

ASTR120/121 COURSE REDESIGN

Derek C. Richardson (Prof.), Sara Frederick (Discussion TA),
Joe DeMartini (Lab TA)

with Melissa Hayes-Gehrke, Alice Olmstead, Fatima Abdurrahman,
Allison Bostrom, Emily Garhart, Sarah Scott, and Holly Sheets

"Engaged Students = Successful Students"

University of Maryland 1856

Innovations in Teaching and Learning Conference, Apr 29, 2016

teaching & learning transformation center

ASTR120/121—Quick Facts

- Required 2-semester intro course for Astronomy *majors*.
- 40–50 students per semester.
- ASTR121 has a lab component.

- In Fall 2014 we received an *Elevate Fellows* grant from the TLTC to help transform the course.

Outcomes for this Panel/Roundtable

Participants will…

…assess what aspects of course redesign are most important to their own goals;

…identify at least one aspect of our course redesign that they may use in their own redesign.

Introductions

- Please take 1–2 minutes to introduce yourselves!
  - Name, course, and what interests you about redesign.

- Panelists will now take 1–2 minutes to describe:
  1. their role in the ASTR120/121 course redesign;
  2. how they got involved in the ASTR120/121 course redesign;
  3. a personal experience that showed students were engaged.

Motivation for Making Changes

- Diversity of student backgrounds and learning styles.
- Later courses reported insufficient student preparation.
- Discussion did not advance course objectives.
- Fragmented and unfocused ASTR121 lab.

Lecture Transformation Ideas

- Align content and assessments with learning outcomes.
- Add active learning elements to lectures, with feedback.
- Reduce stereotype threat with two-stage exams.
- Reflect on what works and what doesn't.

Outcomes Strategy

- Course Learning Goals
- Lecture Learning Goals
- Content & Assessment Alignment

Learning Strategy

- Assigned Reading with Muddiest Point Surveys
- Discussion Focused on Learning Goals
- Self-Guided Labs
- Faded Scaffolding for Lab Reports

Engagement Strategy

- Think-Pair-Share Peer Instruction
- Whiteboards
- Group Work in Discussion
- Lab Peer Review

