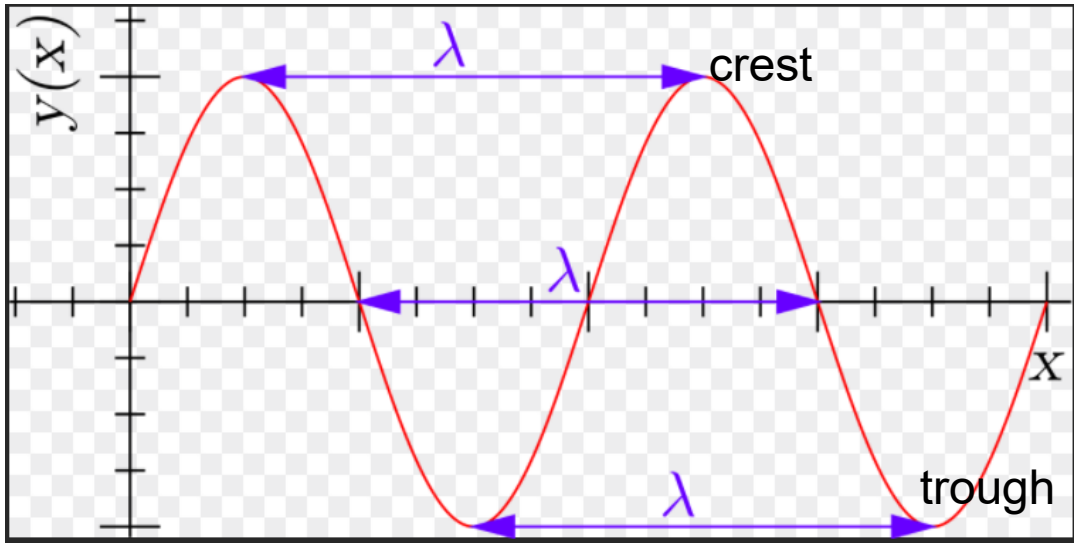
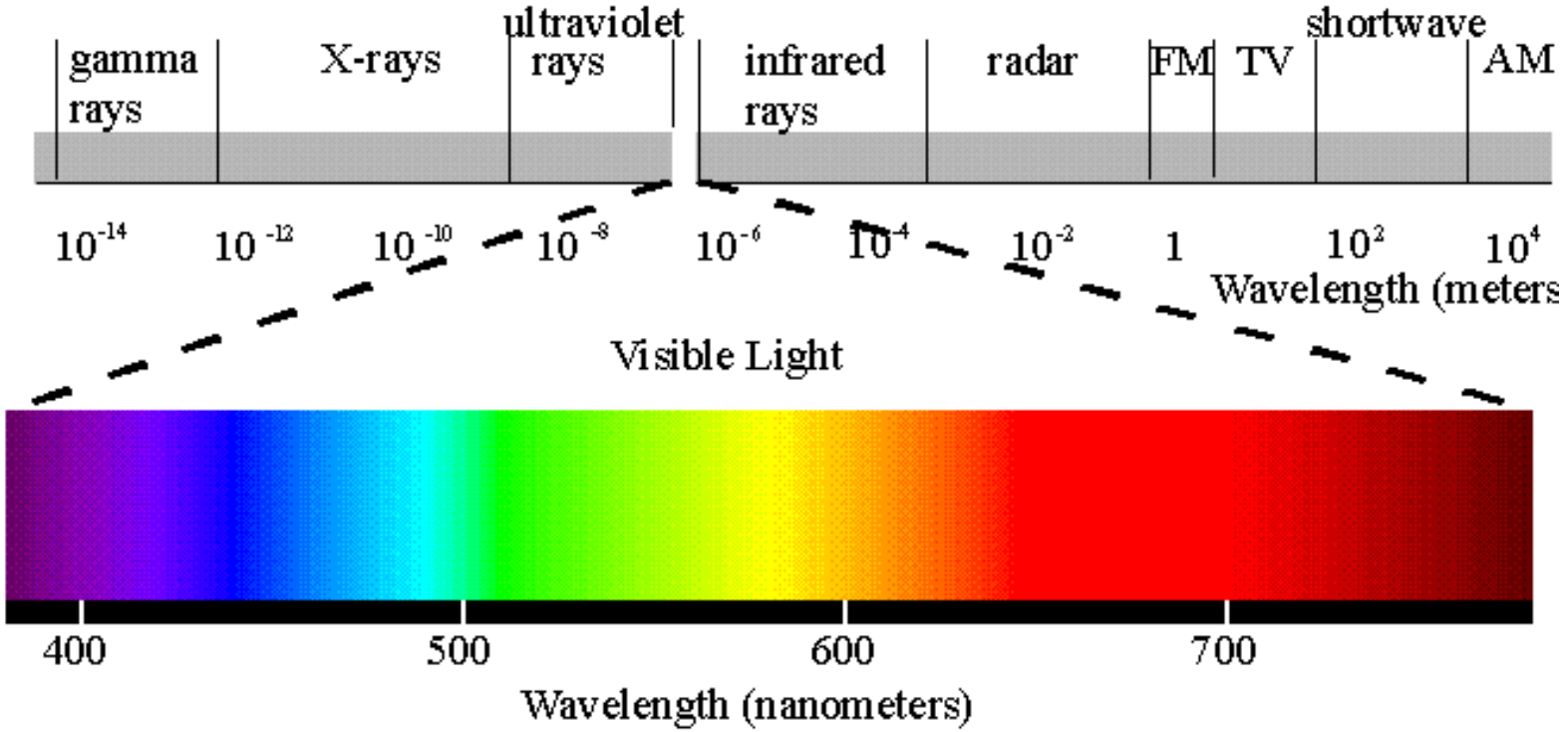
Electromagnetic waves

A wave is a way to transfer energy. Energy is moving shaking is moving.
Wavelength (m) = size of wave in meter. Frequency 9Hz) = number of shaking / second
Speed of wave (m/s) = wavelength x frequency.
High frequency → low wavelength.



//phet.colorado.edu/sims/html/wave-on-a-string/latest/wave-on-a-string_en.html

LIGHT for medical imaging / electromagnetic spectrum



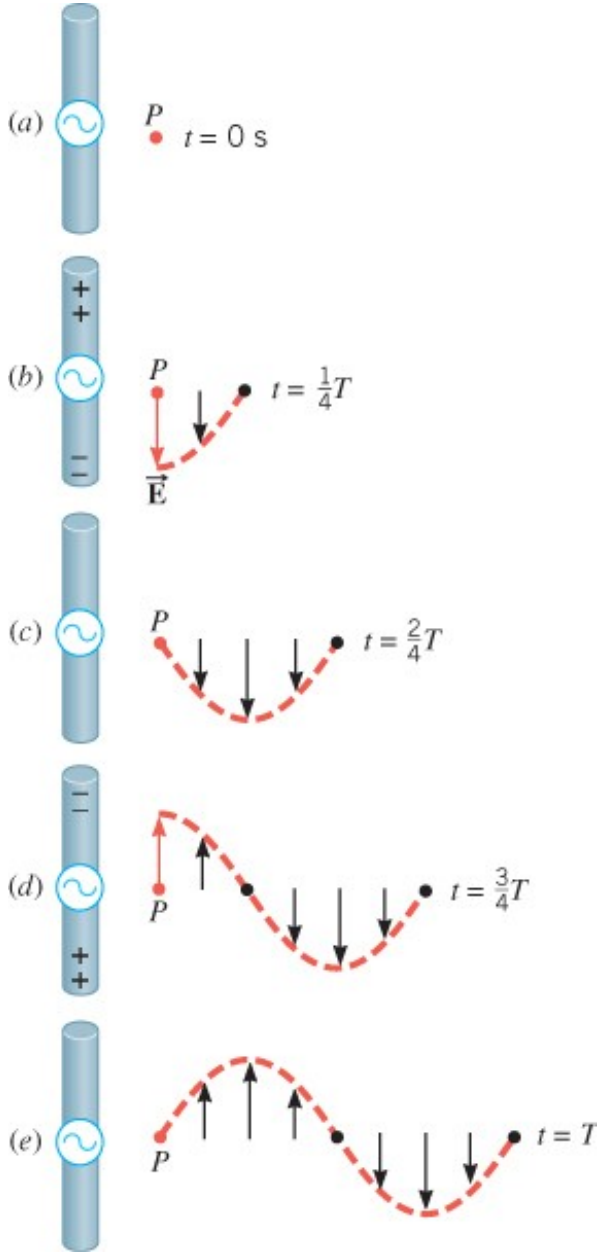
https://phet.colorado.edu/en/simulation/radio-waves

The Van de Graaf generator gets charged
And creates a static electric field in the space

If you shake the Van de Graaf the electric field shakes = electromagnetic wave.

The frequency is small so a radio wave is created.
The wave can be detected by an antenna.

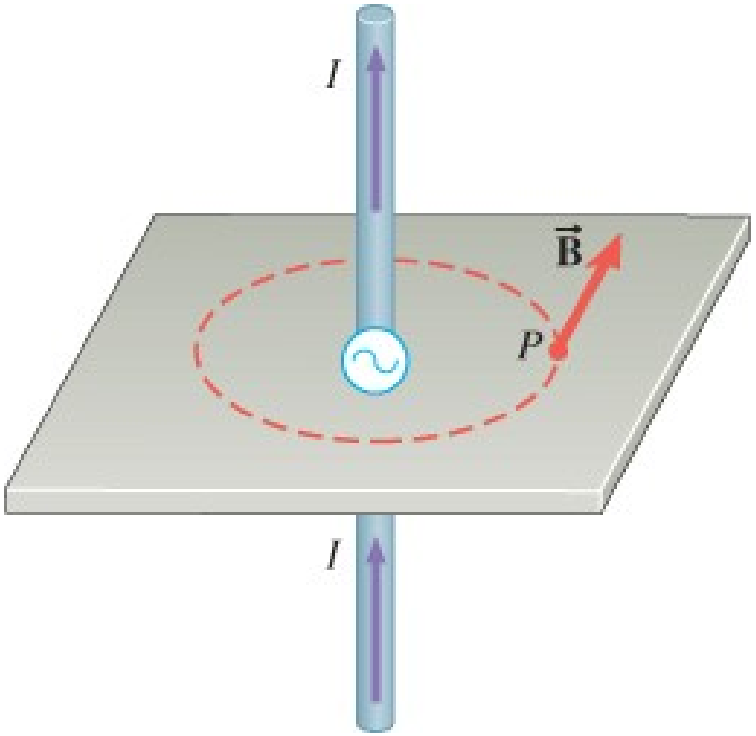
https://phet.colorado.edu/en/simulation/radio-waves



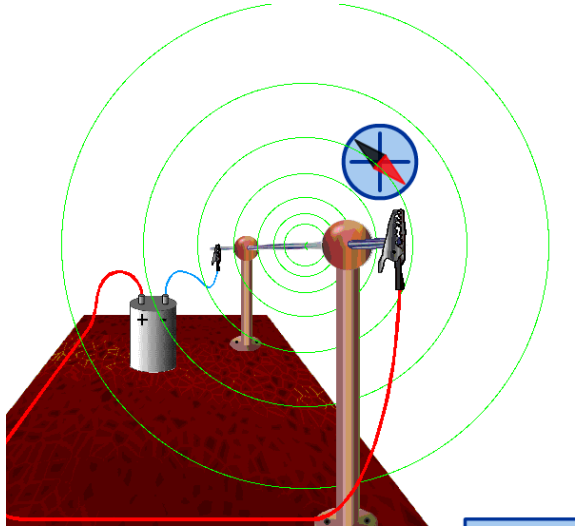
Like wise electrons “shaking “ or oscillating in an antenna creates an oscillating electric field.

Two straight wires connected to the terminals of an AC generator can create an ***electromagnetic wave***.

Only the electric wave traveling to the right is shown here.



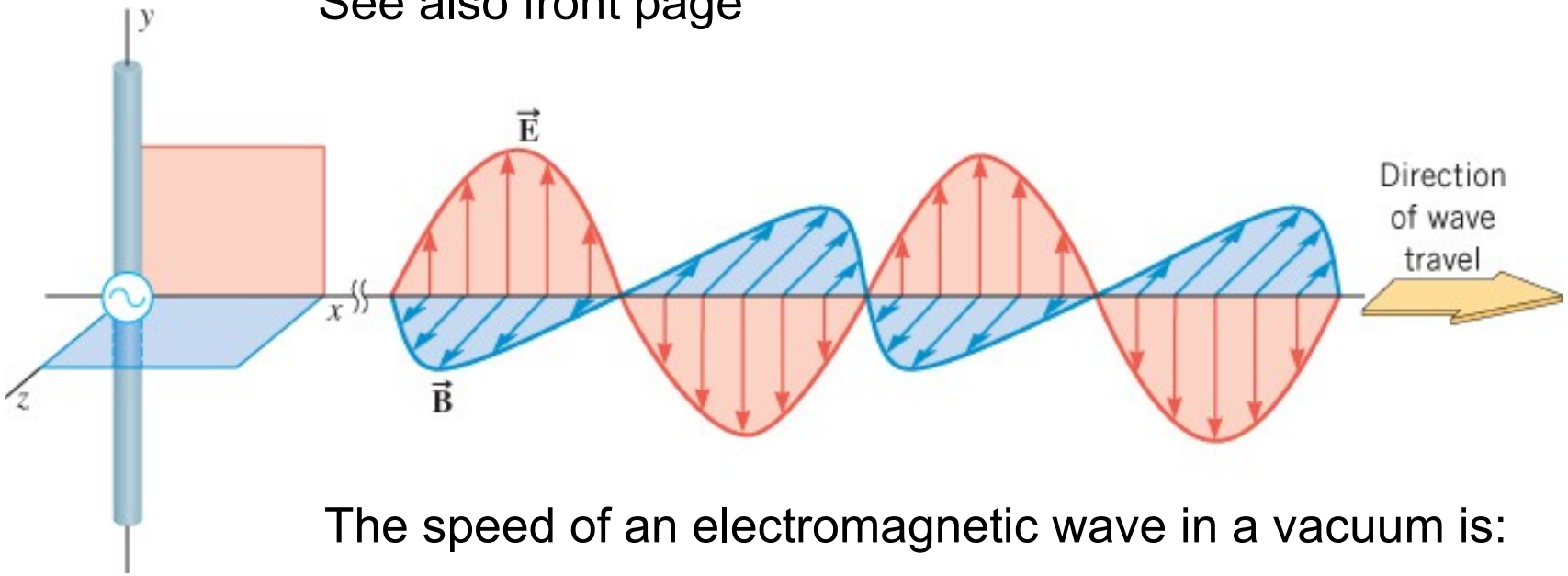
Remember that a current-carrying wire creates a magnetic field circulating around the wire ?



The current used to generate the electric wave creates a magnetic field.

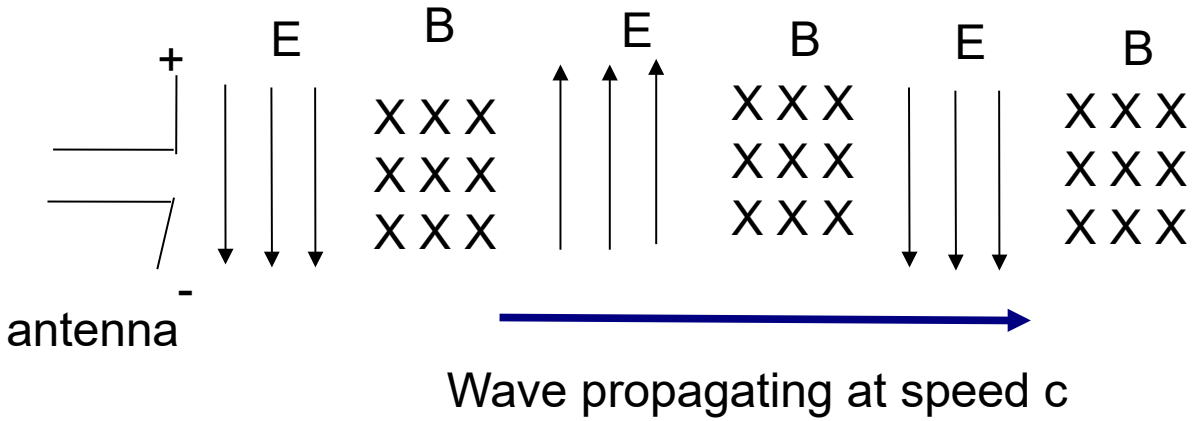
This picture shows the wave of the radiation field far from the antenna.

