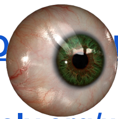

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https://scioly.org/wiki/index.php/Astronomy/Stellar_Evolution

https://scioly.org/wiki/index.php/Astronomy/Variable_Starshttps://scioly.org/wiki/index.php/Astronomy/Variable_Stars

Parsec: 3.26 light years
Light year: 9.46*10^15 meters

Table of Contents

Stellar evolution

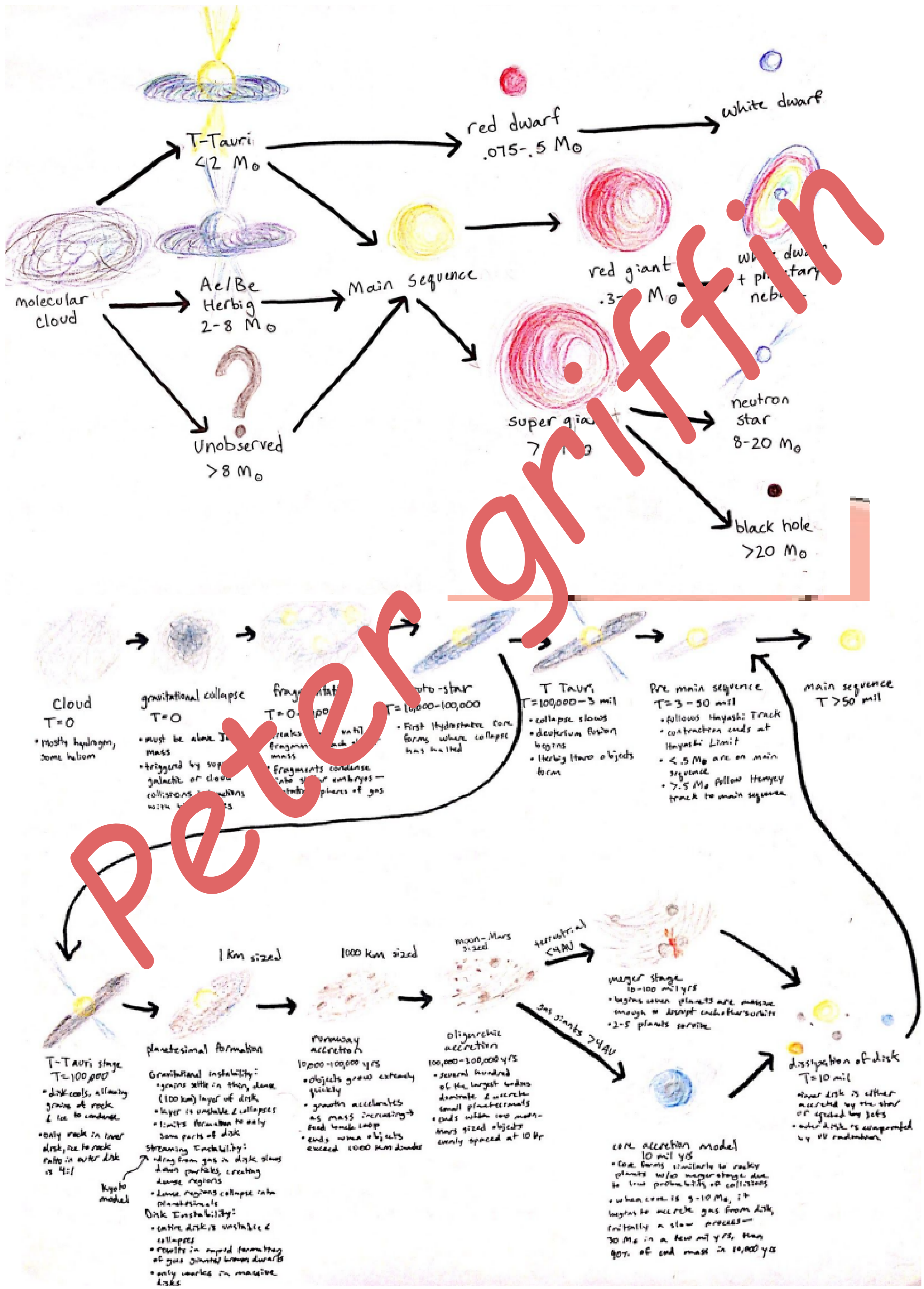
Classifications
- Star classifications
- Hertzsprung-Russel diagram
- Supernovae classification