Equity Strategies

- Minimize Student Cost
- Two-Stage Exams
- Videos of Math Derivations

Support Funds

- Funding for LAs/TAs
- Course Materials

Reflection

- Course Reflection Logs
- Weekly Group Meetings
- Self-Assessments

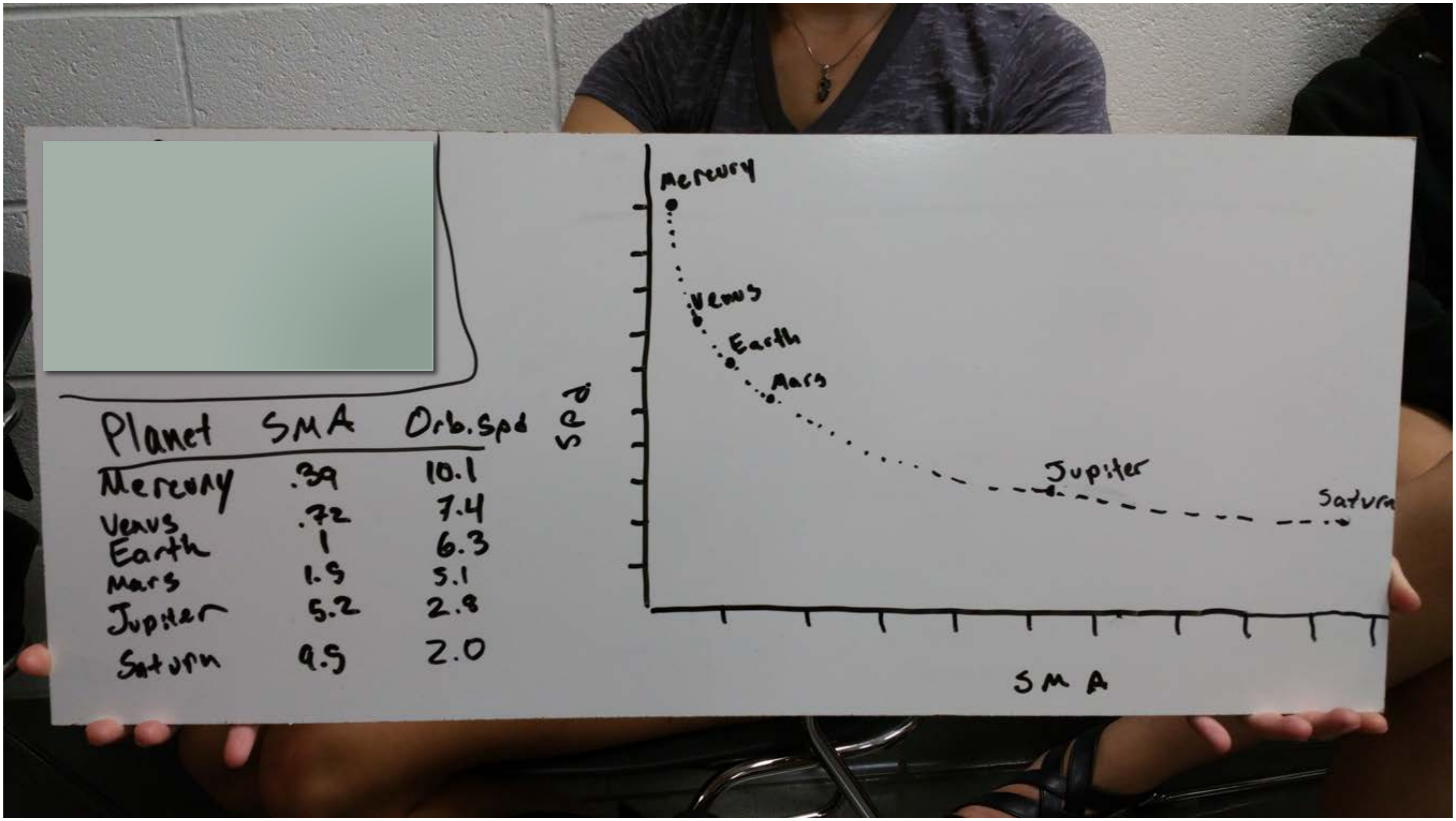
Reflection

- Please take a few minutes to write down at least one new idea that came to you during this discussion, and share.

- Slides from today's discussion are here: ter.ps/astr121lab

Supporting Content

Group Engagement: Whiteboards

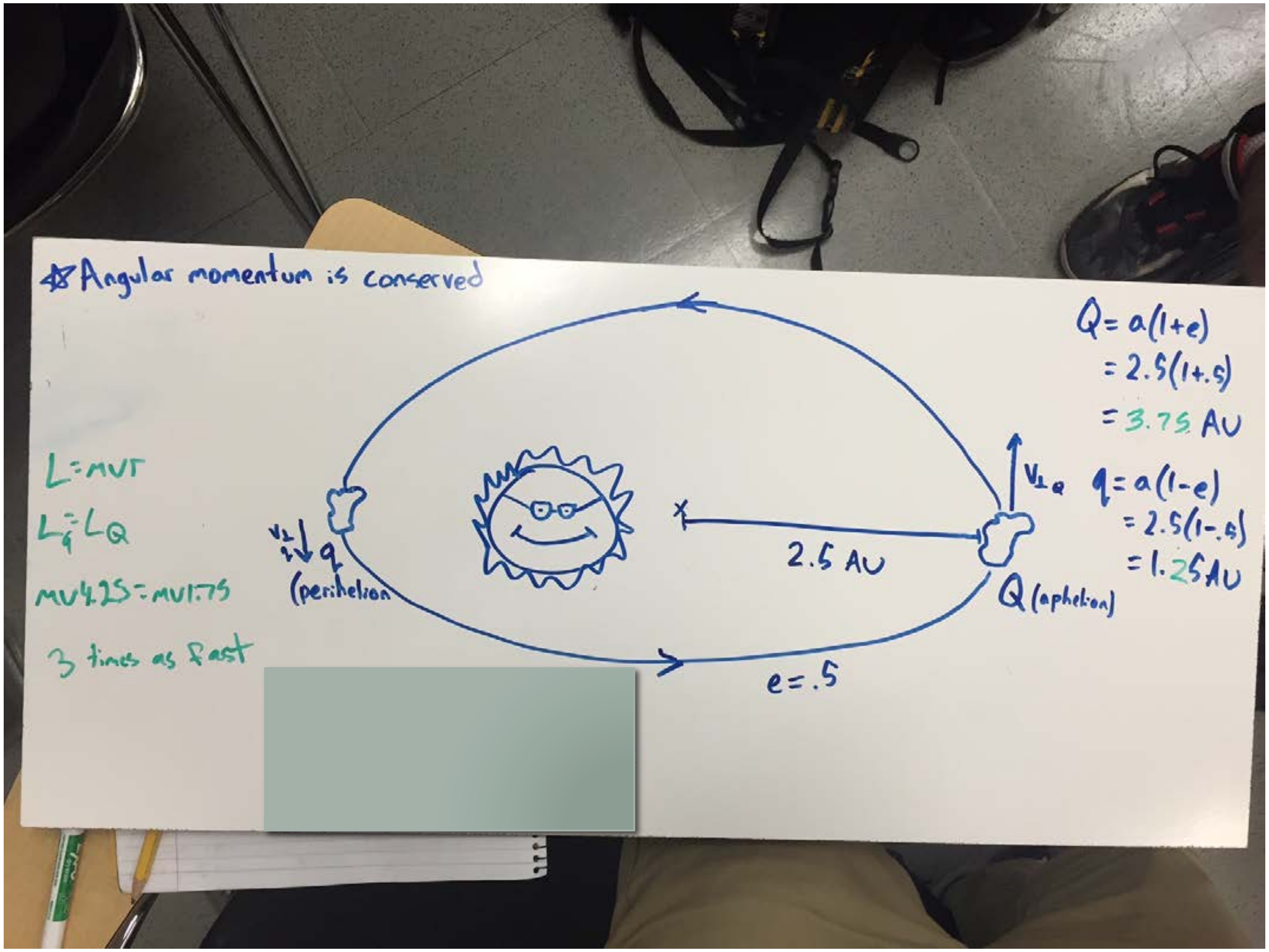


Try it yourself!

