



An Introduction to the  
Night Skies  
Week 3

Presented by:  
Mike Bradley, Garth Jones  
and Members of RASC Sunshine Coast  
Centre

---

# WHAT TOOLS DO WE HAVE FOR STUDYING THE STARS & SUN?



# Aristarchus of Samos (310-230 BCE)

---

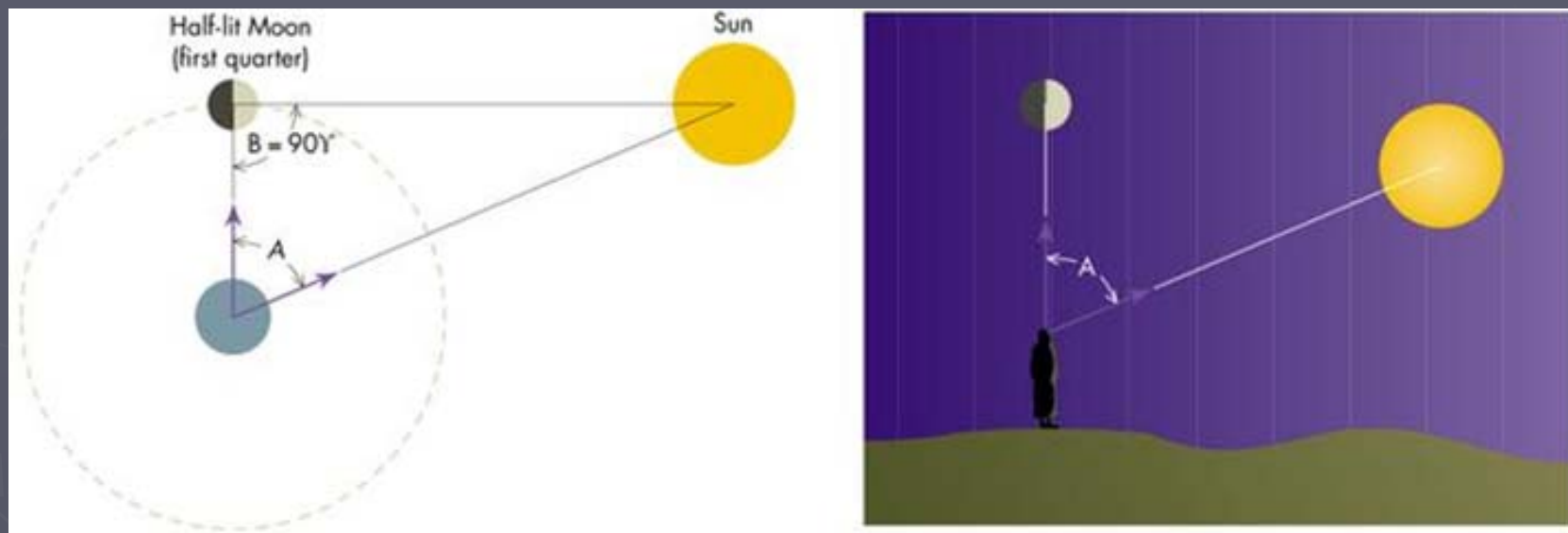
- ▶ An early person making astronomical measurements was Aristarchus of Samos.
- ▶ He was both a mathematician and astronomer and is most celebrated as the first to propose a sun-centered universe. He is also famed for his pioneering attempt to determine the sizes and distances of the sun and moon.
- ▶ He estimated the distance to the Moon by timing how long it took the Moon to pass through the Earth's shadow during an eclipse. His result was a distance of 70 Earth radii. (close!)

# Aristarchus of Samos

---

- ▶ From his measurements and calculations Aristarchus found that the Sun was many times larger than the Earth.
- ▶ It seemed more reasonable to him that a tiny Earth would orbit around a large Sun rather than a large Sun orbit around a tiny Earth.
- ▶ His sun-centered model failed to change the minds of the Aristotelians. The earth-centered model persisted.

# Aristarchus of Samos



When the moon is exactly half full the triangle is a perfect right angle. By measuring the angle "A" the ratio between the earth-moon and earth-sun can be calculated.

The principle was correct but measuring exact half moon Position and centre of the solar disk is difficult so his estimate was well out (20 vs 400). He did demonstrate that the sun is much further from us than the moon though

