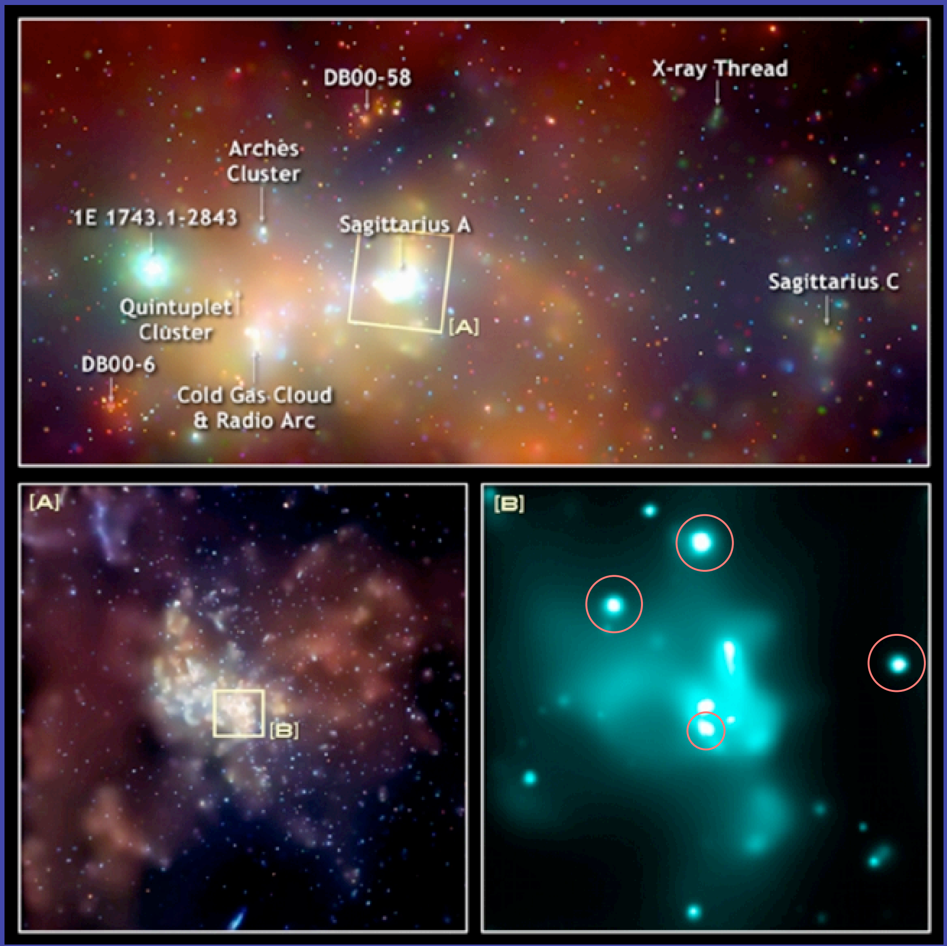
In the News...



CHANDRA
X-RAY OBSERVATORY
CXC OPERATED FOR NASA BY SAO
A NASA STRUCTURE & EVOLUTION OF THE UNIVERSE MISSION.

Chandra monitoring of the center of the Milky Way reveals the presence of a surprisingly large number of compact X-ray sources.

IR view from the Midcourse Space Experiment

Also in the News...

Saturday, January 22, 2005

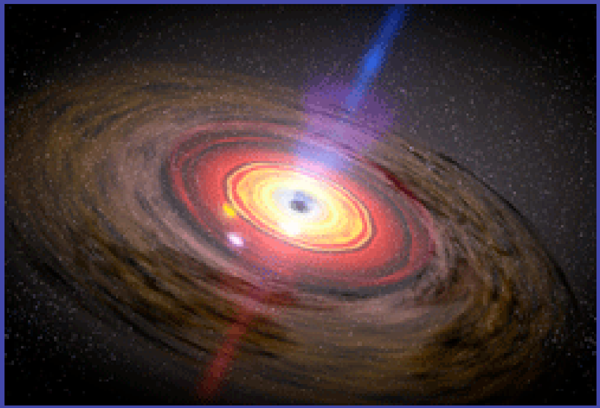
NASA scraps Hubble repair plans

By Guy Gugliotta / The Washington Post

WASHINGTON -- NASA is scrapping plans to service the Hubble Space Telescope, either with the space shuttle or with a robot repairman, a decision likely to set up a fresh confrontation with Congress over the fate of the orbiting observatory.