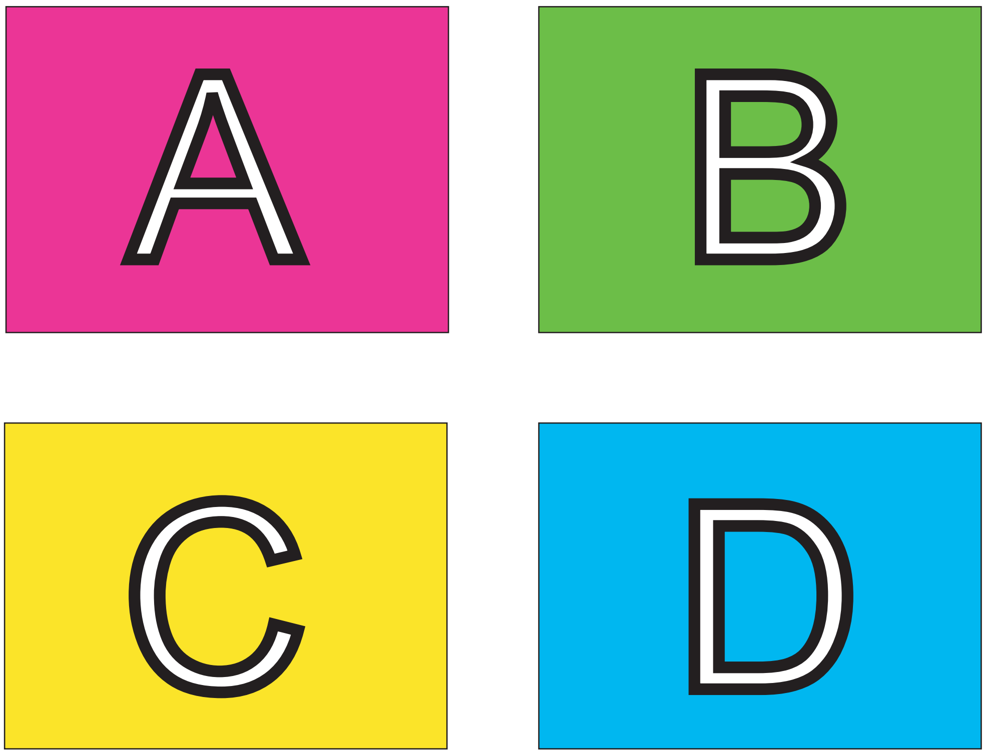
Break into groups, and collaboratively do the following…

Sketch your place in the universe!

Group Engagement: Whiteboards



Peer Instruction (Think-Pair-Share)



- Get instant feedback.
- Give students time to consider their answer before voting.
- Have students talk it out in groups if no consensus.
- Vote again. Repeat as needed!
- Voting cards are a less expensive option for students.

Try it yourself!

Visualization

The Moon appears to have different shapes in the sky, called "phases." The cause of these phases is:

1. The Moon physically changes shape as it orbits the Earth.
2. The Earth casts a shadow on the Moon, causing phases.
3. We see different parts of the Moon illuminated as it orbits the Earth.
4. More than one of the above.
5. None of the above.

Full moon rising in the east.

Crescent moon setting in the west.

Lecture Learning Goals

- In addition to course goals, have ~3 goals *per lecture*.
- Learning goals should be reasonably high level (not just memorization) and *must be assessable*.
- Our group typically iterated on each learning goal.

Proposed…

> …explain how planetary interiors gain and lose heat, and how this is related to geological activity, including the presence or absence of magnetic fields;

Revised…

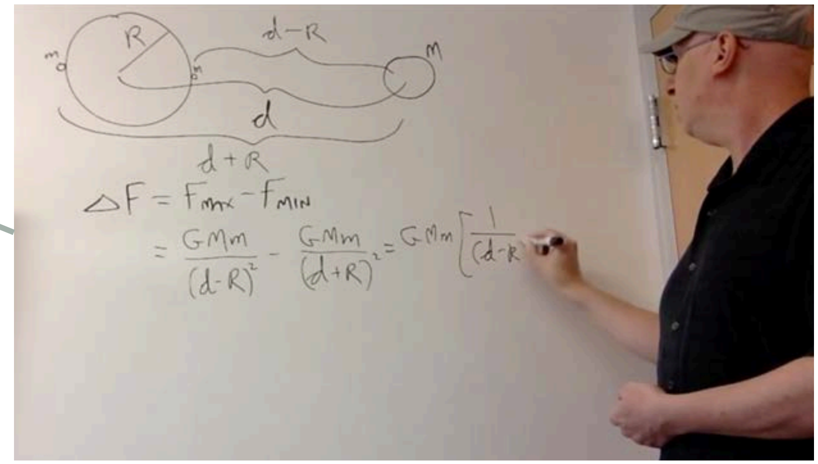
> …predict the interior structure and geological activity of a terrestrial planet, and whether the planet has a magnetic field, based on the planet's size, spin, distance from its star, and age;

Two-stage Exams (Retests)

- Designed to reduce exam stress/stereotype threat.
- After each midterm, students take a copy with them.
- Students may work together, use notes, textbooks, etc.
- Hand in the retest 1 week later for grading.
- Only zero, half, or full marks for retest questions.
- Midterm score is average of original and retest, if higher.
- Final exam augmented by best retest improvement.

