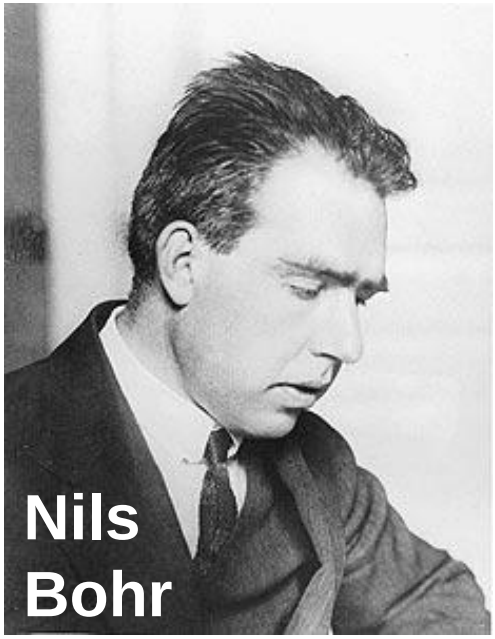
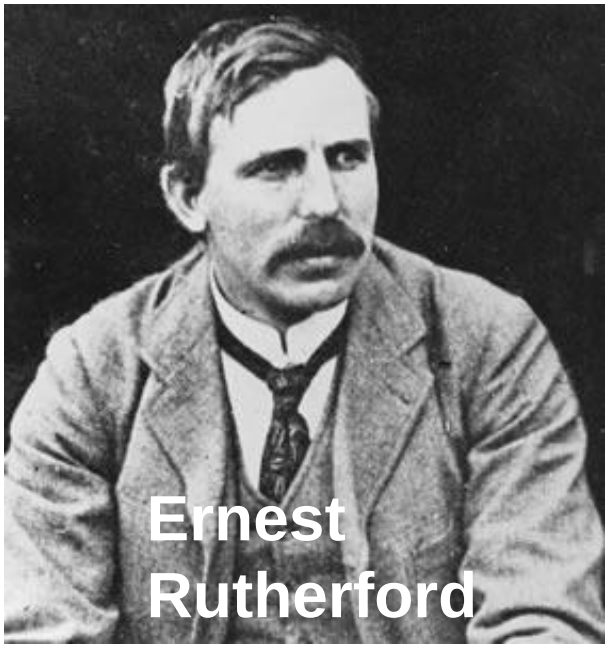
The Bohr-Rutherford Atom

