

# Are we alone in the Universe?



*Class 6.*

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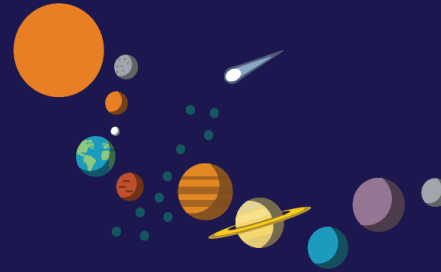
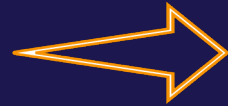
*High School Summer Course, 2023*



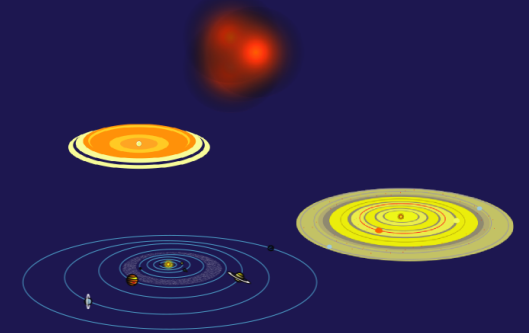
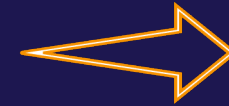
# Our Map:



What are there in the Universe?  
Scales involved in describing Universe



Our planet and Solar system



How did the Solar system form?  
Is it unique?

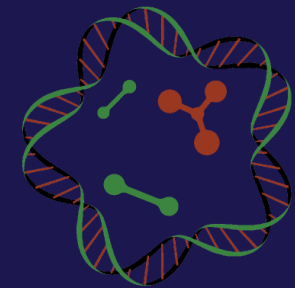
## Are we alone in the universe?



What form of life would you look for and how? Possibility of life on other planets.



How can we look for ET life?  
Atom and EM spectrum.



What is life?  
How did life on Earth begin? Building blocks of life, first form of life on Earth.

A person is sitting on a large, dark rock in the foreground, looking up at a vast night sky. The sky is filled with stars and the Milky Way galaxy, which is visible as a bright, colorful band of light stretching across the sky. The colors of the Milky Way range from blue and purple to orange and red. The background is a soft, hazy glow, possibly from a light source or a reflection on a surface.

# Today's goals... (learning objectives)

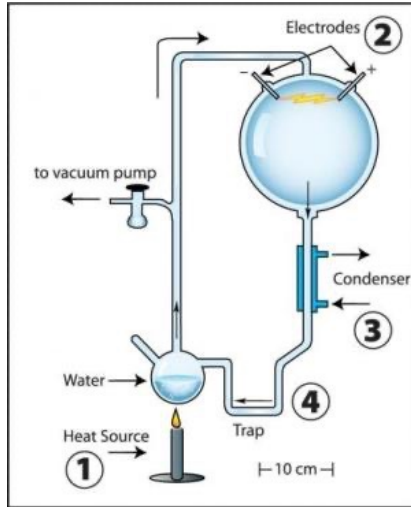
## Class 8.

By the end of this class, you should be able to:

1. Describe one **exoplanets detection method**
2. Describe how we can study stars' and exoplanets' properties using **EM spectra**

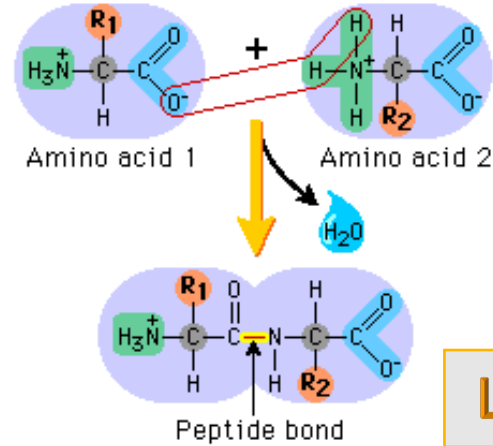


# Chemical Evolution



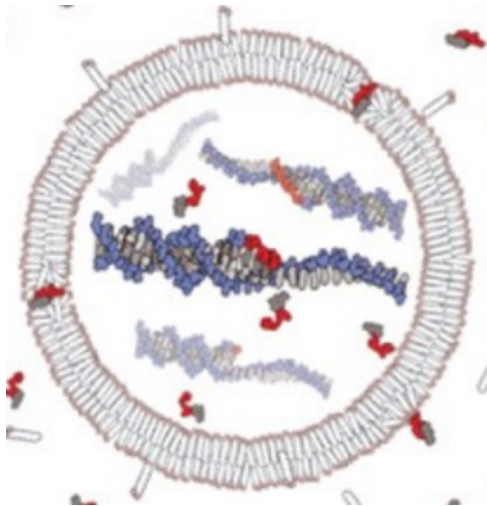
1. Synthesis of monomers (amino acids, nucleotides, ...)

Small molecules



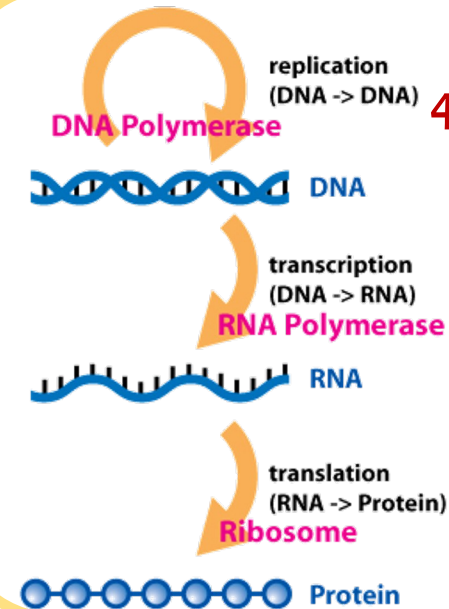
2. Polymer formation (e.g., RNA)

Large molecules



3. Protocell formation

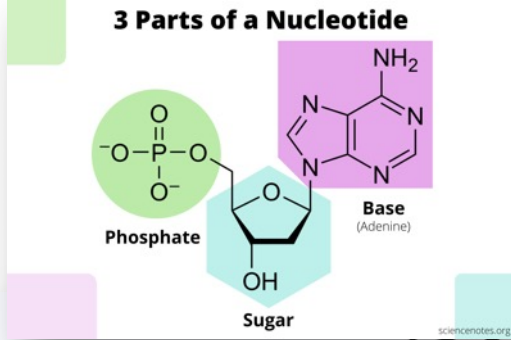
Cell membranes enclose the genetic material



4. Self-replication (The origin of RNA and DNA)



# “RNA world” hypothesis



## DNA vs. RNA

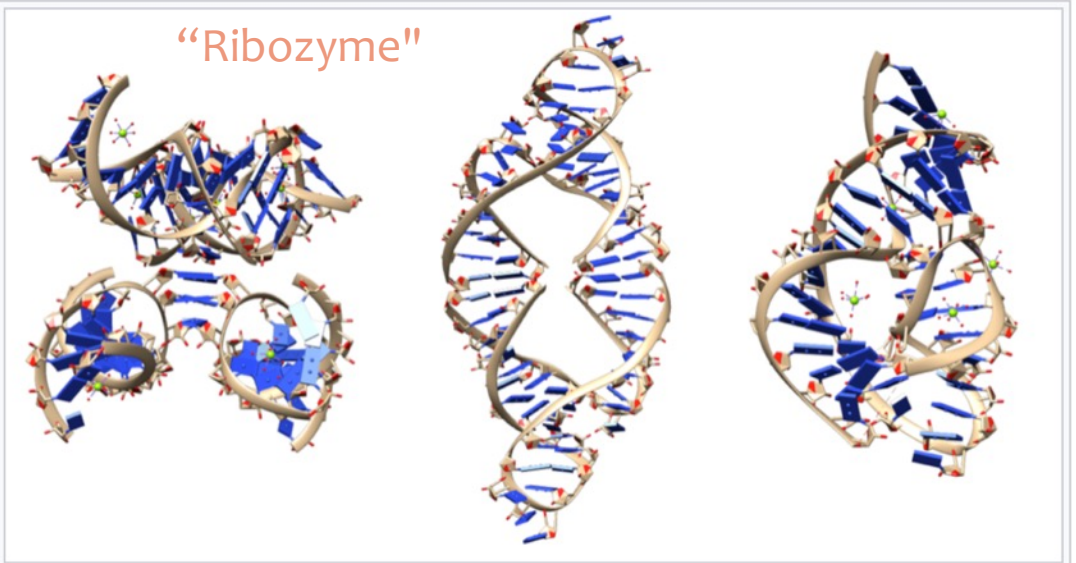
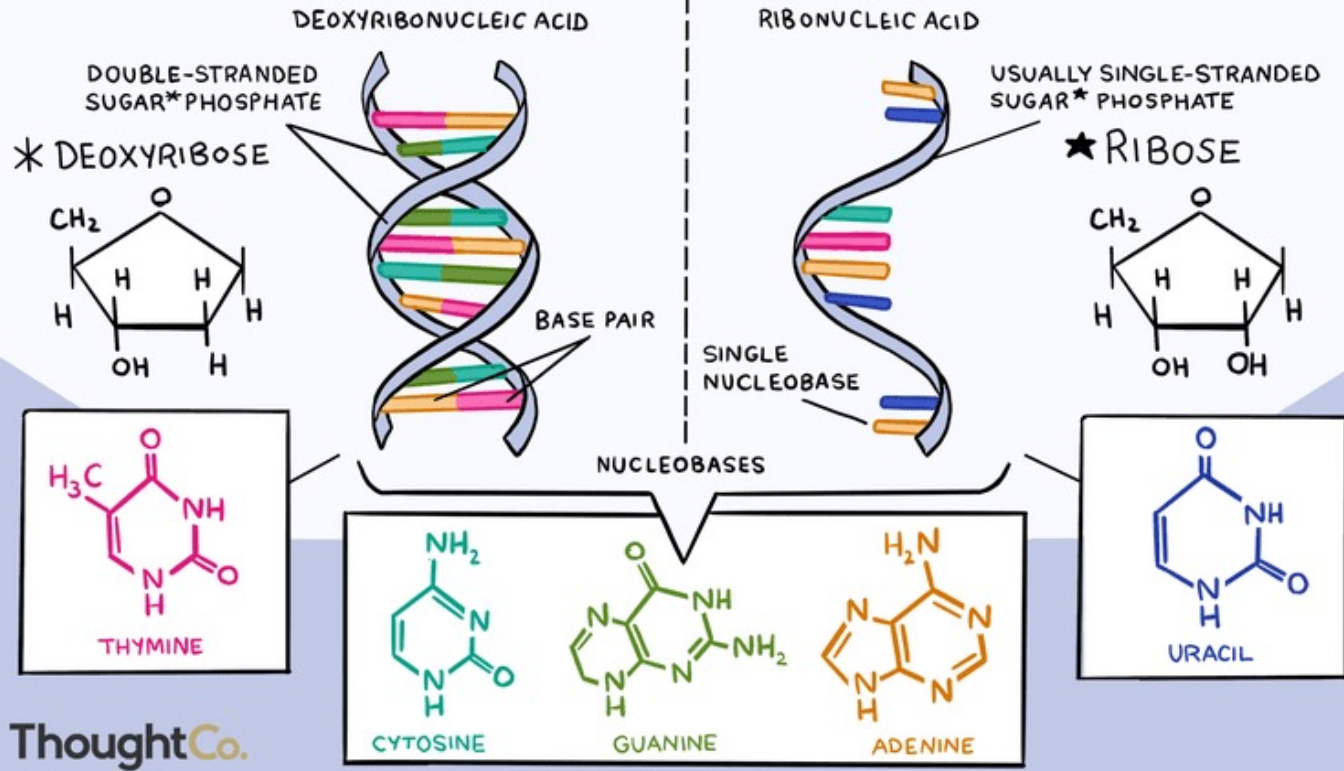


