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Memorie della

Asiago eclipsing binaries program

Observations vs theory

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Abstract. The aim of Asiago Eclipsing Binaries Program is to derive accurate orbits and physical parameters (in particular masses and radii) for a selection of double-lined eclipsing binaries by means of Echelle high resolution, high S/N spectroscopy, and B, V photometry. Atmospheric parameters ($T_{\rm eff}$, $\log g$, [M/H], ξ, $V_{\rm rot}$) and individual chemical abundances are provided by spectral analysis. Reddening is derived from intensity of NaI (5890.0 & 5895.9 Å) and KI (7699.0 Å) interstellar lines. The observational results are used to check theoretical models and to constrain their input physics.

Key words. Stars: fundamental parameters – Binaries: spectroscopic – Binaries: eclipsing – Star: individual: V505 Per – Star: individual: V570 Per – Star: individual: V432 Aur

1. Introduction

Global physical parameters from double-lined eclipsing binary systems (SB2 EBs) represent a formidable benchmark for the current generation of stellar evolutionary models. Nevertheless, in order to properly use binary systems to constrain the accuracy of theoretical tracks and isochrones, masses and radii should be known at the 1% level and should be accompanied by accurate determination of $T_{\rm eff}$ and [M/H], which are not a direct product of orbital solution. Andersen (1991) listed about fifty SB2 EBs for which fundamental stellar parameters at the level of 1-2% have been obtained so far in the literature from the modeling of their orbits. Pols et al. (1997) presented a detailed quantitative comparison of these fundamental data with evolutionary models. More recently, other tests were made by different authors on a chosen selection of SB2 EBs of Andersen list (Ribas et al. 2000, Young et al. 2001, 2005). However, the precision of these tests usually is limited by accuracies of the observed $T_{\rm eff}$ and, most of all, by the lack of published metallicity determinations using high-resolution spectroscopy. Thus, it is crucial that accurate orbital solutions be coupled with spectroscopic atmospheric analysis for stars used as test cases of stellar evolution.

The aim of Asiago Eclipsing Binaries Program is to derive the orbit and fundamental physical parameters for a selection of SB2 EBs by means of high resolution, high S/N spectroscopy and B, V photometry. Spectroscopic observations are carried out with the Echelle+CCD spectrograph mounted at 1.82m telescope, operated by INAF OAPd (Mt. Ekar, Asiago). Accurate atmospheric pa-

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Table 1. Orbital solutions for V505 Per, V570 Per and V432 Aur. Formal errors of the solutions are given. The last lines gives the distance of the systems from the revised Hipparcos catalogue (van Leeuwen 2007) compared to the one obtained from the orbital solution. The metallicity as derived by χ^2 fitting analysis is reported in the last line.

	V505 Per			V570 Per			V432 Aur		
P (d)	4.22201998	±	0.00000033	1.9009382	±	0.0000008	3.0817438	±	0.0000014
T_0 (HJD)	2447808.5985	±	0.0003	2448500.1615	±	0.0010	2451571.41150	±	0.00027
a ($R_\odot$)	14.965	±	0.004	9.0929	±	0.012	11.749	±	0.027
V_γ (km sec^{-1})	+ 0.21	±	0.02	+ 22.81	±	0.03	+10.22	±	0.002
$q = \frac{m_2}{m_1}$	0.9859	±	0.0005	0.9319	±	0.0007	1.133	±	0.005
i (deg)	87.95	±	0.04	77.44	±	0.32	90.0	±	0.9
T_1 (K)	6512	±	21	6842	±	25	6685	±	8
$T_1 - T_2$ (K)	50	±	12	262	±	70	605	±	85
R_1 ($R_\odot$)	1.287	±	0.014	1.505	±	0.081	1.230	±	0.006
R_2 ($R_\odot$)	1.266	±	0.014	1.362	±	0.072	2.460	±	0.020
M_1 ($M_\odot$)	1.2693	±	0.0011	1.4487	±	0.0052	1.080	±	0.014
M_2 ($M_\odot$)	1.2514	±	0.0012	1.3500	±	0.0050	1.220	±	0.018
$M_{bol,1}$	3.72	±	0.04	3.17	±	0.13	3.710	±	0.056
$M_{bol,2}$	3.79	±	0.03	3.55	±	0.14	2.610	±	0.064
$\log g_1$ (cgs)	4.32	±	0.01	4.25	±	0.05	4.29	±	0.008
$\log g_2$ (cgs)	4.33	±	0.01	4.30	±	0.05	3.74	±	0.010
d_{Hip} (pc)	61.5	±	1.9	123	±	11	118	±	25
d_{orb} (pc)	60.6	±	1.0	122	±	8	134	±	3
metallicity (from spectral analysis)	−0.12	±	0.03	+0.02	±	0.05	−0.60	±	0.05

rameters ($T_{\rm eff}$, $\log g$, [M/H], ξ, $V_{\rm rot}$) are obtained from χ^2 fitting to the grid of synthetic spectra of Munari et al. (2005) and tailored spectral analysis provides individual chemical abundances. Reddening is derived from equivalent width of interstellar NaI (5890 & 5896 Å) and KI (7665 & 7699 Å) doublets.