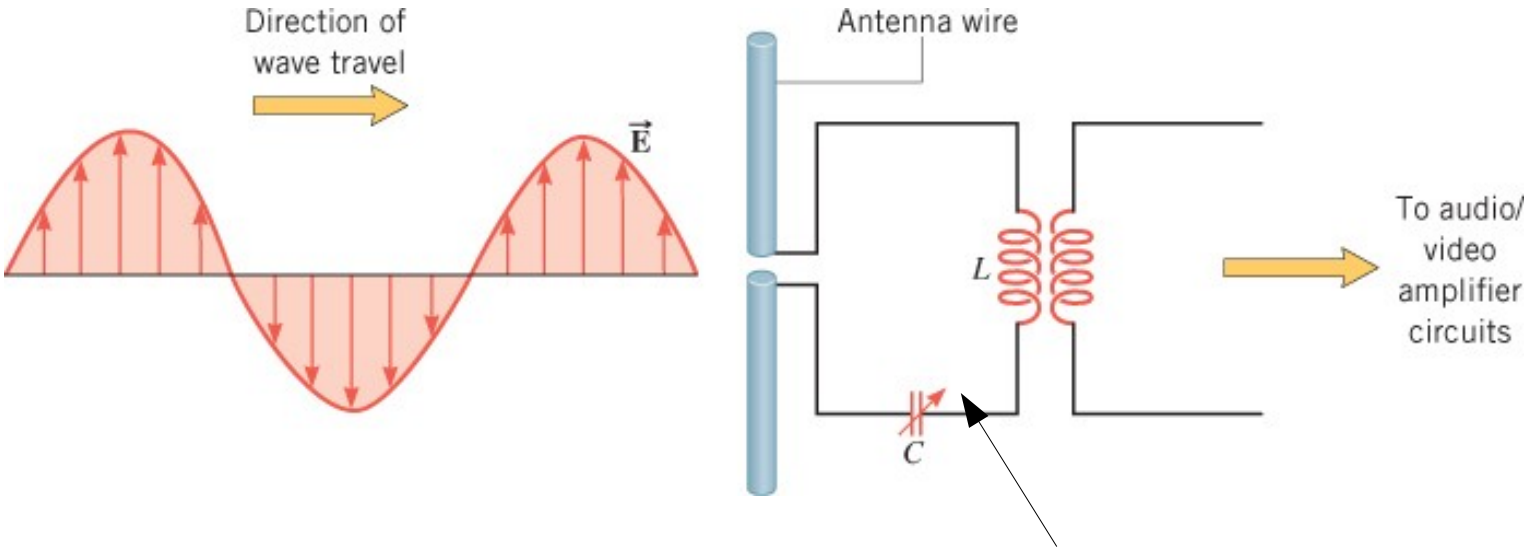
See also front page



The speed of an electromagnetic wave in a vacuum is:

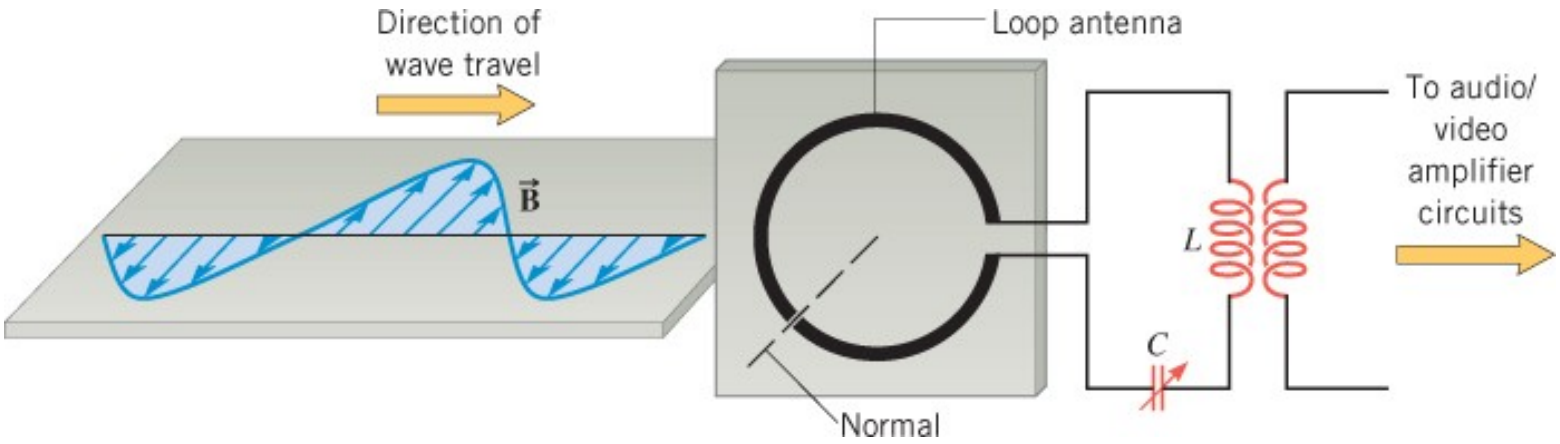
$$c = 3.00 \times 10^{8}\ m/s$$





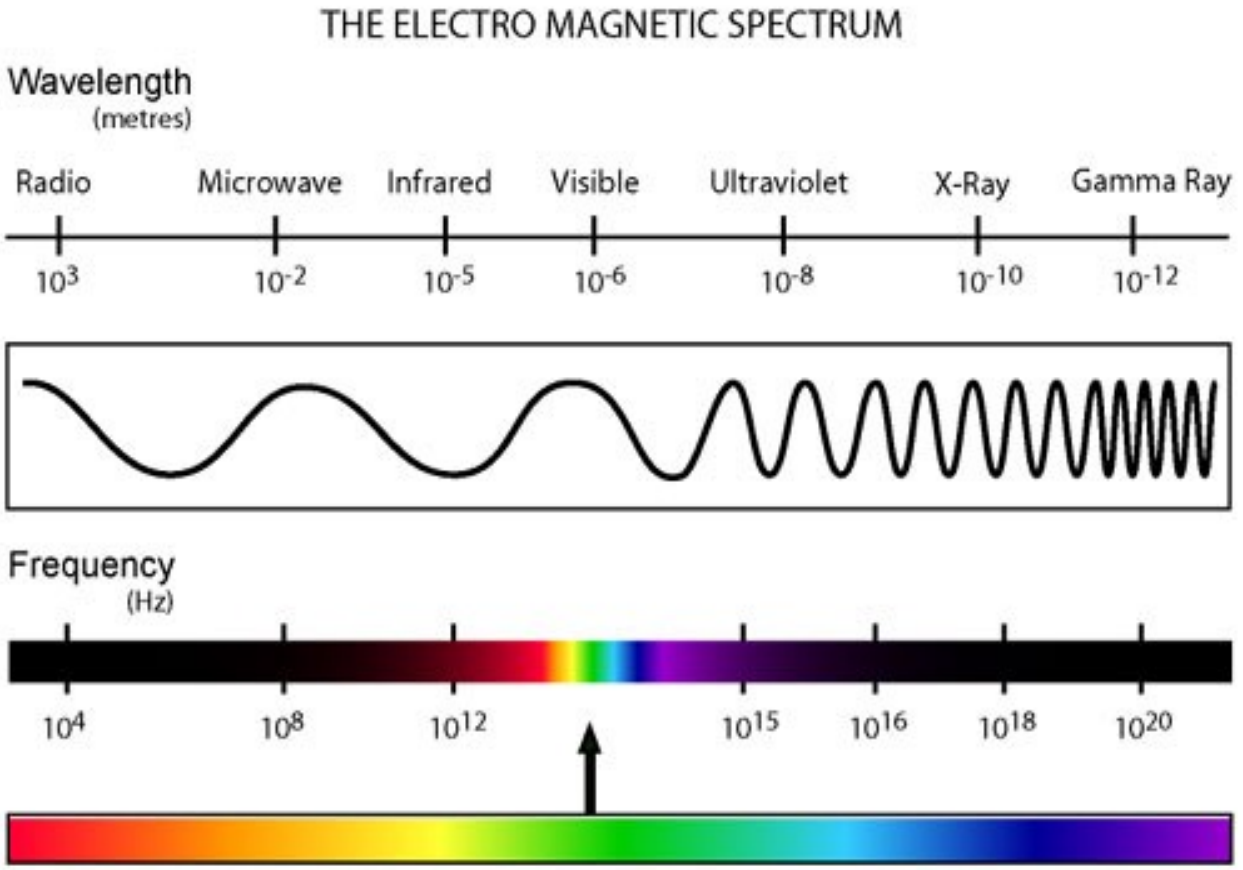
Resonant circuit. If frequency= natural frequency of circuit oscillations are amplified and transferred to audio/video

A radio wave can be detected with a receiving antenna wire that is parallel to the electric field.



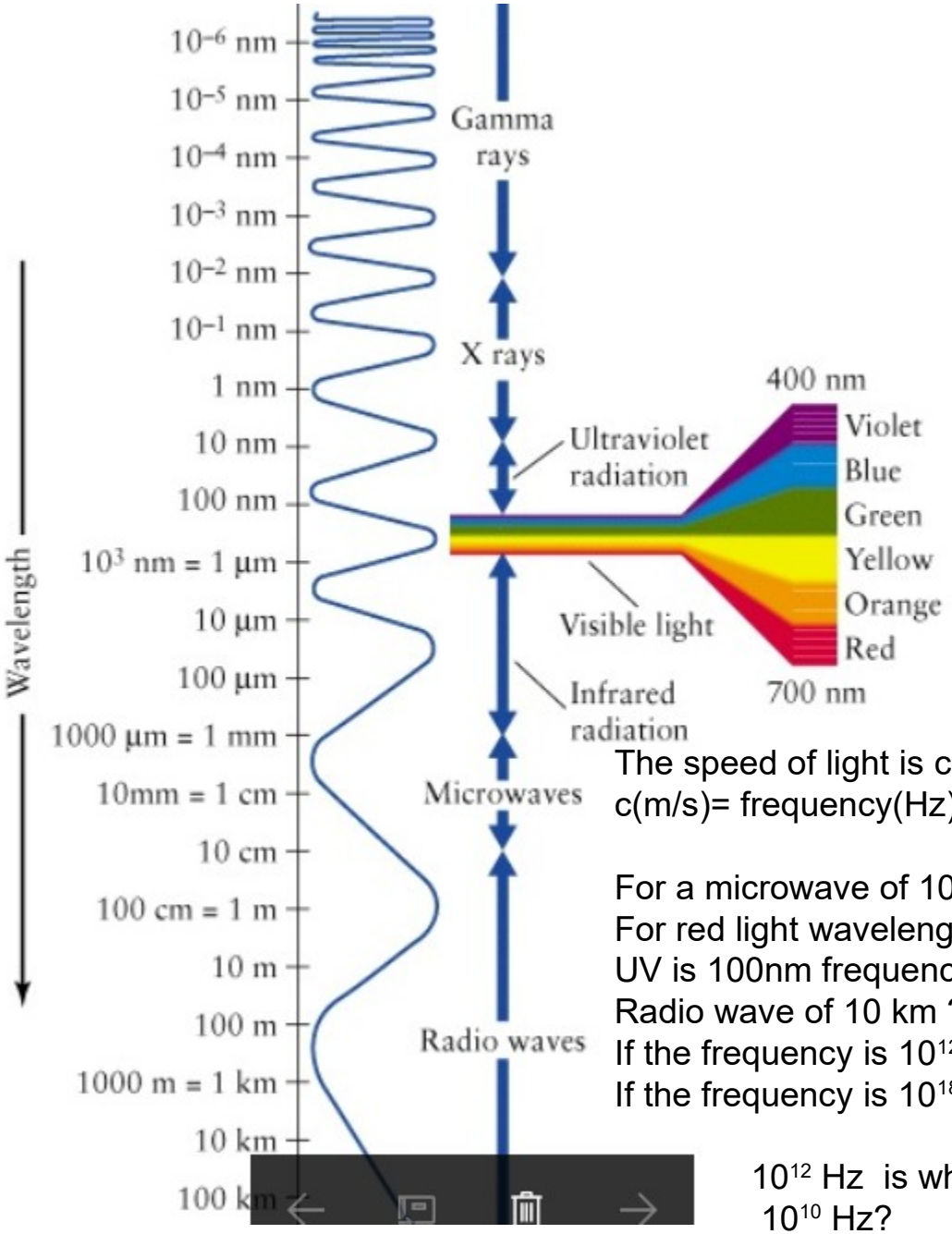
With a receiving antenna in the form of a loop, the magnetic field of a radio wave can be detected.

Electromagnetic waves carry energy



Like all waves, electromagnetic waves have a wavelength and frequency related by:

$$c = f\lambda$$



Convert :

10^{-6} nm in meters

10^{-1} nm in meters

100 um (micro m) in meters

10km in meters

10^3 cm in meters

The speed of light is c =3 10^8 m/s

c(m/s)= frequency(Hz) x wavelength(m)

For a microwave of 10cm what is the frequency?

For red light wavelength = 650nm what is the frequency

UV is 100nm frequency is ?

Radio wave of 10 km ?

If the frequency is 10^{12} Hz (gamma rays) what is the wavelength ?

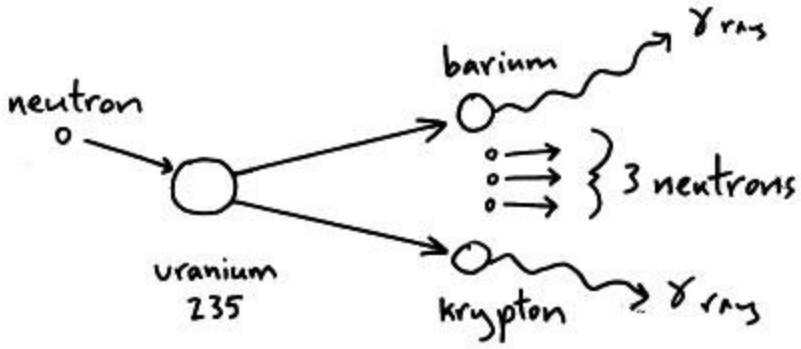
If the frequency is 10^{18}Hz (xray) what is the wavelength ?

10^{12} Hz is what wavelength ? What is this wave ?

10^{10} Hz?

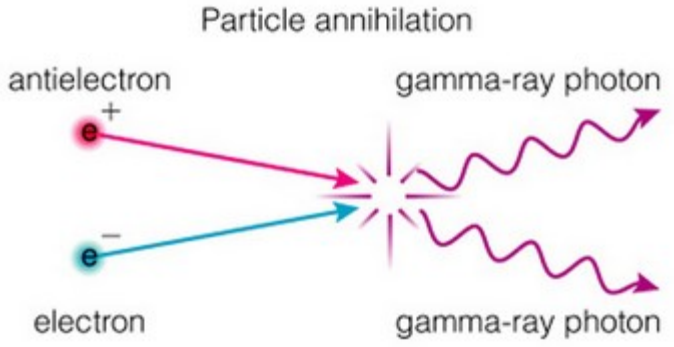
GAMMA RAYS:

Highest frequency range from 3 10^{19} Hz to 10^{23} Hertz. Wavelength same size of nuclei (10^{-12}m and smaller) Emitted in nuclear processes;
radioactive decay,Fission, fusion .. damaging. Ionizing radiation.
Can cause radiation sickness and Death or induce cancer. But used for imaging.



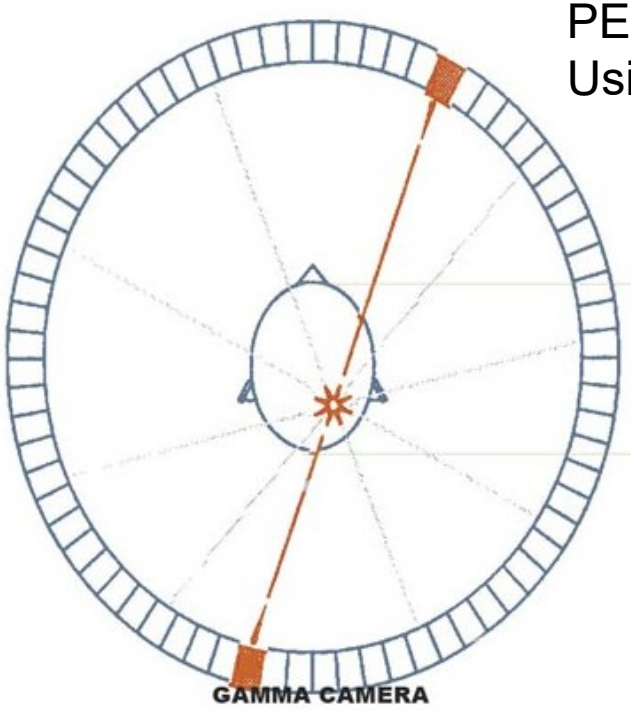
Gamma rays can be emitted when a nucleus decays. Here Is reaction of fission used for the atomic bomb

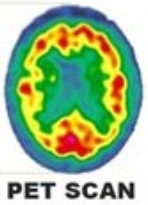
Explosive and violent event in space
Can produce gamma ray bursts.
It involves neutron stars and black holes.

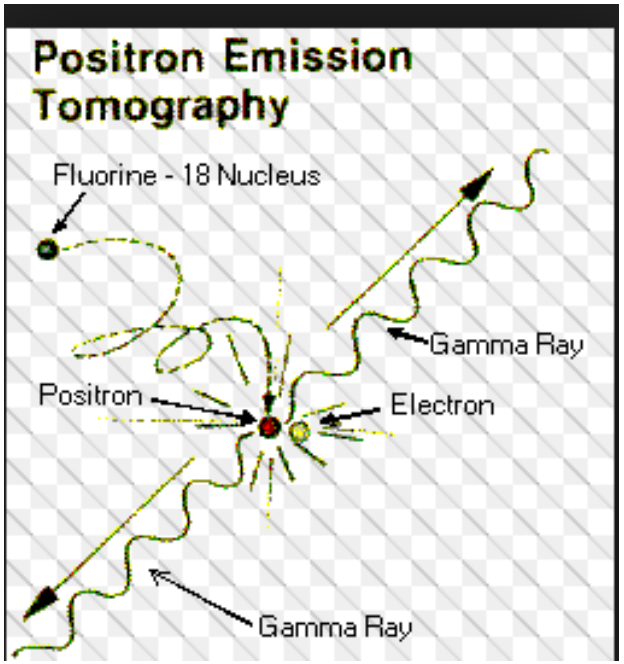


Gamma rays can be produced when an Electron and an anti-electron (positron) collide.
Matter+ anti_matter = energy

PET SCAN
Using gamma rays







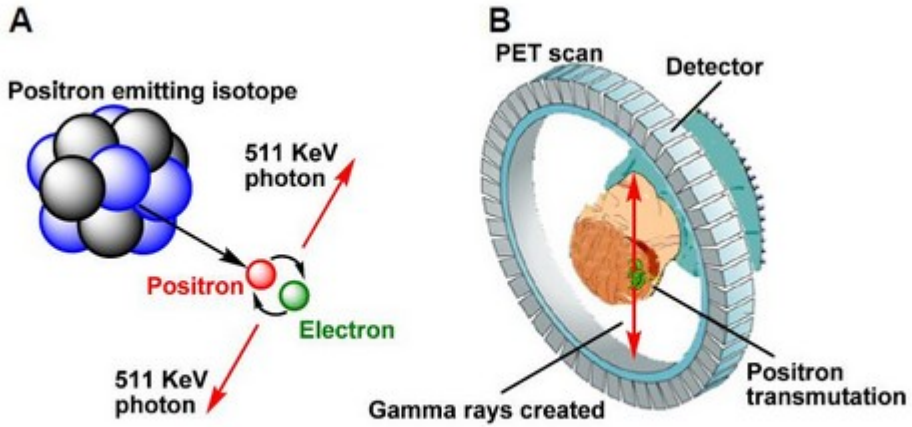
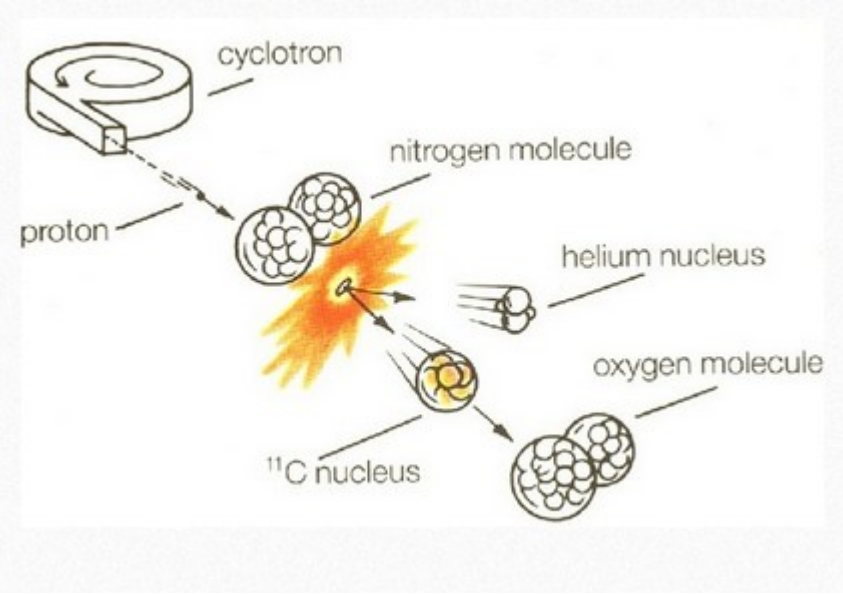


Fig. 1. (A) A positron and an electron annihilate producing two 511 keV photons travelling in opposite directions. (B) The 511 keV photon was registered by the circular gamma ray detector array in the PET camera.