Image showing the diversity of ribozyme structures. From left to right: leadzyme, hammerhead ribozyme, twister ribozyme  
<https://en.wikipedia.org/wiki/Ribozyme>

### The Nobel Prize in Chemistry 1989



Photo from the Nobel Foundation archive.  
 Sidney Altman  
 Prize share: 1/2

Photo from the Nobel Foundation archive.  
 Thomas R. Cech  
 Prize share: 1/2

<https://www.nobelprize.org/prizes/chemistry/1989/summary/>

The Nobel Prize in Chemistry 1989 was awarded jointly to Sidney Altman and Thomas R. Cech "for their discovery of catalytic properties of RNA."



# “RNA world” hypothesis

...and life starts

But the recent discovery indicates...



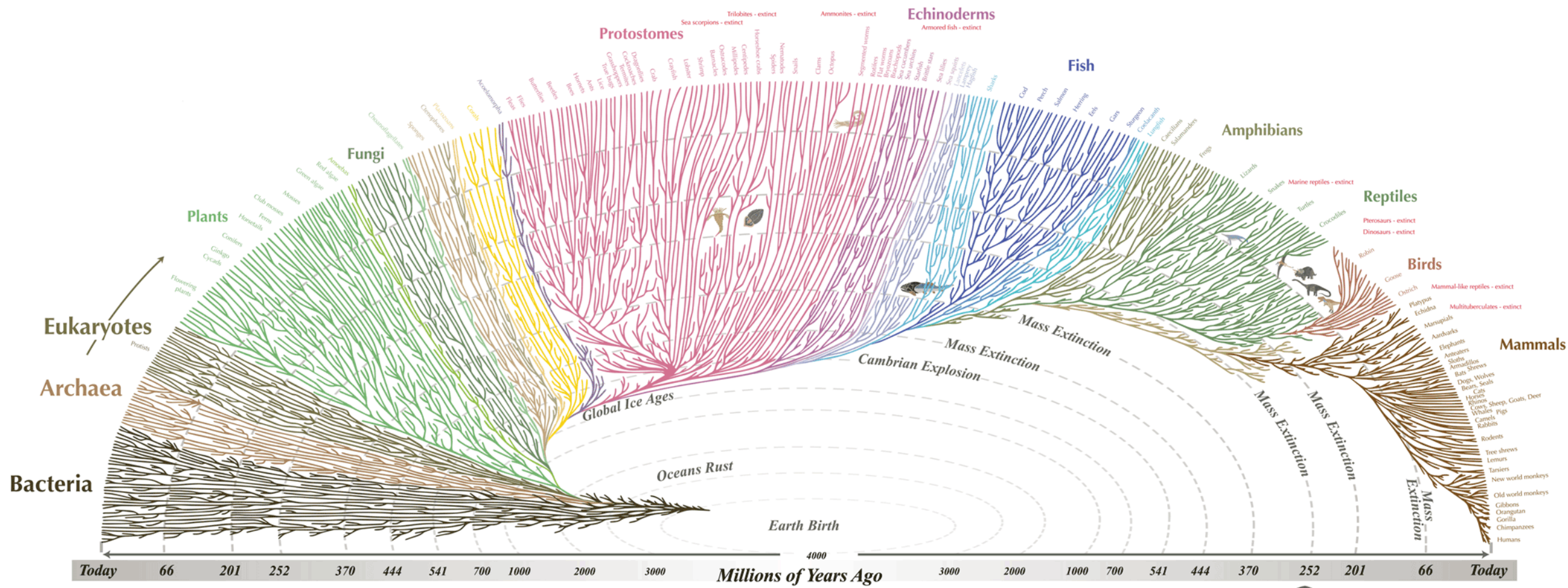
<https://phys.org/news/2020-12-discovery-boosts-theory-life-earth.html>




<https://link.springer.com/article/10.1007/s10531-015-0888-6>

Quiz: What is the main idea of the **chemical evolution** theory of origin of life?





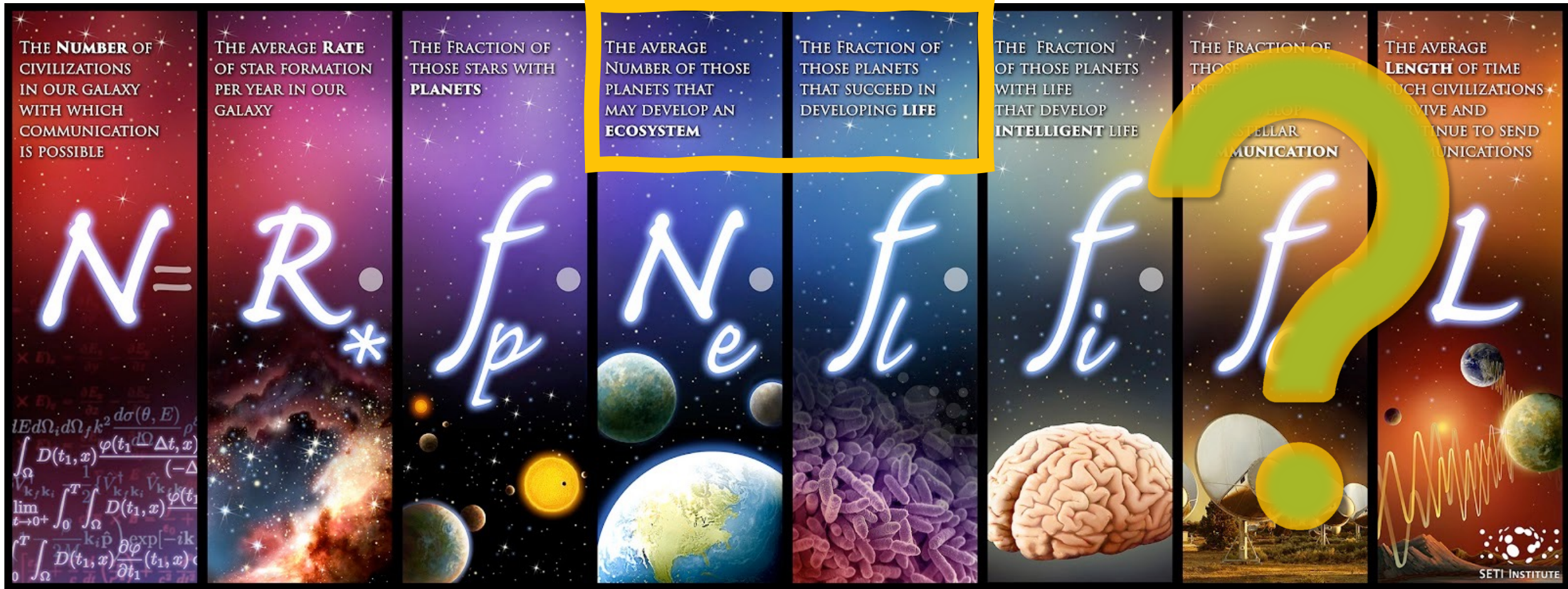
All the major and many of the minor living branches of life are shown on this diagram, but only a few of those that have gone extinct are shown. Example: **Dinosaurs - extinct** 

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What is the chance of an intelligent life developing...?



# Drake Equation







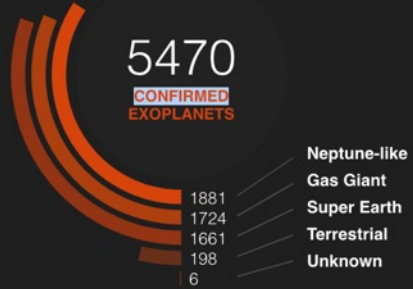
How do we look  
for extraterrestrial  
life?

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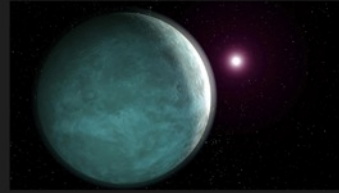




## Planet Types



## New Discovery



PLANET NAME  
TOI-908 b

PLANET TYPE  
Neptune-like

DISCOVERY DATE  
2023

DETECTION METHOD  
Transit

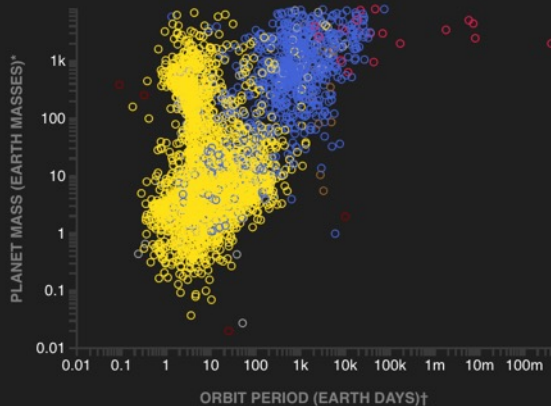
› More about this planet

<https://exoplanets.nasa.gov/alien-worlds/ways-to-find-a-planet/>

## Exoplanet Census

Display limited to planets with both measured or estimated orbital period and mass