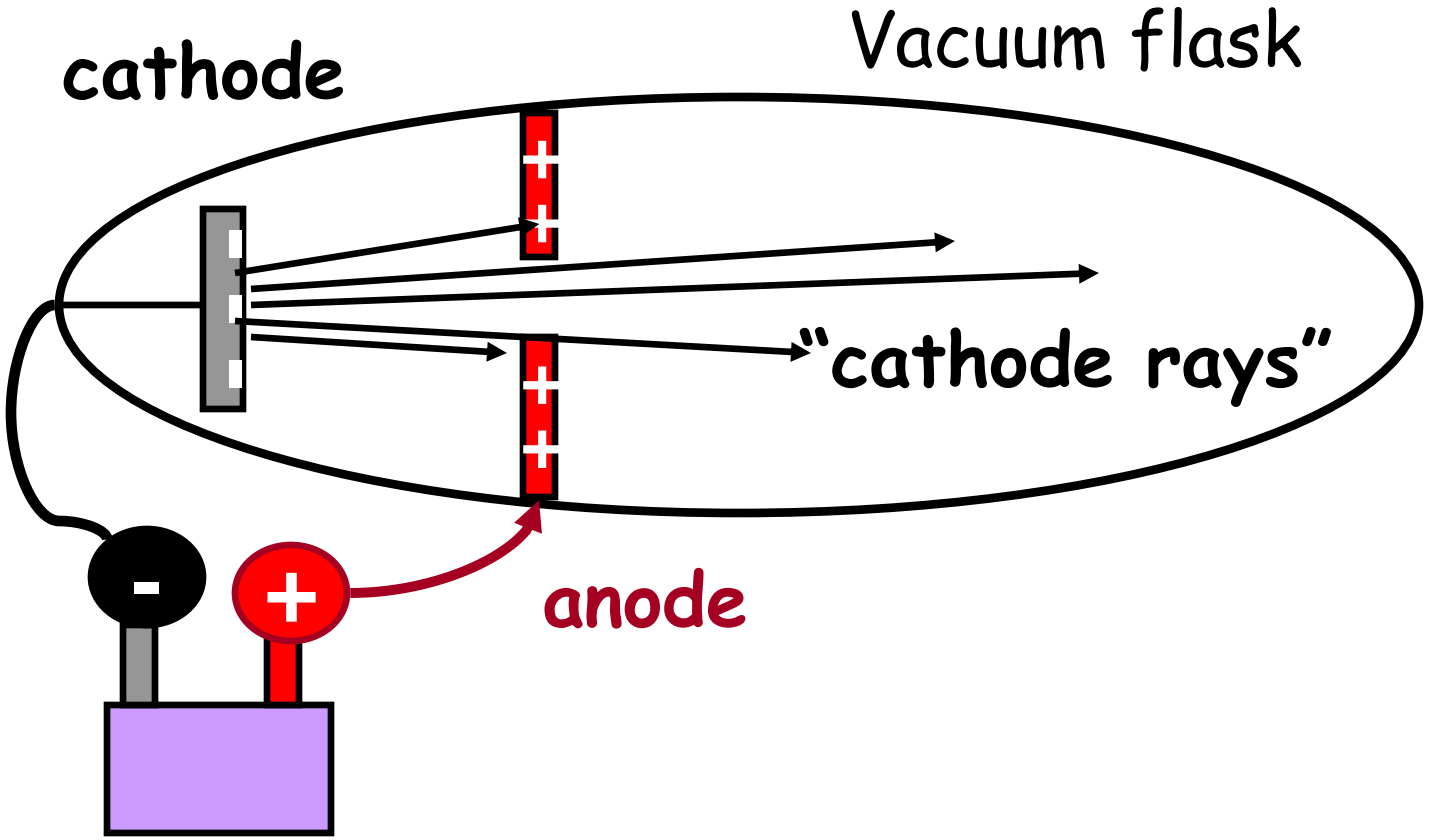




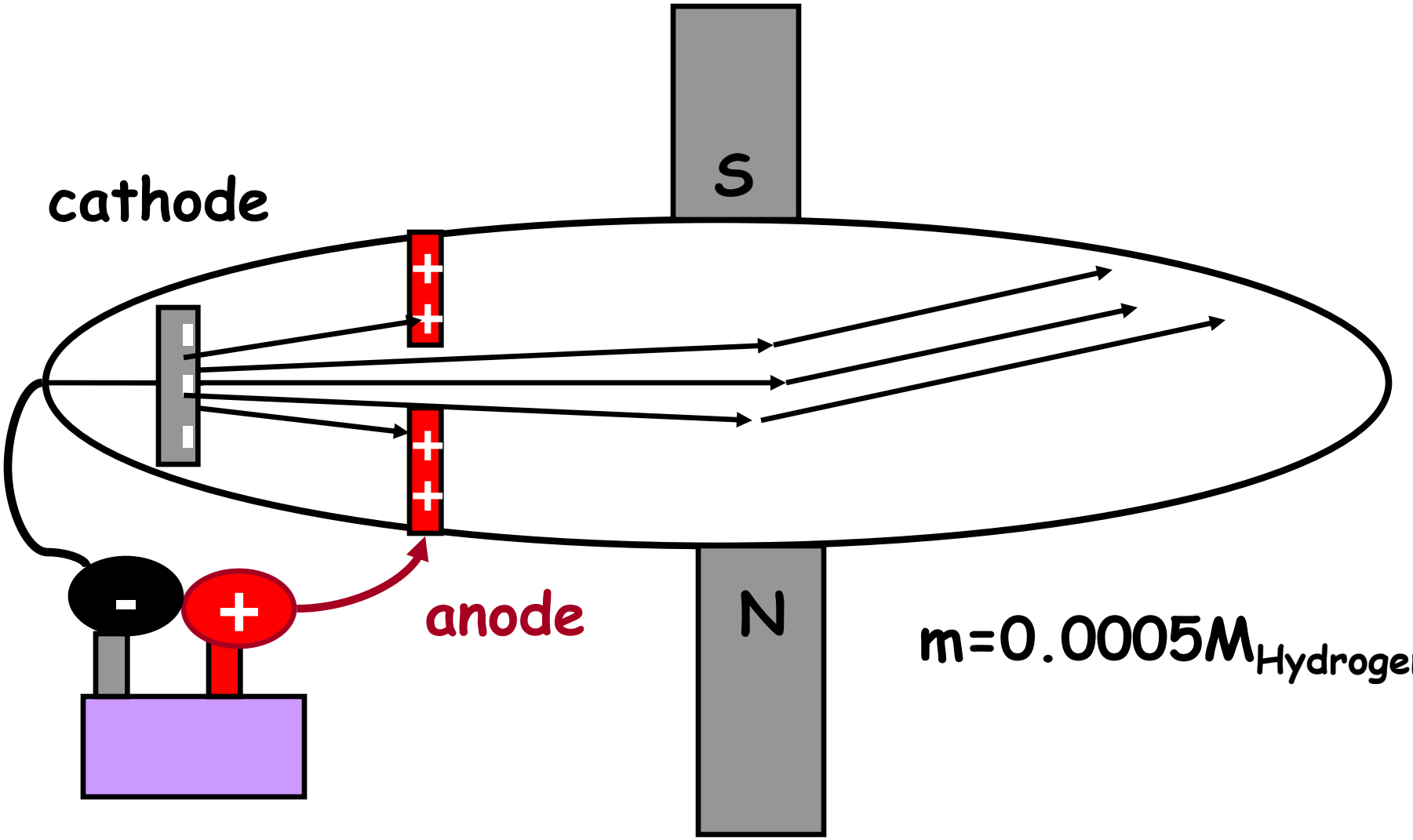
Physics 100

Chapt 23

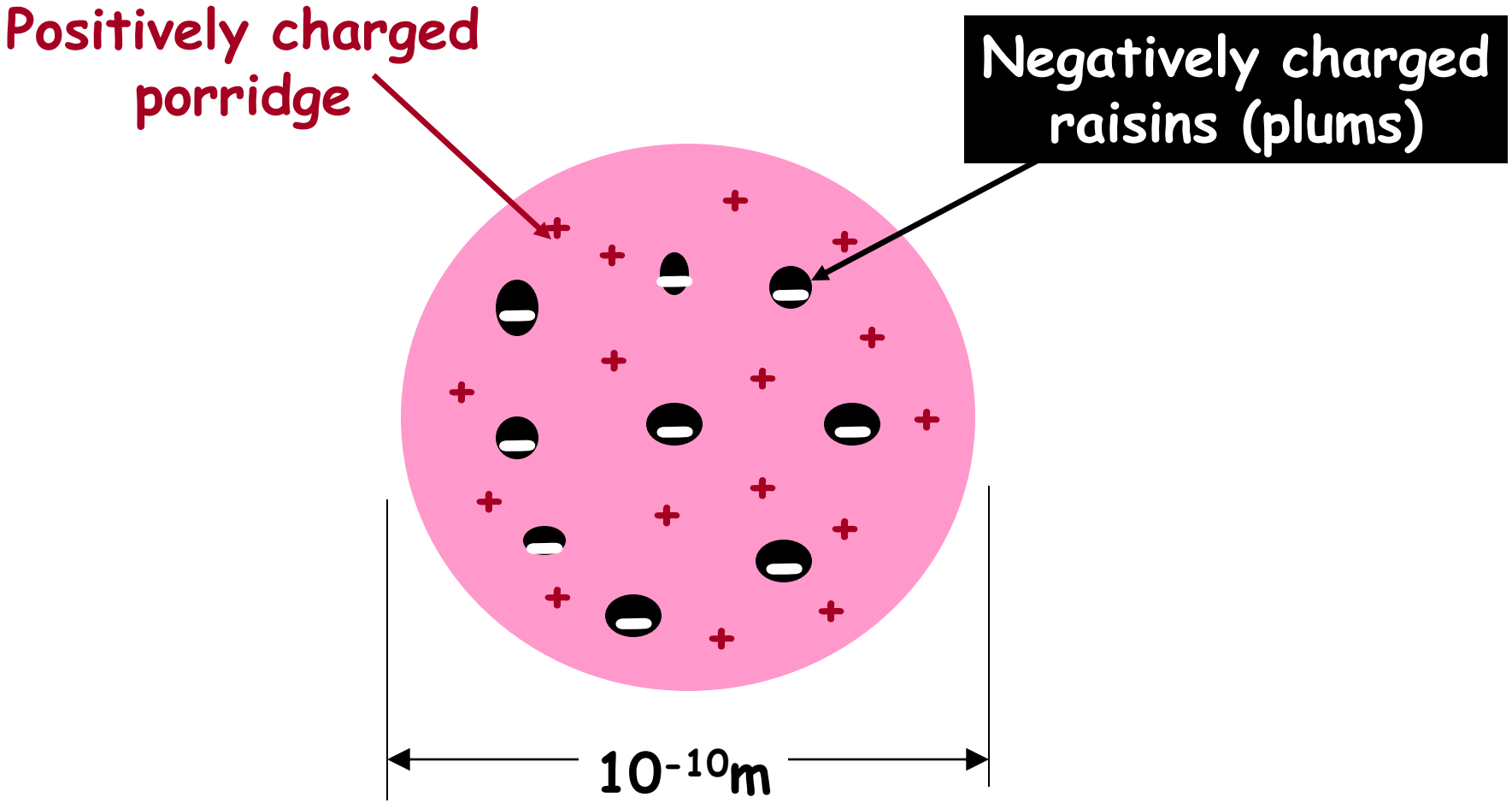
1895 J.J. Thomson discovered electron



Cathode rays have negative charge and very small mass



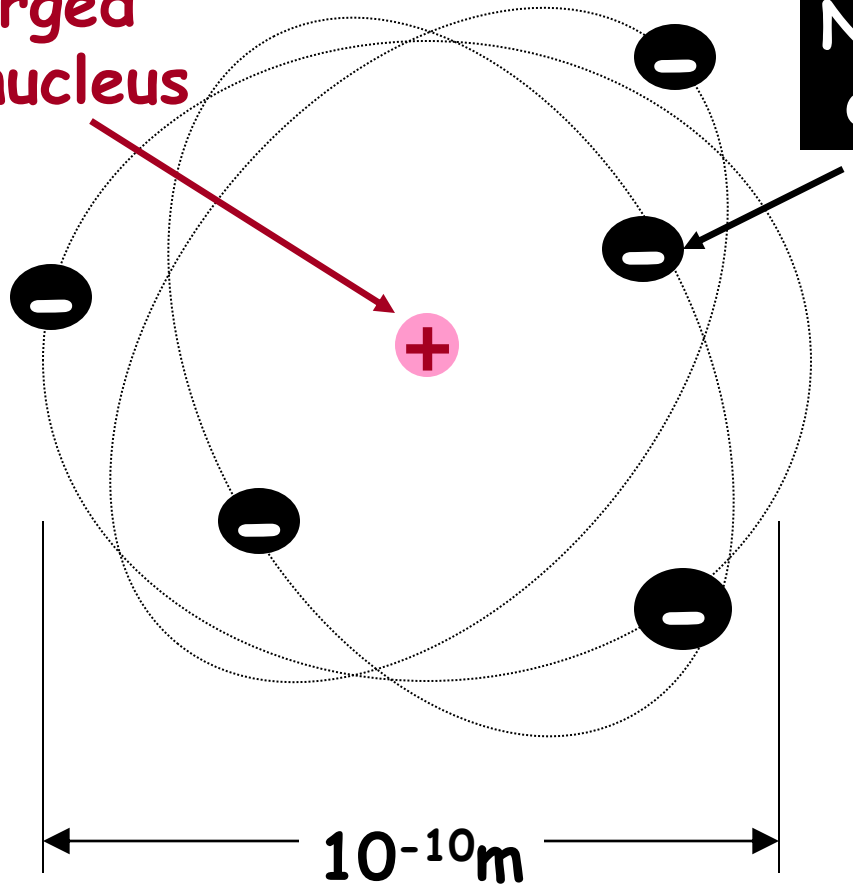
Plum pudding?



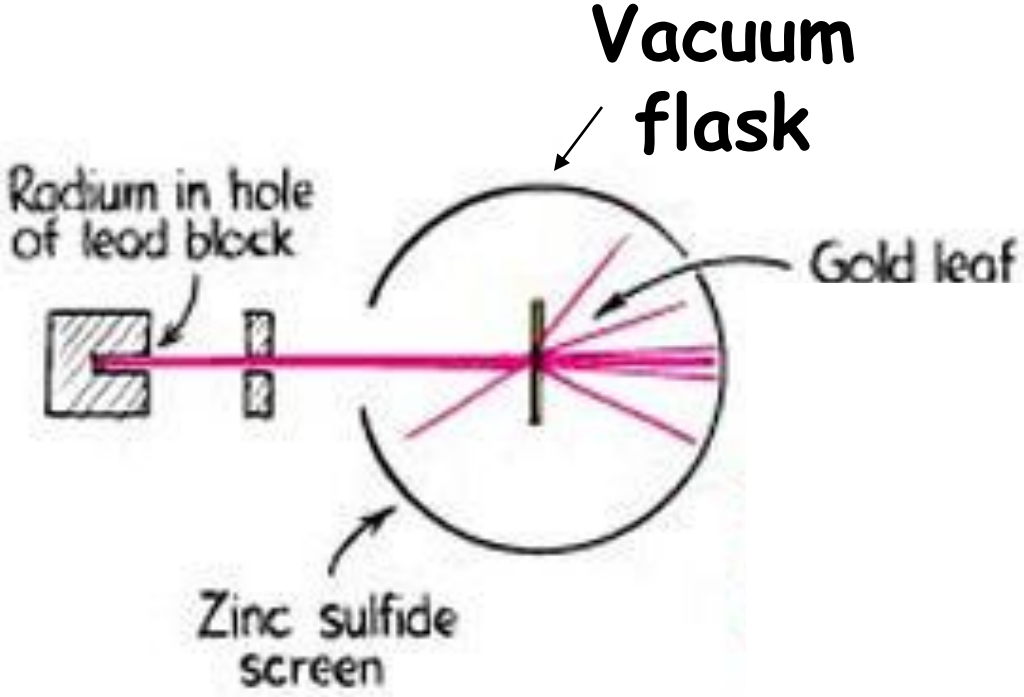
Planetary-like?

