SECTION I: MAIN PAPERS, GENERAL DISCUSSIONS, AND TWO PANEL DISCUSSIONS

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WHAT ARE LBV'S? -- THEIR CHARACTERISTICS AND ROLE IN THE UPPER H-R DIAGRAM

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1. INTRODUCTION

Only ten years ago a symposium on the special class of stars we now call Luminous Blue Variables (LBV's) would not have been possible. At that time we were only just beginning to recognize the similarities among the stars we call S Doradus variables, P Cygni stars, and Hubble-Sandage variables, and their importance in the evolution of the most massive stars.

About a decade ago it became clear that the observed H-R diagram has an upper luminosity limit and that η Car, P Cyg, and S Dor are all near the temperature-dependent boundary for hot stars. With hindsight the luminosity boundary can be seen in an H-R diagram for hot stars published by Hutchings (1976), but the full temperature range is necessary to show that it really exists. When more data became available in 1977--1978, including the evolved and cool supergiants, the upper luminosity limit became obvious; and we proposed that an instability causing **rapid** and **unsteady** mass loss (*i.e.*, LBV's) is the basic reason for this boundary (Humphreys and Davidson 1979). We emphasized the temperature-dependence of the boundary for the most luminous hot stars, the lack of cooler counterparts at similar luminosities, the nearly temperature-independent limit to the luminosities of cool hypergiants, and the critical role that objects like η Car, P Cyg, and S Dor may play in the evolution of the most massive stars.

The location of these LBV's near the luminosity limit was crucial to understanding its possible cause. The empirical boundary could in principle be explained by steady mass loss, but only at rates much higher than normally observed; and LBV's are notorious for their **sporadic** mass-ejection events, their "eruptions". A stability limit, probably caused by radiation pressure, is a possibility, but the classical Eddington limit due to electron scattering did not show the observed dependence on temperature for the hot stars. However, as temperatures decrease below 30000 K, opacity tends to increase as low-level ions such as H I, Fe II, *et al.*, begin to appear; so we can imagine a **modified** Eddington luminosity limit which decreases with decreasing temperature, like the observed limit. Unfortunately this is not as simple an explanation as it might seem at first sight. Opacities depend on density as well as on temperature, and as the limit is approached a classical static atmosphere would puff up and its opacity would tend to decrease to the electron-scattering value after all. Nevertheless, an instability may occur under these circumstances and several people have written about the hypothetical modified Eddington limit (Humphreys and Davidson 1984; Appenzeller 1986, 1987; Lamers 1986; Davidson 1987; Lamers and Fitzpatrick 1988). Other processes such

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as interior evolution or atmospheric turbulence may contribute to the instability (de Jager 1980, 1984; Maeder 1983).

It should be emphasized that there was no theoretical prediction of the luminosity boundary or stability limit in the upper H-R diagram. Eta Car, P Cyg, and S Dor have been famous for many decades, but it is only recently that we have learned enough about these unstable, massive stars to begin to discuss "the Physics of LBV's." There has actually been very little theoretical work on the mechanism of LBV eruptions and the origin of the instability (see Stothers and Chin 1983, Appenzeller 1986, and *Instabilities in Luminous Early Type Stars*, edited by Lamers and de Loore, 1987). In this field, theory has followed observation.

2. WHAT IS AN 'LBV'?

The term Luminous Blue Variable or LBV was first proposed by Peter Conti (1984) to describe the S Dor variables, Hubble-Sandage variables, and P Cyg stars in recognition of the many properties they share. Luminous Blue Variables are characterized by:

1) *Variability* — Photometric variations are observed on different timescales and to vastly different degrees:

a) Eruptions or outbursts of ≥ 3 mag refer to sudden ejections of large amounts of mass. The best example is of course η Car's famous outburst from 1837 to 1860 when it became the second brightest star in the sky. The timescales for these giant eruptions are of course very uncertain, but because we see so few, hundreds to thousands of years are reasonable estimates of the frequencies of these events.