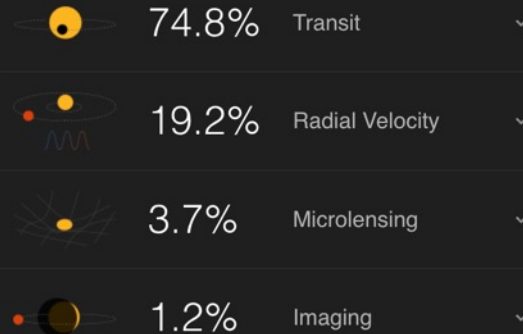
● Transit (4063) ● Radial Velocity (1037) ● Microlensing (10)  
● Imaging (19) ● Pulsar Timing (6) ● Other (50)



YEAR 2023 | DISCOVERIES‡ 5470

1989 2023

## By Method



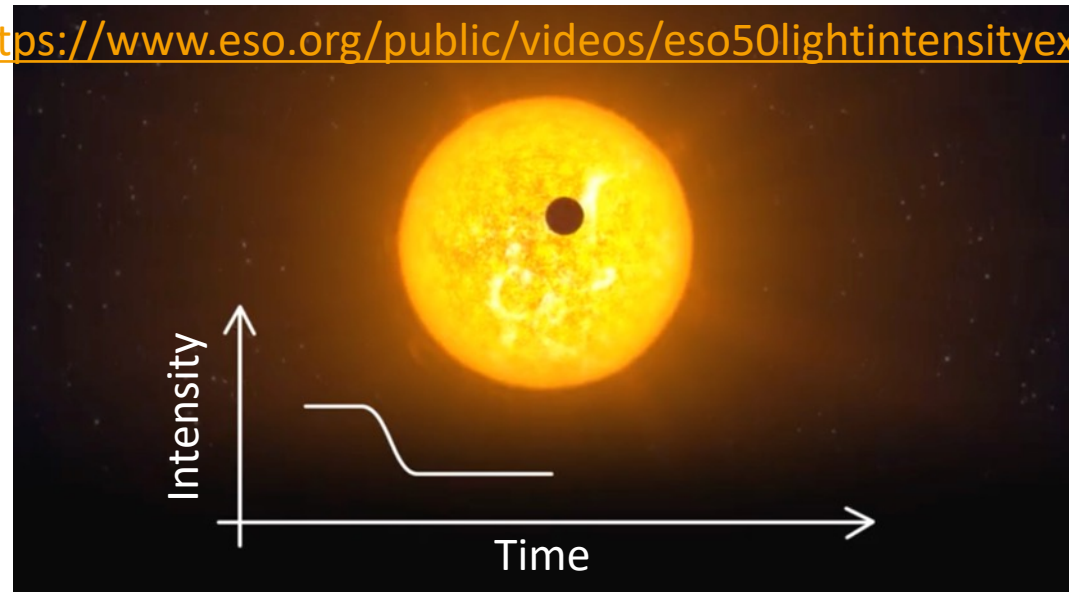
0.46% Transit Timing Variations, 0.31% Eclipse Timing Variations, 0.16% Orbital Brightness Modulation, 0.13% Pulsar Timing, 0.04% Astrometry, 0.04% Pulsation Timing Variations, 0.02% Disk Kinematics

› More about planet-hunting methods

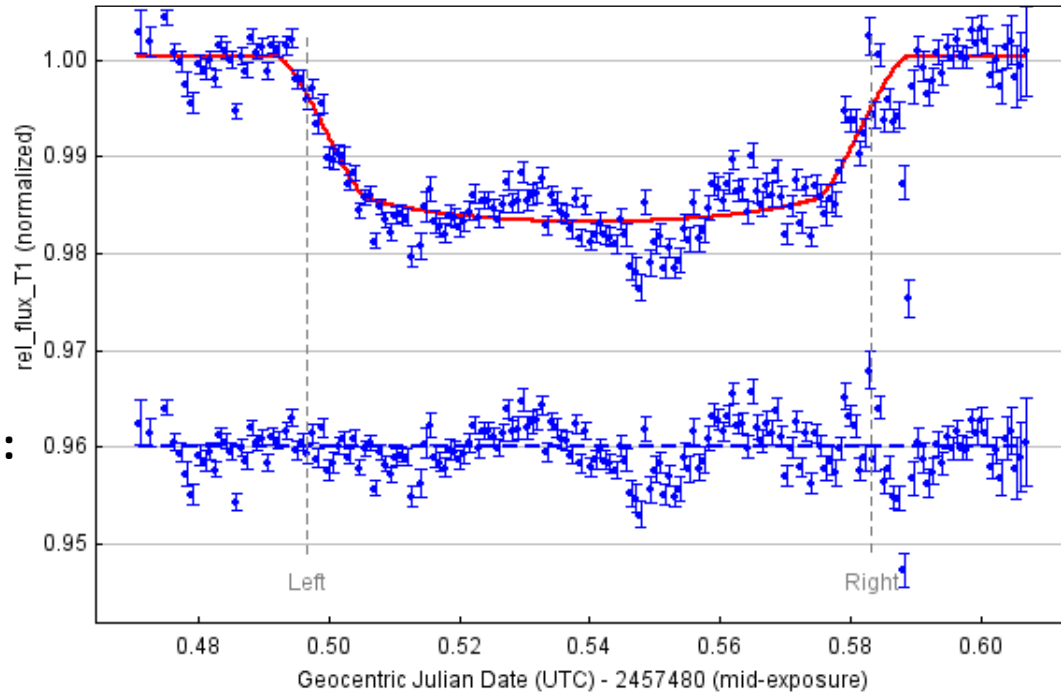
<https://exoplanets.nasa.gov>



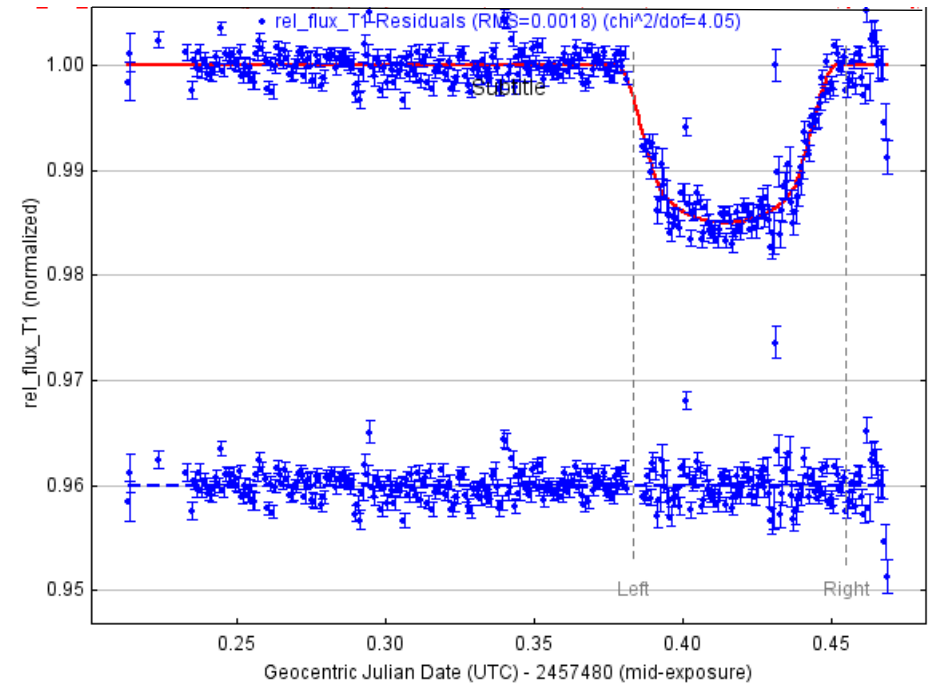
# Transit of an exoplanet



Observed:

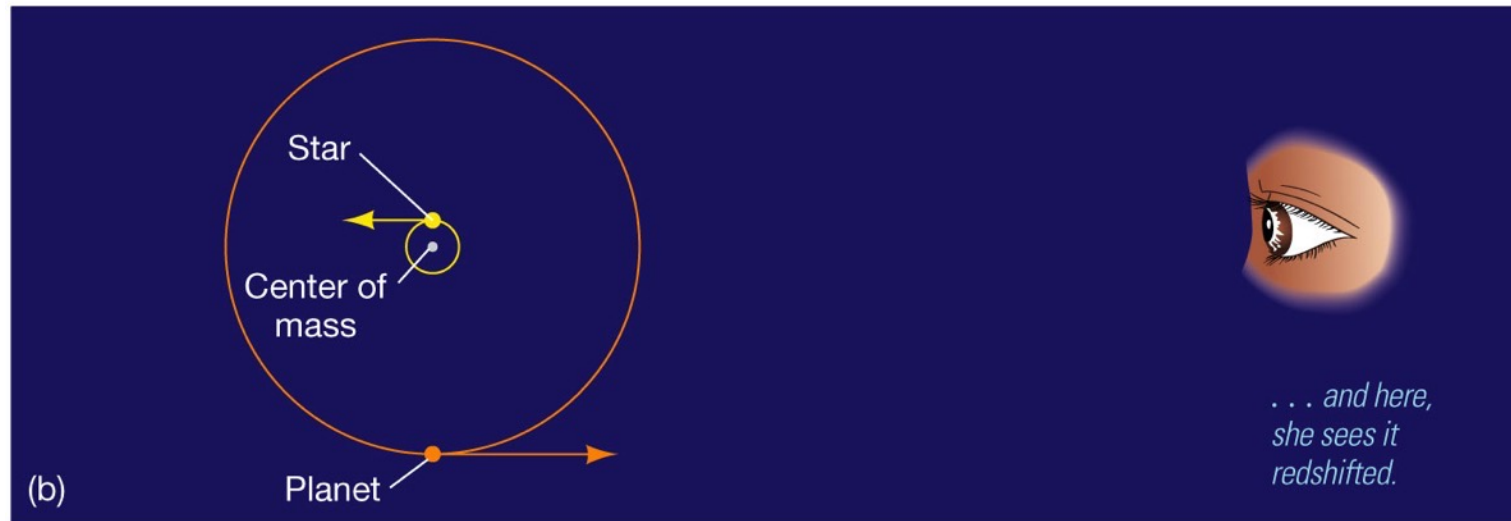
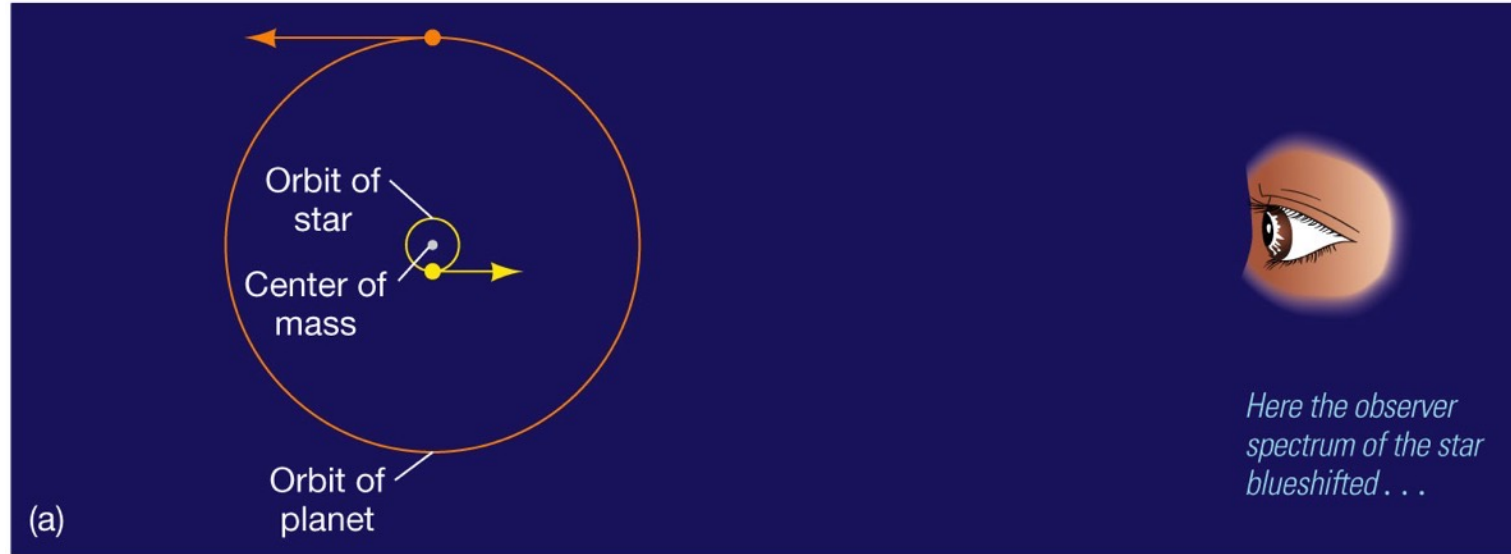


