COSMOS 2007: From Molecules to the Milky Way

Astronomy Course Playbook

Kathy Cooksey

IMPORTANT EVENTS

- Mon Jul 9 11:00-noon: Lisa Hunter presents on presence of CfAO in Cluster 7
- Tue Jul 10 9:00: assign *Astronomy Challenge* and *APOD Presentation*, distribute planispheres
- Wed Jul 11 3:00-4:00: Cluster meeting
- Fri Jul 13 10:15-10:20: APOD presentation Group 1
    - 1:00-1:05 APOD presentation Group 2
    - 1:05-1:30: Lisa Hunter describes *CfAO Online Treasure Hunt*
    - 2:30-2:35: APOD presentation Group 3
- Tue Jul 17 9:00-9:05: APOD presentation Group 4
    - 10:15-10:20: APOD presentation Group 5
    - 10:20-noon: Astrobiology lecture by Tiffani
    - 1:00-1:05: APOD presentation 6
    - 2:00: Pick up vans and food for Lick Observatory field trip
- Wed Jul 18 3:00-4:00: Cluster meeting
- Thu Jul 19 1:00-4:00: Thimann 133 lab clean up
    - 5:00-???: CLS design team set up
- Fri Jul 20 11:00-1:00: Supply lunch for CLS design team
    - 4:00-5:00: Inquiry clean-up
    - 5:00-7:00: CLS design team debrief
- Mon Jul 23 10:15-10:30: Project advisor presents for Project Selection
    - 11:30-11:45: Project team announcement
    - 9:00-11:00: Sky observing (optional) ← **Organize with RA**
- Tue Jul 24 9:00-11:00: Remote observing (Organize with RA)
- Tue Jul 31 9:00-noon: UCSC admissions counseling by Sharon Dirnberger

POINTS TO REMEMBER

- Thank you notes:
    - Ellie Gates, Patrik Jonsson (observing)
    - Facilitators: Jeremy, Julia, Diane (Ryan)
    - UCSC Counselor: Sharon Dirnberger
    - Hilary (BBQ)
    - Lisa (talks)

GENERAL OVERVIEW

- *What is the primary ("Tier 1") type goals:*
  - *Attitude*
    - The students will feel like they are "real" accomplished astronomers (scientists), having worked with (their own) astronomical data, interacting (collaborating) with astronomers, and presenting their astronomical knowledge.
      - WHY: The students will feel empowered and motivated by the course to pursue future scientific endeavors.
  - *Process*
    - The students will experience the "scientific process"—asking and answering questions: gathering science data; analyzing data to prove (or disprove) their hypotheses; gathering more and/or reanalyzing data as their interests are peaked; and present their understanding.
      - WHY: The students will develop their analytical and problem-solving skills and apply them to other aspects of their education.
  - *Content*
    - Instruments and tools of astronomers (telescopes, CCDs, AO)
      - WHY: Because light is all astronomers have and we must treat it well (see below)
    - Basic astrophysics of stars and cosmology
      - WHY: stars are fundamental "units" of astronomy with physics that apply to planets and galaxy structure; cosmology is the sexy "wow" factor of astronomy that compels most people into the field
    - *What is overall theme/flow of content?*
      - All astronomers have is light from which to gather their evidence and to develop their hypotheses/models.
  - *Why are these primary?*
    - (See above)
- *What type(s) of goals is addressed by:*
  - *Lectures*
    - Content—HOW: Direct, clear statement of what instruments astronomers use and how they use them; fundamentals for use in other elements of course (from which content will be learned)
  - *Hands-on activities/labs*
    - Process—HOW: actively engage the students in the scientific process in a well-planned manner that gives the students ownership
    - Attitude—HOW: since the activities (e.g. inquiry) will have authentic content goals that the students meet, the students will feel accomplished as scientists
  - *Field trips*
    - Attitude —HOW: build the community of scientists being interested in e.g. Lick Observatory or the Exploratorium exhibits;

    show the students they understand concepts used/presented at real research institutes and/or science museums

- *Discussion session(s)* [assuming astrobiology topic]
    - Content—HOW: in tying astronomy course to biology course, the students will synthesis and codify their own understanding and also learn from their peers
    - Process—HOW: the students will discuss their area of expertise based on how well they learned content from the various cluster elements; it will be like a conference; they will use their creativity to tie the two courses together
    - Attitude—HOW: the students will be excited to be creative in finding links between astronomy and biology, they will see what they have learned has "real-world" implications (motivation to keep learning!)
- *How do these activities address the goals?*
    - (See above)

- *What preparation and/or prior knowledge will the students need for:*
    - *Field trips*: Lick Observatory
        - Optics
            - WHY: fundamental to understanding telescopes
        - Telescopes
            - WHY: the students will see and use the two types of telescopes at Lick (refractor and reflector); see why size and location of telescope matters
        - CCDs
            - WHY: all astronomers have is light (content) and CCDs are how we quantify that light; need to know the limits of such instruments
        - AO
            - WHY: that's the cutting-edge science being pioneered at Lick and why the CfAO exists (represent!)
    - *Small-group projects*
        - All: how instruments work
            - WHY: understand uses and limits of their data
        - Variable stars: need to know stars come in pairs often and hint of planet detection via eclipses
            - WHY: clues to figuring out mystery light curve
        - Galaxy morphology: meanings of colors of stars
            - WHY: extrapolate to why galaxies have colors and how colors and morphologies trace each other
        - Open and Globular clusters: meanings of colors of stars; life cycle of stars
            - WHY: determine why the two clusters differ in their colors, ages and morphologies
    - *Why will they need that prep/knowledge?*
        - (See above)

- *How are the roles defined:*
    - *Instructors*: in charge of lectures and hands-on activities/labs; handles logistics for course
    - *Project advisors*: in charge of their group and all that goes on during project time; will keep instructor informed so instructor can monitor progress across the groups
    - *[Teacher fellow]*: external monitor of students feelings about pace of course and interest in topics; develop the transferable skills most pertinent to course (e.g. presentation skills)
    - *What are the responsibilities of each role?*
        - Instructor must help keep course a cohesive and collegial unit
        - Project advisors most entrusted with how the students will ultimately feel (the close, intense, small-group project time is the most rewarding and memorable)
            - P.A.'s should respect the instructors input because the instructor is focusing on the larger course picture
        - Teacher fellow adds the experience of a high school teacher
    - *Who has ownership of what aspect of the course?*
        - Instructor owns the lectures
        - Instructor organizes the hands-on activity/labs but appreciates the project advisors help
            - The project advisors will be seen around and the students will feel more comfortable selecting that project advisor for the project time
        - Project advisor is in charge of all research project time
    - *What is the hierarchy, if there is one?*
        - Aside for logistics and experience, the instructor and project advisors are collaborators with equal say
- *What cross-course activities do we want to have?*
    - *Field trip (e.g. Exploratorium)*
    - *College/Grad School/Life Q&A*
        - YES—WHY: the students should see the possibility of pursing a career in science and should be told how that actually works
    - *Reunion picnic*
        - YES—WHY: relaxing social time with the staff when they aren't driving; meet previous cluster 7 members and see what the alumni have learned from their experience 1, 2, … years later
    - *College counseling*
        - YES—WHY: the UCSC counselor is very knowledgeable about how to get into a UC or CSU campus; detailed information that high school counselors may not have
    - *4th week discussion activity*
        - YES—WHY: break from project time; intellectual play with acquired knowledge (see 'Discussion session(s)' above); give students a "social justification"/"why should we care" for learning about astronomy and/or biology

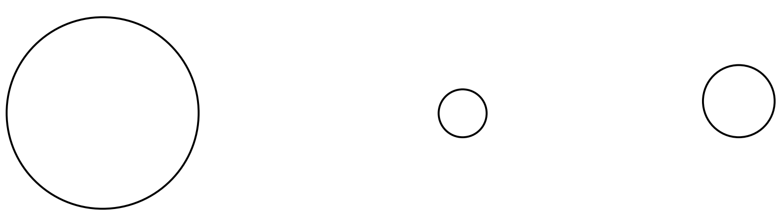
- *Why do we want them?*
    - (See above)

ASTRONOMY CHALLENGE

- Leave time for re-do, make due one or two lectures before end of course
- Ask for questions
- Review problems every lecture

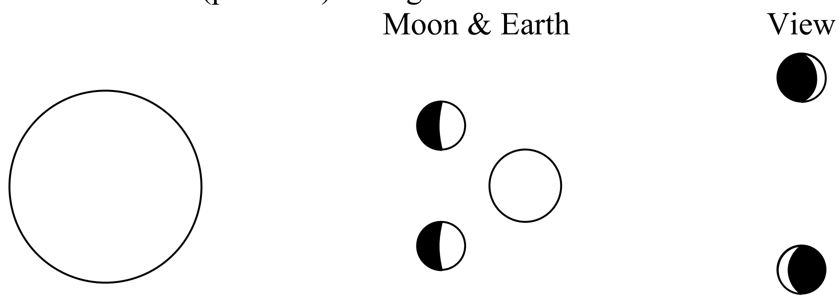
Solutions and hints:

1) Astrological sign and planisphere
   a) Get feel for how constellations are ordered.. Aries (go to noon April 20th, Aries front and center)
      i) Noon May 21st Taurus
      ii) Noon July 6th Gemini
      iii) Noon July 31st Cancer
      iv) Noon Aug 29 Leo
      v) Noon Oct 5th Virgo
      vi) Noon Nov 6th Libra
      vii) Noon Dec 5th Scorpio
      viii) Noon Dec 28th Sagittarius
      ix) Noon Feb 5 Capricorn
      x) Noon Feb 23 Aquarius
      xi) Noon Mar 31 Pisces
   b) So constellations rise in East and set in West (like Sun) over the year
   c) What does everyone notice about their dates and signs? Any *rough* relation?
   d) HINT: The astrological sign dates given are independent of when precisely in time you were born on your birthday but the bonus question depends on your time
   e) Now, everyone got o 9pm on the day they were born
      i) Where is your sign?
      ii) Now, simulate the *night* sky, go from 9pm to 9am and see what the sky does
      iii) What has happened to your sign?
      iv) At what time does your sign "rise" on the day you're born?
   f) Can we draw a picture of what's going on?
      i) Think of the stars painted on a sphere around our solar system
2) Earthshine
   a) They might think it's solar eclipse
      i) So let's draw solar eclipse



   b) What causes things to be visible? What allows us to see?
   c) Let's look at a picture of a solar eclipse (OK to Google this)
   d) What causes phases of moon?
   e) What phase does this look like?

f) Let's draw that (previous) configuration



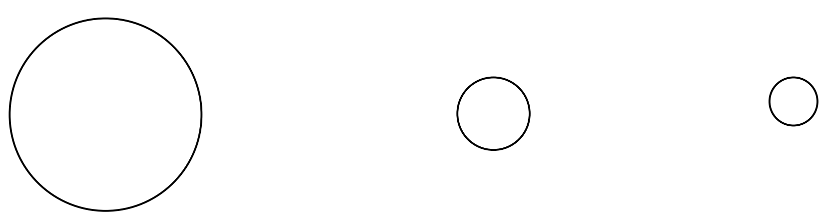
g) Where must light come from for us to see the whole moon outline?
h) Albedo

3) Earthrise
   a) Phase of Earth—3rd quarter ("left") – waning
   b) Let's draw this

   c) Now let's hop to Earth

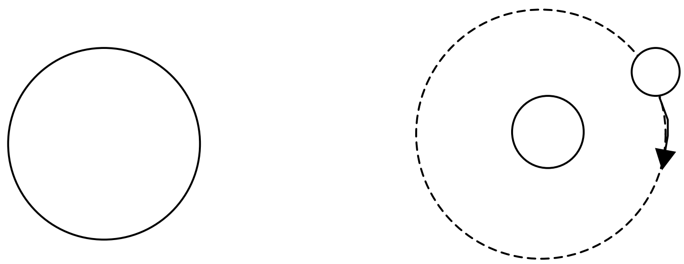
   d) Let's enact this with people\

4) Tricky Moon
   a) Let's put up big version on screen
   b) What is on the moon?
      i) Craters
      ii) Light spots (more craters)
      iii) Dark spots ("lunar oceans"—older material)
   c) What is the configuration when there's a full moon?



   d) What are shadows?
   e) What are differences between Figure 4 and 5? (Minutea)

   f) *Not* the other side of the moon
   g) Let's look at phases of moon picture
5) Lunar eclipse
   a) Ultimate hint: think of why we study AO
   b) More interested in the last two stages
   c) Let's draw lunar eclipse



   d) What's obscuring the Moon?
   e) What is the Earth like? (Most special place)
   f) Why is the sky blue?

APOD PRESENTATIONS

OVERVIEW & INTRODUCTION

1) History of cluster
   a) Emphasize that this is new format for cluster (which is always evolving)
   b) Introduce notion of CfAO and how we're very focused on improving science education and opportunities
2) Topics we'll cover
   a) I only have a few lectures so I'm targeting wide but we'll explore whatever you'd like
   b) CLS is an inquiry and an important opportunity to really investigate like researchers/scientists
3) Some of the more exciting non-lecture activities
   a) Lick Observatory is a fun adventure at a real astronomical observatory
   b) At that trip we'll see the telescope we'll use to collect research data for the astronomy projects
   c) Since we do care about your futures, whatever you choose to do, we want to try informing you of your various options after high school
   d) Project time is a large portion of this cluster because we value time spent with lots of attention to one specific topic
   e) DON'T PANIC: Presentation day is harmless
4) Project time
   a) Just a quick taste of what's to come in the 3rd week (so far away but yet so close)
5) Image of Crab Nebula
   a) **Concept question:** what do you see in this image? What questions does it inspire?
6) Nature of Questions
   a) I am VERY interested in improving your ability to ask and answer questions
   b) Answering questions verbally but also answering in the sense of *research*
   c) Let me be frank about the manipulation point, if you're sitting in a lecture and you're bored with the topic, ask questions and navigate to more interesting material
   d) Answering questions from the research perspective is something you CAN learn
   e) Answering questions in front of an audience is something I'm still learning; it just requires practice
7) "Scientific Process"
   a) Since we're talking about research and questions, let's touch upon the scientific process as you may have learned it in school
   b) It's NOT linear, there is revision and branches at every step
      i) There are also people that skip steps or work in reverse
8) Interesting observation: Crab Nebula
   a) In this case, we have an historical basis (I love this aspect of astronomy)
   b) Crab Material is moving at 1500 km/s (and that maybe a measurement based on size, distance, and time)
   c) Astronomers only have radiation (visible light, microwaves, ultraviolet, infrared…) to tell us about our objects of interest
9) Telescopes

   a) Light buckets
   b) All shapes and sizes and locations and peak wavelengths
10) CCDs and AO
   a) CCDs are exactly what you find in your digital cameras
   b) AO is one of many image correction techniques, this one specifically for fixing blurring due to the turbulent atmosphere
   c) Active optics correct large mirrors for gravitational distortion
   d) Anecdote: original myopia of HST led to great imaging (post-)processing techniques that turned out to be great for mammogram imaging!!
11) Crab Nebula: Color
   a) As we'll learn, colors in astronomy can tell us a great deal of things about composition and temperature… sometimes even relative motions
   b) In this case, hydrogen shows up red (in emission)
   c) Blue indicates a great amount of energy whirling around
   d) He is orange-ish, oxygen is green
   e) Spectra can show C, N
   f) Spectra can also show that it's expanding at 1500 km/s
12) Crab Nebula: Morphology
   a) To astronomers, this is spherical
   b) But you see a lot of structure (filaments) within it
   c) There is density variations, as you can see from colors and transparency, this implies a lot of random motions
13) Crab Nebula: Other Radiation
   a) Radiation is the name for all forms of light and it relates to the energy of the source
      i) Blue light typically is more energetic than red, so ultraviolet light is more energetic than infrared
   b) From this we learn about the central engine of this object, what's giving off so much energy, what's the hint to it's past
   c) There was a supernova here
14) Crab Nebula: Central Pulsar
   a) Whenever something shows time variation that we can observe, it's very cool
   b) This shows the accretion disk around the pulsar (varies on time-scales of months)
15) Conclusion
   a) **Concept question:** what do you think are my conclusions?
   b) I also want to be clear about my *goals* for you in this course: **YOU CAN BE A SCIENTIST AND I WANT TO HELP**
      i) The processes of scientific research can be *learned* like the content of science

OUR PLACE IN THE UNIVERSE & TAXONOMY

1) Let's take an introductory trip through the Universe
   a) Beginning with the Solar System---one star surrounded by at least 8 planets
   b) Our star is but one of billions in the Milky Way
   c) And the Milky Way is just one galaxy of billions
   d) Galaxies are not just the matter we see but also matter we don't see (and energy we barely know what to think of)
2) Can we even comprehend the size of the Universe? Even our solar system?
   a) I have trouble understanding the size of a mile
   b) **Concept question:** give everyone clay and a planet to miniaturize for a solar system with a water polo ball
      i) Planets: Mercury, Venus, Earth, Mars, Jupiter
   c) Watch the campy 'Powers of Ten' movie
   d) How does *The Simpsons* version differ?
3) Distance units in astronomy
   a) Preferred units change based on the system under study
   b) Lend intuition to the values of the numbers
   c) Time and distance on large scales are degenerate
      i) When you look in the mirror, you only ever see yourself in the infinitesimally distant past
4) Parsec is the difficult unit
   a) Closer objects appear to move with respect to more distant objects
      i) Think of when you stare out a car window
   b) Use the apparent movement of the object to geometrically measure it's distance
   c) Arcsecond = 1/3600 of a degree
   d) 1 parsec = 3.3 light-years
   e) Galaxies are measured on 1000 parsec scales (kiloparsec)
   f) Universe measured on 1,000,000 parsec scales (Megaparsec)
   g) *Star Wars* fans: what kind of nonsense did Han Solo mean when he said the Millennium Falcon made the Kessel run in 8.3 parsec (whatever)
5) Let's get back to our tour of the Universe
   a) What are these images again?
6) The Solar System
   a) What is the bare minimum you need to have a star system?
   b) We have an overabundance of stuff:
      i) One star (curious it's alone)
      ii) **Eight** planets
      iii) Every planet has at least one moon
      iv) Asteroids are leftovers from solar system formation (so are moons, usually)
         (1) Asteroid belt, Kuiper Belt (trans-Neptunian objects)
      v) Comets are more leftovers but they come from farther away (Oort Cloudy)
7) **Pluto** and IAU Resolution
   a) IAU0603: 2006 General Assembly (24 August 2006, Prague)
      ESOLUTION 5A
      The IAU therefore resolves that "planets" and other bodies in our Solar System,

except satellites, be defined into three distinct categories in the following way:

(1) A "planet"1 is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighbourhood around its orbit.

