ASSA NATIONAL SYMPOSIUM – 1992

RECENT VARIABILITY IN THE S DORADUS-TYPE STAR AG CARINAE

T.P. COOPER

Abstract

After a long period of inactivity the S Doradus-type variable star AG CARINAE recently underwent an outburst. Historical details of this and other S Dor-type variable stars, as well as light curves showing the recent variability of AG Carinae are presented.

What are S Doradus varibles

S Doradus stars, also known as luminous blue variables (LBV's) are a small number of stars characterised by slow irregular brightness variations over periods of years or decades.

They were previously known as P Cygni stars [1] due to spectral similarities with that star, ie: broad emission lines flanked by narrow blue-shifted absorption lines. Since the same P Cygni phenomenon is also seen in other stars which do not show variability the reclassification was made to the prototype S Doradus.

S Doradus variables are characterised by masses > 40-50 $\mathcal{M}_\odot$, spectral type B or A and high luminosity, m≈-8±2. The P Cygni spectral profile arises from a massive outpouring of gas away from the surface of the star to a surrounding circumstellar shell. The blue-shifted absorption lines are caused by gas moving in the direction of the observer [1]

Occurrence of S Doradus Variables

Hoffmeister [1] lists seven stars definitely of S Dor type, and these are listed in Table 1. Z CMa is also listed but its inclusion is in doubt due to lower luminosity. Bateson [2] and Morel [3] list a further ten candidates as S Dor or S Dor ?, and these are listed in Table 2. Most of the stars in these two tables can be monitored by amateur astronomers.

Sharov [4] and Viotti [5] list a number of bright irregular variables, known as Hubble Sandage variables (HSV's), in the galaxies M31, M33, M101 and NGC 2403. These are thought to be S Dor-type variables, but are beyond the reach of most amateur instruments.

Table 1 S Dor stars after Hoffmeister

AE AND
AF AND
AG CAR
HR CAR
η CAR
P CYG
S DOR

Table 2 S Dor stars after Bateson and Morel

V766 CEN
V4029 SGR
HD 37836
HDE 269006
CPD-69 420 ?
HD 32763 ?
HD 34664 ?
HDE 269700 ?
HDE 269858 ?
NSV 2499 ?

Evolution of S Doradus Variables

The following evolutionary path has been theorised for the S Doradus stars [6,7,8]. They probably begin life on the Main Sequence of the HR diagram as O-type stars of about 60 solar mass and spend about 3 x 10 years at this stage burning oxygen into helium. Initially they lose matter slowly, like other hot OB stars. However, as the hydrogen becomes depleted, the mass and the temperature decreases, the outer layers expand leading to dramatic episodes of mass loss and buried helium becomes exposed as the new atmosphere. Heating up again, the stars subsequently fade, but being too unstable to evolve into red giants they may become supernovae or Wolf-Rayet stars, characterised by high luminosity and temperature, strong emmission lines including those of helium, and an expanding atmosphere. The LBV stage may last for about 10 years. Thus they are transient objects which explains why so few of them are known.

Historical Details of some S Doradus-type Stars

eta CAR
Probably the best known of the class. eta Car was first seen as a magnitude 4 star by Halley in 1677 (6). Figure 1 shows the magnitude variations since 1826 (2, 6, 9). There was also a smaller well defined maximum in 1889 not shown in Figure 1. (10).

P CYG
This star probably brightened from magnitude 6 in 1597 to magnitude 3 in 1602 (5, 6). It fluctuated between magnitude 3 and 6 until 1715 with a possible second maximum in 1655. It has remained fairly constant since 1715 at magnitude 5. This long period of inactivity has also been observed in other HSV's (5) and implies that some stars of this type remain to be discovered.

S DOR
Prototype of the class. Figure 2 shows the magnitude variations of this star. It showed deep minima in 1891, 1900, 1930, 1940, 1955 and 1964 (11). It appears to have started a further decline during 1991(2).

HR CAR
Figure 2 also shows the magnitude variations of this star. It appears to show quiescent states at about magnitude 9.5 with broad maxima lasting up to 10 years and reaching magnitude 8 or brighter. Since 1987 it has brightened from magnitude 8.5 to nearly magnitude 7 at present.

