Astronomy 350L

(Spring 2005)

The History and Philosophy of Astronomy

(Lecture 18: Birth of Astrophysics I)

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The University of Texas at Austin

Big Q: What is the Nature of the Stars?

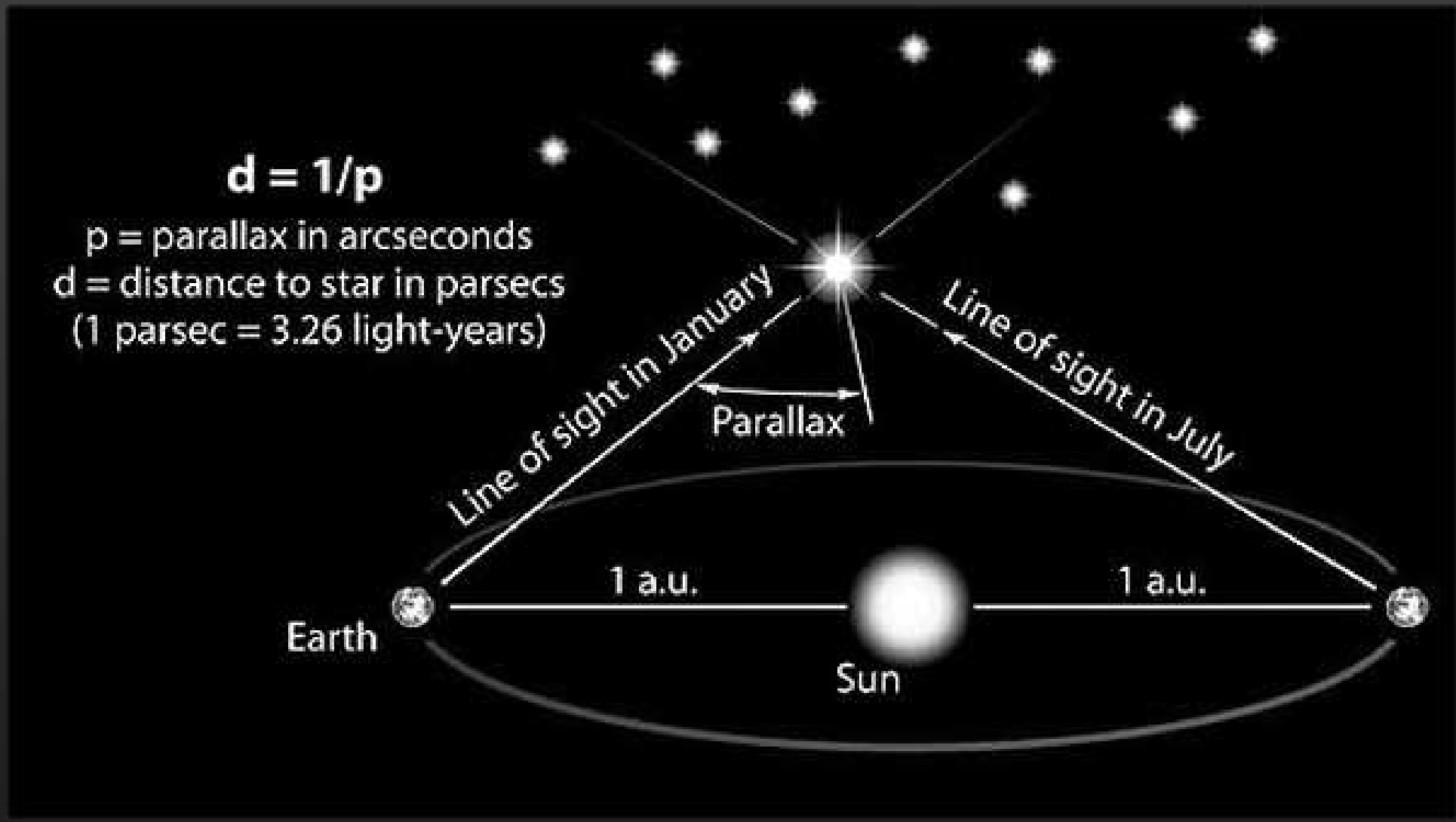
Can we ever know the `Physics of the Stars'?

(= astrophysics)

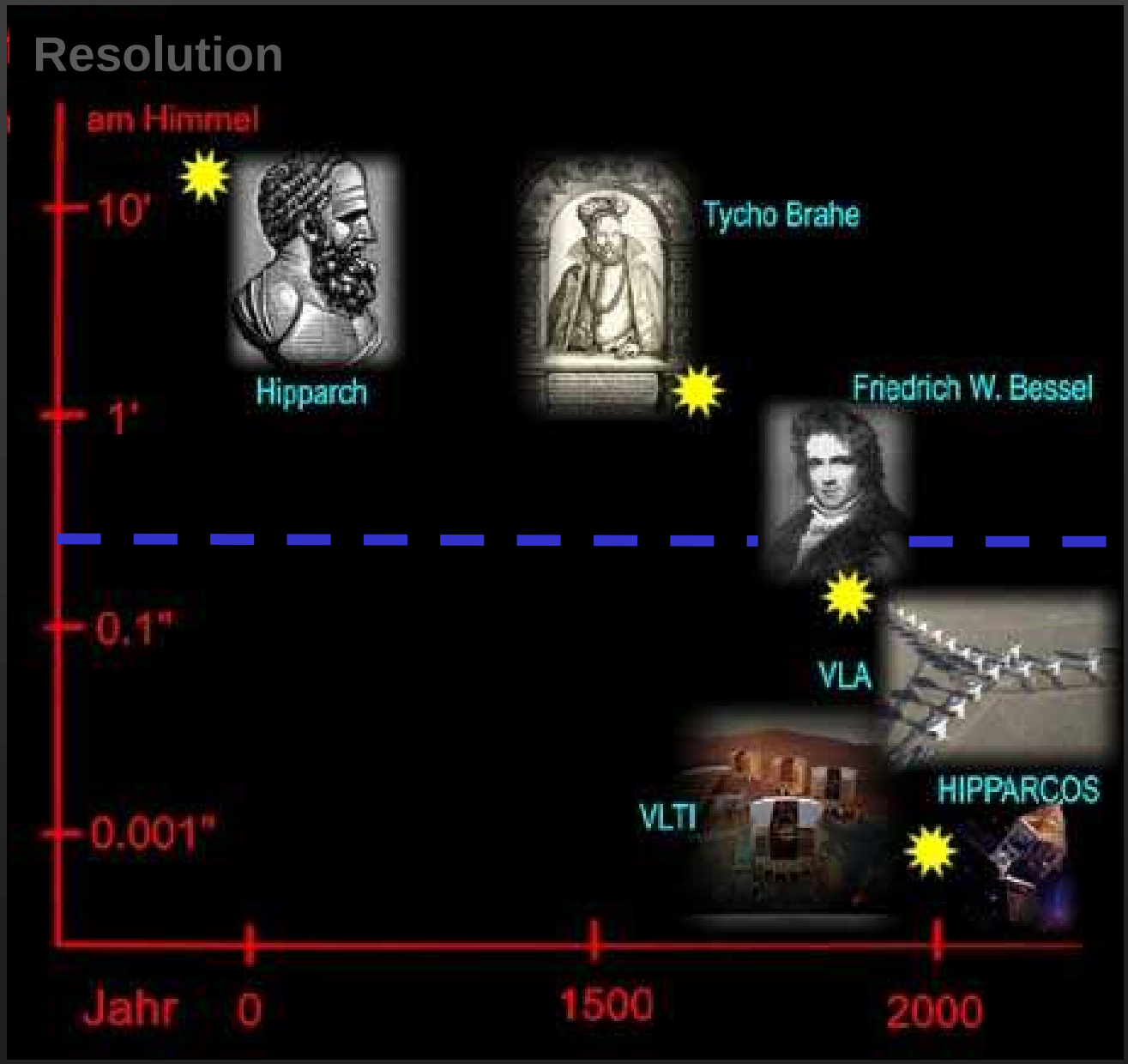
- Auguste Comte (1798-1857)
- founder of `Positivism'
  - real knowledge only due to hard facts, e.g., laboratory science, measurements
- claimed that we will never know the nature of the stars
  - distant stars are forever out of our reach
  - we cannot conduct laboratory experiments with them

- **Which questions would an astronomer have asked about the stars in the early 1800s?**
  - How far away are they (stellar distance scale)?
  - What are the stars made of (stellar composition)?
  - How massive are they?
  - How long do they live (stellar lifetimes)?
  - By what mechanism do they shine?
  - Is the Sun just a (nearby) star?
    A: Yes, already widely believed (Descartes, Newton)

The Hunt for Stellar Parallax!



The Hunt for Stellar Parallax!



Measuring the Distance to the Stars

- Friedrich Wilhelm Bessel (1784-1864)
- highly talented in astronomy and mathematics ("Bessel functions")
- director of Königsberg Observatory
- 1838: First stellar parallax

Q: How to select promising candidates?

