ASP 5203, Estrellas Variables

2019-1

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Tarea 2

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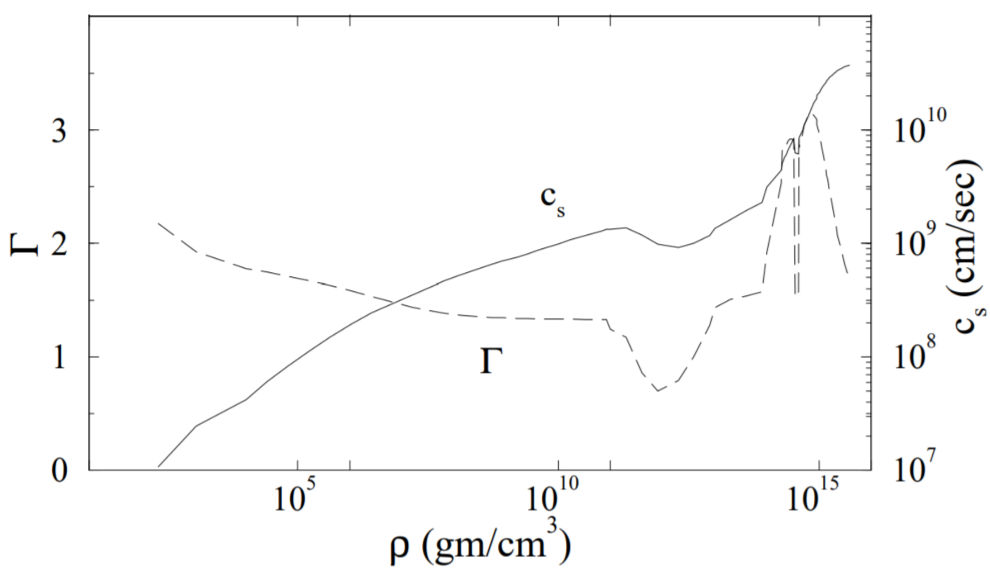
Problem 1. In the following figure (adapted from Balberg & Shapiro 2000; see this link for further details) one can find how the speed of sound (denoted c_s) changes with density, in the high-density regime that characterizes white dwarfs and neutron stars. The calculations are based on a highly accurate equation of state, taking quantum and relativistic effects properly into account.

a) Estimate the typical mean density for white dwarf stars. What is the speed of sound that corresponds to this density regime?

b) Estimate the corresponding pulsation timescale, assuming pulsation to be due to pressure waves propagating in the stellar interior. How does this compare with the typical pulsation periods that are found in white dwarfs? What can you conclude from this comparison?



[1] This assignment should be turned in electronically, in the form of a single pdf file. Please upload it to the "Buzón de Tareas" on the course's official web page. As in the case of the previous assignment, it is recommended that you use a journal format in LaTeX.

Problem 2. The following table (adapted from *Astrophysical Quantities*, 4th ed.) provides average physical properties of different classes of pulsating variable stars along the "classical" instability strip. The first column shows the logarithm of the pulsation period (in days), referring in all cases to the fundamental mode.

a) Obtain a value for the "pulsation constant Q" for each subclass, and compare with the values obtained in class. Discuss possible variations that may be present within a given subclass, as well as among the different subclasses.

b) Evaluate the possible existence of period-luminosity (PL), period-radius, and period-surface gravity relations for the classical Cepheids. How reliably can such relations be extrapolated to the RR Lyrae and δ Scuti domains?

c) For the same classical Cepheids as in the previous item, evaluate whether a temperature or color term should be added to the PL relation (thus turning it into a so-called period-luminosity-color, or PLC, relation), explaining the criteria adopted in your answer.

$\log P$	M_V	$B-V$	$\log L/L_\odot$	$\log R/R_\odot$	$\log T_{\rm eff}$	$\log \mathcal{M}/\mathcal{M}_\odot$	$\log g$
				Classical Cepheids			
0.4	−2.4	0.49	2.81	1.41	3.76	0.54	2.2
0.6	−2.9	0.57	3.05	1.55	3.75	0.61	1.9
0.8	−3.5	0.66	3.30	1.70	3.74	0.68	1.7
1.0	−4.1	0.75	3.55	1.85	3.72	0.75	1.5
1.2	−4.7	0.84	3.80	2.00	3.71	0.82	1.3
1.4	−5.3	0.93	4.06	2.15	3.70	0.89	1.0
1.6	−5.8	1.01	4.32	2.29	3.70	0.97	0.8
1.8	−6.4	1.10	4.58	2.44	3.69	1.04	0.6
				δ Sct/Dwarf Cepheids[b]			
−1.4	+2.7	0.20	0.90	0.07	3.91	0.21	4.5
−1.0	+1.7	0.25	1.22	0.37	3.88	0.25	3.9
−0.7	+0.8	0.29	1.58	0.59	3.86	0.31	3.6
				RR Lyrae stars[c]			
−0.5	0.7	0.20	1.47	0.54	3.86	−0.26	3.1
−0.3	0.7	0.25	1.57	0.67	3.82	−0.26	2.8
−0.1	0.7	0.38	1.59	0.76	3.78	−0.26	2.7

Problem 3. Evaluate the ratio between the pulsational and Kelvin-Helmholtz (or thermal) time scales for stars of different spectral types and luminosity classes. Use representative values for the different types of stars from, for example, Table 15.8 in *Astrophysical Quantities, 4th ed*. (table copied below). From your results, and considering the distribution of the different classes of pulsating stars in the H-R diagram (schematically shown in Fig. 3.2 of Catelan & Smith 2015), for which types of pulsating variables would you expect non-adiabatic effects to become most pronounced, and for which the least?

