UBC
ASTRONOMY 205
Stars and Stellar Populations
Second Midterm Examination
March 11, 2019 – 50 Minutes

This exam consists of 8 pages. There are 5 numbered questions, please attempt all of them. Write directly in the space provided on the exam. A simple hand-held calculator is also allowed – no graphing or programmable ones permitted. There is a blank page at the end for rough work – it will NOT be marked. A formula sheet together with useful constants is found on the following page.

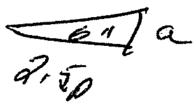
STUDENT NAME: ______________________________

STUDENT NUMBER: ______________________________

Some of the following constants and equations might prove useful.
speed light $c = 3x10^8$ m/sec;
1 AU = $1.5x10^8$ km; 1 light year = $9.5x10^{12}$ km;
1 parsec = 3 x 10^{13} km
Wien's Law $\lambda_{max} = 3x10^6/T$, λ_{max} is in nanometers, T in degrees K;
Stefan-Boltzman law $F = \sigma T^4$; $\sigma = 5.67x10^{-8}$ W/m^2K^4;
Kepler's Third Law $p^2 = 4\pi^2a^3/G(M_1+M_2)$;
Gravitational Force $F=GM_1M_2/r^2$;
206265 arcsec/radian;
$F = L/4\pi d^2$ where F is the flux, L the Luminosity and d the distance;
$G=6.67x10^{-11}$ Nm^2/kg^2;
$\theta_{radian} = 1.22\lambda/D$;
1 micrometer $=10^{-6}$m;
1 nanometer (nm) = 10^{-9}m;
Mass of Sun=$2x10^{30}$ kg;
Radius of Sun=$7x10^8$ m;
Luminosity Sun=$4x10^{26}$ watts;
Latitude Vancouver = 49 Degrees;
Distance (pc) = $1/\pi$, π in arcsec;
Velocity-Redshift $\Delta\lambda/\lambda = v/c$, c is speed light, v is velocity;
m2 – m1 = 2.5 log(b1/b2), m's are magnitudes b are fluxes
(m-M) = 5 log (d/10) + A; m apparent mag, M absolute mag, d distance in pc,
A is extinction = 3E(B-V) where E is the colour excess;
$B_\lambda(T) = (2hc^2/\lambda^5)(1/e^{hc/\lambda kT} - 1)$ w m^{-2} m^{-1} sterad^{-1} B(T) is Planck Function
$1/\lambda = R_H(1/4 - 1/n^2)$ R_H Rydberg Constant = 1.09677 x 10^7 m^{-1}
Boltzmann Formula: $N_B/N_A = D\ e^{-(X_{AB}/kT)}$ N's are the numbers in various states, D depends on state, X_{AB} is energy difference between states, k is Boltzmann constant = 1.38 x 10^{-23} m^2 kg s^{-2} K^{-1},T temperature
$F(m) = pv^3/2\pi G$ is mass function p is period v velocity
$F(m) = m_2^3\sin^3 i/(m_1 + m_2)^2$
$L \alpha M^{3.5}$
P.E. = $-3GM^2/5R$
$P=(1/\mu)k\rho T/m_H$ $\quad$ $dP/dr = - GM_r\rho(r)/r^2$
$dM(r)/dr = 4\pi r^2\rho(r)$ $\quad$ $dL(r)/dr = 4\pi r^2\rho(r)\varepsilon(r)$
$dT/dr = (-3/4ac)\ (\kappa\rho(r)/T^3)\ (L_r/4\pi r^2)$
mass hydrogen atom 1.67 x 10^{-27} kg

1. A visual binary star has a parallax $\pi = 0.4$ arcsec, a maximum separation $a = 6.0$ arcsec, and an orbital period $P = 80$ years. What is the total mass of the binary system assuming a circular orbit. **[5 marks]**

$\pi = 0.4 \rightarrow D = 2.5\ pc$ $\quad 6'' @ 2.5\ pc =$



$6'' = \frac{a}{2.5\ pc}$ $\quad \therefore \frac{6}{206265} = \frac{a}{2.5\ pc}$

$\therefore 2.91 \times 10^{-5} = \frac{a}{2.5\ pc}.$

$\Rightarrow a = 7.27 \times 10^{-5}\ pc = 15\ AU.$

$\therefore P^2 = a^3 / (M_1 + M_2)$

M in solar mass, P in yr, a in AU.

