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**MASTER**

TITLE DELTA SCUTI VARIABLES,
Lecture 6

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AUTHOR(S) A. N. Cox, T-6

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Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

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# DELTA SCUTI VARIABLES

We now come to a class of variables near or on the upper main sequence that are reasonably well understood. The δ Scuti variables have been known since 1900 when Wright (1900) at high spectral dispersion discovered that the radial velocity of δ Scuti was variable. Colacevich (1935) observed radial velocities of this star in the 1930's and Fath (1935) made photometric observations simultaneously to show that there were indeed pulsations. Other early discoveries were made by Walker (1953) for DQ Cep and by Lindblad and Eggen (1953) for CC And. It seems that any star of spectral type between A2V and F1V on the main sequence and between A5III and F8III in the giant region can pulsate in this class. Thus there are many of these stars known. Breger (1979) lists 129 of them in his rather comprehensive review article. While these stars are cool enough to be driven into pulsation by hydrogen and helium ionization and their cyclical variations, the interesting thing is that not all the stars in the instability strip actually are observed varying. There seem to be no exceptions for the yellow giants, such as the Cepheids, the RR Lyrae and the BL Her variables, but like the B stars, pulsation of the stars in the δ Scuti instability strip does not always seem to occur.

These stars appear in many ways like the population II horizontal branch RR Lyrae stars, with shorter periods. Many papers such as ones by Fitch (1955) for VZ Cnc and even as recently as Fitch (1967), discussing CC And and the β Cephei variable σ Sco, and Fitch and Szeidl (1976) in analyzing AC And, have considered at least the longer period ones to be RR Lyrae variables. With the construction of evolution tracks, however, and the clarification of the horizontal branch stars by Iben (1967), it became apparent that our variables are on the first crossing of the Hertzsprung gap. They occur all the way from the main sequence to the Cepheid region, but in the Cepheid region they evolve so fast on this first crossing, they are hard to discover. The only one I know in the Cepheid brightness range is AC And, but of course, perhaps some of the Cepheids themselves are first crossing stars and therefore really δ Scuti variables.

Eggen (1956) suggested that there was a real difference between the low amplitude δ Scuti variables and those with higher amplitudes, which until recently have been called the RRs stars. Many have questioned this distinction because they all have spectral types A or F and their periods range from 0.02 to 0.3 day. Breger (1979) strongly proposes that they all be called δ Scuti variables, and that the other earlier names be dropped. One problem with these stars is that they frequently display two or more periods. Walraven (1955) produced data for both SX Phe and AI Vel which clearly indicated two periods were present at all times. It may be that the interference between the two or possibly many more periods can confuse observations and lead to a large range observed for the pulsation amplitudes.

The subject of δ Scuti variables has been reviewed a number of times in the last 10 years. The paper by Baglin et al. (1973) is useful in cataloguing these stars and in providing a very extensive bibliography. Fitch (1976) has considered especially those stars that show two or modes. Petersen (1976) has given the theoretical status at that time, discussing whether these stars could be of very low mass. Baglin (1976) emphasizes the fact that there seem to be nonpulsators in the instability strip which may be due to the gravitational settling of the driving element helium. She also considers how there can be levitation of metallic elements which can occur when the helium convection zone disappears with decreasing helium as this helium sinks. Breger (1976) discussed the subject noting that the dwarf Cepheids did not seem to be any different than the δ Scuti variables. In a review paper, actually not presented but published, Auvergne et al. (1980) gave the viewpoint of the Nice group which remains very active in discovering and observing these variables. This group, in a paper by Valtier, Baglin, and Auvergne (1979) has proposed that the pulsation driving can be due to hydrogen alone in stars where the helium has sunk too deep. This has been disputed by Cox, King and Hodson (1979b). Breger (1979, 1980) has discussed in particular the presence of nonradial pulsation modes. Kurtz (1982) has reviewed the related Ap stars and their possible connection with our δ Scuti variables. We should also mention that Percy and his group in Toronto and McNamara and collaborators at Brigham Young University are currently also very active observing these stars.

The current issues are not only the usual ones about the masses, radii, and luminosities, but also the age, rotation, element diffusion to change the surface layer composition, the occurance of convection, and the presence of radial and nonradial pulsation modes. I believe that it is generally agreed now that these stars are all on or just off the zero age main sequence for population I, or especially in the case of SX Phe, population II stars. This puts their masses ranging from just over one solar mass to three solar masses as for the triple mode variable AC And with its fundamental mode period of 0.71 day. The age then depends on the mass, but ranges from about half a billion to over several billion years.

The earliest spectral classes can retain their rotation because there is not too much braking by deep envelope convection, and this rotation often keeps these higher luminosity varaibles well mixed. This keeps the helium in the surface layers and keeps the pulsation driving strong and the amplitude of pulsation large. If the rotation gets rather slow, there is the possibility that over the large age of stars with masses less than about two solar masses there can be downward settling of the helium. Curiously, it is these slow rotators in the giant region that most often pulsate. If this helium is depleted too much, then the helium convection zone disappears and levitation of some metals such as Sr, and heavier elements can occur to form Am stars. For the main sequence dwarfs and the hotter giants, this loss of helium for slow rotation logically prevents pulsation.

Cooler δ Scuti variables seem to pulsate in radial modes as do the lower mass population II horizontal branch RR Lyrae variables of similar luminosities and periods, but the hotter, A and early F variables seem to pulsate in the first or even second overtone and occasionally in a nonradial mode.

Figure 1 shows the light curves of two of our stars chosen by Breger (1979). BN Cnc (A9V) with a period of 0.037 day shows an amplitude of only 0.014 magnitude in the V filter. AD CMi (F3III) at 0.123 day shows the more rare large amplitude of 0.294 mag in the V filter. These light curve samples are the simplest of all those variables on the upper main sequence.