Positively charged dense central nucleus

Negatively charged orbiting electrons

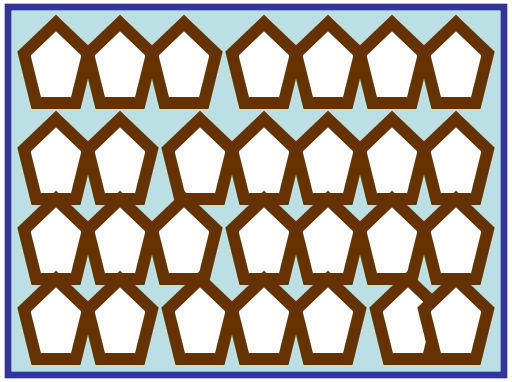


Rutherford Experiment



What's in the box?

Is all the mass spread throughout as in a box of marshmallows"?



or is all the mass concentrated in a dense "ball-bearing"?

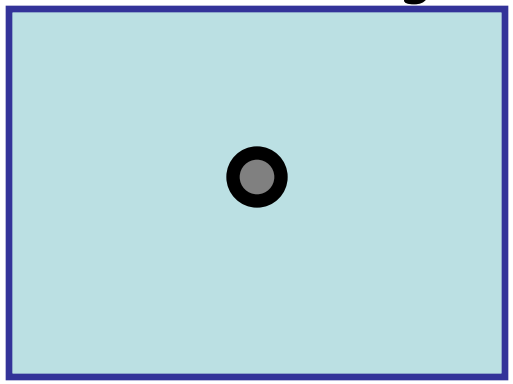
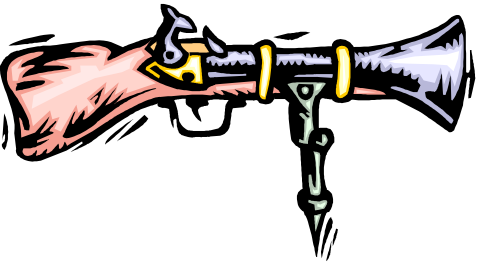
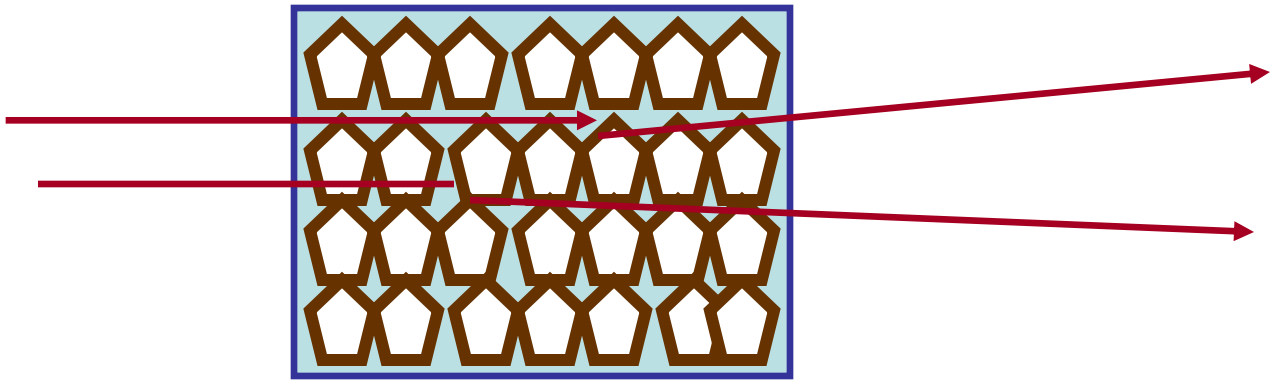


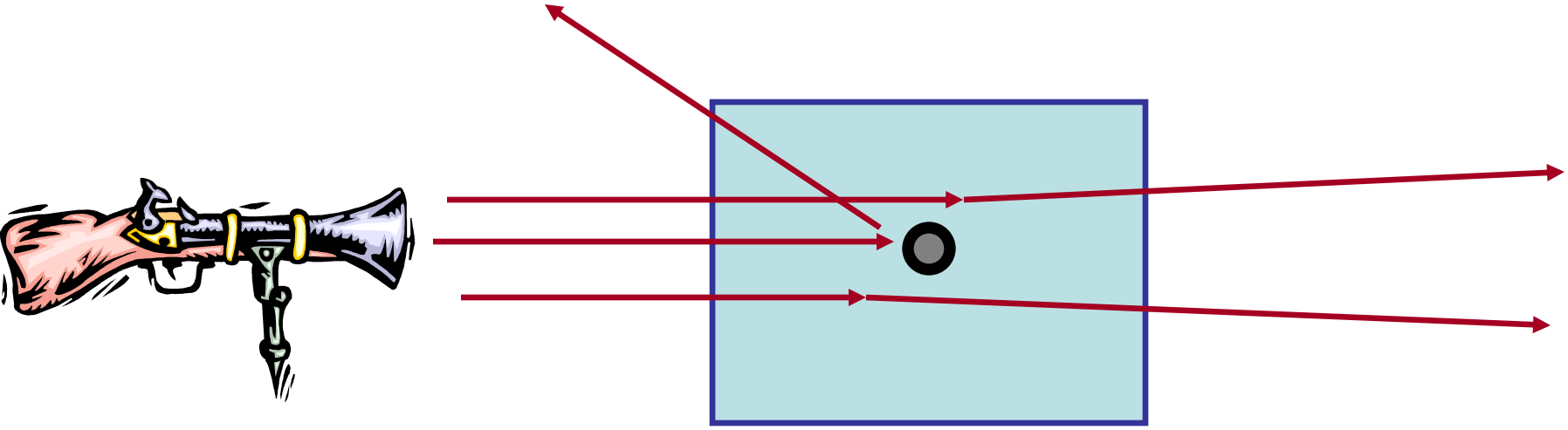
Figure it out without opening (or shaking)





Shoot bullets randomly through the box. If it is filled with marshmallows, all the bullets will go straight through without (much) deflection

Figure it out without opening (or shaking)

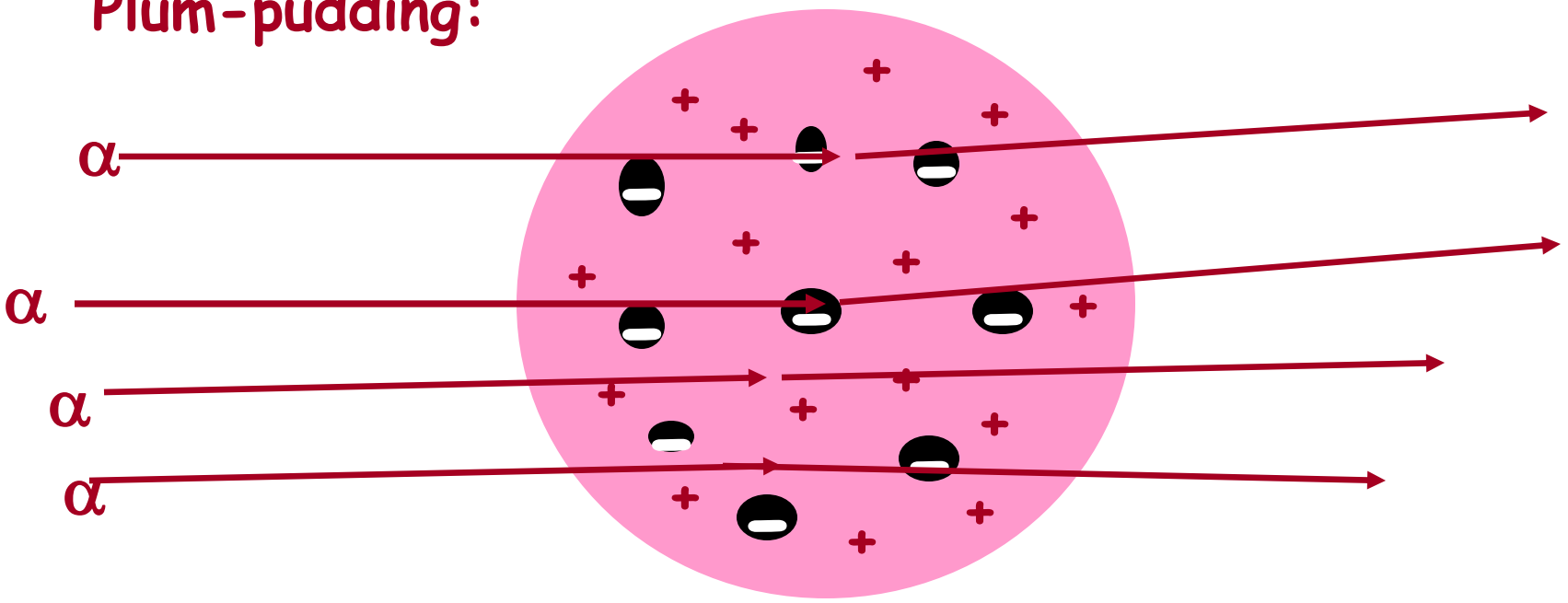


If it contains a ball-bearing *most* the bullets will go straight through without deflection---but not *all*

Occasionally, a bullet will collide nearly head-on to the ball-bearing and be deflected by a large angle