Other Elements

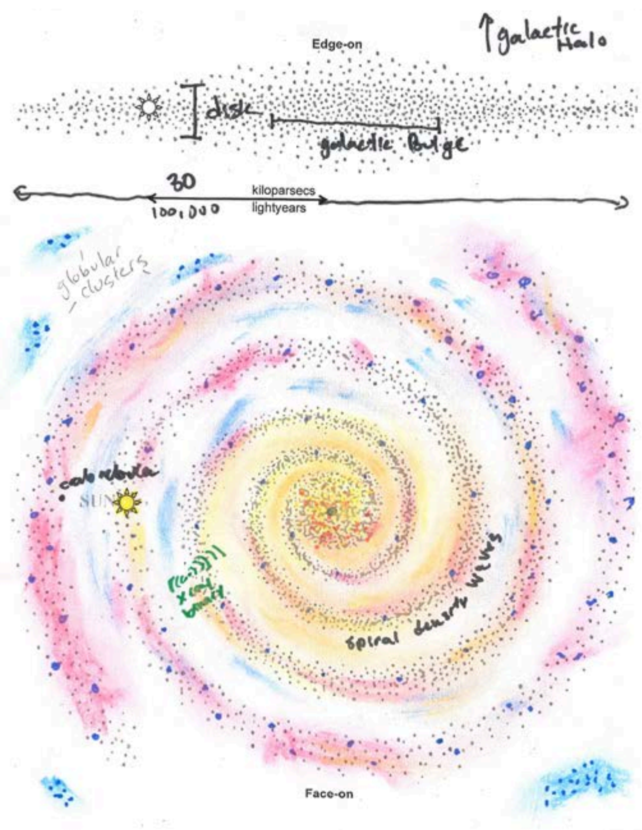
- Videos of math derivations.
- Muddiest point surveys based on assigned reading.
- *Lecture-Tutorials* in discussion.



"I still don't understand all the details of the higher temperature phase transitions. For example, how does a high temperature ionize an atom?"

Example Discussion Activities

Sketch the Milky Way



Student-Led Review

"I understand that most galaxies tend to be red-shifted because the universe is expanding but does that mean we are near the epicenter of said expansion if most of the galaxies are moving away from us?"

"How exactly does the cosmic distance ladder work? We understand individual components of it, but are still confused as to how they fit together."

"Why are active galactic nuclei in the local universe not as energetic as quasars, and how do we know this?"

In Your Own Words: Spiral Density Waves

"Think of the spiral arms of the Milky Way as waves moving through gas instead of water. Within the wave itself, gas becomes bunched up and closer together, which leads to more gas clouds collapsing under their own gravity, which leads to more star formation. So as the spiral arms move through the gas of the Milky Way, the gas will always be more concentrated within them, explaining why the most star formation takes place in these regions."

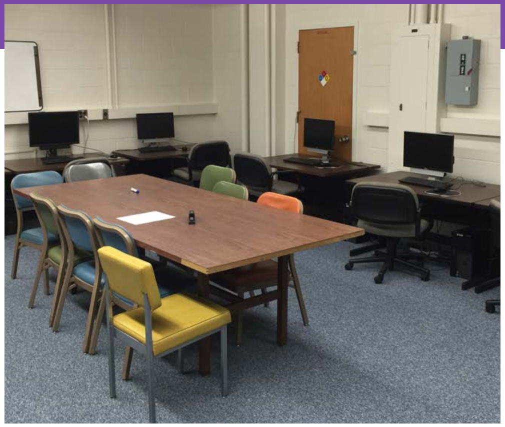
In Your Own Words: Temporal Variability 1

"If someone was messaging you in Morse code, which takes a while to type out, and they had almost reached the end of the message when someone else started sending a new message, and your machine, for a while, had two messages overlapping. This is what would happen if an object varied in apparent brightness, because light can take a while to travel, just like it takes a while to send a message in Morse code."

In Your Own Words: Temporal Variability 2

"Think of varying brightness as switching a light on and off. If you have a large area, like the center of a galaxy, then the light from the far end of the galaxy can take much longer to reach us than the light from the close end. If you switch off both lights, the light from the far end trails behind the light from the close end by their distance divided by the speed of light."

ASTR121 Lab



- Focus on fundamental topics.
- Give guidance, not cookbook instructions.
- Connect to current research with pre-lab reading.
- Consistent use of MATLAB throughout.
- Faded-scaffolding for lab reports, with detailed rubric.
- Students work in pairs, engage in peer review.

- Modified E-CLASS survey (Zwickl+13) shows students' expectations of what is important to experts are aligned with assessments.

> *15. "Working in a group is an important part of doing astronomy experiments."*

Reflection

- With all these changes, it is important to reflect each lecture (and discussion) on what worked and what didn't.
- We use shared google docs to write out these reflections and comment on them, 1 for lecture, 1 for discussion.
- Very useful for adjusting approach as you go, and for making changes the next time you teach the course.
- Other self-assessment includes "stop-go-change" mid-semester student survey, and the usual course evaluation.
- We also used certain research-based assessments.

How we used *Elevate* funds.

- Hired a learning assistant (LA) each semester.
- Paid for part of Alice's time (one semester).
- Covered conference registrations (AAPT).
- Bought supplies (whiteboards, erasers, pens).

EXTRA SLIDES

Timeline of Changes

- Fall 2014:
  - Think-pair-share in lecture with voting cards.
  - Augmented *Lecture-Tutorials* in discussion.
  - Retests.
  - *Elevate Fellows* funding application.
- Spring 2015:
  - ASTR121 lab transformation with LA support.
  - *Elevate Fellows* activities/planning.
- Fall 2015:
  - Learning outcomes with aligned assessments, cumulative exams.
  - Whiteboards, in-class quizzes, videos, muddiest point, reflections.
  - *MasteringAstronomy* for guiding student reading.

