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JUST ONE NEW MEASUREMENT OF THE B[e] SUPERGIANT HEN-S22

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This paper reports one new photometric measurement of the most peculiar B[e] supergiant Henize-S 22 (HD 34664, hereafter S 22), and accentuates the problems of transformability of magnitudes and colour indices from one photometric system to another for stars with very peculiar spectra.

S 22 is a luminous star of the LMC that was for the first time studied by Henize (1956), who listed it as an $11^{m}_{.}4$ object. The star is located in `Association 38` (NGC 1871), as defined by Lucke & Hodge (1970). The object exhibits the B[e] phenomenon, and thus belongs to one of the most peculiar classes of stars known (according to Zickgraf 2006, only 15 such stars are known in the Magellanic Clouds). Zickgraf (2000) gives a definition of B[e] stars by naming physical conditions in the circumstellar environment, rather than by identifying intrinsic stellar properties. He points out that in this widely inhomogeneous group of stars, **it is the similarity of the circumstellar conditions that prevails over the dissimilarity of the stellar properties**.

The spectrum of S 22 is dominated by a curtain of narrow emission lines – allowed and forbidden – of singly-ionised iron, with almost no other absorption lines than the Balmer series (Muratorio 1978). Allen & Glass (1976) found a large infrared excess, which they attributed to circumstellar dust clouds.

Bensammar et al. (1983) investigated the complex gaseous environment of the star, and speculated that the stellar energy distribution comes from radiation formed in an accretion disk, rather than from an optically thin free-free emission region. These authors also found spectroscopic similarities with LBVs, in particular with η Car.

Shore (1990) reported that the star underwent massive shell ejection, and that it displayed one of the most extreme optical Fe II and [Fe II] emission spectra of any of the massive LMC supergiants. This author concludes that S 22 likely is in the luminous blue variable (LBV) shell-ejection phase, having been stable during 1980–1983, and he alerts for possibly dramatic changes to come. Shore (1992) consequently shows evidence that the optical brightness of S 22 has increased by more than one magnitude since 1983.

Two questions on the light constancy of B[e] stars remained unanswered for long:

1. do these stars exhibit light variations on short time scales, and
2. what is their behaviour in the long run, i.e., on time scales of decades.

Van Genderen & Sterken (1999) showed that S 22 undergoes microvariations up to $0^{m}_{.}1$ in the Walraven V band, accompanied by colour variations of similar amplitudes. These authors recognise a low-amplitude S Doradus cycle (large-amplitude long-term variability in light and colour on time scales of years) on a time scale of about 7 years, and classify

S 22 as a weak-active LBV. These findings were recently confirmed by Szczygieł et al. (2010), who find evidence for a similar S Dor-like oscillation of the order of six years.

Table 1 gives a synoptic overview of all available photometric data on S 22, and their characteristics, and Fig. 1 shows the resulting light and colour curves. The data are described chronologically, hence the new data are discussed under items 11 and 12 below.

Table 1. The photometric data on S 22: photometric system, detector (with photocathode specification), full width at half maximum (FWHM), symbol (S) in Fig. 1, standardised or not (+ sign means that standard stars are listed, – sign means that standard stars are not specified), aperture size (in arcsec), type of photometry: all-sky or differential (comparison star given). The last column indicates whether photometric transformations were made within one photometric system (intra), or from one system to another (inter).

#	Photometric system	Detector (photocathode)	FWHM	S	Std	Ap.	Type	Transf.
1	photographic $m_{\rm ph}$	Kodak photographic plate	–	△	no	–	all-sky	–
2	Johnson V	PMT RCA-1P21 (S-4)	90	∗	yes+	?	all-sky	intra
3	Walraven $VBLUW$	PMT RCA-1P21 (S-4)	72	×	yes–	16.5	all-sky	inter
4	Johnson UBV	PMT EMI6256 (S-13)	90	□	yes+	15	all-sky	intra
5	Johnson UBV	PMT EMI 9502 and 9558	90	▲	yes–	18	all-sky	intra
6	Johnson UBV	PMT RCA-1P21	90	○	yes+	?	all-sky	intra
7	Johnson UBV	PMT EMI6256 (S-13)	90	⋆	yes–	15	all-sky	intra
	Bessell $UBVRI$	PMT RCA31034A	85	⊛	yes–	15	all-sky	intra
8	Walraven $VBLUW$	PMT Hamamatsu R928 (S-20)	72	×	yes–	16.5	HD 33486	inter
9	IUE FES no filter	PMT (S-20)	250†	■	no	8	all-sky	–
10	ASAS-3 V	CCD THX7899M	80	−	no	45	all-sky	–
	ASAS-3 V	CCD THX7899M	80	+	no	45	all-sky	–
11	Strömgren $uvby$	PMT EMI 9789	24	♦	no	17	HD 34144	inter
12	Bessell V	CCD KAF6303E	85	•	no	18	HD 269209	inter

