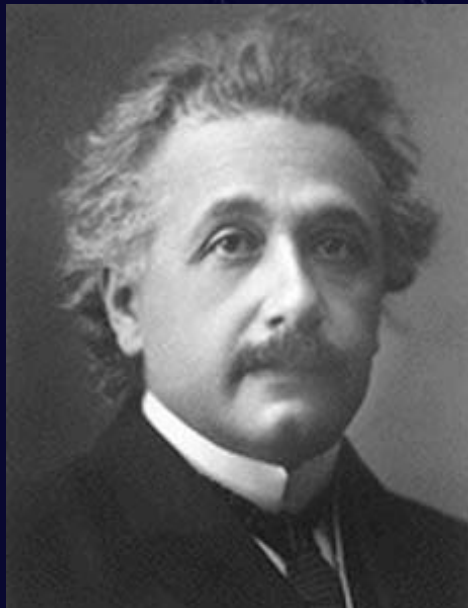


Einstein's Universe



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GLASGOW



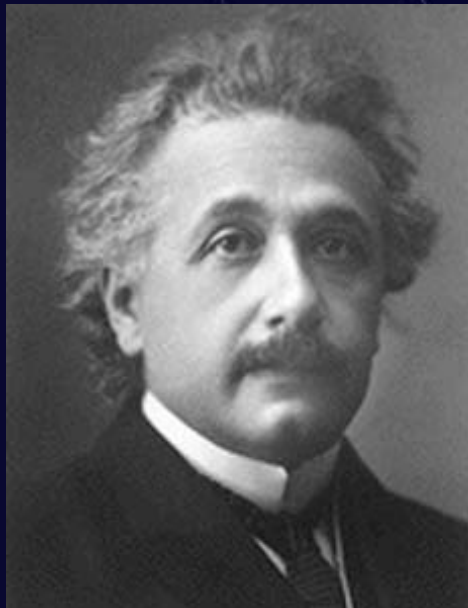
Dr Martin Hendry

*Dept of Physics and Astronomy
University of Glasgow, UK*

Light in Lumps or Ripples?



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Einstein and the Quantum Revolution



Isaac Newton
1670 – 1672
Investigated the
refraction of Light





Isaac Newton
1670 – 1672
Investigated the
refraction of Light





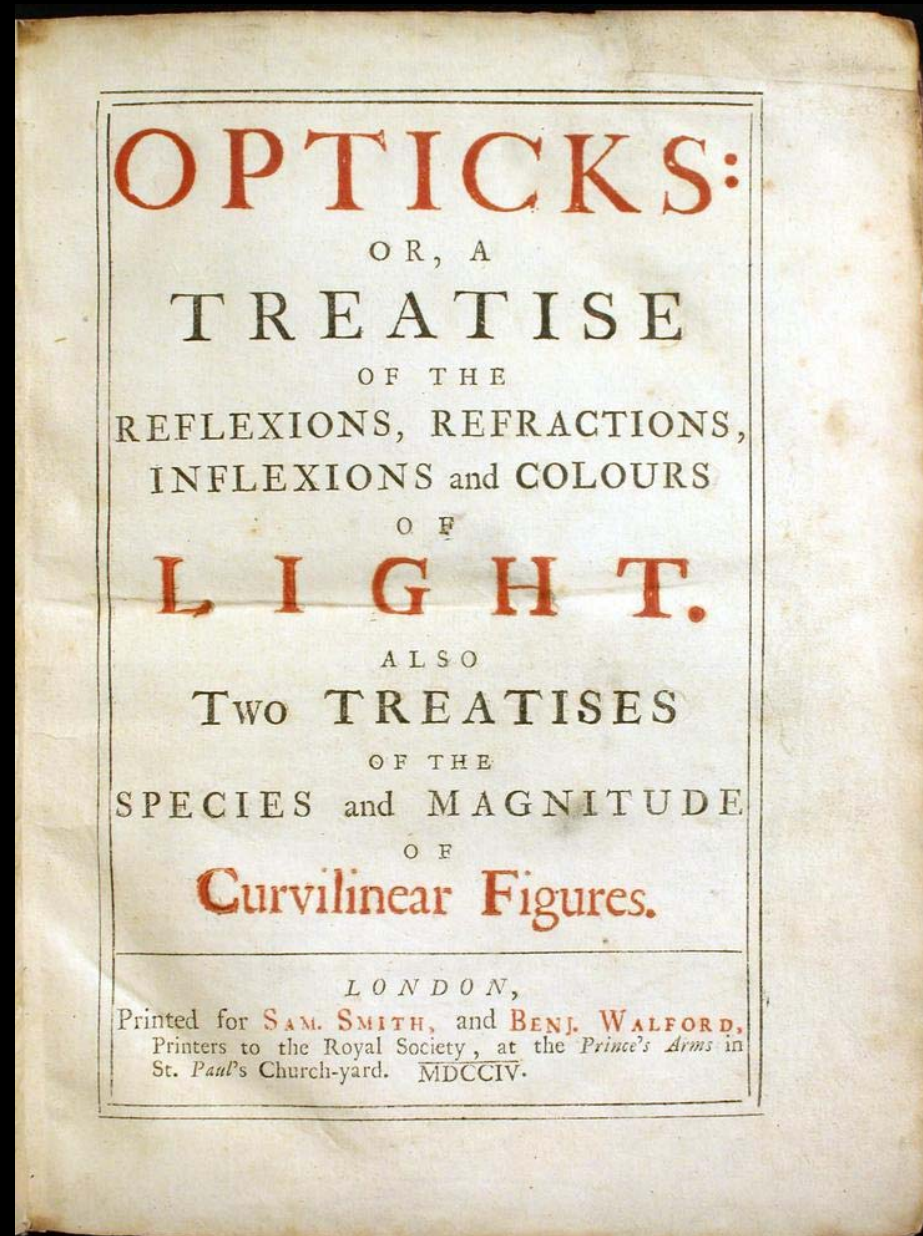
Isaac Newton
1670 – 1672
Lectures on Light

Replica of Newton's
reflecting telescope

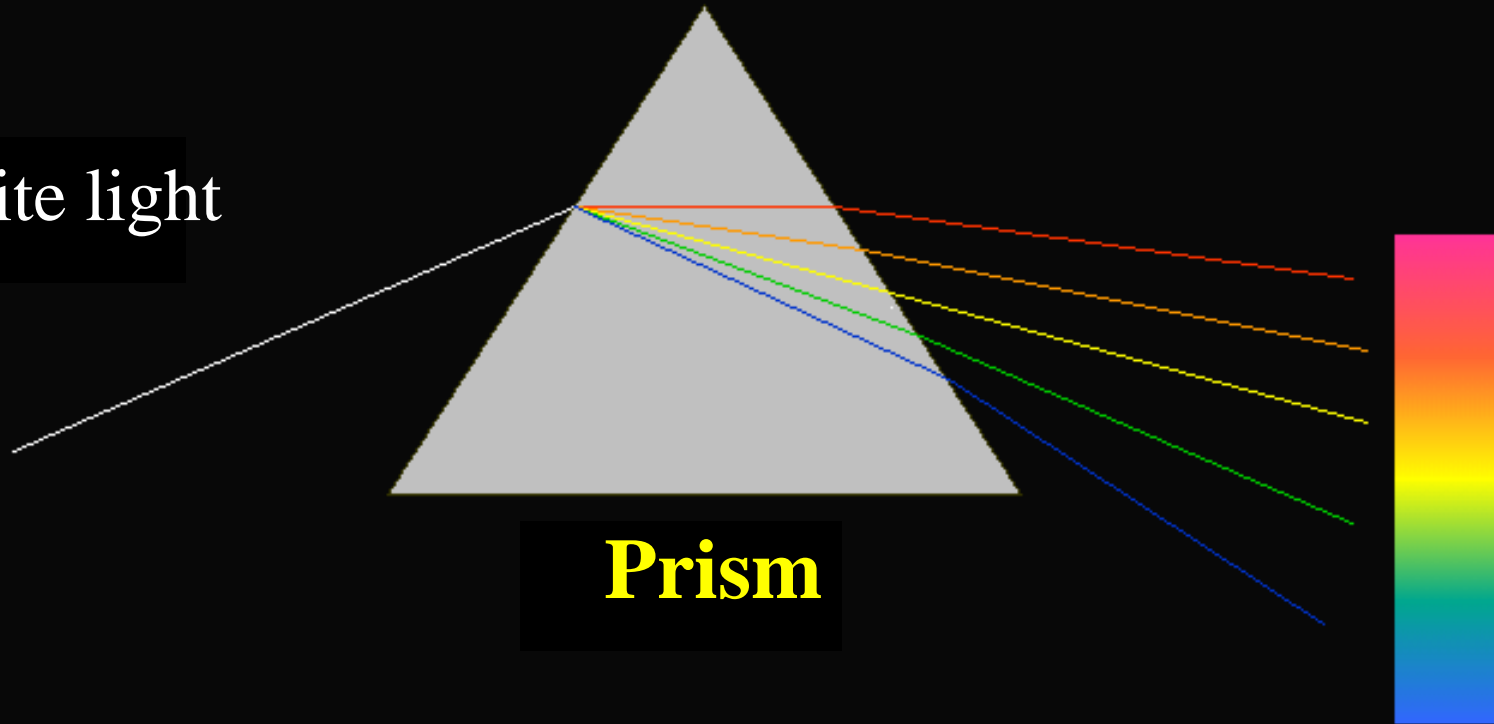




Isaac Newton
Opticks (1704)