(2) A "dwarf planet" is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape2 , (c) has not cleared the neighbourhood around its orbit, and (d) is not a satellite.

(3) All other objects3 except satellites orbiting the Sun shall be referred to collectively as "Small Solar-System Bodies".

1The eight "planets" are: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.
2An IAU process will be established to assign borderline objects into either dwarf planet and other categories.
3These currently include most of the Solar System asteroids, most Trans-Neptunian Objects (TNOs), comets, and other small bodies.

RESOLUTION 6A
The IAU further resolves:

Pluto is a "dwarf planet" by the above definition and is recognized as the prototype of a new category of trans-Neptunian objects.

   b) Conspiracy theory: Pluto was the first and last planet discovered by an American (Kansas farmboy); then "Xena" was discovered by another American (Mark Brown at Caltech) and that's when the controversy started; you might think the international community is sending a message against anything American (sort of like Jimmy Carter being awarded the Nobel Peace Prize)

8) Phases of the Moon (**crucial** to the homework) ← need slide handout
   a) **Concept question:** What causes the moon to go through phases?
      i) Common misconception: phases due to Earth's shadow on Moon
9) Why doesn't a solar eclipse happen every month?
   a) Think of relative sizes (and we'll see this more concretely in a moment)
10) Are lunar eclipses more common?
11) Overall structure of the solar system is a plane
   a) This is a shape that is common in astronomy
   b) Flattening like pizza dough when you take a spherical object and spin it fast
12) Classification of planets
   a) Classification is a common theme in astronomy
      i) You'll learn a lot about it if you do the Galaxy Morphologies project
      ii) The biology course also emphasizes classification schemes

b) **Concept question:** what are the important qualities? Why are they?
   i) *Formation*: terrestrial planets formed in a different environment from the gas giants
   ii) *Size and shape*
   iii) *Density*
   iv) *Location*
   v) *Environement*: this partially differentiates the dwarf planets from planets
c) Dwarf planets are a recent thing (see above about IAU Resolutions)
   i) They're small with "moons" that are comparable in size
   ii) Typically trans-Neptunian
   iii) Ceres is in the asteroid belt
   iv) They're spherical as opposed to random shapes like asteroids

13) Rings are smeared out elements of would-be moons
   a) Colors tell about chemical composition (water versus types of rocks)
14) Galilean Moons are just cool (we might be able to see them at Lick)
   a) Largest to smallest (size and mass): Ganymede, Callisto, Io, Europa
   b) Distance from Jupiter: Io, Europa, Ganymede, Callisto
   c) Io: most volcanically active in solar system; perhaps has magnetic field; thin sulfur dioxide atmosphere
   d) Europa: smooth; layer of water (ice and liquid) around mantle; perhaps being stretched by pull of Jupiter and Ganymede
   e) Ganymede: largest moon in solar system; verified magnetic field; water ice and small oxygen atmosphere
   f) Callisto: one of the most heavily cratered satellites; layer of ice above layer of water; small atmosphere of carbon dioxide
15) Scale model of the solar system
16) The Sun: the only star we can see during the day
   a) Sunspots are actually cooler regions (4000-4500 K) thought to due to base of strong magnetic field lines
   b) Increase in number density for 11 years and then decrease for 11 years
      i) Start at poles and migrate towards center
   c) Though sunspots mean cooler regions of Sun, indicate higher solar activity, and typically more insolation in general
17) Solar flares typically occur near sunspots (so also due to magnetic fields)
   a) Extremely energetic ejection of charged particles (lead to auroras on Earth)
   b) Aurora color shows chemical composition of material (green and red is oxygen)
18) Stars: building blocks of the Universe
   a) Not very dense
   b) Typically come in close systems (our Sun is unusual)
      i) Also the hints of planets
   c) Variety of sizes, larger being more rare, smaller being very common (implies also that planets are more common yet)
   d) Environments
      i) In part determine the life of the object
      ii) Colors are important
19) ISM: Stuff between stars

a) It's stuff that's been in stars and will be in stars again
b) It's been all churned up so that it's not like dust on the top of the TV but the garbled stuff you don't clean enough
c) If close and dense enough, no background like comes through it (though there may be lots going on inside)
d) Other ISM clouds are in such an environment that they can reflect like
   i) **Concept question:** what must the dust be like to reflect light?
   ii) The reflection may be from external or internal source
e) Dust can also get warm enough to glow (blackbody nature)

20) Planetary Nebulae
   a) Fate of stars about the size of our Sun
   b) **Concept question:** what does the shapes lead you to think?
21) Neutron Stars: he other fate of stars
   a) Massive but not too massive stars end up as neutron stars
   b) When atoms when so compact that electrons mush into protons to become neutrons and only neutrons have enough strength to stop further collapse into black holes
   c) As typical in astronomy, the large spinning sphere becomes a smaller, faster spinning sphere, and roughly the magnetic field becomes denser (hence stronger)
22) Black holes: cool
   a) Highest mass star's death
   b) Black holes are only known by signatures: bent light, fast-moving matter, high energy emission
   c) So massive they bend light!
   d) Anecdote: Let's talk about tossing *female* astronomers into black holes…
23) Galaxies: all shapes, sizes, colors
   a) How can we see what we're in? How do you take a picture of the forest when you're in the thick of it?
   b) Similar to star clusters, the environments of galaxies tell about what has happened to them and what is likely to happen to them
   c) It's surprising there's a jet in an elliptical galaxy because they typically don't have much miscellaneous gas and the configuration to accrete gas and eject it
   d) It's very important to consider projection effects when looking at astronomical objects because there's a whole big Universe out there that we can only see in 2D
   e) Irregulars are a good catch all for things we don't quite understand, but more likely they're galaxies in turmoil
24) Galaxy groups
   a) Many types of galaxies in a galaxy group (unlike galaxy clusters)
   b) Galaxies clusters much like stars do (all thanks to gravity)
   c) Milky Way is in a rather sparse part of the Universe
      i) But we're finding new ones all the time actually
25) Interacting galaxies
   a) With greater density, there is more chance for galaxies to get entangled, as it were
   b) Note with the Seyfert's Sextet, there's a foreground (or background) galaxy not actually involved with the rest of the mess
26) Galaxy clusters

a) Even denser than galaxy groups
b) Rarer
c) Typically elliptical galaxies

27) HDF
a) 1995
b) WFPC2
c) 10 total DAYS of observing, near the Big Dipper
d) (Southern version similar from 1998)

28) UDF
a) 11.3 days with ACS in 2003-2004
b) Taken in center of HDF-S

29) **Concept question:** what new fact did you learn?

TELESCOPE/OPTICS ACTIVITY

Timeline:

1:00-1:10	Introduce activity and describe timeline
1:15-1:25	Gather prior knowledge of students about telescopes
1:25-1:30	Assemble cardboard telescopes
1:30-1:50	Play outside with telescopes having student make concrete observations (starter)
1:50-2:00	Generate questions as group and record (sorting as able; "gallery walk")
2:00-2:30	Have students form groups and explore one lens with raybox (early investigation)
2:30-2:45	Regroup and share knowledge of one lens ("break")
2:45-3:15	Have groups create 2D telescope and explore (late investigation
3:15-3:45	Regroup and group share out/ synthesis
3:45-4:00	Allow students to play with other raybox optics

Content Goals:
1) Refracting telescope uses (convex) lenses
2) Simple (2 optics) refracting telescope magnifies and invert images
3) Farther the object distance the shorter the telescope length
4) Convex lenses bring parallel light to a point (focus)
5) More curved lenses bend light more sharply (shorter focal length)

Process Goals:
1) Simplify system and understand each component
2) Question generation
3) Making subtle observations (seeing the results through the noise)
4) Find motivation in a narrowly defined and supplied activity
5) Ray tracing (model of physical set up)
6) Presentation skills (distinct clear statement of observations)

Equipment:
- Cardboard telescope kits for everyone
- Graph paper covered tables
- Rulers
- 6 rayboxes
- Large plano-convex raybox lenses (as many as possible)
- Large convex raybox lenses
- Small convex raybox lenses (same thickness as large and hopefully of different thickness)
- Extra materials:
    - Concave raybox lenses, convex and concave raybox mirrors, etc
    - Large concave and convex lenses and mirrors
    - Lasers

Activity Outline:

1) Outline to the students the nature of this inquiry-esque activity
   a) Introduce Julia
   b) Learn about telescope and optics through hands-on investigation
      i) Not everything will be explained today but finish during lecture next day
   c) Practice asking and investigating questions
      i) Will be useful for the full inquiry later
   d) Practice sharing new knowledge
   e) Share classic elements of inquiry for learner
      i) Nature of facilitators
      ii) Frustration is key to furthering understanding
      iii) Done stuck and stuck stuck
      iv) Discover as group but respect how each other learns (including pace and point of view)
      v) Form groups yourselves but try to match with people of similar knowledge
2) Prior knowledge: poll the students for what they know about telescopes
   a) Record on posters
3) Starter: give the students cardboard telescope kits and assemble
   a) Go outside and play with telescope
   b) Students should notice (or help some notice):
      i) Image inverted
      ii) To focus on farther objects requires the telescope to be shorter
      iii) Primary lens is very thin (but make them notice it is curved)
      iv) Eyepiece has thicker lens (it's shaped as half sphere but that doesn't matter)
      v) Looking through primary lens first causes everything to shrink
4) "Gallery Walk": Return and group question generate
   a) Turn the above observations into question
      i) Why is the image inverted?
         (1) Prior knowledge: some students may know that one lens inverts the image so why doesn't the second lens re-invert the image?
         (2) May also know that eye inverts image and wonder how that affects
      ii) Why is the telescope shorter when looking at objects farther away?
      iii) Is the primary lens really curved?
         (1) Why is it so thin?
      iv) How does the half sphere eyepiece lens work?
      v) Do all telescopes shrink images when viewed in reverse?
      vi) What is the bare minimum needed to build a telescope
      vii) What would happen if we had a larger lens?
         (1) This could be a QWWWNDATT
   b) QWWWNDATT include questions about:
      i) Mirrors and reflecting telescopes
      ii) Size of primary mirror
      iii) Diverging lenses (magnifying glasses)
5) Early Investigation: Have students work in 3's and explore nature of one convex lens with raybox
   a) Some groups will have very curved, semicirclular lens ("plano-convex")
   b) Other groups will have usual convex raybox lens

c) Advanced students may get curved mirrors or other optics
d) Make sure raybox is parallel
    i) But students can play with non-parallel light
e) Guide students to understanding the image inversion by blocking individual rays
f) Measure focal point of optics

6) "Break": Regroup and discuss what everyone has learned
    a) There is a point where all light converges (focuses)
        i) This is only the focal point if the light is parallel
    b) Image inversion is due to how light from one point along the source is bent across the parallel of the optic
    c) Lens is symmetric (even if one side is curved and other flat, the properties of the lens is the same no matter which side the light enters)
7) Late Investigation: next explore with two lenses
    a) (Going to have equipment shortage of large curved lens?)
    b) Thin curved primary
    c) Thick curved secondary
    d) Measure distance between rays before entering primary and after exiting secondary
        i) Rays closer together indicate magnification, because a larger field of view will be in a smaller area for viewing
    e) Facilitate students to realize that distance between optics (to re-collimate light) is sum of focal lengths of optics
8) Synthesis
    a) Have students each share one new piece of knowledge
        i) Record
    b) Point out how students cover content goals (hopefully!)
    c) Effect of eye in system
        i) Eye optimized for parallel light
        ii) Eye traces light back to "image" (which may be real or imaginary)
    d) Ask how we might extend our study to different optics
        i) Concave lenses
        ii) Concave mirrors
        iii) Convex mirrors
    e) Also have follow-up lecture next day

Figures:

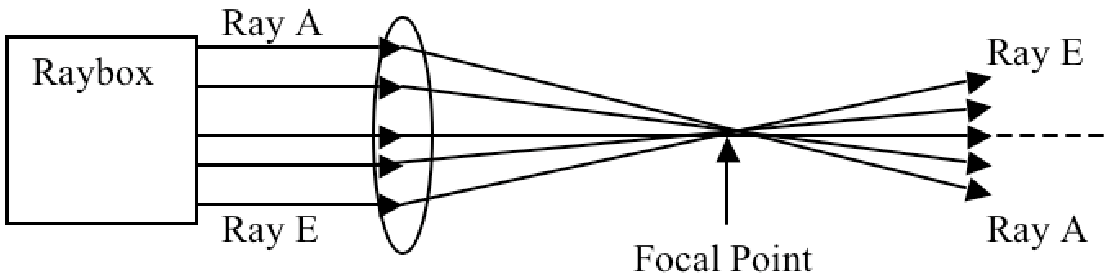


Figure 1: Single lens setup

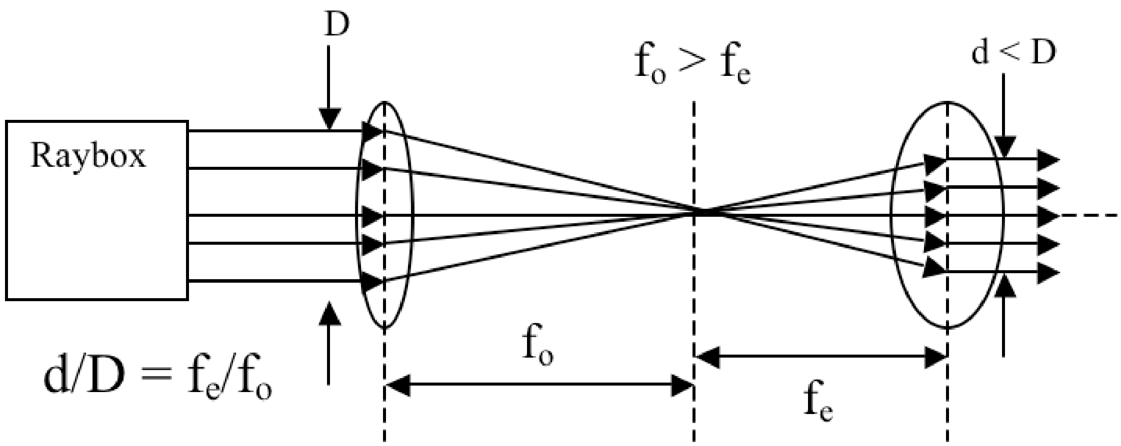


Figure 2: Raybox "telescope"

TELESCOPES

1) Discuss refraction and lens equation, relation between focal point, image distance and object distance
   a) Note the symmetry
2) Refracting telescope
   a) Ray diagram
3) Cardboard telescope activity
   a) See if they can figure out image inversion and how eye plays into it
4) Two main purposes of telescope
   a) Sensitivity (larger light bucket area)
   b) Resolution (detail)
5) Sensitivity scales with area (proportional to diameter squared)
6) Resolution scales with diameter directly
7) Beware the effect of exposure time and why
   a) Telescopes have to be able to point very well for minutes to hours
8) Telescopes can be constructed to peak in a variety of wavelengths
   a) Primarily due to coatings
   b) This brings in the topic of the electromagnetic spectrum
9) Electromagnetic spectrum
   a) PAUSE on this slide and navigate them through it
   b) Atmosphere limits what we can see from Earth's surface
      i) Thankfully too, because the high energy stuff can rip our DNA to shreds!
10) So there are telescopes in space and on Earth
    a) And the ones are Earth can be in different places depending on what wavelengths they are interested in
11) Reflectors vs Refractors
    a) Emphasize, all modern astronomy uses reflectors
    b) Ray-trace diagrams and examples of telescopes that use that format
       i) Arecibo is radio and it's ok if it has to observe through atmosphere
12) All modern astronomy telescopes are reflectors
    a) Easier to make to precision required and be large
    b) Doesn't deform over time (fluid glass)
    c) Can be segmented
13) Primary mirrors
    a) Hard to make large glass lenses hold their shape so turn to mirrors
    b) Hard to make quality large mirrors
    c) Keck tried making small mirrors and lining up well
    d) Others use *active optics* and actually bend the mirror in real time just a touch to fix things up
14) Science still going on at Lick Observatory, which we'll visit shortly
    a) And it's a site with poor seeing that's still important because it is a test bed for adaptive optics
15) The trouble with the atmosphere
    a) Classical analogy, air above hot pavement and how everything is wavy behind it
    b) Telescopes in space *completely* avoid the problem

16) Summary
   a) Refracting telescopes have a primary lens
      i) AKA refractors
   b) Reflecting telescopes have a primary mirro
      i) AKA reflectors
   c) Sensitivity is amount of light
   d) Resolution is amount of detail
   e) Always want larger telescopes (30-m!)
   f) Space is above the atmosphere and the troubles it causes

CCDs

Materials:

- Example CCDs
- Tarp
- Large bag of confetti
- Hand held buckets for everyone (about half-gallon sized)
- Read-out grid on large poster
- Camera