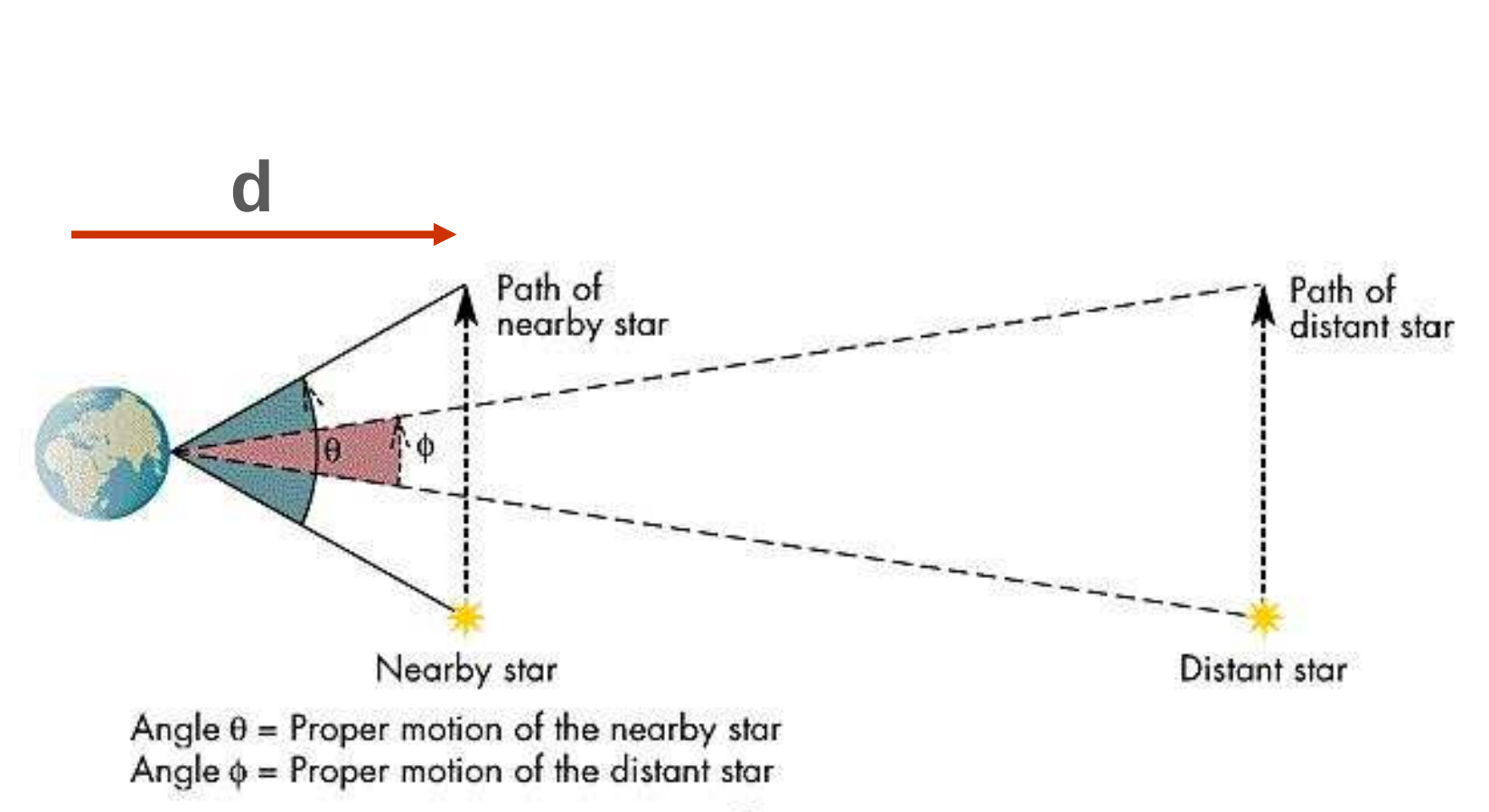
- possible criteria:

  1) brightest stars

  2) most rapid proper motion

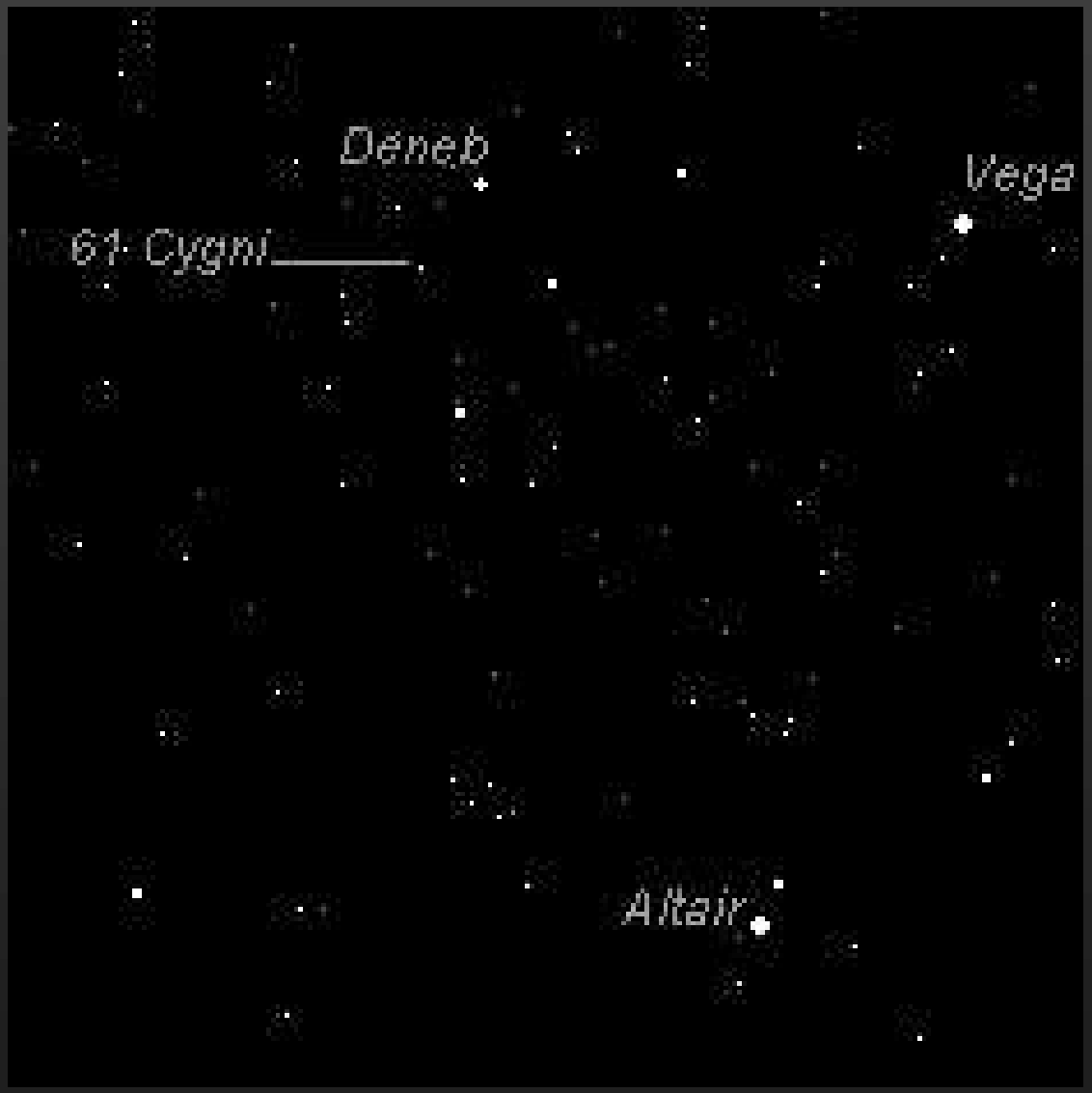
  Bessel’s choice!

Stellar Motions on the Sky



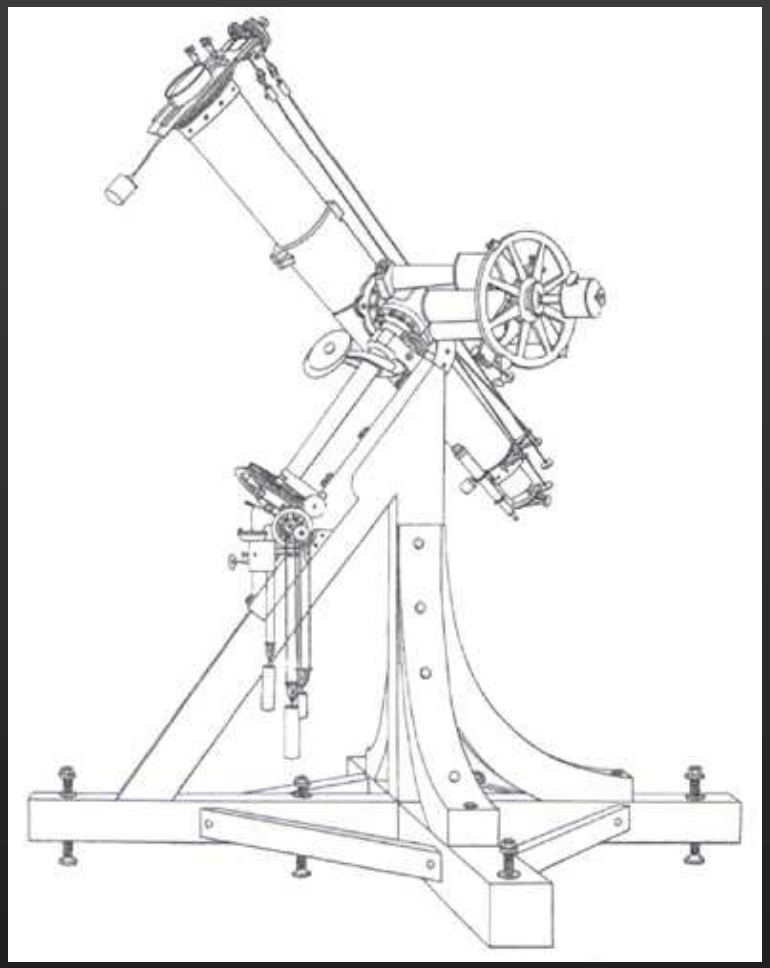
- proper motion $\alpha 1/d$

Q: How to select promising candidates?