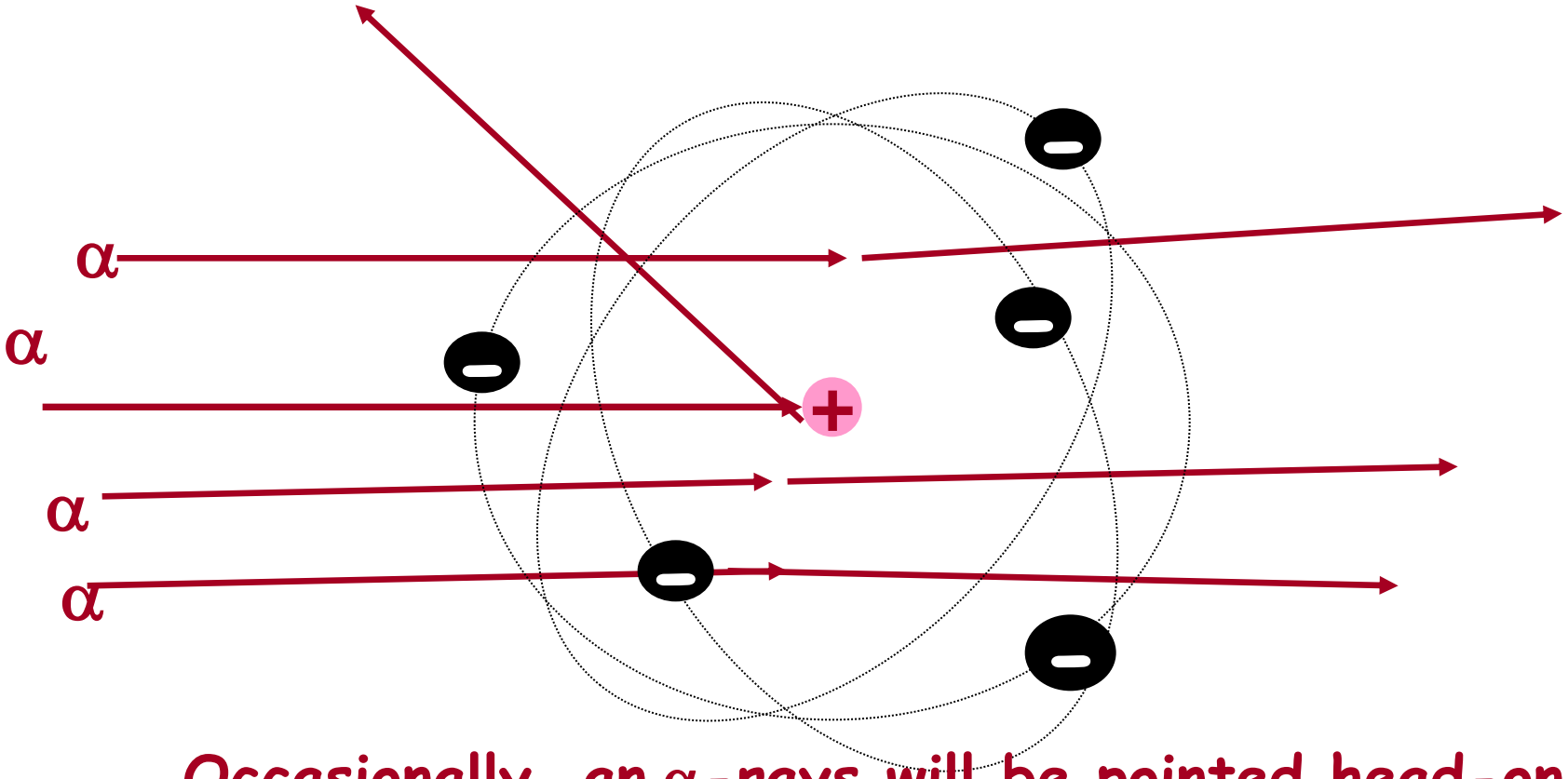
Rutherford used α-ray "bullets" to distinguish between the plum-pudding & planetary models

Plum-pudding:



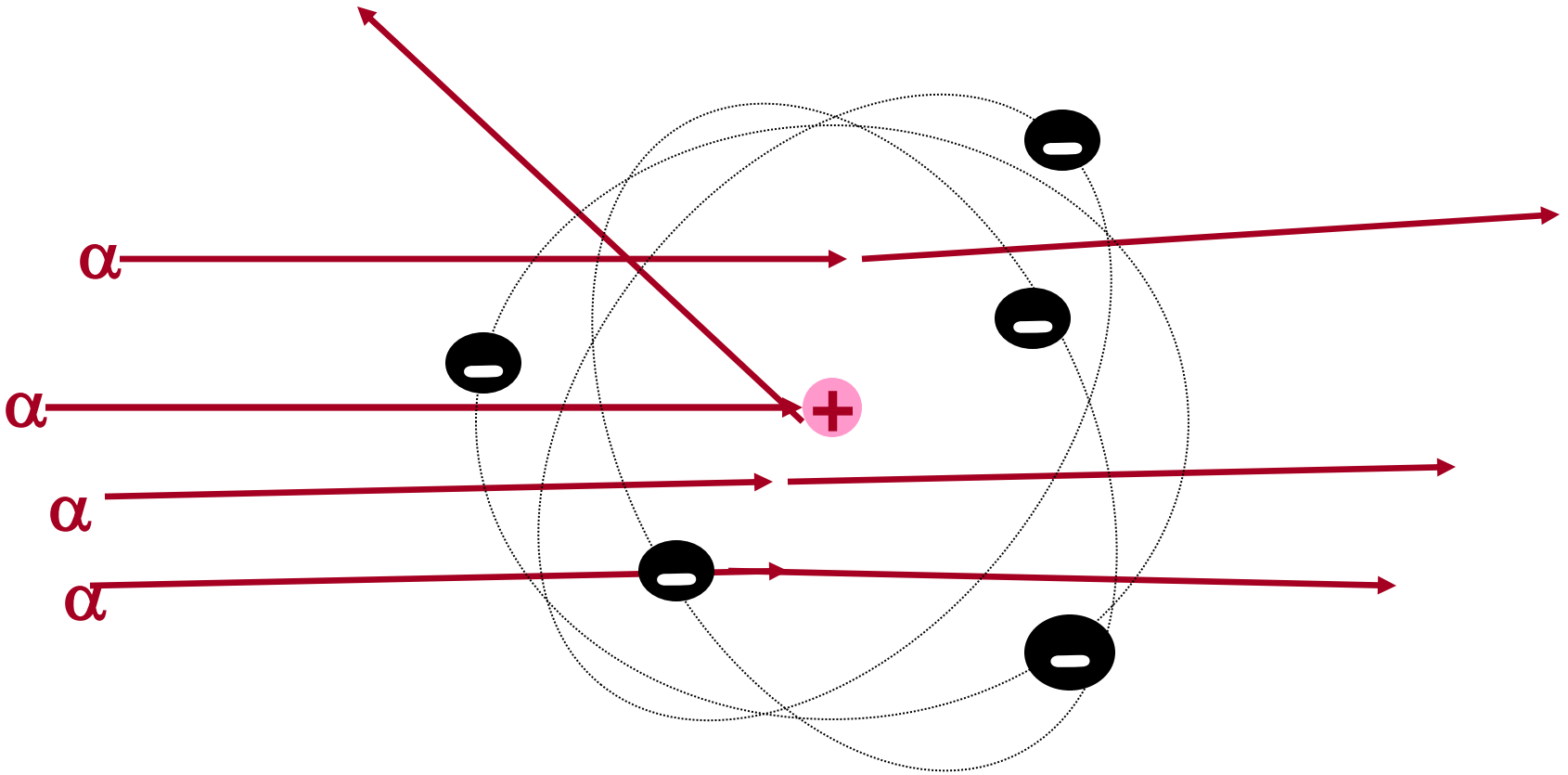
no way for α-rays to scatter at wide angles

distinguishing between the plum-pudding & planetary models



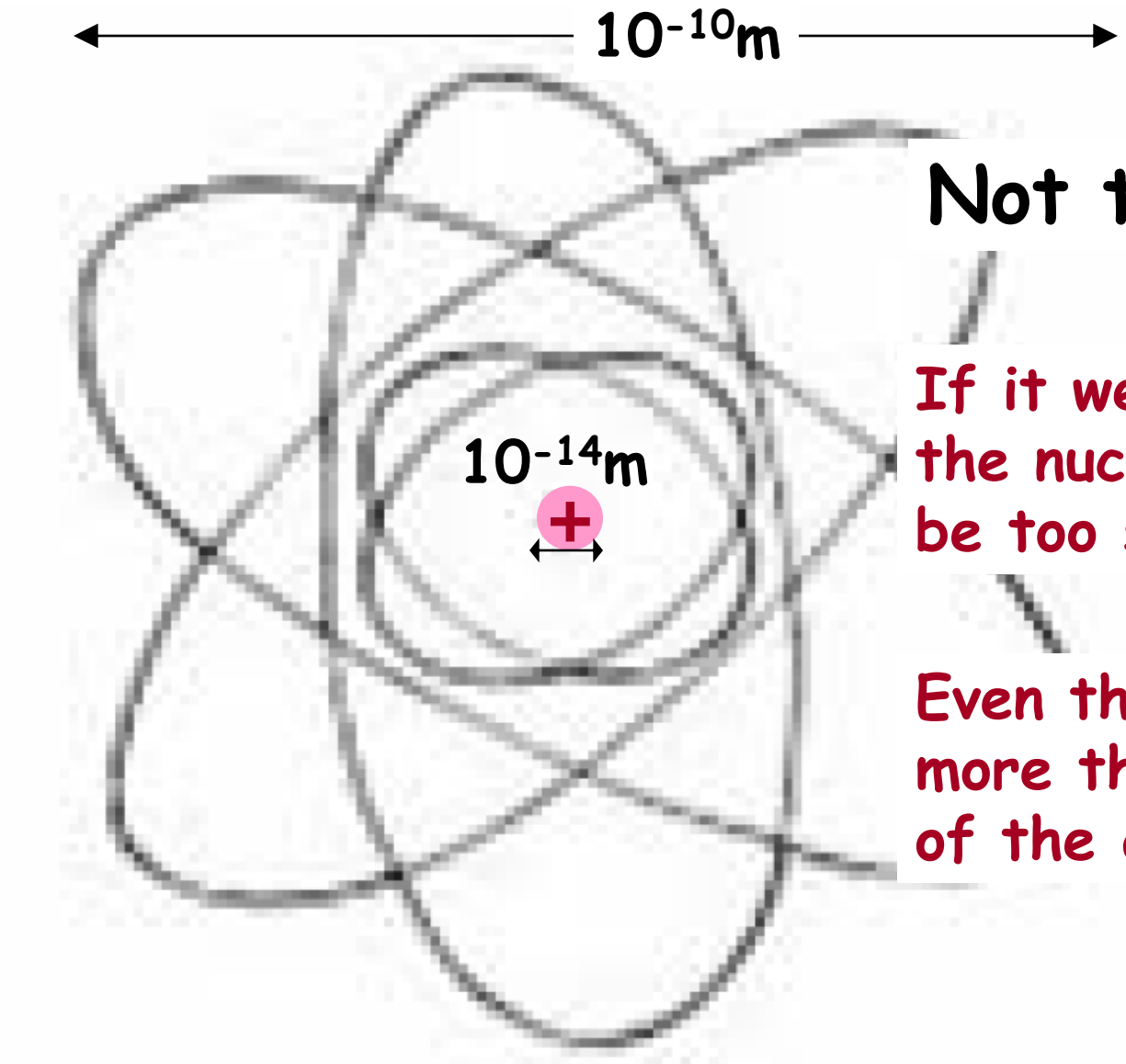
Occasionally, an α-rays will be pointed head-on to a nucleus & will scatter at a wide angle

