Announcements

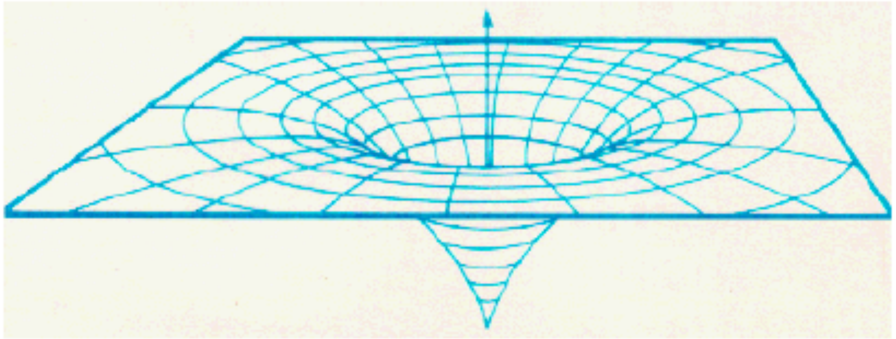
- Help room hours (1248 BPS)
  - Ian La Valley(TA)
  - Mon 4-6 PM
  - Tues 12-3 PM
  - Wed 6-9 PM
  - Fri 10 AM-noon
- LON-CAPA #9 due on Thurs Nov 15
- Third hour exam Thursday Dec 6
- Final Exam Tuesday Dec 11 7:45-9:45 AM

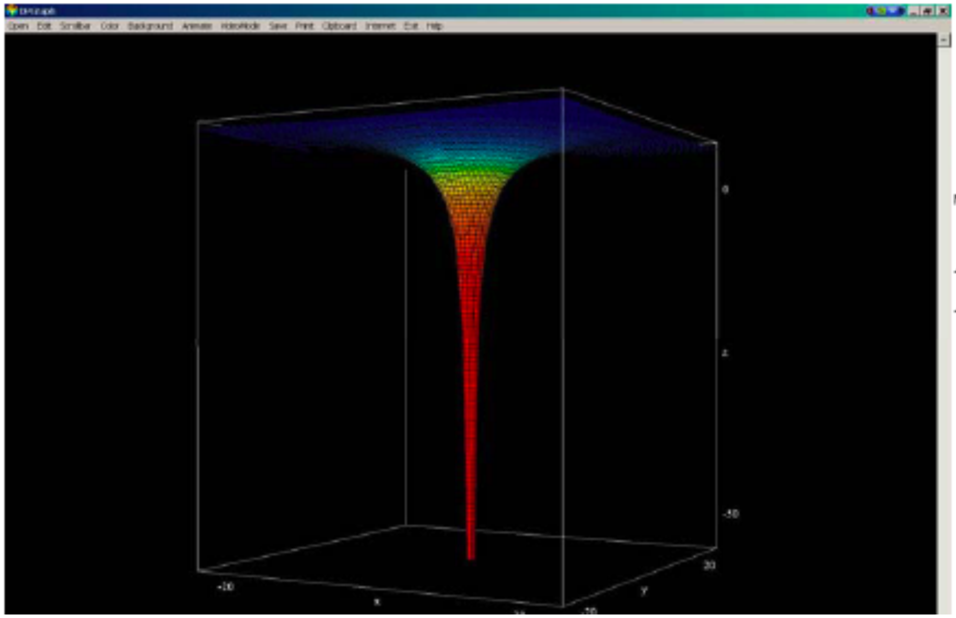
Grading scale for exams 1+2

75-80	4.0
70-75	3.5
60-70	3.0
50-60	2.5
35-50	2.0
<35	1.5

i.e. a black hole

The concentrated mass stretches space.





The “hole” in space is so deep that light can not escape.

Schwarzschild radius

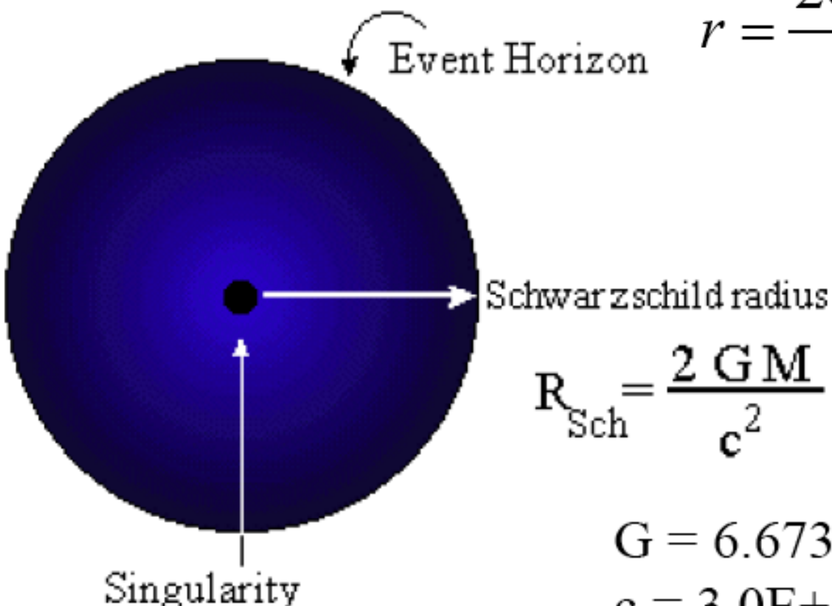
We normally refer to the size of a black hole by its Schwarzschild radii. This is the distance inside of which nothing can escape.

What is the radius of a black hole with the mass of our Sun?

M_{sun} = 1.99E30 kg

G = 6.67E-11 N*m^2/kg^2

$$r = \frac{2GM}{c^2} = \frac{2 \cdot 6.67E-11 \cdot 1.99E30}{(3.00E8)^2} = 1470\ m$$



