The pulsational stability of models of normal and metallic-line A stars

John R. Percy  David Dunlap Observatory and Erindale College,
Department of Astronomy, University of Toronto, Toronto, Ontario, Canada M5S 1A7

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Summary. A grid of models of A and F stars of population I has been constructed. These models have been tested for stability against radial pulsations, using the linear, non-adiabatic approach. Radiation pressure was included throughout, and opacity quadratically interpolated from tables. The results are compared with observations of δ Scuti pulsating stars, and the agreement is quite satisfactory. Models of a metallic-line (Am) star have also been constructed, under the hypothesis that the Am phenomenon is the result of diffusive element separation (Vauclair, Vauclair & Pamiatnykh). These models have also been tested for stability against radial pulsations. The initial (homogeneous) model was unstable, but after 10⁶ yr the model becomes stable, due to the diffusion of helium from the envelope of the star. This result is consistent with the observed pulsational stability of Am stars.

1 Introduction

Among the A and F stars near the main sequence there are several interesting subgroups of stars. To begin with, the Cepheid instability strip crosses the main sequence between A5 and F2, and 30 per cent of the stars in this range pulsate as δ Scuti stars with $\Delta m \geq 0.01\,\text{mag}$ (Baglin et al. 1973). A second group of pulsating variables – the dwarf Cepheids – inhabits this same region of the H–R diagram, but Breger (1976) and others believe that most dwarf Cepheids are simply large-amplitude δ Scuti stars.

Two groups of stars with apparent abundance anomalies are also found in this part of the H–R diagram. From A4 to F1, at least 30 per cent of main sequence stars are metallic-line (Am) stars; their frequency is at least 50 per cent at A7 (Smith 1971a). From B8 to F1, at least 10 per cent of all main sequence stars are peculiar (Ap) stars. At about F1, there is a transition from radiative envelopes to convective envelopes, and from fast rotation to slow rotation; it is probable that these four phenomena: pulsation, apparent abundance anomalies, envelope structure and rotation are related in an intimate and complex way.

For example, Breger (1970) has found that not one Am star between A5 and F2 pulsates with $\Delta m \geq 0.01\,\text{mag}$, whereas 30 per cent of normal stars in this range pulsate. Although some specific exceptions to this exclusion have been proposed, they have in each case been
rejected (Kurtz et al. 1976). There is also some evidence that among Ap stars, pulsation is rare and/or of low amplitude (Percy 1975a).

The exclusion between pulsation and the Am phenomenon must surely result from an interference between the mechanism which causes the pulsation and the mechanism which causes the Am phenomenon. The cause of pulsation is well understood (see Cox 1974 for instance): it is the destabilizing effect of the ionization zones of hydrogen and helium. The cause of the Am phenomenon is believed to be element separation by diffusion in the stellar envelope (Watson 1970; Smith 1971b), a mechanism which was first proposed by Michaud (1970) in connection with the Ap stars. According to this hypothesis, upward radiative pressure is not, for a given element, exactly balanced by downward gravitational force, and diffusion — upwards or downwards — gradually occurs. Vauclair et al. (1974) have shown that helium, for instance, gradually diffuses downwards, depleting the envelope of the star. In fact, Smith (1974) has found helium to be deficient in two hot Am stars. Pulsation and the Am phenomenon may therefore be mutually exclusive because diffusion, by depleting the helium, would reduce the destabilizing effect of the helium ionization zones, while pulsation, by generating turbulence in the envelope, would prevent diffusion (hence the Am phenomenon) from occurring. Both these possibilities have been discussed qualitatively by others; in fact, Pamjatnykh (1975) has made some calculations regarding the first possibility, but no details of these calculations have been given. Vauclair (1976) has recently published an extensive and illuminating discussion of this whole problem.

The purpose of the present paper is two-fold: to compare the pulsation properties of the observed δ Scuti stars with the pulsation properties of models of normal A stars and to investigate the pulsational stability of models of Am stars, assuming these to be stars in which diffusion has taken place.

