

Rainbows, Stars & Atoms

Quantum 4 Kids

Of All Ages !!!

The size of things &
How they are related

A special presentation for the



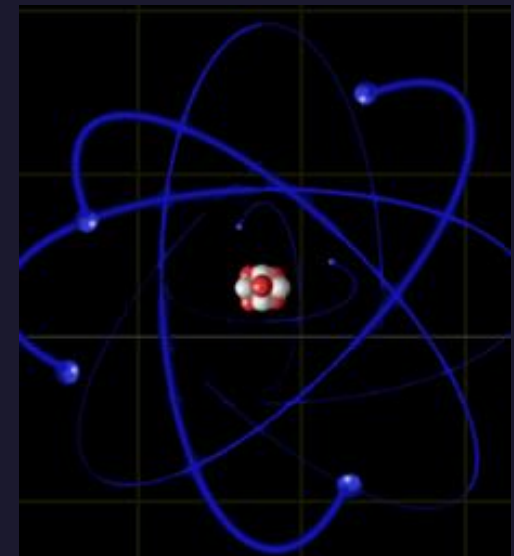
Donn Silberman

Optics Institute of Southern California

<http://oisc.net>



Image credit: NASA, ESA, CSA, and STScI



Carbon Atom
 3.40×10^{-10} m in diameter

Introduction

Who am I?

And Why am I here talking to you?

- QuantumOpticsAge –
- <https://donn601.wixsite.com/opticsage>



Welcome to EdQuantum Project

HYBRID CURRICULUM IN ADVANCED OPTICS, SPECTROSCOPY, AND QUANTUM TECHNOLOGIES FOR TECHNICIANS



THE UNIVERSITY OF ARIZONA



Society of Physics Students



eLas Americas



OptoBoticssm
Robots need eyes too

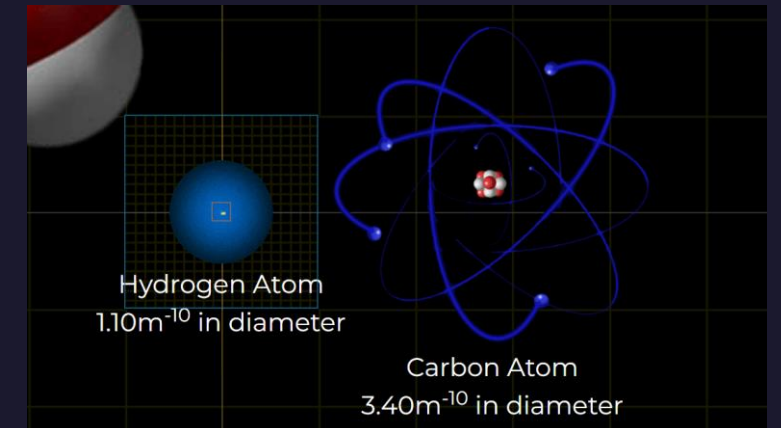


Topics for Today

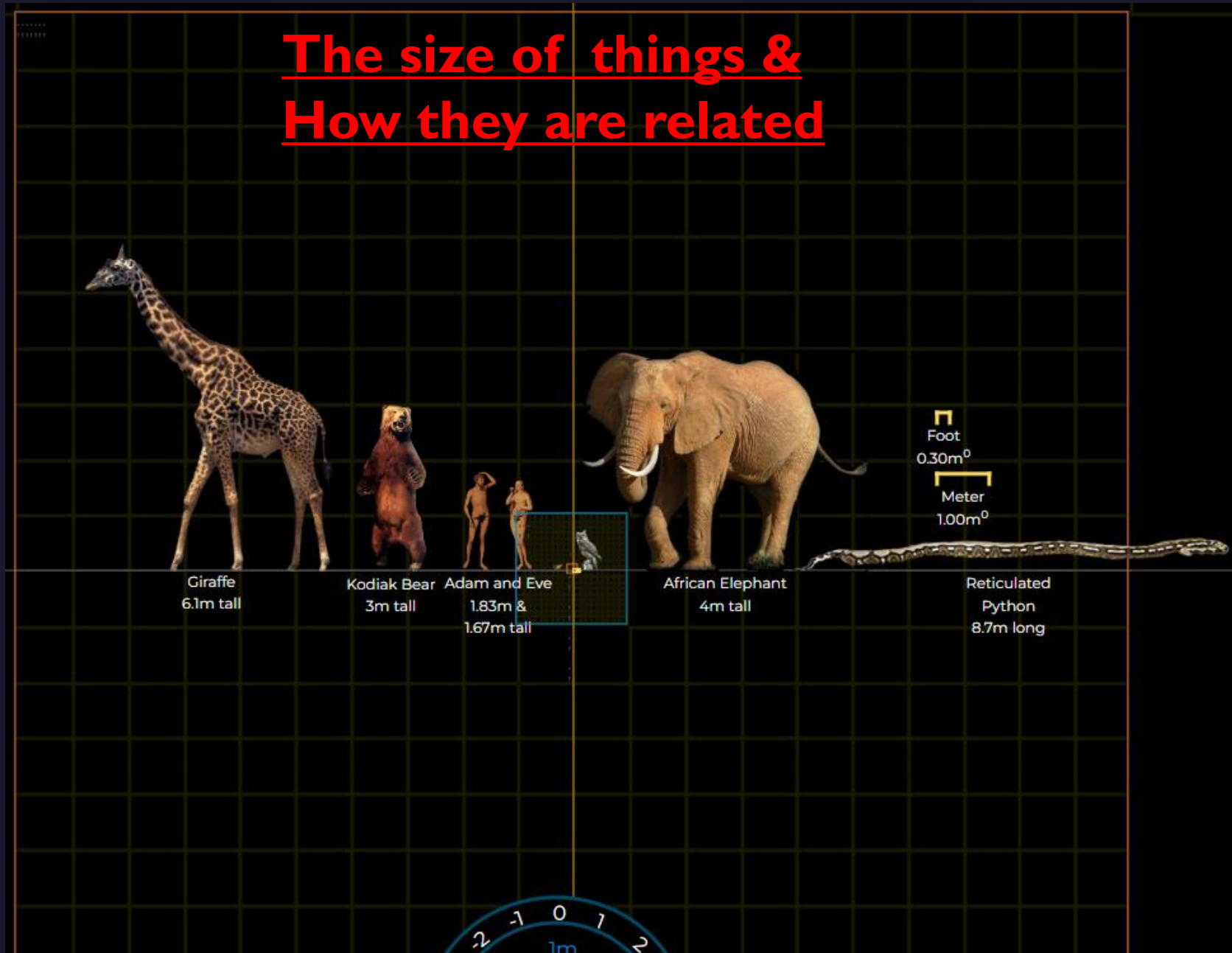
1. The size of things and how they relate.
2. What are Rainbows & why should you care?
3. What are stars & how do we know?
4. How do we know about atoms?
5. How do we use this information?
6. On-line and In-Person Resources
7. Questions & Answers



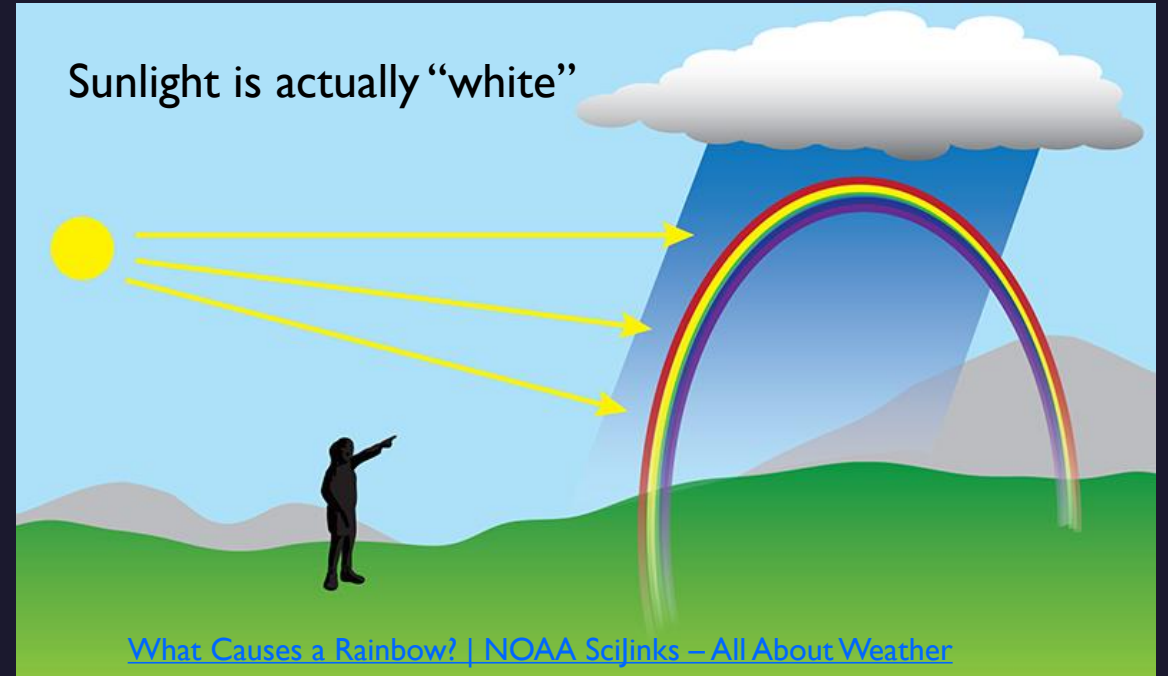
Image credit: NASA, ESA, CSA, and STScI



The size of things & How they are related



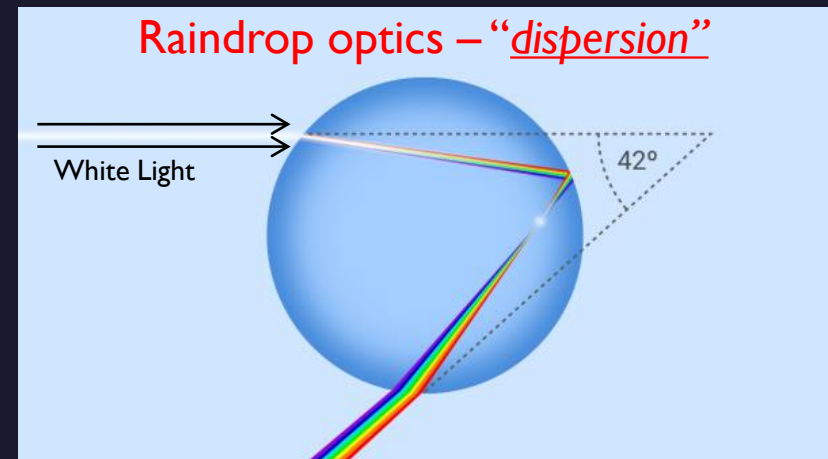
What are Rainbows?



Raindrops + Sunlight = Rainbows

But why should you care ???

All modern civilization is based on what we learned about rainbows !!!
We'll get to the details when we talk about stars & atoms !!!



You can make your own rainbows !!



[Water sprayed from a garden hose can produce a rainbow. | U.S. Geological Survey \(usgs.gov\)](https://www.usgs.gov/edu/you-can-make-your-own-rainbows)

[Rainbows \(Water and Light\) | U.S. Geological Survey \(usgs.gov\)](https://www.usgs.gov/edu/you-can-make-your-own-rainbows)



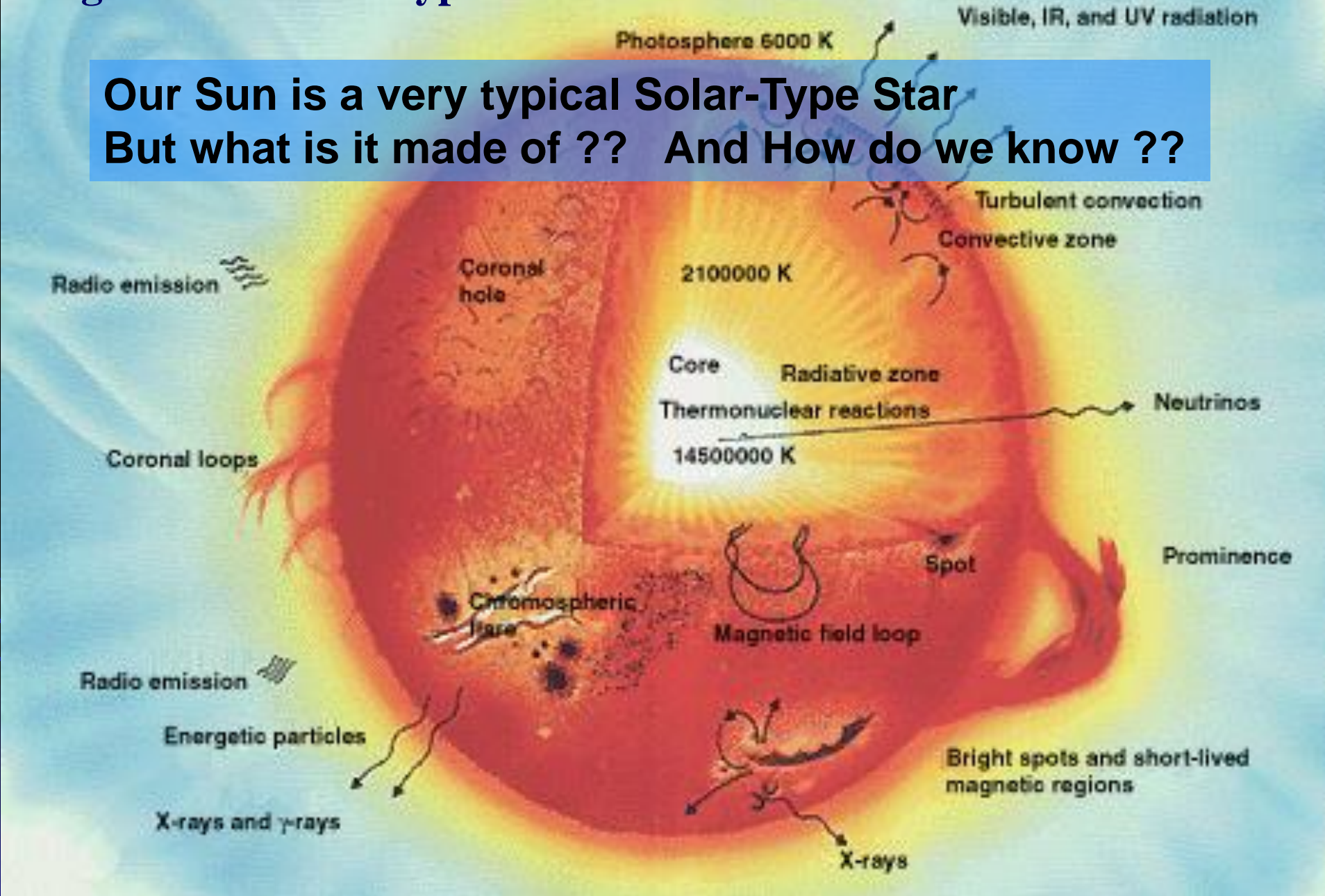
Twinkle, Twinkle, Little Star ... How I Wonder What You Are ...

- Did you ever wonder what stars are?
- Did you notice that stars have different colors?
 - The different colors indicate different:
 - Temperatures
 - Sizes
 - Masses
- Do you know where the nearest star is located?



