Review of chapter 2 !!

Core of ancient astronomy: The Universe is comprehensible!

Correct science predicts correct behavior.

Astronomy lead directly to discovery of fundamental laws of nature.

Origins of sun-centered universe.

- "common sense" was Earth-centered, but lacked explanation for many observations.
- Copernicus' sun-centered system simplified (and unified) explanations for planets.
- Copernicus' system was not complete – stars did NOT orbit the Sun.

Configurations are relationships between the Earth the other planets and the Sun.

Keplers Laws (elliptical orbit, areas swept, periods**2 = semi-major axis**3)

Newton's Laws – explained Kepler's laws and unified "heaven" and earth motion.

Conservation of Angular Momentum

Reviewing physics

The elements of basic mechanics: mass (m), time (t) distance (s,**x**, **y**…), speed and velocity **v**, and acceleration, **a.** **v** = d**x**/dt**,** **a** = d**v**/dt**.**

bold = vector

First year courses in Physics primarily focuses on the action of objects under **constant acceleration**:

a) **constant direction** linear (gravity) a = d**v**/dt

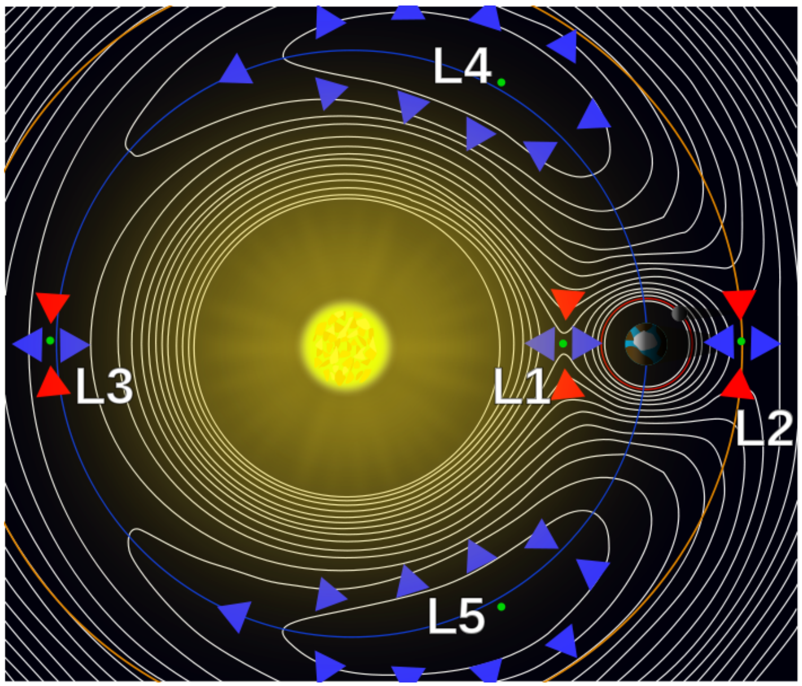
b) **constant speed** circular motion. a = v^2/R

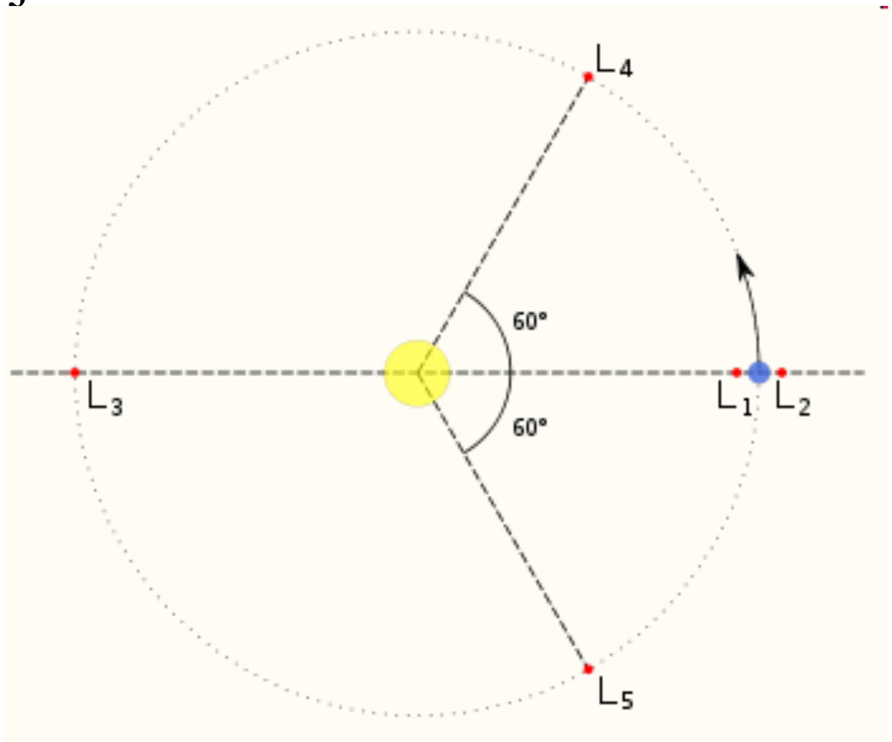
In both these circumstances the force causing the acceleration is expressed as **f** = m***a** of the object's motion. **Weight** vs. mass

When the object is still or moving at **constant velocity**, the **net force** on that object is **zero.**

Three and more bodies – Lagrange points

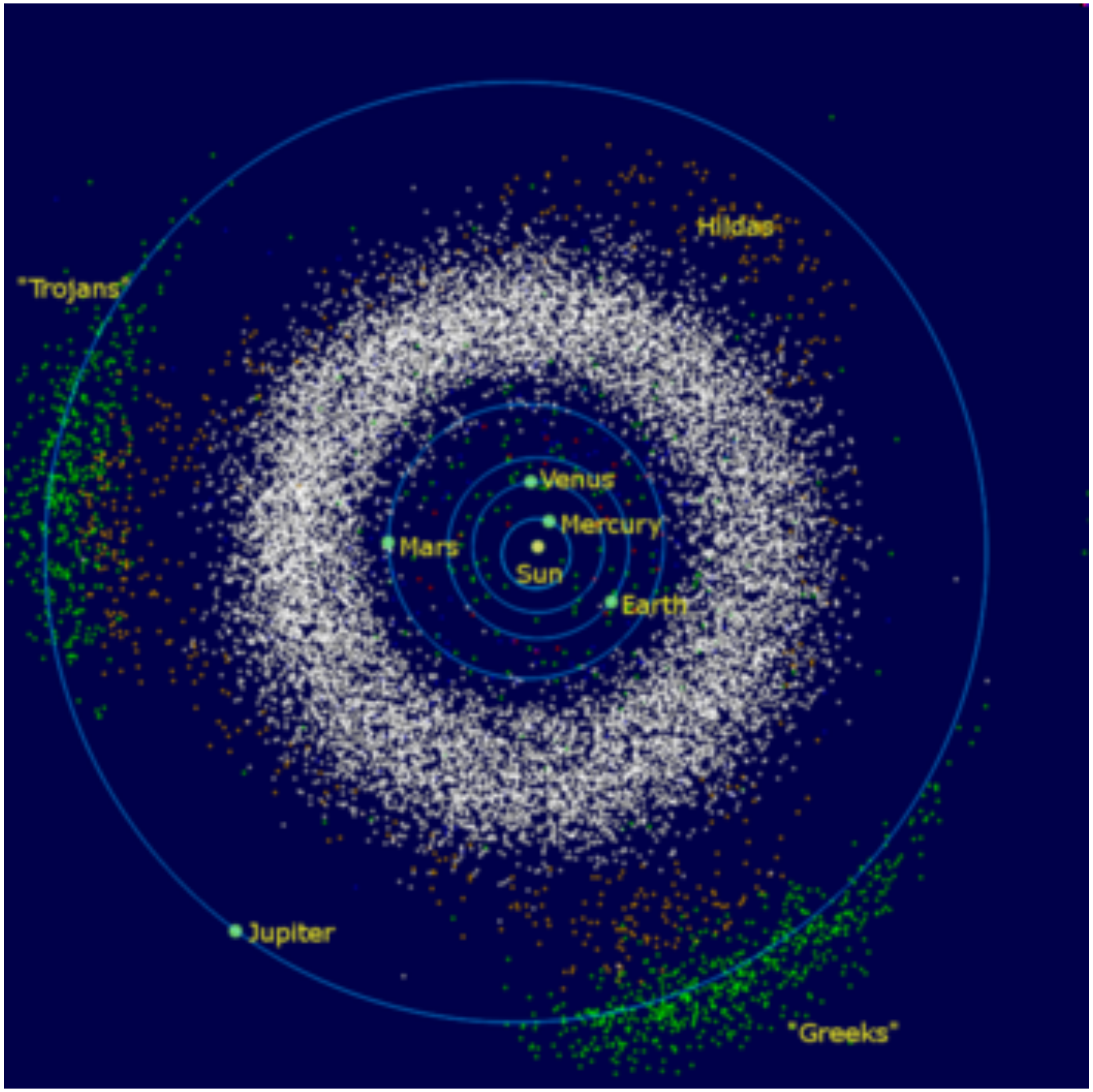
- Five positions in an orbital configuration where a small object affected only by gravity can theoretically be part of a constant-shape pattern with two larger objects





