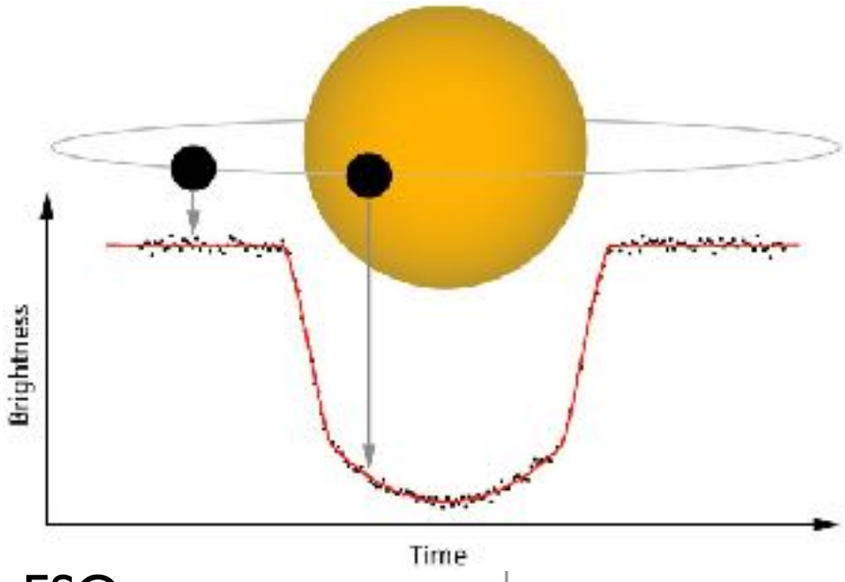
PHY 517 / AST 443:
Observational Techniques in Astronomy

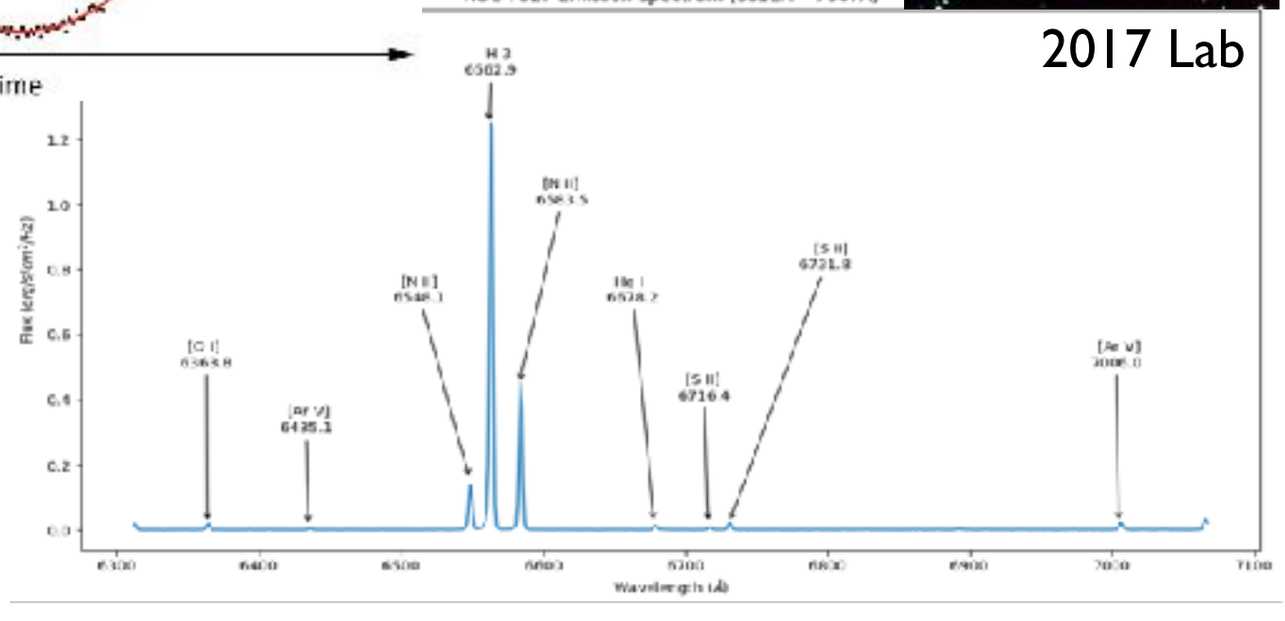
Simon Birrer



ESO

SBU Astro Club

AvdL



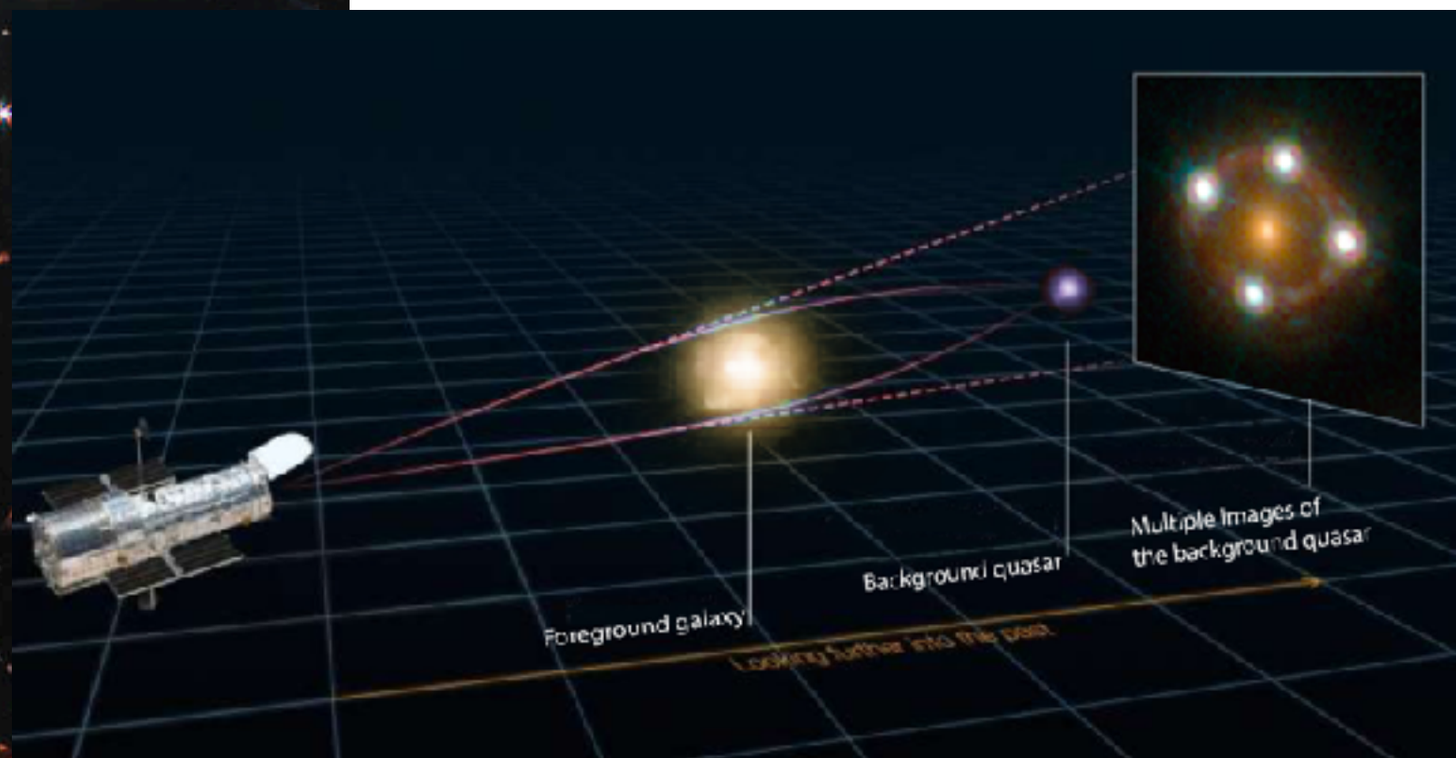
2017 Lab

Spring 2026

Hello!

I am an observational cosmologist using strong gravitational lensing to learn about dark matter and dark energy.

NASA



My Bio

undergrad: ETH Zurich (exchange in Hong Kong)

PhD: ETH Zurich 2013 - 2016

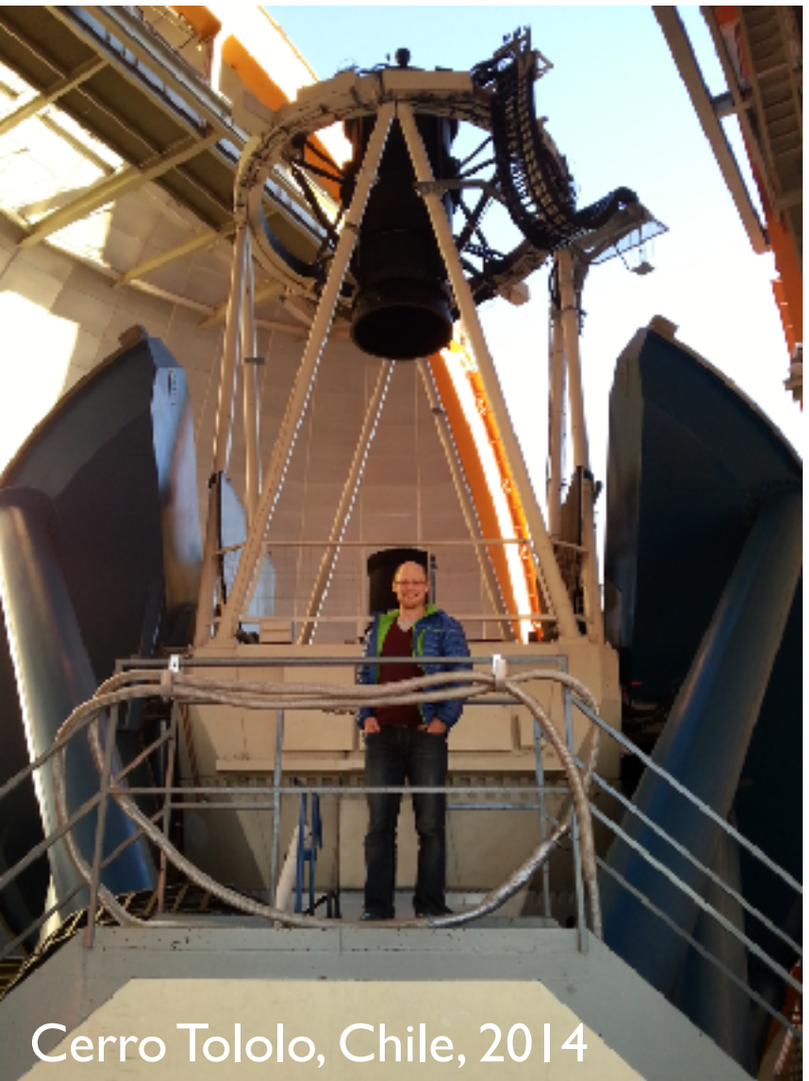
post-docs: University of California, Los Angeles 2017 - 2019

Stanford University 2019 - 2022

since Jan. 2023: faculty at SBU

Big questions - big data!