Radionuclide	Half-life	Chemical Form	Nuclear Reaction(s)
^{11}C	20 min	$^{11}CO_2$ / $^{11}CH_4$	$^{14}N(p,\alpha)^{11}C$
^{13}N	10 min	$^{13}NH_4^+$ / $^{13}NO_x$	$^{16}O(p,\alpha)^{13}N$
^{15}O	2 min	$^{15}O_2$	$^{15}N(p,n)^{15}O$ $^{14}N(d,n)^{15}O$
^{18}F	110 min	$^{18}F^-$ or $^{18}F_2$	$^{18}O(p,n)^{18}F$ $^{20}Ne(d,\alpha)^{18}F$

http://www.imperial.ac.uk/people/a.gee/research.htm

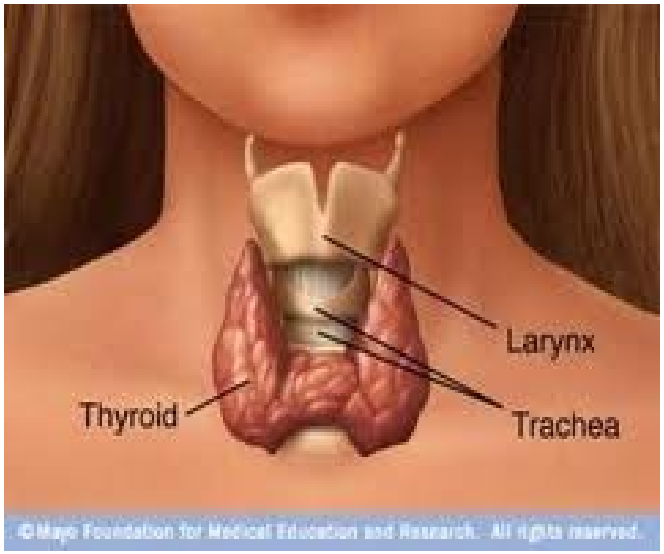


The radioisotopes used for PET scan have to be made in the hospitals using a cyclotron. (remember a magnetic field is used to trap protons around a circular path. An electric field is used to speed them up.)

Here is a list of some positron emitters :

Carbon-11 (20 min)
Nitrogen -13 (9 min)
Oxygen-15 (2min)
Fluorine-18 (110 min)
Iodine-124 (4.2 days)

$$^{11}\mathrm{C} \rightarrow {}^{11}\mathrm{B} + \beta^{+} + \nu_e.$$



The radioisotopes have a very short life. They have to be " made" in the hospital Before the session. This is expensive because it requires accelerators.

In beta plus decay, a proton is converted, via the weak force, to a neutron, a positron (also known as the "beta plus particle", the antimatter counterpart of an electron), and a neutrino.

Iodine-124 for example, goes to the thyroid. Doctors can detect if there Is blank spots or hyperactivity by detecting gamma radiation.

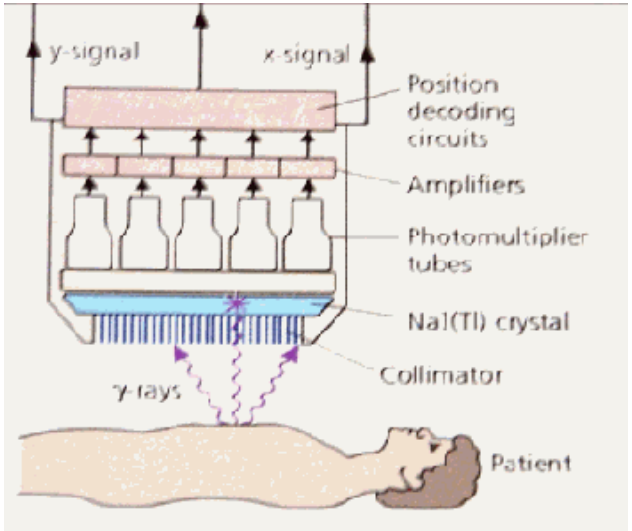
O-15 can flow to the brain for probing the brain.
C-11 can flow to biological compounds.

http://www.isotopeworld.com/filestore/EIR_Medical%20Isotopes%20in%20the%2021st%20Century.pdf

http://www.search.com/reference/Positron_emission

SPECT (single photon emission tomography)

Like PET but cheaper:



SPECT is similar to PET in its use of radioactive tracer material and detection of gamma rays. In contrast with PET, however, the tracer used in SPECT emits gamma radiation that is measured directly, whereas PET tracer emits positrons that annihilate with electrons up to a few millimeters away, causing two gamma photons to be emitted in opposite directions. A PET scanner detects these emissions "coincident" in time, which provides more radiation event localization information and, thus, higher resolution images than SPECT (which has about 1 cm resolution). SPECT scans, however, are significantly less expensive than PET scans, in part because they are able to use longer-lived more easily-obtained radioisotopes than PET

http://www.fas.org/irp/imint/docs/rst/Intro/Part2_26d.html

http://www.slideshare.net/PanduEkoyudho/spect-medicine

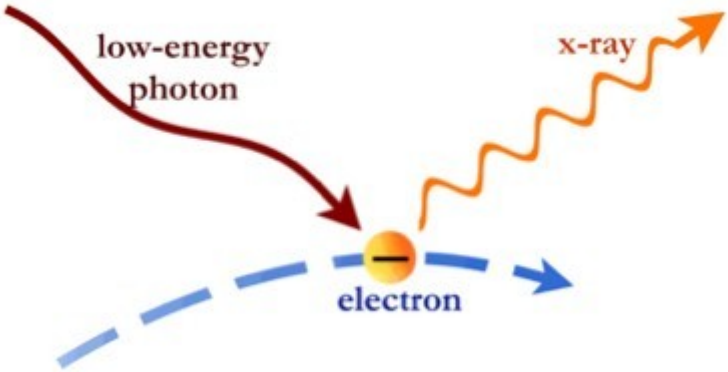
Radioisotopes for this are imported from Canada.

http://en.wikipedia.org/wiki/Single-photon_emission_computed_tomography

http://www.umsl.edu/~tsytsarev/tsytsarev_files/Lecture18.htm

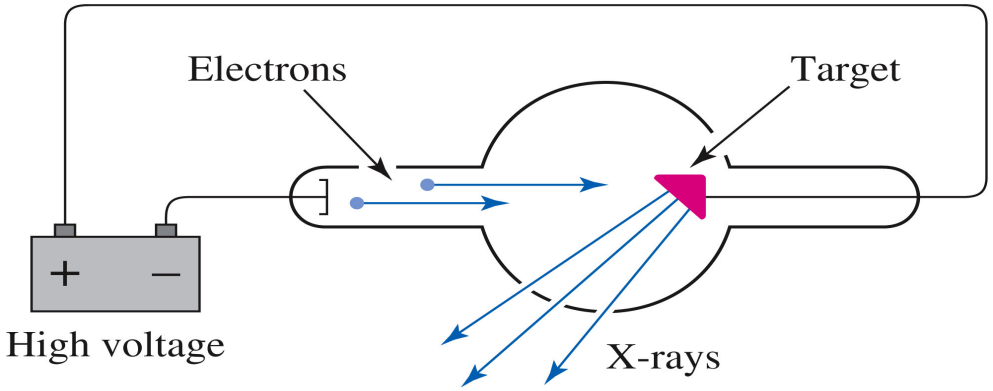
Other ways gamma Rays are emitted.

Crab nebula, electrons decelerate so much, they emit flares of X-rays and Gamma rays.



X-RAYS

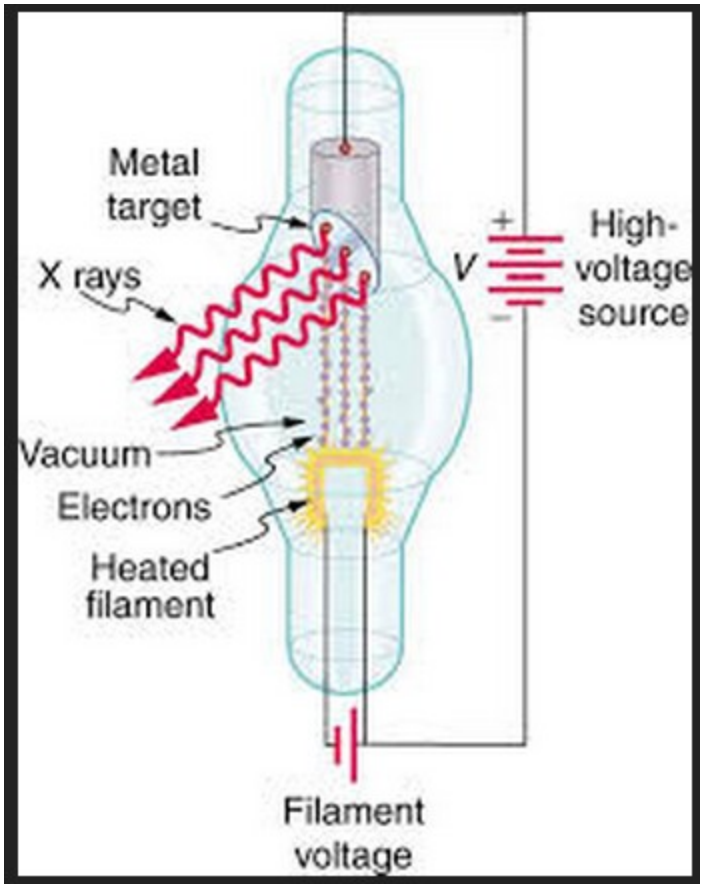
- penetrating and ionizing too. Can cause damage to cell too.
Size of atoms and molecules (10^{-10}m). Can be used to probe crystals and molecules.
X-rays are produced by smashing high-speed electrons into a " target" made of Tungsten or other metal. This is how x-rays are produced in hospitals.

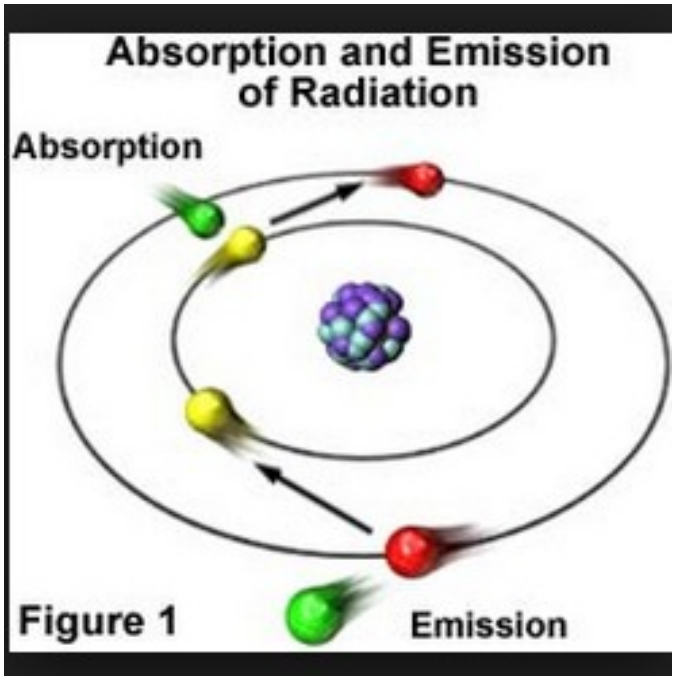


See next slide

The electron lose their kinetic energy when decelerating as radiation.
Plus they kick out some electrons in the metals.
Other electrons (from higher energy Levels) take their Place
Emitting X-rays.

http://www.youtube.com/watch?v=lRBKN4h7u80

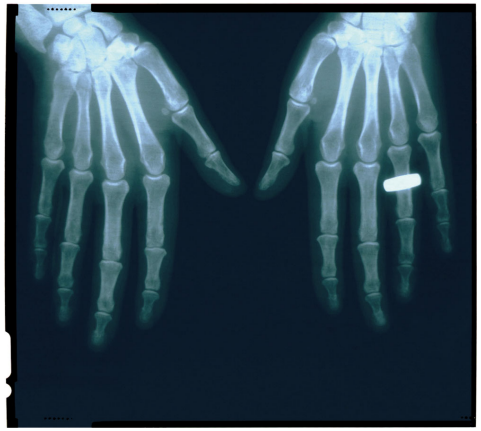




IF_05_15_EmissionLine.htm

X-RAYS

X-rays pass through the body but they are absorb by large atoms like calcium.
Carbon and hydrogen let them got through. Lead atoms stop x-rays.
Discovered by 1895 by Wilhelm Conrad Röntgen,
who received the first Nobel Prize in Physics in 1901.
He used a cathode ray tube and didn't know what
These radiations were. He called them X-rays !!
Very quickly used in the medical field.
First, damaging. Now very safe.



http://onlinephys.com/giants2.htm
|

In the 50s, the used Xrays in shoes stores.

See links on website.

Radiation was 30 rem. Find the probability to get cancer in %
1 rem u have a change of 1/2500 to get cancer
If 100,000 people use the machine. How many cancer ? (1200)

CT SCAN or CAT SCAN

The disadvantage is that it uses x-rays.
(you increase the probability of cancer).

CT scans are made by taking x-rays from
Different directions. That's the tomography part.

Less expensive then PET but more invasive
The radiation received is more important.
Not efficient at probing soft tissue.

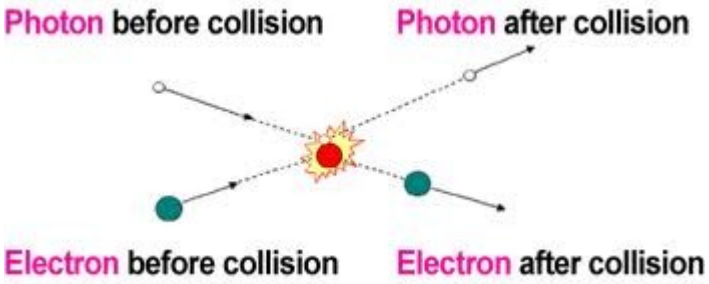
http://health.learninginfo.org/pneumothorax.htm

http://www.ctlab.geo.utexas.edu/overview/index.html

http://www.physicscentral.com/explore/action/scans-1.cfm

XRAY backscatter

Remember : X-ray behaves more like
particle than wave because of
The high energy of the photons
(frequency). The X-ray can either go through
The object but they can also bounce off electrons.
The amount of back scatter
Is roughly determined by the density of the material.



http://articles.cnn.com/2010-05-06/travel/tsa.scanner.assault_1_full-body-scanning-tsa-screener?_s=PM:TRAVEL

Illegal immigrants Attempting to enter Southern Mexico from Guatemala in truckload of Bananas !

