Stellar Astronomy and Astrophysics (SS11)

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Exercise 5

1. Period-Luminosity relation for Cepheids

In the lecture we derived

1. the period-density relation $P \propto \rho^{-1/2}$,
2. A Mass-Luminosity relation $L \propto M^{\alpha}$,
3. and have shown that the instability strip for pulsation is restricted to a narrow strip of almost constant T_{eff} in the HRD.

a) If we assume that for Cepheids $\alpha = 4$ (a somewhat higher value than for main-sequence stars), show that a period-luminosity relation ($\log L$ vs. $\log P$ exists. Hint: Use Stefan-Boltzmann's law.

b) Assume that the instability strip is not at $T_{\text{eff}} = $ const. but more accurately given by $\log L = \beta \log T_{\text{eff}} + \delta$. How does the period-luminosity function look like in this case?

c) Is this relation sufficient to determine the distance of a Cepheid from measuring its period and an apparent magnitude?

2. Cepheids in M100

Several remote classical Cepheids were discoved in 1994 by the Hubble Space Telescope in M100, which is a member of the Virgo cluster. The Fig. 2 from a paper by Freedman et al. (1994) shows the period-luminosity releation for these Cepheids. Use the two Cepheids nearst the figure's best-fit line in the upper panel (for the V magnitude) to estimate the distance to M100. Use the period-luminosity relation

$$M_V = -2.81 \log_{10} P_d - 1.43, \qquad (1)$$

where M_V is the average absolute V magnitude and P_d is the pulsation period in units of days. The mean visual extinction is $A_V = 0.15 \pm 0.17$ magnitudes for the M100 Cepheids. Compare your result to the distance of 17.1 ± 1.8 Mpc obtained by Freedman et al. (1994).

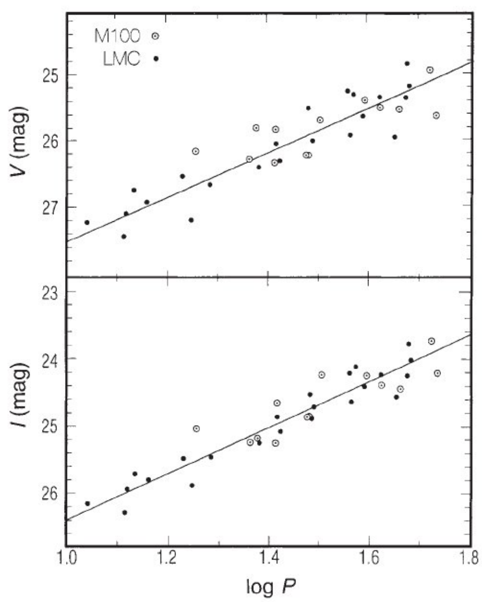

FIG. 2 Composite period-luminosity relations (V-band upper panel; I-band lower panel) for Cepheids in M100 (white circles) and Cepheids in the LMC (black circles, shifted to the distance of M100). Apparent V and I distance moduli for M100 are obtained by minimizing the residuals in the combined P–L relations for the two galaxies, and determining the relative offset with respect to the calibrating LMC sample. Consistent with previous studies[3,20], only high signal-to-noise variables (those having an average of their absolute deviations from the mean exceeding 1.5 times the mean error) are plotted, whereas only stars with $\log P < 1.8$ are included in the fit. The difference in the V and I apparent moduli for M100 is assumed to be due to interstellar dust present both in M100 and our own galaxy. Correcting for this effect yields a reddening-corrected (true) distance to M100 of 17.1 ± 1.8 Mpc.

3. The Helium Main Sequence

Similar to the "normal" main sequence, defined for stars consisting mostly of hydrogen and generating energy through hydrogen fusion, a "helium" main sequence can be theoretically defined, for stars consisting purely of helium and generating energy through helium fusion.

a) Where in the HRD would you expect, qualitatively, the location of the He-MS as compared to the H-MS?

b) If the stellar core could be regarded as a star by itself, in which evolutionary phase might it fall on the He-MS or close to it?

c) Regarding now the star as a whole, what could happen to it that would bring it very close to the He-MS? Try to think of two different processes that could, theoretically, lead to such a state. How (un)likely are these processes in reality, in your opinion?