Astronomy and Cosmology are data driven!


Cerro Tololo, Chile, 2014

My advisor: "Simon, touch the data!"


Strong Lensing Group, January 2025

Course TAs

Paras Sharma
<paras.sharma@stonybrook.edu>

Bela Arwen
<bela.arwen@stonybrook.edu>

Course Purpose

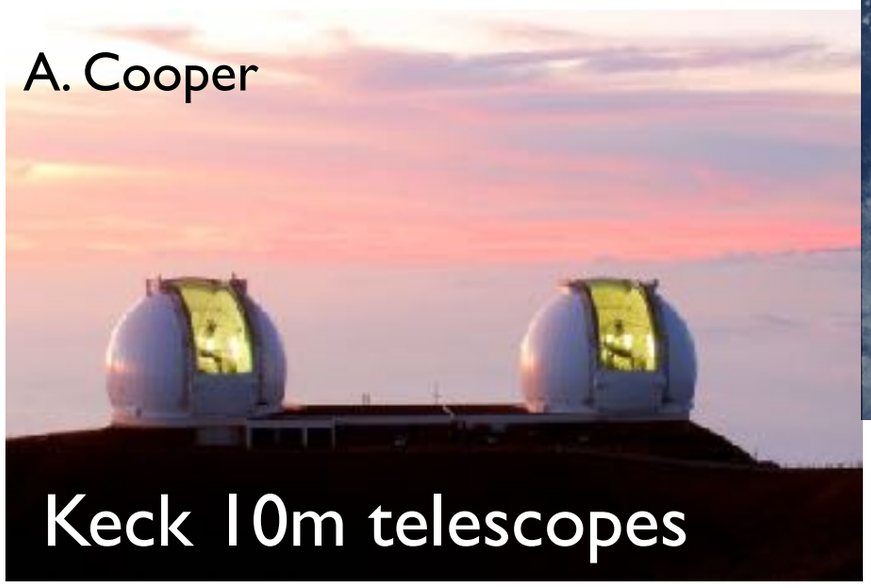
- graduate-level class (PHY 517), cross-listed for advanced undergraduates (AST 443) planning to go to grad school for astronomy

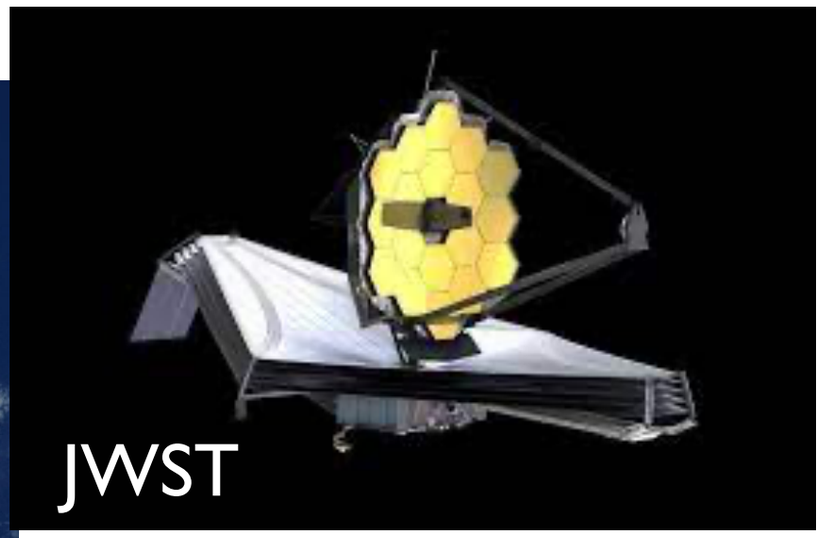
- purpose:
  - teach you the basics of how to be an observational astronomer*
  - research practices (collecting data -> making a scientific statement)

*this is the *only* class at SBU with this purpose: we have a lot to cover

Course Objectives

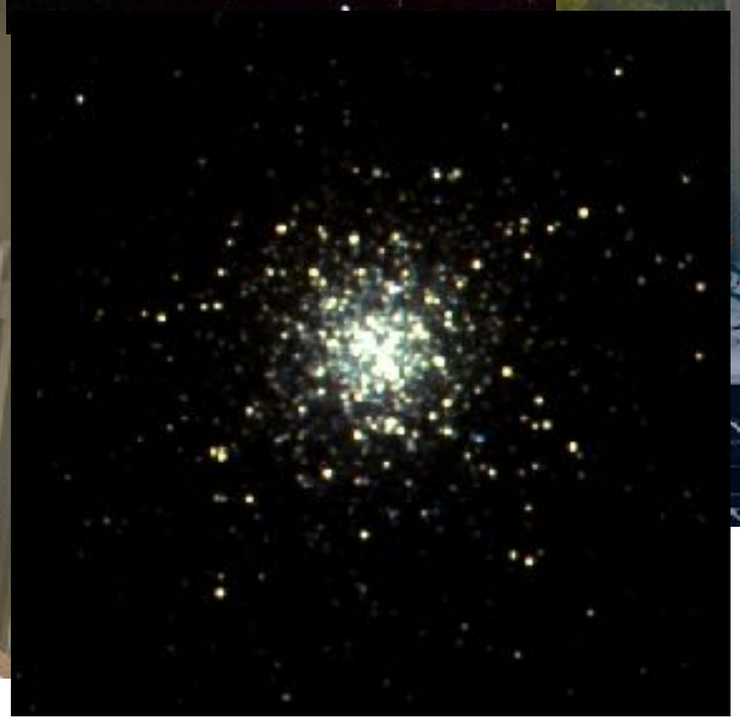
- introduction to observational astronomy
- design, take, analyze and interpret astronomical observations
- report your work in a scientific paper
- same concepts as needed for these:





Mt Stony Brook Observatory

- roof-top dome + telescope (14-inch) + CMOS camera + spectrograph



SBU Astronomy Club

How to be an observational astronomer

1. come up with an interesting idea / hypothesis
2. search for and analyze archival observations
3. write a telescope proposal
4. plan and execute your observations
5. analyze your data
6. write a journal paper
7. present your work at conferences

We'll deviate a bit ...

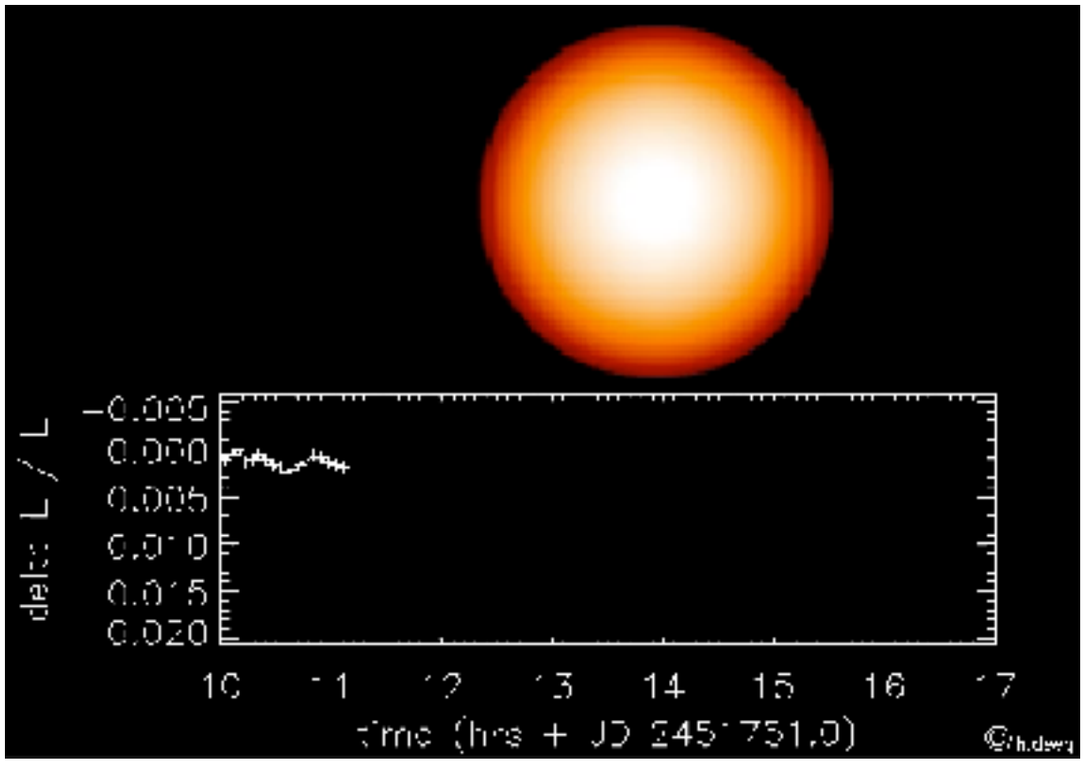
1. conduct and analyze observations
2. lab report → journal paper
3. write a telescope proposal
4. serve on a Time Allocation Committee (TAC)
5. present your work in class

Lab 1 - CCD cameras and images

- measure properties of our CCD cameras
- understand the role of calibration data
- familiarize yourself with the equipment
- make a pretty image of an interesting astronomical object

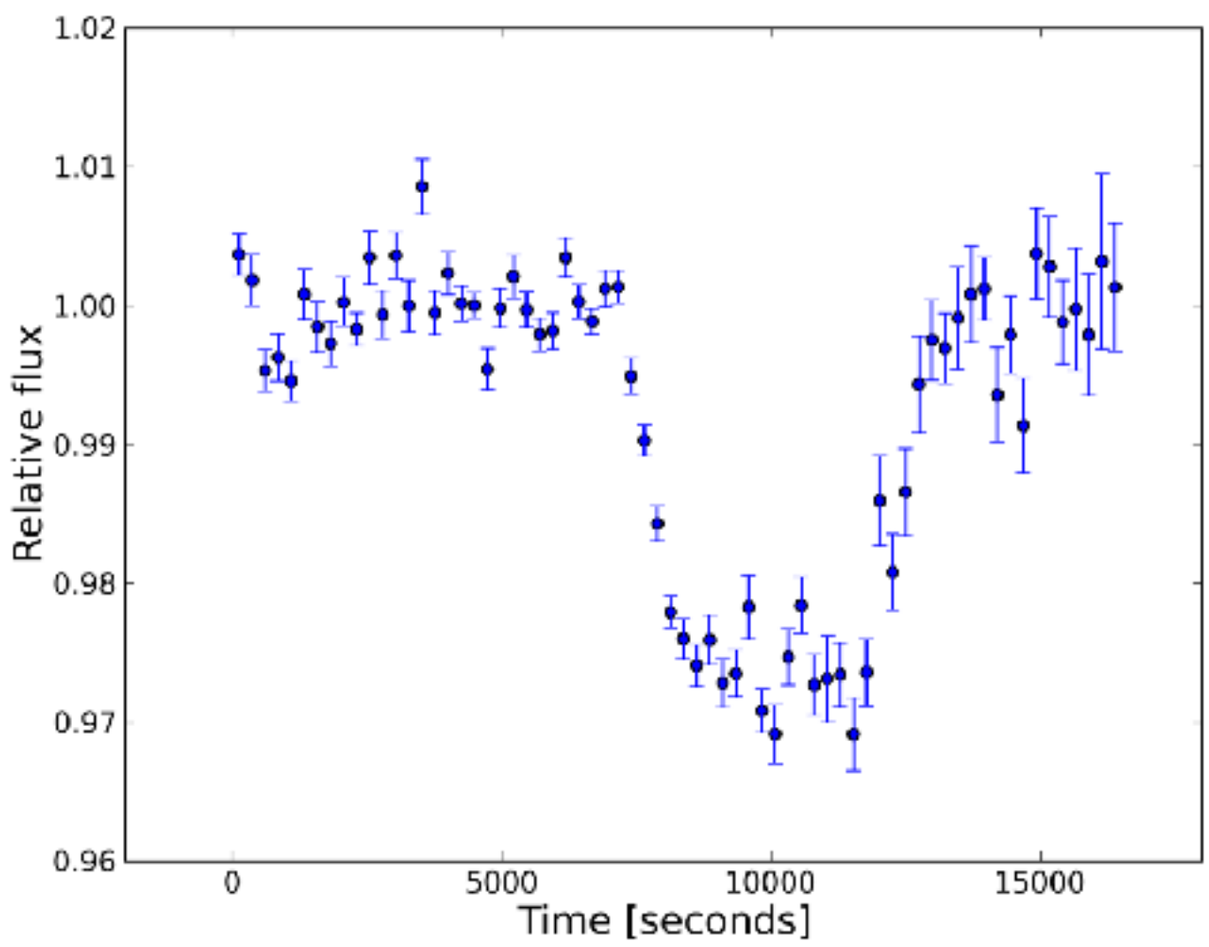
Lab 2.1 - optical imaging; time-series photometry