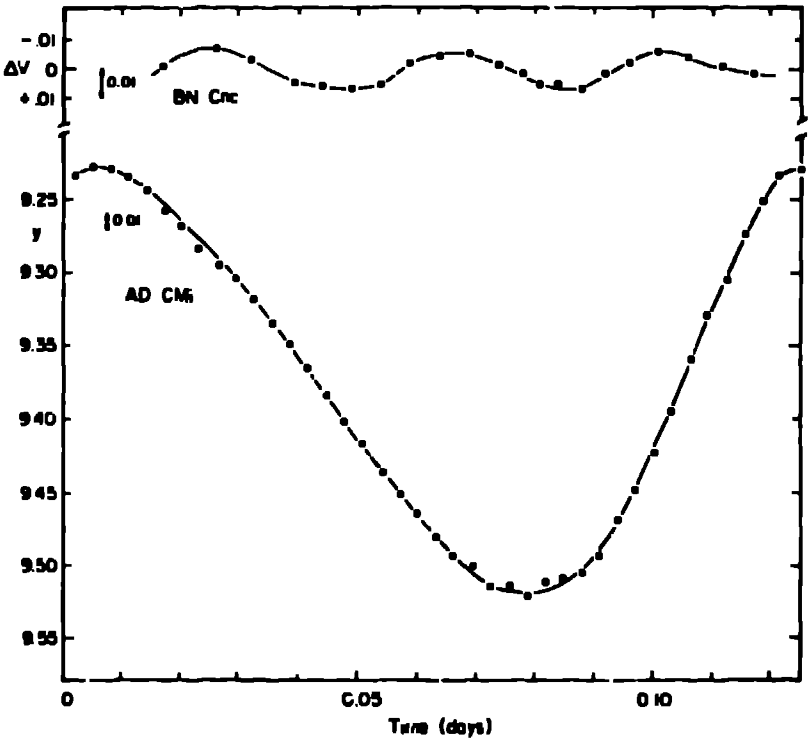

Figure 1 - Light Curves of two Delta Scuti stars: BN Cnc ($A_V$ = $0.^{m}014$) and AD CMi ($A_V$ = $0.^{m}294$). Most Delta Scuti stars resemble BN Cnc. However, a continuous range of amplitudes exist from $0.^{m}01$ to $0.^{m}8$.

Figure 1. Light curves of two δ Scuti variables plotted by Breger.

Narrow band photometry (Crawford 1975) allows the luminosity to be obtained for the late A and the F stars. For some of our stars, their luminosities are known from a trigonometric parallax or from membership in a galactic cluster with a known distance. This luminosity, and the color, allows us to plot the observed period-luminosity-color diagram of Figure 2. Here Breger (1979) has used the statistical relation

$$M_V = -3.052 \log P + 8.456 (b-y) = 3.121 \ (\pm 0.31 \text{ mag})$$

obtained from the sometimes uncertain periods of his best known 129 variables. Much of the scatter around the mean line can come from the uncertainty of 0.25 magnitude in $M_V$ in the narrow band photometry. But there is also a scatter that indicates that more than one pulsation mode occurs, as one might expect.

We now use the methods developed in the preceeding lecture to determine the masses of the δ Scuti variables. On the H-R diagram, a line of constant radius slopes upward to the left. These lines are almost lines of constant period for a fixed pulsation mode. Consider a

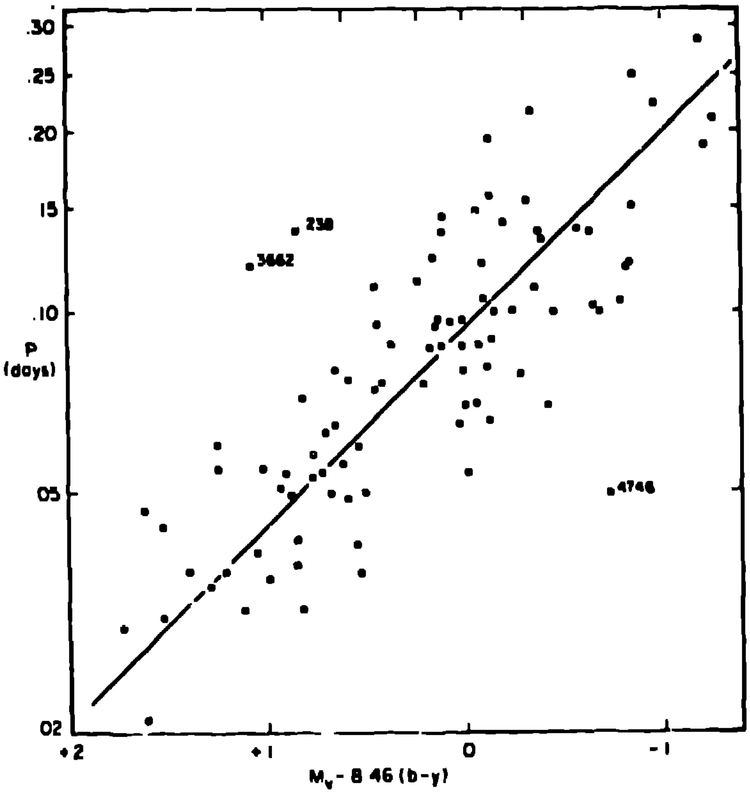

Figure 4 - Comparison of periods (or timescales of variations) with absolute magnitude after a color correction. This diagram shows that despite the poor period determinations, the derived periods do have meaning in a statistical sense.

Figure 2. The period-luminosity-color relation for δ Scuti variables. The scatter is large due to errors in both the period and luminosity. Three stars whose HR numbers are given seem to have large errors in either the period or luminosity.

point along an evolution track for a mass like 2.25 solar masses. At this point in the instability strip the mass, radius and luminosity is known, and if we assume a composition, we can use our linear pulsation theory to calculate the periods and growth rates for low order radial modes. Repeating this at many points, we can draw lines of constant period on the H-R diagram. With an observed period and effective temperature, we can seek the intersection of the line of constant temperature with the line of constant, say fundamental mode, period. By noting the mass of the theoretical evolution track passing trhough that point, we can determine what I call a theoretical mass. These masses for stars for which we are very sure of the pulsation modes, the double-mode δ Scuti variables, are given in Table 1 (Cox, King, and Hodson 1979a).