Other possible examples of these violent eruptions are P Cyg's behavior in the 1600's (see de Jager 1980 and Lamers 1986 for reviews), when it brightened from invisibility to about third magnitude, and V 12 in NGC 2403 (Tammann and Sandage 1968). After such major outbursts, these stars remain relatively quiescent. Davidson's description of 'Plinian' outbursts in this volume gives more information on these violent outbursts.

b) Moderate variations of 1 to 2 mag are often observed on timescales of 10 to 40 years. From the minimum or quiescent phase, the star may brighten by up to two magnitudes, often within a few months. Both the minima and the maxima may last several years, although smaller variations may be superposed. At visual maximum, the star's atmosphere is greatly expanded to form an optically thick pseudo-photosphere. S Dor and R 71 in the LMC, plus several of the Hubble-Sandage variables (Hubble and Sandage 1953) are good examples of this type of variability which may even be semi-regular. Wolf will discuss moderate LBV outbursts (these proceedings).

c) Smaller oscillations of about half a magnitude are often observed on timescales of months to a few years, on top of the longer-term moderate variations.

d) Microvariations of ≤ 0.1 mag have been described by van Genderen *et al.* (1985) for R71, but these variations have also been reported in normal supergiants.

2) Their *spectra* typically show prominent emission lines of H, He I, Fe II, and [Fe II] often with P Cygni profiles when observed at sufficiently high resolution. The spectra are variable, corresponding to the photometric variations.

At visual minimum or quiescence an LBV has the spectrum of a hot supergiant with H and He I emission; the Fe II and [Fe II] emission is strongest at minimum. At visual maximum, the optically thick pseudo-photosphere resembles a much cooler supergiant of spectral type A or F. At maximum the Fe II emission is weaker. At high resolution, P Cyg profiles are still observed in hydrogen and other lines.

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3) The *temperature variations* correspond to the spectral and photometric variations. At visual minimum when the LBV is hottest, its temperature is ≥ 15000--20000 K and at maximum the LBV's all seem to have minimum temperatures near 8000 K. Davidson (1987) showed that the expanded pseudo-photospheres asymptotically approach a minimum value near 7500 K no matter how high the mass-loss rate.

4) As their name implies, the LBV's are stars of *high intrinsic luminosity*. Their bolometric magnitudes remain essentially constant during visual light variations of up to 2 mag (see Appenzeller and Wolf 1982 and Wolf *et al.* 1981 concerning R 71; Stahl and Wolf 1986 for R 127; and Leitherer *et al.* 1985 for S Dor.) The well-studied LBV's have absolute bolometric magnitudes brighter than -9 mag ($L \geq 10^{5.5}\ L_{\odot}$).

5) The active or shell ejection (pseudo-photosphere) phase of an LBV coincides with *high mass-loss rates*, typically 10^{-5} to $10^{-4}\ M_{\odot}$/yr. These rates are 10 to 100 times those of normal supergiants. In quiescence their mass-loss rates are more like those of normal supergiants of the same temperatures and luminosities. The observed mass-loss rates as well as most of our information on temperatures have resulted from extensive moderate- and high-resolution ground-based and UV studies of these stars in our galaxy and the LMC by many different groups.

6) Most LBV's show some evidence for an excess of *infrared radiation* and *circumstellar ejecta*. A small excess in the near-IR (1--3 μm), due to free-free and free-bound emission, is common (Humphreys *et al.* 1984; Leitherer *et al.* 1985). Many of these stars also have longer-wavelength radiation due to circumstellar dust (McGregor *et al.* 1988). In the case of η Car the dust is thick enough to obscure the star (Westphal and Neugebauer 1969). These circumstellar shells and ejecta are produced by the high mass loss and ejection of shells from the LBV's.

Some of this ejecta is clearly visible, as in the 'homunculus' of η Car, although this case is perhaps exceptional. More common is the presence of a ring nebula as in AG Car (Thackeray 1977; Stahl 1987). Papers in this volume by Stahl, Paresce, and McGregor will review observations of circumstellar shells and ejecta. If LBV's shed a few × 10^{-5} $M_{\odot}$/yr, then during the LBV phase, usually estimated as 10^4--10^5 yr, they may lose up to a solar mass or slightly more.

But there is considerable circumstantial or *circumstellar* evidence that the total mass lost in the LBV phase may be much more than inferred from the nominal few × 10^{-5} $M_{\odot}$/yr. Eta Car probably lost 2--3 $M_{\odot}$ during its famous 1840's outburst and its current mass-loss rate is estimated at 10^{-4} to $10^{-3}\ M_{\odot}$/yr.

