

# Stars



# HOW CAN WE STUDY THE STARS?

## Astro paparazzi

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## CELEBRITY NEWS



**LEONARD NIMOY RUSHED TO ER!**  
Star *Trek*'s beloved MR. SPOCK, **LEONARD NIMOY** stricken and rushed to the hospital, according to reports.  
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**OJ SIMPSON DENIED APPEAL - STAYS JAILED!**  
**NEW DETAILS:** Creepy double murder acquittee **OJ SIMPSON** remains behind bars as Nevada Supreme Court refuses to overturn his conviction on armed robbery and kidnapping.  
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**EDWARDS GAG ORDER ISSUED!**  
**LATEST!** The ENQUIRER has learned that the judge in the **JOHN EDWARDS- RIELLE-HUNTER** sex tape war has issued a gag order meaning all lips **MUST BE sealed OR ELSE!**  
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**VERGARA DIVORCE SHOCKER**  
Gorgeous **SOFIA VERGARA** will flip when she learns her on-again, off-again BF, trust-fund baby **NICK LOEB**, is secretly refusing to end the relationship with his wife, say sources.  
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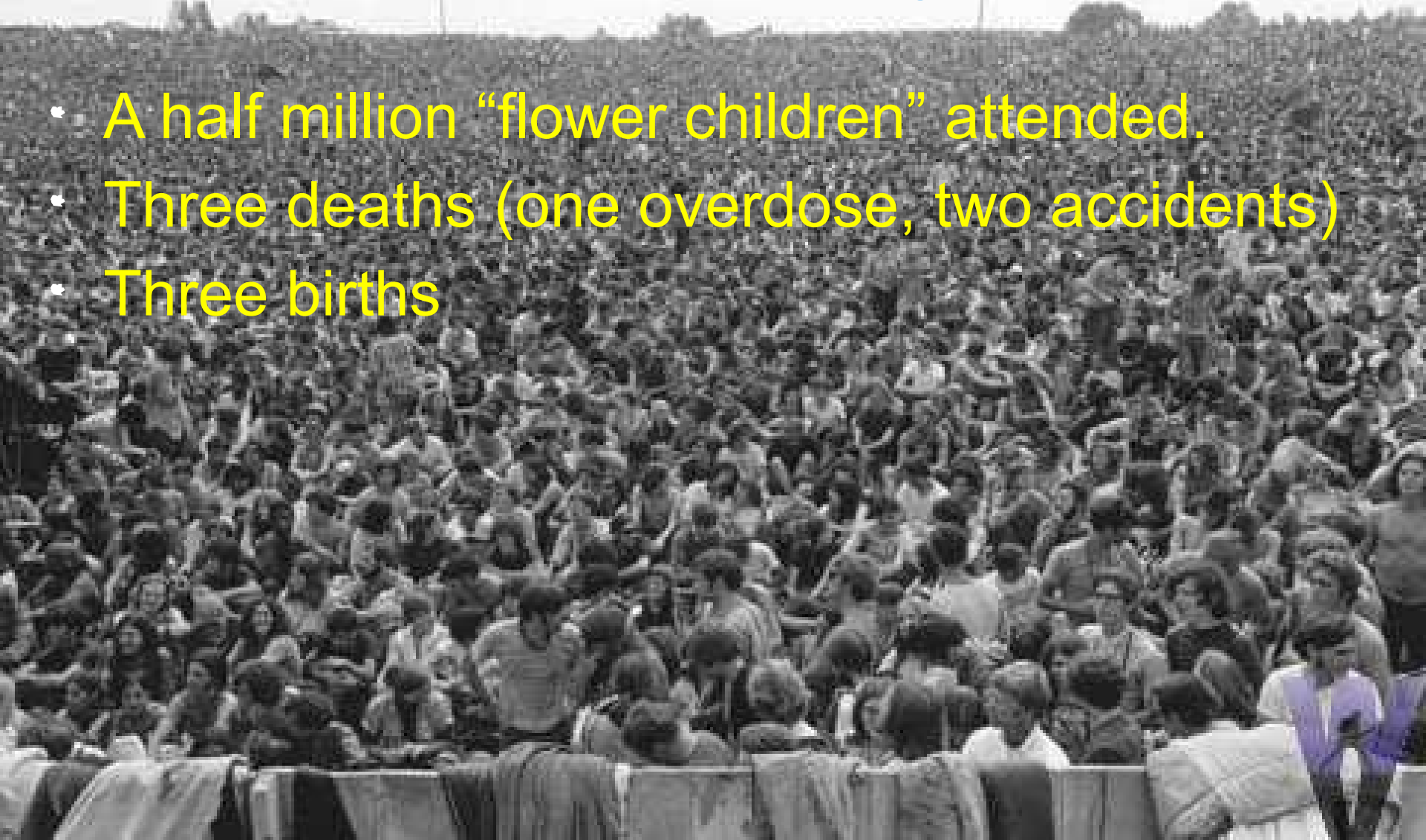
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# How can we Study the other Stars?