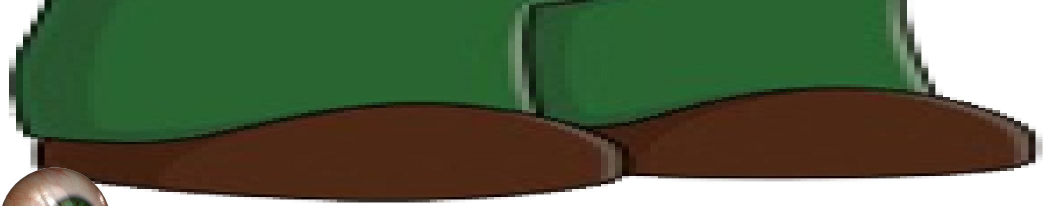
Variability:

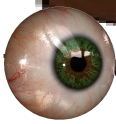
Mathematics portion
- Orbital mechanics

Formula sheet

Stellarlution





Classions

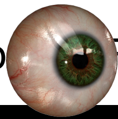
Star classifications

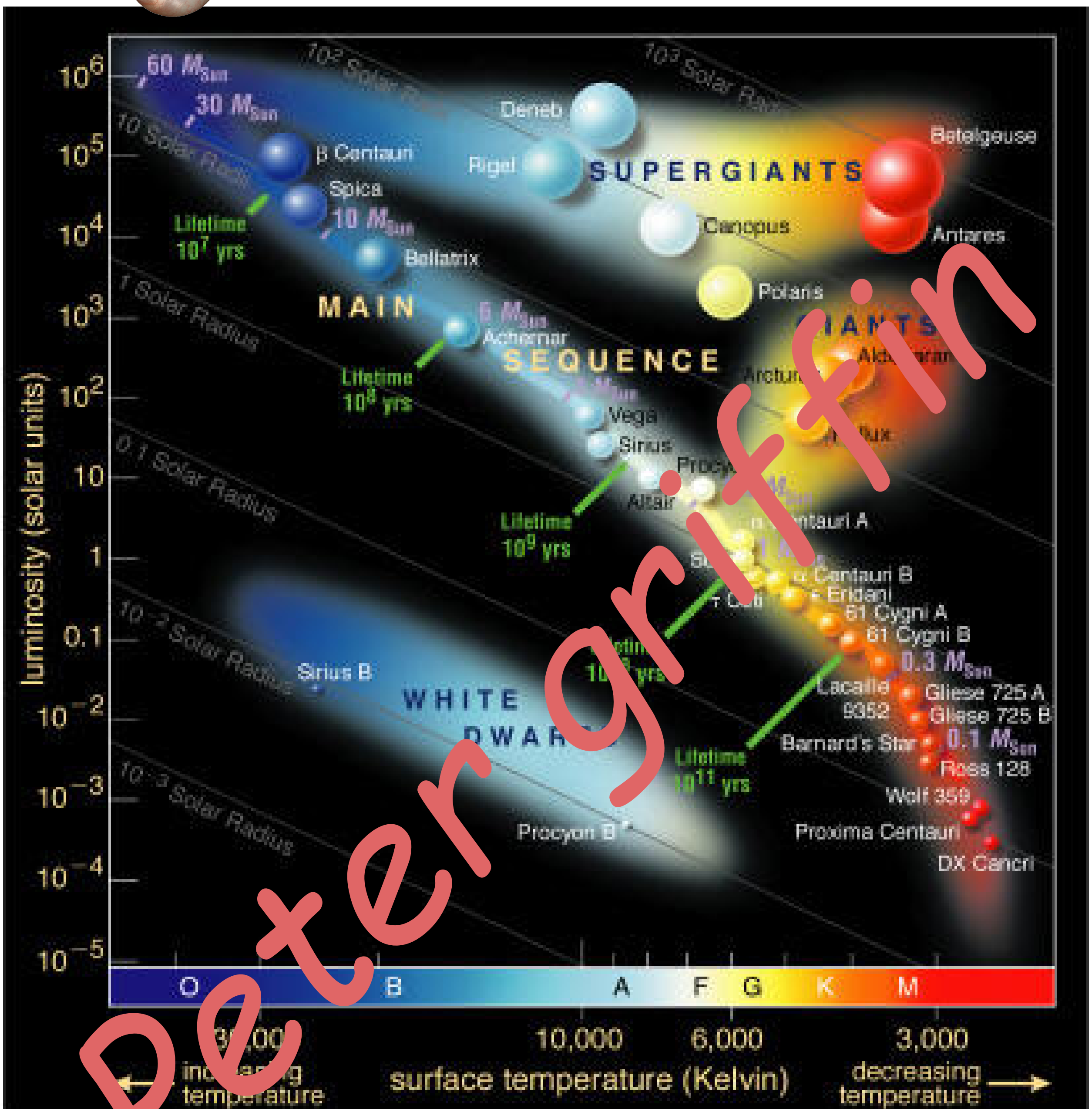
Temperatures: in kelvin
O: 28,000-50,000
B: 10,000-28,000
A: 7,500-10,000
F: 6000-7500
G- 5000-6000
K- 3500-5000
M - 2500-3500
Further classification: lower number is hotter; so A0 is hotter than A7