References. 1: Cannon & Pickering (1918); 2: Smith (1957); 3: van Genderen (1970, 2011); 4: Ardeberg et al. (1972); 5: Dachs (1972); 6: Lucke (1972, 1974); 7: Zickgraf et al. (1986); 8: van Genderen & Sterken (1999); 9: Shore (1990); 10: – Szczygieł et al. (2010), + Szczygieł et al. (2010), adjusted; 11: this paper; 12: this paper.
Note †: FWHM of item 9 was derived from the width at half maximum of the photocathode spectral response curve, as shown in Fig. 3 of Morrison (1967). The S-20 photocathode picks up radiation from 250 to 800 nm.

1. Photographic magnitude: Henize (1956) lists $m_{\rm ph}$ taken from the Henry Draper Catalogue. Observing date is uncertain, but most probably around 1917. This photographic magnitude is not directly comparable with V.

2. Vintage $m_{\rm v}$ magnitude: measurement made in January 1954, with a Corning 3384 filter glass, the same type as described in Johnson & Morgan (1951), though it is not clear whether this measurement is on the Johnson–Morgan system that was developed in 1953. No photometer aperture size is given.

3. Early Walraven $VBLUW$: measurement obtained by van Genderen with the Walraven 90-cm light collector in South Africa ($f/14$ optics). V and $B-V$ were derived from the Walraven $\log I$ indices with the transformation formula of Pel (1987).

4. Johnson UBV photometry: ESO 1-m telescope at La Silla, Chile, $f/15$ optical system.

5. Johnson UBV photometry: Bochum 61-cm telescope at La Silla, Chile. The V filter consisted of one Schott GG 495 glass only.

6. Johnson UBV photometry: Cerro Tololo 36″, Chile. No aperture size is given.

7. UBV and $UBVRI$: ESO 50-cm telescope at La Silla, Chile. Partly Bessell $UBVRI$ (these three magnitudes and color indices are encircled in Fig. 1).

8. Walraven $VBLUW$: Walraven differential photometry (intensity scale, relative to the comparison HD 33486) from Figs. 4–6 of van Genderen & Sterken (1999). The magnitudes and $B-V$ indices were transformed to their Johnson V, $B-V$ equivalents using a transformation formula from Pel (1987). Note that the PMT is different from the one used in item 3. Quasi-simultaneous observations with Zickgraf et al. (1986) yields $V = 11.837 \pm 0.006$, $B-V = 0.240 \pm 0.003$ for van Genderen & Sterken (1999), and $V = 11.765 \pm 0.010$, $B-V = 0.27 \pm 0.01$ for Zickgraf et al. (1986).

