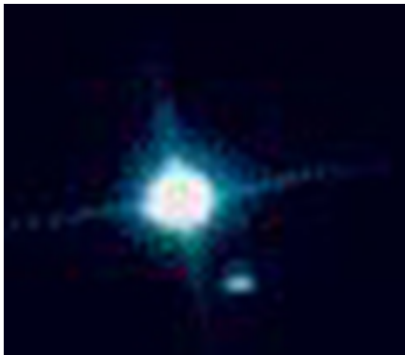
Discovery of White Dwarfs—8 Oct

- Homework 4 is due on Mon.
- Hertzsprung-Russell diagrams
- Magnitude, apparent & absolute
- Adams' discovery

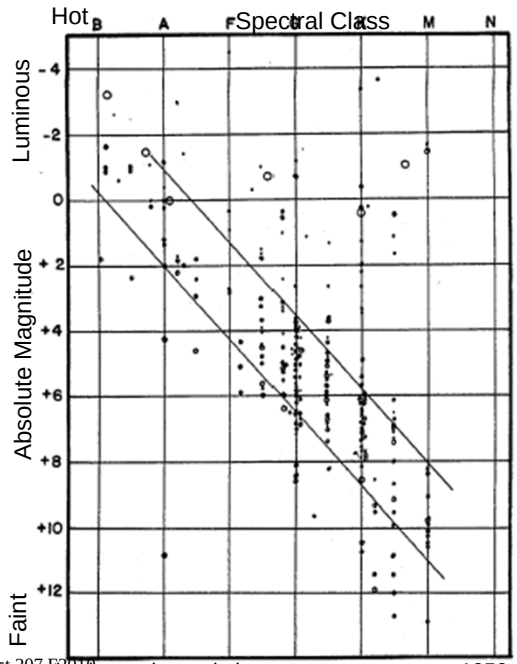


Sirius A & B
http://chandra.harvard.edu/photo/2000/0065/0065_optical.jpg

Hertzsprung-Russell diagram

- H-R Diagram is plot of temperature & luminosity
- Stefan-Boltzmann Law: $L = AT^4$

1. A star is gets hotter and its size does not change. In the H-R diagram, it moves
   A. up & left
   B. up & right
   C. up-down
   D. left-right
   E. not at all

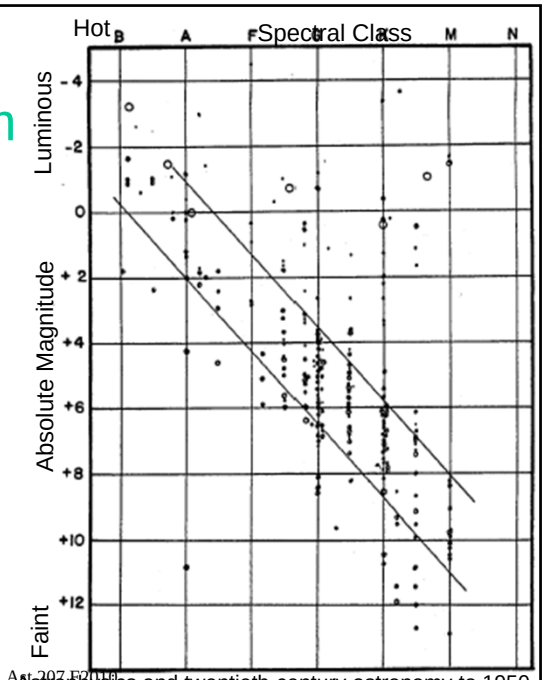


Astrophysics and twentieth-century astronomy to 1950, O Gingerich, ed., Cambridge, 1984

Hertzsprung-Russell diagram

- H-R Diagram is plot of temperature & luminosity
- Stefan-Boltzmann Law: $L = AT^4$

