Announcements

- Only day labs (3:30 p.m.) left for the semester
- All grading should be caught up on by now
  - Let me know if you have any questions
- A little late since we are done with the night labs… but please make sure you are writing your lab using what you actually observe - i.e. not planets that are not even above the horizon

Variable Stars

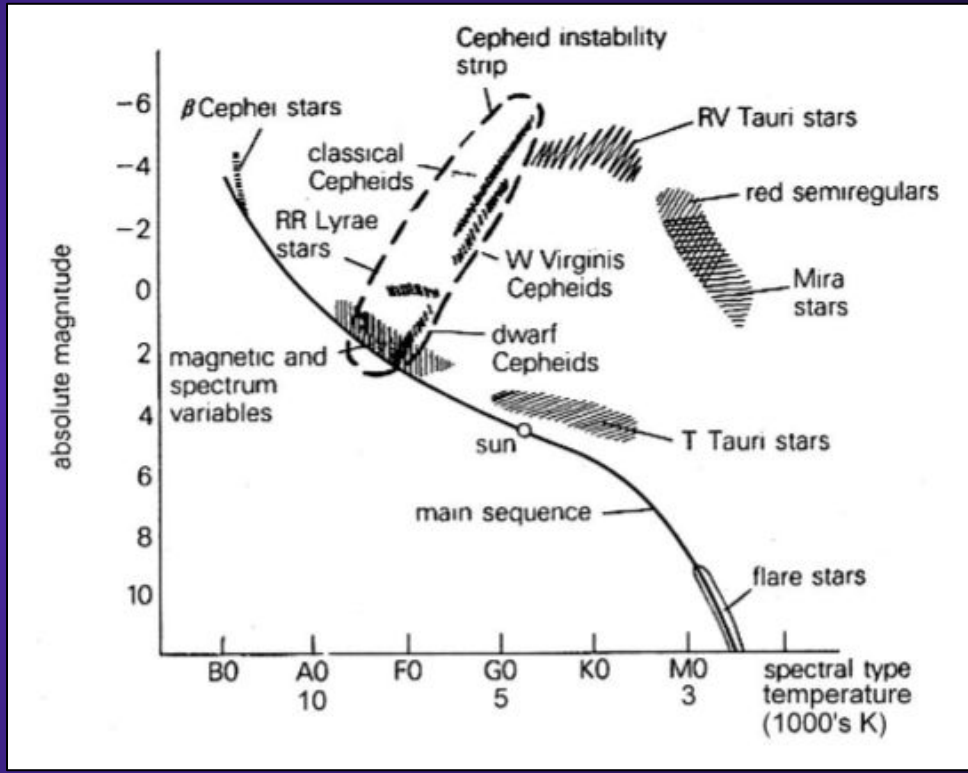
RR Lyraes, Cepheids, and Binaries, oh my

Variable Stars

- Variable stars are stars whose brightness varies cyclically over time
  - Technically, all stars change as they age
    - But today we are interested in the ones that go through a cycle

