Planets Beyond our Solar System:

The New Astronomical Revolution

KITP Teacher Workshop, University of California at Santa Barbara, 2010

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Outline

- (I) Stars versus Planets
  – How are they different from each another?
- (II) Habitable planets
  – What makes a planet a “habitable planet?”
- (III) Some tools to detect planets
- (IV) Mixed Problems (across the curriculum)
  – This is where physics, biology, chemistry, geology/earth science and social studies meet

Stars versus Planets

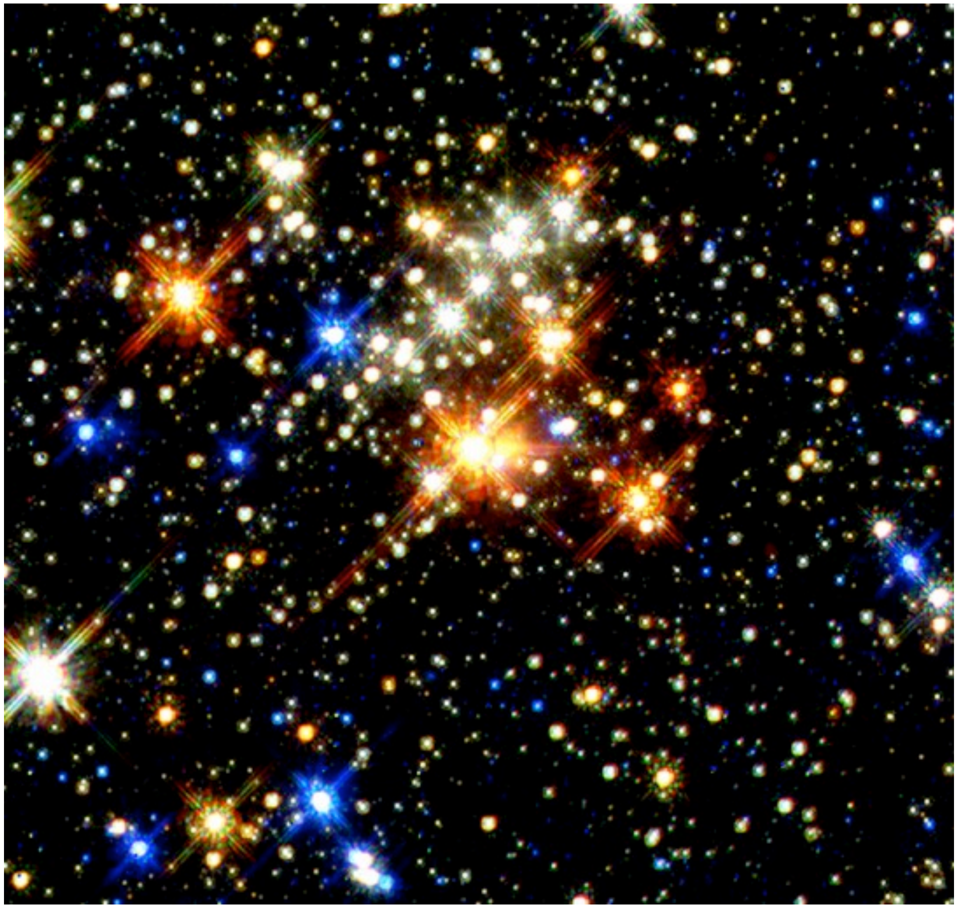
(I)

“They came to a round hole in the sky…glowing like fire. This, the Raven said, was a star.”

Eskimo myth, Cosmos, p. 167
Carl Sagan, Random House, NY, 1980

Stars

- All stars shine; they generate heat and visible light via nuclear fusion reaction
- They are easier to see
- Made out of hot plasma
- Exception to this rule is brown dwarfs, in which no nuclear fusion, no shining occurs.