$$R_{Sch} = \frac{2\,G\,M}{c^2}$$

G = 6.673E-11 N m^2/ kg^2

c = 3.0E+8 m/s

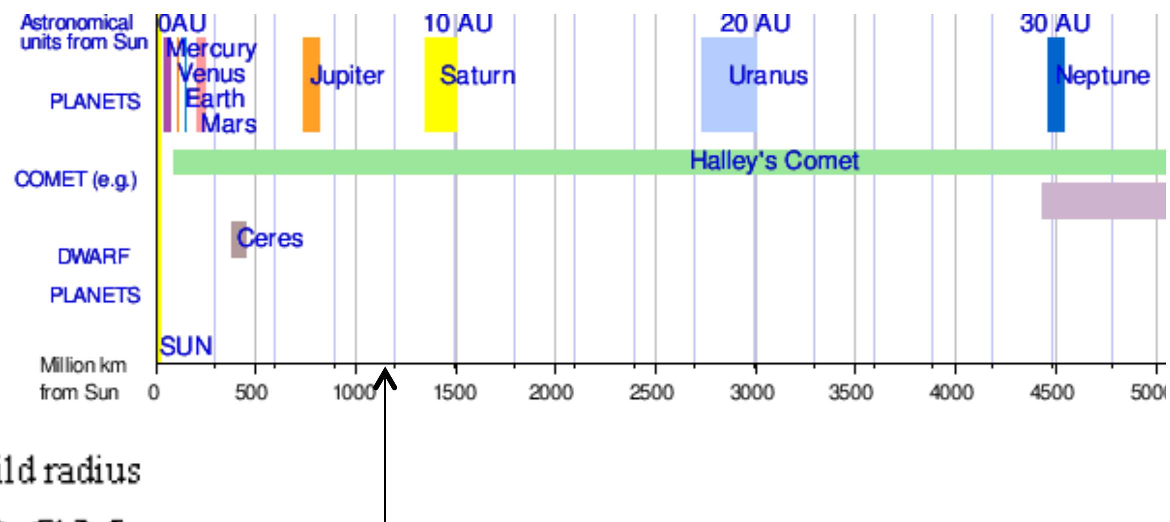
M = mass of the black hole

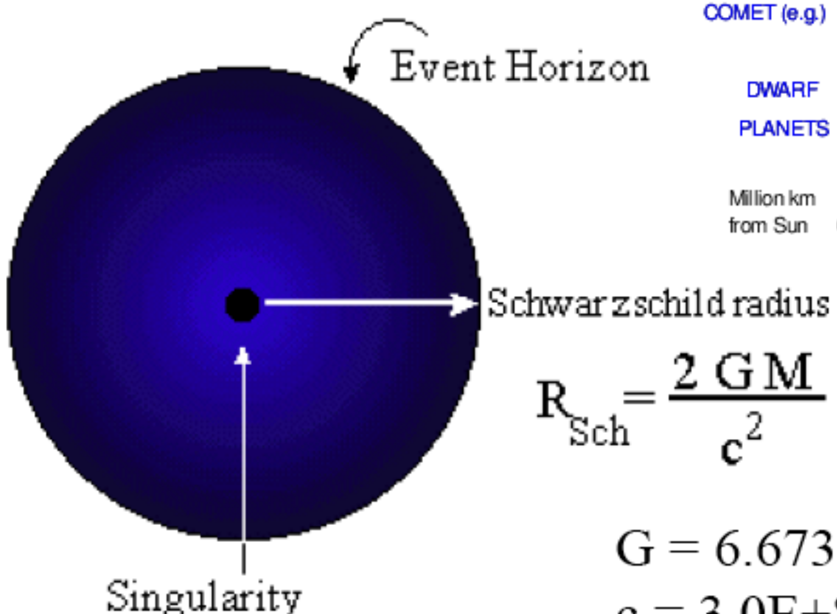
Schwarzschild radius

$$R_{milkyway} = \frac{2GM}{c^2} = \frac{2(6.67X10^{-11}\,Nm^2/kg^2)(4X10^6)(1.99X10^{30}\,kg)}{\left(3X10^8\,m/s\right)^2}$$

$$R_{milkyway} = 1.18X10^9\,km$$

- The black hole at the center of our galaxy has the mass of about 4 million times that of the sun





$G = 6.673E\text{-}11\ N\ m^2/\ kg^2$

$c = 3.0E{+}8\ m/s$

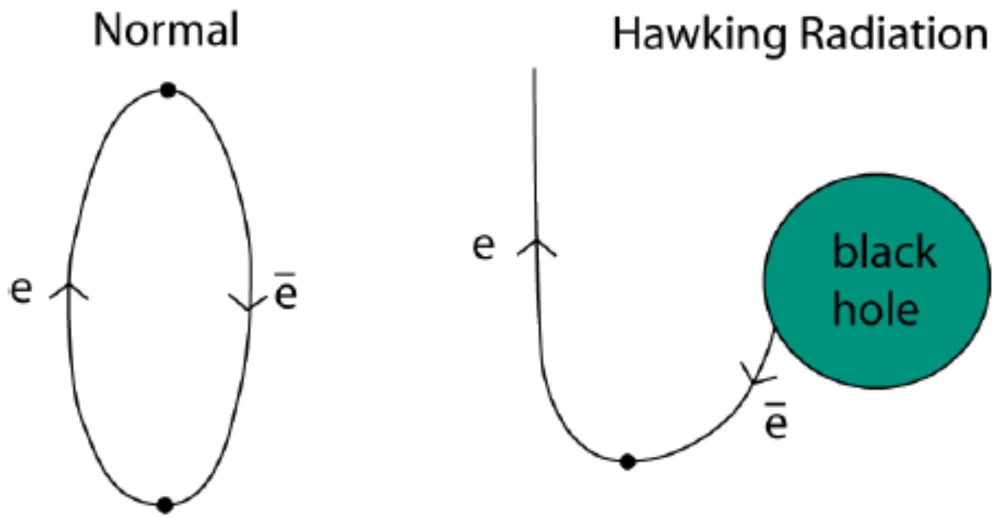
M = mass of the black hole

- in other galaxies they can b as massive as billion of times the mass of the sun
- the Schwarzchild radius is over a light year

Are black holes permanent? Hawking radiation

Black holes eventually evaporate, but it takes 10^{100} years.

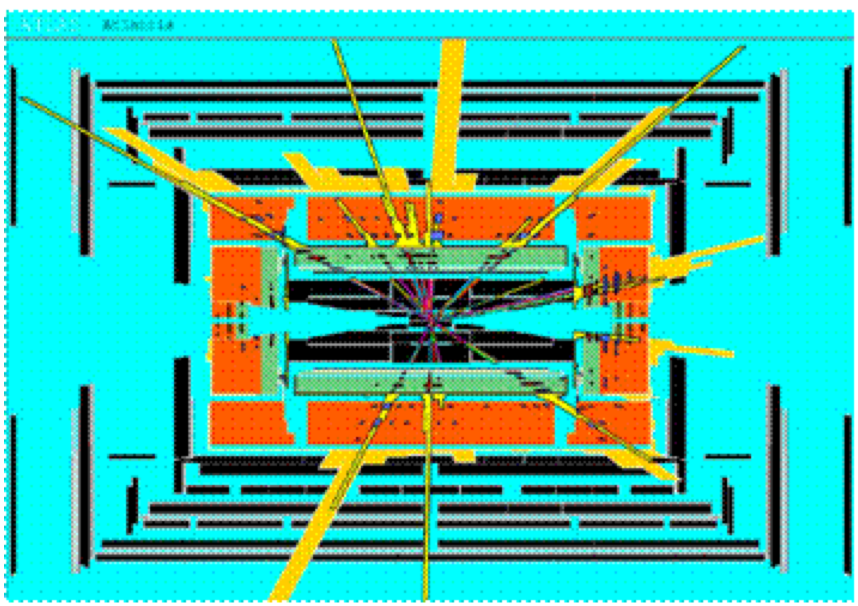
Vacuum fluctuations cause a particle-antiparticle pair to appear close to the event horizon of a black hole. One of the pair falls into the black hole whilst the other escapes. By this process the black hole loses mass, and to an outside observer it would appear that the black hole has just emitted a particle.