More typical examples are P Cyg, AG Car, and R 127. In quiescence P Cygni's mass-loss rate is ~ 1.5 × $10^{-5}\ M_{\odot}$/yr. If it is like other LBV's, then the rate during its outburst was 10--100 times greater or 10^{-4} to $10^{-3} M_{\odot}$/yr. From direct imaging of circumstellar shells around AG Car, R 127, and others, Stahl (1987) estimated their kinematic ages and masses and concluded that their average mass-loss rate must be > $10^{-4} M_{\odot}$/yr. In our poster paper on the LBV's in M31 and M33 we show that a shell of photoionized gas around AE And contains > 6 × $10^{-3} M_{\odot}$. This is probably the material ejected during its last maximum, which lasted ~ 20 years, implying > 3 × $10^{-3} M_{\odot}$/yr during the ejection event. Thus, a massive star could lose several solar masses during its LBV stage.

Quantitative analyses of the ejecta, as in η Car, and the atmospheres and circumstellar envelopes of these stars and related objects show that they are nitrogen- and helium-rich (Davidson *et al.* 1982, 1986; Allen *et al.* 1985; and review by Walborn 1988). This is presumably CNO-processed material brought to the surface by mixing and mass loss.

The observed characteristics are consistent with a scenario for the LBV's as *evolved, very luminous, unstable* hot supergiants which suffer *irregular ejections*. The cause of their instability is very likely radiation pressure (see refs. cited above), resulting in a greatly enhanced average mass outflow which leads to the formation of a pseudo-photosphere (Leitherer et al. 1985) at visual maximum. At this stage the slowly expanding (100--200 km/s) envelope is cool (8000---9000 K) and dense (N ~ 10^{11} cm^{-3}), and the star resembles a very luminous A-type supergiant. At minimum light, or the quiescent state, the LBV is at its 'normal' high temperature (> 15000--20000 K) and the mass-loss rate is lower. During these variations the bolometric luminosity remains essentially constant. The visual light variations are caused by the apparent shift in the star's energy distribution driven by the instability.

With these remarkable properties, it is not surprising that the LBV's have come to play a critical role in our current thinking about the evolution of the most massive stars. With their high luminosities, enriched ejecta, and high mass-loss rates, similar to WR stars, they are commonly considered to be evolved objects in transition to the WR stage (Maeder 1983). Thus the LBV's may be a relatively short, highly unstable, but important phase in the lives of the most massive stars.

An alternative possibility, first proposed by Bath (1979) and further developed by Gallagher *et al.* (1981) and Kenyon and Gallagher (1985), is that LBV's are contact binaries (or at least close binaries) of lower mass (~ 20 $M_{\odot}$) and their peculiarities are then caused by mass flow onto an accretion disk. There is no evidence for mass exchange in the LBV's, but R81 in the LMC is an eclipsing binary (Stahl et al. 1987). Gallagher will discuss the possible role of binaries later in this volume.

Much of our information about LBV's has derived from studies of only a few well-known examples, especially P Cyg, S Dor, η Car, and more recently R127 and AG Car. There are actually very few known or confirmed LBV's. The known LBV's in nearby galaxies are listed in Table 1. Although there are many luminous emission-line stars, most are not known to be significantly variable. Because long quiescent periods are possible, some of those stars may also eventually be found to be LBV's. Although I expect more LBV's to be identified, only careful analyses will show whether they are LBV's or other types of luminous emission-line stars.

Table 1. CONFIRMED LBV'S IN NEARBY GALAXIES*

Milky Way:	η Car, AG Car, HR Car, P Cyg.
LMC:	S Dor, R71, R127, HDE 269582.
M31 (1,2,3,4):	AE And, AF And, Var A-1, Var 15.
M33 (1,2,3):	Var A (?), Var B, Var C, Var 2, Var 83.
NGC 2403 (5):	V12, V22, V35, V37, V38.
M81 (6):	I1, I2, I3.
M101 (7):	V1, V2, V10.

*The underlined stars are included in Table 2 as relatively well-studied LBV's.
Refs.: (1) Hubble and Sandage 1953; (2,3) Humphreys 1975, 1978; (4) Rosino and Bianchini 1973; (5) Tammann and Sandage 1968; (6,7) Sandage 1983, 1984.