Only two points, L4 and L5 are stable – can capture asteroids

Trojan points of Jupiter



One asteroid found at Earth's Trojan point. See 162 webpage

Kepler's Laws

- Kepler's Laws can all be derived from Newton's laws of motion and force of gravity.
- Previous class simplified to circular orbit, but gravity causes elliptical orbits where planet moves faster when closer to the Sun as force of gravity is larger there. (Equal areas swept per unit time ➔ conservation of angular momentum).
- Third Law actually

$$D^3 = (\text{Mass(sun) and Mass(earth)}) \times P^2$$

D=distance from Sun, and P=period

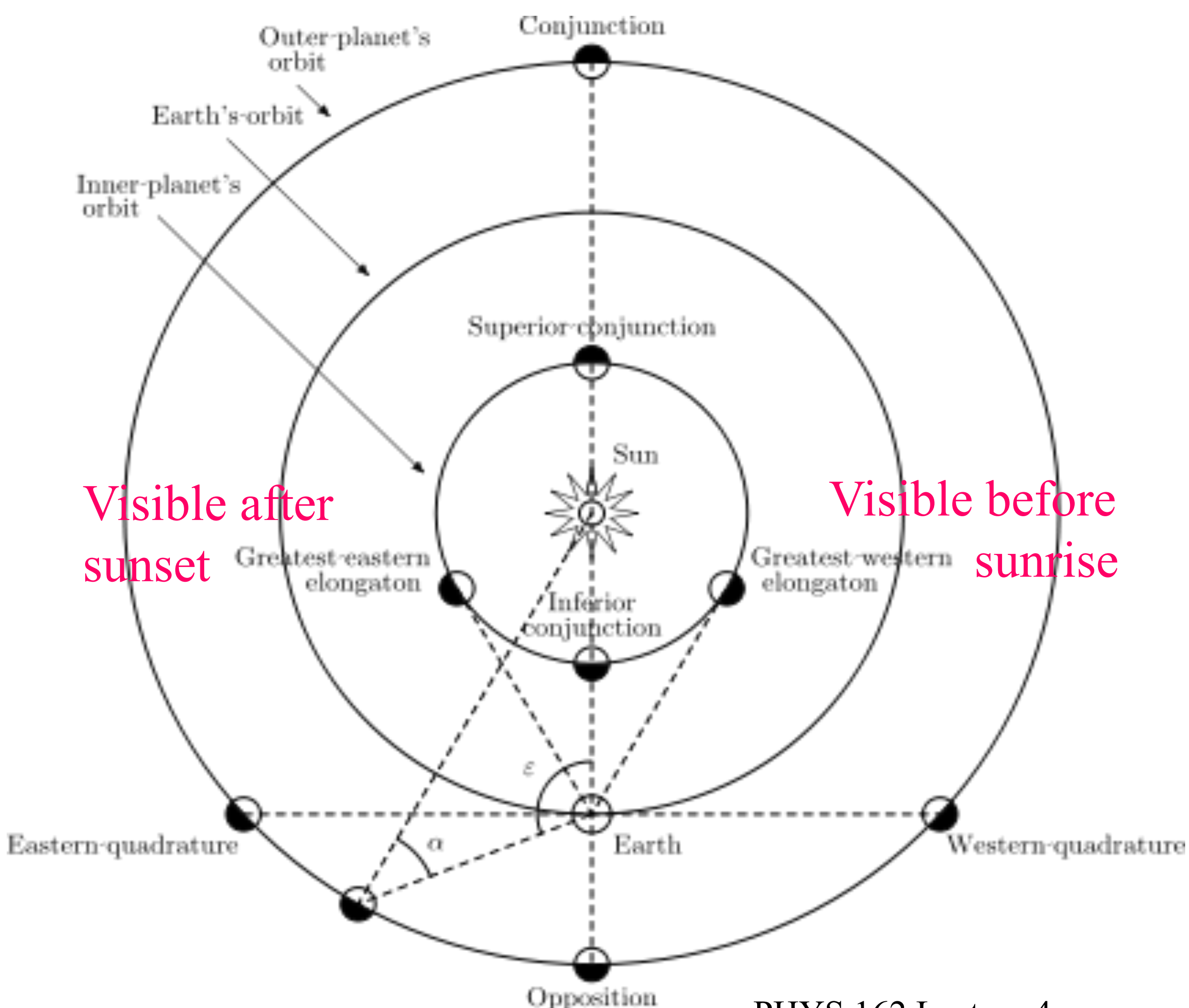
- As mass Sun much larger can mostly ignore mass planet (but Sun does move slightly due to planet's pull)

Orbital Periods

- Study orbital periods → get masses
  - planets around Sun → Sun's mass
  - Jupiter's moons around Jupiter → Jupiter's mass
- Also used for stars (more on this later)
  - two nearby stars orbiting each other → their masses
  - an exoplanet orbiting a star will cause the star to wobble a bit → can give mass of exoplanet
- see some animations at (from wikipedia) http://nicadd.niu.edu/~macc/162/Center.html

Some Traditional Astronomy Terms

- Elongation and Conjuction



Venus probes!

- http://www.spacetoday.org/SolSys/Venus/VenusMissionsTable.html

- Extreme heat (450 degrees F +)
- Extreme atmospheric pressure.
- Russians dominated… many failures (some firsts)
  - **First planetary atmosphere probe, (crushed at an attitude of about 16 miles)**
  - **First successful planetary landing**
  - **First pictures of the surface of Venus, 4-month orbital photo study of clouds**

Venus probes!

Past Explorations of the Planet Venus

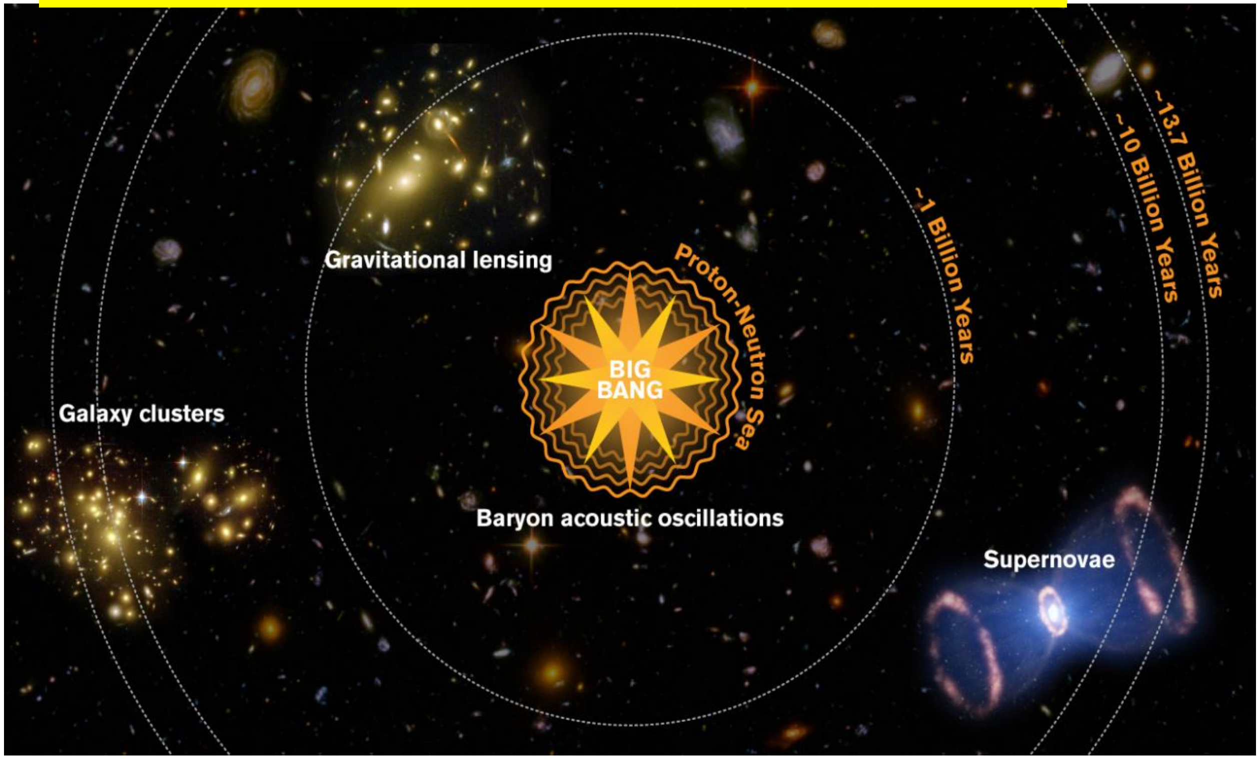
LAUNCH	FROM	NAME	INTENTION	RESULT
1961 Feb 4	USSR	*1VA - 1*	impact	Stranded in Earth orbit
1961 Feb 12	USSR	Venera 1	impact	Lost when attitude control sensor overheated
1962 Jul 22	USA	Mariner 1	flyby	Lost and splashed in North Atlantic
1962 Aug 25	USSR	*2MV-1 - 1*	landing	Stranded in Earth orbit
1962 Aug 27	USA	Mariner 2	flyby	First successful planetary mission found Venus has small magnetic field
1962 Sep 1	USSR	*2MV-1 - 2*	landing	Stranded in Earth orbit
1962 Sep 12	USSR	*2MV-2 - 1*	photo flyby	Stranded in Earth orbit
1964 Mar 27	USSR	*3MV-1 - 5*	landing	Stranded in Earth orbit
1964 Apr 2	USSR	Zond 1	landing	Pressure loss and corona discharge
1965 Nov 12	USSR	Venera 2	flyby	Thermal control failure
1965 Nov 16	USSR	Venera 3	landing	First impact on another planet. Thermal failure
1965 Nov 23	USSR	*3MV-4 - 6*	flyby	Exploded in Earth orbit
1967 Jun 12	USSR	Venera 4	landing	First planetary atmosphere probe, crushed at an attitude of about 16 miles
1967 Jun 14	USA	Mariner 5	flyby	Fly-by, radio occultation
1967 Jun 17	USSR	*V-67 - 2*	landing	Stranded in Earth orbit
1969 Jan 5	USSR	Venera 5	landing	Successful, crushed at an altitude of about 11 miles
1969 Jan 10	USSR	Venera 6	landing	Successful, crushed at an altitude of about 11 miles
1970 Aug 17	USSR	Venera 7	landing	First successful planetary landing
1970 Aug 22	USSR	*V-70 -*	landing	Stranded in Earth orbit
1972 Mar	USSR	Venera 8	landing	Measured surface illumination