*Class**	*Color Descr.*	*Actual Color*	*Mass ($M_\odot$)*	*Radius($R_\odot$)*	*Lumin.($L_\odot$)*
O	Blue	Blue	≥ 16	≥ 6.6	$\geq 30,000$
B	Blue-white	Deep B-W	2.1-16	1.8-6.6	25-30,000
A	White	Blue-white	1.4-2.1	1.4-1.8	5-25
F	Yellow-white	White	1.04-1.4	1.15-1.4	1.5-5
G	Yellow	Yellowish-W	0.8-1.04	0.96-1.15	0.6-1.5
K	Orange	Pale Y-O	0.45-0.8	0.7-0.96	0.08-0.6
M	Red	Lt. Orange-Red	0.08-0.45	≤ 0.7	≤ 0.08

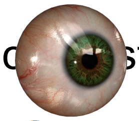
LUMINOSITY CLASSES (Also uses "OBAFGKM")

O – hypergiants
I – supergiants
II – bright giants
III – normal giants
IV – subgiants
V – M.S. (dwarfs)
VI – subdwarfs
VII –white dwarfs

HertzspRussel diagram



Stellar chemistry

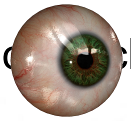


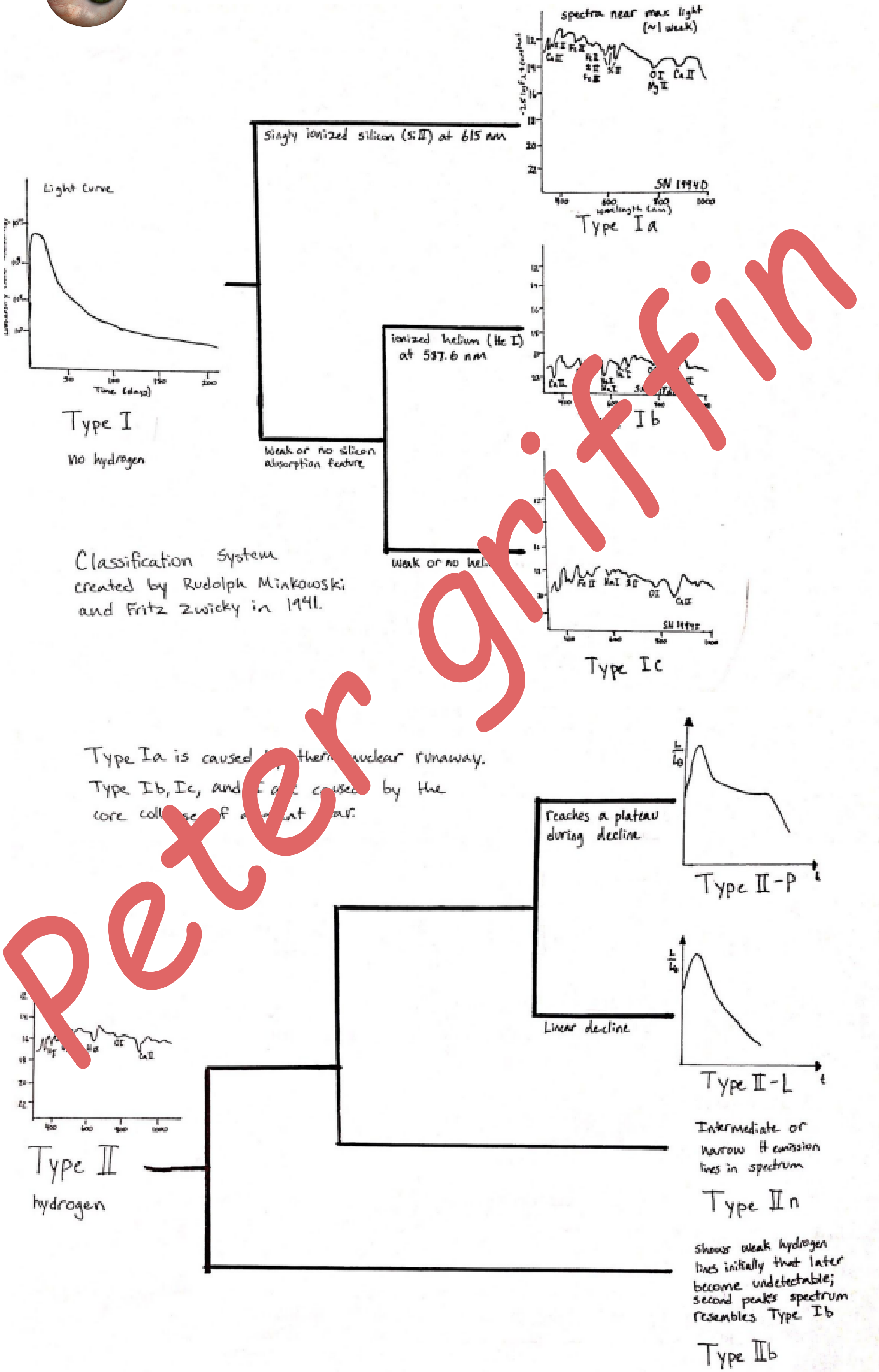
Class	*Characteristics*
O	Dominant He II absorption (and sometimes emission) lines and prominent ionized (Si IV, O III, N III, C III) and neutral helium lines which strengthen from O5-O9 with prominent hydrogen Balmer lines
B	Neutral helium lines, most prominent at the B2 subclass, with moderate hydrogen lines. Balmer series hydrogen lines grow stronger through the B class. Ionized metals include Si II and Mg II
A	Balmer series lines peak, with strong hydrogen lines. Also present are lines of ionized metals, including Fe II, Mg II, and Si II, which are at a maximum at A0. Ca II lines strengthen at this point.
F	Strengthening *H* and *K* lines of Ca II. Neutral metals Fe I and Cr I make gains on ionized metals by late F. Weaker hydrogen lines and ionized metals characterize the class.
G	Very prominent *H* and *K* lines of Ca II, peaking at G2. Have weaker hydrogen lines than F. Along with ionized metals, neutral metals lines are present in the spectra.
K	Extremely weak, sometimes nonexistent, hydrogen lines. Mostly neutral metals (Mn I, Fe I, Si I)

SPECTRA IN-DEPTH (MAIN SEQUENCE)