FIGURE 1
PREVIOUS VARIABILITY IN ETA CARINAE

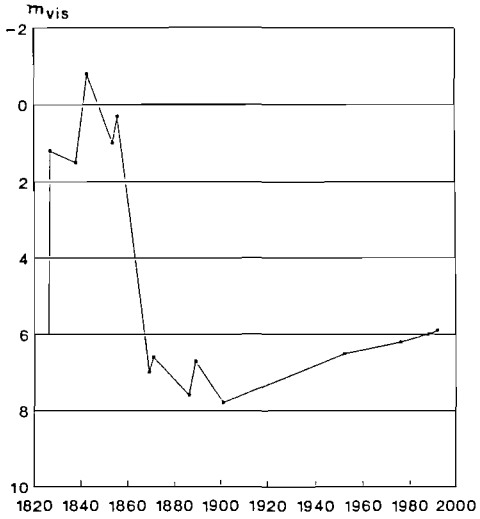
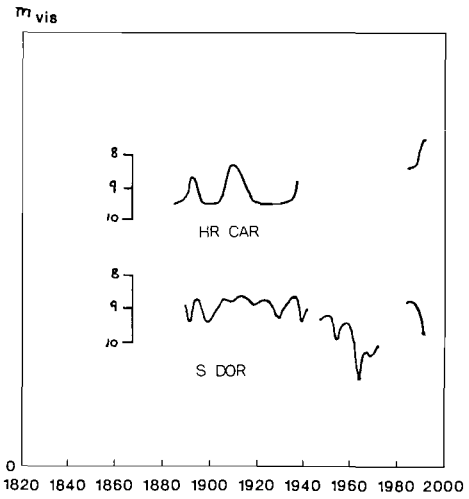


FIGURE 2
PREVIOUS VARIABILITY IN SOME S DOR STARS



V776 CEN
Observations began in 1988 (2) with the star at magnitude 7.8. The star has since fluctuated between magnitude 7.0 and 7.5.

V4029 SGR
Observations began in 1988 (2). The star has remained at a constant magnitude of 8.3

Variability of AG Carinae

This star lies at the centre of a hollow oval planetary nebula PK 289-0.1, blown out by an episode of extensive mass loss [8]. The nebula was described by Thackeray [12] and is shown in Figure 3. It was probably ejected in a nova-like outburst about a thousand years ago [13].

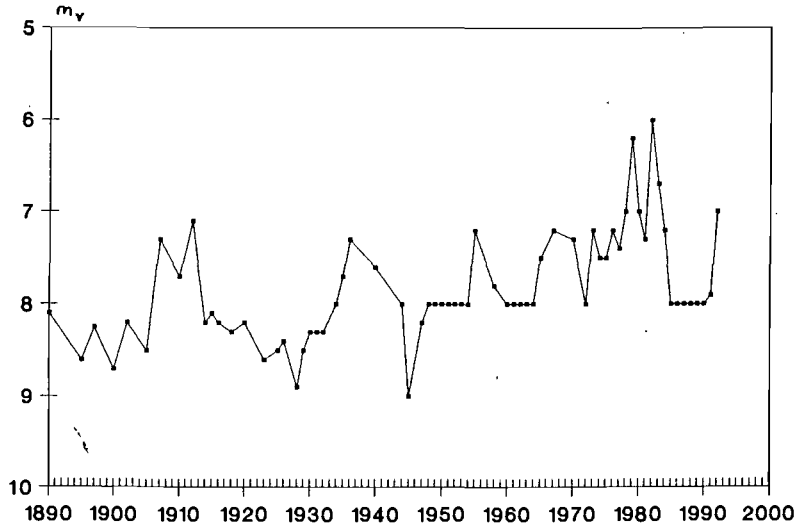
The nebula appears as a elliptical ring with outside dimensions of 39" x 30" with major axis in PA about 150°. The width of the ring is about 5".

Variability in AG Carinae is shown in Figures 4, 5 and 6. Figure 4 shows a composite light curve from 1890 to the present time, derived from [2, 4, and 5]. Figure 5 shows more recent behaviour from 1978 based on data kindly submitted by the Variable Star Section RASNZ [2]. Figure 6 is based on observations made by the author, commencing at December 1985, and shows more clearly the 1991 outburst.

Thackeray mentions AG Car as being unusually bright in 1911. The composite light curve is in agreement, the star having brightened to about magnitude 7.1. Subsequent outbursts are apparent; in 1936 reaching magnitude 7.3, in 1955 reaching magnitude 7.2, in 1967 and 1973 reaching 7.2, in 1979 reaching 6.2 and 1981 reaching magnitude 6.0. Mayall [14] says the star brightened in 1964 from magnitude 7.9 in August to 7.4 in October.

Figure 3
PK289-0.1 and AG CAR

Figure 4
Composite light curve of AG Car



After the 1981 outburst, AG Car faded slowly to magnitude 8.0 over a period of three years. From 1985 to 1990 it remained at about this magnitude with possible small amplitude variations.