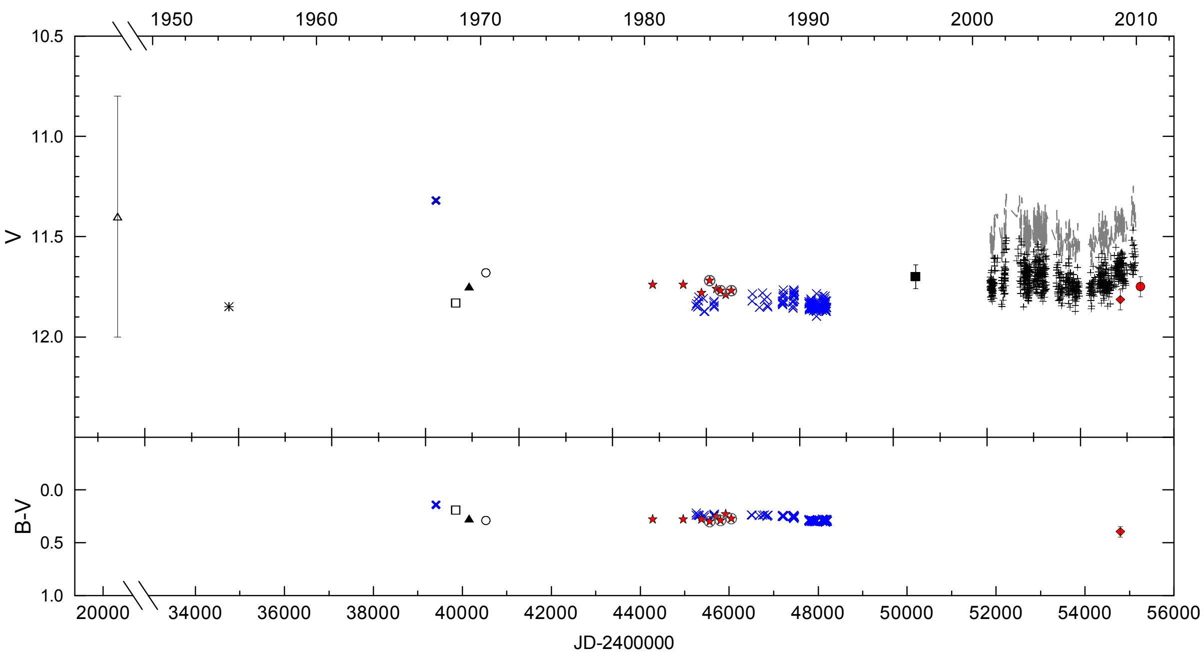

Figure 1. V, $B-V$ light and colour curve of S 22. Symbols are explained in Table 1.

9. IUE quasi-*V*: this data point was obtained with the IUE Fine Error Sensor (FES). The FES was an image dissector with a photocathode response that extended from 250 to 800 nm, with a resulting effective wavelength of about 520 nm. FES measured unfiltered light, and had potential for providing an estimate of V with a precision of about $0\overset{\text{m}}{.}06$ – that is, for stars that have normal spectra. The large FWHM listed in Table 1 is entirely due to the response of the S-20 photocathode that embraces many more emission lines than any of the other V-like passbands in Table 1.

10. ASAS-3 *V*: S 22 is identified as 0513536726.9 in the All Sky Automated Survey catalog (Pojmánski 2002, `http://www.astrouw.edu.pl/asas/?page=acvs`). The V data were obtained with an XBSSL/V filter (from Omega Optical) consisting of a 2.0-mm GG 495, and a 3.0-mm S-8612 Schott glass, with an incident beam of $f/2.8$. 846 V magnitudes yielding an average $V = 11.489$ with a standard deviation of $0\overset{\text{m}}{.}064$ were discussed in Szczygieł et al. (2010). These data are plotted in Fig. 1 with greyish lines appearing above the + symbols that were obtained from the same dataset, after applying a correction of $0\overset{\text{m}}{.}22$, as explained below.

11. Strömgren *uvby*: this new measurement is the average of two measurements obtained on 24 and 25 November 2008 with the Strömgren Automatic Telescope (SAT) at ESO La Silla, Chile. A diaphragm of 17″ was used, linear extinction coefficients were determined from the observations of comparison stars, and generic transformation equations to the standard *uvby* system, were applied. The measurements were made differentially with respect to HD 34144, and resulted in $y = 11.82 \pm 0.05, b-y = 0.36 \pm 0.05$. $b-y$ was transformed to $B-V$ using formula (1) of Sterken et al. (2008).[1] Attempts to observe S 22 on Christmas eve of 2008, and on 24 January and 20 February 2009 failed, because the star could not be visualised in the photometer diaphragm viewer.