Physical Processes

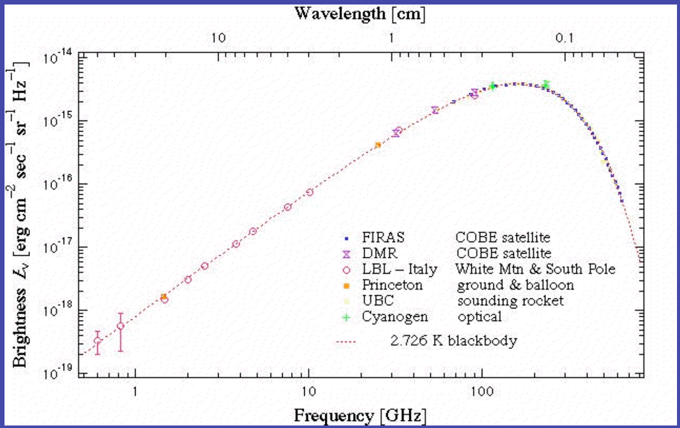
Jan 26, 2005



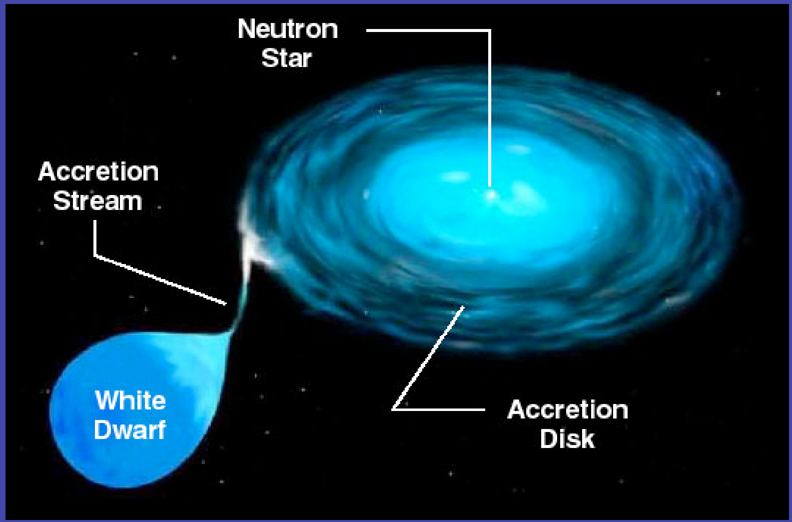
gravity and particle acceleration

The Universe as a Laboratory:

Some examples

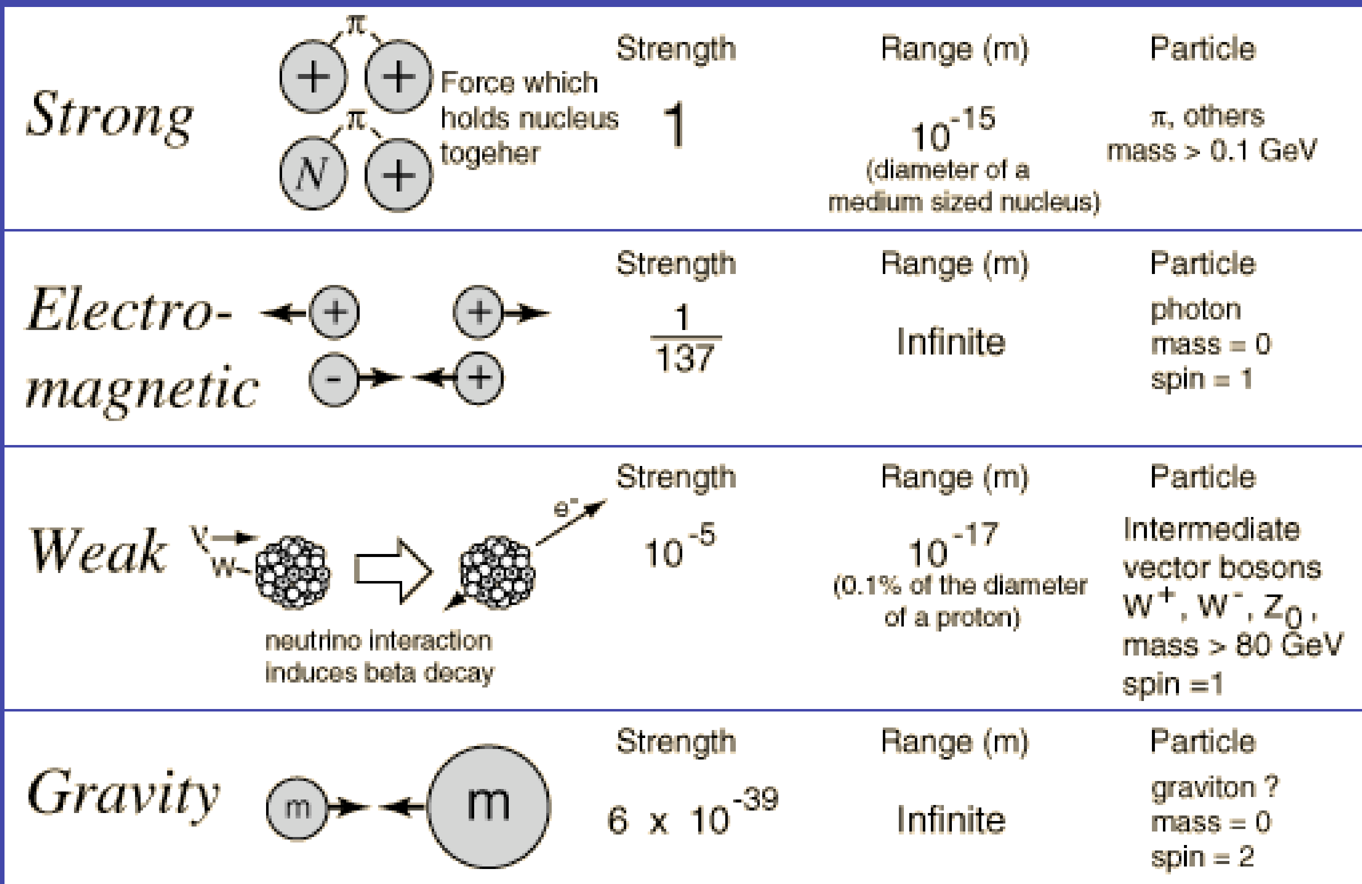


blackbody radiation



orbital dynamics & quantum mechanics

Fundamental Forces



		Strength	Range (m)	Particle
Strong	π, π, N; Force which holds nucleus togeher	1	10^{-15} (diameter of a medium sized nucleus)	π, others mass > 0.1 GeV
Electro-magnetic		$\frac{1}{137}$	Infinite	photon mass = 0 spin = 1
Weak	ν, W; e⁻; neutrino interaction induces beta decay	10^{-5}	10^{-17} (0.1% of the diameter of a proton)	Intermediate vector bosons W^+, W^-, Z_0, mass > 80 GeV spin =1
Gravity	m, m	6×10^{-39}	Infinite	graviton ? mass = 0 spin = 2

extremely weak but most important force on a cosmic scale

http://hyperphysics.phy-astr.gsu.edu/hbase/forces/funfor.html

Gravity

Newton's Law: for 2 masses M and m separated by a distance r, the gravitational force of attraction between them is

$$F = \frac{GMm}{r^2}$$

where

$$G = 6.67 \times 10^{-8}\ \mathrm{gm}^{-1}\mathrm{cm}^{-3}\mathrm{s}^{-1}$$

F is a vector, directed along the line connecting M and m

Potential energy

The gravitational field *g* due to a distribution of masses can be written as the gradient of a scalar potential ϕ:

$$g = -\nabla\phi$$
$$F = -m\nabla\phi$$
$$\phi = -G\frac{M}{r}$$

alternatively the gravitational force can be written

as the gradient of a scalar U, where U is the gravitational potential energy

$$F = -\nabla U$$
$$U = -G\frac{Mm}{r}$$

Conservation of Energy

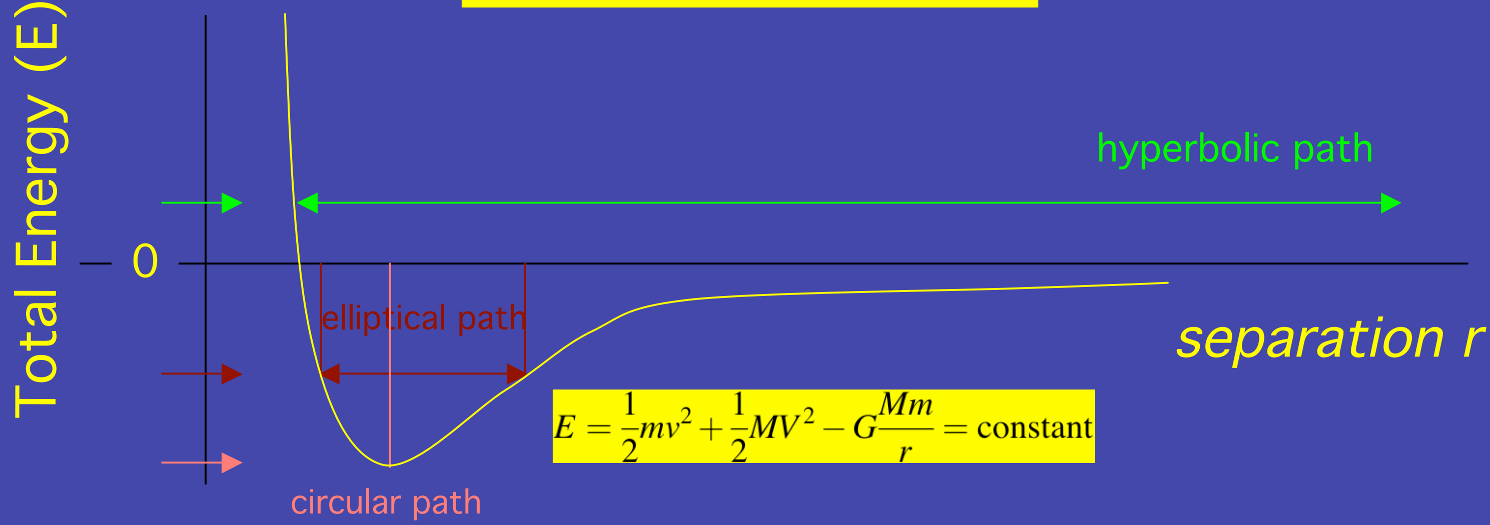
Gravity is a conservative force: in a system in which the only interaction is gravitational, energy is conserved:

$$E = \frac{1}{2}mv^2 + \frac{1}{2}MV^2 - G\frac{Mm}{r} = \text{constant}$$

Gravitational Dynamics

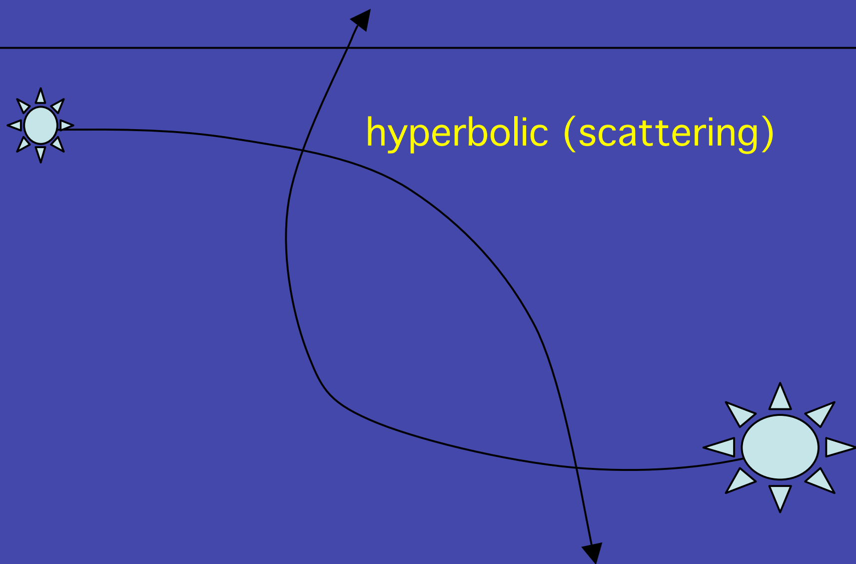
For two masses in motion, the sum of the gravitational potential energy (which couples the masses together) and their individual kinetic energies (which each possesses independently) is constant, and determines the future evolution of the system