www.le.ac.uk

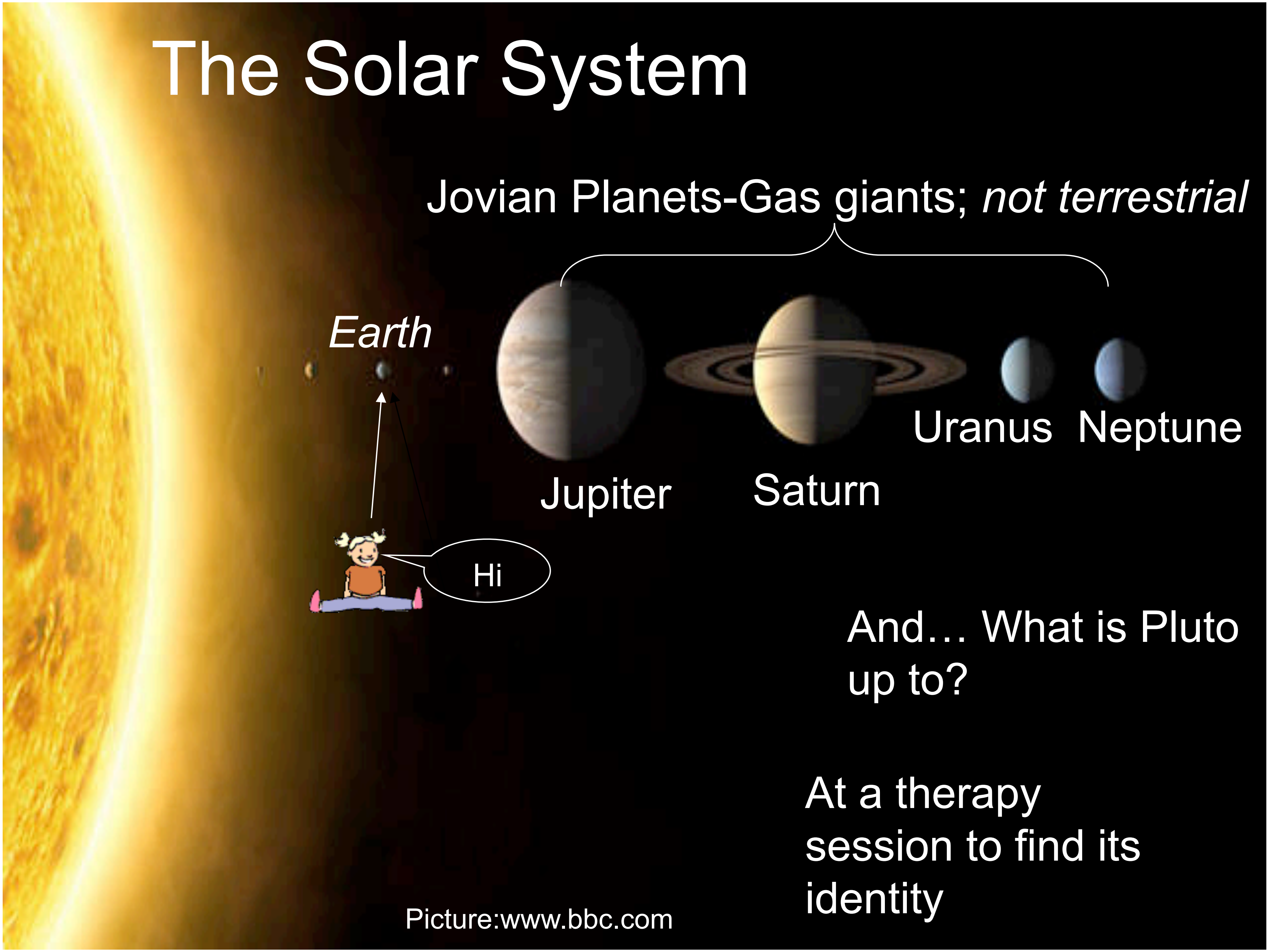
Planets

- Do not shine like stars
- Orbit around other stars
- Most planets have rocky debris (terrestrial)
- The best example for a planet is our Earth.

Image: Kasting, How to find a habitable planet?, KITP 2010

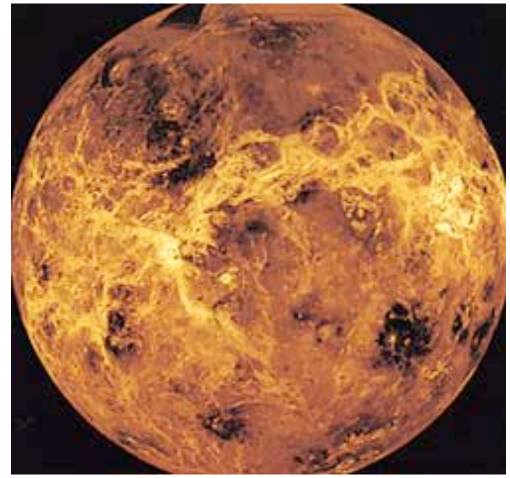
(II) Habitable planets

- First, a brief look at our solar system is a must in search of habitable planets
- Our solar system contains one star, our sun, at the center
- Total of eight planets
- *And*…


The Solar System
Jovian Planets-Gas giants; *not terrestrial*
Earth
Jupiter
Saturn
Uranus
Neptune
Hi
And… What is Pluto up to?
At a therapy session to find its identity
Picture:www.bbc.com

That leaves us with *three planets*

- **Mercury**
  - Nearest planet to the sun
  - Dry, extremely hot
  - Temperatures range from 450 ^{o}C to -170 ^{o}C
  - Almost airless
  - *Not* much chance for life



- **Venus**
  - Atmosphere: CO_2, SO_2, CO, Ne
  - Atmospheric pressure is 90 times greater than that of the Earth
  - Surface temperature 465 ^{o}C
  - *Not* much chance for life

Images: nasa.gov

Mars

- Fourth planet in the solar system
- Was thought to be the most likely planet to start human traveling
- Very thin atmosphere, mostly CO_2
- Temperature ranges from -140 ^{o}C to 20 ^{o}C
- *Not* an ideal place to raise kids