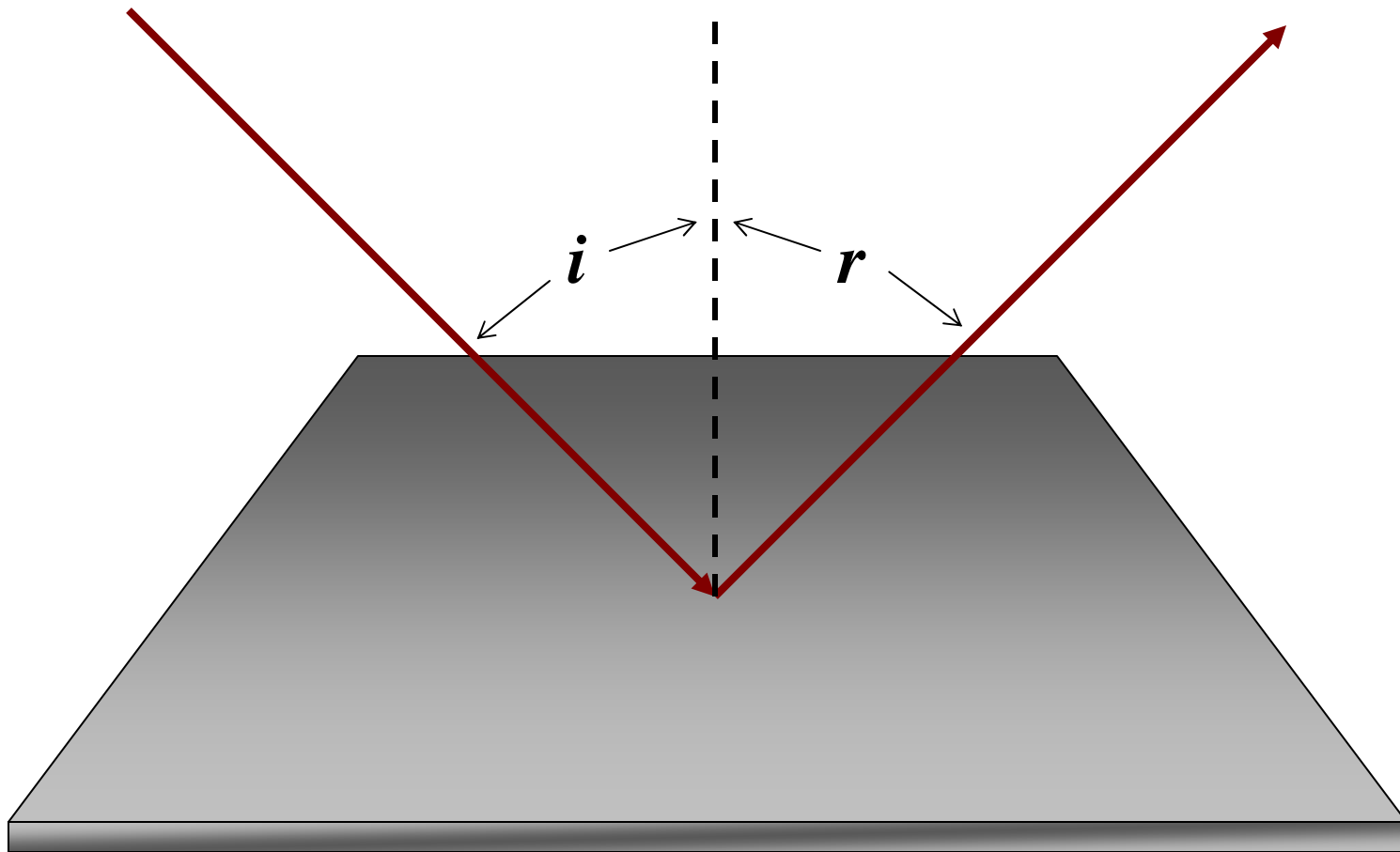
White light



Prism

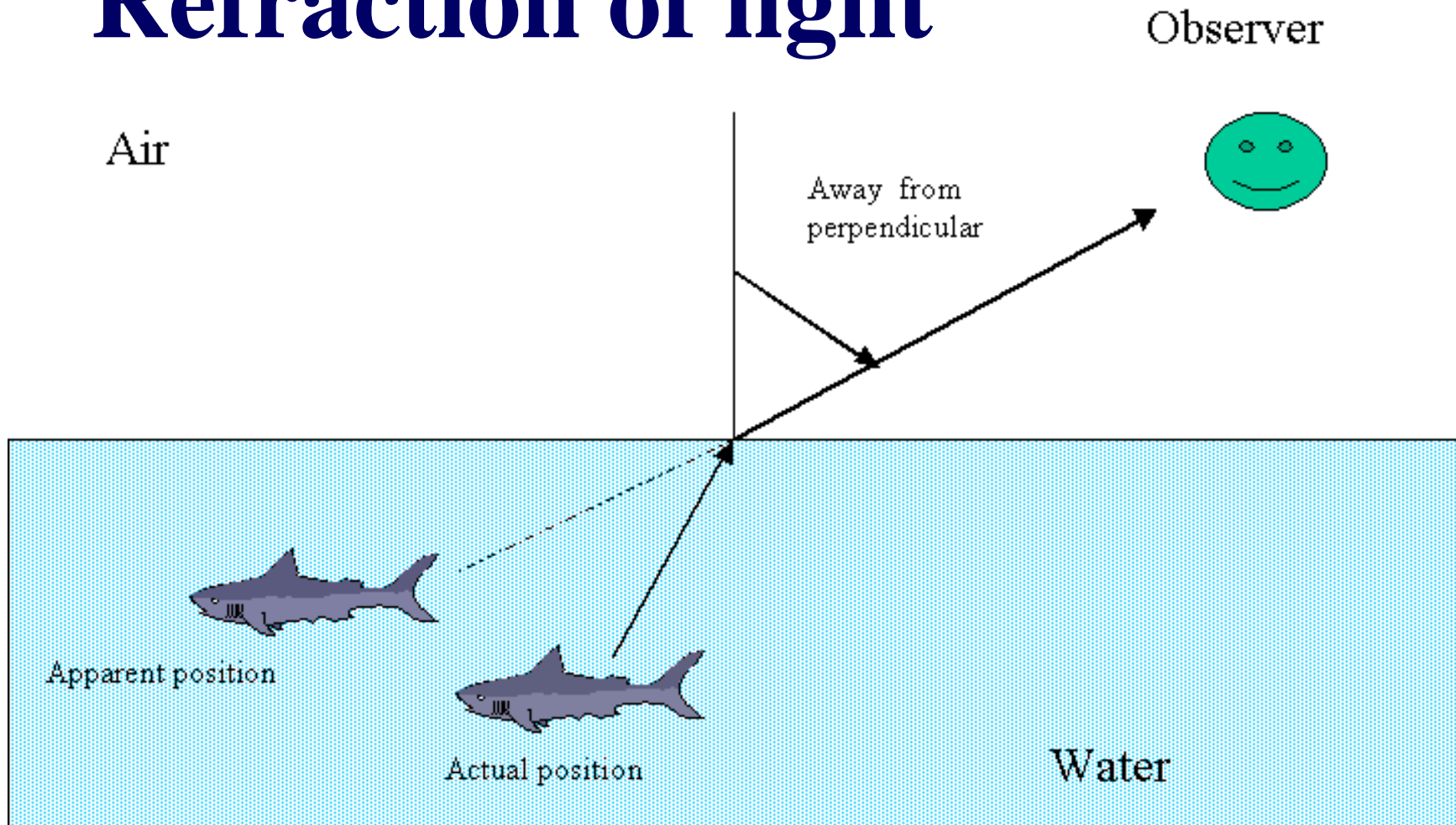
Corpuscular theory of light

Reflection of light

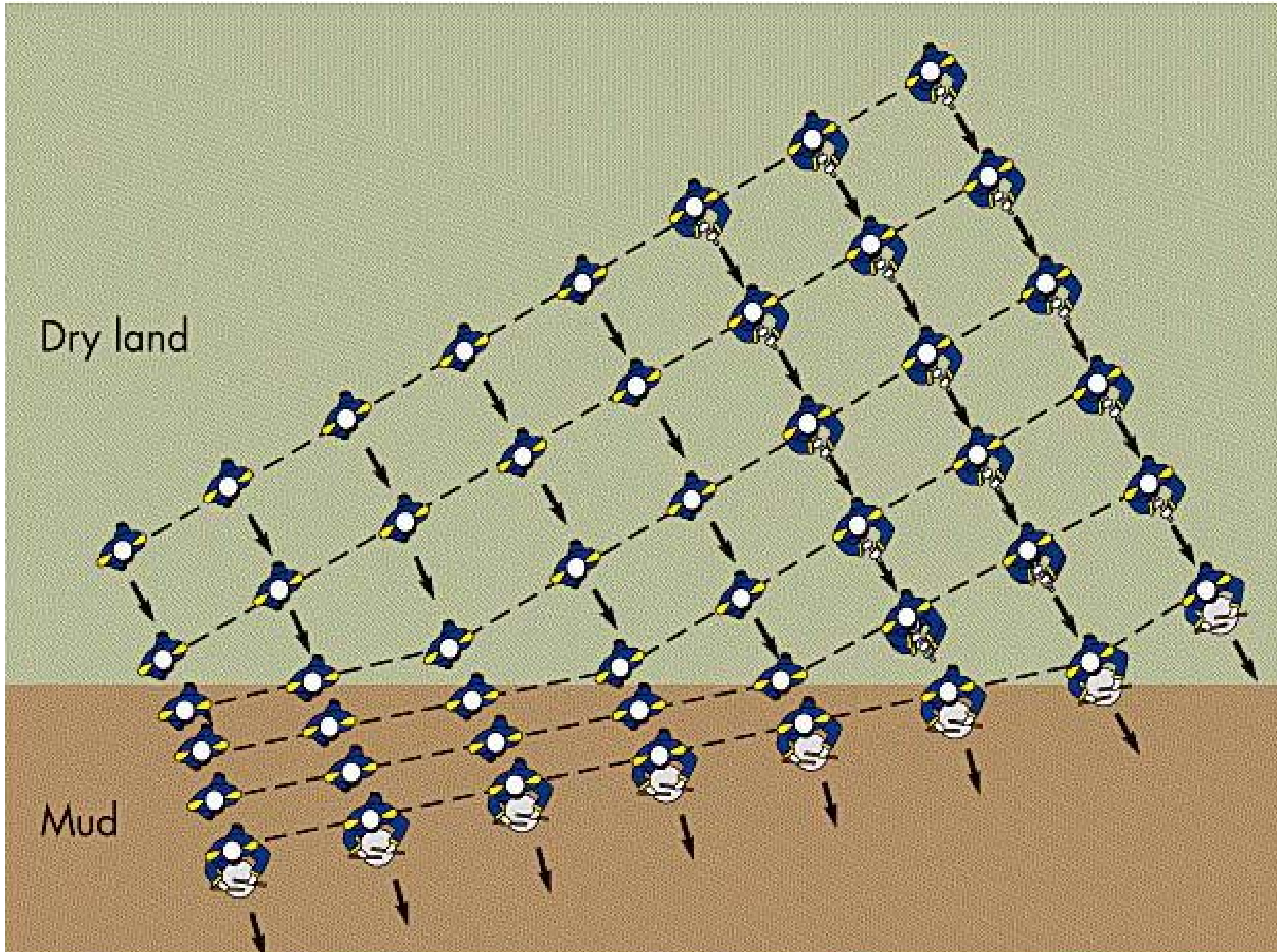


Incident angle (i) = Reflected angle (r)

Refraction of light



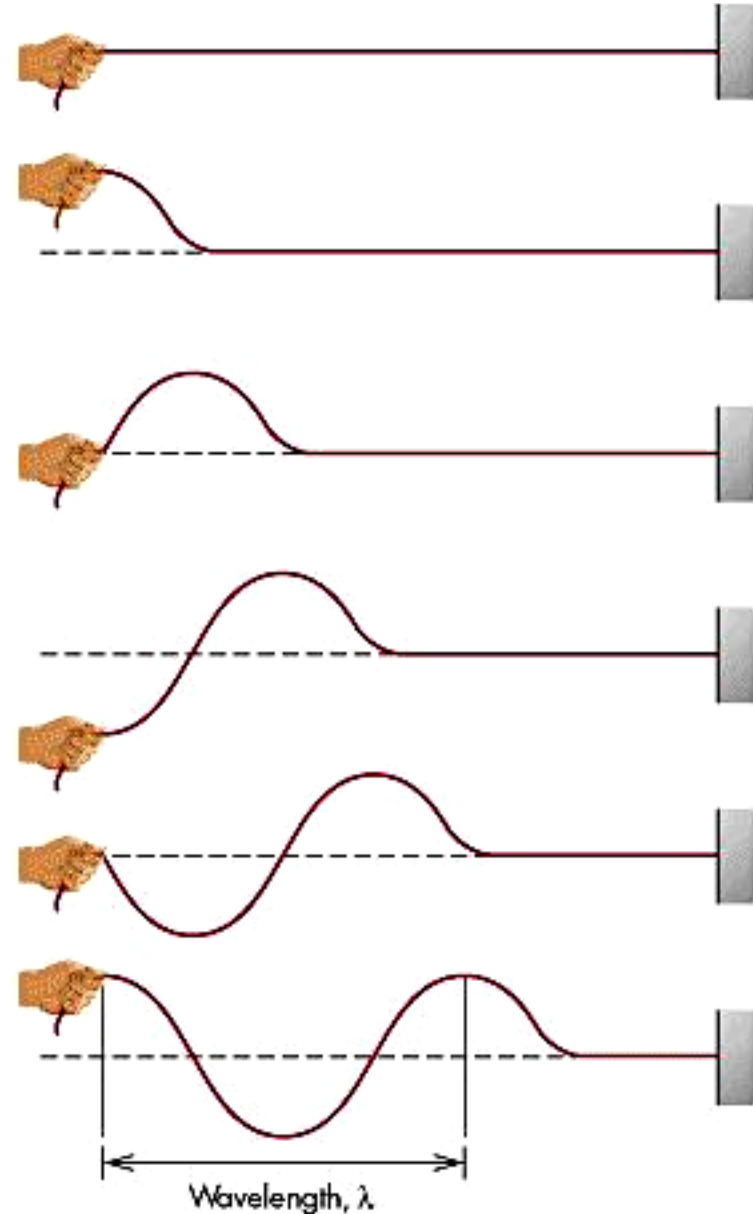
Particles move faster in more “optically dense” medium



**Rival theory due to
Christian Huygens**

**Light waves propagate
through the
*luminiferous ether***

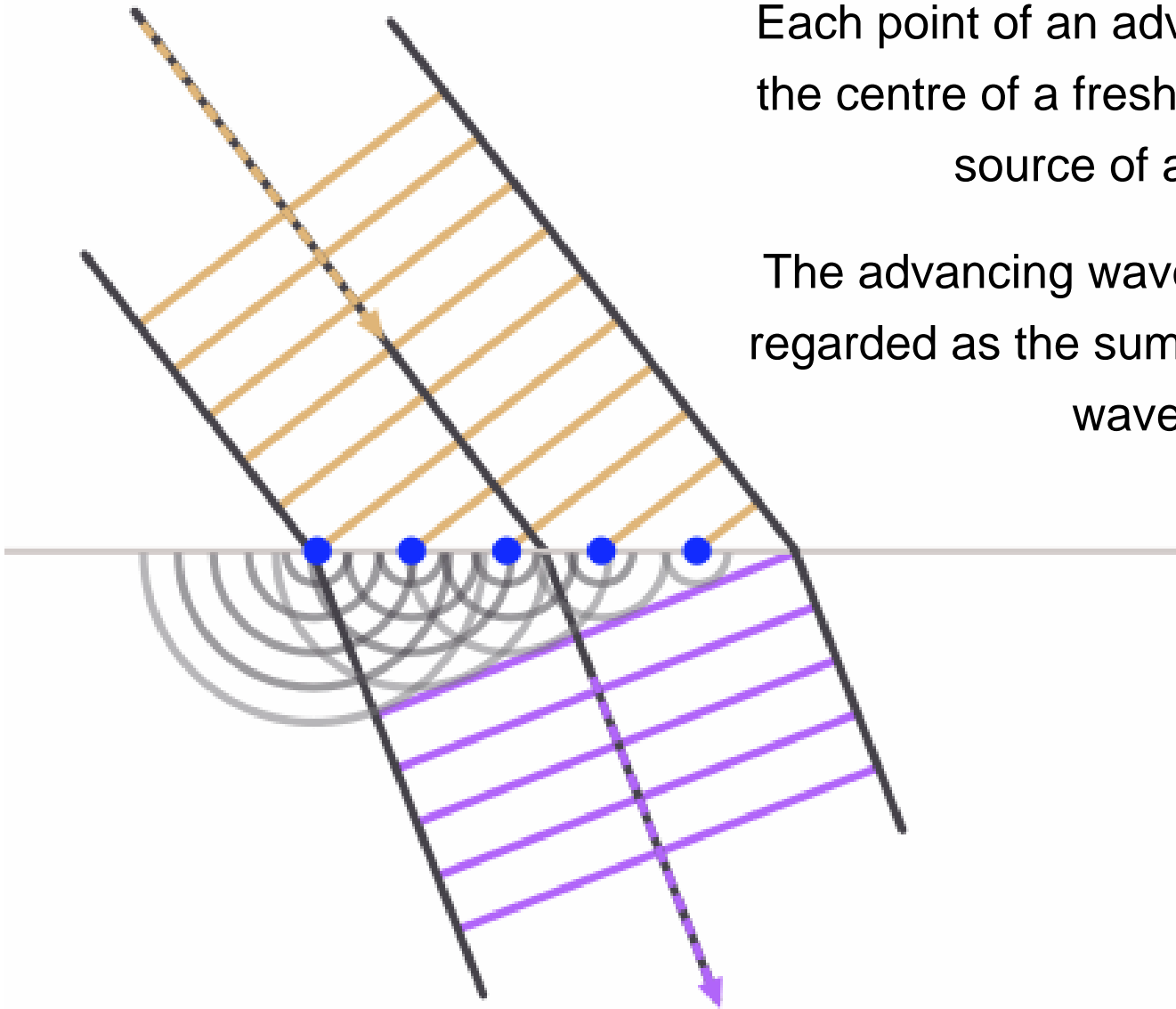
**Wave theory could
explain refraction
equally well**



Huygens Principle

Each point of an advancing wave front is the centre of a fresh disturbance and the source of a new train of waves.

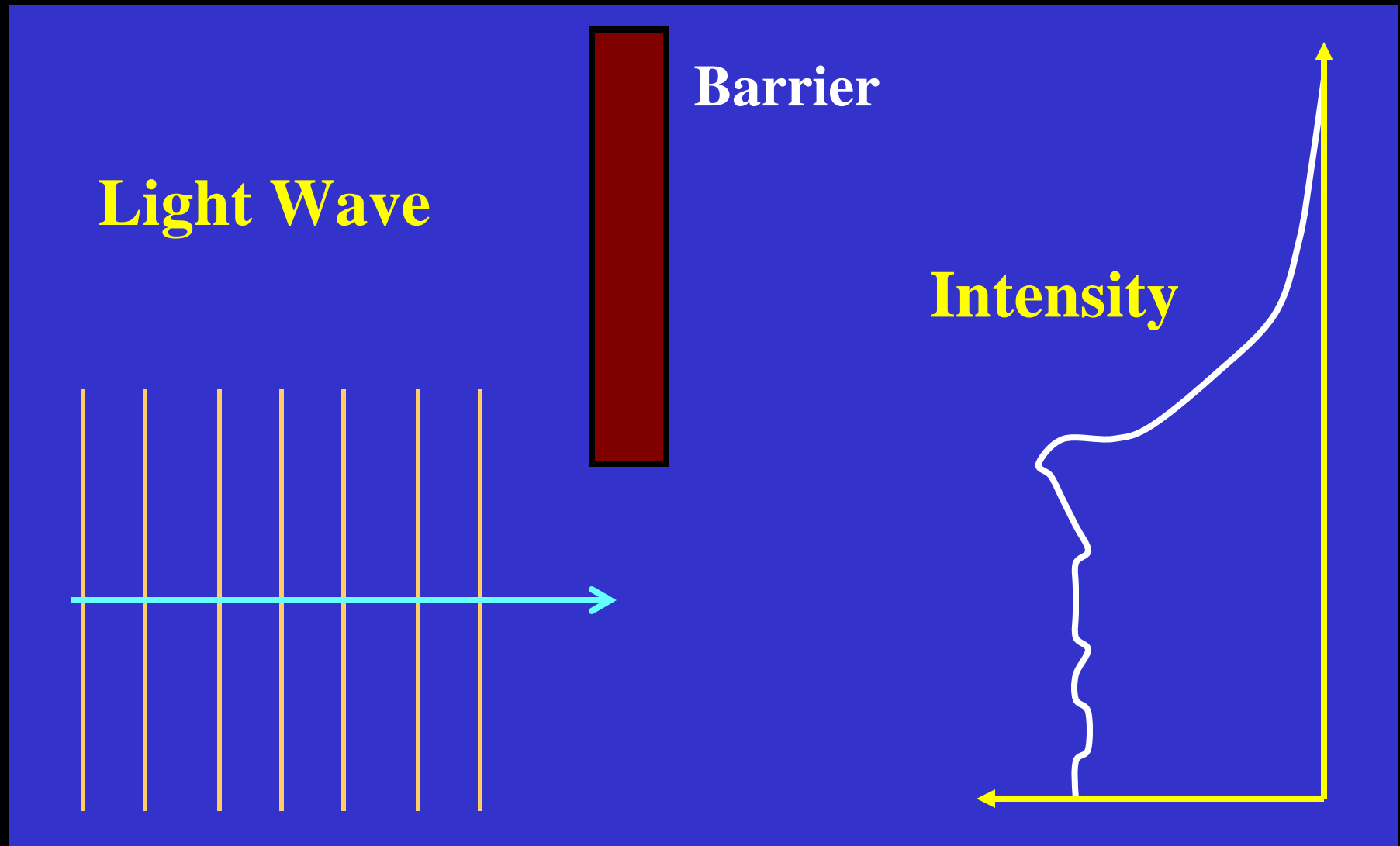
The advancing wave as a whole may be regarded as the sum of all the secondary waves arising from points already traversed

