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The Effect of Proper Motion on $\dot{P}$ in Pulsating Stars

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Abstract. We show that the proper motion of a pulsating star results in a secular increase of the radial velocity of the star and consequently contributes to the observed $\dot{P}$. We found that this mechanism is very important in studying period changes in pulsating DA white dwarfs, where its effect is comparable with the expected evolutionary period change in these stars due to their cooling.

While a pulsating star is travelling in space, the variation of its line-of-sight position causes the Doppler shift of arrival of the pulsation's maxima, by changing the travel time of light between the star and the observer. The observed period $P_{\rm obs}$ of the star is coupled to the period P in the star's rest frame by the formula:

$$P_{\rm obs} = P(1 + v_{\rm r}/c) \tag{1}$$

Differentiating eq.(1), under assumption that the total relative velocity of the star is constant we obtain:

$$\dot{P}_{\rm obs} = \dot{P}(1 + v_{\rm r}/c) + P\dot{v}_{\rm r}/c \simeq \dot{P} + Pv_{\rm t}^2/(cr) \tag{2}$$

The first term in eq. (2) describes the rate of pulsation period change intrinsic to the star, while the second ("proper motion") term ($\dot{P}_{\rm pm}$) results from the spatial motion of the star. Note that always $\dot{P}_{\rm pm} \geq 0$, independently of the direction of motion of the star.

The discussed mechanism was originally proposed by Shklovskii (1970) in his study of period behaviour of high-velocity pulsars. To say something about the significance of the proper motion term for other groups of pulsators, let us rewrite the proper motion term in a form more useful for direct applications:

$$\dot{P}_{\rm pm} = 1.081 \cdot 10^{-19} P[{\rm s}](v_{\rm t}[{\rm km/s}])^2(r[{\rm pc}])^{-1} \tag{3}$$

and let us consider the following cases:

- white dwarf pulsators (DAV, DBV and DOV)

  For the DAVs the expected evolutionary values of $\dot{P}$ for g-modes range from $10^{-14}{\rm ss}^{-1}$ to $10^{-15}{\rm ss}^{-1}$ (Bradley et al. 1992). The observed rate of a secular period increase for the dominant pulsation mode in DA white dwarf G117-B15A was recently reported by (Kepler 1993); the obtained value $3.2 \cdot 10^{-15}{\rm ss}^{-1}$ is completely consistent with the value expected for

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secular evolution. The expected values of $\dot{P}$ for DAV stars are the lowest among all pulsating white dwarfs – for DB pulsators they are one order and for DOVs several orders of magnitude higher. Making assumption, that for white dwarfs the distance $r \simeq 50$pc, $v_t \simeq 50$km/s (Lang 1992), $P \simeq 500$ s we can roughly estimate the proper motion term: $\dot{P}_{pm} \simeq 3 \cdot 10^{-15}$ss^{-1}. We can see that the proper motion term can be very significant in the case of DAV's and can contribute to the observed value as much as the expected evolutionary term, so its effect should be subtracted from the observed period derivative for a proper evaluation of $\dot{P}$ – see Pajdosz (1995).

- δ Sct, roAp and β Cep stars

  The stellar evolution calculations yield the expected values of rates of pulsation period changes of the order of 10^{-11}ss^{-1} for δ Sct variables, while the observed values are still one or two orders higher (Breger 1990). For roAp stars the predicted values are 10^{-12}–10^{-13}ss^{-1} (Heller & Kawaler 1988), but they have not been confirmed observationally yet (Kurtz 1993). $O-C$ diagrams for β Cep stars were studied recently by Pigulski (1992). He estimated the evolutionary rates of period increase to be 10^{-10}–10^{-11}ss^{-1} in good accordance with theoretical predictions.

  We put these three groups of variables together, because their kinematical characteristics are similar; these stars are characterized by low relative space velocities (Harwit 1988). Assuming, that $r > 50$pc, $v_t \simeq 20$km/s, $P \simeq 10000$ s we get $\dot{P}_{pm} < 10^{-14}$ss^{-1}. We can see that the proper motion term is several orders of magnitude too small to be important.

- other pulsators

  For stars which do not fall into the first two categories even if we assume their velocities to be extremely high ($v_t \simeq 200$km/s), a distance greater than 50pc, pulsation period below half a day we obtain that the $\dot{P}_{pm}$ should not be higher than $4 \cdot 10^{-12}$ss^{-1}.

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