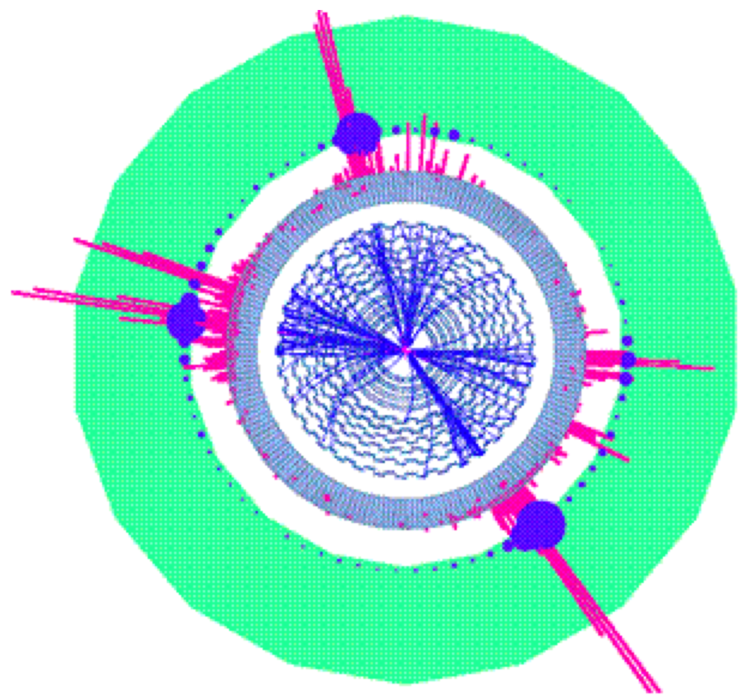


More when we discuss quantum mechanics

What about mini-black holes?

- May have been created right after the Big Bang, but have now all decayed away
- If some theories of the universe having extra dimensions are correct, we may be able produce them at the LHC
- …but they would immediately decay away from Hawking radiation, the products of which we would detect
- So far nothing





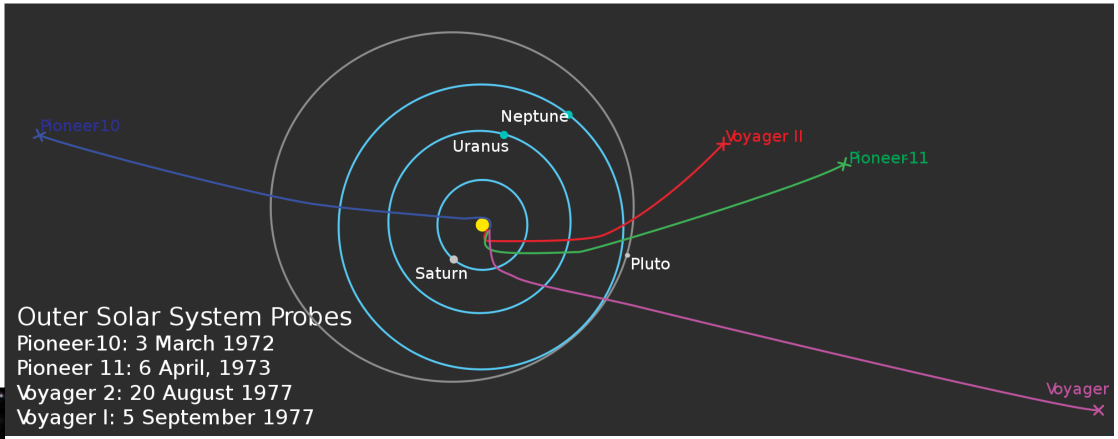
Clicker question

- What would happen to the Earth if the Sun were replaced by a black hole of the same mass?
  - A) the Earth would spiral into the Sun
  - B) the Earth would fly away from the Sun
  - C) nothing
  - D) the radius of the Earth's orbit would double
  - E) the radius of the Earth's orbit would decrease by a factor of 2

Steven Hawking action figure

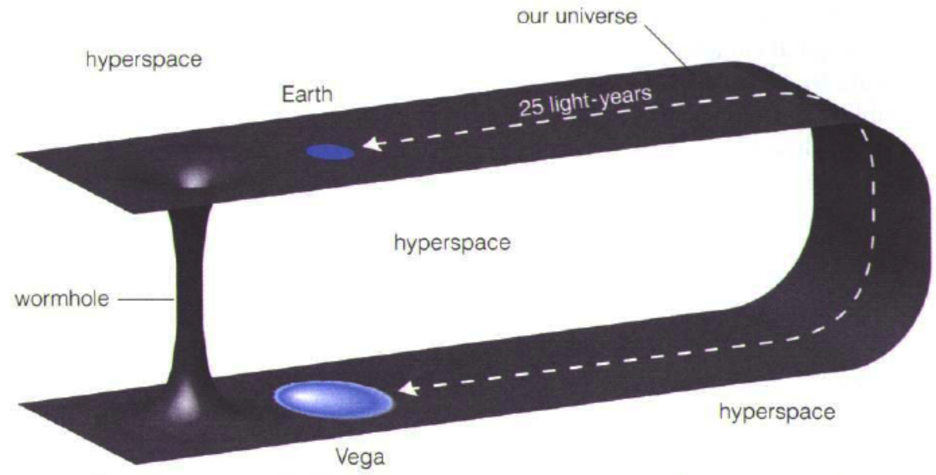
Interstellar travel

- Distances to even nearby stars are daunting, making the possibility of travelling to them difficult or even impossible
- The spacecraft furthest from the Sun is Voyager 1; it's around 1.8X10^{10} km from the Sun, travelling at 61,000 km/hr
- If it were travelling in the direction of the nearest star, it would take 74,000 years to reach it
- Could try to travel faster with other technology such as solar sails, but that would still take thousands of years