## A Woodstock Photograph

- A half million “flower children” attended.
- Three deaths (one overdose, two accidents)
- Three births



# How can we Study the Stars?

- A star can live for millions to billions of years.
  - we will never observe a particular star evolve from birth to death so how can we study stellar evolution?
- The key is that all stars were not born at the same time.
  - the stars which we see today are at different stages in their lives
  - we observe only a brief moment in any one star's life
  - by studying large numbers of stars, we get a “snapshot” of one moment in the history of the stellar community
- The stars we observe also have different masses.
  - by counting stars of different masses, we can determine how long stars of a given mass remain in a certain stage of life

# Naming the Stars

- Star names were originally based on:
  - their brightness
  - their location in the sky

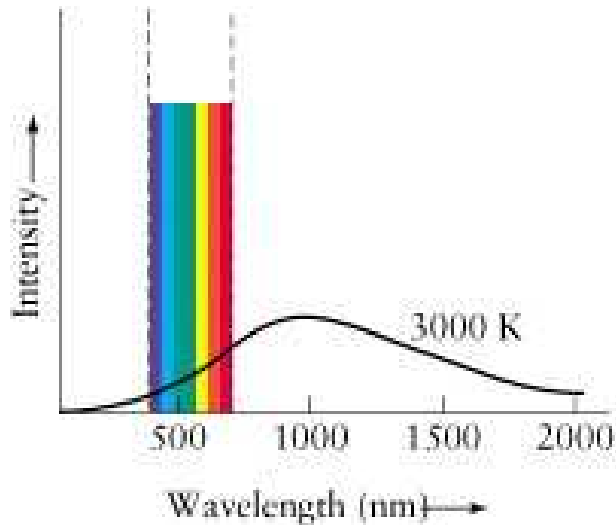
Order of brightness  
within a  
constellation

Latin Genitive of  
the constellation

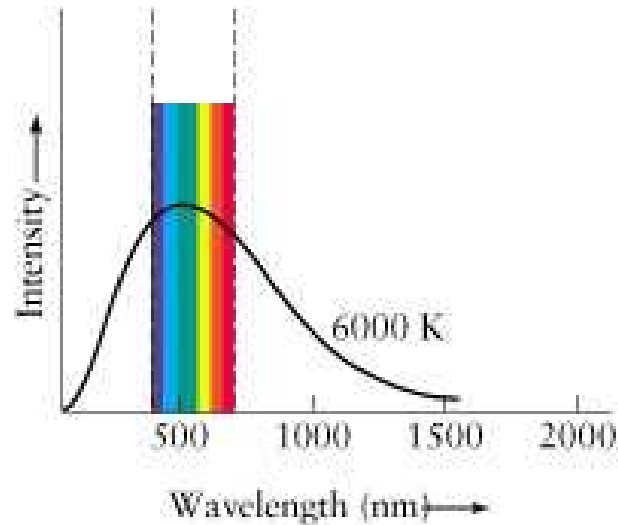
Orionis  
Geminorum

- These names told us little about a star's true (physical) nature.
  - a star could be very bright because it was very close to us; not because it was truly bright
  - two stars in the same constellation might not be close to each other; one could be much farther away
- In the 20th Century, astronomers developed a classification system based on:
  - a star's **luminosity**
  - a star's **surface temperature**
- Since these properties depend on a star's mass and its stage in life:
  - measuring them allows us to reconstruct stellar life cycles

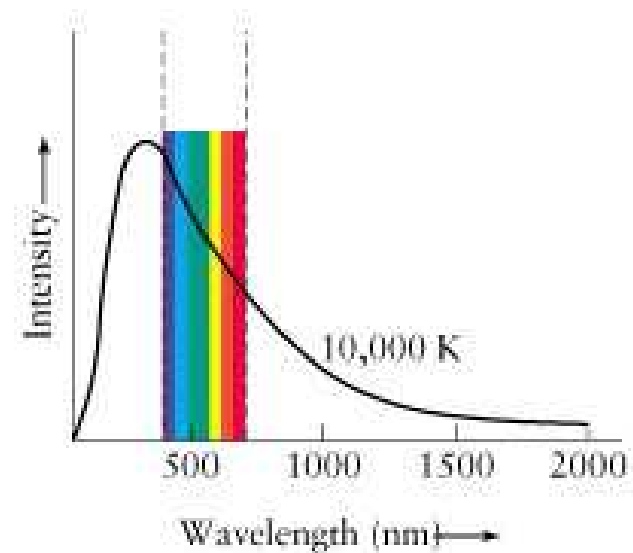
# A star's color reveals its surface temperature



