ATMOSPHERIC PHENOMENA IN ETA CARINAE
AND THE HUBBLE-SANDAGE VARIABLES

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ABSTRACT. From the analysis of the galactic counterparts of the HS variables, η Car, AG Car and P Cyg we conclude that their atmospheres are near critical physical conditions so that small changes of the mass outflow could produce a large variation of the atmospheric structure and nova-like explosions at nearly constant Mbol.

The Hubble-Sandage variables (HSV) are bright objects in outer galaxies which are known for their large photometric variability on very long time scales. The HSV's are among the most luminous stellar objects and may represent a phase of the evolution of very massive stars after having left the main sequence. The problem is to find the origin of their variability and its relation with the stellar parameters and position in the HR diagram close to the observational Humphreys-Davidson upper boundary. HSV's are difficult to study because of their apparent faintness. There are however a number of HSV homologues in our Galaxy and in the Magellanic Clouds which show a similar behaviour and are commonly considered as the galactic or MC counterparts of HSV's. The best known objects in the Milky Way are η Car, AG Car and P Cyg. In the following we shall discuss the main properties of these stars and their evolutionary implications.

a. The light curves. η Car is known for its large luminosity variations which took place the last century. During 1830-1850 the star was variable between 0 and 2 mag. Since 1856 . Car gradually faded to the seventh magnitude in about 14 years. Actually this fading was only apparent. In fact Andriesse et al. (1978) found that the present bolometric magnitude (=0.0) is close to the estimated bolometric magnitude during the bright phase. This suggests that η Car is presently surrounded by a dust envelope formed during the fading phase, which is absorbing most of the optical and UV radiation from the central star.

The P Cygni star AG Car has displayed in recent years large luminosity variations from V=6 to 8, associated with deep spectral change. The equivalent spectral type was A at maximum luminosity in 1981, and became B in 1983 and Of/WN in 1984 (Viotti et al. 1984; Stahl 1986). Viotti et al. from an analysis of UV to IR energy distribution of AG Car found that the variations occurred at almost constant bolometric magnitude (about -8.3) in spite of the large visual luminosity variations. Large photometric variations have been observed in luminous P Cygni stars in the LMC. Also in this case it has been found that these variations are caused by flux redistribution in the atmospheric envelope, whilst the bolometric luminosity remains nearly constant (e.g. Wolf and Stahl 1983).

This was probably also the case of P Cyg itself which has been rather stable since around 1780, but previously was found variable with light maxima in 1600-06 and 1639-59 when the star reached the third magnitude and was 'reddish'. Deep minima were recorded during 1606-56 and 1659-83 with occasional fadings below visibility (see de Groot 1969). If the star at maximum was redder than today, then most of the light was probably emitted at optical wavelengths, and its bolometric correction should have been close to zero. Since according to Lamers et al.(1983) the present BC of P Cyg should be close to -1.6,the magnitude difference between the bright phase (V=3) and now (4.8) is practically equal to the difference in BC's. The conclusion is that during the 17th century maxima P Cyg probably had the same bolometric luminosity than now and that no major 'explosion' occurred at that time. The variations between 3 mag and 5-6 mag should be ascribed to change of the temperature of the atmosphere at

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and 5-6 mag should be ascribed to change of the temperature of the atmosphere at constant Mbol and to the related energy redistribution like in the case of AG Car and of the LMC variables discussed above. The deep fadings during 1600 are most likely associated with dust formation like in η Car. The following brightening should be the result of the destruction or dilution of the circumstellar dust envelope (Viotti 1987).

b. Chemical composition. The chemical composition of the atmospheres of these objects is difficult to be determined because of their peculiar spectrum. A comparison of the optical spectrum of AG Car with P Cyg and other B and Be stars led Caputo and Viotti (1970) to conclude that carbon and oxygen should be underabundant in the expanding atmosphere of AG Car. This star is surrounded by a ring nebula formed about 4000 years ago and probably containing dust particles (Viotti et al. 1987). A chemical anomaly seems also to be present in η Car. Altamore et al. (1986) from the absence of the CIII] and CII] lines in the UV spectrum of η Car suggested a low C/N abundance ratio. Also the ejected condensations surrounding the central star appear to be nitrogen rich (Davidson et al. 1982). In η Car dust is continuously condensing in the expanding wind (Andriesse et al.1978) and the chemical composition should have an important role in the process of dust formation and growth. Andriesse et al. suggested that the gas condenses in the form of a cluster of silicates. It should be important to investigate the effect of the anomalous chemical composition on the process of dust formation in AG and η Car.

To conclude, observations indicate that in the galactic and MC luminous blue variables large variations occur at constant bolometric magnitude associated with change in the structure of the atmospheric envelope and/or to dust formation and destruction. From a study of the light curves of HSVs we conclude that the same should happen in those objects. Probably the atmospheres of these very luminous, high mass losing stars are subject to instabilities whose effects are enhanced by a sudden increase (or decrease) of the line opacity. Thus the star becomes yellower and its visual luminosity increases. Probably an occasional consistent but not necessarily very large increase of the mass loss rate might produce a drastic decrease of the temperature even below the grain condensation temperature followed by dust condensation in the outer atmospheric layers. In this case molecular opacity should play an important role as in M supergiants. This process has been observed in η Car and produces a large and sudden luminosity fading like those observed in many HSV's. This fading is only apparent since most of the radiation is emitted in the IR.

There are many aspects of the HSV phenomenon which should require much future work. One problem is their possible multiplicity. Hofmann and Weigelt (1986) found that η Car is (at least) a quadruple system. This has a strong impact on the estimate of the luminosity and mass loss rate of the central star. If the frequency of multiple systems in the luminous blue variables is high (e.g. Mayor and Mazeh 1987), their evolutionary stage as well as the upper boundary of the HR diagram should be reconsidered.

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