

What's out there...  
... how we learn about it ...  
... and why it's awesome.

Our Place in the Universe  
Syracuse University, Fall 2020  
Walter Freeman

August 25, 2020

# Welcome!

The size and age of the Cosmos are beyond ordinary human understanding. Lost somewhere between immensity and eternity is our tiny planetary home. In a cosmic perspective, most human concerns seem insignificant, even petty. And yet our species is young and curious and brave and shows much promise. In the last few millennia we have made the most astonishing and unexpected discoveries about the Cosmos and our place within it, explorations that are exhilarating to consider. They remind us that humans have evolved to wonder, that understanding is a joy, that knowledge is prerequisite to survival.

I believe our future depends powerfully on how well we understand this Cosmos in which we float like a mote of dust in the morning sky.

—Carl Sagan, from *Cosmos*

# The first theme of our class

You are here at Syracuse to get an education. Why?

Type in chat (Zoom or Twitch) what you hope to do with the skills you learn here at SU.

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Education is about *empowerment*. That's in our university's motto: "Suos cultores scientia coronat." The crown of knowledge is the ability to create our own future.

This leads us to the first theme of our class:

"Science lets us write our own better future."

# Who are you?

Take a moment to type in chat – either Zoom or Twitch:

- Your major
- How you hope that the skills you learn in your study here will let you change the world for the better

# Welcome!

Today:

- Who we are
- Who you are
- What this class will be
- How we're going to conduct it

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Today:

- Who we are
- Who you are
- What this class will be
- How we're going to conduct it
- What the Universe is, too  
*(and how we measure it)*

# Who you'll be learning from in this class

Walter Freeman, professor

*Lead graduate teaching assistants:*

Faraz Chahili   Suman Kundu   Mario Olivares

*Graduate teaching assistants (TA's):*

Vidyesh Anisetti	Jeff Frelier	Clayton Larson
Vincent Musso	Hang Pham	Penelope Taylor
	Yuezhe Yao	

*Lead coaches:*

Junying Chen   Blake Moyer   Laurel White

*Undergraduate coaches:*

Adam Aly	Roshan Fernandez	Quincy Gray
Alyssa Grzesiowski	James Harford	Xinning (Lisa) Li
Lexin Lu	Elena Murphy	Elise Newhouse
Christian Pilarski	Chris Ruan	Aaron Trowbridge

... and all of your brilliant colleagues:

John Abbott	Katrina Abuls	Sean Adams	Rehan Ahmed
Isabella Al-Hachem	Isaiah Alexis	Benjamin Alfano	Sultan Alhameli
Mariam Almohamad	Gregory Altamore	Kaerod Amare	Mia Angioletti
Frank Anselem	Emma Arczynski	Zachary Askarinam	Sam Auerbach
Diana Avila	Enrique Aviles	Samual Ayers	Sara Ayers
Oluwaseminire Babafemi	Anayancy Barajas	Annabelle Barbara	Kenneth Barrist
Justin Barron	Drew Bartelstein	Hamelin Batista Camilo	Thomas Bauer
Jackson Beers	Ryan Bell	Anthony Bellman	Courtney Bennett
Jacob Bennett	Madison Bequer	Sydney Bergan	Martin Berishaj
Jacob Bernardine	Jacopo Bertone	Sharif Bey	William Birks
Leia Bisgard	Alex Bisignani	Megan Bisson	Ebhani Blackwood
Ryan Blowers	Corey Blum	Nicole Boadu	William Boatl
Maxwell Bockmann	Phillip Bogan	Maxwell Boise	Jenna Bondy
Leonardo Bonilla	Hannah Boyer	Ryan Bradley	Caitlyn Brady
Nya Bragg	Sarah Bragg	Bailie Brown	Samuel Brownstein
Kaeleigh Broyles	Bryan Brush	Dylan Buck	Laura Bueno
Kimy Alexi Buere	Jordan Bullock	Thomas Burke	Charles Burns
Allison Burtt	Tatia Buziashvili	Jenna Byers	Megan Caffey
Alycia Cahn	Yushi Cai	Nicholas Calbo	Ian Calder
Kevin Camelo Bonilla	Douglas Camp	Christian Campbell	Emily Campbell
Xiaopeng Cao	Camila Carbajal	Elizabeth Carlson	Zoe Carlson
Luca Carney	Jackson Carrel	Grace Carrigan	Adam Carter
Michael Caruso	Daniel Cavalier	Luke Ceccoli	Aminata Ceesay
Tanya Cervantes	Sarah Chadwick	Christin Chae	Benjamin Chairnoff
Isaac Chapin	Guoliang Chen	Suyun Chen	Yubo Chen