2. Some challenges for stellar models

Our observational results are used to provide strong constraints on the different approaches/assumptions adopted in stellar model computations. We compute tailored evolutionary models fully consistent with those provided by Pietrinferni et al. (2004; the BaSTI library) for the exact masses and chemical mixtures observed in each binary, so to better highlight the effects expected from overshooting, diffusion and solar heavy elements distribution. This objective is accomplished by selecting binary systems whose stellar components have suitable masses and are in a appropriate evolutionary stage, i.e. core and shell H-burning phases. In fact, the reliability of stellar models is still partially hampered by our poor knowledge of some physical processes at work in real stars, such as (*a*) the efficiency of core convective overshoot during the core H-burning phase in intermediate mass stars, (i.e. stars with mass $M \geq 1.1 - 1.2$ $M_\odot$, the exact value depending on the chemical composition, cf. Cassisi 2004 and reference therein), (*b*) how the efficiency of core convective overshoot decreases with decreasing stellar mass, in the mass range where the transition between fully convective to fully radiative stellar cores occurs, (*c*) the efficiency of convection in the super-adiabatic layers (cf. Ribas et al. 2000), or (*d*) the efficiency of diffusive processes (atomic diffusion and radiative levitation).

3. V505 Per, V570 Per, V432 Aur: observations vs theory

In Fig.1 we compare on the H-R diagram the position of the components of three binaries of our program, V505 Per, V570 Per and V432 Aur (orbital solutions are reported in Table 1), with BaSTI stellar tracks selected from a grid of models computed on purpose for exactly the obtained masses and varying the helium and heavy elements content, both in the standard canonical scenario as well as including overshooting. All BaSTI models properly account for both helium and heavy elements diffusion. In the case of V505 Per, the initial $[M/H]_{tracks}$=−0.03 metallicity decreases to $[M/H]_{tracks}$=−0.13 at stellar surface for the ~0.9 Gyr age of the binary,

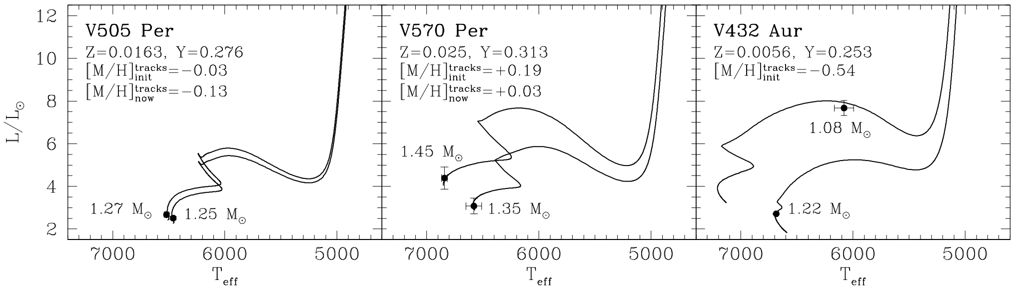

Fig. 1. Comparison between the observational results for three binaries included in our program and the prediction of tracks from the BaSTI library. Metallicity, helium content and masses and labeled.

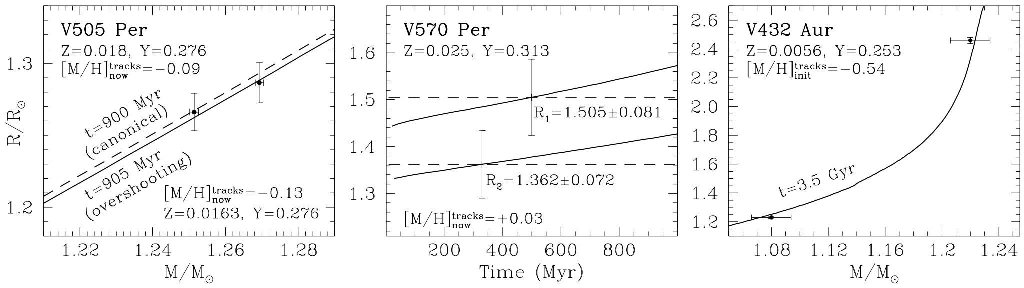

Fig. 2. As Fig. 1, but for the mass/radius and radius/time diagrams.

in excellent agreement with spectroscopically observed $[M/H]_{spectra}$=−0.12±0.03. Similarly, for V570 Per the diffusion decreases the initial $[M/H]_{tracks}$=+0.19 to $[M/H]_{tracks}$=+0.03 (in ~420 Myr), perfectly matching the observed $[M/H]_{spectra}$=+0.02±0.05. On the contrary, for V432 Aur diffusion seems to be compensated by levitation, as is reported for metal poor stars of globular clusters (cf. Richard et al. 2002 and references therein), and the initial $[M/H]_{tracks}$=−0.54 is already in agreement with observed $[M/H]_{spectra}$=−0.60±0.05 at the ~3.5 Gyr age of the system.

With well-determined masses and radii, we can try to investigate in detail the role of overshooting. In fact, to properly reproduce the location of both components of the binaries in the H-R, and mass/radius or time/radius diagrams (cf. Fig. 2) and their current spectroscopic metallicity, we compute BaSTI models for different efficiencies of the convective core overshooting (cf. Pietrinferni et al. 2004 for the definition of λ_{OV}). Either V505 Per and V570 Per, have an overshooting region already pretty low, but not null, described by λ_{OV} = 0.093 and 0.087 for the 1.27 and 1.25 $M_\odot$ of V505 Per, and λ_{OV}= 0.14 and 0.11 for the 1.45 and 1.35 $M_\odot$ of V570 Per.

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