$$E < 0; \text{system bound}$$
$$E \geqslant 0; \text{system unbound}$$

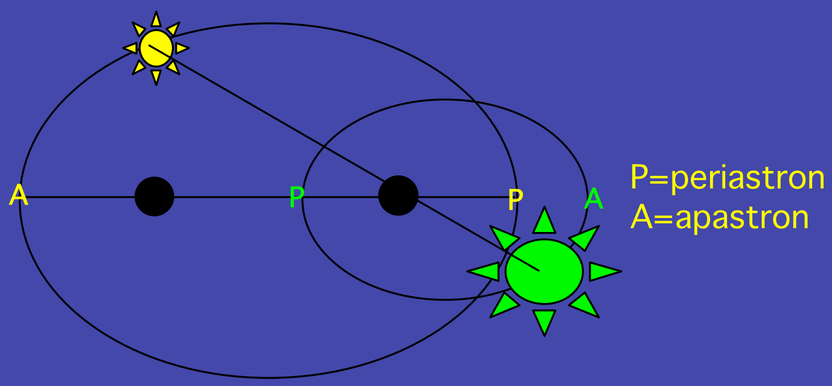


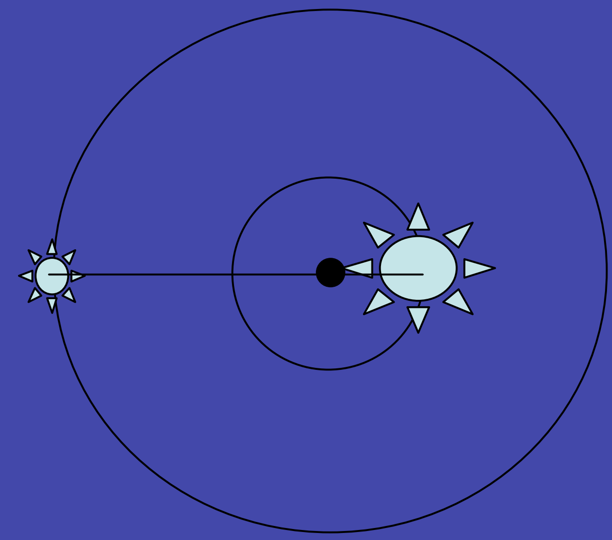
$$E = \frac{1}{2}mv^2 + \frac{1}{2}MV^2 - G\frac{Mm}{r} = \text{constant}$$

Orbits



Orbits are some type of conic section





Circular (unequal masses)

elliptical (bound)
center of mass is one focus of ellipse, other empty
bodies orbit around the center of mass

Kepler's 3 Laws

(bound) Orbits are elliptical; the force center is one of the foci of the ellipse

The radius vector of (bound) orbiting bodies sweeps out equal areas in equal times

Orbital periods are related to total system mass (for bound orbits) by

$$P^2 = \frac{a^3}{M_{total}}$$

where *P* is the period in years, *a* is the semi-major axis($=a_1+a_2$) in astronomical units, and M_{total} the total system mass in solar mass units

Particles and Radiation

Electromagnetic radiation is produced by the acceleration of charged particles (mostly electrons)

Important Particles	electron	proton	neutron	photon
type	lepton/fermion	baryon/fermion	baryon/fermion	boson
charge	-1	1	0	0
mass	1	1836	1839	0
sub-particle	-	quark:uud	quark:ddu	-
anti-particle	positron	anti-proton	anti-neutron	-

EM radiation can be thought of as a wave, characterized by a wavelength (λ), a frequency (ν) and a speed (c, which depends on the medium through which the wave is moving). An EM wave carries energy E.

h = Planck's Constant)

= 6.63×10^{-27} erg s

Relations

$$\nu\lambda = c$$

$$E = h\nu$$

$$p = E / c$$ ← p=momentum

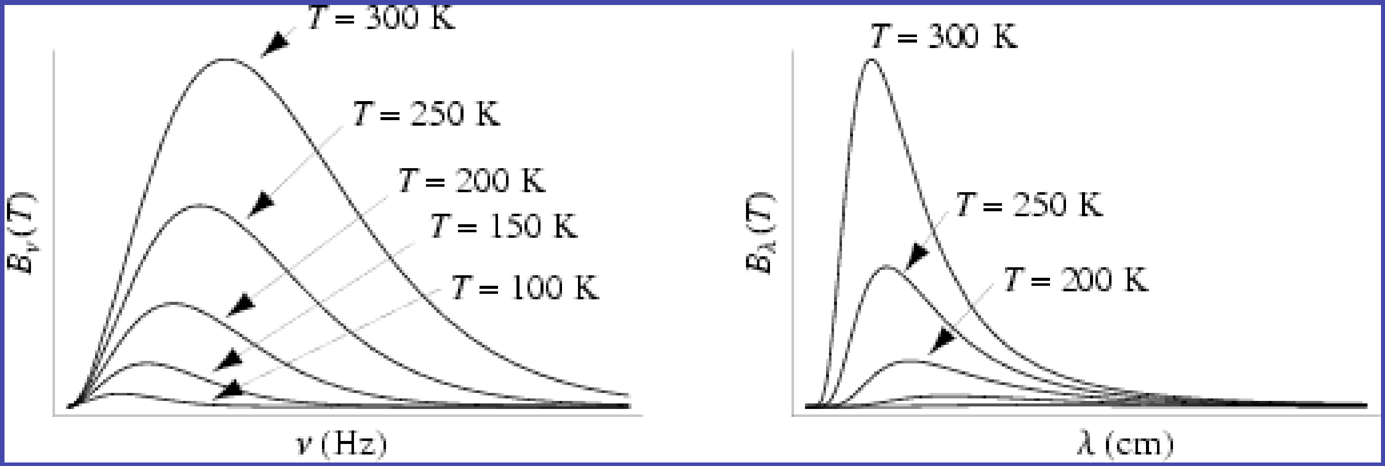
$$\lambda = h / p$$ ← de Broglie wavelength

Continuum radiation

An accelerated charge can produce EM radiation over a continuous range of frequencies (energies).