LAUNCH	FROM	NAME	INTENTION	RESULT
27				
1972 Mar 31	USSR	*3V*	landing	Stranded in Earth orbit
1973 Nov 3	USA	Mariner 10	photo flyby	First good pictures of Venus followed by gravity assist to Mercury
1975 Jun 8	USSR	Venera 9	orbit and landing	First pictures of the surface of Venus, 4-month orbital photo study of clouds
1975 Jun 14	USSR	Venera 10	orbit and landing	Same as Venera 9, one of two cameras failed on each lander
1978 May 20	USA	Pioneer 12	orbit	Radar mapping, photo study of clouds, operated 14 years
1978 Aug 8	USA	Pioneer 13	impact	Cluster of 5 atmosphere probes
1978 Sep 9	USSR	Venera 11	flyby and landing	Spectra from clouds to surface, atmosphere chemical analysis
1978 Sep 14	USSR	Venera 12	flyby and landing	Both color cameras, rock analysis, failed on both Venera 11 and 12
1981 Oct 30	USSR	Venera 13	flyby and landing	Color images and rock analysis
1981 Nov 4	USSR	Venera 14	flyby and landing	Color images and rock analysis
1983 Jun 2	USSR	Venera 15	orbit	High resolution radar mapping
1983 Jun 7	USSR	Venera 16	orbit	High resolution radar mapping
1984 Dec 15	USSR	Vega 1	flyby and landing	Night landing of a balloon probe dropped enroute to Halley's comet encounter
1984 Dec 21	USSR	Vega 2	flyby and landing	Same as Vega 1
1989 May 4	USA	Magellan	orbit	High resolution radar mapping
1989 Oct 18	USA	Galileo	flyby	Images of Venus then gravity assist to Jupiter
1997 Oct 15	USA	Cassini	flyby	Images of Venus and then gravity assist to Saturn

SOURCE: STO

Recent Dark Energy Survey News…

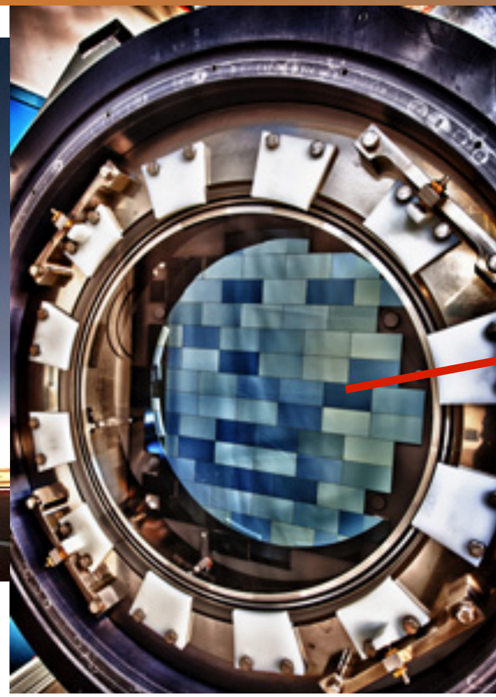
http://www.darkenergysurvey.org/index.shtml

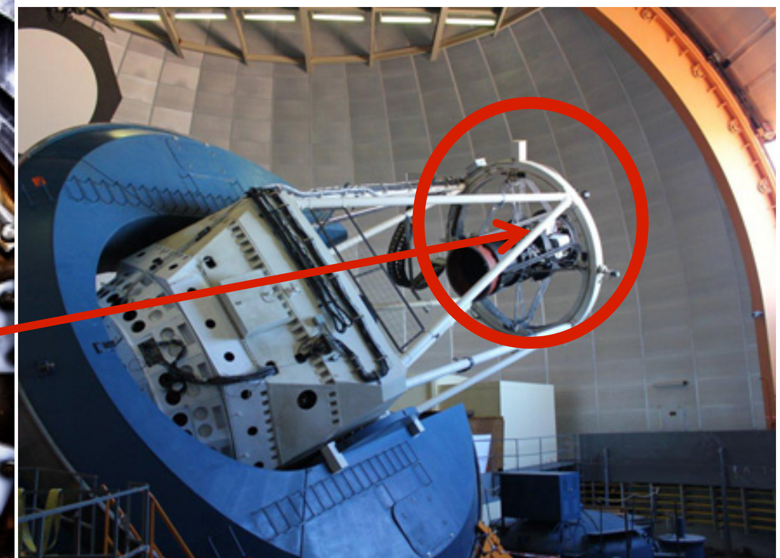


In 1998, two teams of astronomers studying distant supernovae made the remarkable discovery that the expansion of the universe is **speeding up**. Yet, according to Einstein's theory of General Relativity, gravity should lead to a slowing of the expansion.

To explain cosmic acceleration, cosmologists are faced with two possibilities: Either 75% of the universe exists in an exotic form, now called **dark energy**, that exhibits a gravitational force opposite to the attractive gravity of ordinary matter, or **General Relativity** must be replaced by a new theory of gravity on cosmic scales. Need to **measure light** from early Universe with high precision.