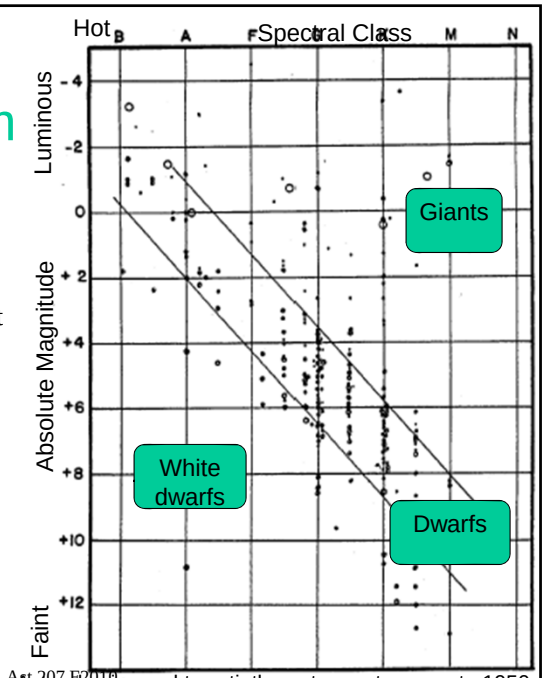
1. Can two stars of the same spectral class have different luminosities?
   - A. No. No such cases exist on the H-R diagram.
   - B. Yes, temperatures differ
   - C. Yes, sizes differ
   - D. Yes, both size & temperatures differ.



Astrophysics and twentieth-century astronomy to 1950, O Gingerich, ed., Cambridge, 1984

Hertzsprung-Russell diagram

- H-R Diagram is plot of temperature & luminosity
- Stefan-Boltzmann Law: $L = AT^4$
- H-R diagram reveals stars cannot have any combination of size and temperature. There are three types of stars.
  - Dwarfs have differing temperatures and approximately the same size. Dwarfs are most common.
  - Giants are large.
  - White dwarfs are small.



Astrophysics and twentieth-century astronomy to 1950, O Gingerich, ed., Cambridge, 1984

Luminosity and flux

- Luminosity = amount of energy per second (Watt) produced by the star
  $L=R^2T^4$
- Flux = energy per second received by a detector on earth (Watt/m^2)
  $F=L/D^2$

1. As viewed from Earth, which is the faintest star?
   A. Sun
   B. Vega
   C. Sirius
2. As viewed from a distance of 10 pc from each star, which is the faintest star?

Use flux

Use luminosity

Star	Apparent mag	Flux		Absolute mag	Luminosity		Distance
		[W/m^2]	[f_{Vega}]		[W]	[L_{sun}]	[pc]
Sun	-26.7	1400	5.2×10^{10}	4.8	3.9×10^{26}	1	5×10^{-6}
Vega	0.0	2.7×10^{-8}	1	0.5	2.1×10^{28}	54	8
Sirius	-1.45	1.1×10^{-7}	3.9	1.4	9.0×10^{27}	23	2.7

Apparent & Absolute Magnitude

- Apparent mag is a logarithmetic expression of flux
- If the apparent mag changes by -2.5, the flux is brighter by a factor of 10.
  - If the apparent mag changes by +2.5, the flux is fainter by a factor of 10.

1. The apparent magnitude of a star is +2.5. Its flux is
   A. 2.7×10^{-6}W/m^2.
   B. 2.7×10^{-7}W/m^2.
   C. 2.7×10^{-8}W/m^2.
   D. 2.7×10^{-9}W/m^2.
   E. 2.7×10^{-10}W/m^2.
2. The apparent magnitude of a star is +5. Its flux is

Star	Apparent mag	Flux		Absolute mag	Luminosity		Distance
		[W/m^2]	[f_{Vega}]		[W]	[L_{sun}]	[pc]
Sun	-26.7	1400	5.2×10^{10}	4.8	3.9×10^{26}	1	5×10^{-6}
Vega	0.0	2.7×10^{-8}	1	0.5	2.1×10^{28}	54	8
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Apparent & Absolute Magnitude

- Apparent mag is a logarithmetic expression of flux
- If the apparent mag changes by –2.5, the flux is brighter by a factor of 10.
- Fluxes and magnitudes of two stars A and B

$$\frac{f_B}{f_A} = 10^{-(m_B - m_A)/2.5}$$

$$m_B - m_A = -2.5 \log_{10} \frac{f_B}{f_A}$$

- Try it
  - If m_B is –2.5 more than m_A, $m_B - m_A = -2.5$, and $f_B/f_A = 10^{-(-2.5)/2.5} = 10^1 = 10$.
  - If B is brighter by a factor of 10, $f_B/f_A = 10$, and $m_B - m_A = -2.5 \log(10) = -2.5$