- 61 Cygni: the `flying star’ (5 arcsec per year)

Great Success: First Stellar Parallax (1838)!

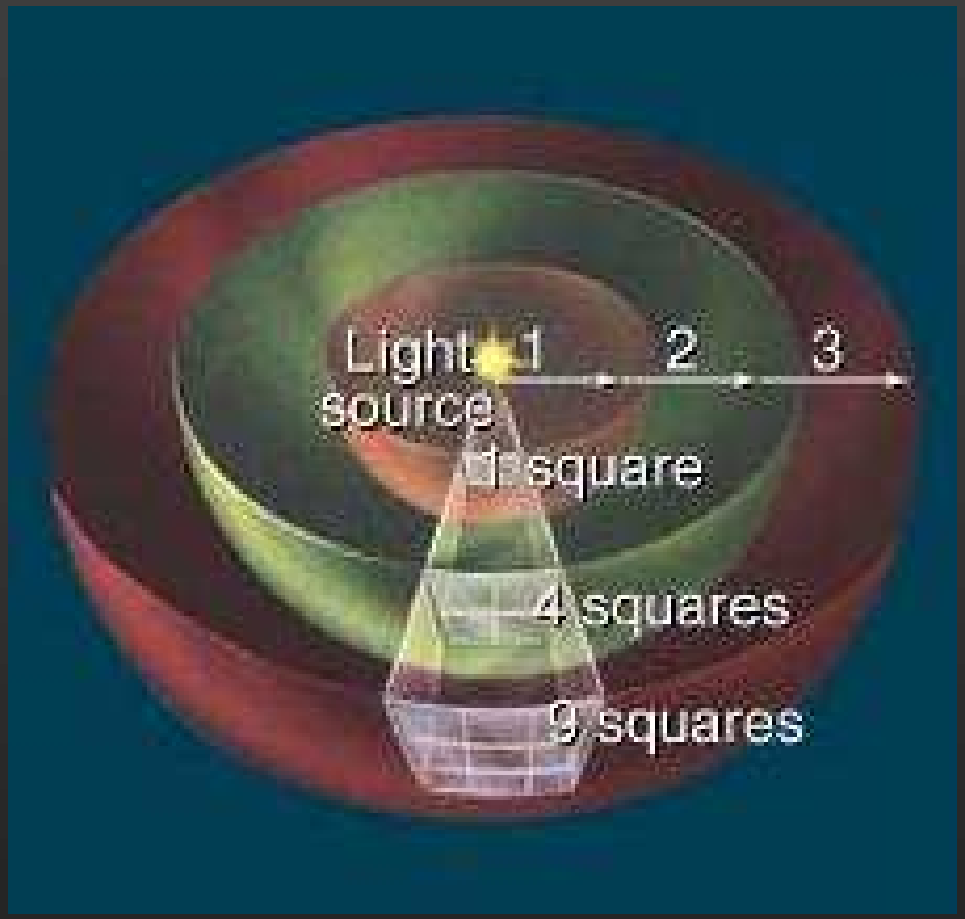


Bessel's heliometer

- Bessel: 61 Cygni
  - 1/3 arcsec → 10.3 Lightyears

- almost simultaneously:
  - Wilhelm Struve: Vega
  - Thomas Henderson: Alpha Centauri

The True Brightness of the Stars

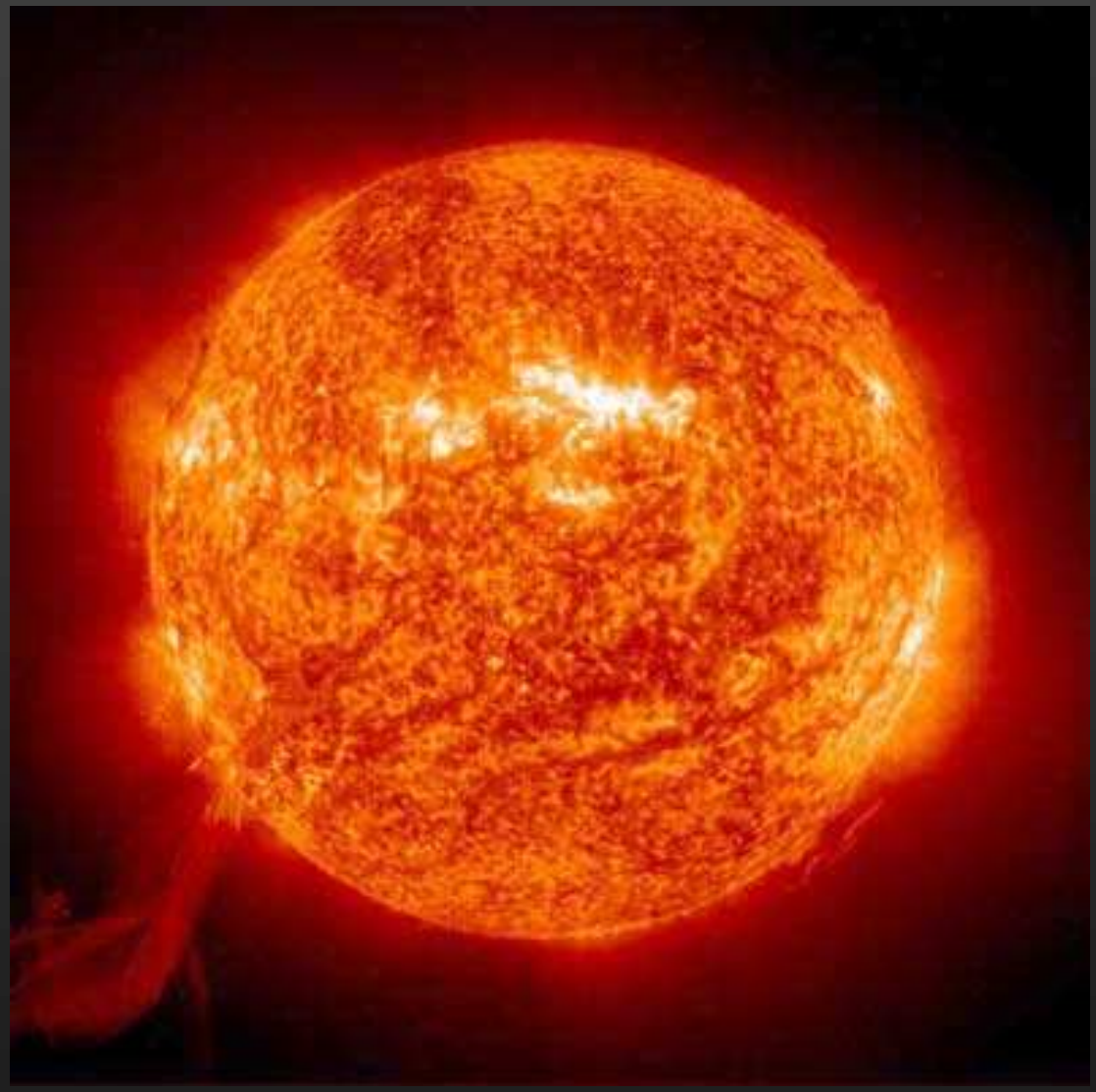


- what we measure:
  flux = energy/area
  (`apparent brightness')

- if distance (d) to star is known, can figure out true (intrinsic) brightness
  = Luminosity (L)

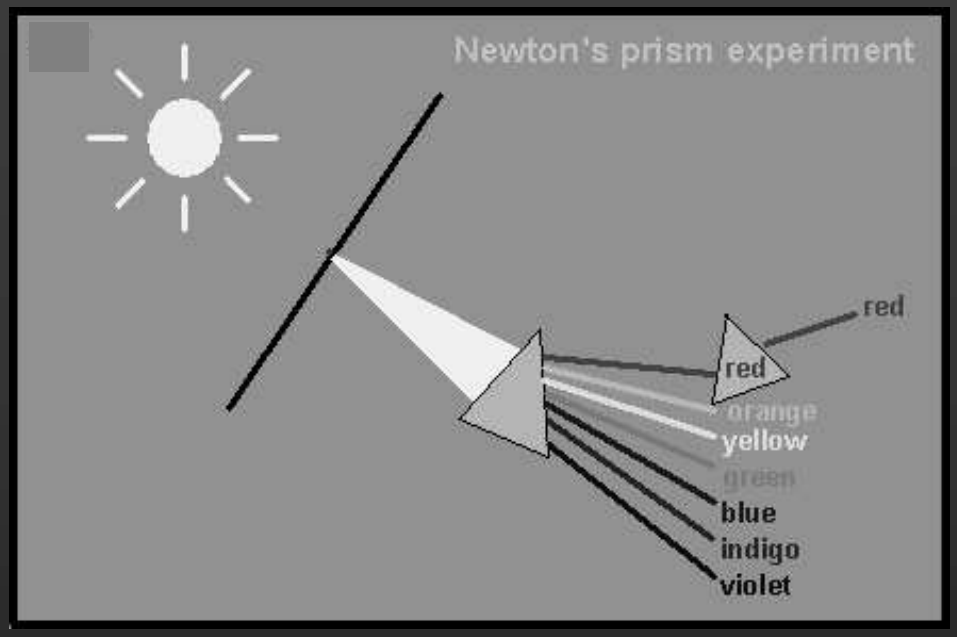
- $L = 4 \times \pi \times d^2 \times \text{flux}$ ("inverse-square law")

What stuff are the Sun and stars made out of?