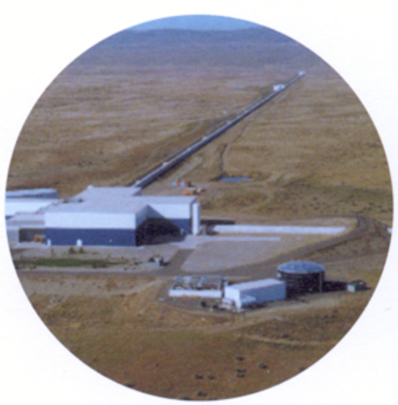
What about wormholes

- Possible solution to Einstein's field equations
- Cosmic shortcut from one part of the universe to another
- …but wormholes are unstable, so would need some type of material that acts as anti-gravity to keep one end open
- Luckily, most of the universe is made up of such stuff (dark energy)
- At the other end of a wormhole, should be a white hole
  - but none has been observed to date
- http://www.youtube.com/watch?v=wogZN94-5QU



Gravity waves

- An accelerated electric charge radiates electromagnetic waves
- An accelerated mass radiates gravitational waves
- But the gravitational force is much smaller than the electromagnetic force, so gravitational waves are much harder to detect
  - it takes catastrophic events and very large detectors to detect gravity waves



Hanford, Washington

Livingston, Louisiana

two very large interferometers, similar (except for size) to what Michelson used to look for the ether

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2. Download, **install** and **run** the BOINC software used by Einstein@Home.
3. When prompted, enter the URL: **http://einstein.phys.uwm.edu/**

If you are a new user **and** you are using one of the following (outdated) BOINC clients, then please use this old-fashioned sign up page.

- Pre-5.0 client
- Mac Menubar
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Returning participants

- Your account - view stats, modify preferences
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- BOINC introduction

Community

- Participant profiles
- Message boards - Discussion and Help
- Frequently asked questions
- BOINC Wiki - BOINC documentation

User of the day

[AF>XTBA>XTC] Palito
Hello,

Je suis un membre de la Mini-Team Xtrem-Team-Cruncher(XTC) de l'Alliance Francophone. Elle regroupe toutes les personnes...

Thank you for your interest in Einstein@Home!

Einstein@Home is a program that uses your computer's idle time to search for spinning neutron stars (also called pulsars) using data from the LIGO and GEO gravitational wave detectors. Einstein@Home is a World Year of Physics 2005 project supported by the American Physical Society (APS) and by a number of international organizations.

If you would like to take part, please follow the "Join Einstein@Home" instructions to the left. Einstein@Home is available for Windows, Linux and Macintosh OS X computers.

Einstein@Home is just in the process of completing its second search (S5R2/S5R3) of data from LIGO's first science run at design sensitivity (S5). We are also beginning a new search (S5R4) using 5280 hours of data from the later (and most sensitive) part of S5. For more information, please see the "Science information" section on the left of this page.

Bruce Allen
Professor of Physics, U. of Wisconsin - Milwaukee and Director, MPI for Gravitational Physics, Hannover
Einstein@Home Leader for the LIGO Scientific Collaboration

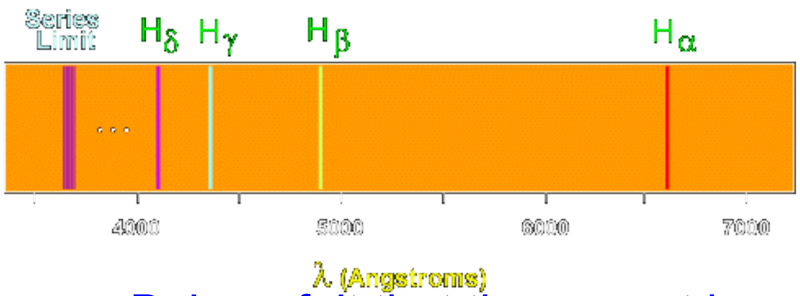
News items

Sep 25, 2008
We have completed processing the S5R3 workunits. S5R3 was the first search using the combined F-stat plus Hough method, which is currently the most sensitive search technique that is known. This search used approximately one year of data from LIGO's first science run (S5) at design sensitivity. The S5R3 post-processing is being led by Dr. Maria Alessandra Papa, one of the inventors of the search technique.

Now we enter the quantum century (20^{th} Century)

Johann Balmer and the hydrogen spectrum

- Hydrogen is the simplest atom with one proton and one electron
- The visible part of the spectrum has 4 spectral lines (light is emitted at 4 specific wavelengths)
  - 656.46 nm
  - 486.27 nm
  - 434.17 nm
  - 410.29 nm



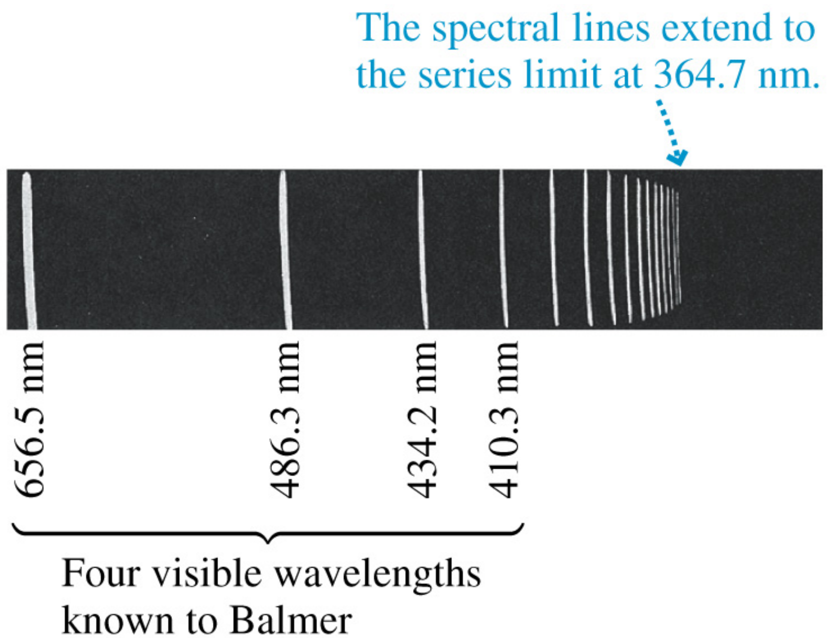
- Balmer felt that there must be some simplifying relation among those wavelengths

…and he was right

- By trial and error, he discovered that the 4 wavelengths in the visible spectrum of hydrogen could be represented by the simple formula

$$\lambda = \frac{91.18nm}{\left(\frac{1}{2^2} - \frac{1}{n^2}\right)} \quad n = 3,4,5,6$$