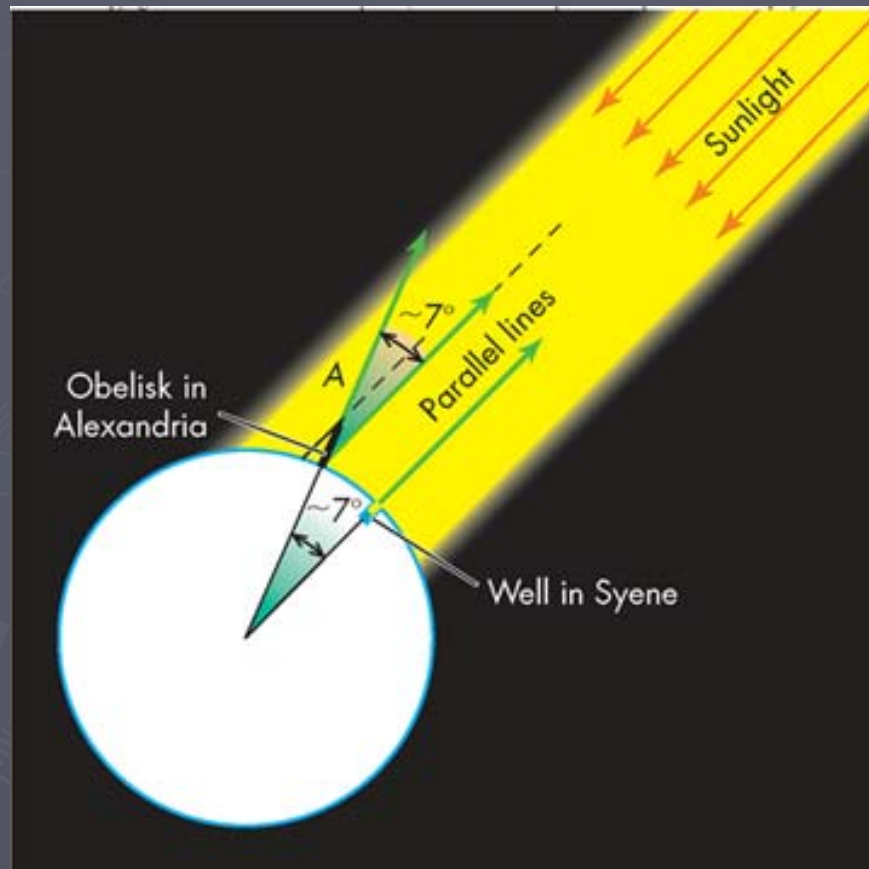
# Eratosthenes (296-195 BC)

---

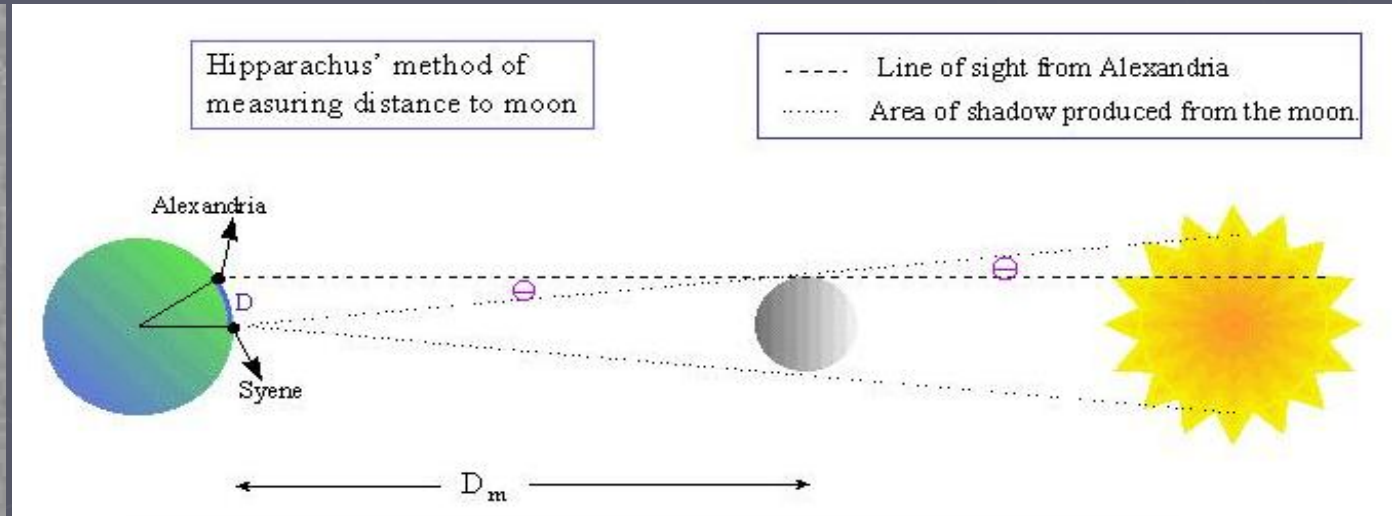
- ▶ Another early example of making astronomical measurements was Eratosthenes.
- ▶ He reasoned that if the sun could be seen from the bottom of a well, the Sun must be directly overhead.
- ▶ Then he measured the angle the Sun made from the vertical in Alexandria (7 degrees).
- ▶ He calculated a diameter of 13,000 km. Very close!

# Eratosthenes

---



# Finally, Hipparchus of Nicaea (190-120 BCE)



Determined the distance to the Moon. When coupled with the work of Aristarchus, this yielded the distance to the Sun.

Though the value was **incorrect**.

# Measuring Distances

---

## ▶ What is a Light Year?

- A light year is the distance light travels in a year. Light moves at a velocity of about 300,000 kilometers (km) each second, about 10 trillion km. per year

## ▶ What is a Parsec?

- about 3.26 light years. One parsec corresponds to the distance at which the radius of the earth's orbit subtends an angle of one second of arc.