# TABLE 1
# THEORETICAL MASSES, RADII, AND LUMINOSITIES FOR DOUBLE-MODE δ SCUTI VARIABLES

| Variable | $\Pi_0$(d) | $\Pi_1/\Pi_0$ | $T_e$(K) | $M_T/M_\odot$ | $R_T/R_\odot$ | $L_T/L_\odot$ | $Q_0$(d) |
|---|---|---|---|---|---|---|---|
| SX Phe* | 0.05496 | 0.778 | 7850 | 1.1 ± 0.1 | 1.3 ± 0.1 | 5 ± 1 | 0.0325 |
| CY Aqr** | .06104 | .744: | 7930 | 1.4 ± 0.1 | 1.7 ± 0.1 | 10 ± 1 | .0326 |
| ZZ Mic | .0654 | .763 | 7500 | 1.4 ± 0.1 | 1.8 ± 0.1 | 10 ± 1 | .0327 |
| AE U Ma | .08602 | .773 | 7500 | 1.6 ± 0.1 | 2.2 ± 0.3 | 14 ± 4 | .0328 |
| RV Ari | .09313 | .773 | 7500 | 1.6 ± 0.1 | 2.3 ± 0.3 | 14 ± 4 | .0328 |
| BP Peg | .10954 | .772 | 7500 | 1.8 ± 0.1 | 3.0 ± 0.3 | 25 ± 5 | .0328 |
| AI Vel | .11157 | .773 | 7620 | 1.8 ± 0.1 | 2.9 ± 0.3 | 25 ± 5 | .0328 |
| V703 Sco | .14996 | .768 | 7000 | 1.9 ± 0.1 | 3.9 ± 0.5 | 33 ± 8 | .0329 |
| VX Hya | 0.22339 | 0.773 | 6980 | 2.2 ± 0.1 | 4.8 ± 0.4 | 48 ± 8 | 0.0330 |

* 1st crossing assumed

** 1st or third crossing

$T_e$ values for SX Phe, CY Agr, AI Vel, and VX Hya from McNamara and Feltz (1978).

For V703 Sco, $T_e$ is from Jones (1975). For all variables the deep interior composition is Z = 0.01 with Y between .2 and .3 except for SX Phe with Z = 0.001 with interior Y between .2 and .3.

# TABLE 2
# 195 ZONE LINEAR THEORY MODEL FOR AI VEL

$1.8\ M_\odot = 3.58 \times 10^{33}$ g  7600 K  $22.4\ L_\odot = 8.73 \times 10^{34}$ erg/s

| | |
|---|---|
| $T < 7000$ K Ross-Aller | |
| $7000\ K < T < 150{,}000\ K$ | Y = 0.23 |
| $150{,}000\ K < T < 10{,}000{,}000\ K$ | Y = 0.23 |
| $10{,}000{,}000\ K < T$ | Y = 0.50 |

Z = 0.02 everywhere

Outer mass shell $1.0 \times 10^{23}$ g

Central mass ball $2.8 \times 10^{32}$ g = 0.08 $M_*$

Zone mass ratio for T > 25,000 K = 1.153

Outer radius ~ Photospheric radius = $1.917 \times 10^{11}$ cm

Inner radius $9.01 \times 10^{9}$ cm = 0.047 $R_*$

Bottom zone $T = 14.4 \times 10^{6}$ K

Central ball luminosity 0.98 $L_*$

mean density 91 g/cm

Hydrogen ionization zone $\ell/H_p = 0.4$

Helium ionization zone $\ell/H_p = 1.0$

No core convection

$\Pi_0 = 0.1104$  $\eta_0 = 7.3 \times 10^{-6}$

$\Pi_1 = 0.0852$  $\eta_1 = 1.1 \times 10^{-4}$

$\Pi_2 = 0.0697$  $\eta_2 = 6.6 \times 10^{-4}$

$\Pi_1/\Pi_0 = 0.772$ (0.773 observed)

Details of a model for the well known variable AI Vel are given in Table 2. In order to get the period and period ratio as observed, we have used a mass of 1.8 solar mass. The observed surface effective temperature of 7620 K needed to be reduced to 7600 K in order to put it into the instability strip at the luminosity of 22.4 solar luminosities. We also needed to deplete the outer envelope of a small amount of helium which, as we will see later, increases the period ratio to that observed. For this model in Figure 3 the temperature, density, and opacity are plotted versus surface mass fraction as we had for the model for $\alpha$ Vir in lecture 1.

The internal variations of the radius during the pulsation are given in Figure 4. For the fundamental and the first two overtones we see, as always, that the motions (sinusoidal in time in our linear theory) are large at the surface and small in the deep denser layers.

The work per cycle to excite the pulsations is shown in Figure 5 for these three modes. These stars show stronger driving for the higher overtones than for the lower ones, and to put them all on the same scale, the fundamental mode is multiplied by 100 and the first overtone multiplied by 10. Near the surface, there is driving by H and HeI (9,000-15,000 K). Deeper we see the largest driving due to H, HeI, and HeII (30,000-60,000 K). At an even deeper layer we get driving that does not occur in other variable stars, and this is due to the ultimate ionization of HeII (1,000,000-180,000 K). This deepest driving was found in the $\beta$ Cephei variables by Stellingwerf (1978). The damping in this model is not enough to overcome the driving and this model will grow in amplitude into the nonlinear regime.