- What's more, they also describe wavelengths emitted by hydrogen in the UV corresponding to n=7,8,9,…
    - to better than a fraction of a %

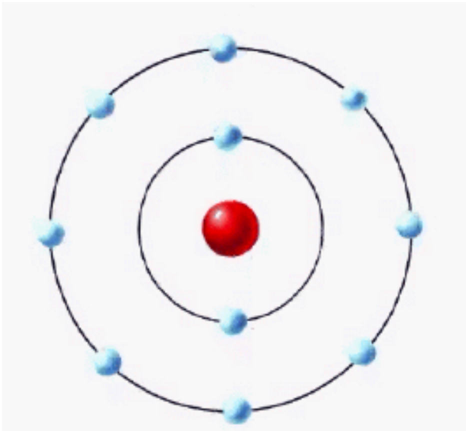


More generally

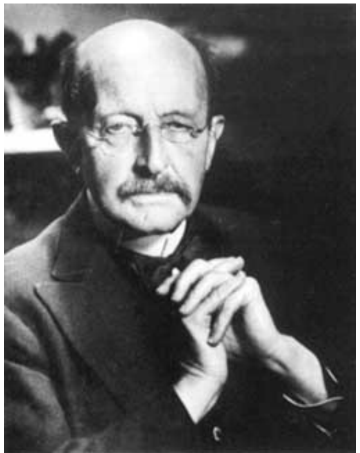
- Hydrogen spectrum can be described by a more general formula, where both m and n are integers
  - m=1 Lyman series (UV)
  - m=2 Balmer series (visible)
  - m=3 Paschen series (IR)
- **Why?** Balmer didn't have any explanation; this was just an empirical fit to the data
- It does imply that there is something discrete about the hydrogen atom; m and n are always integers

$$\lambda = \frac{91.18nm}{\left(\frac{1}{m^2} - \frac{1}{n^2}\right)}$$

Later we'll talk about the Bohr model for the atom, inspired by this finding of Balmer's



Max Planck came to the rescue



- Planck assumed that
  - atoms or molecules that emit light could only have discrete units of energy E_n given by
    - $E_n = nhf$
    - n is integer and f is frequency
  - molecules can emit or absorb energy in discrete units called quanta or photons
    - they do so by jumping from one quantum state to another

h = Planck's constant

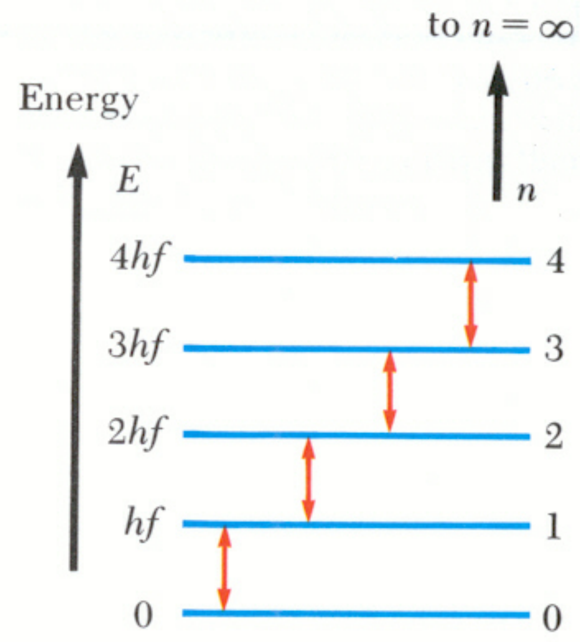
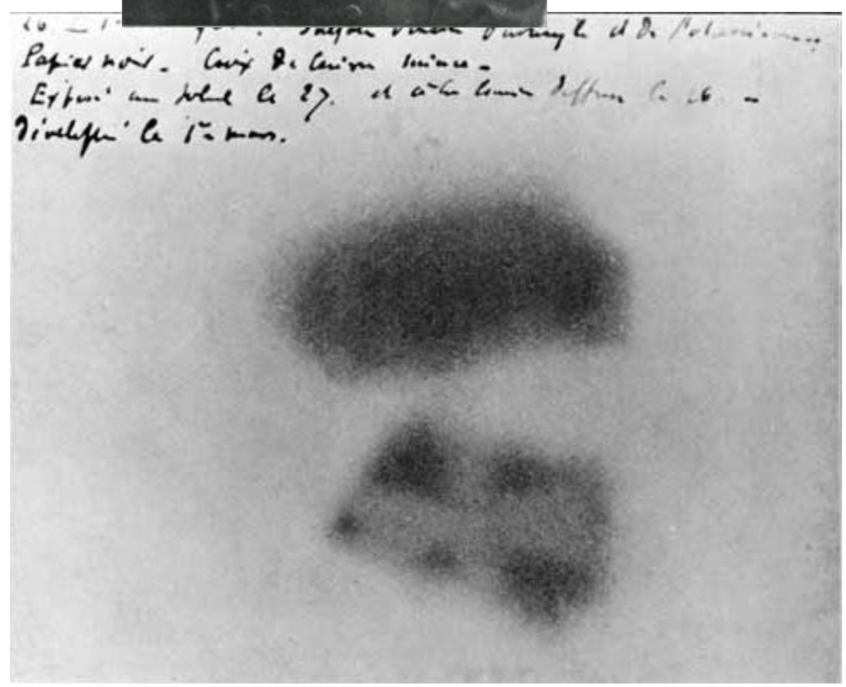


Figure 40.4 Allowed energy levels for an oscillator of natural frequency *f*. Allowed transitions are indicated by vertical arrows.

