Term Information

Effective Term	Autumn 2025

General Information

Course Bulletin Listing/Subject Area	Astronomy
Fiscal Unit/Academic Org	Astronomy - D0614
College/Academic Group	Arts and Sciences
Level/Career	Undergraduate
Course Number/Catalog	1100
Course Title	Astronomy IRL: An Influencer's Guide to Science
Transcript Abbreviation	Astronomy IRL
Course Description	Science shapes our lives, but with so much “scientific” info out there, how do we know what to trust? This course sharpens your ability to evaluate scientific information, using astronomy as a concrete way to develop your understanding of the methods and nature of science. To ensure you can apply this knowledge beyond astronomy, we'll put you to the test in real-world social media contexts.
Semester Credit Hours/Units	Fixed: 4

Offering Information

Length Of Course	14 Week
Flexibly Scheduled Course	Never
Does any section of this course have a distance education component?	Yes
Is any section of the course offered	100% at a distance
Grading Basis	Letter Grade
Repeatable	No
Course Components	Laboratory, Lecture
Grade Roster Component	Lecture
Credit Available by Exam	No
Admission Condition Course	No
Off Campus	Always
Campus of Offering	Columbus, Lima, Mansfield, Marion, Newark, Wooster

Prerequisites and Exclusions

Prerequisites/Corequisites	Completion of Math 1075 or higher or a Math Placement score of “N” or higher.
Exclusions	
Electronically Enforced	Yes

Cross-Listings

Cross-Listings	

Subject/CIP Code

Subject/CIP Code	40.0201
Subsidy Level	Baccalaureate Course
Intended Rank	Freshman, Sophomore, Junior, Senior

Requirement/Elective Designation

Natural Sciences

Course Details

Course goals or learning objectives/outcomes

- Course ELO 1.1 Demonstrate proficiency in fundamental scientific competencies including astronomical units and unit conversion, scientific notation, SI prefixes, interpreting graphs, common proportions, percentages and scaling relations.
- Course ELO 1.2 Comprehend the scale of the Universe and its constraints on astronomical observation and exploration.
- Course ELO 1.3 Recall and explain basic facts, principles and theories of modern astronomy.
- Course ELO 2.1 Apply and explain the scientific methods used by modern astronomy to characterize the Universe, and explain the limitations and associated uncertainties of these methods.
- Course ELO 2.2 Identify how key events in the development of modern astronomy contribute to the ongoing and changing nature of scientific knowledge and methods in the field.
- Course ELO 2.3 Demonstrate an understanding of fundamental scientific literacy concepts including uncertainty and bias in data, variable control, confounding factors, and evaluating the validity of sources of information.
- Course ELO 2.4 Describe and analyze the nature and process of scientific inquiry including the premises and boundaries of its application, and the merit and evolving nature of scientific theories.
- Course ELO 3.1 Analyze the inter-dependence and potential societal impacts of scientific and technological developments.
- Course ELO 3.2 Demonstrate an understanding of ethical practice in science and the responsible use of information from the natural sciences.
- Course ELO 4.1 Demonstrate an appreciation for the need for scientific literacy in everyday life.
- Course ELO 4.2 Interpret and critically evaluate the scientific merit of reported information both within and outside the field of astronomy.

Content Topic List

- Unit 1: Science Unlocked: How to Talk the Talk and Walk the Walk
- Unit 2: Behind the Scenes: Where Do Scientists Get Their Facts From?
- Unit 3: Guessing or Slaying? How Theories Evolve and Get Verified
- Unit 4: Game On! Tackling Tough Topics in Science Like a Boss

Sought Concurrence No

Attachments

- Astron1100_Astronomy IRL_ASC Distance Learning Syllabus Template.docx: Syllabus

  (Syllabus. Owner: Westraadt,Lindsay)
- Astron1100_Astronomy IRL_ASC-distance-approval-cover-sheet-fillable Updated 2-1-24 APPROVED.pdf: Approved Cover Sheet

  (Cover Letter. Owner: Westraadt,Lindsay)
- Astron1100_Astronomy IRL_ASC-distance-approval-cover-sheet-fillable Updated 2-1-24.pdf: Pre-approved Cover Sheet for easier reading

  (Cover Letter. Owner: Westraadt,Lindsay)
- ge-foundations-submission.pdf: GE Submission Form

  (Other Supporting Documentation. Owner: Westraadt,Lindsay)
- Revisions Cover letter.pdf: Revisions Cover Letter

  (Cover Letter. Owner: Westraadt,Lindsay)
- Astron1100_Astronomy IRL_REVISED Syllabus.pdf: Revised Syllabus

  (Syllabus. Owner: Westraadt,Lindsay)
- Course Plan.pdf: Course Plan

  (Other Supporting Documentation. Owner: Westraadt,Lindsay)
- VLab1 Discovering the Night Sky for Yourself.pdf: Example lab 1

  (Other Supporting Documentation. Owner: Westraadt,Lindsay)
- VLab3 Standing on the Shoulders of Giants.pdf: Example lab 2

  (Other Supporting Documentation. Owner: Westraadt,Lindsay)
- Mastering Astronomy TOC.pdf: Text TOC 1

  (Other Supporting Documentation. Owner: Westraadt,Lindsay)
- An Influencer's Guide to Science IRL TOC.pdf: Text TOC 2

  (Other Supporting Documentation. Owner: Westraadt,Lindsay)
- Revision Cover letter V2.pdf: Revision Cover Letter - Revision 2

  (Cover Letter. Owner: Westraadt,Lindsay)
- Astron1100_Astronomy IRL_REVISED Syllabus V2.pdf: Revised Syllabus - Revision 2

  (Syllabus. Owner: Westraadt,Lindsay)
- Astron1100_Astronomy IRL_REVISED Syllabus V2.docx: Revised Syllabus - Revision 2 - with Track Changes

  (Syllabus. Owner: Westraadt,Lindsay)

Comments

- Please see Subcommittee feedback email sent 04/09/2025. *(by Hilty,Michael on 04/09/2025 08:52 AM)*
- See feedback email sent to department 12-17-2024 RLS *(by Steele,Rachel Lea on 12/17/2024 01:14 PM)*
- There is a small typo in the approved ODE cover sheet. The course number is Astronomy 1100, not Astronomy 1000. This was corrected after sending the document for approval. *(by Westraadt,Lindsay on 11/22/2024 02:54 PM)*

Workflow Information

Status	User(s)	Date/Time	Step
Submitted	Westraadt,Lindsay	11/22/2024 02:57 PM	Submitted for Approval
Approved	Thompson,Todd Alan	11/22/2024 03:03 PM	Unit Approval
Approved	Vankeerbergen,Bernadette Chantal	12/02/2024 08:31 AM	College Approval
Revision Requested	Steele,Rachel Lea	12/17/2024 01:14 PM	ASCCAO Approval
Submitted	Westraadt,Lindsay	03/04/2025 09:52 AM	Submitted for Approval
Approved	Thompson,Todd Alan	03/04/2025 09:55 AM	Unit Approval
Approved	Vankeerbergen,Bernadette Chantal	03/19/2025 01:19 PM	College Approval
Revision Requested	Hilty,Michael	04/09/2025 08:52 AM	ASCCAO Approval
Submitted	Westraadt,Lindsay	04/23/2025 12:58 PM	Submitted for Approval
Approved	Thompson,Todd Alan	04/23/2025 02:51 PM	Unit Approval
Approved	Vankeerbergen,Bernadette Chantal	04/30/2025 03:02 PM	College Approval
Pending Approval	Jenkins,Mary Ellen Bigler Hanlin,Deborah Kay Hilty,Michael Neff,Jennifer Vankeerbergen,Bernadette Chantal Steele,Rachel Lea	04/30/2025 03:02 PM	ASCCAO Approval

To the NMS Subcommittee,

Please see our response to the latest revision requests below. Subcommittee comments/requests are stated in blue.

The following attachments accompany this syllabus revision:

- Revision Cover Letter V2 (this document)
- Revised Syllabus (Astron1100_Astronomy IRL_REVISED Syllabus V2) – to assist the committee in tracking the latest revisions, the Word version of the revised syllabus with track changes selected has been uploaded along with the pdf of the final document.

The Subcommittee would like to see more diversity in how the instructional team will interact with students throughout the course. While they appreciate the implementation of the Astro Chat sessions, they were unconvinced that, in the current form, there is enough instructor interaction/presence within the course and would like to see additional evidence of the required Regular and Substantive Interaction (RSI). As a recommendation, the Subcommittee would like to provide some guidance from the ASC Office of Distance Education as to how the course proposer may increase instructor presence within the course, which can be found on their website here.

At present, direct instructor presence is created through weekly introductory/overview mini lessons presented by the instructor, and instructor presence in subsequent mini-lesson recordings. As indicated on page 1 of the syllabus, the instructor will also be available daily for office hours via zoom. Further RSI is fostered through weekly small-group Astro Chat discussions, which are facilitated live via zoom. Students will also co-create certain sections of *An Influencer's Guide to Science IRL* (the key reference collating the science literacy skills developed in this course) – these annotations will be guided and graded by the instructor and facilitated using Hypothes.is as part of the weekly Astro Chat preparation assignments.

The reason we opted for asynchronous mini-lesson recordings (with instructor presence) over traditional live lecture recordings is because we wanted to design a course that was better suited for the online space and the needs of online students (who typically require the flexibility of asynchronous lessons). Mini lessons will be presented using ThingLink, allowing for the integration of checkpoint quizzes into the lesson sequence. This combination of short videos with embedded graded quizzes will optimize student focus and engagement and avoid students by-passing lecture recordings and jumping straight to knowledge check quizzes (the weekly summative quiz).

Regarding the weekly live Astro Chat sessions, we acknowledge the committee's concern that these sessions will be facilitated by GTAs. The reason why the instructor was not assigned as the lead facilitator for Astro Chat sessions is that we wanted to keep these groups small (< 10 people) to ensure quality engagement. We anticipate high numbers for this course, of the order of 100-300 students. For smaller classes (< 60 students) the instructor will absolutely facilitate discussions, but for larger classes, this is not feasible, and we will need to rely on well-trained GTAs to ensure the level of participation and feedback necessary for learning. To address the committee's concerns, for large classes, the instructor will attend at least 6 discussion sessions per week, alternating between groups to ensure equal engagement with all groups.

Regarding RSI for the remaining course components, namely V-labs and unit assessments, the committee is referred to the next discussion on grading and instructor feedback.

The syllabus has been revised, to better convey RSI in the syllabus, with the majority of revisions made to the **Pace of online activities** section. See track changes for all revisions.

The Subcommittee noted that a significant portion of the course assignments (as found on pages 12-13 of the syllabus) appear to be automatically graded within CarmenCanvas and offer few opportunities for substantive feedback and interaction from the course instructor. The Subcommittee would like to see some of the course assignments either be redesigned or reimagined to allow for more opportunities for students to interact and engage with the material and the instructional team, as they believe this will help the course to better fulfill the requirements of the GEN Natural Sciences ELOs. Additionally, as a guide to assist the proposer in redesigning the course assignments, the Subcommittee recommends that at least 25% of all course assignments allow for substantive interaction and feedback from the instructional team.

Based on the information previously provided, it is not clear whether the committee would like 25% of each individual assignment to allow for substantive interaction and feedback, or for 25% of assignments as a whole to meet this requirement. If it is the latter, then this requirement is already met. The committee is reminded of the table extract below from the previous revision's cover letter which inversely states that 25% of the course material is not auto graded. Further comments on each assignment category and current revisions are provided below:

- **Mini lesson checkpoint quizzes (20% of grade)**: These checkpoint quizzes (previously referred to as review quizzes) are embedded into mini-lesson sequences using ThingLink. Their purpose is to encourage participation in lessons and develop the foundational knowledge necessary for higher level thinking and discussion. It focuses on the lowest level of Bloom's Taxonomy (Remember) and is sufficiently and efficiently assessed with auto-graded MCQs.
- **V-labs (25% of grade):** Virtual labs focus on the next two levels of Bloom's Taxonomy (Understand and Apply). It develops understanding through exploration of concepts and application of astronomical methods. As demonstrated in the previous revision's cover letter and sample V-labs, manually graded reflection questions will be added to each lab to allow students to demonstrate understanding and receive feedback. About 20% of each V-lab will be manually graded, constituting **5% of the final grade.**
- **Astro chat (10% of grade):** Weekly discussions, which contribute **10% of the final grade**, are fully manually graded with in-person feedback provided during live discussions. Weekly discussions focus on higher levels of Bloom's Taxonomy, including Analyze and Evaluate. To add to the rigor of feedback, this revision requires students to submit written responses to the week's discussion topic as part of their discussion prep. This will then be graded, allowing for feedback and RSI from the instructional team.
- **Knowledge checks (30% of grade):** Knowledge checks are summative assessments, assessing whether students gained the appropriate knowledge and understanding of the week's topics. It will assess all levels of Bloom's Taxonomy, with the exception of Create. To allow for higher levels of assessment like Understand and Analyze, this revision will require 20% of knowledge check grades to be manually graded, constituting **6% of the total grade**.

- **Unit assessments (15% of grade):** Unit assessments are summative assessments aimed at progressively assessing all levels of Boom's Taxonomy. Details of unit assessments are provided under **Description of major course assignments** in the syllabus. Unit 1 and 2 assessments focus on the first three levels of Bloom's Taxonomy (Remember, Understand and Apply). These outcomes are efficiently and sufficiently assessed with two auto-grade escape room challenges and one manually graded ongoing activity (see Ongoing Activity 1). Unit 3 and 4 assessments assess the highest three levels of Bloom's Taxonomy (Analyze, Evaluate and Create). These assessments require students to create, present and discuss content based on what they have learned. These are manually graded assignments, presented and discussed during Astro Chat in small groups. As previously stated, 3 of the 5 unit assessments are manually graded. This constitutes 60% of the unit assessment grade, and **9% of the final course grade**.

In summary, **30% of the revised grading scheme relies on manual grading**, contributing to RSI and allowing for feedback from the instructional team where necessary. The grading scheme is designed to be efficient and effective. Since we are anticipating high student numbers, we make use of auto-grading and auto-feedback where appropriate and rely on manual grading and instructor feedback only when beneficial. Depending on the size of the class, grading will either be completed by the instructor (for small classes) or well-trained GTAs (for larger classes), with priority being given to instructor presence in weekly Astro Chats. To accommodate for grading-related queries and to further encourage RSI, students will continuously be reminded that the instructor is available daily for office hours.

Table extra from previous revision cover sheet:

	Subcommittee comments	Course updates
d	The Subcommittee asks that the department amend or add to the course's assessments so that students are completing further discussions and/or writing-focused assignments and receiving feedback from instructors. They note that many of the course ELOs include asking students to "explain", "demonstrate" "describe" or "analyze" (syllabus, pp. 3-4); however, it will be difficult for students to demonstrate mastery of these ELOS without assessments that require more robust feedback from their instructors. At this time, it appears that the majority of the course grading will be automated via Carmen rather than graded by an instructor, and that there is a	The updated grading structure for this course is as follows: (see table below) Roughly 75% of assessments are auto-graded, including mini lesson review quizzes, V-labs, knowledge checks and 2 of the 5 unit assessments in the form of escape room challenges. Mini lesson review quizzes and knowledge checks are fully auto-graded MCQ quizzes. Auto-feedback will be built into review quizzes to give answer-specific feedback. V-labs are predominantly auto-graded (see **VLab1** and **VLab3**), however, V-labs will be implemented in Carmen using H5P, allowing for a range of question types and a more interactive experience. We will make use of the auto-feedback functionally in H5P to provide real-time feedback and hints on auto-graded

Assignment Category	**Percentage**
Mini lesson review quizzes	20%
V-labs	25%
Astro chat	10%
Knowledge checks	30%
Unit assessments	15%
Total	**100%**

	possibility that *all* assignments will be auto-graded (syllabus, p. 14).	questions, highlighting incorrect answers and guiding re-attempts, allowing students to learn as they go. In addition, manually graded reflection questions will be added to each lab to allow students to demonstrate understanding and receive feedback (see **VLab1** and **VLab3**). The main assignments dedicated to assessing and proving feedback on higher-level learning outcomes are the weekly **Astro chat** discussions and the remaining **Unit assessments**. See the attached **Course Plan** for each week's Astro chat topics as well as a description of Unit assessments provided at the start of each unit.