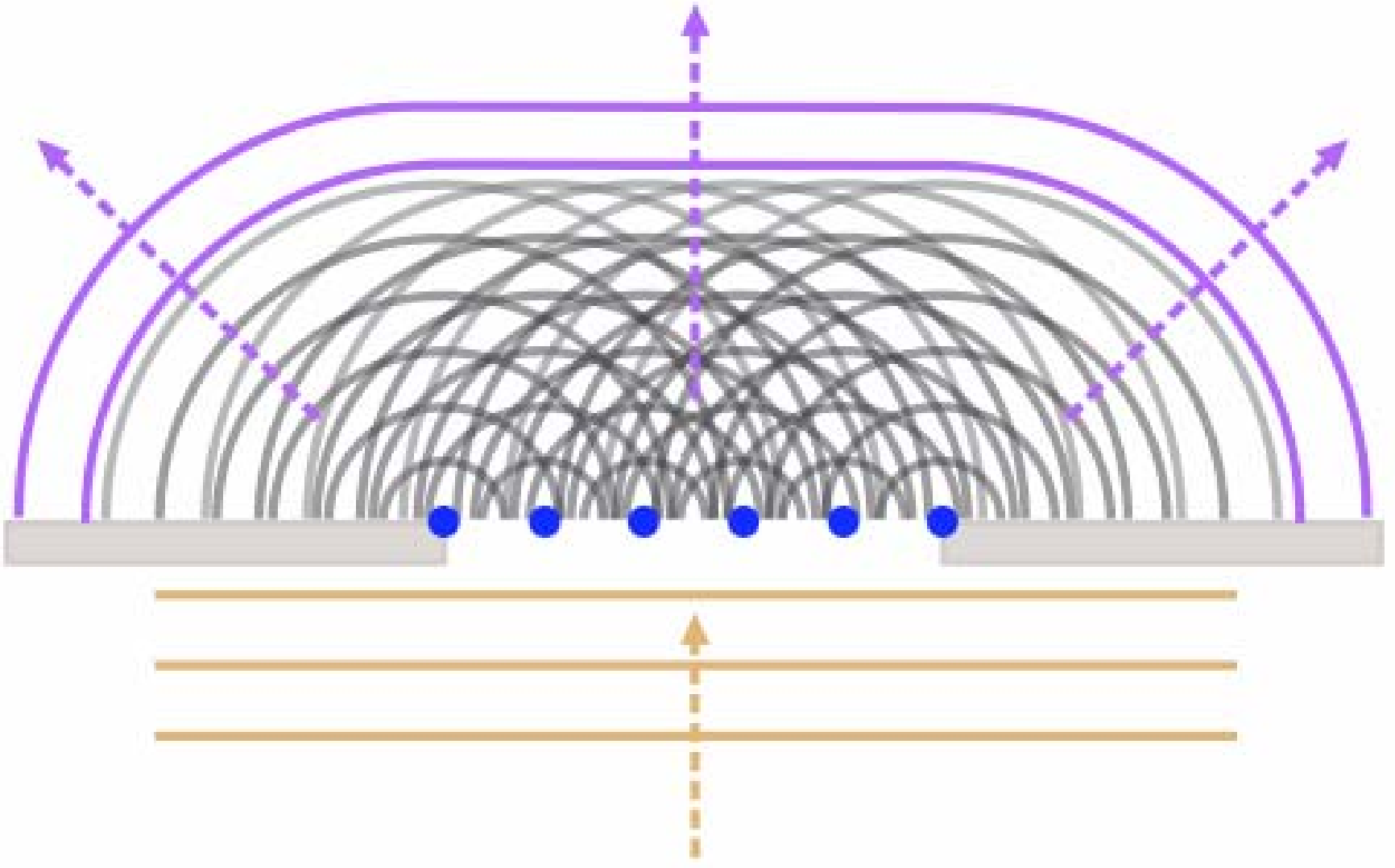


**Particle theory dominated
until early 1800s:**

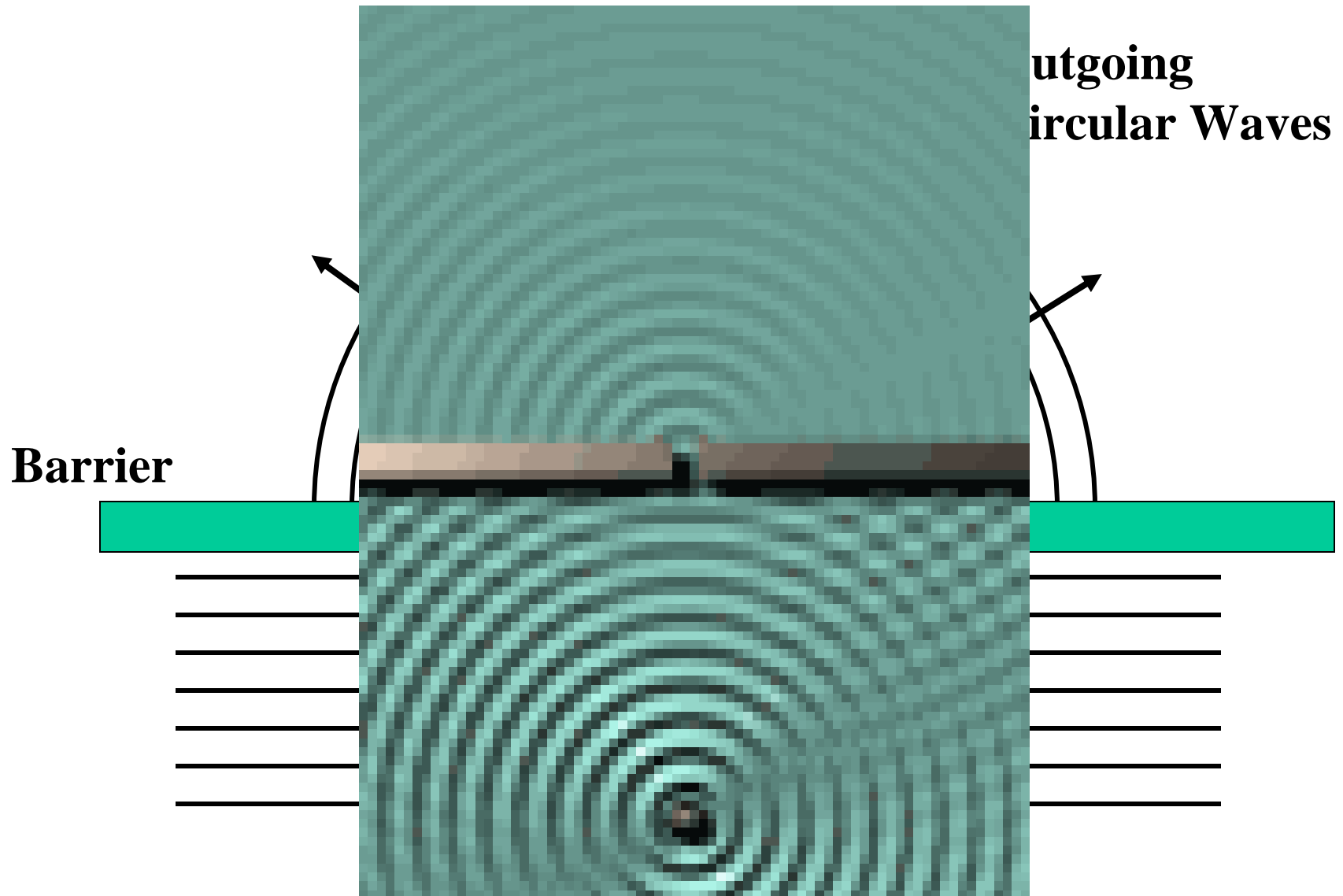
**Experiments by
Thomas Young and Augustin
Fresnel changed all that!**