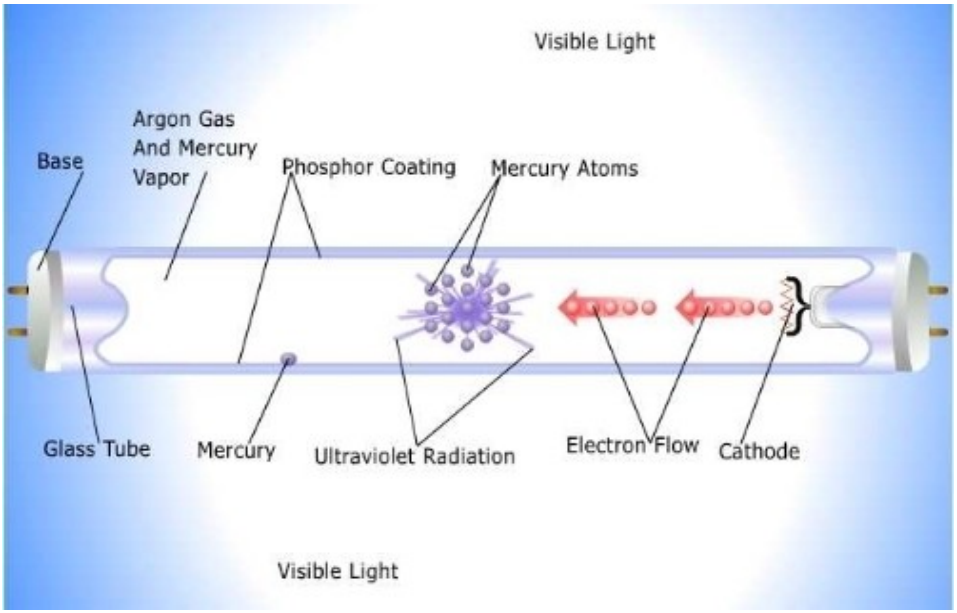
UV radiation

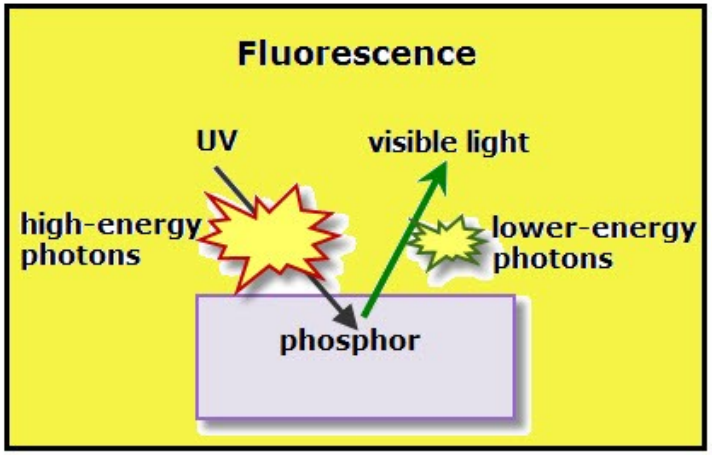
Just above the violet. Still energy high enough to induce skin cancer. Trigger a Chemical process responsible for tanning. Not penetrating like x-rays and gamma rays. Emitted by very hot objects. The UV radiation from the Sun is blocked by the Ozone layer. Application : Indian-born physicist Dr. Ashok Gadgil developed a cheap Way to kill the germ in water using UV radiation. Can treat 15 liters per minute. http://www.wipo.int/ipadvantage/en/details.jsp?id=2564
Used to sterilize tools and workplaces. UV laser are used in dermatology and metallurgy(engraving), forensic (to detect body fluid).

Also in fluorescent lamps.
Atoms of mercury are excited by electric discharge.
Emit UV. UV absorbed by a powder coating the lamp.
Fluorescent materials. Re emit visible light.

Also in **fluorescent lamps.**

Atoms of mercury are excited by electric discharge.
Mercury changes from liquid to gas. The electrons of mercury
Are bumped to higher levels of energy by collisions (with the
When the electron go back to lower energy level they emit
UV photons. The UV photons excite in turn the
Electrons of the phosphor coating the inside of
The lamp/ When they go back, visible is
Emitted.





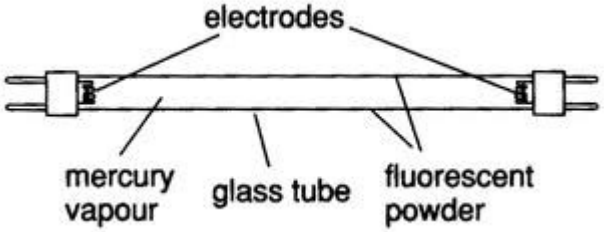
http://www.myclimatechange.net/default.aspx?cat=3&subjectId=51

WHITER THAN WHITE

UV light is absorbed by phosphor or fluorescent chemical (for making the jump between energy gaps) and re emit light.

We use this idea in fluorescent light.

Fluorescent minerals and **laundry soap** .

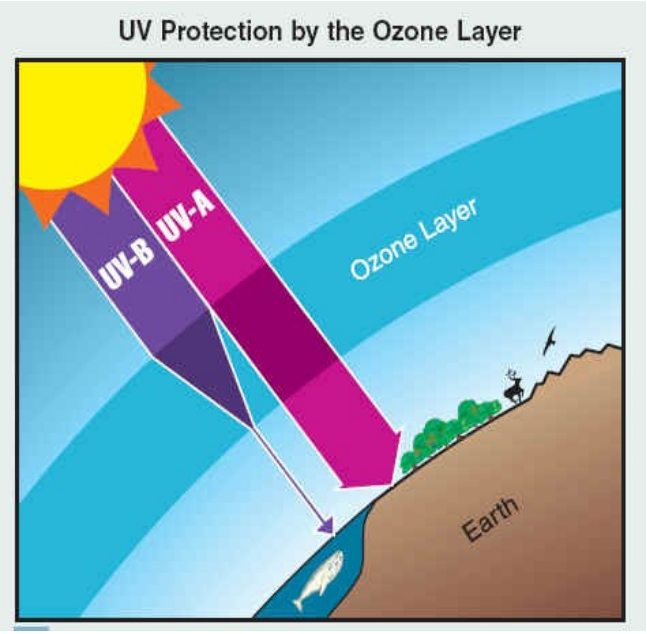


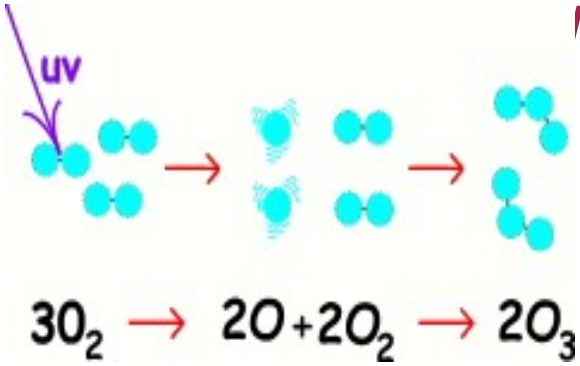
cloth washed with fluorescent chemicals will appear Whiter under the Sun.

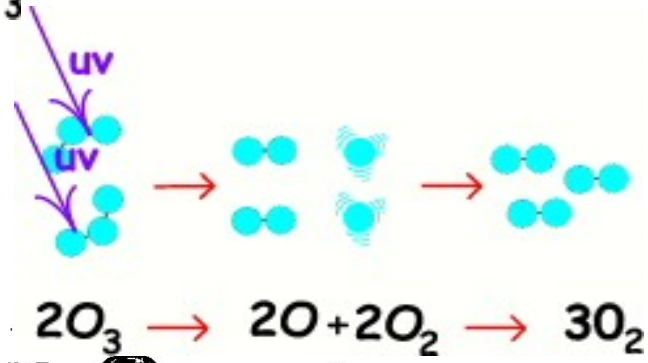
UV radiations are absorbed and visible Light emitted Making white brighter.

http://blogs.discovermagazine.com/notrocketscience/2011/12/23/why-do-scorpions-glow-in-the-dark-and-could-their-whole-bodies-be-one-big-eye/#.WsfpMpW5vIV

/ UV / Freon and CFCs







https://www.youtube.com/watch?v=lniJx-vRHG0

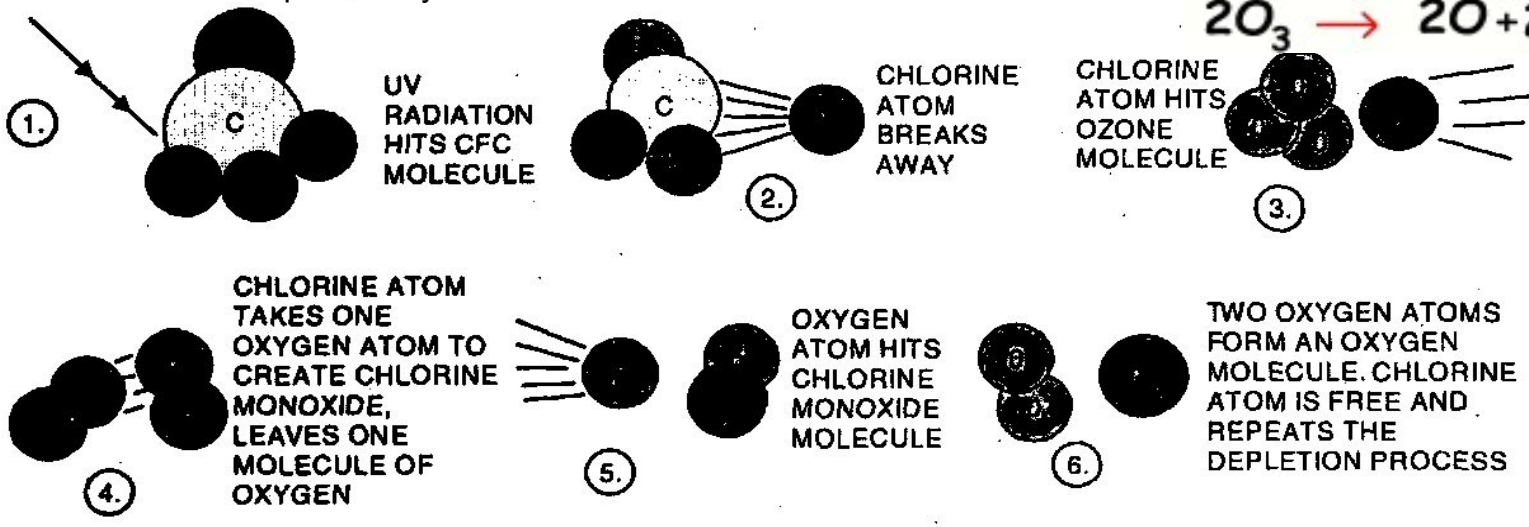
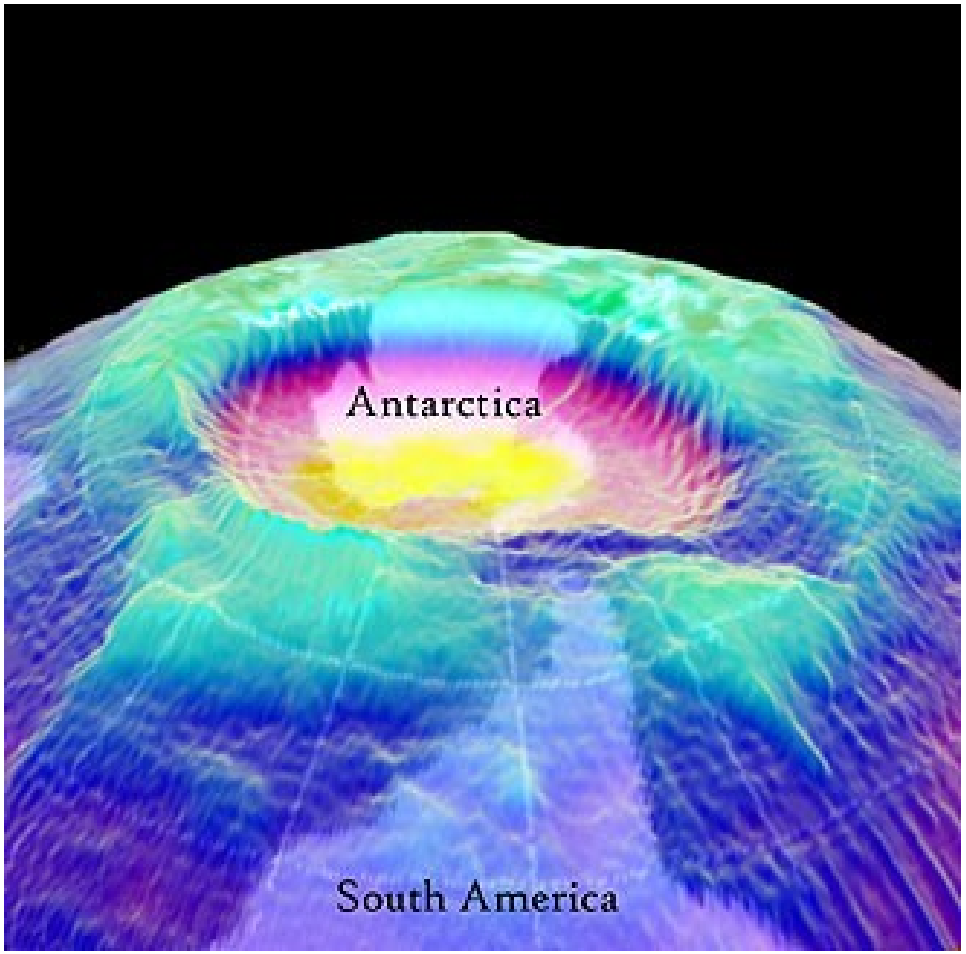


Fig. 1.9. Interaction of CFCs and UV radiation damaging the ozone layer.

http://resources.yesican-science.ca/trek/scisat/final/grade9/ozone1.html



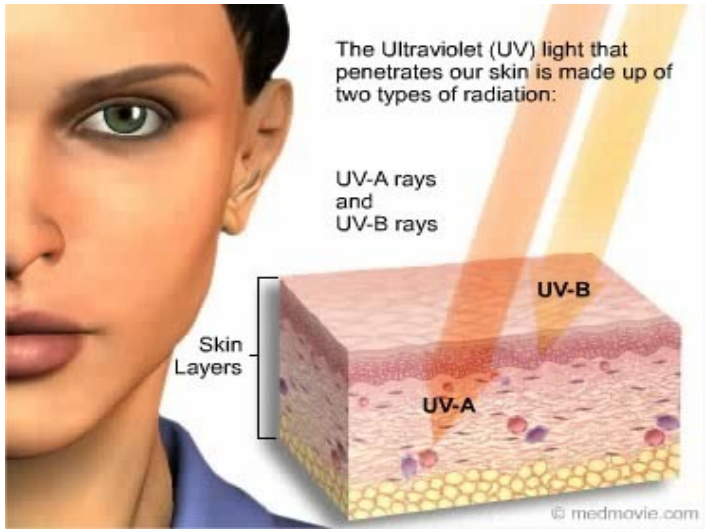
Nobody knew why the hole
Was above Antarctica and not
Some where else. Scientists
Realized that certain crystals
Of nitric acid formed there
In the early spring, and on the
Surface of those crystals,
The chlorine and fluorine
Was far more effective at
Destroying the ozone.

Freon was used in AC,
Refrigerator and propellants. Now,
It's illegal but the CFCs stick for
A long time.

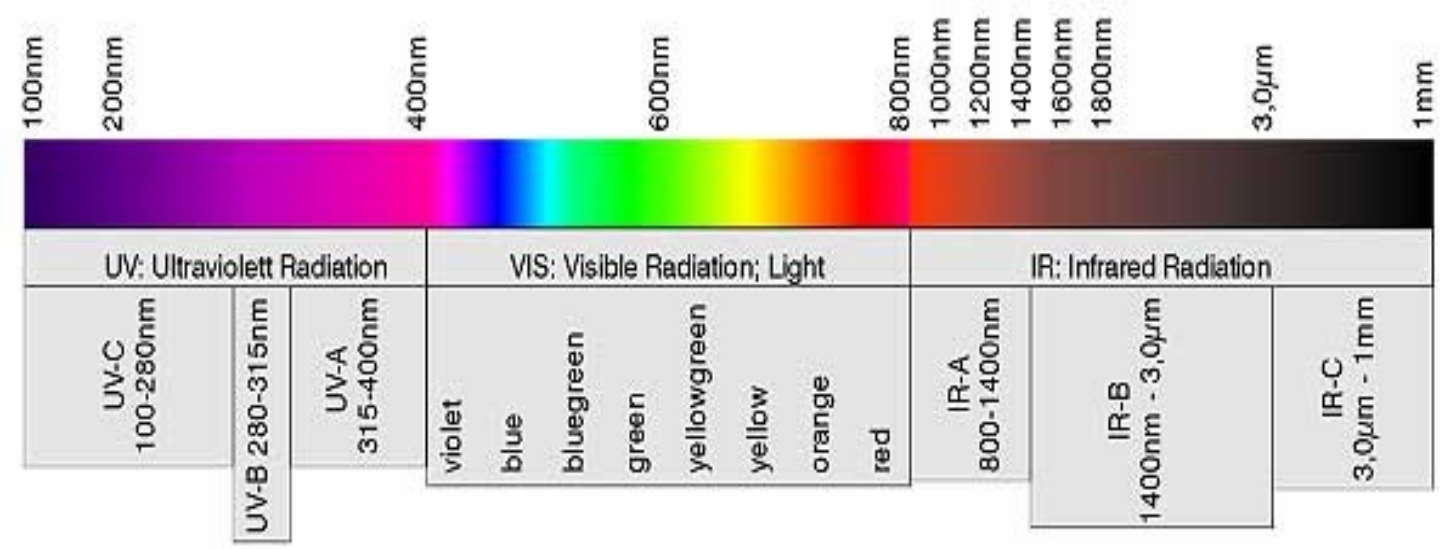
Ozone layer between 40,000 ft to 60,000 ft

http://www.freedomsphoenix.com/News/049633-2009-05-01-ozone-hole-purportedly-modifies-antarctic-winds.htm?EdNo=001&From=

Today, nitrous oxide is used as a propellant



Notice:
You have near IR and Far IR

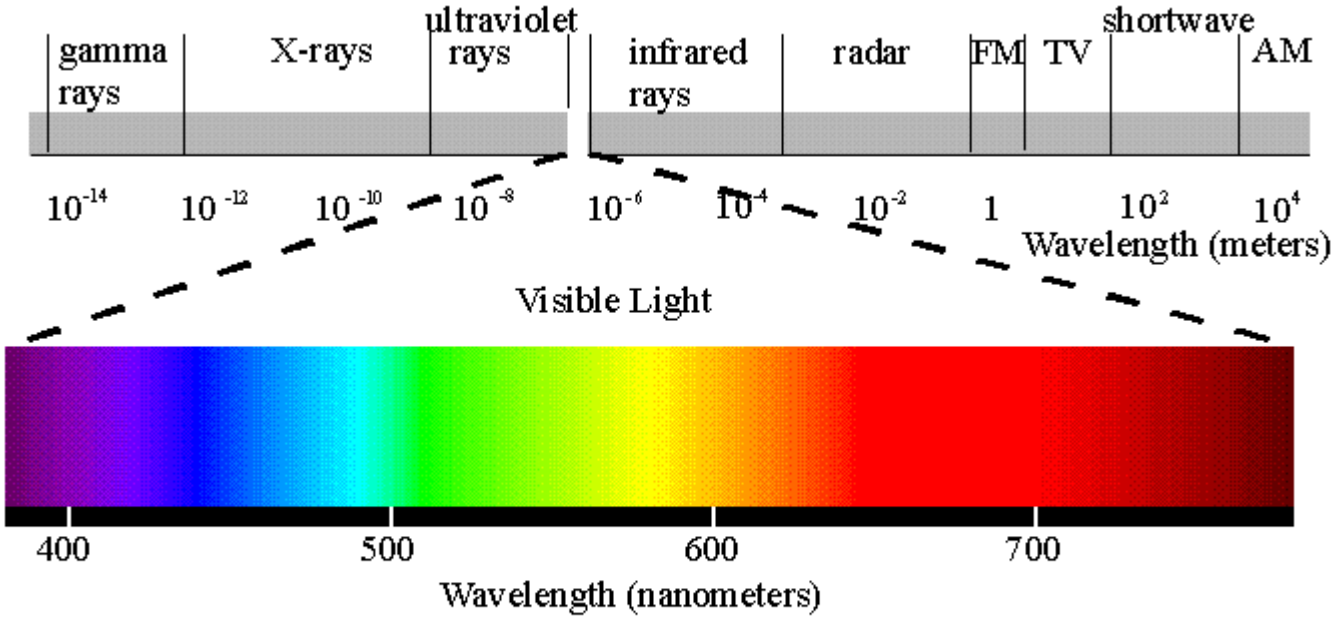


The form of UV that is most potent for burning and cancer has a wavelength Of about 300nm. This kind of radiation is absorbed by ordinary window glass.