Rutherford saw ~1/10,000 a-rays scatter at wide angles



from this he inferred a nuclear size of about 10^{-14}m

Rutherford atom



Not to scale!!!

If it were to scale, the nucleus would be too small to see

Even though it has more than 99.9% of the atom's mass

Relative scales

Aloha stadium

Golf ball

$\times 10^{-4}$

Atom

Nucleus

99.97% of the mass

Classical theory had trouble with Rutherford's atom

Orbiting electrons are accelerating

Accelerating electrons should radiate light

According to Maxwell's theory, a Rutherford atom would only survive for only about 10^{-12} secs

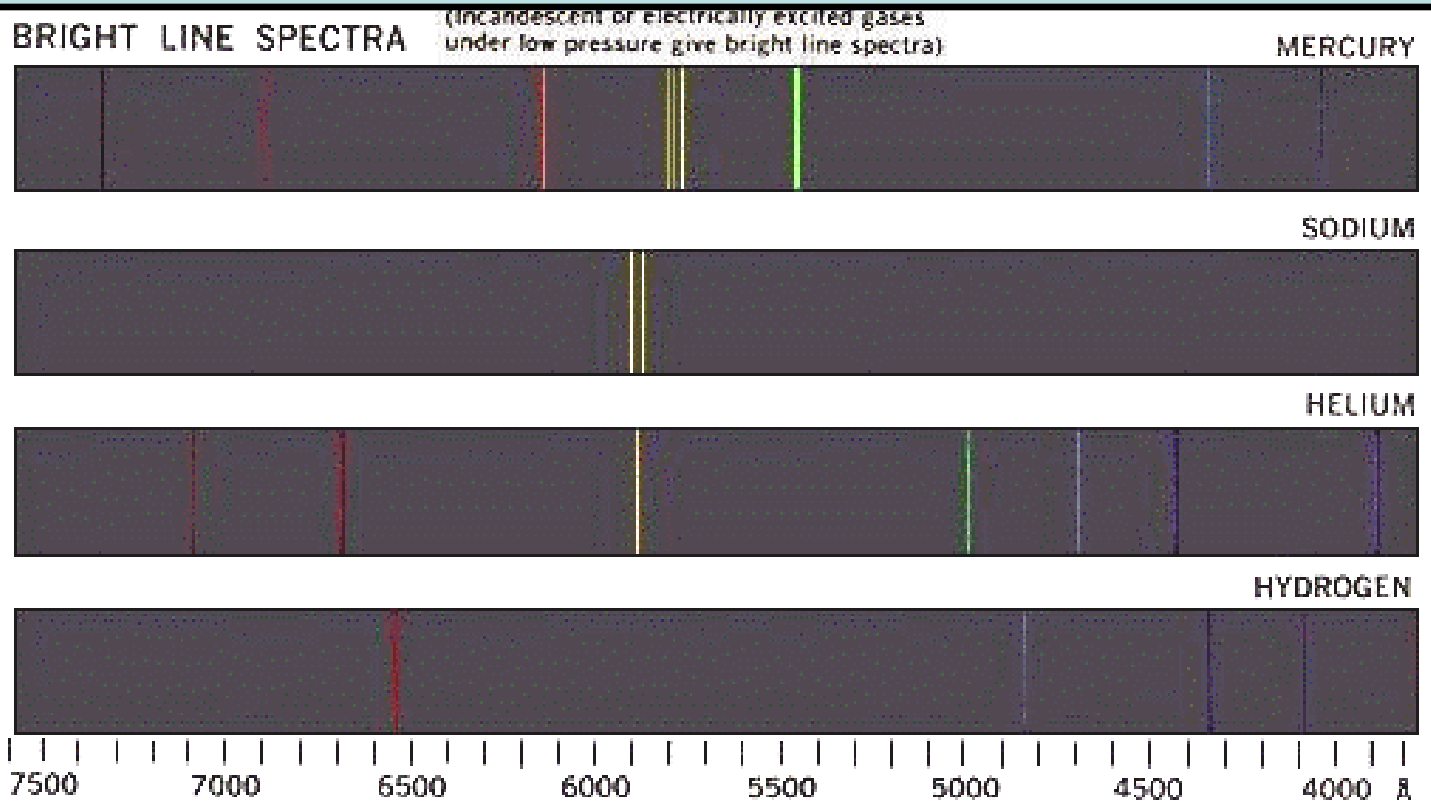
Other peculiar discoveries:

Solar light spectrum:

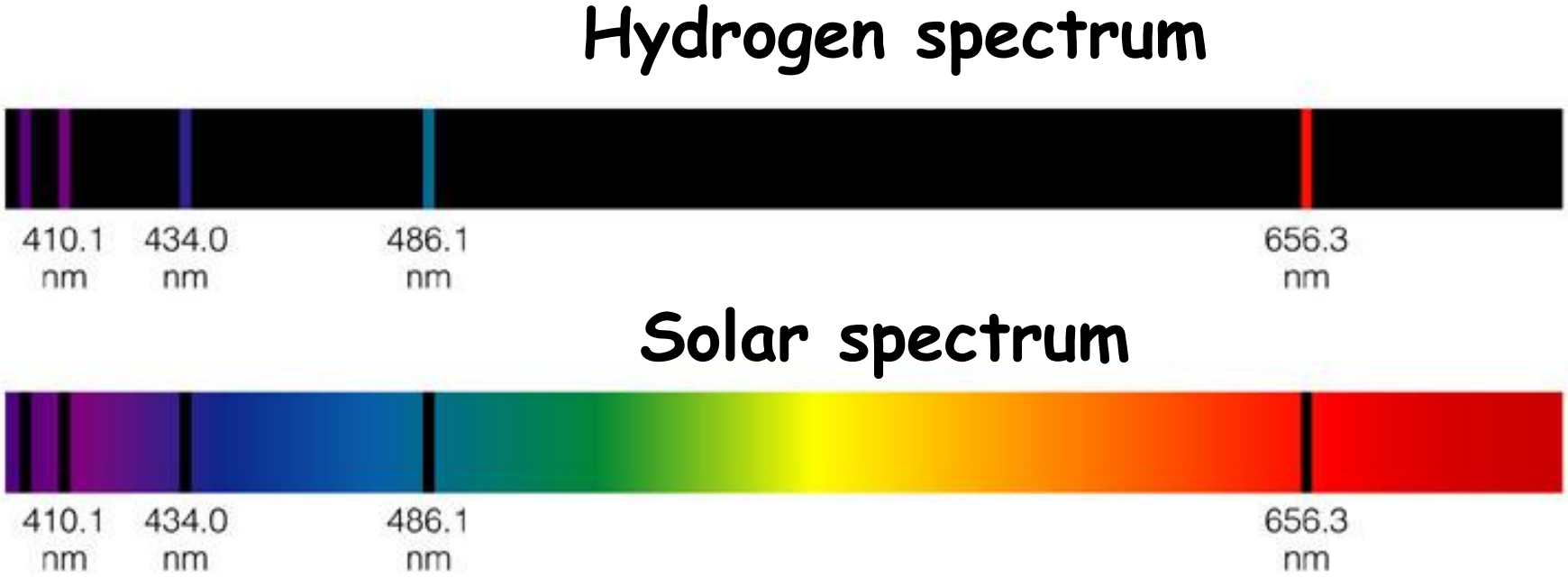
Fraunhofer discovered that some wavelengths are missing from the sun's black-body spectrum