Zhennan Chen	Chuyuan Cheng	Jamie Chernett	Conor Chesterman
Calvin Christoforo	Anthony Cibulsky	Steven Claffey	Alana Coffman
Catherine Cohen	Ryan Cohen	Thomas Cohen	Zachary Cohen
Jermaine Coles	Maeva Collatos	Ryan Conner	Jaden Constant
Rody Conway	Zoe Copeland	Gabriela Corso	Colin Crawford
Liam Creeden	Madeline Crooke	Zachary Crowe	Stella Crowther
Antonio Cruz	Zhiqi Cui	Zhiwei Cui	Brittney Cunningham
Daniel Cunningham	Hope D'Angero	Aryan Daga	Ryan Daly
Beckett Dardia	Otitodirichukwu Oto Darl Uzu	Tyler Dawson	Chad de la Rosa
Anicia De Pina	Timothy Dean	Hamere Debebe	Joseph Deblasio
Victoria Decoster	Devon Degen	Lang Delapa	Samantha Denaro
Jiaxing Natalia Deng Yuan	Jack Desmarais-Harris	Amia Diakite	Daouda Diawara
Yaya Diawara	Christopher Diaz	Michael Dibiasi	Pierre Didisheim
Imani Diggs	Cori Dill	Dara Dilmaghani	Samantha Dinerman
Andrew Dinnhaupt Jr	Tessa Diserafino	Alexander Dougherty	Matthew Dragon
Ann Drennan	Xiaoyang Du	Liwen Duan	Robert Dube
Jackson Dubrulle	Claire Easton	Danielle Edelstein	Kiersten Edwards
Michael Egidio	Isabel Eisen	Rewina Embaye	Blessing Emole
Zachary Epstein	Daniel Espinoza	Morgan Fahy	Matthew Fairfax
Zongli Fang	Alexi Farnes	Ella Farrell	Carly Feller
Paulina Ferguson	Matteo Ficarella	Jake Fienberg	John Finnerty Jr
Anthony Firenze	lexi flood	Pamela Flores	Joshua Foley
Gabriel Foltz	Logan Forbes	Natalie Fournell	Jacob Fowler
Caroline Francoeur	Karina Freeland	Christopher Freeman	Eric Freudigman
Jessica Friebely	Ariella Friedman	Emily Friedman	Joshua Friedman