The Subcommittee notes, on page 5 of the syllabus, that the course states it will operate "96% online". They believe what it is meant is that this course will operate 96% asynchronously online and 4% synchronously. They ask that this be updated as there are no in-person components of the course and this will likely be confusing to students.

Agreed. This has been corrected.

Best regards,
Lindsay Westraadt

Syllabus

ASTRONOMY1100

Astronomy IRL: An Influencer's Guide to Science

Autumn 2025

4 Credit Hours

Online

Course overview

Instructor (TBD)

- Name
- Email Address
- Phone Number
- Course Zoom Link
- Office Hours
    - Zoom Link
    - Office hours will take place daily via zoom. Times TBD.

Note: My preferred method of contact is office hours or email communication.

Course description

Science shapes our daily lives, from the food we eat to the news we read. Yet, with so much information claiming to be "scientific," how do we know what to trust? Saying "science isn't for me" is no longer an option—we all rely on it, whether we realize it or not.

This course is designed to sharpen your ability to evaluate scientific information and apply it to real-life decisions. We focus on universal science literacy skills, using astronomy as a concrete way to introduce and practice them. You'll explore key methods and topics in modern astronomy, using them as a lens to understand the nature and tools of science – while experiencing the wonders of our universe along the way! You'll also apply these skills in real-world scenarios, including creating your own responsible social media content.

So, why "Influencer"? Whether you create content or simply consume it, you are part of the cycle of influence. We are all shaped by online information, and at some point, we shape others. This course is for both the influenced and the influencer—helping ensure that science is used responsibly in the digital age.

Prerequisites

Completion of Math 1075 or higher or a Math Placement score of "N" or higher.

General education goals and expected learning outcomes

The goals of the *Foundations: Natural Sciences* category of the General Education curriculum are as follows:

GE Goal#1: Successful students will engage in theoretical and empirical study within the natural sciences while gaining an appreciation of the modern principles, theories, methods and modes of inquiry used generally across the natural sciences.

GE Goal#2: Successful students will discern the relationship between the theoretical and applied sciences while appreciating the implications of scientific discoveries and the potential impacts of science and technology.

As part of the *Foundations: Natural Sciences* category of the General Education curriculum, this course is designed to prepare students to be able to do the following:

GE ELO 1.1 Explain basic facts, principles, theories and methods of modern natural sciences, and describe and analyze the process of scientific inquiry.

GE ELO 1.2 Identify how key events in the development of science contribute to the ongoing and changing nature of scientific knowledge and methods.

GE ELO 1.3 Employ the processes of science through exploration, discovery and collaboration to interact directly with the natural world when feasible, using appropriate tools, models and analysis of data.

GE ELO 2.1 Analyze the inter-dependence and potential impacts of scientific and technological developments.

GE ELO 2.2 Evaluate social and ethical implications of natural scientific discoveries.

GE ELO 2.3 Critically evaluate and responsibly use information from the natural sciences.

This course achieves the outcomes of GE Goal 1 by using astronomy as a concrete way to introduce and develop an understanding of the methods and nature of science, and of universal scientific literacy skills. To promote the extension of this knowledge beyond astronomy and into everyday experiences, the outcomes of GE Goal 2 will be achieved by applying these universal skills in the context of real-life social media influences. To this end, the course has been structured into the following four units:

Unit 1: Science Unlocked: How to Talk the Talk and Walk the Walk: How do we separate science from pseudoscience? How do we separate truth from misleading claims? This unit kicks off your science IRL journey by building the skills needed to think, talk and walk like a scientist. Through the lens of astronomy, we'll trace the birth and development of science, learning what science is and how to recognize it. And we'll catch you up on the math and physics you need to go all the way in this course! Expect to have some fun along the way – we're going to put your bull$#!t detector and logic to the test as we lay the groundwork for deeper cosmic exploration ahead.

Unit 2: Behind the Scenes: Where Do Scientists Get Their Facts From? This unit builds on the previous unit and develops trust in the scientific method by exploring how we know seemingly impossible things. You'll build domain knowledge by expanding your map of physics and exploring the astronomical methods and technologies that make discovery possible. We'll put constraints on discovery by introducing the concept of uncertainty in measurement —whether due to the vast scale of the universe, technological constraints, or inherent uncertainties in observations. You'll continue to learn how to think like a scientist as we explore what "uncertainty" means to a scientist, how they account for uncertainty and error, and that good science always reports its limitations.

Unit 3: Guessing or Slaying? How Theories Evolve and Get Verified: Now that we've covered the basics of how science works, we're letting you loose in the world of modern astronomy! This unit builds trust in the scientific method by showing how scientific theories are born, tested, and refined. We'll dive into four hot topics in astronomy, exploring key concepts, theory development, and open questions. You'll also learn about current and upcoming surveys tackling these mysteries. Plus, it's your time to shine as a responsible influencer—get ready to create media content on a trending astronomy topic!

Unit 4: Game On! Tackling Tough Topics in Science Like a Boss: Now that you've got a solid grip on the scientific process, it's time to put those skills to work IRL! This unit is all about using science literacy in decision-making—spotting and debunking false claims, evaluating source trustworthiness, understanding the significance of claims, and asking whether it matters IRL! With the rise of AI tools that can answer just about anything, the real challenge isn't finding information—it's knowing the right questions to ask and how to validate the answers. Plus, get ready to level up on your influencer game! Be prepared to tackle more complex topics and up your appeal!

How this online course works

Mode of delivery

This course is 100% online.

Pace of online activities

You are only required to participate in one 30-minute live **Astro Chat** discussion per week. All other weekly tasks can be completed throughout the week at your own time. Each week will typically follow a similar pattern:

- You will complete the following tasks **before** Astro Chat (due Thursday, midnight):
    - First complete the introductory mini lesson (The Big Idea).
    - Then complete the remainder of the week's mini lessons and the virtual lab (V-lab). These can be completed in parallel as you see fit.
- You will then attend your live 30-minute Astro Chat session with me (or a member of the instructional team) on Zoom:
    - Your Astro Chat sessions will take place on Fridays or Mondays. You will select your fixed timeslot at the start of the semester.
- **After** completing all the week's tasks and participating in Astro Chat, you will complete the week's Knowledge Check by Monday midnight of the following week.

In addition to weekly tasks, you will also need to spend time completing and/or preparing for unit assessments each week. A more detailed description of work expectations is provided in the next section.

Since this is a mostly asynchronous course, you are strongly encouraged to communicate any questions or concerns as they arise via email or during office hours. I am available daily via Zoom for drop-in office hours (see **Course Overview** for information on days and times).

Credit hours and work expectations

This is a **4-credit-hour course** with a practical component. According to Ohio State policy (go.osu.edu/credithours), students should expect around 12 hours of engagement with the class each week to receive a grade of (C) average. Actual hours spent will vary by student learning habits and the assignments each week.

Weekly tasks include roughly 7 **mini lessons**, a **V-lab**, an **Astro Chat** virtual discussion and a **Knowledge Check** quiz. In addition to weekly tasks, students will complete **unit assessments** at the end of, or during, each unit that will test the astronomy-related concepts and science literacy skills developed throughout the unit. See **Course Schedule** for information on the scheduling of unit assessments.

An overview of the weekly tasks and the estimated hours required is given in the table below.

Activity	Description	No. per week	Hrs. per week
Mini lessons	Mini lessons are designed for knowledge building and skills development and comprise of readings, instructional videos, and/or interactive activities. Each mini lesson is roughly 30 minutes long, with an additional 10 minutes allocated to embedded checkpoint quizzes. **Mode of delivery and assessment:** Carmen assignment	7	~4.5
V-lab	Virtual labs are aimed at hands-on exploration of the week's topic/s and	1	3

	are designed to be completed within 3 hours. **Mode of delivery and assessment:** Carmen assignment		
Astro chat	Virtual discussions will center on the week's key theme and offer students a space to deepen their understanding while engaging with their peers and the instructional team. Each small-group discussion will take place at a fixed 30-minute time slot in CarmenZoon each week, with an expected 1 hour of preparation required. **Mode of delivery and assessment:** Carmen assignment (preparation) and CarmenZoom session (discussion), facilitated and graded by a member of the instructional team.	1	1.5
Knowledge check	At the end of each week, students will take a knowledge check quiz. Students can expect to spend 1 hour on knowledge checks – 30 minutes to prepare and 30 minutes to compete the quiz. **Mode of delivery and assessment:** Carmen quiz	1	1
Unit assessments	In addition to weekly tasks, students will complete a unit assessment for each unit. It is anticipated that students will spend roughly 2 hours completing		2

	and/or preparing for unit assessments each week. **Mode of delivery and assessment:** Variable. See **Description of major course assignments** for details.		
TOTAL			12

Participation requirements

Participating in online activities

You are only required to participate in one 30-minute virtual **Astro chat** discussion on CarmenZoom per week. All other weekly tasks can be completed throughout the week at your own time. See **Pace of online activities** for an overview of weekly activities and due dates.

Office hours and live sessions

The attendance of office hours and any ad hoc live sessions is optional. Recordings of ad hoc live sessions (excluding office hours and Astro Chat) will be made available for asynchronous access.

Course communication guidelines

Writing style

All formal written communication in this course, including emails, discussion posts, and assignments, should adhere to standard grammar and punctuation. Use complete sentences and clear language, avoiding overly casual language or abbreviations. Please proofread communications to ensure clarity and accuracy.

Tone and civility

This course is designed to foster a respectful and supportive learning environment. All interactions, whether with peers or instructors, should be conducted with courtesy and thoughtfulness. Approach discussions and communications with an open mind, especially in cases of differing perspectives. In situations of disagreement, focus on constructive dialogue. Any disruptive or disrespectful behavior may be addressed formally according to The Ohio State University's student conduct policies. As your instructor, I am committed to responding to inquiries thoughtfully and encouraging an inclusive and respectful space for all students.

Citing your sources

Proper citation is essential in this course to maintain academic integrity and respect intellectual property. When referencing material in assignments or discussions, provide comprehensive citations. For example, include the following information where applicable: author(s), title, publisher, publication date, page numbers (if applicable), and a link for online sources. Use a consistent citation style (e.g., APA, MLA) throughout.

Protecting and saving your work

To safeguard your work, please compose assignments in a word processing tool before submitting them on Carmen. Saving your work offline provides a backup in case of internet connectivity issues, browser timeouts, or failed submissions. Ensure you regularly save your progress to avoid data loss and keep copies of submitted assignments until you receive a grade confirmation.

Course materials and technologies

Required Textbook

Bennett, J., Donahue, M., Schneider, N., & Voit, M. (2023). The Cosmic Perspective (10th ed.). Pearson. The online textbook is included in your course fees and accessible via Carmen.

Supplementary reference material, including An Influencer's Guide to Science IRL, will be made available for download on Carmen.

Course technology

Technology support

For help with your password, university email, Carmen, or any other technology issues, questions, or requests, contact the Ohio State IT Service Desk. Standard support hours are available at it.osu.edu/help, and support for urgent issues is available 24/7.

- Self-Service and Chat support: it.osu.edu/help
- Phone: 614-688-4357(HELP)
- Email: 8help@osu.edu
- TDD: 614-688-8743

Technology skills needed for this course

- Basic computer and web-browsing skills
- Navigating Carmen (go.osu.edu/canvasstudent)
- CarmenZoom virtual meetings (go.osu.edu/zoom-meetings)

Required Equipment

- Computer: current Mac (MacOs) or PC (Windows 10) with high-speed internet connection
- Webcam: built-in or external webcam, fully installed and tested
- Microphone: built-in laptop or tablet mic or external microphone
- Other: a mobile device (smartphone or tablet) to use for BuckeyePass authentication

Required software

- Microsoft Office 365: All Ohio State students are now eligible for free Microsoft Office 365. Full instructions for downloading and installation can be found at go.osu.edu/office365help.

Carmen Access

You will need to use BuckeyePass (buckeyepass.osu.edu) multi-factor authentication to access your courses in Carmen. To ensure that you are able to connect to Carmen at all times, it is recommended that you take the following steps:

- Register multiple devices in case something happens to your primary device. Visit the BuckeyePass
- Request passcodes to keep as a backup authentication option. When you see the Duo login screen on your computer, click **Enter a Passcode** and then click the **Text me new codes** button that appears. This will text you ten passcodes good for 365 days that can each be used once.
- Download the Duo Mobile application to all of your registered devices for the ability to generate one-time codes in the event that you lose cell, data, or Wi-Fi service

If none of these options will meet the needs of your situation, you can contact the IT Service Desk at 614-688-4357(HELP) and IT support staff will work out a solution with you.

Hypothes.is

This course requires the use of a digital social annotation tool called Hypothes.is. Hypothes.is allows students to engage with course readings and online content by highlighting text and adding comments directly on web pages or PDFs. This tool will be used to foster collaborative learning and facilitate discussions about the course material. Students will be able to annotate readings, share insights, ask questions, and respond to peers, creating a dynamic learning environment. The instructor may also monitor and participate in the annotations, providing feedback, guiding discussions, and answering questions to enhance the learning experience.

If you encounter an issue with access to this tool, please contact your instructor at their name.#@osu.edu and ascode@osu.edu.

Accommodation and assistance will be arranged for you to complete any work required with this tool free of penalty.

V-Lab Equipment

The following equipment will be required for V-labs:

- Calculator
- Ruler
- Phone camera
- Craft materials to model our solar system at home, including Styrofoam base and balls, skewers and a lamp. Any replacement items serving the same function can be used. For example, a phone torch can be used instead of a lamp, and clay balls can be used instead of Styrofoam balls.
- Diffraction grating glasses. These will be available for collection from the Astronomy Department. Students unable to collect glasses, can create their own diffraction grating at home using an old CD.

Details of equipment requirements will be provided at the start of each lab. Please reach out with any equipment-related concerns.

Accessibility Statement

This course utilizes web-based planetarium tools such as Stellarium and NASA's Eyes, which are highly visual applications. If you have difficulty accessing this content due to a visual impairment or other accessibility concerns, equivalent alternative assignments will be provided as needed. Please reach out if you require accommodations.

At times, this course may require outdoor explorations such as moon observations and walking the Solar System to Scale on North Campus. If you are unable to participate in outdoor explorations due to safety or accessibility concerns, or being out of town, equivalent alternative assignments will be provided as needed. Please reach out for assistance.

Grading and instructor response

How your grade is calculated

Assignment Category	**Percentage**
Mini lesson checkpoint quizzes	20%
V-labs	25%
Astro chat	10%
Knowledge checks	30%
Unit assessments	15%
Total	**100%**

Description of major course assignments

Assignment categories

See **Credit hours and work expectations** for an overview of the assignment categories listed above.

Below are the details of the unit assessments. See **Course Schedule** for due dates.

Unit 1 assessments

Escape Room: Smoke and Mirrors

This escape room will be based on the course content from Weeks 1-3. See the learning outcomes listed at the start of each activity to guide your preparation.

Duration: 1 hour

Format and grading: Auto-graded Carmen assignment

Ongoing Activity 1: You Be the Scientist!

In this ongoing activity you will craft your own physical model of the Earth-Moon-Sun system, use your model to make predictions about when you should see each phase of the moon, test your predictions by watching the sky, and then refining your model if needed.

An alternative version of this assignment is available on request for students with accessibility concerns.