a This star looks red

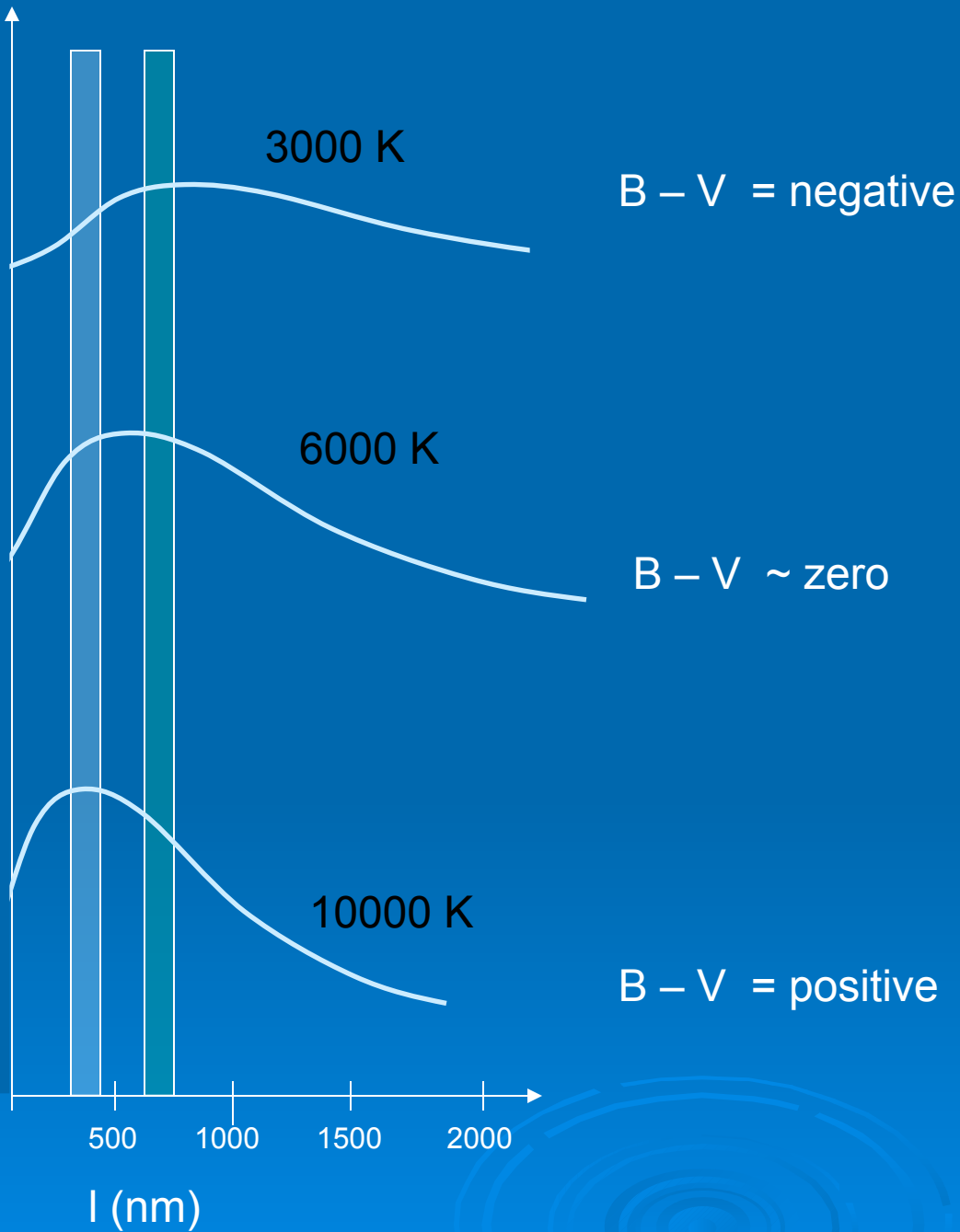


b This star looks yellow-white



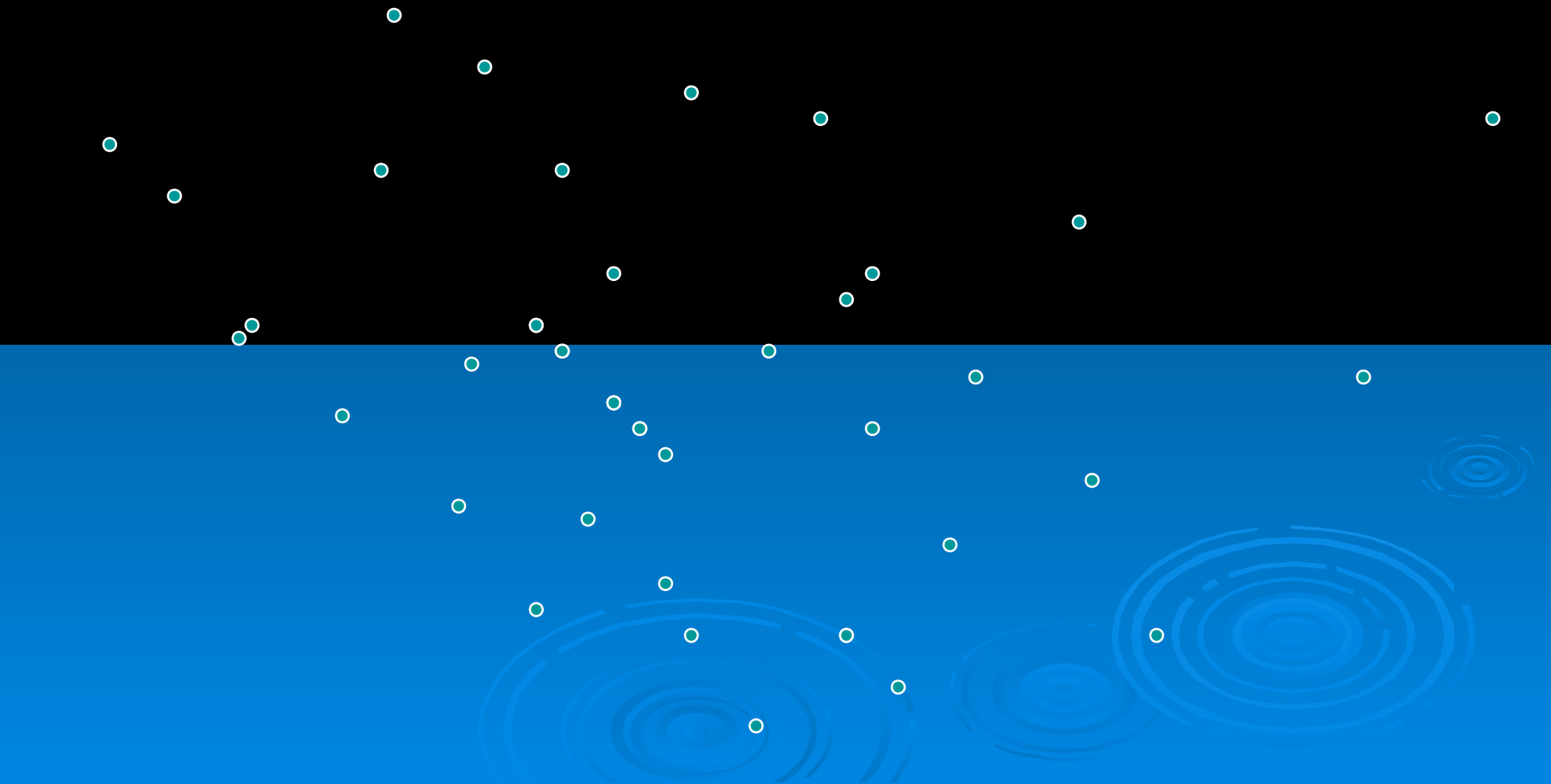
c This star looks blue-white

# BVR Filters



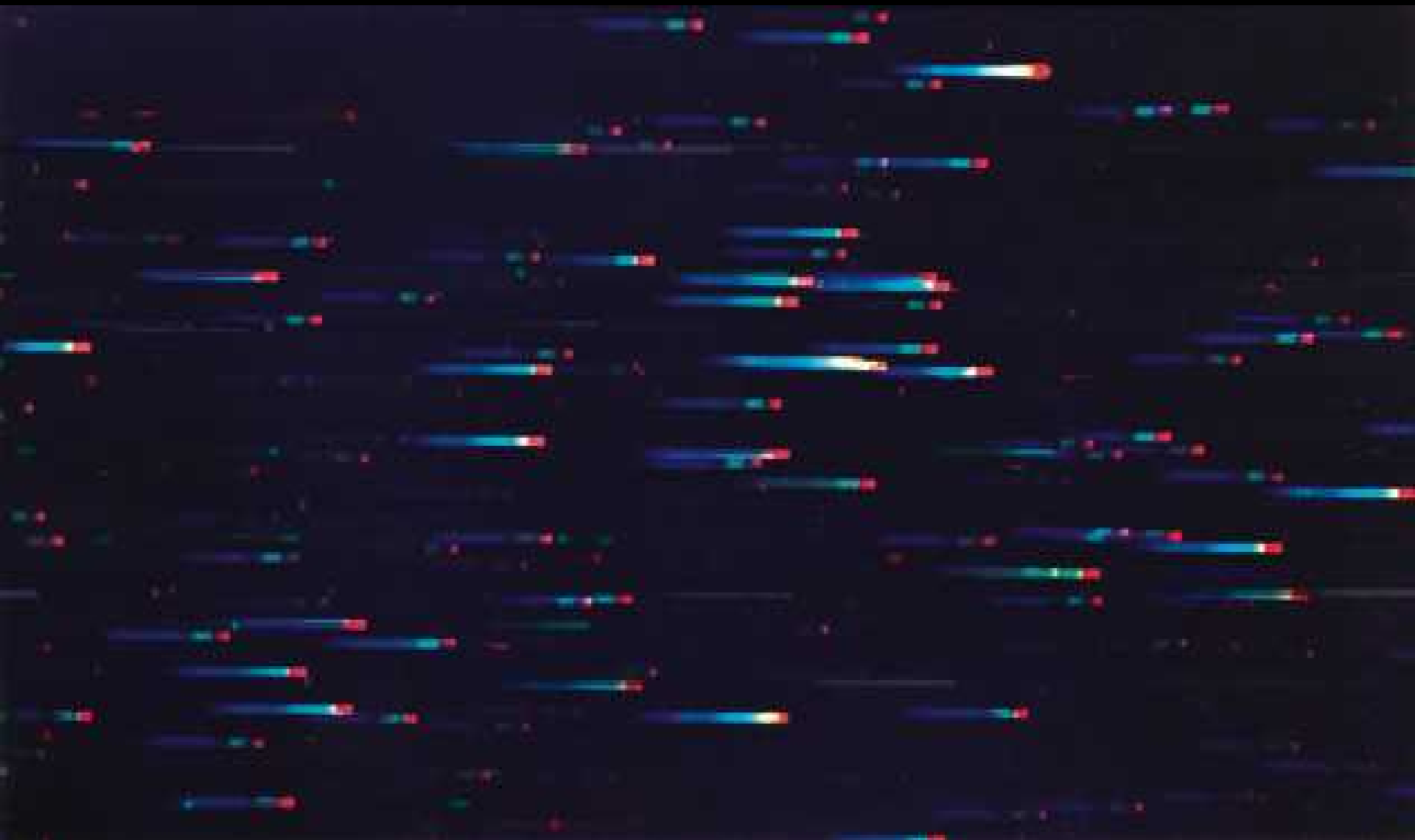


# Photographs of Star Clusters



# Spectra of Star Clusters







What do you do when  
you don't understand  
the data?

**CLASSIFY!**

# Wide Field Spectra



**But, who is  
going to  
classify all  
this data?**

# Women at Harvard

- Much of the work in classifying and explaining stellar spectra was done by women at Harvard around 1890.