1) Difficult to make a perfect optical system
   a) From a perfectly formed mirror to a perfect CCD, it just doesn't happen
   b) Have to worry about image processing
2) CCDs are pretty electronics
3) How CCD works
   a) Grid of regularly spaced pixels
   b) Each pixel is a light bucket
      i) It's a bucket brigade to gather and move along
   c) Each pixel is a potential well (locus of positive charge) into which electrons can be gathered (and later counted)
      i) The oppositely charged edges create a potential barrier
4) Human CCD Activity
   a) Be very clear what is going on
   b) Emulate a point-source with PSF
   c) Actually have someone be a counter (as opposed to just dumping)
   d) Then try various problems
      i) Saturation
      ii) Integration time
      iii) Read noise
      iv) Low-quantum efficiency pixel
      v) Dead pixel
      vi) Bias
      vii) Sky
      viii) Hot pixel
   e) Take TIME to explain things as we go along
5) How CCD works (review)
   a) **Remember:** focus on having the students map the concepts to the activity
6) Extrinsic problems—Stuff the astronomer should be aware of
   a) PSF is summary of many imperfections in telescope system
   b) Saturation is a poor choice (but occasionally necessary) on behalf of the astronomer
   c) Dust donuts are grains on the filters not in focus
   d) Cosmic rays are energetic particles that just over-energize single pixels
7) Intrinsic problems—Also stuff astronomer should be aware of but can be helped with a better detector

a) In manufacturing, individual pixels (or rows or columns) aren't up to snuff and just don't work as planned
b) Same problem with bias, electrons are everywhere, it's tough clearing them out completely
c) Similarly, for QE, pixels don't want to behave exactly the same (like high school students with the same homework assignment, everything ends up different)
d) Read noise problems was exampled by us as we were trying to move around confetti and someone tried to estimate what was up

8) Color images
   a) CCDs are BLIND!
   b) Use filters to trace only the light of interest
   c) Combine (as will happen in Galaxy Morphology project) to make beautiful false or real color images
      i) Transmission functions of example filters
   d) Slightly different in digital cameras
      i) It interpolates between pixels that *only* see one color (so it's not true color you see with your eyes)
      ii) Another method is to have tri-colored images combined later
9) **Concept question:** What have you learned?
   a) Let the students name what they think was important or new
   b) Ask them if they know something that I don't (or at least didn't share)
10) Summary
   a) KNOW why astronomers have to have CCDs and how they work
   b) Image processing is an important part of astronomer
      i) Accounts for flaws in the system: in CCD, in telescope optics, due to exposure time, due to read-out
   c) CCDs are color blind

ASTROPHYSICS I: COSMOLOGY

1) **Concept question:** How do you think the Universe began and evolved to its present state?
   a) Another phrasing: what do you think cosmology is?
   b) Asking students to piece together what they collectively have learned from wherever
   c) Maybe heard about
      i) Dark matter and dark energy
      ii) Expanding Universe
      iii) Accelerating Universe
      iv) Big Bang
      v) How long things have taken to evolve?
2) Big Bang timeline
   a) http://www.pbs.org/wnet/hawking/universes/my_html/bigbang.html
   b) Big Bang occurred everywhere, not at a point
      i) Marks the beginning of what we can know
   c) Technically, we can know from $t = 10^{-43}$ s, which is the Planck time
      i) Quantum mechanics limit, I believe
   d) At 10^{-43} s gravity separates from electromagnetic and nuclear forces
      i) 10^{32} K
   e) At 10^{-35} s strong nuclear force separates from weak and electromagnetic forces
      i) 10^{27} K
      ii) Inflation begins (until 10^{-32} s)
         (1) Universe is homogeneous and isotropic
         (2) Required so that one distant part of the Universe can look like the other (when they are causally separated)
      iii) Quarks and anti-quarks dominate the Universe
   f) At 10^{-12} s weak and electromagnetic force separate
      i) Protons and neutrons form
   g) At 0.01 s electron and positrons form
      i) 10^{11} K or 100 GK
   h) At 1 s Universe transparent to neutrinos
   i) At 3 minutes neutrons and protons combine into hydrogen and helium
      i) 10^{9} K
   j) At 300,000 years ($z \sim 1000$) electrons combine with ions to form neutral atoms
      i) 3,000 K
      ii) Universe transparent to light—Cosmic Microwave Background
      iii) Last scattering surface
   k) At 1 Gyr ($z \sim 6$) galaxies begin to form
      i) 20 K
3) Cosmic Microwave Background
   a) Microwave is about one centimeter
   b) Strongest evidence for the Big Bang theory
      i) And inflation
   c) 2.725 K and RMS of 18 micro-Kelvin

    i) Redshifted from 3,000
    ii) Most perfect blackbody radiation detected in nature
d) Universe is homogeneous and isotropic
e) CMB is isotropic (uniform) to one part in 100,000
f) Discovered in 1965 by Penzias and Wilson at Bell Labs
    i) Classic story
    ii) Discovered more noise in their new microwave dish than expected
    iii) Not bird poop
    iv) Same amount of noise night and day, any direction
        (1) Must be external to atmosphere and *everywhere*
        (2)

ADAPTIVE OPTICS

ASTROBIOLOGY

GENERAL ASTRONOMY

LICK FIELD TRIP

- Remind students that the tour will be outside where it is HOT and SUNNY
    - Bring hats and wear sunblock
- Remind students it will be cold at night
- Remind students how awful ride up can be for motion sickness
- Remind Ellie (or guide) not to mention eclipsing binaries

COLOR, LIGHT, & SPECTRA INQUIRY

DEBRIEF

- Need second small black light
- Be more heavy-handed earlier
- Hang up on shape of filament and effect on spectra with hand held gratings
    - Use hot dog bulb and send in curly compact bulb
- Emphasize drawing more
- Focus on hypothesizing and control
- BULB BURN SAFETY statement
- Ray boxes color mixing as important avenue of seeing white light is all colors but wasn't used

PROJECT SELECTION

- Good brief presentations (<2m and <2 slides per advisor)
- Students may felt rushed and made arbitrary decisions
- Prep by asking students to hold questions until end, don't choose friends but choose project, and rank projects on ballot
    - Make it more apparent how instructors are going to piece out the project groups

SKY OBSERVING

Materials:

- Green laser pointer
- Headlamp
- Red lights
- Planispheres
- Starry Night software
- Small telescope and someone who can use it

REMOTE OBSERVING

- Make sure instructors hand out observing manual
  - Know about flat fields and bias
  - Now about slewing telescope to target
    - RA, DEC
    - HA and airmass (atmosphere)
    - LST, PST, UT, …
  - Understand about filters and exposure time
    - Saturation limits but also want enough counts for signal
  - Readout time
  - Focusing, pointing
- Nickel set up
  - Record!
  - Bin by 2
  - Slow read
- During each observation, students will need to modify…
  - Image name
  - Filter
  - Exposure time
  - Filter
- Students should record on log sheet…
  - Observation number
  - Object
  - RA, DEC
  - Filter
  - Exposure time
  - Time (whether PST, UT)
  - Airmass
  - Any comments (counts)
- Instructors should know the HA limits of the Nickel (Javiera) to know when things are out of range
- Typical galaxies:
  - M63 (13:15:54, 42:01:45)
  - M101 (14:03:19.5, 54:20:57)
  - M102 (15:06:40.2, 55:46:26)
  - M51
- Typical galaxy exposure times
  - B: 420 to 480 s
  - V, R: 300 s
- Typical variable star exposure time (SZ Her)
  - Readout dominated
  - Minimum B: 50 s
  - Minimum V: 40 s
  - Ingress/egress B, V: 30 s
  - "Continuum" B: 20 s

- "Continuum" V: 10 s

ASTROPHYSICS II: STARS

1) Basic properties of stars
   a) Primarily composed of H, He
      i) Some heavier elements (metals): C, N, O, Cr, Fe (TiO)…
      ii) Concept of "metals" in astronomy is different than in chemistry
   b) Fuse H into He for majority of life
   c) Mass determines life time
      i) More massive stars have shorter life
   d) Color primary indication of temperature
      i) Hotter, brighter, bluer
      ii) Cooler, dimmer, redder
2) Three types of spectra
   a) Resources
      i) http://www.mhhe.com/physsci/astronomy/arny/instructor/graphics/ch03/0313.html
      ii) http://www.solarobserving.com/halpha.htm
   b) Shown is H but apparently the green line can be excluded
      i) H-alpha is transition from 3rd level to 2nd (emission) (red)
      ii) Also is 4 to 2, 5 to 2, 6 to 2 (latter two are close purple lines, while the first is cyan)
3) Stellar spectra (stack)
   a) Stellar classification indicates temperature, color, brightness of object as well as some info on the chemical composition seen in spectra
4) Blackbody radiation
   a) Blackbody is idealized object that absorbs all radiation falling on it
      i) Light energizes atoms, causing them to move faster, causing them to collide more often, which results in more light re-emitted (with higher energy)
   b) The radiation blackbody emits is purely due to temperature
      i) NOT to be confused with reflected light
      ii) School bus example
   c) Common blackbodies
      i) Electric stove coils or metal heated in flame
   d) Peak wavelength proportional 1/T (Wien's Law)
   e) Intensity proportional to T to the fourth power (Stefan-Boltzmann Law)
5) How to make a star
   a) Collapse interstellar clouds
   b) This is the fundamental principle
   c) Rest is just details
6) Orion Nebula in optical and IR wavelengths
   a) Nebula in this case is a bunch of gas and dust, like a cloud
   b) IR helps see the protostars that are obscured in visible light
7) How to make systems
   a) Common property of astronomy spheres, if they're even slowly rotating as they begin to collapse under influence of gravity, they'll flatten and spin up
   b) Why disks are so common in astronomy

c) **CLS tie**
    i) We can detect rotation with "rotation curve" and look at blue- and red-shifted sides