Normal glass blocks all of UVB but allows UVA to come through.

Example 1 The Wavelength of Visible Light

Find the range in wavelengths for visible light in the frequency range between 4.0×10^{14}Hz and 7.9×10^{14}Hz.



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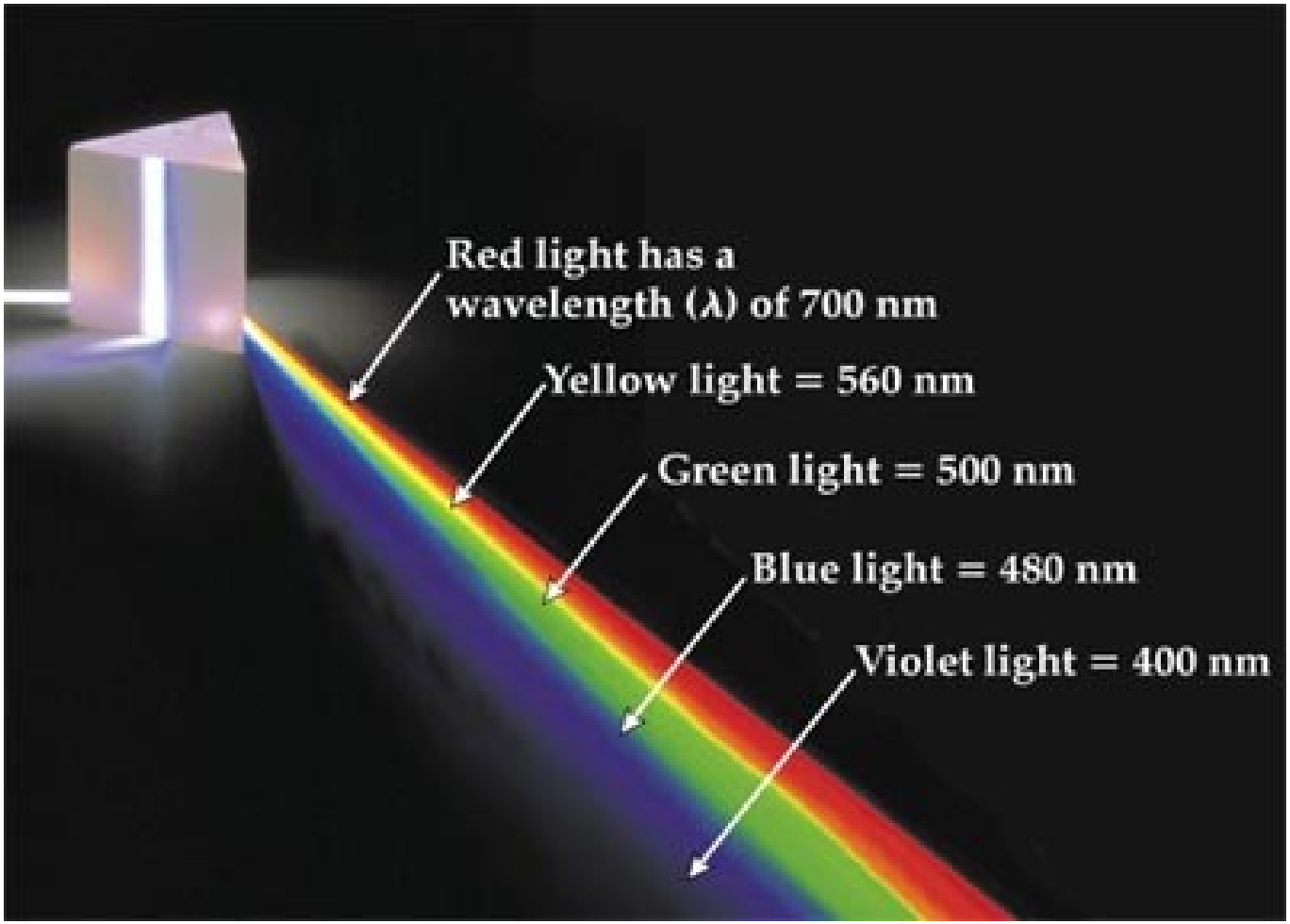
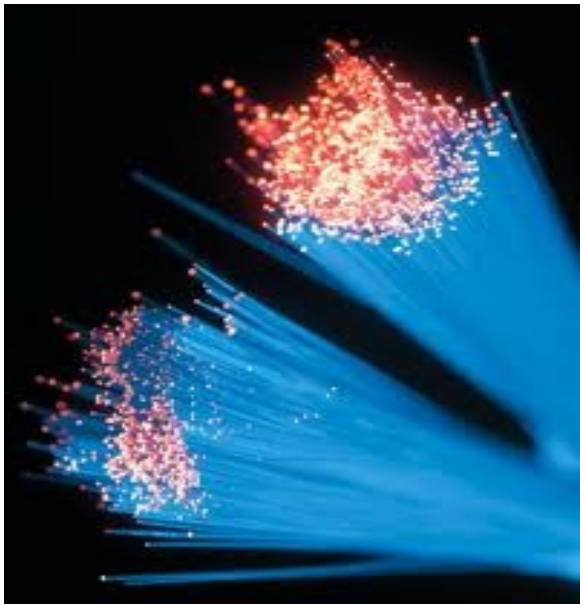
Visual Stimulus


Red light has a
wavelength (λ) of 700 nm
Yellow light = 560 nm
Green light = 500 nm
Blue light = 480 nm
Violet light = 400 nm

fiber optics: visible light can transport more data

The optical fibers have became very efficient to transport information.



Because of the high frequency of visible light,
You can transport more data per second.
The bits per second is called the baud.
The number of bits of second you can transport
Is the frequency of the wave. (about).

Indeed, information is coded are series of 0 and 1.
So you turn off and on the wave carrying the
Information. You can not send signal faster than the
Frequency. The number of on or off per second =
Frequency of the wave at most.

So you can transport about 10^{14} bits per second. Higher is the frequency, more information can Be transmitted per second.

So visible light can transport more info than Radio wave (smaller frequency).

This rule was found in 1940 by Claude Shannon,

INFRA RED radiations

Heat waves. Produced by any warm body. (any thing with temperature).
Emitted by the molecules jiggling around.
Used in low energy lasers. Remote Control. Objects in space emit in the IR.
Used by military to detect tank, planes ...

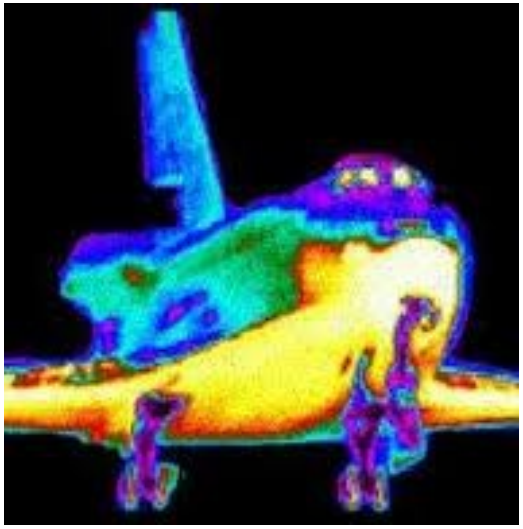
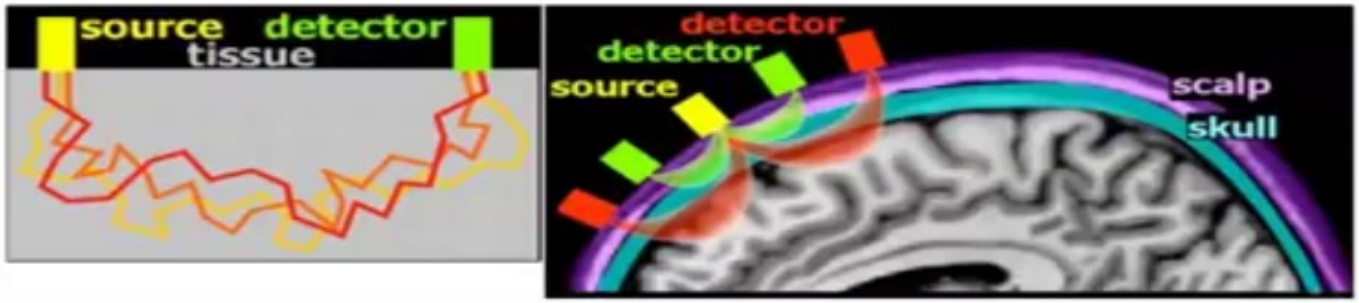


Table 8.1 Approximate Frequencies and Wavelengths of Different Colors

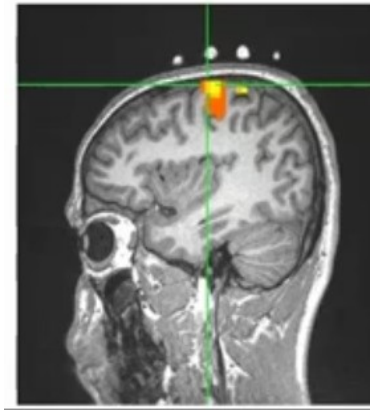
Color	Frequency Range ($\times 10^{14}$ Hz)	Wavelength Range ($\times 10^{-7}$ m)
Red	4.0–4.8	7.5–6.3
Orange	4.8–5.1	6.3–5.9
Yellow	5.1–5.4	5.9–5.6
Green	5.4–6.1	5.6–4.9
Blue	6.1–6.7	4.9–4.5
Violet	6.7–7.5	4.5–4.0

Functional Near-Infrared Spectroscopy (fNIRS)

- Each source-detector pair probes a 'banana-shaped' region
- fNIRS can only image the surface of the brain (cerebral cortex)
- Multiple source-detector pairs are used simultaneously to map neuronal activity on the brain's surface



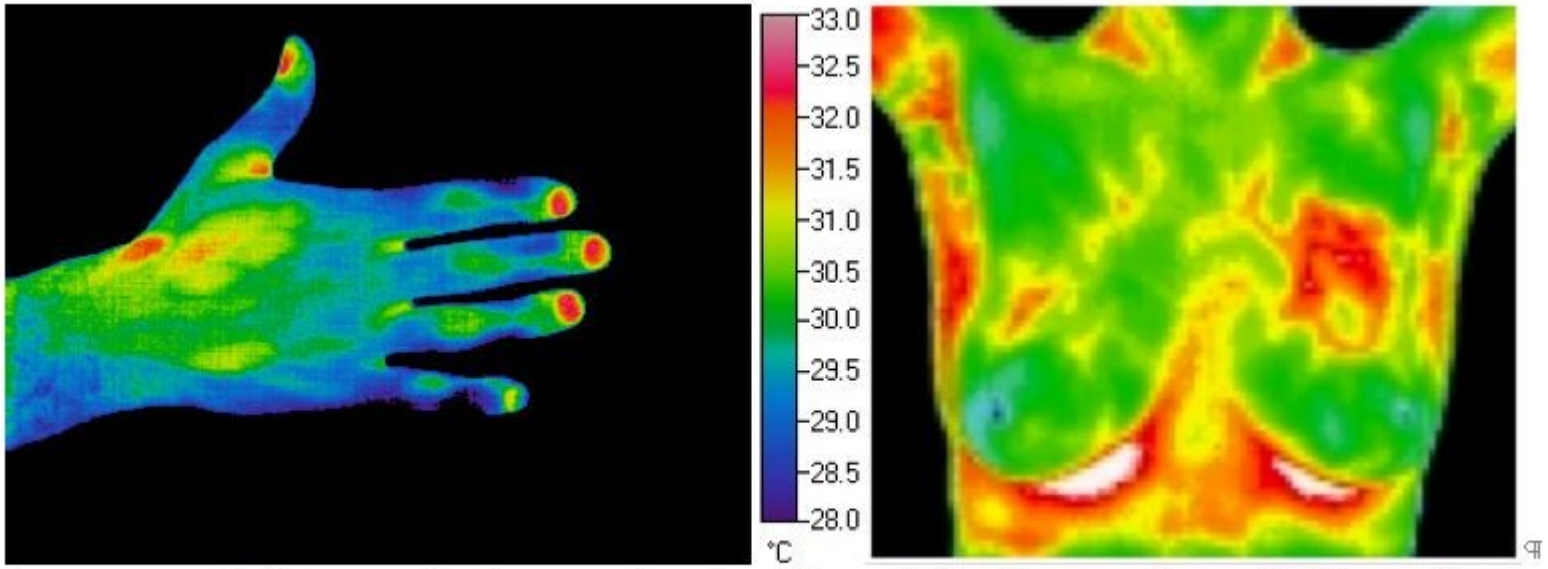
Using NIR to probe the surface of the brain.



https://en.wikipedia.org/wiki/Near-infrared_spectroscopy

A thermogram can also depict abnormal heating indicating infection

In the image below, the right foot of the patient is noticeably cooler, suggesting reduced circulation related to nerve damage



Thermograph image of a human hand, with an infection on the wrist (near the thumb), and thermograph showing breast cancer (on upper breast on right). (Left photo from NASA; right photo copyright Meditherm.)

http://www.fas.org/irp/imint/docs/rst/Intro/Part2_26d.htm
l

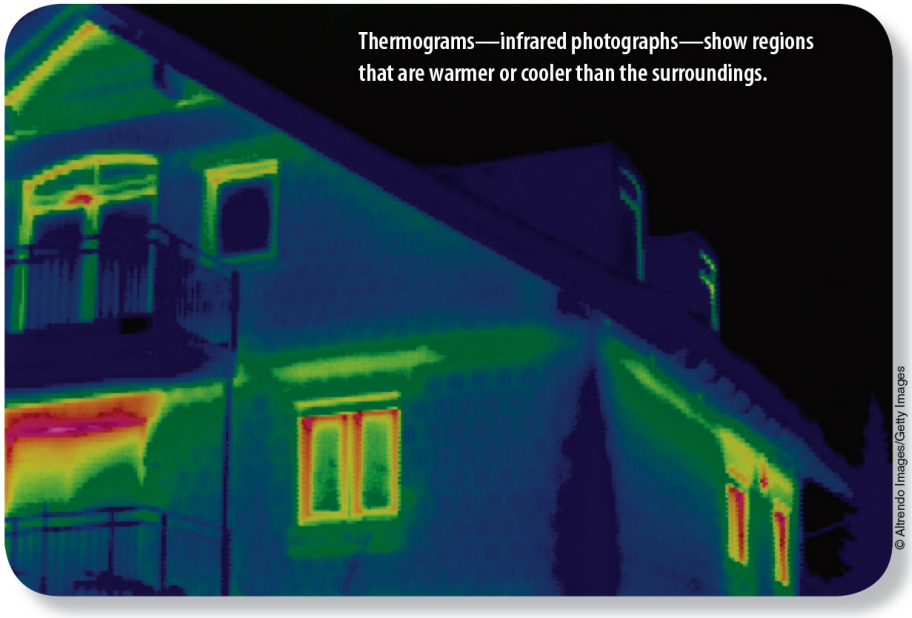
Note: thermography can also be done by painting the skin with a chemical (known as a liquid Crystal) that shows visible color change with temperature

Blackbody radiation=

radiation emitted by thermal emitter (any thing with temperature) .
Power (energy/second) proportional to temperature raised to the 4^{th} power.

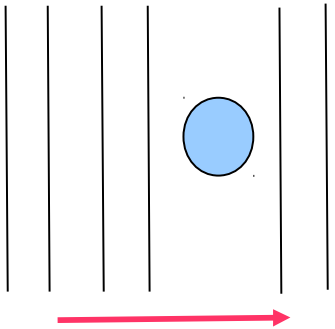
This means we can determine the temperature of an object my measuring the EM radiation it emits.

A *thermogram* is a "picture" of the IR radiation emitted by an object.