M15

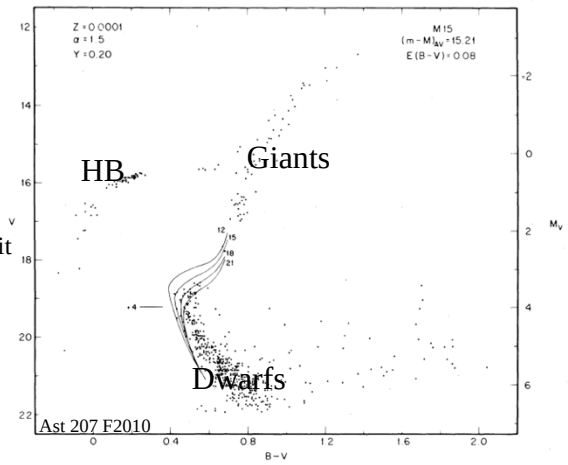
- Globular cluster M15
  - All the stars were born at the same time.
  - Bright orange stars are giants.
  - Blue stars are dwarfs.

NASA: HST

Hertzsprung-Russell Diagram of a star cluster M15

- Observations of a globular cluster M15 show
  - Main-sequence or dwarf stars
  - Giants
  - Horizontal-branch stars
  - White dwarfs are too faint for these observations.
- Giants are dying stars.
  - A star lives a long time as a dwarf. It is on the main sequence.
  - When it runs out of fuel, it becomes a giant and subsequently "traces out the giant branch."

1. At its brightest, a giant becomes __ times as bright as it was as a dwarf.
   A. 1000
   B. 100
   C. 10
   D. 1/10
   E. 1/1000



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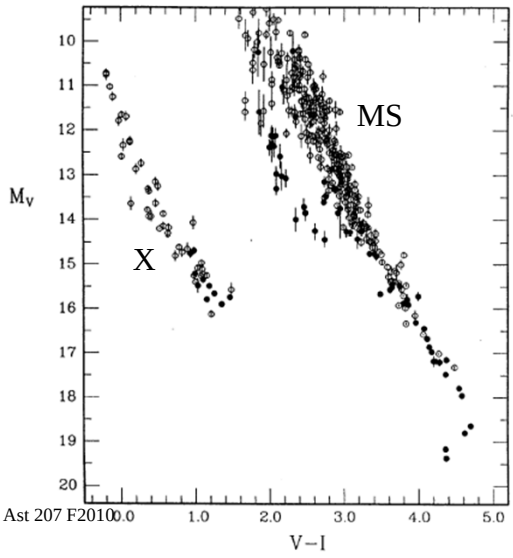
Hertzsprung-Russell Diagram of nearby stars

1. Stars in region X are
   A. Dwarfs
   B. Giants
   C. White dwarfs



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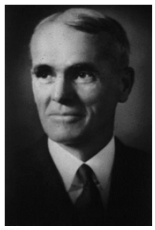
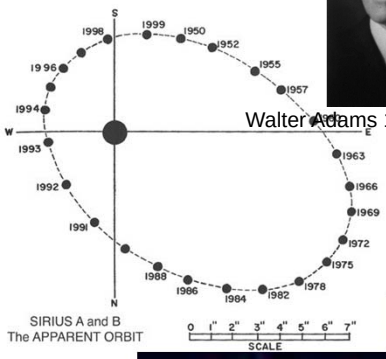
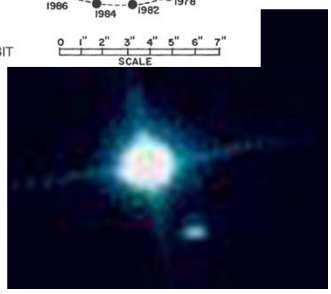
Sirius A and Sirius B

- We are Walter Adams of the Mt. Wilson Observatory in 1914. We are studying the double star Sirius A and B. (Sirius A & B orbit each other.)
- Sirius B is much fainter than Sirius A.