Image: Kasting, How to find a habitable planet?, KITP 2010

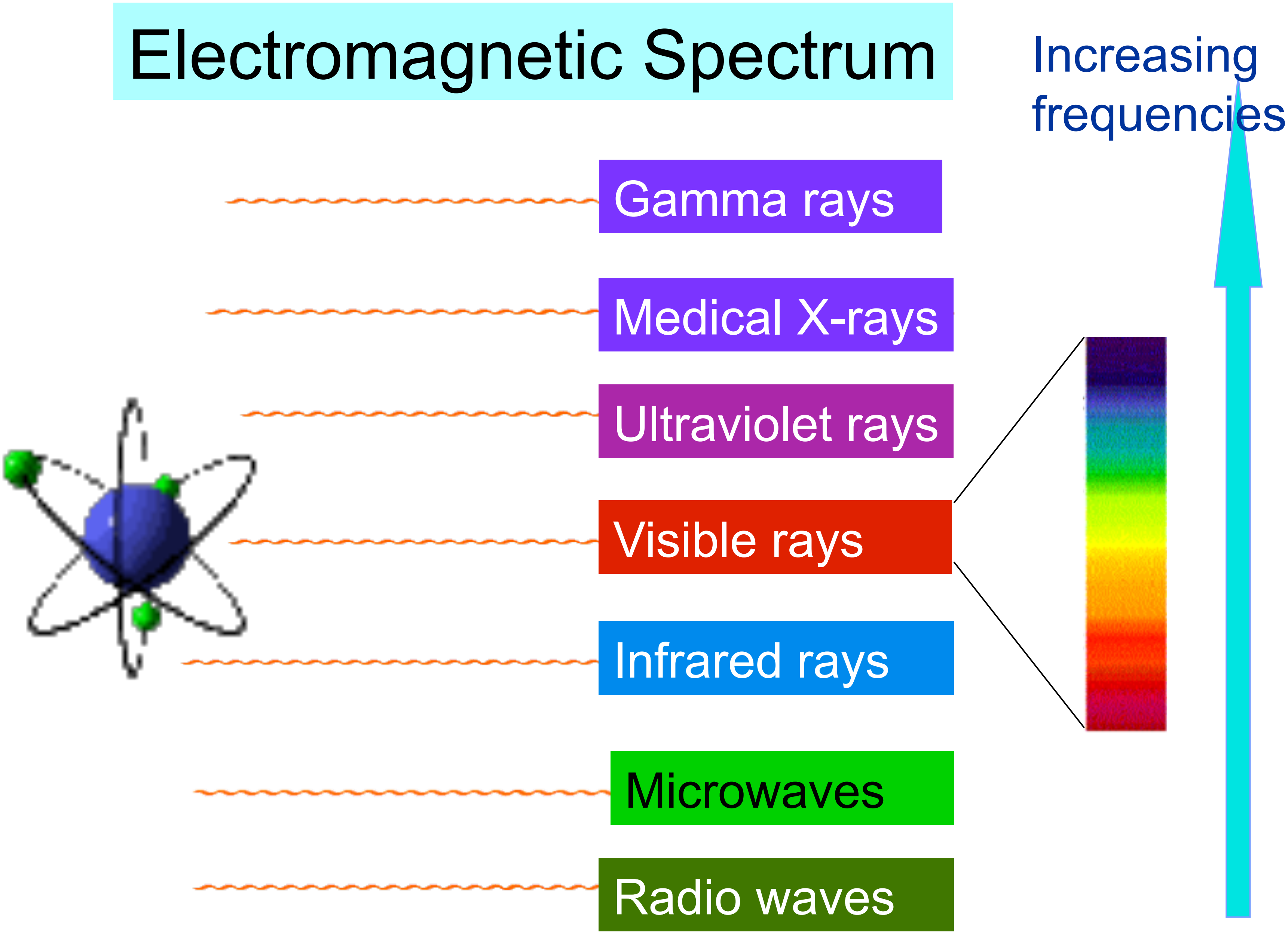
What makes Earth habitable?

- To begin with, life is *carbon-based* (DNA, RNA, and proteins)
- That requires liquid water
- Breathable air; mostly oxygen and nitrogen
- Atmosphere that protects us from high energy radiation, such as ultraviolet rays (UV)
- Are there any Earth-like planets to support life *outside* of our solar system?

