UNIVERSITY OF CAPE TOWN
EXAMINATION ANSWER BOOK

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(Fold over on dotted line and seal with stickers supplied.)

Surname (In block letters) Petersen

First Name(s) Bevan Uriel

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Student No. T 0 0 9 0 4 6 8

All answer books must be numbered

Number of books handed in	1
Number of this book	1

B	M					

Date 09 June 2025

Degree/Diploma/Certificate for which you are registered (e.g. BA BSc) Msc Astronomy

Course code and description (to be copied from the heading on the Examination Paper) Compact Binaries

Paper No (to be copied from the heading on the Examination Paper) 1

Venue: Astronomy Seminar Room

EVERY CANDIDATE MUST enter below the book number and the number of each question answered (in the order in which it has been answered); leave columns (3) and (4) blank.

1	2	3	4
Book Number	Question Number	Internal	External
	1	0	
	2	3	
	3	3	
		6	
Examiner's Initials		SBP	

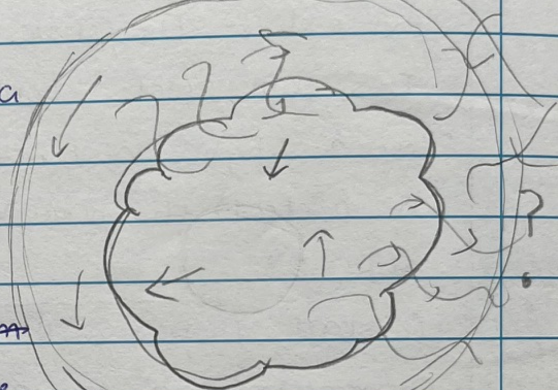
STUDENTS ARE TO READ THE IMPORTANT NOTES AND WARNINGS ON THE BACK COVER.

Any dishonesty will render the candidate liable to disqualification and to disciplinary action.

thin layer of Hydrogen covers a dense cloud of mass that photons can never reach. In fact the mean distance due to the hydrogen atoms can only true a few atoms before being emitted back out showcasing Hydrogen absorption points while radio waves can provide a beter way to reach the core beyond the boundary. X

0

(c) Describe how a corona forms in the case of an thin boundary layer, and explain how this can give rise to the siphon effect.



Thin boundary layers don't have a dense structure for gravity to condense it to a point. X
Thus ~~if the~~ over time the thin boundary layer can depart ~~from~~ ~~the~~ outwards, still keeping close to the dense core while spreading out into a halo / corona form around the denser substance at the centre. X

This corona can expand such that it may also capture stray photons, particles or clouds of gas. This may cause the corona to grow or even become like border to which stray particles will be attracted to.
The siphon effect is when the ~~outer layer~~ layer of particles start to move and develop an angular momentum that feeds on stray particles. For the corona to have an angular momentum, it has to come across stray particles feeding its angular momentum and will even strip gas from ~~ot~~ other coronas if the developed angular momentum is greater. X

0

(3)

3) (a) Describe the physical conditions and processes occuring in the boundary layer between a non-magnetic accreting primary and its surrounding accretion disk.

The faster and denser of materials ~~form~~ rotate closer to the primary. ✓ This makes the inner rings denser than the outer.

Particles are consistlingly getting excited and emitting photons making the particles move outwards towards the end of the disk. ✓

This will create light field of atoms that absorb and reemit light in quick succession ✓ blocking off (at least in spectral) ~~the~~ photons from reaching deeper ~~in the~~ into the disk.

Constant friction within the disks ~~angular~~ varying angular momentum can mean certain atoms will moving in

3 nearer ~~the~~ to the white dwarf, while some atoms are realeased ~~out~~ either outside star through the poles or particles into the accretion disk

(b) How does the spectral energy distribution differ between optically thick and optically thin boundary layers, and what observation evidence supports these distinction?

Optically thin boundary layers allow for light to reach to core of the entire cloud. ✗ Photons ~~and~~ being reflected and re-emitted showcasing a complex spectrum when analysed by our telescopes. ✗

For Optically thick boundary layers, only a ~~thin~~ light

3)

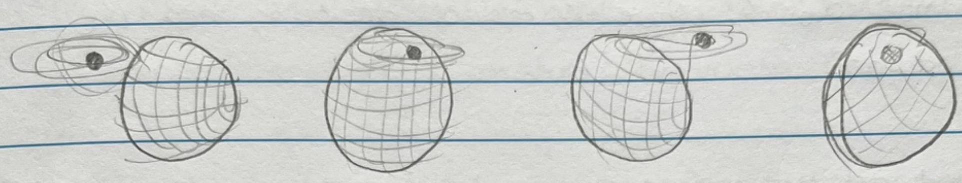
The outer layer of the red dwarf is less dense than the white dwarf, thus particles of that layer slowly move off ~~&~~ flowing into the Roche lobe. ~~into~~ It connecting ~~by~~ the hotspot forming ~~the~~ accretion disk around the white dwarf, where it resides accreting into the white dwarf.