Table 15.7. *Calibration of MK spectral types.*

Sp	*M(V)*	*B − V*	*U − B*	*V − R*	*R − I*	T_{eff}	BC
MAIN SEQUENCE, V							
O5	−5.7	−0.33	−1.19	−0.15	−0.32	42 000	−4.40
O9	−4.5	−0.31	−1.12	−0.15	−0.32	34 000	−3.33
B0	−4.0	−0.30	−1.08	−0.13	−0.29	30 000	−3.16
B2	−2.45	−0.24	−0.84	−0.10	−0.22	20 900	−2.35
B5	−1.2	−0.17	−0.58	−0.06	−0.16	15 200	−1.46
B8	−0.25	−0.11	−0.34	−0.02	−0.10	11 400	−0.80
A0	+0.65	−0.02	−0.02	0.02	−0.02	9 790	−0.30
A2	+1.3	+0.05	+0.05	0.08	0.01	9 000	−0.20
A5	+1.95	+0.15	+0.10	0.16	0.06	8 180	−0.15
F0	+2.7	+0.30	+0.03	0.30	0.17	7 300	−0.09
F2	+3.6	+0.35	0.00	0.35	0.20	7 000	−0.11
F5	+3.5	+0.44	−0.02	0.40	0.24	6 650	−0.14
F8	+4.0	+0.52	+0.02	0.47	0.29	6 250	−0.16
G0	+4.4	+0.58	+0.06	0.50	0.31	5 940	−0.18
G2	+4.7	+0.63	+0.12	0.53	0.33	5 790	−0.20
G5	+5.1	+0.68	+0.20	0.54	0.35	5 560	−0.21
G8	+5.5	+0.74	+0.30	0.58	0.38	5 310	−0.40
K0	+5.9	+0.81	+0.45	0.64	0.42	5 150	−0.31
K2	+6.4	+0.91	+0.64	0.74	0.48	4 830	−0.42
K5	+7.35	+1.15	+1.08	0.99	0.63	4 410	−0.72
M0	+8.8	+1.40	+1.22	1.28	0.91	3 840	−1.38
M2	+9.9	+1.49	+1.18	1.50	1.19	3 520	−1.89
M5	+12.3	+1.64	+1.24	1.80	1.67	3 170	−2.73
GIANTS, III							
G5	+0.9	+0.86	+0.56	0.69	0.48	5 050	−0.34
G8	+0.8	+0.94	+0.70	0.70	0.48	4 800	−0.42
K0	+0.7	+1.00	+0.84	0.77	0.53	4 660	−0.50
K2	+0.5	+1.16	+1.16	0.84	0.58	4 390	−0.61
K5	−0.2	+1.50	+1.81	1.20	0.90	4 050	−1.02
M0	−0.4	+1.56	+1.87	1.23	0.94	3 690	−1.25
M2	−0.6	+1.60	+1.89	1.34	1.10	3 540	−1.62
M5	−0.3	+1.63	+1.58	2.18	1.96	3 380	−2.48
SUPERGIANTS, I							
O9	−6.5	−0.27	−1.13	−0.15	−0.32	32 000	−3.18
B2	−6.4	−0.17	−0.93	−0.05	−0.15	17 600	−1.58
B5	−6.2	−0.10	−0.72	0.02	−0.07	13 600	−0.95
B8	−6.2	−0.03	−0.55	0.02	0.00	11 100	−0.66
A0	−6.3	−0.01	−0.38	0.03	0.05	9 980	−0.41
A2	−6.5	+0.03	−0.25	0.07	0.07	9 380	−0.28
A5	−6.6	+0.09	−0.08	0.12	0.13	8 610	−0.13
F0	−6.6	+0.17	+0.15	0.21	0.20	7 460	−0.01
F2	−6.6	+0.23	+0.18	0.26	0.21	7 030	−0.00
F5	−6.6	+0.32	+0.27	0.35	0.23	6 370	−0.03
F8	−6.5	+0.56	+0.41	0.45	0.27	5 750	−0.09
G0	−6.4	+0.76	+0.52	0.51	0.33	5 370	−0.15
G2	−6.3	+0.87	+0.63	0.58	0.40	5 190	−0.21
G5	−6.2	+1.02	+0.83	0.67	0.44	4 930	−0.33
G8	−6.1	+1.14	+1.07	0.69	0.46	4 700	−0.42
K0	−6.0	+1.25	+1.17	0.76	0.48	4 550	−0.50
K2	−5.9	+1.36	+1.32	0.85	0.55	4 310	−0.61
K5	−5.8	+1.60	+1.80	1.20	0.90	3 990	−1.01
M0	−5.6	+1.67	+1.90	1.23	0.94	3 620	−1.29
M2	−5.6	+1.71	+1.95	1.34	1.10	3 370	−1.62
M5	−5.6	+1.80	+1.60:	2.18	1.96	2 880	−3.47

Problem 4. Obtain a form for the energy conservation equation analogous to those seen in class, and following a similar procedure, but starting from a functional dependence of the form $E = E(P, T)$. Your final result must be expressed in terms solely of the variables P, T, L_r, and ε (in addition, of course, to the usual independent variables, as well as physical constants and the relevant thermodynamical quantities, such as specific heats and adiabatic exponents, if applicable).

Problem 5. Demonstrate the linearized version of the energy conservation equation as studied in class, obtained when one expresses the internal energy as $E = E(\rho,T)$.