(III) Some tools to detect exoplanets

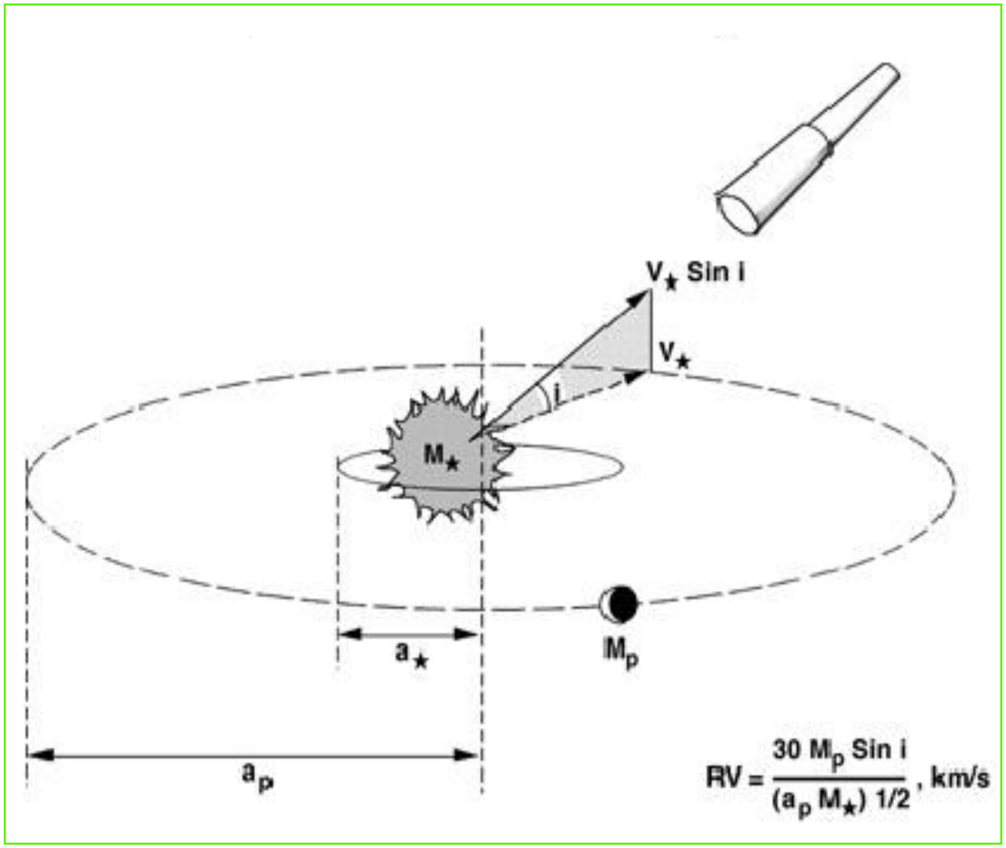
Spectrographic Imaging

- We can look at planets with different *non-visible frequencies* that they give off
- Not only we can look at the spectrum from the planets' surface, but also from their atmospheric compositions, such as the ratio of oxygen, nitrogen etc.
- The problem is the planets are *too remote* for detailed studies
- Recall the electromagnetic spectrum…



Animation: Armağan

Radial Velocity Method



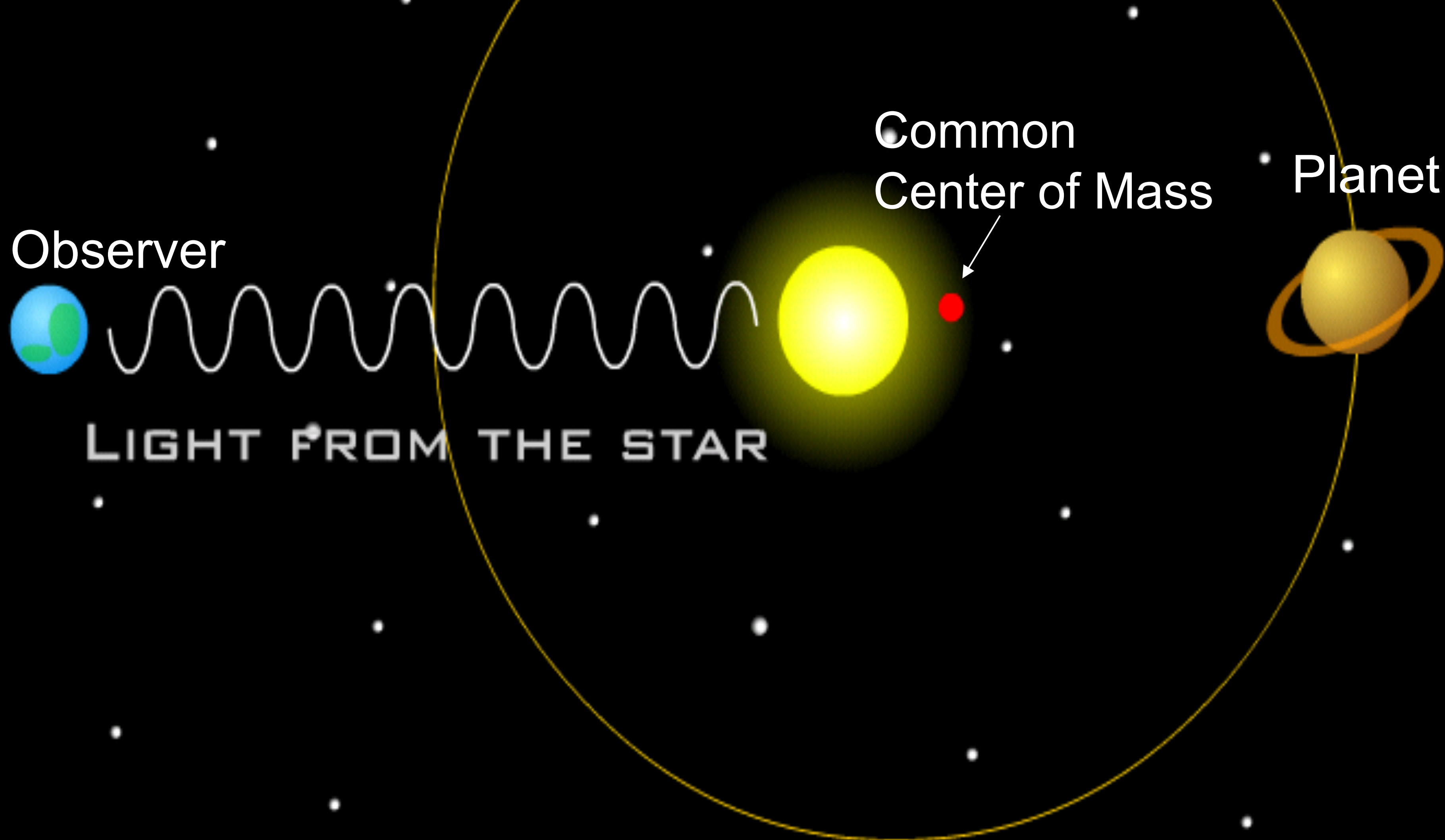
http://obswww.unige.ch/exoplanets/method.html

- As the universal law of gravity dictates that every mass exerts a force on every other mass
- A planet exerts a gravitational attraction on the star
- This causes the star to wobble but also gives information about the planet
- The bigger the mass of the planet and smaller the orbital distance, the bigger the wobble.

