Astronomy 241 Problem Set #10

Due 29 April 2024, in Box

Please submit your work in PDF form, for which the filename includes your name(s) and the number of the assignment, e.g. payne_hw1_solo.pdf or baade-zwicky_hw2_team.pdf.

If it's being submitted for a regrade, prepend Regrade_ to the file name.

All team problems. Team **Clotho** is Joey, Lara, Rianna and Waly. Team **Lachesis** is Angel, Ethan, Conor and Nora. Team **Atropos** is Amii, Annie, Avi and Rafe.

DQ Herculis is a close white dwarf – main-sequence binary, with mass transferred from the latter to the former mainly via an accretion disk. It was a bright, V = 1.5 mag, nova (1934) whose appearance and media coverage is thought by some literary critics to have influenced the writing of Superman (1938), specifically infant Superman's escape from Krypton shortly before its host star exploded.

Nova Herculis 1934 was a classical nova: thought to have been produced by thermonuclear explosion of a white-dwarf atmosphere. Since then DQ Her has been a mere intermediate polar.

DQ Her is an eclipsing system, so its kinematic properties are well determined, while its photometric properties must be selected for avoidance of the eclipse. Here are the measurements (AAVSO, Schaefer 2020, Harrison+2013, Zhang+1995, Patterson 1994, Horne+1993):

Distance d	386^{+33}_{-29} pc	
Orbital period P	$0.1936208977 \pm 0.0000000017$ day	
Stellar distance a	$(1.41 \pm 0.05) R_\odot$	
Luminosity L, extinction corrected	$4.7 \times 10^4 L_\odot$	at peak during 1934-1935 outburst
	$0.204 L_\odot$	recent out-of-eclipse average
	$0.017 L_\odot$	recent eclipse-minimum average
Primary, DBe white dwarf	$M_1 = (0.60 \pm 0.07) M_\odot$	
	$m_B = 1.9 \times 10^{32}$ gauss cm^3	
Secondary, Pop I M2.5V star	$M_2 = (0.4 \pm 0.05) M_\odot$	

X. Calculate the distances between each star and the inner Lagrange point, ℓ_1 and ℓ_2.

Y. Use your white-dwarf code, from homework 9, to calculate the primary's radius, R_1.

Z. i. To good approximation: neglect emission from the stars; and assume the disk to be magnetically truncated, so that it lacks a boundary layer on its inner rim. As usual, assume the disk to be opaque. Then show that the system luminosity L is

$$L = \frac{3}{2} G M_1 \dot{M} \left(\frac{1}{r_{\rm in}} - \frac{1}{r_{\rm out}} \right) \quad ,$$

where $$r_{\rm out} = a\left[\frac{1}{2} - 0.227 \log\left(\frac{M_2}{M_1}\right)\right] \quad \text{and} \quad r_{\rm in} = \frac{1}{2}\left(\frac{m_B^4}{2GM_1\dot{M}^2}\right)^{1/7} \quad .$$

ii. Make another approximation, and solve for the the mass accretion rate $\dot{M}$. Calculate $\dot{M}$, expressing your result in $M_{\odot}$ year^{-1}.

iii. Why are all the suggested approximations good ones?

Γ. Take the accretion disk's viscosity parameter to be $\alpha = 0.2$.

i. Obtain formulas for temperature, pressure scale height, and surface density, $T(r)$, $H(r)$, and $\Sigma(r)$, as functions of *r*.

ii. Plot $T(r)$, $H(r)$, and $\Sigma(r)$ as functions of *r*.

iii. Calculate the disk's total mass, M_{disk}, in solar units. If the secondary stopped supplying mass, about how long would the disk last?