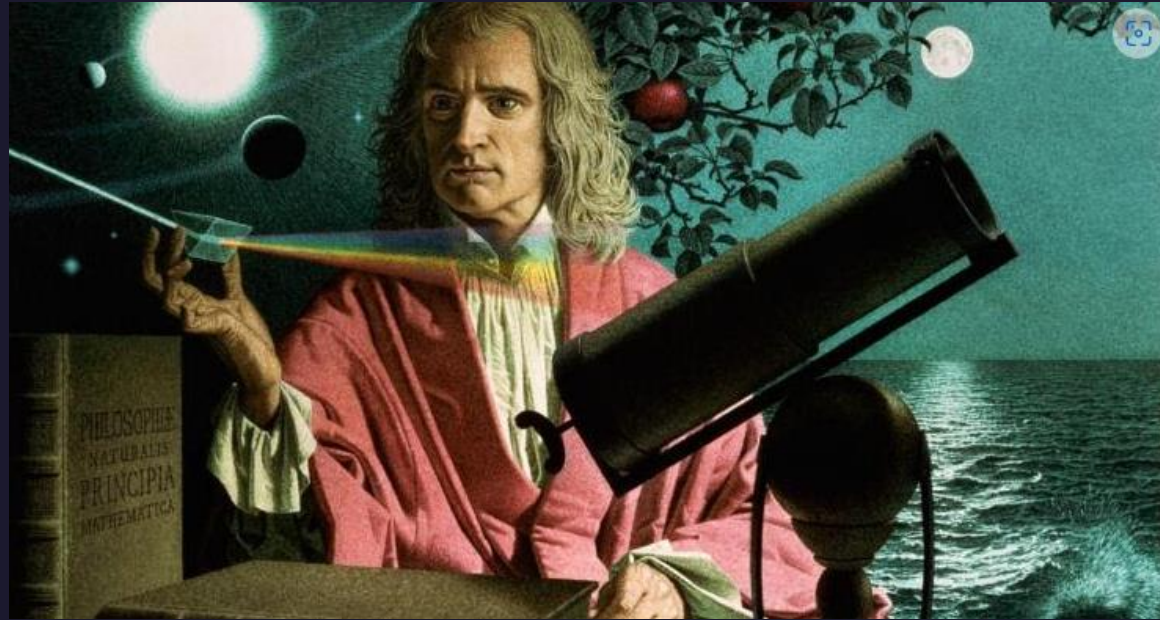
Diagram of a Solar-Type Star

**Our Sun is a very typical Solar-Type Star
But what is it made of ?? And How do we know ??**



What are the Stars ?

And how do we know?

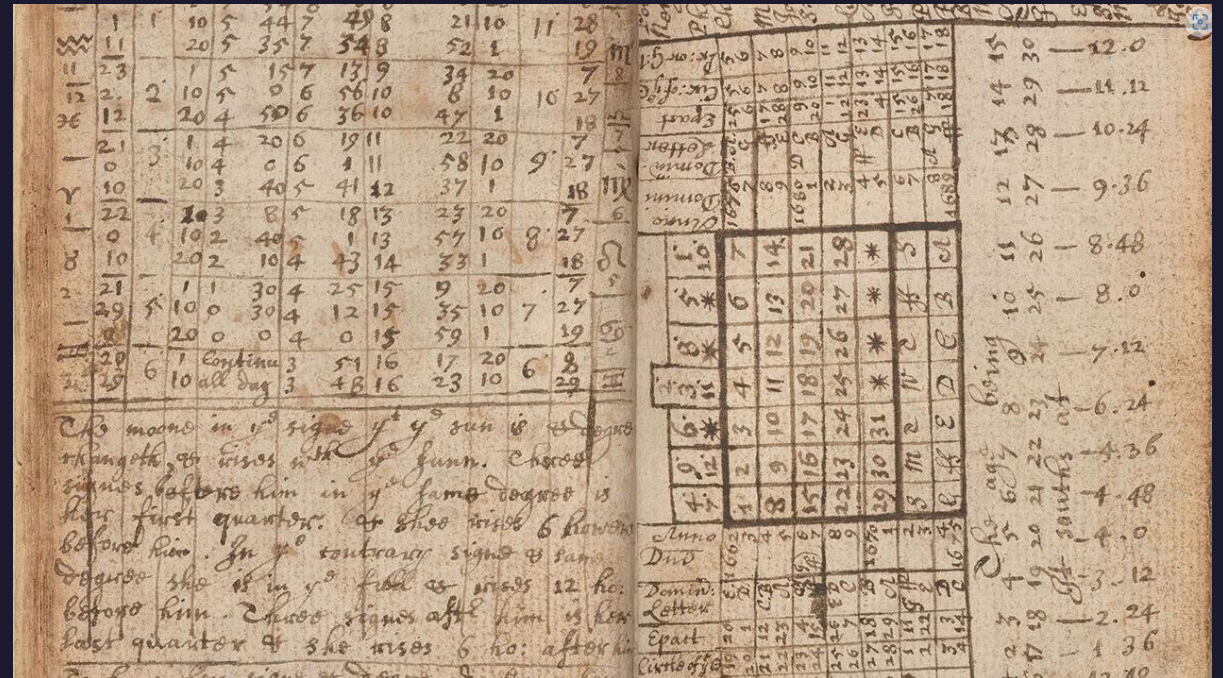
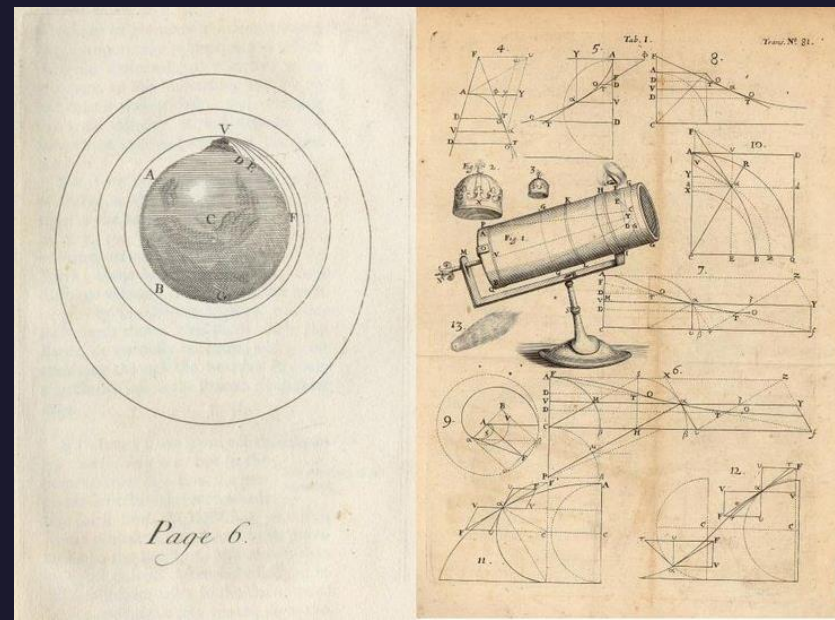


Isaac Newton and his reflecting telescope (1672).
(350 years ago)

Pages from Newton's notebook recording his astronomical observations.

The prism separates the white light into the colors of the rainbow. (Just like raindrops.)

[Isaac Newton - Wikipedia](https://en.wikipedia.org/wiki/Isaac_Newton)



Recording observations (data) by hand in a notebook. ||

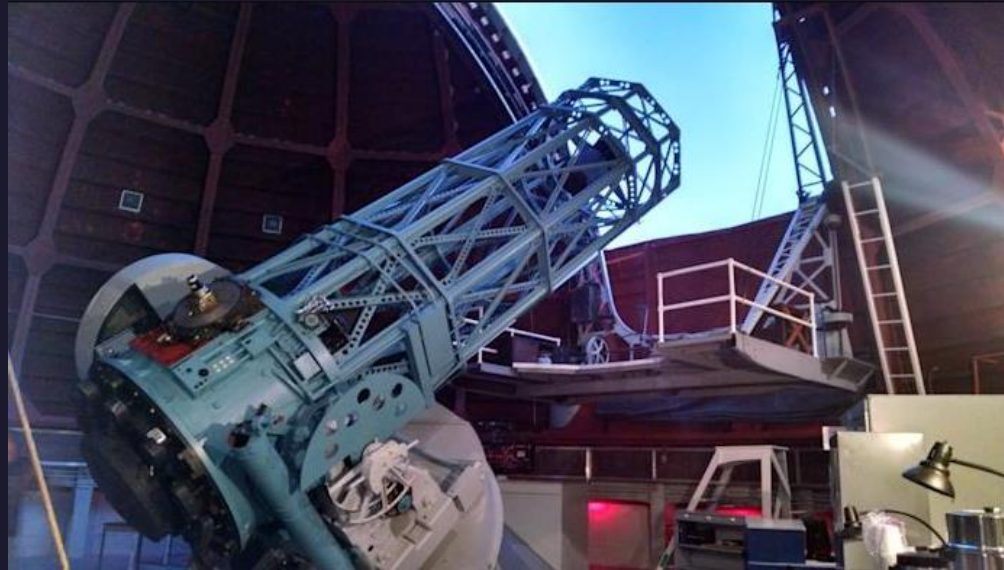
Edwin Hubble

Doing research with the 100" Hooker Telescope (1917 – 1922 and beyond.) {250 yrs after Newton}
Using photographic glass plates to record the images of the stars & galaxies.
Also documenting observations in notebooks and on the photographs.



A young **Edwin Hubble** at Mount Wilson's 100-inch telescope circa 1922, ready to make history.

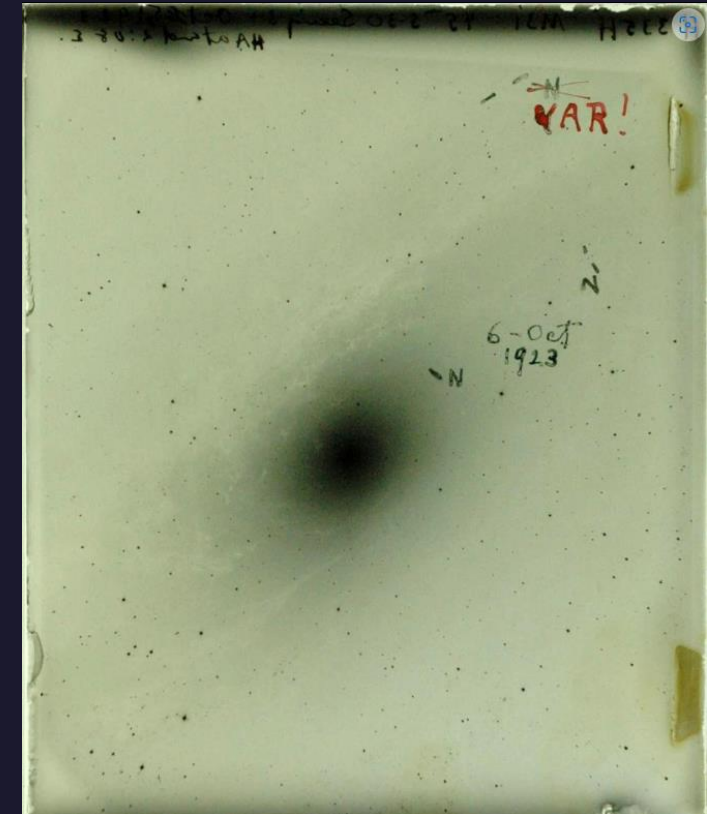
[Hubble's Other Telescope And The Day It Rocked Our World | KERA News](#)



Mt. Wilson Observatory – 100" Hooker Telescope Completed in Nov. 1917 in the Los Angeles area.

[Mount Wilson Observatory | Building the 100-inch Telescope \(mtwilson.edu\)](#)

You can look through this telescope now
Open to the public – by appointment only



This glass side of a photographic plate shows where Hubble marked novae. The red VAR! in the upper right corner marks his discovery of the first Cepheid variable star — a star that told him the **Andromeda Galaxy** isn't part of our Milky Way.
Courtesy of the Carnegie Observatories

Mt. Palomar Observatory – 200” Hale Telescope



Historic image of the **Andromeda Galaxy** (M31) taken by Edwin Hubble with the 200” Hale Telescope. Feb. 5, 1924



Mount Wilson Observatory



A Second Century for America's Observatory



1.5+ hour drive





**DISCOVERY
SCIENCE CENTER**



~3-hour drive



**200-INCH HALE TELESCOPE
PALOMAR TESTBED INTERFEROMETER**



The Hubble Space Telescope

[Messier 31 \(The Andromeda Galaxy\) | NASA](#)

84 years after Hubble's photo on the 200" Hale Telescope

Hubble's M31 mosaic image, taken by the Panchromatic Hubble Andromeda Treasury (PHAT) program, is shown in context with a ground-based image of the entire galaxy. Despite the size of Hubble's massive mosaic, it does not span even half of the galaxy.

Credits: NASA, ESA and Z. Levay (STScI/AURA); PHAT Mosaic: NASA, ESA, J. Dalcanton, B.F. Williams, L.C. Johnson (University of Washington), the PHAT team and R. Gendler; Ground-based Background Image of M31 (c) 2008 R. Gendler, used with permission

M31

Not taken with a photographic plate.

More like the camera in your cell phone !!!

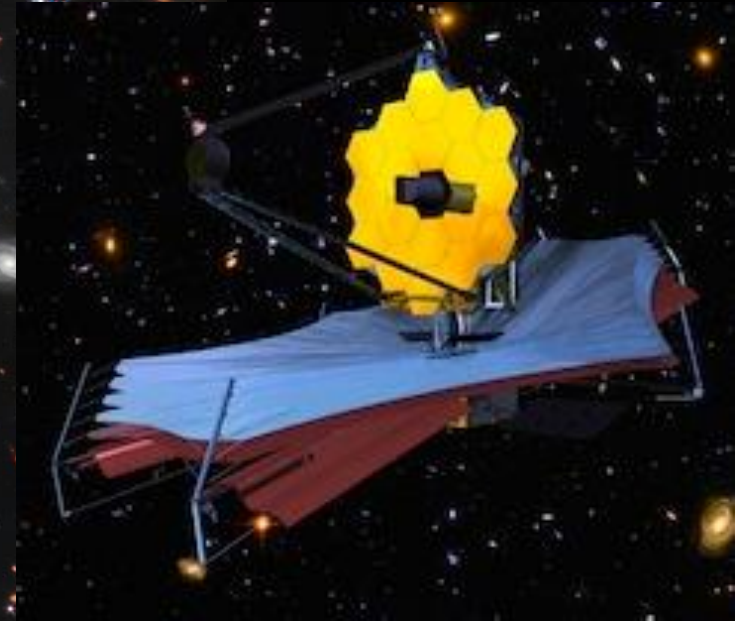


Compared to the ground-based telescope image

NASA released the James Webb Space Telescope's first color images. They're awesome. - Vox



The Hubble Space Telescope



James Webb Space Telescope

“What makes this image so mind-blowing is how small it is, and how large it is, at the same time.

It's small in the sense that this image represents only a teensy tiny portion of the night sky. Imagine you are holding out a grain of sand at arm's length. The area of sky that grain covers — that's the size of the area captured in the above image.