## ▶ Why do we use these units?

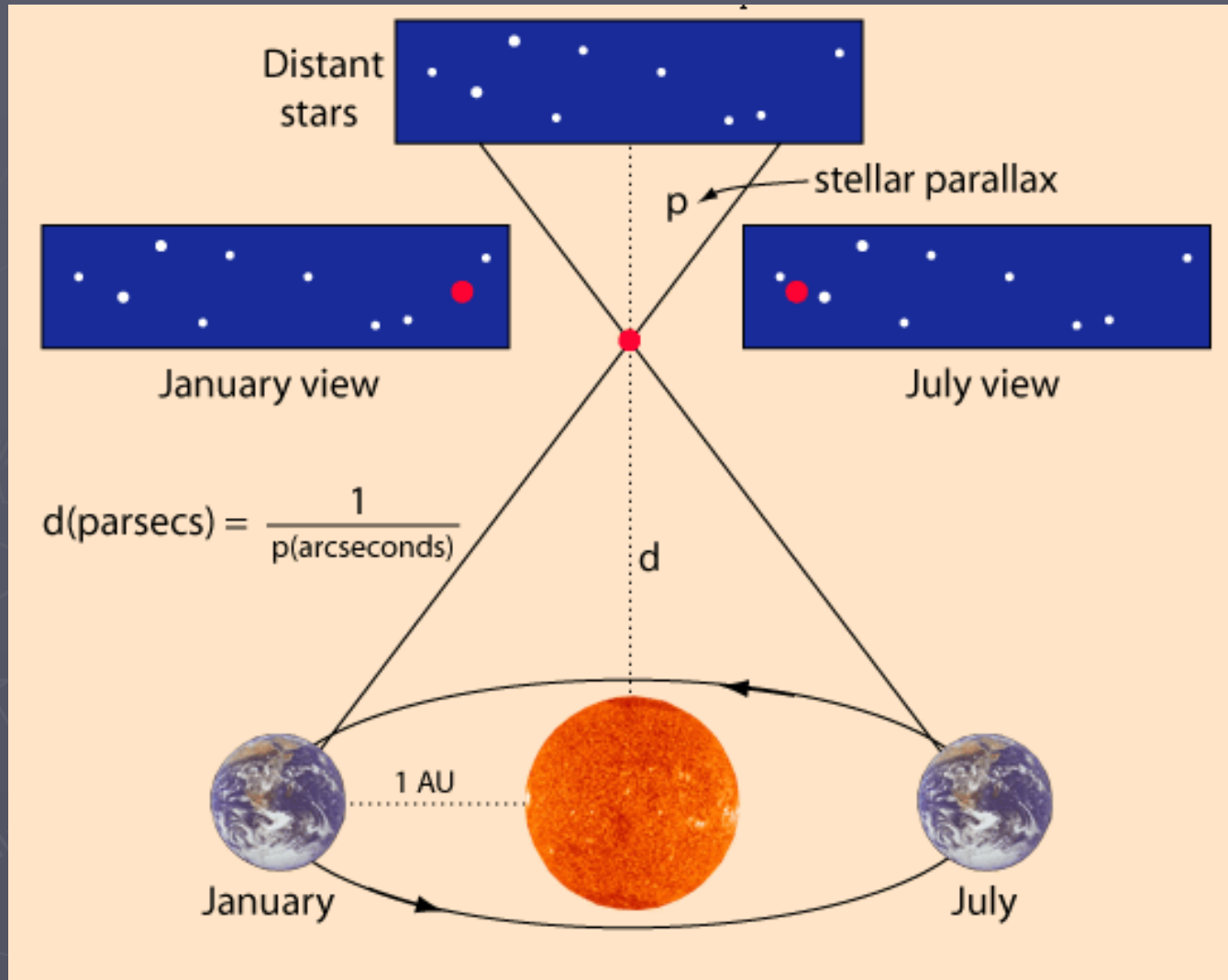
- We need practical units that make sense to us on a cosmic scale.

# Stellar Parallax

---

- ▶ A nearby star's apparent movement against the background of more distant stars as the Earth revolves around the Sun is referred to as Stellar Parallax.
- ▶ The parallax can be used to measure the distance to the few stars which are close enough to the Sun to show a measurable parallax. The distance to the star is inversely proportional to the parallax.

# Stellar Parallax



# Early Results from Stellar Parallax

---

- ▶ First stellar parallax: 61-Cygni (in Cygnus the Swan) by Bessel in 1838. Measured **0.31"** compared to modern value of **0.29"**, or 11 light-years from Earth
- ▶ Other nearby stars followed: Alpha Centauri, Vega... But by 1900, fewer than 100 results.
- ▶ Then photographic techniques took over and the field expanded, but still not many more than 100 to 5% precision!

# Standard Candles

---

- ▶ Light from a point source diminishes according to the purely geometrical inverse square law.
- ▶ If we had a light source with a constant and dependable absolute luminosity, then the measured intensity at the detector could be used to calculate its distance from us. Well, we do!
- ▶ This is often referred to as the "standard candle" approach.