Other discoveries…

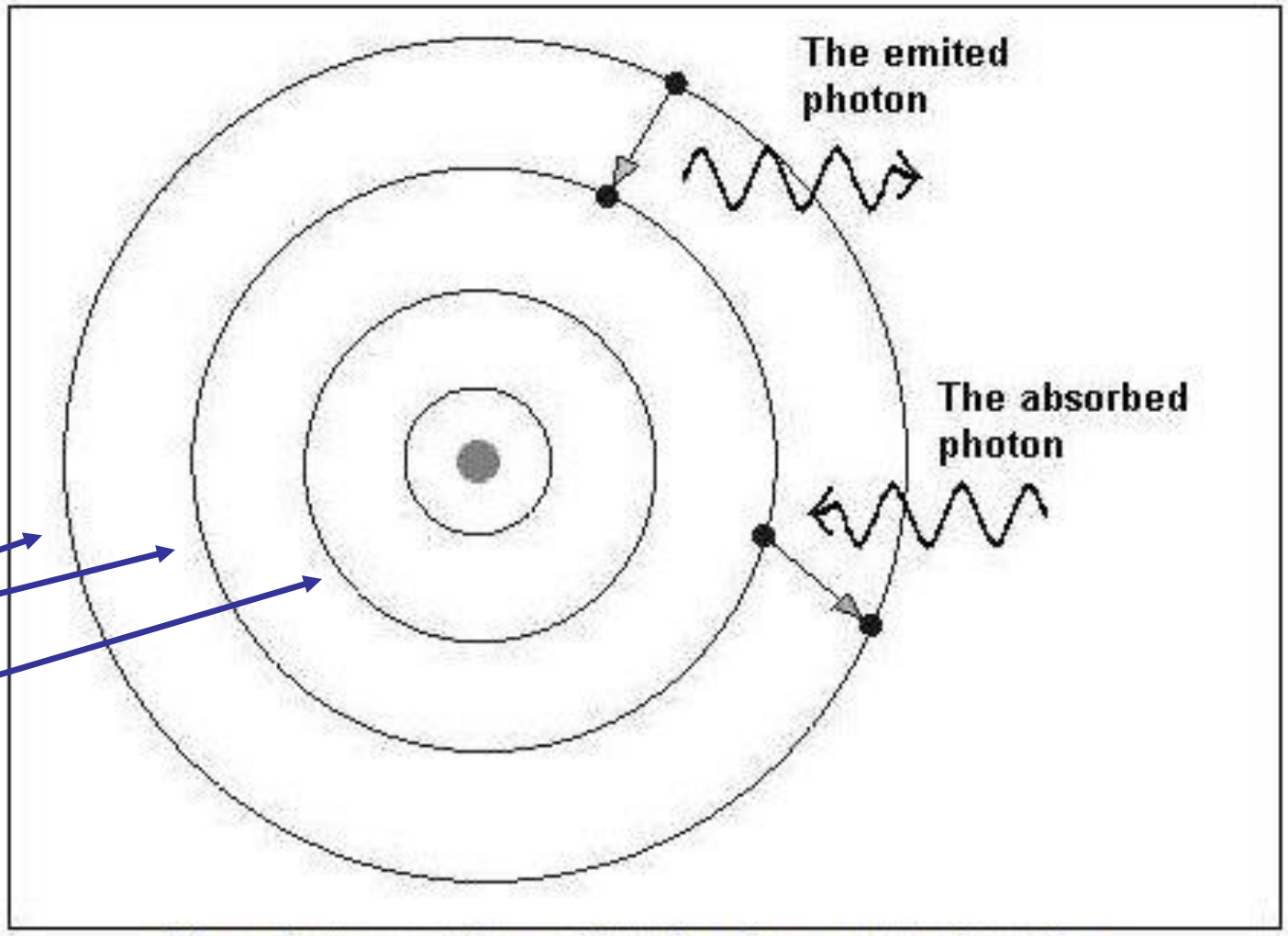
**Low pressure gasses, when heated,
do not radiate black-body-like spectra;
instead they radiate only a few specific colors**



bright colors from hydrogen match the missing colors in sunlight



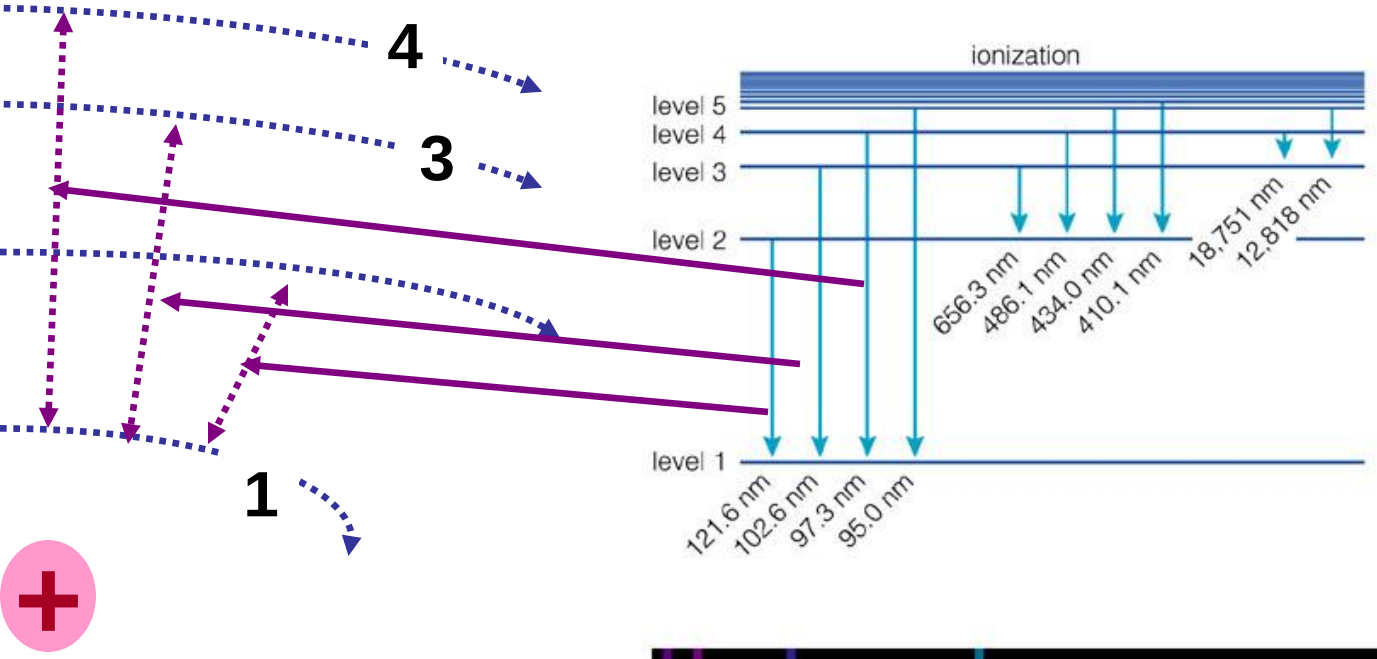
Bohr's idea



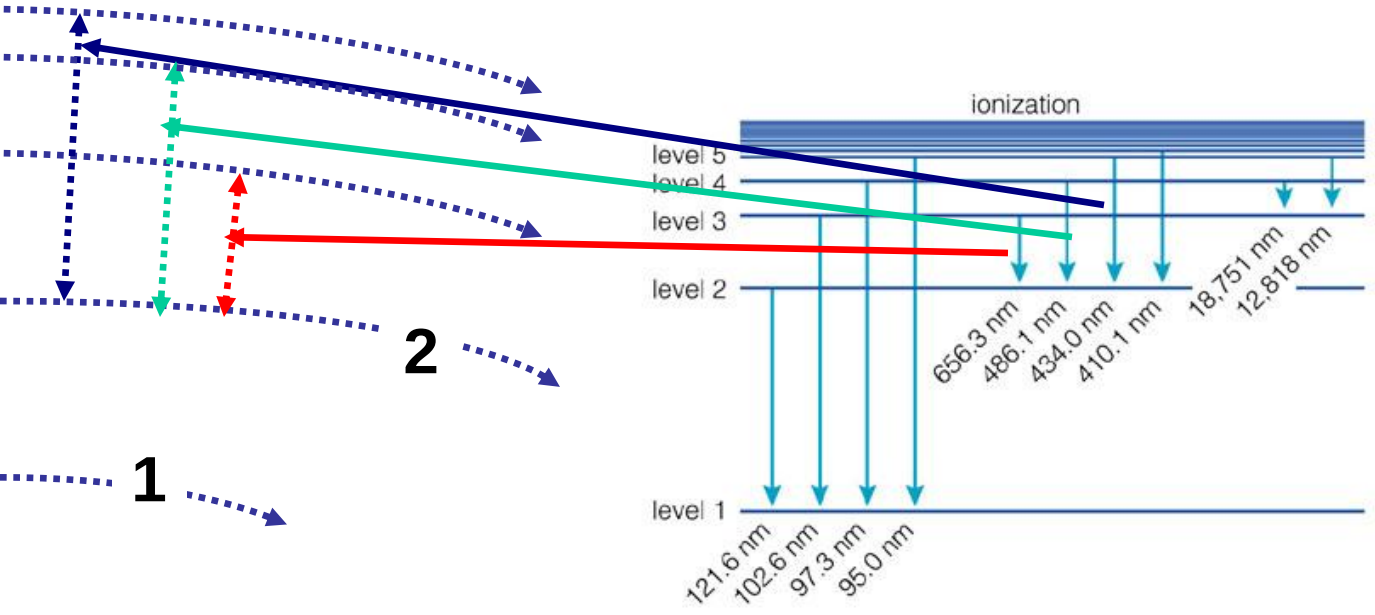
"Allowed" orbits

The electron emits or absorbs the energy changing the orbits.

