

*Letter to the Editor***On the recent brightening of η Carinae***C. Sterken^{1,**}, L. Freyhammer^{1,2}, T. Arentoft¹, and A.M. van Genderen³¹ University of Brussels (VUB), Pleinlaan 2, B-1050 Brussels, Belgium² Nordic Optical Telescope, Apartado 474, E-38700 Santa Cruz de La Palma, Spain³ Leiden Observatory, Postbus 9513, 2300 RA Leiden, The Netherlands

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Abstract. We report and discuss the steady brightening of η Carinae, and conclude that this brightening is not an eruption, but an expected LBV S-Doradus phase which, typically, displays intense brightening coupled to strong reddening when the star moves redwards in the H-R diagram. The brightness gradient amounts to $-0.15 \text{ mag } \text{y}^{-1}$ over the last two years.

Key words: techniques: photometric – stars: variables: general – stars: supergiants – stars: oscillations – stars: individual: η Carinae

1. Introduction

The most recent in-depth report on the light variability of η Carinae (HD 93308) was published by van Genderen et al. (1999). These authors discuss a quarter-century of optical photometry of η Car, and come to the conclusion that the core of η Car hides a normal S Dor variable – that is, an LBV (Luminous Blue Variable): it shows light variations on a time scale of 1–4 y, with superimposed micro oscillations. Their analysis of the brightness of η Car in the ultraviolet passbands of three photometric systems (Walraven, Strömgren and Geneva) reveals the presence of an important variable ultraviolet source with a striking 200 d-oscillation during the last 5 years.

Recently, Davidson et al. (1999) report that Hubble Space Telescope STIS observations show that the *central star* of the η Car system unexpectedly increased in brightness by a factor of about two (0.6–0.8 mag.) between Dec. 1997 and Feb. 1999 at wavelengths around 800 nm; the images and slit spectra also show similar brightening in at least the inner parts of the Homunculus nebula. This evidence is supported by ground-based photometry yielding $V \sim 5^{\text{m}}.25$ indicating a $0^{\text{m}}.45$ difference since the end of 1997, appearing to be the largest and most rapid brightening of η Car in the past half century.

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We have obtained more than 1500 Strömgren-band CCD frames in 1997–99 at the Dutch 91 cm telescope at ESO, La Silla with the ESO #33 CCD (512×512 pixels, FOV $3'.5 \times 3'.5$). These observations were obtained in the frame work of the Long-Term Photometry of Variables (LTPV) project (Sterken 1983, 1994). Integration times in y were about 4 seconds in 1997, and gradually decreased to a mere 2 s in 1999 due to the steady brightening of the object.

The data frames were properly corrected for bias and flatfield (sky-flats), and were reduced using aperture photometry based on the IRAF reduction package. A circular diaphragm of $13''$ was used for calculating aperture photometry of the central core with some contributed light of the surrounding homunculus. The y and b magnitudes were left in the instrumental system, but a zero-point offset was applied using observations of the nearby (constant) comparison star HD 93502 (see van Genderen et al. 1995).

In view of the importance of this object for the planning of follow-up observations by different teams later this year, we present in this letter our most complete light curve. The fully-calibrated four-colour light curves, complemented by the results from dozens additional frames, will be submitted for publication by the next η Car observing season.

2. Light- and colour curves

Fig. 1 shows the nightly averages in the Strömgren y band, and the corresponding nightly averaged $b - y$ colour index. The overlapping data (+) discussed by van Genderen et al. 1999 and the new data (●) fit very well. The dashed line indicates the expected run of $b - y$ deduced from the behaviour of the Geneva photometric colour indices as reported by van Genderen et al. (1999). The figure reveals a steady brightness increase till the end of 1998, followed by a decline after February 1999. $b - y$ indicates a marked reddening from 1997 on, with outspoken blueing since the last months of 1998. As this evidence illustrates, the rise in brightness since mid-1997 is not at all unexpected, nor does it represent an eruption: the light- and colour behaviour is the signature of a typical S Doradus phase.