- detect an exoplanet transit



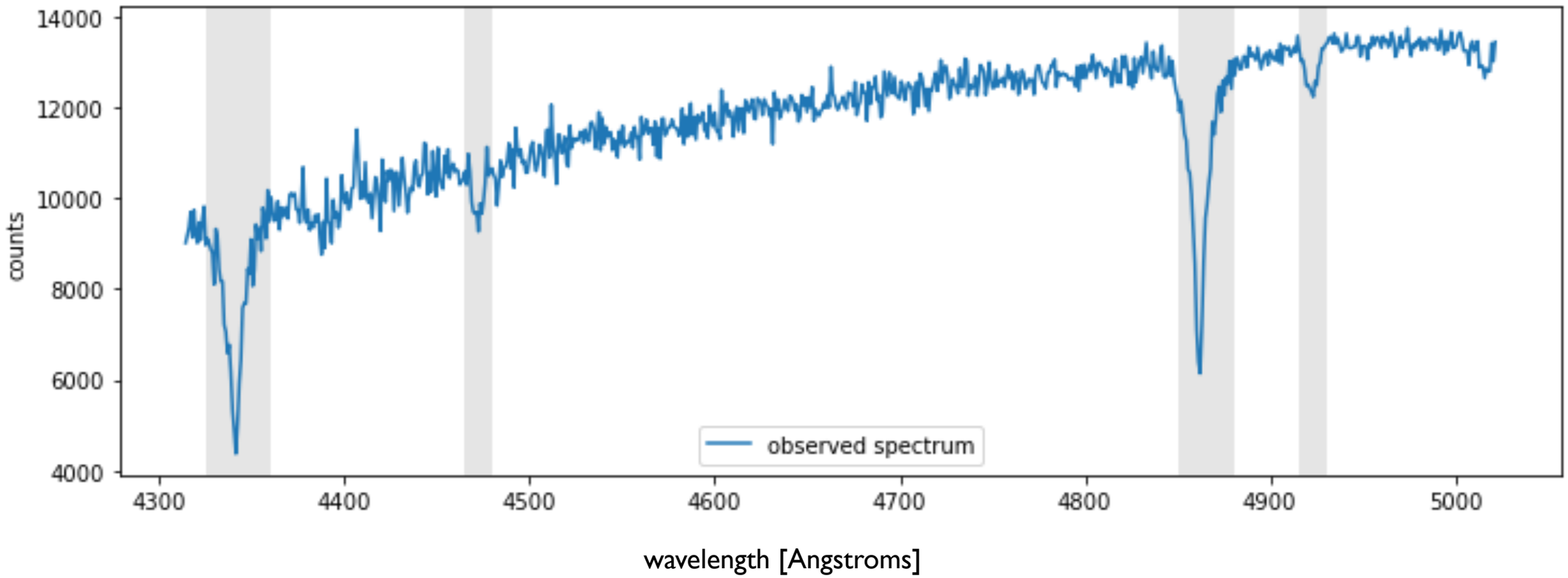
Deeg & Garrido 2000

2016 lab



Lab 2.2- optical spectroscopy

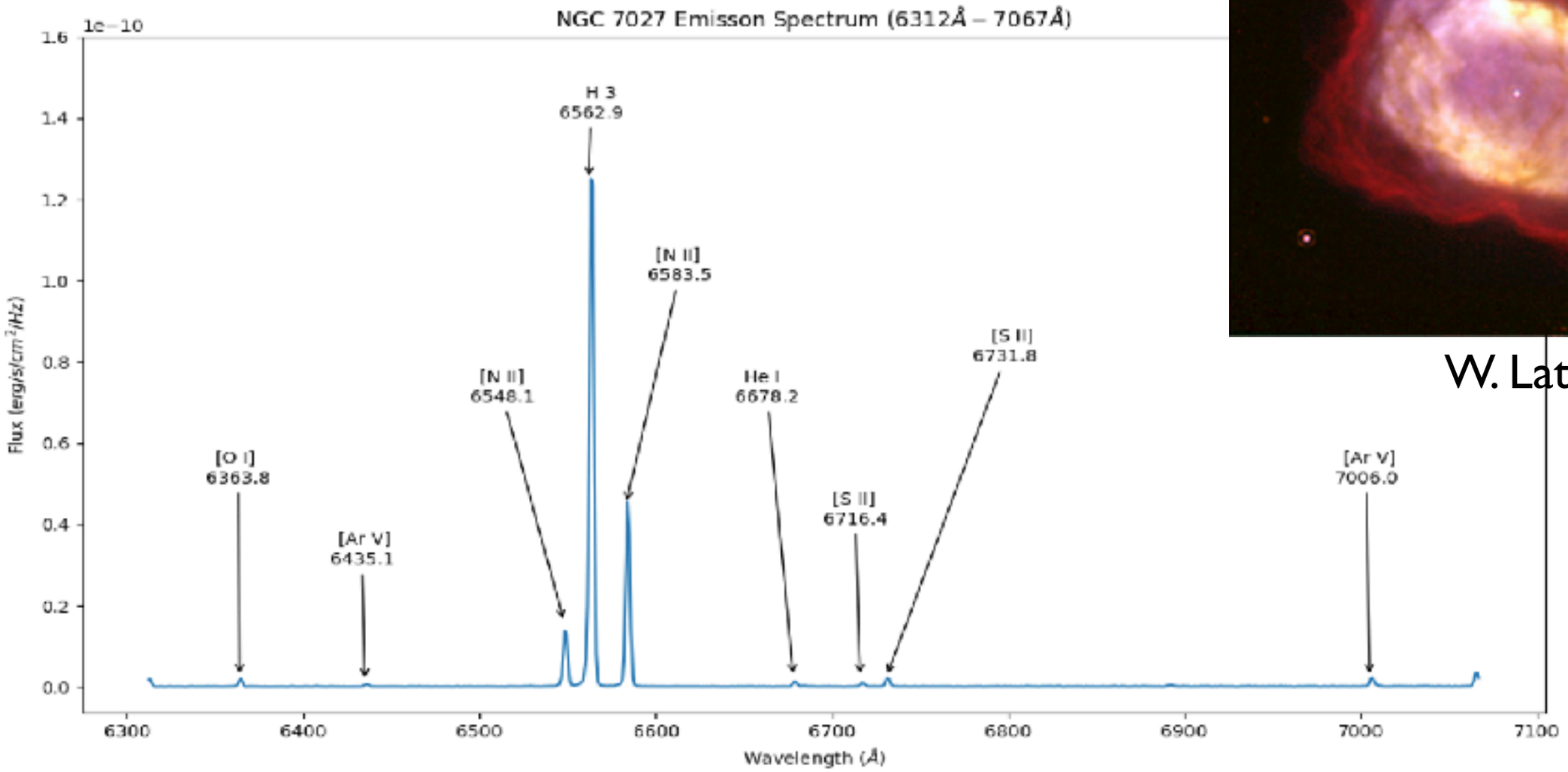
- compare spectra of stars with range of temperatures