Model subtracted:

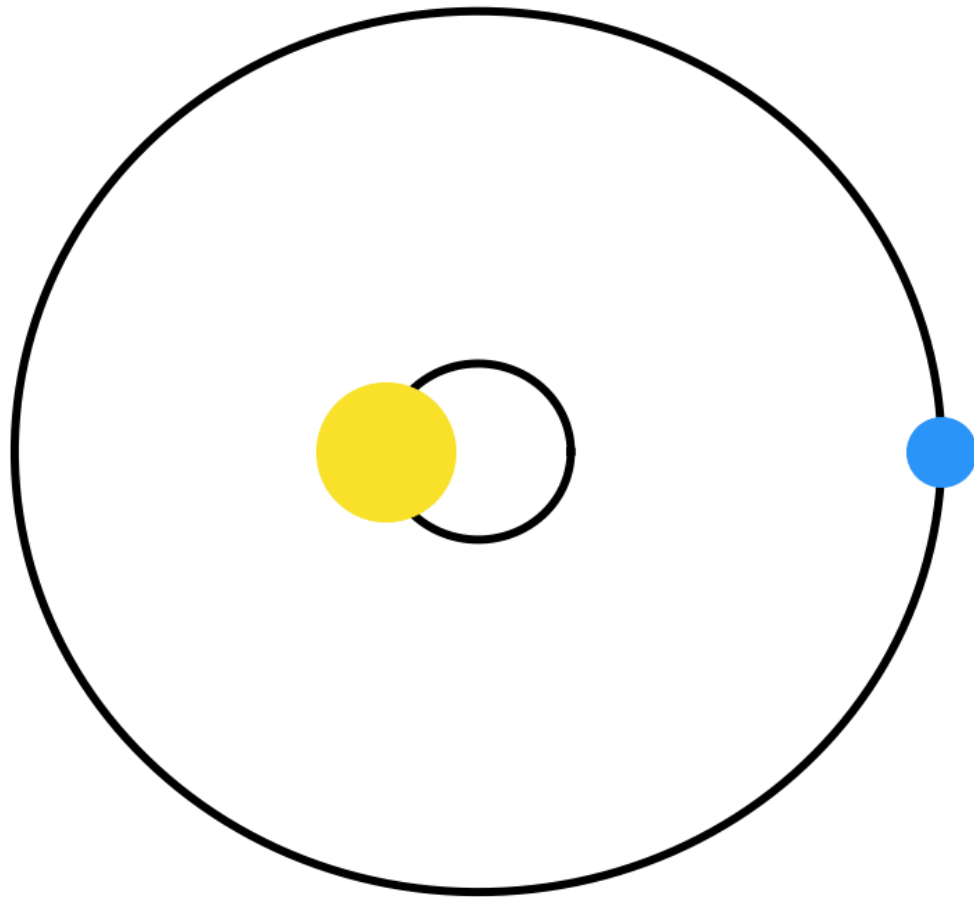




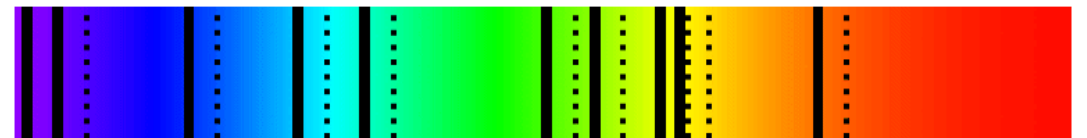
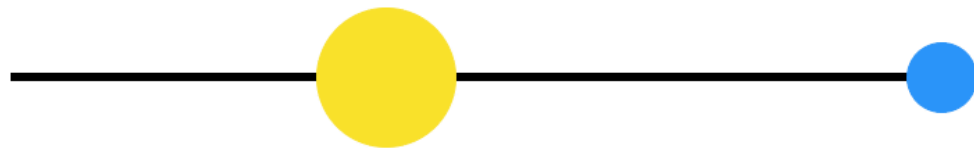
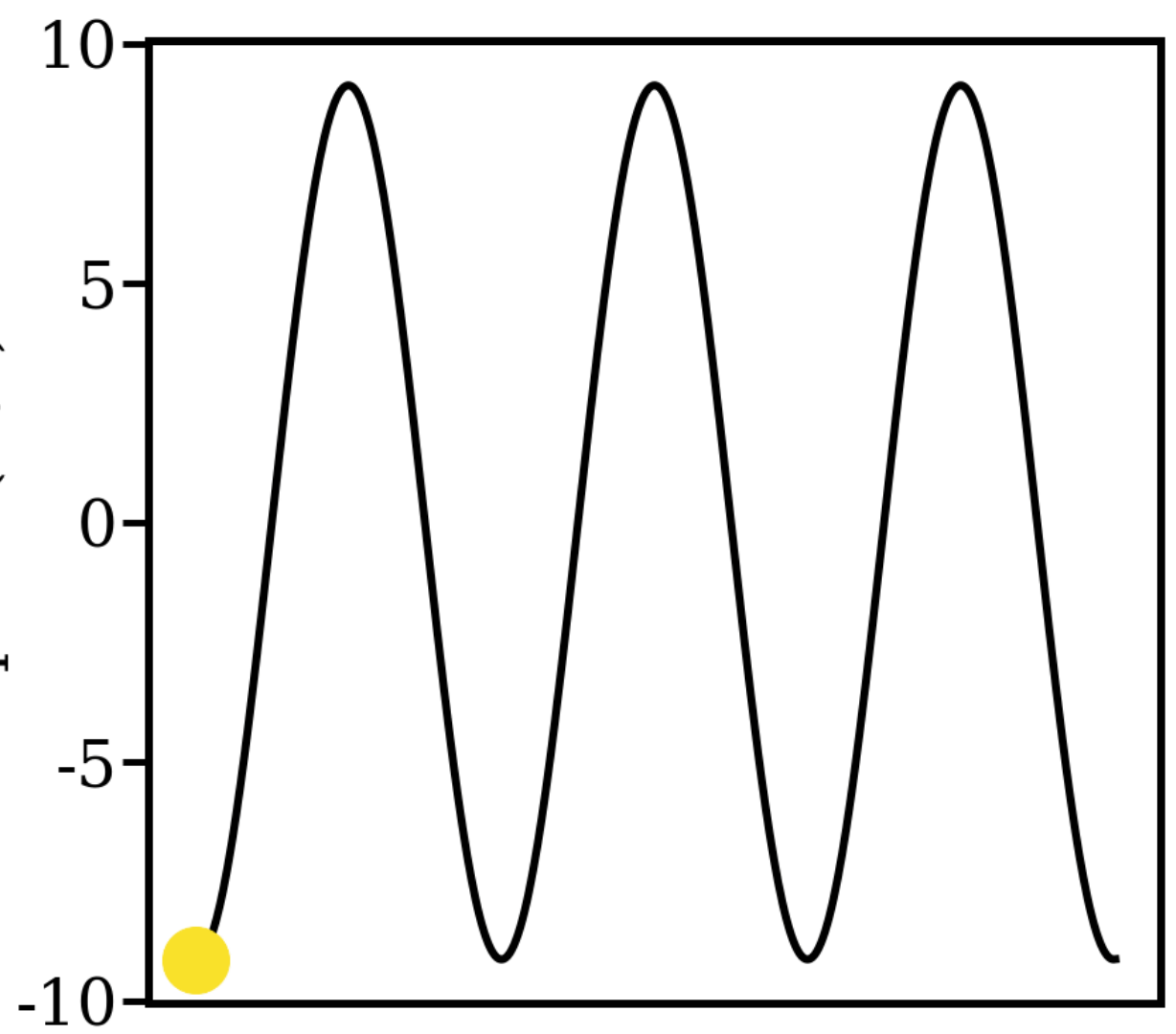
# Finding planets from the star's wobble!