[1]Note that Sterken et al. (2008) underline that this equation **"should not be considered as a photometric transformation in the true sense, but as a statistical relationship between the observables $b-y$ and $B-V$"** (*i.e.*, for this sample of 18 LBVs). These data support a linear relationship between both variables, and adding a nonlinear term does not significantly improve the goodness of fit. Fig. 4 of Sterken et al. (2008) shows such a nonlinear inter-system transformation relation derived for more normal stars.

12. CCD V measurement on two consecutive nights in February 2009: to establish without doubt that S 22 had not faded beyond the limiting centering magnitude of the SAT, several exposures were obtained with a piggyback-mounted 20-cm refractor, equipped with an SBIG STL6303E CCD camera. The $f/9$ optical system incorporated a focal extender rendering an $f/20$ beam. The V magnitude was obtained differentially with respect to nearby HD 269209 – the brightest star in association NGC 1871 – with spectral type K2, and $V = 10.58, B-V = 0.97$ (Dachs 1972). Since no extinction nor colour correction was applied, the colour difference would lead to errors[2] of $\sim 0^{\rm m}\!.015$ in V, hence this datum is to be considered only as a control measurement to check on the visual disappearance of S 22, and not as an exact magnitude.

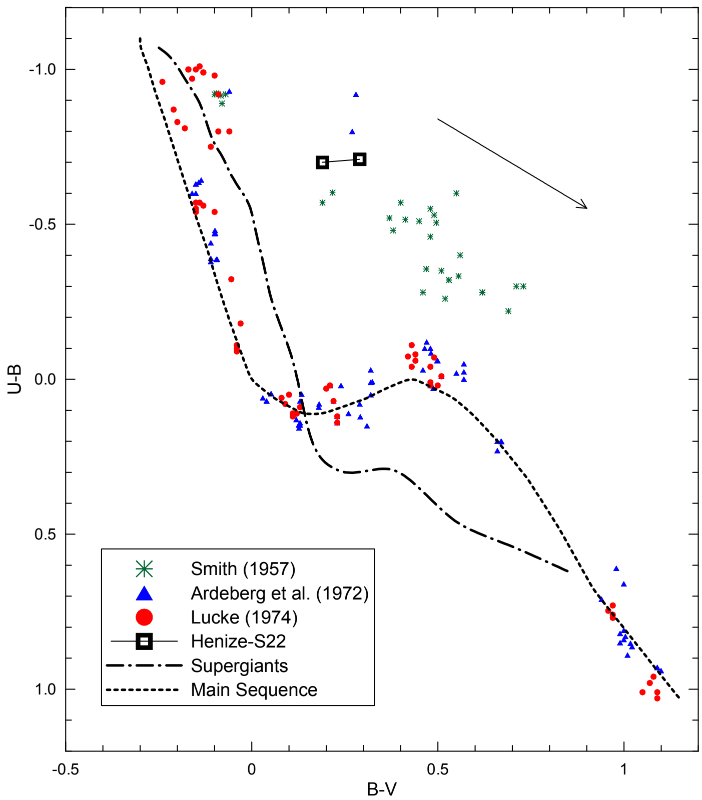

Figure 2. $B-V$, $U-B$ diagram of B0–K5 standard stars used for observations listed in Table 1. The dashed lines represent the intrinsic colors of main-sequence stars and supergiants as determined by Johnson (1966). The arrow gives the slope of the reddening line.

The basic principles of photometric standardisation. Sterken (2003) summarised the basic requisites for bringing long-term photometric data to a common standard. The following discussion centralises on two basic assumptions in astronomical photometry: *i*) that the data were obtained in a well-defined photometric system – thus **the problem of standardisation**, and *ii*) that the data can be transposed from one such system into another – thus **the problem of transformability**. This discussion bears on elements of hardware, as well as on the selection and the spectral nature of the observed targets and the standards.

1. A photometric system is defined by the set of filters, by the detector, by the set of standard stars that were used to define the system, and by the data reduction procedure.

[2]The multiplicative colour term in V is of the order of -0.03 (Landolt 2011).

2. All transformations from instrumental system to their parent standard system (labeled *intra* in Table 1) that use matrix manipulations (involving magnitudes and color indices) require compatible (and partly overlapping) passbands (see Young 1994 for a discussion), and spectral energy distributions that have continuous derivatives in the interval covered by the passbands. Note that extinction corrections (atmospheric as well as interstellar) also participate in the transformations.
3. All transformations from one standard system into another (labeled *inter* in Table 1), involve even more stringent requirements (as hinted at in the footnote on item 11).

