Astronomy 82 - Midterm #2 Name: IJC-TA

Spring 2008 Dr. Larkin

You have 50 minutes to complete the exam. You may only use a pencil and a calculator. No other outside assistance is allowed, although you may of course ask a question if you believe there is a mistake or if something is not clear. The exam has a total of 100 points. The following equations and constants may be helpful:

$c=2.998\times10^{8}$ m/s	$G=6.673\times10^{-11}$ m^{3}kg^{-1}s^{-2}	$h=6.6261\times10^{-34}$ J·s
$k=1.3807\times10^{-23}$ J/K	$m_e=9.1094\times10^{-31}$ kg	$m_p=1.6726\times10^{-27}$ kg
AU=1.496×10^{11}m	parsec=3.0857×10^{16}m	$M_{sun}=1.991\times10^{30}$ kg
$\sigma = 5.669\times10^{-8}$W/(s K^4)	amu = 1.6605×10^{-27} kg	$R_{sun}=6.96\times10^{8}$ m

$E = m c^2$ $F = -G M m / r^2$ $a = v^2 / r$

$L = A \sigma T^4$ $mag = -2.5 \log (flux)$ $P.E. = -(3/5) G M^2 / R$

$E = (3/2) k T$ $E = \frac{1}{2} m v^2$ $E = -G M m / r$

Short Problems (7 points each):

1. Why doesn't a statistical parallax measurement give an accurate distance for individual stars?

Statistical parallax uses angular measurements of many, associated stars over the course of many years — the sun's motion through space providies a longer baseline. Because other stars also move, though, you can't be sure how far away a single star is with this technique. Using many associated stars, though, the random velocities average out.

2. How do we define the color excess of a star due to dust extinction (words or equation)?

Color excess is caused mainly by dust in the interstellar medium, which absorbs some colors of light more easily than others. It is defined as:

Color excess $\equiv E_{B-V} = (B-V)_{observed} - (B-V)_{intrinsic}$

It is empirically related to observed extinction, A, by

$$\boxed{E_{B-V} \approx \frac{A}{3}}$$

3. How is the local standard of rest (LSR) defined?

The LSR is defined as the average motion of stars near the sun around the galaxy. The sun is not at rest in the LSR.

4. What two properties of spiral galaxies are used to determine distances in the Tully-Fischer relation?

The Tully-Fischer relation describes a correlation between the luminosity and the rotation speed of spiral galaxies. It is, roughly,

$$L \propto V_{rot}^{3.7}$$

5. Describe the Chandrasekhar limit. What is it caused by and what is its numerical value?

The Chandrasekhar limit is the maximum mass of a White Dwarf, equal to $\sim 1.4\ M_{\odot}$.

As the electrons in a W.D. are squeezed by higher and higher pressures, they each have less space to call their own – by the Heisenberg uncertainty principle, this means they start moving faster. However, they can never travel faster than the speed of light, so eventually they can't provide additional pressure for support.

6. Why are Type Ia supernovae considered good standard candles? How is it useful for determining distances?

Type Ia SN always occur from (nearly) the exact same initial conditions: a white dwarf just over the Chandrasekhar limit exploding as it undergoes degenerate fusion everywhere in the star at once. Thus, the same amount of energy is always released: if you see one, you know its intrinsic brightness — its absolute magnitude. Given an estimate of extinction, you can use its observed and absolute luminosities to calculate a distance.

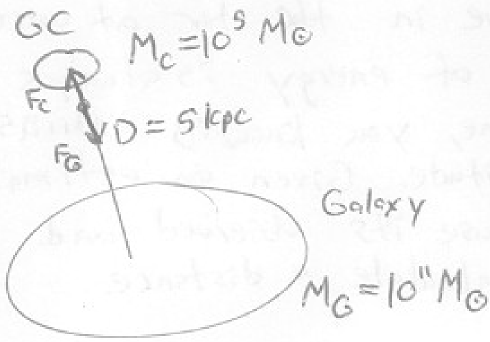
7. Can a type II supernova repeat? Why or why not?

No. A Type II SN is the collapse of ~~a~~ the iron core of a massive ($\gtrsim 8 M_\odot$) star, throwing off most of the mass and resulting in a neutron star or black hole. These remnants do not form Type II SN... thus Type II's cannot repeat.

Exercises (17 points each)

Complete all three of the exercises:

1. At what radius from a 10^5 M_{sun} globular cluster can stars be stripped by the host galaxy, which has a mass of 10^{11} M_{sun} and is separated by 5 kpc from the cluster? In other words, what is the tidal radius of the globular cluster?



The tidal radius is the point at which a star feels equally strong pulls from the cluster and the galaxy. You can use a star of mass M_* as a test mass, and say the forces are equal:

$$F_{cluster} = F_{galaxy}$$

Let R_T be the tidal radius.

$$\frac{\cancel{G} M_c \cancel{M_*}}{R_T^2} = \frac{\cancel{G} M_G \cancel{M_*}}{D^2}$$