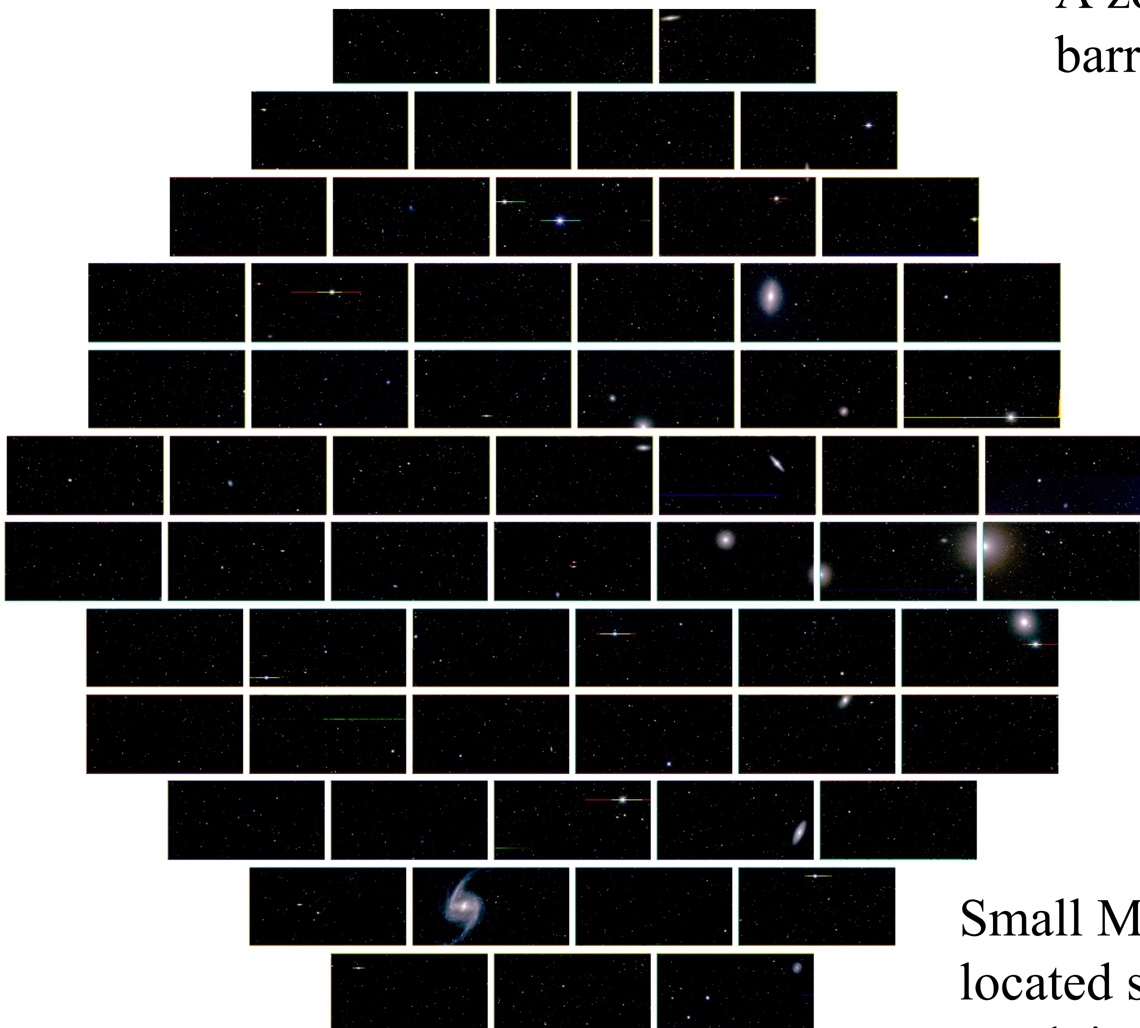
Dark Energy Survey Measurements



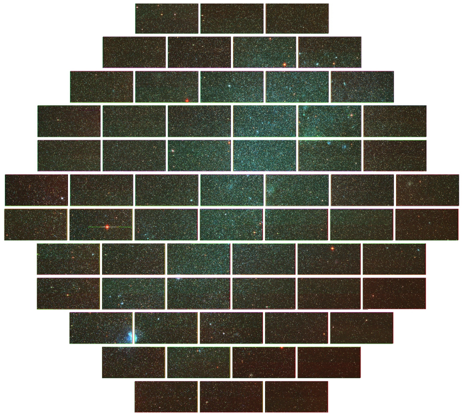


The Dark Energy Survey (DES) is designed to probe the origin of the **accelerating universe** and help uncover the nature of **dark energy** by measuring the 14-billion-year history of cosmic expansion with high precision This collaboration is building an extremely sensitive 570-Megapixel digital camera, DECam, and will mount it on the Blanco 4-meter telescope at Cerro Tololo Inter-American Observatory high in the Chilean Andes. Main studies: **Supernovae, Gravitational lensing, Galaxy clusters, Baryon acoustic oscillations.**

First DES Pictures!



A zoomed-in view highlights the barreled spiral galaxy NCG 1365:

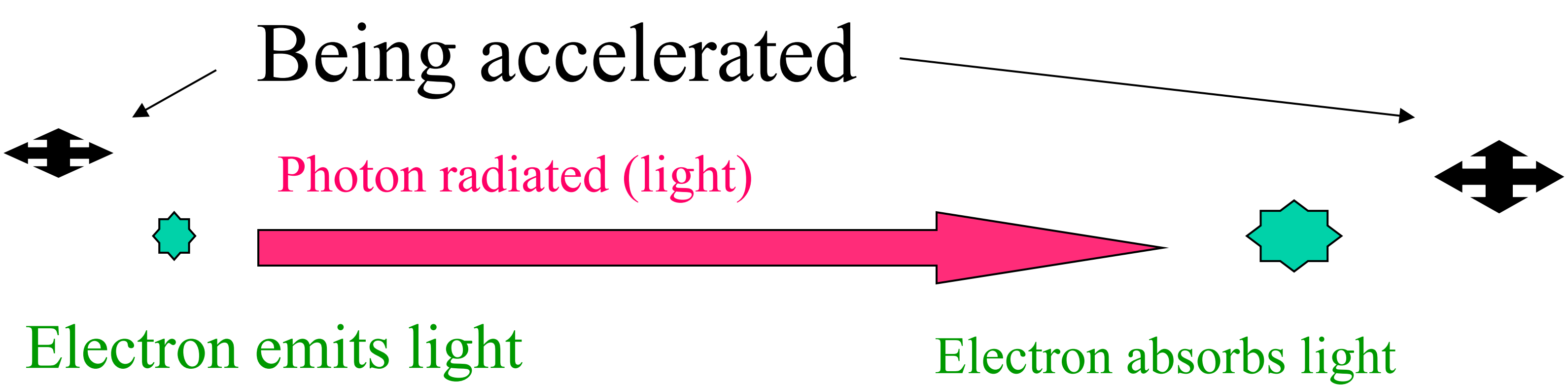


Small Magellanic Cloud dwarf galaxy, located some 200,000 light years from Earth in the constellation Tucana.

http://fnal.gov/pub/presspass/press_releases/2013/DES-2013-images.html

LIGHT

- Visible light, infrared, UV, radio are all types of Electromagnetic Radiation. They differ by having different frequencies → different colors
- EM Radiation is caused by accelerating electric charge (usually electrons since they are the lightest)



Electromagnetic Force

- There is a force between any two bodies 1 and 2

  $F = Cq_1q_2 /r^2$

with q_1 and q_2 being the charges and r being the distance between 1 and 2

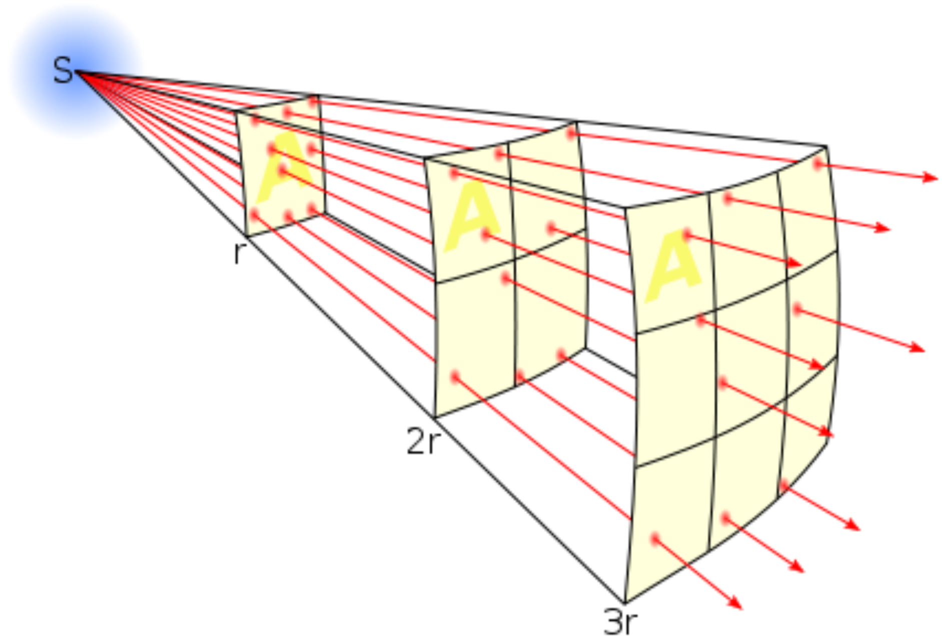
- Both attractive and repulsive charges
- Depends on the charges of the two bodies
- Decreases as the distance increases
- Is the same force everywhere in the Universe
- Stronger than Gravity but average charge usually equal 0

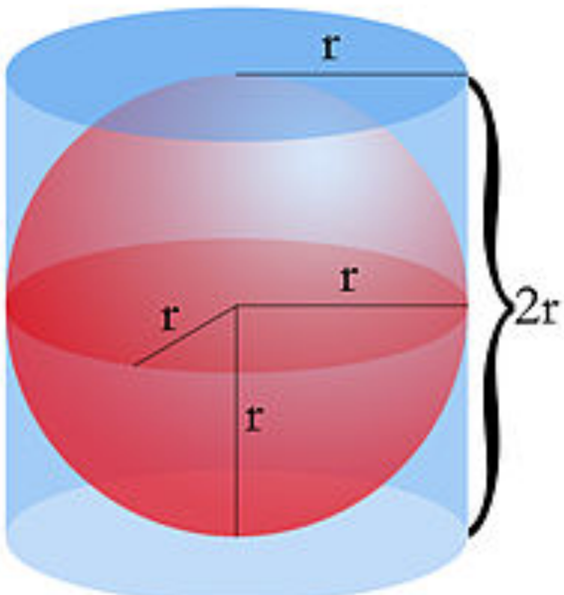
Electricity and Magnetism are **different aspects** of the same force

Breaking down the Force….