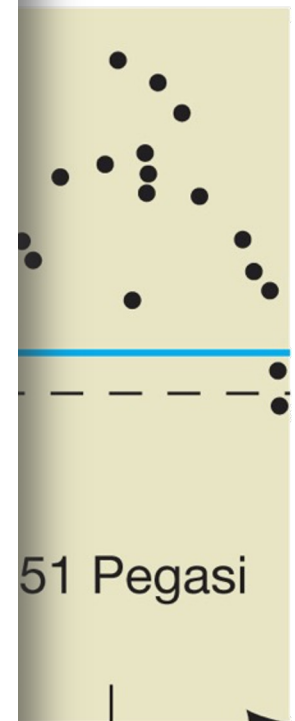
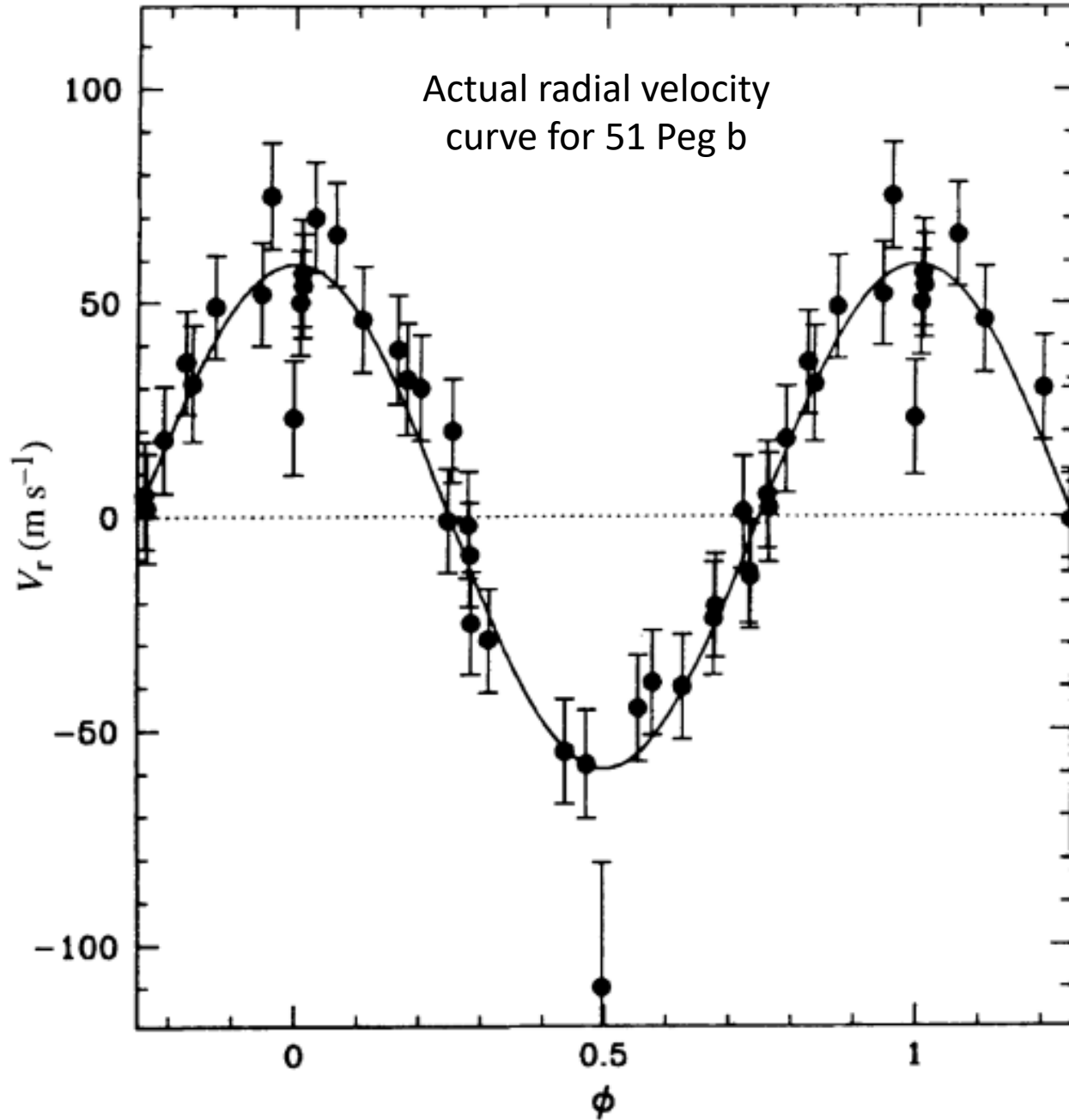


Speed (m/s)





# 51 Pegasi Planet Detection



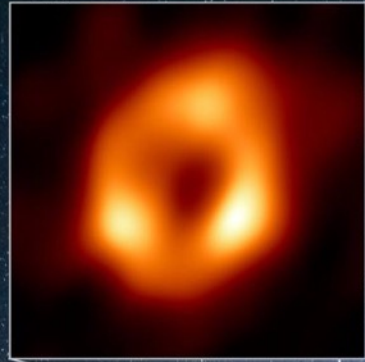
51 Pegasi

4.2

1 Pegasi  
er mass

*The blue lines show the maximum possible signal produced by Jupiter orbiting the Sun.*





Supermassive  
blackhole of our  
galaxy!

<https://scitechdaily.com/stunning-reveal-first-image-of-the-black-hole-at-the-center-of-our-milky-way-galaxy/>

Also see <https://www.nobelprize.org/prizes/physics/2020/press-release/>

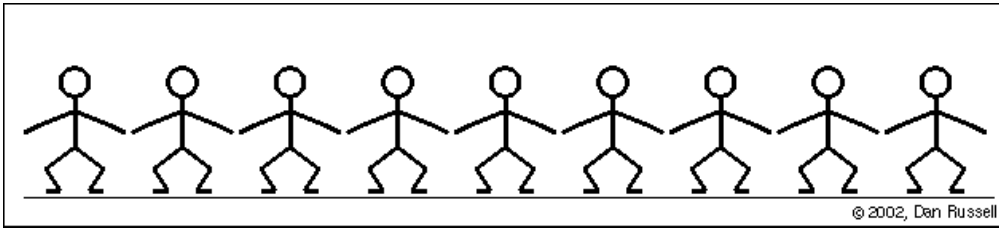
Sagittarius A\*  
 $\sim 10^6 M_{\text{Sun}}$



# What is a wave?

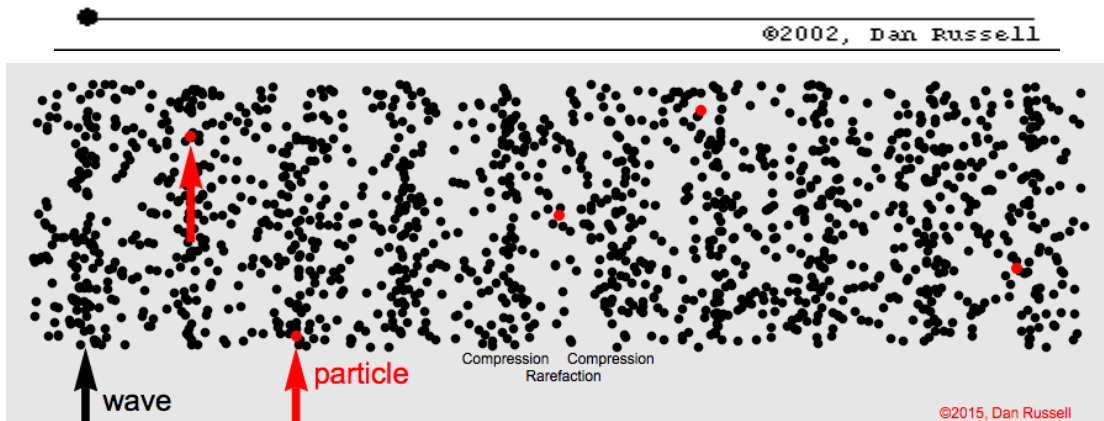
A wave is a disturbance that propagates through space and time, **transferring energy** without transporting matter.

- The disturbance could be elastic deformation, fields (electric, magnetic), motion of particles, etc.



Wave does not transport matter, only the energy.