Figure 6 gives a theoretical H-R diagram based on the evolution calculations reviewed by Iben (1967). Tracks are shown for 1.25, 1.5, and 2.25 solar masses which span the mass range. On this diagram we have plotted the 9 $\delta$ Scuti variables that are given in Table 1. We can see that the lower mass and luminosity variables are either in the evolution stage before or after hydrogen core exhaustion. For the giants, however, they are all in the later shell hydrogen burning stage. We will give the observational instability strip boundaries later, but even from these few stars, on can see that there is a region of instability which, at higher luminosity, goes right into the Cepheid region. The age of the 2.25 solar mass $\delta$ Scuti variables is about 0.5

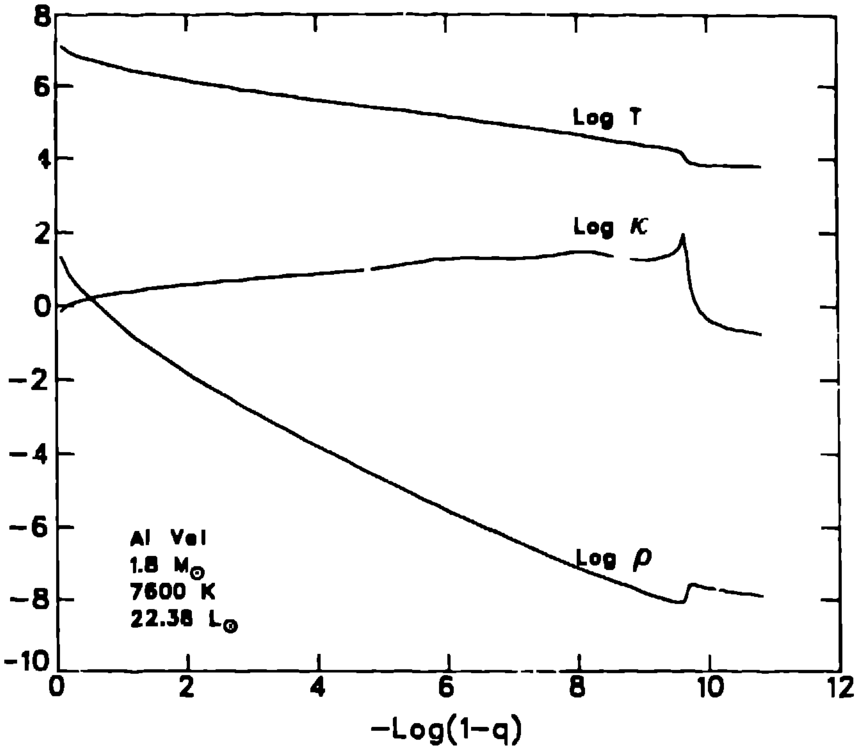

Figure 3. The temperature, density, and opacity is plotted versus surface mass fraction for our AI Vel model.

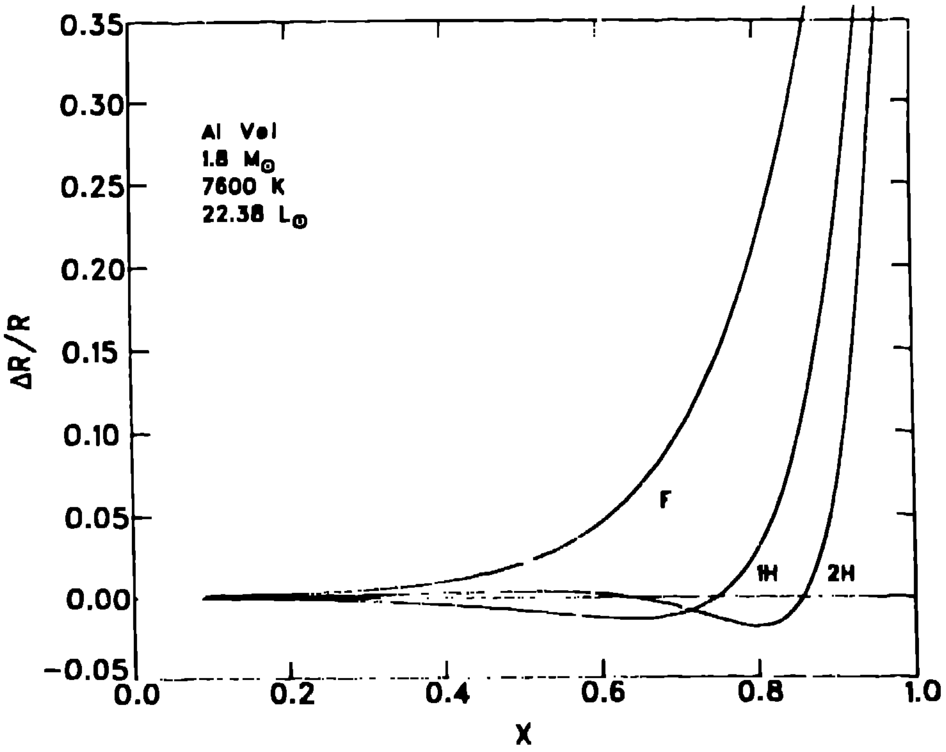

Figure 4. Eigenvectors for the internal variations of the radius perturbation are given for the fundamental, and first and second overtones in our AI Vel model.

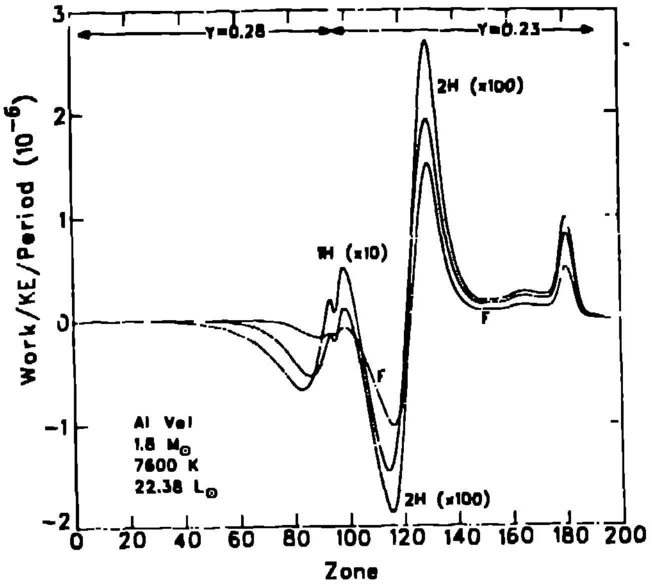

Figure 5. The work per cycle to cause pulsations is plotted for the three lowest radial modes for our AI Vel model. The fundamental mode curve is multiplied by 100, and the first overtone is multiplied by 10 in order to put the curves together conveniently.