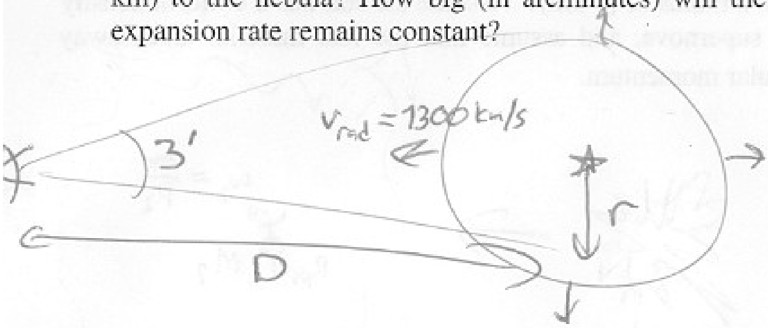
$$\frac{M_c}{R_T^2} = \frac{M_G}{D^2}$$

$$R_T^2 = \frac{M_c}{M_G} D^2 \Rightarrow \boxed{R_T = \sqrt{\frac{M_c}{M_G}}\, D}$$

$$= \sqrt{\frac{10^5}{10^{11}}}\,(5\text{ kpc}) = 5 \times 10^{-3}\text{ kpc}$$

$$= \boxed{5\text{ pc}}$$

2. The Crab supernovae exploded in 1054 and the remnant is now 3 arcminutes in diameter. If the expansion velocity is measured as 1300 km/s, what is the distance (in km) to the nebula? How big (in arcminutes) will the nebula be in 100 years if the expansion rate remains constant?



It exploded $(2008-1054) = 954$ years ago

It's radial expansion rate is 1300 km/s, and its angular radius is $1.5' = 90''$. Therefore,

$$\theta_r = \frac{r}{D} \Rightarrow D = \frac{r}{\theta_r}. \qquad r = (V_{rad})(t)$$

$$= (1300\,\text{km/s})(954\,\text{yr})(3.16\times10^7\,\text{s/yr})$$

$$= 3.92\times10^{13}\,\text{km} = 1.27\,\text{pc}$$

$$\text{so } D = \frac{1.27\,\text{pc}}{90''} \times \frac{206265''}{1\,\text{rad}} = 2910\,\text{pc}$$

$$\boxed{D = 3000\,\text{pc}}$$

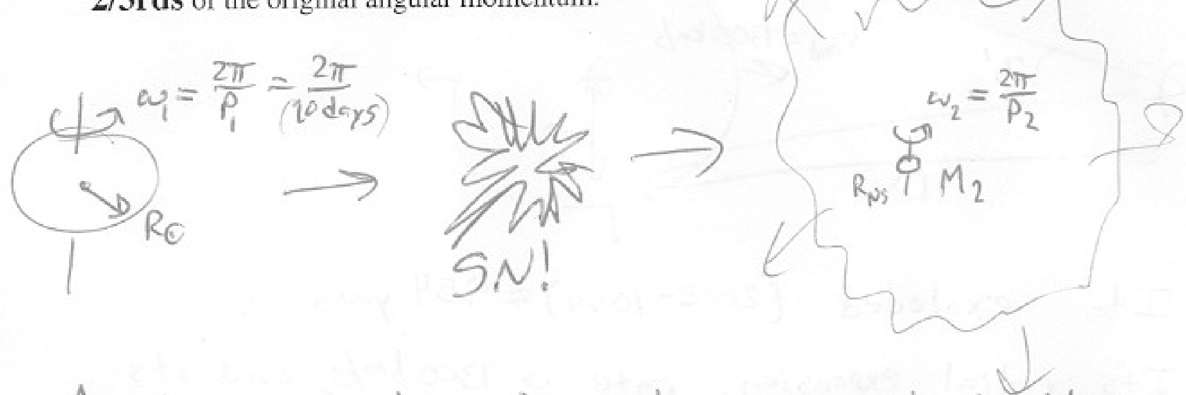
If the expansion remains constant, then the nebular size in 100 years will be

$$\theta_{neb,2108} = \left(\frac{1054\,\text{yrs}}{954\,\text{yrs}}\right)\theta_{neb,2008}$$

$$= \left(\frac{1054}{954}\right)(3')$$

$$= \boxed{3.3\text{ arcmin}}$$

3. A solar radius star (6.96 x 10^5 km) initially rotates with a period of 10 days. What is the rotation period if it loses half of its mass during a supernova event and the remnant becomes a neutron star with a radius of (7 km)? Assume the star has a uniform density both before and after the supernova, and assume that the lost material takes away **2/3rds** of the original angular momentum.



Angular momentum is not conserved in this problem – but we know how much is lost:

$$L_2 = \frac{1}{3} L_1$$

Generally, $L = I\omega$

For a constant-density sphere, $I = \frac{2}{5} M R^2$.

So, $\cancel{\frac{2}{5}} M_2 R_2^2 \omega_2 = \frac{1}{3} \cancel{\frac{2}{5}} M_1 R_1^2 \omega_1$ $\qquad M_2 = \frac{1}{2} M_1 \;;\; \omega = \frac{2\pi}{P}$

$$\frac{\cancel{M_1}}{2} R_2^2 \frac{\cancel{2\pi}}{P_2} = \frac{1}{3} \cancel{M_1} R_1^2 \frac{\cancel{2\pi}}{P_1}$$

$$\frac{R_2^2}{P_2} = \frac{2}{3} \frac{R_1^2}{P_1} \Rightarrow \boxed{P_2 = \frac{3}{2}\left(\frac{R_2}{R_1}\right)^2 P_1}$$

$$P_2 = 1.5 \left[\frac{6.96 \times 10^5 \text{ km}}{7 \text{ km}}\right]^{-2} (10 \text{ days}) = 1.5 (1.0 \times 10^{-5})^2 (10 \text{ days})$$

$$= (15 \text{ days}) \times 10^{-10} \times \left(\frac{86400 \text{ s}}{1 \text{ day}}\right) = 1.3 \times 10^{-4} \text{ sec}$$

$$\boxed{P_2 = 130\ \mu\text{sec}}$$