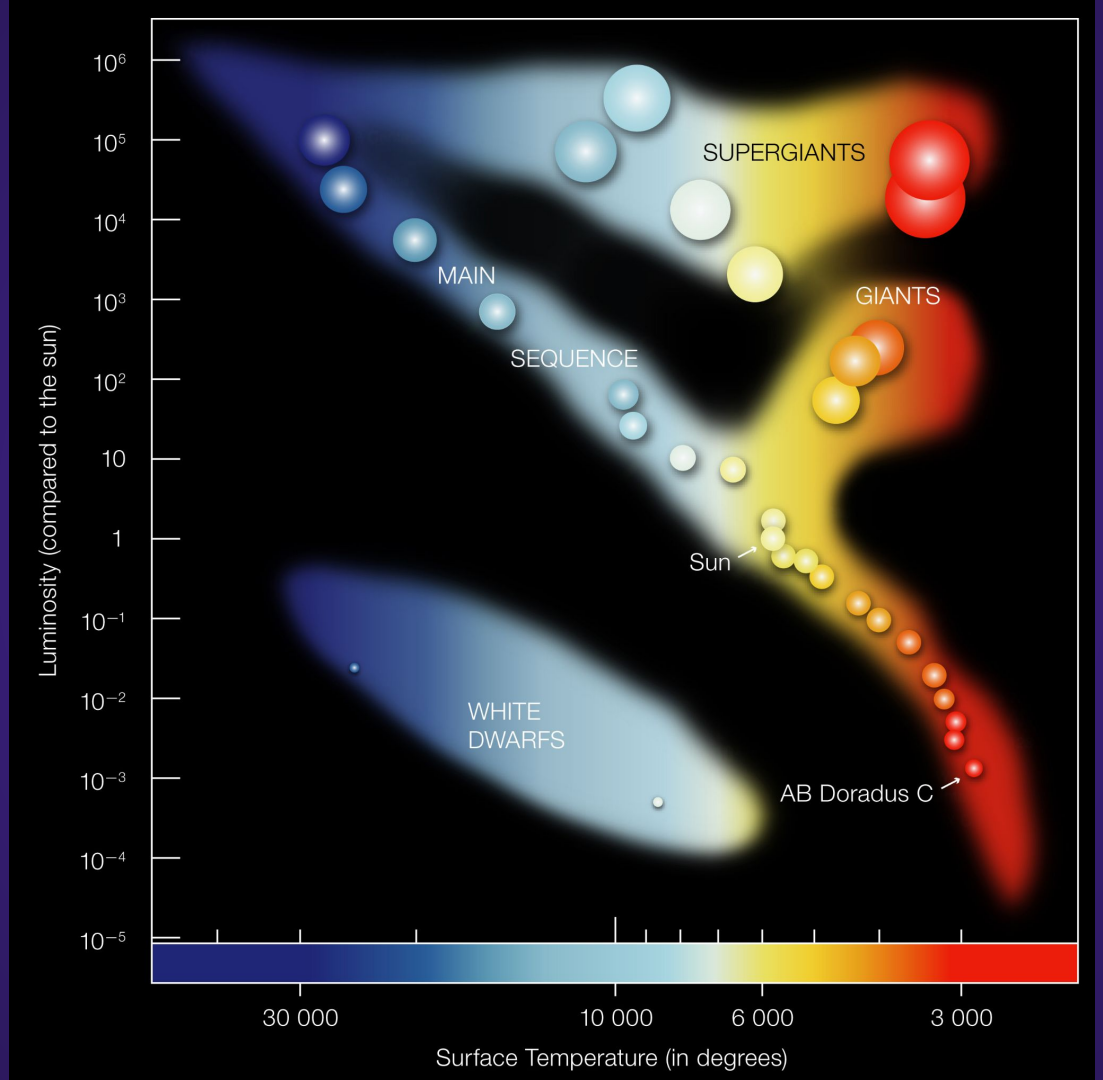
Common Types

- RR Lyrae Stars:
  - Small (relatively - still several times bigger than the Sun)
  - Change in brightness due to the size changing up and down from internal instability
  - All have an average absolute magnitude of around **0.5**
  - Period is less than a day



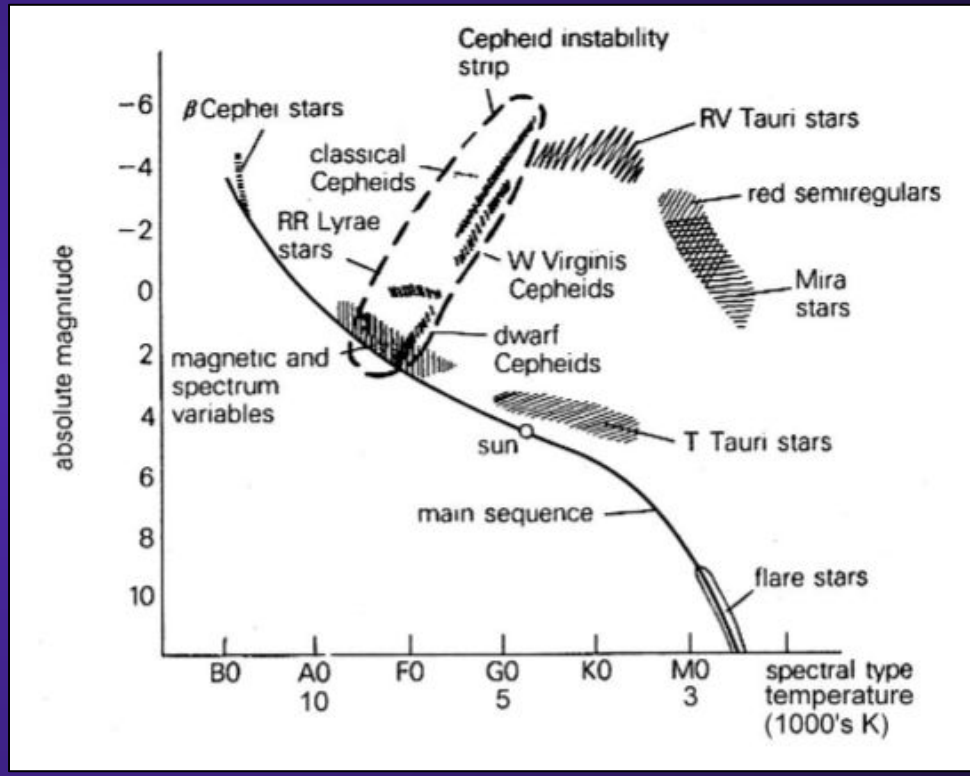
HR Diagram (next week's lab) for Variable Stars