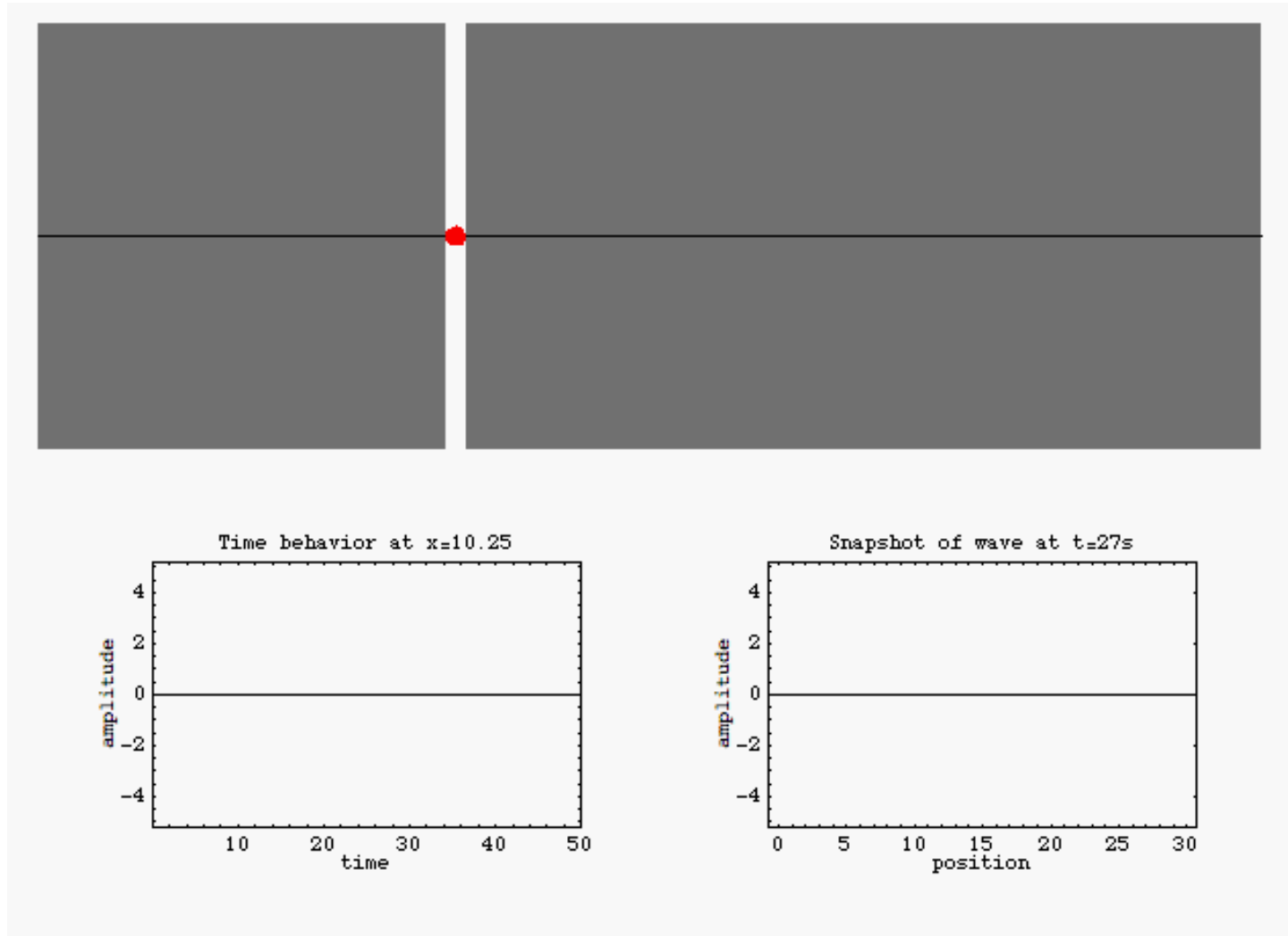
Transverse wave



Longitudinal wave

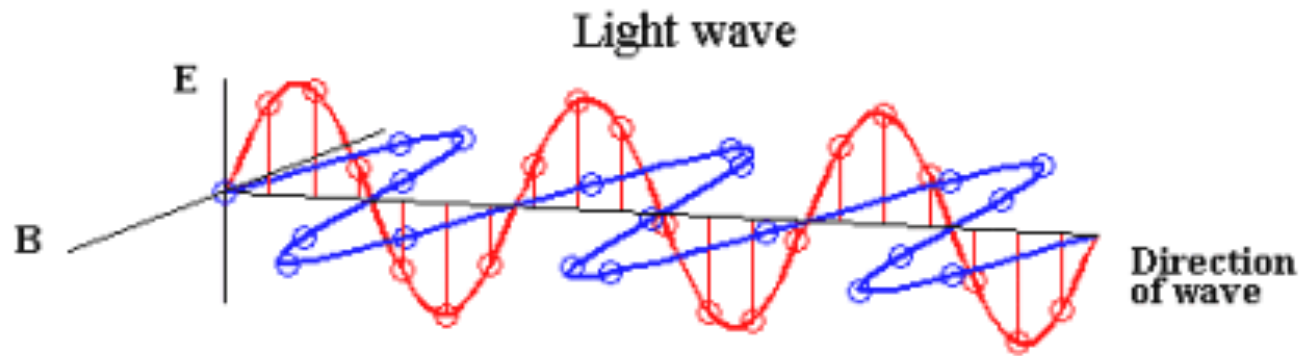
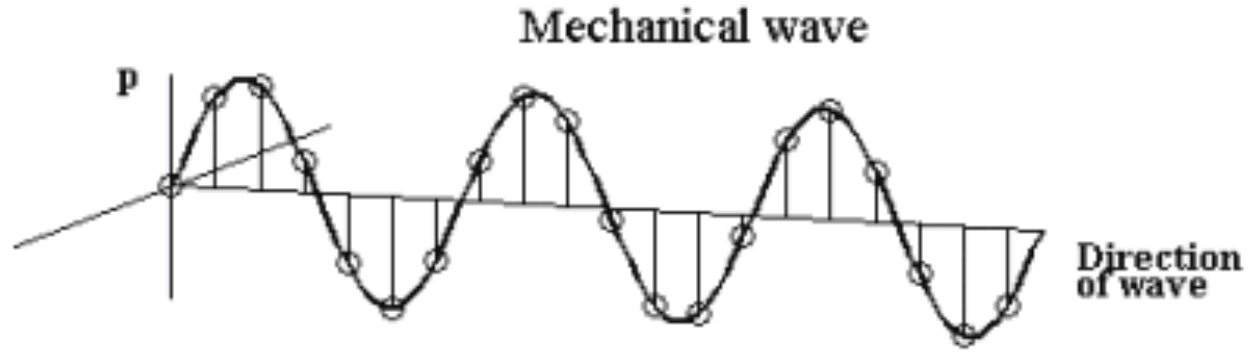
# Waves... Fundamental properties

- **Period ( $T$ ):** The time it takes to complete one cycle (s)
- **Wavelength ( $\lambda$ ):** Distance between two successive peaks (crests or troughs)
- **Frequency ( $f$ ):** Number of peaks passing through a point in unit time. (1/s, Hz). Or number of vibrations in unit time.





# Light is an electromagnetic wave

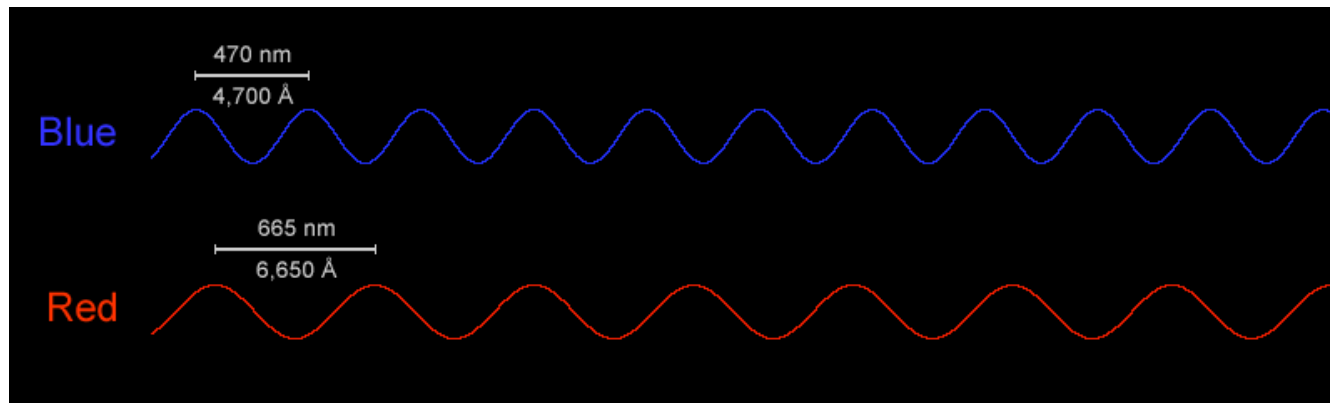


# Speed of a wave

$$\begin{array}{l} \text{Speed } (v) = \text{wavelength} \times \text{frequency} = \lambda f \\ \text{[m/s]} \qquad \qquad \text{[m]} \qquad \qquad \text{[1/s]} \end{array}$$

For EM (electromagnetic) waves:  $v = c$  (speed of light) =  $3 \times 10^8$  m/s (in vacuum)

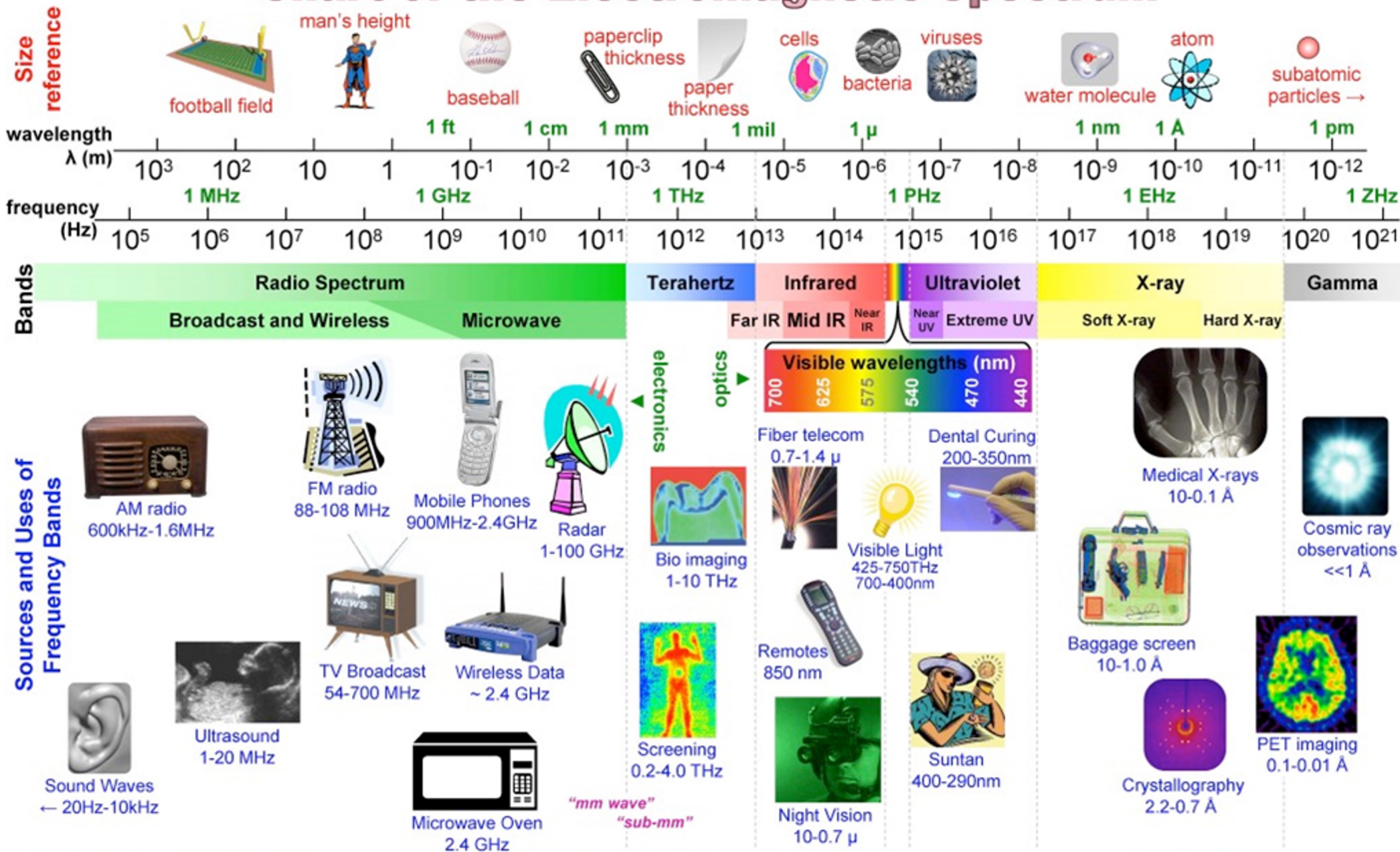
- EM waves can travel without medium! with the speed independent of wavelength or frequency
- The full range of wavelengths and frequencies makes up the “**spectrum**” of EM radiation



