Problem Set 4

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Due at start of lecture (11 am) on Wednesday Dec 4, 2019.

This problem set is based on the relativistic white-dwarf binary system we encountered in Problem Set 1, ZTF J1539+5027 (hereafter J1539). The system is described in a paper by Burdge et al. (2019), accessible on the arXiv (a pre-print server) at https://arxiv.org/pdf/1907.11291.pdf. As usual, points will be awarded for explanations of your reasoning as well as the numerical answers.

Question 1. The primary (more massive) star in the system has a surface temperature of 50,000 K, and an apparent g-band magnitude of 20.38.

(a) (2 points) The equivalent width of the interstellar Na I D_2 absorption line in the spectrum of J1539 is 0.2 Angstrom. Using the results presented in https://arxiv.org/pdf/1503.02697.pdf, and assuming that the V and g bands have the same effective wavelengths, estimate the g-band extinction in magnitudes.

(b) (3 points) Accounting for this extinction, and assuming an effective wavelength of 4770 Angstrom for the g-band, calculate the distance to J1539. Explain any differences between your estimate and the Burdge et al. estimate of 2.34 kpc.

Question 2. (8 points) Using the NED coordinate converter, derive the Galactic sky-coordinates of J1537 from the equatorial coordinates RA 15:39:32.16, DEC +50:27:38.8. Assuming a distance to the system of 2.34 kpc, and a distance between the Earth and the Galactic Center of 8.4 kpc, calculate the distance between J1539 and the Galactic Center. Roughly estimate the acceleration of the acceleration of J1539 in the Galactic potential, assuming a spherical shape for the Milky Way. What is the apparent rate of change (due to the Doppler effect) of the binary orbital period (which is $P = 6.9\,\mathrm{min}$) because of this acceleration, in units of seconds per second?

How does your answer compare with the rate of change of the orbital period due to gravitational-wave emission reported by Burdge et al.?

Question 3. (7 points) Let J1539 have a proper motion on the sky of μ, in units of radians per second. Show that this results in an apparent rate of change of the binary orbital period of

$$\dot{P} \approx \frac{\mu^2 D P}{c}, \tag{1}$$

where D is the distance to J1539. This is known as the Shklovskii effect. For the observed proper motion of J1539 of 5.1 milliarcseconds per year, and assuming $D = 2.34\,\mathrm{kpc}$, estimate the magnitude of the Shklovskii effect for J1539.

How does your answer compare with the rate of change of the orbital period due to gravitational-wave emission reported by Burdge et al.?

Question 4. (≥ 3 points) Estimate the size of the Stromgren sphere surrounding J1539, accounting only for radiation from the primary star, and assuming standard diffuse-ISM conditions. Discuss the observability of this Stromgren sphere.