UBC ASTR 102 Formula Sheet

Formulae

$D = \frac{ad}{206{,}265}$
d = distance, D = diameter, a = angular size (arcseconds)
$c = \lambda\nu$
λ = wavelegth, ν = frequency
$F = \sigma T^4$
F = energy flux (power per unit surface area),
T = temperature
λ_{max} (in nm) = $(3.0 \times 10^6$ K nm) / T (in K)
$E = h\nu = \frac{hc}{\lambda}$
E = energy
$\frac{1}{\lambda} = R\left(\frac{1}{n^2} - \frac{1}{m^2}\right)$
n = final state, m = initial state
$\frac{\Delta\lambda}{\lambda_0} = \frac{\lambda-\lambda_0}{\lambda_0} = \frac{v_r}{c}$
λ_0 = original wavelength, v_r = radial velocity
negative v_r = source is approaching
$F = ma$
F = force (N), m = mass (kg), a = acceleration (ms^{-2})
$F = \frac{Gm_1m_2}{r^2}$
r = distance between m_1 and m_2
$E_k = \frac{1}{2}mv^2$
E_k = kinetic energy
$E_p = mgh$
E_p = potential energy
$U = -\frac{GMm}{r}$
U = gravitational potential energy for object in orbit
$v_{esc} = \sqrt{\frac{2GM}{r}}$
v_{esc} = escape velocity, M = larger mass
$L = 4\pi\sigma T^4 R^2$
L = Luminosity (Watts), R = radius
$E = mc^2$
d (parsecs) $= \frac{1}{p}$ (arcseconds)
d = distance, p = parallax angle
$v_t = 4.74\mu d$
v_t = transverse (tangential) velocity (kms^{-1}),
μ = proper motion (arcsec/year), d = distance (parsec)
$v = \sqrt{v_t^2 + v_r^2}$
$b = \frac{L}{4\pi d^2}$
b = apparent brightness (Wm^{-2})
$\frac{L_1}{L_2} = \left(\frac{d_1}{d_2}\right)^2 = \frac{b_1}{b_2}$
$\frac{b_1}{b_2}$ (ratio of brightness of stars) $= (2.512)^{\Delta m}$
Δm = difference in apparent magnitude of stars
$m_2 - m_1 = 2.5\log_{10}\left(\frac{b_1}{b_2}\right)$
m_1, m_2 = apparent magnitudes, b_1, b_2 = brightness
$m - M = 5\log d - 5$
m = apparent magnitude, M = absolute magnitude
d = distance in parsecs.
$\frac{b_V}{b_B}, \frac{b_B}{b_U}$ = color ratios (lower is hotter)
$M_1 + M_2 = \frac{a^3}{P^2}$ (Kepler's 3^{rd} law for binary stars)
a = orbital separation (in AU), P = orbital period (in years)
$\frac{M_1}{M_2} = \frac{a_2}{a_1}$
$\frac{L}{L_\odot} \simeq \left(\frac{M}{M_\odot}\right)^{3.5}$
$\tau_{MS} \simeq \left(\frac{M}{M_\odot}\right)\left(\frac{L_\odot}{L}\right)$ Gyr
τ_{MS} = main sequence lifetime, Gyr = Giga year
$E = fMc^2$
Energy derived from $H->He$ conversion
$f = 7 \times 10^{-4}$
$L = \frac{E}{t}$
L is Luminosity, t is time
$Lt = fMc^2$
$t = \frac{fMc^2}{L} \propto \frac{M}{L} \propto \frac{M}{M^{3.5}} \propto M^{-2.5}$
$r_s = \frac{2GM}{c^2}$
black hole's event horizon, schwarzschild radius
$P = \frac{2\pi r}{v}$
The Sun's orbital period
$M = \frac{rv^2}{G}$
amount of matter inside the Sun's orbit

Constants

c (speed of light)	3×10^8 ms^{-1}
σ (Stefan-Boltzmann constant)	5.67×10^{-8} $\mathrm{Wm}^{-2}\mathrm{K}^{-4}$
h (Planck's constant)	6.626×10^{-34} Js
R (Rydberg constant)	1.097×10^7 m^{-1}
G (Newton's constant)	6.67×10^{-11} $\mathrm{Nm}^2\mathrm{kg}^{-2}$
g (gravity)	9.8 ms^{-2}

Conversions

`1 degree`	60 arcminutes
`1 arcminute`	60 arcseconds
`1 lightyear`	9.46×10^{12} km
`1 AU`	1.5×10^{11} m
`1 parsec`	3.26 lightyears
`1 m`	10^9 nm
`1 Gyr`	10^9 years