O	- Main-sequence (hydrogen-burning core) star, spectral type O and luminosity class V - Very rare, very massive, with extremely short lifespans (first to leave main seq.) - 0.00003% of local stars are of spectral type O - Most output is in the ultraviolet range
B	- Main-sequence star, spectral class B, luminosity class V - Extremely luminous, short lifespans, rarely found far from area of formation - ~0.125% of stars in solar neighborhood (M-S) are of spectral class B. - Natural helium spectra with moderate hydrogen lines
A	- Main-sequence star, spectral type A, luminosity class V - More common naked-eye stars with higher tendency to have massive planets - 0.625% of stars in solar neighborhood belong to class A. - Strong hydrogen lines with strengthening Ca II lines
F	- Main-sequence star, spectral type F, luminosity class V - Technically a "dwarf star," so may be referred to as a yellow-white dwarf. - 3.03% of stars in the solar neighborhood are class F stars. - Weaker hydrogen lines and strengthening lines of Ca II
G	- Main-sequence star of spectral type G, luminosity class V - Lifetime of ~10bn years until Hydrogen fusion ceases and transitions to a red giant - ~7.5% of local stars are of class G, the most well-known being the Sun, of class G2V - Yellow supergiants are extremely rare; most supergiants are between O-B or K-M
K	- Main-sequence star of spectral type K, luminosity class V - Due to low mass and intermediate size, have longer lifespans (15-30bn years) - ~12% of main-sequence stars in the solar neighborhood belong to class K - AKA "orange dwarves" with mostly neutral metals lines and weak hydrogen lines
M	- Very low-mass, main-sequence stars of spectral type M, luminosity class V - Due to low mass and low surface temperature, red dwarves are very dim stars - ~76% of local main-sequence stars are class M stars, making them very common - Have incredibly long lifespans due to lack of buildup at core, lifespans of 10tn+ years

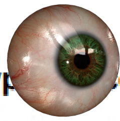
Superno classification





Classification System created by Rudolph Minkowski and Fritz Zwicky in 1941.

Type Ia is caused by thermonuclear runaway.
Type Ib, Ic, and II are caused by the core collapse of a giant star.



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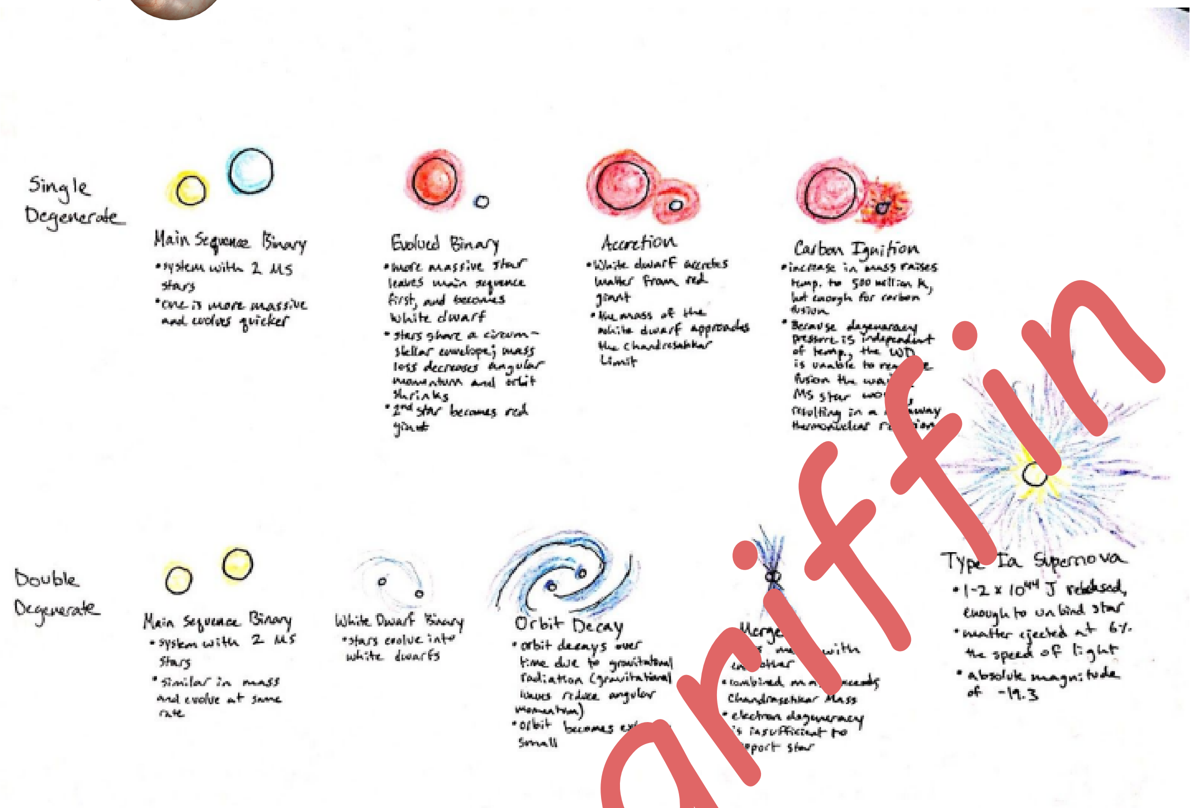
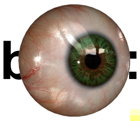