Diffraction could, in principle, distinguish the models

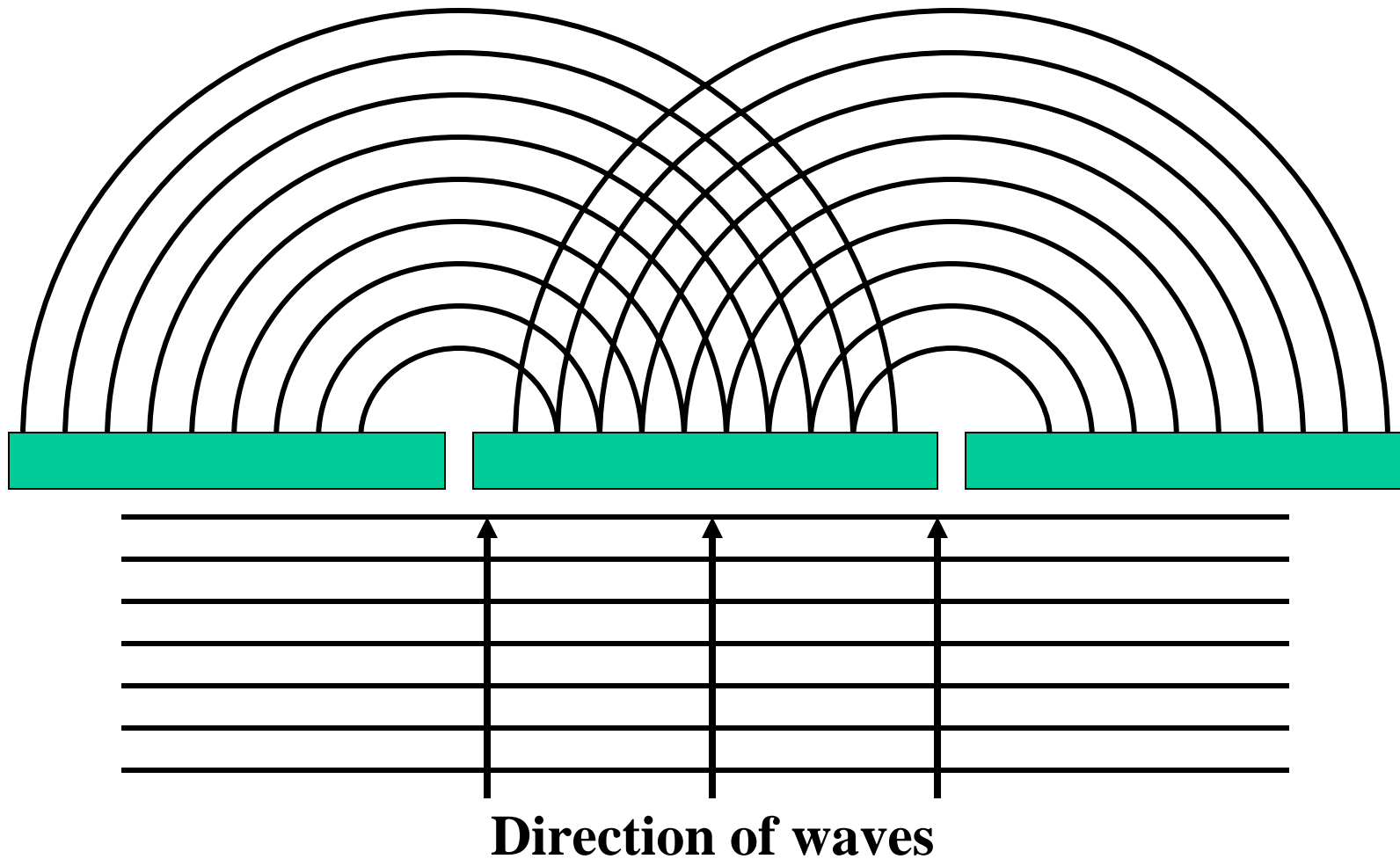




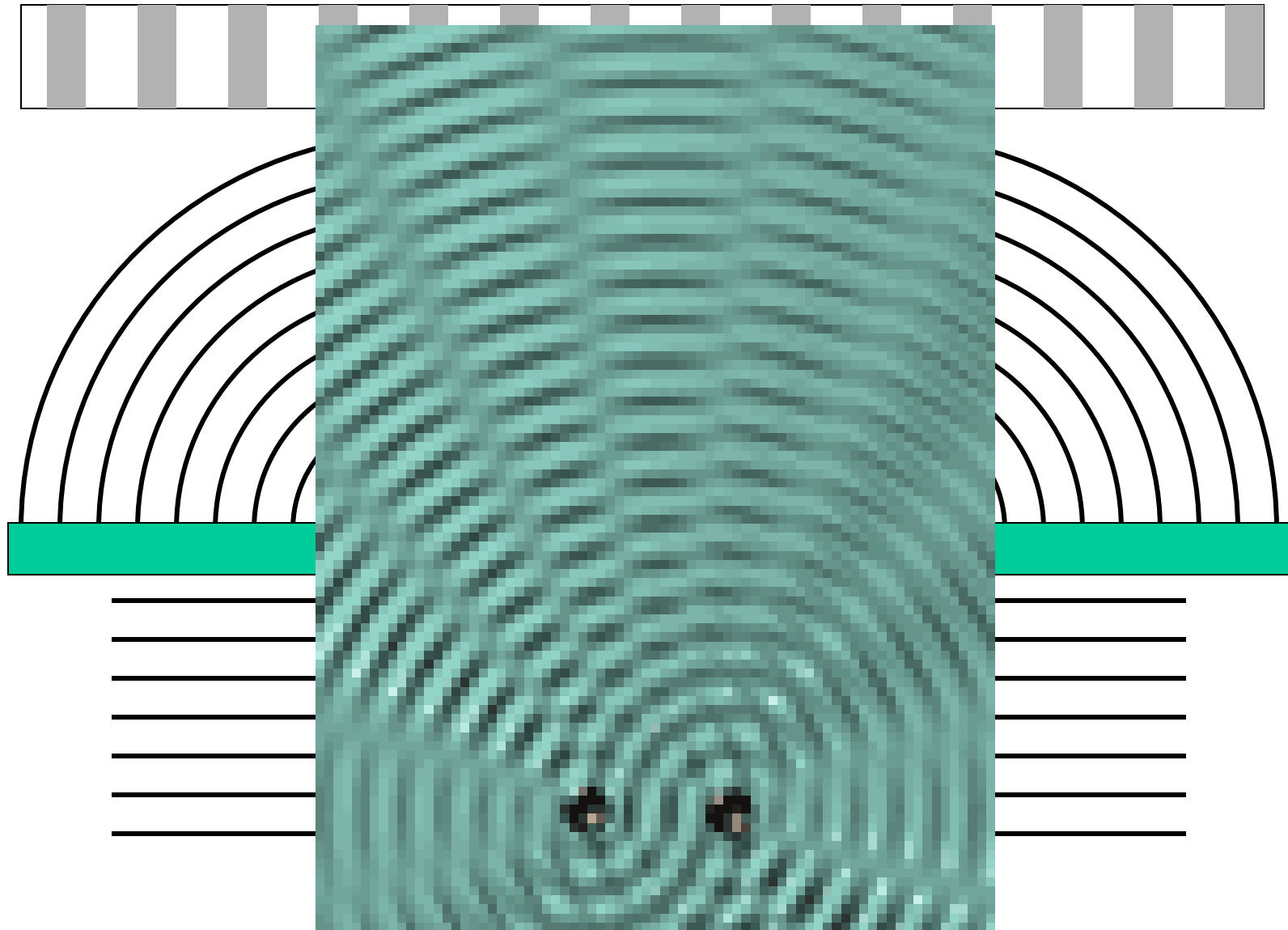
Diffraction of light

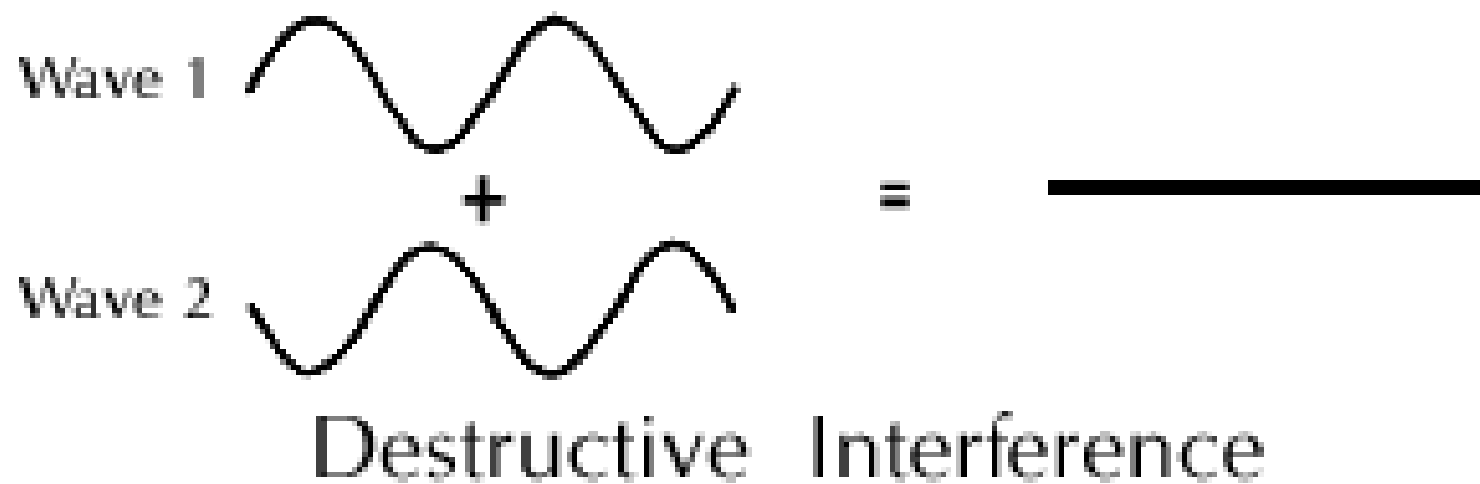
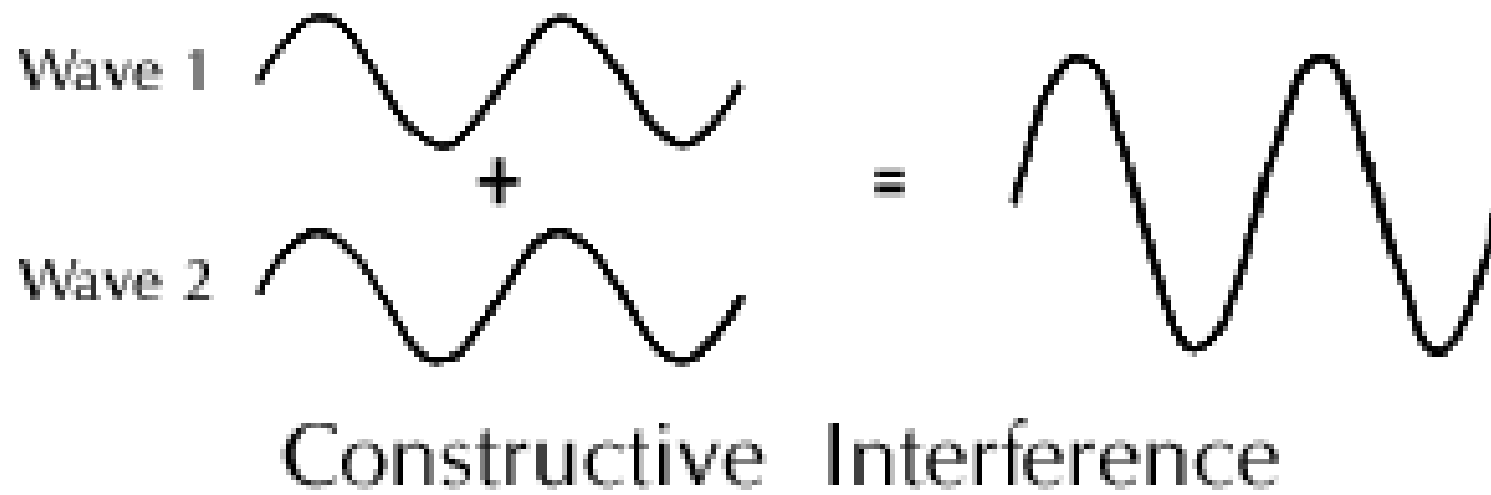


Interference of light

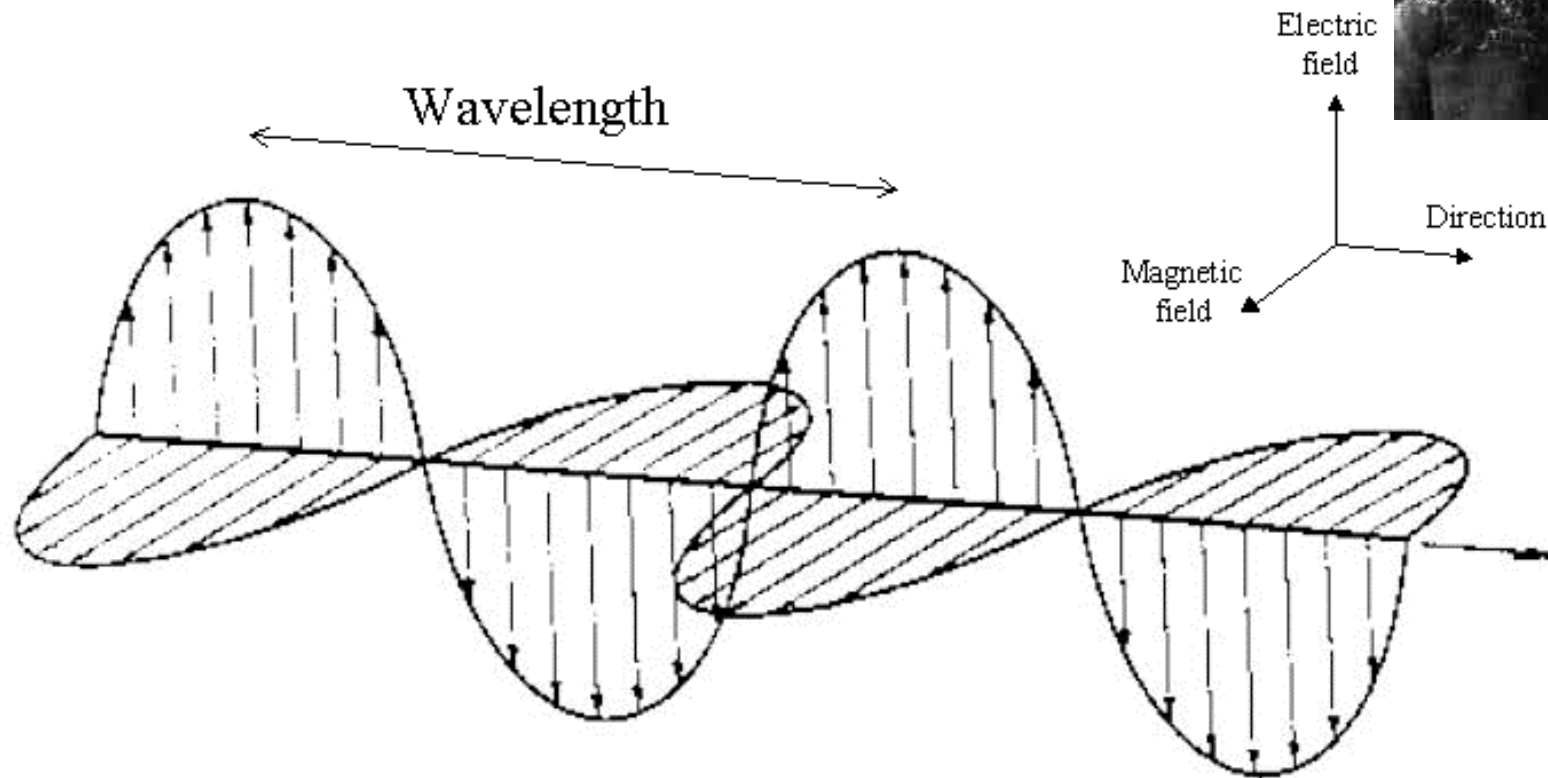


Interference of light



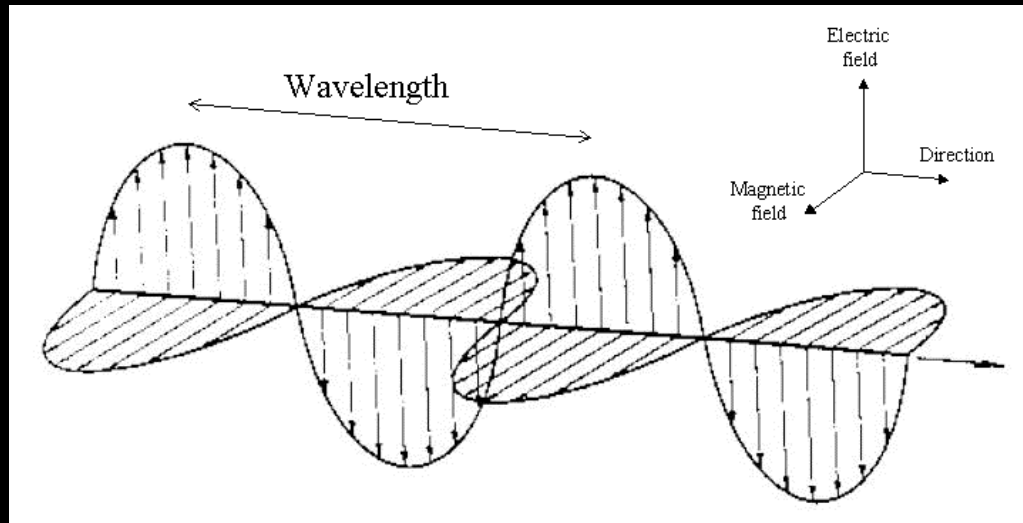


Maxwell's theory of light

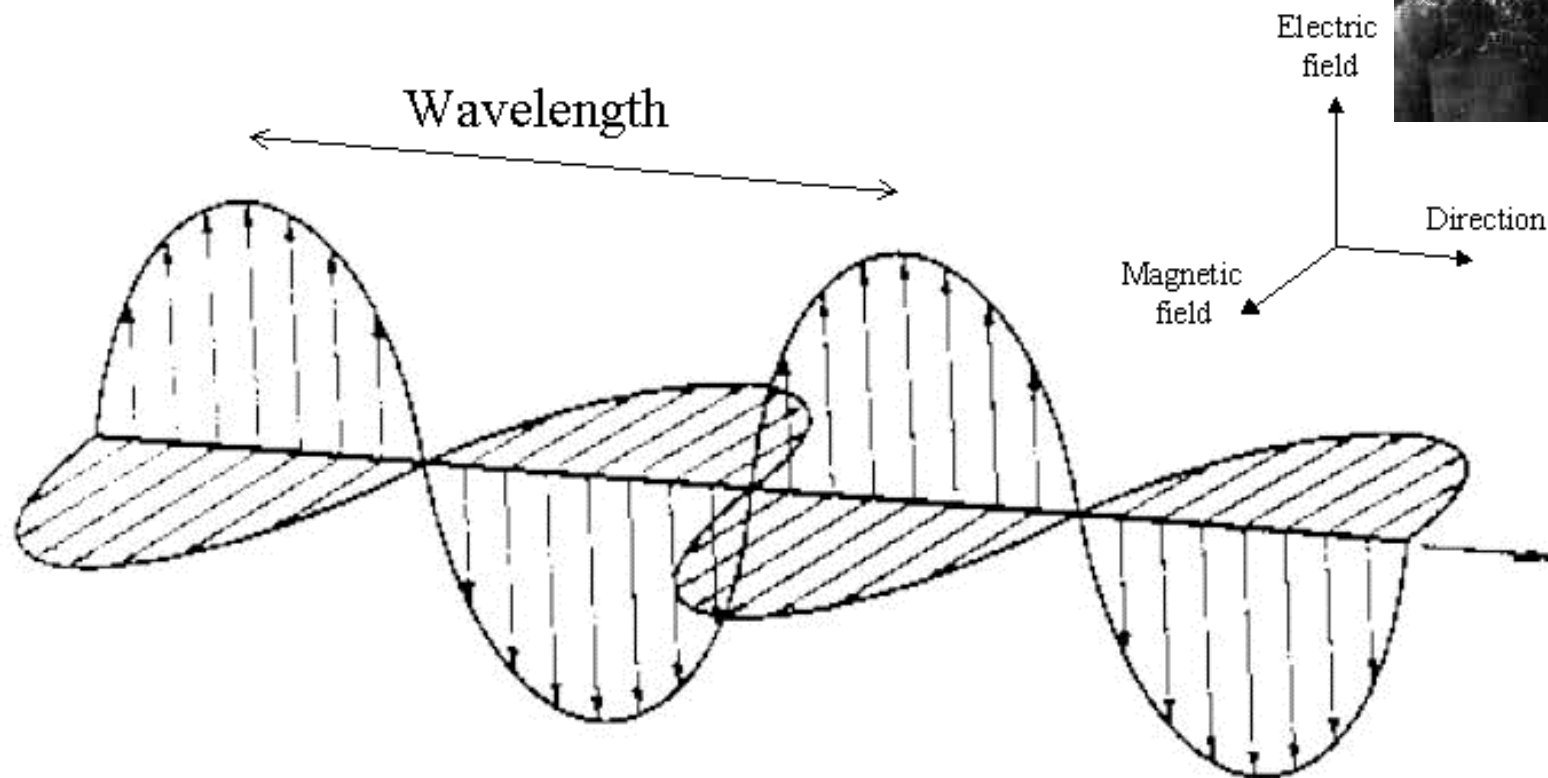


Special Relativity: 1905

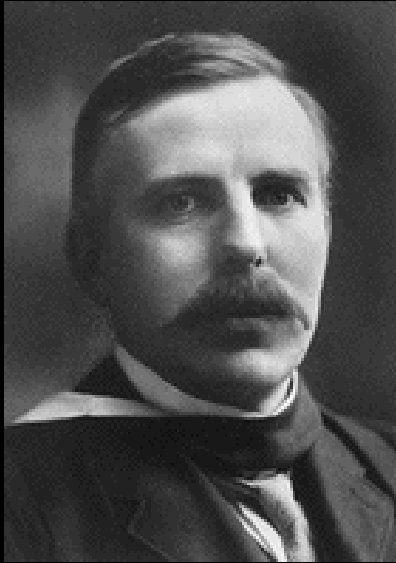
"Maxwell's Equations of Electromagnetism are the same for all observers, regardless of their relative motion"