8) Protostars nnd Disks
    a) Runaway accretion effect, the bigger a clump gets, the more it accretes
    b) This is true of stars as well as future planets (planetiesimals)
9) Once you have a star
    a) Mass determines rest of it's life
    b) Massive stars burn brightest and flame out
        i) Like rock stars (Laura Chomuik's analogy)
    c) More mass means more pressure in core
    d) More pressure causes more fusion and eats through supply faster
10) Life of Stars
    a) Lifecycle of stars like our Sun (not moving in loop)
11) Main sequence
    a) Delicate balance between gravity pushing in and radiation pressure pushing out
    b) Fuse H into He in core
    c) Longest phase of star's life
12) What next?
    a) H fuel runs out in *core*
    b) Start changing appearance and property of star
    c) "THE END" depends on *mass*
        i) Low mass < 8 solar masses
        ii) High mass > 8 solar masses
        iii) "Solar masses" is a useful unit because it relates to size we sort of understand (like how we use AU)
13) Red Giants
    a) Core collapse, gravitational energy translates to puffing up outer layers
    b) No heat source so everything cools and becomes *redder*
    c) Core contracts until enough pressure to fuse He into C
    d) Could save from the fate of being eaten by outer layers by long term planning and comments (Laughlin story)
14) End for low mass stars
    a) Core contracts and heats once He runs out
    b) Carbon cannot fuse in low-mass case
    c) Increasing density in core until supported by electron degeneracy pressure
15) Electron degeneracy
    a) Electrons don't like being close together and will exert great force to stay apart
    b) Essentially make crystalline structure where all electrons can be evenly spaced
16) Current state of dying star
    a) Core dead, nothing fusing and no more contracting
    b) Shells have puffed of, continue expanding (revealing core), and cooling
    c) Revealed core heats the nearest layers and helps them glow
17) Planetary nebula (Ring Nebula)
18) White dwarf
    a) Remnant carbon core

b) Size of earth (but a thousand times more dense)
c) No more fusion, NO LONGER A STAR
d) Glow by remaining heat, eventually fade to black dwarf

19) High-mass stars
   a) Initial phases like low-mass stars, up to core fusing He
   b) Next contraction allows higher element burning (also faster and faster)
   c) Can't fuse Fe into anything else (most stable element, anything beyond it is not favored energetically)
20) End for high-mass stars
   a) Fuel runs out
   b) Core collapses and rebounds
   c) Supernova!
   d) Eject gas and new elements far away, into interstellar medium, for future stars to use
   e) Every element heavier than Fe created in supernova explosion because enough excess energy around to fuse
21) We are stardust
   a) Phosphorus of DNA made inexplosion
   b) Gold, silver, titanium
22) About the core
   a) Not all material dispelled outwards
   b) Still dense contracting core (runaway collapse due to gravity)
   c) Electron degeneracy not enough
   d) Stops because of neutron degeneracy pressure
23) Supernova
   a) Rebound from neutron degeneracy pushing outwards
24) Stellar lifecycle summary
   a) Low-mass stars
      i) Like Sun (< 8 times as massive as Sun)
      ii) Long lived (measured in *billion* of years)
      iii) Fuse to mostly He
      iv) Planetary nebula and white dwarf end state
      v) Most common
   b) High-mass stars
      i) > 8 times more massive than Sun
      ii) Short lived (measured in *millions* of years)
      iii) More fusion (C, N, O…)
      iv) Supernova and neutron star or black hole
      v) Makes most important elements (to humans!)

PROJECT TIME

COLLEGE COUNSELING & COLLEGE/GRAD/LIFE Q&A

- Contact Sharon Dirnberger (Senior Admissions Evaluator/Counselor, Office of Admissions); 831.459.2131, sharond@ucsc.edu
- Photocopy transcripts and send to Sharon
    - Supplement with students writing their spring semester 2007 classes and grades, if possible
- 9:00-9:30 General intro of UC and CSU requirements
- 9:30-noon small group evaluations
    - Divide groups by age
    - Group 1 (11th+): Angela (GM), Trevor* (LW), Gerald* (AB)
    - Group 2 (9th): Carla* (GM), Ankur (AB), Victor* (LW)
    - Group 3 (10th): Jenny (LW), Stacy (GM)
    - Group 4 (10th): Mark, Kaila, MaryAnne* (all AB)
    - Group 5 (10th): Maggie*, Sanaya, Olivia (all VS)
    - Group 6 (9th): Marcella, Betty*, Megna (all B&B)
    - *Indicates ED Grade > 4 (arbitrary cut)
    - GM: Galaxy Morphology; VS: Variable Stars; AB: Astrobiology; B&B: Birds & Bees; LW: Life of Whales
    - This system will allow the groups to be notified easiest
- 9:30-9:50 Trevor, Gerald (Anglea optional)
- 9:50-10:10 Carla, Ankur, Victor
- 10:10-10:30 Jenny, Stacy
- [Break—reset scheduling]
- 10:45-11:05 Mark, Kaila, MaryAnne
- 11:05-11:25 Maggie, Sanaya, Olivia
- 11:25-11:45 Marcella, Betty, Megna

COLLEGE/LIFE/GRAD Q&A (2:30-4:00 then off to picnic)

i) Resources:
   (1) http://www.nsf.gov/statistics/infbrief/nsf06304/
   (2) http://www.back2college.com/library/reports.htm

ii) Facts
   (1) InfoBrief: *2003 College Graduates in the U.S. Workforce: A Profile* (Science Resources Statistics)
      (a) "Over one-third (38 percent) of all employed college graduates in the United States have attained degrees higher than a bachelor's degree"
      (b) "Individuals with higher levels of degree attainment also command higher salaries. Those with professional degrees (including law and medical degrees) earned the highest median salaries ($95,000), followed by those with doctorates ($70,000), then master's degrees ($54,000) and bachelor's degree ($47,000)."
         (i) This is the *median* so half will earn more
      (c) "Nearly half (49 percent) of all college graduates in the United States are women"

(i) "Women have been more likely than men to enroll since the late 1980s, and the gender gap is widening." [*Education Pays 2004*, CollegeBoard]

(2) *Education Pays 2004—The Benefits of Higher Education for Individuals and Society* (CollegeBoard)

(a) Though possible to have great economic future without college degree (e.g. Bill Gates, athletic stars), any personal attributes that would lend themselves to such a future will most likely still be there after college—so why not attend college?

(b) "In 2003, the average full-time year-round worker in the United States with a four-year college degree earned $49,000, 62 percent more than the $30,800 earned by the average full-time year-round worker with only a high school diploma."

(i) As seen in *Trends in College Pricing*, the average student having attended a 4-year public university has $15,500 worth of debt.

(ii) "The typical student who borrows to finance a bachelor's degree graduates with less than $20,000 in total debt." [*Trends in Student Aid 2005*, CollegeBoard]

(iii)Such students are easily set to pay off this expense.

(c) Disclaimer: "While the average high school graduate might not increase his or her earnings to the level of the average college graduate simply by earning a bachelor's degree, careful research on the subject suggests that the figures cited here do not measurably overstate the financial return of higher education."

(d) "Accounting for the fact that some of the higher earnings are many years in the future, the increased earning power of a college education is worth about $450,000 in today's dollars. Including advanced-degree holders increases the lifetime earnings premium to about $570,000."

(e) "By the age of 33, the typical college graduate who enrolled at age 18 has earned enough to compensate for both tuition and fees at the average public four-year institution and earnings forgone during the college years."

(i) Though paying debt off until 33, still have money to spend (and more than had previously if not more than would-have-had.)

(f) "According to Census data, the average annual earnings for college graduates between the ages of 25 and 34 are $14,700 higher than the average earnings for high school graduates, over three times the annual tuition at a four-year public college in 2003-04."

(g) As for diversity, everyone (whites, blacks, Hispanics, Asians, men, women) *does* win by going to college, but white men win most

(i) Everyone "wins" 50% more income from having a college degree than just having a high school degree

(ii) Unfortunately, the gain for Hispanics is not as much as for whites (which is not as much as for Asians!)

(iii)Unfortunately, women do not "win" as much as men (men earn about 60% more whereas women earn about 58%)

(iv) There is some hope: "enrollment rates by socioeconomic status narrowed slightly over this 20-year [1972-2002] period."

(h) "Women with four-year degrees or higher earned 9 percent more in inflation-adjusted dollars in 2002 than in 1972. Women with lower levels of education experienced declines in real earnings ranging from 10 percent to 17 percent."
   (i) Because it's a "man's world," women really need a college degree

(i) Unfortunately, the rich get richer and poor get poorer from 1972 to 2002 (the highest quartile earned more while the lowest quartile earned less).
   (i) Education scales with socioeconomic status.
   (ii) Having attained higher education oneself will increase the well-being of one's family.
      1. Unfortunately, currently, "Students who are independent of their parents are not included here. They constitute almost half of all students and are disproportionately from less affluent families."