- scrutinize the light that we receive!

The Message of Starlight (Newton 1666)

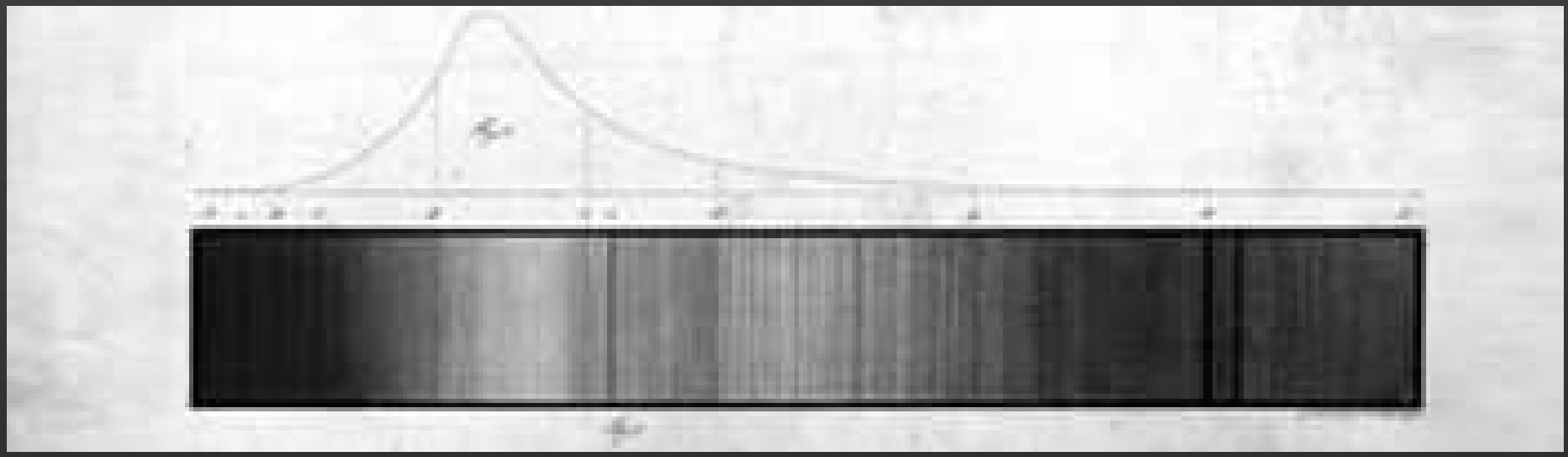


- white light is composed of different colors!

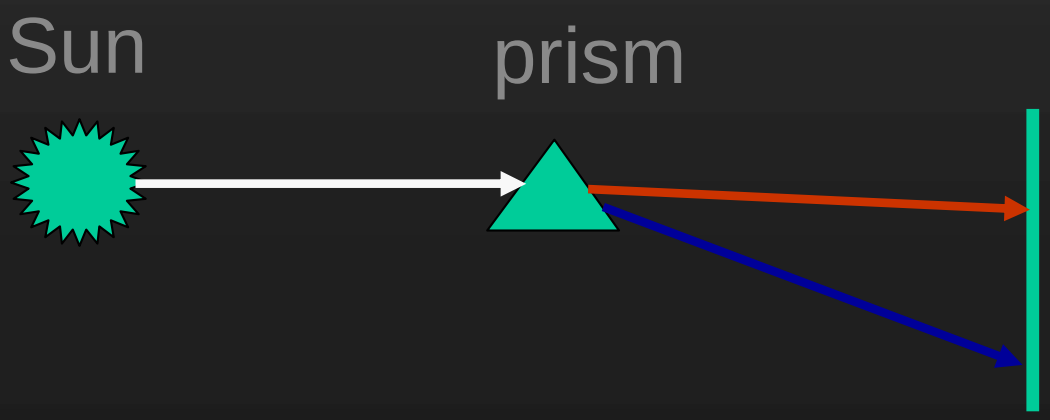
The Spectrum of the Sun

- Joseph Fraunhofer (1787-1826)
- master optician and telescope builder
- 1814: Discovery of Spectral Lines in Solar Light (= `Fraunhofer lines')

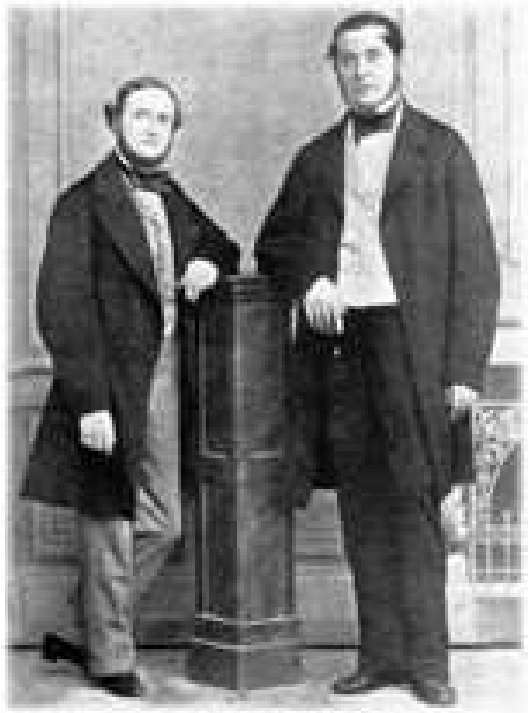
The Spectrum of the Sun (1814)



- Fraunhofer lines: dark lines



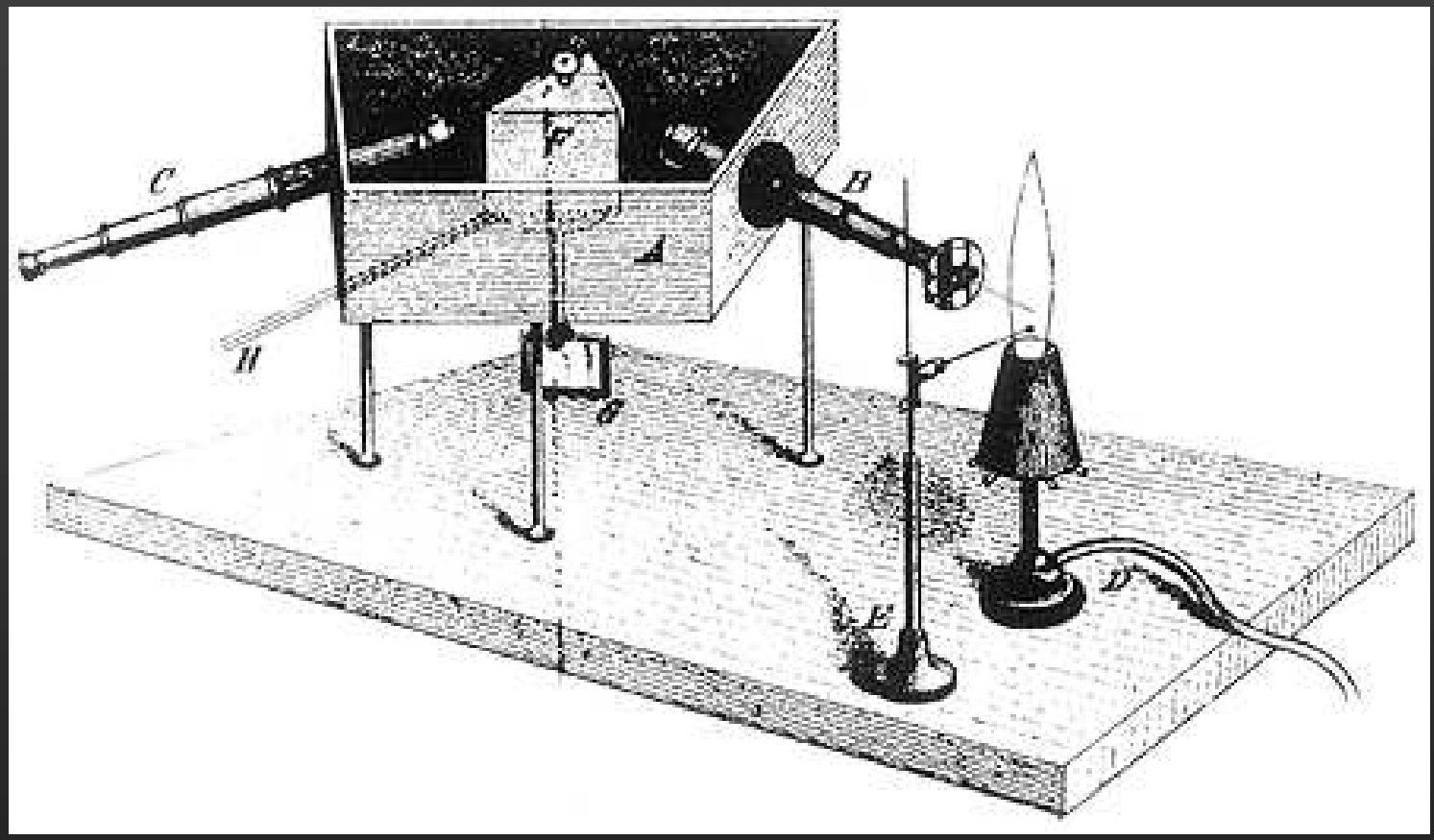
What are the Spectral Lines?