# Women Computers (1890)





Henrietta Leavitt (1868-1921)

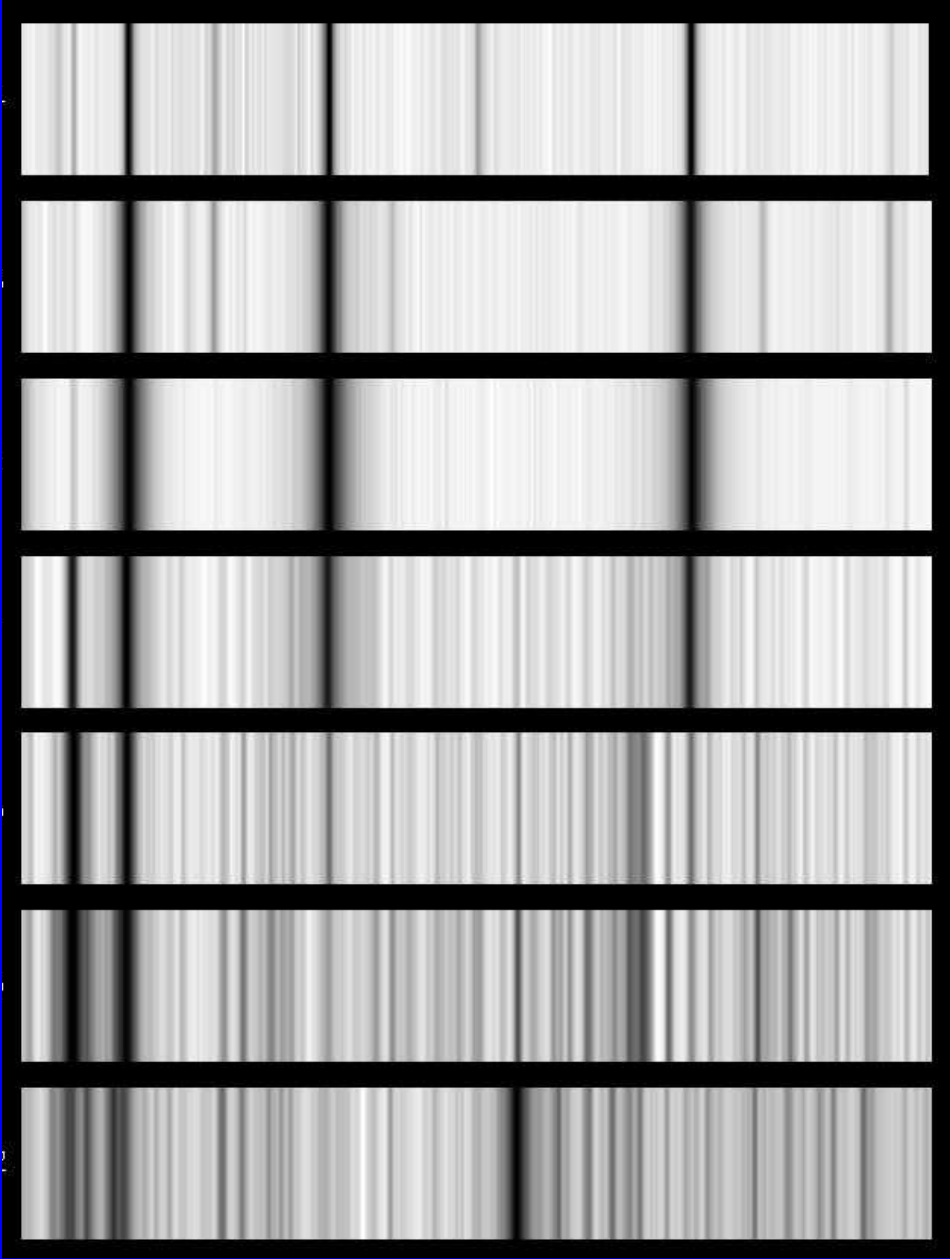


# *Classification Scheme*

A  
B  
C  
D  
E

Fleming's system based on the strength of the Hydrogen lines in the spectrum

Hydrogen Lines

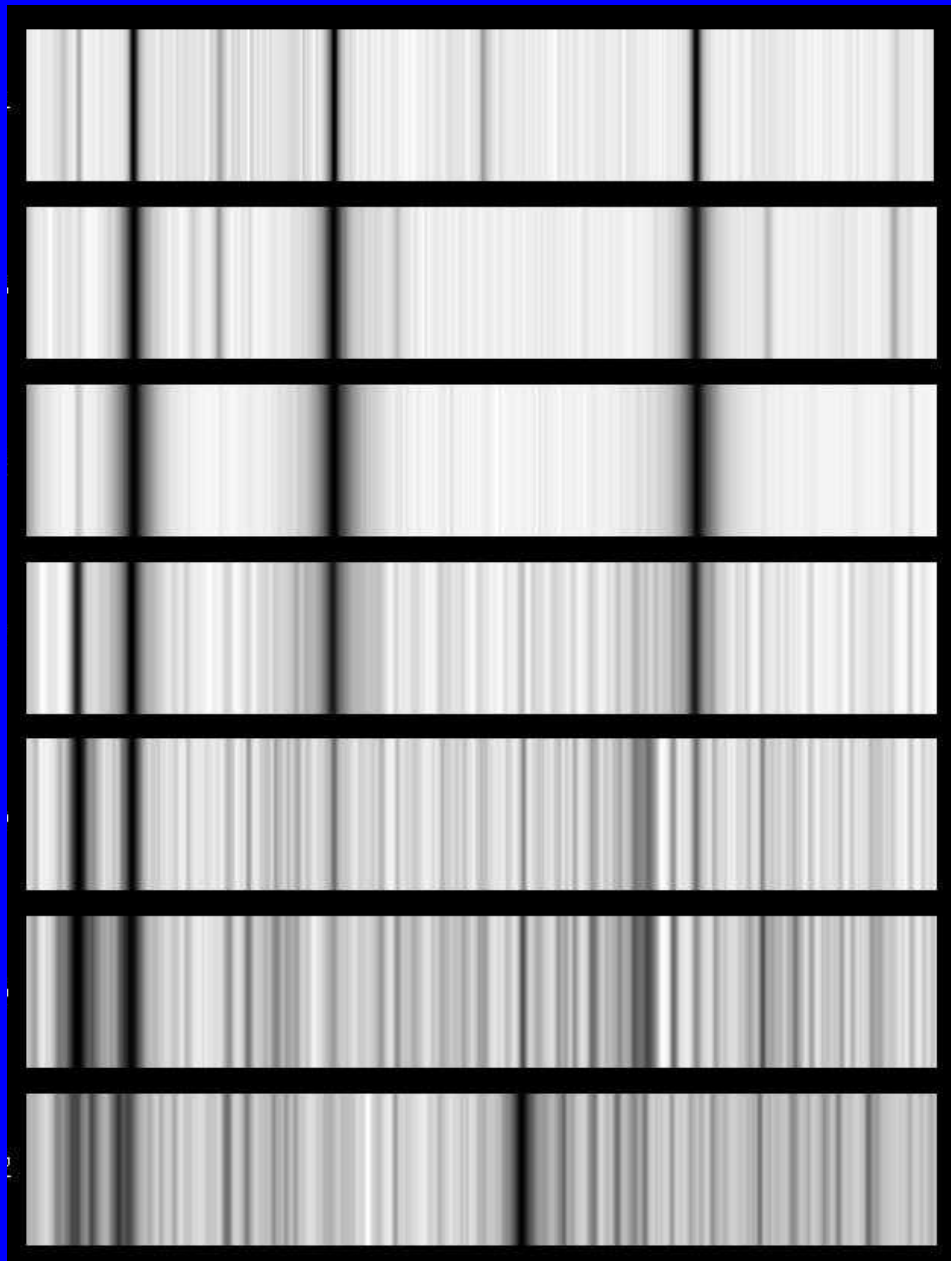




Annie Jump Cannon (1863-1941)

# Annie Jump Cannon:

- Single-handedly classified more than 250,000 stellar spectra.