$$\lambda \propto \frac{1}{f} \propto \frac{1}{\text{Energy}}$$

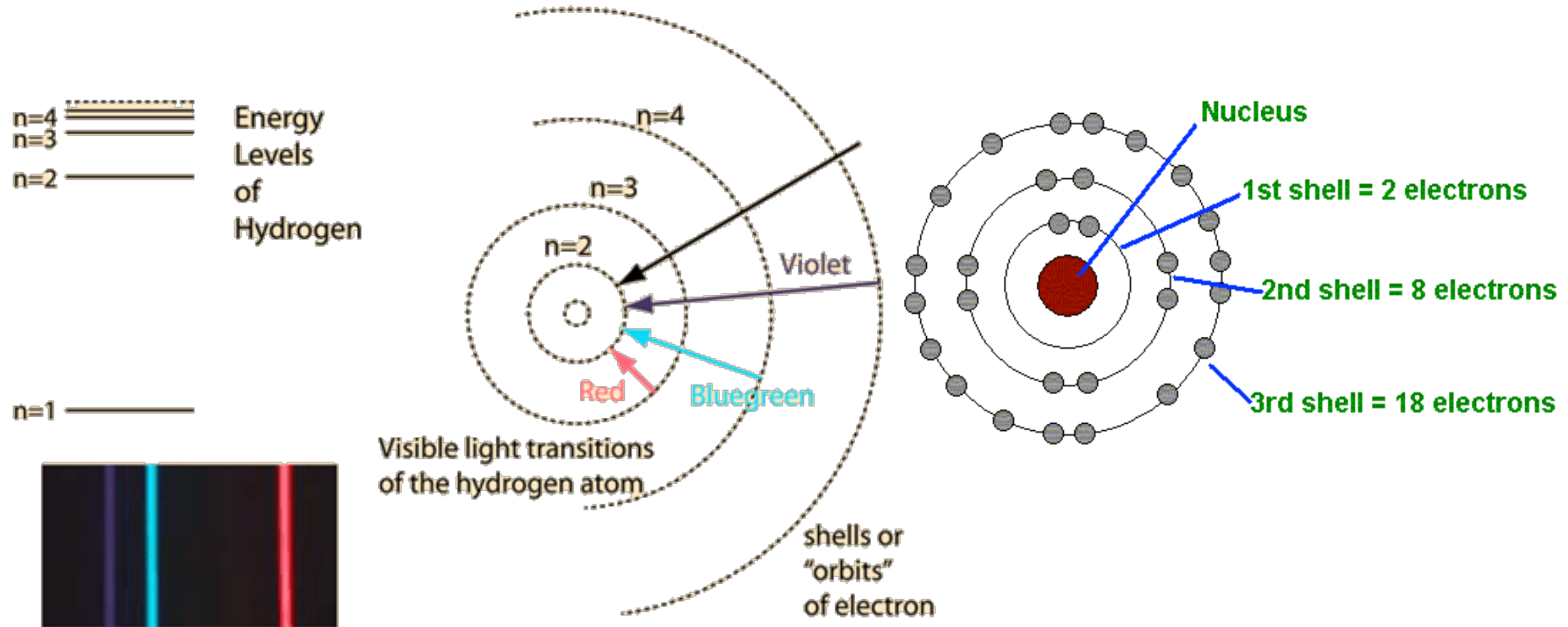


# Chart of the Electromagnetic Spectrum



$$\lambda = 3 \times 10^8 / \text{freq} = 1 / (\text{wn} \times 100) = 1.24 \times 10^{-6} / \text{eV}$$

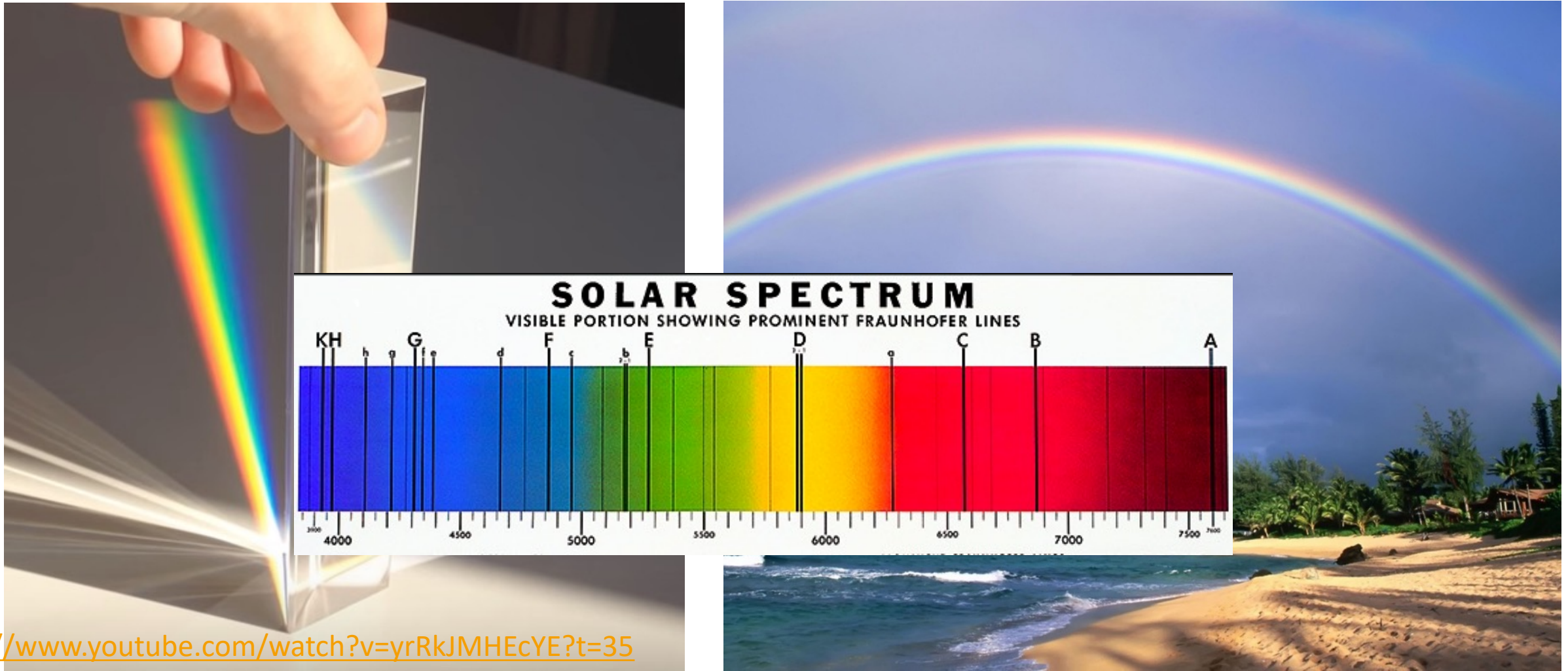
# GIFT of NATURE to SCIENTISTS: Quantum Physics



