

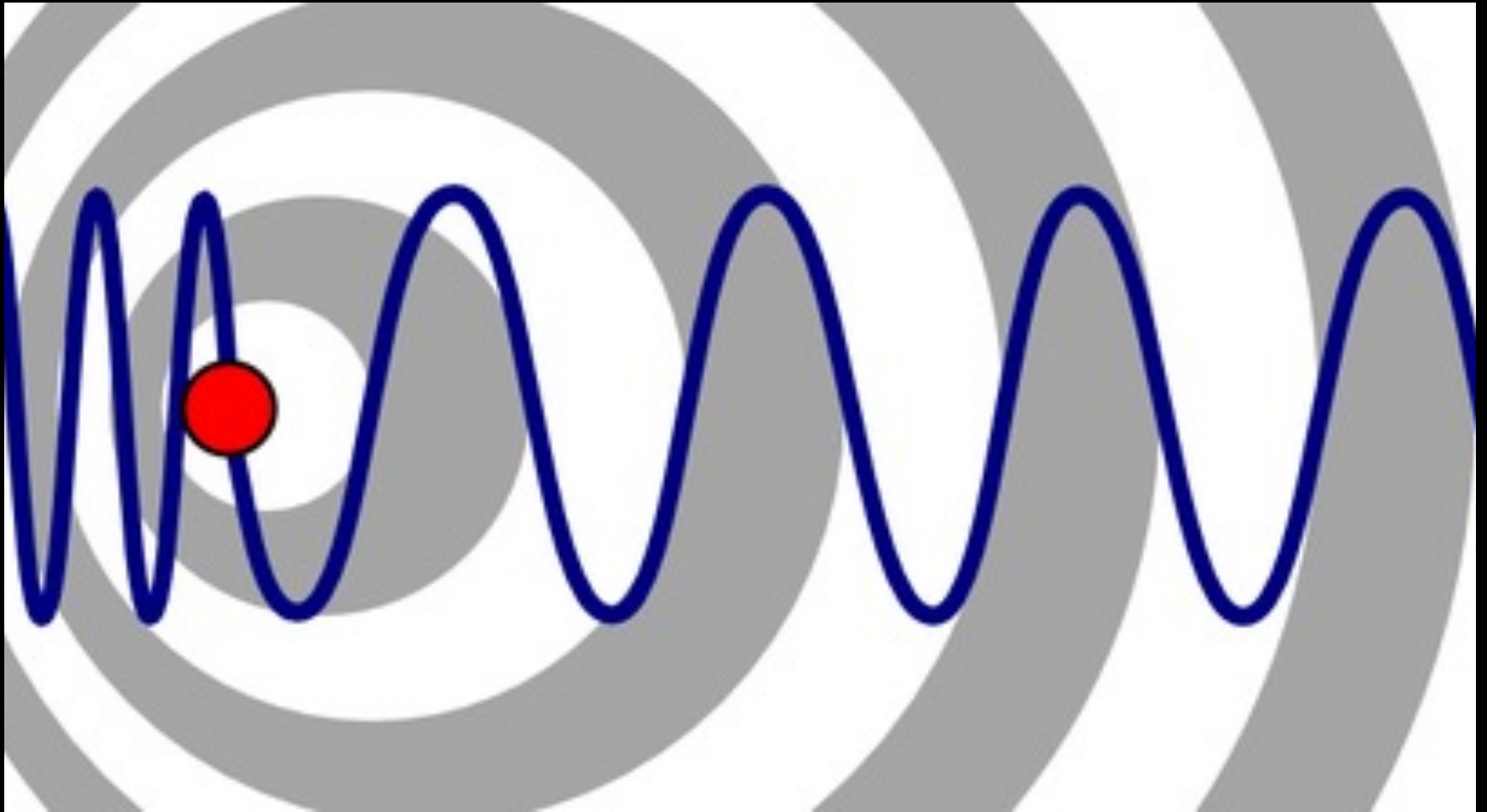
How the technology of the
police speed trap enables us
to find distant planets

by
Tony Heyes

The Doppler Effect (1842)

- A wave phenomena
- True of Sound waves and Electromagnetic Waves (Light, Radio etc)
- Needs movement. This can be the Source, the Receiver, the Medium or all or any of them!