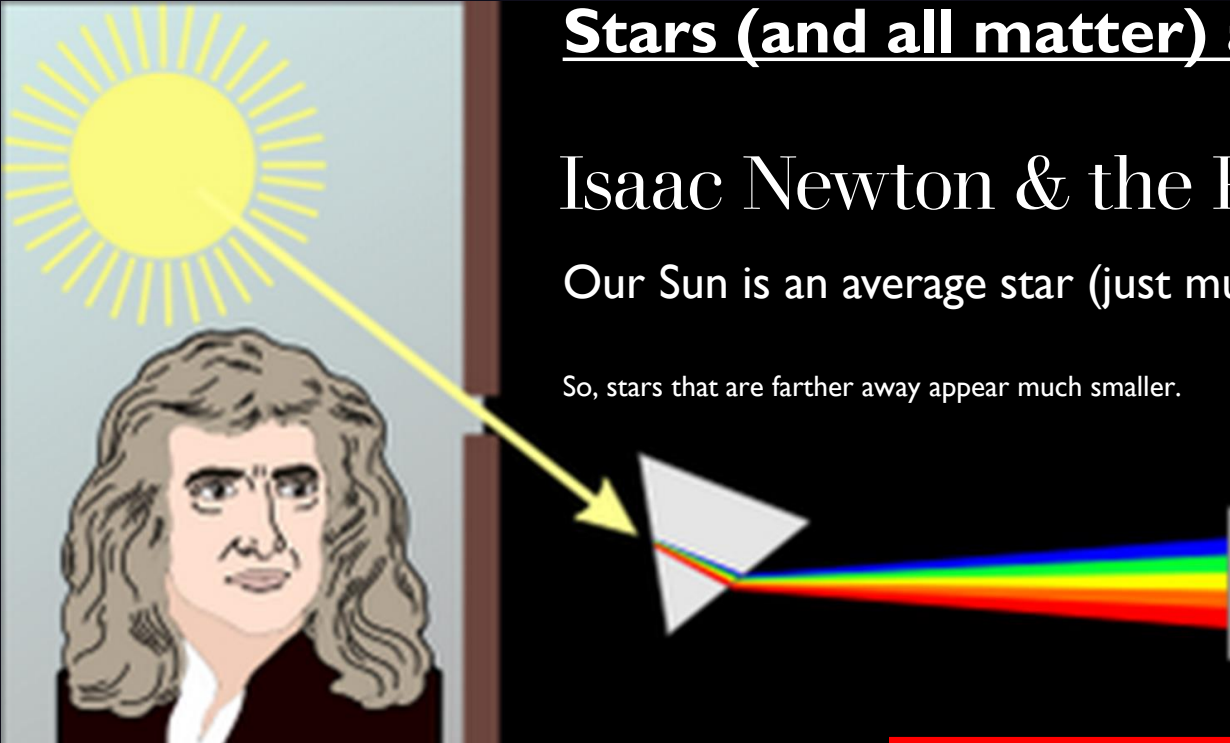
But it's huge in the sense that nearly every object in this image is a galaxy (besides the bright spiky starbursts, which are stars in the foreground). Think about that: In every pinprick of sky, there are thousands and thousands of galaxies, at least.”

Stars (and all matter) are made of **ATOMS**

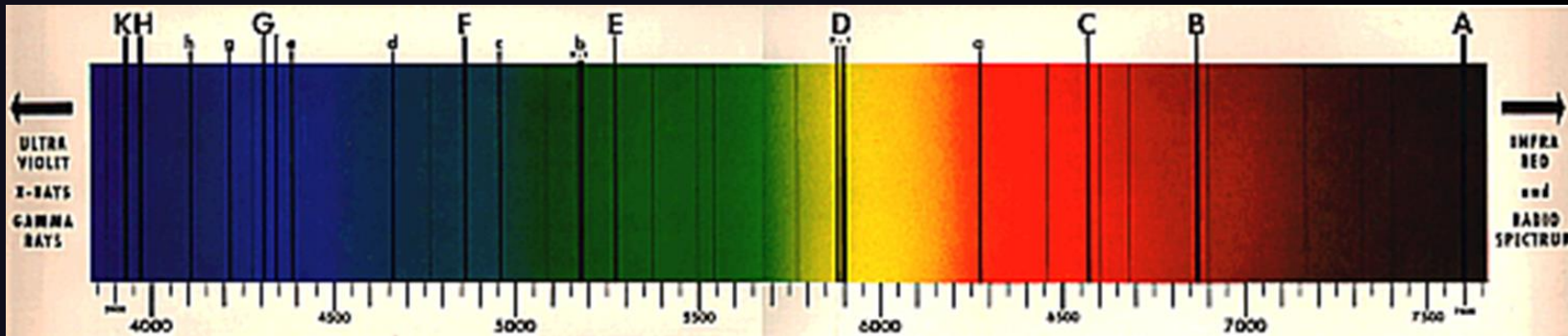
Isaac Newton & the Prism

Our Sun is an average star (just much closer to earth)

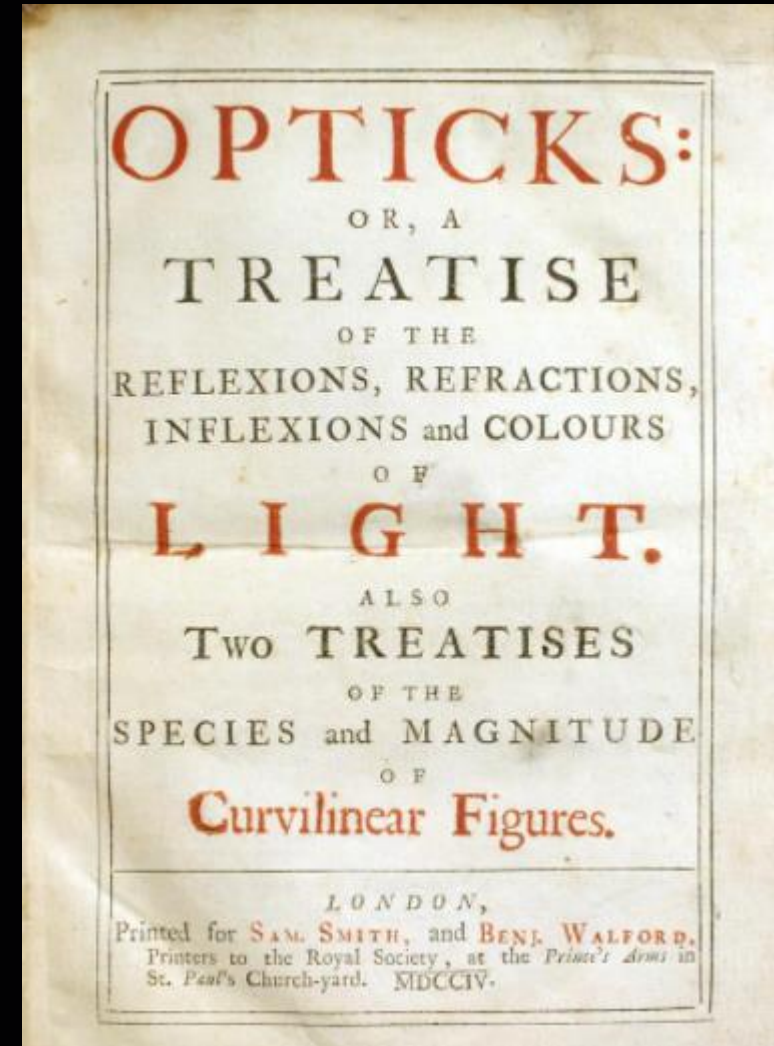
So, stars that are farther away appear much smaller.



The Solar Spectrum with Fraunhofer Lines



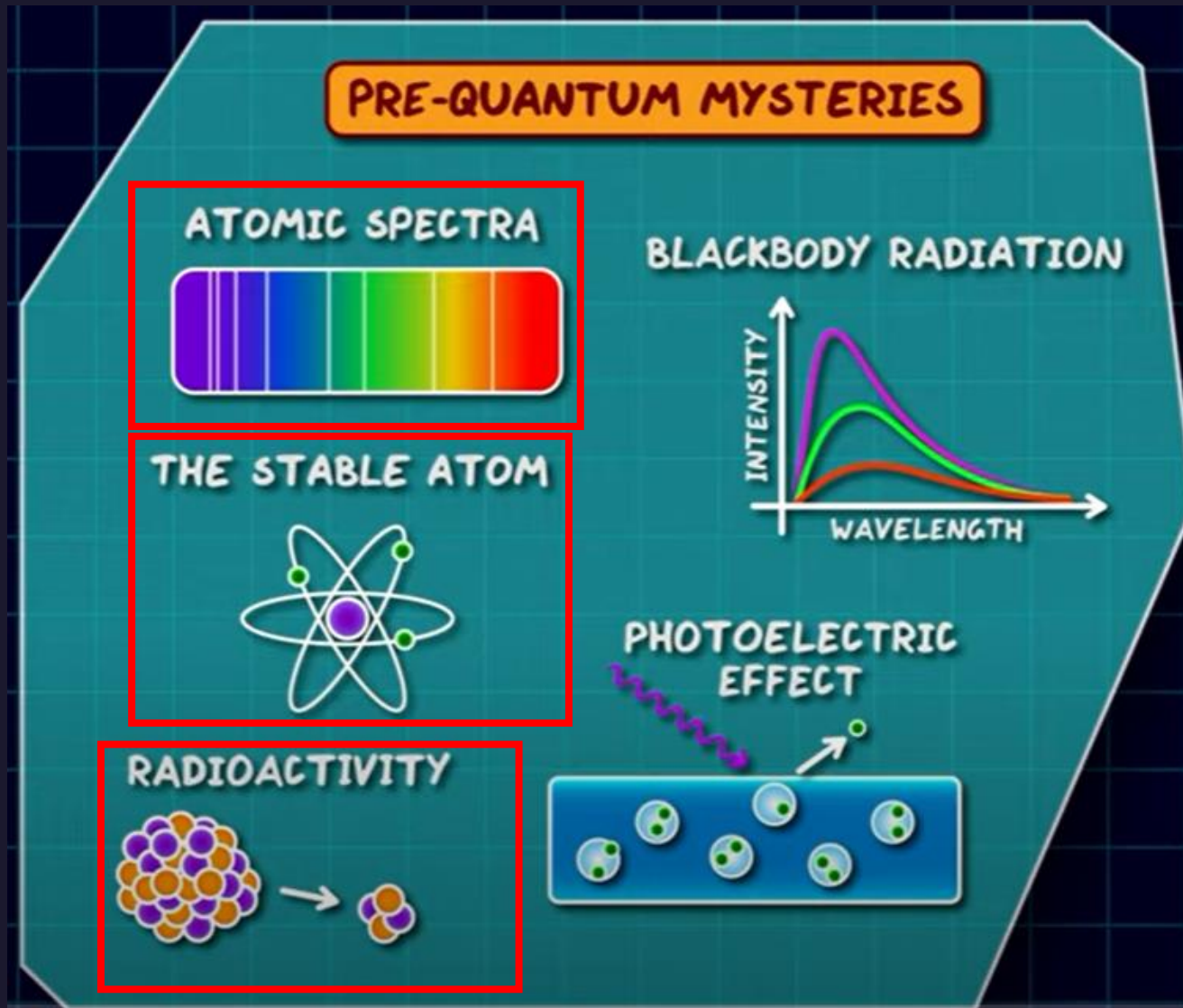
Discrete spectral lines correspond to the energy levels of various **atoms** that are burning in the Sun.



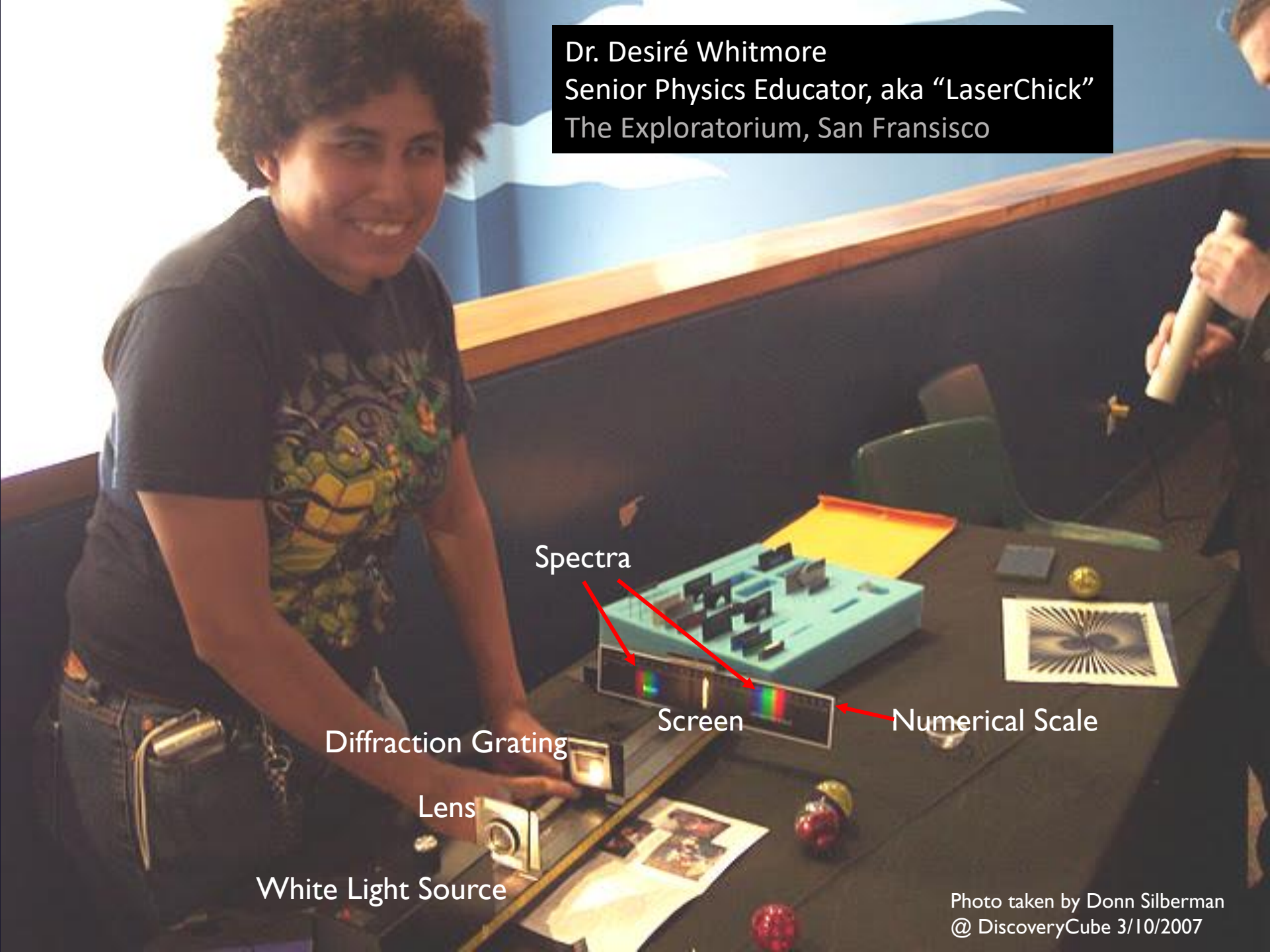
The first, 1704, edition of *Opticks: or, a treatise of the reflexions, refractions, inflexions and colours of light.*

What about Atoms??

It gets a little complicated now !!!