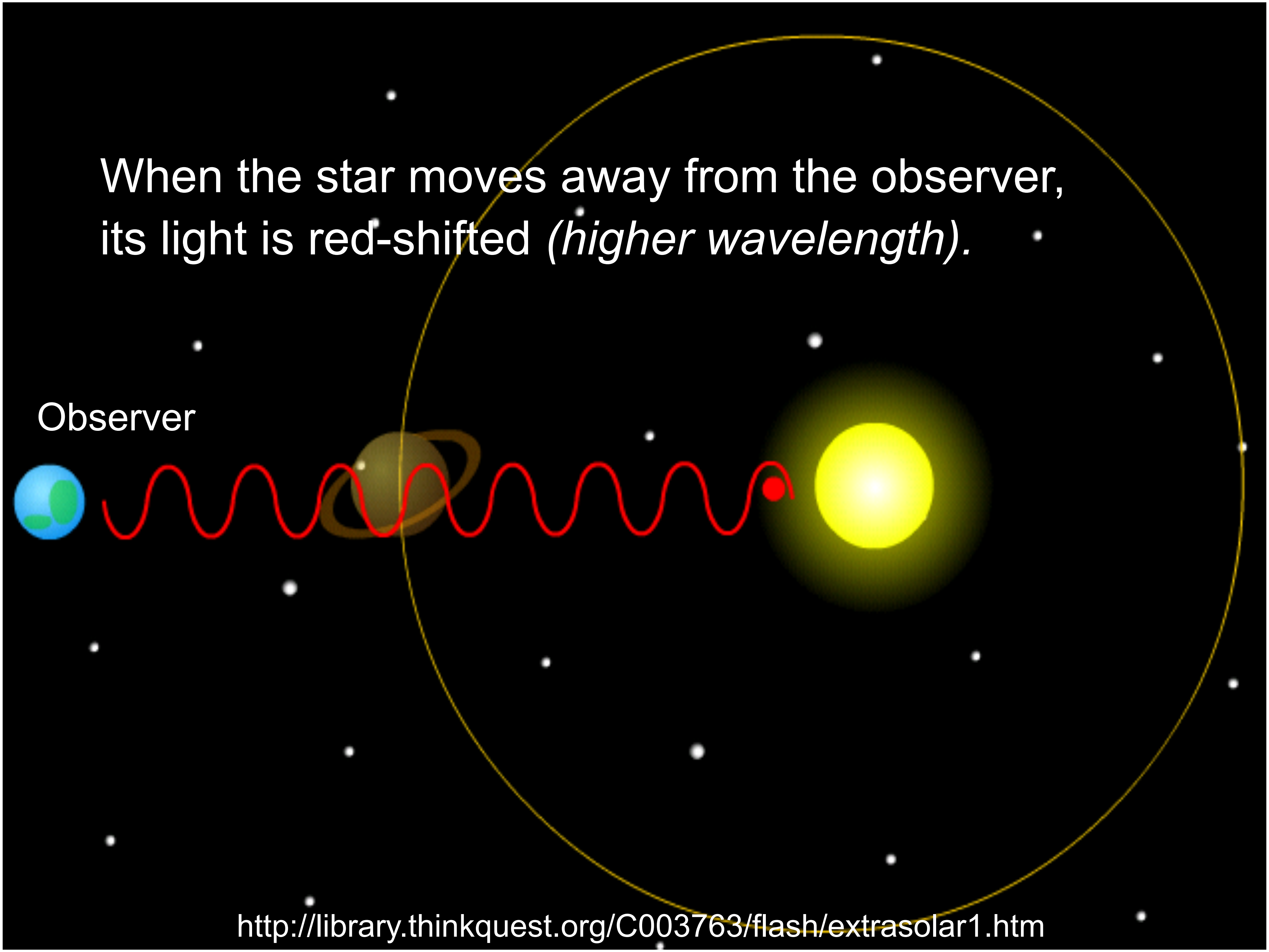
The Doppler Shift

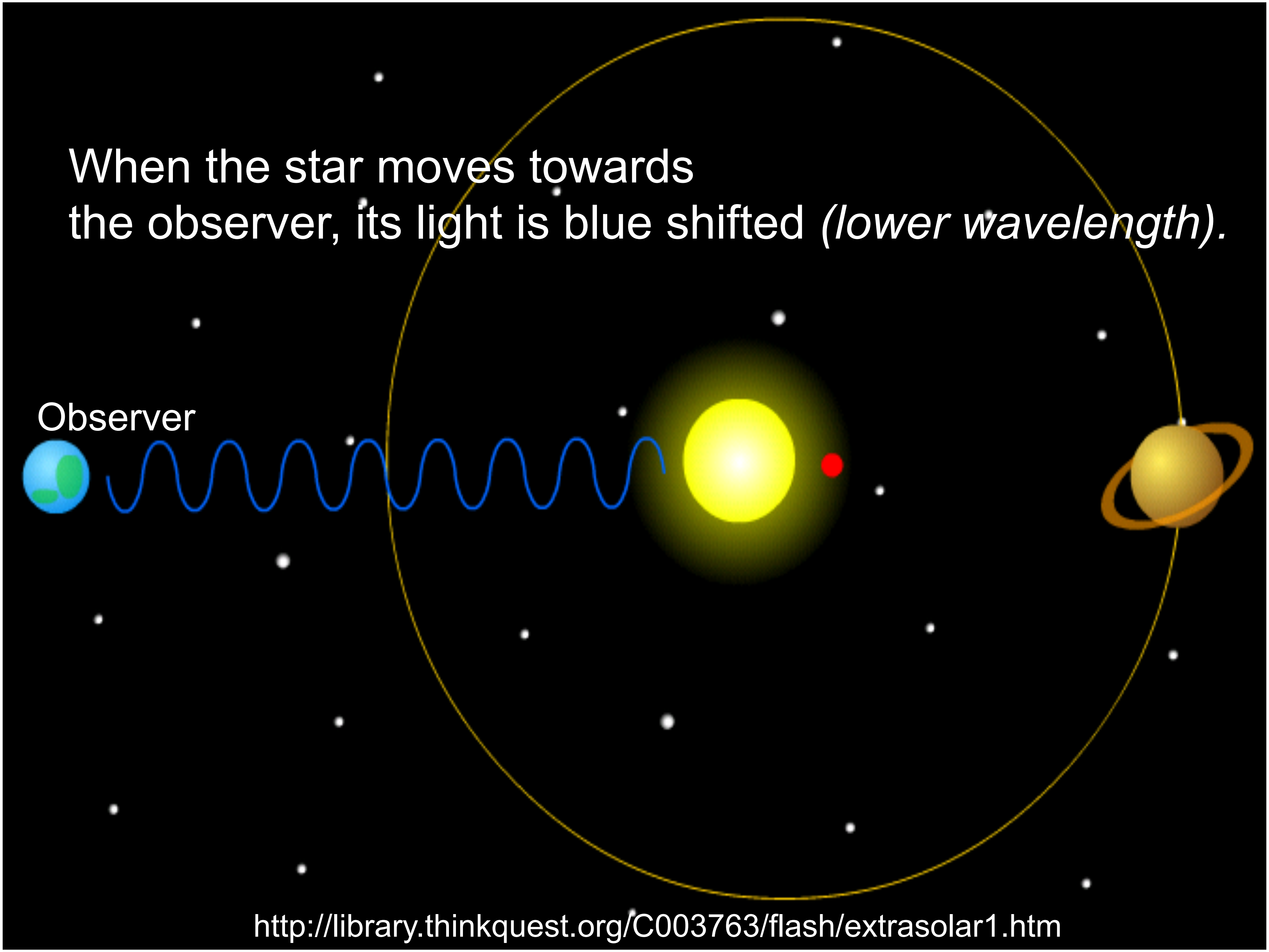
- Just as sound changes its frequency when it moves from the observer, the same thing is also valid for light.
- As the star moves, the light that it emits changes according to the location of the observer.
- This phenomena is known as the *Doppler Shift or Effect.*

When a planet orbits around a star, because of the mutual gravitational attraction, both star and planet orbit about a common center of mass.



http://library.thinkquest.org/C003763/flash/extrasolar1.htm


When the star moves away from the observer,
its light is red-shifted *(higher wavelength).*
Observer
http://library.thinkquest.org/C003763/flash/extrasolar1.htm


When the star moves towards
the observer, its light is blue shifted *(lower wavelength).*
Observer
http://library.thinkquest.org/C003763/flash/extrasolar1.htm

Summarizing Doppler Technique

- A periodic Doppler shift of the star light *reveals* the presence of the planet, as long as there is precision to see the variations.
- Going from ***red shift*** to ***blue shift*** continues periodically.
- Therefore a star without a planet would not have this type of spectrographic shifting.
- We can measure this shift.