Hydrogen energy levels



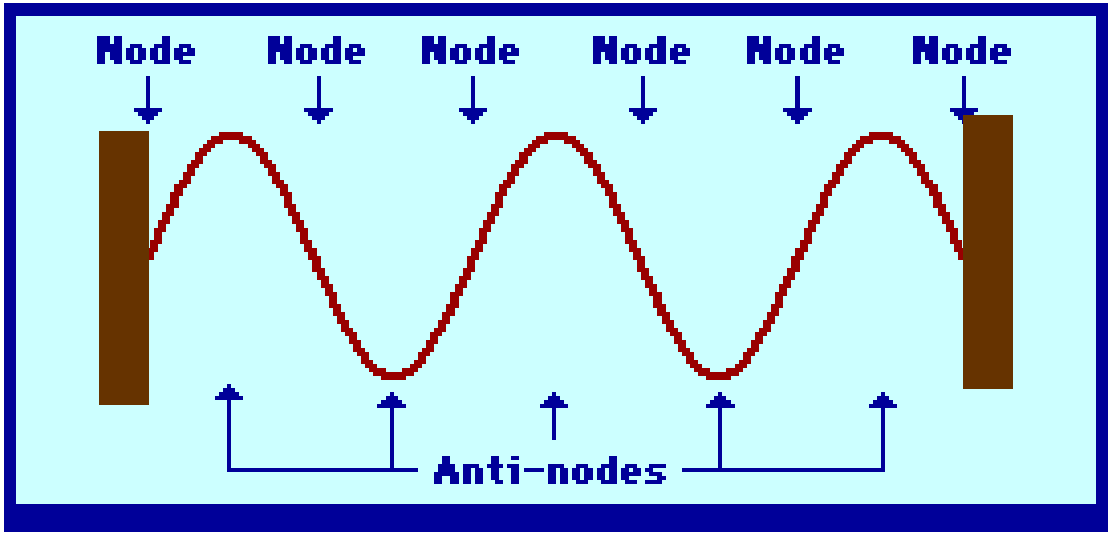
Hydrogen energy levels



What makes Bohr's allowed energy levels allowed?

Recall what happens when we force waves into confined spaces:

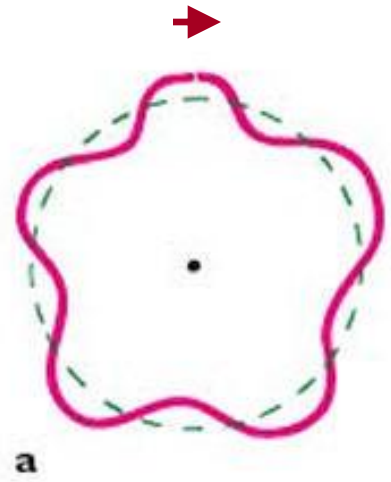
Confined waves



Only waves with wavelengths that **just fit in** survive
(all others cancel themselves out)

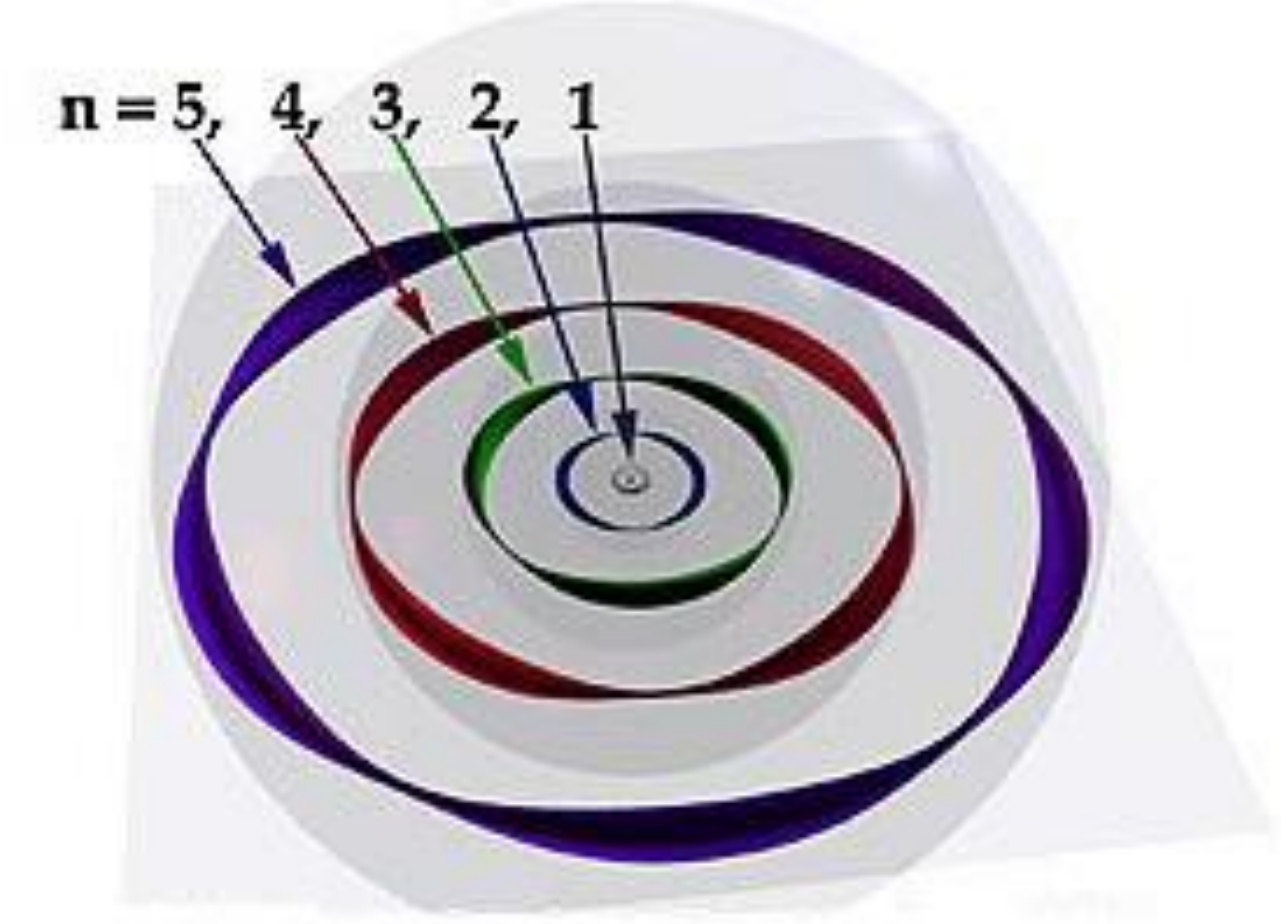
Electrons in atoms are confined matter waves ala deBroglie

However, if the circumference is exactly an integer number of wavelengths, successive turns will interfere constructively

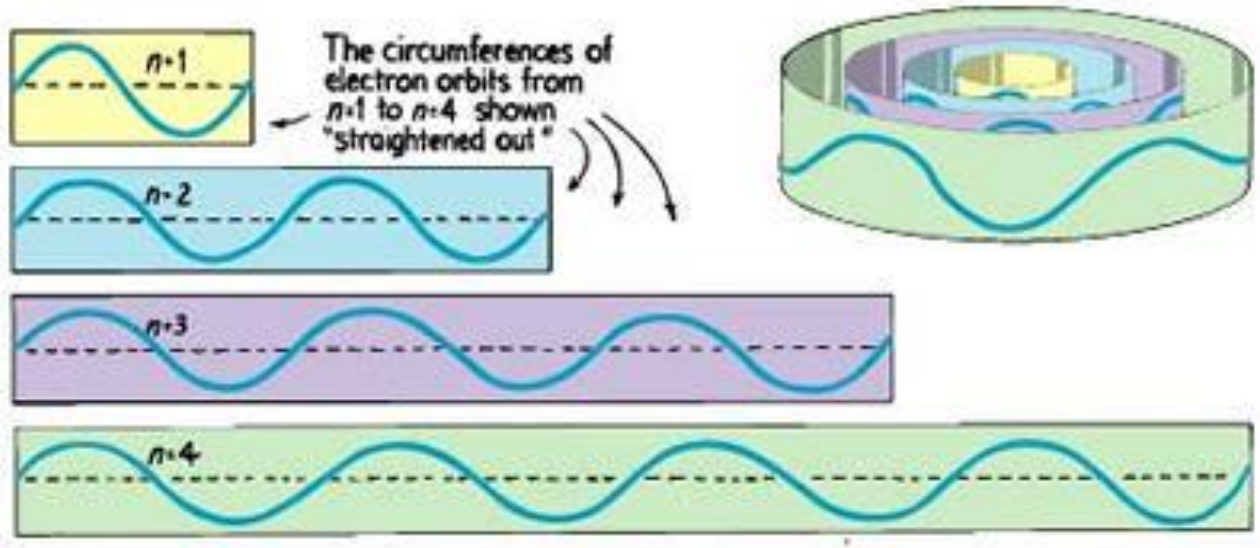


Bohr's allowed energy states correspond to those with orbits that are integer numbers of wavelengths

Bohr orbits



Bohr orbits


n=1
The circumferences of electron orbits from n=1 to n=4 shown "straightened out"
n=2
n=3
n=4