(j) Higher education helps maintain employment (and helps lower reliance on social/federal aid.)
   (i) "It costs about $26,000 a year to maintain a prisoner."
      1. Cheaper to send them to college!
   (ii) "Estimates from the RAND study suggest that overall every dollar spent on equalizing college entrance rates across racial/ethnic groups would yield between $2.00 and $3.00 in public savings, with a third to half of the benefits coming from savings on social programs and the rest from increased tax revenues."
   (iii) "Controlling for other differences, Moretti (2004) found that a 1 percentage point increase in the proportion of four-year college graduates in a city increases the wages of workers without a high school diploma by 1.9 percent, and the wages of high school graduates by 1.6 percent." (*Education Pays Update 2005* CollegeBoard)

(k) Higher education correlates with better health.
   (i) "Statistical analysis reveals that even after controlling for income, education level explains a significant portion of the difference in smoking patterns."

(l) Unfortunately, standardized tests are how our society work, and test scores track with who goes to college and who gets money to go to college.
   (i) Fortunately, test-taking is a skill that can be *learned*.
   (ii) "Income differences tend to have a smaller impact on college enrollment rates of high school graduates with high test scores than those with lower test scores."

(m) "The United States ranks highest in the world in terms of four-year degree attainment among older adults."

        (i) Could be interpreted that these older adults realized they *needed* better degrees to get better jobs.

(3) *Education Pays Update 2005* (CollegeBoard)
    (a) It's becoming the standard to attend college (the number of college graduates is increasing).

(4) *Trends in College Pricing 2005* (CollegeBoard)
    (a) Statistics only for full-time students and are enrollment weighted (by institution)
    (b) Some colleges charge different for different degree programs
        (i) This may be due to the variable institutional cost to maintain staff and facilities for different programs (e.g. engineering professors need to be paid a lot to keep them in academia and not industry, and this is reflected in the cost to the institution per credit hour.)
    (c) "the largest component of the cost of being a student is actually forgone earnings, which are not addressed in the report."
    (d) Unfortunately, "recent changes in student aid policies have favored those in the upper half of the income distribution."
    (e) Ultimately, getting degree quickly saves money.
    (f) Students should see if their preferred college(s) hold tuition and fees fixed for the four years to degree or by how much the tuition and fees increase each year (previously).
        (i) Students should see how their financial aid (grants, loans, scholarships) scale with increasing tuition.
    (g) Unfortunately: "Not apparent in the average prices illustrated here [net prices for public four-year colleges and universities] is the reality that both federal and education tax benefits and the changing distribution of state and institutional grant aid have reduced the average net price for middle- and upper-income students relative to the net price for lower-income students."
        (i) "On average, grants from all sources plus federal tax credits and deductions cover about 60 percent of tuition and fees and 27 percent of published tuition, fee, and room and board charges for full-time public four-year college students."
            1. "On average, grants from all sources plus federal tax credits and deductions cover about 81 percent of tuition and fees and 27 percent of tuition, fees, and commuter room and board charges for full-time public two-year college students."
        (ii) Fortunately, the COSMOS students are exceptional and so probably can have >60% (>27%) covered.
    (h) "Fifty-nine percent of full-time undergraduates enrolled in public four-year institutions and 53 percent of those attending public two-year colleges receive federal, state, or institutional grant aid"
    (i) Total published price at public four-year college or university was $5,491 in 2005-2006 and room and board was $6,636 (total: $12,127).

(i) The net price of tuition, after accounting for grants and tax benefits from federal and state governments, institutions, and private sources, is about $2,200.

(ii) The net price of tuition, fees, room and board is about $9,000.

Figure 2: Sample Average Undergraduate Budgets, 2005-06 (Enrollment-Weighted)

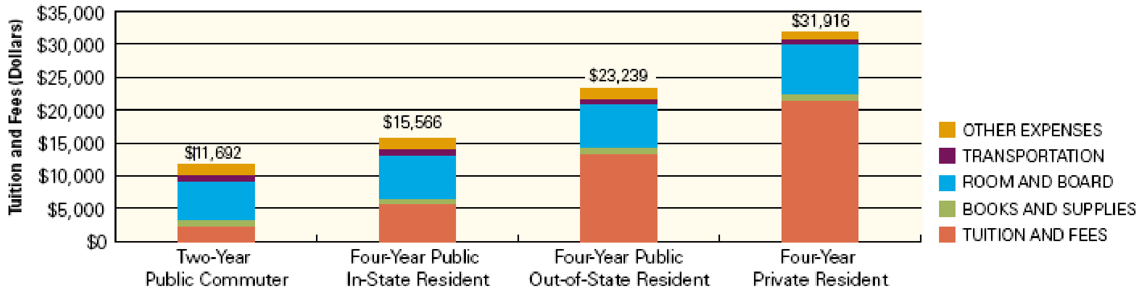


Figure 8c: Net Price: Published Tuition and Fee Charges Compared to Tuition and Fees After Average Grant and Education Tax Benefits Per Full-Time Student, Public Four-Year Colleges and Universities, in Constant (2005) Dollars, 1995-96 to 2005-06

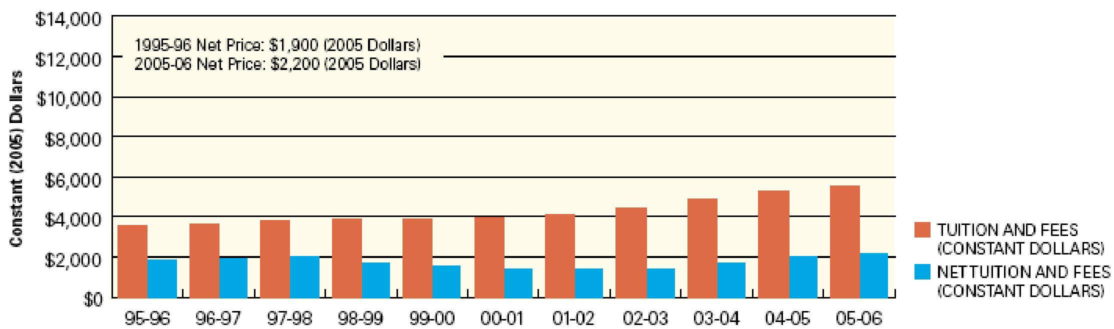
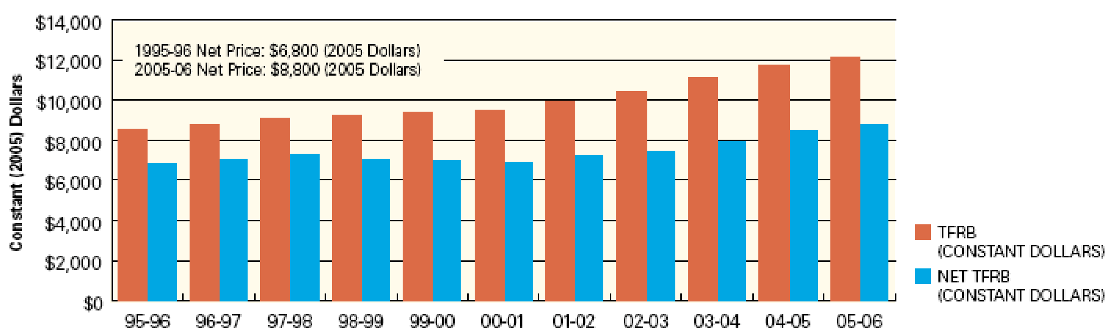


Figure 8d: Published Tuition, Fee, Room and Board (TFRB) Charges Compared to TFRB After Average Grant and Education Tax Benefits Per Full-Time Student, Public Four-Year Colleges and Universities, in Constant (2005) Dollars, 1995-96 to 2005-06



(5) *Trends in Student Aid 2005* (CollegeBoard)

(a) "As the price of attending college has increased and family incomes, grant aid, and federal loans have failed to kepe pace, the volume of student borrowing from private sources has skyrocketed and now equals about 22 percent of federal education loan volume."

(i) "Private" loans = un-subsidized (more interest, accumulate interest faster, etc)

(b) Pell grants: “need-based federal grants”
   (i) Largest source of aid to lower-income families
(c) Stafford loans: “education loans involving any federal funding”
   (i) Subsidized Stafford loans (“43 percent of federal education loans) “must be repaid after students complete their education, they involve significant subsidies since the federal government pays the interest while the student is in school and subsidizes the interest throughout the life of the loans”
   (ii) “The unsubsidized Stafford Loan Program, comprising 41 percent of federal loans, has a much smaller subsidy component because interest accrues while the student is in school. However, like subsidized Stafford loans, these loans are guaranteed by the federal government and the interest rates are below market levels.”
   (iii) Delivered through the Ford Direct and Federal Family Education Loan Programs
(d) Parent Loans to Undergraduate Students (PLUS)
   (i) Delivered through the Ford Direct and Federal Family Education Loan Programs
   (ii) http://www.parentplusloan.com/plus-loans/
   (iii) Non-need based
   (iv) Parents borrow low-interest loan to pay for student/child’s tuition, fees, room, and board
      1. Interest is fixed by government (8.5% as of July 1, 2006)
   (v) Requires parents have good credit history
   (vi) Requires *no* collateral and interest may be tax deductible
(e) WARNING:
   (i) Avoid “private” loans
   (ii) Avoid credit card debt!!!
(f) “The typical student who borrows to finance a bachelor’s degree graduates with less than $20,000 in total debt.”
(g) “Federal education loans paid directly to students make up 87 percent of all loans. These consist of 43 percent subsidized Stafford Loans, 41 percent unsubsidized Stafford Loans, and 3 percent Perkins and other lions. Parent Loans to Undergraduate Students constitute 2 percent of federal education loans.”
(h) “The percentage of students receiving Pell Grants [is] 23 percent in two-year public colleges […] 28 percent in four-year public colleges, and […] 27 percent in private four-year colleges [in] 2003-04.”
(i) Fortunately (mostly), “The proportion of students receiving Pell Grants increased among both full-time and part-time students, among both dependent and independent students, and among all racial/ethnic groups with the exception of Asian Americans.”
(j) “States awarded an average of $500 in grant aid per full-time equivalent student in 2003-04.”