HR Diagram: A graph of stars with magnitude (brightness) on the y-axis and temperature (color) on the x-axis


SUPERGIANTS
MAIN
SEQUENCE
GIANTS
Sun
WHITE
DWARFS
AB Doradus C
Luminosity (compared to the sun)
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
30 000
10 000
6 000
3 000
Surface Temperature (in degrees)

Common Types Cont.

- Cepheid Variable Stars:
  - Big (10s to 100s of times more than the Sun)
  - Change in brightness due to the size changing up and down from internal instability (same mechanism as RR Lyrae)
  - Absolute Magnitude varies based on size
  - Period can be 1 day to around 100 days
  - Importantly: **Their period and luminosity** (absolute magnitude) **have a direct relationship**



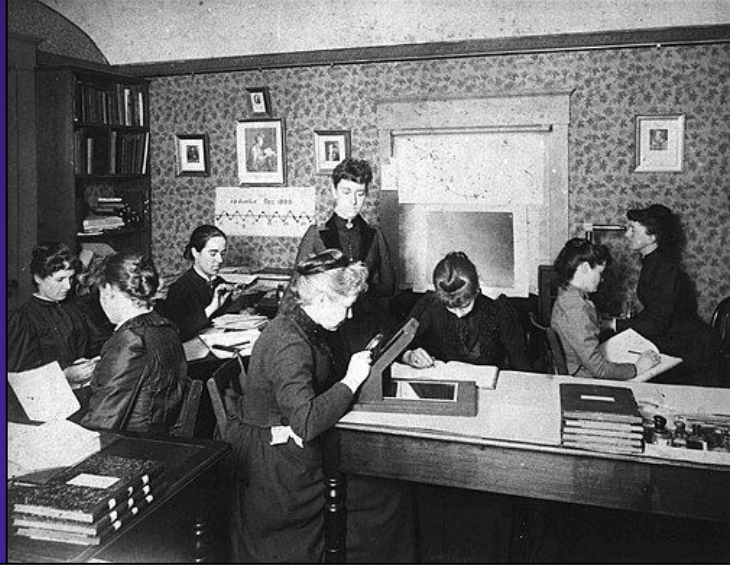
HR Diagram (next week's lab) for Variable Stars

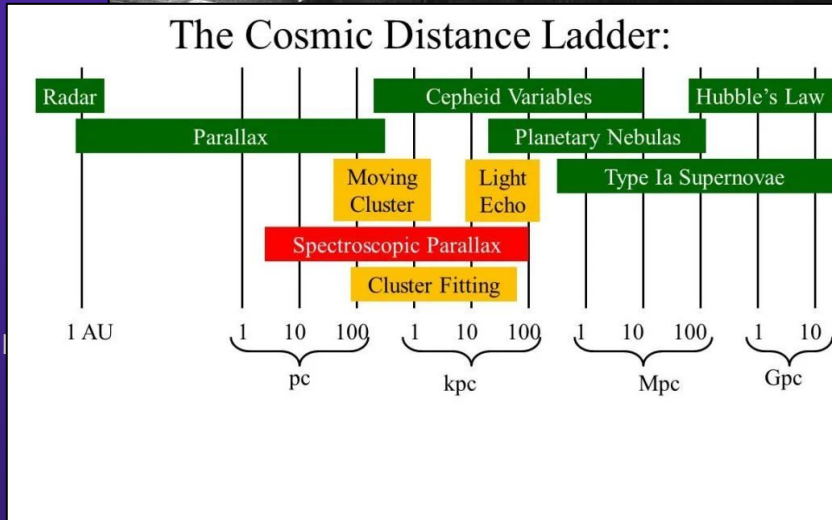
HR Diagram: A graph of stars with magnitude (brightness) on the y-axis and temperature (color) on the x-axis