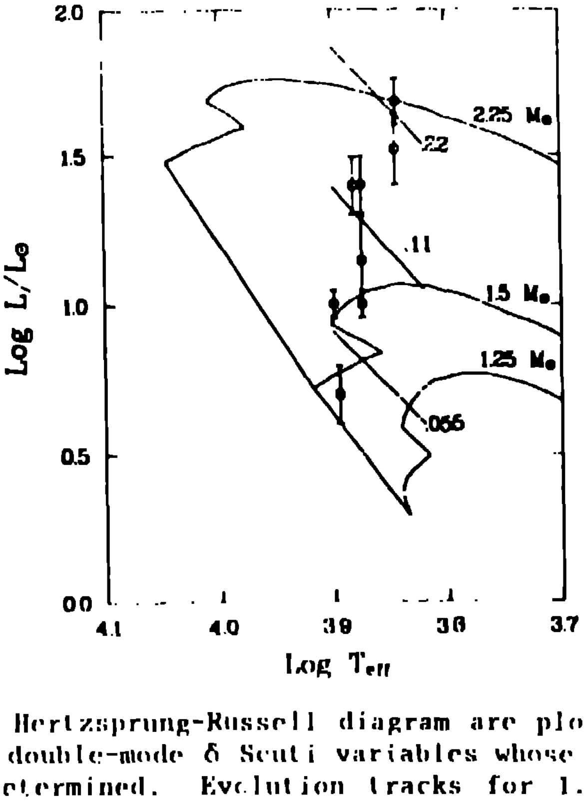

Figure 6. On the Hertzsprung-Russell diagram are plotted the positions of the nine double-mode δ Scuti variables whose theoretical masses have been determined. Evolution tracks for 1.25, 1.5, and 2.25 solar masses are shown as well as lines of constant period for 1.2 solar mass at the 0.05 day, 1.5 solar mass at the 0.11 day, and 2.0 solar mass at the 0.22 day periods.

billion years, while the age of the 1.25 solar mass star would be maybe 3.0 billion years, plenty of time for gravitational settling of helium from below its convection zone if there is no strong mixing.

Another theoretical result of interest has been given by Andreasen, Hejlesen, and Petersen (1983). They have made stellar evolution calculations and have determined radial low order pulsation periods in the adiabatic approximation for models along the tracks. Figure 7 from these authors plots the fundamental period versus the effective temperature. Just as before, an observed period and effective temperature can be used on this plot to determine the mass of the variable. Masses from logM=0.15 to 0.40 are used. The observed pulsation instability strip is indicated on the tracks as dotted sections.

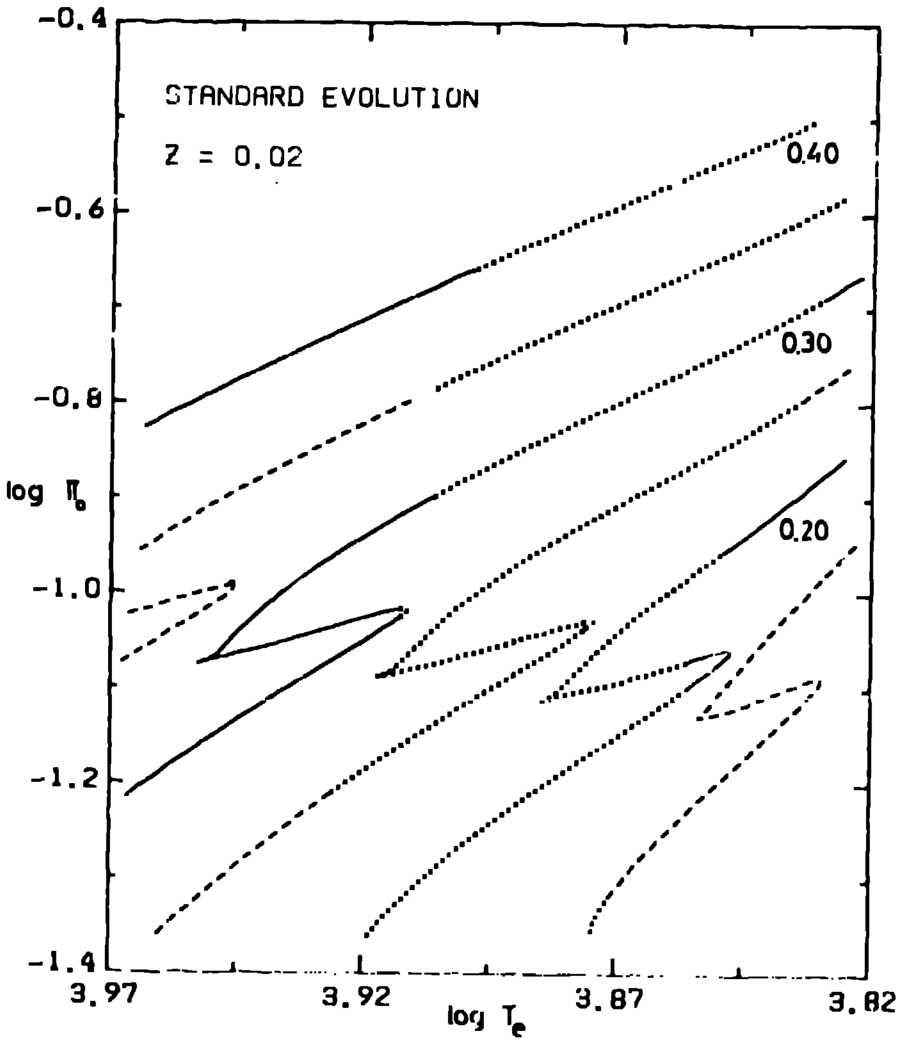

Figure 7. The Andreasen, Hejlesen, and Petersen evolution tracks for six masses (1.4-2.5 solar mass) in the logT$_e$,logP plane for the fundamental radial mode. The regions where the stars are observed to vary are dotted.