Duration: 6 weeks

Format and grading: Scientific report, completed according to template. See rubric for grading guidelines.

Unit 2 assessment

Escape Room: The Mystery of the Dead Star

This escape room will be based on the course content from Weeks 4-7. See the learning outcomes listed at the start of each activity to guide your preparation.

Duration: 1 hour

Format and grading: Auto-graded Carmen assignment

Unit 3 assessment

Ongoing Activity 2: You Be the Influencer!

This ongoing activity will be issued at the start of Unit 3. Using the science communication tips in your user guide, you'll create responsible content explaining one of the astronomy topics from the provided list. If you want to choose a different topic, check with us first to ensure it meets the assignment's learning goals. Your content should be engaging for your target audience and meet all the requirements outlined in the grading rubric.

Format of submission: Your content can take the form of a popular science article or a YouTube video. For YouTube videos, you can submit either a voice-overed storyboard or go ahead and create the final video—your choice!

Due date and grading: Your final product will be due in the first week of the next unit. You'll present it to your Astro Chat discussion group, where your instructor and peers will grade it based on the grading rubric.

Unit 4 assessment

Ongoing Activity 3: You Be the Influencer – Boss Level!

In the previous unit, you gained hands-on experience creating science content and received feedback on your work. Now, it's time to level up! We'll tackle more complex topics and be even more selective when it comes to judging the appeal of your content.

This ongoing activity will be issued at the start of Unit 4. Using the science communication tips in your user guide, create a responsible YouTube video on one of the astronomy topics from our list of hot topics. Your video should be engaging for your target audience and cover all the hallmarks of responsible reporting, as outlined in the grading rubric.

Format of submission: You can submit either a storyboard with an accompanying script or go ahead and create the final video—your choice!

Due date and grading: Your video (or voice-overed storyboard) will be due in the last week of term. You'll present it to your Astro Chat discussion group, where your instructor and peers will grade it based on the grading rubric.

Academic integrity and collaboration guidelines

The completion of all mini lesson review quizzes and knowledge check quizzes are strictly closed-internet with no collaboration. Students may however reference course notes when completing quizzes. Unless otherwise stated, the same rules apply to unit assessment escape rooms.

V-labs, Astro chat preparation and content creation assignments are typically open-internet, open-notes and collaboration is permitted. However, unless otherwise stated, students are expected to submit their own work for grading.

Late assignments

Late submissions will incur a 10% grade deduction for each day past the deadline.

Missed assignments will automatically receive a grade of zero.

All activities need to be submitted for grading by the last day of class.

Exceptions to the above rules can be made for cogent reasons on request. The responsibility is on the student to request an extension as soon as possible. **Extension requests received more than one week after the original deadline may be denied if no valid reason for the delay is provided.**

Grading Scale

- 93-100: A
- 90-92: A–
- 87-89: B+
- 83-86: B
- 80-82: B–
- 77-79: C+
- 73-76: C
- 70-72: C–
- 67-69: D+
- 60-66: D
- Under 60: E

Instructor feedback and response time

Grading and feedback

The results of auto-graded assignments will be released automatically once the assessment has closed. For assignments requiring manual grading, results will typically be made available within a week after the due date.

Preferred contact method

Students can ask questions, voice concerns or query grades during office hours or via email. The typical response time for email enquiries is 1-2 business days.

Academic policies

Academic integrity policy

See **Descriptions of major course assignments**, above, for my specific guidelines about collaboration and academic integrity in the context of this online class. Suspected infringements of these requirements will be reported to the Committee on Academic Misconduct for further investigation.

It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term "academic misconduct" includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-487). For additional information, see the Code of Student Conduct: http://studentlife.osu.edu/csc/.

If I suspect that a student has committed academic misconduct in this course, I am obligated by university rules to report my suspicions to the Committee on Academic Misconduct. If COAM determines that you have violated the university's Code of Student Conduct (i.e., committed academic misconduct), the sanctions for the misconduct could include a failing grade in this course and suspension or dismissal from the university.

If you have any questions about the above policy or what constitutes academic misconduct in this course, please contact me.

Other sources of information on academic misconduct (integrity) to which you can refer include:

- Committee on Academic Misconduct web page (go.osu.edu/coam)
- Ten Suggestions for Preserving Academic Integrity (go.osu.edu/ten-suggestions)

Copyright for instructional materials

The materials used in connection with this course may be subject to copyright protection and are only for the use of students officially enrolled in the course for the educational purposes associated with the course. Copyright law must be considered before copying, retaining, or disseminating materials outside of the course.

Statement on title IX

Title IX makes it clear that violence and harassment based on sex and gender are Civil Rights offenses subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories (e.g., race). If you or someone you know has been sexually harassed or assaulted, you may find the appropriate resources at http://titleix.osu.edu or by contacting the Ohio State Title IX Coordinator at titleix@osu.edu.

Commitment to a diverse and inclusive learning environment

The Ohio State University affirms the importance and value of diversity of people and ideas. We believe in creating equitable research opportunities for all students and to providing programs and curricula that allow our students to understand critical societal challenges from diverse perspectives and aspire to use research to promote sustainable solutions for all. We are committed to maintaining an inclusive community that recognizes and values the inherent worth and dignity of every person; fosters sensitivity, understanding, and mutual respect among all members; and encourages each individual to strive to reach their own potential. The Ohio State University does not discriminate on the basis of age, ancestry, color, disability, gender identity or expression, genetic information, HIV/AIDS status, military status, national origin, race, religion, sex, gender, sexual orientation, pregnancy, protected veteran status, or any other bases under the law, in its activities, academic programs, admission, and employment. (To learn more about diversity, equity, and inclusion and for opportunities to get involved, please visit: https://odi.osu.edu/ or https://cbsc.osu.edu)

Land acknowledgement

We would like to acknowledge the land that The Ohio State University occupies is the ancestral and contemporary territory of the Shawnee, Potawatomi, Delaware, Miami, Peoria, Seneca, Wyandotte, Ojibwe and Cherokee peoples. Specifically, the university resides on land ceded in the

1795 Treaty of Greeneville and the forced removal of tribes through the Indian Removal Act of 1830. I/We want to honor the resiliency of these tribal nations and recognize the historical contexts that has and continues to affect the Indigenous peoples of this land.

More information on OSU's land acknowledgement can be found here: https://mcc.osu.edu/about-us/land-acknowledgement

Your mental health

As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. The Ohio State University offers services to assist you with addressing these and other concerns you may be experiencing. If you or someone you know are suffering from any of the aforementioned conditions, you can learn more about the broad range of confidential mental health services available on campus via the Office of Student Life's Counseling and Consultation Service (CCS) by visiting ccs.osu.edu or calling 614-292-5766. CCS is located on the 4th Floor of the Younkin Success Center and 10th Floor of Lincoln Tower. You can reach an on-call counselor when CCS is closed at 614-292-5766 and 24 hour emergency help is also available 24/7 by dialing 988 to reach the Suicide and Crisis Lifeline.

Accessibility accommodations for students with disabilities

Requesting accommodations

The university strives to maintain a healthy and accessible environment to support student learning in and out of the classroom. If you anticipate or experience academic barriers based on your disability (including mental health, chronic, or temporary medical conditions), please let me know immediately so that we can privately discuss options. To establish reasonable accommodations, I may request that you register with Student Life Disability Services. After registration, make arrangements with me as soon as possible to discuss your accommodations so that they may be implemented in a timely fashion.

If you are ill and need to miss class, including if you are staying home and away from others while experiencing symptoms of a viral infection or fever, please let me know immediately. In cases where illness interacts with an underlying medical condition, please consult with Student Life Disability Services to request reasonable accommodations. You can connect with them at slds@osu.edu; 614-292-3307; or slds.osu.edu.

Religious accommodations

Ohio State has had a longstanding practice of making reasonable academic accommodations for students' religious beliefs and practices in accordance with applicable law. In 2023, Ohio State updated its practice to align with new state legislation. Under this new provision, students must be in early communication with their instructors regarding any known accommodation requests for religious beliefs and practices, providing notice of specific dates for which they request alternative accommodations within 14 days after the first instructional day of the course. Instructors in turn shall not question the sincerity of a student's religious or spiritual belief system in reviewing such requests and shall keep requests for accommodations confidential.

With sufficient notice, instructors will provide students with reasonable alternative accommodations with regard to examinations and other academic requirements with respect to students' sincerely held religious beliefs and practices by allowing up to three absences each semester for the student to attend or participate in religious activities. Examples of religious accommodations can include, but are not limited to, rescheduling an exam, altering the time of a student's presentation, allowing make-up assignments to substitute for missed class work, or flexibility in due dates or research responsibilities. If concerns arise about a requested accommodation, instructors are to consult their tenure initiating unit head for assistance.

A student's request for time off shall be provided if the student's sincerely held religious belief or practice severely affects the student's ability to take an exam or meet an academic requirement and the student has notified their instructor, in writing during the first 14 days after the course begins, of the date of each absence. Although students are required to provide notice within the first 14 days after a course begins, instructors are strongly encouraged to work with the student to provide a reasonable accommodation if a request is made outside the notice period. A student may not be penalized for an absence approved under this policy.

If students have questions or disputes related to academic accommodations, they should contact their course instructor, and then their department or college office. For questions or to report discrimination or harassment based on religion, individuals should contact the Office of Institutional Equity.

Policy: Religious Holidays, Holy Days and Observances

Course Schedule

Refer to our Carmen course page for up-to-date assignment due dates. See **Late assignments** for more information on late or missed tasks and assignments.

Week	Topics and Tasks	Assessments Due
Unit 1: Science Unlocked: How to Talk the Talk and Walk the Walk		
1	**Is it Science?** Astronomy mini lessons topics: Patterns in the Night Sky; The Science of Astronomy Science IRL mini lessons topic: Is it Science? V-lab: Discovering the Night Sky for Yourself Astro chat: How good is your bull$#!t detector? Is it even science? Ongoing Activity 1: You Be the Scientist!	Mini lesson checkpoint quizzes Knowledge check
2	**How to Speak and Think Like a Scientist** Astronomy mini lessons topic: A Modern View of the Universe Science IRL mini lessons topic: How to Speak and Think Like a Scientist V-lab: The Power of Math: Scaling Relations	Mini lesson checkpoint quizzes Knowledge check

Week	Topics and Tasks	Assessments Due
	Astro chat: How good is your bull$#!t detector? Data and logic edition Ongoing Activity 1: You Be the Scientist!	
3	**A Map of Physics** Astronomy mini lessons topic: Orbital Mechanics Science IRL mini lessons topic: A Map of Physics V-lab: Standing on the Shoulders of Giants Astro chat: When common-sense fails you! Ongoing Activity 1: You Be the Scientist!	Mini lesson checkpoint quizzes Knowledge check
Unit 2: Behind the Scenes: Where Do Scientists Get Their Facts From?		
4	**How far can and have we gone?** Astronomy mini lessons topics: Our Planetary System; Solar System Exploration Science IRL mini lessons topic: A Map of Physics V-lab: Exploring the Scale of our Solar System Astro chat: Our evolving definition of a planet	Mini lesson checkpoint quizzes Knowledge check **Unit 1 Assessment: Escape Room**

Week	Topics and Tasks	Assessments Due
	Ongoing Activity 1: You Be the Scientist!	
5	**If we can't *go* there, how do we know so much?** Astronomy mini lessons topics: How we use light; Surveying the Stars Science IRL mini lessons topic: A Map of Physics V-lab: Properties of Stars Astro chat: The hidden world of light Ongoing Activity 1: You Be the Scientist!	Mini lesson checkpoint quizzes Knowledge check
6	**Are there limits to our observations?** Astronomy mini lessons topics: How we use light; Exoplanets Science IRL mini lessons topics: A Map of Physics; Sources of Error V-lab: Transiting Exoplanets Astro chat: Do aliens know we exist? Ongoing Activity 1: You Be the Scientist!	Mini lesson checkpoint quizzes Knowledge check **Ongoing Activity 1 due**
7	**If only we had a cosmic measuring tape!**	Mini lesson checkpoint quizzes

Week	Topics and Tasks	Assessments Due
	Astronomy mini lessons topics: Counting galaxies; Measuring galactic distances; Lookback time Science IRL mini lessons topics: A Map of Physics; Sources of Error V-lab: Parallax Astro chat: Each crayon of light tells a story	Knowledge check
Unit 3: Guessing or Slaying? How Theories Evolve and Get Verified		
8	**Stellar evolution** Astronomy mini lessons topic: Stellar Evolution Science IRL mini lessons topic: - V-lab: Scaling Relations and Stellar Evolution Astro chat: We are made of star stuff! Ongoing Activity 2: You Be the Influencer!	Mini lesson checkpoint quizzes Knowledge check **Unit 2 Assessment: Escape Room**
9	**Dark matter** Astronomy mini lessons topic: Dark Matter Science IRL mini lessons topic: A Map of Physics	Mini lesson checkpoint quizzes Knowledge check

Week	Topics and Tasks	Assessments Due
	V-lab: Galaxy Rotation Curves Astro chat: Newtonian Gravity vs. General Relativity Ongoing Activity 2: You Be the Influencer!	
10	**Cosmic expansion and dark energy** Astronomy mini lessons topics: Cosmic expansion; Dark energy Science IRL mini lessons topic: - V-lab: The Expanding Universe Astro chat: What's at the edge of the universe? Ongoing Activity 2: You Be the Influencer!	Mini lesson checkpoint quizzes Knowledge check
11	**The early universe** Astronomy mini lessons topic: The Birth of the Universe Science IRL mini lessons topic: A Map of Physics V-lab: Rewinding the Universe Astro chat: Inflation – faster than the speed of light?! Ongoing Activity 2: You Be the Influencer!	Mini lesson checkpoint quizzes Knowledge check

Week	Topics and Tasks	Assessments Due
Unit 4: Game On! Tackling Tough Topics in Science Like a Boss		
12	**Is it reliable science?** Astronomy mini lessons topic: Life in the Universe Science IRL mini lessons topics: A Basic Guide to Science IRL: Checkpoint 1 and 2 V-lab: Finding and evaluating scientific sources: Life in the Universe Astro chat: Extraordinary claims: Aliens are visiting Earth Ongoing Activity 3: You Be the Influencer – Boss Level!	Mini lesson checkpoint quizzes Knowledge check **Ongoing Activity 2 due**
13	**Does it warrant action?** Astronomy mini lessons topic: Planetary Atmospheres Science IRL mini lessons topic: A Basic Guide to Science IRL: Checkpoint 3 V-lab: Finding and evaluating scientific sources: Climate change Astro chat: Is this politics or the real deal? Ongoing Activity 3: You Be the Influencer – Boss Level!	Mini lesson checkpoint quizzes Knowledge check

Week	Topics and Tasks	Assessments Due
14	**Does it matter IRL?** Astronomy mini lessons topic: Black holes Science IRL mini lessons topic: A Basic Guide to Science IRL: Checkpoint 4 V-lab: Evaluating the technological and socio-economic impact black hole of research Astro chat: Is taxpayer funding for blue sky research justified? Ongoing Activity 3: You Be the Influencer – Boss Level!	Mini lesson checkpoint quizzes Knowledge check
15		**Ongoing Activity 3 due**
Finals		This course has no final exam.

An Influencer's Guide to Science IRL

Contents

1. About this User's Guide

Science shapes our daily lives, from the food we eat to the news we read. Yet, with so much information claiming to be "scientific," how do we know what to trust? Saying "science isn’t for me" is no longer an option—we all rely on it, whether we realize it or not.

This guide is designed to sharpen your ability to evaluate scientific information and apply it to real-life decisions. In today’s world, powerful AI tools can help answer science-related questions—if you know what to ask. This guide will show you which questions matter and how to use AI effectively to find reliable answers.

So, why "Influencer"? Whether you create content or simply consume it, you are part of the cycle of influence. We are all shaped by online information, and at some point, we shape others. This guide is for both the **influenced** and the **influencer**—helping ensure that science is used responsibly in the digital age.

