Of Variability, or its Absence, in HgMn Stars

Sylvain Turcotte  
*Lawrence Livermore National Laboratory, L-413, P.O. Box 808, Livermore, CA 94551, USA*

Olivier Richard  
*Département de physique, Université de Montréal, Succ. Centre-Ville, Montréal, Québec, Canada*

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**Abstract.** Current models and observations of variability in HgMn stars disagree. We present here the models that argue for pulsating HgMn stars with properties similar to those of Slowly Pulsating B Stars. The lack of observed variable HgMn stars suggests that some physical process is missing from the models. Some possibilities are discussed.

**Keywords:** abundance anomalies, pulsations

1. Introduction

HgMn stars are late B type stars featuring large and varied abundance anomalies. They are slowly rotating, non-magnetic and mostly young stars and are thought to be the purest examples of stars undergoing microscopic diffusion without the complications posed by mixing processes in cooler stars with convective upper layers (Vauclair & Vauclair, 1982). From a pulsation point of view they are as of yet entirely constant with a maximum photometric variability estimated at less than 5 mmag (Adelman, 1998). There has only been a few studies of spectral variability in HgMn stars leading to suggestions of some variability in Hg lines (Adelman et al., 2002). There are no serious suggestions of pulsations in line profile variations at this time (see e.g. Turcotte et al. in these proceedings). There have been claims of rotational variability linked to possible magnetic fields or abundance spots (Adelman et al., 2002).

HgMn stars share a part of the HR diagram in which pulsating stars are present as shown in Fig. 1. Those stars, the Slowly Pulsating B stars (SPBs), are in many ways similar to HgMn stars, many seem to be slowly rotating, but differ in that they are chemically normal. In addition, there is a theoretical expectation that pulsations should be driven in HgMn stars at least as much as those in SPBs, suggesting that detailed studies of the stability of HgMn stars, both observationally...
Figure 1. HR Diagram showing some HgMn stars (asterisks), some SPB stars (open circles), and the theoretical limit of the SPB instability region (Pamyatnykh, 1999). The evolutionary tracks for models of 3 and 4 M_☉ are shown and the location of the model which will be discussed here is indicated by the filled circle.

and theoretically, is likely to yield new information on the structure and dynamics of B stars.

2. Theoretical Expectations

Sophisticated models of diffusion in stars can now be made for cool B stars following the work of (Richer et al., 2000) and (Richard et al., 2001). In those papers, it has been demonstrated that diffusion in A and B stars can lead to a substantial increase in opacity in the region where heavy elements contribute the most to it, at a temperature around 200,000 K. In some cases, when metals are allowed to accumulate enough, a convection zone can form in that region. It is also the same region in which pulsations in B stars (both SPBs and hotter β Cephei stars) are driven (Pamyatnykh, 1999).

The increase in opacity in the model with diffusion is illustrated on the left-hand side of Fig. 2 and the resulting changes in the integrand to the work integral is shown on the right-hand side. Though the opacity differs in both models throughout the upper envelope, the work integral for this and other high order g-modes depends very little on the regions cooler log T < 5.0. This may imply that these modes may not be damped efficiently at low temperature that will be discussed in the next section.

Adding mixing to prevent the formation of abundance stratification in the models, would ensure that solar metallicities would be retained
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Figure 2. The left-hand side shows the logarithm of the Rosseland opacity with respect to temperature. The solid line is for a 4 M\(_\odot\) model at 100 Myr with diffusion while the dotted curve is a similar model with practically no diffusion. The right-hand side shows the integrand of the work integral for the same models for a \(\ell = 1, n = 26\) gravity mode. Pressure modes and low order radial modes are damped while high order gravity modes are excited. In this case both the mode is overstable in both models but with a slightly larger growth rate in the model with diffusion.

and one would therefore expect driving as it occurs in SPB stars leading to a normal fraction of variable HgMn stars, i.e. roughly 50% of HgMn stars in the instability region would be variable with amplitudes of approximately 10 mmag.

3. Reconciling the Models with the Observations

As the models are contradicted by observations in B stars it is obvious that some additional physical process or processes need to be included in the models either to reduce the metallicity in the driving region or to increase damping elsewhere.

It is fair to ask if the models with diffusion are representative of HgMn stars. In fact they do not reproduce the surface anomalies of typical HgMn stars very well. The models require that the entire upper envelope, from the iron convection zone to the photosphere, be mixed to avoid numerical problems. This is unlikely to the case in real stars. The very large and very varied anomalies found in HgMn stars most likely show that diffusion occurs in the atmosphere. In fact, it this difficult to argue that surface abundances tell us much about the internal composition of HgMn stars. It is therefore unlikely that the abundance profiles in our models reproduce well those in real HgMn stars. As a result the opacity profile can also be expected to be different.
Models with varying homogeneous chemical abundances in the superficial mixed zone have been examined to infer the effect of abundance variations in possibly damping pulsations. No hints that it may be case has been found but a more detailed analysis is needed to rule out this possibility.

Mass loss could also be invoked to explain the differences between SPBs and HgMn stars. Mass loss can remove surface abundance anomalies and after some time could possibly empty the reservoir of iron-peak elements in the driving region for pulsations. It would require a fine tuning of the mass loss rate to remove chemical anomalies in SPB stars in a short time scale (while remaining unobserved), and a metallic mass loss (Babel, 1996) fast enough in some elements to lower the opacity in the driving region, and slow enough for other elements so they can accumulate in the atmosphere.

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