NASA's Kepler Mission

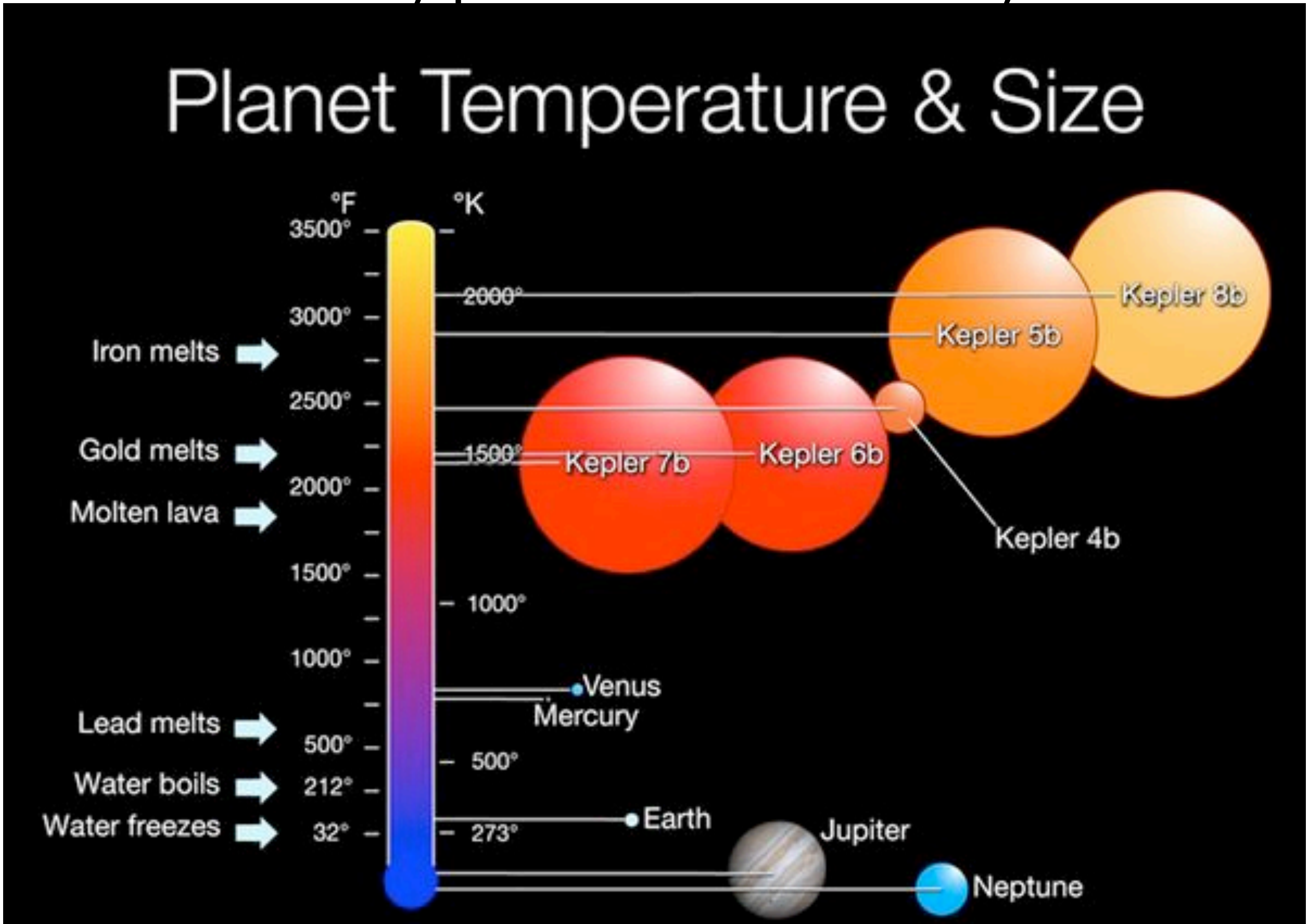
Photometry Method-Luminosity

A planet changes the brightness (luminosity) of its parent star as it passes directly between the star and its field.

Monitors brightness of 100,000 stars that are brighter than 14th magnitude in Cygnus and Lyrae

nasa.gov

Five new planets are much hotter and bigger than any planet in our solar system.



National Geographic: Illustration courtesy William Borucki NASA

Conclusion

- Discovering exoplanets takes a long time, painstaking effort, clever ways to collect data, and collaboration among many scientists.
- Discovering exoplanets may open up doors to find intelligent Earth-type life forms to whom we could talk.
- As of August 2010;
  - the current planet count: 473
  - stars with planets: 402
  - Earth-like planets: 0 (jpl.gov)

(IV) Mixed Problems and Questions
(across the curriculum)

1. (General physics) Neptune is 4.4×10^9 km away from the Earth. If we were to send an electromagnetic signal to its surface, how long would it take for the signal to come back to Earth? About 8 h
2. (General physics) Do the same problem for the moon and compare it with the result from problem 1 (moon's distance from Earth: 3.84×10^5 km) 2.6 s
3. (Conceptual/web-based) New planet CoRoT-7b was discovered 485 light years from the Earth. What can you tell about this planet? Is it habitable? Why or why not? It is very close to its star, making surface temperature vary from 2200 ^oC to – 210 ^oC (on the dark side).
4. (Conceptual) If astronomers are detecting around 650 nm wavelength of signal during a planet's shift, what kind of Doppler shift is that and why? Red shift because of corresponding 650 nm
5. (Conceptual) What is the "limitation" of the speed of light? Even though the speed of light is the fastest thing as we know, because of the vast distances in our universe, it takes 'time' to reach to far places.

(IV) Mixed Problems and Questions

(across the curriculum)

6. (Conceptual): Suppose we found a planet that is twice as wide and twice as massive as the Earth. How would your weight be different on this planet? Explain. Twice as wide means twice the distance you would be from the center of gravity. That would make you weigh 1/4th, as force varies by inverse square of the distance. But twice as massive would make you weigh two times heavier too. So taking all these into consideration 2 (1/4) gives ½ the weight of the Earth.
7. (Social): What would be the *three cons* of finding an Earth-like planet to which we can actually travel? Answers may vary
8. (Social): Write an essay on the ethics of interstellar space travel in terms of who should decide who can go. Should it be based on financial ability or intellectual abilities? Or should anyone be allowed to travel? Answers may vary
9. (Biology): What are the physiological issues of space travel on people? Loosing bone mass density, orientation, effects of microgravity on the heart and circulatory systems, radiation effects

(IV) Mixed Problems and Questions
(across the curriculum)

10. (Physics/Astronomy): We discovered an Earth-like planet 20.5 light years from Earth. Suppose that *you* are chosen as one of the astronauts to go along as the first explorers. A) If the current fastest speed that space shuttle can achieve is 7860 m/s, how long would it take you to get there? B) Is this a realistic scenario? Why or why not?

