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Name: ....

ASTRONOMY 1102 – 1

Instructor: Juhan Frank

Third Test – Friday April 9, 1999

Part I – Multiple Choice questions (5 pts/question; total = 60 pts)
Identify the correct answers by placing a check between the brackets [ ]. Check **ALL** correct answers in the questions identified by a *.

*1) Some true statements about black holes:

[ ] They suck everything up from any distance. *only from very close*
[x] There is no return once the event horizon is crossed.
[ ] A BH of 10 $M_\odot$ is huge, bigger than the sun. $R_S = 30\ km$
[x] Some light can escape from anywhere outside the event horizon.
[x] The central singularity is invisible.

*2) A 35 $M_\odot$ star, after evolving away from the main sequence,

[x] becomes a red supergiant several times.
[x] may become a blue supergiant.
[ ] dies ejecting a planetary nebula.
[x] explodes as a type II supernova.
[ ] explodes as a type Ia supernova.

3) A white dwarf is

[ ] the endpoint of the evolution of massive stars (greater than 8 $M_\odot$).
[ ] supported by thermal pressure, with prominent hydrogen lines.
[x] supported by electron degeneracy, with no steady nuclear burning.
[ ] a large star with hydrogen shell burning.
[ ] produced only when stars less massive than the sun die.

4) Some main sequence stars are known as

[ ] white dwarfs.
[x] red dwarfs.
[ ] protostars.
[ ] black dwarfs.
[ ] brown dwarfs.

5) The generally accepted model for pulsar emission is based on a

[ ] rapidly spinning magnetic white dwarf.
[x] rapidly spinning magnetic neutron star.
[ ] rapidly spinning magnetic black hole.
[ ] close neutron star–neutron star binary.
[ ] close white dwarf–white dwarf binary.

6) The orbital period of a close compact binary gets shorter

[ ] because of the electromagnetic emission during spin down.
[x] because of the emission of gravitational waves.
[ ] because of the effects of Newtonian gravity.
[ ] due to effects in Special Relativity.
[ ] as the binary separation increases.

*7) Pulsars were *first* discovered

[x] by Jocelyn Bell and Anthony Hewish in Cambridge, England.
[ ] by Russell Hulse and Joseph Taylor from Arecibo.
[ ] by optical band observations.
[ ] by X-ray observations.
[x] by radio observations.

8) A Main sequence star of 3 $M_\odot$

[ ] burns hydrogen for a longer time than the sun. *burns faster!*
[x] dies ejecting a planetary nebula and becoming a carbon WD.
[ ] goes through the He flash at the tip of the RGB.
[ ] dies in a supernova explosion becoming a neutron star.
[ ] belongs to luminosity class I.

9) The Chandrasekhar mass is

[ ] the maximum mass possible for neutron stars ($3M_\odot$).
[ ] the maximum mass possible for white dwarfs ($3M_\odot$).
[x] the maximum mass possible for white dwarfs ($1.4M_\odot$).
[ ] the maximum mass possible for black holes ($3M_\odot$).
[ ] the minimum mass required to burn hydrogen on the main sequence. pulsars.

10) The following processes partake in the formation of a WD:

[x] CNO cycle. *for stars with* $M \gtrsim 1 M_\odot$
[x] p–p chain and He flash. *for stars with* $M \lesssim 1 M_\odot$
[ ] photodisintegration, neutronization and bounce.
[ ] alpha–process, s–process and r–process.
[ ] convection, conduction and radiation.

11) A carbon-Detonation Supernova (Type Ia) occurs when

[ ] the iron core collapses.
[x] a WD exceeds the Chandrasekhar Mass by accretion or merger.
[ ] hydrogen is exhausted in the core
[ ] the triple alpha process produces carbon
[ ] a star becomes a red giant.

12) One true statement about stellar evolution:

[ ] all stars, regardless of their mass, become red giants.
[ ] all stars when they die produce a WD.
[ ] stars with masses exceeding 8 $M_\odot$ produce always BH
[ ] nothing of interest happens after a WD is formed.
[x] some stars with masses $M < 8M_\odot$ experience the He flash.

Part II – Problems (10 pts/problem; total = 40 pts) **NO CALCULATORS!**

Problem 1: Describe the processes of photodisintegration, neutronization and bounce. What are they? Where do they occur and what is the outcome?