- Space is homogeneous and isotropic implies that LIGHT emanates equally in all directions in 3 dimensional space ...

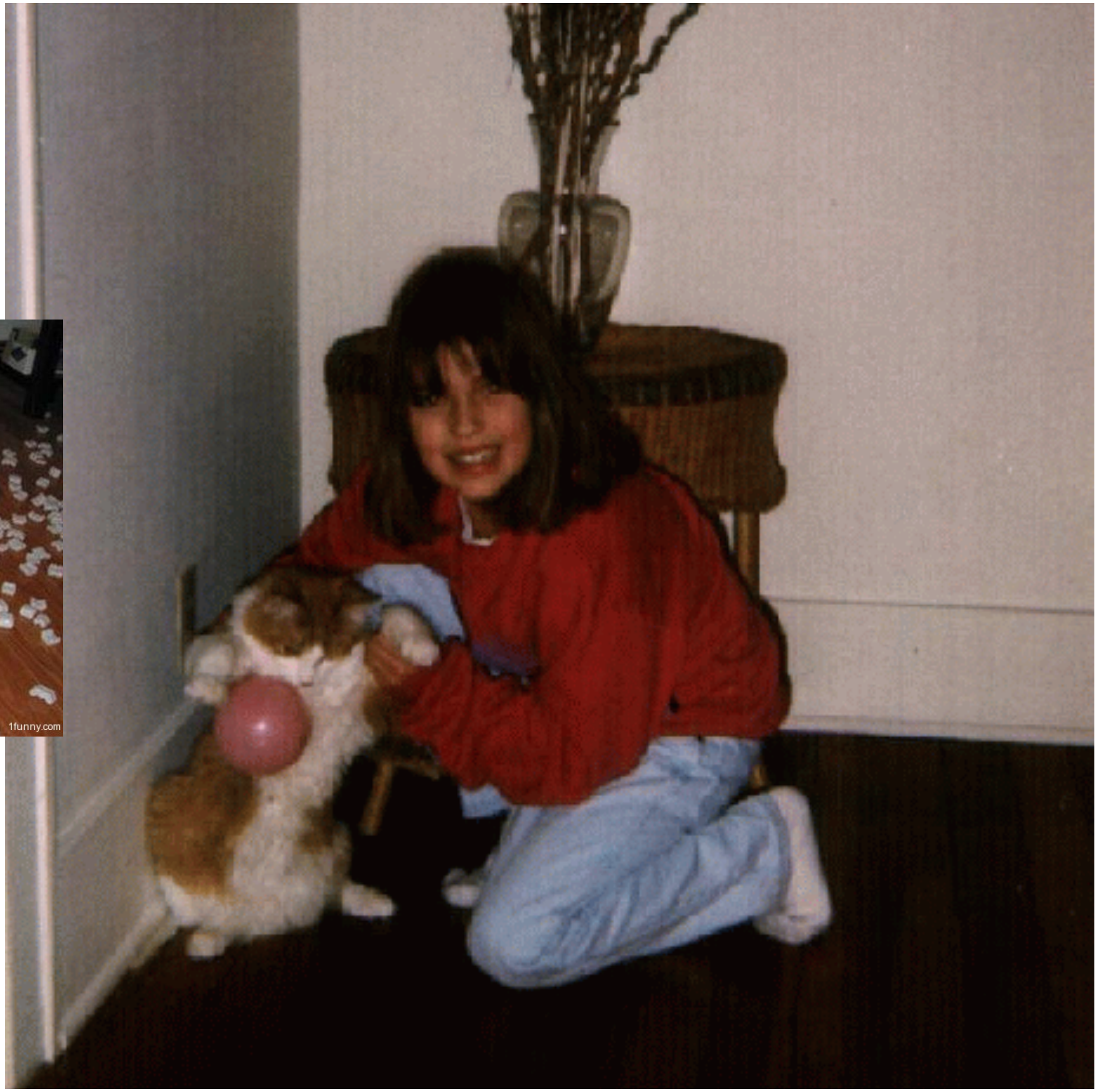
The surface of a sphere = $4\pi R^2$. If a source is at the center of the sphere, its **flux** is spread out over an area that is **increasing** in proportion to the square of the distance from the source.





The lines represent the flux emanating from the **source**. The **total number** of flux lines depends on the **strength** of the source and is **constant** with increasing distance.

Electromagnetic Force Example



Gravity vs Electric Force

- Electric force dominates daily life

→ all senses

→ all chemistry

- Easy to observe much stronger then gravity

→ floor prevents us from falling to Earth's center

→ can stick a balloon to the wall

→ levitating magnets

- Why gravity is so weak is one of the unanswered questions in physics. Extra Dimensions? more later in course

Gravity vs. Electric Force

- electric and gravitational forces → same form
- compare strengths for electron and proton in Hydrogen

$$F_{gravity} = G\frac{mass_1 mass_2}{R^2}$$

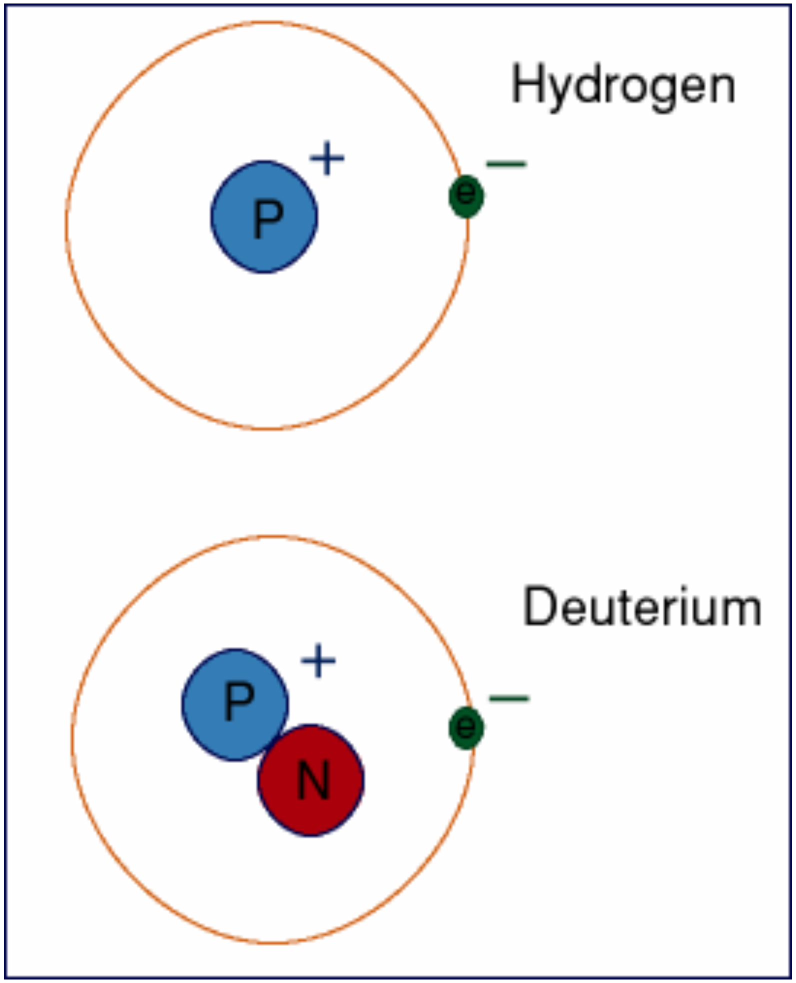
$$F_{electric} = E\frac{charge_1 charge_2}{R^2}$$

$$\frac{F_{gravity}}{F_{electric}}(Hydrogen) = 10^{-39}$$

$$= 0.00000000000000000000000000000000000001$$

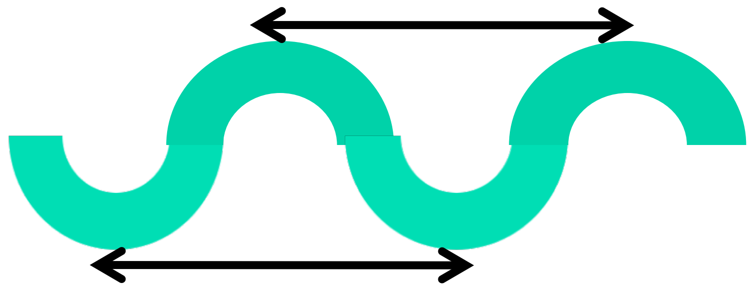
Hydrogen

- Simplest atom – just one electron and one proton
- “heavy” hydrogen or deuterium adds one neutron to the nucleus