Table 2. OBSERVED PROPERTIES OF WELL-STUDIED LBV'S

Galaxy	*Star*	*Observed temperature* (K) 'at min'	'at max'	M_{bol}	$\dot{M}$ ($M_\odot$/y)
Milky Way	η Car	27000:	---	-11.3	10^{-3} to 10^{-1}:
	P Cyg	19000	---	-9.9	2×10^{-5}
	AG Car	25000:	9000	-10.1	3×10^{-5}
LMC	S Dor	20000--25000:	8000	-9.8	5×10^{-5}
	R 71	13600	9000:	-8.8	5×10^{-5}
	R 127	30000	8500	-10.5	6×10^{-5}
M 33	Var C	20000--25000	7500--8000	-9.8	4×10^{-5}
	Var A	3500:	8000:	-9.5	2×10^{-4}

Except for the LMC, the galaxies with confirmed LBV's are all spirals. There are no known LBV's in the SMC and as far as I know none have been confirmed yet in IC 1613 or NGC 6822, two less luminous irregular galaxies. This may be primarily a statistical effect, because these smaller galaxies have fewer of the most massive stars; they also contain few WR stars. The lack of LBV's is consistent with the ideas that LBV's are in a relatively short stage in the evolution of massive stars ($\geq 40\ M_\odot$) and that they are possible progenitors of WR stars.

3. THE ROLE OF LBV'S IN THE UPPER H-R DIAGRAM AND THEIR RELATIONSHIP TO OTHER EVOLVED MASSIVE STARS

As I mentioned above, the upper H-R diagram is characterized by an obvious upper envelope to stellar luminosities. The temperature dependence of the observed boundary for the hot stars and the relatively well-defined upper luminosity limit for the late-type hypergiants suggest that this is a critical location in the diagram (Humphreys and Davidson 1979, 1984). Garmany and Fitzpatrick will discuss the observed luminosity/stability limit in these proceedings.

Figure 1 shows a schematic H-R diagram with the well-studied LBV's from Table 2. The LBV's maintain essentially constant luminosity between their quiescent (minimum visual light) and shell-ejection (visual maximum) phases. The dashed lines in Fig. 1 show their variations in photospheric temperature between these phases. The solid lines are the upper luminosity boundary for the hot stars and for the cool hypergiants, although the limit for the hot stars is not yet precisely defined.

Very massive stars ($\geq 40\ M_\odot$ in their post-main sequence evolution eventually encounter the stability limit as they attempt to evolve to cooler temperatures, leading to enhanced mass loss, the pseudo-photosphere stages. Apparently the usual result is unsteady behavior (outbursts) rather than an enhanced long-term steady wind. After an LBV has lost enough mass in an eruption, the instability is temporarily relieved and the star returns to its quiescent state, presumably until the instability develops again. Appenzeller (1986) and Lamers (1986) suggested that the LBV instability is caused by radiation pressure in numerous ultraviolet Fe lines. Then the modified Eddington luminosity should depend on metallicity. The observed luminosity boundary and the