The study of δ Scuti stars is facilitated by the fact that they are bright and numerous. A few δ Scuti stars have complex light curves, containing several distinct pulsation modes; however, most have light curves in which the variation is small (typically 0.03 mag) and

![Figure 1. Hertzsprung–Russell diagram, showing the location of most of the known δ Scuti stars, as determined by uvby′ photometry. The assignment of the pulsation mode (shown) is done on the basis of the observed Q value. The theoretical blue edges for fundamental (F), first harmonic (1H) and second harmonic (2H) radial pulsation are taken from the models described in this paper.](https://academic.oup.com/mnras/article-abstract/181/3/563/988701)
sinusoidal; non-linear effects are not likely to be important. Their absolute magnitudes ($M_V$) and effective temperatures ($T_e$) can be obtained with good accuracy from a calibration of the $uvby$ photometric system. Breger & Bregman (1975) have derived $M_V$ and $T_e$ for most of the $\delta$ Scuti stars, and have then used the observed periods to determine $Q = P(\delta\beta_0)^{1/2}$. These values were then compared with theoretical $Q$ values (Petersen & Jorgensen 1972) for the fundamental (F), first overtone (1H) and second overtone (2H) radial modes; the stars are then assigned to the pulsation mode for which the observed and theoretical $Q$ values agree most closely. The results of their analysis are shown in Fig. 1. In this H–R diagram, the error bars indicate the estimated uncertainty in $M_V$ and log $T_e$, although the presence of an unseen binary companion could cause a systematic error larger than this. Also, the assigned pulsation mode may be in error if the period is in error; in some of these stars, the variation is exceedingly complex. This analysis assumes that the $\delta$ Scuti stars are pulsating in a radial mode. Although there is evidence for non-radial pulsation in one or two $\delta$ Scuti stars, radial pulsation is capable of explaining the variability of all of the others.

Fig. 1 shows that the instability strip is sharply bounded on the cool side, apparently because of the dominant role of convection in the envelopes of cooler stars (Deupree 1977). Stars cooler than 7600 K tend to pulsate in the F mode, stars hotter than 7600 K tend to pulse in the 1H or 2H mode, and stars hotter than about 8500 K do not pulsate at all. The position of this observed ‘blue edge’ at 8500 K depends rather critically on the status of the two hottest $\delta$ Scuti stars: 97 Psc and Trumpler 410 in the Pleiades. The distribution of fundamental and overtone pulsators is similar to that in the RR Lyr stars, except that no known RR Lyr star pulsates purely in the 2H mode.

Some studies of the pulsation properties of model $\delta$ Scuti stars have already been made. Petersen & Jorgensen (1972) have studied adiabatic periods and period ratios. Chevalier (1971) was the first to construct a realistic model of a $\delta$ Scuti star and to show that it was unstable against radial pulsation, although Baker had apparently carried out similar calculations previously, but had never published them. Cox, King & Tabor (1973) constructed some models of $\delta$ Scuti stars as part of a general survey of the population I and II instability strips. Pamjatnykh (1975) has also described some interesting analyses of models of normal and metallic-line A stars, although the details of the calculations and results are not given. Stellingwerf has carried out an extensive survey of models of $\delta$ Scuti stars, using both a linear and a non-linear approach; a summary of the results was presented at the AAS–ERDA conference at Los Alamos (Stellingwerf 1976).

2 Model construction and stability analysis

For the first part of this study, an extensive grid of models was constructed, with hydrogen content $X = 0.70$ and 0.75, metal content $Z = 0.02$, log gravity $= 3.6$ and 4.1 and other parameters as listed in Table 1. The chemical composition, masses and luminosities are consistent with the population I nature of the $\delta$ Scuti stars. The boundary temperature and pressure were interpolated from a grid of model atmospheres as described by Percy (1975b), hereafter Paper I. The stability analysis was carried out using the linear, non-adiabatic approach, as described in Paper I. The radiative opacity was interpolated (linearly in log density, quadratically in log temperature) from tables given by Cox & Stewart (1970), and radiation pressure was included in both the model construction and the stability analysis. It turns out (see Section 4 of this paper) that a careful treatment of both the opacity and the radiation pressure is necessary for the accurate determination of the growth rates.

For the second part of this study, we adapted the results of Vaquero et al. (1974), who have constructed ‘evolutionary’ models of an Am star with the properties $M = 1.5 M_\odot$, $L = 1.4 L_\odot$. $\omega$,
Table 1. Linear, non-adiabatic stability analyses of models of normal A and F type stars.