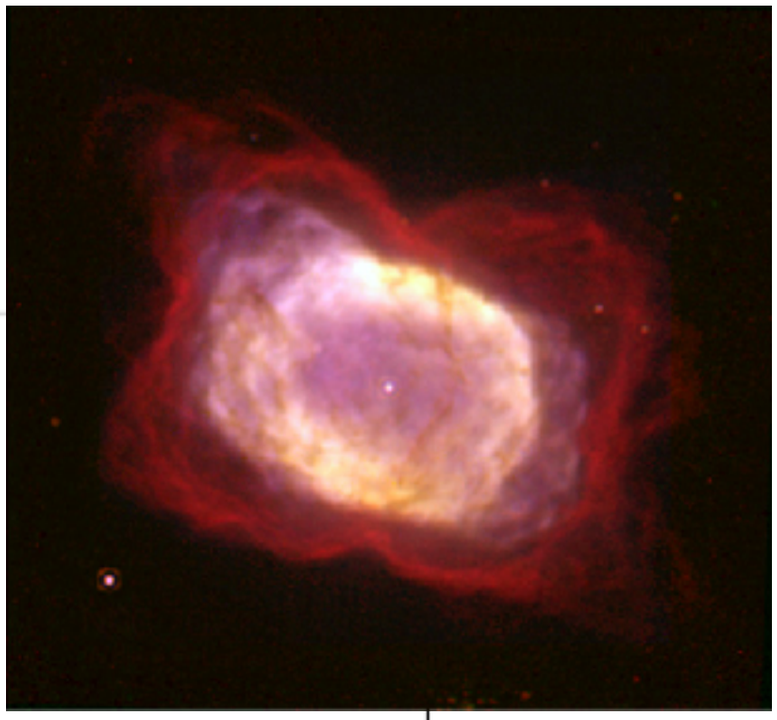


Lab 2.2 - optical spectroscopy

- OR: measure the gas temperature of a gaseous nebula

2017 lab





W. Latter / NASA

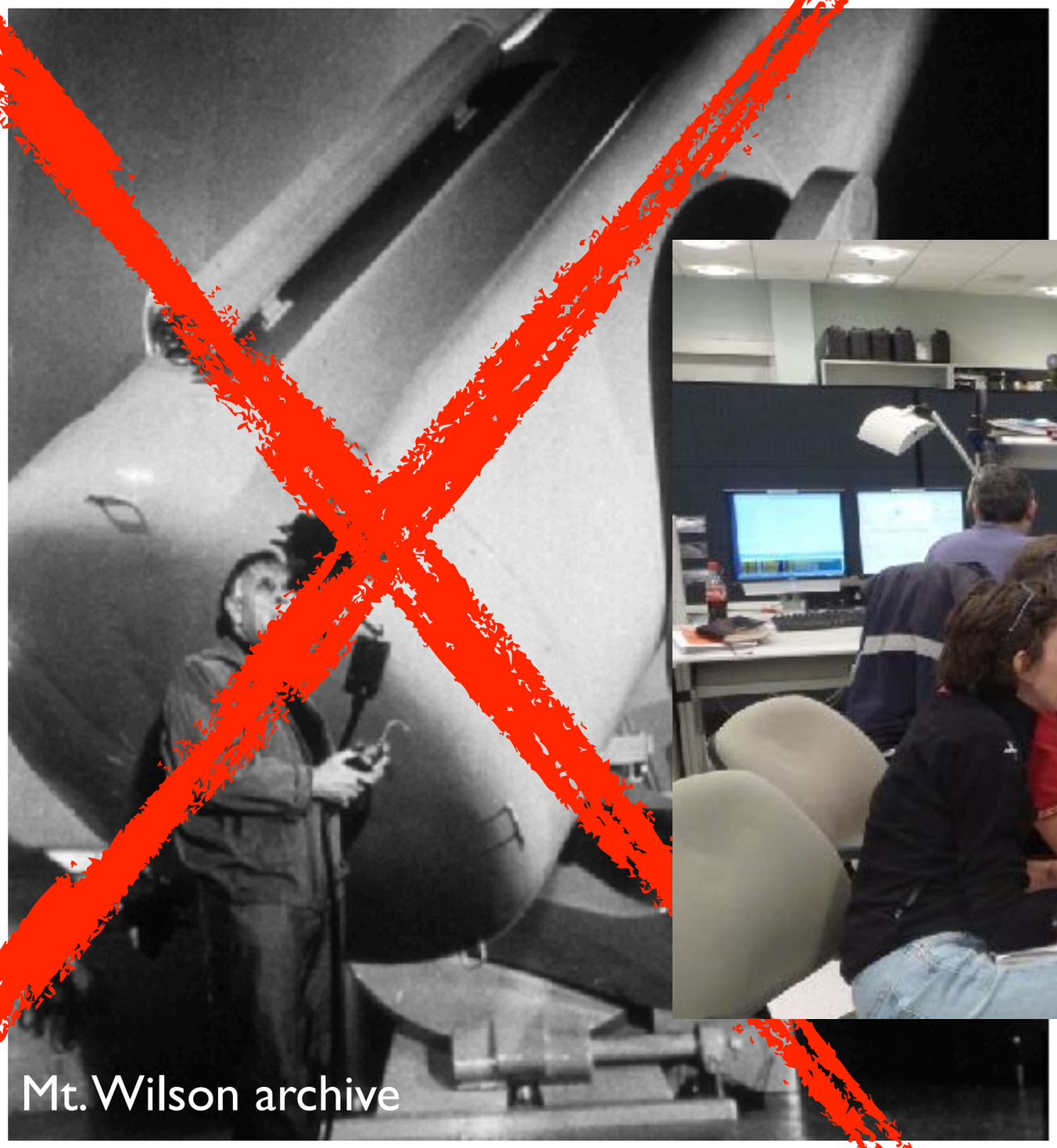
Lab 3 - your proposal

- come up with your own project idea, write a telescope proposal for the Mt. Stony Brook telescope
- we will hold a Time Allocation Committee - just like real astronomers!
- each lab team will conduct their top-ranked project

Have some fun pursuing your own ideas!

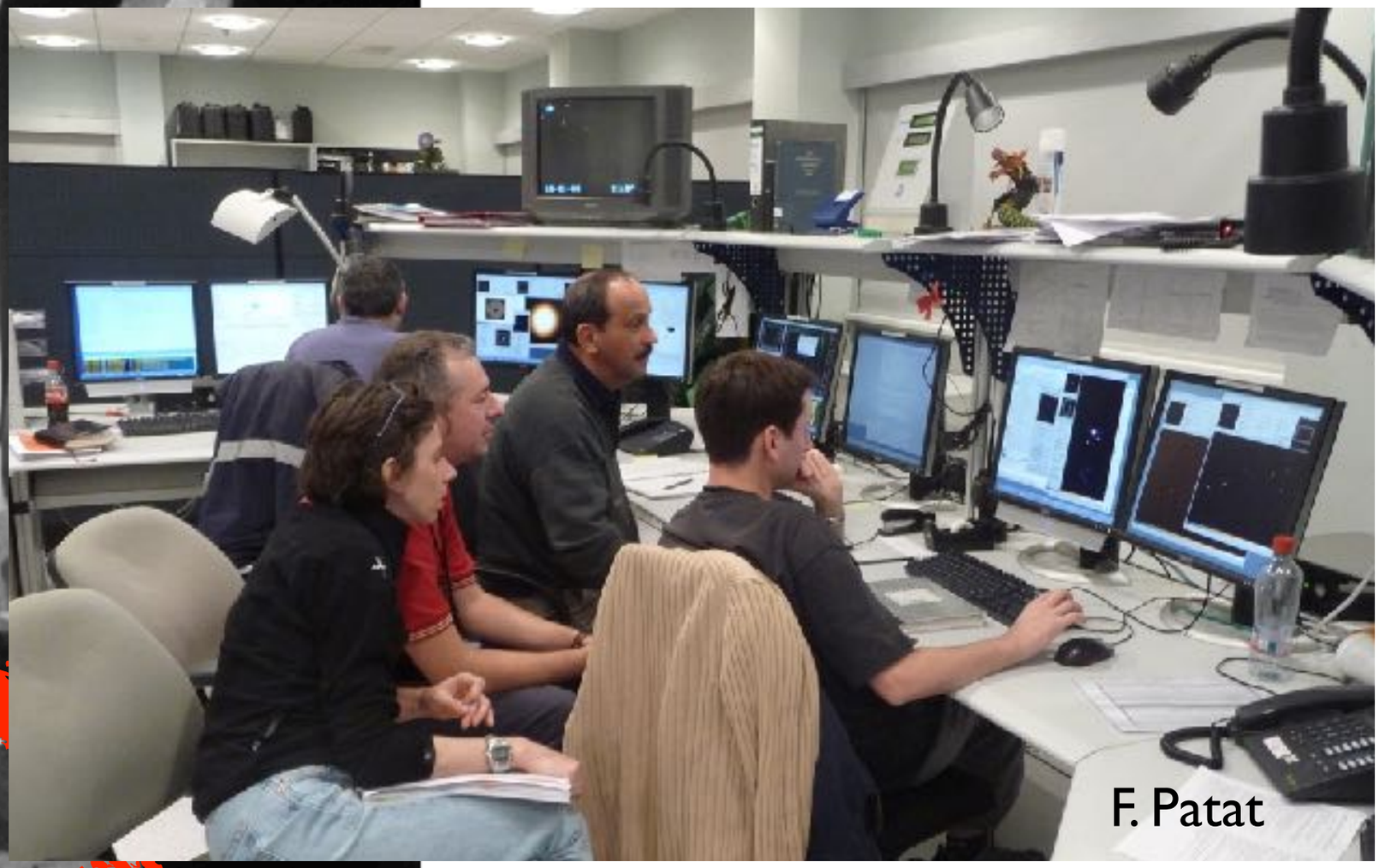
Data analysis

astronomy ~100 years ago:



Mt. Wilson archive

astronomy today:



F. Patat

Data analysis

- CCD cameras and digital image processing were revolutionary for astronomy
- first CCD cameras used on telescopes ~1980
- the Sloan Digital Sky Survey (SDSS), designed in the 90s, was one of the first "Big Data" projects; today we are preparing for the Rubin Observatory's Legacy Survey of Space and Time (LSST), ~20 TB per night, every night for 10 years

- *research in astronomy requires programming, and statistical analysis of large datasets*

- we will use several common astronomy software packages:
  - Photutils
  - Source Extractor
  - ds9
  - astrometry.net
  - FTOOLS
- most astronomy research is done on Unix / Linux. `bash` provides an integrated scripting language
- `python` is becoming ubiquitous in astronomy as higher-level programming language
- however, this is not a class on programming. we will provide basic instructions and help, but you will have to figure out many things on your own (search engines are your friend!)

Computing Resources

- all necessary software is installed on two machines in the Astro Computing Lab (uhura and vulcan)
- you can work in the Lab, and/or you can ssh into these machines from your laptop
- you will receive a username and password (valid for all computers in the lab); please change your password - make it complex!
- keep your password safe! our computers are under constant attack
- back up your data! e.g. google drive. minimum: your raw data, scripts to analyze the data, data that you used for final plots

Class structure

Class times:

- Mon + Wed 3:30-6:20pm
- ~6 lectures in the beginning
- other sessions: tutorials / data analysis help sessions with interludes
- Midterm exam: Mar. 09
- Proposal deadline: Mar. 13, 2pm
- Time Allocation Committee: Mar. 23
- Final Presentations: May 04 + May 06

Class structure

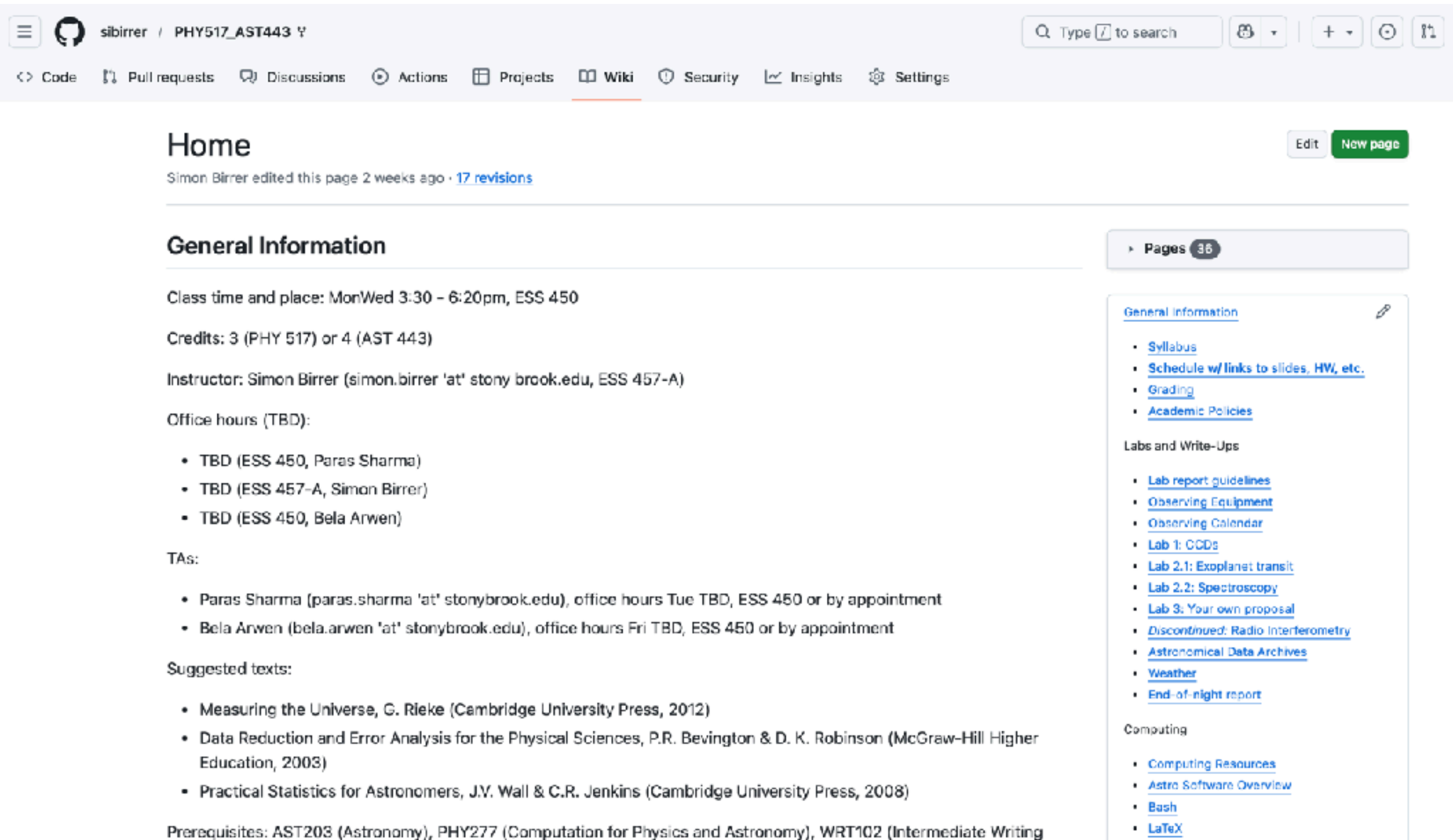
Data taking:

- scheduled separately from class time
- Lab 1: evening-time
- Labs 2+3 - observational labs: evenings / nights; you need good weather → schedule target night + 2 back-up nights for each lab

It is essential that you get your data - you will need to be flexible about scheduling night-time observations!

Course webpage:

https://github.com/sibirrer/PHY517_AST443/wiki



sibirrer / PHY517_AST443

Type / to search

Code | Pull requests | Discussions | Actions | Projects | Wiki | Security | Insights | Settings

Schedule Spring 2026

Edit | New page

Simon Birrer edited this page 2 weeks ago · 1 revision

Date	Topics	Slides	Tutorials	Homework
Jan 26	Intro, Coordinate Systems	Lecture 0, Lecture 1		HW1, due Jan 28
Jan 28	Time, Magnitudes, Atmosphere, Telescopes	Lecture 2		HW2, due Feb 4
Feb 02	CCDs, FITS files	Lecture 3	Python1,Python2	
Feb 04	Spectroscopy	Lecture 6		
Feb 09	Statistics 1	Lecture 4		HW3, due Feb 16
Feb 11	Statistics 2	Lecture 5	Tu4	HW4, due Feb 18
Feb 16	Data Analysis Help Session			
Feb 18	Data Analysis Help Session		Tu5	
Feb 23	Instructions: Proposal Writing	Lecture 7, wiki link		
Feb 25	Data Analysis Help Session			
Mar 02	Data Analysis Help Session			
Mar 04	Data Analysis Help Session			
Mar 09	**Midterm exam**			
Mar 11	Data Analysis Help Session			
Mar 13	**Proposal deadline, 2pm**			

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General Information

- Syllabus
- Schedule w/ links to slides, HW, etc.
- Grading
- Academic Policies

Labs and Write-Ups

- Lab report guidelines
- Observing Equipment
- Observing Calendar
- Lab 1: CCDs
- Lab 2.1: Exoplanet transit
- Lab 2.2: Spectroscopy
- Lab 3: Your own proposal
- *Discontinued:* Radio Interferometry
- Astronomical Data Archives
- Weather
- End-of-night report

Computing

- Computing Resources
- Astro Software Overview
- Bash
- LaTeX
- Python
- jupyter
- GitHub
- ds9
- SExtractor

Lecture notes, etc. will be linked from schedule

sibirrer / PHY517_AST443

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Code | Pull requests | Discussions | Actions | Projects | Wiki | Security | Insights | Settings

Manuals etc. for all observing equipment

Observing Equipment

Edit | New page

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Mt. Stony Brook 14-inch telescope

Our Department operates the Mt. Stony Brook observatory, housing a 14-inch Meade LX200-ACF telescope on a Mesu-200 German Equatorial Mount. This will be the workhorse telescope for the imaging and spectroscopic components of the course.

Telescope instructions
Telescope manual
Mesu mount Set-Up Instructions
SiTech Controller Manual
The mount has GoTo functionality through the software Cartes du Ciel.

ZWO DUO CMOS camera for imaging

Imaging observations with the 14-inch telescope will be taken with the ZWO ASI2600MM DUO camera. The camera is mounted on the back end of the telescope and is controlled through a laptop computer. A set of standard broad-band BVRI and a narrow-band H-alpha filters are available. The camera has a second, smaller sensor that can be used for auto-guiding.

ZWO Quick-Start Guide
ZWO ASI2600MM DUO manual
CCDCiel Manual
PHD2 Guiding

Spectrographs

We have two DADOS spectrographs; one has the low-resolution grating (200 l/mm) installed, the other the high-resolution grating (900 l/mm).

Step-by-step instructions
Spectrograph manual

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Observing Calendar

Observing Calendar

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Edit | New page

The observing calendar be found here.

Mt Stony Brook Observing Calendar

Today | September 2022 | Print | Week | Month | Agenda

Mon	Tue	Wed	Thu	Fri	Sat	Sun
29	30	31	Sep 1	2 7pm Open Night	3	4
5 Labor day - no cla	6	7	8 No observing	9	10 Full Moon	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	Oct 1	2

Events shown in time zone: Eastern Time - New York

Google Calendar

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Lab Instructions

CCD Lab

Edit | New page

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Experiment Description:

https://github.com/sibirrer/PHY517_AST443/blob/master/ccd_lab/ccd_lab.pdf

Equipment Instructions:

Please see the Observing Equipment page for links to all manuals.

The Quick-Start instructions required for this lab are:
Telescope Step-by-Step Instructions
ZWO Step-by-Step Guide Spectrograph Step-by-Step instructions
CCDSoft Step-by-Step Guide

Reference materials:

ZWO ASI2600MM DUO manual
Neon arc lamp spectrum
Mercury arc lamp spectrum

Preparation:

1. Schedule your daytime data acquisition with the TAs. This part of the lab takes about 3-4h; if necessary, this can be split into two parts (imaging and spectroscopy). **The weekly check-in deadlines start with taking the day-time data!**
2. **Make sure to read and understand all of the instructions linked above before the lab!** You will be quizzed on the concepts that the lab conveys. Moreover, good preparation will allow you to complete the lab faster. *If you are not adequately prepared, you will have to reschedule the lab, and will receive a grade penalty.*
3. Schedule the nighttime observing as instructed in the homework.

Computing Resources

Simon Birrer edited this page 2 weeks ago · 10 revisions

The Astro Student Computing Lab

Data analysis sessions and tutorials will take place in the Astro Computing Lab in ESS. You will receive an envelope with your username and password to these computers at the beginning of the course. The machines should have all needed astronomy software installed (except python, which for which you can find installation instructions here). In addition, `kirk` is the central server. Note that this machine is not physically accessible. You can also choose to use your own laptop to do so instead (see instructions below). There are enough computers so that every group can use one, but not enough for all students, so please bring your laptop if you have one.

The computers in the Astro Computing Lab all run Linux, with which you should be familiar from PHY 277. If you are a bit rusty on your Linux command line skills, you may find a "cheat sheet" such as this one useful.

Your log-in

You will receive either an e-mail, or a sheet of paper with your username and initial password. **Do not give this paper to anybody else, or leave it lying around.** With this account, you can log into any computer in the computing lab, directly or remotely (remote access is describe below). Your first action should be to change your password (see below).

When using the astro lab computers in person

The fastest (and recommended) desktop manager on our systems is `MATE`. To select it, click on the settings wheel on the screen where you enter your password. **Please make sure to log out when you are done!** Do not just leave the computer with the screen locked.
Do not restart the computer!

Set-up, home and data directories

The first time that you log into a specific machine in the lab (e.g. `spock`), it will set up basic configuration files in your account's home directory on that machine, `/home/<username>`. This will make subsequent log-ins to the same machine faster. **Everything else in /home/username will be deleted every night.**

Astro Computing Cluster Instructions

Computing

- Computing Resources
- Astro Software Overview
- Bash
- LaTeX
- Python
- jupyter
- GitHub
- ds9
- SExtractor
- Topcat
- Astrometry.net
- Image arithmetic (+ftools)
- Stacking images

Specific software descriptions

Home

Edit | New page

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General Information

Class time and place: MonWed 3:30 - 6:20pm, ESS 450

Credits: 3 (PHY 517) or 4 (AST 443)

Instructor: Simon Birrer (simon.birrer 'at' stony brook.edu, ESS 457-A)

Office hours (TBD):

- TBD (ESS 450, Paras Sharma)
- TBD (ESS 457-A, Simon Birrer)
- TBD (ESS 450, Bela Arwen)

TAs:

- Paras Sharma (paras.sharma 'at' stonybrook.edu), office hours Tue TBD, ESS 450 or by appointment
- Bela Arwen (bela.arwen 'at' stonybrook.edu), office hours Fri TBD, ESS 450 or by appointment

Suggested texts:

- Measuring the Universe, G. Rieke (Cambridge University Press, 2012)
- Data Reduction and Error Analysis for the Physical Sciences, P.R. Bevington & D. K. Robinson (McGraw-Hill Higher Education, 2003)
- Practical Statistics for Astronomers, J.V. Wall & C.R. Jenkins (Cambridge University Press, 2008)

Prerequisites: AST203 (Astronomy), PHY277 (Computation for Physics and Astronomy), WRT102 (Intermediate Writing Workshop)

