Spectrophotometry of Very Bright Stars in the Southern Sky

Kevin Krisciunas\textsuperscript{1,2}, Nicholas B. Suntzeff\textsuperscript{1,2}, Bethany Kelarek\textsuperscript{1}, Kyle Bonar\textsuperscript{1}, and Joshua Stenzel\textsuperscript{1}

\textsuperscript{1}Texas A. & M. University, Department of Physics & Astronomy; 4242 TAMU, College Station, TX, USA 77843; krisciunas@physics.tamu.edu
\textsuperscript{2}Texas A. & M. University, Department of Physics & Astronomy, George P. and Cynthia Woods Mitchell Institute for Fundamental Physics & Astronomy, 4242 TAMU, College Station, TX, USA

Received 2016 December 1; accepted 2017 February 3; published 2017 April 4

Abstract

We obtained spectra of 20 bright stars in the southern sky, including Sirius, Canopus, Betelgeuse, Rigel, Bellatrix, and Procyon, using the 1.5-m telescope at Cerro Tololo Inter-American Observatory and its grating spectrograph RCSPEC. A 7.5 magnitude neutral density filter was used to keep from saturating the CCD. Our spectra are tied to a Kurucz model of Sirius with \( T = 9850 \text{ K}, \log g = 4.30, \) and \([\text{Fe}/\text{H}] = +0.4.\) Because Sirius is much less problematic than using Vega as a fundamental calibrator, the synthetic photometry of our stars constitutes a Sirius-based system that could be used as a new anchor for stellar and extragalactic photometric measurements.

Key words: stars: fundamental parameters – techniques: spectroscopic

Online material: color figures, supplementary files

1. Introduction

Flux calibration, whether it be for photometry or spectroscopy, is a fundamental aspect of observational astronomy (Hearnshaw 1996, 2014). Vega (\( \alpha \) Lyr) has been a fundamental photometric and spectroscopic standard for decades (Hayes & Latham 1975; Bohlin 2014; Bohlin et al. 2014). In the 1980's the Infrared Astronomy Satellite (IRAS) discovered circumstellar material around Vega. Subsequently, observations with the Spitzer Space Telescope characterized this material as a debris disk (Su et al. 2005, 2013). Vega may be spectroscopically variable as well (Butkovskaya 2014). Bohlin (2014) comments on the non-variability of Vega. In any case Vega is problematic as a fundamental calibrator.

The Sloan Digital Sky Survey committed to using four principal photometric standards (Fukugita et al. 1996), but in the end relied primarily on the star BD +17\textdegree 4708. Recently, it was revealed that this star brightened by 0.04 mag in the \( UBV R \) bands from 1986 to 1991 (Bohlin & Landolt 2015).

Here we present a set of bright spectrophotometric standards, many of the brightest stars visible in the southern hemisphere during the southern summer. Our data expand the lists of stars observed by Hamuy et al. (1992, 1994) and Stritzinger et al. (2005). Given the increase in sensitivity of instrumentation over the years, it might be the first time in 40 years that carefully calibrated spectra of most of these bright stars have been obtained. Using well-defined bandpasses (Bessell 1990), we can use our spectra to generate \( BVRI \) photometry tied to a model of Sirius, which is a “well behaved” star compared with Vega.

2. The Target Stars

The target stars are situated from \(-70\textdegree\) to \(+9\textdegree\) declination, and all but one have right ascensions ranging from \( \sim 5 \) to 13 hours (see Figure 1 and Table 1). About half the target stars are members of binary or multiple star systems. \( \alpha \) CMa (Sirius) and \( \alpha \) Car (Canopus) are the two brightest stars in the night sky. \( \zeta \) Ori is the brightest O-type star in the sky.

Two other notable stars are \( \epsilon \) CMa and \( \beta \) CMa. The former was the brightest star in the sky 4.7 million years ago (with visual magnitude \(-3.99\)). The latter was the brightest star in the sky 4.4 million years ago (with visual magnitude \(-3.65\)). This was not due to changes in their \textit{intrinsic} luminosities. It was due to their changing \textit{distances} from the Sun (Tompkin 1998).

\( \alpha \) Ori (Betelgeuse) is a variable star. On the basis of 17 years of photoelectric photometry by one of us (KK), we found that its \( V \)-band magnitude ranges from 0.27 to 1.00 (Krisciunas 1982, 1990). A photoelectric light curve obtained from 1979 through 1996 is shown in Figure 2. The mean brightness during these years was \( V = 0.58 \).

On the basis of all sky photometry and differential photometry with respect to \( \phi^2 \) Ori, it appears that HR 1790 (\( \gamma \) Ori; Bellatrix) ranges in brightness in the \( V \)-band by as much as \( 0.07 \) mag (Krisciunas & Fisher 1988).
Only three of our targets ($\beta$ Ori, $\alpha$ CMa, and $\alpha$ CMi) are fundamental $UBV$ standards of Johnson & Morgan (1953). Their targets are primarily northern hemisphere objects.

3. Data Acquisition and Reduction

Three nights were allocated to this project on the CTIO 1.5-m telescope in 2003 January, and eight more nights were allocated in 2005 January. However, due to a variety of hardware and weather programs, we only obtained useful data on two nights, 6 January 2003 and 21 January 2005 (UT). On the first night all the spectra were taken with the blue grating. On the second night all the spectra were taken with the red grating.