Tangent about the Harvard “Computers”

- A group of women hired to analyze and catalog astronomical data/images from the observatory in the late 1800s and early 1900s
  - They are arguably responsible for much of modern astronomy
    - Including a stellar classification system that we still use (a modified version of) today (Annie Jump Cannon, 1922)
      - O,B,A,F,G,K,M
    - And (relevant to this lab) the **Cepheid period-luminosity relationship** (Henrietta Leavitt, 1908)
      - This was the first way we had to determine the distance to astronomical objects other than pa
      - It further influenced the creation of Hubble’s Law (last lab of semester)

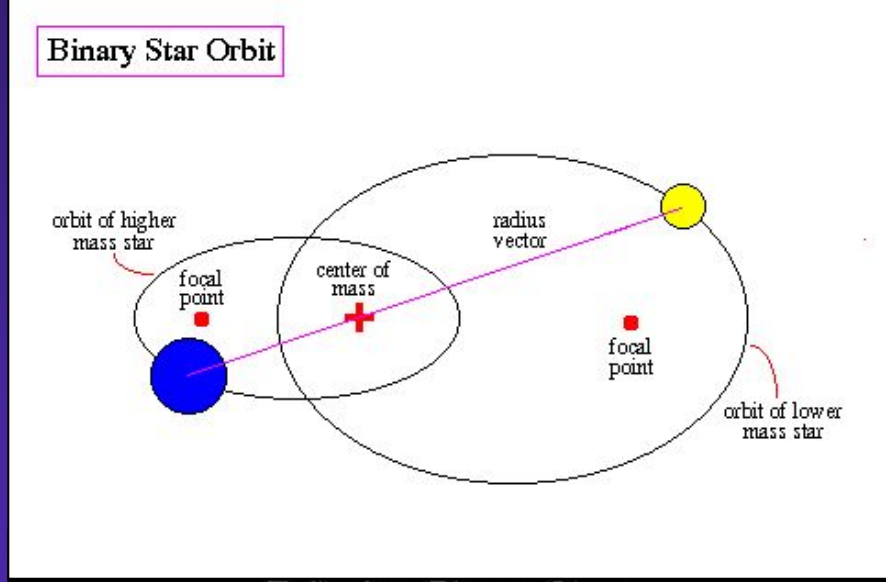
For more: look into the play *Silent Sky* by Lauren Gunderson

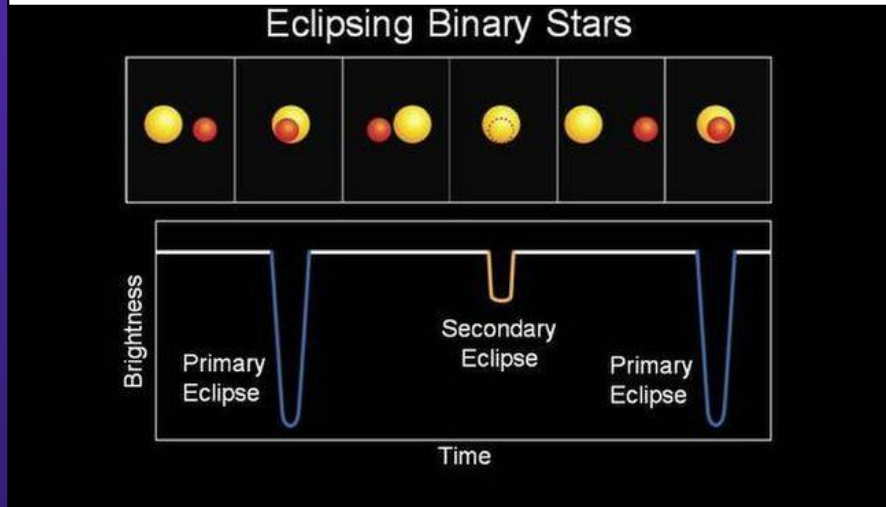




Common Types Cont.