Quantum Mechanics

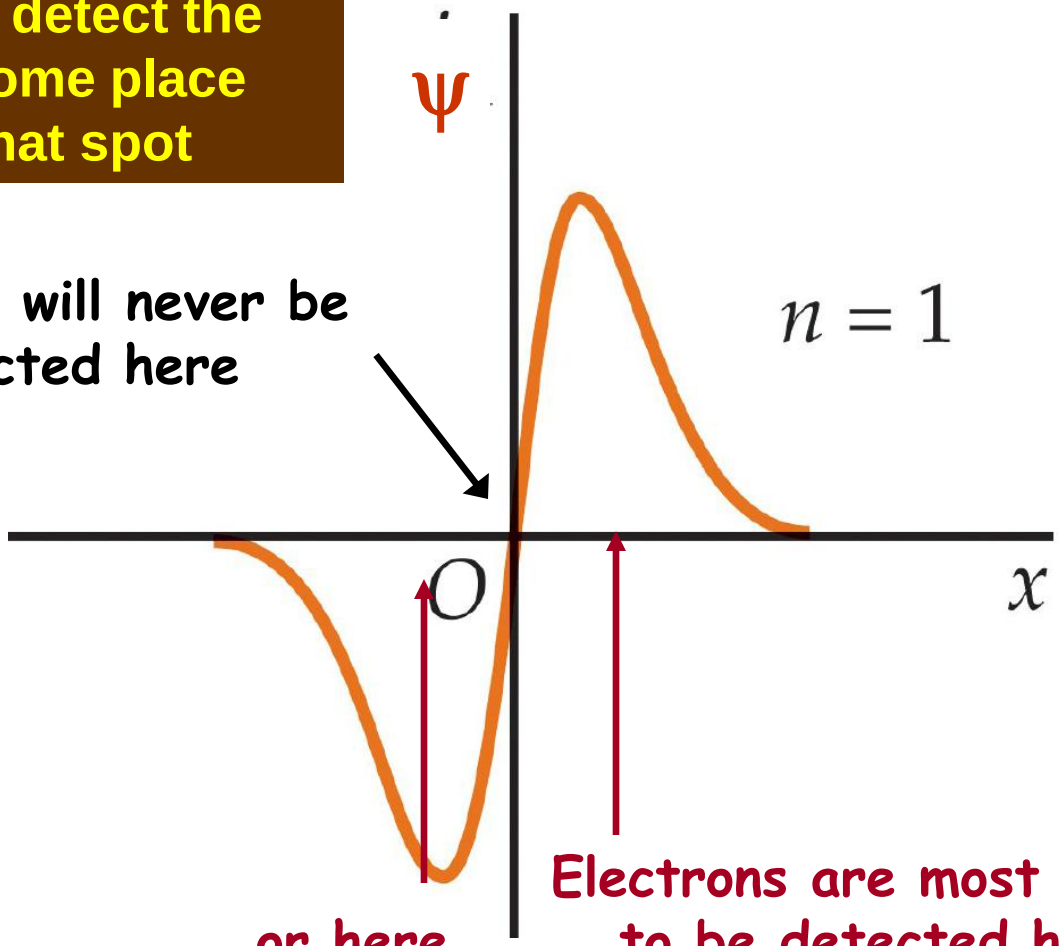
Erwin Schrodinger

$$-\frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2}+V(x)\psi=E\psi$$

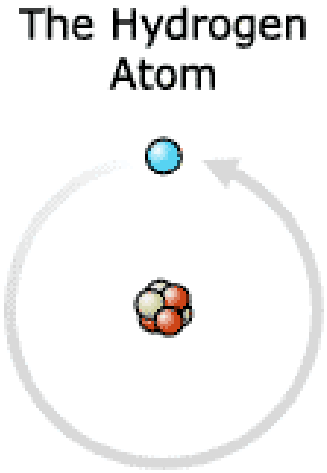
Schrodinger's equation

Matter waves are “probability” waves

Probability to detect the electron at some place is $\propto \psi^2$ at that spot



Quantum mechanical atom



Bohr's original idea

Different QM states of the H atom

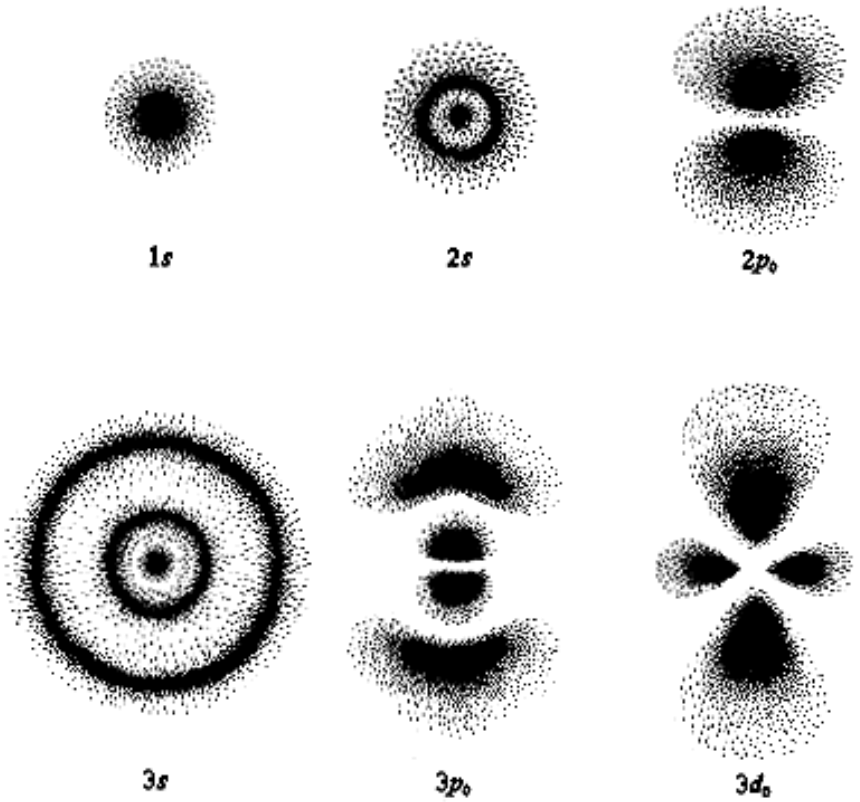
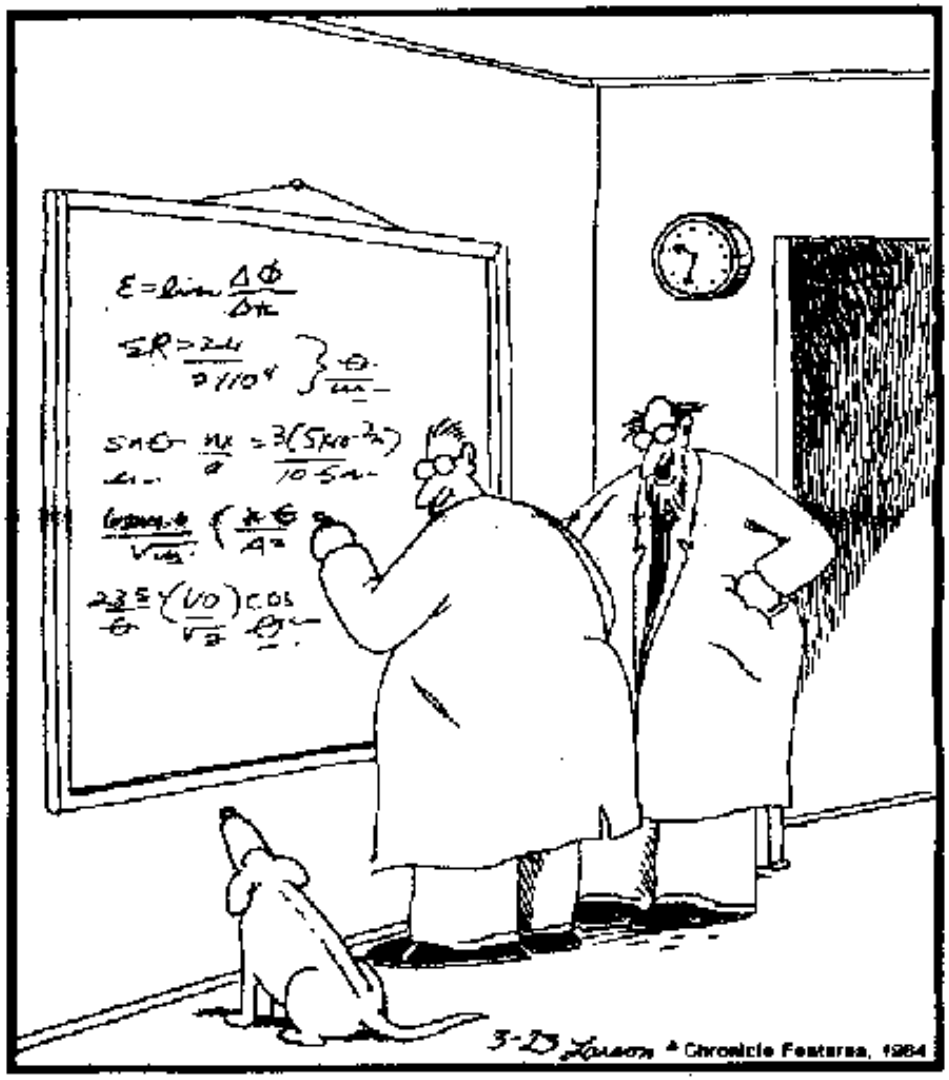


Figure 6-12. Probability density plots of some hydrogen atomic orbitals. The density of the dots represents the probability of finding the electron in that region.

THE FAR SIDE By GARY LARSON



"Ohhhhhhh . . . Look at that, Schuster . . . Dogs are so cute when they try to comprehend quantum mechanics."