(k) "In 2003-04, public four-year colleges and universities awards an average of $1,200 in institutional grant aid to full-time dependent students from families with incomes below $32,375."

(l) "On average, institutional grant aid covered 23 percent of tuition and fees for the lowest income students, 18 percent for the second quartile, 16 percent for the third quartile, and 13 percent for students from families with incomes above $91,754."

Figure 2: Estimated Student Aid by Source for Academic Year 2004-05 in Current Dollars (in Billions)

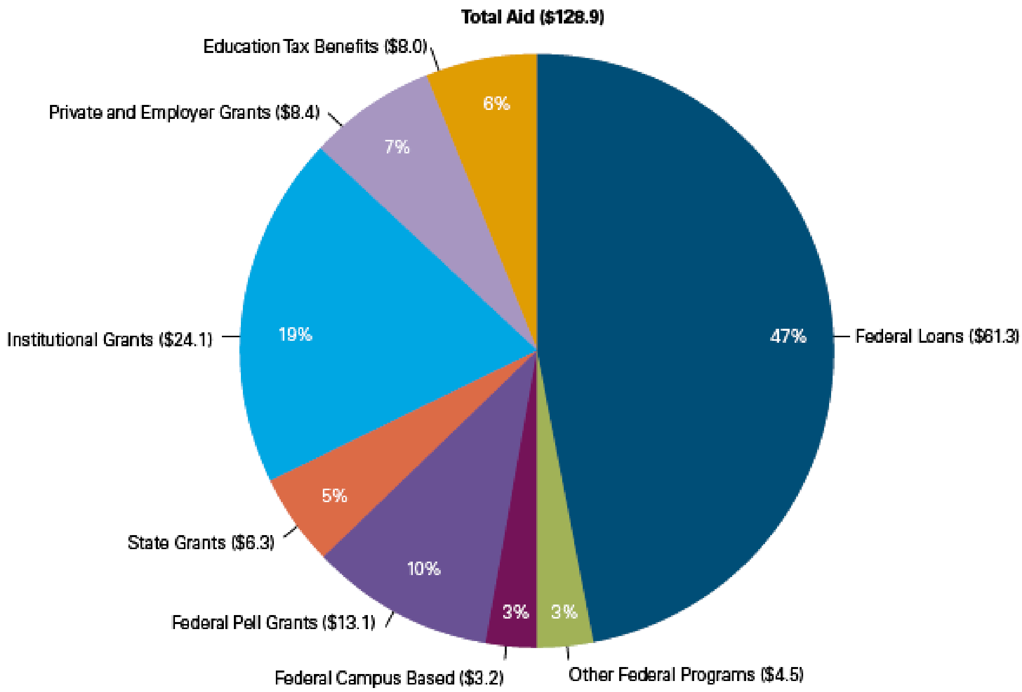


Figure 5: Debt Levels of Undergraduate Degree Recipients by Degree and Institution Type, 2003-04

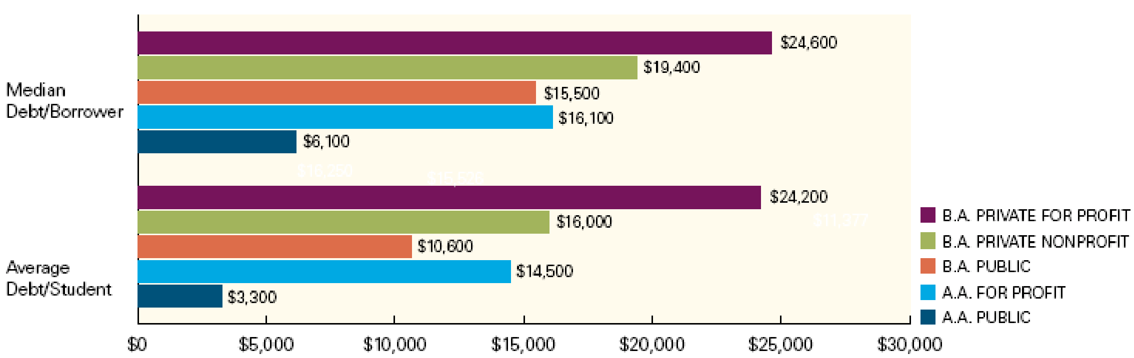
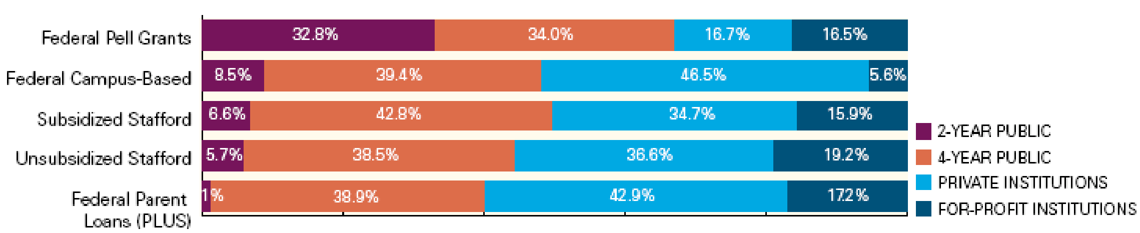


Figure 5a: Percentage Distribution of Federal Aid Programs, 2004-05



iii) 17 students, 3 instructors, 4 project advisors, 1 teacher fellow: 25 people
iv) Ryan, Tiffani, and Kathy lead discussion groups
  (1) Students count off by 6's
  (2) Kathy: 6 students (Angela may be staff and stay), 1 staff (Patrick)
  (3) Ryan: 6 students, 2 staff (Kristel, Aaron)
  (4) Tiffani: 5 students, 2 staff (Javiera, Jeff)
v) Take home messages
  (1) "Where there is a will, there is a way"
  (2) Many paths through life
    (a) Aim for one academic degree higher than currently want (more options)
  (3) Worth the investment to attain higher education
vi) Schedule
  (1) 2:30-3:00 Intro and money matters
  (2) 3:00-3:25 Small group discussion 1
  (3) 3:25-3:45 Small group discussion 2
  (4) 3:45-4:00 Group wrap-up and "Take home messages"
  (5) 4:00 (if not earlier) leave for the beach
vii) Intro
  (1) Timeline and purpose
  (2) DISCLAIMER: we're not experts, and indeed we're oddballs in the fact we're pursuing PhDs
    (a) But we know stuff
  (3) Compile questions on board for small groups to address
  (4) Malika's "Follow your College-brick road" handout plus other info
    (a) Many options
    (b) Why not over-educate?
      (i) We want you to aim for a degree higher than your current plans
  (5) Money matters
    (a) College increases amount of money you can make in short order, so worth the investment
    (b) Scholarships
      (i) Gates Millennium fellowship
      (ii) College dispensed
      (iii) Random community or philanthropy
    (c) Fellowships/grants
    (d) Loans (college or federal)
      (i) FAFSA
      (ii) Low interest
      (iii) Don't accrue interest until after stop attending school (so college can bleed into graduate school)
    (e) Work-study at college
    (f) NSF REU
    (g) Grad school pays for you (physical sciences)
viii) Small group discussion 1

(1) Field questions from students
(2) Prompts for discussion:
    (a) What level of education do you want?
    (b) What do you see as the biggest hindrance?
    (c) What do you value in a college? How do you pick?
    (d) How do you view the idea of picking a major?
(3) In prep for group swap, count off students by 2's and send 1's to one other group and 2's to the other

ix) Small group discussion 2
(1) Prompts for discussion:
    (a) What new thing did you learn in previous group?
    (b) What questions did it raise?
    (c) How is your view of higher education changing?
    (d) Any concerns about diversity (ethnic, gender, economic) in college?
    (e) State vs. public? Large vs. small?

x) Large group wrap-up
(1) What new thing did you learn?
(2) Bring up remaining questions with staff in the time remaining
(3) "Take home messages"
    (a) "Where there is a will, there is a way"
    (b) Many paths through life
    (c) Worth the investment

REUNION PICNIC

PRESENTATION PREP

- Do not let students start in powerpoint until they have an outline
- Make them create the simplest presentation with text and figures before adding fancy effects
- Once satisfied the bare bones are present, students can jazz it up
    - Previously students have had to rearrange slide order and rearrange all their custom made slide effects

PRESENTATION DAY

CLOSING DAY