<table>
<thead>
<tr>
<th>log $\mu$</th>
<th>log $R$</th>
<th>log $L$</th>
<th>$M_{\text{bol}}$</th>
<th>log $T_e$</th>
<th>log $g$</th>
<th>F</th>
<th>1H</th>
<th>2H</th>
<th>$\eta$ (F)</th>
<th>$\eta$ (1H)</th>
<th>$\eta$ (2H)</th>
</tr>
</thead>
<tbody>
<tr>
<td>33.493</td>
<td>11.109</td>
<td>34.518</td>
<td>2.452</td>
<td>3.862</td>
<td>4.1</td>
<td>0.0659</td>
<td>0.0495</td>
<td>0.0399</td>
<td>+0.18E-5</td>
<td>+0.24E-4</td>
<td>+0.11E-3</td>
</tr>
<tr>
<td>33.512</td>
<td>11.118</td>
<td>34.604</td>
<td>2.237</td>
<td>3.879</td>
<td>4.1</td>
<td>0.0664</td>
<td>0.0499</td>
<td>0.0401</td>
<td>+0.20E-5</td>
<td>+0.28E-4</td>
<td>+0.14E-3</td>
</tr>
<tr>
<td>33.530</td>
<td>11.126</td>
<td>34.690</td>
<td>2.023</td>
<td>3.896</td>
<td>4.1</td>
<td>0.0669</td>
<td>0.0502</td>
<td>0.0404</td>
<td>+0.27E-5</td>
<td>+0.35E-4</td>
<td>+0.18E-3</td>
</tr>
<tr>
<td>33.539</td>
<td>11.130</td>
<td>34.733</td>
<td>1.915</td>
<td>3.905</td>
<td>4.1</td>
<td>0.0671</td>
<td>0.0503</td>
<td>0.0404</td>
<td>+0.24E-5</td>
<td>+0.37E-4</td>
<td>+0.20E-3</td>
</tr>
<tr>
<td>33.548</td>
<td>11.135</td>
<td>34.776</td>
<td>1.808</td>
<td>3.913</td>
<td>4.1</td>
<td>0.0676</td>
<td>0.0506</td>
<td>0.0407</td>
<td>-0.67E-6</td>
<td>+0.55E-5</td>
<td>+0.83E-4</td>
</tr>
<tr>
<td>33.557</td>
<td>11.140</td>
<td>34.819</td>
<td>1.700</td>
<td>3.922</td>
<td>4.1</td>
<td>0.0681</td>
<td>0.0509</td>
<td>0.0410</td>
<td>-0.25E-5</td>
<td>-0.20E-4</td>
<td>-0.39E-4</td>
</tr>
<tr>
<td>33.566</td>
<td>11.144</td>
<td>34.862</td>
<td>1.593</td>
<td>3.930</td>
<td>4.1</td>
<td>0.0683</td>
<td>0.0511</td>
<td>0.0410</td>
<td>-0.38E-5</td>
<td>-0.40E-4</td>
<td>-0.14E-3</td>
</tr>
<tr>
<td>33.582</td>
<td>11.403</td>
<td>34.971</td>
<td>1.320</td>
<td>3.828</td>
<td>3.6</td>
<td>0.167</td>
<td>0.128</td>
<td>0.102</td>
<td>+0.17E-4</td>
<td>+0.17E-3</td>
<td>+0.76E-3</td>
</tr>
<tr>
<td>33.618</td>
<td>11.421</td>
<td>35.143</td>
<td>0.890</td>
<td>3.862</td>
<td>3.6</td>
<td>0.170</td>
<td>0.130</td>
<td>0.104</td>
<td>+0.93E-5</td>
<td>+0.17E-3</td>
<td>+0.11E-2</td>
</tr>
<tr>
<td>33.627</td>
<td>11.425</td>
<td>35.186</td>
<td>0.782</td>
<td>3.871</td>
<td>3.6</td>
<td>0.171</td>
<td>0.130</td>
<td>0.104</td>
<td>+0.26E-4</td>
<td>+0.27E-3</td>
<td>+0.15E-2</td>
</tr>
<tr>
<td>33.636</td>
<td>11.430</td>
<td>35.229</td>
<td>0.675</td>
<td>3.879</td>
<td>3.6</td>
<td>0.172</td>
<td>0.131</td>
<td>0.105</td>
<td>+0.25E-4</td>
<td>+0.27E-3</td>
<td>+0.15E-2</td>
</tr>
<tr>
<td>33.645</td>
<td>11.435</td>
<td>35.272</td>
<td>0.568</td>
<td>3.887</td>
<td>3.6</td>
<td>0.173</td>
<td>0.132</td>
<td>0.106</td>
<td>+0.20E-4</td>
<td>+0.24E-3</td>
<td>+0.14E-2</td>
</tr>
<tr>
<td>33.654</td>
<td>11.439</td>
<td>35.315</td>
<td>0.460</td>
<td>3.896</td>
<td>3.6</td>
<td>0.174</td>
<td>0.132</td>
<td>0.106</td>
<td>-0.51E-4</td>
<td>-0.43E-3</td>
<td>-0.14E-2</td>
</tr>
<tr>
<td>33.663</td>
<td>11.444</td>
<td>35.358</td>
<td>0.353</td>
<td>3.904</td>
<td>3.6</td>
<td>0.175</td>
<td>0.133</td>
<td>0.107</td>
<td>-0.62E-4</td>
<td>-0.54E-3</td>
<td>-0.19E-2</td>
</tr>
<tr>
<td>33.672</td>
<td>11.448</td>
<td>35.401</td>
<td>0.245</td>
<td>3.913</td>
<td>3.6</td>
<td>0.175</td>
<td>0.134</td>
<td>0.107</td>
<td>-0.62E-4</td>
<td>-0.53E-3</td>
<td>-0.19E-2</td>
</tr>
</tbody>
</table>
Table 2. Effects of hydrogen content.