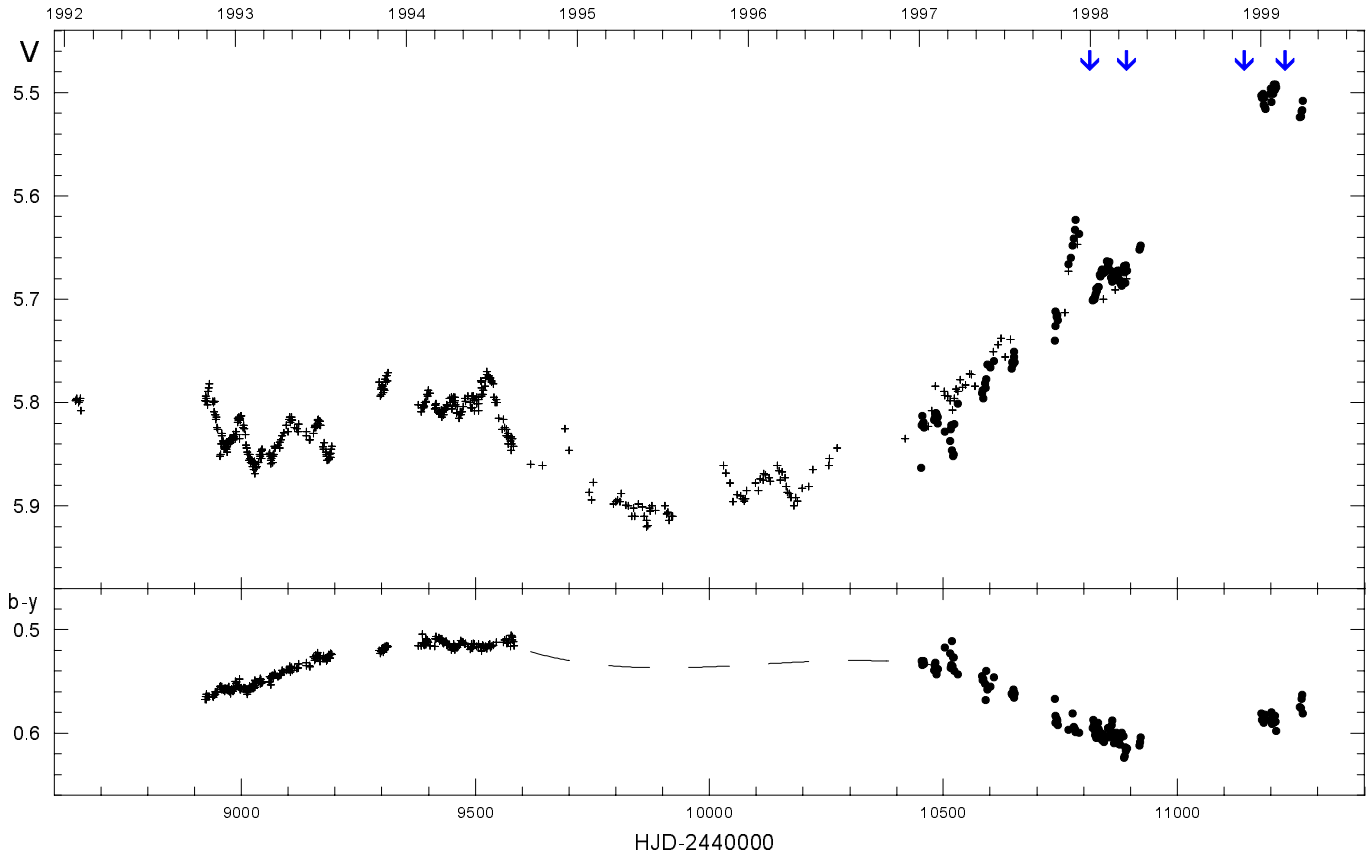


Fig. 1. V (based on Walraven and Geneva V and Strömgren y) light curve and $b - y$ colour index of η Car (nightly averages): + are data discussed by van Genderen et al. (1999), • are new data obtained since. The dashed line is based on Geneva colours as derived from Fig. 2 of van Genderen et al. (1999) and fills in the lacking $b - y$ information. Arrows indicate the times of HST-STIS observations given by Davidson et al. (1999).

3. The difficulties of η Car photometry

η Car, by its appearance as an extended object and by its spectral anomalous nature, is the single most difficult stellar object to measure or to monitor over a long time interval. The problems belong to several levels: very limited availability of an astrophysically appropriate photometric system, the presence of strong (and variable) emission lines, the need for a telescope with a suitable f -ratio, and the steadily decreasing possibilities to collect data over a long period of time.