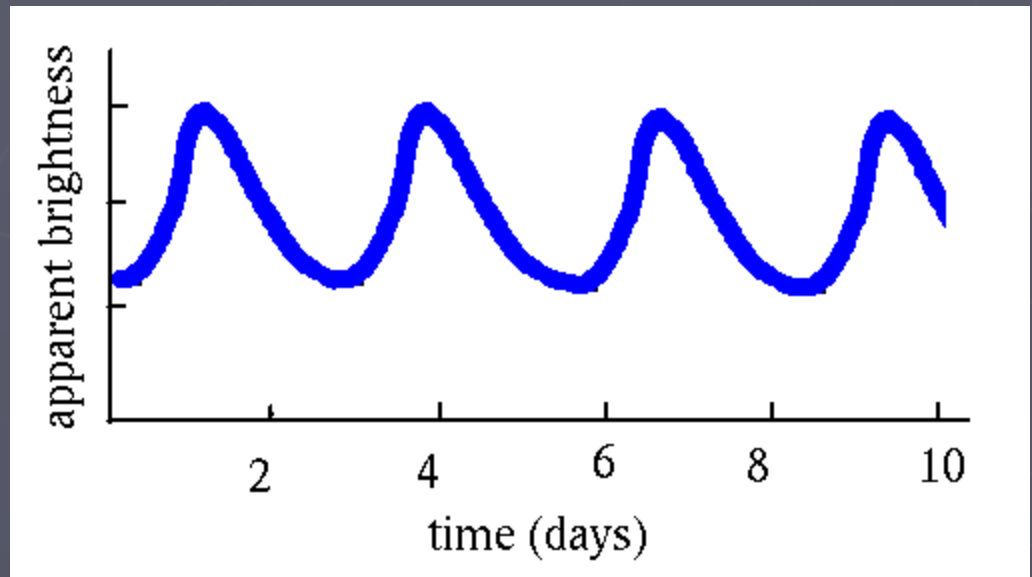
# Cepheid variable stars

---

Cepheid variable stars vary in brightness over periods of from one day up to about 50 days.

The period is simple to measure, as is the apparent brightness at maximum brightness.

Unfortunately the unknown and varying amount of dust in interstellar space affects the accuracy that can be achieved



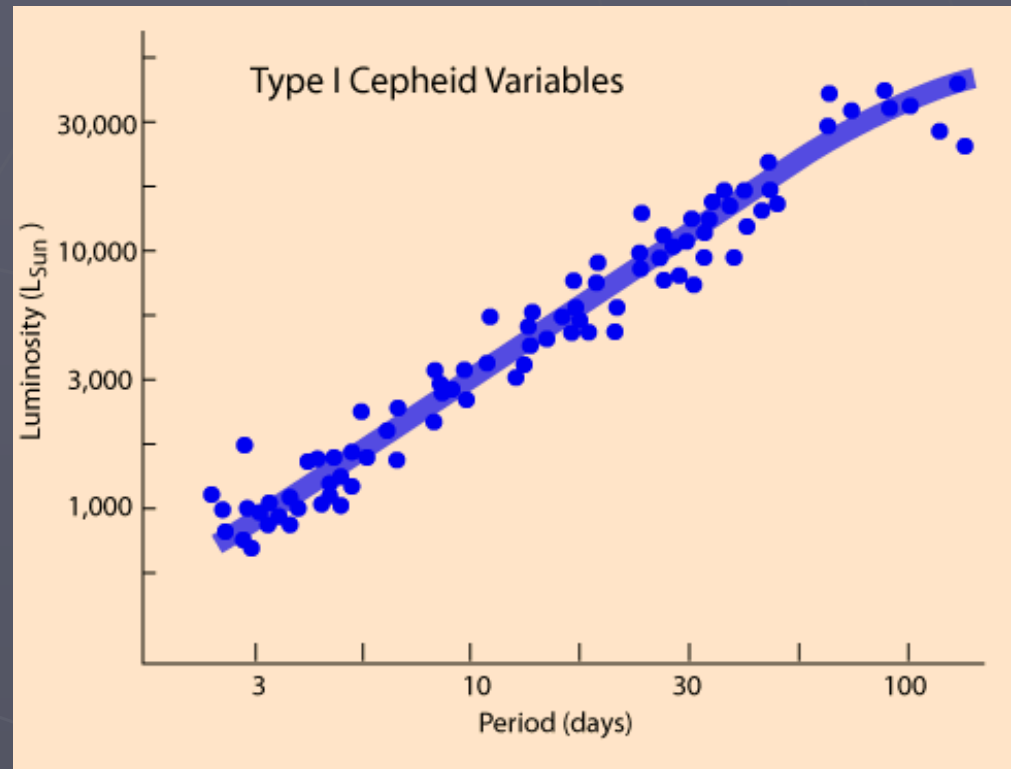
# Cepheid variable stars

---

There is a relationship between the period of a Cepheid and its luminosity

So:

- 1) find the period.
- 2) this gives the luminosity
- 3) measure the apparent brightness
- 4) determine the distance from the luminosity and brightness.



# Where did this period/luminosity relation come from?

---

- ▶ American astronomer Henrietta Leavitt looked at many Cepheid variables in the Small Magellanic Cloud (ca 200,000 lt-yrs).
- ▶ She identified the period/luminosity relationship.
- ▶ We need a distance measurement from some other method for at least one Cepheid. The “original” Cepheid variable,  $\Delta$  Cephei, is close enough that we have a parallax value for it.

# Cepheid variable stars

---

- ▶ Cepheid variable stars have proven to be one of the most valuable methods for distance determination because their period of variability has been shown to be related to their absolute luminosity by a period-luminosity relationship.
- ▶ They can then be calibrated as **standard candles** for distance calculation.

# Precision Astrometry Era: 1989-1993

---

- ▶ European Collecting Satellite until 1993 readings for
- ▶ Parallax of stars. This up to 500
- ▶ **Problem** it failed to orbit. Only



High Precision Parallax operation night, it took distortion.

18 "nearby" stellar distances

problems mean stationary to be useful.