Let us return to the rather important features mentioned earlier, the fact that not all stars in the instability strip pulsate and the fact that many of these variables have very small amplitudes. Figure 8 is the observational H-R diagram with coordinates $M_V$ and (b-y). Less than half, perhaps only one third of the stars in this stage of evolution seem to vary. Actually if one looks at the the number of stars in selected amplitude ranges, the number increases dramatically as one goes to smaller amplitudes. Perhaps many of these stars vary, but at undetectable amplitudes. But perhaps, on the other hand, that there is depletion of helium and the blue edge for the low helium is redder than expected as discussed by Cox, King, and Tabor (1973).

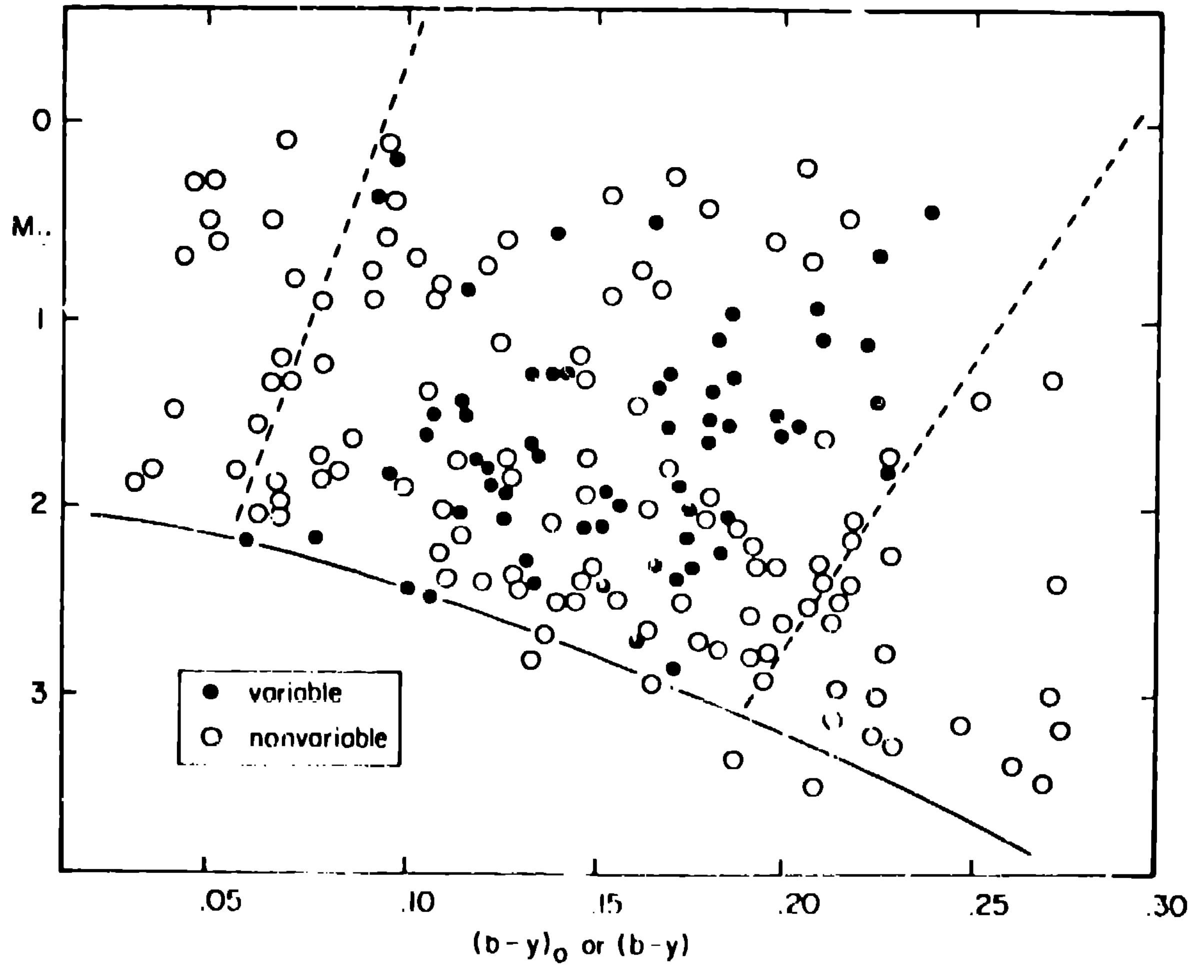

Figure 8. On the observer's H-R diagram are plotted the variable and nonvariable stars in the δ Scuti region.

The theoretical expectation is that if there is enough helium in the pulsating envelope, all stars should pulsate. This is evidently different than the earlier spectral types, such as all the B stars, where I feel they pulsate only after a suitable jolt. If that jolt is not repeated often enough, the pulsations of the several radial and nonradial modes excited decay away. For the δ Scuti stars, however, if there is pulsation excitation, the pulsation will be excited every cycle, and the star will always be at the limit cycle where the driving and damping are equal. I speculate that the truly nonpulsating δ Scuti stars have lost so much helium by gravitational settling that the damping dominates at all amplitudes and the stars do not pulsate.