The Doppler Effect



Christian Doppler (1803 – 1853)

An Austrian



Experimental verification in Sound by Buys Ballot in 1845

Utrecht-Amsterdam railway line

Two trumpet players both playing A
above middle C (440Hz)

One player on the moving train one
on the platform

$$f = \left(\frac{c \pm v_r}{c \mp v_s} \right) f_0$$

where

c is the velocity of waves in the medium

v_r is the velocity of the receiver relative to the medium
towards the source.

v_s is the velocity of the source relative to the medium
away from the receiver.

Buy's Ballot is reported to have heard
a beat frequency of 3 Hz
ie. 440 Hz and 443 Hz as the train
approached,
And 440 Hz and 437 Hz and the train
receded

From the formula we calculate that the train must
have been travelling at
7.2 m/s ie. 25.92 km/h

Show examples.....









The human ear is particularly good at detecting changes in pitch

Scientific instruments are particularly good at measuring frequency and changes in frequency

This is equally true for sound and for light

Speed Traps

Use Radar – EM waves at radio frequencies

Radar can measure distance – time of flight

Radar can measure relative speed by comparing the echo frequency with the transmitted frequency

Blood Flow

Use Ultrasonics – high frequency sound

Echo signal from blood cells

An abnormal high speed suggests a problem

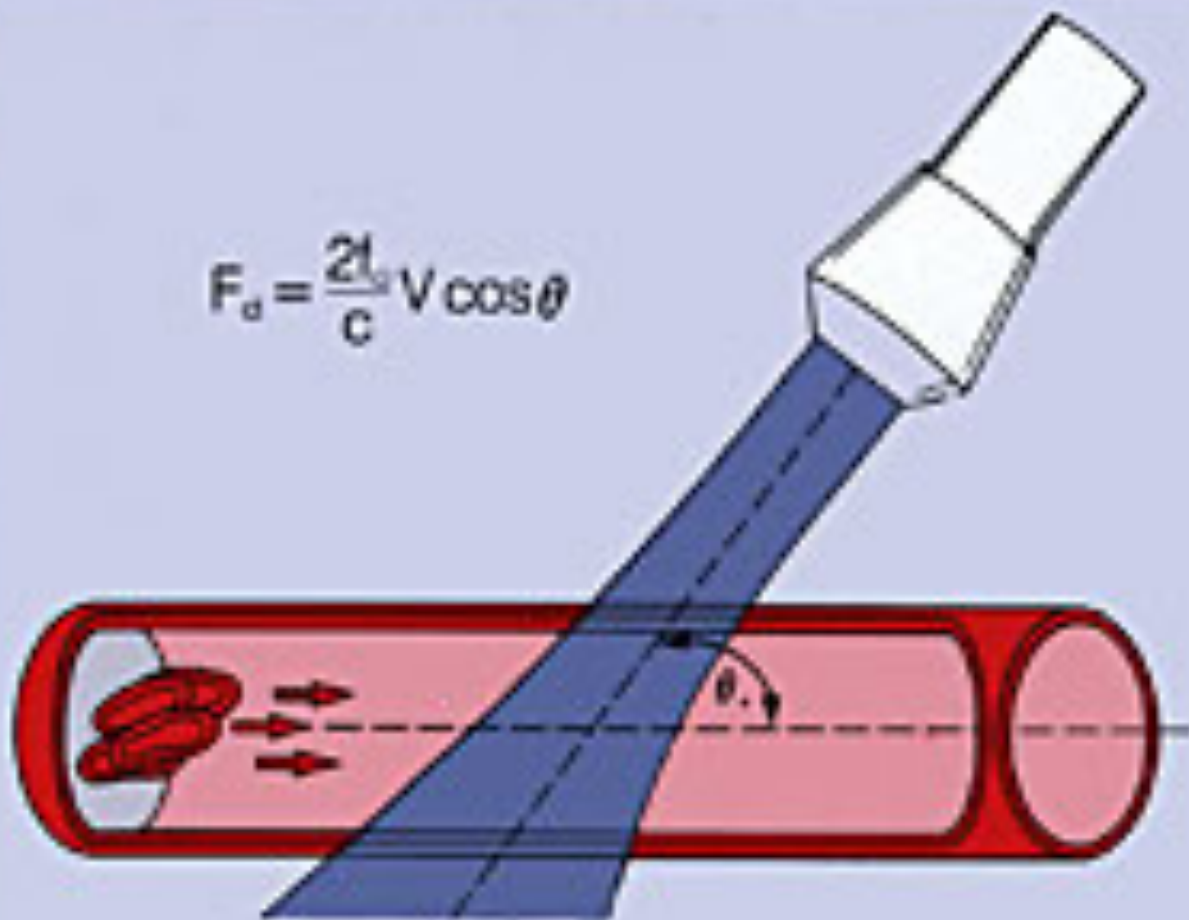
Laminar Flow



Turbulent Flow



$$F_d = \frac{2\mu_0}{c} V \cos \theta$$



Christian Doppler in his 1842 paper had suggested the use of *the effect* to examine the motion of binary stars

Please explain!

