LUMINOUS BLUE VARIABLES - AN EVOLUTIONARY PICTURE

S.R. Sreenivasan and W.J.F. Wilson
Department of Physics
The University of Calgary
Calgary, Alberta T2N 1N4
Canada

1. INTRODUCTION

A considerable amount of observational information has been gathered on the so-called Hubble-Sandage Variables or S Doradus variable stars, largely due to the efforts of the Heidelberg group (see Wolf, this volume for a review). It is believed that the star P Cygni also belongs to this category. This group of objects is now being referred to as Luminous Blue Variables because they are massive (>10 $M_\odot$), evolved (spectral type B or later) objects showing variability of more than one kind, and evidence of nuclear processed material at the surface.

From an evolutionary point of view they are thought to be in a state just prior to those of Wolf-Rayet Stars (Maeder 1983). Stothers (1983) has presented a detailed first look that these objects and examined several scenarios, without identifying any preferences. We present, in the following pages, a possible evolutionary picture, although alternatives have been presented at this symposium.

2. THE EVOLUTIONARY PICTURE

We have studied recently the evolutionary history of pop I massive stars in the mass range 15 $M_\odot \geq M_* \geq$ 120 $M_\odot$, including the effects of mass-loss, spin and enlargement of the core due to differential rotation (Sreenivasan and Wilson 1978a,b; 1982, 1985a,b; 1986; Narasimha and Sreenivasan 1986a,b), to the point of helium exhaustion in the core. One evolutionary track so far unpublished is shown below. We find, as reported earlier, at other mass ranges, that mass-loss increases not only due to rotation but with evolution due to enhanced differential rotation with age. Surface rotation is reduced to zero well before hydrogen is exhausted in the core, angular momentum is continuously carried away by stellar winds.

The models are overstable to nonradial pulsation for all tested prograde modes (ℓ=2k m=-2; ℓ=4, m=-4, etc...). Typical periods are between a few hours to days (Narasimha and Sreenivasan 1986b) with a slow modulation of amplitude over a period of years. As the core

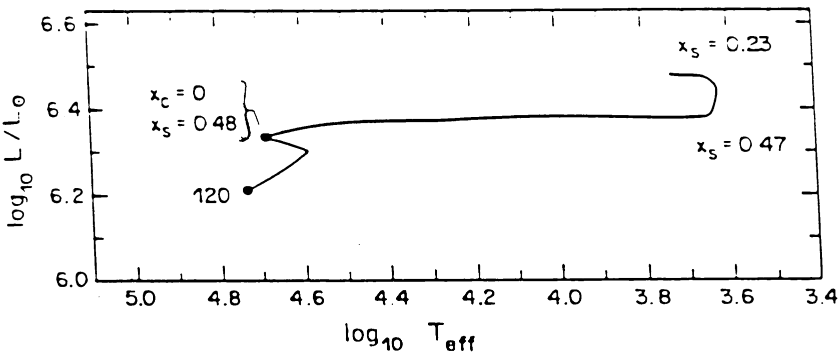
I. Appenzeller and C. Jordan (eds.), Circumstellar Matter, 425–427.

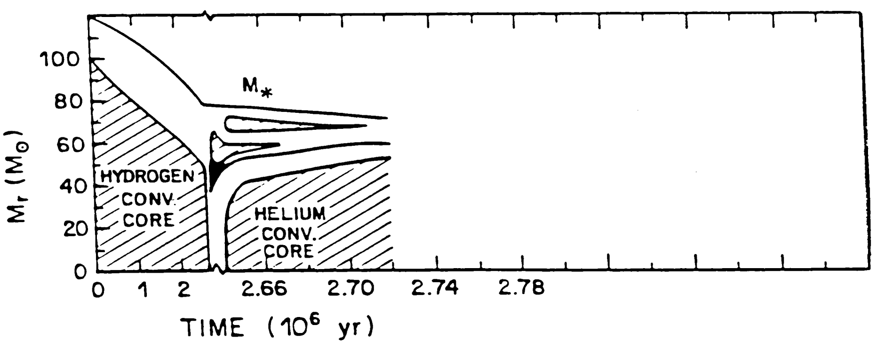
https://doi.org/10.1017/S0074180900156864 Published online by Cambridge University Press

expands and the outer layers are being peeled off at an increasing rate with age, efficient meridional circulation is brought into action not only aiding angular momentum transfer outwards from the core but mixing the nuclear processed core material with the outer layers.