Dr. Desiré Whitmore
Senior Physics Educator, aka "LaserChick"
The Exploratorium, San Francisco



Spectra

Screen

Numerical Scale

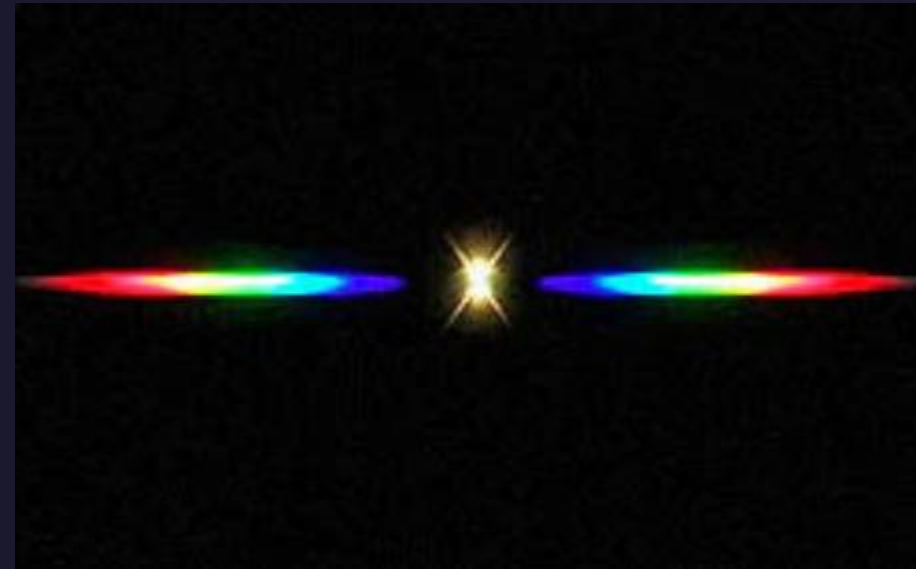
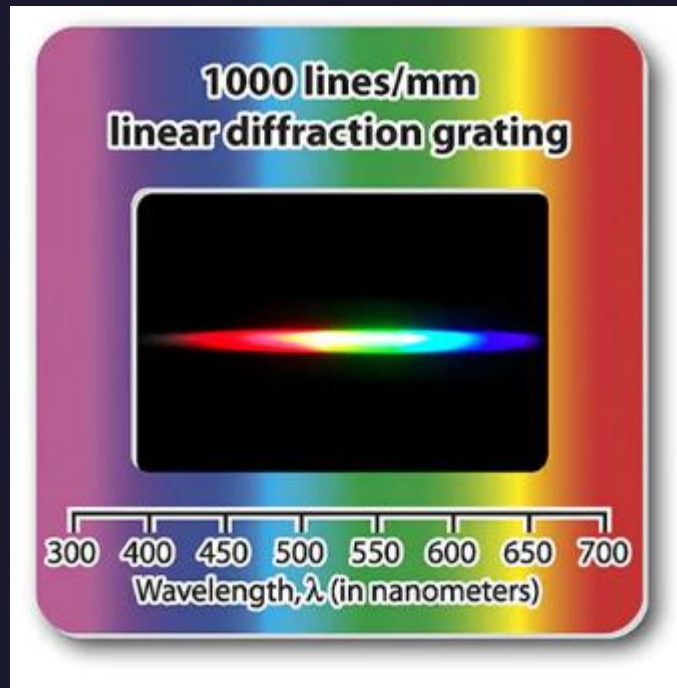
Diffraction Grating

Lens

White Light Source

Photo taken by Donn Silberman
@ DiscoveryCube 3/10/2007

Diffraction Gratings



The grid of bumps in the plastic **diffract** the colors of the white light into the **visible spectrum**.

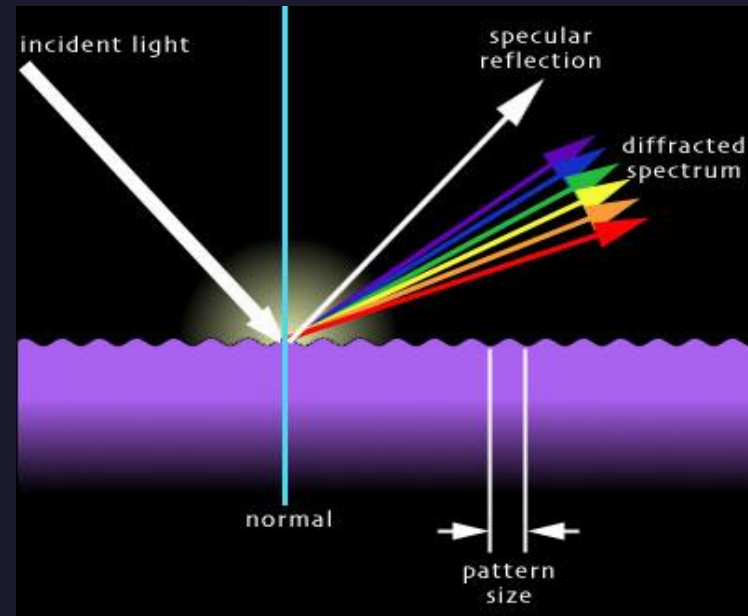
Diffraction Gratings

Colors are **mixed together** to make many types of lights.

Lights are separated into its constituent **colors** by **diffraction**

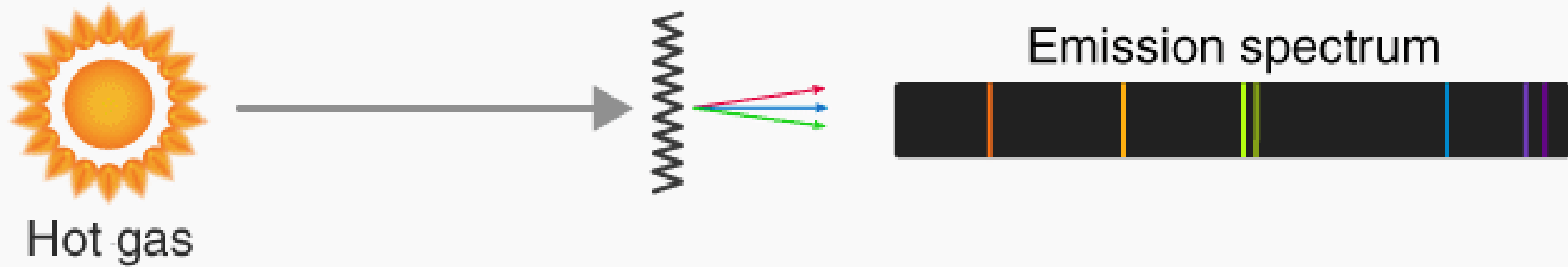


CDs or DVDs

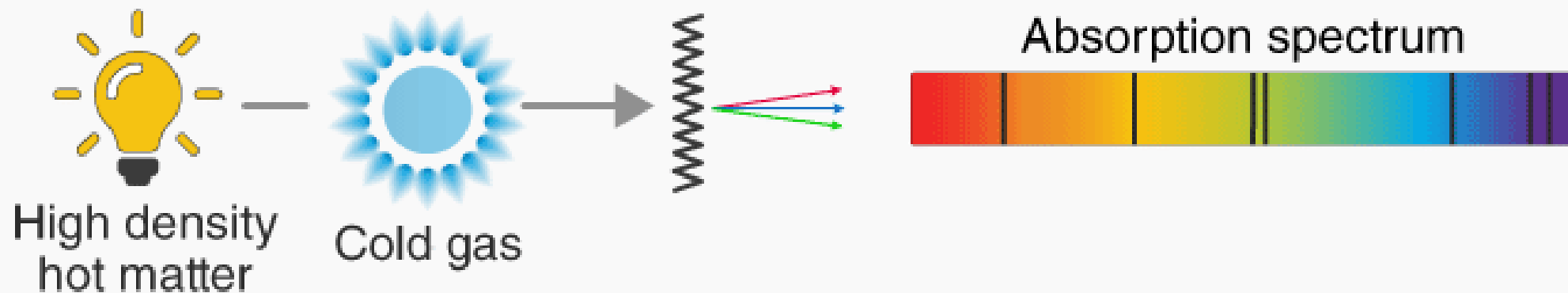


EMISSION VS. ABSORPTION SPECTRA

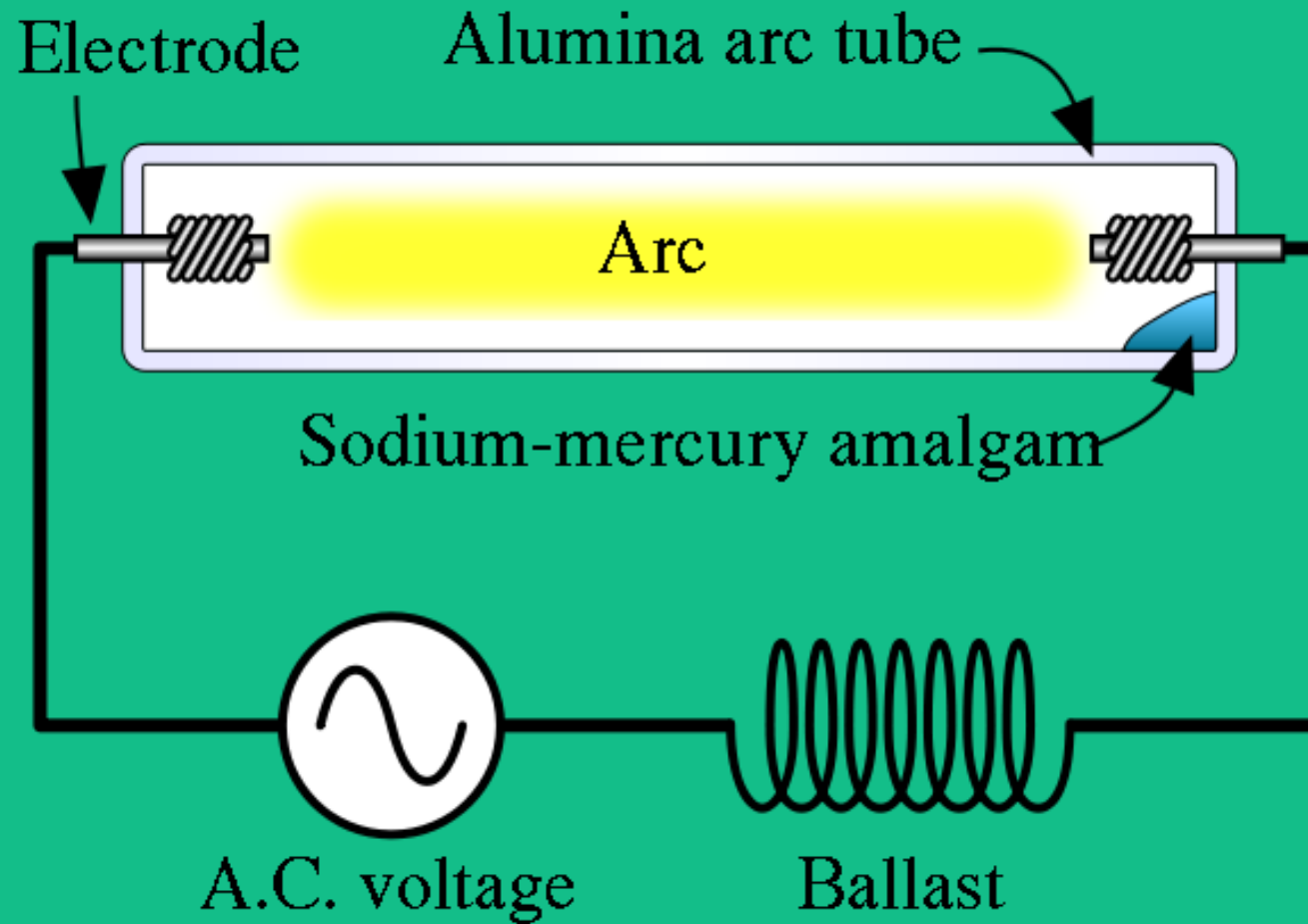
(a) Emission Spectra



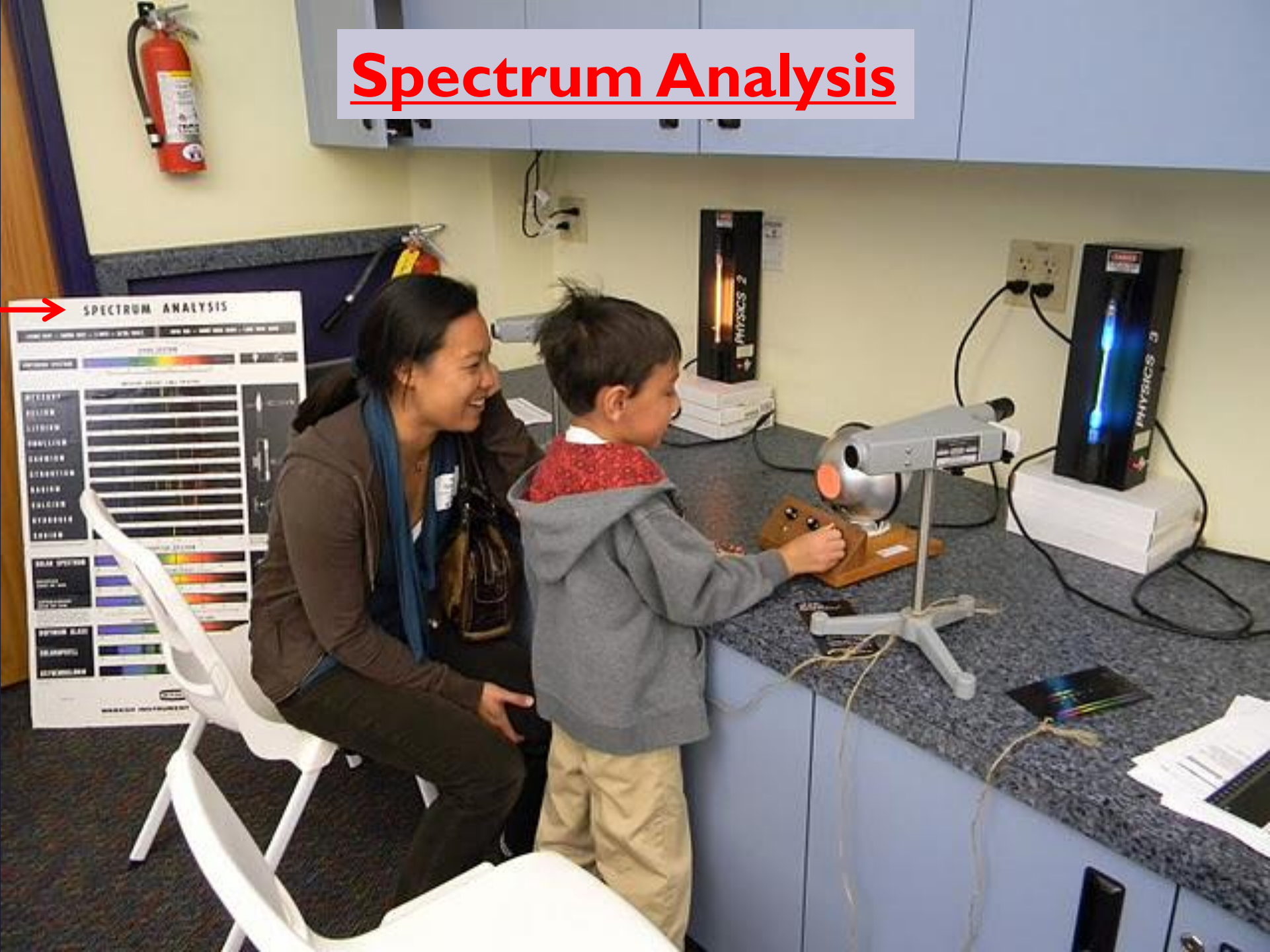
(b) Absorption Spectra



Gas-Discharge Lamps (“Neon” Lights)