Avrienne Froman	Samantha Fuss	Shanhaoyu Gao	Daniel Gavilondo
Jing Ge	Brandon Gecaj Sr	Allison Geller	Andronikos Georgalas
David George	Jaden Gerard	Lee Gerstman	Noa Getzug
Olivia Gladu	Mihika Gogate	Emily Gold	Dylan Goldberg
Dylan Goldberg	Rachel Goldberg	Joshua Golden	Laura Goldin
Dylan Goldman	Zachary Goldman	Sofya Golubovskaya	Angel Gonzalez
Anya Gonzalez	Jack Gonzalez	Jack Gordon	Madeline Gorewitz
Bailey Gorman	Tucker Gralewski	Brandon Grant	Duncan Grant
Jay Grant	Stephanie Gratzel	Madison Grebler	Samantha Greco
Jordan Greene	Teresa Greenwood	Liam Griffin	Margaret Grinnell
Chen Gu	Grace Guido	Campbell Gulbrandsen	Alex Guo
Forrest Gurl	Romane Gutenbrunner	Derek Gutierrez	Gabrielle Guzda
Dean Gwadz	Anthony Haak	Brian Hall	Sami Halperin
Joseph Han	Lingxu Han	Alan Harding	Justin Harrington
Tia Hartley	Greta Hartwyk	Daniel Hassett	William Hauben
Tawny Hawthorne	Aidan Hayes	Hanne Haynes	Sara Haynes
Hongkai He	Miranda Heard	Anya Hegde	David Heiman
Madison Hennig	William Hentschel	Vanessa Hernandez	Michael Hernandez Jr
Taylia Hinds	Amr Hines	Mia Hinz	Jackson Holzer
Benjamin Hornick	Xinran Hou	Andrew Hoyt	Kunkun Hu
Hao Huang	Sierra Huff	Katelyn Hughes	Caroline Hurlebaus
Jeremiah Hurst	Faith Hutson	Alexander Huynh	Rachel Iannarelli
Trevis Ifandy-Smith	Jessica Infante	Andrew Jackson	Rhys Jansen
Ryan Jermyn	Joshua Jezak	Chenxi Ji	Joyce Jing
Colleen Johnson	Jabari Johnson	Camryn Johnson-Andrews	Dean Johnston

Joshua Jones	Maximus Jones	Alan Jos	Hailey Joseph
Kato Josiah	Connor Joy	Kadija Kaba	Alexa Kahn
Cody Kaiser	Sophie Kaiser	Jordan Kakuyo	Ryan Kalata
Nicholas Kalaw	Zev Kalechofsky	Luke Kaleeba	Timothy Kalinowski
Anabella Kalish	Wayne Kaminski	Cyrus Kamkar	Ju Hyun Kang
Marykate Keevins	Juliette Keller	Victoria Kelly	Maxwell Kennedy
Cassidy Kepcher	Madison Kettering	Annastacia Kilgallon	Justin King
Ellen Kingman	Zaria Kirkland	Sahil Kirpalani	Katherine Kjellberg
Matthew Klemenz	Ikuo Kobayashi	Lily Koller	Jami Kopf Jr
James Korenman	Emily Korzendorfer	Matthew Krengel	Jacob Kronberg
Abhishek Kumar	Jake Kurtz	Michael Kwan	Anna Labarca
Alexandra Lain-Hedden	Ethan Lake	Roberto Lamas	Emma Lambiaso
Greer Lammens	Sydney Lance	Jonah Landow	Tessa Lank
Branden Lantz	Mateo Lariviere	Justin Laurent	Joseph Lauria
Luka Lazarevic	Andrew Leconte	Lewis Ledyard	Elvis Lee
Renata Lee	Chloe Leger	Lagarthucin Legrand	Neil Lepard
Eli Lesser	Ethan Letwat	Cheuk Kiu Justin Leung	Brandon Levine
Eli Levine	Jason Levy	Michael Leyne	Brianna Liberman
Josh Linder	Bruce Liska	Hongchen Liu	Jiaqi Liu
Xiangfeng Liu	Yifei Liu	Kayla Lohman	Anthony Loiacono
Luis Lopez-Crespo	Caitlin Lorenz	Keer Lu	Youhao Luo
Sophia Lusardi	Courtney Lynch	Sophie Lynch	Junyi Lyu
Sitong Lyu	Xinran Ma	Luke Maddren	Luka Madhok
Morris Mahana	Catherine Maher	Isabel Maine-Torres	Daniel Mallea
Madison Manczko	Shanice Manning	Tyler Marma	Matthew Martin