Light

- Light is a bunch of photons → EM radiation or EM waves
- wavelength (λ) = distance between waves



- Period = time between wave peaks
- Frequency (ν) = 1/period = how rapidly wave is changing

So 60 Hz = 60 Hertz = 60 beats per second is the same as a period of 0.016 seconds

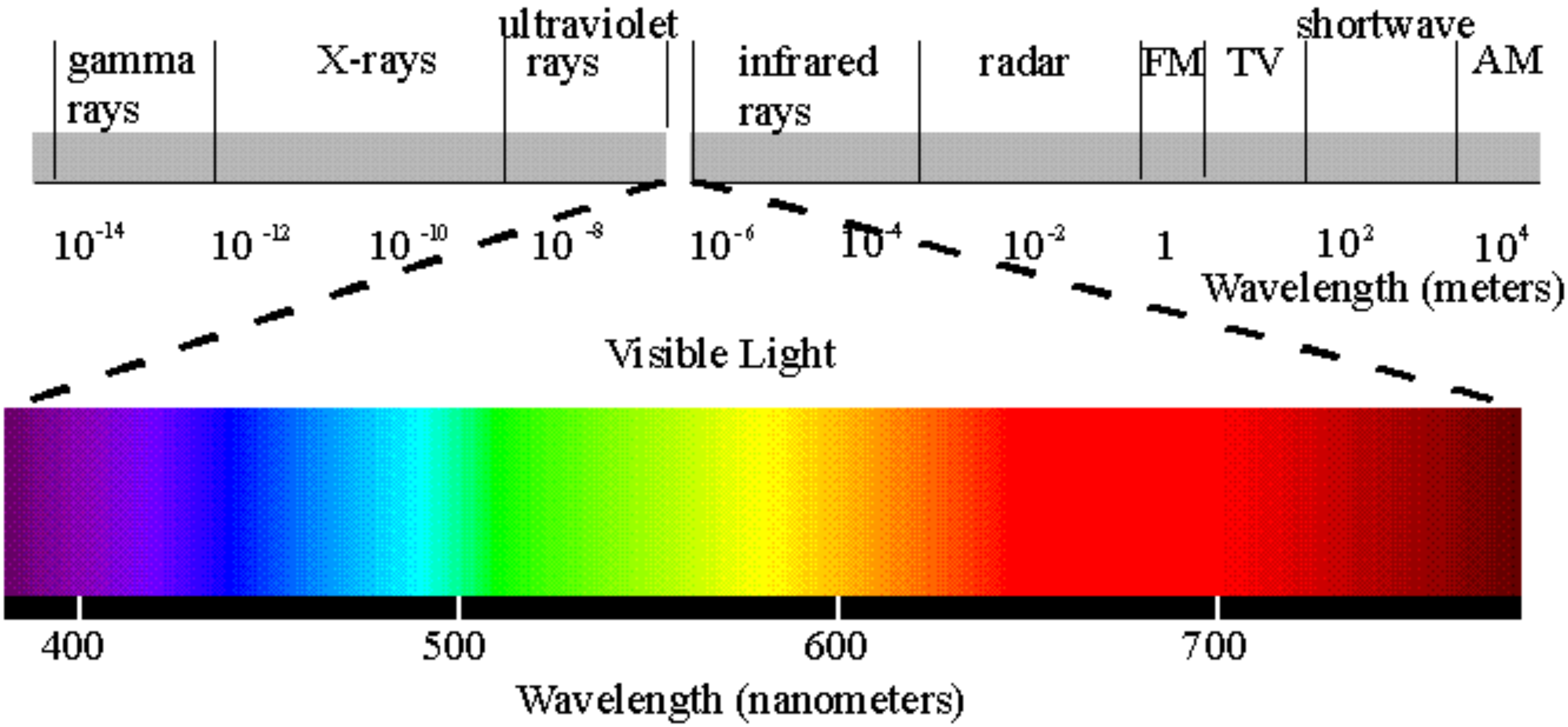
velocity = wavelength X frequency

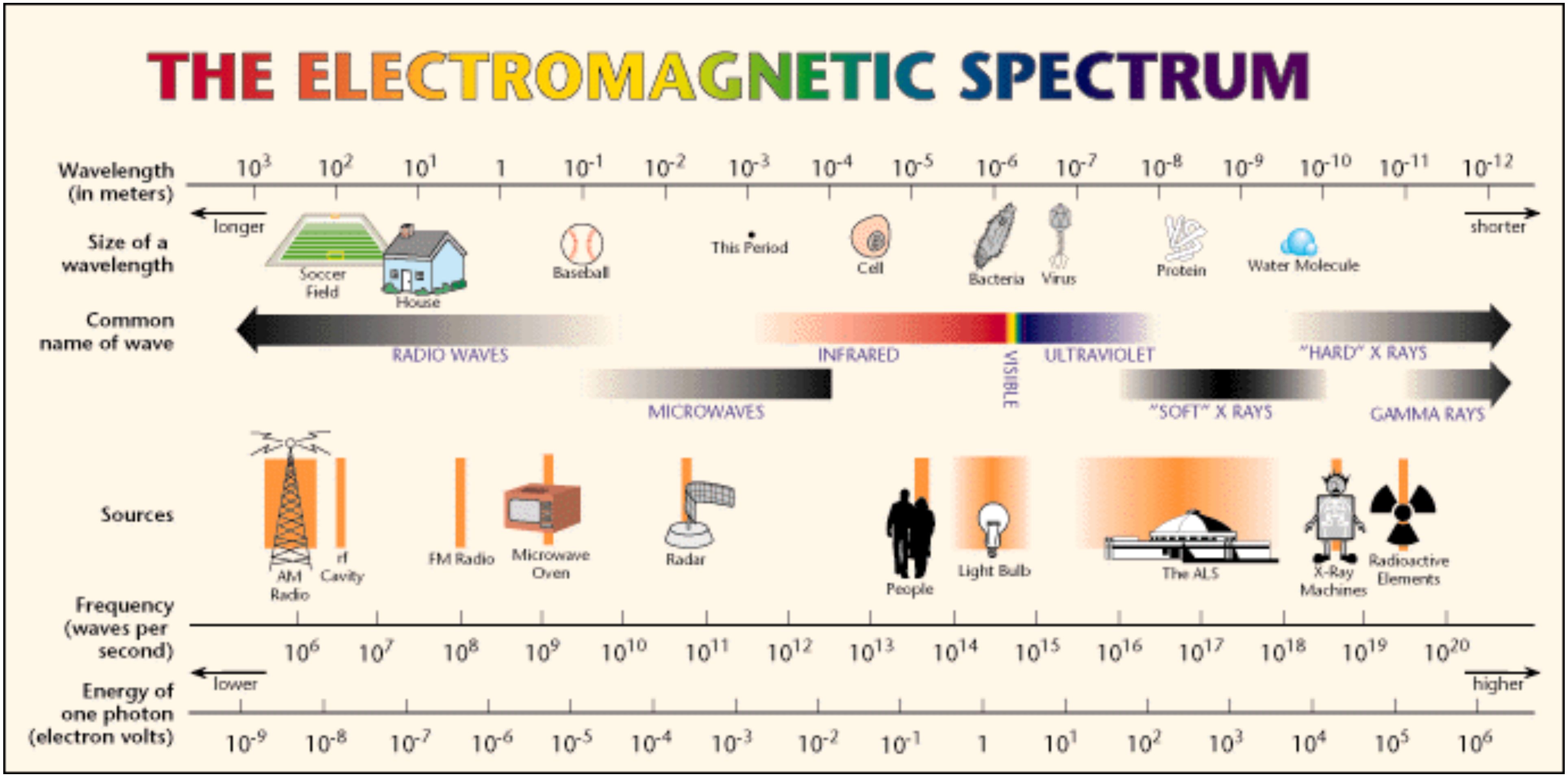
sound = 1 mile/5 seconds

light = 1 mile/5 microseconds = 300,000 km/sec

high energy ~
high frequency

low energy ~
low frequency




THE ELECTROMAGNETIC SPECTRUM
Wavelength (in meters)
10^3 10^2 10^1 1 10^-1 10^-2 10^-3 10^-4 10^-5 10^-6 10^-7 10^-8 10^-9 10^-10 10^-11 10^-12
longer
shorter
Size of a wavelength
Soccer Field
House
Baseball
This Period
Cell
Bacteria
Virus
Protein
Water Molecule
Common name of wave
RADIO WAVES
INFRARED
VISIBLE
ULTRAVIOLET
"HARD" X RAYS
MICROWAVES
"SOFT" X RAYS
GAMMA RAYS
Sources
AM Radio
rf Cavity
FM Radio
Microwave Oven
Radar
People
Light Bulb
The ALS
X-Ray Machines
Radioactive Elements
Frequency (waves per second)
10^6 10^7 10^8 10^9 10^10 10^11 10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20
lower
higher
Energy of one photon (electron volts)
10^-9 10^-8 10^-7 10^-6 10^-5 10^-4 10^-3 10^-2 10^-1 1 10^1 10^2 10^3 10^4 10^5 10^6