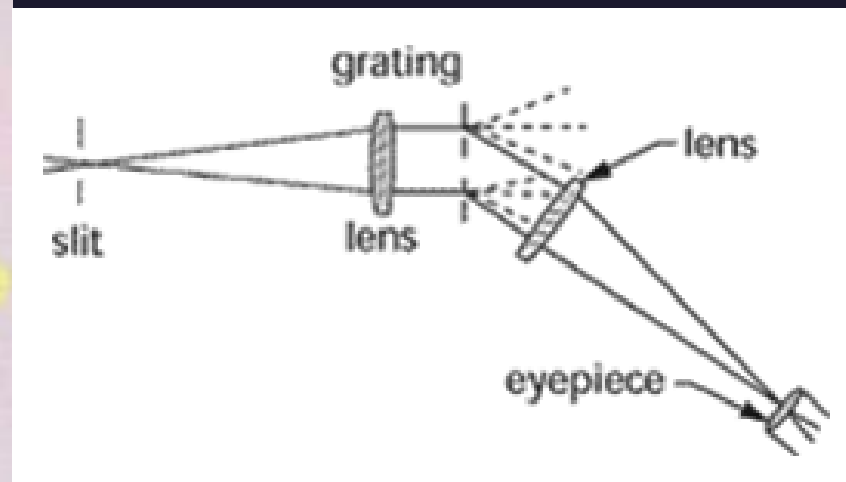
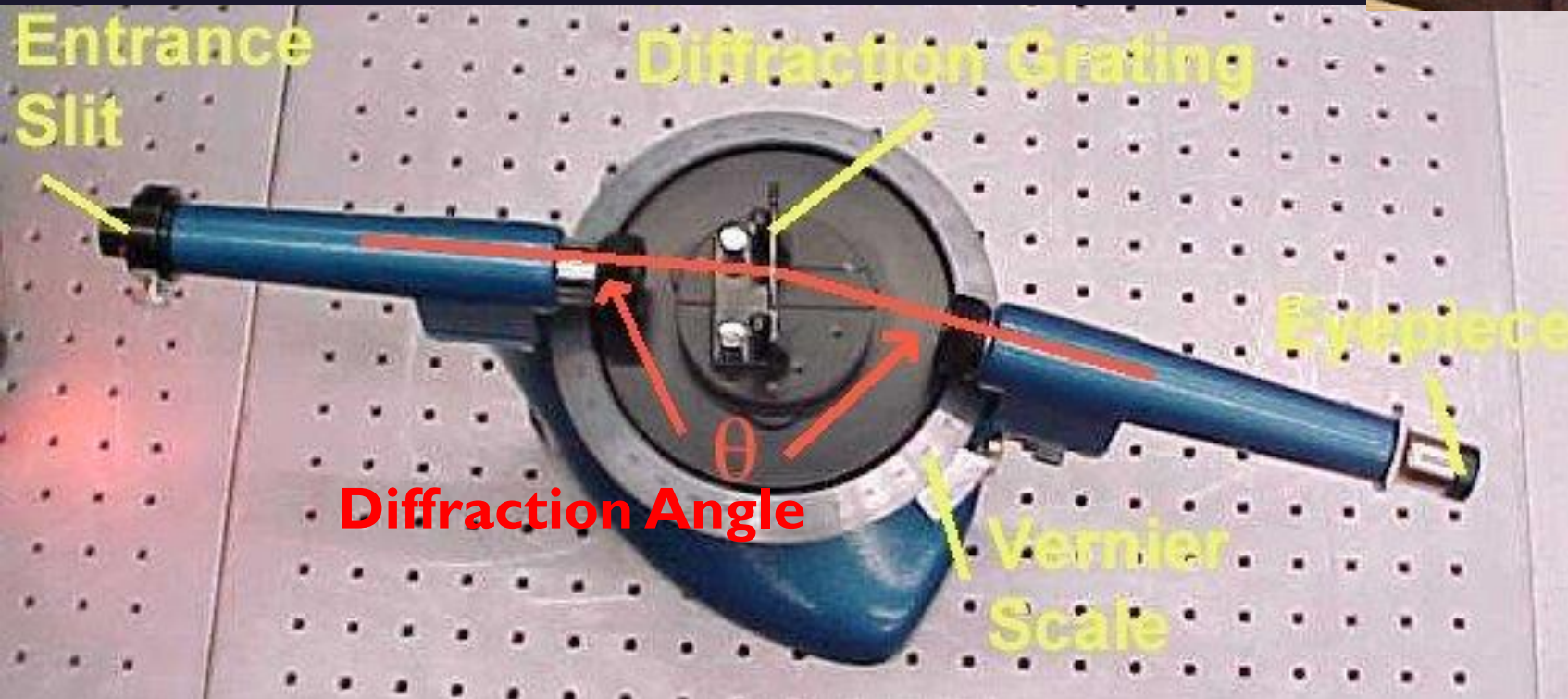
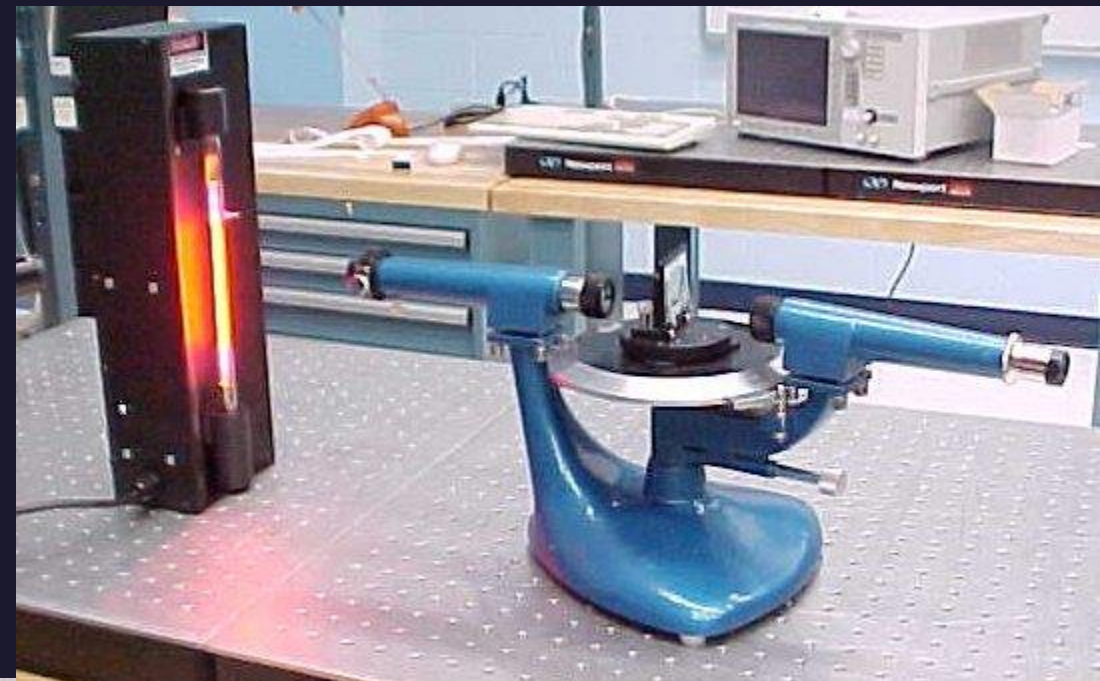


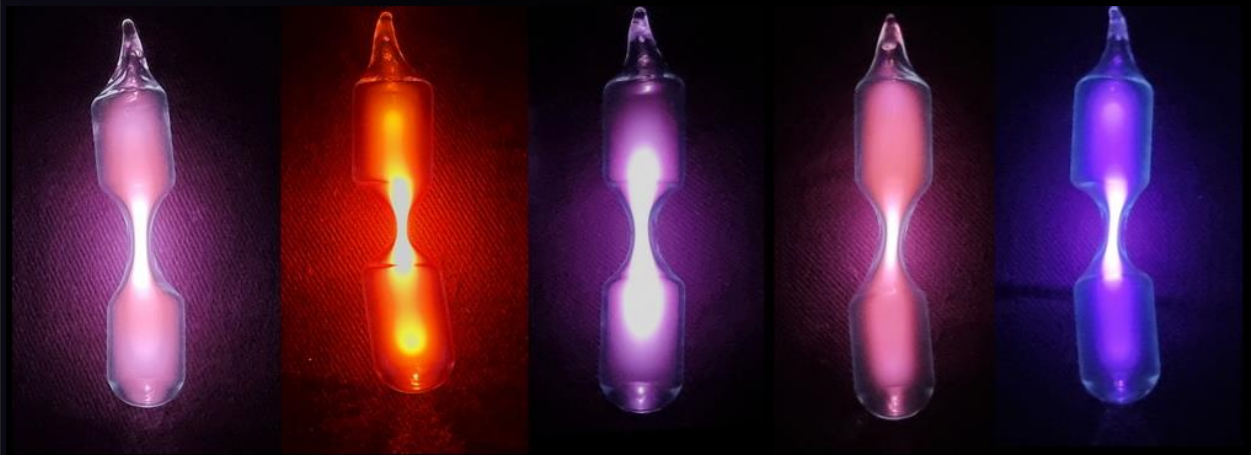
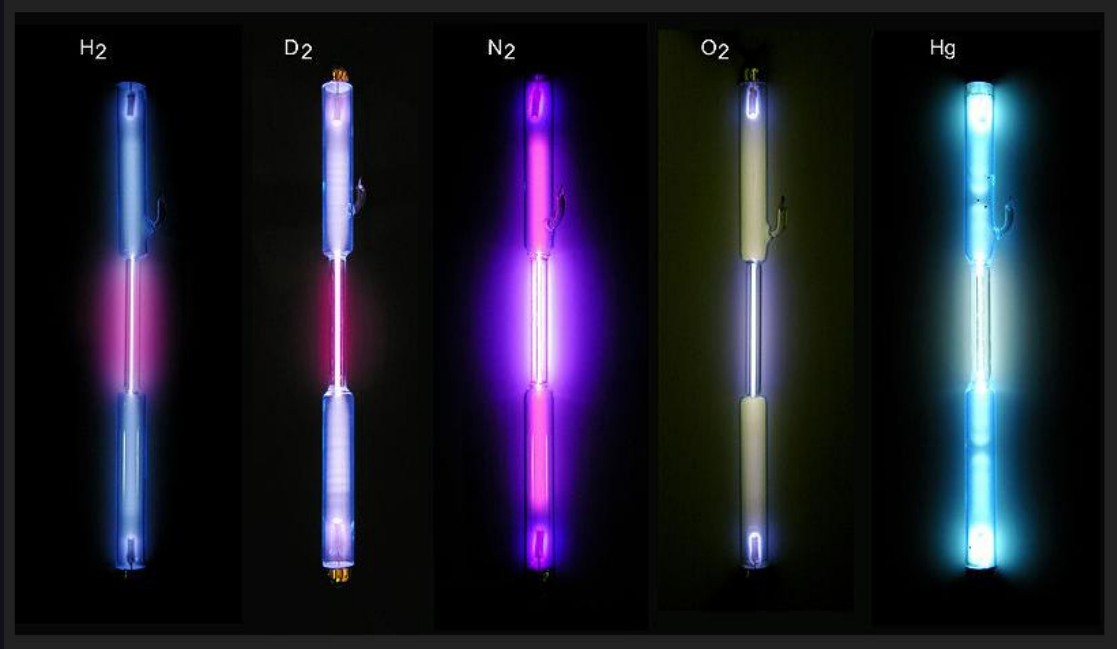
Spectrum Analysis