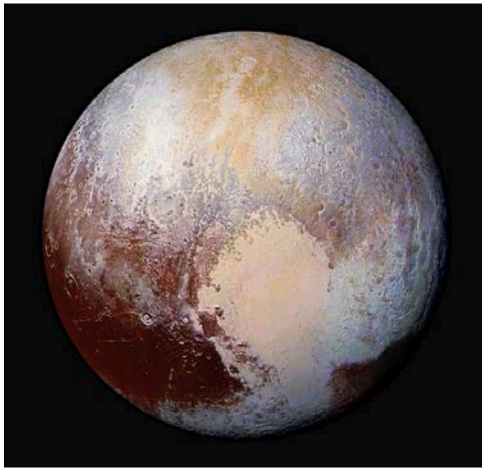
ASTR120 (Solar System) Outcomes

- Develop an appreciation for our place in the universe.
- Convey the current state of knowledge regarding basic astronomy, our solar system, and extrasolar planets to a non-specialist.
- Solve complex problems requiring application of multiple astrophysical concepts.
- Collaborate with others to develop shared knowledge.
- Write scientifically and communicate your results effectively.
- Critically evaluate your own and your peers' work.

Try it yourself!

In 2006, professional astronomers voted to “demote” Pluto from planet to “dwarf planet.” This was because:

1. Pluto is too small to be a planet.
2. Pluto is not round enough to be a planet.
3. There are other (but smaller) objects like Pluto at a similar distance from the Sun.
4. More than one of the above.
5. None of the above.



Pluto

Teaching the Skills of Professional Astronomy through Collaborative Introductory Labs

Derek Richardson, Fatima Abdurrahman, Alice Olmstead, Sarah Scott, Melissa Hayes-Gehrke

University of Maryland, College Park

Introductory Astrophysics

- ASTR120 & ASTR121 (with lab).
  - Two-semester sequence for science majors.
- Students taking the lab should:
  1. Experience astronomy through practical exercises.
  2. Develop skills needed for professional astronomy, e.g., collaboration, data analysis, critical thinking.

Transforming the Lab

1. Focus on fundamental topics (6 labs, not 10).
2. Think about the approach (freedom to explore).
3. Connect to current research (prelab reading).
4. Write comprehensive reports (formal sections).
5. Collaborate & critique (group work).

1. Focus on Fundamental Topics

- Just six labs:
  1. Intro to MATLAB.
  2. Stellar Parallax.
  3. Blackbody and Stellar Spectra.
  4. Cluster H-R Diagrams.
  5. HI Rotation Curves.
  6. Hubble's Law.

Each lab spans 2 *weeks* (4 hours in-lab time).

1 ugrad LA per section (20 students per LA).

2 sections.

ASTR 121 – Spring 2015

Lab 5 – HI Rotation Curve of the Milky Way

Important dates:

- Prelab due: Monday, April 13, 2015
- Rough draft due: Monday, April 20, 2015
- Final draft due: Friday, April 24, 2015

Science Goals:

At the end of this lab, you should be able to…

- Determine the tangent velocity of HI clouds using 21 cm data
- Determine the orbital speed and orbital radius of the clouds via the tangent point method
- Construct a rotation curve of the galaxy based on these measurements

MATLAB Goals:

In this lab, you will apply MATLAB knowledge to…

- Plot data with x and y error bars
- Fit experimental data and determine information from a fit

2. Think About the Approach

- Lab manual gives broad instructions. It's not a cookbook.

"For each pair of images, you will determine the plate scale s and the apparent separation a of a star between the two images."

- Questions provide students opportunities to reflect on their work.

"What real systems can be represented by each of these rotation curves?"

3. Connect to Current Research

- Required pre-lab assignment to read a related "astrobites" article and answer a few questions.
  - http://astrobites.org/

4. Write Comprehensive Reports

- We use *faded scaffolding*:
  - Students provided with a template for each lab report, with some (mostly) filled-out sections.
  - Each new lab has fewer pre-filled report sections.
  - The last lab report has no pre-filled sections at all.
- Graded using a detailed rubric.