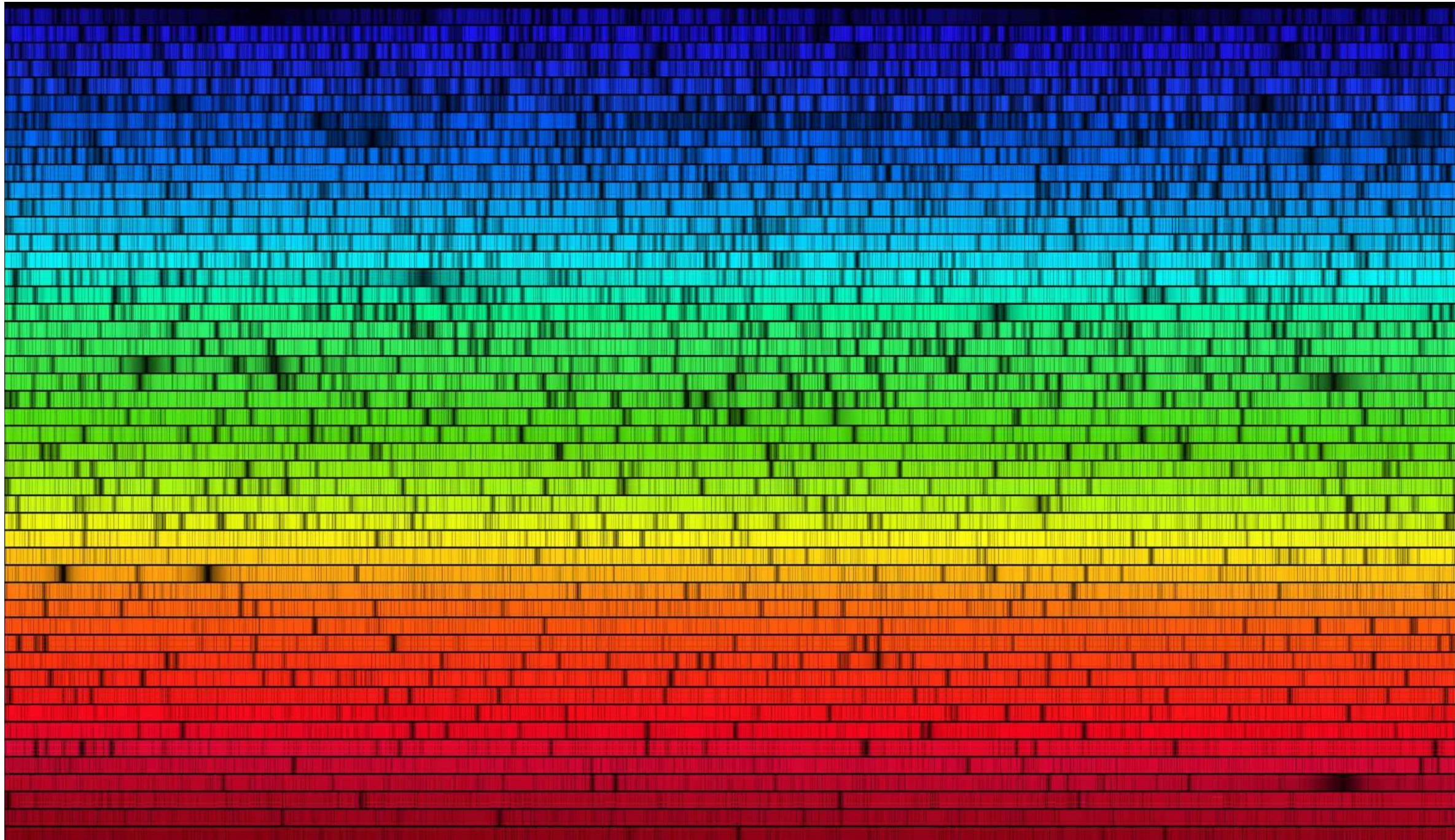
$$E_n = -13.6 \text{ eV} / n^2$$



# Spectrum?

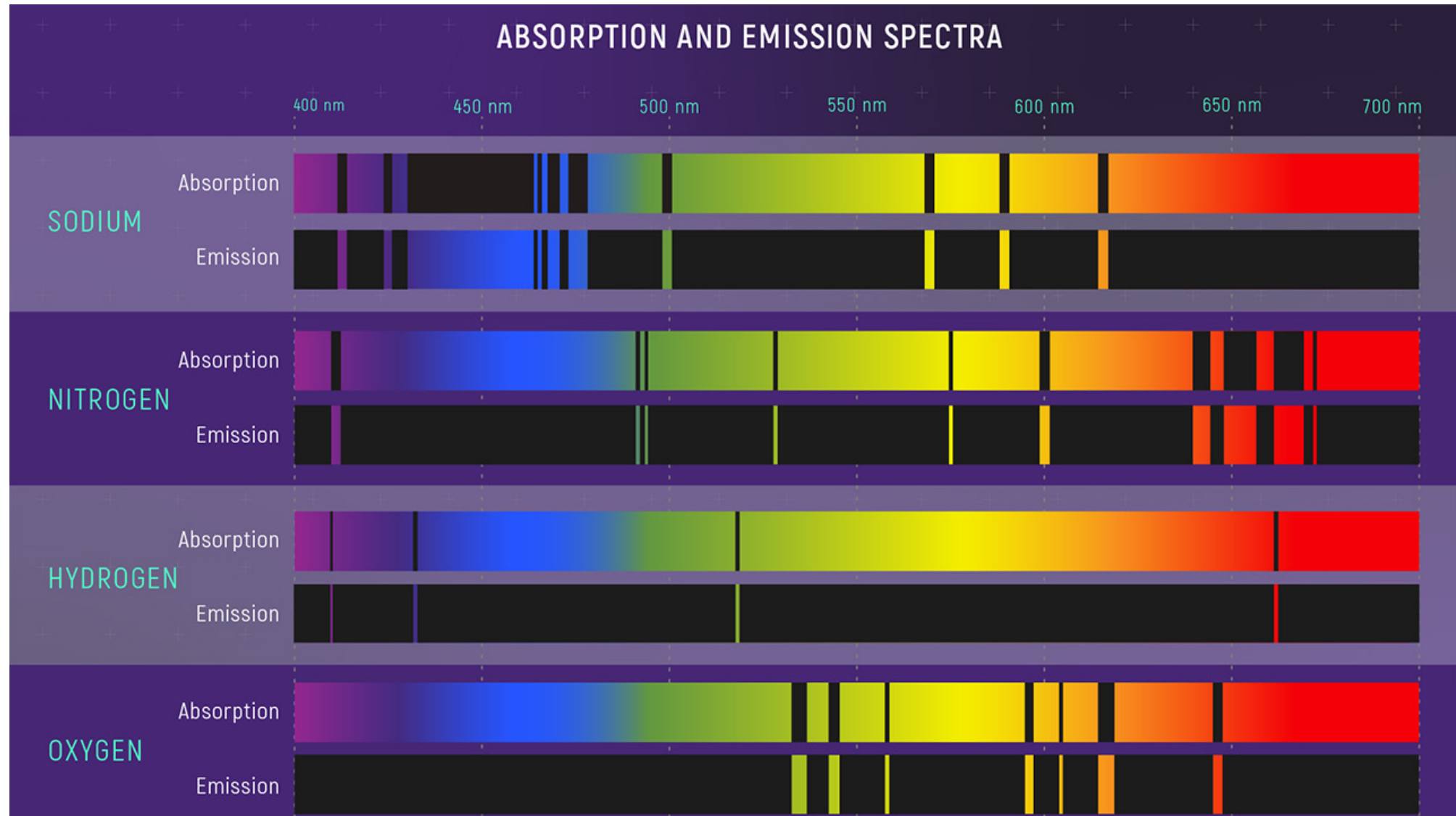








# Spectral lines = Fingerprints of elements



# PERIODIC TABLE OF THE ELEMENTS

## Emission Spectra of the Elements

PERIOD	GROUP 1 IA		GROUP NUMBERS IUPAC RECOMMENDATION (1985)										GROUP NUMBERS CHEMICAL ABSTRACT SERVICE (1986)						GROUP 18 VIIIA	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
1	1 1.0079 <b>H</b> HYDROGEN																	2 4.0026 <b>He</b> HELIUM		
2	3 6.941 <b>Li</b> LITHIUM	4 9.0122 <b>Be</b> BERYLLIUM											5 10.811 <b>B</b> BORON	6 12.011 <b>C</b> CARBON	7 14.007 <b>N</b> NITROGEN	8 15.999 <b>O</b> OXYGEN	9 18.998 <b>F</b> FLUORINE	10 20.180 <b>Ne</b> NEON		
3	11 22.990 <b>Na</b> SODIUM	12 24.305 <b>Mg</b> MAGNESIUM											13 26.982 <b>Al</b> ALUMINIUM	14 28.086 <b>Si</b> SILICON	15 30.974 <b>P</b> PHOSPHORUS	16 32.065 <b>S</b> SULPHUR	17 35.453 <b>Cl</b> CHLORINE	18 39.948 <b>Ar</b> ARGON		
4	19 39.098 <b>K</b> POTASSIUM	20 40.078 <b>Ca</b> CALCIUM	21 44.956 <b>Sc</b> SCANDIUM	22 47.867 <b>Ti</b> TITANIUM	23 50.942 <b>V</b> VANADIUM	24 51.996 <b>Cr</b> CHROMIUM	25 54.938 <b>Mn</b> MANGANESE	26 55.845 <b>Fe</b> IRON	27 58.933 <b>Co</b> COBALT	28 58.693 <b>Ni</b> NICKEL	29 63.546 <b>Cu</b> COPPER	30 65.38 <b>Zn</b> ZINC	31 69.723 <b>Ga</b> GALLIUM	32 72.64 <b>Ge</b> GERMANIUM	33 74.922 <b>As</b> ARSENIC	34 78.96 <b>Se</b> SELENIUM	35 79.904 <b>Br</b> BROMINE	36 83.798 <b>Kr</b> KRYPTON		
5	37 85.468 <b>Rb</b> RUBIDIUM	38 87.62 <b>Sr</b> STRONTIUM	39 88.906 <b>Y</b> YTTORIUM	40 91.224 <b>Zr</b> ZIRCONIUM	41 92.906 <b>Nb</b> NIOBIUM	42 95.96 <b>Mo</b> MOLYBDENUM	43 (98) <b>Tc</b> TECHNETIUM	44 101.07 <b>Ru</b> RUTHENIUM	45 102.91 <b>Rh</b> RHODIUM	46 106.42 <b>Pd</b> PALLADIUM	47 107.87 <b>Ag</b> SILVER	48 112.41 <b>Cd</b> CADMIUM	49 114.82 <b>In</b> INDIUM	50 118.71 <b>Sn</b> TIN	51 121.76 <b>Sb</b> ANTIMONY	52 127.60 <b>Te</b> TELLURIUM	53 126.90 <b>I</b> IODINE	54 131.29 <b>Xe</b> XENON		
6	55 132.91 <b>Cs</b> CAESIUM	56 137.33 <b>Ba</b> BARIUM	57-71 <b>La-Lu</b> Lanthanide	72 178.49 <b>Hf</b> HAFNIUM	73 180.95 <b>Ta</b> TANTALUM	74 183.84 <b>W</b> TUNGSTEN	75 186.21 <b>Re</b> RHENIUM	76 190.23 <b>Os</b> OSMIUM	77 192.22 <b>Ir</b> IRIDIUM	78 195.08 <b>Pt</b> PLATINUM	79 198.97 <b>Au</b> GOLD	80 200.59 <b>Hg</b> MERCURY	81 204.38 <b>Tl</b> THALLIUM	82 207.2 <b>Pb</b> LEAD	83 208.98 <b>Bi</b> BISMUTH	84 (209) <b>Po</b> POLONIUM	85 (210) <b>At</b> ASTATINE	86 (222) <b>Rn</b> RADON		
7	87 (223) <b>Fr</b> FRANCIUM	88 (226) <b>Ra</b> RADIUM	89-103 <b>Ac-Lr</b> Actinide	104 (267) <b>Rf</b> RUTHERFORDIUM	105 (268) <b>Db</b> DUBNIUM	106 (271) <b>Sg</b> SEABORGIUM	107 (272) <b>Bh</b> BOHRIUM	108 (277) <b>Hs</b> HASSIUM	109 (276) <b>Mt</b> MEITNERIUM	110 (281) <b>Ds</b> DARMSTADIUM	111 (280) <b>Rg</b> ROENTGENIUM	112 (285) <b>Cn</b> COPERNICIUM	113 (...) <b>Uut</b> UNUNTRIUM	114 (287) <b>Fl</b> FLEROVIUM	115 (...) <b>Uup</b> UNUNPENTIUM	116 (291) <b>Lv</b> LIVERMORIUM	117 (...) <b>Uus</b> UNUNSEPTIUM	118 (...) <b>Uuo</b> UNUNOCTIUM		

LANTHANIDE

57 138.91 <b>La</b> LANTHANUM	58 140.12 <b>Ce</b> CERIUM	59 140.91 <b>Pr</b> PRASEODYMIUM	60 144.24 <b>Nd</b> NEODYMIUM	61 (145) <b>Pm</b> PROMETHIUM	62 150.36 <b>Sm</b> SAMARIUM	63 151.96 <b>Eu</b> EUROPIUM	64 157.25 <b>Gd</b> GADOLINIUM	65 158.93 <b>Tb</b> TERBIUM	66 162.50 <b>Dy</b> DYSPROSIUM	67 164.93 <b>Ho</b> HOLMIUM	68 167.26 <b>Er</b> ERBIUM	69 168.93 <b>Tm</b> THULIUM	70 173.05 <b>Yb</b> YTTERBIUM	71 174.97 <b>Lu</b> LUTETIUM
--	-------------------------------------	---	--	--	---------------------------------------	---------------------------------------	---	--------------------------------------	---	--------------------------------------	-------------------------------------	--------------------------------------	--	---------------------------------------

ACTINIDE

89 (227) <b>Ac</b> ACTINIUM	90 232.04 <b>Th</b> THORIUM	91 231.04 <b>Pa</b> PROTACTINIUM	92 238.03 <b>U</b> URANIUM	93 (237) <b>Np</b> NEPTUNIUM	94 (244) <b>Pu</b> PLUTONIUM	95 (243) <b>Am</b> AMERICIUM	96 (247) <b>Cm</b> CURIUM	97 (247) <b>Bk</b> BERKELIUM	98 (251) <b>Cf</b> CALIFORNIUM	99 (252) <b>Es</b> EINSTEINIUM	100 (257) <b>Fm</b> FERMIUM	101 (258) <b>Md</b> MENDELEVIUM	102 (259) <b>No</b> NOBELIUM	103 (262) <b>Lr</b> LAWRENCIUM
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