Chemical Processes

proton proton chain
triple alpha process

Diagrams

Blackbody spectrum
Cumulative Luminosity
Temperature and Density from the core
HR diagram

Miscellaneous 1

- absolute magnitude: apparent magnitude a star would have if it were located exactly 10 parsecs from Earth
- 10% of the mass of the star will be converted from H to He while it is on the main sequence.
- emission nebulae glow because UV knocking off electrons, which then recombine, and release photons in the visible spectrum.
- dark nebulae is caused due to dust, required for star formation, don't block infrared.
- reflection nebula contain fine grains of dust, they scatter short wavelength blue light efficiently, causing a reddening effect on stars.
- Protostars are initial stars formed in dark nebulae.
- Larger protostars take a shorter amount of time to reach the main sequence.
- planet $< 0.012M_\odot <$ brown dwarf $< 0.08M_\odot <$ main sequence stars $< 200M_\odot$
- high mass stars burn through their fuel first
- open clusters - held together by gravitational forces
- stellar association - fast moving cluster, mostly O, B stars (OB association)
- globular clusters - large, old clusters
- CO helps predict star formation
- A red dwarf is a main-sequence star with less than about 0.4 solar masses. Helium star.
- End of H fusion: core starts to cool, pressure in the core starts to decrease, the core compresses/shrinks, the temperature to increase again, and outer layers will expand.
- In red giants with a mass less than about 2 to 3 $M\odot$ but still more than 0.4 $M\odot$, helium fusion begins explosively and suddenly, in what is called the helium flash.
- If the core is contracting (no fusion): Core temperature goes up, Heat transfers to the outer layers, The outer layers expand, (Low mass: Luminosity increases)
- If the core is expanding (fusion): Core temperature goes down, Less heat to the outer layers, The outer layers shrink (Low mass: Luminosity decreases)
- black hole properties; mass, charge and spin.

Miscellaneous 2

`violet light`	400 nm
`red light`	700 nm
`blue shift`	approaching (short λ)
`red shift`	receding (longer λ)
$L_\odot$	Luminosity of the sun
$M_\odot$	Mass of the sun
`layers of sun`	Thermonuclear $->$ radiative $->$ convection
$m - M$	Distance modulus (apparent - absolute)
OBAFGKM	current ordering of stars (hot to cold)
L, T, Y	brown dwarf spectral classes

Miscellaneous (post midterm)

- Population II stars are old and metal poor
- Population I stars are young and metal heavy
- Cepheid variables brighten and fade because their outer envelope cyclically expands and contracts. They are found throughout the galaxy. Pulsation period 1 to 50 days. Luminosity positively related to period.
- RR Lyrae stars. Found in globular clusters. Pulsation periods less than a day. All have the same luminosity.
- They are very bright and can be seen to large distances, and obey a relationship between luminosity and pulsation period
- protostar $->$ H is over $->$ red giant $->$ helium flash $->$ horizontal branch $->$ helium is used up $->$ asymptotic giant branch $->$ thermal pulses $->$ planetary nebula $->$ end of nuclear reactions $->$ white dwarf
- photodisintegration happens in core collapse of core mass $> 8\ M_\odot ->$ star becomes a neutron star.
- type Ia supernova: red giant companion, white dwarf explodes. (No He, H. Produces Si)
- When the total mass of the white dwarf approaches the Chandrasekhar limit ($1.4\ M_\odot ->$). "standard candle"
- type Ib supernova: Core collapse of massive red giant. outer layers have no H(No H. Produces He)
- type Ib supernova: Core collapse of massive red giant. outer layers have no H or He (No H or He)
- type II supernova: Core collapse of massive red giant. outer layers intact. (Produces H)
- $M > 25M_\odot ->$ black hole
- $M > 8M_\odot ->$ neutron star
- $M > 0.4M_\odot ->$ white dwarf
- $M > 0.08M_\odot ->$ red dwarf star
- $M < 0.08M_\odot ->$ brown dwarf
- gravitational waves: Ripples in the fabric of spacetime generated by the acceleration of matter
- short-duration gamma-ray bursts: neutron star mergers
- long-distance gamma-ray bursts: Type Ic supernova
- We can observe where the neutral hydrogen atoms are in our Galaxy and in others by looking for emission corresponding to the spin flip of the electron, from aligned with the proton's spin to aligned. The spin flip results in the release of a photon of wavelength 21 cm (frequency 1420 MHz)
- MACHOs: brown dwarfs, white dwarfs, or black holes, are called massive compact halo objects
- WIMPs: Weakly Interacting Massive Particles
- Elliptical galaxies have virtually no interstellar gas or dust, and no evidence of young stars in most elliptical galaxies. For the most part, star formation in elliptical galaxies ended long ago.