The colour of a star depends on its temperature

Binary stars revolve around each other

A star moving towards us will appear more blue than normal, one moving away will appear more red

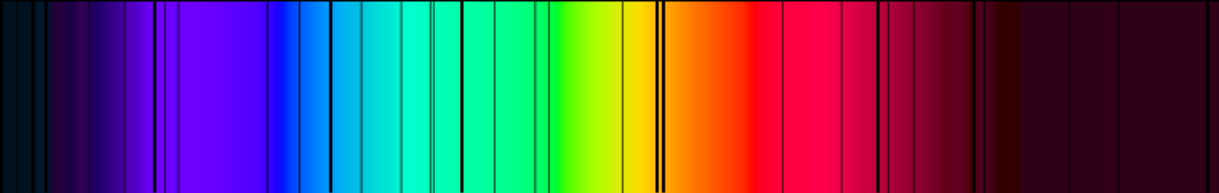
But there is more to it than that!

Isaac Newton (1642 – 1727)



Joseph von Fraunhofer (1787 – 1826)

spectral absorption lines



About 45 years later Kirchhoff and Bunsen noticed that several Fraunhofer lines coincide with characteristic emission lines identified in the spectra of heated elements

It enabled scientists to determine the chemical composition of stars



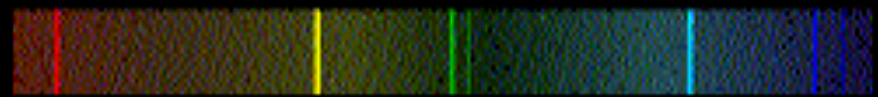
Continuous Spectrum



Hot Gas



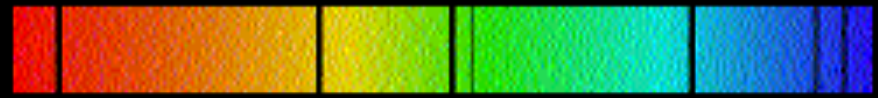
Emission Spectrum



Cold Gas



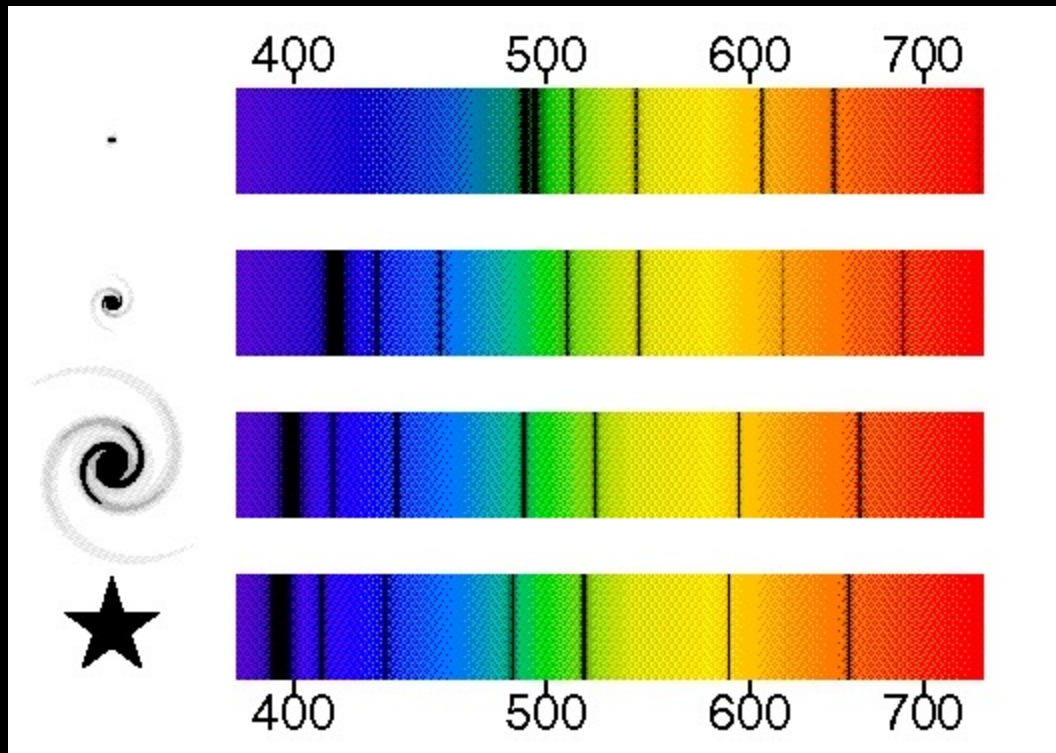
Absorption Spectrum



The element Helium was discovered in the sun *before* it was found on earth. Hence the name.