Gabriel Martinez	Wura Martins-Kuye	Gabriella Mashaal	Karthik Mathew-Malik
Anna Matjucha	Logan Mccabe	Colleen McConnell	Zoe Mccreary
Isabela McDonald	John McGovern	Ross McKee	Michael McKeon
Jordan McKey	Ryan McLaughlin	Thomas McMullen	Brenden McNamara
Nathan McPeak	Skyy McQueen	Creagan Mee	Miranda Mellen
Kevin Mendez	Gerta Meshi	Margaret Metcalfe	Josh Meyers
Michael Midkiff	Jillian Miele	Amanda Miller	Taylor Miller
Hope Millner	Ethan Mitchell	Kimberly Mitchell	Lauren Mix
Hanlin Mo	Abygail Moloughney	Sam Moore	Charlie Moreno
Jacob Morris	Taylor Moss	Emily Murcko	Emerson Murphy
Grant Murphy	Alister Murray Jr	Samantha Mussman	Grace Myron
Sydney Nadel	Connor Napierala	Allison Nelson	Jake Newman
Zhishan Ni	Jordan Nichols	Matthew Niwelt	Nicholas Nizza
Andrew Noesner	Sean Nusdeo	Tyler O Neill	Erin O'Brien
Henry O'Brien	Maxum O'Halloran	Nora O'Malley	Shane O'Neil
Michele Orleans	Skyla Owens	Matthew Paden	Andrew Paek
Tao Pang	Alexandra Papalcure	Brendan Parlee	Danielle Parr
Laurhen Parvin	Erykah Pasha	Daniel Pease	Jordyn Pegues
Ying Pei	Natalie Pereira	Jeronimo Perez	Lauren Perillo
Devanand Persaud	Petey Peterson	Ramon Phenix	Benjamin Phillips
Grace Phillips	Leilani Phommaniraj	Connor Pignatello	Sierah Pilson
Alexandra Pinedo	Nicholas Piro	Gianluca Pisacane	Caitlin Plemons
Andrew Pogue	Haley Popowitz	Faith Porter	Jennifer Porter
Olivia Porter	Lucas Portnoy	Marissia Potamianos	Olivia Potter
Maya Pow	Matthew Powers	Tessa Pulgar	Nicole Pullano

Brianne Quinlan	Jonah Quinn	Nicolette Rafferty	Alejandro Ramirez
Ernest Joseph Ramos	Faris Rassac	Louise Rath	Harrison Ray
Hana Redzepagic	Maxwell Reed	Matthew Reese	Christopher Reilly
Evan Reiner	Celia Reistrom	David Religa	Emma Repice
Adam Revoir	Neftali Reyes Jr	Elizabeth Ricchetti	Matthew Ricciardi
Catherine Rice	Victor Richardson	Joseph Ritchie	Fidel Rivera
Skyler Rivera	Bailee Roberts	Kevin Robertson	Mia Rodriguez
Zachary Rohrer	Thomas Romano	Brandon Rook	Timothy Rose
Reed Rosen	Sydney Rosenbaum	Noah Rosenthal	Allyson Ross
Bonaccorso Rosselli Del Turco	Aaron Rothschild	Bryce Ruvo	Dorothy Sabo
Aicha Sacko	Will Saferstein	Ava Salazar	Melanie Salazar
Benjamin Salinger	Dominic Samangy	Andres Sanclemente	Ashley Santore
Kayleigh Sattler	Samuel Saunders	Catherine Schickling	Benjamin Schiller
Sophie Schlosser	Conrad Schmidt	Samuel Schneider	Preston Schoenberg
Adam Schwartz	Ziqian Shan	Mackenzie Shane	Georgia Shanker
Brady Sheehan	Maeve Sheehan	Henry Sher	Jane Shevlin
Ethan Shifman	Molly Shoap	Julia Short	Xiaoxin Shu
Xiangjie Si	Christopher Sifre	Michael Silverman	Joseph Simon
Noah Simpson	Ashtha Singh	Kyra Singh	Karhan Sistolou
Timothy Skeval	Stephen Sklar	William Slaski	Conn Slattery
Quinn Smith	Ryan Smith	Zion Smith	Stanley Smudin
Sophia Soderlund	Max Solomon	Chengjing Song	Aashika Soorakulanthakan
Andrew Spana	Cory Spangler	Robert Spano	Rhea Srivastava
Gabriel Stavenhagen	William Steinberg	Benjamin Stickle	Ashley Strauss
Summer Stubbmann	Alexander Styrt	Yuri Suh	Sierra Sule