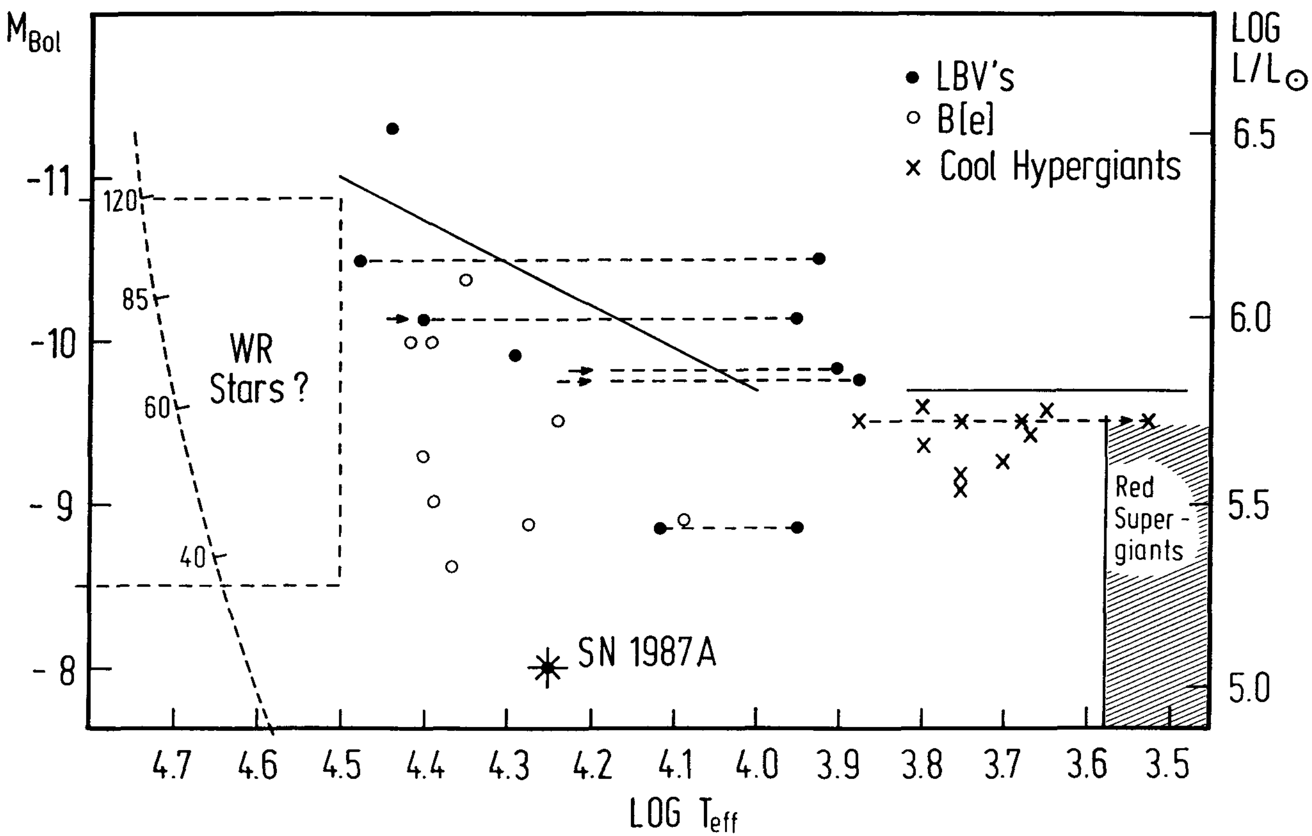

Figure 1. The upper HR diagram showing the location of the LBV's in Table 2, the B[e] supergiants and the cool hypergiants. The solid lines mark the temperature-dependent luminosity boundary for the hot stars and luminosity limit for the cool supergiants.

luminosities of LBV's should be higher in low-metallicity systems. This is not discernible in the available data for massive stars in different galaxies, but other effects such as population statistics may dominate.

Several of the stars in Figure 1 deserve special comment:

R 127 is especially important because it was one of the few Of/WN stars originally recognized by Walborn (1977) before its recent eruption (Stahl *et al.* 1983). It is now at maximum light and its spectrum is nearly identical with that of S Dor at maximum.

Var C in M33, after nearly 40 years of relative quiescence, is now in its false-photosphere stage (Humphreys *et al.* 1988). In 1985 it was at visual maximum with a spectrum like a very luminous F-type supergiant, and it is still bright.

Var A, another of the original Hubble-Sandage variables in M33, is perhaps the most peculiar. Its spectrum at maximum in the early 1950's was that of a very luminous F-type supergiant. It then declined rapidly by nearly 4 mag, becoming red. Recent observations reveal a very large infrared excess (Humphreys, Jones, and Gehrz 1987) and its total luminosity today is equal to that at maximum light. What is peculiar about Var A is its current spectrum; rather than being a hot star within a dust shell, it has the TiO bands of an M supergiant. Our best explanation for its remarkable behavior is that Var A is not a true LBV but rather is an evolved very luminous hypergiant, very close to its stability limit, which ejected an optically thick shell (*cf.* papers by Smolinski and by de Jager, this volume, on cool supergiants). Whether it will actually evolve to the red supergiant stage is uncertain. Its location on the HR diagram at maximum and minimum is shown in Figure 1 together with the location of cool hypergiants. I think Var A should be considered with the cool hypergiants, many of which are unstable, such as ρ Cas and HR 8752.