But what about a moving star

Red Shift



Edwin Powell Hubble (1889 – 1953)



But back to our galaxy

- Douglas Adams - The Hitchhiker's Guide to the Galaxy
- “Space is big. You just won't believe how vastly, hugely, mind-bogglingly big it is. I mean, you may think it's a long way down the road to the chemist, but that's just peanuts compared to space.”

Exoplanets

- Exoplanets are planets in orbit around stars other than the sun.
- When I was a lad it was axiomatic – even if they did exist, we would never know
- Why? Because they would be so dim

Early Speculation

- Giordano Bruno, an early supporter of the Copernican theory put forward the view that the fixed stars are similar to the Sun and are therefore probably accompanied by planets

He was burned at the stake for his ideas

Detection round a Sun like star

- Michel Mayor and Didier Queloz 1995
- 2019 Nobel Prize in Physics awarded to Michel Mayor and Didier Queloz for having pioneered a new field in astronomy with the discovery of 51 Pegasi b and many more exoplanets after.

How did they do it?

Planets do not go round the centre of the star, rather they orbit in an ellipse around the mutual centre of gravity

Thus the star wobbles

The radial wobble can be measured by the Doppler Shift.

Sensitivity

Extremely small radial-velocity variations can be observed, down to roughly 1 m/s.

Detection methods

Planets orbiting a pulsar: Doppler shift of pulsar interval: a timing method.

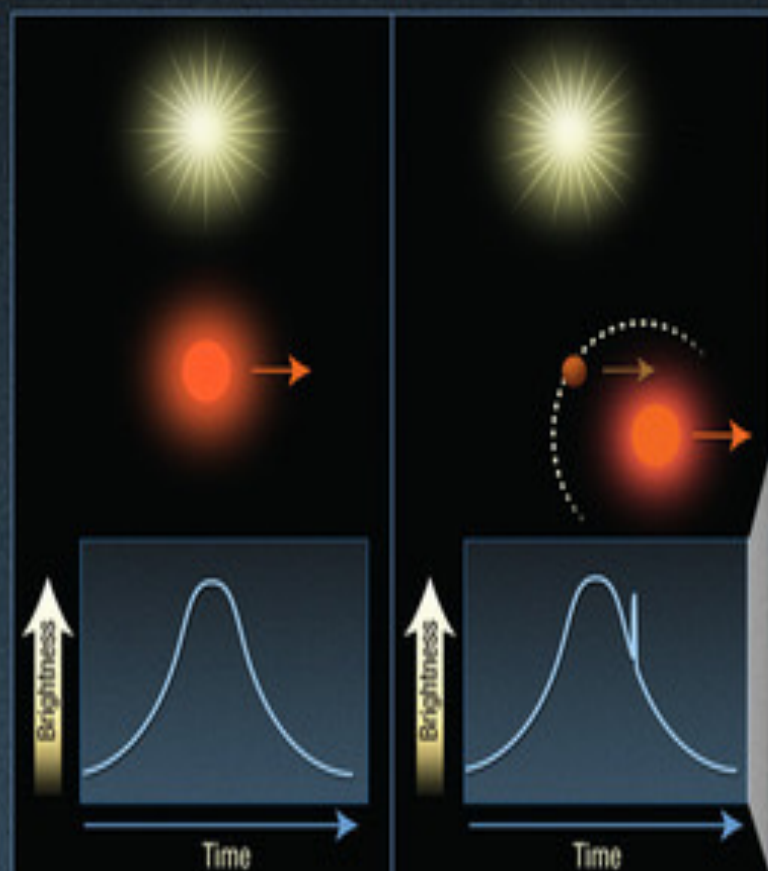
Radial Velocity Measurements by Doppler shift of light: a spectroscopic method.