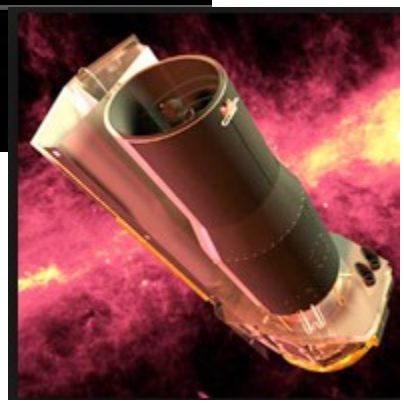


FIRE fighter can use INFRARED CAMERAS to see through the smoke.
Long wavelength diffract more than small wavelength so IR
Diffract around dust and smoke particles

http://www.infraredcamerasinc.com/infrared-thermography-firefighting.html

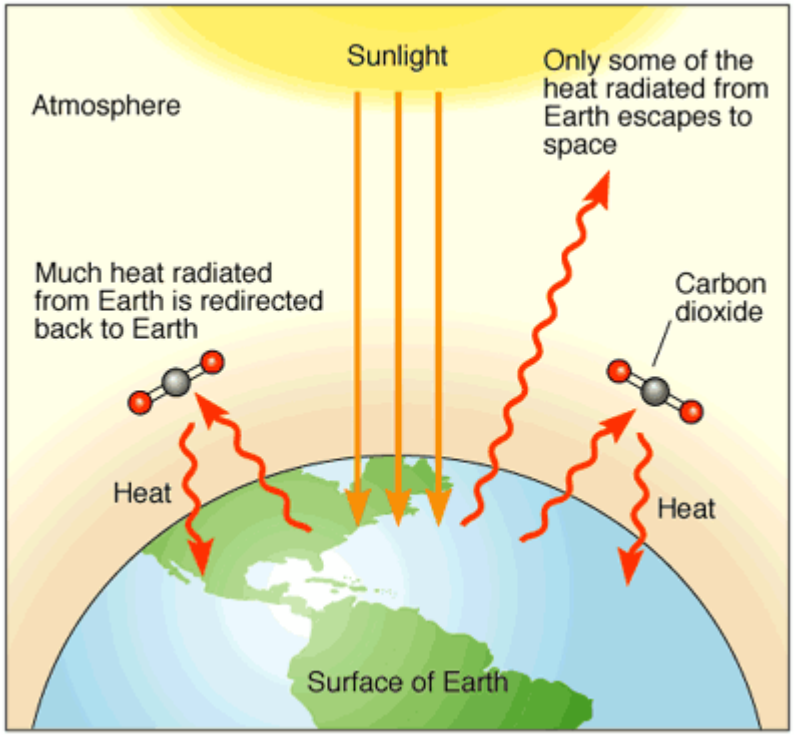


In Astronomy we can pick into nebulae To observe star s



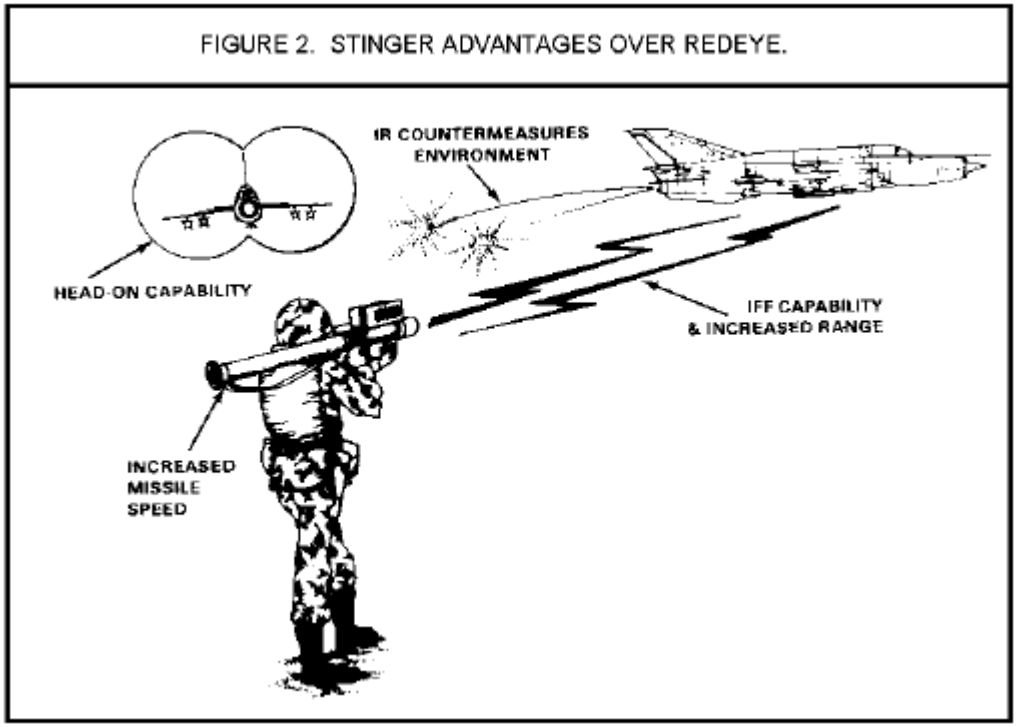
Sptizer telescope

GREENHOUSE EFFECT



H_2O, CO_2 and O_3
Absorb IR radiation.
IR radiations are trapped warming the Earth.

IR can be sensed by Pit Vipers, mosquitoes and stingers !!



Stingers are high tech missiles
That sense the IR radiation
From a warm source.

Stingers were given to Taliban
when they were US friends.
Taliban sold them to Rwanda
Rebels. One of these missiles
Hit the plane to the president.
That was the beginning of the
genocide.

Stingers are only 35 pounds about
And reaches 10,000 ft.

Mosquitoes (female) have IR sensors to find you !!

We can use this ability to get rid of them, !!! see links below.

http://uniquedistributors.com/armksmokisy.html

http://www.youtube.com/watch?v=8GXOByRq4Uk&feature=player_embedded#!

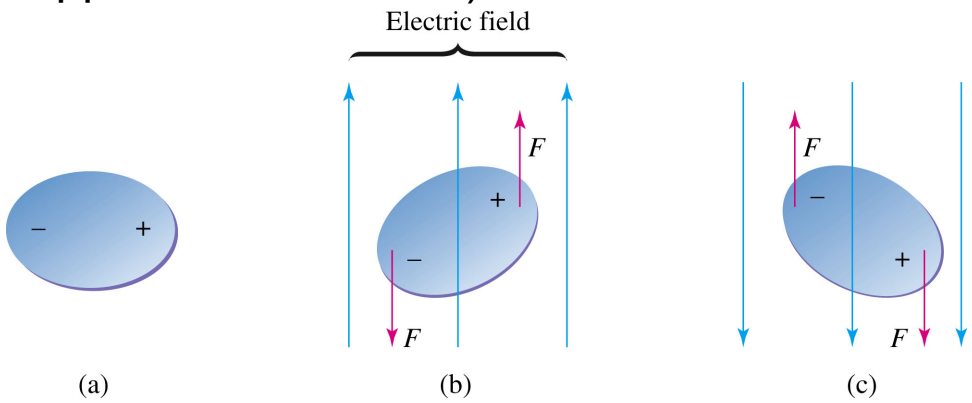
HEAT VISION

They operate at a wavelength of about
10 micrometers to see human. (our range
See below to compute that).

The goggles can also also emit an IR light so they can
See each other. This is the Infra red transmission
Technology. Wavelength is 2 micrometers.

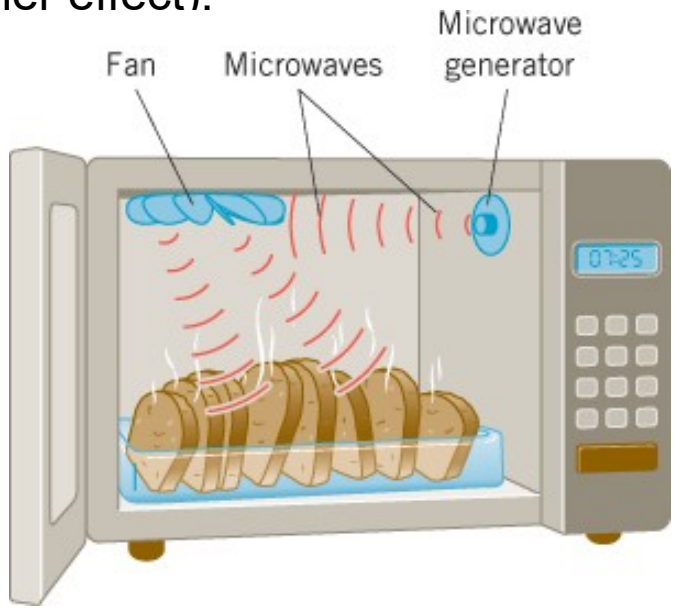
MICROWAVE

- upper limit of radio waves. Range from 0.3m to 0.3mm (so not micrometer). Resonant wavelengths for molecules of water. The water molecules are Bipolar (+ and -) and feel the electric field of the waves. They start vibrating and heat the Food in the process. (torque is applied to molecules).
This is because the temperature
Is proportional to the
Kinetic energy of
The molecules.
2,450 MHz is used in most ovens



Used in communication. Blue-tooth, Wi-Fi signals. Used for radars (echolocation + Doppler effect). Can map surface of planets or Earth.

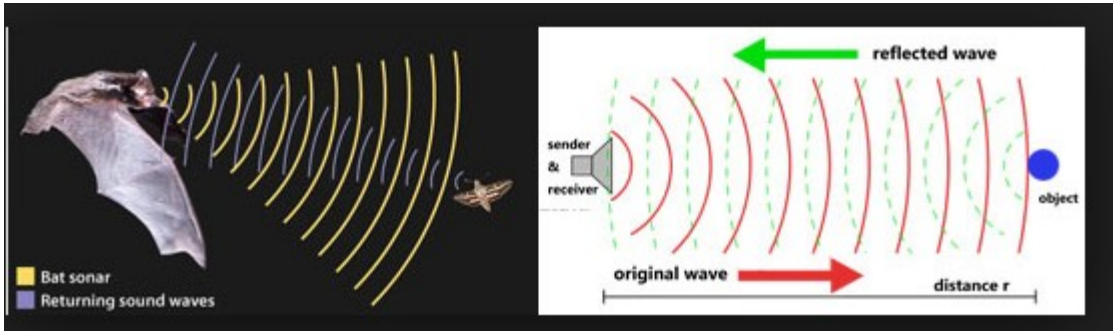
http://phet.colorado.edu/en/simulation/microwaves



Microwaves spread less than
Radio waves because they have
Shorter wavelengths.
It' s is easier to focus to use for RADAR.

Because the wavelength is large enough,
It go through cloud.

MICROWAVES = used in radar and cell phone. Small wavelengths so diffract less.
Microwave dish acts like a lens. Can be aimed at some distant target.



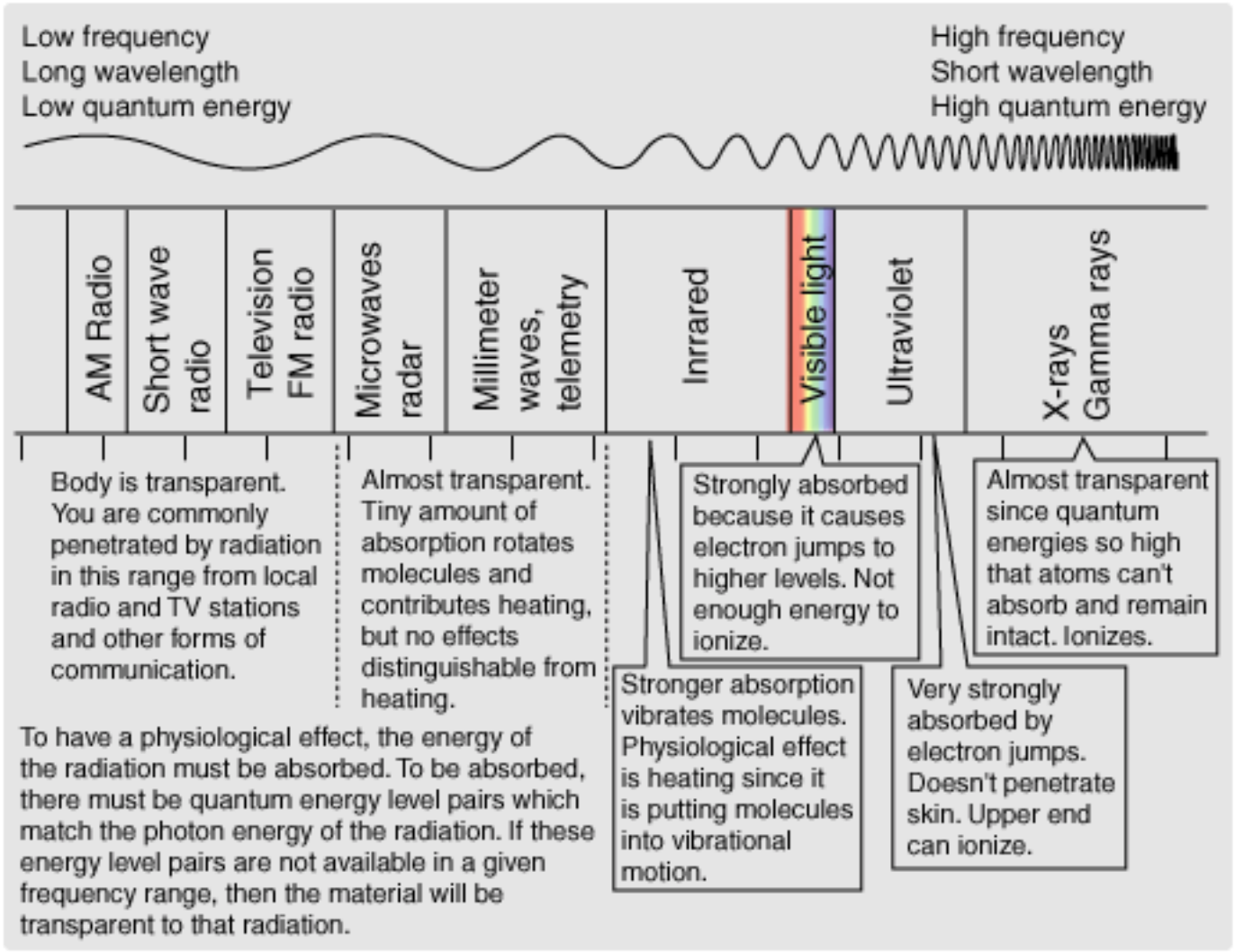
MICROWAVE

RADIO WAVES

- very large range from 100 Hz to 1000 megahertz. Frequencies given in kilohertz and megahertz. Radio waves are produced using AC with the appropriate frequency using an antenna. AM = long wavelength reflected by atmosphere. FM=short wavelength go through the atmosphere. Narrow frequency bands are Assigned for specific purposes. 88 to 108 MHz for commercial FM radio. Some bands are assigned to government and private communication.

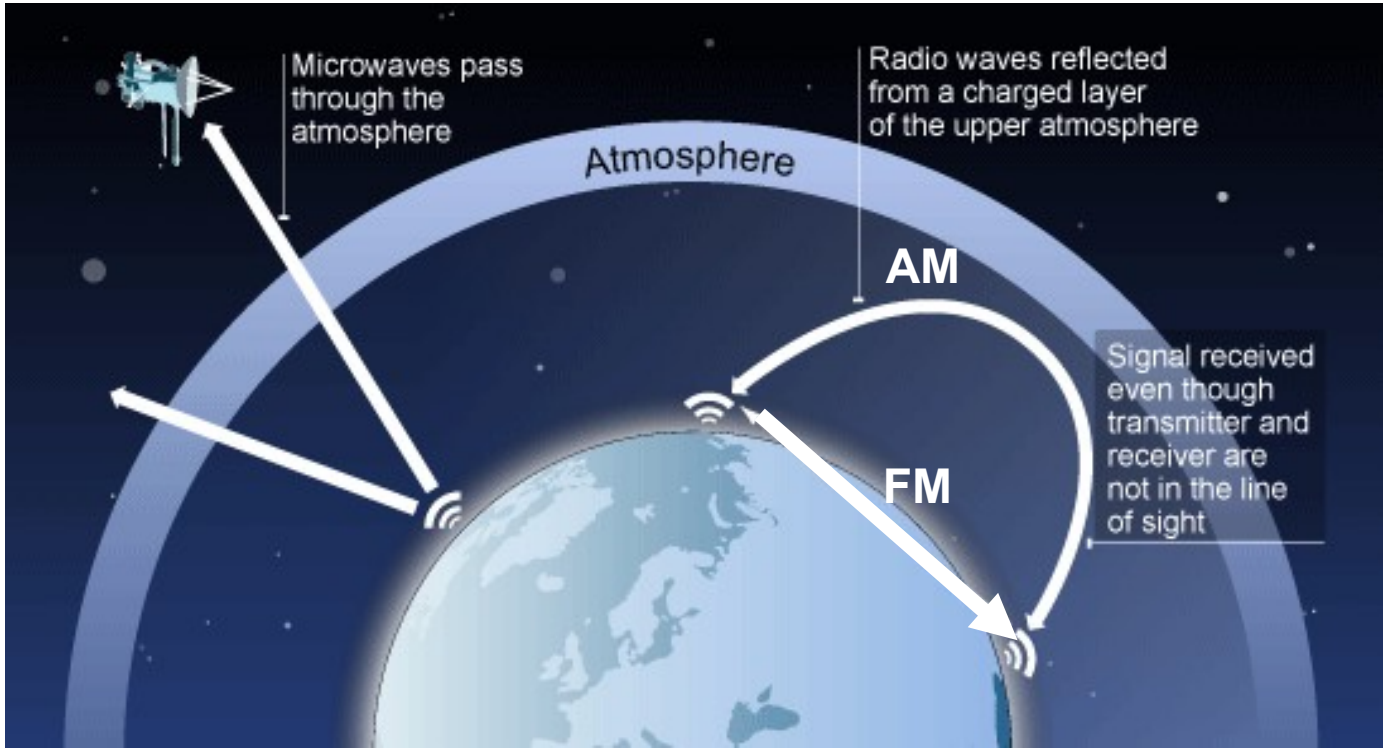
Note: radio waves do go through the body but they do not ionize. Only gamma-rays, X-rays and UV can ionize (and cause cancer or radiation sickness). The Wavelengths are small to the rays behave like photons. Bundles of energy.

