UNIVERSITY OF CAPE TOWN
EXAMINATION ANSWER BOOK

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

FOLD

Surname (In block letters): Martin

First Name(s): Aidan

Student No. MRTAID003

All answer books must be numbered

Number of books handed in	1
Number of this book	1

1	8	1	9	4	6	1

Date: 09/06/2025

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

Course code and description: ~~NAAS~~ NASSP Masters
(to be copied from the heading on the Examination Paper)

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

Venue: Ast Seminar

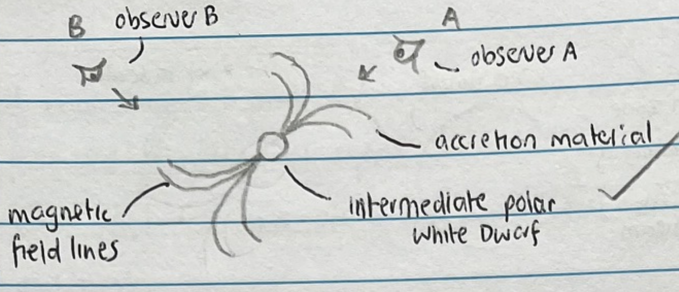
EVERY CANDIDATE MUST enter below the book number and the number of each question answered (in the order in which it has been answered); leave columns (3) and (4) blank.

1	2	3	4
Book Number	Question Number	Internal	External
	2	18	
	4	14	
	5	14	
		46	
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.

5b.



The accretion curtain model is a model used to explain the changes is X-ray luminosity that is observed for polars and intermediate polars (IPs). When observing, an IP will spin on its axis, providing different views of it depending on when it is observed.

In the sketch above, observer A will see little X-ray emission, as the accreting material obscures vision of the accretion zone where most of the X-ray emission comes from, and the other pole of the IP is completely blocked from line of sight as its on the other side of the WD.

5

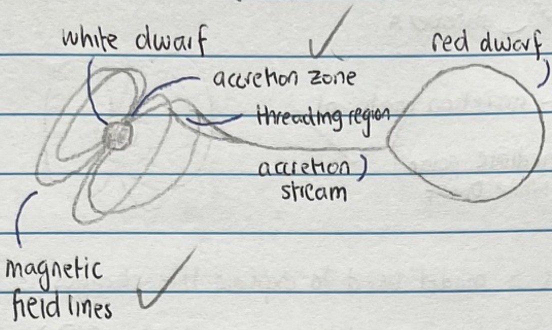
After the WD spins half a cycle, observer B will see the WD from another angle. Here both poles are visible, and this view is not blocked by the accretion stream of material, so the accretion zone can be seen w/ x-ray emission high, from both poles.

Fourier analysis can be used to detect periodicities by finding dominant frequencies (and therefore periods) and analyzing these to determine which are harmonics and which are orbital, beat, and WD spin periods.

14

Q5

5a.



A polar consists of a WD and red dwarf in standard CV configuration, but the WD has a sizable magnetic field. ~~if the~~ This causes two regions, a region that acts like a normal CV, where the magnetic field has little effect due to fall off at large radii, and a region in which the magnetic field is dominant, the magnetosphere. When the accretion stream from the red dwarf reaches the magnetosphere, the strength of the field stops a disc from forming, instead causing the accreting matter to follow the magnetic field lines. These B-field lines move material to the pole (magnetic pole) of the WD, to a threading region where all of the B-field lines grow close enough to allow the accreting material to combine. This can be in the form of diffuse material or 'blobs' of material. The material is led to the accretion zone, where the material interacts and is accreted to the WD.

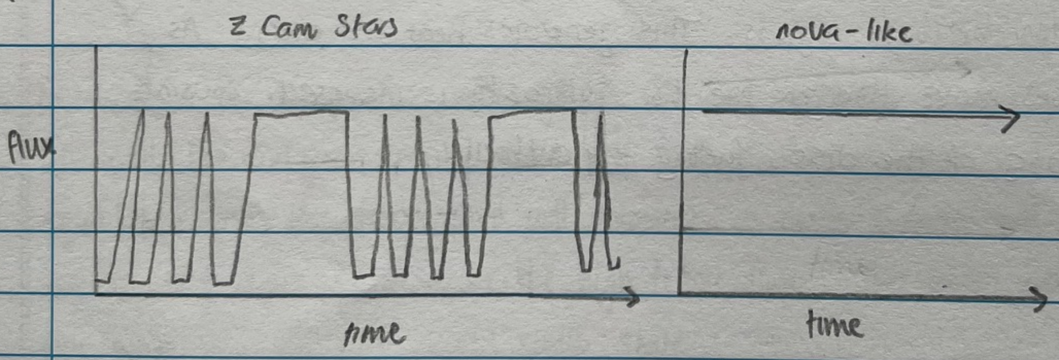
9

Diffuse material is heated, spreading and causing the formation of an accretion column due to the shocks created as material near free-falls onto the WD. The 'blobs' of non-diffuse material is able to ignore the shocks, and fall into the WD itself, and be consumed. The diffuse material is seen as hard X-ray emission, while the non-diffuse blobs are ~~emitted~~ radiated as blackbody radiation in the X-ray regime, specifically the soft-x-rays.