These three processes lead to the formation of a neutron star once a massive star has formed an iron core whose mass is close to or exceeds the Chandrasekhar limit. As no nuclear burning beyond the iron peak elements is possible (fusion beyond Fe uses energy rather than producing it), the core contracts and heats up in a vain attempt to stop gravitational collapse. As the temperature rises, the average photon reaches energies capable of splitting the nuclei present. So the nuclei that have been built up in the core are now disintegrated by absorbing energetic photons: this is "photodisintegration". Eventually all nuclei are split into protons and neutrons and all atoms are ionized so there is plenty of free electrons around. Now protons and electrons are combined to form neutrons in the process of "neutronization". Each of these steps actually tends to cool the core which contracts even more rapidly until the collapse is suddenly halted by the pressure of degenerate neutrons and a neutron star forms. The outer layers of the core now "bounce" and infall turns to outflow. A strong shoch propagates outward and eventually the rest of the envelope is expelled in a SN type II explosion.

Problem 2: Answer the following questions about **neutron stars:**

a) They are supported against their own gravity by the pressure of *degenerate neutrons.*

b) They have a radius of approximately *10 km.*

c) They are the endpoint of evolution of *massive main sequence stars* $8M_\odot < M < 50M_\odot$.

d) The maximum mass a NS can have is *approximately 3* $M_\odot$.

e) The envelope of the progenitor star is ejected as a *supernova remnant.*

$R_S = 3(M_{BH}/M_\odot)$ km, $1.585^2 = 2.512$ $1.585^3 = 4.$ $1.585^4 = 6.3$

$\lambda = cT$ $\lambda f = c$ $\frac{\Delta\lambda}{\lambda_{\rm emi}} = \frac{\lambda_{\rm obs}-\lambda_{\rm emi}}{\lambda_{\rm emi}} = \frac{v}{c}$ $\lambda_{\rm obs} = \lambda_{\rm emi} + \Delta\lambda$

1 pc = 3.26 LY $d(\text{pc}) = 1/p(\text{arcsec})$ $\lambda_{\rm max} \propto 1/T$ $E \propto T^4$ $Flux \propto 1/d^2$

$L \propto R^2T^4$ $\sqrt[5]{10} = 1.585$ $\sqrt[5]{100} = 2.512$ On the MS: $L \propto M^3$, $R \propto M$

Problem 3: Suppose that you are in a powerful rocket that allows you to go close to a black hole and remain there stationary without falling in. Let's suppose that your feet point in the direction toward the center of the BH ("below") so that "above" means overhead. You look at the black hole and you look at the starry sky. Where are you with respect to the event horizon and the photon radius if

a) the BH appears as a circle of total blackness ("below") and all the stars in the sky including those "behind" the BH are seen around you, some multiply imaged near the edge of the dark circle.

Since I see the event horizon as a circle rather than occupying the lower half of the sky, I must be outside the photon radius/sphere.

b) a flash light pointed at right angles to your body (90 degrees from the radial direction) would appear to come back behind your back.

That means that light sent along the apparent horizon will circle the black hole. Therefore we are at the photon sphere.

Problem 4: A SN of type Ia is seen in a distant galaxy at a peak magnitude of 19. Knowing that the absolute magnitude of this kind of SN peaks at $M = -19$, estimate the distance to the galaxy in Mpc.

The distance modulus is $m - M = 19 - (-19) = 17 + 19 = 38$. *Since* $36 = 35 + 3$, *the distance must be*

$$d = (1.585)^3 \times 10^{(35/5)} \times 10pc \approx 4 \times 10^8 pc.$$

Expressing d in Mpc,

$$d \approx 400Mpc.$$

${}_1H^1$							${}_2He^4$
${}_3Li^7$	${}_4Be^9$	${}_5B^{11}$	${}_6C^{12}$	${}_7N^{14}$	${}_8O^{16}$	${}_9F^{19}$	${}_{10}Ne^{20}$
${}_{11}Na^{23}$	${}_{12}Mg^{24}$	${}_{13}Al^{26}$	${}_{14}Si^{28}$	${}_{15}P^{31}$	${}_{16}S^{32}$	${}_{17}Cl^{35}$	${}_{18}Ar^{40}$