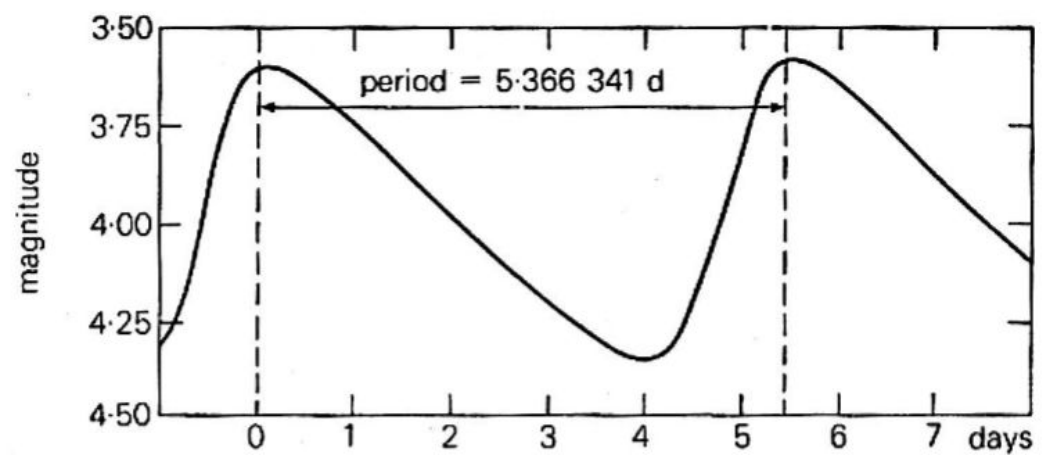
- Eclipsing Binaries:
  - Any size
    - 2 star binary (or more!) system
  - Brightness changes due as the stars pass in front of each other (from our perspective) blocking some of the light
- This is similar to one of the most effective ways of finding exoplanets (planets around other stars) (see exoplanets lab in AST 111)
  - In fact, one of the hardest parts of finding exoplanets is figuring out if you are looking at a star with a planet, a variable star, or even both at once (or something else i.e. sunspots)





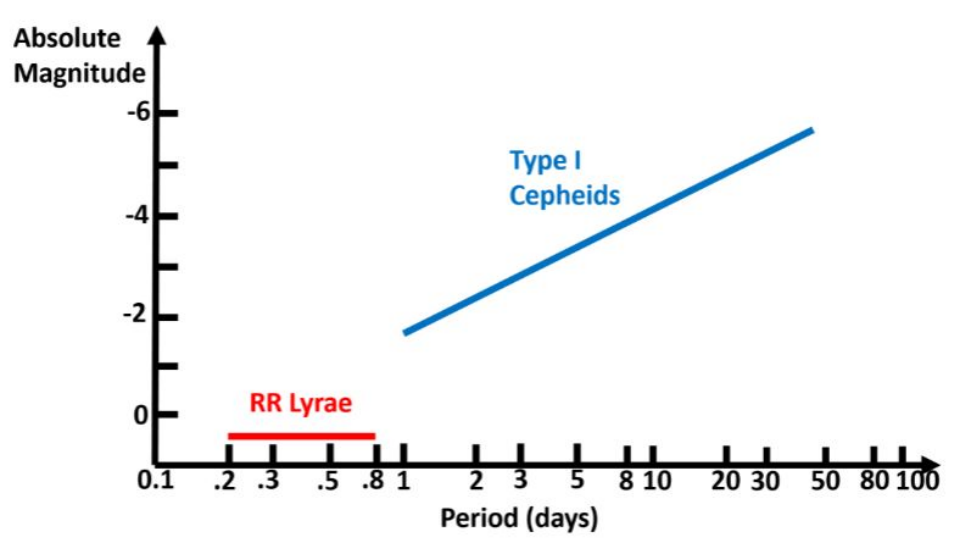
What is a “Light Curve” and How to Read Them

- A curve in this context is a mathy word for a shape on a graph
  - In this case, showing brightness/luminosity/magnitude on the y-axis and time on the x-axis
    - So you can see how the star changes over time
- To read them, look for a cycle - two identical points on the graph (usually the brightest or dimmest points, depending on the graph)
  - The time between these points is the “period” or how long one cycle lasts