1.1. How this guide will be used in this course

This guide summarizes the science literacy tools we aim to introduce and develop in this course. While these tools are universal, we will strengthen your science literacy skills by applying them specifically to astronomy, providing a concrete way to learn and practice these concepts.

In **Module 1: Science Unlocked**, we will cover **Sections 2 to 4** of this guide, laying the foundation for deeper exploration of the scientific method in later modules. We will:

- Define what science is—and what it is not (**Section 2: Is it Science?**), enabling you to assess the scientific validity of incoming information.
- Teach fundamental number handling, graphing, and logic skills (**Section 3: How to Speak and Think Like a Scientist**), helping you navigate the sometimes complex language of scientific data.
- Introduce the core principles of physics (**Section 4: A Map of Physics**), which form the basis of all astronomical inferences.

In **Module 2: Behind the Scenes** and **Module 3: Guessing or Slaying?**, we will further develop the concepts introduced in Module 1. These modules will illustrate science in action—showing how astronomers make measurements and observations, and how they develop rigorous theories about the universe. Along the way, you will expand your Map of Physics and continue learning How to Speak and Think Like a Scientist.

Finally, in **Module 4: Game On!**, we will cover **Section 5: A Basic Guide to Science IRL** and **Section 7: AI Tools**. This module will integrate all the skills developed in the course, offering a step-by-step approach to using scientific information in real life—from assessing scientific validity to evaluating the relevance and significance of information in everyday contexts.

Lastly, from Module 2 onwards, you will start developing your own responsible social media content! Using the tips form **Section 6: Notes on Science Communication**, you will create astronomy-related YouTube content that responsibly wows your audience!

V-Lab 1: Discovering the Night Sky for Yourself

Design notes: Design notes are in red and provide information on how this lab will be implemented online. Labs will be incorporated into Carmen Canvas using H5P and will use a variety of auto graded (AG) as well as manually graded (MG) response options. Response fields are indicated in square brackets e.g. [MCQ-AG] indicates an auto graded multiple choice response field.

Aims of This V-Lab

- **Recreate the Curiosity of Early Astronomers**
  Practically explore and reproduce **naked-eye observations** that would have intrigued early scientists and sparked the birth of modern science.
- **Test and Refine Your Understanding**
  Put modern models of the **celestial sphere and solar system** to the test! Just like in the scientific process, you'll compare your own mental model against real-world observations. If predictions don't match reality, you'll refine your model—just as scientists do.
- **Experience the Scientific Cycle in Action**
  Engage in the full **scientific cycle**—from **observations to model development, predictions, testing, and refinement, then back again**. This process will be repeated throughout the course, reinforcing the **hallmarks of science** as we go. This V-Lab serves as your **first hands-on introduction** to this ongoing cycle of discovery.

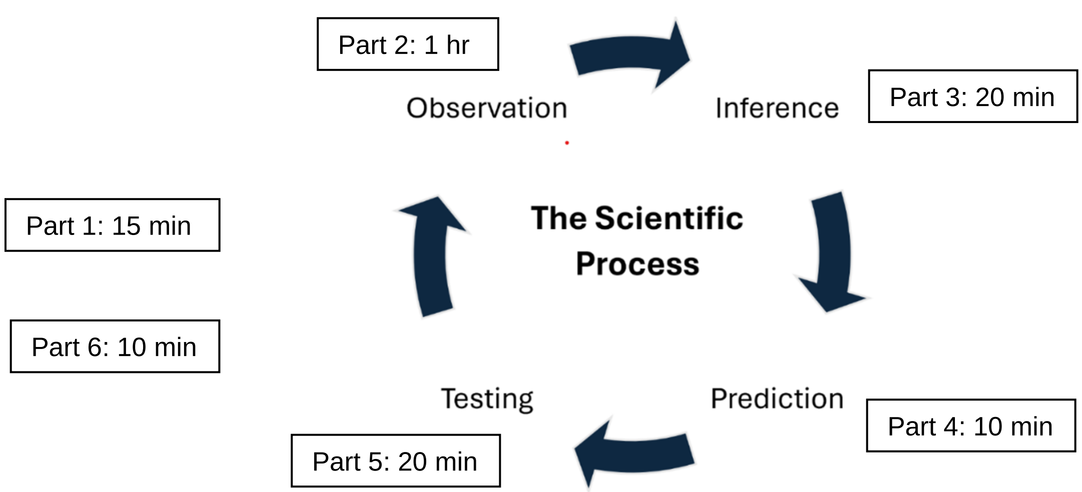
Equipment

- Stellarium planetarium software
  http://stellarium-web.org/

Navigation

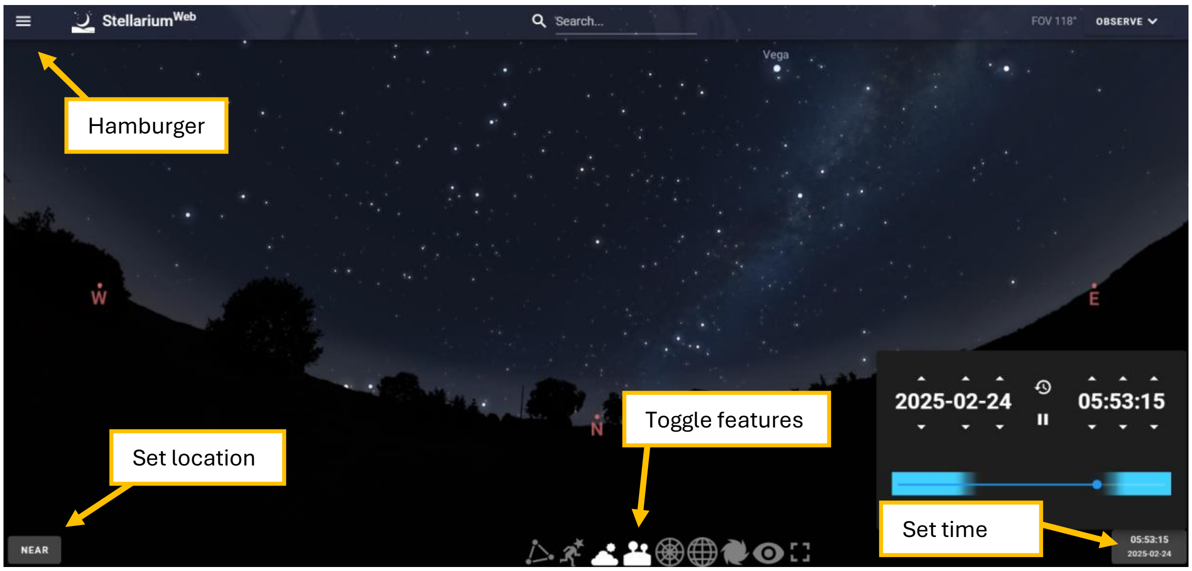
Design note: To emphasize the cyclical nature of scientific discovery, students will navigate this V-Lab through embedded links on this landing page.

Let's get started! Click on Part 1 to start this week's V-Lab.



Part 1: Access Stellarium

1. Go to http://stellarium-web.org/, which is the web interface for the software.
2. Once Stellarium loads, click the hamburger in the top left corner (three lines) to close the left panel. Your screen will look something like the one below. If you are accessing the webpage in the day, you will see a daytime scene. For now, you won't see the expanded time settings in the bottom right corner.



3. Spend a few minutes learning how to navigate the page. At the bottom middle, you can toggle features on and off. Click on each option and see what they do. For now, start with the features selected above.
4. You can pinch zoom in and out of the sky using your fingers on a track pad or phone. Try it out.
5. You can change the time in the lower right corner. We've shown you the expanded time settings in the above picture. Spend a few minutes learning what these different settings do. See what happens when you move the slide bar. Press pause and see what happens when you flip through different months or days.
6. You can change your location in the lower left corner. Keep the default setting with autolocation on.

Side note: Stellarium is also a free desktop app if you find you want to explore more or find it better to install it. **You do not have to pay for an app**. The mobile version of this app is also really useful for stargazing: simply point your phone at the sky and you'll find out in seconds whether that strange bright object in the West is really Jupiter, or maybe just a star, or a satellite!

Part 2: Observe
From within Stellarium, let's explore and reproduce some of the naked-eye observations that intrigued early scientists and sparked the birth of modern science!

Motion of stars:

7. Look North and find Polaris. You can see the name and details of a star by clicking on it – Stellarium provides a wealth of information, some of which we will unpack throughout this course. Click on Polaris and observe how its position changes over time by adjusting the time settings. Try different times, days and even years.
   What do you observe about the motion of Polaris?
   [MCQ-AG]

8. Still looking North, observe the motion of other stars. Pick three stars of your choice, the first one close to Polaris, the next a little further away, and the next close to the horizon. Now observe the motion of each of your stars as you did for Polaris.
   What do you observe about the motion of stars other than Polaris?
   [MCQ-AG]

9. What is a circumpolar star?
   [MCQ-AG]

10. How does the visibility of seasonal stars change throughout the year?
    [MCQ-AG]

11. Does the South Pole have a South Star?
    [MCQ-AG]

Motion of constellations:

12. Let's set things up so that you can view the constellations. Using the feature bar at the bottom of the page, turn on Constellations and Constellations Art. Face North and click on Polaris. Observe how the constellations move throughout a 24-hour period by adjusting the time settings one hour at a time.
    What do you observe about the motion of the constellations through the sky?
    [MCQ-AG]

13. Turn around and face South. Click on the hamburger in the top left corner and select Ecliptic Line under View Settings. Click the hamburger again to hide the left panel. You will now see the ecliptic line in red. This is the path that the Sun appears to follow in the sky. Go to your time settings. Click pause to make navigation easier. Set the date to January 25. Any year is fine. Drag the slide bar to just before sunrise. You are now ready to explore the zodiac constellations! For each month, starting in January, slide the slide bar a little to the right to see which constellation the Sun is "travelling through" that month.
    Use your observations to sort the list of zodiac constellations below in order of appearance.
    [Ordered list-AG]

Motion of the Sun:

14. Still facing South, remove the constellations from your viewing window and deselect the Ecliptic Line under View Settings. Choose any day and observe the Sun as it moves across the sky.
 What do you observe about the Sun's motion through the sky?
 [MCQ-AG]

Motion of planets:

15. Face South with the Ecliptic Line selected. With the time settings on pause, set the time to 22:00 on any given day. Run through time one day at a time by holding down the day up-arrow for a couple of years. Observe Mars closely.
 What do you notice about the motion Mars over a period of months? How does its behavior differ from the stars, the Sun and the moon?
 [MCQ-AG]

16. What is this type of motion called?
 [MCQ-AG]

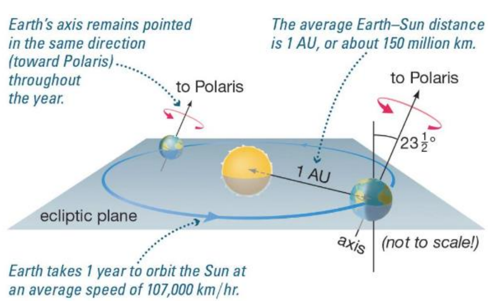
Side note: Looking to experience stargazing IRL? Check out **Stargazers' Hub** under **Astro Central** on Carmen for **stargazing tips, star party dates, and astro student orgs**! There are plenty of ways to get involved—come join the fun!

Part 3: Model

In this section, we will give you time to pause and briefly review the modern scientific models used to explain the patterns in our night sky, including the observations you made in Part 2. These models were introduced in this week's lessons. Take some time understanding these models. We will ask you to make predictions based on your understanding in the next section!

The key models used to explain the patterns in our night sky include:

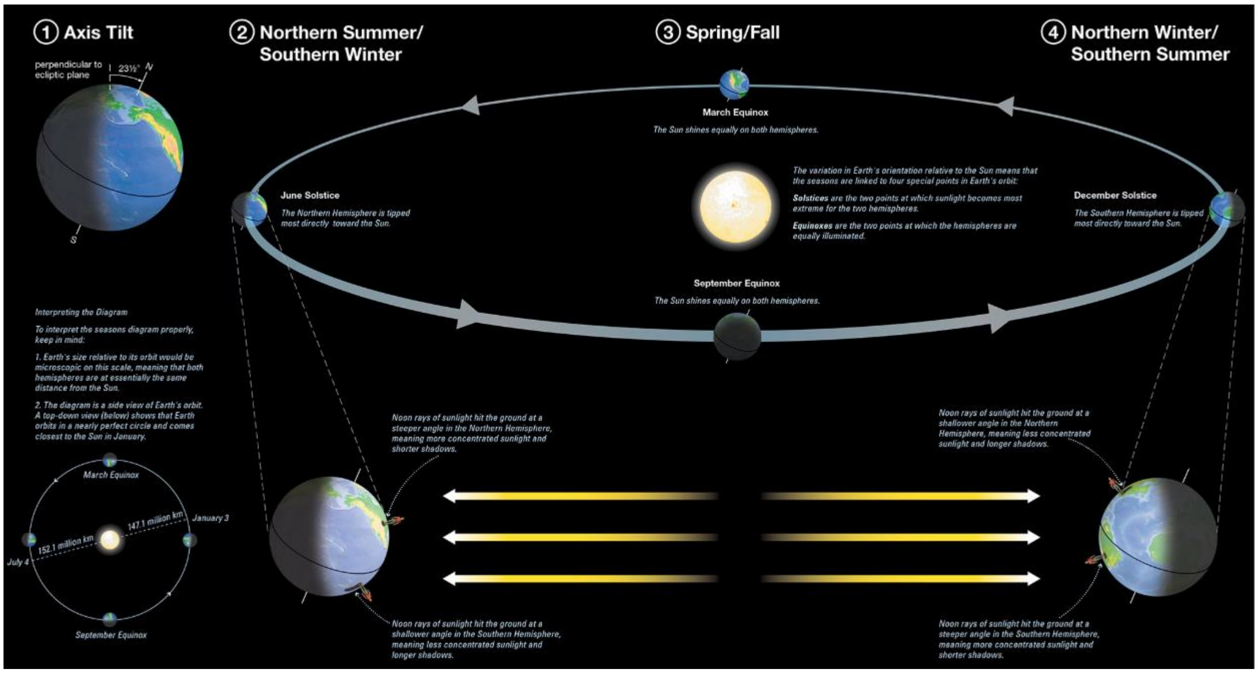
The model of Earth's daily rotation and yearly orbit around the Sun: both of which are counterclockwise as viewed from above the North Pole. The Earth, together with the other planets, rotate around the Sun, confined close to the ecliptic plane.