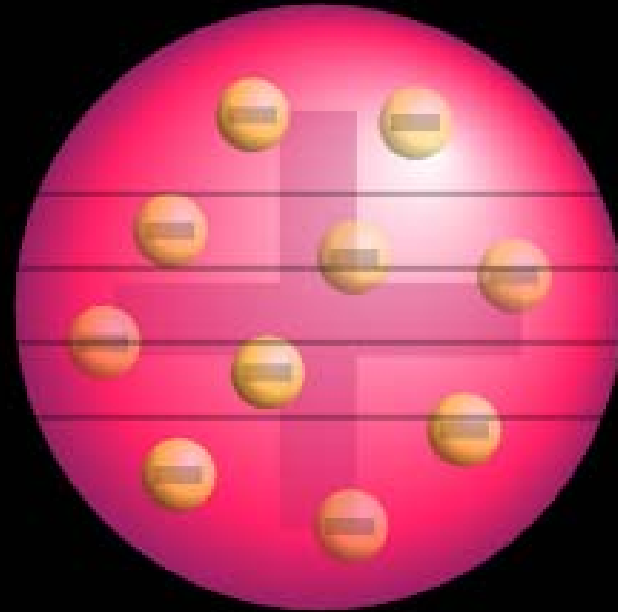
Maxwell's theory of light



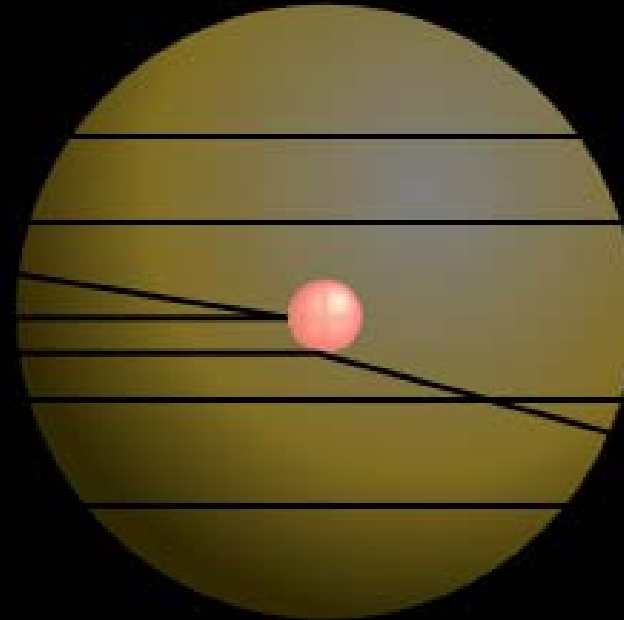
Early 1900s: accelerated electron radiates