Increased Sensitivity

Early detected exoplanets were all Gas Giants

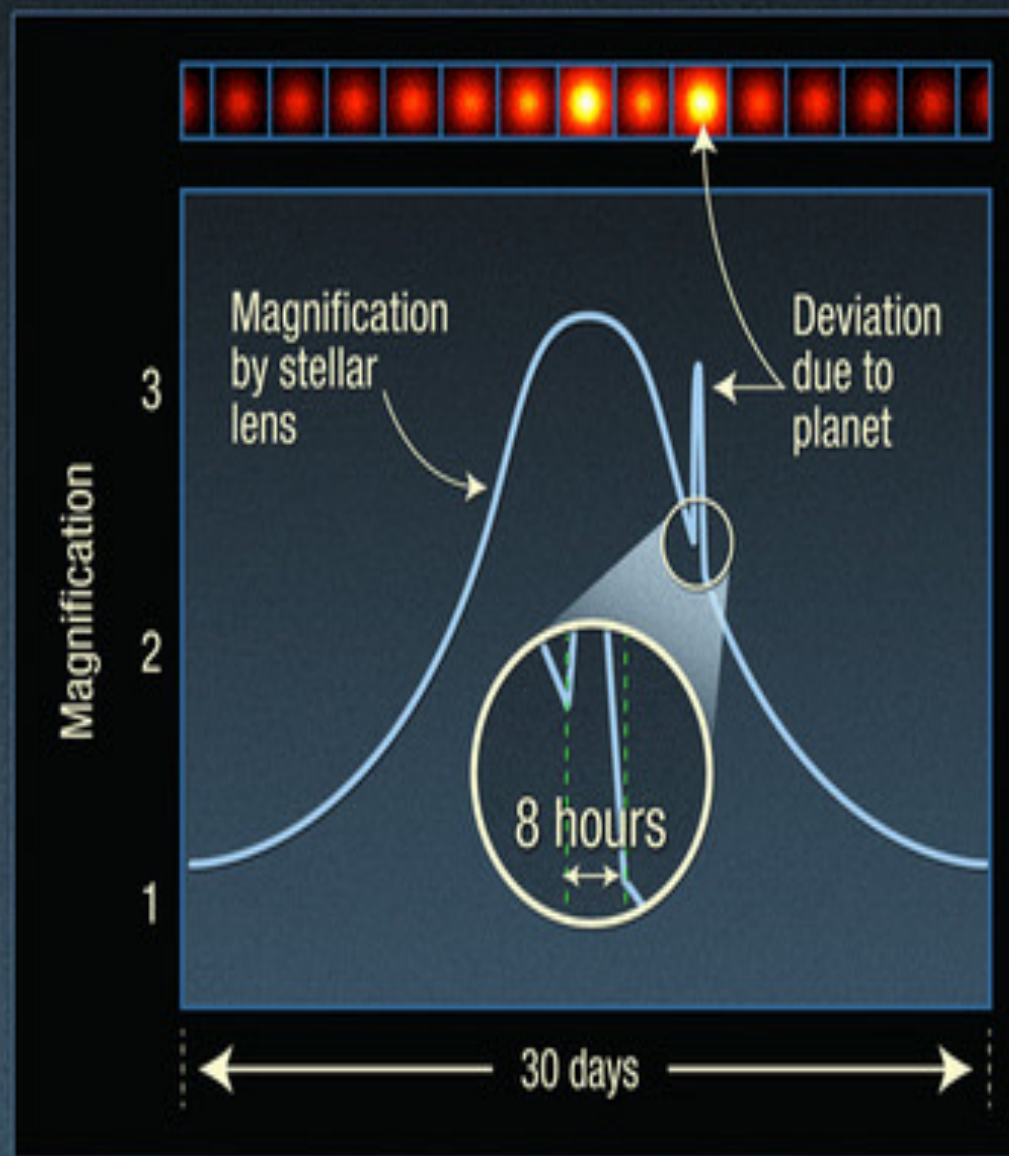
Increased sensitivity has led to the finding of the rocky earths

Extrasolar planet detected by gravitational microlensing



1 When a foreground star (red) passes in front of a background star, it brightens the light of the background star. The gravitational field of the foreground star warps space to create a gravitational lens that magnifies light.

2 If a planet is orbiting the foreground star, it, too, will gravitationally lens the background star for a shorter duration.



Exoplanet Transitions

A non Doppler technique whereby the intensity of the light dips

Could lead to the detection of exolife

IN OUR LIFETIME

Exoplanet count

By May 2017

Number of Exoplanets found

> 4000

Three short films

- [The Kepler Telescope](#)
- [The Kepler Mission](#)
- [The James Webb Telescope](#)