Walter Adams 1876-1956





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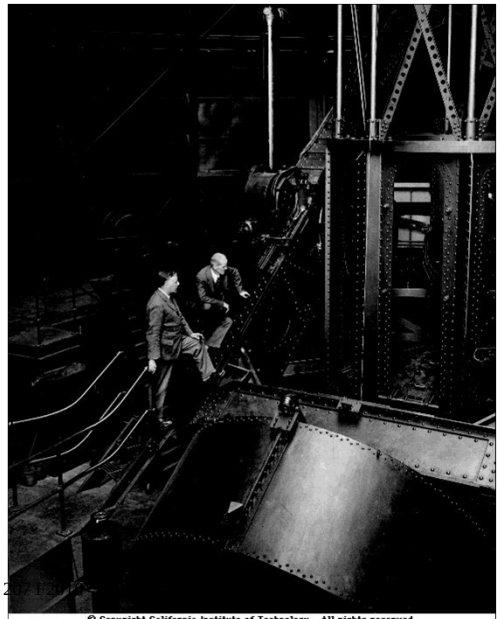
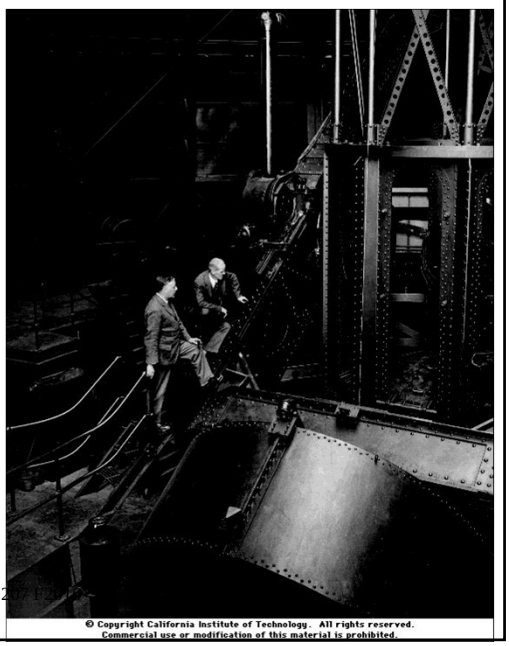
http://chandra.harvard.edu/photo/2000/0065/0065_optical.jpg

1. Sirius B may be faint for two reasons. It may be small or it may be
   A. farther away
   B. closer
   C. cooler
   D. hotter

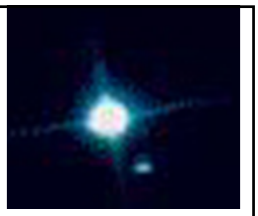


Ast 2

1. Sirius B may be faint for two reasons. It may be small or it may be
   A. farther away
   B. closer
   C. cooler
   D. hotter
- Adams found that Sirius A and B have about the same color. Therefore Sirius B is smaller.



Ast 2



Sirius A and Sirius B

- Adams found that Sirius A and B have about the same color. Therefore Sirius B is smaller.
  - $L=R^2T^4$
- How much smaller is Sirius B?
- Apparent mag of Sirius A is –1.5
- Apparent mag of Sirius B is 8.7

1. The mag of Sirius B is approximately __ steps of 2.5 fainter than that of Sirius A.
   A. 4
   B. 5
   C. 6
   D. 10
2. The flux of Sirius B is approximately _ fainter.
   A. a factor 10
   B. a factor of 100
   C. a factor of 1000
   D. a factor of 10,000.

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http://chandra.harvard.edu/photo/2000/0065/0065_optical.jpg

Discovery of white dwarfs

- Adams found that Sirius A and B have about the same color. Therefore Sirius B is smaller.
  - $L=R^2T^4$
1. The mag of Sirius B is 4 steps of 2.5 fainter than that of Sirius B.
2. The flux of Sirius B is approximately a factor of 10,000 fainter.

- The radius of Sirius B is 1/100 that of Sirius A.
  - Sirius B is about the size of the Earth.
- Tiny stars are called white dwarfs.
- Main-sequence stars and white dwarfs use different laws of physics.

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http://chandra.harvard.edu/photo/2000/0065/0065_optical.jpg