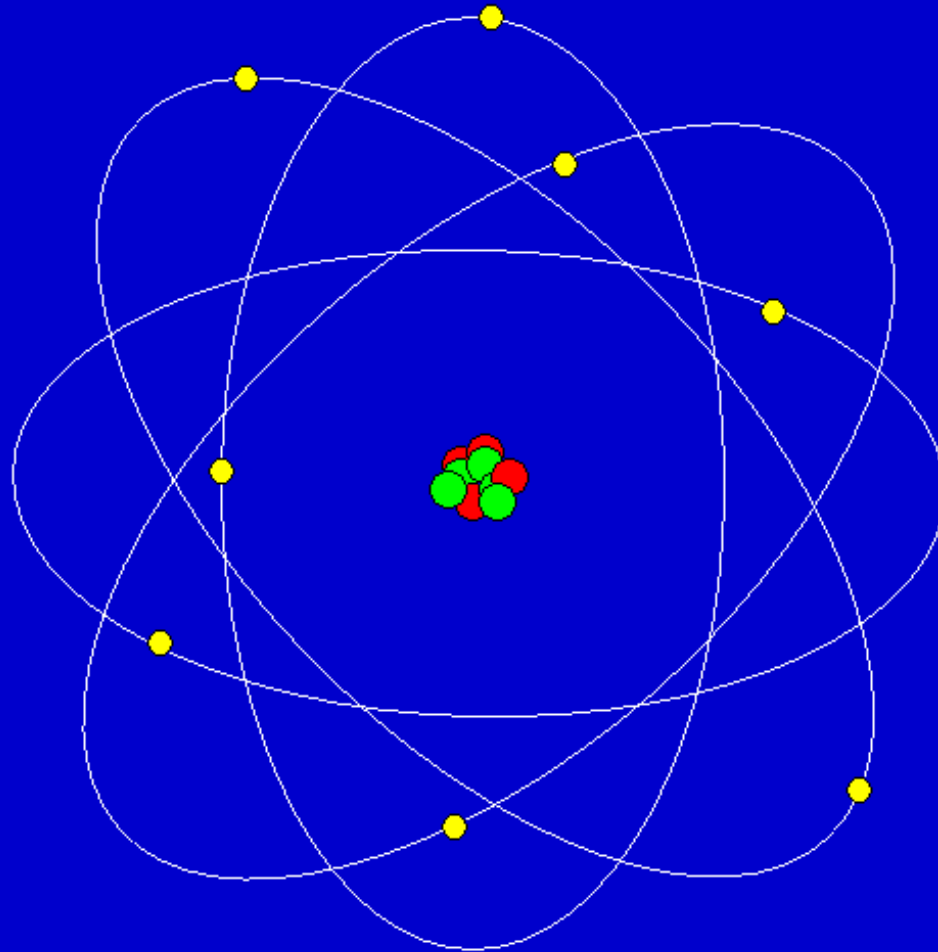
Ernest Rutherford



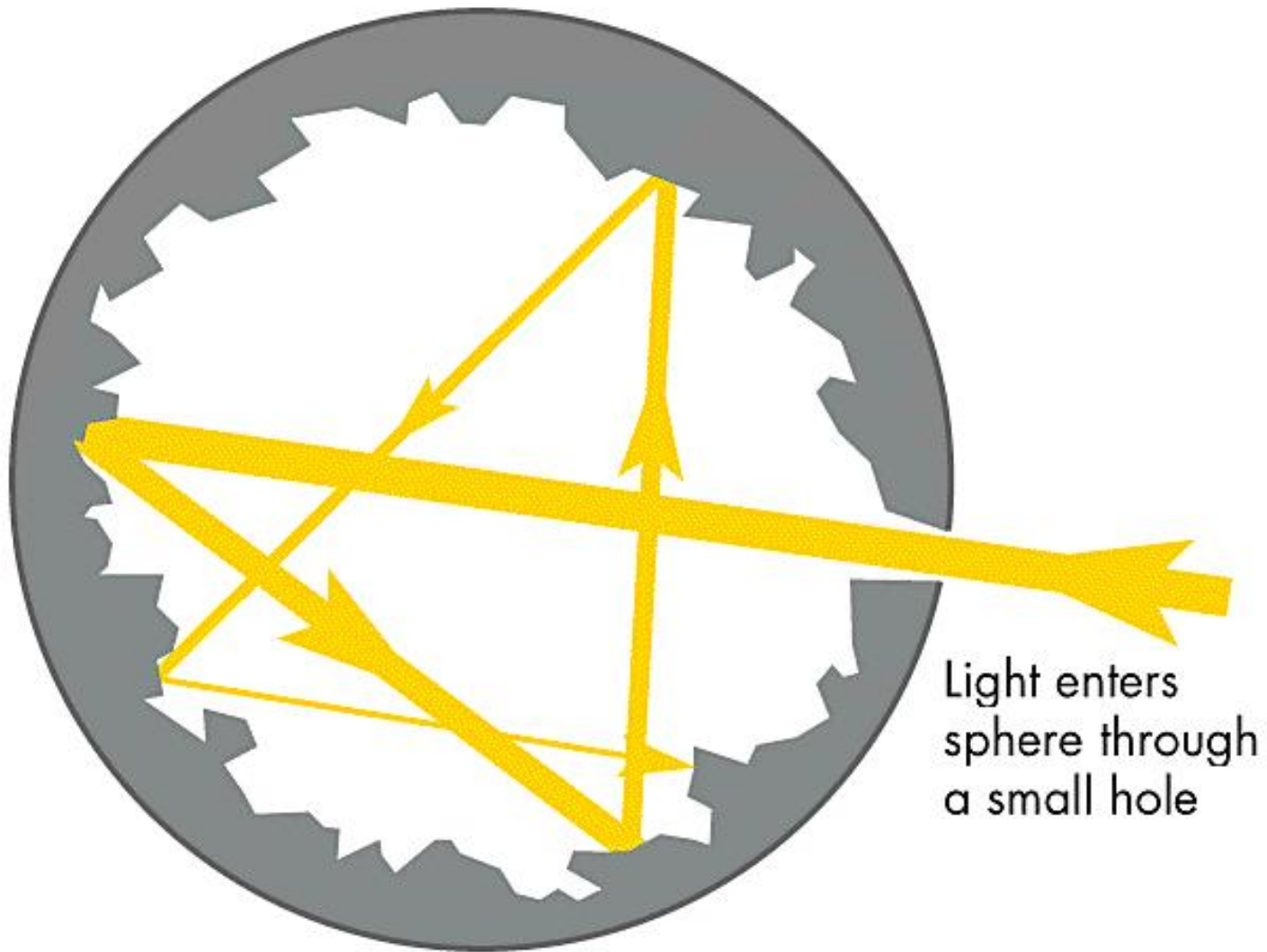
J.J. Thomson

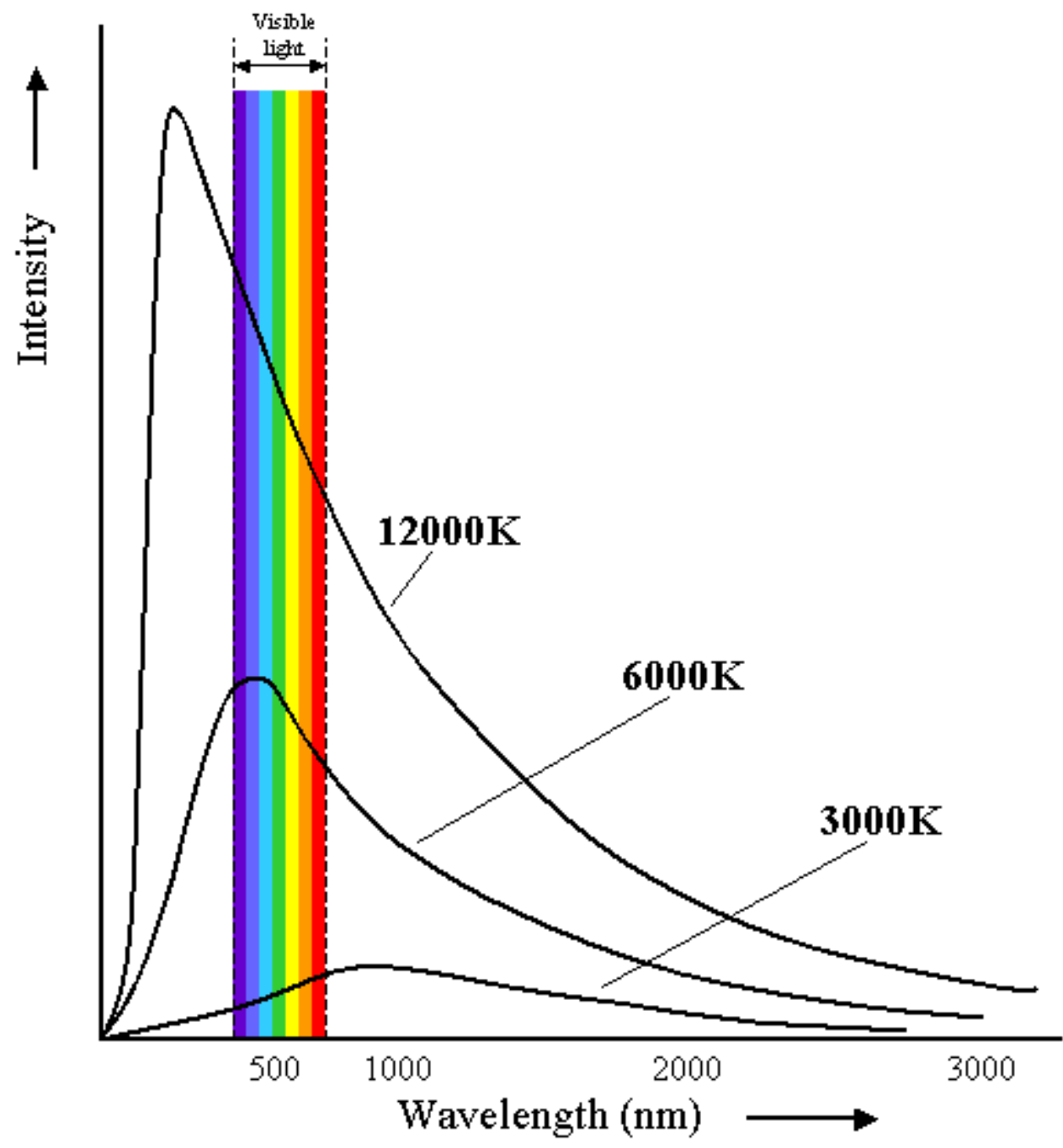


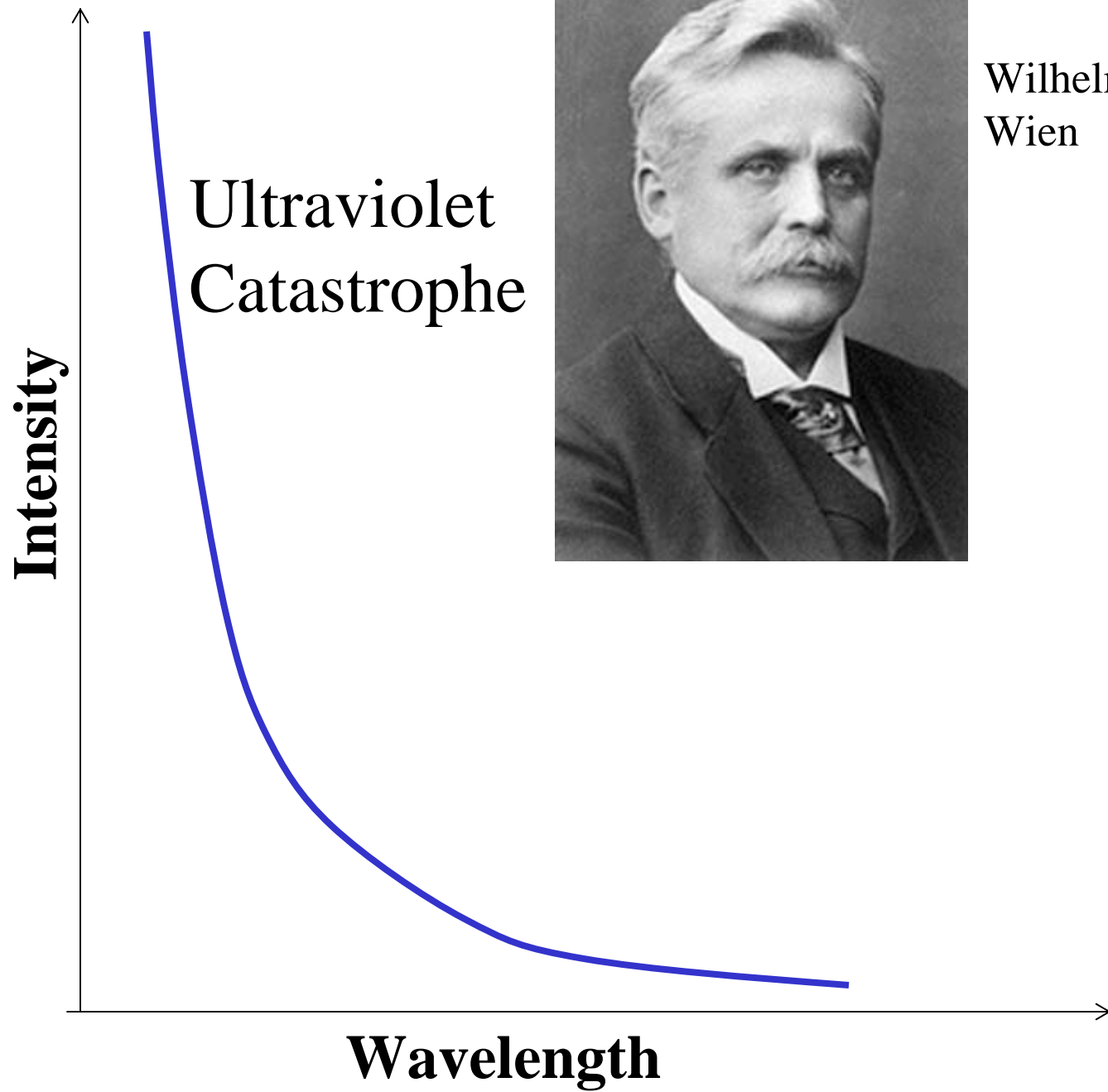
How do atoms persist?



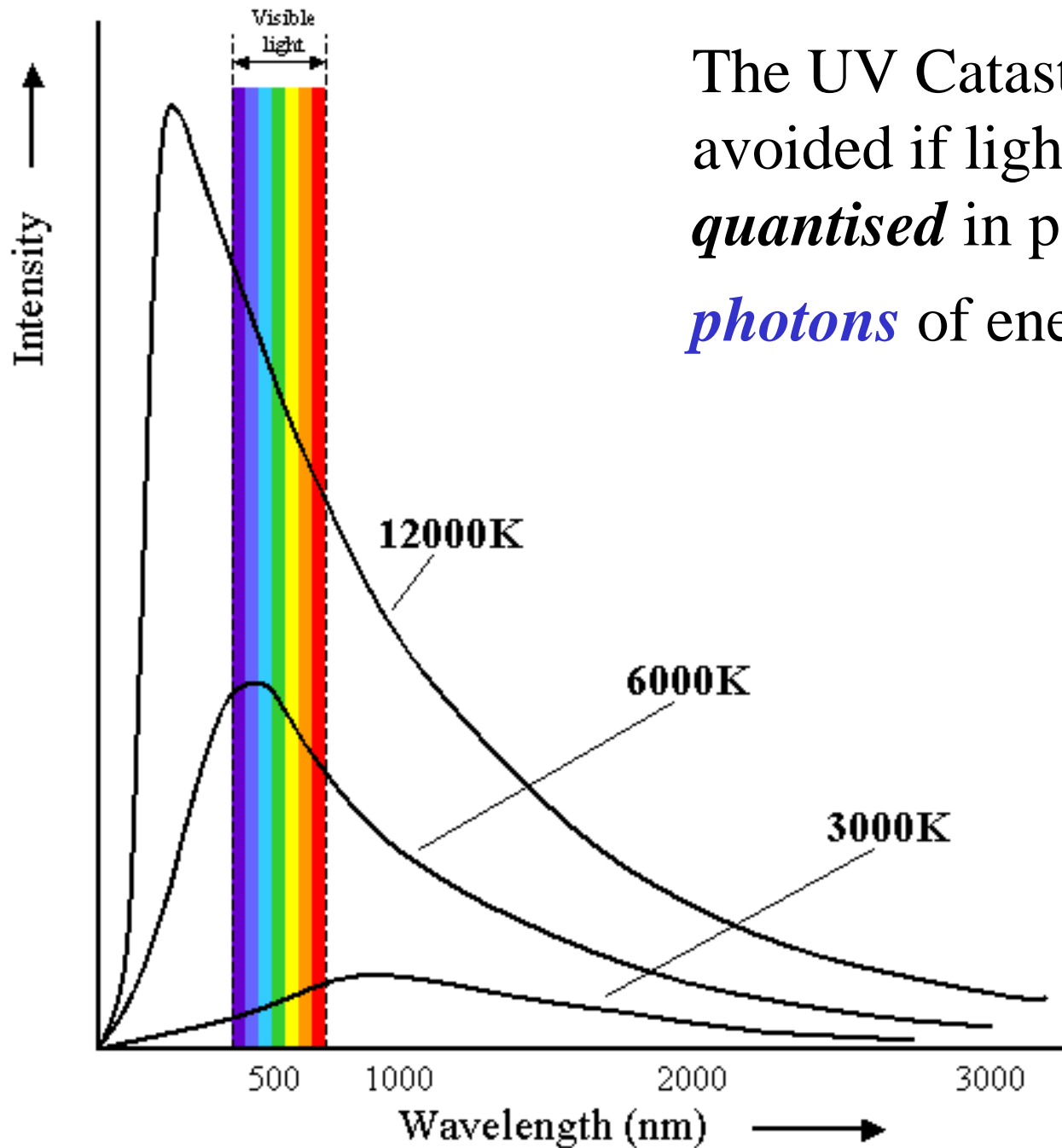
Black-body radiation



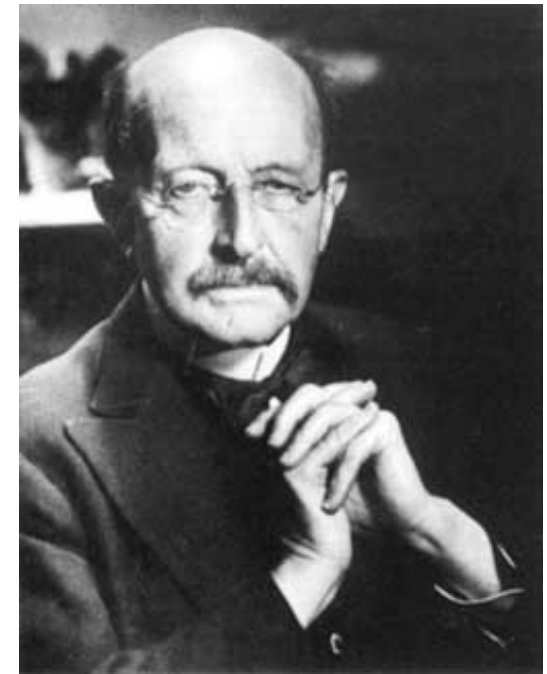




Wilhelm
Wien

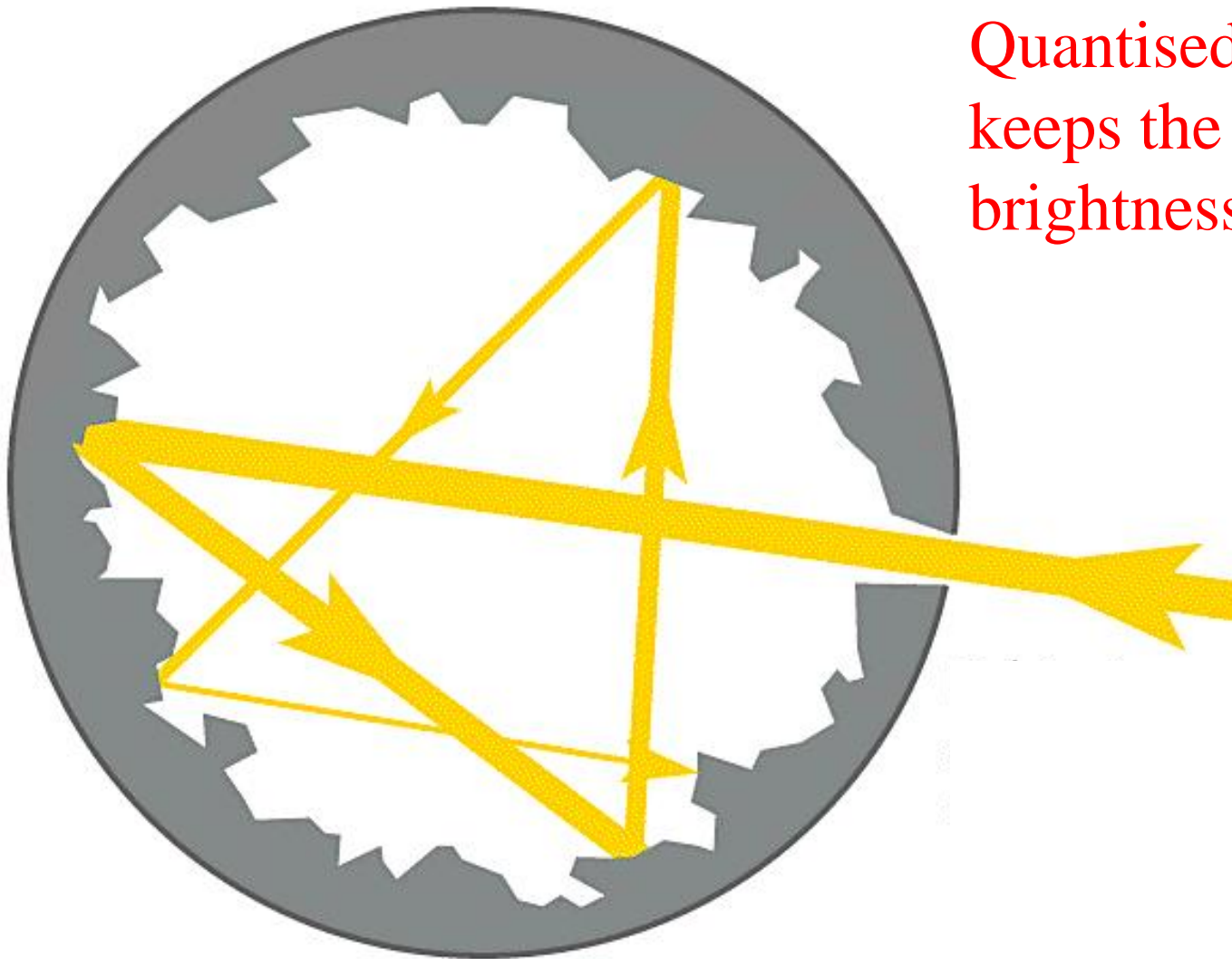


The UV Catastrophe could be avoided if light energy was *quantised* in packets, or *photons* of energy $E = hf$