Radio waves can have other physiological effects. Electric field act upon our ions. A wave is both an electric field and a magnetic field shaking.



https://www.quora.com/How-is-it-that-radio-waves-can-go-through-concrete-and-x-rays-through-muscle-What-determines-whether-photons-will-pass-through-without-interacting

RADIO WAVES



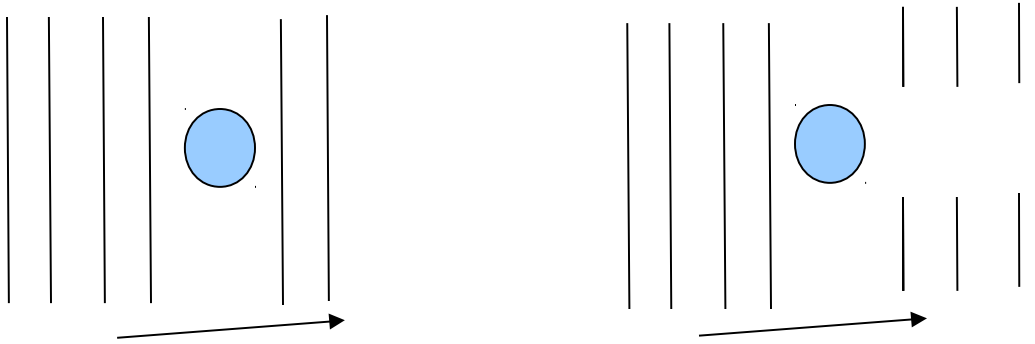
FM + TV = high frequency, better resolution =better music because more info fit
In the signal but smaller wavelength means less diffraction. So a building will shade
The signal.

AM=larger distance, even larger at night so they decrease the power.
Hard to listen at night.

Conceptual Example 2 The Diffraction of AM and FM Radio Waves

Diffraction is the ability of a wave to bend around an obstacle or the edges of an opening. Would you expect AM or FM radio waves to bend more readily around an obstacle such as a building?

AM has longer wavelength (frequency about 100 kHz)
FM has sorter wavelength (frequency about 100 MHz)
Which one is which ?



RADAR can be used for imaging cities / surface of Earth / planets.

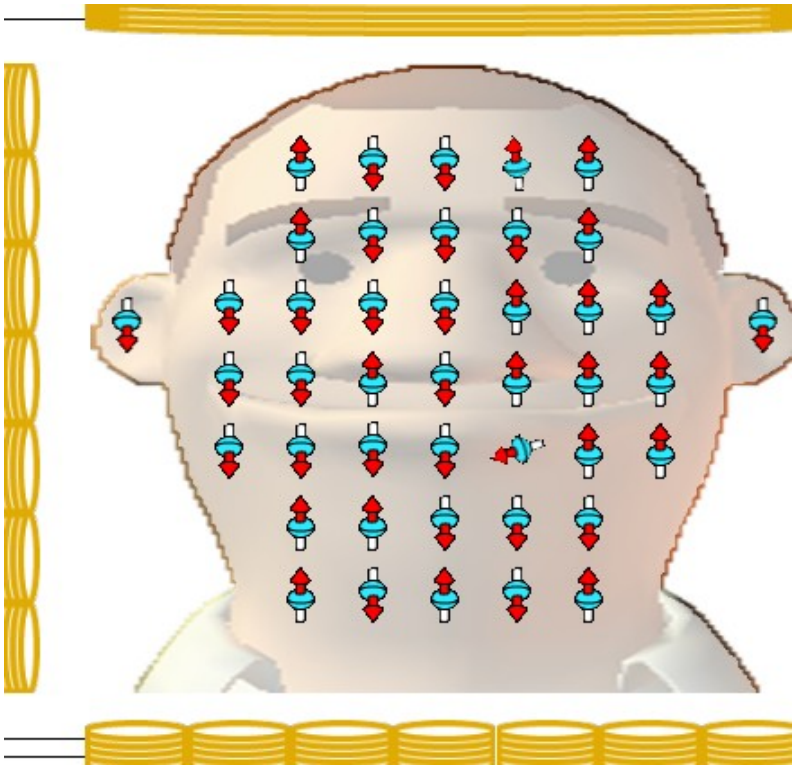
The technology Is called SAR.

http://en.wikipedia.org/wiki/Synthetic_aperture_radar

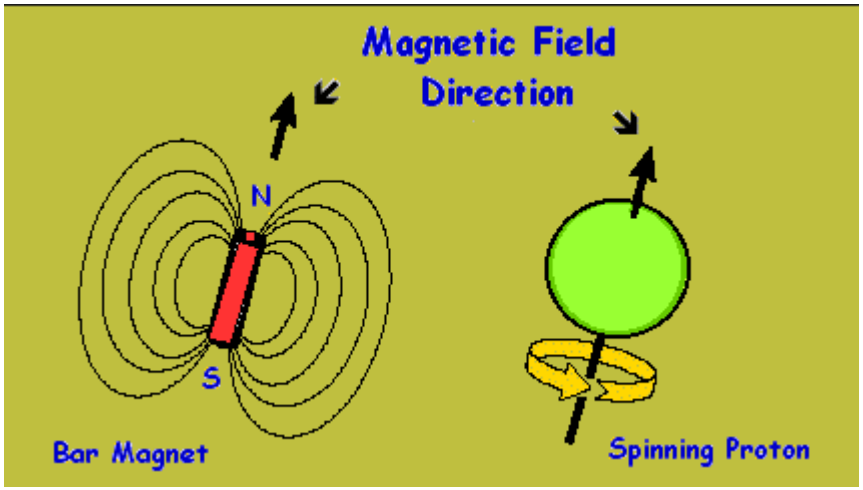
single beam-forming antenna from which a target scene is repeatedly illuminated with pulses of radio waves at wavelengths anywhere from a meter down to millimeters. The many echo waveforms received successively at the different antenna positions are coherently detected and stored

http://www.thespacereview.com/article/790/1

MRI



1 T ↔ 40MHz radio wave.

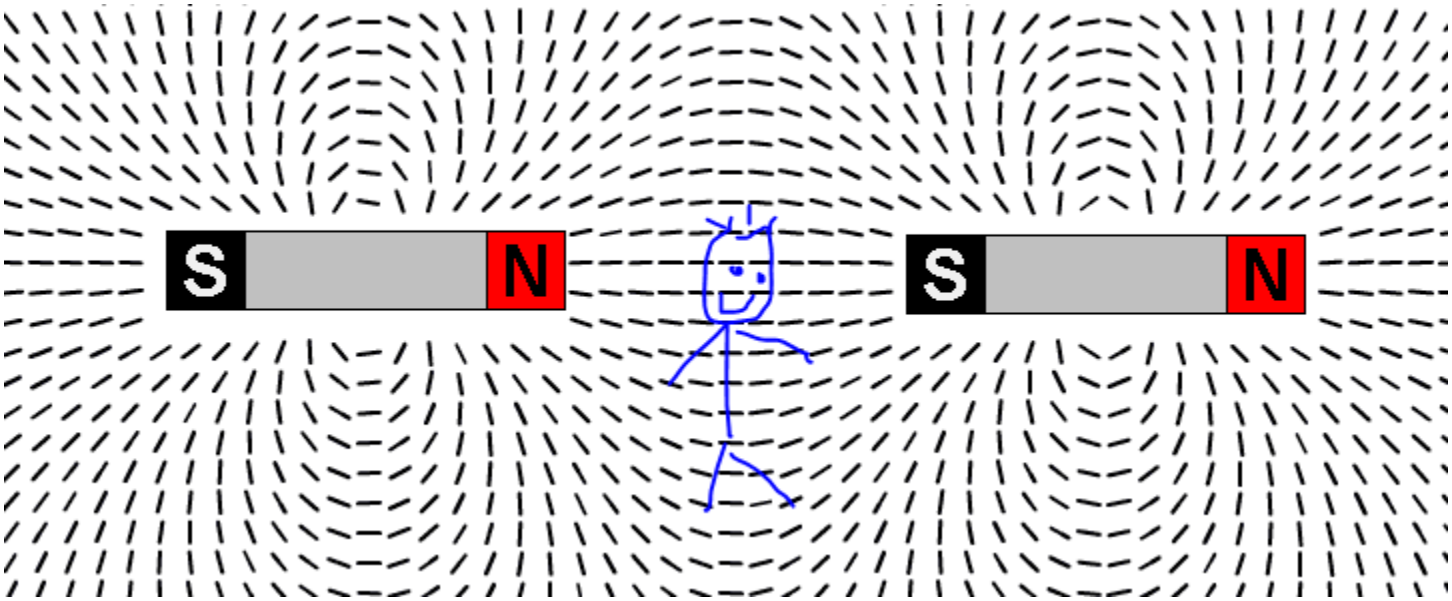


The protons behave like small magnets and are aligned in A VERY strong magnetic field. If you excite them with a Radio wave with the right frequency they jump to a higher level Of energy (they flip) and when they “relax” they burp out Radio waves used to illuminate the brain from inside out.

http://phet.colorado.edu/en/simulation/mri

http://www.schoolphysics.co.uk/age16-19/Atomic%20physics/Atomic%20structure%20and%20ions/text/MRI/index.html?PHPSESSID=4efb7b210aababb8e14bd5e7c386b2a1

How to turn the MRI into a rail gun
https://www.youtube.com/watch?v=plvIEf7JsKo&nohtml5=False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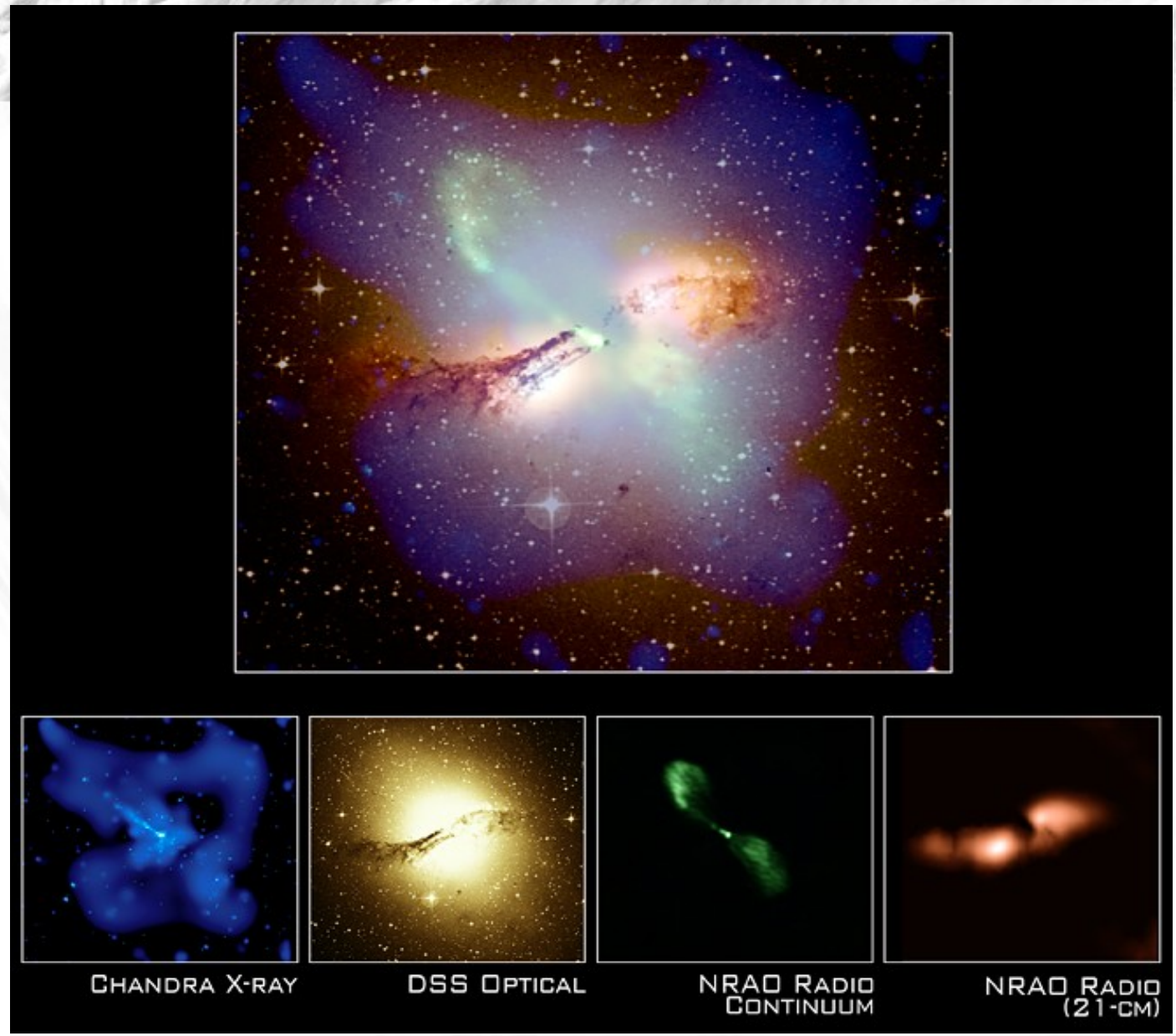
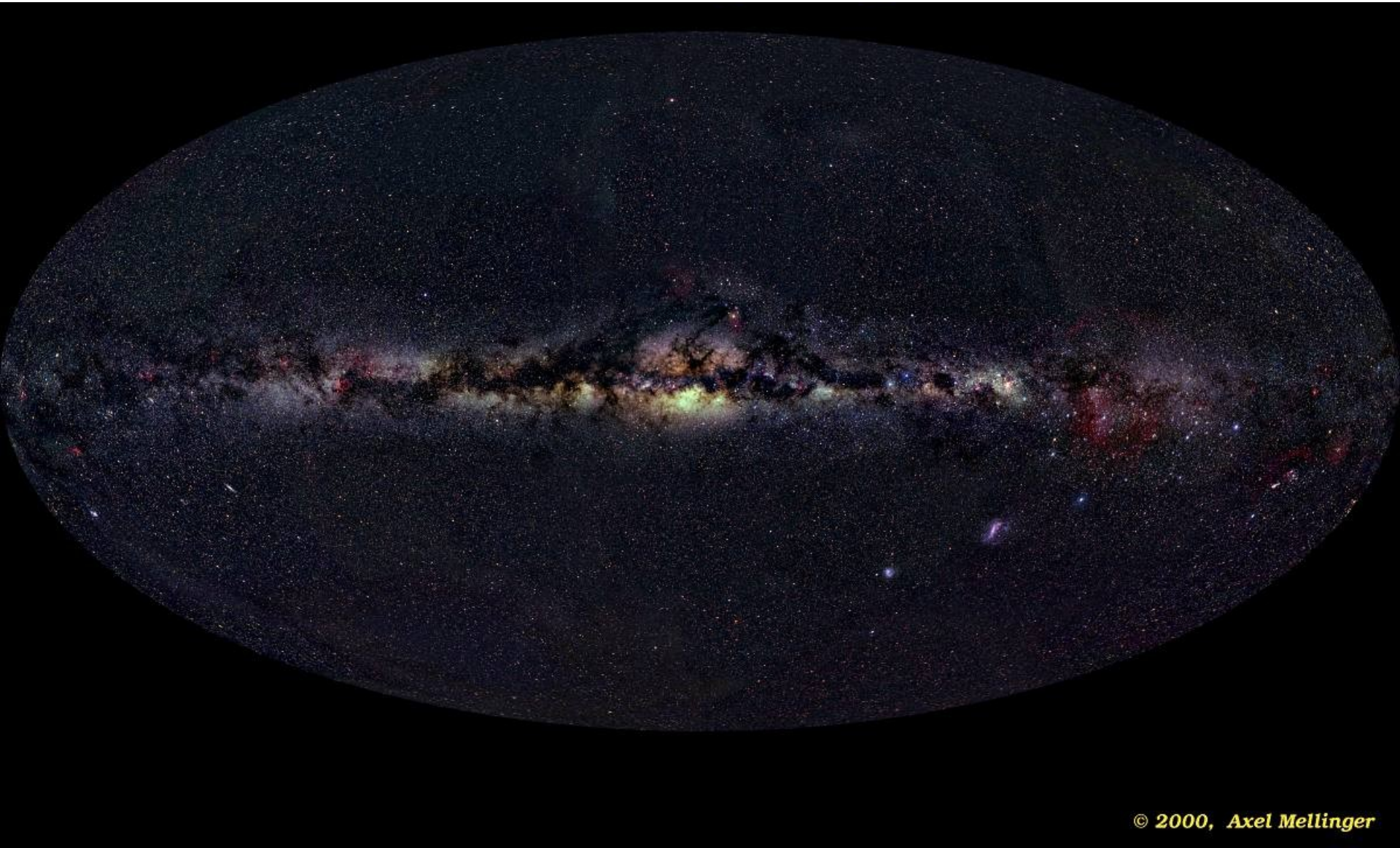
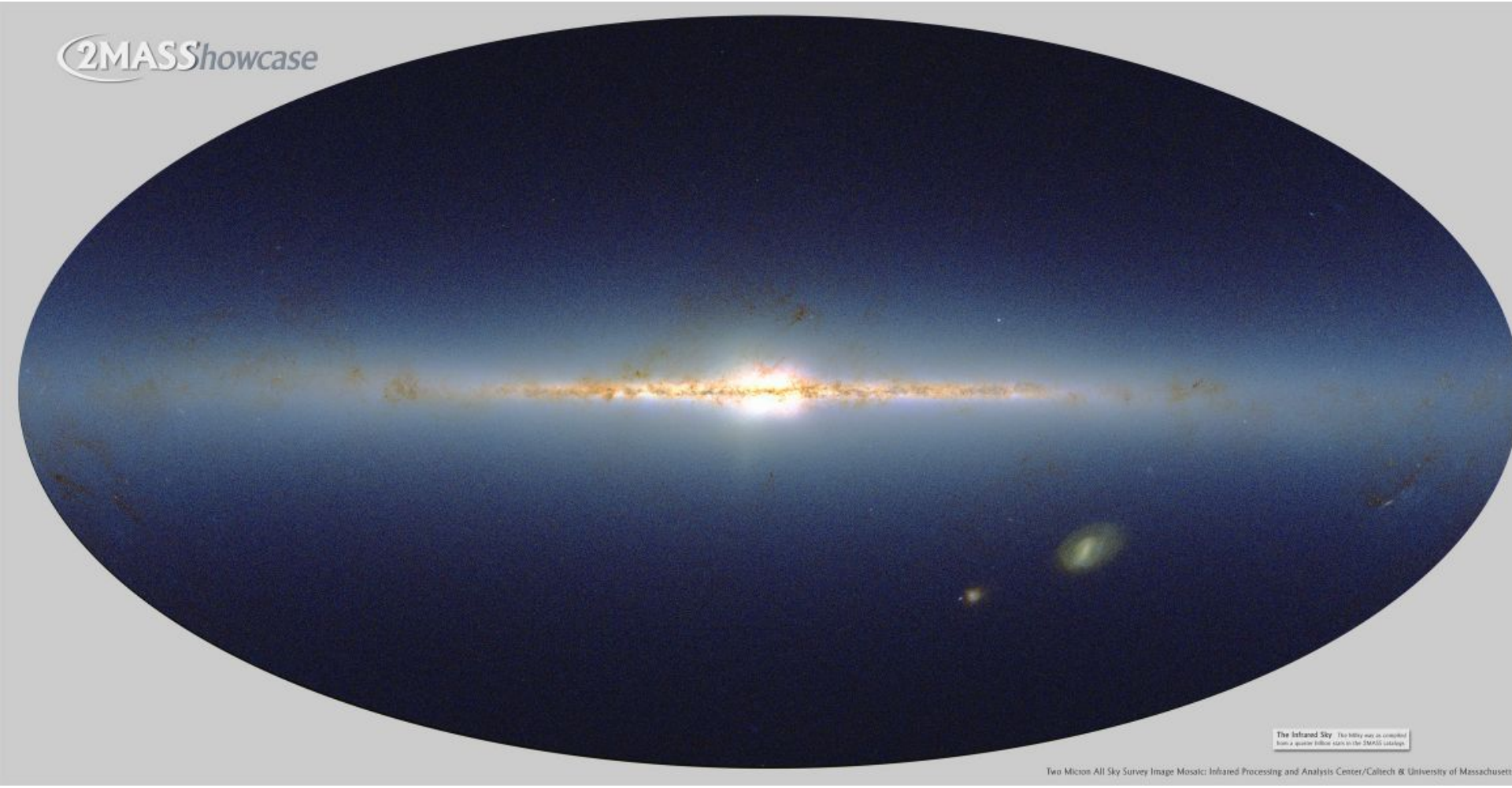