<table>
<thead>
<tr>
<th>( M_{\text{bol}} )</th>
<th>( \log T_e )</th>
<th>( \log g )</th>
<th>( \eta (F) )</th>
<th>( \eta (1H) )</th>
<th>( \eta (2H) )</th>
<th>( \eta (F) )</th>
<th>( \eta (1H) )</th>
<th>( \eta (2H) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.915</td>
<td>3.905</td>
<td>4.1</td>
<td>+0.24E-5</td>
<td>+0.37E-4</td>
<td>+0.20E-3</td>
<td>+0.26E-5</td>
<td>+0.42E-4</td>
<td>+0.23E-3</td>
</tr>
<tr>
<td>1.808</td>
<td>3.913</td>
<td>4.1</td>
<td>-0.67E-6</td>
<td>+0.55E-5</td>
<td>+0.83E-4</td>
<td>-0.95E-6</td>
<td>+0.51E-5</td>
<td>+0.95E-4</td>
</tr>
<tr>
<td>1.700</td>
<td>3.922</td>
<td>4.1</td>
<td>-0.25E-5</td>
<td>-0.20E-4</td>
<td>-0.39E-4</td>
<td>-0.32E-5</td>
<td>-0.26E-4</td>
<td>-0.54E-4</td>
</tr>
<tr>
<td>1.593</td>
<td>3.930</td>
<td>4.1</td>
<td>-0.38E-5</td>
<td>-0.40E-4</td>
<td>-0.14E-3</td>
<td>-0.48E-5</td>
<td>-0.50E-4</td>
<td>-0.17E-3</td>
</tr>
</tbody>
</table>

Figure 2. Growth rates for F, 1H and 2H radial pulsation, as a function of \( \log \text{effective temperature} \), for models of normal A stars with \( X = 0.70 \), \( Z = 0.02 \) and population I masses. The growth rate is the fractional change in pulsation energy per cycle.

\( \log T_e = 3.886 \) and \( M_{\text{bol}} = 2.836 \). In these models, they have determined the element separation which occurs due to the diffusion processes. In particular, they have determined helium abundance profiles in the envelope of the star at various times \((0-2 \times 10^6 \text{ yr})\) after diffusion begins. These profiles are shown in their Fig. 4.

In the present paper, models of an Am star were constructed with the same parameters and the same helium abundance profiles given by Vauclair et al. (1974). These models were then analysed for stability against radial pulsation using the linear, non-adiabatic approach described in Paper I.
Most of the calculations were made at the Institute of Astronomy, University of Cambridge; some were subsequently refined at the University of Toronto. A summary of the results and their implications has been presented at the AAS–ERDA conference (Percy 1976).