- Confirmed work of Antonia Maury that classes made more sense if arranged by temperature

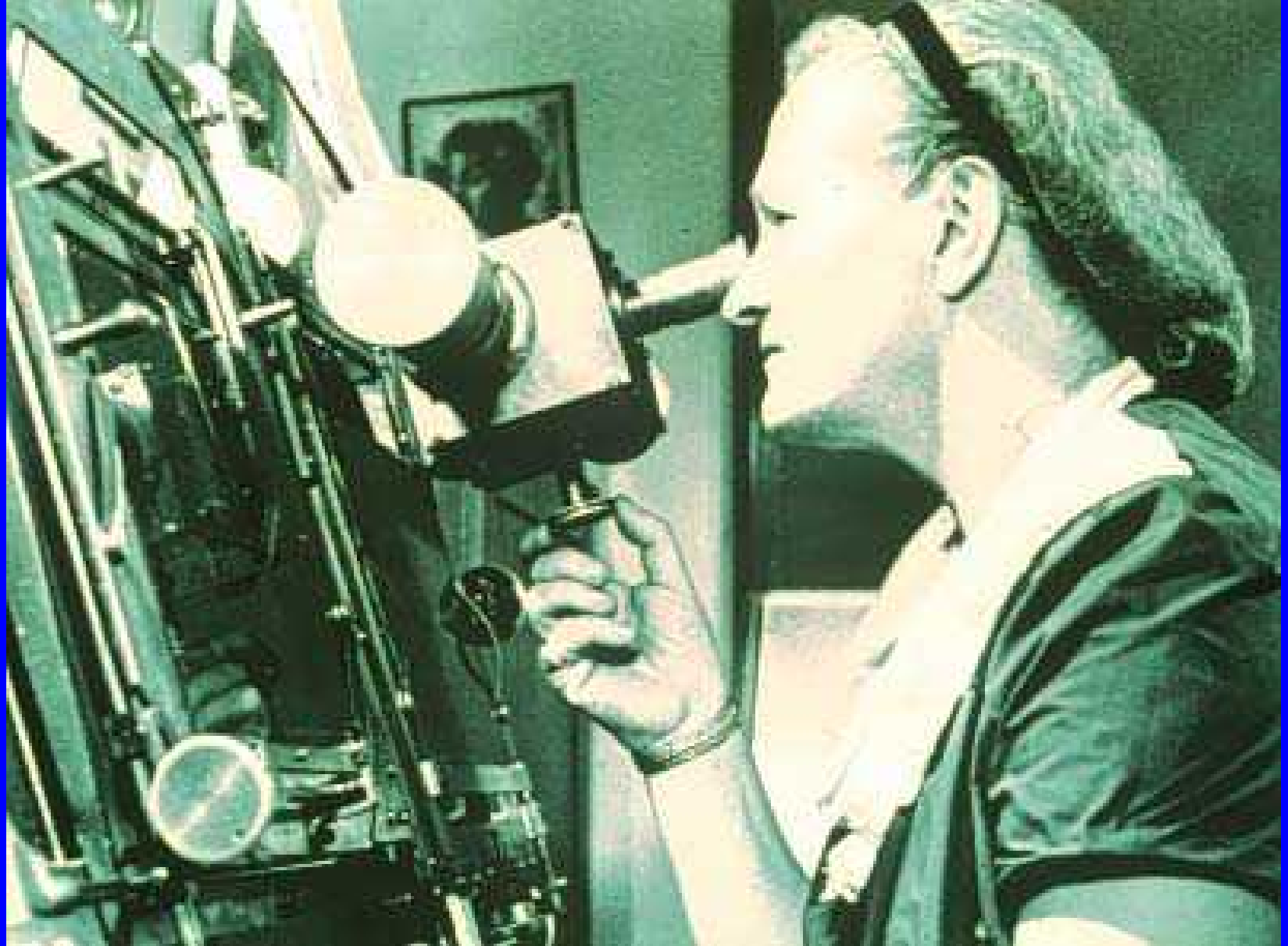


Temperature



# BUT WHY?

- Most astronomers believed that the differences were due to subtle differences in chemical abundance.
- Indian physicist Meghnad Saha offered another explanation, which was confirmed at Harvard.



