RADIAL AND NONRADIAL PERIODS AND GROWTH RATES OF AN AI VELORUM MODEL

J. A. GUZIK
Applied Theoretical Physics Division, Los Alamos National Laboratory

Abstract. Walraven, Walraven and Balona recently discovered several new periodicities in addition to the well-known fundamental and first overtone periods of the high-amplitude δ Scuti star AI Velorum. Linear nonadiabatic pulsation calculations were performed for an AI Velorum model of mass $1.96M_\odot$, $24.05L_\odot$, and $T_{\rm eff}$ 7566 K for the radial and low-degree nonradial modes to help verify the tentative identifications made by Walraven, et al. Comparison of the calculated periods with the observations suggests some alternatives to the identifications proposed by Walraven, et al.

Walraven, and Balona (1991) analyzed photometric observations of the high-amplitude δ Scuti star AI Velorum made in 1951–53, 1979, 1987, and 1989, and discovered a number of new periodicities. In addition to the radial fundamental (P_0 = 0.1115740 d) and first overtone (P_1 = 0.0862086 d) modes, periods P_2 = 0.0444014 d, P_3 = 0.0626077 d, P_4 = 0.109438 d, and P_5 = 0.091575 d were found. Walraven et al. make the following tentative mode identifications: P_2 is identified as the fifth radial overtone. If an aliasing problem occurred, and F_3 = 16.973 d^{-1} instead of 15.973 d^{-1}, P_3 could be 0.058917 d, which is near the third radial overtone. P_4 cannot be a radial mode, and is proposed to be the $n = 1$, $l = 1$ p-mode. P_5 is interpreted as a nonlinear interaction between P_2 and P_1, since the frequency difference F_2–F_1 is very close to F_5, and the amplitude of P_5 is proportional to the amplitude of P_2.

This paper presents the radial and low-l nonradial linear nonadiabatic periods and growth rates for an AI Velorum envelope model with fundamental and first overtone periods that closely match the observed periods. The 250-zone model has $M = 1.96M_\odot$, $L = 24.05L_\odot$, $T_{\rm eff}$ = 7566 K, mixing length/pressure scale height α = 1.5, and fixed composition Y=0.29, Z=0.01, comprises 74% of the total mass, and uses the Stellingwerf (1975a, 1975b) analytical fit to the Cox-Tabor (1976) opacities. The period ratios and growth rates were found to be sensitive to the depth of the envelope, but were not affected significantly by modest changes in opacity or helium abundance, or by finer zoning.

The static model and linear radial nonadiabatic periods and growth rates were calculated using a code developed at Los Alamos, and described by Cox (1983). Linear nonradial nonadiabatic periods and growth rates were calculated using a code developed by Pesnell (1990). Tables I–IV summarize the periods and growth rates for this AI Vel model.

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TABLE I
Linear Radial Periods and Growth Rates for AI Vel Model

Mode	Period	Growth Rate/Period
F	0.111573	5.4e-06
1H	0.086197	7.9e-05
2H	0.070316	4.4e-04
3H	0.058872	1.4e-03
4H	0.050293	3.2e-03
5H	0.043882	5.6e-03
6H	0.038934	5.3e-03
7H	0.034899	−3.8e-04

TABLE II
Linear Nonradial Periods and Growth Rates for AI Vel Model, $l = 1$

Order n	Period	Growth Rate/Period
1	0.107402	8.5e-06
2	0.082299	1.2e-04
3	0.067036	6.1e-04
4	0.056228	1.8e-03
5	0.048310	3.9e-03
6	0.042426	6.1e-03
7	0.037834	5.0e-03
8	0.034055	−1.0e-03

TABLE III
Linear Nonradial Periods and Growth Rates for AI Vel Model, $l = 2$

Order n	Period	Growth Rate/Period
0	0.111460	3.7e-06
1	0.091683	3.3e-05
2	0.075178	2.4e-04
3	0.062506	9.3e-04
4	0.053011	2.4e-03
5	0.045967	4.9e-03
6	0.040639	6.2e-03
7	0.036382	3.3e-03
8	0.032835	−4.0e-03

TABLE IV
Linear nonradial periods and growth rates for AI Vel Model, $l = 3$

Order n	Period	Growth Rate/Period
0	0.107304	3.6e-06
1	0.087681	6.0e-05
2	0.071041	4.0e-04
3	0.059152	1.3e-03
4	0.050421	3.2e-03
5	0.043987	5.7e-03
6	0.039065	5.8e-03
7	0.035061	1.1e-03
8	0.031710	−7.2e-03

It is interesting that many modes that have not been observed are calculated to have large growth rates. The $P_2 = 0.0444014$ d periodicity agrees well with the 5th radial overtone, as proposed by Walraven, but also is close to the $l = 3$, $n = 5$ p-mode period. $P_3 = 0.0626077$ d agrees well with the $l = 2$, $n = 3$ mode period, but its alias of 0.058917 d also matches the 3rd radial overtone period. $P_4 = 0.109438$ d cannot be a radial mode, but does not match closely any low-l nonradial period either; the closest matches are $l = 1$, $n = 1$ (0.107402 d), $l = 2$, $n = 0$ (0.111460 d), and $l = 3$, $n = 0$ (0.107304 d). The interpretation of the $P_5 = 0.091575$ d periodicity as an interaction between P_2 and P_1 is most plausible, but P_5 also is close to the $l = 2$, $n = 1$ period.

References

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