Convection and the Bump Cepheid Resonance

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Abstract

Bump Cepheids display a resonance between the fundamental and second overtone modes in the form of a bump on descending light for periods less than 10 days and on the ascending light curve for longer periods. A long-standing problem has been how to explain this resonance for stellar masses consistent with evolution theory, rather than significantly lower ones. New Livermore OPAL intermediate coupling opacities now produce stellar models that are less density concentrated in the outer 1/4 of the radius, and all radial mode periods are increased. The second overtone to fundamental mode period ratio is reduced. This reduction then requires larger masses for the bump resonance, much closer to those from the old Becker, Iben, and Tuggle and the new Stothers and Chin stellar evolution results with no or very little core convection overshooting and the standard (X=0.70 and Z=0.02) composition. This achievement of the OPAL opacities is not adequate, though, because the period ratios have not quite decreased enough. There is another missing ingredient suggested to me by Norman Simon. A second deep "iron line" convection zone now appears between 145,000 and 205,000 K for higher Cepheid luminosities and masses like 7 and 8 $M_{\odot}$. This convection is necessary to transport the higher luminosities that cannot be carried by radiation alone. An increase in the ratio of the mixing length to the pressure scale height to about 1.5 for 7 $M_{\odot}$ and 2.0 or more for 8 $M_{\odot}$ can give an appropriate convection efficiency and the required deep convection zone structure. Thus OPAL opacities, when used with the full physics of convection models all across the instability strip and nonadiabatic pulsation analyses, actually do explain the bump Cepheid puzzle. Further, the unknown convection efficiency for intermediate mass yellow giants can apparently be calibrated as a function of stellar mass.

Bump Cepheid Models Period Ratios

$\ell/Hp=$	0.0		1.0		1.5		2.0	
T_e (K)	Π_0	Π_2/Π_0	Π_0	Π_2/Π_0	Π_0	Π_2/Π_0	Π_0	Π_2/Π_0
7 $M_{\odot}$								
5350	9.81	0.511	9.93	0.510	10.07	0.500	10.61	0.464
5700	7.92	0.524	7.98	0.524	8.03	0.519	8.13	0.511
6000	6.66	0.533	6.68	0.534	6.70	0.533	6.74	0.530
8 $M_{\odot}$								
5350	13.67	0.497	13.81	0.496	13.97	0.486	14.43	0.465
5700	11.01	0.509	11.06	0.510	11.13	0.506	11.24	0.499
6000	9.24	0.519	9.24	0.519	9.28	0.519	9.31	0.517