The Cepheid Period-Luminosity Relationship

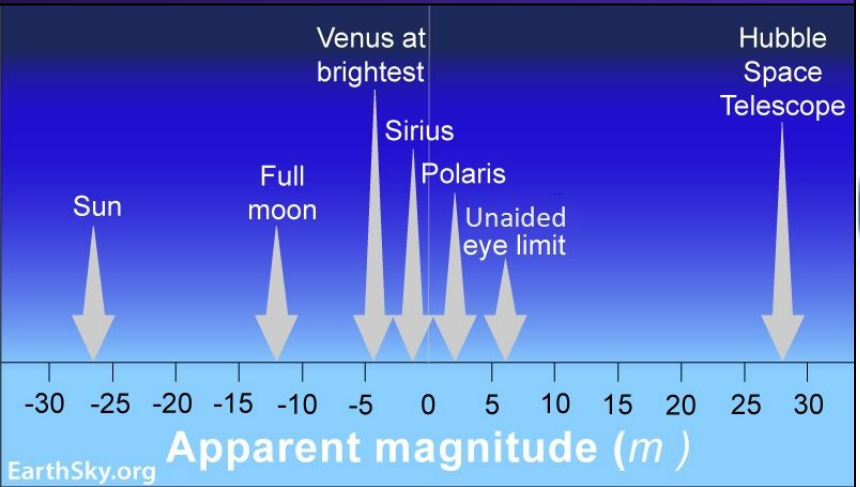
- This graph is similar to a light curve, but the x-axis is the period instead of total time
- To use it:
  - Get the period from the light curve
  - Find it on the x-axis here
  - What y-value does that spot have on the line
    - That is the absolute magnitude

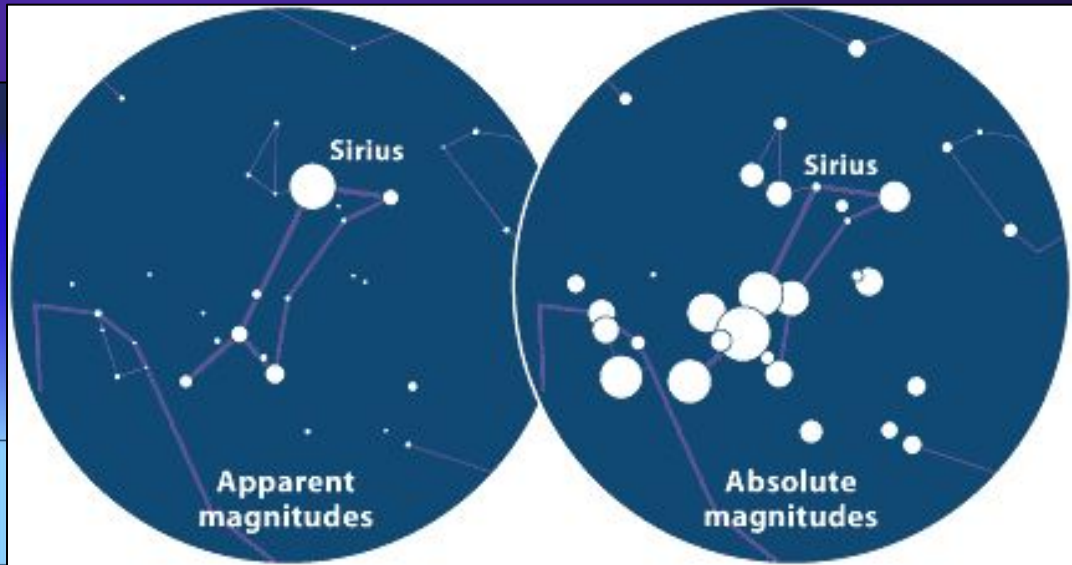


This graph is also in your lab script and is very important for completing this lab

Math and Magnitude Reminders

- Magnitude is a reversed scale - smaller numbers (including negative) are brighter than bigger numbers
- The Distance Modulus:
  - $m - M = 5 \times \log_{10}(d) - 5$ Solve for distance, d:
  - $10^{(m - M + 5) / 5} = d$





Today

- Do questions 1-3
- Fill out the table using the light curves found on the last 3 pages
  - Not every cell will be used
    - Look at your answers to question 1 to determine which to use for each light curve
- Then finish the remaining questions (4-12)
- ***Extra Credit Opportunity:***
  - Go to "zooniverse.org"
  - Go to "Projects" and search "SuperWASP"
  - Make at least 15 classifications
  - Attach to your lab (or email me):
    - Screenshot of your profile stats page showing the number of classifications
    - A paragraph description of what you thought of the project (i.e. was it interesting, did it help your understanding of variable stars, etc)