Single Degenerate
Main Sequence Binary
•system with 2 MS stars
•one is more massive and evolves quicker
Evolved Binary
•more massive star leaves main sequence first, and becomes white dwarf
•stars share a circum-stellar envelope; mass loss decreases angular momentum and orbit shrinks
•2nd star becomes red giant
Accretion
•White dwarf accretes matter from red giant
•the mass of the white dwarf approaches the Chandrasekhar Limit
Carbon Ignition
•increase in mass raises temp. to 500 million K, but enough for carbon fusion
Double Degenerate
Main Sequence Binary
•system with 2 MS stars
•similar in mass and evolve at same rate
White Dwarf Binary
•stars evolve into white dwarfs
Orbit Decay
Type Ia Supernova
•1-2 x 10^44 J released, enough to unbind star
•matter ejected at 6% the speed of light
•absolute magnitude of -19.3

Variab:

Variable star periods:
- RR Lyrae (period of less than a day)
- Cepheid (period of one day to about a year)
- Mira (period of over a year)

Intrinsic vs Extrinsic: Intrinsic variable stars change in luminosity due to physical changes in the star, while extrinsic change in luminosity due to external changes (two main ones being rotating and eclipsing)

Intrinsic Variable Stars:
Three main types: pulsating, eruptive, and explosive

Pulsating Variable Stars: Stars that periodically swell and shrink
- Pulsating stars that have short periods are called Cepheids, which tend to have more regular periods than long period variables.
- Important examples include the Delta Cephei variables, W Virginis variables, RR Lyrae variables, Mira A (Omnicron Ceti A) variables, and Beta Cephei variables.
- Long period variables have longer periods than cepheids (>1 year) and are sometimes bigger and cooler than cepheids. F)
- Long period variables can be split into three subgroups
    - Irregular variables: They are usually red supergiants and have almost no regular period.
    - Semi-regular variables: They sometimes go through regular periods,, then change and go on irregular periods.
    - Non-radial pulsators: Variables that change to shapes other than the sphere to change magnitude

The Instability Strip: A region on the H-R Diagram in which many variable stars can be found. The strip extends through the A, F, and occasionally G classes above and below the main sequence. In this strip, stars have a tendency to be unstable and pulsate, thus causing them to have some variability. Cepheids, RR Lyrae, W Virginis, and ZZ Ceti stars can all be found in this region, as well as other, less common variable stars.

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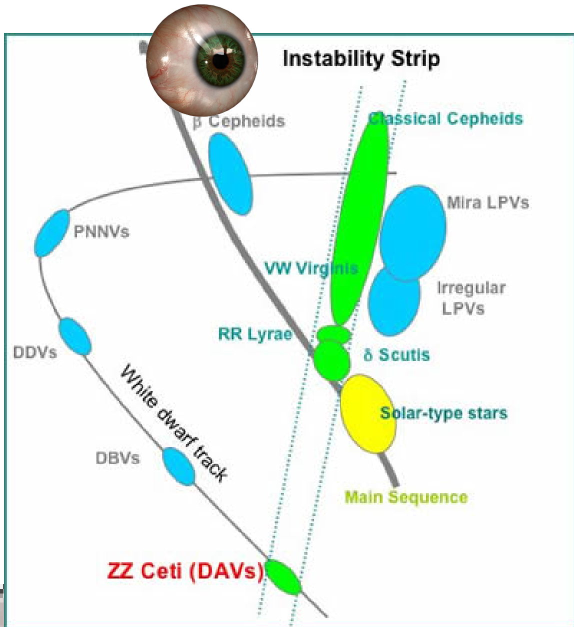

Eruptive Variable Stars: Mostly pre-main sequence stars, but few main sequence stars are eruptive variables.