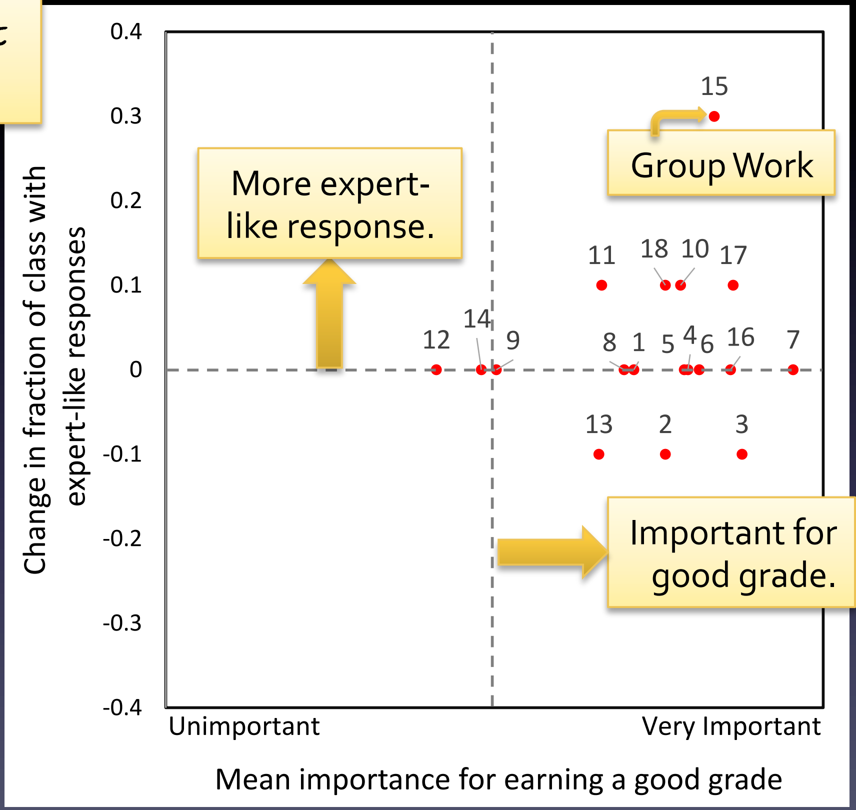
5. Collaborate & Critique

- Students work in pairs.
- Whole class encouraged to cooperate.
- At the start of the second week of each lab, pairs exchange draft lab reports for comment.

Evaluating Our Success

15. "Working in a group is an important part of doing astronomy experiments."

- Modified E-CLASS survey (Zwickl+13) shows students' expectations of what is important to experts are aligned with assessments.



Summary

- We have transformed the UMD ASTR121 lab to make it more collaborative and relevant for students.
- Student views on astronomy labs became more expert-like.
- Will continue to refine the improvements this year (spring 2016).
- Materials available online (plus teaching manual): ter.ps/astr121lab
- We thank the UMD TLTC Elevate program for support.
- Related poster: PST2A07 (yesterday, sorry!).

Extra Slides

Excerpt from Lab 4 (Cluster H-R Diagrams)

Part 1: Examining Star Cluster Data and Exploring Photometric Filters

In this part of the lab, you will examine the data for an open cluster.

1. In a MATLAB script, read in the data for the open cluster M41. Create a CMD by plotting V apparent magnitude as a function of (B-V), remembering to flip axes as needed. As this is a set of individual points representing distinct stars, have the figure plot points rather than connecting them in a line. Add appropriate axes and title, and include this figure in your report. *Which direction does temperature increase on the x-axis? What features can you identify on this CMD?*

2. On your CMD, look for a main sequence star with (B-V) of 0.5. *What surface temperature would this star have?* Using your Planck function from the previous lab, plot the blackbody curve of an object with this temperature. Include this figure in your report.

3. The data includes apparent magnitudes in the B and V filters. Show on your blackbody plot which wavelength range each filter allows through, as well as the central wavelength of each filter. Include this figure in your lab report.

Excerpt from Lab 5
(HI Rotation Curves)

Part 1: Exploring Rotation Curves

In this part of the lab, you will construct rotation curves for different mass distributions. You will use the equation for orbital speed v around an enclosed mass M_r at an orbital radius r,

$$v = \sqrt{\frac{GM_r}{r}},$$

where G is the gravitational constant.

1. Consider a system in which almost all the mass is concentrated in a point at the center, resulting in a constant value of M_r. Construct a rotation curve for this system by plotting orbital speed as a function of orbital radius. To set a reasonable scale, use a value of M_r equal to the total mass of the Milky Way and take r to vary on kiloparsec scales.

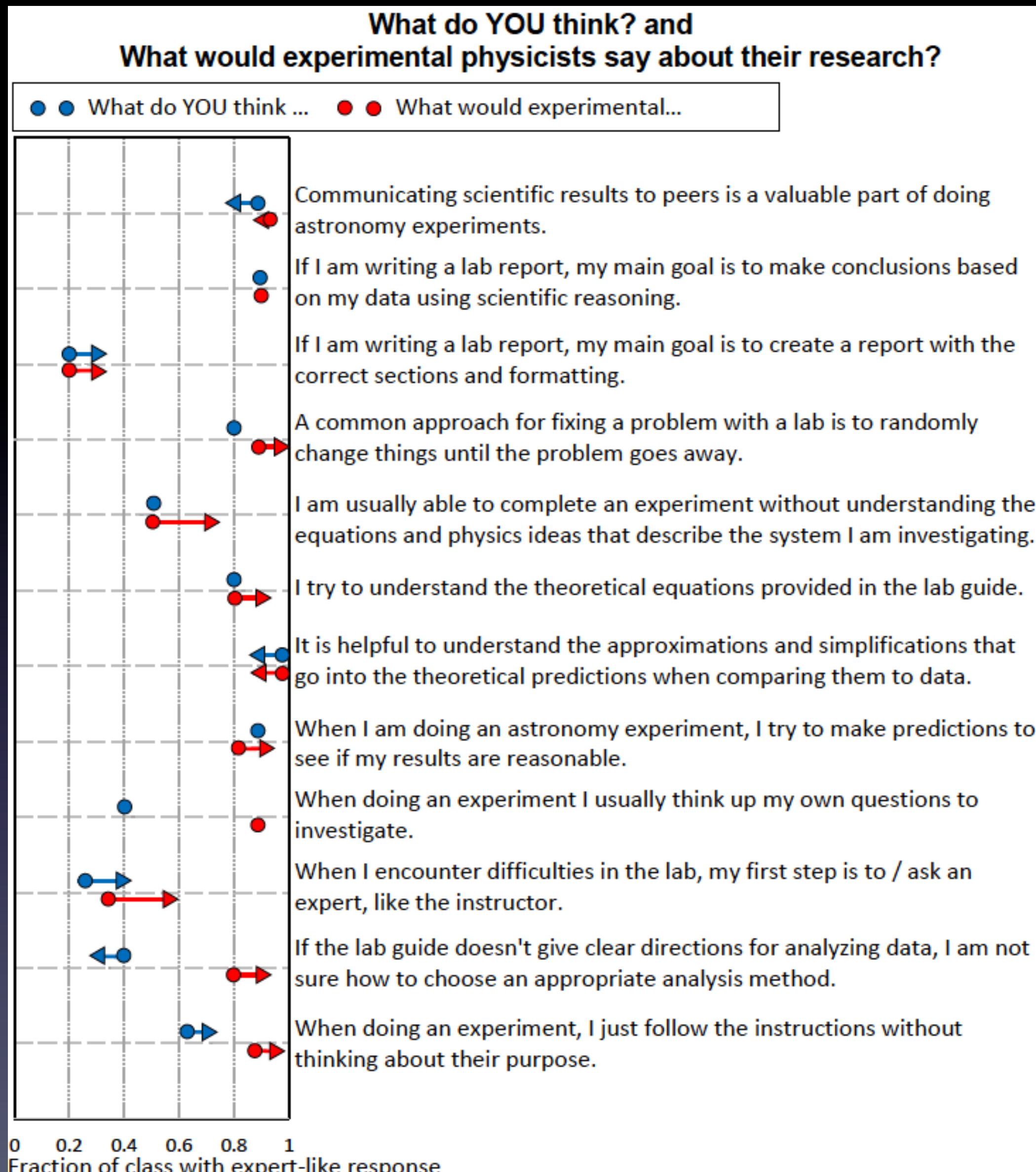
2. Plot a similar curve for a system where enclosed mass is proportional to orbital radius, $M_r \propto r$. Use similar scales as for the previous model and show them together.