Black Body: An ensemble of charges which absorbs all radiation incident. The absorbed energy raises the temperature of the body, which radiates some of this energy. The radiation has a characteristic brightness distribution ($B_\nu(T)$), called the Planck curve:

$$B_\nu(T) = \frac{2h}{c^2}\frac{\nu^3}{e^{h\nu/kT}-1}$$ ergs s^{-1} cm^{-2} Hz^{-1} $steradian^{-1}$



Blackbody Laws

Blackbody radiators obey Wien's Law and the Stefan-Boltzmann Law:

$$\text{Wien's Law: } \lambda_{max} T = 0.29\text{cm K}$$

where λ_{max} is the wavelength of the peak of the Planck curve, and T is the temperature of the black body

$$\text{Stefan-Boltzmann law: } f = \sigma T^4$$

where f is the flux emitted from a blackbody at a temperature T, and $\sigma = 5.67\times10^{-5}$ ergs cm^{-2} s^{-1} K^{-4}

flux has units of energy per unit area per time, and is the amount of radiant energy passing through a surface each second.

Other Continuum Sources

Synchrotron radiation: a moving electron in the presence of a magnetic field *B* feels an acceleration *a* given by

$$a = \frac{e\,v}{m\,c} \times B$$

which causes the electron to spiral around the B field. The acceleration of the electron produces synchrotron radiation

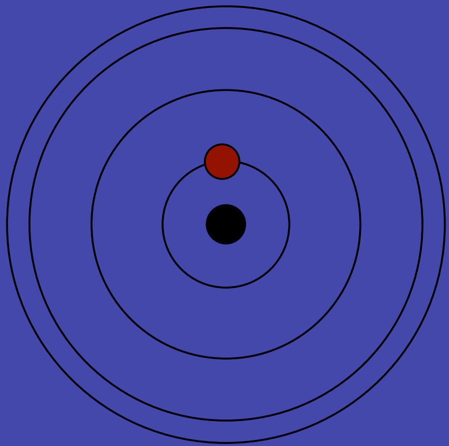
Bremsstrahlung radiation: "braking" radiation, occurs in ionized gases (plasmas) when thermal electrons are accelerated by passing near another electron or an ion.

Black body emission and Bremsstrahlung are sometimes called thermal emission (because the statistical motion of the charged particles depends on temperature). Synchrotron emission is an example of non-thermal emission since the statistical motion of the charged particle depends on the magnetic field strength.

Specific Emission

Electron in bound orbitals around an atomic nucleus of nuclear charge Z can produce radiation at specific frequencies or energies, since electrons can only orbit the atomic nucleus in a well-defined set of allowed orbits.

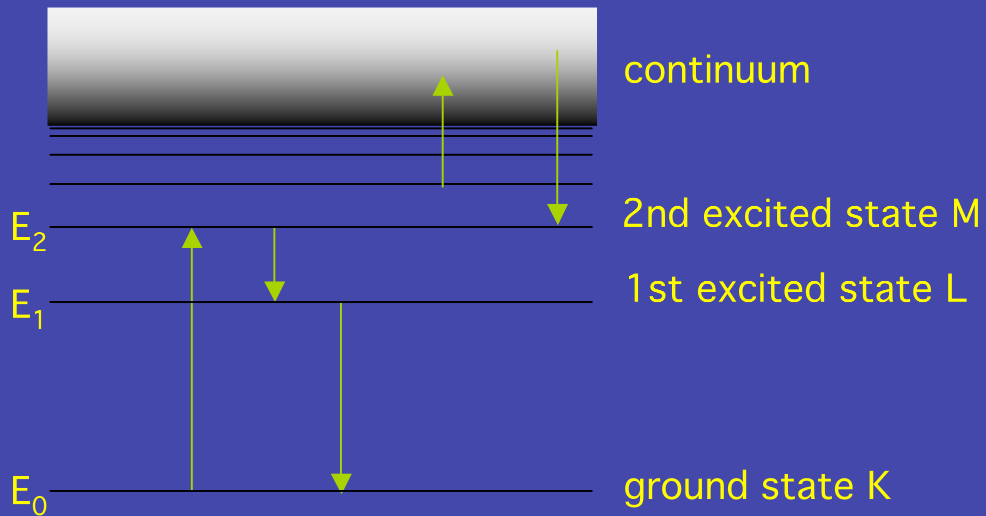
Each orbit is associated with an electron energy, so are sometimes called energy levels. An electron has to gain energy to move from an inner to an outer energy level. An electron loses energy when moving from an outer to an inner energy level.