How a spectroscope works

Like combining a telescope and a microscope

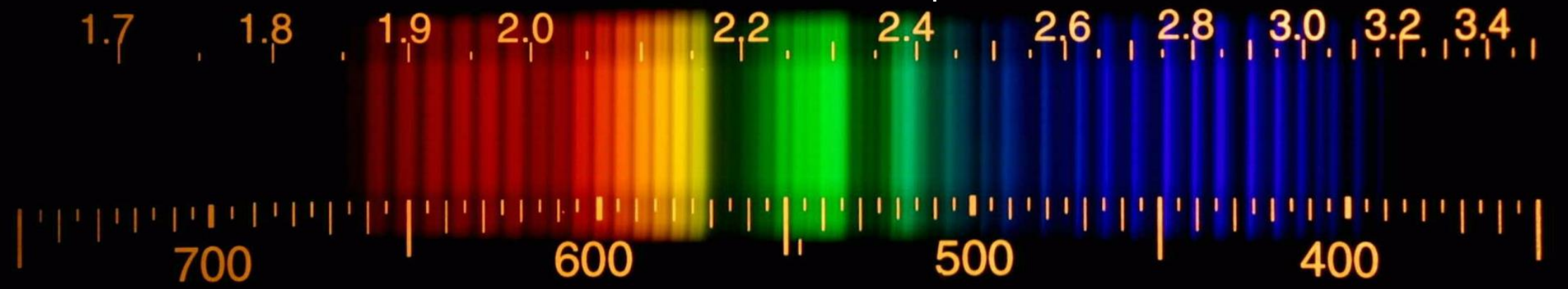




He Ne Ar Kr Xe



SPECTRUM OF NEON from pitt.edu



Diffraction Atomic Emission Spectra

Hg
Mercury 80
200.59



Lithium

Cd
Cadmium 48
112.41

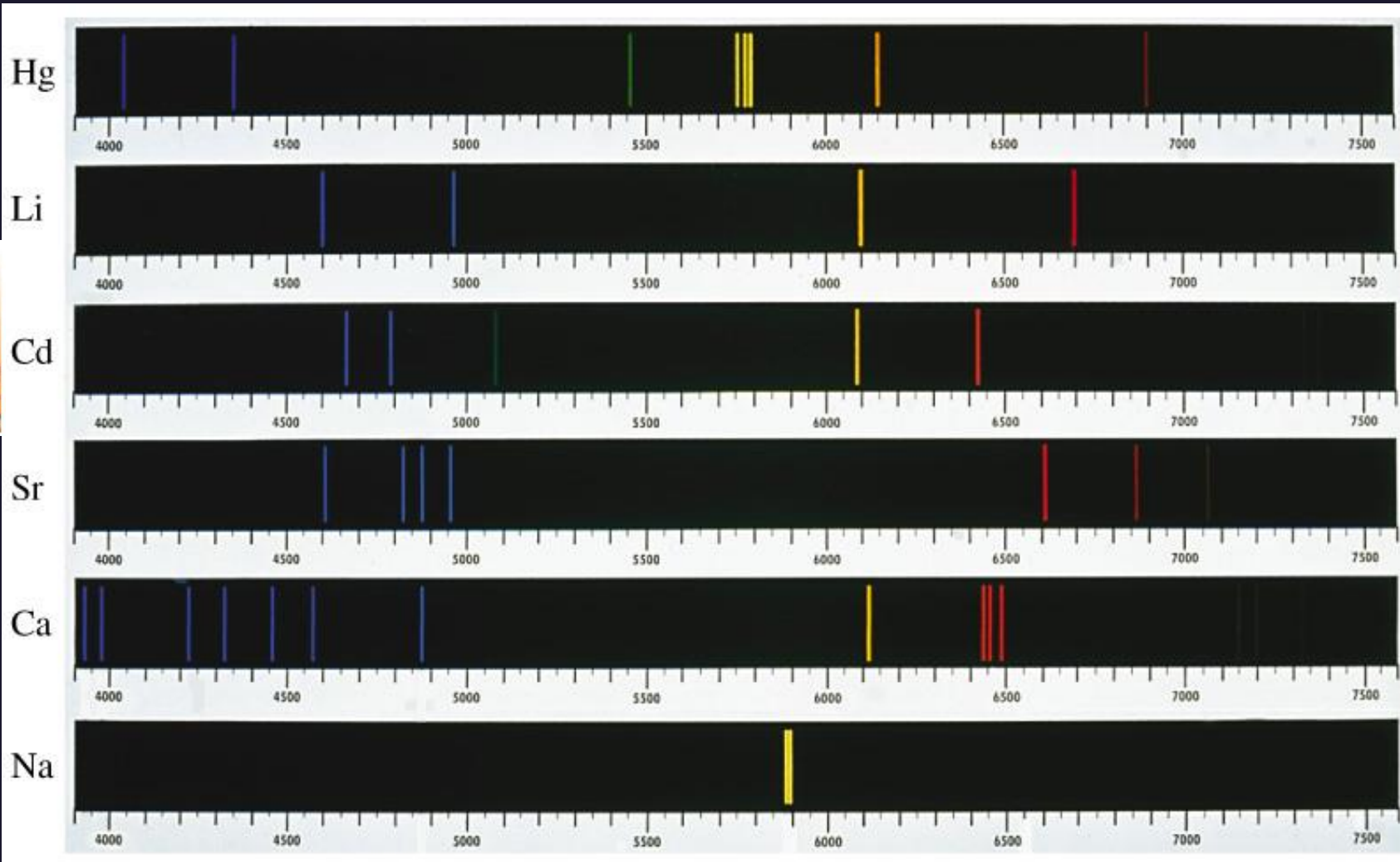


Strontium

Ca
Calcium 20
40.08

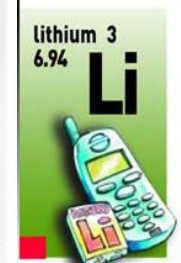


Sodium



Mercury

Li
Lithium 3
6.94



Cadmium

Sr
Strontium 38
87.62



Calcium

Na
Sodium 11
22.99



PERIODIC TABLE of the ELEMENTS



Privately sponsored by the SHUTTLEWORTH FOUNDATION

He
Helium 2
4.00

H
Hydrogen 1.01

Li
Lithium 7
6.94

Be
Beryllium 4
9.01

Mg
Magnesium 12
24.31

Na
Sodium 11
22.99

K
Potassium 19
39.10

Ca
Calcium 20
40.08

Rb
Rubidium 37
85.47

Sr
Strontium 38
87.62

Ba
Barium 56
137.33

Cs
Cesium 55
132.91

Ra
Radium 88
226

Fr
Francium 87
223



DMITRI MENDELEYEV (1834 - 1907)

The Russian chemist, Dmitri Mendeleev, was the first to observe that if elements were listed in order of atomic mass, they showed regular (periodic) repeating properties. He formulated his discovery in a particular table of elements, now regarded as the backbone of modern chemistry.

The crowning achievement of Mendeleev's periodic table lay in his grouping of then, unobserved elements. In 1869, the year he published his periodic classification, the elements gallium, germanium and scandium were unknown. Mendeleev left spaces for them in his table and even predicted their atomic masses and other chemical properties. Six years later, gallium was discovered and his predictions were found to be accurate. Other discoveries followed and their chemical behaviour matched that predicted by Mendeleev.

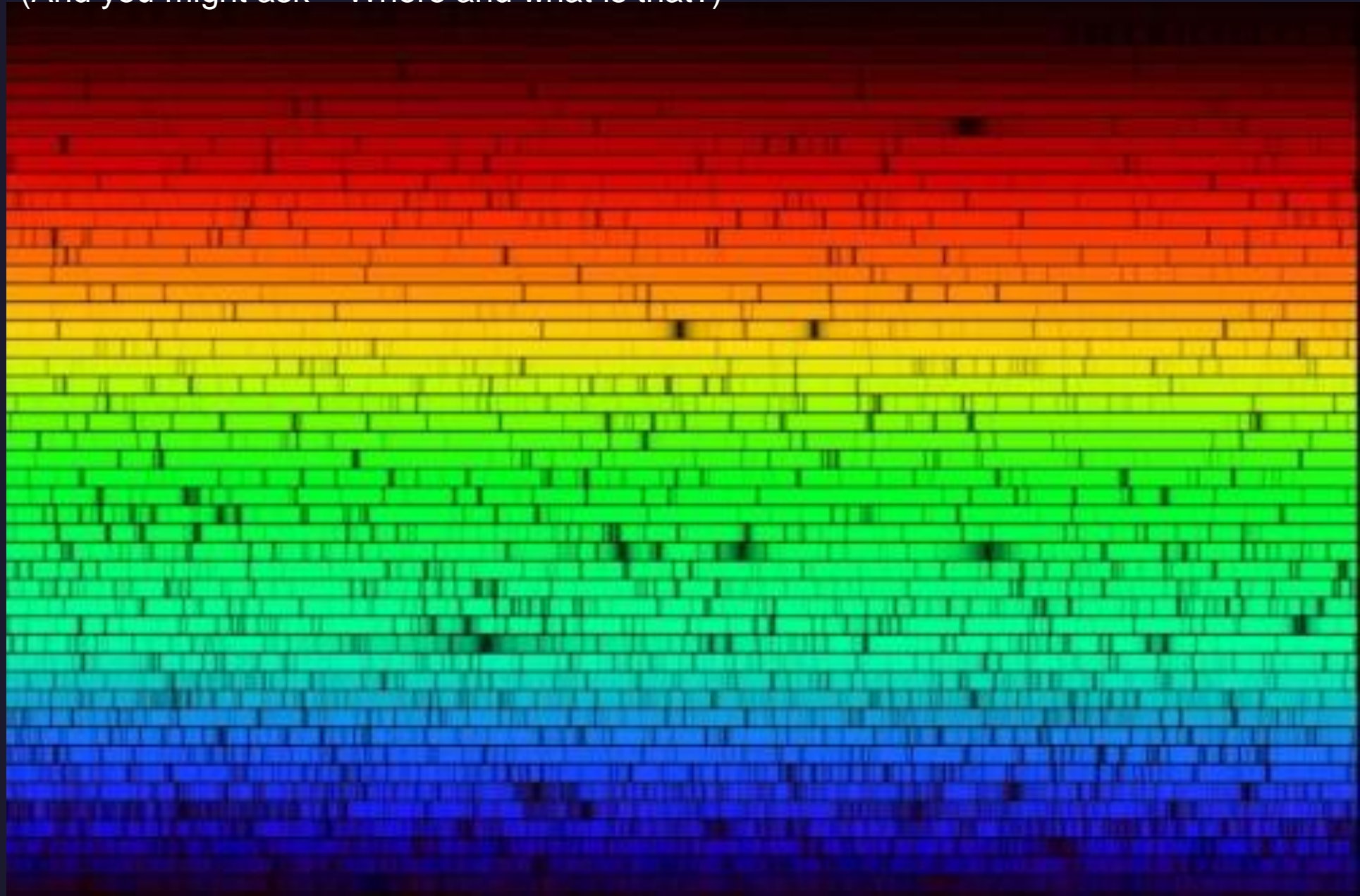
This remarkable man, the youngest in a family of 17 children, has left the scientific community with a classification system so powerful that it became the cornerstone in chemistry teaching and the prediction of new elements ever since. In 1956, element 101 was named after him, Md, Mendelevium.



Scandium 21 44.96	Titanium 22 47.88	Vanadium 23 50.94	Chromium 24 52.00	Manganese 25 54.94	Iron 26 55.85	Cobalt 27 58.93	Nickel 28 58.69	Copper 29 63.55	Zinc 30 65.39	Gallium 31 69.72	Germanium 32 72.61	Arsenic 33 74.92	Selenium 34 78.96	Bromine 35 79.90	Krypton 36 83.80						
Yttrium 39 88.91	Zirconium 40 91.22	Niobium 41 92.91	Molybdenum 42 95.94	Technetium 43 (98)	Ruthenium 44 101.07	Rhodium 45 102.91	Palladium 46 106.42	Silver 47 107.87	Cadmium 48 112.41	Indium 49 114.82	Tin 50 118.71	Antimony 51 121.76	Tellurium 52 127.60	Iodine 53 126.90	Xenon 54 131.29						
Lanthanide Series	Hafnium 72 178.49	Tantalum 73 180.95	Tungsten 74 183.85	Rhenium 75 186.21	Osmium 76 190.23	Iridium 77 192.22	Platinum 78 195.08	Gold 79 196.97	Mercury 80 200.59	Thallium 81 204.38	Lead 82 207.2	Bismuth 83 208.98	Poisonous 84 (209)	Astatine 85 (210)	Radon 86 (222)						
Actinide Series	Rutherfordium 104 261	Dubnium 105 262	Seaborgium 106 263	Berkelium 107 264	Hassium 108 265	Mt 109 266	La 57 138.91	Ce 58 140.12	Pr 59 140.91	Nd 60 144.24	Pm 61 145	Sm 62 150.36	Eu 63 151.96	Gd 64 157.25	Tb 65 158.93	Dy 66 162.50	Ho 67 164.93	Er 68 167.26	Tm 69 168.93	Yb 70 173.05	Lu 71 174.97
	Ac 89 227	Th 90 232	Pa 91 231	U 92 238	Np 93 237	Pu 94 244	Am 95 243	Cm 96 247	Bk 97 247	Cf 98 251	Es 99 252	Fm 100 257	Md 101 288	No 102 289	Lr 103 260						



Famous very high-resolution Solar Spectrum taken at Kitt Peak's Solar Observatory
Using the McMath-Pierce Solar Telescope.
(And you might ask – Where and what is that?)