3. Add a third plot showing a distribution where enclosed mass is proportional to volume, $M_r \propto r^3$. *What real systems can be represented by each of these rotation curves?*

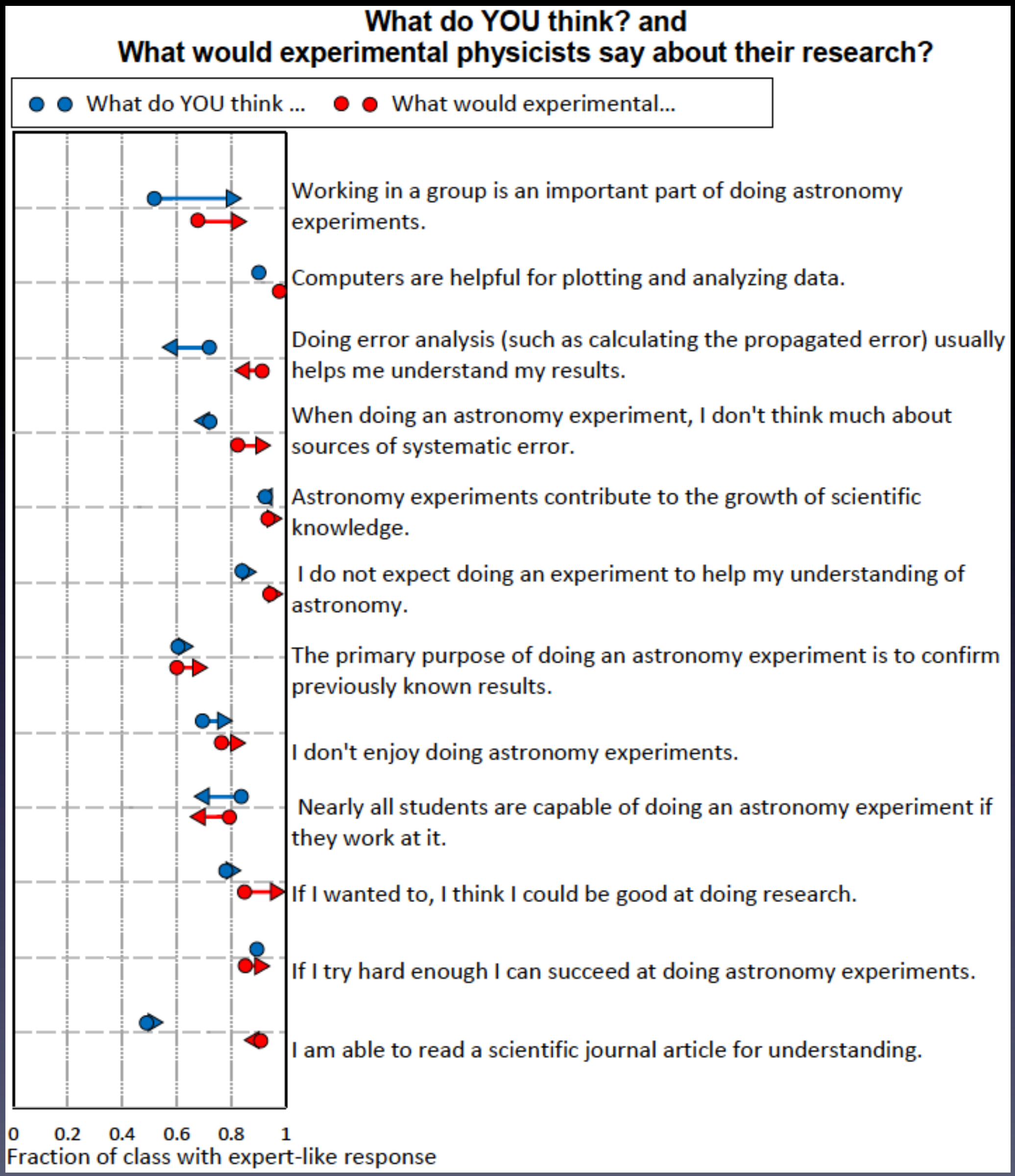
ASTR121 Lab Report Rubric – 38 Points Total