- Pre-main sequence (protostars) are stars that have not completed the process of becoming a main-sequence star from a gas nebula and are not yet condensed. While condensing they change in magnitude.
- Eruptive Main-sequence variables are usually extremely larger or extremely smaller than the average main sequence star.
- Some eruptive variables are red giants since they easily lose their gases.
- Binary eruptive stars: They flare up and can stay that way for 1-4 years.
- Important eruptive variable stars: Orion Variables, Wolf-Rayet variables, and RS Canum Venaticorum variables.

Explosive/Cataclysmic Variable Stars: Show outbursts which are caused by thermonuclear burst processes in the surface (novae) or deep in the interior of the star (supernovae).

- Supernovae: The most dramatic of the explosive variables, they only occur in extremely massive and old stars, or in white dwarfs that gain enough mass to go supernova. The outer layers of the star are expelled at high speeds creating a supernova remnant or nebula. A white dwarf or pulsar is usually left behind.
- Novae: Dramatic explosions caused by a pair of close binaries (covered later) but don't cause the total destruction of the star.
- Dwarf Novae: Similar to novae, but are just two binary white dwarfs that regularly have outbursts.
- Z Andromedae variables: Less common type, caused by a double star system containing a red giant and a hot blue star enclosed in a cloud of dust and gas.

<u>Extrinsic Variable Stars:</u> Change in luminosity due to external changes

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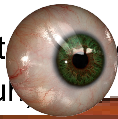
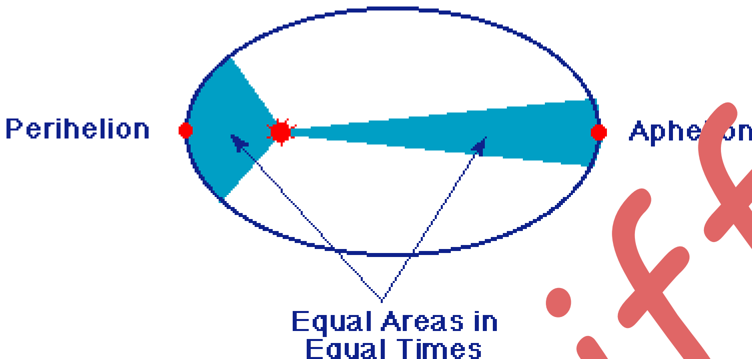
- Rot otating variable stars change in luminosity due to rotation of the star (Dul
    - Can occur because of things like sunspots on the surface as it rotates. Can also occur when two close binary stars change shape due to mutual gravity. Fluctuations in magnetic fields can also cause magnitude changes.
- Eclipsing

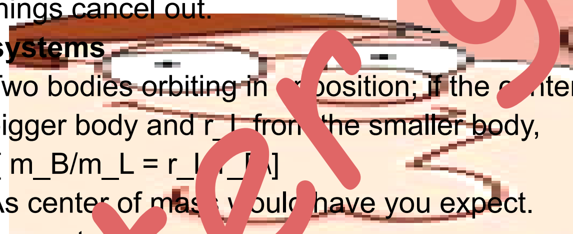
Mathecs portion

Orbital mechanics

- Kepler's laws:
    - 1: Orbits are elliptical
    - A planet traces out equal areas in equal times.



    -
    - Square of period is proportional to length of semimajor axis.
    - In particular,
    - $$p^2=\left(\frac{4\pi}{GM} \right) a^3.$$
    - If p is solar years, M is solar masses, a is AU, we may assume $p^2=a^3$ since things cancel out.
- **Binary systems**



    - Two bodies orbiting in opposition; if the center of mass has distance r_B from the bigger body and r_L from the smaller body,
    - $$m_B/m_L = r_L/r_B$$
    - As center of mass would have you expect.

Formula sheet on next page.