Each element has its own unique set of energy levels:

$$E_N = -\frac{13.58Z^2}{N^2}\text{electron volts (eV)}$$

Electronic Processes



$E_0<E_1<E_2$ (it takes energy to move the electron away from the positively charged nucleus)

Atomic Energy Level Diagram (Schematic)

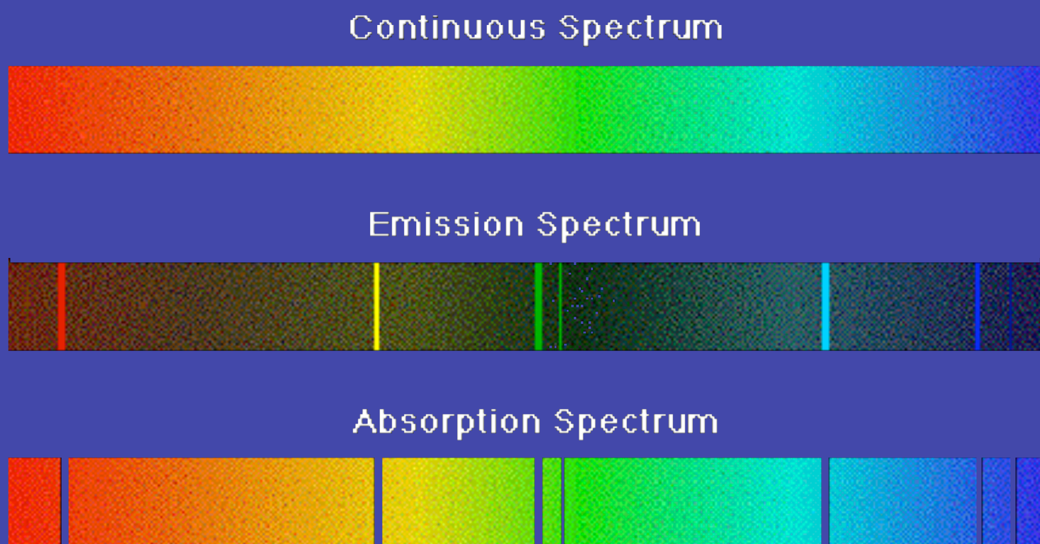
Excitation: an electron absorbs radiation of energy $E=E_N-E_M$ and jumps from energy level M to level N (M<N)

De-excitation: an electron jumps from level N to level M (M<N) and emits a quantum of radiation (a photon) of energy $E=E_N-E_M$

Ionization: an electron jumps from level N to the continuum (E_∞) after absorbing a photon of energy $E > E_N$. The energy required to ionize an atom from its ground state is called the Ionization Potential.

Recombination: A free electron is captured by an atom into some energy level N.

Spectra



ex: black body, recombination

ex: hot gas cloud with de-excitation

ex:blackbody surrounded by a gas cloud in which atoms are excited by the blackbody’s radiation field

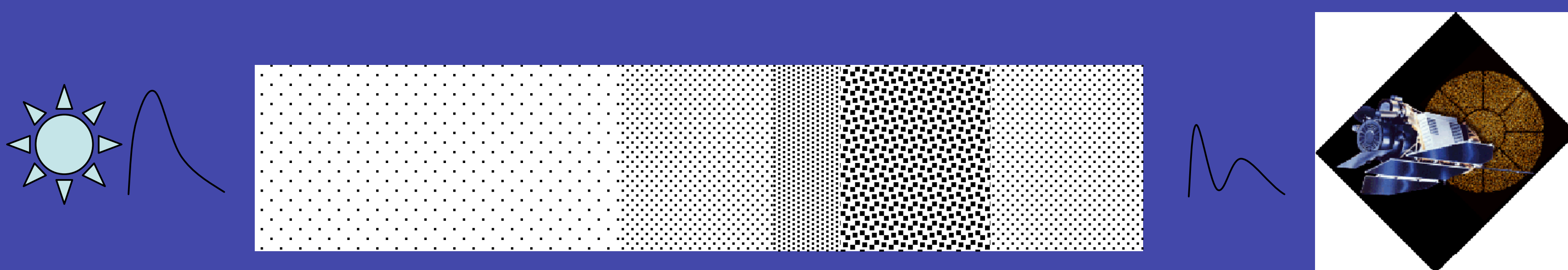
Absorption

As radiation passes through a medium, in general the medium will absorb some of the radiation, and emit some radiation. Thus the radiation received at a detector will be different from that emitted by the source. For a source of intensity I_0 whose light passes through an absorbing medium, the observed intensity I is