An indication of the depletion of helium was given in the AI Vel model discussed before. In order to get its well observed period ratio, we needed to reduce the helium from $Y=0.28$ to 0.23 in the surface layers exterior to a temperature of 150,000 K. At this low helium abundance, the helium convection zone extends only to just over 60,000 K, accounting for a one scale height overshooting. If there was more helium, the convection zone would be deeper. Overshooting between the formal hydrogen and helium convection zones can keep the composition uniform from the surface to the 60,000 K depth. I think that for AI Vel, the low helium means that its blue edge is redder than it would be if it had normal helium. As a matter of fact, the variable is exactly at the theoretical blue edge for $Y=0.23$. The occurance of the two modes may be an indication that the blue edge for this star is moving redward by helium depletion faster than the star is evolving redward, and the mode will eventually switch completely to the first overtone. However, if evolution wins the race, a switch to a pure fundamental mode will occur. Perhaps theory soon will indicate which is faster, the downward settling or the redward evolution, and then the expectation can be checked by observing the relative energy in the two modes and how it has changed since the Walraven observations in the 1950's (Walraven 1955). I would bet on the evolution winning because it goes very fast, and the sinking of the helium has not progressed very far yet.

There is the possibility that many of the giant stars in our region of the H-R diagram have helium poor envelopes due to this settling. Unfortunately, the helium abundance cannot be measured for the δ Scuti variables except by the period ratio for the few double mode cases, but at higher temperatures several stars just to the blue of the instability strip, $\alpha$ Gem and $\theta$ Leo, do confirm helium deficiency as do some B stars also. When evolution brings the stars to the red giant region, the deeply settled helium is once again mixed to the surface by an extensive convection zone. Cepheids on the second crossing have homogeneous envelopes if not enhanced helium by a Cepheid wind, Cox, Michaud, and Hodson (1978).

Rotation can, of course, keep the helium mixed. Indeed there may be a problem because rotation as low as 20 km/s probably prevents helium from sinking. This would make it hard to form any Am stars. I must leave this subject to other lectures in this course, but I would like to note that if the short settling time of perhaps only a million years can occur with little mixing, a $\mu$-barrier will be set up to prevent further mixing by meridonal circulation.

The Andreasen, Hejlesen, and Petersen paper presents further theoretical results along the evolution tracks. They obtain only adiabatic periods and period ratios, but since the pulsations do not involve much energy flow from mass shell to mass shell because of the short periods, these periods and period ratios are adaquate. Figure 9 shows the evolution in the period, period ratio plane for the normal helium abundance and for two depletions with $Y = 0.05$ down to 300,000 K and to 1,000,000 K. These are deep depletions and maybe too deep for the age of these stars, but if the authors had considered a complete drainage of the helium, depletion to depths at lower temperatures would give the same effect. Anyway, note that with these depletions, very large period ratios appear at logM 0.2 and 0.3. For AI Vel at a period ratio of 0.773, it seems that even without further depletion of helium, the period ratio should increase as the star evolves redder to longer periods. Could it be that the very large period ratio, (0.80) that Fitch (1976) reports for VZ Cnc, indicates considerable helium settling?

We at Los Alamos looked into the nonadiabatic effects in response to the Nice proposal that hydrogen alone can cause pulsation when the helium is all lost. The key result is given in Figure 10. These data have used the linear methods and opacities for various helium abundance mixtures discussed in previous lectures, and they have been published by

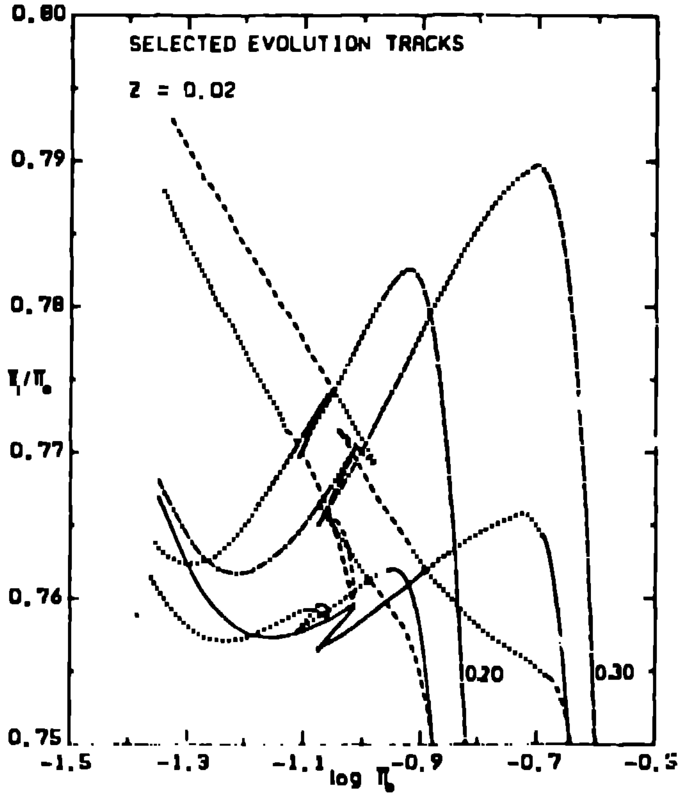

Figure 9. For 1.6 and 2.0 solar masses, the evolution tracks of Andreasen, Hejlesen, and Petersen are plotted on the period-period ratio plane. The solid curve is for normal helium, while the dash-dot curve is for substantial helium depletion down to logT=5.5 and the dashed curve is for deeper depletion to logT=6.0. Dotted sections of the curves indicate the regions where the δ Scuti stars vary.

Cox, King, and Hodson (1979b). At five effective temperatures, models at 0.11 day period have been constructed for several different envelope helium abundances. Near the observed blue edge, logTe=3.895, it takes a helium mass fraction of 0.38 or larger to cause pulsation in the fundamental mode. Overtones occur for hotter temperatures. The contribution of hydrogen is always considered with its proper abundance in these models. At $\log T_e$ 3.875, a more normal Y 0.28 gives pulsations. The importance of the hydrogen driving increases at lower temperatures, and at the observed red edge, the pulsations can exist with no helium at all. The problem is that for stars anywhere in the instability strip, it seems that at least a little helium is needed for pulsation. I suggest that the low amplitude pulsators are highly, but not completely, depleted of helium, and that when the helium is all gone, the stars no longer vary. If they have a mass above about 1.5 solar mass, they just