$\therefore (M_1 + M_2) = \frac{a^3}{P^2} =$

$(M_1 + M_2) = 0.53\ M_\odot$

2 (a) Jupiter's orbital period around the Sun is 11.86 years and the semi-major axis of its orbit is 5.2 AU. Its mass is 0.0000955 of that of the Sun.

(a) Assuming that Jupiter's orbit is circular, what is Jupiter's orbital velocity? **[1 mark]**

$$\text{velocity} = \frac{2\pi R}{P} = \frac{2\pi \times 5.2 \times 1.5 \times 10^{8}}{11.86 \times 3 \times 10^{7}} \ \text{km/s}$$

$$= 13.77 \text{ km/s.}$$

(b) What is the velocity of the Sun around their mutual centre of mass? **[1 mark]**

$$\frac{a_1}{a_2} = \frac{M_2}{M_1} \qquad \frac{a_2}{a_J} = .0000955$$

$\therefore A_{sun} = .0000955\, a_J = 74,490$ km $\times 2\pi = 468.034$

$\div$ 11.86 yr = ~~2...~~ km/s = ~~...~~

1.32×10^{-3} km/s $\quad$ 1.3 m/s

(c) Provide 2 reasons why the radial velocity technique for detecting planets around other stars would make it difficult to discover a Jupiter-like planet in a Jupiter-like orbit around a star like our Sun. **[2 marks]**

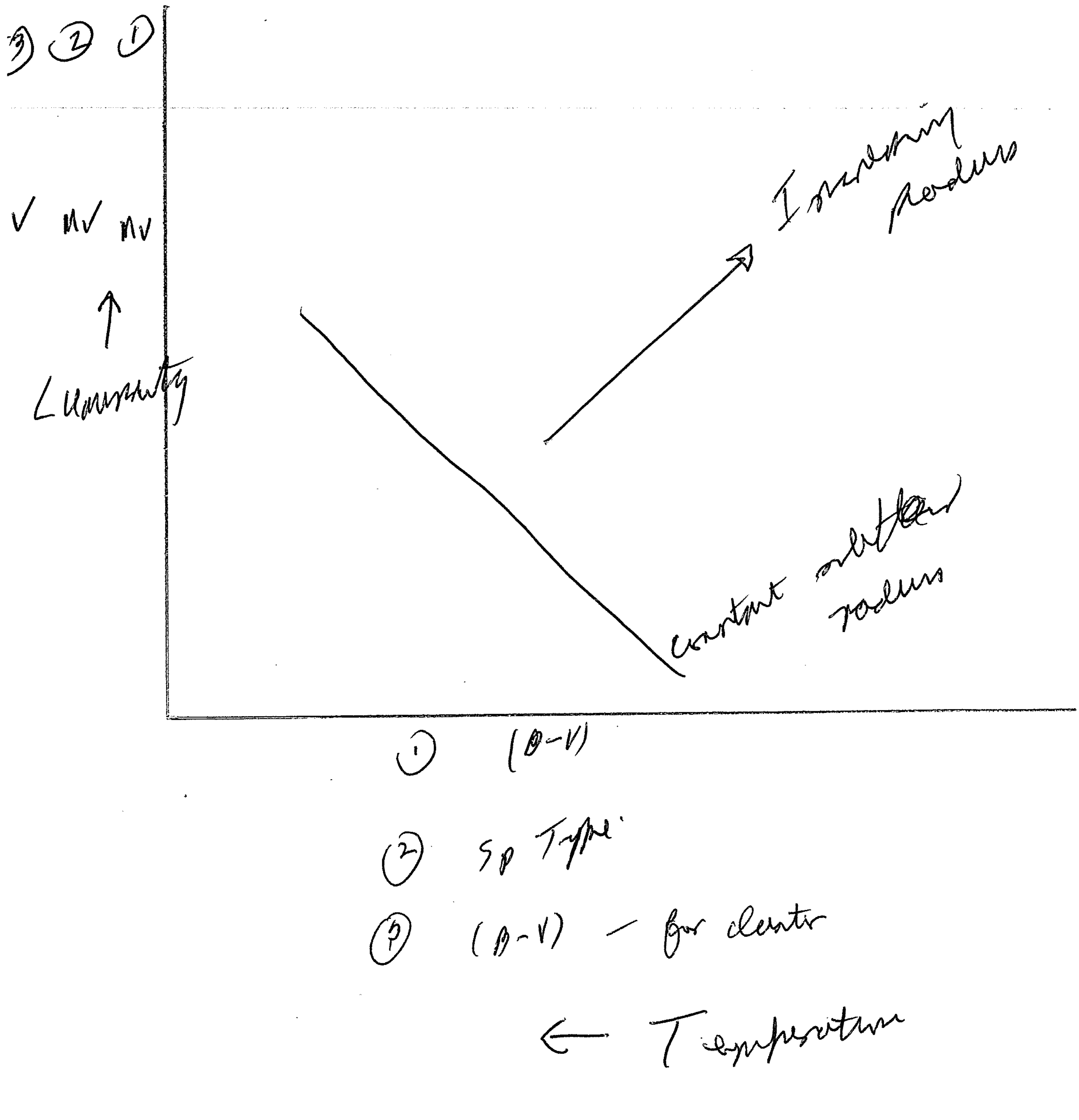
(c) It has a very long period (~12 yrs)