4c Z Cam stars are ~~stars~~ CVs with periods of ~~outburst~~ successive outburst followed by a period of ~~supero~~ sustained outburst. Nova-like CVs are CVs that live in a state of permanent superoutburst, a sustained outburst. ✓

Nova-likes are believed to maintain this permanent outburst mode by remaining in an ionized state, the C region in the diagram from Q4a. ✓ Z Cam stars extended outbursts start from a normal outburst, but are maintained for longer. This could be due to a build-up of material in the disc that is never fully released by a standard outburst. When this build-up becomes too high, a regular outburst is sustained, until the build-up is used up. ✓ The following outburst then starts another build-up of material gradually, until eventually another superoutburst occurs after many normal outbursts, and the cycle repeats. ✓

4



(14)

Heating waves spread through the disc during outburst from the region they were triggered. Viscosity increases as this wave move along the disc, until the disc is fully ionized. This is unless the heating wave does not have enough energy and is met with a cooling wave ~~pre~~ early. There are inside-out waves that start near the inner region of the disc, causing shorter outbursts, and outside-in heating waves that start near the outer region of the disc, causing longer outbursts. This is because the heating wave can propogate more easily when moving inward due to it following the flow of material and not losing to outward carrying angular momentum.

Cooling waves stop the heating waves, ending the outbursts. These propogate from the outside-in, and can end outbursts early if the heating wave does not make it to the end of the outer disc.

Viscosity is important as disc have Keplerian orbits, so the material in the inner disc moves faster in orbit than outer disc material, which causes a lot of friction between regions. This generates heat and energy. As heating waves move through the disc, viscosity is increased, causing more heating of the disc, fuelling the outburst.

10

4b.

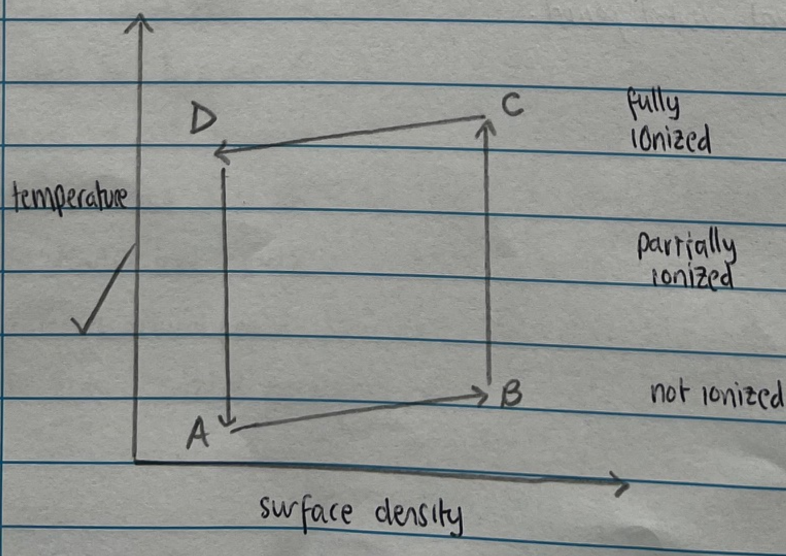
0

Q4

4a The dwarf nova begins in a quiescent, cool state, with low surface density. ~~Its surface density increases~~ as the WD is accreted onto, ~~as~~ more matter is fed to the disc, causing a build-up of matter gradually, and therefore the surface density. This is when the accretion rate onto the WD is less than the rate at which the red dwarf is losing mass. With an increase in surface density, the temperature gradually increases.

The temperature increase continues until matter becomes partially ionized. Any further matter being accreted simply increases the temperature even more, ~~until~~ causing a dramatic increase in temperature, until the matter is fully ionized. At this point, a new equilibrium is reached, where the outburst has peaked, and will remain in outburst until the equilibrium is lost. The matter being fed to the disc is ionized and the temperature is stable due to the inflow of material, and viscosity being high.

Eventually, the temperature will begin to cool, as the material is accreted to the WD and the surface density decreases. At a point, the ~~system~~ disc will lose equilibrium, and the temperature will plummet, as matter becomes ~~not~~ no longer ionized and unable to maintain the high temperatures. This causes the disc to return to its quiescent, cool, stable state.



At an orbital period of ~3 hours, there is a drop in the numbers of CVs. This is due to magnetic braking and gravitational waves. At Porb ~ 3 hours, the red dwarf has become a bit unstable. Mass loss due to mass transfer means that there is less pressure on the core, and less nuclear reactions, so the red dwarf collapses a bit due to gravity. Because of this, the magnetic braking switches off.