Brendan Sullivan	Eamonn Sullivan	Annika Swientek	Luke Talago
Francis Tang	Blake Taub	Gordon Taubenfeld	Eden Tefera
Brett Tenaglia	Gina Tette	Phyoe Thandar	Matthieu Theard
Tyler Thibeau	Siron Thomas	Jacob Thomassen	Erin Thompson
Harrison Thompson	Olivia Thompson	Reid Thompson	Samuel Thorogood
Marco Sebastian Tinetto	Andrew Todd	Shoshanna Tokar	Megan Townsend
Alexis Trainor	Win Tran	Christopher Trentham	Sofya Treshcheva
Olivia Troilo	Maya Tsimer	Remi Tsunoda	Kun Tu
Alexandra Tummon	Shoshana Turek	Brandon Turney	D'Angelo Valdez
Colette Van Olden	Adam Van Treuren	Sara Vanden Assem	Gerrit Vanvracken
Anna Vila	Jose Vilchez	Kathryn Voler	Luka Vrbaski
Telusila Vunipola	Jacob Waldron	Vanessa Walker	Davonta Wallace
Charlotte Walsh	Celine Wang	Chong Wang	Jing Wang
Tao Wang	Xuechun Wang	Yueru Wang	Lily Warren
Layla Watkins	Nina Watson	Caleb Welsh	Holly Westbrook
Cecelia Westwater	Amara Wilson	Elizabeth Wolf	Myra Wong
Beyonce Wood	Chengting Wu	Honglin Wu	Xiaojie Wu
Jieying Xi	Xinyu Xing	Jiajun Xu	Zijian Xu
Zhekai Yan	Yang Yang	Qiaomu Yao	Yuyang Yao
Ciara Young	Jacob Yousem	Huaye Yu	Xiaoping Yuan
Yiyi Yuan	Charles Zeeve	Bangshi Zeng	Fengze Zhang
Ji Zhang	Ruiyun Zhang	Zhenyu Zhang	Wanyi Zhao
Ziwei Zhao	Huaermu Zhuoma	Iman Zia	Owen Zides
Capeley Zimet	Joshua Zitomer	Olivia Zoeckler	Joana Zuluaga
	Matthew Zumbolo		

(Plus whoever registered late...)

# Where to find all of our information

We'll be using a bunch of technology this semester (and we will change what we use based on *your feedback!*). But there are *two* places where you can find all of our material:

## The course website:

<https://walterfreeman.github.io/ast101/>

- Announcements
- Tasks for you to do
- Slides from class
- Links to recordings
- Links to assignments and labs
- The schedule, the syllabus...



## The course Piazza page:

<https://piazza.com/class/kdxey00cpbh76q0/>



- Quick answers to questions about anything
- **An opportunity for extra credit (“ask the physicists”)**
- Answers to your classmates' questions
- Links to assignments and labs

# Our class in the age of COVID-19: group work

Students tell me that the thing they miss the most is the sense of *community*.

In this class, you will do almost *all* of your work in groups of three:

- You'll work on the labs in your groups
- You'll work on your homework in groups, writing things *for an audience of another group*
- You'll evaluate each other's work in groups, too

If you are all in the same place, you may work on your labs in person outdoors – even if you are working with instructors who are remote. (You should each bring a computer with you. We'll give you instructions each week.)

Make sure you answer the Blackboard survey so we can put you in groups. If you want to switch lab sections, you can do it this way.

# Being a student in the age of COVID-19

I'm not going to lecture you about SU's "Stay Safe Pledge". You know what it says already.