(b) has a very low and hard to measure velocity.

(d) Explain why radial velocity detections of extrasolar planets yield only lower limits on the masses of the orbiting planets. **[1 mark]**

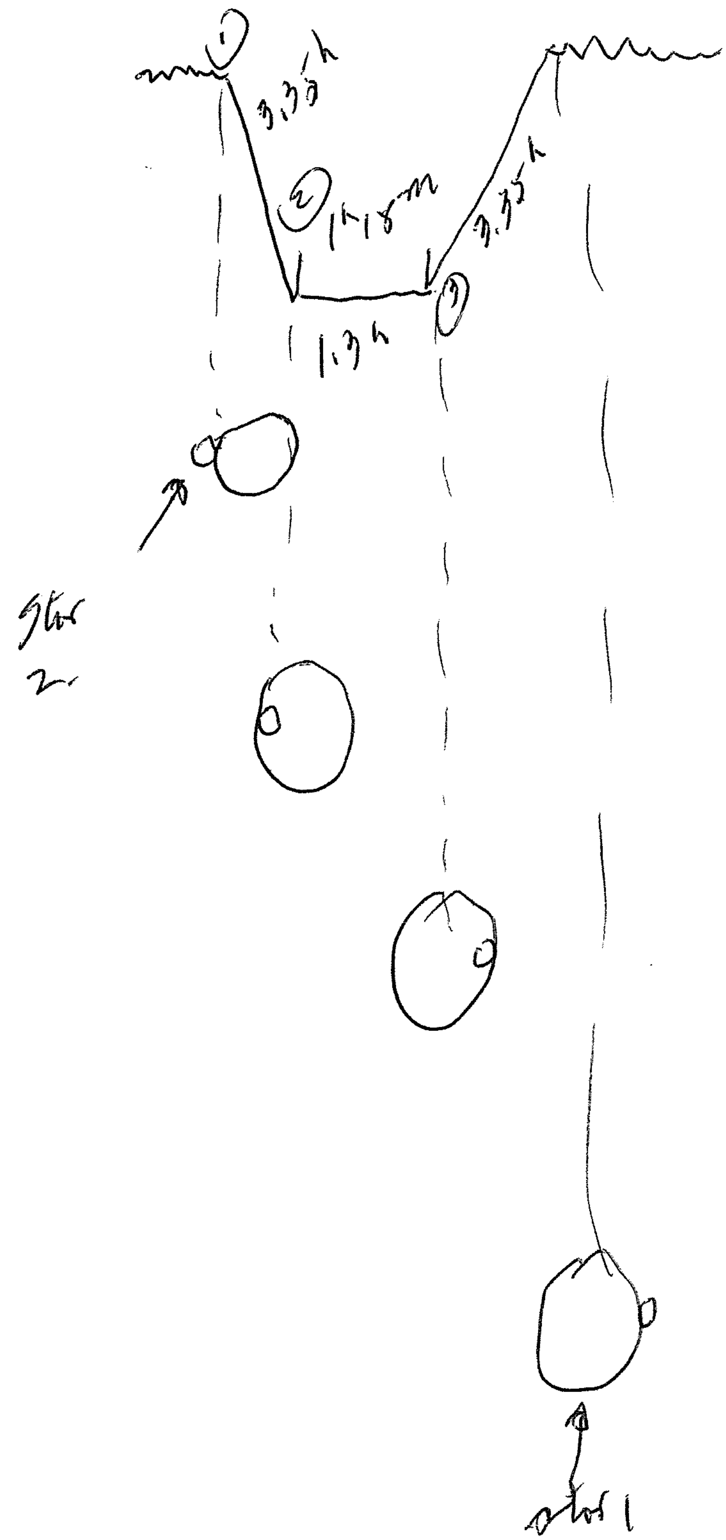
Don't know inclination of the orbit so if assume $i = 90°$ (edge on) get lower limit to mass planet