R 71, with absolute bolometric magnitude ≈ -9.0, is below the observed luminosity limit and is the faintest of the well-studied LBV's. Since it is in the LMC, there is little uncertainty in its distance. It has a lower temperature at minimum light than other LBV's (Wolf *et al.* 1981). It certainly deserves further attention.

AG Car has usually been assigned a distance of ~ 2500 pc corresponding to the large young associations in the Carina region. At that distance its luminosity would be only $M_{bol} \approx -8.7$ mag, far below the stability limit. For this reason I recently looked for other clues to its distance. Its systemic velocity of +18 km/s, measured by Wolf and Stahl (1982) from the center of the P Cygni profiles of the strongest Fe II lines, or +21 km/s, measured from Fabry-Perot interferometry of the nebula (Johnson 1976), implies a distance far beyond 2500 pc. If this velocity is due to differential galactic rotation, then its kinematic distance is 7 kpc and M_{bol} is around −11.2 mag, a luminosity more appropriate to its spectral characteristics. In their poster paper at this meeting, Lamers and his collaborators present additional evidence for a larger distance based on its extinction. Stahl (1986) has noted that the spectrum of AG Car at minimum is very similar to the Of/WN9 stars.

The close relationship between the Of/WN9 stars and LBV's such as R 127, AG Car, and HDE 269582 = MWC 112 provides important support for suggestions that LBV's are the predecessors of WR stars. There are now seven known Ofpe/WN9 stars in the LMC (Walborn 1972, 1982, 1985). R 127 is one of the Of/WN9 stars and of course is a known LBV. Two others, R 84 and R 99, are also variable with smaller amplitudes (Stahl *et al.* 1984) and are probably related to the LBV's. Obviously this is a group of stars that should be closely monitored and more effort should be made to find their counterparts in our Galaxy (*e.g.*, He3 - 519 -- Stahl 1986).

Many luminous emission-line stars share spectroscopic characteristics, such as H and He I emission with P Cygni profiles and Fe II and [Fe II] emission, with LBV's. Among them are the B[e] ("B-bracket" or "B-bracket-e") supergiants. Zickgraf *et al.* (1985, 1986) have identified several important distinctions between LBV's and B[e] supergiants. The B[e] stars are not variable; their emission-line spectra are hybrid with narrow Fe and [Fe II lines but broad absorption components in H, He I, and UV resonance lines with terminal velocities typical of B supergiant winds. These hybird characteristics are explained by a two-component model with a normal B supergiant wind from the poles and a denser, slower-moving equatorial disk. Zickgraf gives more information about the B[e]'s in this volume. Their location in the H-R diagram is shown in Figure 1. They overlap the LBV region but tend to be somewhat less luminous on the average. Is there a possible evolutionary connection between the B[e] supergiants and LBV's? Can the latter recover from their instability, shed their angular momentum, and evolve to the red supergiant stage, or are they binaries?

The H-R diagram in Figure 1 illustrates the variety of objects and the diversity of behavior near the luminosity/stability limit. We have made great progess in our understanding of the structure and evolution of the most massive stars, but as we learn more about the different stars that populate the upper H-R diagram, the situation appears not to be as straightforward as we might have assumed a few years ago.

4. QUESTIONS AND FUTURE PROBLEMS

New observations of LBV's and other objects in the upper H-R diagram continually reveal new and important clues to their evolution and therefore to physical processes inside them. Spectroscopic and photometric monitoring of these unstable stars must continue. An important observational problem is how to identify more LBV's for better statistics on their relationships to other objects.

The scenario in which LBV's have evolved primarily from very massive stars and are progenitors of WR stars is increasingly clear. A possible sequence is

$$\mathrm{O} \rightarrow \mathrm{Of} \rightarrow \mathrm{LBV} \longleftrightarrow \mathrm{Of/WN} \rightarrow \mathrm{WR}.$$

What about their relationship to other luminous massive stars? In the upper H-R diagram we also observe the B[e] supergiants, unstable cool hypergiants, and luminous red supergiants with high mass-loss rates, some with thick circumstellar shells. What are the relationships among the different kinds of massive stars near the luminosity/stability limit? Is the LBV phenomenon indirectly responsible for the red-supergiant upper limit which is so useful as an extragalactic distance indicator? And precisely what are the roles of initial mass, age, evolutionary status, rotation, internal angular momentum distribution, and binarity?