Gustav Kirchhoff (left) and Robert Bunsen.

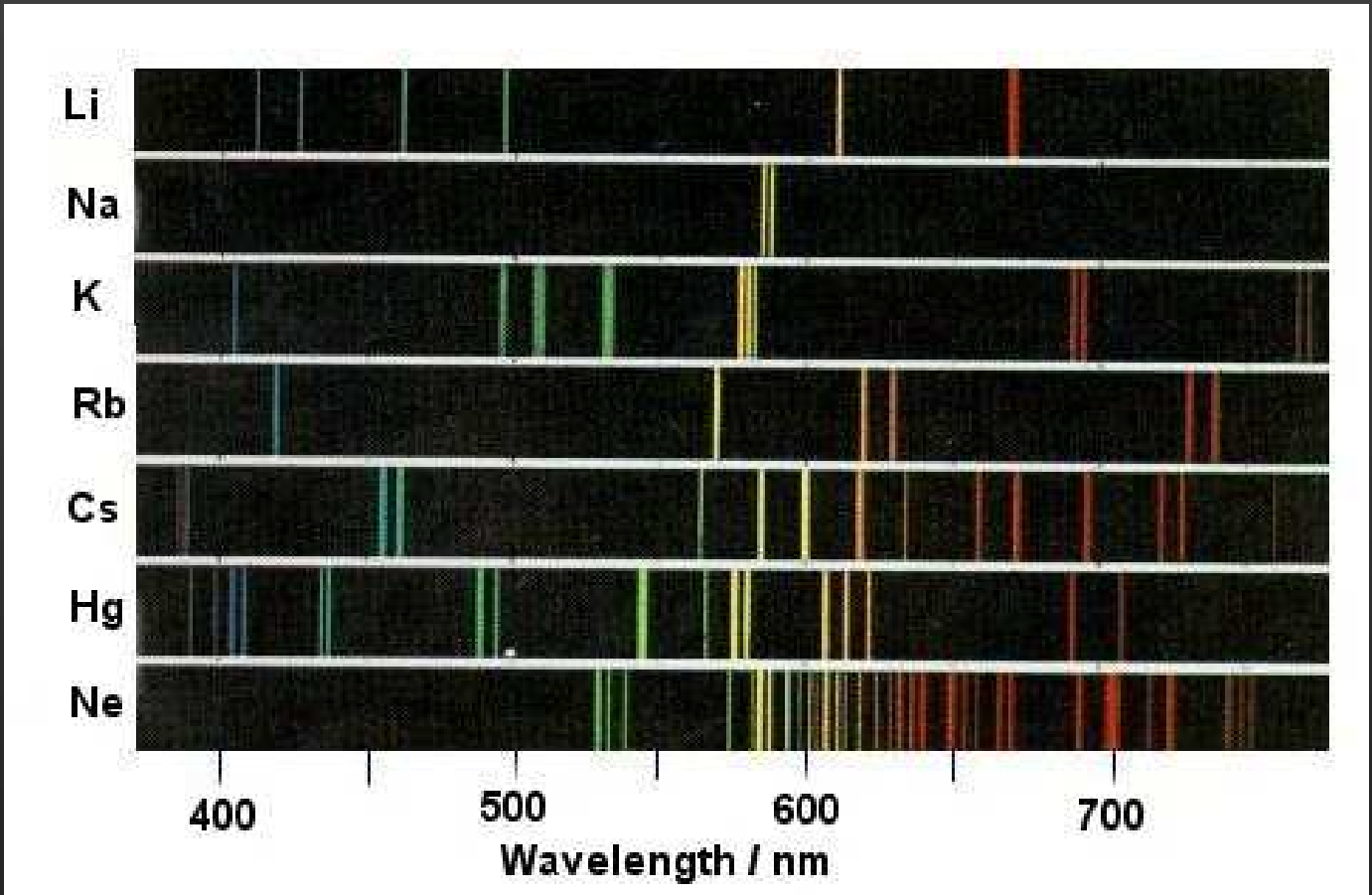
- Heidelberg in 1850s and 60s:
- Gustav Kirchhoff (1824-87) and Robert Bunsen (1811-99)
  - **discover the `Laws of Spectral Analysis'**
- Robert Bunsen (`Bunsen burner')

What are the Spectral Lines?



- `Flame test' (Spectral Analysis):
  - each chemical element has a distinct fingerprint!

What are the Spectral Lines?



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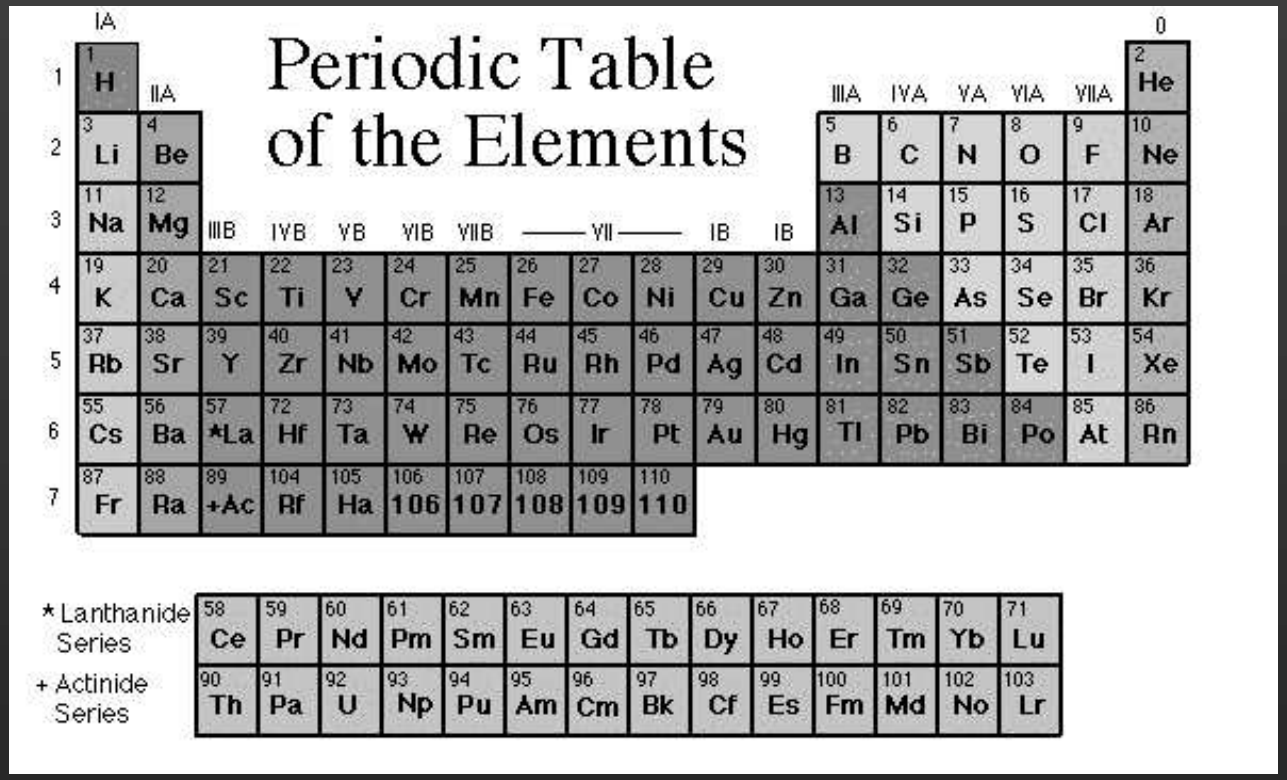
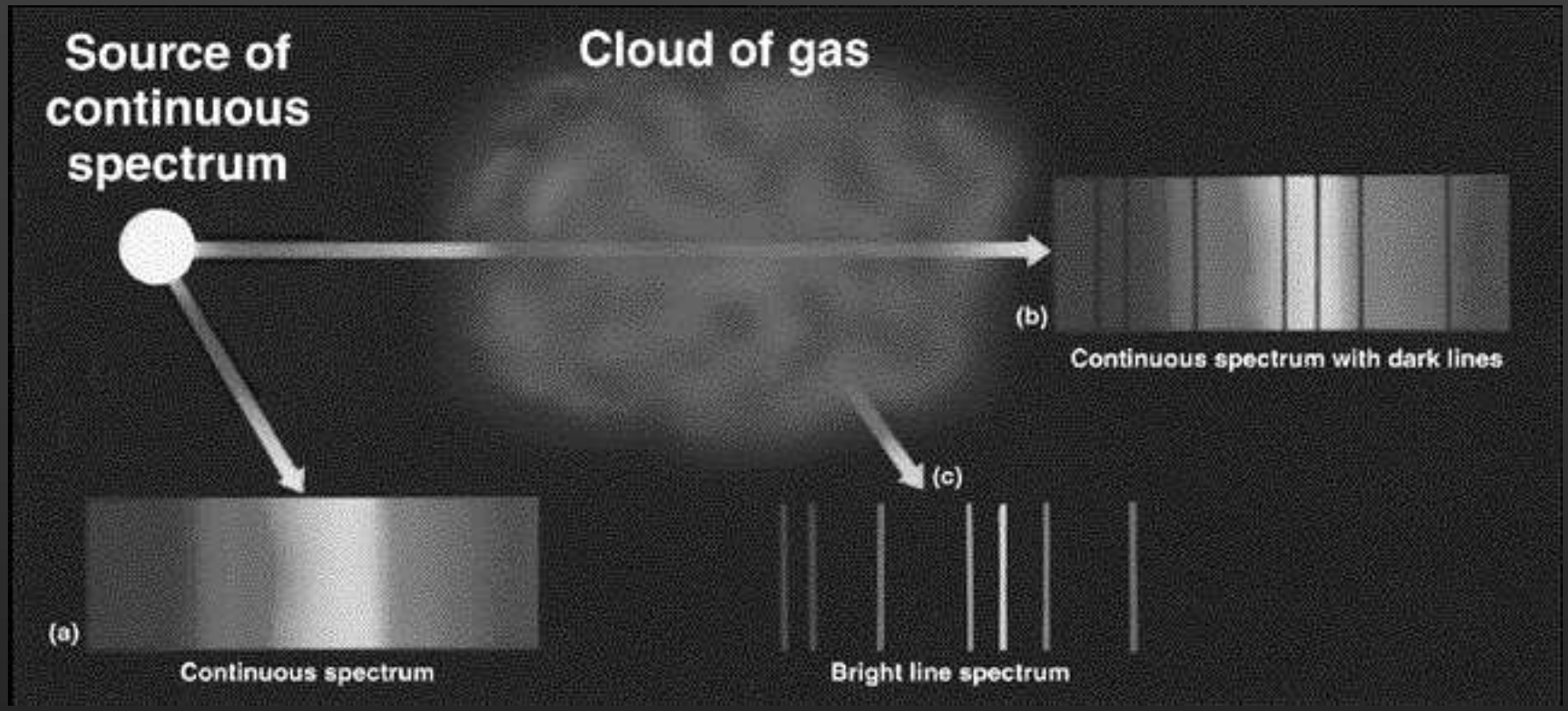