Source: Mastering Astronomy

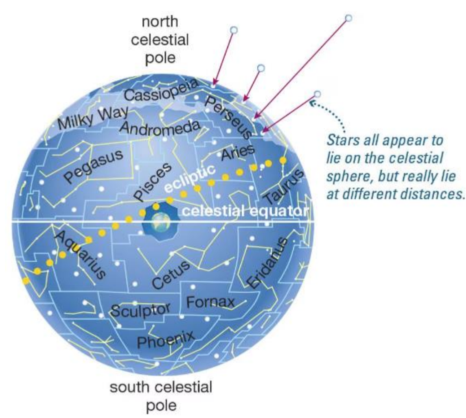
17. Consider the diagram above. In Part 2, why do you think we looked South when we wanted to view the Sun or the planets?
[MCQ-AG]

The model explaining the reason for the seasons:



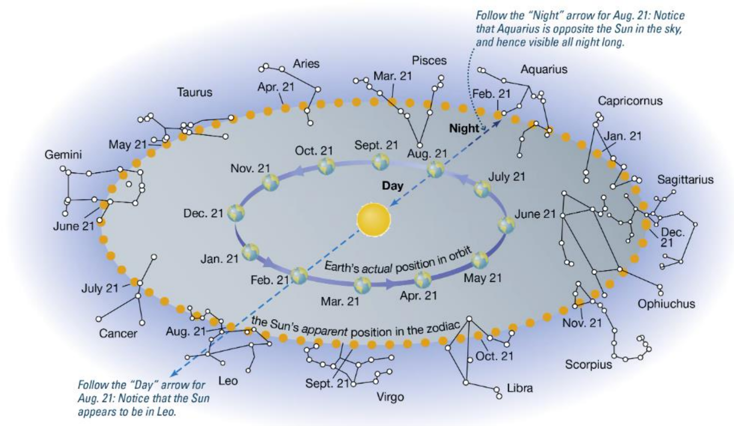
Source: Mastering Astronomy

The Celestial Sphere: The stars and constellations appear to lie on a celestial sphere that surrounds Earth. This is shown in the diagram to the right. This is an illusion created by our lack of depth perception in space, but it is useful for mapping the sky. The celestial sphere is a representation of how the entire sky looks as seen from Earth. Imagine you were sitting on a stationary beach ball in space. If you look in any direction, you will always see the same stars. It's the same on Earth. Since the Earth is spinning, you take a full 360° view of the sky every day, but you still see the same stars in each direction every day. That is, you would, if the Sun didn't block out half the sky during the day!



Source: Mastering Astronomy

As you orbit around the Sun, the Sun determines which half of the sky you can see by blocking out the half of the sky behind it. The Sun appears to move steadily eastward along the ecliptic as Earth orbits the Sun, so we see the Sun against the background of different zodiac constellations at different times of year. For example, on August 21 the Sun appears to be in Leo, because it is between us and the much more distant stars that make up Leo. The zodiac constellations are made up of stars on the celestial sphere that happen to lie along the ecliptic.



Source: Mastering Astronomy

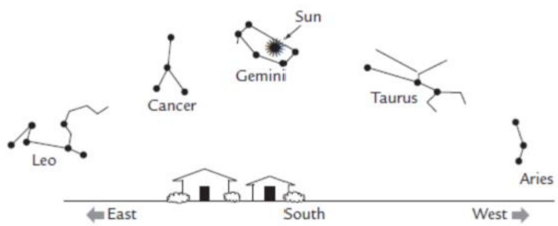
For a model simulation explaining the **retrograde motion of planets**, click here to watch a short video.

Part 4: Predict

Now you will put your understanding of the models described in Part 3 to the test by making predictions that you will test in Part 5.

Answer the following questions. Give your honest answers. These questions will be graded on participation, not correctness, and are design to give you feedback on how well you understand current models of our solar system.

18. **Prediction 1:** Since the Earth's axis is always tilted towards Polaris, which of the following viewing directions will result in seeing mostly the same stars night after night? Select all that apply.
    a. N in the Northern Hemisphere
    b. S in the Southern Hemisphere
    c. S in the Northern Hemisphere
    d. N in the Southern Hemisphere
    e. W or E in the Northern Hemisphere
    f. E or W in the Southern Hemisphere
    [Multi-select MCQ-AG]



19. **Prediction 2:** If you could see stars during the day, the drawing above shows what the sky looks like at noon on a given day. The Sun is at the highest point it will reach on this day and is near the stars of the constellation Gemini. What is the name of the constellation that will be closest to the Sun at sunset on this day?
    a. Leo
    b. Gemini
    c. Cancer
    d. Taurus
    e. Aries

    [MCQ-AG]

20. **Prediction 3:** The picture above shows the position of the stars at noon on a certain day. How long would you have to wait to see Gemini at this same position in the sky at midnight?
    a. 1 year
    b. 6 months
    c. 12 hours
    d. Gemini is never seen at this position at midnight
    e. 24 hours

    [MCQ-AG]

21. **Prediction 4:** Which of the following statements is true about the Sun's motion across the sky?
    a. The Sun rises due West every day and sets due East.
    b. The Sun rises roughly East every day and sets roughly West.
    c. The Sun's highest point in the sky is directly above your head on most days.
    d. The Sun rises due East every day and sets due West.
    e. The Sun rises roughly West every day and sets roughly East.

    [MCQ-AG]

Part 5: Test and Refine Model

Just like scientific models of the Universe are refined through prediction and observational feedback, in this section, you will develop your understanding of the above models by making predictions and testing your interpretation through observational feedback. This is what we call hypothetical-deductive reasoning, and it is the basis of science! And a great way to learn.

Ready? Let's put your predictions to the test! Using Stellarium, check your answers to the questions in Part 4 and then answer them again with your updated knowledge. This time we will grade on correctness!

Prediction 1

22. **Test:** Go ahead and test your initial prediction for this question. How did you use Stellarium to test your prediction?
    [Text-MG]

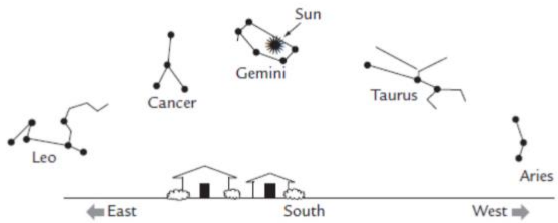
23. **Update your model:** Since the Earth's axis is always tilted towards Polaris, which of the following viewing directions will result in seeing mostly the same stars night after night? Select all that apply.
    a. N in the Northern Hemisphere
    b. S in the Southern Hemisphere
    c. S in the Northern Hemisphere
    d. N in the Southern Hemisphere
    e. W or E in the Northern Hemisphere
    f. E or W in the Southern Hemisphere
    [Multi-select MCQ-AG]

24. **Reflect:** How did testing your initial answer with observational evidence grow your understanding? There is no right or wrong answer to this question.
    a. It didn't, I understood this concept the first time.
    b. It didn't, I still don't understand what is going on.
    c. My understanding grew! I now know enough to answer the question, but there's still some things I need to understand. Maybe some more time making and testing predictions will develop my understanding further.
    d. My understanding grew! I now understand this concept fully!

    [MCQ-AG]

Prediction 2

25. **Test:** Go ahead and test your initial prediction for this question. How did you use Stellarium to test your prediction?
    [Text-MG]



26. **Update your model:** If you could see stars during the day, the drawing above shows what **the** sky looks like at noon on a given day. The Sun is at the highest point it will reach on this day and is near the stars of the constellation Gemini. What is the name of the constellation that will be closest to the Sun at sunset on this day?
    a. Leo
    b. Gemini
    c. Cancer
    d. Taurus
    e. Aries

    [MCQ-AG]

27. **Reflect:** How did testing your initial answer with observational evidence grow your understanding? There is no right or wrong answer to this question.
    e. It didn't, I understood this concept the first time.
    f. It didn't, I still don't understand what is going on.
    g. My understanding grew! I now know enough to answer the question, but there's still some things I need to understand. Maybe some more time making and testing predictions will develop my understanding further.
    h. My understanding grew! I now understand this concept fully!

    [MCQ-AG]

Prediction 3

28. **Test:** Go ahead and test your initial prediction for this question. How did you use Stellarium to test your prediction?
    [Text-MG]

29. **Update your model:** The picture above shows the position of the stars at noon on a certain day. How long would you have to wait to see Gemini at this same position in the sky at midnight?
    a. 1 year
    b. 6 months
    c. 12 hours
    d. Gemini is never seen at this position at midnight
    e. 24 hours

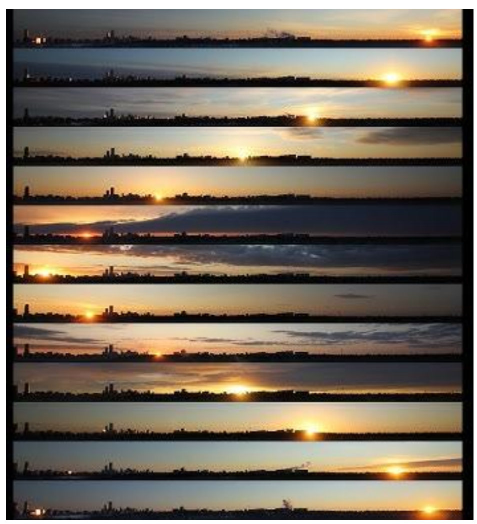
    [MCQ-AG]

30. **Reflect:** How did testing your initial answer with observational evidence grow your understanding? There is no right or wrong answer to this question.
    i. It didn't, I understood this concept the first time.
    j. It didn't, I still don't understand what is going on.
    k. My understanding grew! I now know enough to answer the question, but there's still some things I need to understand. Maybe some more time making and testing predictions will develop my understanding further.
    l. My understanding grew! I now understand this concept fully!

    [MCQ-AG]

Prediction 4

31. **Test:** To test your answer to this question, you are going to observe sunrise and sunset every month for a year! Go to your time settings. Click pause to make navigation easier. Set the date to January. Any day and year are fine. For each month, starting in January, use the slide bar to view sunrise, follow the Sun's path through the sky, and view sunset. Note the position of sunrise and sunset each month.
    Using your observations, sort the screenshots below in order of appearance, starting with what you observed in January.
    [Ordered list-AG]



1. **Update your model:** Which of the following statements is true about the Sun's motion across the sky?
    a. The Sun rises due West every day and sets due East.
    b. The Sun rises roughly East every day and sets roughly West.
    c. The Sun's highest point in the sky is directly above your head on most days.
    d. The Sun rises due East every day and sets due West.
    e. The Sun rises roughly West every day and sets roughly East.

    [MCQ-AG]

32. **Reflect:** How did testing your initial answer with observational evidence grow your understanding? There is no right or wrong answer to this question.
    a. It didn't, I understood this concept the first time.
    b. It didn't, I still don't understand what is going on.
    c. My understanding grew! I now know enough to answer the question, but there's still some things I need to understand. Maybe some more time making and testing predictions will develop my understanding further.
    d. My understanding grew! I now understand this concept fully!

    [MCQ-AG]

Part 6: Final Reflections

33. Comment on your experience in this V-Lab. Did you enjoy using Stellarium? What did you learn? How did you experience the hypothetical-deductive approach to learning? What was new for you? Did you find the lab valuable? What would you have liked to see more of? Write a paragraph on any ONE of these or another related topic.
    [Text-MG]

Lab 3: Standing on the Shoulders of Giants

Design notes: Design notes are in red and provide information on how this lab will be implemented online. Labs will be incorporated into Carmen Canvas using H5P and will use a variety of auto graded (AG) as well as manually graded (MG) response options. Response fields are indicated in square brackets e.g. [MCQ-AG] indicates an auto graded multiple choice response field.

Aims of This V-Lab

- **Illustrate the Cumulative Nature of Scientific Knowledge**
  Explore how scientific understanding evolves over time, with each discovery building upon previous work as new technology emerges.
- **Illustrate the Power of Mathematical Models**
  See how mathematics allows us to study distant and unseen worlds, revealing hidden aspects of the universe.
- **Experience the Scientific Cycle in Action**
  In this V-Lab, you will step into the role of a scientist, experiencing firsthand the challenges and excitement of discovery. You'll navigate the unknown with limited information, confront technological constraints, and feel the thrill of uncovering new insights—all while practicing the extreme patience that real scientific progress demands.

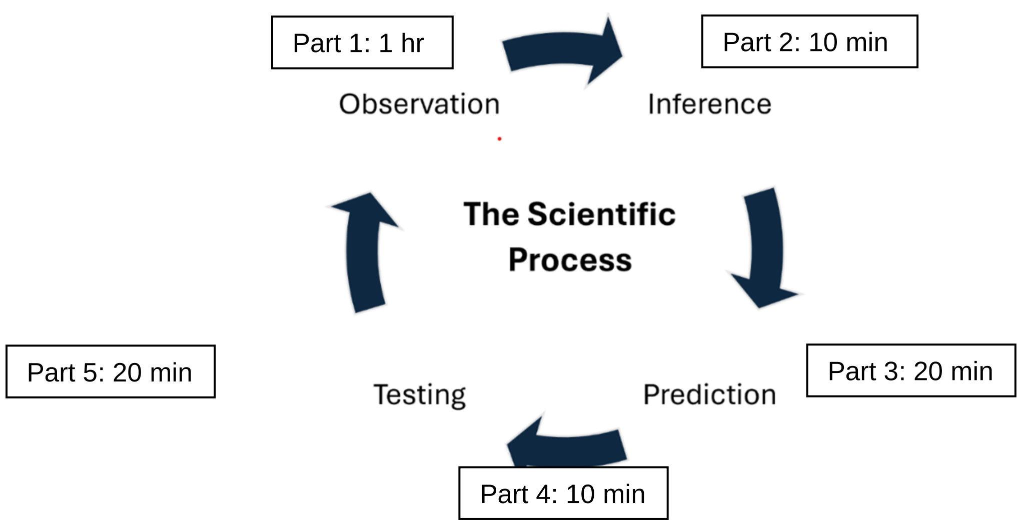
Equipment

- Calculator

Navigation

Design note: To emphasize the cyclical nature of scientific discovery, students will navigate this V-Lab through embedded links on this landing page.

Let's get started! Click on Part 1 to start this week's V-Lab.



Part 1: Observe

Galileo and the Moons of Jupiter:

Let's go back in time to 1609. You are the not-yet famous Galileo Galilei, and you've recently perfected your version of the new-fangled "spy-glasses" that you saw at a traveling show. You are excited to use this device to explore the night sky! You spot 4 very intriguing points of light very close to Jupiter, all in a line. They look something like the image below:

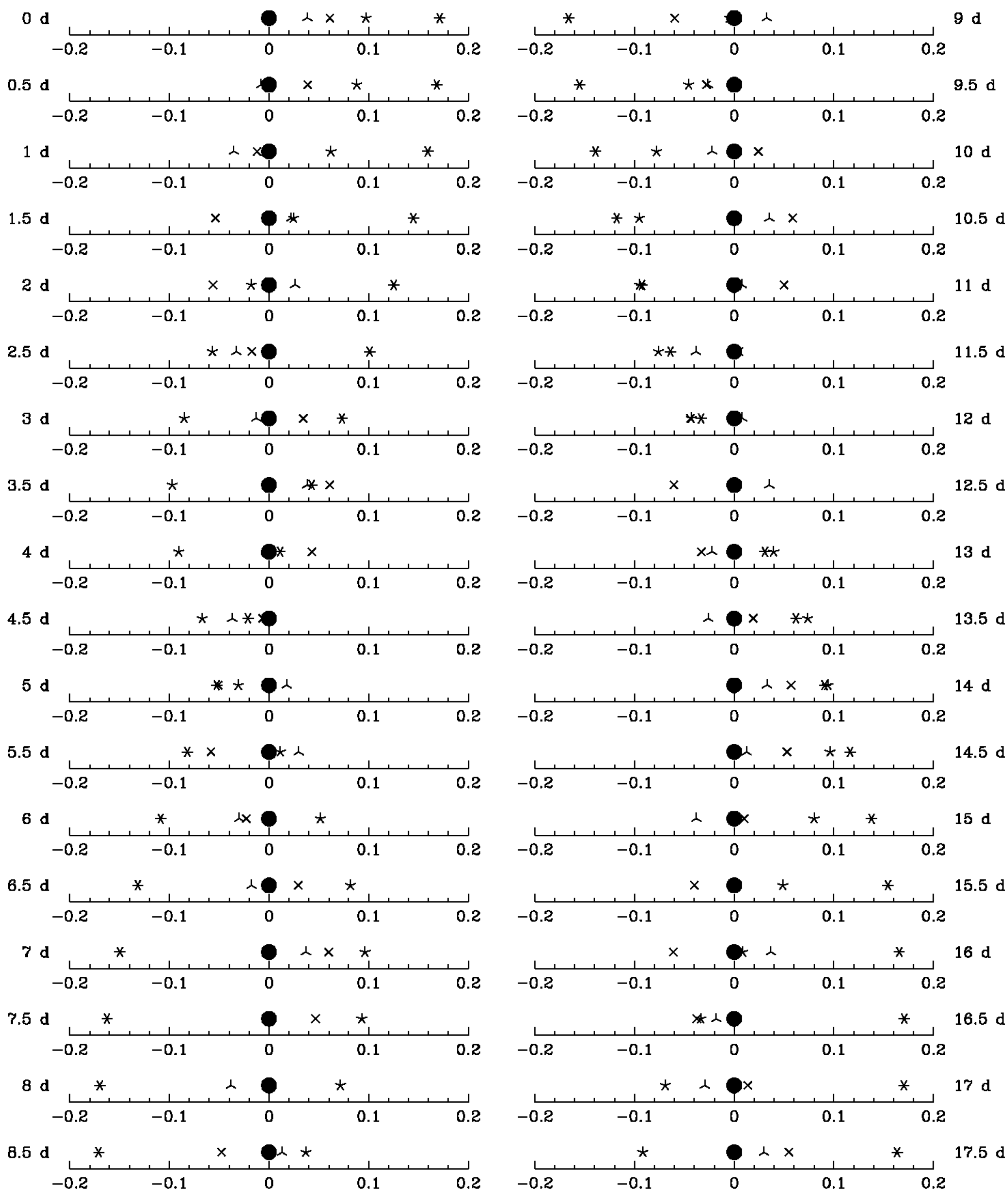
Design note: Reproduce the image for copyright purposes.