Cecelia Payne-Gaposchkin (1900-1979)

# Cecelia Payne-Gaposchkin

- Gave theoretical explanation for Cannon's classification scheme.
- Argued that differences in spectra (absorption lines) are due to temperature not abundance (*Saha Equation*)
- Differences in temperature create differences in the observed absorption spectra.
- Also, she provided the convincing argument that stars are mostly made of hydrogen.



# What does this give us?

- a new way to measure temperature

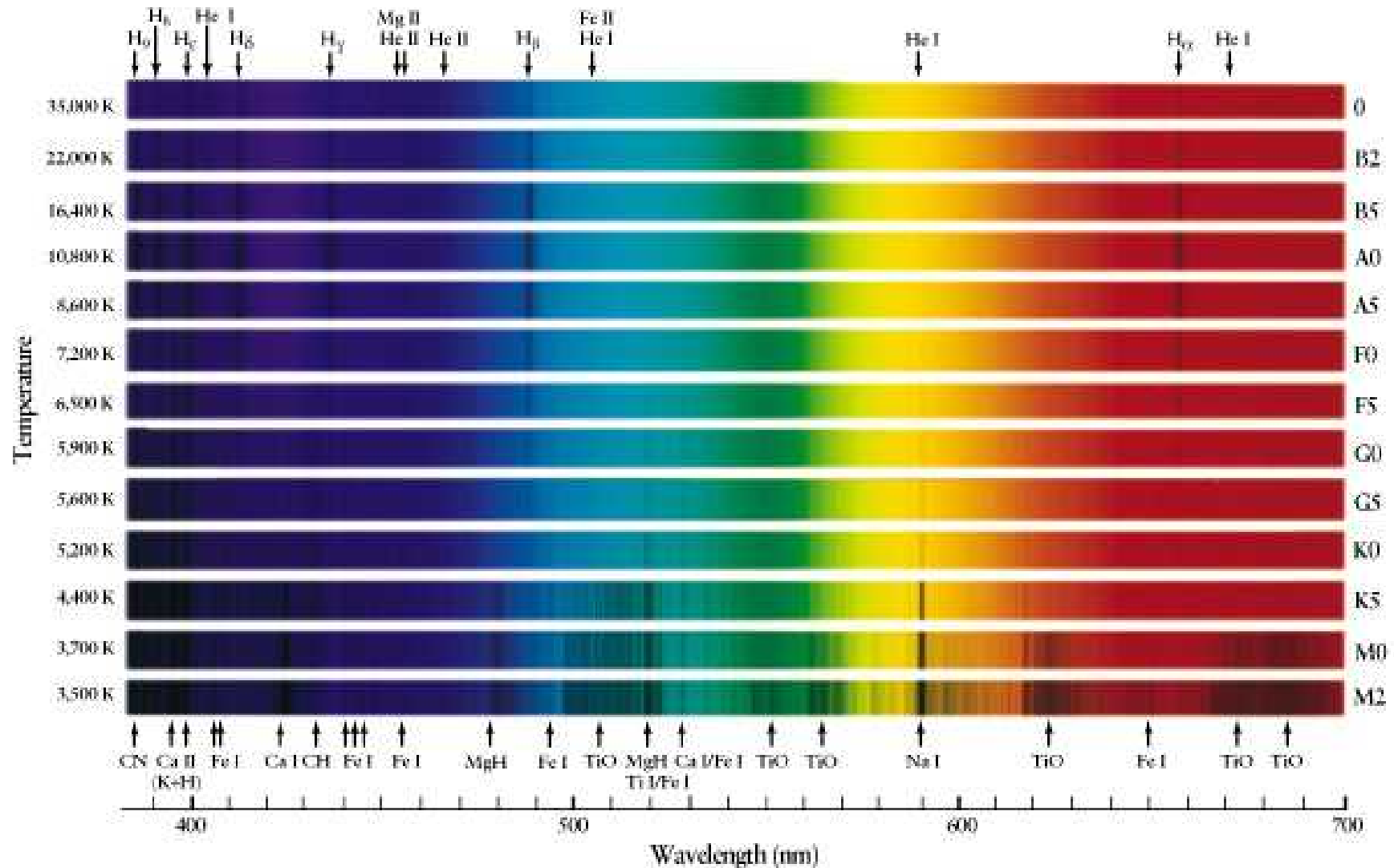
- can speak of color, spectral class or temperature

*(we needed both spectral class and temperature for many stars to establish this connection)*

# Summary of Spectral Classes

<b>O</b>	<b>hotter than 25,000 K</b>
<b>B</b>	<b>11,000 - 25,000 K</b>
<b>A</b>	<b>7500 - 11,000 K</b>
<b>F</b>	<b>6000 - 7500 K</b>
<b>G</b>	<b>5000 - 6000 K</b>
<b>K</b>	<b>3500 - 5000 K</b>
<b>M</b>	<b>cooler than 3500 K</b>