Continuous Spectrum

- Radiation of light due only to Temperature of object
- All frequencies

- Peak of frequency spectrum depends on Temperature

  $\text{wavelength}_{max} = 3{,}000{,}000/T$

with wavelength in nanometers and T in Kelvin

- Total energy emitted

  $E = \text{sigma} \times T^4$ sigma=constant

Temperature

Temperature <=> Velocity <=> Energy

At higher Temps

higher velocities

more acceleration of electrons

more light emitted

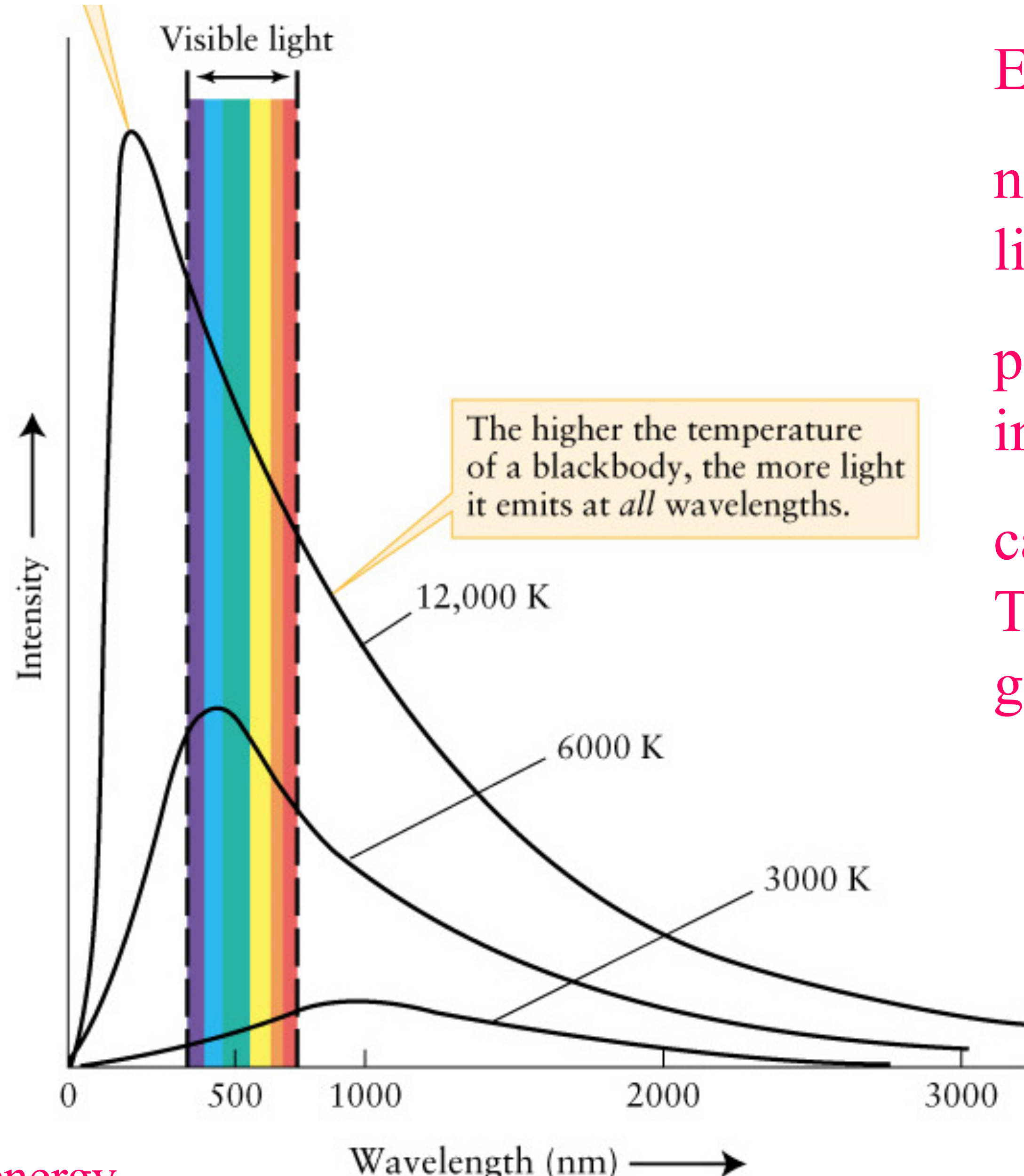
- Kelvin Scale

Absolute 0 = 0^0 K

= -273^0 C

= -459^0 F

at high T Kelvin and Centigrade about same



EXAMPLES

normal, incandescent light bulbs T=5000K

people T=300K → infrared

campfires, stoves T=600-1000K, start to glow red

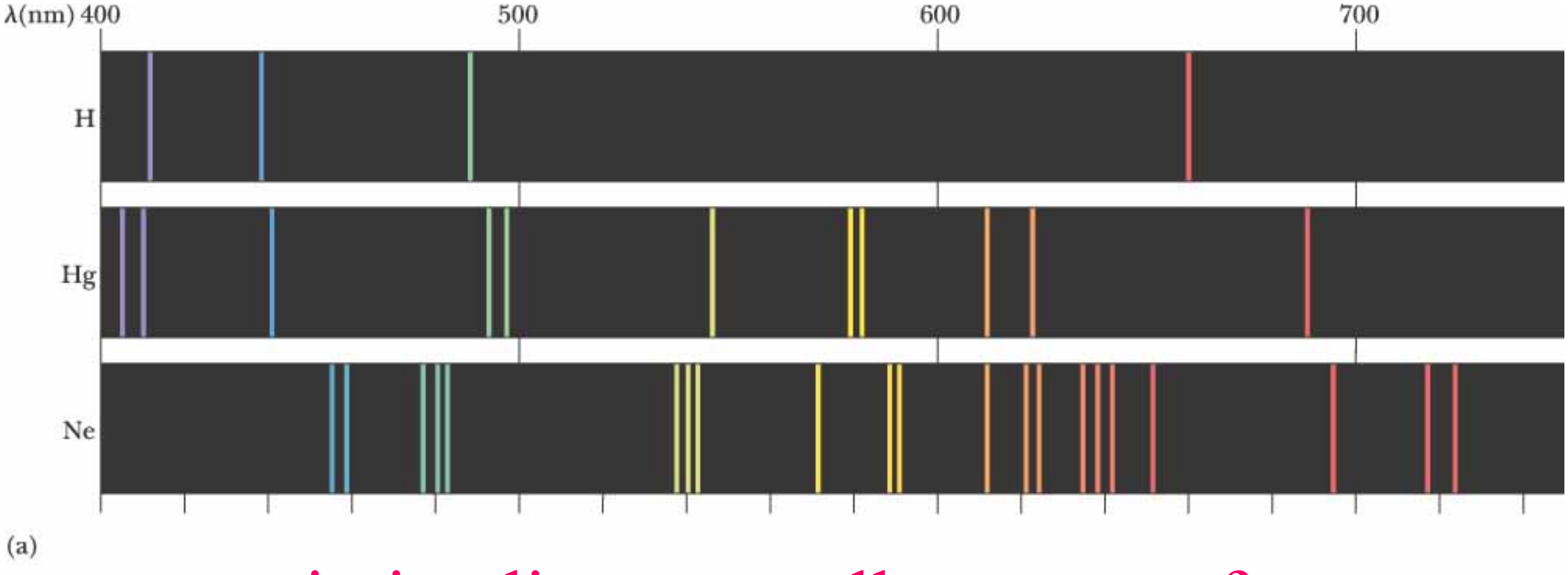
low energy photons

high energy

Discrete Spectrum

- “Spikes” at specific frequencies
- Depends on which atoms are present
- Examples include fluorescent or Neon or Mercury lights
- Can be used to identify chemical composition of objects (spectroscopy)