In our class we expect you to:

- Stay six feet away from everyone when possible
- Wear a mask indoors (except when alone in a room with people you live with or romantic partners)
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Instead, I want to appeal to our first theme: "Science lets us write our own better future."

What kind of semester we will have depends on how we act.

# Online large-class meetings

This class will meet over Zoom and/or Twitch for the whole semester. (I'll be reading both Zoom and Twitch chat.)

We will (hopefully) be doing some group work in *class*, starting Thursday. We'll do this in either Zoom or Blackboard Collaborate. This group work will get you a start on your homework.

Please send me feedback about how well Zoom and Twitch are working for you, and which platform you prefer!

# Labs

Labs will start *next week*. **Do not go to lab this week!**

You will do *all* your lab work in groups. You are primarily responsible to your lab group, not to us, for your lab work.

Make sure you fill out the lab survey. This will help us put you in groups that work for you, and make sure that each time slot has the right number of instructors in person and online. **This is very important!** We want to give you maximum flexibility, but to do this we need some information so we can plan.

If you need to reschedule your lab, then you *must* work with your group and find a time that will work for all of you.

Depending on your choices and the time you go to lab, you will work in one of the following ways:

- Working in-person with a TA that is there with you, outdoors
- Meeting with your group in person, with coaches physically present, but with a TA who is remote
- Meeting with your group online, working with instructors who are online

Regardless of how you work, you and your group will do some activities, recording your thoughts and observations in a shared Google or Office 365 document. You'll submit this document to us when you're done.

# Discussion time (“office hours”)

If anyone wants to talk to me – about this class or anything else – I'll have discussion hours when you can come visit.

These will always either be *outside* or *online*.

The first of these will be today from 4:30-6:30 PM in front of Holden Observatory. Stop by and say hello (but wear a mask!)

If you can't be there in person but want to say hello, then join the same Zoom link as this class.

# Group projects

You will do a number of group projects in this class, and they'll be a major part of your grade.

This homework will be different from what you're used to.

Tell me in chat: how did you get a good grade on your homework for your high school science classes?

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- I'll post an assignment – a document that you can import into either Google Docs or Office 365.
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- We will look at those assessments to make sure they're reasonable
- You'll get grades on both your work and on your assessment of the other group's

# Papers

You'll write a few papers this semester, and do a freeform creative project.

I'll talk about these later, but know that they're coming.

# Exams

How should we handle exams online? Tell me in chat what you'd prefer to do. Tell me stuff like:

- How much of your grade should come from exams?
- How should we structure them so that they're fair?
- How many should we have?
- What about people cheating on them?

Tell me about these images:



@Lisaaa



@Lisaaa

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@Lisaaa



@Lisaaa

*Photography by Lisa Li, physics/photography/film studies major and AST101 coach  
Taken from Labrador Hollow, 20 miles south of Syracuse, this summer*

# The beauty of the cosmos



@Lisaaa

When we contemplate the whole globe as one great dewdrop, striped and dotted with continents and islands, flying through space with other stars all singing and shining together as one, the whole universe appears as an infinite storm of beauty.

—John Muir, from *Travels in Alaska* (1915)

# The eclipse of 2017



(by Keith Lisk, shot in Paducah, KY: <https://www.dpreview.com/forums/post/60016117>)

# The eclipse of 2017



(photographers Andrew Studer and Ted Hesser; climbers Tommy Smith and Martina Tibell; Smith Rock State Park, OR)

[https://www.dpreview.com/articles/5501288570/  
how-the-viral-climber-eclipse-photo-and-video-were-shot](https://www.dpreview.com/articles/5501288570/how-the-viral-climber-eclipse-photo-and-video-were-shot)

## Our second theme: the beauty of nature

The things in the sky have inspired poets, artists, writers, and dreamers for millennia.

Now – in this scientific age – they do so even more than ever.

“The world around us is beautiful.  
The more we learn, the more beautiful it gets.”

# Astronomy's broader impact on human thought

Astronomy has been inspiring art, philosophy, music, and literature since those things have existed.

Why is the fourth planet named Mars?

