LA-UR -85-4109

CONF-8510265--2

RECEIVED BY OSTI DEC 06 1985

LA-UR--85-4109

DE86 003652

TITLE: THEORETICAL INTERPRETATIONS OF ANOMALOUS CEPHEID PULSATIONS.

AUTHOR(S) Arthur N. Cox, T-6
Charles R. Proffett, University of Washington

SUBMITTED TO TO BE SUBMITTED AT A COOL STAR WORKSHOP, IN SANTA FE, DATED OCTOBER 16-18, 1985

THEORETICAL INTERPRETATIONS OF ANOMALOUS CEPHEID PULSATIONS

Arthur N. Cox
Theoretical Division
Los Alamos National Laboratory
and
Charles R. Proffitt
University of Washington

Anomalous Cepheids are variable stars found in metal poor systems, with a low mass main sequence turnoff, that are significantly brighter (0.4 to 1.0 magnitude) than the RR Lyrae variables in the same system. They do have similar periods and effective temperatures. In dwarf spheroidal systems such as Draco, Leo II, Sculptor and Ursae Major, they are quite common, but they are rare in globular clusters. Only one is well known in the globular cluster NGC 5466 (Zinn and Dahn, 1976), but there are other possible candidates in M15 and omega Cen. Similar objects are found in the SMC, but none are seen in the LMC.

The period of a pulsating star can be used to measure its mass if its effective temperature, luminosity and pulsation mode are known. These first two allow calculation of the stellar radius. The pulsation constant $Q_i=P_i(M/R^{**}3)^{**}1/2$ for mode i can be calculated from theoretical models where the units used here are days, and solar mass and radius. The slow variation of Q with the effective temperature, M, L, and R has been determined by use of a grid of models with parameters covering the range appropriate for the anomalous Cepheids.

These theoretical models have been studied with a linear, nonadiabatic, radial pulsation eigensolution program based on the method of Castor (1971). Earlier pulsation constants and an analytic fit to them are available from Wallerstein and Cox (1984). In the new models, up to 85 percent of the mass is included in the envelope consisting of 195 Lagrangian mass shells. The temperature increase from zone to zone is restricted so as to achieve very fine resolution in the hydrogen ionization zone. Periods are probably accurate to about one percent, and they seem independent of reasonable compositions.

Convective transport of luminosity in the model is allowed for by use of the standard mixing length theory. In the pulsation analysis, the usual assumption that the convective luminosity does not vary with time is made. In some of the models used for obtaining Q values, the opacity in the convective regions is an average over three different kinds of material, the matter at that point, and the matter in both the rising and falling eddies. This theory has been proposed by Deupree (1979) in studies of the influence of convection of the red edge of the RR Lyrae instability strip. The rising and falling elements have a temperature difference from that of the mean material calculated assuming that the eddies came from one mixing length above or below. This allowance greatly reduces the opacity, and gives a much larger hydrogen ionization region with much stronger opacity effect pulsation driving. Figure 1 shows the hydrogen ionization zone driving around zone 180 and the helium ionization zone driving between zones 120 and 130 for the fundamental and two overtone modes.

Some models also include the effects of turbulent pressure in the convection zone. There is, howerver, no significant effect on growth rates of the radial pulsation modes using the turbulent pressure.

In any case, the periods are not affected much at all by these convection improvements, and the devived masses are essentially the same as those given by Zinn and Searle (1976) and by Deupree and Hodson (1976). Strong pulsation instability is found for both the fundamental and first overtone modes, making it impossible to distinguish between them for any of the observed anomalous Cepheids.