Periodic Table: Dmitri Mendeleyev (1869)

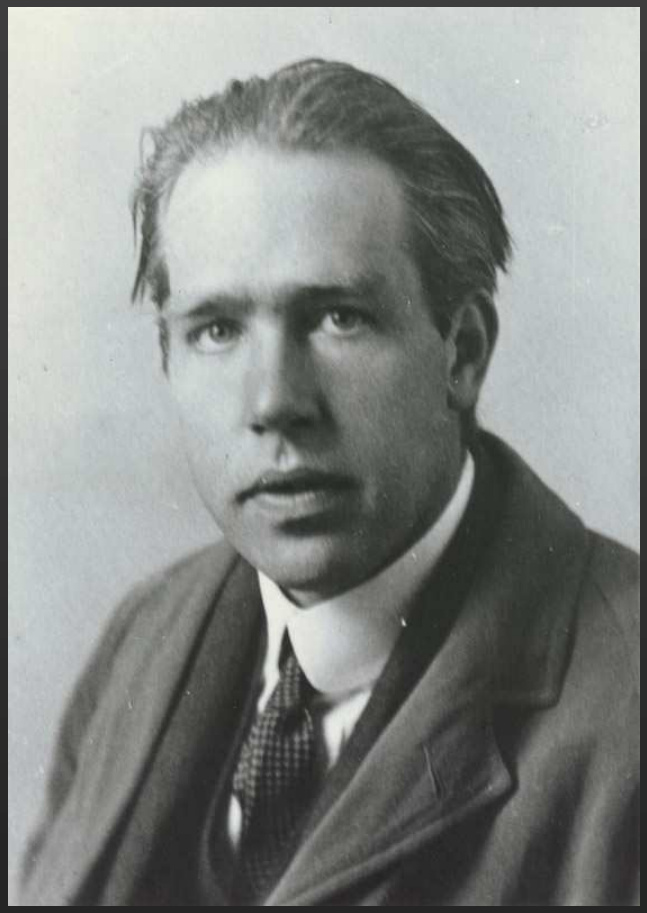
- `Flame test' (Spectral Analysis):
  - Kirchhoff/Bunsen discover new elements (Rubidium, Caesium)

What are the Spectral Lines?

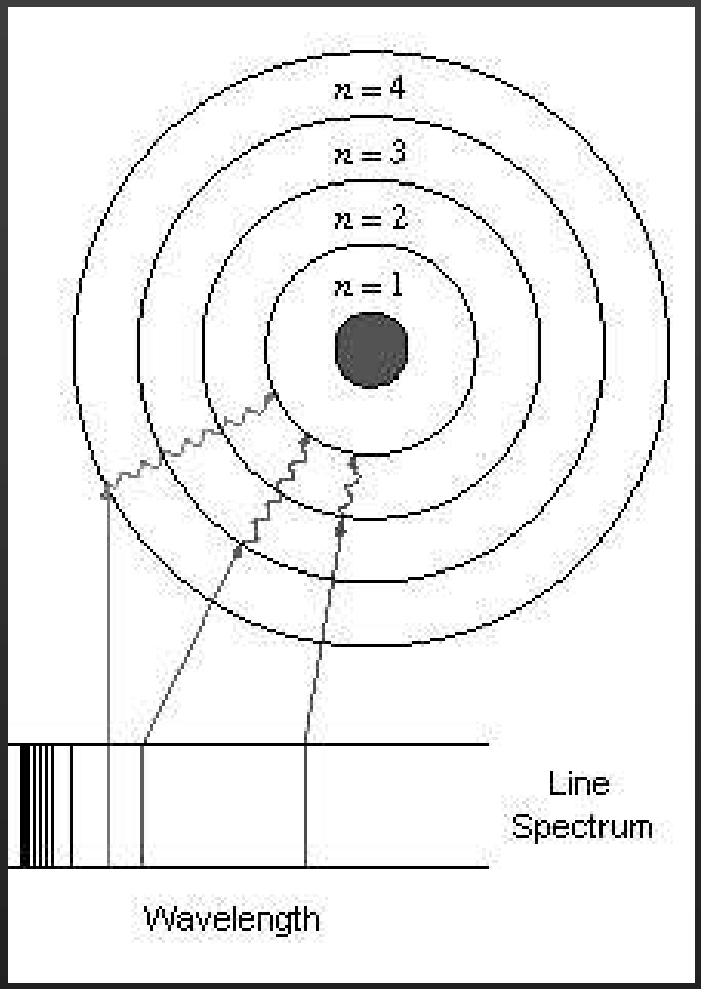


- The Laws of Spectroscopy:
  - dark lines = absorption lines
  - bright lines = emission lines

What are the Spectral Lines?

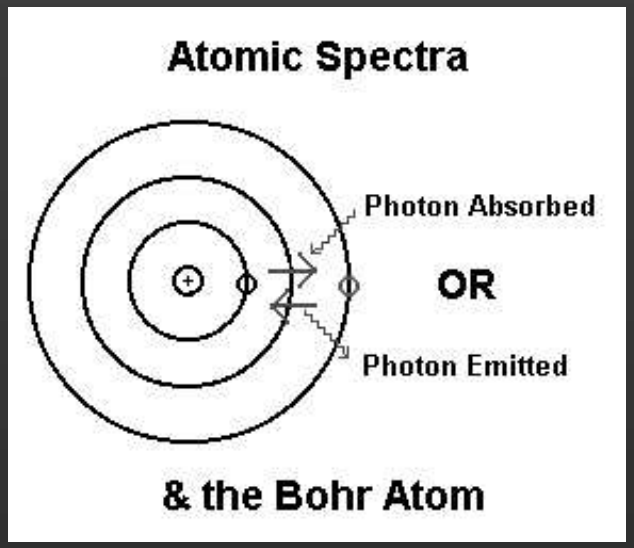


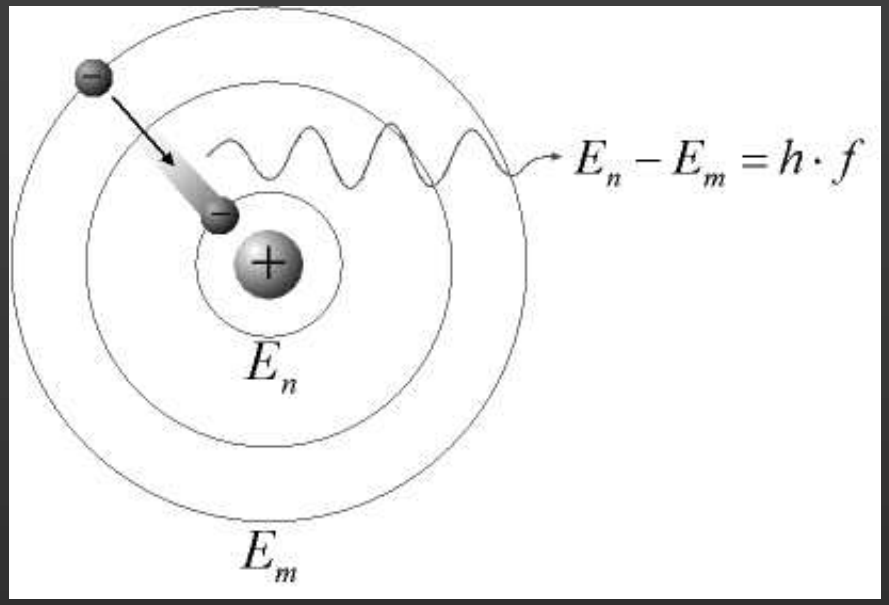
Niels Bohr (1885-1962)