3 Results

3.1 Models of normal A stars

The properties of the static models and the results of the stability analyses are presented in Tables 1 and 2, and the growth rates \( \eta \) for the F, 1H and 2H modes are shown in Fig. 2. The growth rates are the fractional changes in pulsation energy, per cycle. The blue edges have been determined from Fig. 2 and plotted along with the observational data in Fig. 1. (A change in \( X \) from 0.70 to 0.75 has only a small effect on the position of the blue edges.) Between the F blue edge and the F red edge, the models are unstable in the F, 1H and 2H modes. Between the 1H and F blue edges, the models are unstable in the 1H and 2H modes. Between the 2H and 1H blue edges, the models are unstable in the 2H mode only. The stability in higher modes than 2H has not been studied here. Cox et al. (1973), Pamjatnykh (1975) and Stellingwerf (1976) found instability to some higher modes immediately to the left of the 2H blue edge, but pure high-mode instability is not apparent among the observed \( \delta \) Scuti stars (Breger & Bregman 1975).

3.2 Models of AM stars

The growth rates \( \eta \) for the F, 1H and 2H modes are presented in Table 3 and shown in Fig. 3. The growth rates are of the order of \( 10^2 \text{yr} \), which is much less than the diffusion time-

![Figure 3](https://example.com/image3.png)

Figure 3. Growth rates for F, 1H and 2H radial pulsation, for an `evolutionary' sequence of models of a 1.5 \( M_\odot \) star, with \( T_e = 7700 \text{ K} \), in which diffusive element separation is occurring (Vauclair et al. 1974).
Table 3. Pulsational stability of models of metallic-line stars: (\( M = 1.5 M_\odot \)), \( M_{\text{bol}} = +2.88 \), \( \log T_e = 3.887 \), \( X = 0.70 \), \( Z = 0.02 \).

<table>
<thead>
<tr>
<th>Model</th>
<th>Age (10^5 yr)</th>
<th>Surface helium</th>
<th>( \eta (F) )</th>
<th>Growth rates</th>
<th>( \eta (2H) )</th>
<th>*Contributions to ( \eta (F) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.28</td>
<td>(+ 0.450 \times 10^{-4})</td>
<td>(+ 1.311 \times 10^{-5})</td>
<td>(+ 0.420 \times 10^{-4})</td>
<td>(0.17 \times 10^{-5}) 0.04 \times 10^{-5}</td>
</tr>
<tr>
<td>2</td>
<td>0.32</td>
<td>0.24</td>
<td>(+ 0.331)</td>
<td>(+ 0.962)</td>
<td>(+ 0.597)</td>
<td>0.16 0.04</td>
</tr>
<tr>
<td>3</td>
<td>0.63</td>
<td>0.20</td>
<td>(+ 0.125)</td>
<td>(+ 0.502)</td>
<td>(+ 0.255)</td>
<td>0.15 0.03</td>
</tr>
<tr>
<td>4</td>
<td>0.95</td>
<td>0.17</td>
<td>(+ 0.035)</td>
<td>(+ 0.141)</td>
<td>(+ 0.201)</td>
<td>0.14 0.03</td>
</tr>
<tr>
<td>5</td>
<td>1.27</td>
<td>0.14</td>
<td>(- 0.465)</td>
<td>(- 0.437)</td>
<td>(- 0.175)</td>
<td>0.12 0.01</td>
</tr>
<tr>
<td>6</td>
<td>1.59</td>
<td>0.11</td>
<td>(- 0.565)</td>
<td>(- 0.716)</td>
<td>(- 0.380)</td>
<td>0.11 0.01</td>
</tr>
<tr>
<td>7</td>
<td>2.22</td>
<td>0.00</td>
<td>(- 0.516)</td>
<td>(- 0.525)</td>
<td>(- 0.162)</td>
<td>0.09 0.02</td>
</tr>
<tr>
<td>8</td>
<td>3.7</td>
<td>0.00</td>
<td>(- 0.788)</td>
<td>(- 0.944)</td>
<td>(- 0.430)</td>
<td>0.06 0.02</td>
</tr>
</tbody>
</table>

*The portions of the star below the He II ionization zone produce a stabilizing contribution of \(0.17 \times 10^{-5}\).*
scale \((10^6 \text{yr})\) or the evolutionary timescale \((10^9 \text{yr})\) for an A star. The contributions to the growth rate from the second ionization zone of helium (He II) and from the first ionization zones of hydrogen and helium (H I, He I) are also given. The periods were the same for each model, namely, 0.0413, 0.0309 and 0.0251 day; thus \(P(1H)/P(F) = 0.75\) and \(P(2H)/P(1H) = 0.81\), in agreement with earlier calculations for models of normal A stars.