You have no idea what these objects are. You think maybe they are stars. You observe that the positions of these objects change – both from night to night, and during an individual night. But even as these objects move, they always stay close to Jupiter. Watching them dance around Jupiter for a while, you conclude that they must be *orbiting* around Jupiter – just like our own Moon orbits around Earth! Remarkable!

You originally referred to these points of light as the Medicean Stars (after the Medici family) and individually numbered them as I, II, III, and IV. The names we use today – Io, Europa, Ganymede, and Callisto – were later given by Simon Marius, a German astronomer who claimed to have discovered them around the same time. His names, inspired by mythological lovers of Zeus, eventually became the standard. But don't worry, we still refer to them as Jupiter's "Galilean" moons – because you discovered them and because we now know that they are moons, not stars as you originally had assumed!

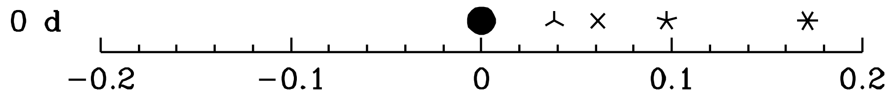
Since you have a keen eye for detail, you carefully record the positions of these objects over time. For an example of your original drawings, see here. Below is a clearer version of what you would have recorded.

Moons of Jupiter



Let’s take a moment to make sense of what you drew:

Angular scale: In each instance, the black circle marks the position of Jupiter, and the asterisks mark the positions of the moons. The angular scale is marked in degrees, as shown below:



See your lesson notes for a reminder of how we measure angular distance in degrees in Astronomy, and how we convert an angular separation between two objects on the celestial sphere into a linear distance. In this picture, the third moon is separated from Jupiter by an angle of about 0.1 degrees.

Time in days: Each entry in your diagram shows an observation at a different time, separated by intervals of 0.5 days, with the time of the observation marked to the left or right (e.g., “5.5d” means that the observation was taken 5.5 days since the beginning of the observing campaign).

Symbols: The picture above (*the first observation*, which we will say occurs at “0 days”) shows a time when each moon is at its maximum angular separation from Jupiter. Each moon is marked with a different symbol, which stays the same through the whole observing campaign. From inner to outer, the moons are: Io, Europa, Ganymede, and Callisto.

Let’s practice taking some readings before we get started with calculations:

1. What is the angular position of Io on day 10?
   [Value-AG]

2. What is the angular position of Ganymede on day 16.5?
   [Value-AG]

Great, you’re ready to get started!

Science as we know it today has not yet been developed, but you can make some inferences about these objects with what you know already. Just by observing the moons, you can determine how far away they are from Jupiter and how long it takes each one of them to complete their respective orbits.

Measuring orbital radii:

3. Read off the scale and record the angular distances (θ) of the four moons from Jupiter, in degrees, at time “0 days”?
   Io: [Dropdown List-AG]
   Europa: [Dropdown List-AG]
   Ganymede: [Dropdown List-AG]
   Callisto: [Dropdown List-AG]

4. Remember, at time "0 days", all the moons are at their maximum distance from Jupiter. This means that if they are orbiting Jupiter on a circular path, the angular distances you just recorded are equal to their orbital radii. This is great!
   You would like to have these radii in kms and not angular units. Recall from lessons that the equation to convert angular distance (θ) to a linear distance (D) is **D = d x (θ / 57.3 degrees)**. All you need is d – the distance of Jupiter from Earth.
   You are in luck! Copernicus, with the use of some clever geometry, has already estimated the distance from Earth to Jupiter to be about 6.3×10^8 km.
   Use this information to compute the orbital radii (R) of the moons' orbits around Jupiter in kilometers.
   Io: [Value-AG]
   Europa: [Value-AG]
   Ganymede: [Value-AG]
   Callisto: [Value-AG]

Measuring orbital periods:

5. From your diagram, determine the orbital periods of each of the four moons. The orbital period is the length of time the moon takes to go around Jupiter once. It is measured in days. Try to measure the orbital period to at least a precision of 0.5 days (e.g., 10.5 days or 16.0 days), or to a finer degree (e.g., 0.1 days) if you can (e.g., 6.7 days or 8.8 days).
   Hint: Start with the outer moon Callisto and work inwards towards the innermost moon, Io.
   Io: [Dropdown List-AG]
   Europa: [Dropdown List-AG]
   Ganymede: [Dropdown List-AG]
   Callisto: [Dropdown List-AG]

6. Convert the orbital period (P) that you measured for each moon from units of days to units of seconds. There are 60 x 60 x 24 = 86,400 seconds in a day.
   Io: [Value-AG]
   Europa: [Value-AG]
   Ganymede: [Value-AG]
   Callisto: [Value-AG]

Simple but powerful:

7. How did Galileo's early telescopic observations support the work of Copernicus and Kepler that proposed that the Earth goes around the Sun?

   [Text-MG]

8. We've been focusing on the four Galilean moons. How many moons does Jupiter actually have that we know of?
   [MCQ-AG]

Side note: Want to see the Galilean moons for yourself? Check out **Stargazers' Hub** under **Astro Central** on Carmen for **stargazing tips, star party dates, and astro student orgs**! There are plenty of ways to get a hands-on stargazing experience—come join the fun!

Part 2: Model

Along came Newton:

Amazingly enough, Galileo's observations contain enough information to determine the mass of Jupiter! The method is straight forward and is still widely used by astronomers today. However, we just didn't have the knowledge to do this until Newton discovered the Law of Universal Gravitation in the late 1660s, roughly half a century after Galileo's original observations!

In last week's lab, you learned all about scaling relations (how we turn observations into math), and we used Newton's Law of Universal Gravitation as an example. Recall $F = G\frac{mM}{R^2}$. We also made some big claims that in this lab you'll see just how useful and amazing math is. Well, it's time, get ready to be amazed! We're going to show you two jaw-dropping instances of the power of math – how it allows us to learn about unreachable places and how it even allows us to discover hidden worlds!

The rest of this V-Lab will refer to Newton's mathematical models of the world. That is, Newton's Law of Universal Gravitation and his laws of motion.

Fun fact: Newton was born the year Galileo died!

Part 3: Infer/Predict

In this section, we're going to show you how we can use math to predict the mass of Jupiter! In this week's lessons, you would have seen that **orbits are a main way that we estimate the masses of astronomical objects**. One excellent application of this comes in a case like this, where a smaller object is on a circular orbit around a much more massive object. In this case, Jupiter's moons have much lower mass than the planet itself.

To the right, we show how the equation for the mass of the central object is derived from Newton's Law of Universal Gravitation and a version of Newton's Second Law of Motion for circular orbits. You absolutely do not need to understand this or

1. **Gravitational Force** acting on a moon orbiting Jupiter:

$$F = \frac{GMm}{R^2}$$

where:

- G = gravitational constant
- M = mass of Jupiter
- m = mass of the moon
- R = orbital radius of the moon

2. **Centripetal Force** keeping the moon in orbit:

$$F = \frac{mV^2}{R}$$

where V is the moon's orbital velocity.

3. **Equating the two forces** ($F_{\text{gravity}} = F_{\text{centripetal}}$):

$$\frac{GMm}{R^2} = \frac{mV^2}{R}$$

4. **Cancel m (since it appears on both sides):**

$$\frac{GM}{R^2} = \frac{V^2}{R}$$

5. **Solve for M:**

$$M = \frac{RV^2}{G}$$

remember it. Just have the visual in your head of how we can go from two equations to a third with mathematical logic!

Ok, let's use this equation to take Galileo's observations and calculate the mass of Jupiter. In this case, the mass of Jupiter, M, is given by **$M = (RV^2) / G$**. In this equation, G is the Newtonian Gravitational *Constant*. As one of the fundamental physical constants, it doesn't change – it's just a number. The value of G is **$G = 6.67 \times 10^{-20}$ $km^3kg^{-1}s^{-2}$** with units using *kilometers*.
Important: the given value of G contains units of kilometers (km), your orbital radii, R, should be in km, and your orbital speeds should be km/sec. The mass formula in bold above will give you an estimate of the mass of Jupiter when you plug in your numbers! Remember to use parentheses and square your speed when calculating.

9. Assume that the moons are on circular orbits (this is not a bad assumption!). The formula for speed = distance/time. For a circular orbit with radius R and a period P, the **orbital speed $V = (2\pi R)/P$**. Use this equation to compute the orbital speeds of the four moons in units of km/sec.
   Io: [Dropdown List-AG]
   Europa: [Dropdown List-AG]
   Ganymede: [Dropdown List-AG]
   Callisto: [Dropdown List-AG]

10. Use the mass formula to estimate the mass of Jupiter from the orbital speed and orbital radius of Callisto.
    [Value-AG]

11. How does your calculated mass of Jupiter compare with 1.89813×10^{27} kg, the current best estimate of the mass of Jupiter?
    [MCQ-AG]

12. What are potential sources of error in your calculation of the mass of Jupiter? Hint: Look at the two main parameters used to calculate M. What sources of error are there in Galileo's measurements of these values?
    [Text-MG]

Part 4: Predict and Test
Now, let's see how math can lead us to discover hidden worlds!

Le Verrier and Adams:
Let's fast forward to 1846. You are the French mathematician, Urbain Le Verrier!

Design note: Short video, recounting the steps of Neptune's discovery from Le Verrier's point of view.

Example content from ChatGPT:

> As I sit at my desk in the quiet of my study, the rhythmic ticking of the clock is a fitting companion to my thoughts. The task at hand has consumed me for some time

now—there is a strange anomaly in the orbit of Uranus. For years, astronomers have been puzzled by slight deviations in its predicted path. These discrepancies have led me to a bold conclusion: something unseen must be exerting a gravitational influence on Uranus, causing its orbit to shift in ways that Newtonian mechanics cannot fully explain.

I trust in Newton's laws; they have served us well, providing the foundation upon which our understanding of the cosmos rests. And if Newton's laws are correct, then there must be another planet, hidden from our view, tugging on Uranus and altering its orbit. The question is: where?

I have spent weeks painstakingly calculating, applying the principles of gravitation, and refining my observations. The force required to explain the discrepancies in Uranus' orbit must come from an object farther out, beyond the reach of our telescopes—until now. After countless equations, adjustments, and revisions, I am confident I have pinpointed the position of this invisible planet. It should lie at a particular location, not far from Uranus, precisely where the gravity from this unseen body would best account for the motion of the distant planet.

It is now time for the next step. I can only trust that my work is sound and wait for confirmation from those with the tools to verify my hypothesis. I reach out to my colleague and friend, the astronomer **Johann Galle** at the **Berlin Observatory**. With a mixture of excitement and anticipation, I send him my calculations, urging him to direct his telescope to the precise coordinates I've calculated. I tell him: if my calculations are correct, this new planet should be visible to the naked eye.

The waiting is agonizing. Days pass, and I cannot help but imagine the moment when the telescope will reveal the object that has eluded us for so long. The thought of finally proving my theory—and unveiling a new world to humanity—drives me to distraction.

Then, the news comes: **September 23, 1846**. Galle has found the planet. **Neptune**. Just where I had predicted it would be.

The sensation of triumph is indescribable. My calculations, grounded in the trust I place in Newton's laws, have brought us to the discovery of a new planet. This is the power of mathematics—an invisible world, hidden from the eyes of astronomers, revealed through careful reasoning and observation. It is a moment of profound vindication, knowing that the universe itself adheres to the predictable, elegant laws of motion that Newton laid down.

Yet, I am not alone in this discovery. **John Couch Adams**, an English mathematician, had also been working on the same problem. His predictions, though similar to mine, had not gained the same attention. The race for this discovery had, in a way, been a quiet competition between our two countries, though it was my name that would be most closely associated with the moment of Neptune’s discovery.

Nonetheless, I know the importance of this moment transcends individual recognition. What we have witnessed is the power of reason, the unyielding pursuit of knowledge, and the confirmation that the universe is governed by laws we can understand. In the end, it is not the credit or fame that matters, but the deeper understanding we now have of the cosmos. The discovery of Neptune—just as predicted—reminds us that there is still much to learn, and the universe is vast beyond our imagining.

13. Briefly describe the sequence of events that led to the discovery of Neptune. Share your thoughts on this. One to two paragraphs are enough.
[Text-MG]

And the story doesn't end here! While Newton's mechanics worked well for most of the solar system, the orbit of Mercury showed small deviations that Newtonian mechanics couldn't fully explain – a subtle sign of greater things to come, albeit centuries later!

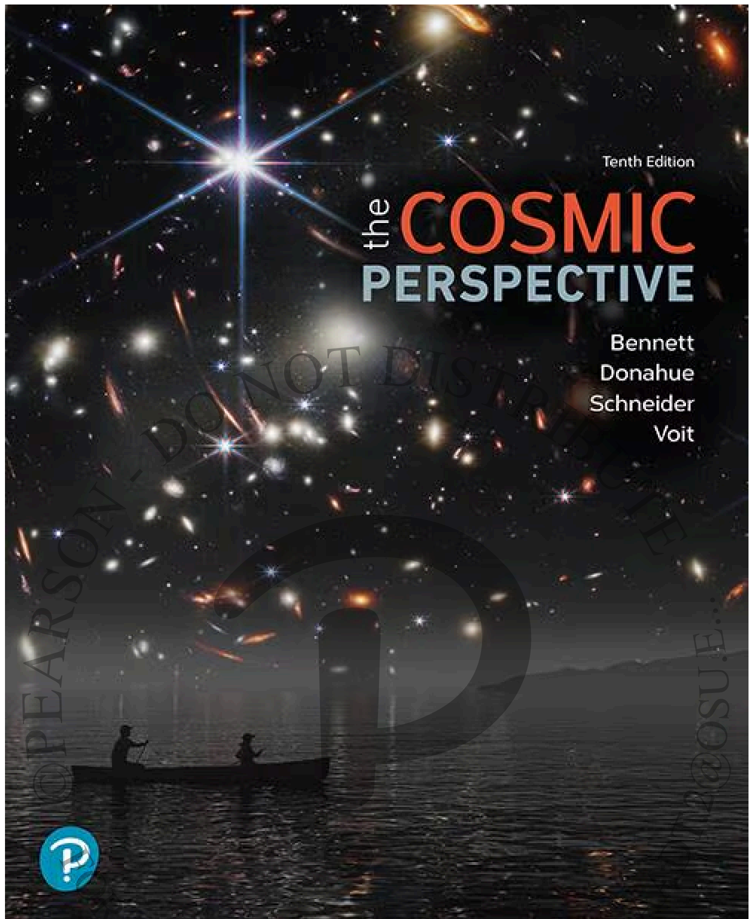
14. For centuries, Newtonian mechanics accurately predicted planetary orbits, motions of celestial bodies, and phenomena like tides, making it an extraordinarily successful theory for its time. We still use it daily for numerous engineering applications! However, in the early 20th century, a new theory came along to supplement Newtonian mechanics for extreme conditions. Can you guess the name of this theory?
[MCQ-AG]

Part 5: Final Reflections

15. Refer to the Hallmarks of Science in your User's Guide. Which hallmarks of science are illustrated in this V-Lab?
[Multi-select MCQ-AG]

16. In this section, you analyzed data that were the first ever recordings of celestial objects done with the help of a TELESCOPE. Explain how technology influenced science in this instance. Bearing in mind that Galileo did not invent the telescope. He learned about the idea at a traveling market.
[Text-MG]

The Cosmic Perspective



TENTH EDITION

Jeffrey Bennett

University of Colorado at Boulder

Megan Donahue

Michigan State University

Nicholas Schneider

University of Colorado at Boulder

Mark Voit

Michigan State University

Pearson

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PART VII LIFE ON EARTH AND BEYOND

Chapter 24

Unit 1: Science Unlocked: How to Talk the Talk and Walk the Walk

What makes something *real* science? How do we separate science from pseudoscience? How do we separate truth from misleading claims? This unit kicks off your science IRL journey by building the skills needed to think, talk and walk like a scientist. Through the lens of astronomy, we'll trace the birth and development of science, learning what science is and how to recognize it. And we'll catch you up on the math and physics you need to go all the way in this course! Expect to have some fun along the way – we're going to put your bull$#!t detector and logic to the test as we lay the groundwork for deeper cosmic exploration ahead.