Key point is the assumption of **quantized energy states**; this marked the birth of quantum theory

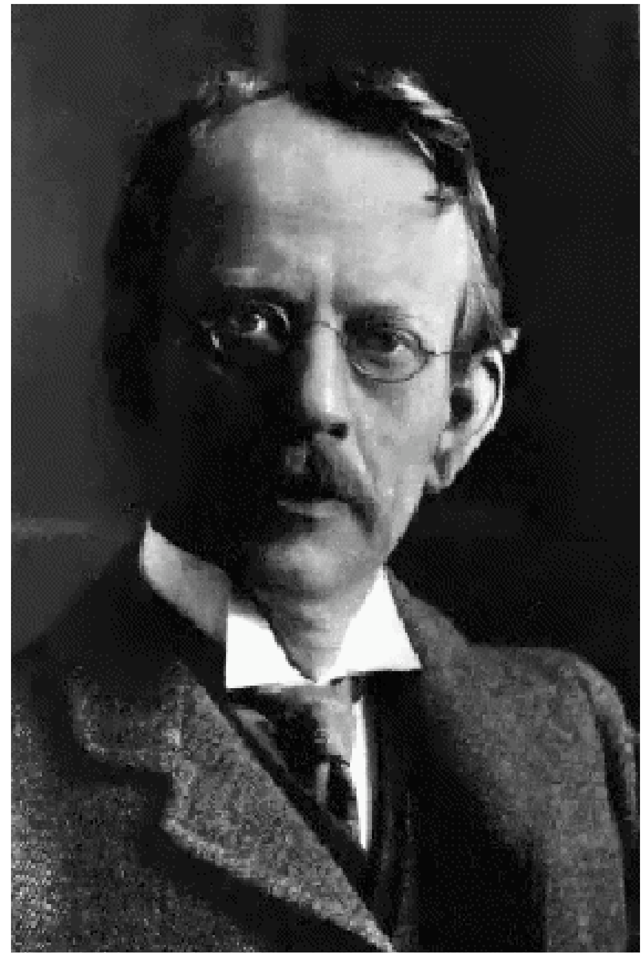
Discovery of radioactivity

- In 1896, a French physicist Henri Becquerel, (accidentally) discovered that uranium salts affected photographic plates, even though the plates were covered
- Some radiation was being emitted by the uranium that was very penetrating
- In fact, some of the uranium atoms were decaying and in the process emitting the radiation
- Atoms were not always stable, as had previously been thought



Atoms are not fundamental

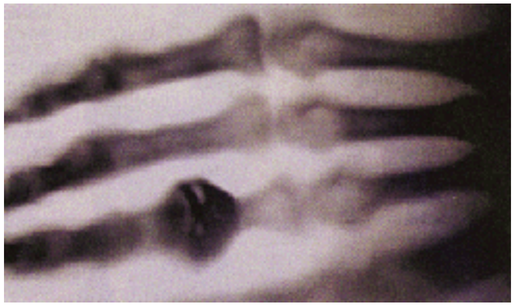
- Enter JJ Thomson
- In the late 1890's, JJ did experiments using cathode ray tube
- By 1895, he discovered that the cathode ray particles were electrons coming out of atoms
- We had been using electricity for some time in our cities by 1895, but did not know that an electric current was the flow of electrons
  - since we didn't know about electrons

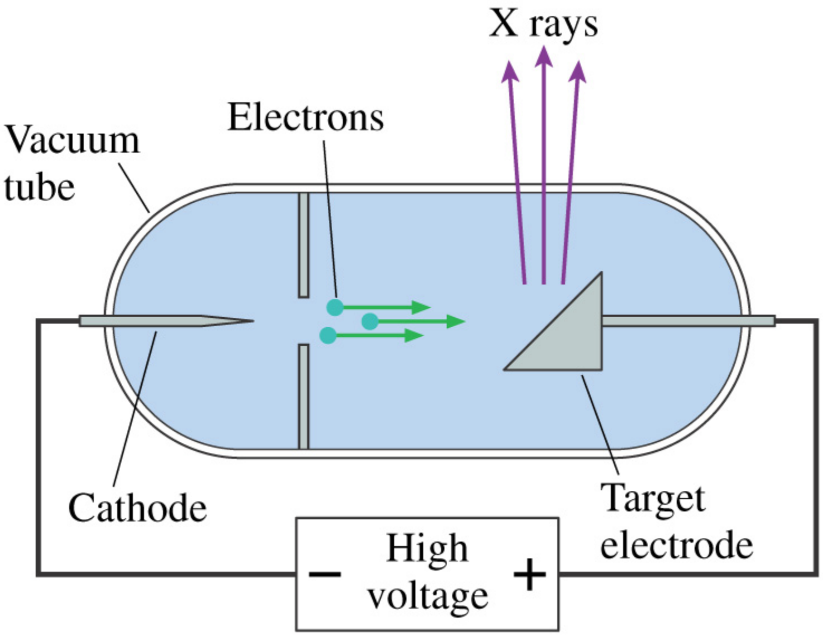


Meanwhile, back at the lab

- Wilhelm Roentgen accelerated electrons in an evacuated glass tube and found that x-rays were produced
  - X because they were unknown
  - caused undeveloped photographic film to be exposed
  - suspicion was that they were some sort of EM radiation, of very short wavelength

