16.1-16.3	• Ch 17.1-17.3
28	W Mar 30 <sup>th</sup>	White Dwarfs and neutron stars	• Ch 17.1-17.3	• Ch 18.1-18.2
29	F April 1 <sup>st</sup>	Black holes	• Ch 18.1-18.2	• Ch 18.3 & 18.4
30	M April 4 <sup>th</sup>	EXAM 3 REVIEW	• Ch 18.3 & 18.4 • Exam 3 goes live after class	• Review
31	W April 6 <sup>th</sup>	EXAM 3: Stars: Ch 14-18	• No class. Remember to take exam!	• None
32	F April 8 <sup>th</sup>	Revealing the Milky Way	• Exam 3 closes at start of class	• Ch 19.1& 19.2
33	M April 11 <sup>th</sup>	The history and evolution of the Milky Way	• Ch 19.1& 19.2	• Ch 19.3 & 19.4
34	W April 13 <sup>th</sup>	Types of Galaxies	• Ch 19.3 & 19.4	• Ch 20.1
35	F April 15 <sup>th</sup>	The distances to other galaxies and the age of the Universe	• Ch 20.1	• Ch 20.2 & 20.3
36	M April 18 <sup>th</sup>	Galaxy Evolution	• Ch 20.2 & 20.3	• Ch 21.1 & 21.2
37	W April 20 <sup>th</sup>	The role of Super Massive Black Holes	• Ch 21.1 & 21.2	• Ch 21.3
38	F April 22 <sup>nd</sup>	The Big Bang Theory and the James Webb Space Telescope	• Ch 21.3	• Ch 22.1 & 22.2

39	M April 25 <sup>th</sup>	Inflation	• Ch 22.1 & 22.2	• Ch 22.3 & 22.4
40	W April 27 <sup>th</sup>	Dark Matter	• Ch 22.3 & 22.4	• Ch 23.1- 23.3
41	F April 29 <sup>th</sup>	Dark Energy and the fate of the Universe	• Ch 23.1-23.3	• Ch 23.4
42	M May 2 <sup>nd</sup>	Life in the Universe	• Ch 23.4	• Ch 24.1- 24.5
43	W May 4 <sup>th</sup>	Exam 4 Review	• Ch 24.1-24.5 • Exam 4 goes live after class	• Review
44	F May 6 <sup>th</sup>	EXAM 4: Galaxies and Cosmology Ch 19- 24	• No class. Remember to take exam! • Exam 4 closes at 2 PM on May 11 <sup>th</sup>	