Max Planck

Black-body radiation

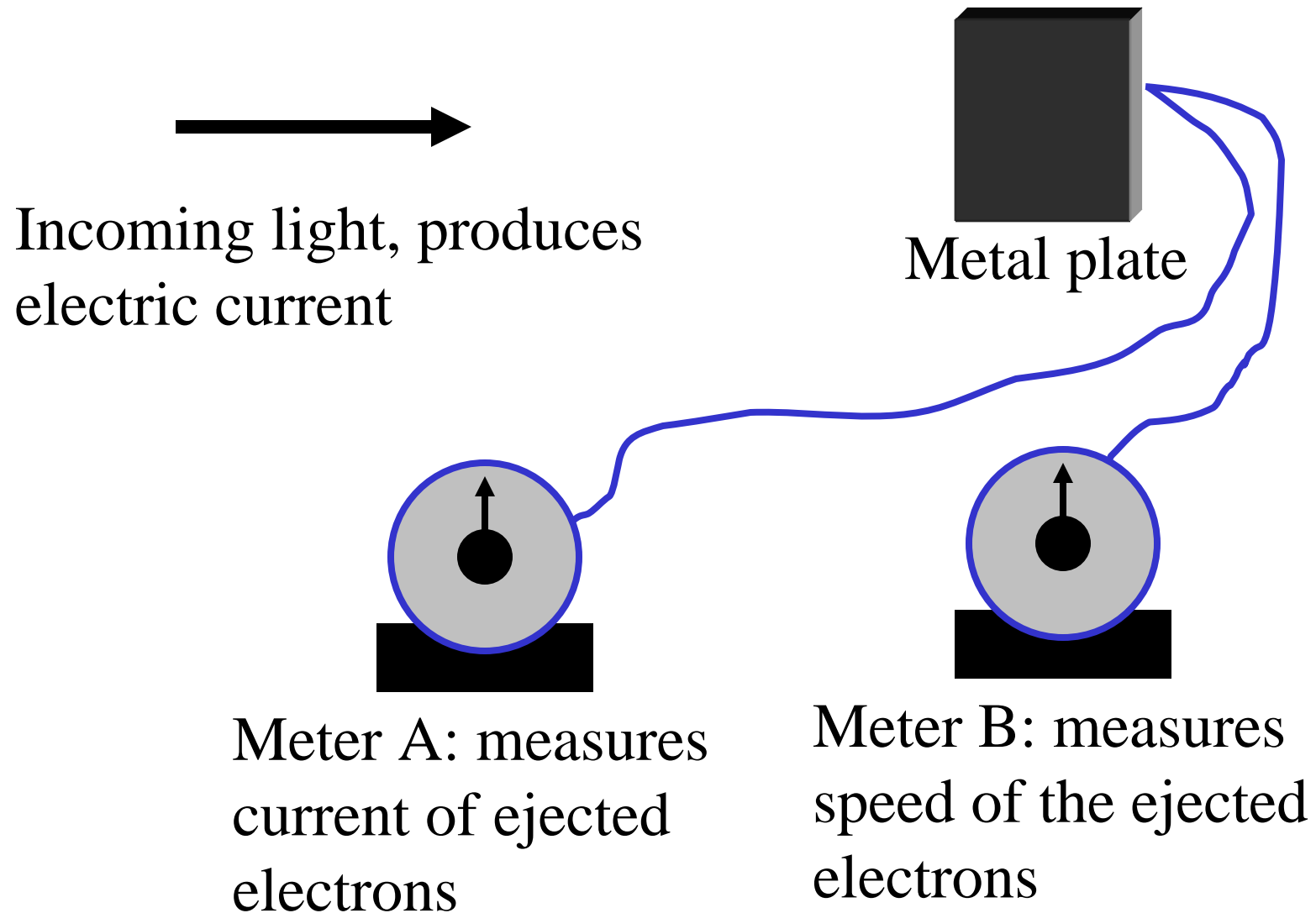


Quantised assumption
keeps the black-body
brightness finite

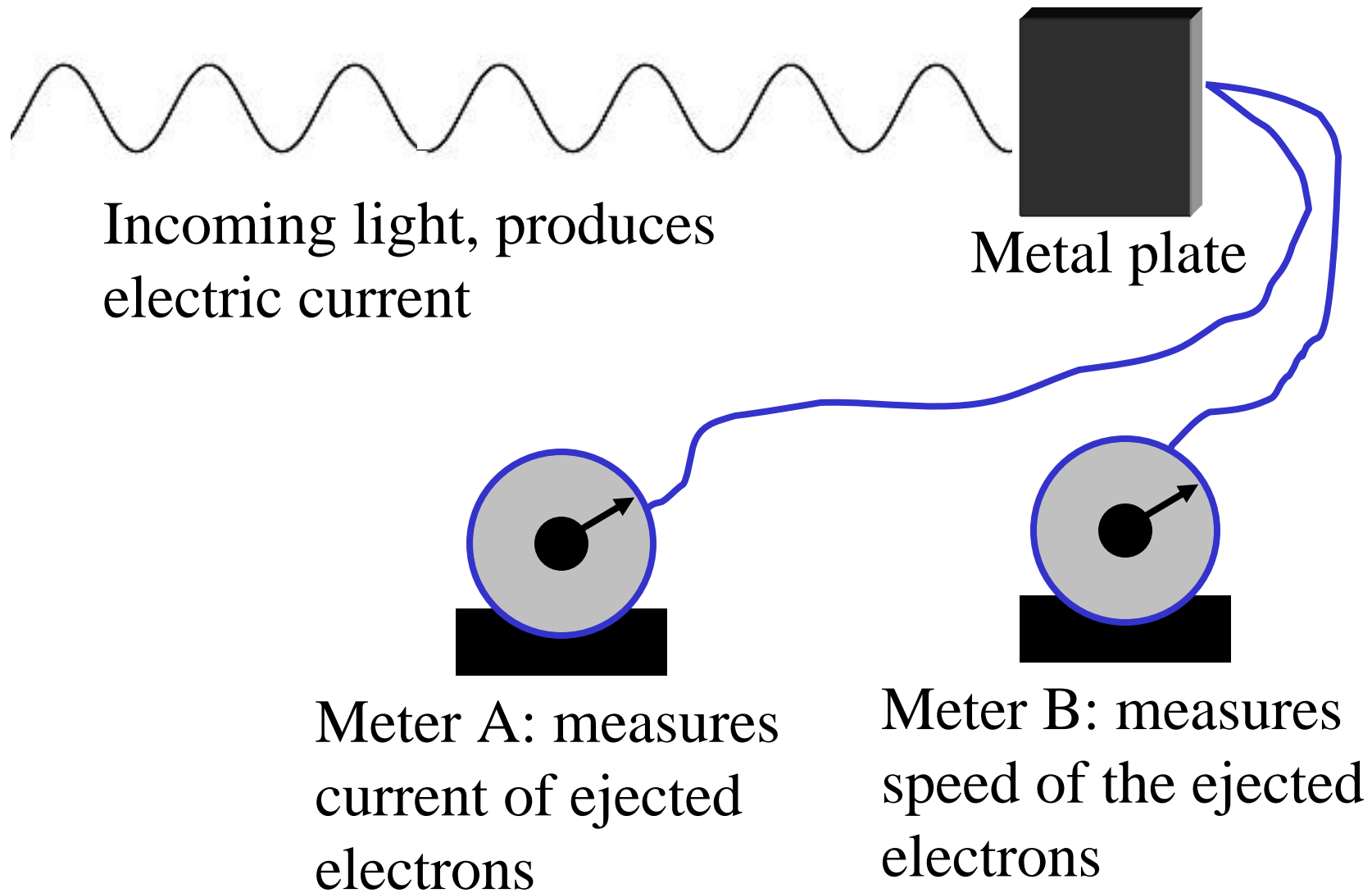


Albert Einstein, 1905

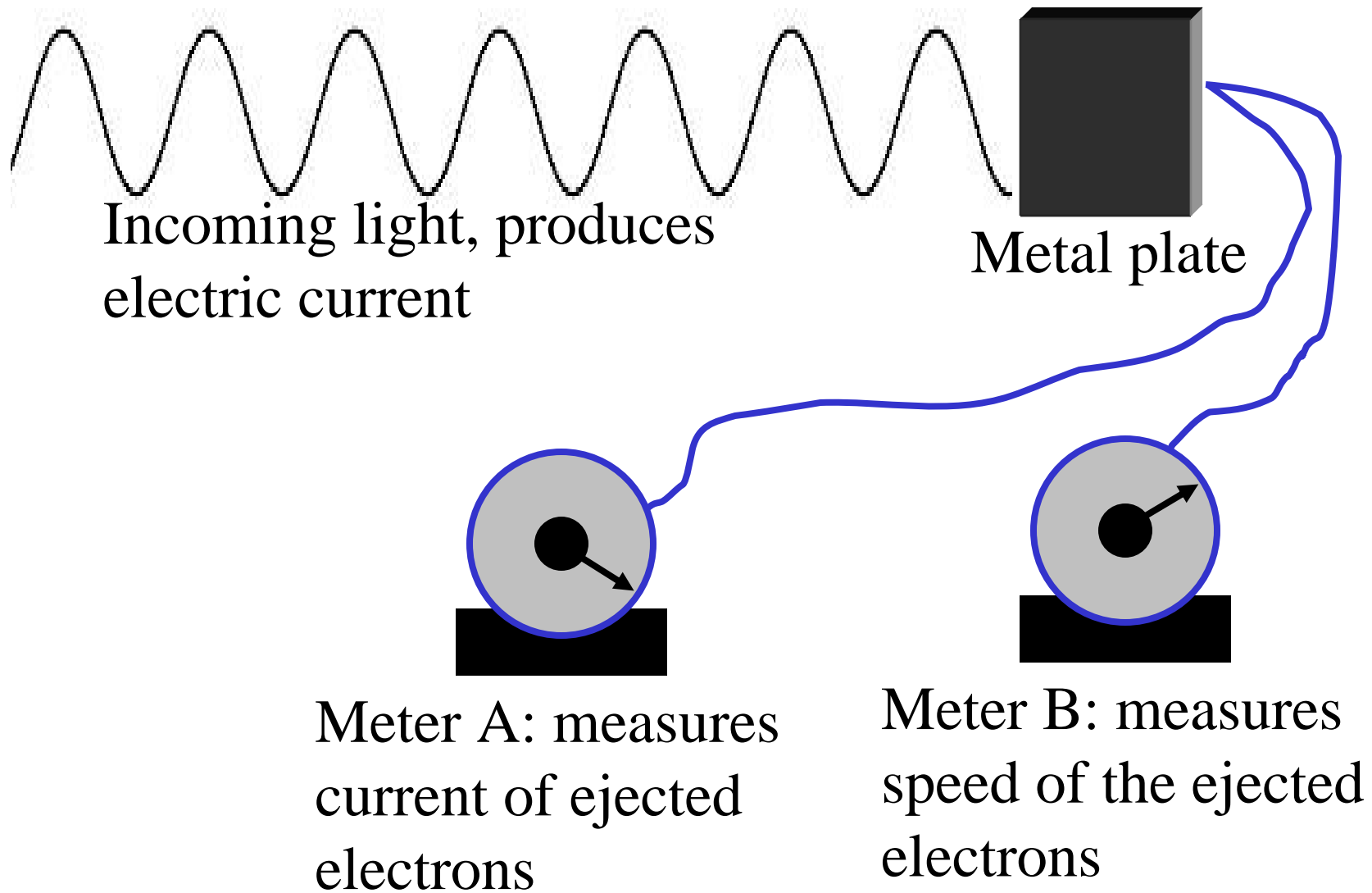
The Photoelectric Effect



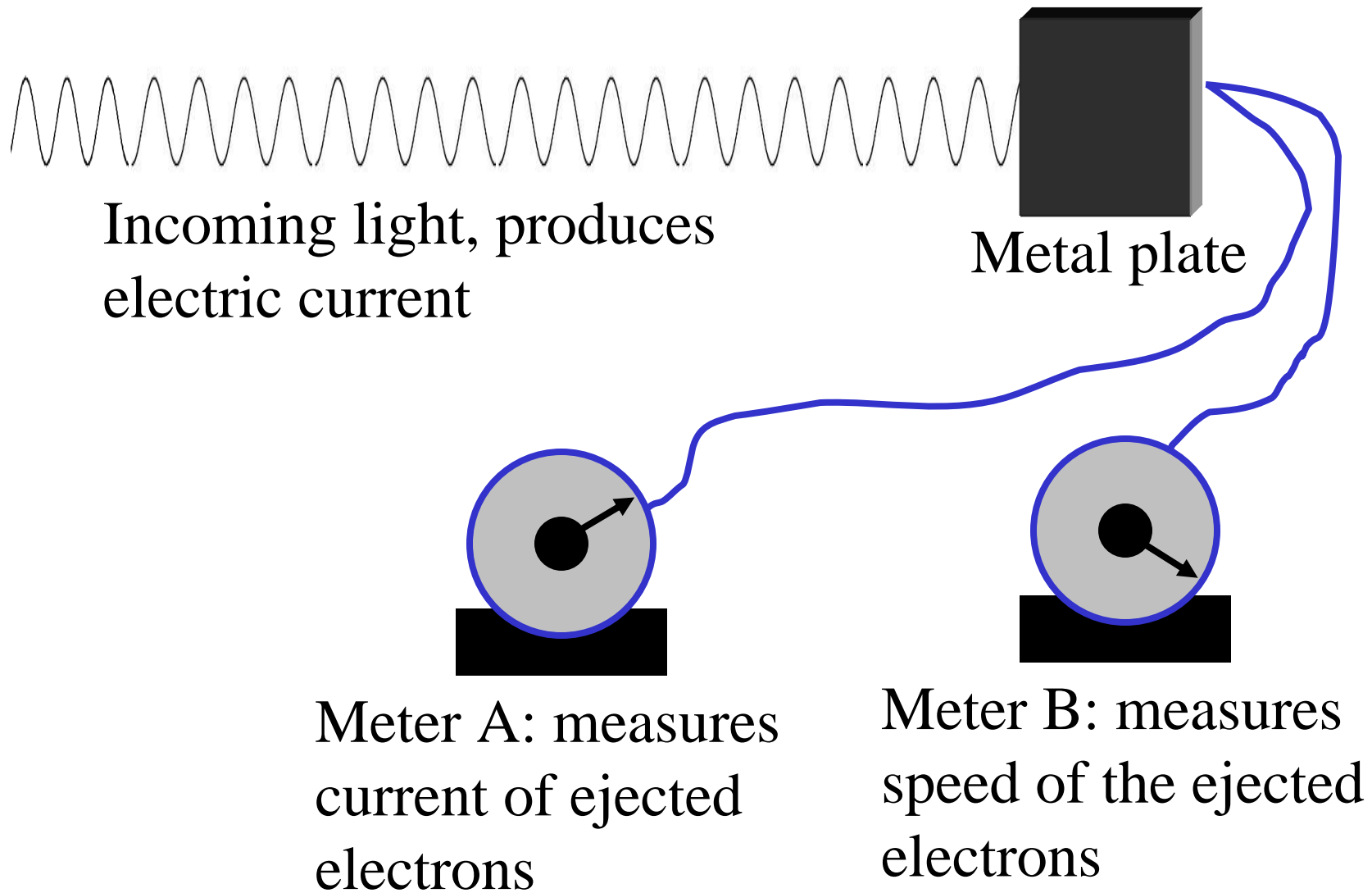
The Photoelectric Effect



The Photoelectric Effect

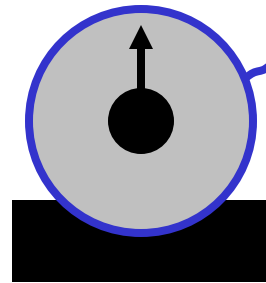
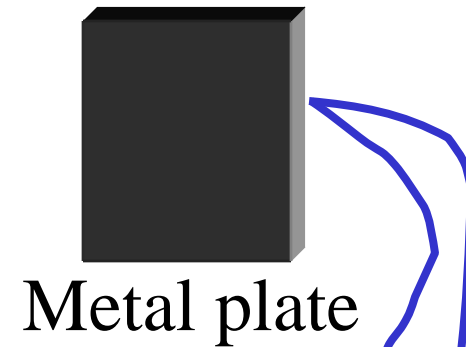


The Photoelectric Effect

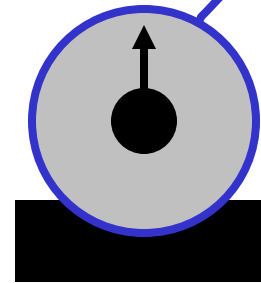


The Photoelectric Effect

Incoming light, produces electric current



Meter A: measures current of ejected electrons

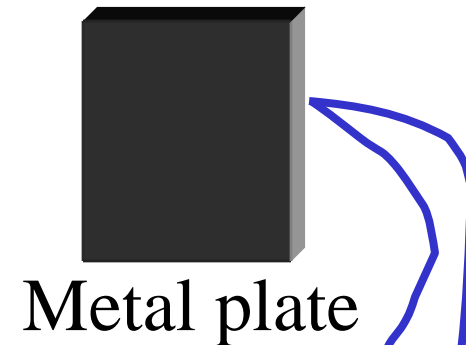


Meter B: measures speed of the ejected electrons

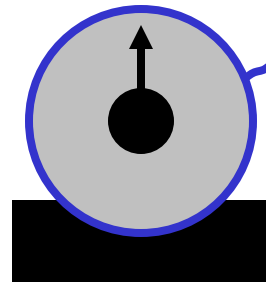
The Photoelectric Effect

No effect for blue light

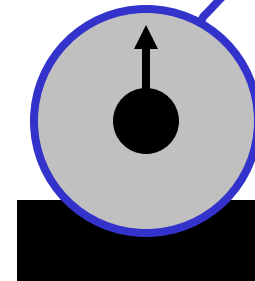
Incoming light, produces electric current



Metal plate



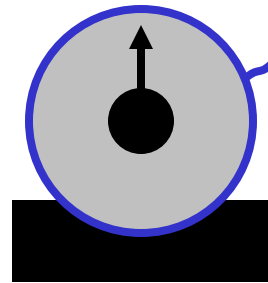
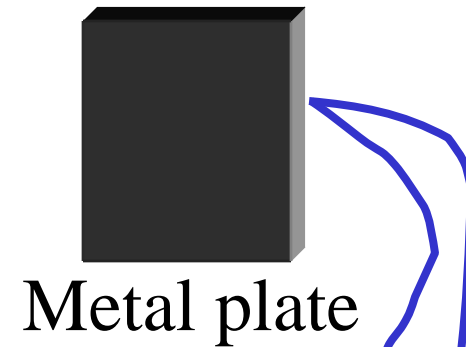
Meter A: measures current of ejected electrons



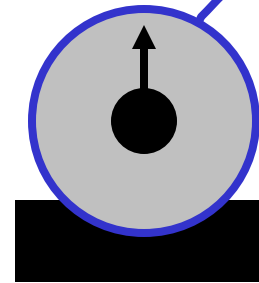
Meter B: measures speed of the ejected electrons