The 'zero-age' (homogeneous) model is unstable against pulsation in the F, 1H and 2H radial modes, as would be expected from the results for the models of normal A stars. After about \(10^6 \text{yr}\) of diffusion, the model becomes stable against pulsation in all three radial modes. The last two columns in Table 3 show the cause of this stabilization: the effects of the He I and He II ionization zones decrease rapidly as helium is depleted from the envelope of the star; the small increase in the effect of the H I ionization zone is not enough to compensate.

4 Discussion

4.1 Normal A Stars

The pattern of stability as a function of decreasing \(T_e\) (stable \(\rightarrow\) 2H \(\rightarrow\) 1H \(\rightarrow\) F \(\rightarrow\) stable) has been extensively discussed and explained in connection with Cepheids and RR Lyr stars (Cox 1974), and will not be discussed further here. Also, the comparison between theoretical and observed periods and period ratios has been extensively discussed elsewhere (see Petersen & Jorgensen 1972 for instance); in fact, the assignment of the pulsation modes in Fig. 1 has already been done by such a comparison.

The blue edges determined in this paper are in reasonable agreement with those already published. They differ on the average by 0.005 in \(\log T_e\) from those of Cox et al. (1973), Pamiatnykh (1975) and Stellingwerf (1976) except for the F blue edge, which is consistently hotter by 0.020 in this study. The reason probably lies in the fact that all of the other studies either neglected radiation pressure or calculated opacity from a formula (rather than tables) or both. Iben (1971) has shown that each of these factors can reduce the log \(T_e\) of the blue edge by 0.010 to 0.015.

The blue edges also agree very well with the observational blue edges, considering the errors in the points of Fig. 1, \(\pm 1000 \text{K}\) in \(T_e\), \(\pm 0.2\) in \(M_e\). This scatter would cause a slight 'spillover' from the true instability strip into the surrounding stable region.

Two stars lie significantly to the left of the theoretical blue edges: HD9100 (97 Psc) and HD23643 (Trumpler 410 in the Pleiades). It is entirely possible that, in each case, the \(\delta\) Scuti star is the cooler component of a spectroscopic binary. HD23643 is considered to be a double-lined spectroscopic binary by Christie & Wilson (1938), and Abt et al. (1965) find a velocity range of 37 km/s. There is also some evidence for velocity variations in HD9100 according to Harper (1937).

The limitations of the linear, non-adiabatic method must be stressed at this point. It is not possible to determine the amplitude of pulsation by this method; therefore it is not possible to determine which mode is dominant in a star which is unstable to two or more modes. A non-linear method is required for this purpose. However, the initial-value approach to the non-linear method is not practical if \(\eta\) is very small, and even the elegant relaxation method of Stellingwerf (1976) seems to break down in the case of the \(\delta\) Scuti stars. We conclude that, although the general features of the pulsation of \(\delta\) Scuti stars have been reproduced and explained in this study, the details of amplitude and mode behaviour have yet to be explained.
4.2 Metallic-line A stars

Previous calculations (Vauclair et al. 1974) have shown that, in the absence of mixing, diffusive element separation \textit{must} occur in a 1.5 $\odot$ star, and does so on a timescale of about $10^6$ yr. According to Table 3 and Fig. 3, this diffusion will cause an otherwise unstable star to become stable against pulsation, because of the depletion of helium from the envelope of the star. At the same time, the diffusion causes the Am phenomenon to occur, because of the separation of the heavy elements in the envelope of the star (Watson 1970; Smith 1971b). Thus, no Am star (older than $10^6$ yr) should pulsate; this is what is observed. A more precise version of this statement requires that we know how much diffusion is required to cause \textit{observable} metallicity.

An immediate question concerns the relative timescales of evolution, of diffusion and of the growth of pulsation. If the growth time is less than the diffusion time, how does diffusion ever occur? This question is discussed in some detail by Vauclair (1976, 1977), and will not be readdressed here.

There are several other interesting questions which might be discussed at this point: the cause of the pulsational stability of the non-variable non-Am A stars, the relationship between pulsational stability, pulsation amplitude and rotation, for example. However, in view of the excellent discussion by Vauclair (1976) and in view of the limitations of the observational data, these questions will also not be pursued here.

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