Unit assessments: There are two unit assessments for Unit 1:

Escape Room: Smoke and Mirrors
This escape room will be based on the mini lessons from Weeks 1-3. See the learning outcomes listed at the start of each lesson to guide your preparation.

Ongoing Activity 1: You Be the Scientist!
In this ongoing activity you will craft your own physical model of the Earth-Moon-Sun system, use your model to make predictions about when you should see each phase of the moon, test your predictions by watching the sky, and then refining your model if needed.
An alternative version of this assignment is available on request for students with accessibility concerns.

Week 1: Is it Science? (Week 1)

Ever wonder if that YouTube video was legit science or total bull$#!t? This week, we sharpen our pseudoscience detectors! We'll trace the birth of modern astronomy—where science began—exploring the scientific process and technology's early impact. After outlining the hallmarks of science, it's your turn: experience science in action with night sky observations and put your skills to the test in "Is it even science? YouTube edition."

		Topics and Activities	
		Mastering Astronomy	Influencer's Guide to Science IRL
The Big Idea: **Is it even science?**		Textbook chapters: 2. Discovering the Universe for Yourself 3. The Science of Astronomy	Influencer's Guide sections: 2. Is it Science? Opening Comments: Present students with a mix of science and pseudoscience YouTube videos related to Astronomy. Ask students to classify each video as science or pseudoscience. We will revisit these videos at the end of the week.
Mini Lessons: **What is science?**	D1L1	2.1. Patterns in the Night Sky	
	D1L2	2.2. The Reason for the Seasons	
	D2L1	2.4 The Ancient Mystery of the Planets	
	D2L2	3.1. The Ancient Roots of Science 3.2. Ancient Greek Science	
	D3L1	3.3. The Copernican Revolution	
	D3L2	3.4. The Nature of Science	2.1. The scientific process: What is science? 2.2. The hallmarks and scope of science
V-Lab		**Discovering the Night Sky for Yourself:** • Recreate the Curiosity of Early Astronomers • Test and Refine Your Understanding • Experience the Scientific Cycle in Action	
Astro Chat		**How good is your bull$#!t detector? Is it even science?** Use hallmarks introduced in Section 2.2. to classify the videos from the opening comments as science or pseudoscience.	
Knowledge Check		MCQ quiz covering this week's lessons.	

Week2: How to Speak and Think Like a Scientist (Week 2)

Confused by scientific gibberish? This week, we start breaking it down! First, we'll explore the universe's vast scales—from subatomic particles to the cosmic horizon—while decoding astronomers' units of measurement. Then, we'll lay the math and graphing foundations you will need to succeed in this course.

Let's be real—you can't escape math in science! But don't worry, we're keeping it light—just the essentials. More importantly, we'll show you why scientists love it (Einstein called it "the poetry of logical ideas"). In V-Lab, you'll see how math elegantly describes the relationship between variables and opens a whole new world of understanding!

And, of course, we'll have some fun along the way—spotting misleading visuals, dodging logical traps, and putting your skills to the test in " How good is your bull$#!t detector? Data and logic edition."

		Topics and Activities	
		Mastering Astronomy	Influencer's Guide to Science IRL
The Big Idea: **What did they say?**		Textbook chapters: 1. A Modern View of the Universe 3. The Science of Astronomy	Influencer's Guide sections: 3. How to Speak and Think Like a Scientist Opening Comments: Present students with information from the media that contains data misrepresentation and/or logical fallacies and briefly assess their ability to identify inconsistencies. We will revisit this information at the end of the week.
Mini Lessons: **How to Speak and Think Like a Scientist**	D1L1	1.1 The Scale of the Universe Appendix C: A Few Mathematical Skills	3.1.1. Working with big and small numbers
	D1L2		3.1.2. Units and unit conversion
	D2L1		3.1.2. Units and unit conversion
	D2L2		3.3.1. Graphs 3.3.2. Data misrepresentation
	D3L1		3.4. The power of math: Scaling relations
	D3L2	3.4 The Nature of Science: Logic and Science	3.6.1. Types of logic 3.6.2. Valid vs. sound arguments 3.6.3. Common logical fallacies
V-Lab		**The Power of Math: Scaling Relations**	
Astro Chat		**How good is your bull$#!t detector? Data and logic edition** Use the knowledge gained in this module, particularly relating to graphs, data misrepresentation and logical fallacies to critically evaluate claims.	
Knowledge Check		MCQ quiz covering this week's lessons.	

Week 3: A Map of Physics (Week 3)

Ever feel like your mind is leaving your body when a scientist rambles on about something that defies common sense? If you can't rely on common sense, how do you evaluate scientific claims? Do you just trust the expert? **No—you need domain knowledge.** Science thrives on skepticism, testing assumptions, and building on centuries of discoveries. There's no shortcut to this knowledge, but this course will get you in the ballpark of knowing what you need to know and what questions to ask!

This week, you'll prove firsthand how easily common sense can fail you and develop an understanding of why domain knowledge is key. We'll start building your map of physics by jumping into the basics of orbital and classical mechanics. In V-Lab, you'll get hands-on, experiencing the cumulative nature of scientific knowledge and exploring the power of physics by measuring Jupiter's mass all the way from Earth!

		Topics and Activities	
		Mastering Astronomy	Influencer's Guide to Science IRL
The Big Idea: **The importance of domain knowledge**		Textbook chapters: 4. Making Sense of the Universe: Understanding Motion, Energy, and Gravity	Influencer's Guide sections: 4. A Map of Physics Opening Comments: Present students with a YouTube video discussing an astronomy topic addressing conceptually challenging physics such as relativity or string theory, illustrating the ineffectiveness of common sense in understanding these topics.
Mini Lessons: **A map of physics**	D1L1		4.1. The importance of domain knowledge 4.2. A map of physics (overview of the main fields of physics introduced in this course)
	D1L2	3.3 The Copernican Revolution: Kepler's three laws of planetary motion	
	D2L1	4.2 Newton's Laws of Motion	
	D2L2	4.3 Conservation Laws in Astronomy	
	D3L1	4.4 The Universal Law of Gravitation	4.2.1. Classical mechanics
	D3L2	4.5 Orbits	4.2.2. Orbital mechanics
V-Lab		**Standing on the Shoulders of Giants:** • Illustrate the Cumulative Nature of Scientific Knowledge • Illustrate the Power of Mathematical Models • Experience the Scientific Cycle in Action	
Astro Chat		**When common-sense fails you!** Discuss pre-selected examples illustrating how common-sense can fail you. For each example, allow students to predict outcomes and then reveal and discuss outcomes as a group. E.g. what will happen if you spin an open bucket filled with water over your head? Will the water fall out? No!	
Knowledge Check		MCQ quiz covering this week's lessons.	

Unit 2: Behind the Scenes: Where Do Scientists Get Their Facts From?

This unit builds on the previous unit and develops trust in the scientific method by exploring how we know seemingly impossible things. You'll build domain knowledge by expanding your map of physics and exploring the astronomical methods and technologies that make discovery possible. We'll put constraints on discovery by introducing the concept of uncertainty in measurement —whether due to the vast scale of the universe, technological constraints, or inherent uncertainties in observations. You'll continue to learn how to think like a scientist as we explore what "uncertainty" means to a scientist, how they account for uncertainty and error, and that good science always reports its limitations.

Unit assessment: Escape Room: The Mystery of the Dead Star
This escape room will be based on the mini lessons from Weeks 4-7. See the learning outcomes listed at the start of each lesson to guide your preparation.

Week 1: How far can and have we gone? (Week 4)

Ever wonder about space travel? How far have humans actually gone, and will we ever be zipping through the universe in spaceships like in Star Wars? This week, we'll explore what we know about our solar system and the past and present missions that got us here. In V-Lab, you'll experience the challenges of direct observation firsthand by physically mapping out the scale of our solar system (bundle up—you're heading outside!). You'll also tackle the question, "What's the fastest we could ever travel?" Get ready for a crash course in special relativity—complete with real-world technological proof and major bragging rights! Finally, in discussion, you'll explore how our understanding of the universe evolves as our observational tools improve.

		Topics and Activities	
		Mastering Astronomy	Influencer's Guide to Science IRL
The Big Idea: **How far can and have we gone?**		Textbook chapters: 7. Our Planetary System S2. Space and Time	Influencer's Guide sections: 4. A Map of Physics Opening Comments: Thematic YouTube video
Mini Lessons: **Exploring our Solar System**	D1L1	7.1. Studying the Solar System	
	D1L2	7.2. Patterns in the Solar System	
	D2L1	7.3. Spacecraft Exploration of the Solar System	
	D2L2	7.3. Spacecraft Exploration of the Solar System	
	D3L1	Special Relativity	4.2.5. Special Relativity
	D3L2	Special Relativity	
V-Lab		**Exploring the Scale of our Solar System**	
Astro Chat		**Our evolving definition of a planet**	
Knowledge Check		MCQ quiz covering this week's lessons.	

Week 2: If we can't *go* there, how do we know so much? (Week 5)

Light! Astronomy is all about observing light, and this week, we're diving into the electromagnetic spectrum and spectroscopy to uncover what light can tell us about stars. You'll learn how we determine key properties like the luminosity, temperature, size, mass and composition of stars by combining observation with validated models—science building on science! In V-Lab, you'll create your own HR diagram, setting the stage for studying stellar evolution in the next unit. And in discussion, you'll actively explore the hidden world of light by building your own diffraction grating!

		Topics and Activities	
		Mastering Astronomy	Influencer's Guide to Science IRL
The Big Idea: **If we can't go there, how do we know so much?**		Textbook chapters: 5. Light and Matter: Reading Messages from the Cosmos 15. Surveying the Stars	Influencer's Guide sections: 4. A Map of Physics Opening Comments: Thematic YouTube video
Mini Lessons: **What we learn from light**	D1L1	5.2. Properties of Light 5.3. Properties of Matter	
	D1L2	5.4. Learning from Light: Composition	4.2.3. Spectroscopy
	D2L1	5.4. Learning from Light: Temperature	
	D2L2	15.1. Properties of Stars	
	D3L1	15.2. Patterns Among Stars	
	D3L2	15.3 Star Clusters	
V-Lab		**Properties of Stars**	
Astro Chat		**The hidden world of light**	
Knowledge Check		MCQ quiz covering this week's lessons.	

Week 3: Are there limits to our observations? (Week 6)

This week, we continue exploring how combining observation with validated theories can deepen our understanding of the universe. We'll focus on exoplanets, their properties, and the surveys and methods used to detect them. A key concept we'll introduce is Doppler shift, which will be crucial for later discussions. We'll also address the limits of observation by examining sources of error in measurement. In V-Lab, you'll gain hands-on experience by analyzing transit data and learning about the effects of noise and bias in measurements. In discussion, we'll further explore the concept of observational bias in exoplanet detection by pondering whether hypothetical aliens can know we exist!

		Topics and Activities	
		Mastering Astronomy	Influencer's Guide to Science IRL
The Big Idea: **Are there limits to our observations?**		Textbook chapters: 5. Light and Matter: Reading Messages from the Cosmos 13. Exoplanets: The New Science of Distant Worlds	Influencer's Guide sections: 3. How to Speak and Think Like a Scientist 4. A Map of Physics Opening Comments: Thematic YouTube video
Mini Lessons: **Exoplanet discovery**	D1L1	5.4. Learning from Light: Doppler Effect	4.2.3. Doppler shift
	D1L2	13.1. Detecting Planets Around Other Stars	
	D2L1	13.1. Detecting Planets Around Other Stars	
	D2L2	13.2. The Nature of Planets Around Other Stars	
	D3L1	13.3. The Formation of Other Solar Systems	
	D3L2		3.2.1. Scientific vs. everyday meaning of uncertainty 3.2.4. Sources of error
V-Lab		**Transiting Exoplanets**	
Astro Chat		**Do aliens know we exist?**	
Knowledge Check		MCQ quiz covering this week's lessons.	

Week 4: If only we had a cosmic measuring tape! (Week 7)

This week is all about quantifying the night sky. How many stars and galaxies are out there? How far away are they? And how do we even measure that? We'll explore how astronomers estimate cosmic numbers using sampling and dive into the cosmic distance ladder—our tool for measuring distances in space. In V-Lab, you'll experiment with parallax, the second rung of the ladder. We'll also continue our discussion on uncertainty, breaking down how each rung introduces new challenges. Plus, did you know astronomers time travel? The further we look, the younger the universe appears—welcome to lookback time! Since distant objects are redshifted, we'll discuss why astronomers use different wavelengths of light to uncover different cosmic stories in our weekly discussion: "Each crayon of light tells a story."

		Topics and Activities	
		Mastering Astronomy	Influencer's Guide to Science IRL
The Big Idea: **If only we had a cosmic measuring tape!**		Textbook chapters: 20. Galaxies and the Foundation of Modern Cosmology	Influencer's Guide sections: 3. How to Speak and Think Like a Scientist 4. A Map of Physics Opening Comments: Thematic YouTube video
Mini Lessons: **Measuring the universe**	D1L1	20.1 Islands of Stars	
	D1L2	Counting galaxies	3.2.2. Sample vs. population
	D2L1	20.2. Measuring Galactic Distances	3.2.4. Sources of error
	D2L2	20.2. Measuring Galactic Distances	
	D3L1	Lookback time	
	D3L2		4.2.3. Each crayon of light tells a story
V-Lab		**Parallax**	
Astro Chat		**Each crayon of light tells a story**	
Knowledge Check		MCQ quiz covering this week's lessons.	

Unit 3: Guessing or Slaying? How Theories Evolve and Get Verified

Now that we've covered the basics of how science works, we're letting you loose in the world of modern astronomy! This unit builds trust in the scientific method by showing how scientific theories are born, tested, and refined. We'll dive into four hot topics in astronomy, exploring key concepts, theory development, and open questions. You'll also learn about current and upcoming surveys tackling these mysteries. Plus, it's your time to shine as a responsible influencer—get ready to create media content on a trending astronomy topic!

Unit assessment: Ongoing Activity 2: You Be the Influencer!