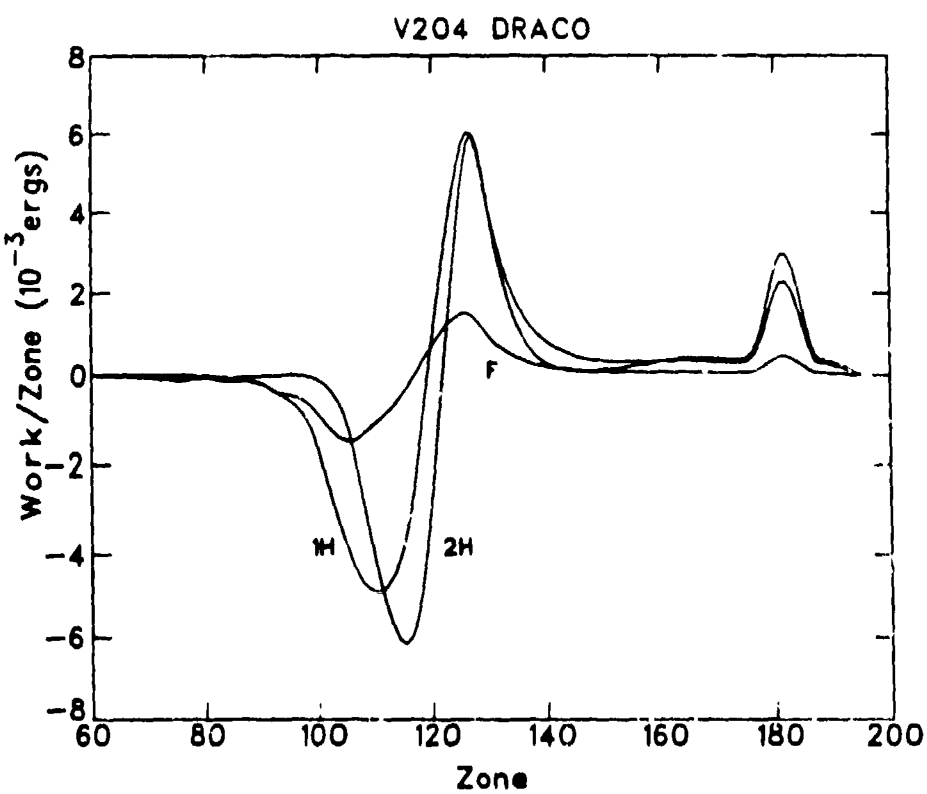

Fig. 1. Location and shape of mode driving and damping regions.

Data for the five Draco Cepheids, the one in NGC 5466, and the possible one in M15 are given in Table 1. The large masses seem unlikely in such evolved systems unless

TABLE 1

Anomalous Cepheid Data

System Star	P(day)	T_e(K)	log $L/L_{\odot}$	M_F	M_{1H}
	Observations			Theory	
Draco					
V134	0.59	7080	2.22	2.00	1.28
V141	0.90	6290	2.16	1.61	1.03
V157	0.94	6680	2.19	1.22	0.78
V194	1.59	6386	2.51	1.76	1.12
V204	0.45	7210	2.04	1.62	1.04
NGC5466					
V19	0.82	7000	2.41	2.24	1.42
M15					
V33	0.58	6557	1.89	1.14	0.73

there has been some coalescence between stars during their red giant evolution stages. Three variables have pulsation masses even larger than 1.6 solar masses, indicating that even more that two stars were joined. This anomaly disappears, however, if the pulsation mode is the first overtone with its smaller pulsation constant. Such a situation is possible for two of these three because their effective temperatures are 7000K or larger. While the fundamental pulsation mode is unstable at these temperatures, it is possible that the selection of the overtone is made near to the fundamental mode blue edge.

The variables with the largest masses, V134 in Draco and V19 in NGC 5466, display opposite evidence for their pulsation modes in their light curves. V134 is probably in the fundamental mode, because it has the typical asymmetric shape. At least the NGC 5466 variable could be in the overtone mode because of its symmetric, typically overtone like, light curve.

The biggest problem is with V134. An observed uncertainty of 100K could imply a smaller radius and smaller mass than given in Table 1. Such a hotter temperature reduces the V194 mass from 1.76 to 1.63, but this 100K is still not large enough for V134. Table 2 shows that an increase of 320 K is needed to put V134 below the coalesced mass of two normal old system stars with 0.8 solar mass.

TABLE 2

Temperature Effects on Masses

	T_e(K)	$M_F(M_\odot)$
V194	6368	1.76
	6468	1.63 about 2 x 0.8
V134	7080	2.00
	7400	1.59 about 2 x 0.8

The situation for V134 is that perhaps there is a normal star population in Draco with a mass of one or more solar mass, there is a coalescence with an older dead star which has already become a white dwarf or neutron star, or there is a large error in the effective temperature data. We propose the second explanation as the one most likely for at least V134 in Draco.

REFERENCES

Castor, J. I. 1971, Ap. J. , 166, 109.
Deupree, R. G. 1979, Ap. J., 234, 228.
Deupree, R. G. and Hodson, S. W. 1976, Ap. J., 218, 654.
Wallerstein, G. and Cox, A. N. 1984, P. A. S. P., 96, 677.
Zinn, R. and Dahn, C. C. 1976, A. J., 81, 527.
Zinn, R. and Searle, L. 1976, Ap. J., 209, 734.