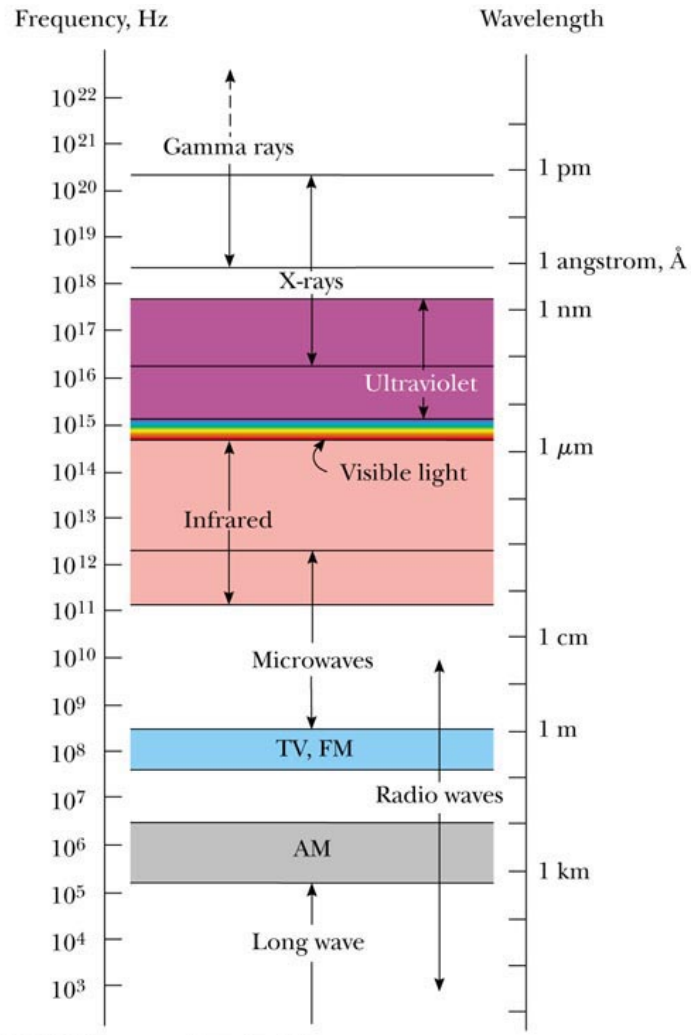
Mrs. Roentgen, the first test subject





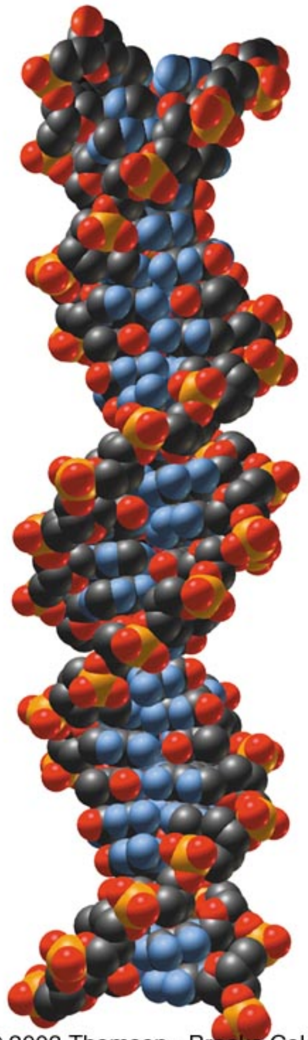
X-rays

- In fact, x-rays are EM radiation of wavelengths of order of 1nm or less



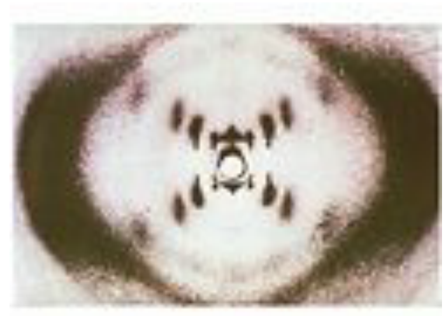
DNA

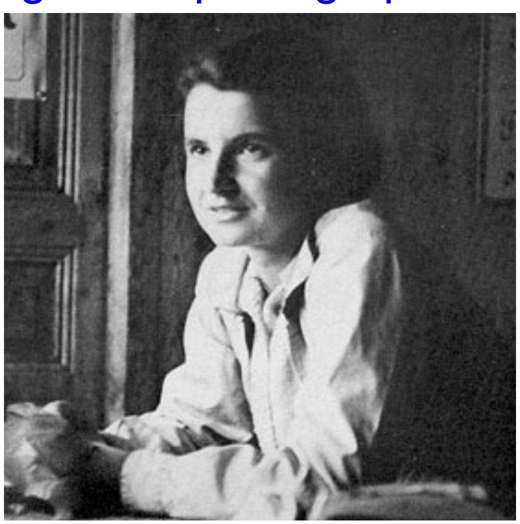
- For example, how was the structure of DNA determined?
- Since the atoms are spaced by about 1 Angstrom apart, then use X-rays of wavelength 1 Angstrom (0.1 nm)



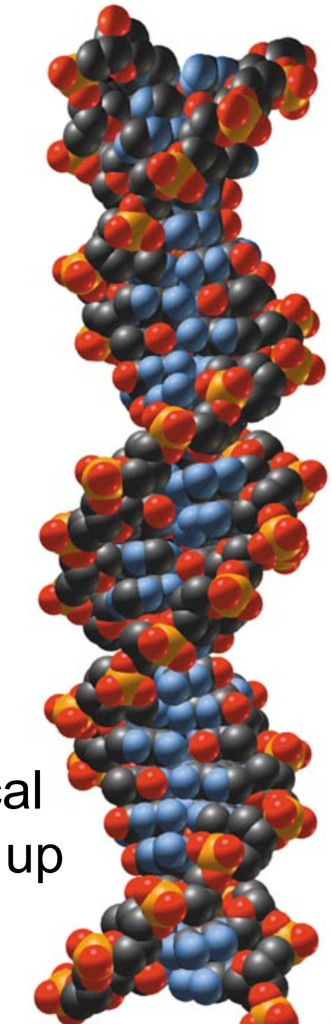
Rosalind Franklin

- “As a scientist Miss Franklin was distinguished by extreme clarity and perfection in everything she undertook. Her photographs are among the most beautiful X-ray photographs of any substance ever taken. Their excellence was the fruit of extreme care in preparation and mounting of the specimens as well as in the taking of the photographs. “





cross pattern of X-ray diffraction picture was a clue that DNA had a helical structure…a clue picked up by Watson and Crick for their Nobel prize winning work 50 years ago



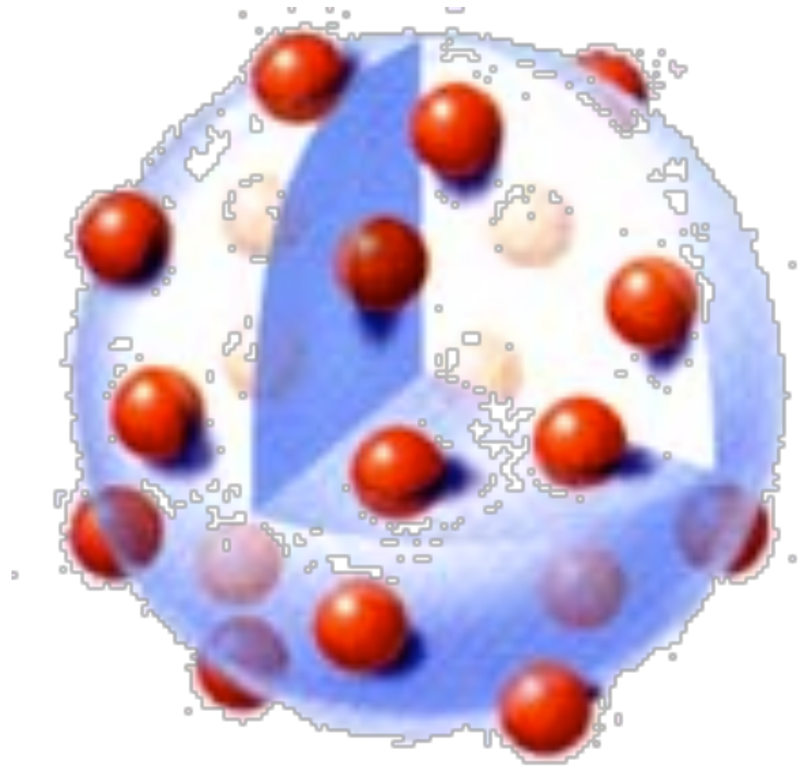
The Eagle Pub

- …which is where Watson and Crick did most of their work on the structure of DNA

James Watson and Francis Crick.