Bohr’s quantum model of the atom (1913)

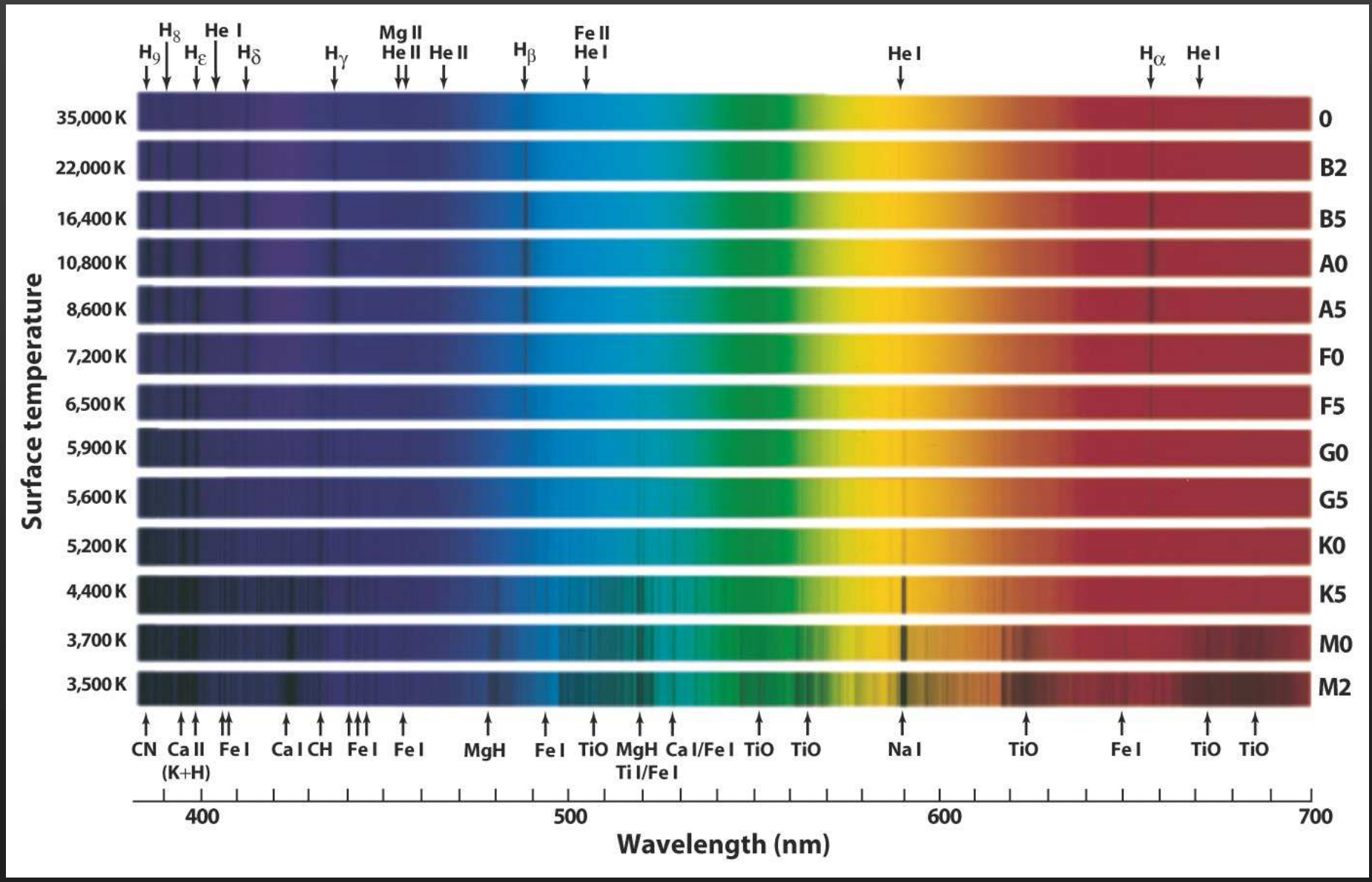
What are the Spectral Lines?



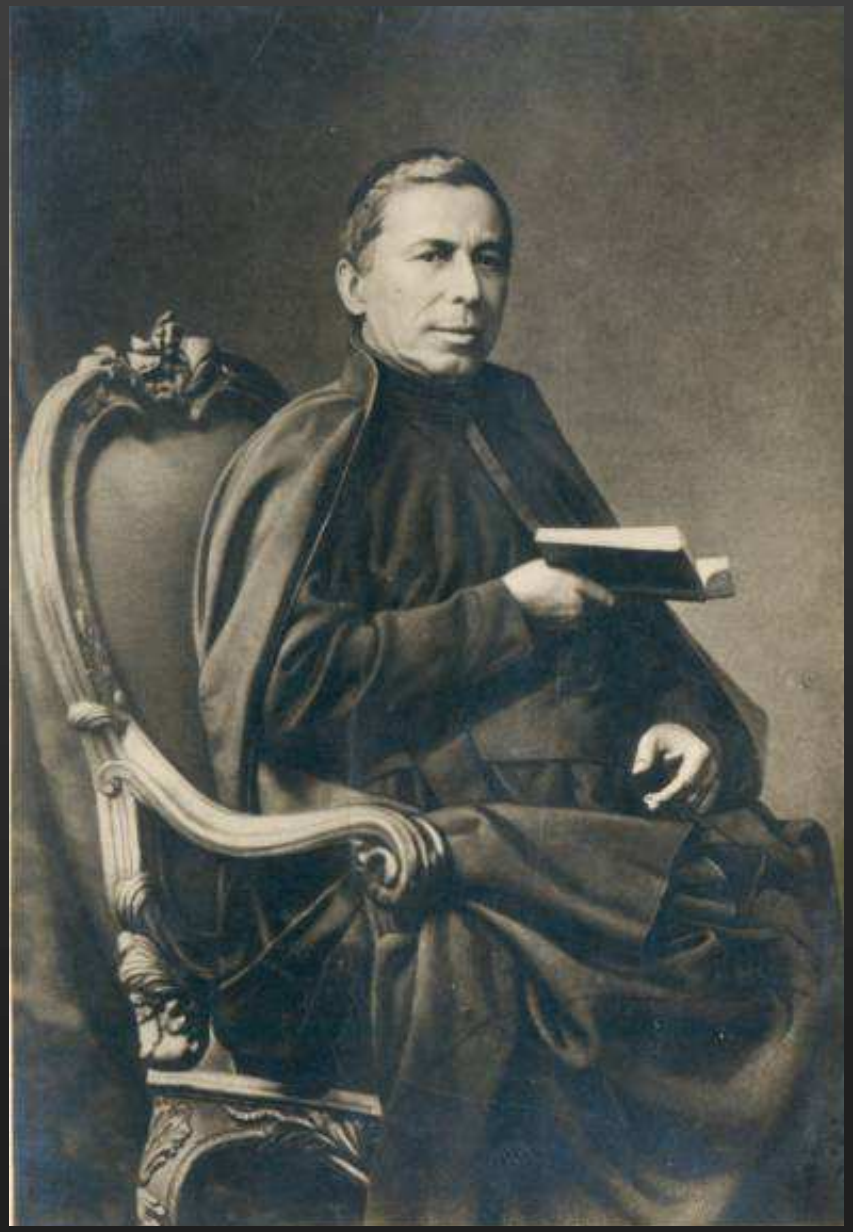


- Bohr's quantum model of the atom (1913):
  - emission and absorption lines!