The above points illustrate that two thirds of the datasets in Table 1 are on a standard system, but that only 25% of them explicitly list the standard stars. Fig. 2 shows the $B-V$, $U-B$ diagram for all published photometry of the B0–K5 stars of these 3 sets, and reveals that two datasets are most probably commensurable, but also uncovers that the set of standards does not really cover the location where S 22 is placed. The publication by Smith (1957) lists 8 bright standards that are closer to S 22 in the two-colour diagram (these stars have declination between $-30°$ and $-40°$, and their standard values were defineded at Mount Wilson).

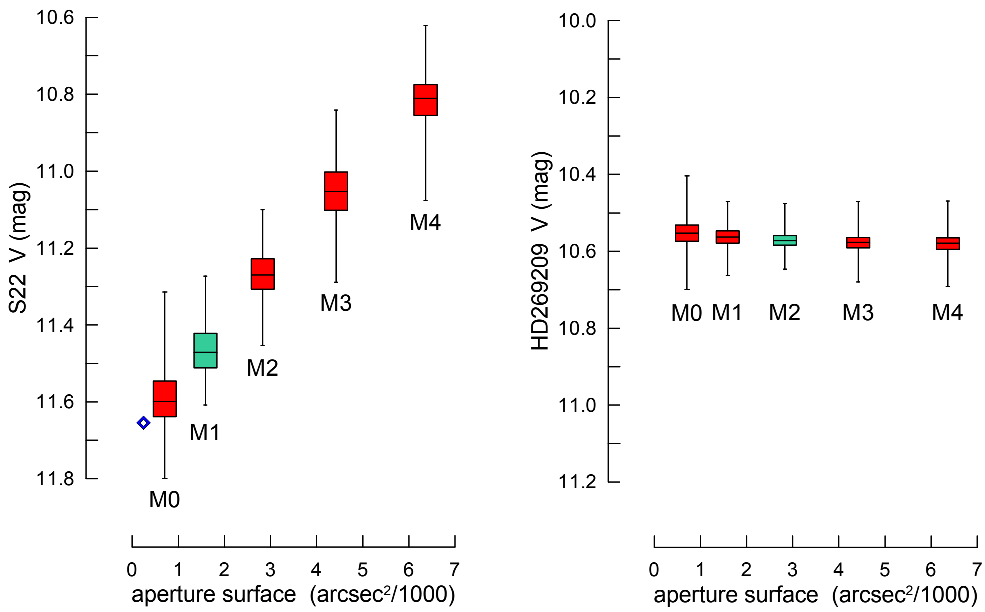

Figure 3. Box-whisker plots of S 22 (left) and HD 269209 for ASAS magnitude columns MAG_0–MAG_4 as a function of aperture surface. The most extreme outliers were clipped in order to keep the whiskers within the lower axis limits. The aperture automatically suggested by the ASAS software (MAG_1 for S 22, MAG_2 for HD 269209) is indicated. ⋄ is the extrapolated ASAS V for a diaphragm of 18″ diameter.

Adjustments. None of the data discussed in Table 1 were adjusted or corrected with any of the other datasets, simply because almost none of these datasets is on a same photometric standard system, or on one that can be rigorously transformed into another – although some of the data (for example, the sets discussed under items 7 and 8) can be brought to a common scale. This point is corroborated by the simultaneous photometry (in the same system) described in item 8, revealing a systematic difference $\Delta V = 0.08$.

The large discrepancy between the ASAS data and the SAT data, however, needs more explanation.