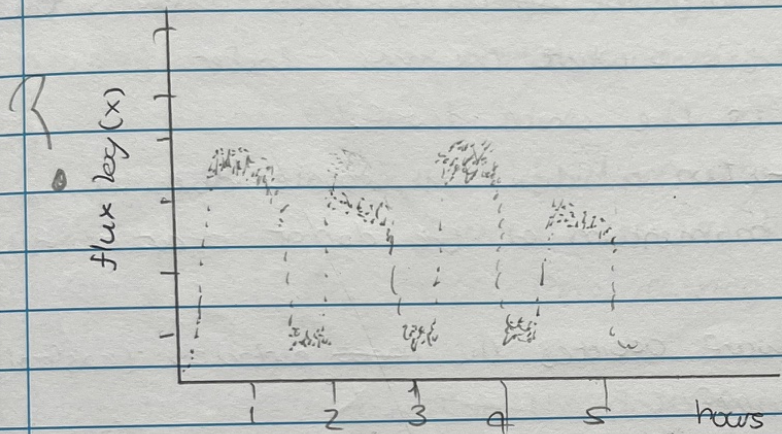
The Red dwarf has a face that ~~wet~~ always points towards the white dwarf and this is where the mass transfer is focused to move to the white dwarf.
Between the ~~white~~ two a disk will rotate due to the ~~mo~~ angular momentum of the donor star around the denser object.
Thus the white dwarf accretes the ~~mass~~ particles transfered from the Red dwarf.

1

3

(b) Using a labelled diagram, describe the orbital period distribution of cataclysmic variables. Identify and explain the key features of the distribution, and indicate the dominant mass transfer mechanisms in each region.

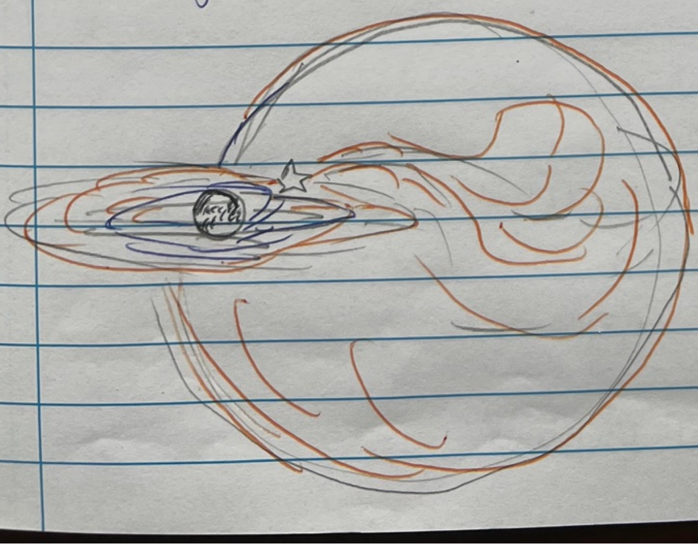


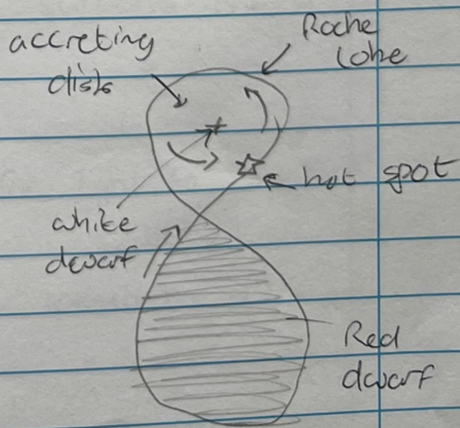


It is important to acknowledge how fast the orbital periods of a cataclysmic variables are.

Them being as short as minutes to the highest ranging periods of ~14 hours or longer depending on conditions of the stars. ~~whe~~ When in view the CV is the brightest part of system and is really only blocked during ~~equ~~ eclipses, when ~~the~~ eithor of the stars ~~bto~~ are infront obscuring the CV.

~~A~~ side profile is best for viewing the CV depending at what angle one is viewing at.





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2) (a) Explain how cataclysmic variable stars form and evolve over time, highlighting the physical ~~mech~~ mechanisms driving their development.

Most star form in binary or even trinary (3) systems ✓ where the co-evolve with each other.

The primary star is the white dwarf the denser, brighter and smaller in radius of the two. The secondary the ✓ red dwarf is the larger one with a surface that can and will transfer some of its material to the white dwarf.

They will circle around each other having the combined mass creating a gravitational "well" where mass can flow to one another.