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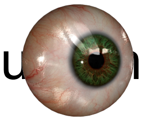
Formu  heet

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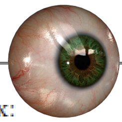
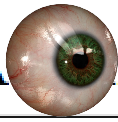


Parallax:	$d = \frac{1}{p}$	d = Distance (pc) p = Parallax Angle (arcseconds)
F Ratio:	$\frac{L_f}{D_O}$	L_f = Focal Length D_O = Objective Diameter
Distance Modulus:	$m - M = -5 + 5log(d)$ $d = 10^{\frac{m-M+5}{5}}$	m = Apparent magnitude M = Absolute Magnitude d = Distance (pc)
Orbit Eccentricity:	$e = \frac{c}{a}$	e = Orbital Eccentricity c = Distance from focus to center a = semimajor axis
Aphelion/Perihelion:	$R_a = a(1+e)$ $R_p = a(1-e)$	R_a = Orbit Aphelion R_p = Orbit Perihelion a = Semimajor Axis e = Eccentricity
Kepler's 3rd Law:	$M_A + M_B = \frac{a^3}{p^2}$ $p^2 = \frac{a^3}{M_A + M_B}$	M = Mass (solar masses) a = Semimajor axis (AU) p = Orbital Period (years)
Mass-Luminosity Relation:	$L = M^{3.5}$	M = Mass (solar masses) L = Luminosity (Solar luminosity)
Stellar Lifetime:	$\tau = 10^{10} M^{-2.5}$	M = Mass (solar masses) τ = Stellar Lifetime (years)
Schwarzschild Radius:	$r_s = \frac{2GM}{c^2}$	r_s = Schwartzchild Radius (meters) G = Gravitational Constant c = Speed of light r = radius (meters)
Universal Gravitation:	$F = G\frac{m_A m_B}{r^2}$	F = Gravitational Force (N) G = Gravitational Constant m = mass (kg) r = radius (meters)
Inverse-Squares Law:	$I = \frac{L}{4\pi d^2}$	I = Light Intensity (W/m^2) L = Luminosity (W) d = Distance (m)
Vacuum Frequency:	$f = \frac{c}{\lambda}$	f = Wave frequency (Hz) c = Speed of Light (m/s) λ = wavelength (m)
Hubble Time:	$T_U = \frac{9.778 \times 10^{11}}{H_0}$	T_U = Age of the Universe (years) H_0 = Hubble Constant (km/s/Mpc)

 Astronomical Constants and Conversions

Constants

Speed of Light = $c = 3 \times 10^8$ m/s

Gravitational Constant = G = 6.67×10^{-11}N m^2/kg^2

Mass of Earth = $M_\oplus = 5.97 \times 10^{24}$ kg

Radius of Earth = $R_\oplus = 6378$ km

Mass of the sun = $M_\odot = = 1.99 \times 10^{30}$ kg

Radius of the sun = $R_\odot = 6.96 \times 10^5$ km

Effective Temperature of the sun = $T_\odot = 5778$ K

Luminosity of the sun = $L_\odot = 3.9 \times 10^{26}$W

Mass of the Moon = $M_☾ = 7.346 \times 10^{22}$ kg

Radius of the Moon = $R_☾ = 1738.1$ km

Mass of a proton = $m_p = 1.6726 \times 10^{-27}$ kg

Mass of an Electron = $m_{e^-} = 9.109 \times 10^{-31}$ kg

Hubble's Constant = $H_0 = 70$ km/s/Mpc (**Note:** There i[illegible] going deba[illegible]e about the actual value)

Stefan-Boltzmann Constant = $\sigma = 5.67 \times 10^{-8}$ W/m^2[illegible]

Planck's Constant = $h = 6.626 \times 10^{-34}$ J s

Boltzmann Constant = $k_B = 1.380 \times 10^{-23}$ m^2 kg s[illegible]^2 K[illegible]

Hα Spectral Line = 656.28 nm

Type Ia Supernova Absolute Magnitu[illegible] = -19.3

Unit Conversions

1 Astronomical Unit = [illegible] = [illegible] × [illegible] km

1 Parsec = 1 pc = 3.09 × [illegible]^{13}km = 3.26 ly

1 Light Year = 1 l[illegible] 9.46 × [illegible] km

1 Arc M[illegible] = [illegible] = $(\frac{1}{60})$ = $(1.667 \times 10^{-2})^\circ$

1 Arcs[illegible]ond [illegible] $1''$ [illegible] = $(1.667 \times 10^{-2})'$

1 year = [illegible]57600 seconds

1 Megaton ([illegible]nergy) = 1,000,000 tons of TNT = 4.184×10^{15} J

Important Note:
If constants or unit conversions are provided on the exam, use those instead of these.