This ongoing activity will be issued at the start of Unit 3. Using the science communication tips in your user guide, you'll create responsible content explaining one of the astronomy topics from the provided list. If you want to choose a different topic, check with us first to ensure it meets the assignment's learning goals. Your content should be engaging for your target audience and meet all the requirements outlined in the grading rubric.

Format of submission: Your content can take the form of a popular science article or a YouTube video. For YouTube videos, you can submit either a voice-overed storyboard or go ahead and create the final video—your choice!

Due date and grading: Your final product will be due in the first week of the next unit. You'll present it to your discussion group, where your TA and peers will grade it based on the grading rubric.

Week 1: Stellar evolution (Week 8)

This week, we look at the basics of stellar evolution, the age of stars, take a walk through the stellar graveyard, and give you a crash course in current research in the field. In V-Lab we will apply this knowledge to learn more about the stars in our night sky and we'll return to scaling relations for a better understanding of the lifetime of stars. In discussion, we unpack Carl Sagan's famous quote, "We are made of star stuff".

		Topics and Activities	
		Mastering Astronomy	Influencer's Guide to Science IRL
The Big Idea: **We are made of star stuff!**		Textbook chapters: 16. Star Birth 17. Star Stuff	Influencer's Guide sections: - Opening Comments: Thematic YouTube video
Mini Lessons: **Stellar Evolution**	D1L1	16.1. Stellar Nurseries	
	D1L2	16.2. Stages of Star Birth 16.3. Masses of Newborn Stars	
	D2L1	17.1. Lives in the Balance	
	D2L2	17.2. Life as a Low-Mass Star	
	D3L1	17.3. Life as a High-Mass Star	
	D3L2	17.4. The Roles of Mass and Mass Exchange Open questions and surveys	
V-Lab		**Scaling Relations and Stellar Evolution**	
Astro Chat		**We are made of star stuff!**	
Knowledge Check		MCQ quiz covering this week's lessons.	

Week 2: Dark matter (Week 9)

This week is all about dark matter—how it was discovered and where research stands today. We'll dive into General Relativity (with real-world validation included!) and compare it to Newtonian gravity in discussion. In V-Lab, you'll explore the observational evidence for dark matter firsthand!

		Topics and Activities	
		Mastering Astronomy	Influencer's Guide to Science IRL
The Big Idea: **Unseen Influences P1**		Textbook chapters: S3. Spacetime and Gravity 23. Dark Matter, Dark Energy, and the Fate of the Universe	Influencer's Guide sections: 4. A Map of Physics Opening Comments: Thematic YouTube video
Mini Lessons: **Dark Matter**	D1L1	General Relativity	4.2.6. General Relativity
	D1L2	General Relativity	
	D2L1	23.2 Evidence for Dark Matter	
	D2L2	23.2 Evidence for Dark Matter	
	D3L1	23.3 Structure Formation	
	D3L2	Open questions and surveys	
V-Lab		**Galaxy Rotation Curves**	
Astro Chat		**Newtonian Gravity vs. General Relativity**	
Knowledge Check		MCQ quiz covering this week's lessons.	

Week 3: Cosmic expansion and dark energy (Week 10)

This week, we delve into cosmic expansion and dark energy research. We'll help you get your head around the tough concept of cosmological redshift, and in V-Lab, you'll explore Hubble's observational evidence that led to the conceptualization of the Big Bang Theory. In discussion, we'll contemplate what is at the edge of the universe.

		Topics and Activities	
		Mastering Astronomy	Influencer's Guide to Science IRL
The Big Idea: **Unseen Influences P2**		Textbook chapters: 20. Galaxies and the Foundation of Modern Cosmology 23. Dark Matter, Dark Energy, and the Fate of the Universe	Influencer's Guide sections: - Opening Comments: Thematic YouTube video
Mini Lessons: **Cosmic expansion**	D1L1	Hubble's Observations	
	D1L2	20.3 The Age of the Universe	
	D2L1	20.3 The Age of the Universe	
	D2L2	23.4 Dark Energy and the Fate of the Universe	
	D3L1	23.4 Dark Energy and the Fate of the Universe	
	D3L2	Open questions and surveys	
V-Lab		**The Expanding Universe**	
Astro Chat		**What's at the edge of the universe?**	
Knowledge Check		MCQ quiz covering this week's lessons.	

Week 4: The early universe (Week 11)

Ready to time travel?! This week we travel back in time, rewinding the universe to learn what happened in the first few minutes! We'll pick up some particle physics along the way, and in discussion, we'll try wrapping our heads around the concept of inflation – did the early universe travel faster than the speed of light?!

		Topics and Activities	
		Mastering Astronomy	Influencer's Guide to Science IRL
The Big Idea: **Rewinding the Universe**		Textbook chapters: S4. Building Blocks of the Universe 22. The Birth of the Universe	Influencer's Guide sections: 4. A Map of Physics Opening Comments: Thematic YouTube video
Mini Lessons: **The BBT**	D1L1	S4.2 Fundamental Particles and Forces	4.2.4. Particle Physics
	D1L2	22.1 The Big Bang Theory	
	D2L1	22.2 Evidence for the Big Bang	
	D2L2	22.2 Evidence for the Big Bang	
	D3L1	22.3 The Big Bang and Inflation	
	D3L2	Open questions and surveys	
V-Lab		**Rewinding the Universe**	
Astro Chat		**Inflation – faster than the speed of light?!**	
Knowledge Check		MCQ quiz covering this week's lessons.	

Unit 4: Game On! Tackling Tough Topics in Science Like a Boss

Now that you've got a solid grip on the scientific process, it's time to put those skills to work IRL! This unit is all about using science literacy in decision-making—spotting and debunking false claims, evaluating source trustworthiness, understanding the significance of claims, and asking whether it matters IRL! With the rise of AI tools that can answer just about anything, the real challenge isn't finding information—it's knowing the right questions to ask and how to validate the answers. Plus, get ready to level up on your influencer game! Be prepared to tackle more complex topics and up your appeal!

Unit assessment: Ongoing Activity 3: You Be the Influencer – Boss Level!

In the previous unit, you gained hands-on experience creating science content and received feedback on your work. Now, it's time to level up! We'll tackle more complex topics and be even more selective when it comes to judging the appeal of your content.

This ongoing activity will be issued at the start of Unit 4. Using the science communication tips in your user guide, create a responsible YouTube video on one of the astronomy topics from our list of hot topics. Your video should be engaging for your target audience and cover all the hallmarks of responsible reporting, as outlined in the grading rubric.

Format of submission: You can submit either a storyboard with an accompanying script or go ahead and create the final video—your choice!

Due date and grading: Your video (or voice-overed storyboard) will be due in the last week of term. You'll present it to your discussion group, where your TA and peers will grade it based on the grading rubric.

Week 1: Is it reliable science? (Week 12)

You've spent nearly this entire course learning what science is, and by now, your bull$#!t detector should be on point. This week, we're stepping it up by looking at what makes a scientific source trustworthy. And what better topic to dive into than aliens and UFOs?! We'll explore the scientific study of life in the universe—what we know, open questions, and surveys. In V-Lab, you'll find and evaluate the trustworthiness of scientific sources studying life beyond Earth. We'll wrap up by using your understanding of the hallmarks of science and trustworthy sources to evaluate the juicy claim that aliens are visiting Earth!

		Topics and Activities	
		Mastering Astronomy	Influencer's Guide to Science IRL
The Big Idea: **Can I trust it?**		Textbook chapters: 24. Life in the Universe	Influencer's Guide sections: 5. A Basic Guide to Science IRL Opening Comments: Thematic YouTube video
Mini Lessons: **Aliens**	D1L1	24.1 Life on Earth	
	D1L2	24.2 Life in the Solar System	
	D2L1	24.3 Life Around Other Stars	
	D2L2	24.4 The Search for Extraterrestrial Intelligence	
	D3L1	24.5 Interstellar Travel and Its Implications for Civilization Open questions and surveys	
	D3L2		Checkpoint 1: Is it science? Checkpoint 2: Can I trust this information?
V-Lab		**Finding and evaluating scientific sources: Life in the Universe**	
Astro Chat		**Extraordinary claims: Aliens are visiting Earth**	
Knowledge Check		MCQ quiz covering this week's lessons.	

Week 2: Does it warrant action? (Week 13)

Throughout this course, you've been developing your understanding of science, how it works, and key points to consider when evaluating information. You're now going to consolidate this information into a framework that can help you decide if a result is truly significant – and you'll put your framework to the test in the context of climate change. We'll explore the basics of planetary atmospheres, and in V-Lab, you'll find and evaluate the significance of climate change research. We'll wrap up with a debate: "Is it politics, or the real deal?!" What information do you need to choose a side and where will you source this information?

		Topics and Activities	
		Mastering Astronomy	Influencer's Guide to Science IRL
The Big Idea: **Is it significant?**		Textbook chapters: 10. Planetary Atmospheres: Earth and the Other Terrestrial Worlds	Influencer's Guide sections: 5. A Basic Guide to Science IRL Opening Comments: Thematic YouTube video
Mini Lessons: **Climate Change**	D1L1	10.1 Atmospheric Basics	
	D1L2	10.2 Weather and Climate	
	D2L1	10.3 Atmospheres of the Moon and Mercury	
	D2L2	10.4 The Atmospheric History of Mars	
	D3L1	10.5 The Atmospheric History of Venus	
	D3L2	10.6 Earth's Unique Atmosphere	Checkpoint 3: How significant are these findings?
V-Lab		**Finding and evaluating scientific sources: Climate change**	
Astro Chat		**Is this politics or the real deal?**	
Knowledge Check		MCQ quiz covering this week's lessons.	

Week 3: Does it matter IRL? (Week 14)

This section goes deeper into science and decision-making, exploring the technological and socio-economic impact of scientific research. The debate can go in many directions—like the consequences of not acting on climate change—but here, we'll focus on funding research. When budgets are tight, how do we justify spending on something as abstract as studying black holes? This week, we'll catch you up on black holes—what we know, open questions, and upcoming surveys. You'll dive into the technological and socio-economic impacts of black hole research and have the chance to voice your opinion on using taxpayer funds for blue-sky research.

		Topics and Activities	
		Mastering Astronomy	Influencer's Guide to Science IRL
The Big Idea: **Does it matter IRL?**		Textbook chapters: 18. The Bizarre Stellar Graveyard	Influencer's Guide sections: 5. A Basic Guide to Science IRL Opening Comments: Thematic YouTube video
Mini Lessons: **Black Holes**	D1L1	18.3. Black Holes What is a black hole?	
	D1L2	What would it be like to visit a black hole?	
	D2L1	Do black holes really exist?	
	D2L2	Open questions	
	D3L1	Planned surveys	
	D3L2		Checkpoint 4: Does it matter IRL?
V-Lab		**Evaluating the technological and socio-economic impact black hole of research**	
Astro Chat		**Is taxpayer funding for blue sky research justified?**	
Knowledge Check		MCQ quiz covering this week's lessons.	

Linking GE ELOs to Course Topics

GE ELO	Topics for Each Unit			
	Unit 1: Science Unlocked	**Unit 2: Behind the Scenes**	**Unit 3: Guessing or Slaying?**	**Unit 4: Game On!**
1.1. Explain basic facts, principles, theories and methods of modern natural sciences, and describe and analyze the process of scientific inquiry. **1.2.** Identify how key events in the development of science contribute to the ongoing and changing nature of scientific knowledge and methods.	**Science IRL:** **W1:** Is it Science? How to Speak and Think Like a Scientist: **W2:** Measuring our Universe **W2:** Data analysis and visualization **W2:** Logic **W3:** A Map of Physics **Astronomy:** Astronomy Facts: **W1:** Key observations and events that led to the birth of modern science. **W2:** Scales of our Universe and astronomical units A Map of Physics: **W3:** Orbital mechanics and classical mechanics	**Science IRL:** How to Speak and Think Like a Scientist: **W3-4:** Dealing with uncertainty in measurement **Astronomy:** Astronomy Facts: **W1:** Our solar system **W2:** Properties and composition of stars **W3:** Exoplanets and their properties **W4:** Cosmic scales: objects, quantities, distances, and time A Map of Physics: **W1:** Special Relativity **W2:** Spectroscopy **W3:** Doppler shift **W4:** Each crayon of light tells a story Astronomy Methods: **W1:** Solar system exploration: Current	**Science IRL:** **W1-4:** A Framework for Understanding Science **W2-4:** Notes on Science Communication **Astronomy:** Key concepts, theory development and open questions: **W1:** Stellar evolution **W2:** Dark matter **W3:** Cosmic expansion and dark energy **W4:** The early universe A Map of Physics: **W2:** General Relativity **W4:** Particle Physics	**Science IRL:** A Basic Guide to Science IRL: **W1:** Checkpoint 1: Is it science? **W1:** Checkpoint 2: Can I trust this information? **W2:** Checkpoint 3: How significant are these findings? **W3:** Checkpoint 4: Does it matter IRL? **W1-3:** Notes on Science Communication **W1-3:** AI Tools **Astronomy:** **W1:** Life in the Universe: What we know, open questions and planned surveys **W2:** Planetary atmospheres: The basics

		missions and limitations of direct observation **W2:** Beyond our solar system: What we learn from light **W3:** Methods of exoplanet discovery **W4:** Estimating and measuring the universe, including quantities of astronomical objects, distances (Cosmic Distance Ladder) and time (lookback time)		**W3:** Black holes: What we know, open questions and planned surveys
1.3. Employ the processes of science through exploration, discovery and collaboration to interact directly with the natural world when feasible, using appropriate tools, models and analysis of data.	**V-Lab:** **W1:** Discovering the Night Sky for Yourself **W2:** The Power of Math: Scaling Relations **W3:** Standing on the Shoulders of Giants **Ongoing Activity 1:** You Be the Scientist!	**V-Lab:** **W1:** Exploring the Scale of our Solar System **W2:** Properties of Stars **W3:** Transiting Exoplanets **W4:** Parallax **Ongoing Activity 1:** You Be the Scientist!	**V-Lab:** **W1:** Scaling Relations and Stellar Evolution **W2:** Galaxy Rotation Curves **W3:** The Expanding Universe **W4:** Rewinding the Universe	**V-Lab:** **W1:** Finding and evaluating scientific sources: Life in the Universe **W2:** Finding and evaluating scientific sources: Climate change **W3:** Evaluating the technological and socio-economic impact of research
2.1. Analyze the inter-dependence and potential impacts of scientific and technological developments. **2.2.** Evaluate social and ethical implications of	**W3:** Technological and socio-economic impact of the telescope. **W3:** Technological validation of classical mechanics IRL	**W1:** Technological and socio-economic impact of missions to mars. **W3:** Technological validation of SR IRL	**W1-4:** Current and planned surveys **W2:** Technological validation of GR IRL	**W1, 3:** Current and planned surveys **W3:** Technological and socio-economic impact of black hole research.

natural scientific discoveries.				
2.3. Critically evaluate and responsibly use information from the natural sciences.	**Critically evaluate (Astro Chat):** **W1:** How good is your bull$#!t detector? Is it even science? **W2:** How good is your bull$#!t detector? Data and logic edition **W3:** When common-sense fails you!	**Critically evaluate (Astro Chat):** **W1:** Our evolving definition of a planet **W2:** The hidden world of light **W3:** Do aliens know we exist? **W4:** Each crayon of light tells a story	**Critically evaluate (Astro Chat):** **W1:** We are made of star stuff! **W2:** Newtonian Gravity vs. General Relativity **W3:** The history of the Big Bang Theory **W4:** Inflation – faster than the speed of light?! **Responsibly use information:** **Ongoing Activity 2:** You Be the Influencer!	**Critically evaluate (Astro Chat):** **W1:** Extraordinary claims: Aliens are visiting Earth **W2:** Is this politics or the real deal? **W3:** Is taxpayer funding for blue sky research justified? **Responsibly use information:** **Ongoing Activity 3:** You Be the Influencer – Boss Level!