η Car photometry unavoidably is a mixture of UBV , Walraven $VBLUW$, Geneva $UBVB_1B_2V_1G$ and Strömgren $uvby$ photometry based on CCD and photomultiplier detectors. Fig. 2 shows the passbands of the four photometric systems that are being used these days. Non-specialists often do not realise that ultraviolet-blue colour indices (like $u - v$, for example) just cannot be transformed to homologous counterparts (such as Johnson $U - B$) because of the fact that the location of the Balmer discontinuity – but also the presence of strong emission lines – drastically influences the related spectral energy gradient. Such transformation problems are less disturbing in the visual passbands, but still render any comparison of isolated photometric magnitudes and colour indices very difficult: the combination of non-overlapping data taken with different detectors, different

diaphragm sizes and different filter systems (even seemingly-close UBV systems) is, to say the least, hazardous. From our previous experience, we estimate that such systematic effects may easily reach 0.1–0.2 mag (see van Genderen et al. 1994, 1995 on the construction of the “ V_J ” magnitude concept). As such, when comparing our η Car V_J magnitudes with isolated Johnson- V measurements, great care must be taken because the unavoidable differences between photometric systems may result in very significant discrepancies. After all, V_{Johnson} is what is measured with a photometer using a Johnson V filter, while V_J is a magnitude *constructed* from y , V_{Walraven} or V_{Geneva} , corrected for the aperture differences.

The data presented in Fig. 1 do not suffer from such effects, since every section of the light curve contains, at least, half a dozen points that overlap with the subsequent part. As such, we can make a safe estimate of the average gradient of brightening: $\sim 0^{\text{m}}15 - 0^{\text{m}}16 \text{ y}^{-1}$ over the last two years.

4. Conclusions

We have documented with new data the light- and colour history of the most recent brightening phase of η Car, which we identify with a normal S Dor phase. Our data are important for placing the HST-STIS measurements in a proper context and will help

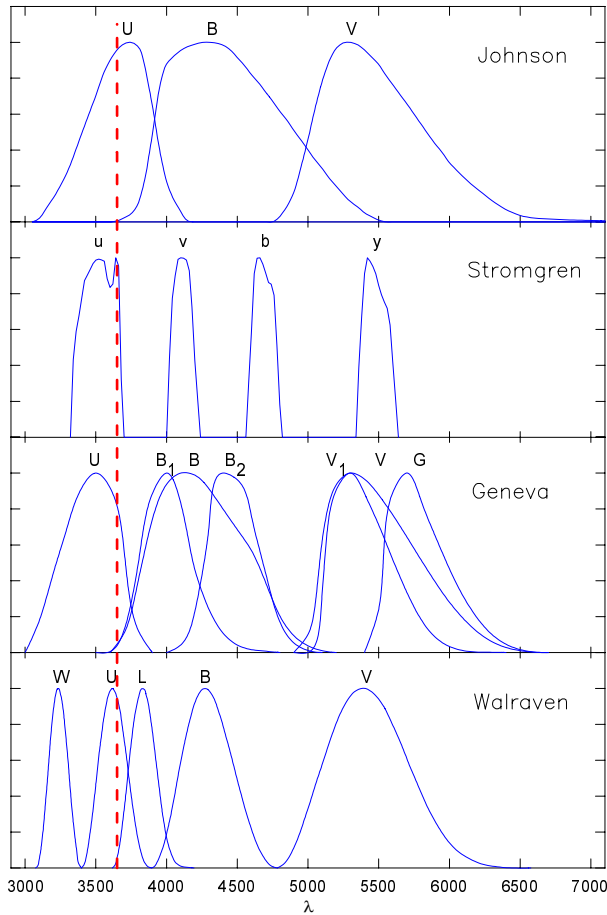


Fig. 2. Passbands of the four photometric systems most frequently used for monitoring η Car. The dashed line represents the position of the Balmer jump.

to outline the basic difference between these sets of measurements: whereas the STIS measurements refer to the central star (near-infrared observations at 0.1 arcsec spatial resolution), the groundbased photometry encompasses the light from the surrounding homunculus.

The ground-based magnitudes and colours will serve as a guide for covering the following phase of decline, at the same time they vividly illustrate that any useful photometric monitoring of this most enigmatic star must satisfy the conditions of

1. being multi-colour – that is, in a suitable multi-colour photometric system
2. delivering a vast amount of data – that is, sparse data sets such as HST observations supplemented with isolated ground-based measurements are inadequate to understand the brightness status of an enigmatic object like η Car
3. yielding data that overlap in time in order to assure contiguous and homogeneous blending of adjacent light-curve sections.

Unfortunately, our attempts to organise simultaneous monitoring of η Car at another site when we concluded our March 1999 observing run have failed.

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