Fig. 3 shows box-whisker plots for the V magnitudes of S 22 and nearby HD 269209 (ASAS 051429-6728.4) for ASAS-3 magnitude columns MAG_0 to MAG_4, as a function of aperture surface. Box-whisker plots display data by showing the minimum of a sample, the lower quartile (which cuts off the lowest 25% of the data), the median, the upper quartile, and the highest data point, *without any assumption of the underlying statistical distribution of the data*. The Figure shows that, whereas the standard deviation of the average V magnitudes in the four apertures is $0\overset{\mathrm{m}}{.}01$ for HD 269209 (see also Fig. 4), it amounts to $\sigma = 0\overset{\mathrm{m}}{.}24$ for S 22. Moreover, **an unmistakable strong trend of brightening with aperture surface is present**. The $\diamond$ is the extrapolated ASAS V (linear fit M_3 to M_0) for a diaphragm of 18″ diameter. The ASAS-3 data were thus first corrected for this aperture effect, and then adjusted differentially with respect to the V value of HD 269209 as measured by Dachs (1972). The + symbols in Fig. 1 show the result of this adjustment.

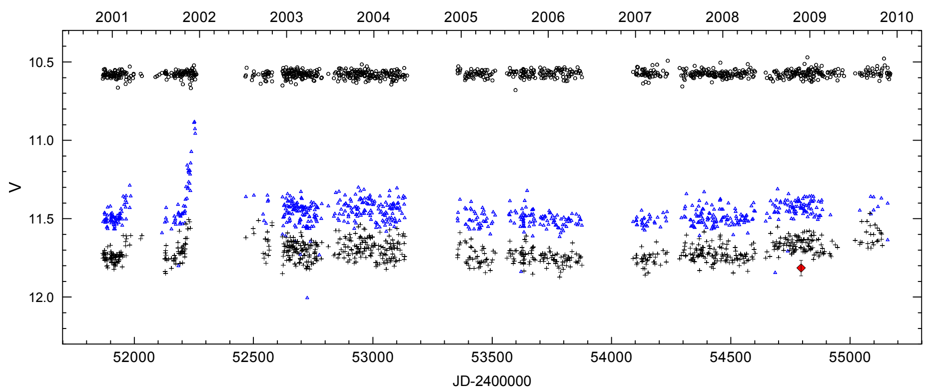

Figure 4. V light curve of S 22 for 2000–2010. Top to bottom: HD 269209 (○); ASAS grade A data from the ASAS-3 catalog (△); adjusted V magnitudes from Szczygieł et al. 2010 (+, the difference between this dataset and the original is that the latter was cleaned by removing points that lie more than 3σ from a local linear model, Szczygieł 2011); ♦: this paper.

Conclusions. This procedure-oriented paper discusses data collected since the 1950s that lead to the following conclusions:

1. the star seems to have brightened by about $0\overset{\mathrm{m}}{.}1$ since the 1990s, with an indication that this brightening is accompanied by a slight reddening – a typical signature of a possible long-term S Dor phenomenon;
2. the detected strong aperture-dependent trend in the ASAS-3 data can be entirely ascribed to the star's environment, as evidenced by the infrared excess, and the nebular emission lines;
3. systematic differences between datasets are evident, and can be ascribed to the different combinations of detectors, filters and diaphragms/apertures (8″–45″), and incident beam widths (off axis rays cause an increase in effective glass thickness);
4. the remaining magnitude residual ASAS/SAT can be ascribed to the lack of colour corrections, and to the causes mentioned in the previous point, as also explained for Wray 751 in Sterken et al. (2008), and for η Car in Sterken et al. (1999).

These conclusions sustain the statement made for η Car (Sterken 2000): **"the unavoidable differences between photometric systems may result in very severe discrepancies, rendering the morphological shape of the light curve piecewise dependent on the instrumental setup."** This is exactly what the case of S 22 proves.

EPILOG

This postscript addresses three questions.

1. **What are the lessons learned from these data?** Besides the arguments listed in the conclusions, there is one most important lesson to be drawn: when discussing the most exotic objects over time scales of half a century or longer, datasets should be calibrated in such a way that data from one epoch are directly comparable to data from another. That principle forcibly excludes two types of photometric data, viz.,

    1. filterless photometry, such as IUE-FES magnitudes described under item 9, and
    2. visual estimates, as mentioned under item 11: the CCD measurements, and the independent ASAS data reveal that the impression that S 22 suddenly dropped below the visual threshold, was unfounded. That the star could not be visually detected may have been the consequence of bad seeing, or of observer fatigue.

    That visual observations – and those made without filter – are unacceptable, was one of the very wise decisions taken by the IBVS Editors (Editorial Note, 4 May 2004).