# Stars are classified by their spectra as O, B, A, F, G, K, and M spectral types



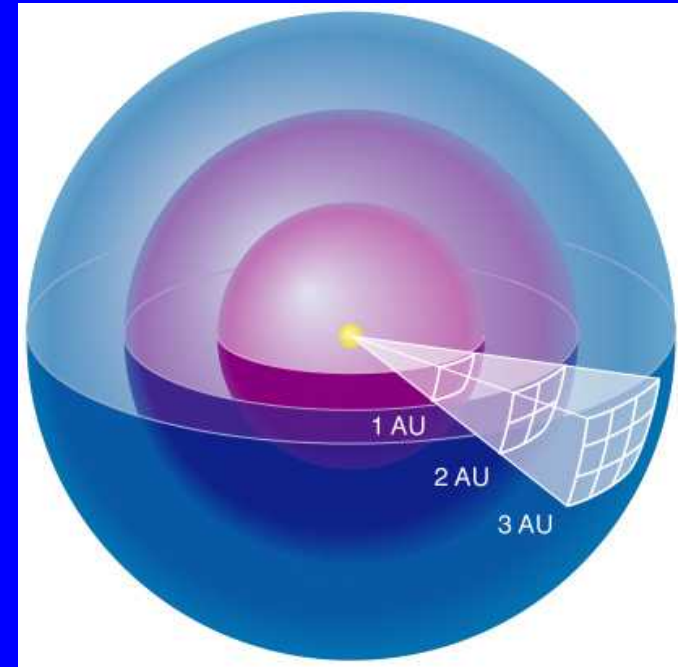
# Stars are classified by their spectra as O, B, A, F, G, K, and M spectral types

- O B A F G K M
- hottest to coolest
- bluish to reddish
- An important sequence to remember:
  - Our Best Astronomers Feel Good Knowing More
  - Oh Boy, An F Grade Kills Me
  - Oh Be a Fine Guy (or Girl), Kiss Me

# Luminosity of Stars

**Luminosity** – the total amount of power radiated by a star into space.

- **Apparent brightness** refers to the amount of a star's light which reaches us *per unit area*.
  - the farther away a star is, the fainter it appears to us
  - how much fainter it gets obeys an *inverse square law*
  - its apparent brightness decreases as the  $(\text{distance})^2$



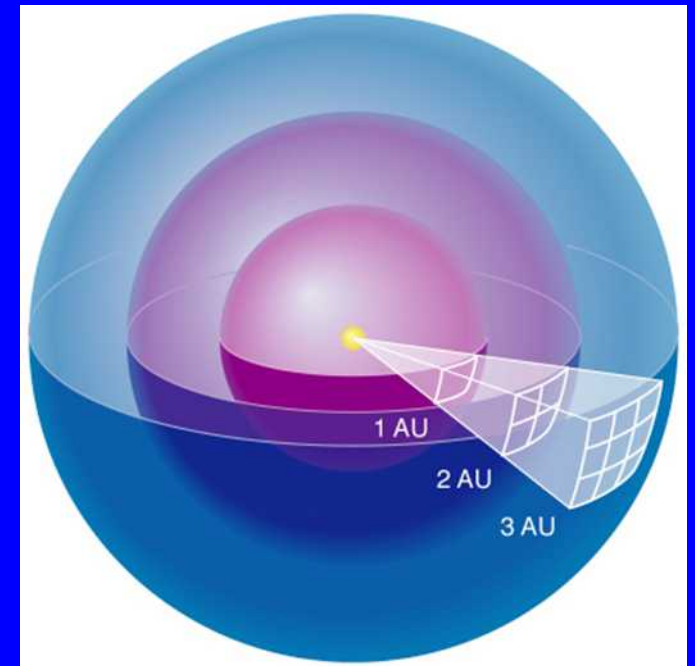
$$f \propto 1 / d^2$$

The apparent brightness (flux of radiant energy (f)) of a star depends on two things:

- How much light is it emitting: luminosity (L) [Watts = Joules/sec]
- How far away is it: distance (d) [meters]

$$f \propto L / d^2$$

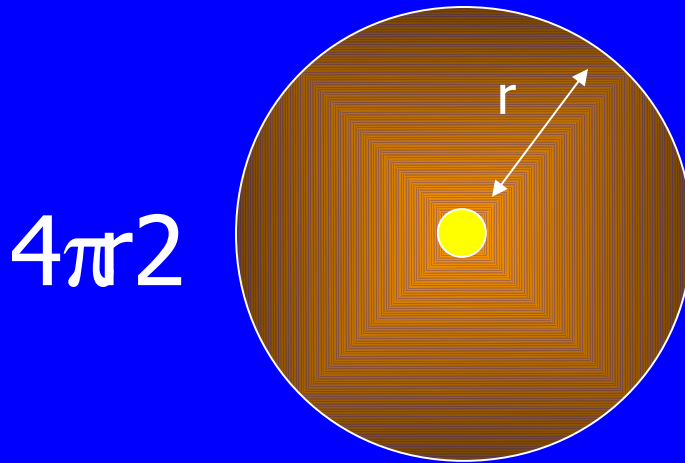
$$f = L / \text{area}$$



Luminosity of the Sun,  $L = 3.9 \times 10^{26}$  Watts

Flux of radiant energy from the Sun =  
luminosity / area =  $f$

$$f = L / 4\pi r^2$$



(Units are  $W/m^2$ )