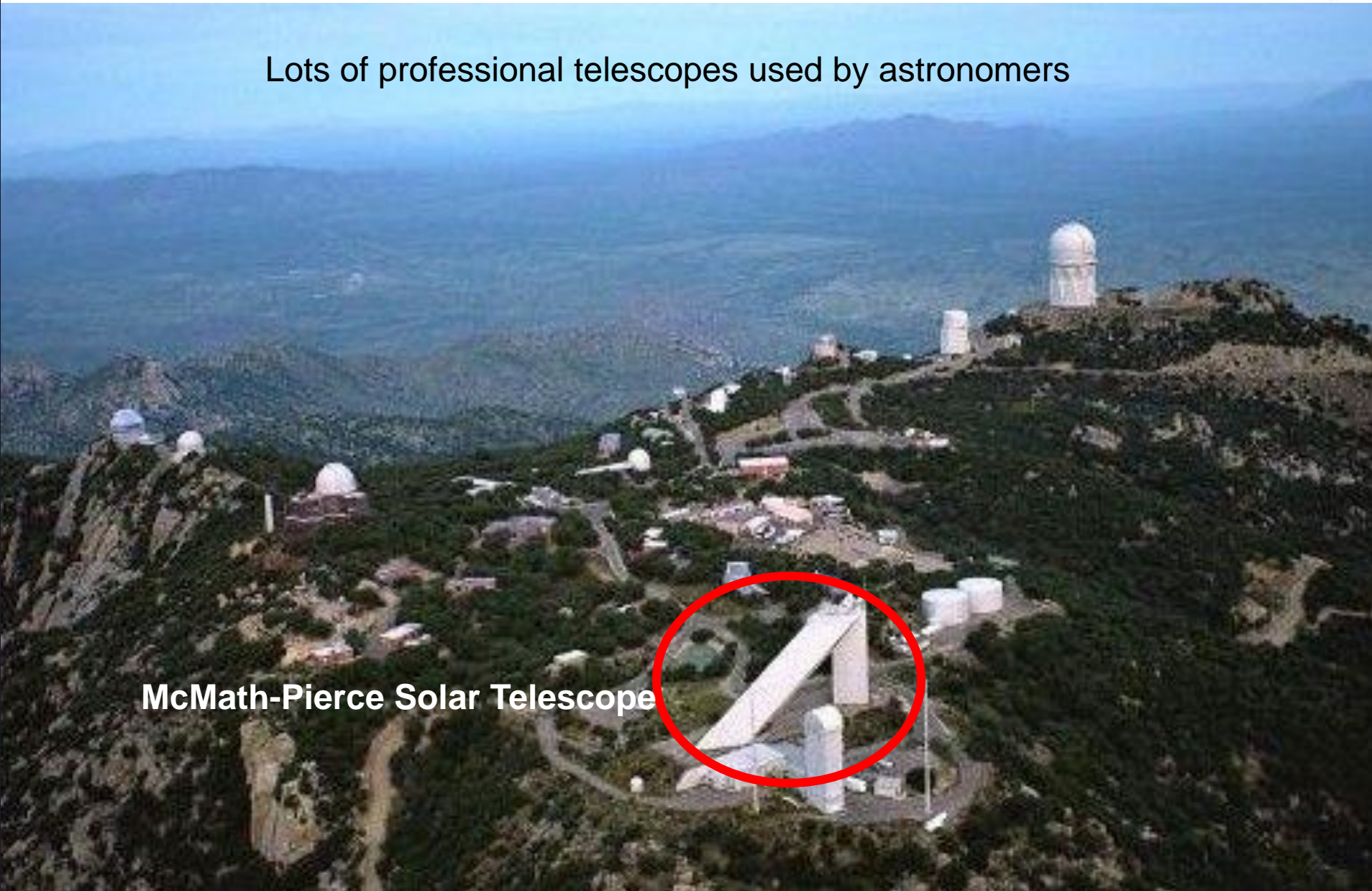




KITT PEAK NATIONAL OBSERVATORY



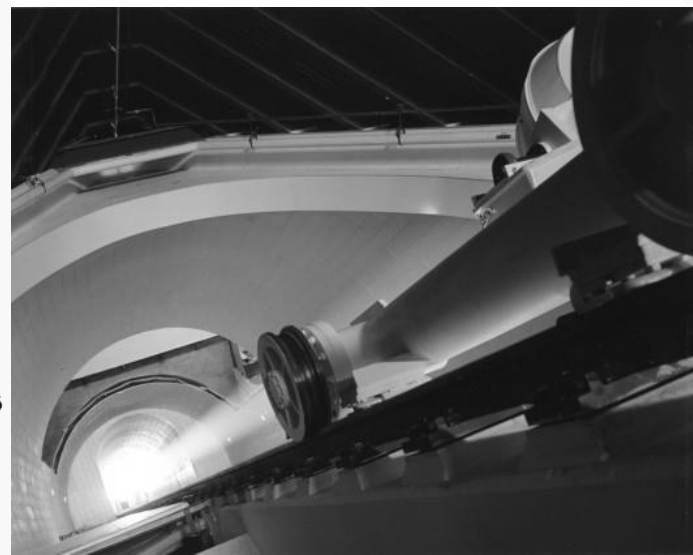
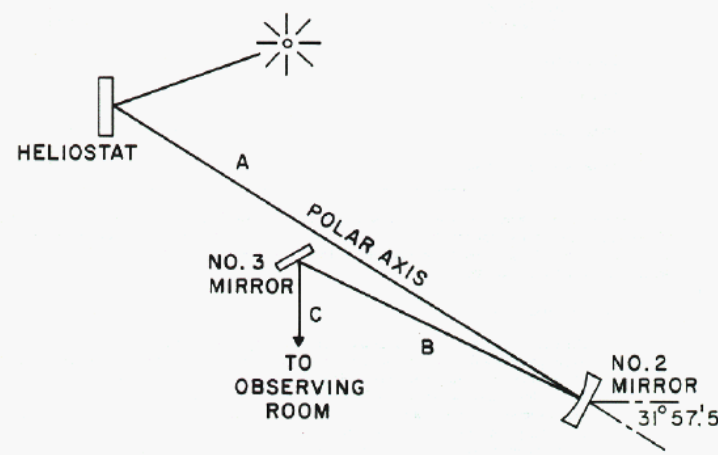
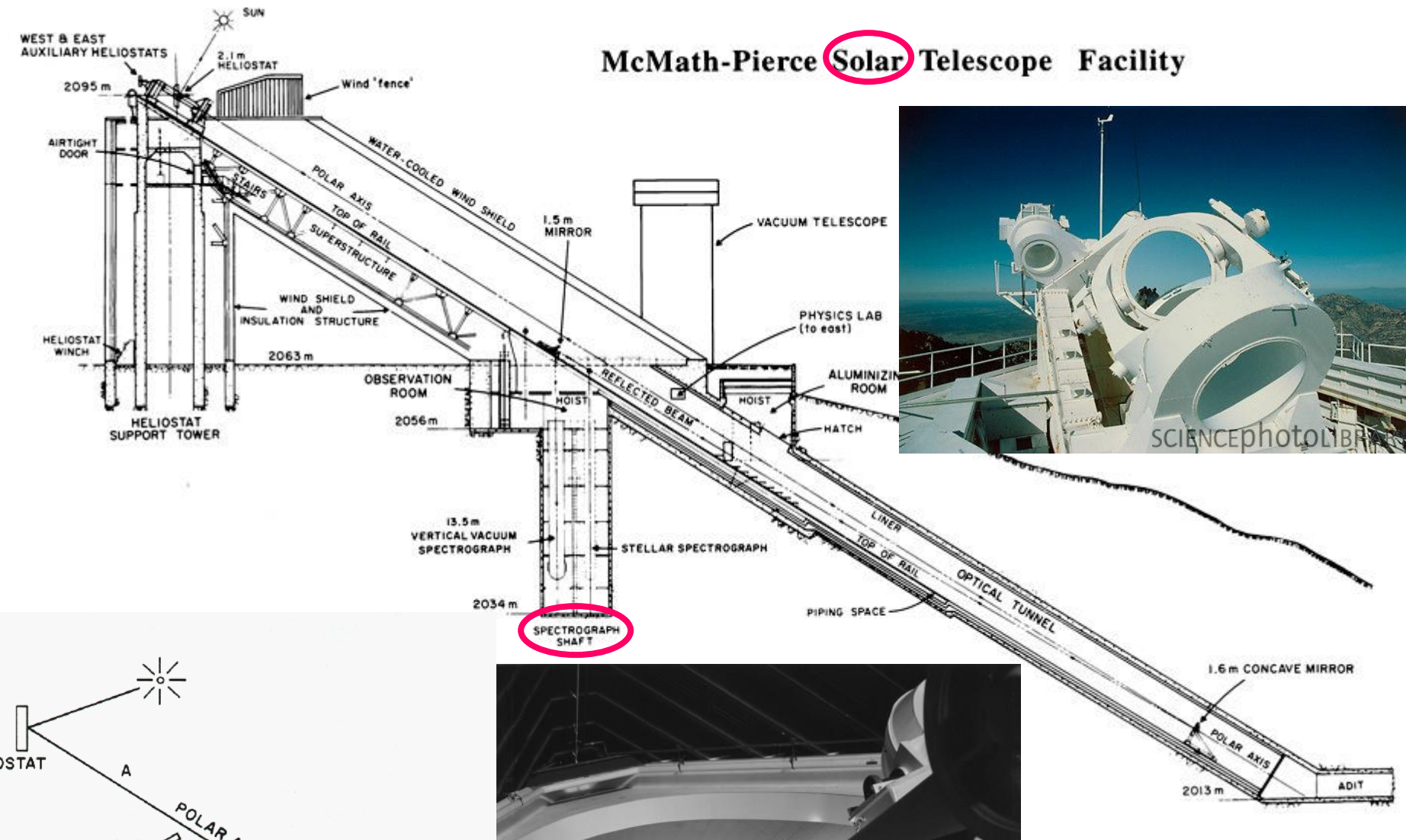
Lots of professional telescopes used by astronomers



McMath-Pierce Solar Telescope

Near Tucson, AZ

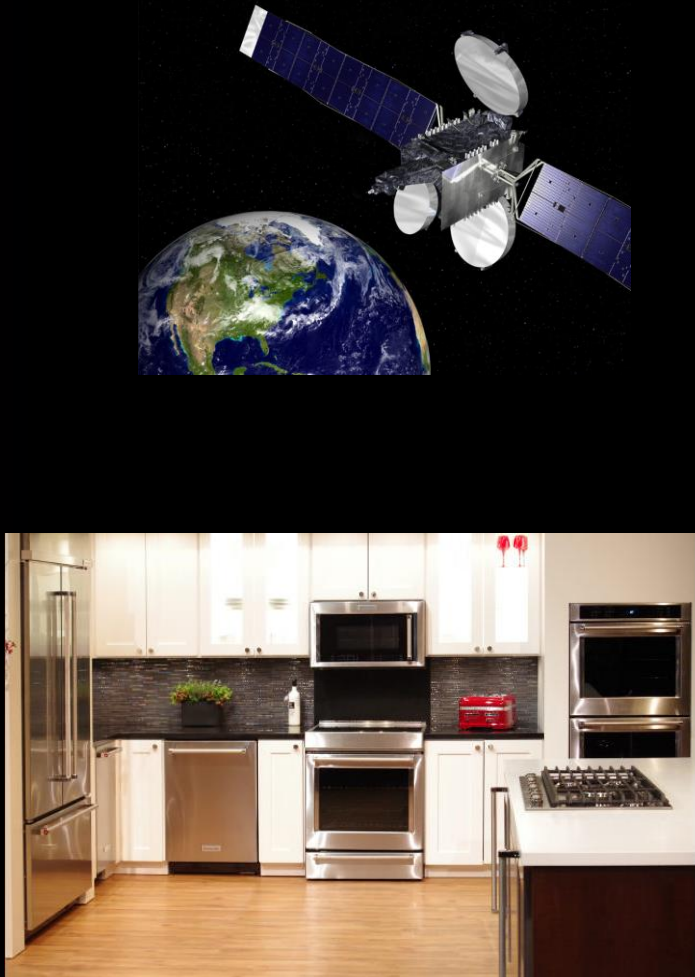
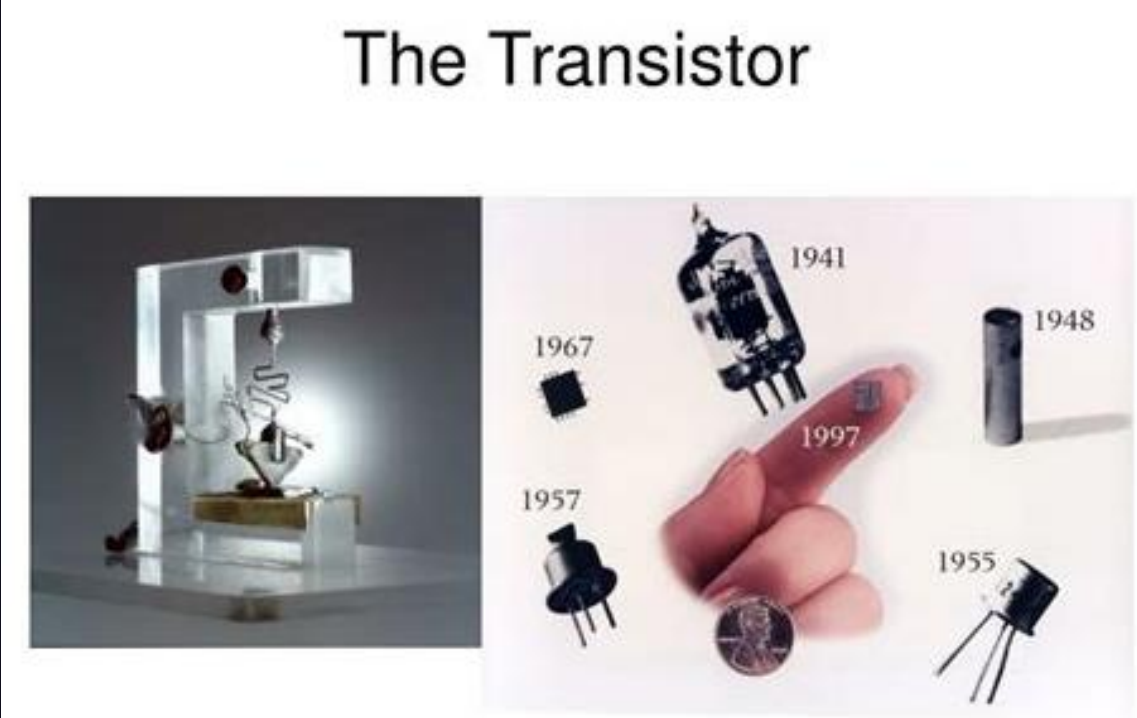
McMath-Pierce **Solar** Telescope Facility



[History of the transistor – Wikipedia](#) “After WWII, Shockley decided to attempt the building of a triode-like semiconductor device. He secured funding and lab space, and went to work on the problem with Bardeen and Brattain. John Bardeen eventually developed **a new branch of quantum mechanics known as surface physics** to account for the "odd" behavior they saw, and Bardeen and Walter Brattain eventually succeeded in building a working device.”

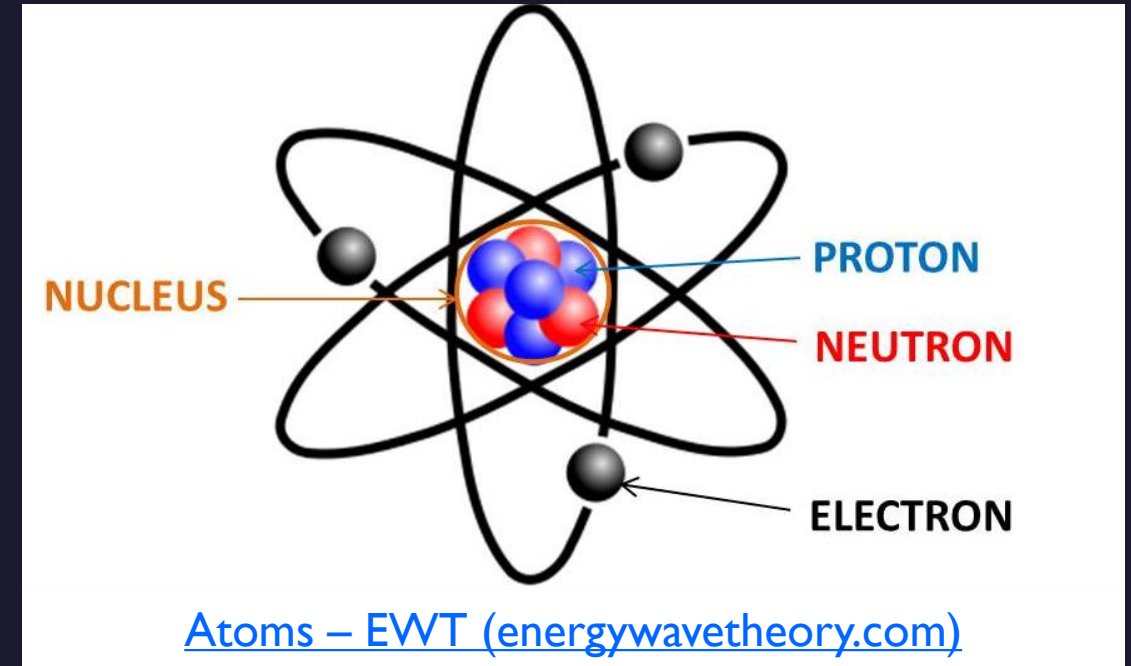
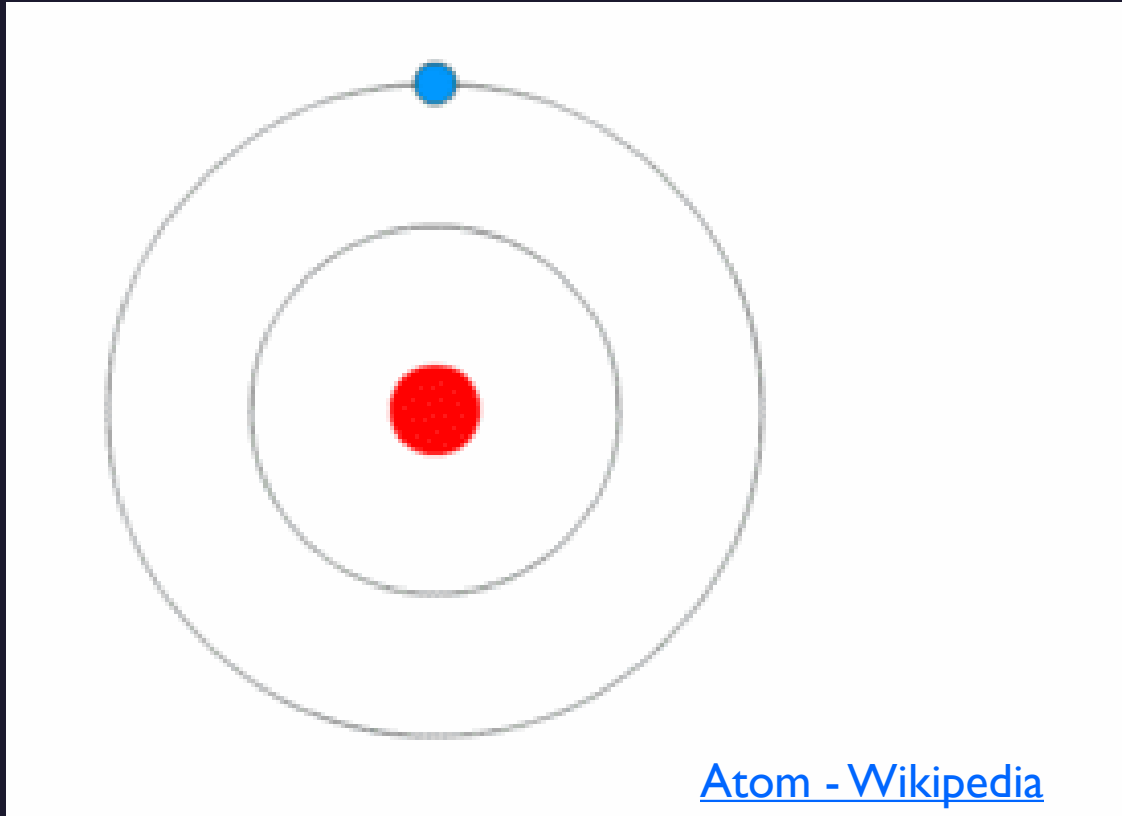


The Transistor



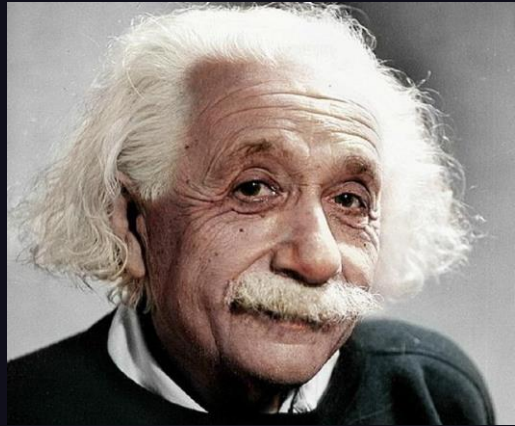
What are atoms & How do we know?

The Bohr model of the atom



The Bohr model of the atom, with an electron making instantaneous "quantum leaps" from one orbit to another with gain or loss of energy. This model of electrons in orbits is obsolete.