Homework reading until Wednesday

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- Bash
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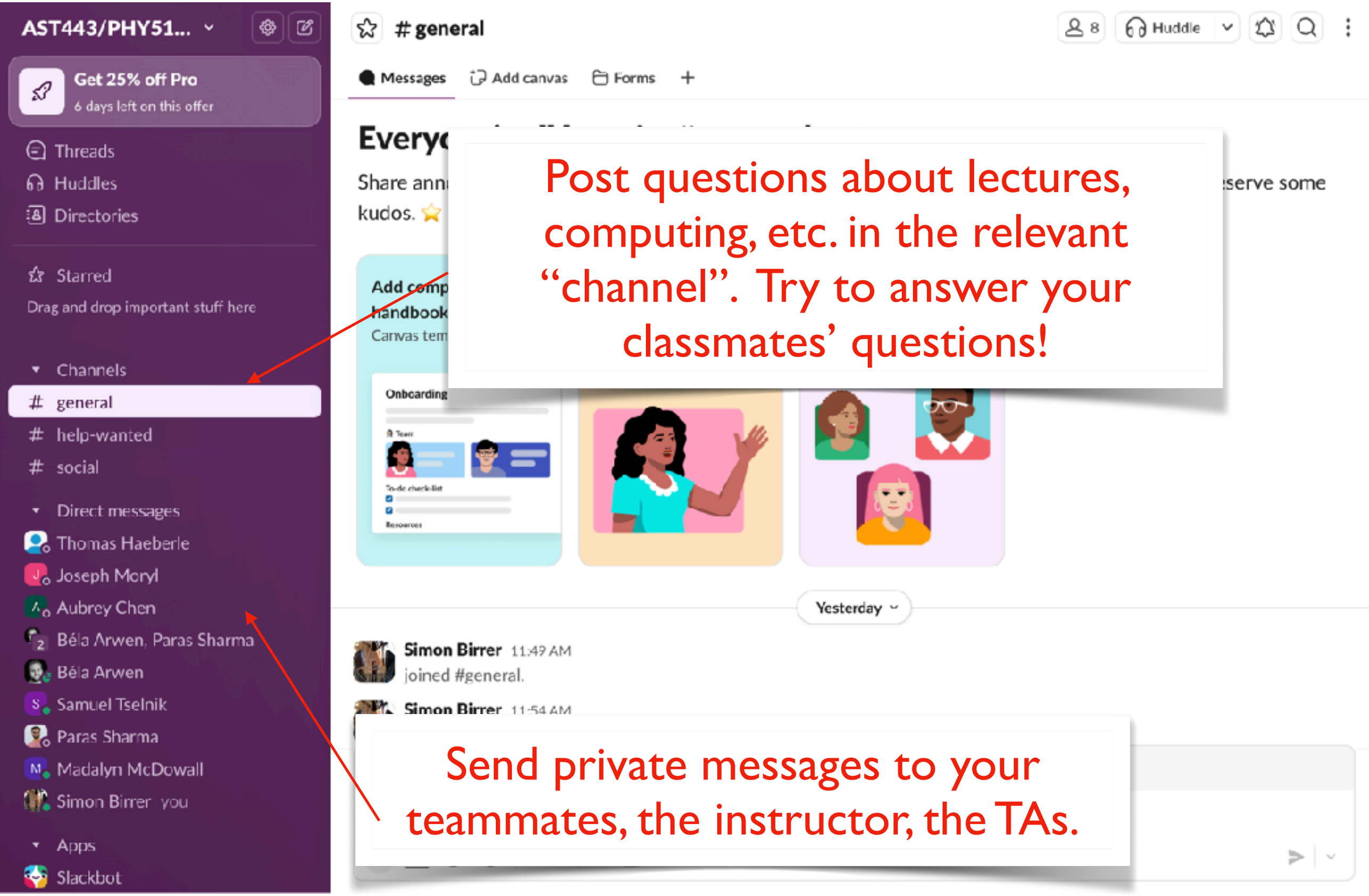
Outside of class, we will use slack for communication - look for an invitation in your e-mail inbox

Best way to keep track of slack: install the App on your computer


AST443/PHY51...
Get 25% off Pro
6 days left on this offer
Threads
Huddles
Directories
Starred
Drag and drop important stuff here
Channels
general
help-wanted
social
Direct messages
Thomas Haeberle
Joseph Meryl
Aubrey Chen
Béla Arwen, Paras Sharma
Béla Arwen
Samuel Tselnik
Paras Sharma
Madalyn McDowall
Simon Birrer you
Apps
Slackbot
general
8
Huddle
Messages
Add canvas
Forms
Share ann
kudos.
serve some
Add comp
handbook
Canvas tem
Onboarding
Yesterday
Simon Birrer 11:49 AM
joined #general.
Simon Birrer 11:54 AM
Post questions about lectures, computing, etc. in the relevant "channel". Try to answer your classmates' questions!
Send private messages to your teammates, the instructor, the TAs.

Team work

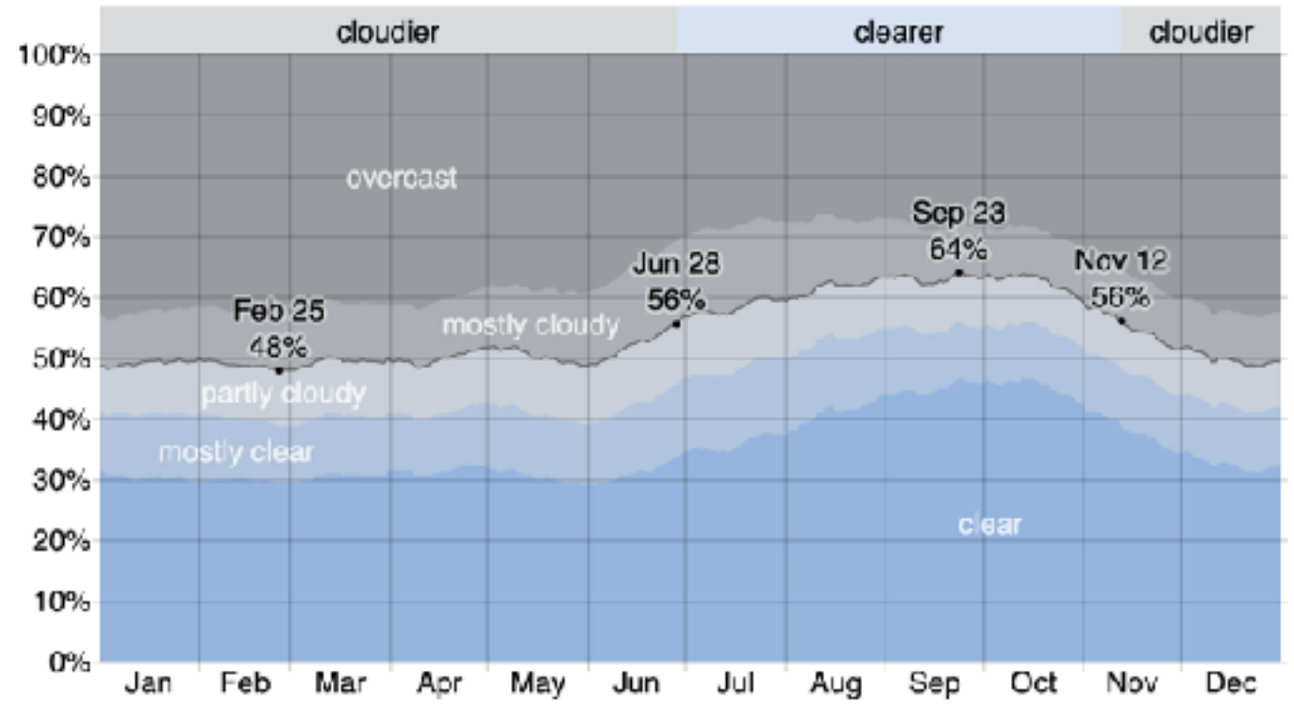
- observational astronomy is done in teams
- for the labs, you will observe in teams of 2 or 3
- you are highly encouraged (and expected) to work together on the data analysis
- **everybody has to submit individual lab reports** (however, proof-reading each other's reports is encouraged)
- I will assign teams based on these criteria:
  - the preferences you submitted
  - weeknight availability
  - diversity: grad / undergrad, Honors / Scholars / WISE, astronomy background, programming background, gender, etc.

(Night-time) observing

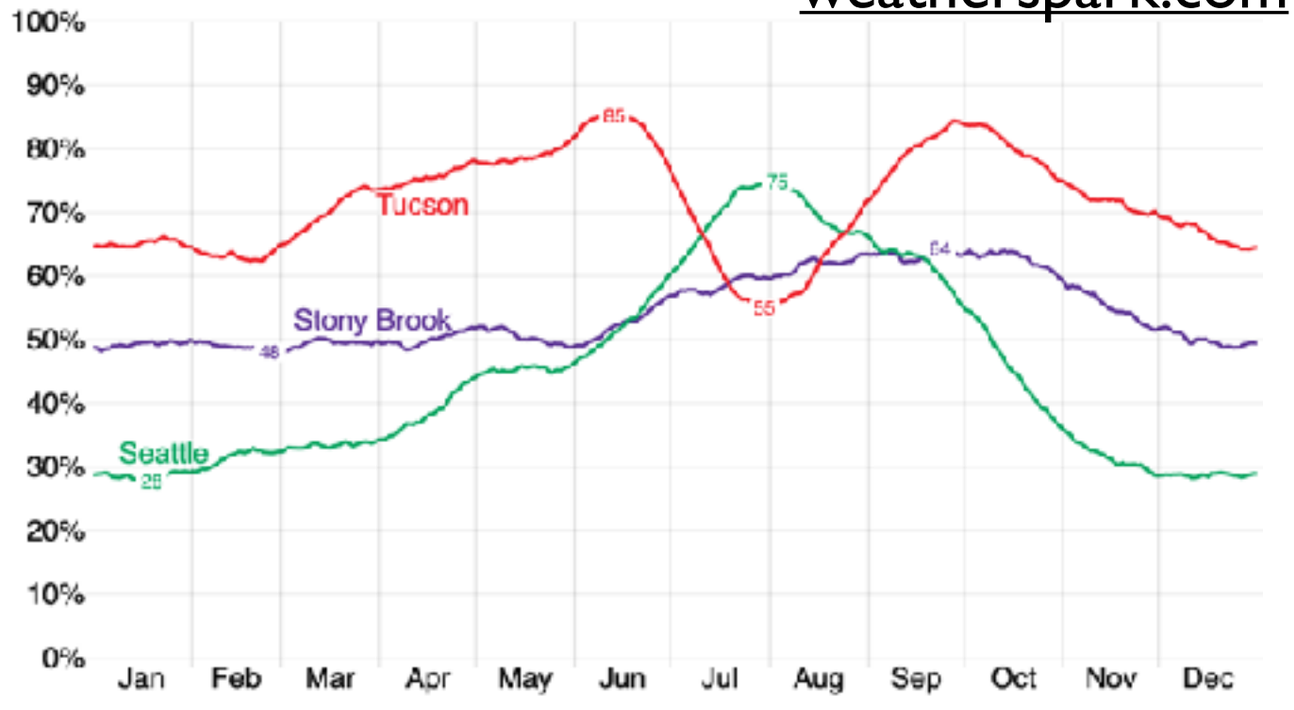
- a TA or instructor must be present (or in the building)
- please plan your observations to be done by ~ 1-2 am
- familiarize yourself with the instructions: you will be quizzed at the beginning
- bring:
  - WARM clothes!
  - a red flash-light / rear bike-light
  - a USB key to take your data home
  - all materials needed for the lab: instructions (printed!), finding charts (printed!), your notebook etc.
  - cookies / chocolate

Weather

- biggest problem: clouds are really, really hard to predict!!!
- if there is a chance that you can get your data, you need to take that chance
- often, cannot decide to cancel until the afternoon
- sometimes, we will make the wrong decision…



weatherspark.com



Weather

Edit | New Page

anjavdl edited this page on Mar 6, 2021 · 4 revisions

Current conditions:

GOES-East loop: https://www.star.nesdis.noaa.gov/goes/sector_band.php?sat=G16&sector=ne&band=GEOCOLOR&length=24

Radar + clouds animation from weather.com: https://weather.com/weather/radar/interactive/l/USNY1412:1:US?layer=radarclouds&animation=true&zoom=7

Webcam: http://wx.somassbu.org/DATA/HSC/WX-HSC.php

Forecasts:

Calsky: https://www.calsky.com/cs.cgi?obs=725993794229 91&Meteo=

Clear Dark Sky for Mt. Stony Brook: http://www.cleardarksky.com/c/MtStnyBrkObNYkey.html?1

Windy: https://www.windy.com/40.926/-73.141?clouds,40.451,-73.141,7,m:eNnad7g
4 models: ECMWF, GFS, NEMS, NAM

Ventuksy: https://www.ventusky.com/?p=40.92;-73.15;6&l=clouds
4 models: GFS, ICON, GEM, HRRR

+ Add a custom footer

Pages 35

General Information

- Syllabus
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Labs and Write-Ups

- Guidelines
- How to write a decent lab report
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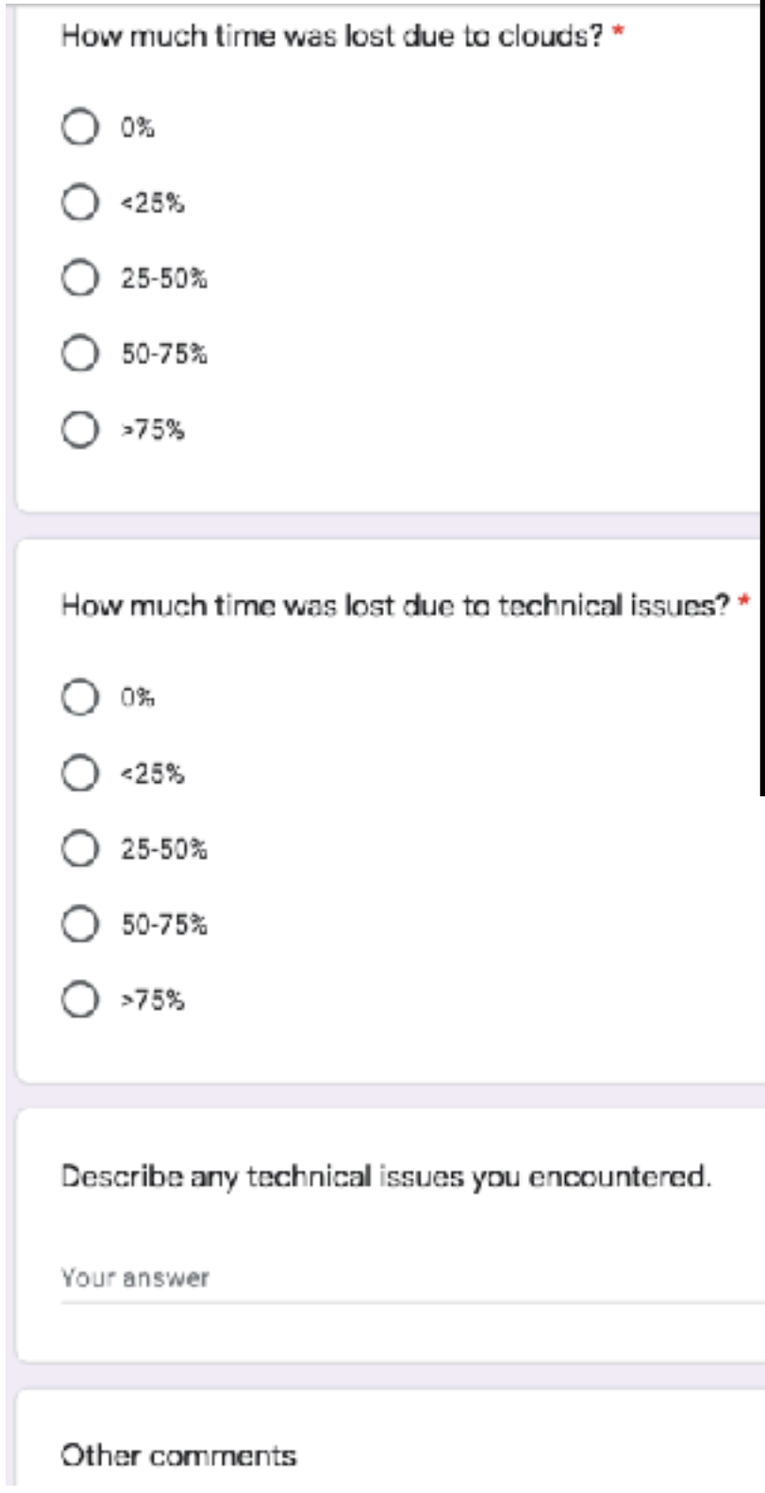
Long-term forecast models: ECMWF, GFS
Short-term forecast models: NAM, HRRR

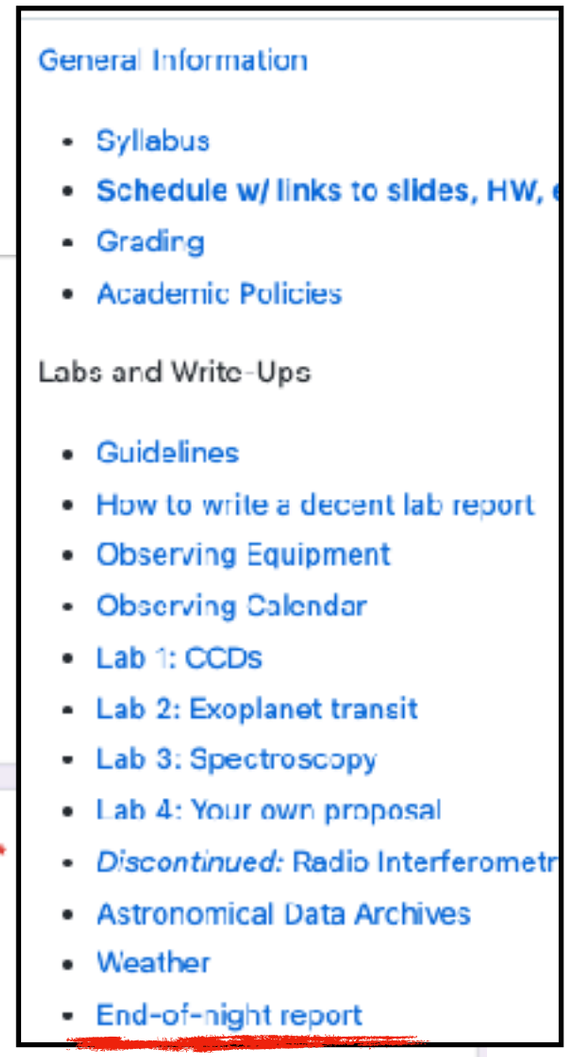
End-of-night report

- when observing, it is imperative that you let the daytime crew (i.e me) know how the observations went ASAP

- fill out the end-of-night report (linked from wiki) at the end of your observations