A composite X-ray (blue), radio (pink and green), and optical (orange and yellow) image of the galaxy Centaurus A presents a stunning tableau of a galaxy in turmoil.
http://chandra.harvard.edu/photo/2002/0157/

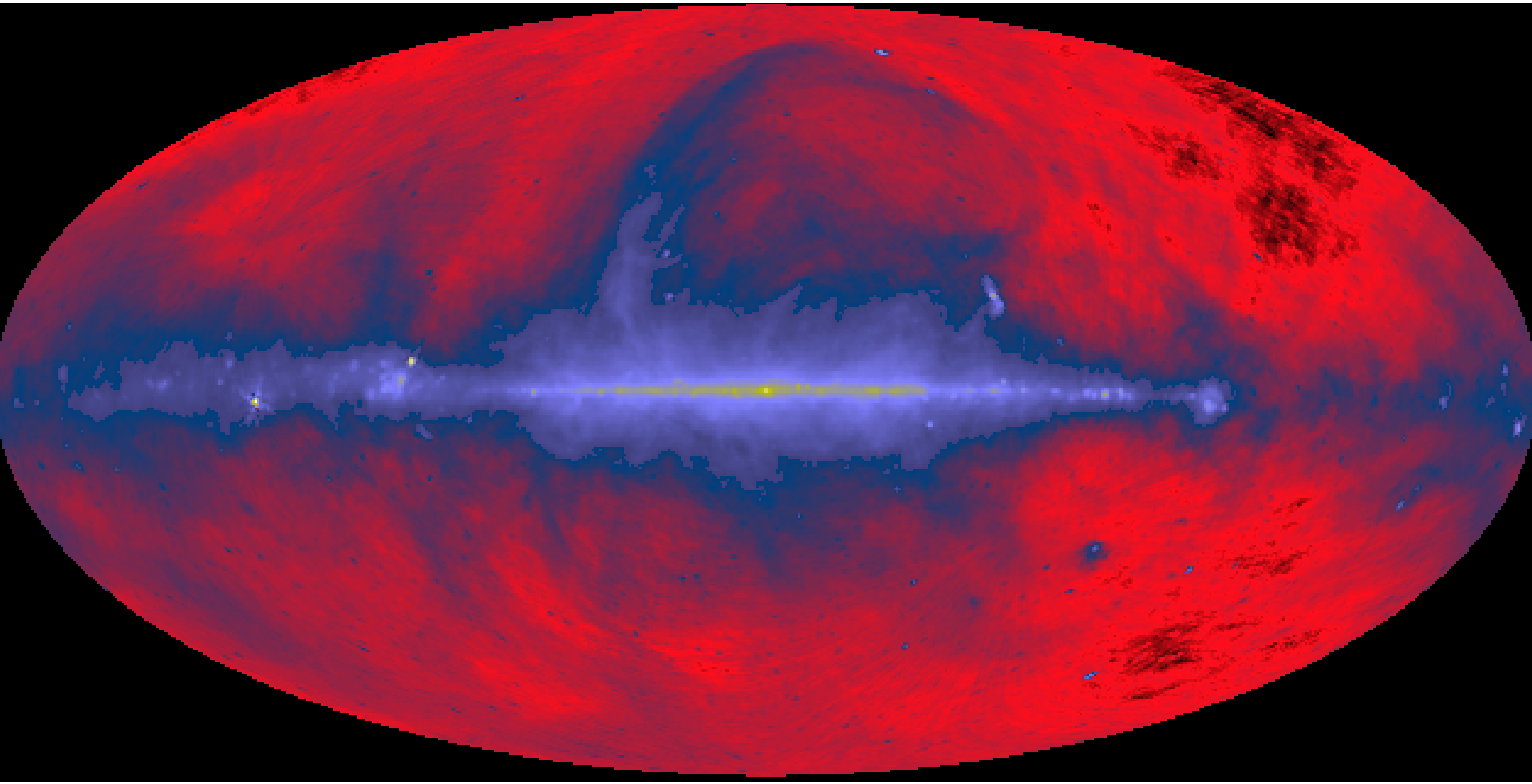
Optical Sky



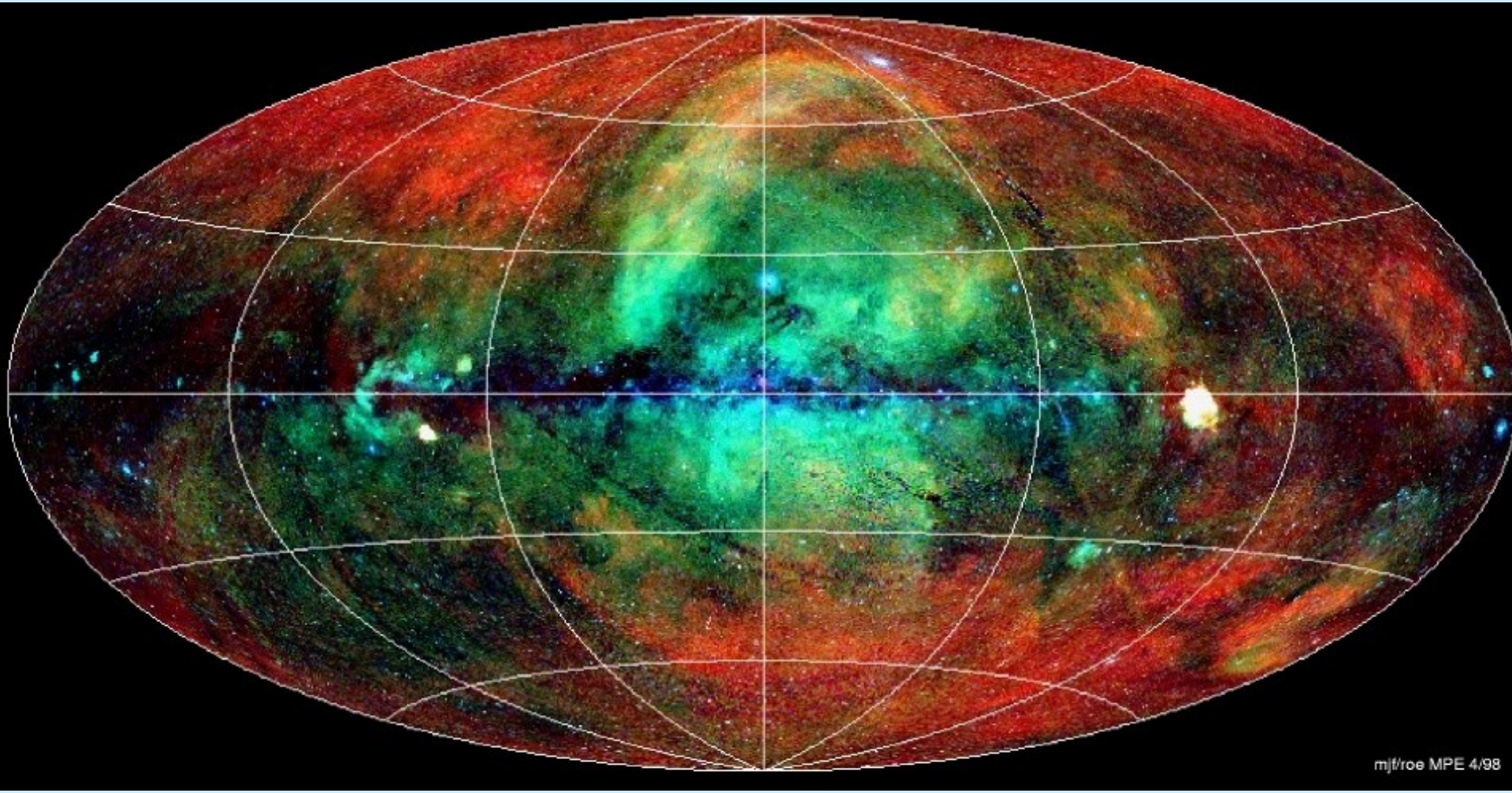
Near-infrared sky

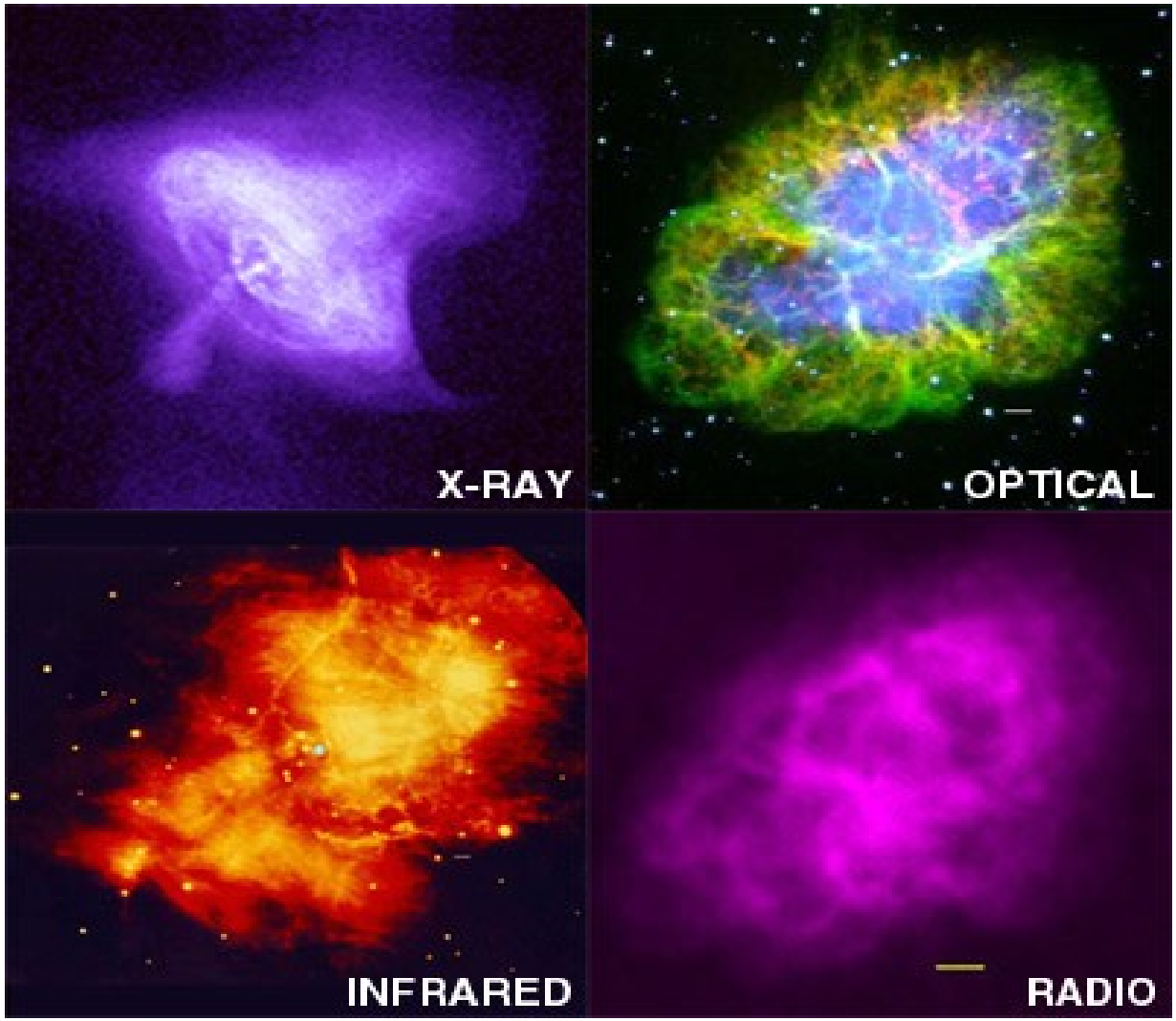


Radio Sky



Soft X-ray Sky





Crab nebula

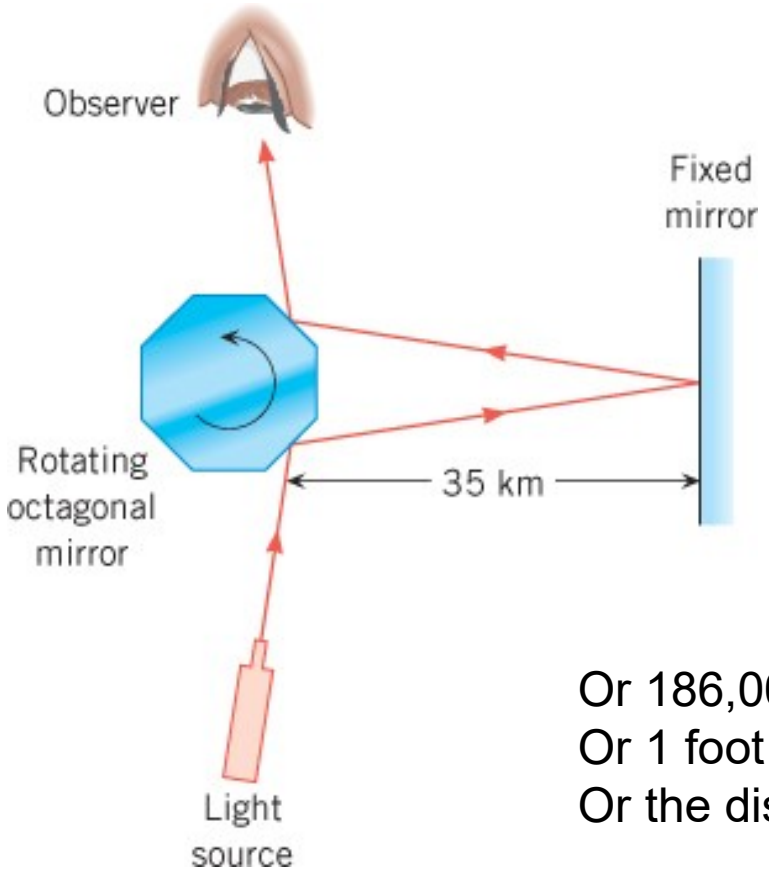
Example 1 The Wavelength of Visible Light

Find the range in wavelengths for visible light in the frequency range between 4.0×10^{14}Hz and 7.9×10^{14}Hz.

$$\lambda = \frac{c}{f} = \frac{3.00 \times 10^{8}\, m/s}{4.0 \times 10^{14}\, \text{Hz}} = 7.5 \times 10^{-7}\, m = 750\ \text{nm}$$

$$\lambda = \frac{c}{f} = \frac{3.00 \times 10^{8}\, m/s}{7.9 \times 10^{14}\, \text{Hz}} = 3.8 \times 10^{-7}\, m = 380\ \text{nm}$$

24.3 The Speed of Light



The speed of light in a vacuum

$$c = 299\,792\,458\ \mathrm{m/s}$$

Or 186,000 miles per second
Or 1 foot in a billionth of a second
Or the distance Earth-Sun (150 million km) in 8 minutes

But the speed of light is finite. And the same in
Any frame of reference (special relativity)

Conceptual Example 3 Looking Back in Time

A supernova is a violent explosion that occurs at the death of certain stars. The figure shows a photograph of the sky before and after a supernova. Why do astronomers say that viewing an event like this is like looking back in time?

(*a*) (*b*)

1) Compute the wavelength of the carrier of your favorite radio station

2) What is the wavelength of the 60,000 Hz radio wave used by " radio-controller" clocks and wristwatches ?

3) Compute the frequency of an EM wave with a wavelength of 1 in (0.0254m)

3) The wavelength of an electromagnetic wave is measured to be 600m.
A) What is the frequency of the wave ?
B) What type of EM wave is it ? (check the scale)

4) Determine the range of wavelengths in the UV radiation band

5) The simplest electromagnetic wave is a sinewave and it is produced by sending alternative current in an Antenna (see below). For best result, the antenna should be half-wavelength long. How long should the antenna be to broadcast at 98MHz (MHz means Mega Hertz or times 1000,0000)?

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