2. **What is the value of the new measurements?** Experimentalists know that one single observation or measurement never can confirm nor refute an independent set of data. The new magnitude measurements reported under items 11 and 12, though taken with different instruments, not only confirm each other, but also allow to bring another set of valuable data closer to a standard value.

3. **What is the value of publishing such data?** The value of publishing these data refers to two aspects: the intrinsic value of the data, and the value of publishing these result in an information bulletin like IBVS.

    1. Fig. 1 shows two datablocks covering nearly a decade (items 8 and 10), and these data, evidently, are valuable, because they describe light and colour variability, together with the time scale of the associated cyclicity. The other datasets cover only a few points, sometimes even only one single measurement. But each of these datapoints is an element of valuable information, the more so because most of them have been obtained by experienced observers.
    2. Where else can such single isolated datapoint be published? The dataset shown in Fig. 1 covers, approximately, the full life time (6000 bulletins) of this journal. The pressure these days to only count (and value) papers in impact-factor indexed journals makes it almost impossible to publish such results in any of the classical ISI-counted journals – although they are of a very labor-intensive character. That IBVS is in full Open Access, i.e., involving reading rights, but also writing rights (no page charges) for the entire world, is a factual bonus and an example of really open scientific communication. That is the true value of this journal, and means much more than the seemingly accurate counts provided by any other bibliometric indicator.

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DEDICATION. I dedicate this paper to Katalin Oláh and Johanna Jurcsik, Editors of IBVS since the year 2000.

References:

Allen, D. A. & Glass, I. S. 1976, ApJ, 210, 666
Ardeberg, A., Brunet, J. P., Maurice, E., Prevot, L. 1972, A&A Suppl., 6, 249
Bensammar, S., Friedjung, M., Muratorio, G. & Viotti, R. 1983, A&A, 126, 427
Cannon, A. J. & Pickering, E. C. 1918, Harvard College Obs. Annals, 92, 1
Dachs J. 1972, A&A, 18, 271
Henize, K. G. 1956, ApJS, 2, 315
Johnson, H. L. 1966, Annual Review of Astron. and Astrophys., 4, 193
Johnson, H. L. & Morgan, W. W. 1951, ApJ, 114, 522
Lucke, P. B. 1972, PhD Thesis (paper not available, data listed in SIMBAD)
Lucke, P. B. 1974, ApJS, 28, 73
Lucke, P. B. & Hodge, P. W. 1970, AJ, 75, 171
Morrison, C. W. 1967, Applied Optics, 6, 573
Muratorio, G. 1978, A&A Suppl., 33, 125
Pel, J. W. 1987, Internal Report, Leiden Observatory
Pojmánski, G. 2002, Acta Astron., 52, 397
Shore, S. N. 1990, IAU Circular No. 5005
Shore, S. N. 1992, ASP Conf. Ser., 22, 342
Smith, H. J. 1957, PASP, 69, 137
Sterken, C. 2000, IBVS, 5000, 1
Sterken, C. 2003, Baltic Astr., 12, 454
Sterken, C., Freyhammer, L., Arentoft, T. & van Genderen, A. M. 1999, A&A 346, L33
Sterken, C., van Genderen, A. M., Plummer, A. & Jones, A. F. 2008, A&A 484, 463
Szczygieł, D. M. 2011, private communication
Szczygieł, D. M., Stanek, K. Z., Bonanos, A. Z. et al. 2010, AJ, 140, 14
van Genderen, A. M., 1970, A&A, 7, 49
van Genderen, A. M., 2011, private communication
van Genderen, A. M. & Sterken, C. 1999, A&A, 349, 537
Young, A. T. 1994, in *The Impact of Long-Term Monitoring on Variable Star Research*, C. Sterken & M. De Groot, Eds., NATO ASI Series C, Dordrecht: Kluwer, 436, 421
Zickgraf, F.-J. 2000, ASP Conf. Ser., 214, 26
Zickgraf, F.-J. 2006, ASP Conf. Ser., 355, 135
Zickgraf, F.-J., Wolf, B., Leitherer, C. et al. 1986, A&A, 163, 119