The 1991 outburst appears to have commenced at about Julian Date 2448 300 and reached a maximum magnitude of about 7.0 about Julian Date 2448 600. It is currently fading again and was at magnitude 7.4 on Julian Date 2448 730.

Figure 5
Observations from RASNZ

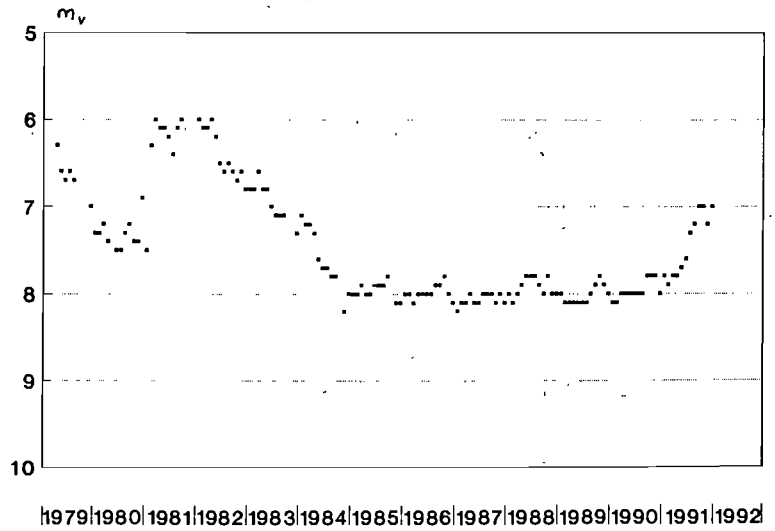
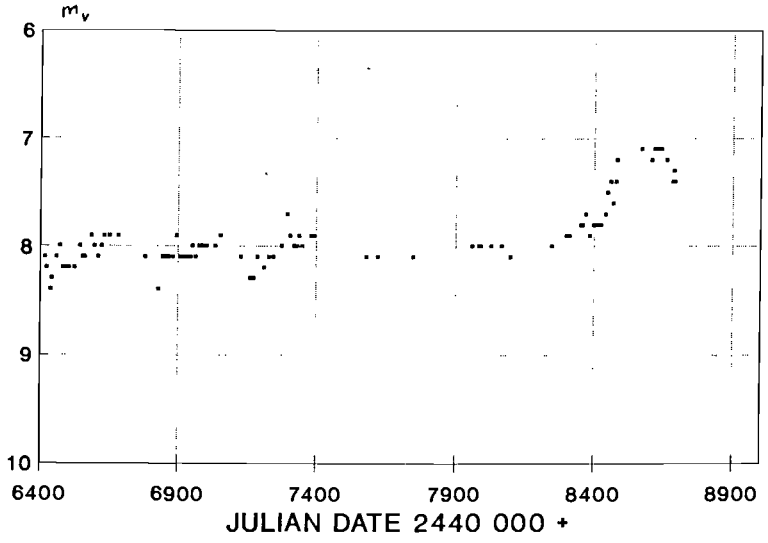


Figure 6
Observations by the Author



Conclusion

The S Doradus stars have been described previously by one eminent South African observer as "Do Nothing Stars". Hopefully this paper shows that these stars are indeed exciting to observe, given a modicum of patience and perseverance.

In light of the importance of these stars in our understanding of stellar evolution, they surely warrant closer observation. Bearing in mind that some astronomers see S. Doradus variables as the precursors to supernovae, the results could be quite rewarding.

Acknowledgements

The author greatly acknowledges the following persons for contributions of information used in this paper:

Dr David Kilkenny, SAAO
Dr Frank Bateson, RASNZ
Danie Overbeek

References

1. Hoffmeister C, Richter G, and Wenzel W;
In Variable Stars, Springer Verlag 1985, p 176

2. Bateson F.M;
Monthly Circulars of the RASNZ, Variable Star Section

3. Morel M;
A visual Atlas of the LMC, 1983

4. Sharov A.S;
IAU Sympo 67, 1975, p 275

5. Viotti R;
In Variable Star Research: An International Perspective,
Cambridge University Press, 1992, p 194

6. Hoffmeister C ibid p 177

7. Sky and Telescope, Vol 61, p 20

8. Sky and Telescope, Vol 79, p 362

9. Sky and Telescope, Vol 51, p 376

10. Sky and Telescope, Vol 54, p 24

11. Bateson F.M;
Changing Trends, No: 23

12. Thackeray A.D; MNRAS 110 p 524
(No: 6 1950)

13. Bateson F.M;
Changing Trends, No: 36

14. Mayall M.W.; JRASCan 60, p 93