# Gaia: ESA's Current Mission (2013-2018)

---

- ▶ GI
- As
- ▶ Ho
- m
- co
- ▶ It
- m
- of
- Mi



al  
s

# Some Gaia Objectives

---

- ▶ Positions and distances of one billion stars to 20 micro arc-sec at magnitude 15.
- ▶ Distances of 200 million stars to  $<10\%$ , as far as the galactic centre (30,000 lt-yrs).
- ▶ Tangential speeds of 40 million stars to  $<0.5$  km/s.
- ▶ Measure orbits, inclinations and true masses of a thousand extra-solar planets.
- ▶ Hoping to detect up to 500,000 quasars.

# Gaia timeline

---



---

# HOW DO WE KNOW THE COMPOSITION OF THE STARS OR THE SUN?

The background is a dark blue-grey color with a faint, light-colored star map overlay. The map shows various constellations and stars, with some labeled with letters like 'N', 'M', and 'S'. A compass rose is visible in the lower-left quadrant, with a needle pointing towards the top-left. The overall aesthetic is scientific and educational.

# How can we study the stars & Sun?

---

No matter how good your telescope, a star is only a point of light to us



- ▶ Our primary way of learning about distant objects is through their light (electromagnetic spectrum).
- ▶ The electromagnetic spectrum of light contains ‘fingerprints’ which provide information about it.
- ▶ How can we “read” these fingerprints and what do they tell us about the star?

# What is the “spectrum” of light?

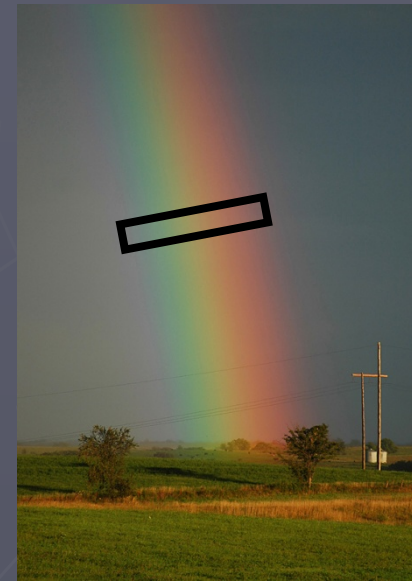
---

- ▶ Anything hotter than absolute zero radiates/emits energy, i.e. light.
- ▶ Sun & stars emit a continuous spectrum of Electro Magnetic radiation.
- ▶ Our eyes are sensitive to “white” light, which is composed of the spectrum of colours visible in a rainbow.
- ▶ Spectrum = “The distribution of energy emitted by a radiant source, e.g. the Sun, arranged in order of wavelengths”.

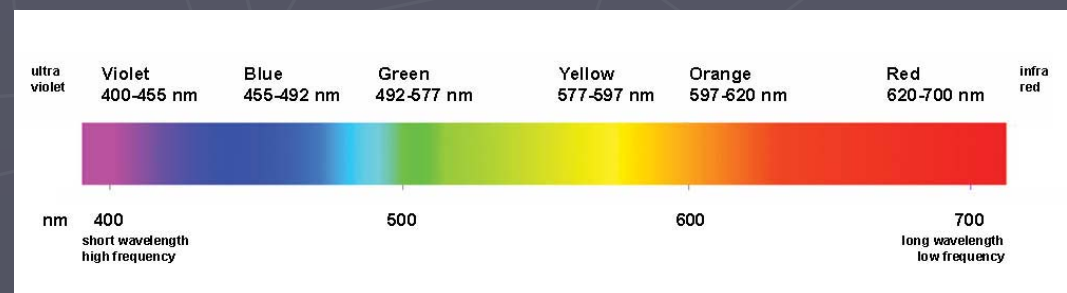
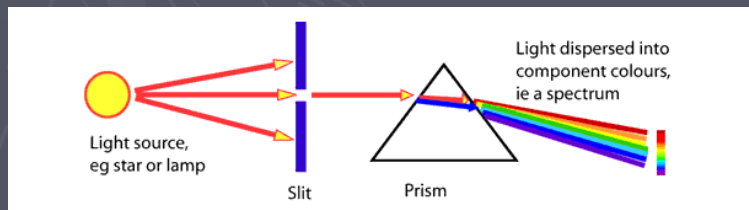


# What is a spectrograph?

- ▶ A relatively simple-to-understand scientific instrument for creating and studying spectra
- ▶ Using a prism or a diffraction grating – it breaks light into its component colours