Atoms and Energy Levels

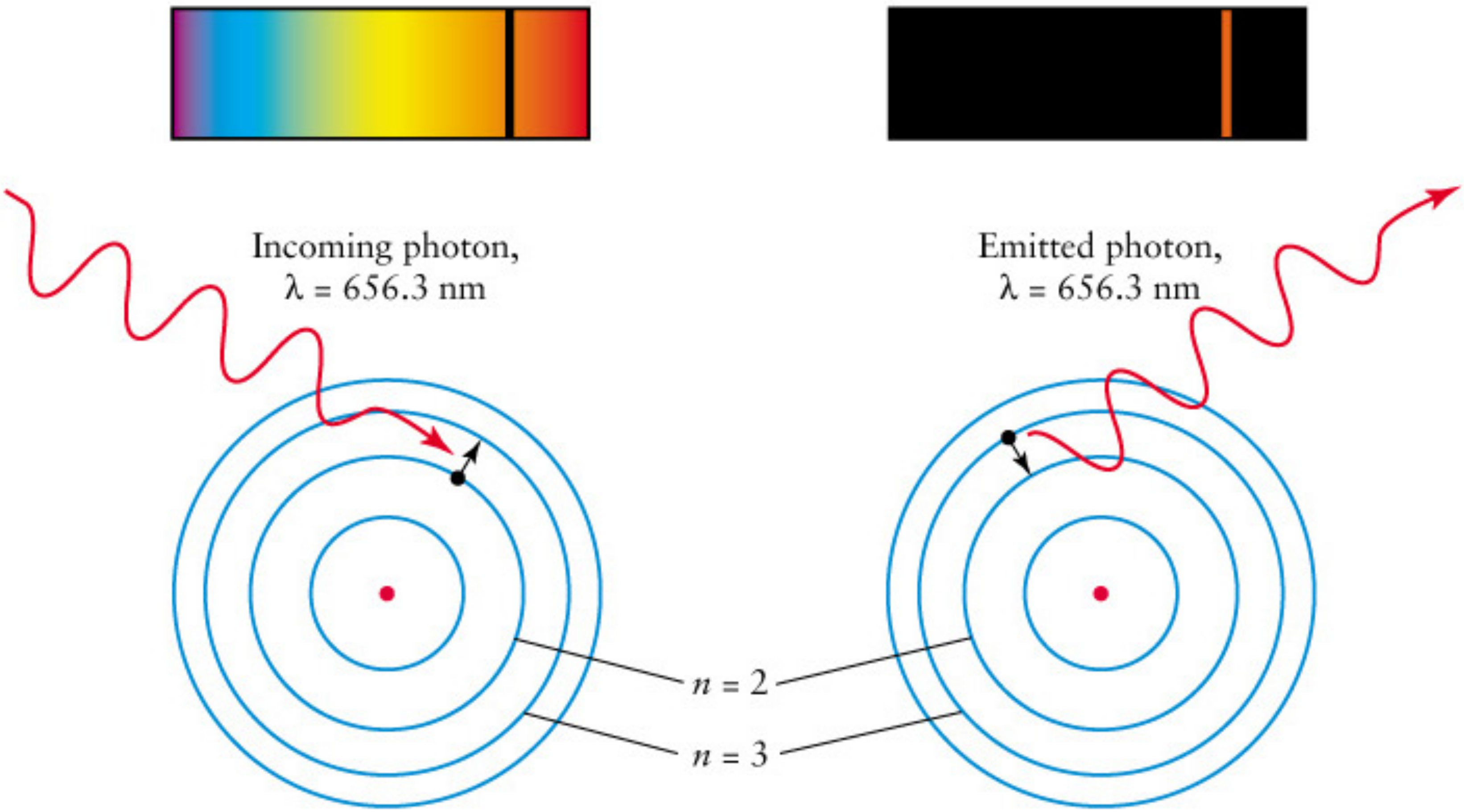


emission lines can tell one atom from another – in this case Hydrogen from Mercury from Neon

Atoms and Energy Levels

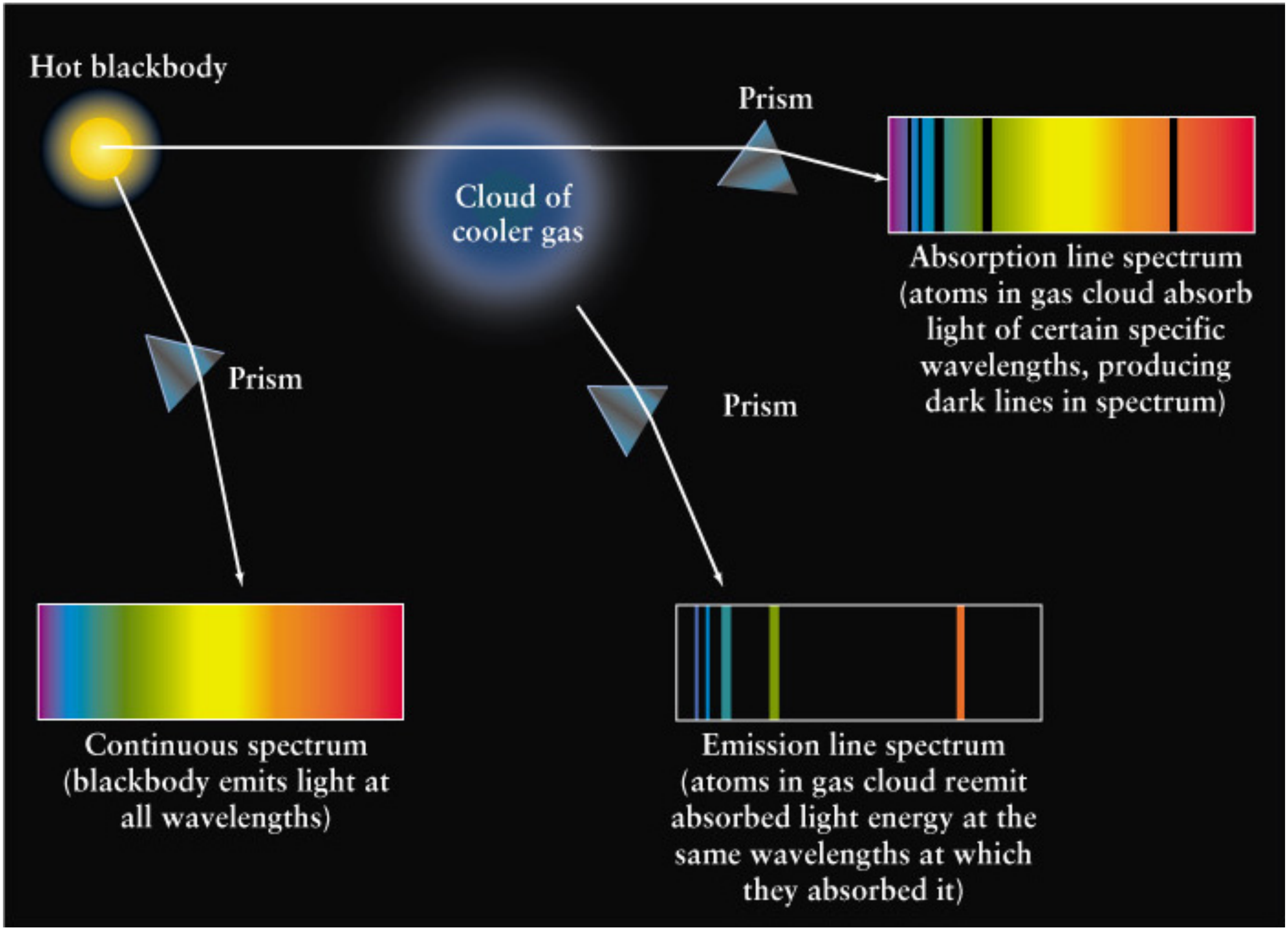
- An atom is a nucleus surrounded by electrons
- held together by the electromagnetic force
- Electron can be in different energy states
- Changes in energy states (Quantum Leaps) produce discrete spectrum

Atoms and Energy Levels



- Transitions between different atomic energy states either emit or absorb light
- The energy of the light (the photon's frequency) is equal to the difference between the atomic energy states
- Pattern of photon frequencies tells what atom is emitting the light

E(photon) = hf
H = Planck's constant
F = frequency


Hot blackbody
Cloud of
cooler gas
Prism
Prism
Prism
Absorption line spectrum
(atoms in gas cloud absorb
light of certain specific
wavelengths, producing
dark lines in spectrum)
Continuous spectrum
(blackbody emits light at
all wavelengths)
Emission line spectrum
(atoms in gas cloud reemit
absorbed light energy at the
same wavelengths at which
they absorbed it)

Demos!!

How fluorescent light works

- Tube filled with Mercury and Argon gas
- Initial HV heat up gas ◊ ?Argon "plasma"
- moves electrons in Mercury to higher energy levels
- •electrons "fall" to lower energy levels and emit UV light
- •UV light absorbed by phosphor coating on walls and is reemitted at lower energy, with mix of colors that appears white