Aspect	**Excellent** (100%)	**Good** (75%)	**Adequate** (50%)	**Poor** (25%)	**Absent** (0%)
Cover Page (2 pts)	Cleary presents name and number of lab, student names and contact information, date, course and section	Missing an aspect	Missing aspects	Missing all aspects	Absent
Abstract (4 pts)	Concisely summarizes the purpose, procedures used, and results of project.	Missing an aspect	Missing aspects; too lengthy or inaccurate	Missing all aspects	Absent
Introduction (4 pts)	• Includes the question to be answered by the project • Develops the reason why the question is relevant/interesting • Discusses general method (without specifics) that will be used to answer the question and develops theoretical background	One is missing	Two are missing	Three are missing	Absent
Methodology (8 pts)	Description of the data used and what was done with the data, complete enough that another scientist could repeat the process.	Some steps are vague or unclear	Only includes generalities, but enough to get the idea	Would be difficult to repeat; reader must guess at some parts	Absent
Analysis (8 pts)	Results and data are clearly displayed, organized in a way that makes it easy to see trends. Figures and charts are appropriately labeled and captioned. Excessive data and Matlab code are included in appendix. Uncertainties in all determined quantities are calculated and explained.	Errors in results, but otherwise well done; flaws in organization	Unclear results; missing labels or captions; disorganized; missing data/plots/tables	Results do not make sense, or not enough to justify conclusions	Absent
Discussion (8pts)	• Summarizes the data used to draw conclusions • Conclusions follow logically from data • Discusses sources of error (random and systematic) • Discusses if conclusions fit expectations and/or seem plausible • Discusses any unusual results or disagreement with theory and speculates on cause • Discusses addition questions/issues asked in hand-out • Discusses real world implication of results	Missing 1-2 aspects	Missing 3-5 aspects	Missing 5-6 aspects	Absent
Format (4 pts)	• Report follows typical scientific format and organization • Any references are cited appropriately in a bibliography • Writing flows well and is easy to read • Grammar, vocabulary, and similar errors are minimized	Some grammar, writing, or formatting issues.	Significant errors in one aspect, minor errors otherwise	Significant errors in many aspects	Paper is nearly unreadable

Modified E-CLASS Survey Results (Part 1)



Modified E-CLASS Survey Results (Part 2)



Modified E-CLASS Survey Question Key

Number	Personal/Professional Statement	How important for earning a good grade in this class was…
1	When doing an astronomy experiment, I don't think much about sources of systematic error.	…thinking about sources of systematic error?
2	It is helpful to understand the assumptions that go into the theoretical predictions when comparing them to data.	…understanding the approximations and simplifications that are included in theoretical predictions?
3	Doing error analysis (such as calculating the propagated error) usually helps me understand my results.	...calculating uncertainties to better understand my results?
4	If I don't have clear directions for analyzing data, I am not sure how to choose an appropriate analysis method.	…choosing an appropriate method for analyzing data (without explicit direction)?
5	I am usually able to complete an experiment without understanding the equations and physics ideas that describe the system I am investigating.	…understanding the equations and physics ideas that describe the system I am investigating?
6	I try to understand the theoretical equations provided in the lab guide.	…understanding the relevant equations?
7	Computers are helpful for plotting and analyzing data.	…using a computer for plotting and analyzing data?
8	When I am doing an astronomy experiment, I try to make predictions to see if my results are reasonable.	…making predictions to see if my results are reasonable?
9	When doing an experiment I usually think up my own questions to investigate.	…thinking up my own questions to investigate?
10	When doing an experiment, I just follow the instructions without thinking about their purpose.	…thinking about the purpose of the instructions in the lab guide?
11	When I encounter difficulties in the lab, my first step is to ask an expert, like the instructor.	…overcoming difficulties without the instructor's help?
12	A common approach for fixing a problem with a lab is to randomly change things until the problem goes away.	…randomly changing things to fix a problem with the experiment?
13	Communicating scientific results to peers is a valuable part of doing astronomy experiments	…communicating scientific results to peers?
14	I am able to read a scientific journal article for understanding.	…reading scientific journal articles?
15	Working in a group is an important part of doing astronomy experiments.	…working in a group?
16	If I am writing a lab report, my main goal is to make conclusions based on my data using scientific reasoning.	…making conclusions based on data using scientific reasoning?
17	If I am writing a lab report, my main goal is to create a report with the correct sections and formatting.	…communicating results with the correct sections and formatting?
18	The primary purpose of doing an astronomy experiment is to confirm previously known results.	…confirming previously known results?

Lab Facility

- 10 PCs for 40 students in 2 sections.
- Students work in pairs.

Classroom

Capacity 50 students.

Pretty crowded!