PARAMETERS FOR 120 $M_\odot$ MODEL

EVOLUTIONARY POINT	AGE (10^6 yr)	MASS ($M_\odot$)	$\dot{M}_{AC}$ ($M_\odot$/yr)	$\dot{M}_{RAD}$ ($M_\odot$/yr)	$\dot{M}_{TOT}$ ($M_\odot$/yr)	$V_{surface}$ (km/s)	V_{core} (km/s)	X_s	Y_c
ZAMS	0	120	0	9×10^{-6}	9×10^{-6}	100	202	0.70	0.27
$X_c = 0$	2.636	77.9	0	1×10^{-5}	3×10^{-4}	0	319	0.48	0.97
BASE RGB	2.641	77.7	7×10^{-5}	0	7×10^{-5}	0	0	0.47	0.96
TOP RGB	2.670	75.1	9×10^{-5}	0	9×10^{-5}	0	0	0.35	0.81





The increasing mass-loss rate with age enables the winds ensuing at later stages to sweep up material carried by those at earlier epochs o form a shell. Such mechanisms have been invoked earlier in connection with planetary nebulae (Kahn 1983, Kwok 1983). The pulsations could couple with the winds not only to excite acoustic modes as has been suggested by Narasimha and Chitre (1986) but also to result in large episodic mass ejections as the differential rotation exceeds critical levels (see also Stothers 1983). We had suggested a similar mechanism for the shell stars earlier (Sreenivasan and Wilson 1980). It is possible that the Luminous Blue Variables are dynamically similar to the Be and Shell stars, being their massive cousins.

We are thus provided with a single unifying mechanism to understand Be and Shell stars and the Luminous Blue Variables through understanding the role of rotation and mixing in massive stars. A more detailed study and a fuller account of it will be presented elsewhere.

Our work is partially supported by an NSERC research grant to SRS.

REFERENCES

Kahn, F.D., (1983). in Planetary Nebulae, ed. D.R. Flowers (D. Reidel).
Kwok, S., (1983). in Planetary Nebulae, ed. D.R. Flowers (D. Reidel).
Maeder, A., (1983). Astron. Ap. 120, 113-129.
Narasimha, D. and Chitre, S.M., (1986). Ap. J. (submitted).
Narasimha, D. and Sreenivasan, S.R., (1986a). BAAS 17, No. 4 (Houston Mtg AAS).
Narasimha, D. and Sreenivasan, S.R., (1986b). in Stellar Pulsation, a memorial to J.P. Cox (in press) ed. A. Cox.
Sreenivasan, S.R. and Wilson, W.J.F., (1978a). A & A 70, 755.
Sreenivasan, S.R. and Wilson, W.J.F., (1980). in Stellar Pulsation Instabilities, ed. D. Fischel et al: NASA TM: 80625, 363-380.
Sreenivasan, S.R. and Wilson, W.J.F., (1982). Ap. J. 254, 287-296.
Sreenivasan, S.R. and Wilson, W.J.F., (1985a). Ap. J. 290, 653.
Sreenivasan, S.R. and Wilson, W.J.F., (1985b). Ap. J. 292, 506-510.
Sreenivasan, S.R. and Wilson, W.J.F., (1986a). Ap. J. (submitted).
Sreenivasan, S.R. and Wilson, W.J.F., (1986b). in Internal Angular Velocity of the Sun: Theory and Observations. ed. B. Durney and S. Sofia (in press).
Stothers, R., (1983). Ap. J. 264, 583-593.
Wolf, B., (1987). these proceedings.