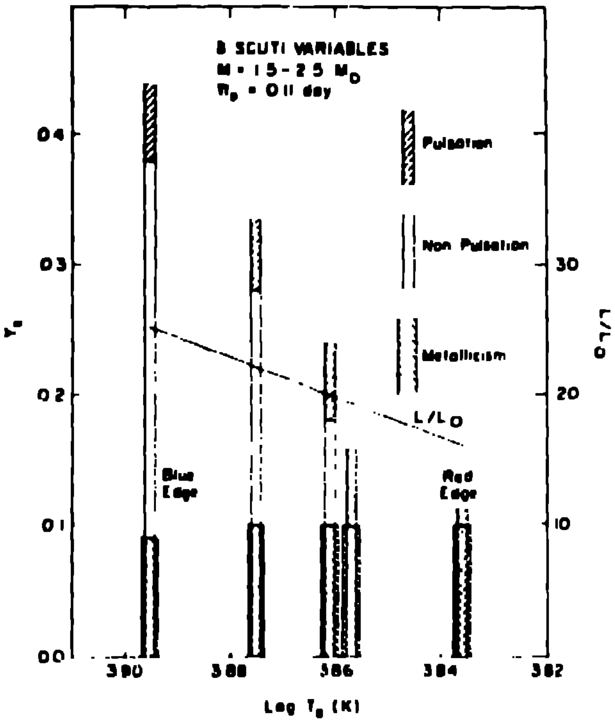

FIG. 6 The surface helium abundance $Y_s$ gives pulsation, nonpulsation, and metallicism for $T_e$ values across the pulsation instability strip. The mass range is 1.5–2.5 $M_{\odot}$ at $0^{d}11$. At the cooler temperatures in the right third of the strip, pulsation and metallicism can occur simultaneously, but for hotter temperatures one excludes the other. Nonpulsating stars need not show metallicism in the hotter two thirds of the strip, but they should show metallicism for the cool third with no He convection zone if there is no other mixing process. The luminosity of the models is given on the right-hand side scale.

Figure 10. The behavior of the pulsation and the occurrance of metallicism is indicated on the $\log T_e$-$Y_s$ plane.

might lose their helium before they enter the instability strip, and they may never pulsate at all. For lower masses, down to just over one solar mass, the stars should pulsate on the main sequence before the settling is too strong.

Figure 10 shows that if the helium mass fraction gets down to less than 0.1, the convection zone disappears. Then selective levitation of the metals, such as Si, V, and every once ionized element heavier than Ni, can occur to display the δ Del or the strong Am phenomenon. The overlap of the δ Del spectral class stars and the δ Scuti variability occurs theoretically only for the cooler stars in the instability strip with $\log T_e < 3.86$.

Finally, let us discuss briefly the nonradial modes. This is appropriate because the more luminous, hotter stars that we will return to in the coming lectures display an overwhelming number of nonradial modes. Table 3 lists the situation for the best known cases. Identifications of the nonradial modes are due to Smith (1982), using line profiles primarily, to Stobie, Pickup, and Shobbrook (1977) and to Kurtz (1980a,b,c,d,e; 1981a,b) using methods discussed by Dziembowski (1977) and by Balona and Stobie (1979a,b). The theoretical nonradial periods given by Fitch (1981) have been disputed by Clancy and Cox (1982). Much further study is necessary.

## TABLE 3
## NONRADIAL δ SCUTI VARIABLES

| Star | Spectral Class | Periods (day) | k | ℓ | m | Author |
|---|---|---|---|---|---|---|
| δ Sct | δ Del | 0.1938 | 0 | 0 | - | S82 |
| | | .1869 | $p_1$ | 2 | ? | |
| | | .1164 | 2 | 0 | - | |
| δ Del B | δ Del | .1568 | 0 | 0 | - | S82 |
| | | .1525 | ? | low | m | |
| | | .1508 | ? | low | m-1 | |
| 1 Mon | F2IV | .1361 | 0 | 0 | - | S82 |
| | | .1338 | $p_1$ | 1 | m | |
| | | .1386 | $p_1$ | 1 | m+1 | |
| 28 Aql | F0III | .1406 | $p_1$ | 2 | -2 | S82 |
| | | .1497 | $p_1$ | 2 | -1 | |
| 14 Aur A | δ Del A9V | .0882 | $p_3$ | 2 | m | S82 |
| | | .0965 | or $p_4$ | 2 | m+1 | |
| 20 CVn | δ Del F0II-IIIp | .121 | nonradial | | | S82 |
| 21 Mon | A8n | .0999 | - | - | - | SPS77 |
| | | .0750 | - | - | - | |
| HR1170 | F0 | .0994 | 0 | - | - | K81a |
| | | .0910 | nonradial | - | - | |
| HD116994 | A5 | .1021 | 0 | - | - | K80f |
| | | .1035 | nonradial | - | - | |
| | | .1015 | nonradial | - | - | |
| HD188136 | δ Del | .1249 | 0 | - | - | K80c |
| | | .1233 | nonradial | - | - | |
| | | .0795 | nonradial | - | - | |
| HD8781 | F0II-III | .1116 | 0 or 1 | - | m+1 | K80a |
| | | .1185 | 1 or 2 | - | m+1 | |
| | | .1098 | 0 or 1 | - | m | |
| | | .1160 | 1 or 2 | - | m | |
| HD31908 | δ Del | .1089 | 0 | - | - | K80b |
| | | .0857 | 1 | - | - | |
| | | .0961 | $p_1$ | ? | ? | |
| HD188520 | A7 IV-V | .0545 | 0 | ? | - | K80d |
| | | .2100 | g | ? | ? | |
| HD132209 | A9-F0IV-V | .1580 | ? | ? | m+1 | K81b |
| | | .1267 | ? | ? | m | |
| | | .0860 | ? | ? | m+1 | |
| | | .0814 | ? | ? | m | |
| θ Tuc | A4 | | nonradial | | | K80e |
| ρ Phe | F2III | | nonradial | | | K80e |
| HR4594 | Am: | | nonradial | | | K80e |

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