The Photoelectric Effect

Incoming light, produces electric current



Meter A: measures current of ejected electrons

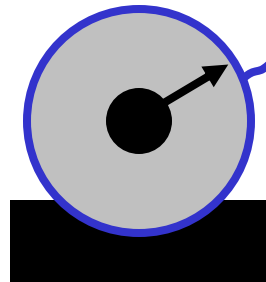
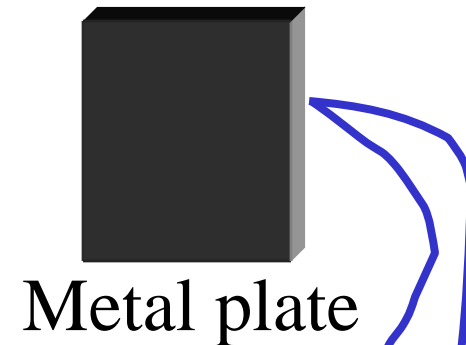


Meter B: measures speed of the ejected electrons

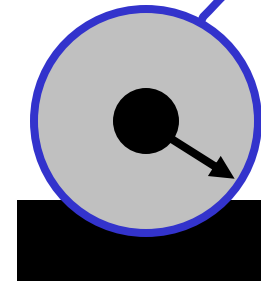
The Photoelectric Effect

Effect seen for UV light

Incoming light, produces electric current



Meter A: measures current of ejected electrons



Meter B: measures speed of the ejected electrons

1909

It is my opinion that the next phase in the development of theoretical physics will bring us a theory of light that can be interpreted as a kind of fusion of the wave and the emission theory

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1911

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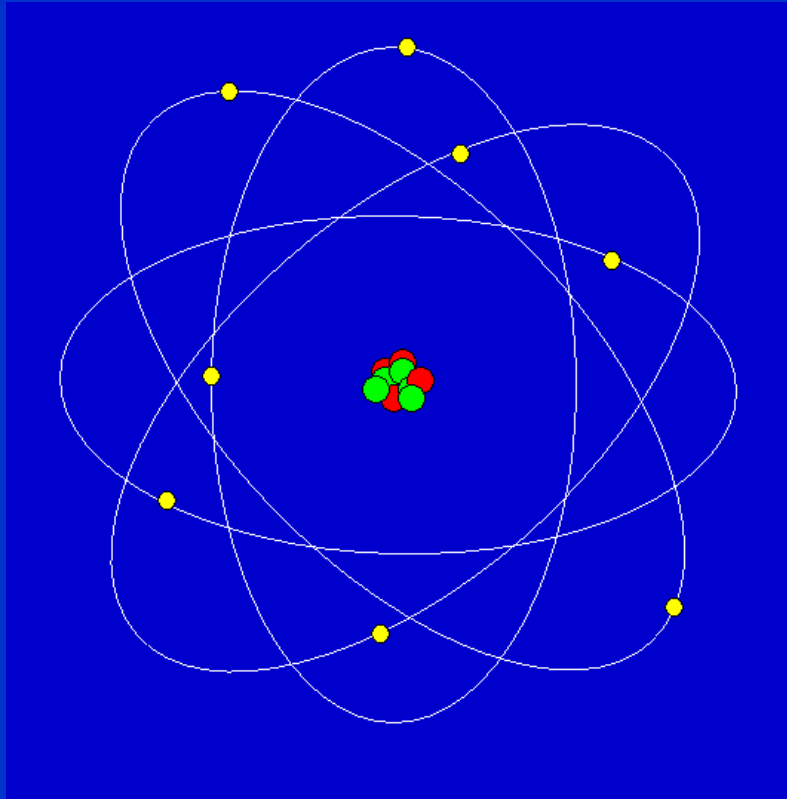
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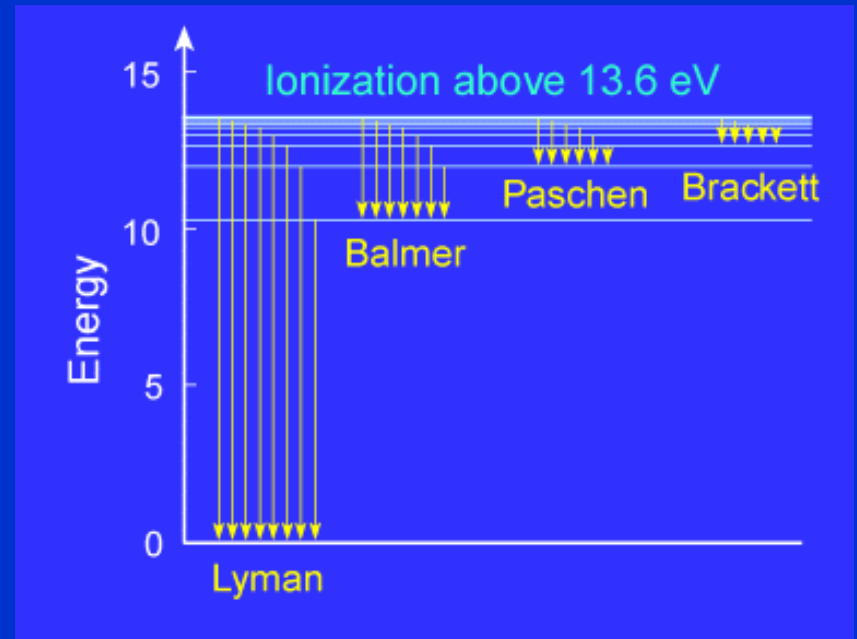
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1924

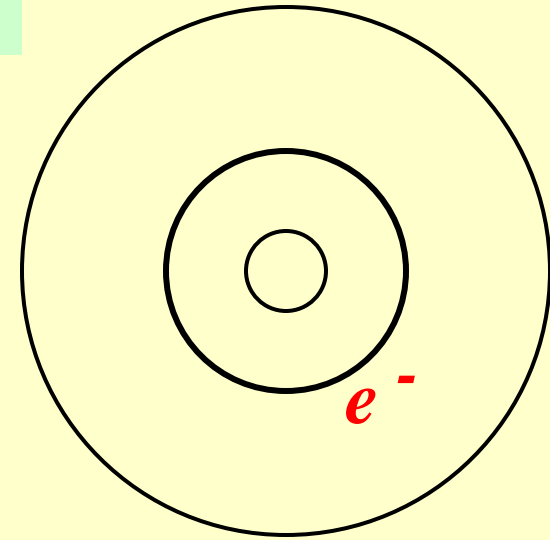
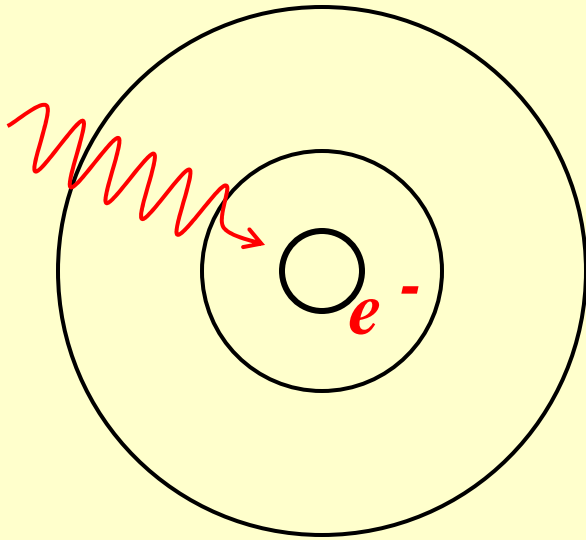
There are therefore now two theories of light, both indispensable...without any logical connection



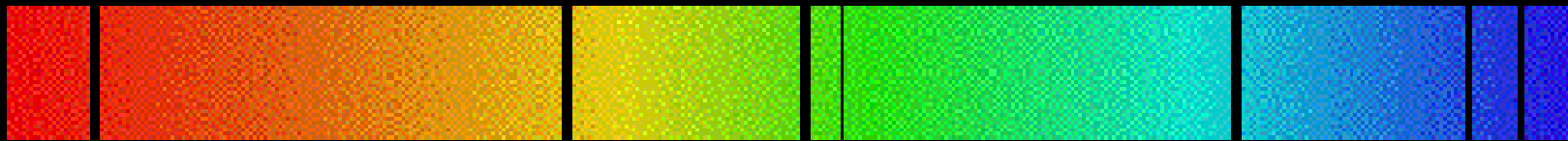
The Bohr atom, 1913



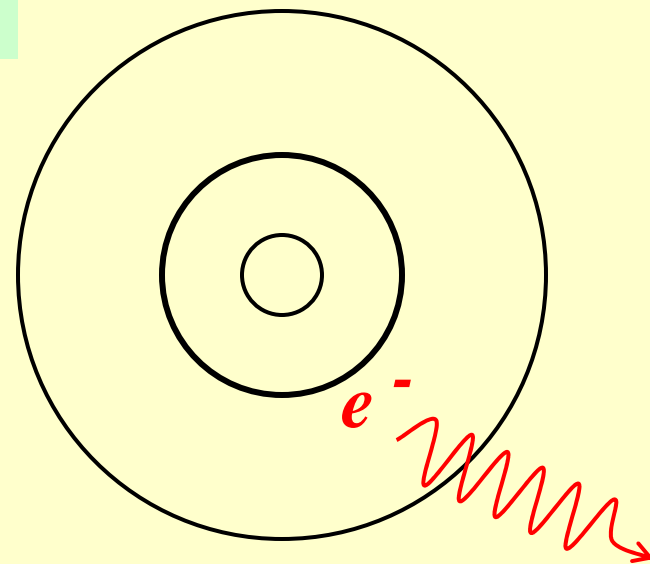
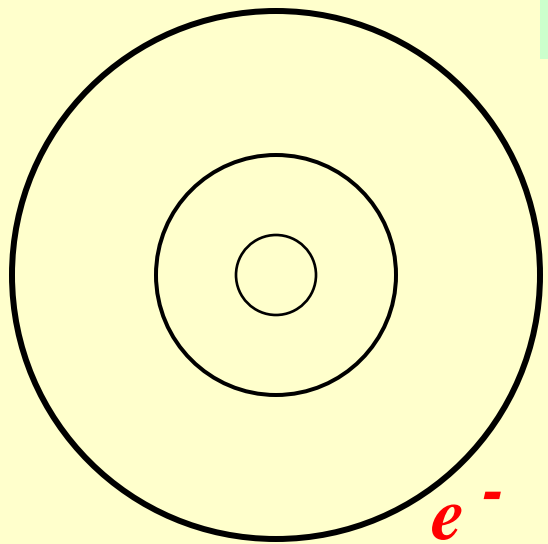
Absorption



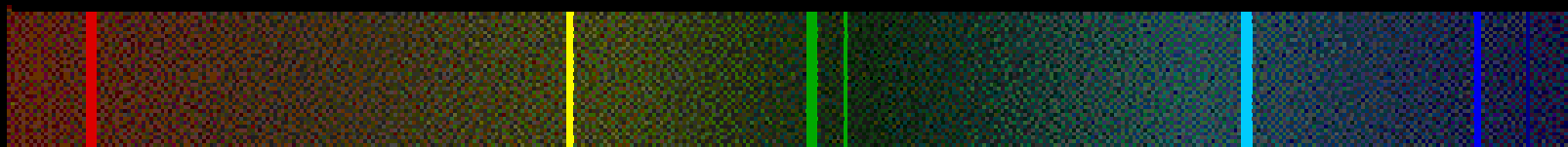
Absorption Spectrum



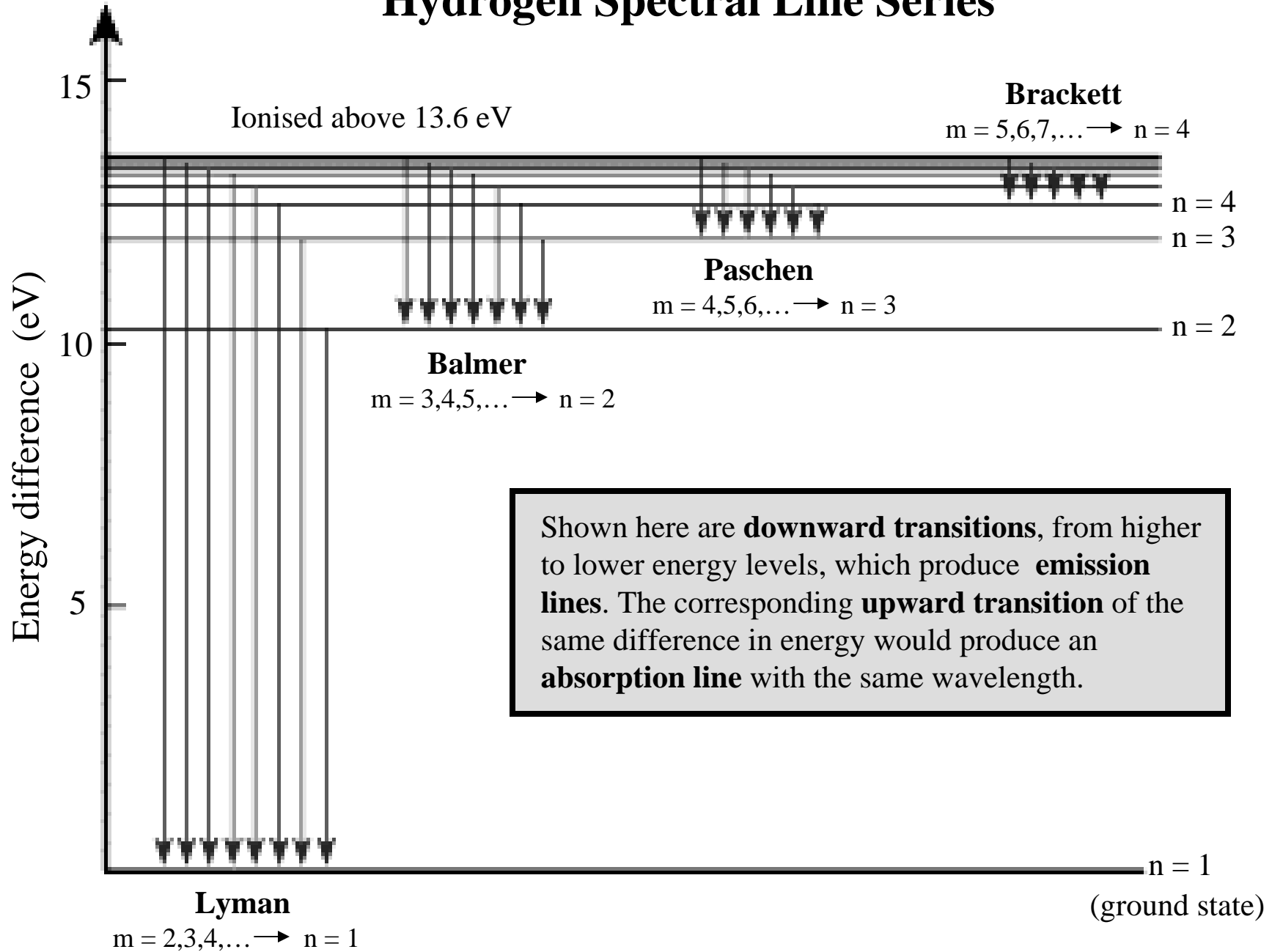
Emission



Emission Spectrum



Hydrogen Spectral Line Series



Solar Spectrum 4300 – 4400 Angstroms