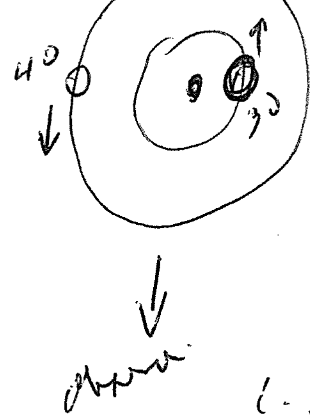
3. Below are the axes of an Hertzsprung-Russell Diagram. (1) Write directly on this plot (along the relevant axis), 3 possible pairs of axes for this plot. (b) Indicate the main underlying physical parameter for each axis and the direction along the axis in which the parameter is increasing. (c) Also indicate right on the plot the direction of constant stellar radius and the direction of increasing radius. **[5 marks]**



4. (a) For an eclipsing binary system with a period of 30 days, the total duration of the primary eclipse is 8 hours. A flat minimum is seen for 1 hour 18 minutes. The radial velocity amplitude for star 1 is 30 km/s and for star 2 it is 40 km/s. For a circular orbit and inclination of 90 degrees (edge on), how large are the radii of the stars (in km)? **[5 marks]**

Relative vel = 70 km/s





(1–2) small star moves by its diameter

$1 \cdot D = 70 \frac{km}{s} \times 3.35 \times 3600$

$D = 8.44 \times 10^5$ km

$R = 4.22 \times 10^5$ km

$D = 1.21 R_\odot$

$R = 0.60 R_\odot$

(1–3) small star moves diameter large star

$= 70 \frac{km}{s} \times 4.65 \times 3600$ km

$= 1.17 \times 10^6$ km diam

$= 5.9 \times 10^5$ radius

$= 0.84 R_\odot$

5. Attached is the colour-colour diagram for stars in the open cluster NGC 2516 (points). Also included in the diagram is the colour-colour sequence for standard stars (continuous line).

(a) Where in the Galaxy is this cluster likely located? **[1 mark]**

likely located in disk of galaxy
likely in a spiral arm

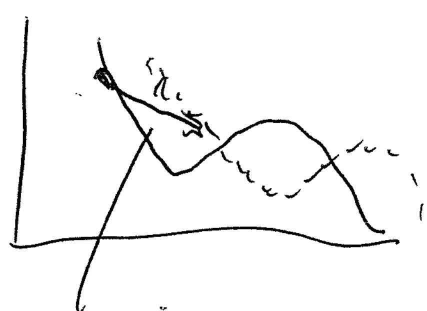
(b) What is the reason that the two plots don't overlap? **[1 mark]**

They don't overlap because the cluster stars are reddened.