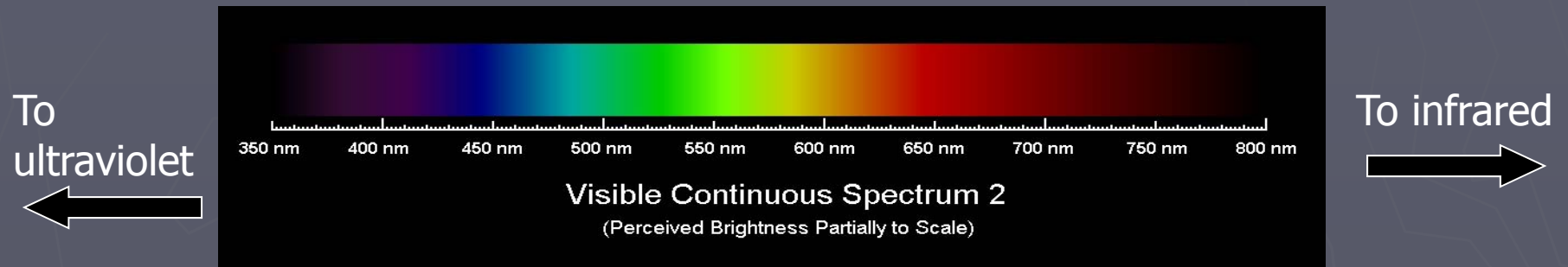


Example output from a spectrograph



# What can a spectrograph tell us?

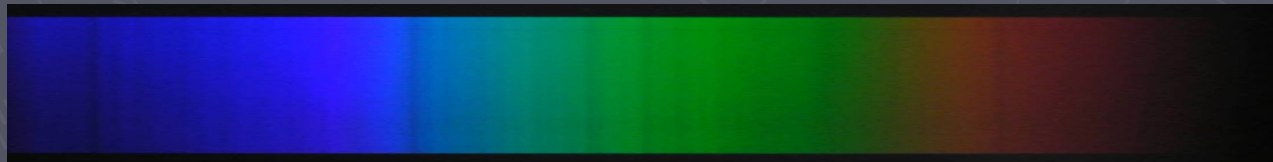
---



Sometimes there are extra bright colours (Emission)



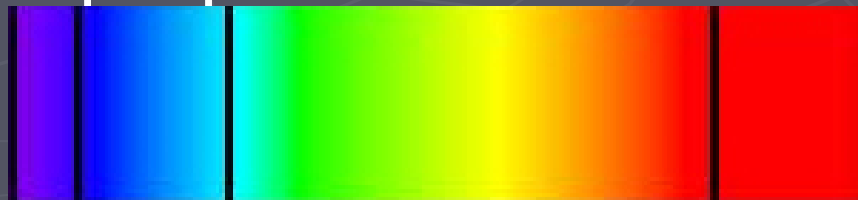
Sometimes there are missing colours (Absorption)



# “Fingerprints” of Light

---

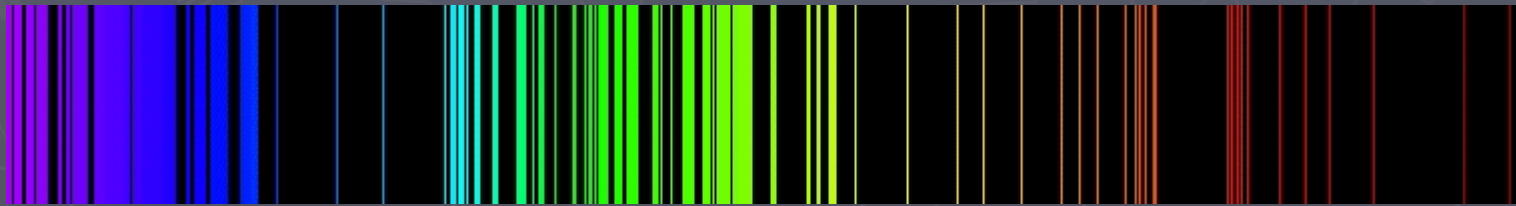
- ▶ The extra or missing colours indicate certain chemical elements (e.g. hydrogen, helium, oxygen, etc.) have affected the light
- ▶ Helium was actually discovered by its presence in the spectrum of sunlight – hence its name.
- ▶ Each chemical element changes the spectrum either by making certain colours brighter or removing certain colours. Each chemical element has a different and unique pattern of colours.



# Emission spectra - the "Fingerprints"

---

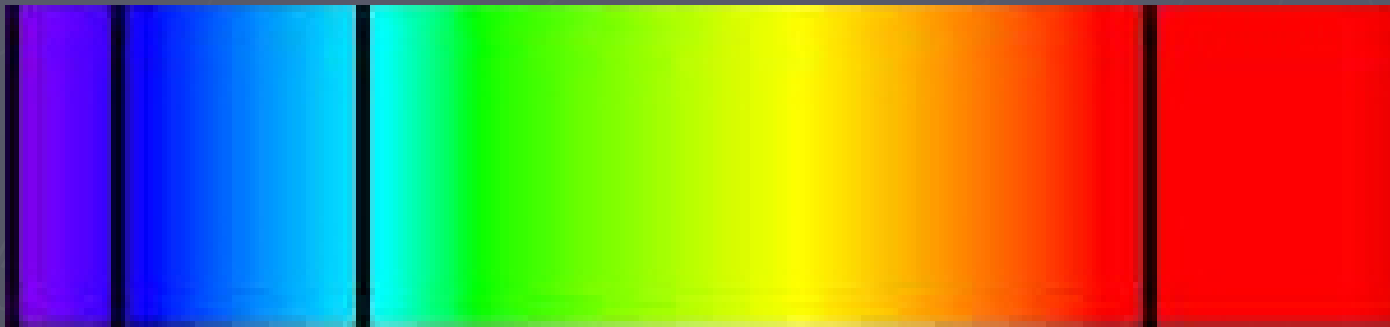
- ▶ When iron is heated until it vaporizes, as in a star, it emits a unique pattern of wavelengths. This is the **emission spectrum** of iron:



# Absorption spectra - the "Fingerprints"

---

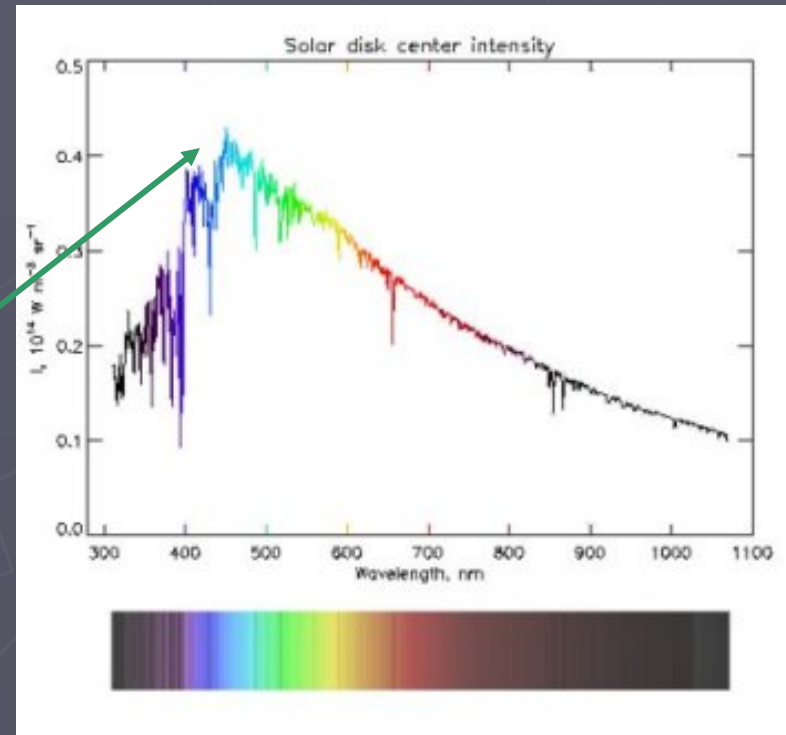
- ▶ This is the Absorption spectrum of Hydrogen



# Spectra tell us star temperatures

---

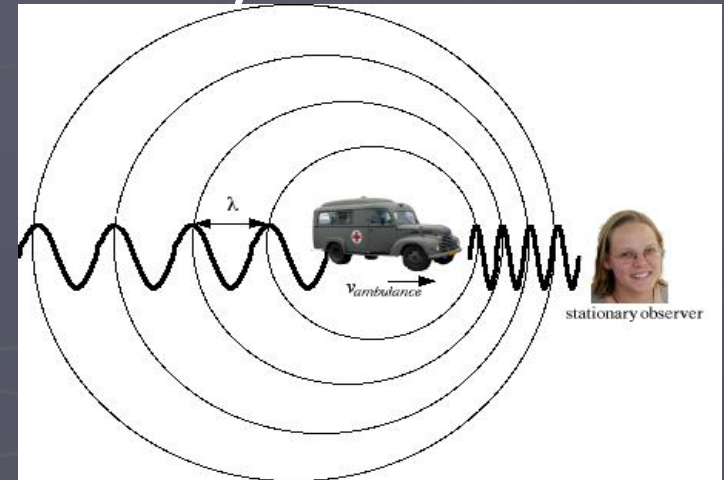
If you look at the strongest colours or wavelength of light emitted by a star, then you can calculate its temperature.



# Spectra can tell us about movement?

---

- ▶ A Doppler shift happens when an object is moving towards or away from us, as in a siren coming towards us:

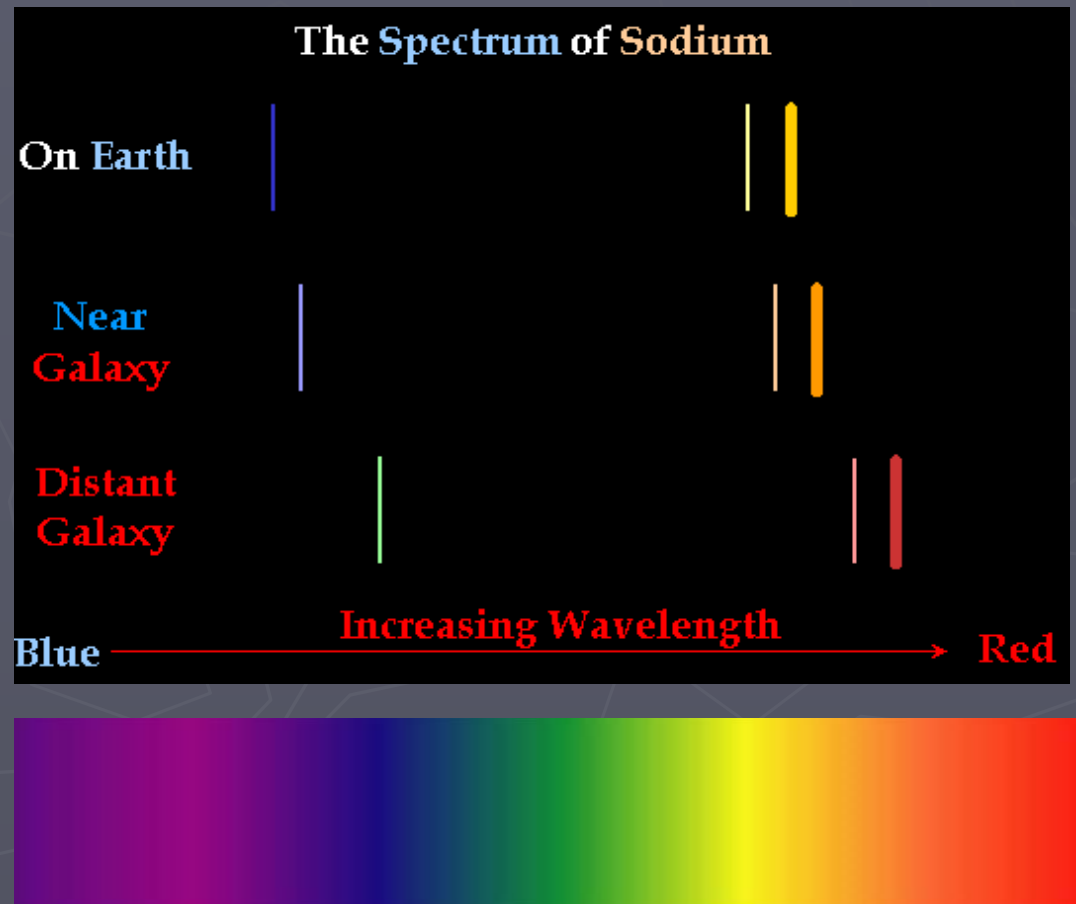


- ▶ Wavelength is changed by the movement
- ▶ This occurs with sound, with light, or with any wave

# Doppler shift, cont'd.

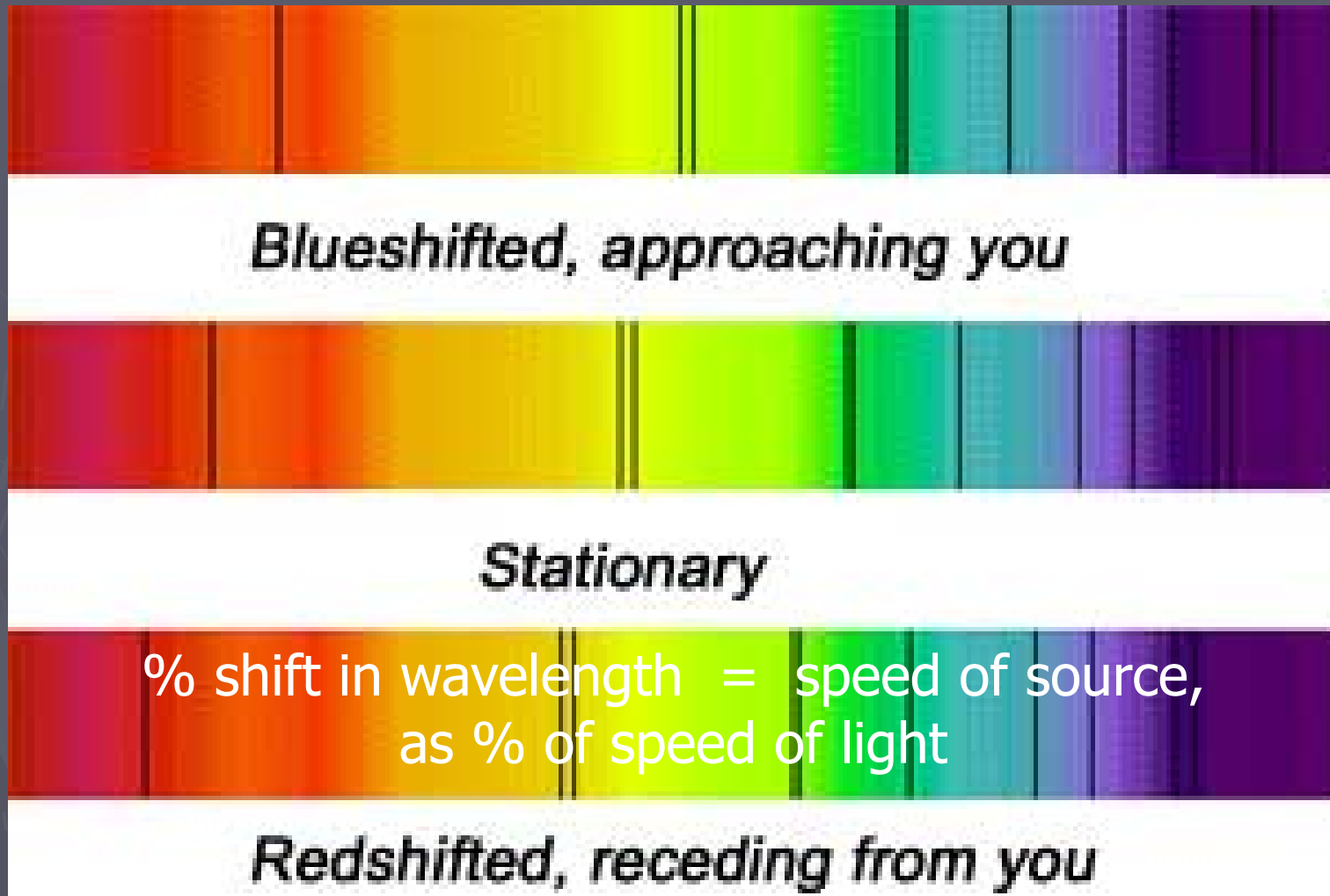
---

- Motion away from us results in a "red shift"
- Motion towards us would result in a "blue shift"



# Doppler-shifted absorption spectra

---





**Thank You!**

# Credits

---

- ▶ Some material included in this presentation was taken from online sources. Particular credit to:
  - <http://www.astro.virginia.edu/class/whittle/astr1230>
  - [www.nobelprize.org](http://www.nobelprize.org)
  - [www.hubblesite.org](http://www.hubblesite.org)
  - Weber State University, Utah, [www.weber.edu](http://www.weber.edu)
  - [Solar-center.stanford.edu](http://Solar-center.stanford.edu)
  - RASC Canada