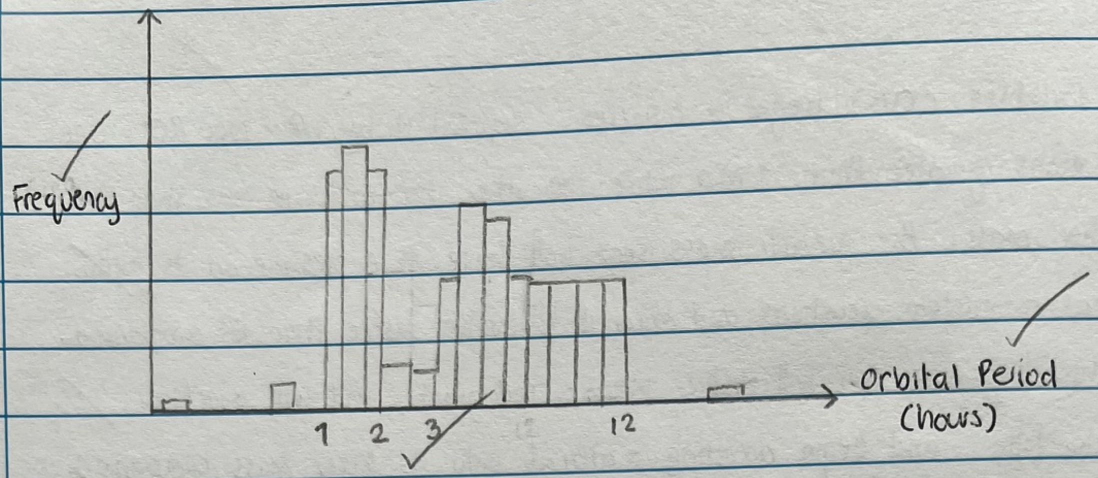
Magnetic braking is a process by which electrons are sped up due to being forced to corotate with magnetic fields, and are eventually expelled, taking angular momentum and energy with them.

Eventually, gravitational waves takes over at Porb ~ 2 hours, where energy is lost due to gravitational ~~pulsations~~ warping caused by the rhythmic orbit of the binary sending out gravitational pulsations in the form of waves.

Inbetween ~2-3 hours orbital period, the red dwarf detaches from its Roche lobe, meaning mass transfer does not kick in until gravitational ~~waves do~~. pulsations do. This means emission from the system is negligable, as a lot of light comes from mass transfer, so the systems are hard to detect.

9 There are some systems that are found in the region of ~2-3 hours orbital period, which is those systems that began in that period range when they first became CVs, ie. it is their natural orbital period.

26.



The figure above is a rough approximation of the orbital period distribution of CVs.

Above ~12 hour orbital periods there is a distinct drop-off due to the mass limitations. White dwarfs (WDs) have a mass limit of ~1.4 M⊙ due to the Chandrasekhar limit, and because WDs are the more massive stars in the binary, the red dwarfs can not be ~~larger than~~ more massive than ~1.4M⊙ either. The orbital period is determined by the distance between the stars, but to have a larger binary seperation, the stars need to be more massive, specifically the red dwarf. This is because if the binary separation is too large, the red dwarf will detach from its Roche lobe, meaning mass transfer will not occur, until the separation decreases. The only way to allow mass transfer would be if the red dwarf was more massive, but that is limited by the Chandrasekhar limit. Therefore, the mass of the red dwarf being limited stops the orbital period from growing past ~12 hours.

Below P_{orb} ~ 78 minutes there is another drop-off. At this orbital period, the red dwarf has become degenerate just like the WD, which means that if it loses mass, it will grow in radius, whereas if it were not degenerate, mass loss would cause it to shrink in size. With the increase in radius, it detaches from its Roche lobe, stopping mass transfer, and increasing binary separation which increases orbital period. This means that when the binary reconnects, it will evolve to higher orbital periods.

Q2

2a Cataclysmic Variables (CVs) begin a binaries, separated by $R \sim 1000 R_\odot$. One star has a mass greater than $1 M_\odot$ while the other has a lower mass than that. Given its higher mass, the greater mass star will have more pressure on its core, which will increase nuclear reactions and allow it to evolve faster than its companion. Eventually, this high mass star will evolve into a red giant, and will overflow, filling its Roche lobe, and begin accreting material onto its lower mass companion. The centre of mass of the system is closer to the more massive star, so when it accretes matter onto the lower mass star, the matter is moving away from the centre of mass. To conserve angular momentum, the separation of the two stars decreases, which in turn decreases the Roche lobe of the massive star. This creates a feedback loop, where the more massive star's Roche lobe is filled, it accretes mass onto the lower mass star, so the binary separation decreases, decreasing the more massive star's Roche lobe, which causes it to accrete onto the companion, and the cycle repeats. Eventually, the lower mass star can no longer take the mass from its companion as it fills its Roche-lobe. Now both stars have filled Roche-lobes, and have reduced their separation to $\sim 1 R_\odot$. With both Roche-lobes filled, the binary enters a 'common envelope' phase, where the mass of the stars that has overflown creates an envelope surrounding both stars. The envelope is eventually expelled as the binary rotates, spiralling inward and acting as a propeller to disperse the envelope, leaving just the binary, now consisting of a white dwarf and a larger, less massive red dwarf.

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