(c) What can you say about the age of the cluster? **[1 mark]**

The cluster must be young because there are still very hot stars in it

(d) Estimate E(B-V) in the direction of the cluster and note what this implies for the extinction (Av) in the direction of the cluster. **[2 marks]**

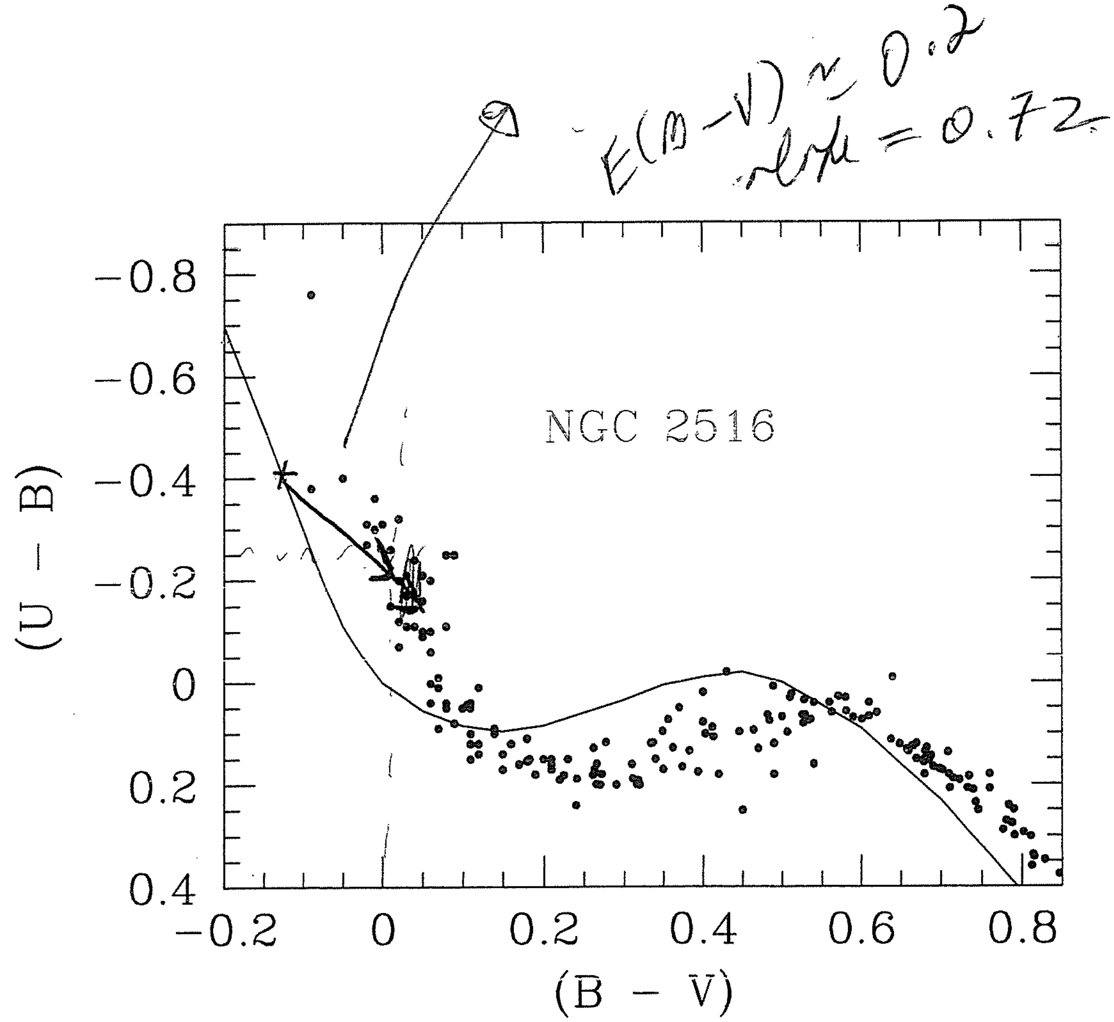


draw line slope 0.72

gives $E(B-V) \simeq 0.2$

$A_V = 3.1\ E(B-V)$

$A_V \simeq 0.62$ mag


E(B−V) ≈ 0.2
NGC 2516
(U − B)
(B − V)
−0.8
−0.6
−0.4
−0.2
0
0.2
0.4
−0.2
0
0.2
0.4
0.6
0.8