This gravitional "well" is called the Roche lobe radius that mass will transfer between the two such that the mass of particles will form around the denser white dwarf.

The material will ~~accrete~~ ~~in~~ orbit around the white dwarf but will give out its own gravitational waves in the orbit of the two stars.

~~Certain~~ Some of the material ~~ma~~ will be faster near the primary star and form into a accretion disk expanding outwards, with slower particles being on the outer ring.

The point at which the material ~~bro~~ will flow into accretion disk will not be coming in the same direction ~~that~~ the ~~m~~ particles in the rings (causing friction) are moving causing a small hot spot that can be captured ~~in the~~ within the cataclysmic variable.

2

$$2K + U = E$$

~~$2\frac{M_2 G}{(R_2+a)^2} + 2$~~

$$2K = -U$$

$$M_2 V^2 = + \frac{M_1 G}{(R_2+a)^2}$$

$$(R_2 + a)^2 = \frac{M_1}{M_2} \cdot \frac{G}{V^2}$$

$$R_2 + a = \sqrt{\frac{1}{q} \frac{G}{V^2}}$$

$$R_2 = \sqrt{\frac{1}{q} \frac{G}{V^2}} + a$$

when: $q < 1, \frac{5}{6}$, the larger the Roche lobe radius of secondry can be.

(b) List and briefly describe the key astrophysical mechanisms by which a cataclysmic variable binary may lose angular momentum.

During mass transfer the accreting disk formed around the white dwarf will have ~~or~~ a variable angular momentum depending on how far the molecules /atoms are away from the star.

The particles will move inwards and outwards due the release of photons into the nearest ~~disk~~ part of accreting disk. X

This means that particles will loose angular ~~momen~~ momentum due to excitation and absorbtion slowing down or speeding up within the accreting disk.

0

Overtime enough of the particles will form around the white dwarf and be ~~orb~~ absorbed in the magnetic poles of the stars to emitted leaving a less dense accreting disk.

(c) Given that the Roche lobe radius of the secondary can be approximated by $R_2 \sim a\{q(1+q)\}^{1/3}$ where $q = M_2/M_1$ demonstrate that under conservative mass transfer, the Roche Lobe of the secondary star increases in size if $q \leq 5/6$

if $q < 5/6$ $M_1 > M_2$

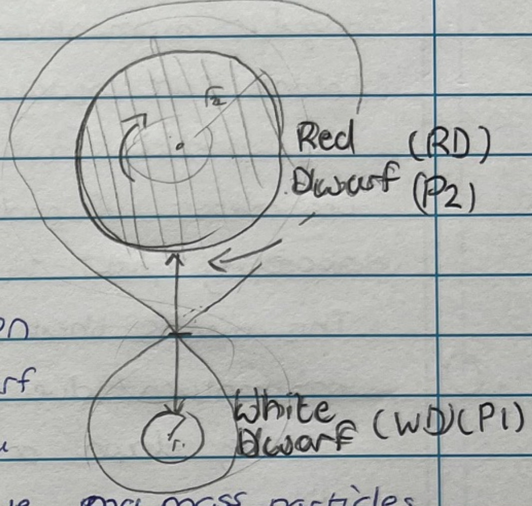
$$R_2 \sim a\{q/(1+q)\}^{1/3}$$

$$\frac{M_1 M_2 G}{(R_2 + a)^2} = F$$

$$\frac{M_1 G}{(R_2 + a)^2} = \frac{F}{M_2}$$

1) (a) By considering the total angular momentum of a binary, and using $P_{\{orb\}}^2 = 4\pi^2 a^3 / G(M_1 + M_2)$

show that, for conservative mass transfer can only occur when $M_2 < M_1$ if there is angular momentum loss from the system.



$$K + U = E$$

$$\sout{K} = -U$$

$$= \frac{\sout{Pm_1}}{r}$$

In a compact binary, the common ~~cat exam~~ case is of ~~t~~ a white dwarf and red dwarf ~~as~~ locked into a rotating ~~ob~~ orbit that would have ~~mat~~ mass particles moving from the red dwarf to the white dwarf.

red dwarf mass $= M_2$

white dwarf mass $= M_1$

$$K + U$$

$$\frac{1}{2}M_2V^2 \pm M_1\frac{V^2}{a}2\pi = 0$$

$$\int \frac{GM_1M_2}{a^2} = F$$

$$\frac{1}{2}M_2V^2 = M_1\frac{V^3}{a}2\pi$$

angular momentum $\left(\frac{V^2}{a}\right) = \frac{GM_2}{4\pi M_1}$

When angular momentum is lost, the Red dwarf is locked into the orbit ~~a~~ having to realease a greater mass transfer in ~~witch~~ ~~wich~~ which to have the binary system to ~~to~~ function and continue rotating.