$$I = I_0 \exp^{-\tau}$$

where τ is the optical depth of the medium. τ is sometimes expressed in terms of an absorption cross-section σ and a column density N (the number of particles in a cylindrical column of unit area in the medium)

$$\tau = N\sigma$$



Sources of opacity

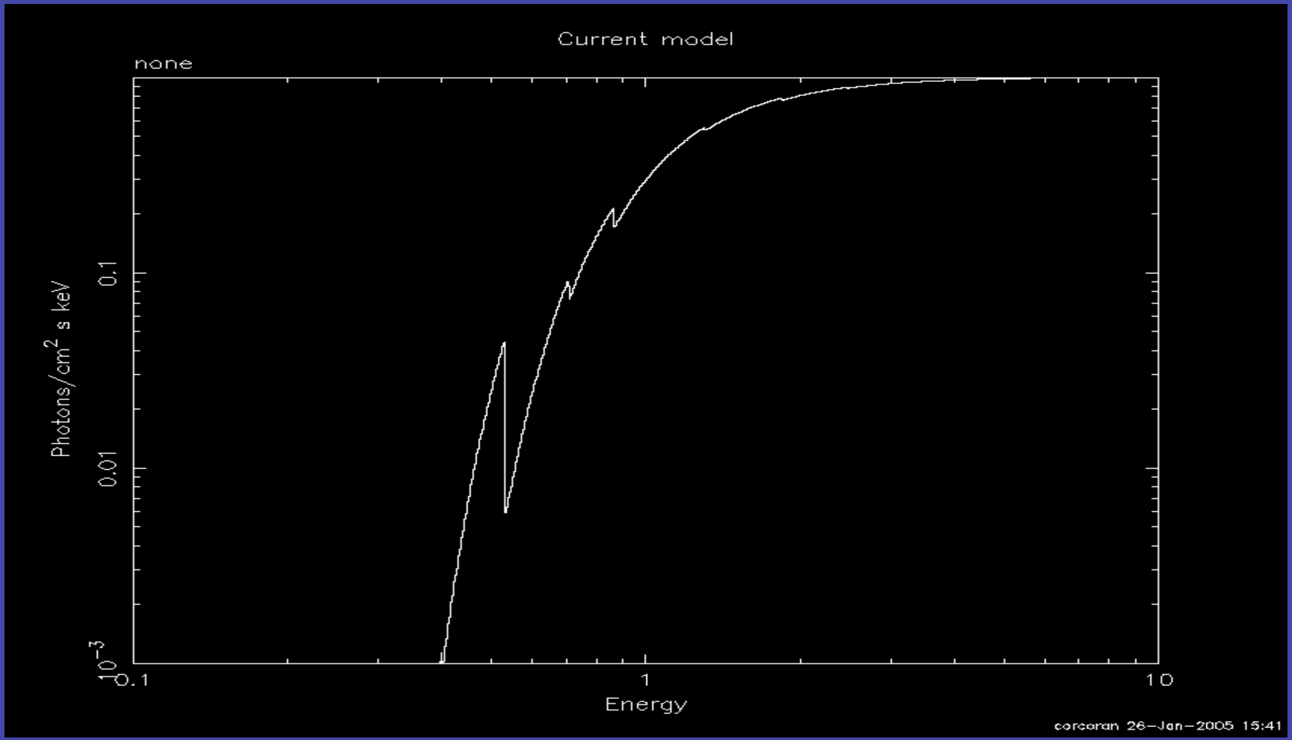
The optical depth of the absorbing medium depends on the nature of the material, and the physical processes occurring therein.

For the interstellar medium, the dominant process is photoelectric absorption in which photons are converted to free electrons by ionization.The photoelectric cross-section is dependent on photon energy and is especially high at energies near the ionization potential of the atom.

In magnetized plasmas, synchrotron absorption may be important

In highly ionized plasmas, Compton scattering may be important.

ISM absorption



This graph shows a the detected brightness of a source which generates a constant number of photons per each energy interval after the radiation passes through the ISM. All low-energy photons are removed via photoelectric absorption from H and lighter elements. The photoelectric cross-section at high energies is low, allowing most of the photons to get through. The large changes in opacity (absorption edges) occur near ionization potentials for abundant atoms like C and O.