We're going to spend much of our class looking up ... but we'll spend a bit of time looking back down, too, to see how astronomy has influenced so many fields of human endeavor.

We'll explore this much more later, as our third theme:

“Science informs our humanity.”

# Course organization: four units

- Naked-eye astronomy
- Astromechanics
- The science of light
- Humanity and the cosmos

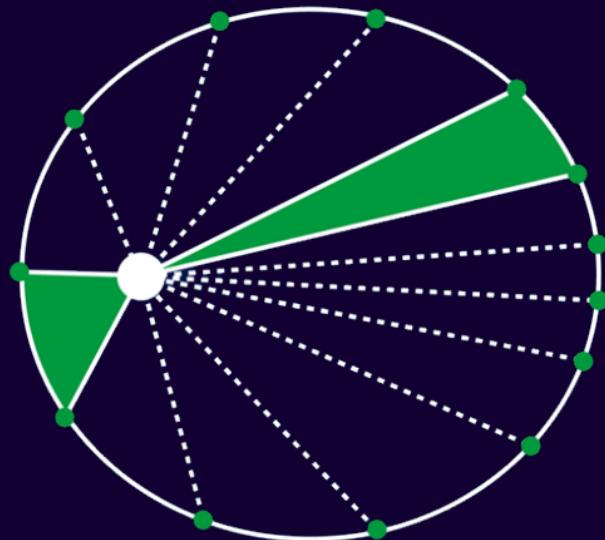
# Naked-eye astronomy

- What can we see from Earth?
- What changes do we see in the sky?
- How are they explained by Earth's motion?



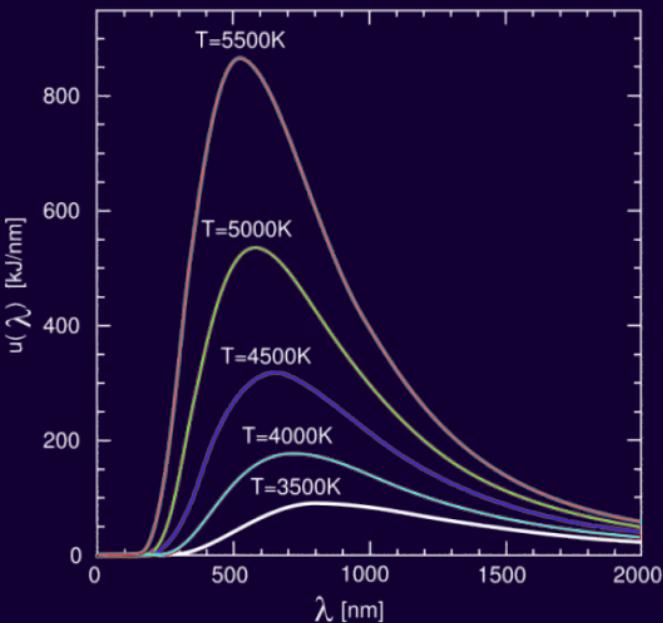
# Astromechanics

- How does scientific thought work?
- How do we know the planets orbit the Sun?
- What do the motions of the planets really look like?
- How do the laws of physics cause them to move this way?