Classifying the Spectra of the Stars



Classifying the Spectra of the Stars



- Father Angelo Secchi (Jesuit, 1818-78)
- first scheme to classify stellar spectra

Classifying the Spectra of the Stars

- great classification effort at
  Harvard College Observatory, beginning in 1880s

Classifying the Spectra of the Stars

- the `women calculators’ of Harvard

Classifying the Spectra of the Stars

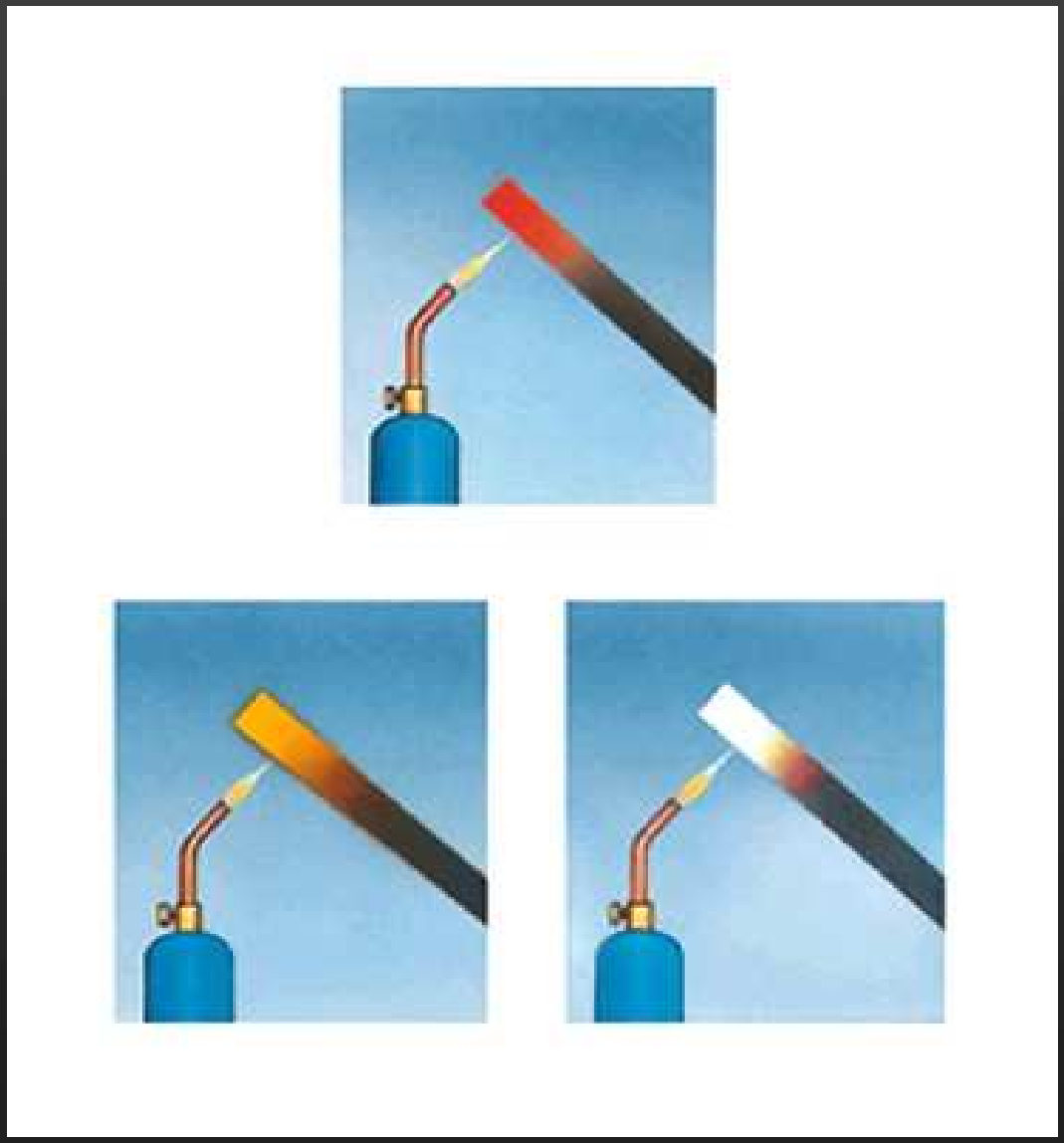
- Annie Jump Cannon (1863-1941)
- master classifyer
- instrumental in publishing the *Henry Draper Catalogue*
  - 1918-24, ~ 225,000 stars:
    - each with spectral type and brightness

The Harvard Sequence of Spectral Types

Traditional mnemonic: “Oh, Be A Fine Girl, Kiss Me!”

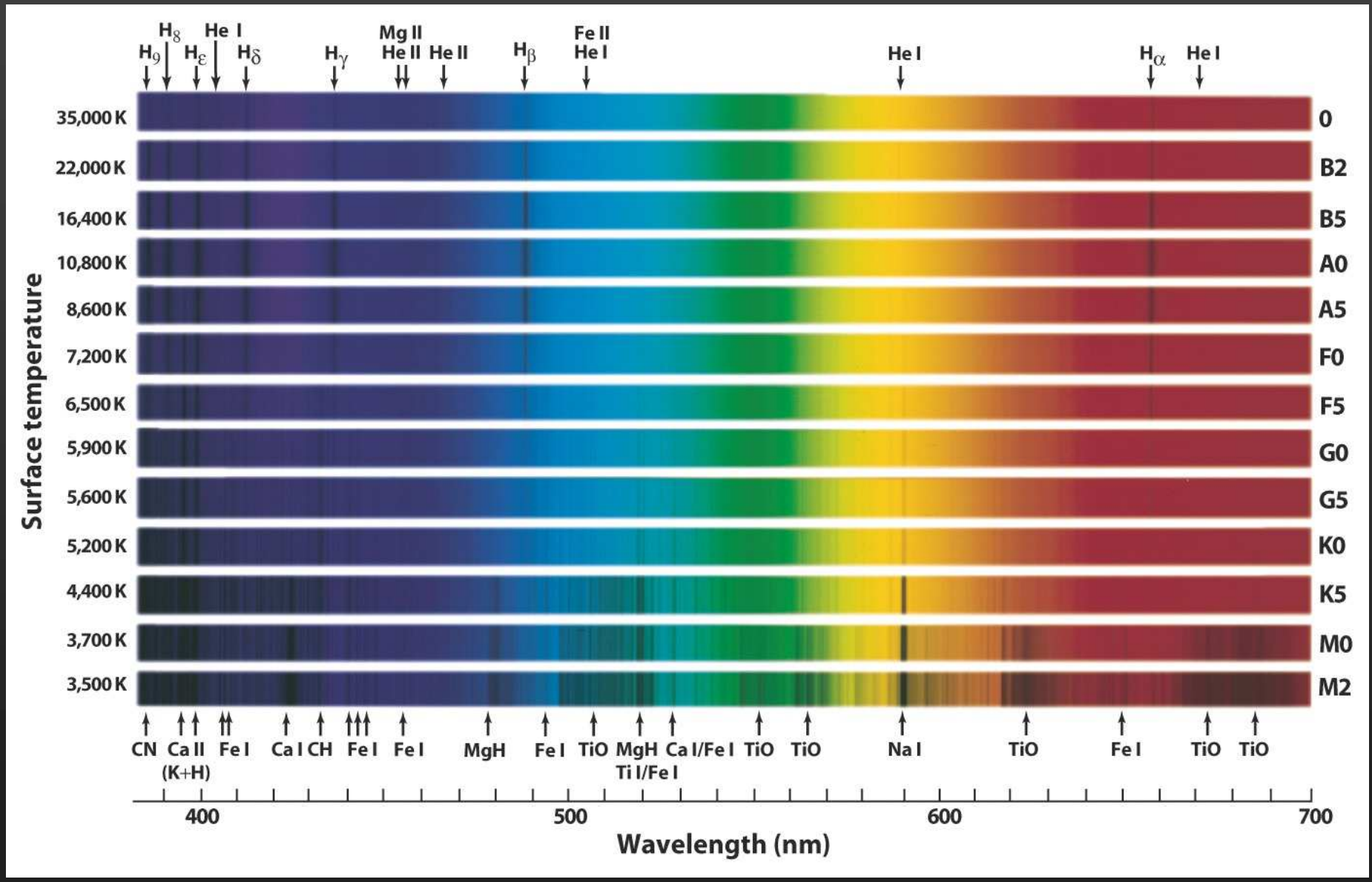
- arranged in order of decreasing temperature on the surface of the star

Spectral Type and Temperature



- Red à lower Temperature, blue à higher T

Classifying the Spectra of the Stars



Chemical Composition of the Stars

- Cecilia Payne-Gaposhkin (1900-79)
- Harvard PhD 1925
- hydrogen and helium are most abundant elements in the universe!

Chemical Composition of the Stars

- measured strength of spectral line (S) =

  abundance (A) x transition probability (P)

  -Metal lines (e.g., Ca):

$$S = a \times P$$

  -hydrogen lines: $S = a \times P$

- Hydrogen is most abundant element!!!

Birth of Astrophysics (part 1)

- Measuring the Distance to the Stars:
  - Friedrich Wilhelm Bessel
  - 1838: First successful stellar parallax
  - 61 Cygni: 1/3 seconds of arc à 10 lightyears
  - “the greatest triumph which astronomy has ever witnessed” (John Herschel)

- Figuring out the composition of the stars:
  - spectral analysis (absorption and emission lines)
  - Harvard classification: stars can be grouped according to spectral type (and thus surface temperature)
  - OBAFGKM
  - Hydrogen and Helium are most abundant elements in the Sun and the stars (Cecilia Payne)