    A) 782,000 y; B) Answers may vary

11. (Physics/Conceptual): What is the new current technology that is underway to developing faster ways to travel through space? Plasma propulsion technologies

12. (Social) What would be the social implications of finding new intelligent species? Explore the pros and cons Answers may vary

13. (Chemistry/Geology/Earth Science): Explain the cycle that regulates CO_2 levels over a long time on Earth? Carbon-silicate cycle

14. (Astronomy/Chemistry/Geology): When looking for an *Earth-like* planet, what are some of the criteria that scientists look for? Planet's proximity to its star, size of the planet, surface temperature and atmospheric composition are some of the considerations.

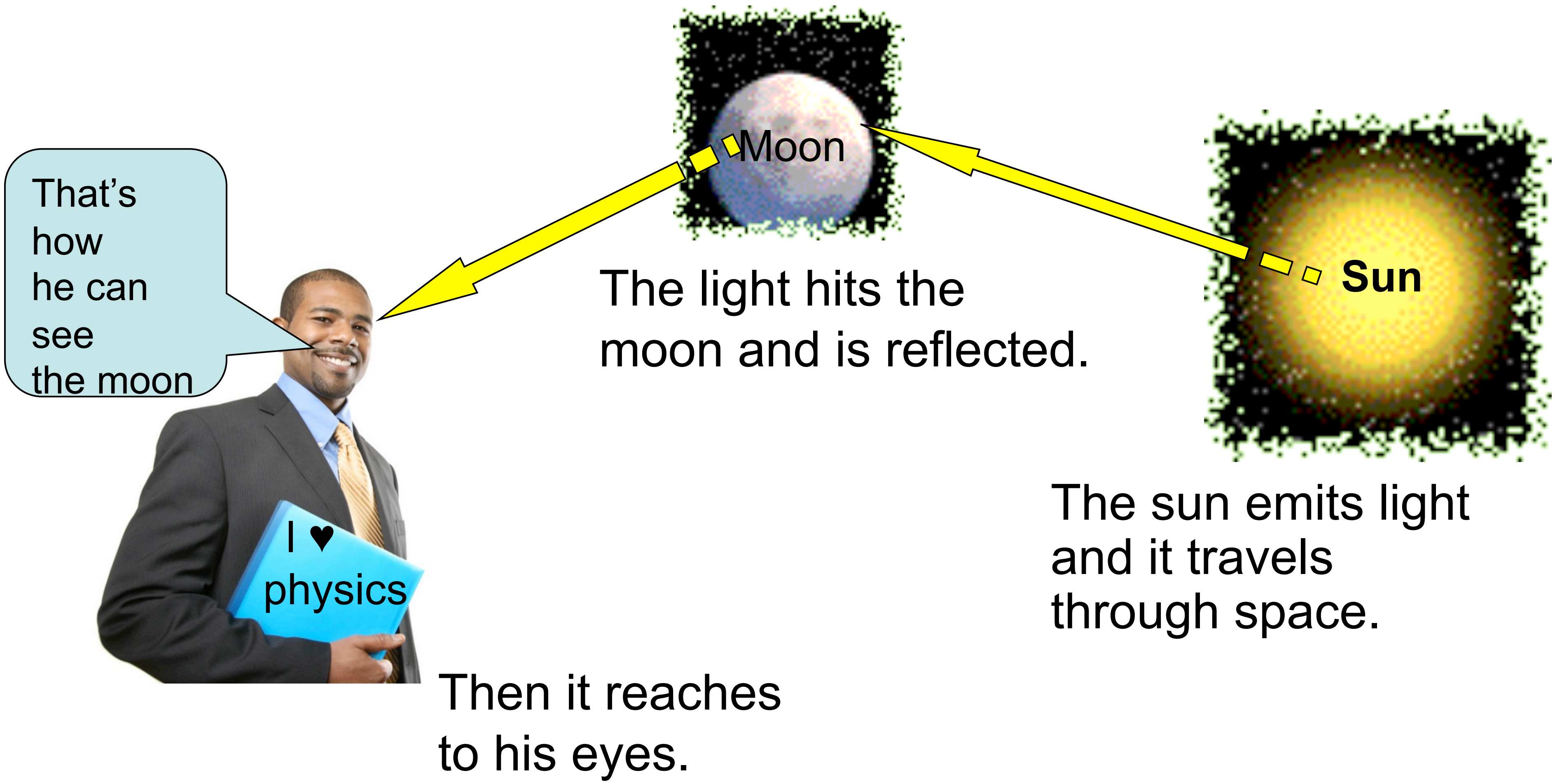
(IV) Mixed Problems and Questions

(across the curriculum)

15. (Biology/Physics/Environment): What are the environmental challenges facing us in space? *Extension*: For each challenge, write an essay.
    Atmosphere, radiation and gravity
16. (Social Implications): What would be the *three pros* of finding an Earth-like planet to which we could actually travel? Answers may vary
17. (Social): What are the psychological issues of space travel on people? confining people in a small place for a long period of time, effects on the nervous system

Extended Slide:
How can we “see” things?

- Since the planets do not emit visible light, like stars do then how could we see them?
- Let’s use our moon as an example.



- Thank you for your attention
- Questions?