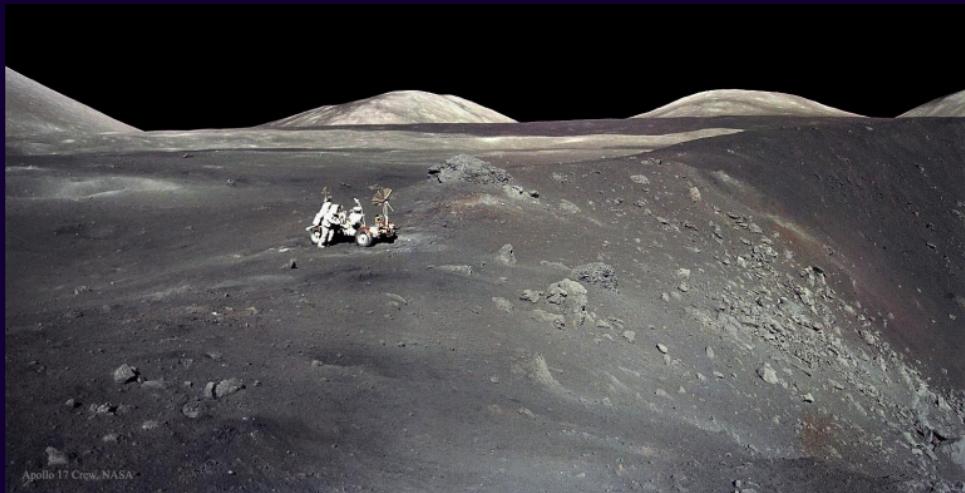
# Light and the electromagnetic spectrum

- What is light?
- How does a telescope work?
- Where does light come from, and what does it do?
- How do we use light to study the sky?
- What has this taught us about the Sun?



# Humanity and the cosmos

- What are the past and present of spaceflight?
- ... what might its future be in our lifetimes and beyond...
- ... and where else in the Universe might we find life, and what might it look like?



Apollo 17 Crew, NASA

# I'm here to help you!

My full-time job is to help you all (and my other students). This is your class, not mine.

This means:

- Type in chat whenever you have a comment in class, and I'll address it right away
- If you have a question, post it to Piazza, and you'll usually get a very quick answer
- Email me and ask for help: [wafreema@syr.edu](mailto:wafreema@syr.edu)
- Come to office hours: today from 4-6 PM in front of Holden Observatory or on Zoom
- If you have questions you'd like addressed ("ask the physicist!"), or course suggestions, please send them to me (and get extra credit, if they're good!)

# The cosmic perspective: measuring distance

“Baltimore is about five hours away.”

Does this statement make sense as a way to describe the distance to Baltimore?

# The cosmic perspective: measuring distance

“China is about  $1/15$  of a second away.”

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(This is something anyone who's tried to play a video game with someone across the ocean knows about!)

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- We can measure long distances by *how long it takes light to get there!*
- ... if China is one-fifteenth of a light-second away, then a *light-year* has to be a pretty long way...

## Three measures of distance...

Inside the Solar System, it's also useful to measure distances with a different yardstick: the distance to the Sun. This is called an **astronomical unit**, or AU.

We have:

- 1 kilometer
  - (good for measuring Earth-size things)
- $1 \text{ AU} = 150 \text{ million km } (1.5 \times 10^8 \text{ km}) = \text{about 9 light-minutes}$ 
  - (good for measuring distances to the planets)
- $1 \text{ light-year} = 60,000 \text{ AU} = 9 \text{ trillion km } (9 \times 10^{12} \text{ km})$

## Three measures of distance...

Inside the Solar System, it's also useful to measure distances with a different yardstick: the distance to the Sun. This is called an **astronomical unit**, or AU.

We have:

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- $1 \text{ universe} = 14 \text{ billion light-years!}$

## Takeaways: size and scale

- Inner planets like Earth are about 10,000 km across
- The Moon is around 400,000 km from Earth
- The inner planets are hundreds of millions of km – around an AU – away from the Sun
- Outer planets like Jupiter are about 100,000 km across and tens of AU from the Sun
- The nearest star is around 250,000 AU (4 ly) from us

The first chapter of your textbook goes into a lot more detail; you should read it.

We don't expect you to memorize exact numbers, but you should have a general idea of the scale of things near us in the Universe.

Another Freeman can explain it better than me!

<https://www.youtube.com/watch?v=44cv416bKP4>

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... where are we in all this?

## Next time: the night sky

Thursday: How does the night sky move each night?

What does the night sky look like from the Syracuse Quad?

### Stuff to do:

- Fill out the survey about how and when you'd like to attend lab
- Go find the course website and read the syllabus once I incorporate your suggestions
- Sign up for Piazza

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