The fundamental question concerns the cause or causes of the LBV instability. The star's evolution has brought it close to the limit of its stability. We talk about radiation pressure and turbulence, but what is the actual mechanism or trigger for the moderate ejections like that of S Dor and the violent outbursts like that of η Car? Is the physics the same for both types of event? Why and how does an LBV recover from its pseudo-photosphere eruptive state? Shedding a lot of mass apparently relieves the instability, but why? Perhaps the most pressing questions about LBV's are more theoretical than observational, though there are enough observational questions! In this colloquium on the 'Physics of Luminous Blue Variables' we may make some progress toward understanding their structure and behavior.

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DISCUSSION

De Jager: Sometimes it has been proposed that LBV's be called hypergiants, but this would not be correct in terms of spectroscopic classification. Hypergiants are stars that show the supergiant spectral characteristics still more pronouncedly than normal supergiants, but have only moderate emission lines or P Cygni profiles, not at all like LBV's. We should note that some hypergiants may be closer to the upper limit than LBV's, but they do not show the large episodical eruptions.

Wolf: I like your new distance to AG Carinae. As I will point out in my talk, there seems to be a correlation between the amplitude of S Dor-type eruptions and luminosity. Accordingly I would expect a much higher luminosity for AG Car than previously thought.

Walborn: The possibility of an amplitude-luminosity relation (later types at visual minimum for less luminous LBV's) is interesting. However, the true minimum states of P Cyg and S Dor may not yet have been observed spectroscopically, so it is possible that at minimum they could also turn out to be Ofpe/WN9 objects.

Humphreys: On this H-R diagram P Cyg is shown in its present quiescence and an arrow indicates that S Dor has probably come from higher temperatures.

Gallagher: Can the radial velocity of AG Car be influenced by the presence of circumstellar dust? For example, optical depth effects could produce an apparent blue shift.

Humphreys: Its radial velocity has been determined in two ways, one of which uses nebular lines. If significant circumstellar optical depth effects occur, the two determinations would presumably differ.

McGregor: The optical depth of the dust in the AG Car shell is low; the extinction is small.

Sreenivasan: You talked about the expansion of the pseudo-photosphere. Do you believe that the observations suggest that the expanding material actually falls back on the star, or do they suggest that the expanding material leaves the star and thereby reveals a hotter object?

Humphreys: The pseudo-photosphere is the apparent surface, representing optical depths of order unity, and material can move through it. After an outburst the pseudo-photosphere presumably contracts back to its former state which may be a photosphere in the normal, static sense.

Appenzeller: At least in one case (S Dor, see Leitherer *et al.* 1985, *Astron. Astrophys.* **153**, 168), the radial velocities of absorption lines formed deep in the pseudo-photosphere indicate that the pseudo-photosphere actually contracts when the visual brightness decreases at the end of an outburst.

Friedjung: I think that we should clarify what is meant by a pseudo-photosphere. In the case of a nova the optically thick region produced by the initial explosion does not last very long. Then one sees an optically thick wind. Does one see optically thick winds in the case of LBV's?

Humphreys: Yes, when they are not in their quiescent states.

Shore: About 100 years after Herschel's remarks about η Car there was a possibly analogous explosion near Alamagordo. In a nuclear explosion, the photosphere initially expands and then stalls, the outer shock breaks away and the pseudo-photosphere recontracts. The effective temperature of this 'photosphere' remains roughly constant, the shock advances and is optically thin, while the photosphere cools and contracts.

Baratta: We show in our work that not only Var C in M33, but also η Car in the actual phase, displays the spectral type of an F supergiant.

Lortet: Where is R81 in the H-R diagram? -- This one may be a non-variable star.

Humphreys: I did not include R81, an eclipsing binary, in this diagram, because its LBV characteristics are somewhat uncertain.

Moffat: Polarization studies are often neglected by astronomers. Particularly, the ejection phenomenon and its geometry (with asymmetries!) can be effectively, even uniquely(?) probed.

Humphreys: That is a good idea. Polarimetry has scarcely been done on the LBV's, except for Hayes' work on P Cyg (1985, *Astrophys.J.* **289**, 726).

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