Fifth Solvay International Conference on **Electrons and Photons** October 1927



Albert Einstein



Niels Bohr



Erwin Schrödinger

The Solvay Conference, founded by the Belgian industrialist Ernest Solvay in 1912, was considered a turning point in the world of physics. Located in Brussels, the conferences were devoted to outstanding preeminent open problems in both physics and chemistry.

The most famous conference was the October 1927 Fifth Solvay International Conference on **Electrons and Photons**, where the world's most notable physicists met to discuss the newly formulated quantum theory. The leading figures were Albert Einstein and Niels Bohr.

Einstein, disenchanted with Heisenberg's uncertainty principle, remarked "God does not play dice". Bohr replied: "Einstein, stop telling God what to do". 17 of the 29 attendees were or became Nobel Prize winners, including Marie Curie, who alone among them, had won Nobel Prizes in two separate scientific disciplines.

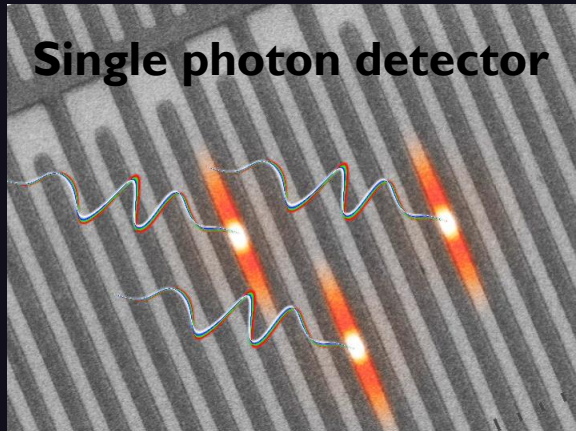
From Wikipedia: QUANTUM

In physics, a quantum is the minimum amount of any physical entity involved in an interaction. The fundamental notion that a physical property can be "quantized" is referred to as "the hypothesis of quantization".

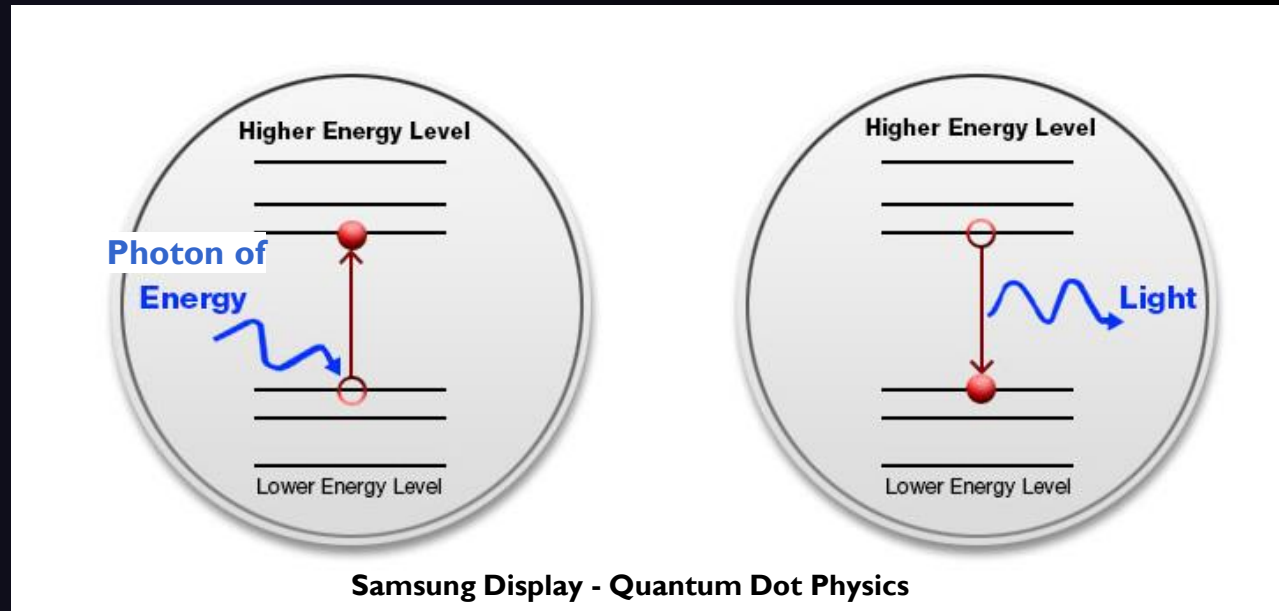
[1] This means that the magnitude of the physical property can take on only **discrete values** consisting of integer multiples of one quantum.

**Can't have 1 1/2 photons
Or 3/4 of an electron**

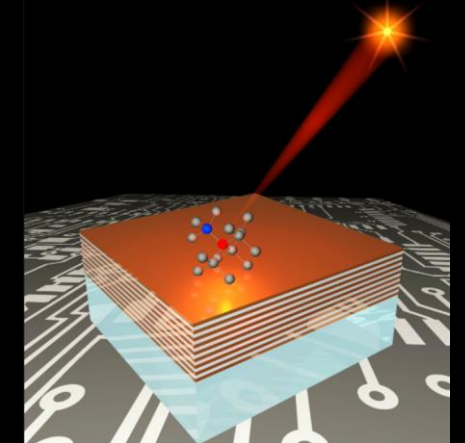
Graphic representation of an **electron (red O)** moving from one energy level to another, emitting or absorbing a **photon (Energy)** of light.



l-singlephoton.jpg (716x536) (b-cdn.net)



Single photon emitter



singlephoton.jpg (1000x1413) (b-cdn.net)

$$E = h\nu$$

frequency of radiation, sometimes written as f giving expression $E = hf$.
Quantum energy of a photon.
 $h = \text{Planck's constant} = 6.626 \times 10^{-34} \text{ Joule}\cdot\text{sec} = 4.136 \times 10^{-15} \text{ eV}\cdot\text{s}$

$$E=mc^2$$

PERIODIC TABLE of the ELEMENTS



Freely sponsored by the SHUTTLEWORTH FOUNDATION



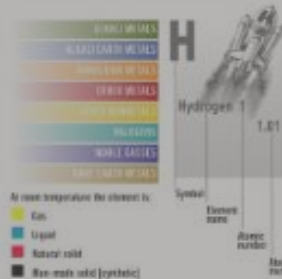
H Hydrogen 1.01

Li Lithium 3 6.94

Be Beryllium 4 9.01

Mg Magnesium 12 24.31

Na Sodium 11 22.99



DMITRI MENDELEYEV (1834 - 1907)

The Russian chemist, Dmitri Mendeleev, was the first to observe that if elements were listed in order of atomic mass, they showed regular (periodic) repeating properties. He formalized his discovery in a periodic table of elements, now regarded as the backbone of modern chemistry.

The crowning achievement of Mendeleev's periodic table lay in his prophecy of then undiscovered elements. In 1869, the year he published his periodic classification, the elements gallium, germanium and scandium were unknown. Mendeleev left spaces for them in his table and even predicted their atomic masses and other chemical properties. Six years later, gallium was discovered and its predictions were found to be accurate. Other discoveries followed and their chemical behaviour matched that predicted by Mendeleev.

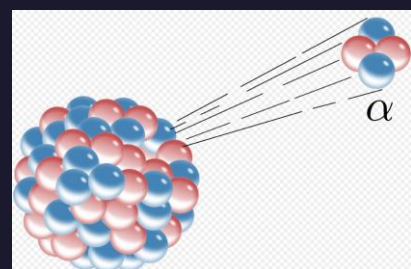
This remarkable man, the youngest in a family of 17 children, has left the scientific community with a classification system so powerful that it became the cornerstone in chemistry teaching and the prediction of new elements ever since. In 1946, element 101 was named after him, Md, Mendeleevium.



K Potassium 19 39.10	Ca Calcium 20 40.08	Sc Scandium 21 44.96	Ti Titanium 22 47.88	V Vanadium 23 50.94	Cr Chromium 24 52.00	Mn Manganese 25 54.94	Fe Iron 26 55.85	Co Cobalt 27 58.93	Ni Nickel 28 58.69	Cu Copper 29 63.55	Zn Zinc 30 65.39	Ga Gallium 31 69.72	Ge Germanium 32 72.61	As Arsenic 33 74.92	Se Selenium 34 78.96	Br Bromine 35 79.90	Kr Krypton 36 83.80
Rb Rubidium 37 85.47	Sr Strontium 38 87.62	Y Yttrium 39 88.91	Zr Zirconium 40 91.22	Nb Niobium 41 92.91	Mo Molybdenum 42 95.94	Tc Technetium 43 (98)	Ru Ruthenium 44 101.07	Rh Rhodium 45 102.91	Pd Palladium 46 106.42	Ag Silver 47 107.87	Cd Cadmium 48 112.41	In Indium 49 114.82	Sn Tin 50 118.71	Sb Antimony 51 121.76	Te Tellurium 52 127.60	I Iodine 53 126.90	Xe Xenon 54 131.29
Cs Cesium 55 132.91	Ba Barium 56 137.33	Lanthanide Series	Hf Hafnium 72 178.49	Ta Tantalum 73 180.95	W Tungsten 74 183.85	Re Rhenium 75 186.21	Os Osmium 76 190.23	Ir Iridium 77 192.22	Pt Platinum 78 195.08	Au Gold 79 196.97	Hg Mercury 80 200.59	Tl Thallium 81 204.38	Pb Lead 82 207.20	Bi Bismuth 83 208.98	Po Polonium 84 (209)	At Astatine 85 (210)	Rn Radon 86 (222)

Fr Francium 87 (223)	Ra Radium 88 (226)	Actinide Series	Rf Rutherfordium 104 (261)	Db Dubnium 105 (262)	Sg Seaborgium 106 (263)	Bh Bohrium 107 (264)	Hs Hassium 108 (265)	Mt Meitnerium 109 (266)
-----------------------------	---------------------------	------------------------	-----------------------------------	-----------------------------	--------------------------------	-----------------------------	-----------------------------	--------------------------------

La Lanthanum 57 138.91	Ce Cerium 58 140.12	Pr Praseodymium 59 140.91	Nd Neodymium 60 144.24	Pm Promethium 61 (145)	Sm Samarium 62 150.36	Eu Europium 63 151.96	Gd Gadolinium 64 157.25	Tb Terbium 65 158.93	Dy Dysprosium 66 162.50	Ho Holmium 67 164.93	Er Erbium 68 167.26	Tm Thulium 69 168.93	Yb Ytterbium 70 173.05	Lu Lutetium 71 174.97
Ac Actinium 89 227.03	Th Thorium 90 232.04	Pa Protactinium 91 231.04	U Uranium 92 238.03	Np Neptunium 93 (237)	Pu Plutonium 94 (244)	Am Americium 95 (243)	Cm Curium 96 (247)	Bk Berkelium 97 (247)	Cf Californium 98 (251)	Es Einsteinium 99 (252)	Fm Fermium 100 (257)	Md Mendelevium 101 (258)	No Nobelium 102 (259)	Lr Lawrencium 103 (260)



Alpha decay by a nucleus emits an alpha particle made of helium's nucleus

Radioactive decay



Designed and produced by: Lorraine Taylor, Andrew Simpson, Bruce Phillips, © Foundation for Education, Science and Technology, 2010. All rights reserved.

Quantum Weirdness

(cat in a closed box – you can't see inside)

Schrödinger's Cat (or Kitten)

Is it dead or alive ??

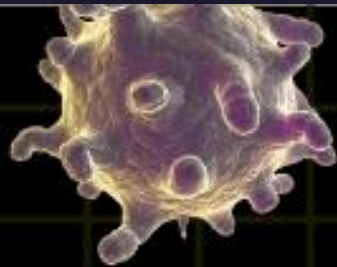


Radioactive Trigger

Drops the hammer
at an unknowable
time.

Breaks the bottle
Containing poison.

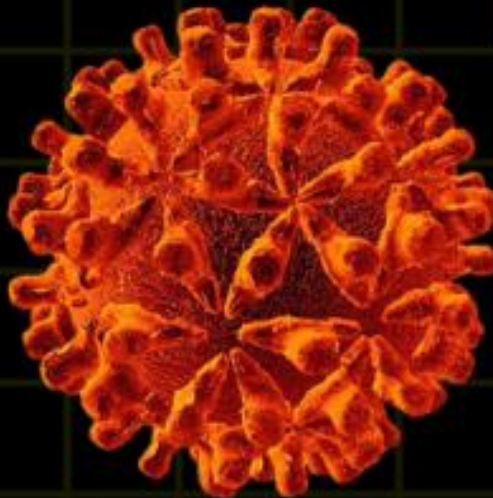
Schrödinger's Kittens



Rhinovirus
 3.00×10^{-8} m in diameter



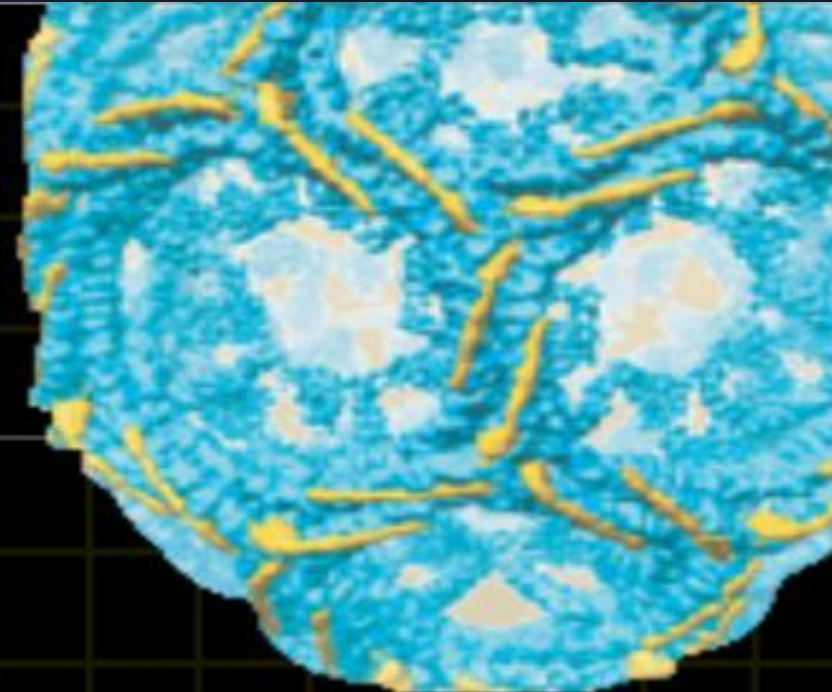
Antibody
 1.20×10^{-8} m long



Hepatitis
 4.50×10^{-8} m in diameter



Ribosome
 3.00×10^{-8} m in diameter



Coated Vesicle
 9.00×10^{-8} m in diameter



Where in the scale of things does Quantum effects take over?

Experience Life in the QuantumOptics Age

OpticsAge is a focal point for Donn Silberman's past Optics Education Adventures. Donn has retired from most of his educational outreach activities and his fulltime job at Starrett. This website will be periodically maintained as an educational resource.

Donn is now focused on his Quantum Explorations and is consulting on EdQuantum.



Follow the Digital White Rabbit

To learn more about:



Contact Us

First Name

Last Name

Email *

Write a message

Submit





Things at the Atomic Scale are very different than at the human scale.

Summary

- The Quantum World underlies our modern civilization.
- And Quantum is about take humanity to the next level.
- You can help make it happen.

Thank You

Donn Silberman

Optics Institute of Southern California

<http://oisc.net>