Now we're getting back to the introduction I gave at the start of the course

- This led JJ to think of the atom as a positively charged mass sprinkled with negative electrons
  - like a plum pudding with the electrons in the role of raisins and the positive charge in the role of the pudding
- The electrons appeared to be the same in different atoms
- Implying that electrons were a fundamental piece of matter



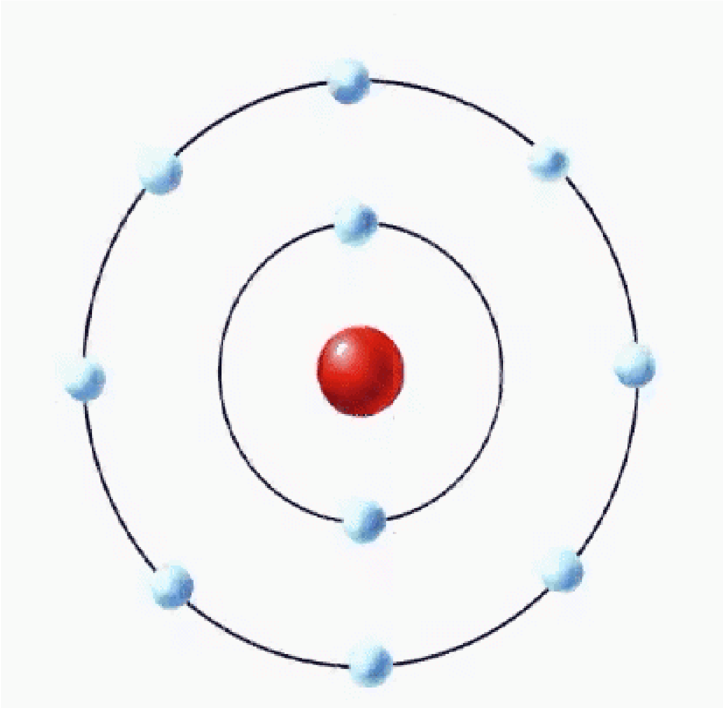
Most of the mass appeared to be in the plum pudding and not in the electrons

Experiments with radioactivity

- Many researchers started to work with radioactive elements
- A typical technique was to bombard some materials with radioactive particles
- The New Zealander Ernest Rutherford was the leader in this type of research

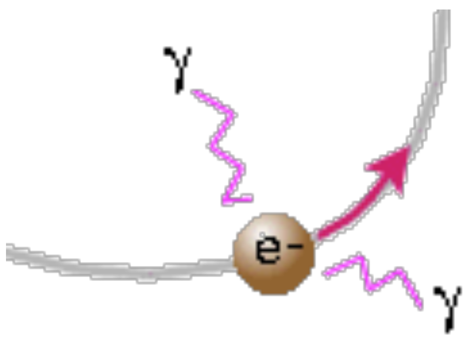
…he came up with the Solar System model

- Distant electrons orbit a massive nucleus due to the electromagnetic attractive force between the positive and negative charges
- The size of the nucleus here is greatly exaggerated
- If an atom were the size of Spartan Stadium, then the nucleus would be the size of a strawberry (at the 50 yard line)
- The vast majority of the atom is nothing but empty space
- That's why when you get rid of all of that empty space in a neutron star, you're left with an incredible density
    - since a neutron star is like a 10 km diameter nucleus



…there's always a but

- What held the positive charges in such a small nucleus
- And we learned that accelerated electric charges give off electromagnetic radiation
- If the electrons are orbiting around the nucleus, they're going in a circle and thus accelerating
- They should quickly spiral into the nucleus

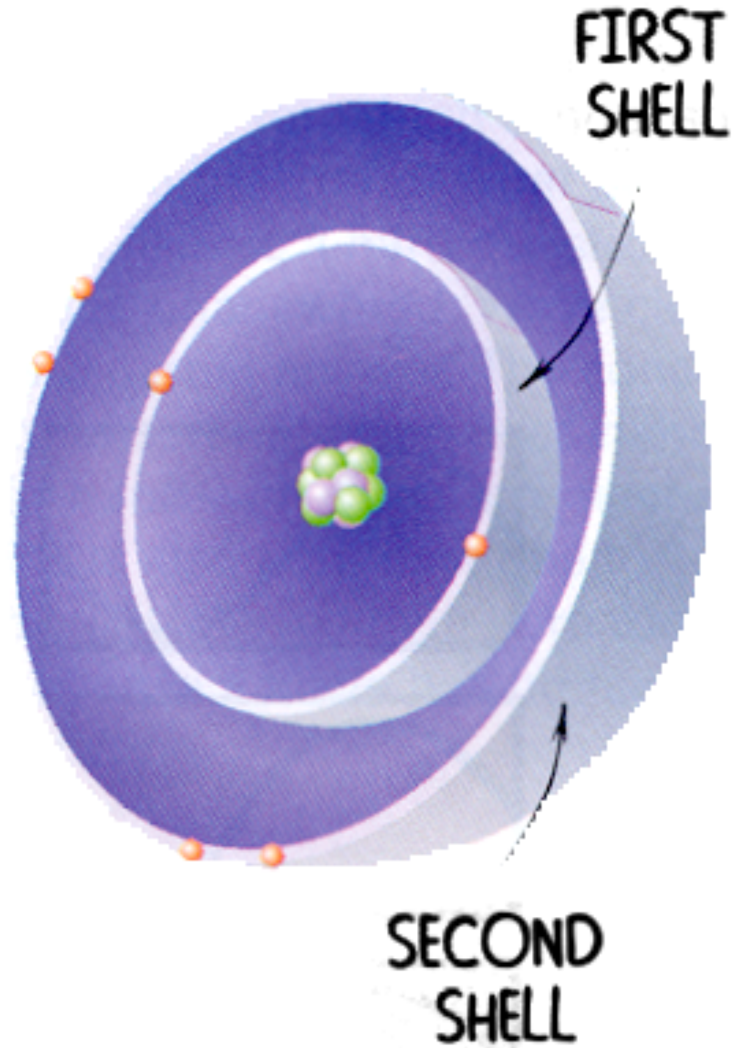


Niels Bohr came to the rescue

- Bohr applied the quantum principle originated by Planck and Einstein to the atom

Niels Bohr, Danish physicist
(1885–1962)

- Only certain stable orbits exist for the electrons in an atom
- While in these orbitals, they cannot give off photons



Quantum world

- Electrons can only move from one orbital to another by gaining or releasing photons (a quanta of energy, E=hf)

$$\lambda = \frac{91.18nm}{\left(\frac{1}{m^2} - \frac{1}{n^2}\right)}$$

- m=1 Lyman series (UV)
- m=2 Balmer series (visible)
- m=3 Paschen series (IR)