- if there were problems, describe them in detail





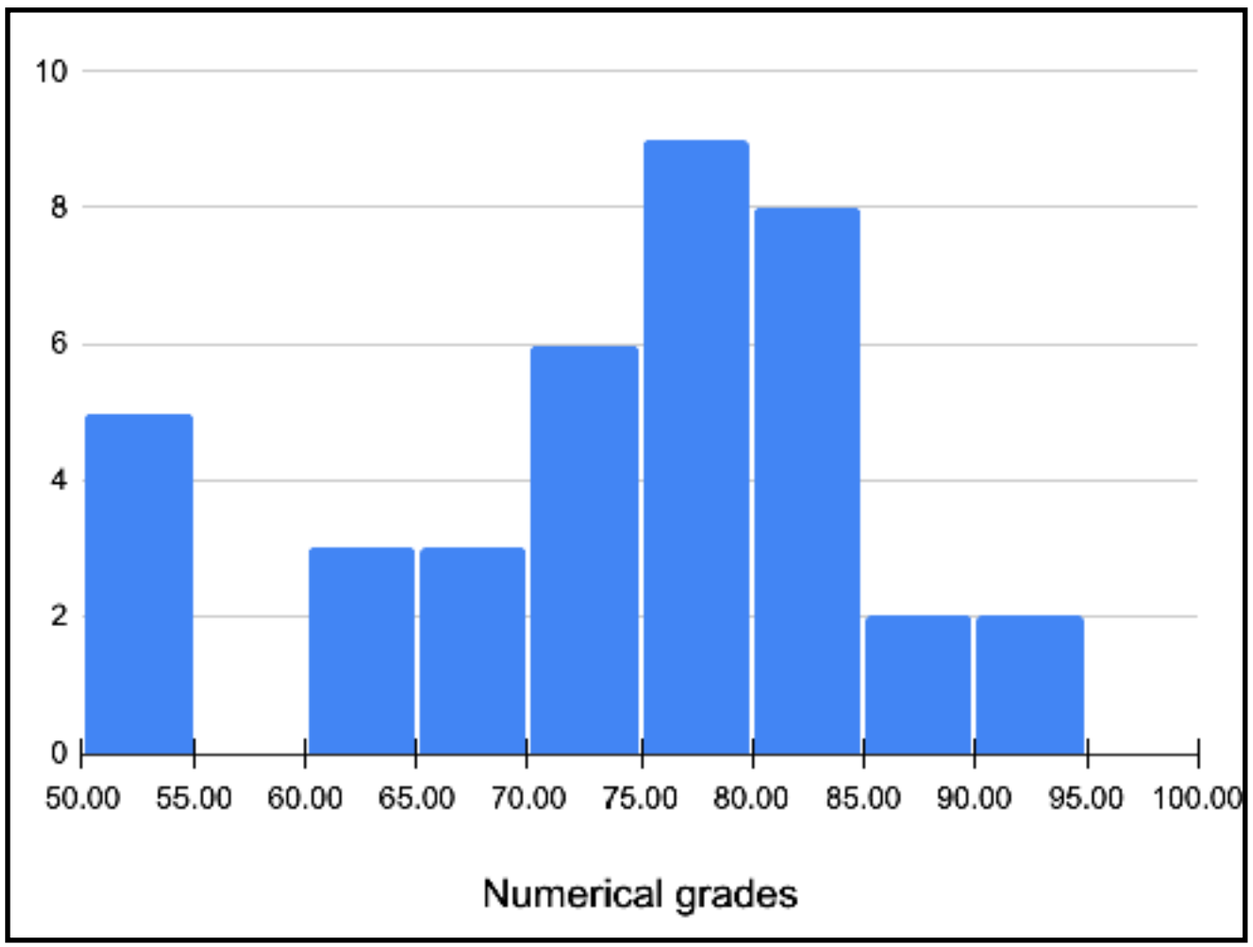
Note

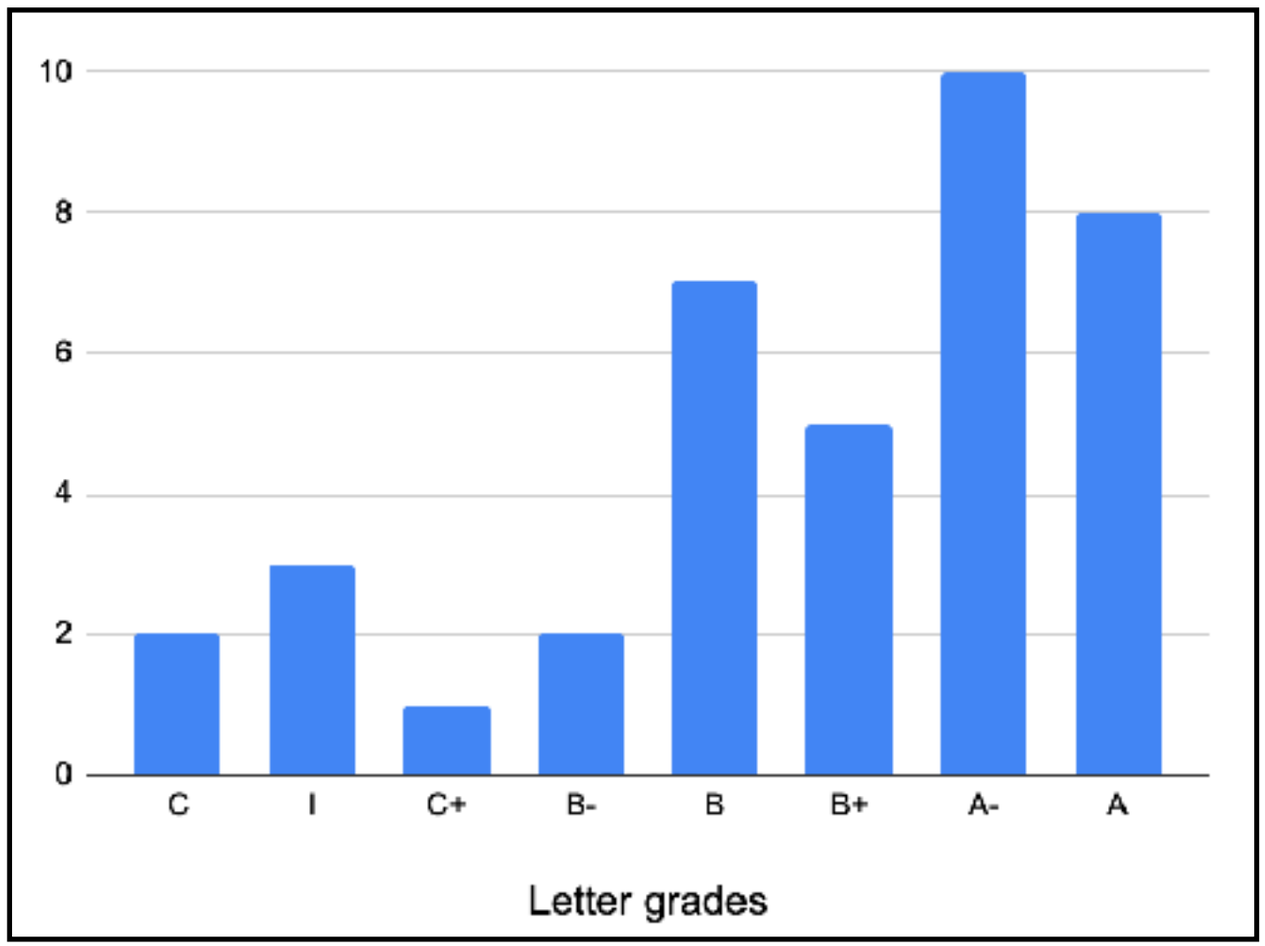
- you are responsible for your own transportation home after observing
- please do not ask the TAs for a ride home! they have to be here way more nights than you, and are also taking classes
- if you live on campus, you can request a walk escort / ride home: https://www.stonybrook.edu/campus-safety/#view-residential-safety

Grading

Assignment	Weight
Lab 1 Analysis + Report	15%
Lab 2 Analysis + Report	20%
Lab 3 Analysis + Report	25%
Homeworks + Participation in discussions	10%
Midterm	10%
Project proposal + evaluation of peer proposal	10%
Final presentation	10%

Grading





(Undergraduate grades only)

Blind Grading

- Lab reports, proposals and homeworks will be graded blindly.
- Put only your SBU ID as author name, and the SBU IDs of your lab-mates as co-authors.

Attendance

- Attendance is mandatory
- Absences can be excused e.g. when you are feeling ill and/or in isolation
    - let me know beforehand
    - will arrange zoom call-in as fitting
- Unexcused absence from lecture, tutorial or data analysis session: 1 grade point (out of 100) penalty on final grade
- You can miss 2 non-consecutive data analysis sessions without penalty (but need to let me know)
- Unexcused absence from Time Allocation Committee / final presentation: forfeit of participation points
- Unexcused absence from your scheduled observations: 50% penalty on lab report grade

Scientific Writing

- Writing is ~50% of the job of a scientist!
- Labs 2 and 3, proposal: in style of scientific papers

- make sure you know how to write a scientific article!
  - read scientific papers to see examples
  - guidelines on wiki

Writing is Thinking!

Check out this article: https://www.nature.com/articles/s44222-025-00323-4

Significant digits

Code output with way too many digits:

$$99.123456789$$
$$\pm 0.004556789$$

Round the uncertainty to one (or two) digits:

$$0.00455679 \rightarrow 0.005$$

The location of this digit tells you the location of the last significant digit:

$$99.123$$
$$\pm 0.005$$

Voila:

$$99.123 \pm 0.005$$

Lab Reports

- every lab comes with weekly deadlines to show us your progress / hand in your report
- e.g. Lab 1: report due 3 weeks after observations
- late penalty: for every day the data analysis check-in / the report is late, the final grade is multiplied by 0.95

- Example:
  - Initial grade of 80%
  - One day late: $0.80 \times 0.95 = 0.76$
  - Two days late: $0.80 \times (0.95)^2 = 0.72$
  - Three days late: $0.80 \times (0.95)^3 = 0.69$
  - One week late: $0.80 \times (0.95)^7 = 0.56$
  - Two weeks late: $0.80 \times (0.95)^{14} = 0.39$

Delay Days

- Occasionally it's just really hard to meet a deadline...
- Everybody gets 7 "delay days" at the beginning of the course
- You can trade in delay days to avoid late penalties (for lab reports and data analysis check-ins, NOT proposals / presentations)
- For data analysis check-ins, delay days have to be used as a group (everybody "spends" a delay day)
- For lab reports, delay days can be used individually

Keeping track

For each group, we will set up a google sheet to track your lab dates, deadlines and delay dates

	A	B	C	D	E	F	G	H
1	**Lab**	**Observations**	**Deadlines**		**Observer**	**SBU ID**	**Delay Days**	**Class absences**
2								
3	Lab 0	2018-09-06	2018-09-13				1	3
4			2018-09-20				0	2
5			2018-09-27				0	1
6								
7	Lab 1	2018-10-01	2018-10-18					
8		2018-10-09	2018-10-25					
9		2018-10-11	2018-11-01					
10			2018-11-08					
11								
12	Lab 2	2018-11-01	2018-11-15					
13		2018-11-06	2018-11-22					
14		2018-11-08	2018-11-29					
15			2018-12-06					
16								
17	Lab 3	2018-10-24	2018-11-21					
18		2018-11-12	2018-11-28					
19		2018-11-14	2018-12-05					
20			2018-12-12					

Plagiarism

- Any incidence of plagiarism will automatically result in a final grade of "Q" (Academic Dishonesty).
- Examples of plagiarism specific to this course:
    - Copying parts of somebody else's lab report verbatim
    - Copying parts of somebody else's lab report, slightly modifying each sentence
    - Copying somebody else's observing proposal
    - Using AI and not declaring their use and referencing the original source
    - ...

Plagiarism

- The first "Q" grade means:
  - You lose your scholarship
  - Class penalty ranges from an "F" for the assignment to an "F" in class
    - You have to enroll in a special class (the "Q" class), otherwise the "Q" will become an "F"
- Full policy available at https://www.stonybrook.edu/commcms/academic_integrity/policies_procedures/index.php and https://www.stonybrook.edu/commcms/academic_integrity/students/faq.php

“This class sounds tough...”

- This course was, by far, the best laboratory I have ever taken at Stony Brook. It is one of the best courses I have taken period. In only one semester, I was able to meaningfully participate in the scientific process in a way that was engaging, rigorous, educational, and purposeful. I learned about python, astronomical equipment, the astronomical bodies I studied, how to write research proposals, how to write scientific papers etc. The list goes on and on.
- This course offers immense value to students with a desire to pursue academic research in the field of Astronomy. This course was difficult, time consuming, and the instructor has very high expectations of her students, which are merited. If we want to pursue research, fundamental skills must be developed. It was nice to be challenged, and I feel strongly that this course helped me improve as a student.
- It gave a sneak peek into the life of an astronomer.
- This is an extremely valuable class for astronomy students interested in going into research. It's really impressive that we were able to use legitimate equipment, targets, and techniques that real observers would use. It's rare that an undergraduate class would give this much real-world experience.
- I learned a lot in this course. The student is responsible to figure out how to do most everything in this class especially when analyzing data from lab experiments and this really prepares students to go into graduate school and into research as an astronomer. I improved my skills in coding, LaTeX, and writing scientific papers in this course. The TAs were very helpful during lab experiments.
- I appreciated that each report covered an area of astronomy very well. Putting in the effort, you can learn the relevant softwares/computing techniques used throughout the course associated to each topic. I also gained much deeper understandings of astronomy techniques, such as how an exoplanet light curve is constructed from just a series of images.
- I learned hands on observational astronomy techniques, I improved my writing skills and I also strengthened my coding skills. What makes this course so valuable is that the experiences I had in class will provide me will useful skills in my career.
- This course gave me a nice insight into the observational world of Astronomy. This was the first time i have been able to get hands on experience with observations.

Speaking of workload

- There's a lot of work to be done... 3 labs + reports, proposals + evaluations, final presentations
- It is unavoidable that you will be working on more than one assignment at a time
- The weekly analysis check-ins are meant to help you by dividing the work into manageable chunks
- Start scheduling your observations as early as possible to avoid too much work pile-up!

- By spacing out what needs to be done. At one point, we had to hand in a fully finished lab report, a data analysis check in of another lab, and had to observe for the third lab all in the same week. This class is extremely labor intensive and you will end up doing most of the things last minute because of other classwork.

Avoiding this situation is your responsibility!

Again…

- this is NOT an "easy" class to avoid the physics lab!
- you will have to work hard
- you will have to figure out things on your own
- this class will challenge you

- ... for many of you, it will be the closest thing to actual research that you have encountered so far

Undergrad Writing Requirement

From undergrad bulletin:

E. Upper-Division Writing Requirement:

Students are certified as satisfying the upper-division writing requirement by registering for the 0-credit AST 459 and completing writing projects within their major. All students majoring in Astronomy/ Planetary Sciences must submit two papers (term papers or independent research papers) to the Astronomy coordinator for Department evaluation by the end of the junior year. If this evaluation is satisfactory, the student will have fulfilled the upper- division writing requirement. Papers should be written in the form of a journal article. All papers must consist of an abstract, introduction, main content, and references. References should be cited throughout the text. Any figures should be numbered and have an appropriate caption. If you are using a lab report for the basis of this requirement, you should expand upon the introduction and describe the connection to topical scientific research.

The topic of the WR needs to be original, meaning that Labs 1-2 are not eligible. You're welcome to discuss with me whether your Lab 3 is suitable.

PHY writing requirement will be treated the same as AST.