Details of the facility spectrograph RCSPEC are discussed by Stritzinger et al. (2005). The blue and red gratings give dispersions of 2.85 and 5.43 Å per pixel, respectively. Stritzinger et al. (2005) give 5.34 Å per pixel as the dispersion of the red grating, but this is a transcription error. The FWHM values are 8.6 Å for the blue grating and 16.4 Å for the red grating. Because of the extreme brightness most of our stars, we included a 7.5 mag neutral density filter in the light path to prevent saturation of the pixels. Our exposure times ranged from 5 to 420 seconds. While the spectra of Landolt standards obtained by Stritzinger et al. (2005) are useful at wavelengths as short as 3100 Å, ours are no good below 3300 Å.

Raw two-dimensional spectra were saved as FITS files 1274 by 140 pixels in size. Batches of four spectra were taken of each star, with the telescope offset 30 arcsec west along the slit between spectra to place the spectrum on a different part of the chip. A He-Ar-Ne arc spectrum was taken before every batch. Once the star was centered in a 2″ slit, the slit width was widened to 21″. Since many of our targets are close binary or multiple stars, this means that many of our spectra are blended spectra of more than one star. On the plus side, such a wide slit eliminates any worries about guiding and seeing, allowing accurate spectrophotometry under clear sky conditions.

For calibration line identification we used A CCD Atlas of Helium/Neon/Argon Spectra, by E. Carder, which can be downloaded at https://www.noao.edu/kpno/KPManuals/henear.pdf.

Figure 1. Positions of our target stars on the sky. The numerical labels are the catalog numbers in The Bright Star Catalogue. Blue dots represent stars that were observed with the blue grating only. Other stars were observed with both the blue and red gratings.

(A color version of this figure is available in the online journal.)
Table 1
Synthetic Photometry of Target Stars

| HR  | Name   | Binary/Multiple? | Spectral Typeb | $X_{\text{blue}}^c$ | $X_{\text{red}}^d$ | B   | V   | R   | I   |
|-----|--------|------------------|----------------|---------------------|---------------------|-----|-----|-----|-----|
| 1544 | $\pi^2$ Ori | N | A1 Vn | 1.338 | 1.427 | 4.381 | 4.365 | 4.365 | 4.351 |
| 1713 | $\delta$ Ori | N | B8 Ia | 1.085 | 1.144 | 0.200 | 0.224 | 0.173 | 0.148 |
| 1790 | $\gamma$ Ori | N | B2 III | 1.253 | 1.352 | 1.425 | 1.653 | 1.756 | 1.888 |
| 1948/1949 | $\delta$ Ori A/B | Y | O9.7b+O9 III+B0 II-IV | 1.376 | 1.223 | 1.635 | 1.826 | 1.874 | 1.968 |
| 2061a | $\alpha$ Ori | N | M1-2 Ia-lab | 1.291 | 1.321 | 2.198 | 0.398 | 0.653 | 1.799 |
| 2299 | $\delta$ CMa | N | B1 II-III | 1.316 | 1.123 | 1.761 | 1.996 | 2.126 | 2.265 |
| 2326 | $\alpha$ Car | N | F0 II | 1.251 | 1.137 | 0.584 | 0.726 | 0.830 | 0.952 |
| 2491f | $\alpha$ CMa | Y | A1 V | 1.123 | 1.077 | 1.425 | 1.420 | 1.408 | 1.400 |
| 2543 | $\alpha$ CMi | Y | F5 IV-V | 1.299 | 1.226 | 0.761 | 0.357 | 0.132 | 0.098 |
| 3307 | $e$ Car | Y | K3 III+B2: V | 1.211 | 1.147 | 3.081 | 1.844 | 1.692 | 0.360 |
| 3685 | $\beta$ Car | N | A2 IV | 1.428 | 1.305 | 1.674 | 1.661 | 1.693 | 1.690 |

Notes. The stars listed in the top half of the table were observed with the blue grating and the red grating. The stars in the bottom half of the table were only observed with the blue grating.

b Harvard Revised number = catalog number in The Bright Star Catalogue.

c From online version of The Bright Star Catalogue, 5th edition, 1991.

d Mean airmass for blue grating spectra obtained on 2003 January 6 UT.

e Mean airmass for red grating spectra obtained on 2005 January 21 UT.

f $\alpha$ Ori is variable. See text for comments.

For reasons we do not understand the final spectrum of each batch often gave an instrumental magnitude that was about $\sim$0.10 mag fainter than the other three. In Figure 3 the slope is $0.237 \pm 0.009$ mag per airmass. The rms residual of the fit is $\pm 0.018$ mag, which is comparable to CCD photometry on a photometric night. The wavelength range for integrating those spectra was 3600 to 5500 Å. This is somewhat wider than the standard B-band filter. From photometry at Cerro Tololo and Las Campanas we find a mean B-band extinction coefficient of $0.262 \pm 0.007$ mag per airmass. The bottom line is that by using RCSPEC as a photometer, we demonstrated that 2003 January 6 was clear the whole night.

Similar considerations for the spectra taken on 2005 January 21 indicate that this night became non-photometric by 05:27 UT. We will only consider spectra taken on this night prior to this time.

The flux calibration of our spectra was carried out with tasks standard, sensfunc, and calibrate within the CTIOSLIT package. With the calibrate task we applied extinction corrections appropriate for Cerro Tololo (found in file onedstds$ctioextract.dat within IRAF).

Spectra were reduced in the IRAF environment. We made extensive use of the spectroscopic reduction manual of Massey et al. (1992). We first bias subtracted, trimmed, and flattened the spectra. One dimensional spectra were extracted with apall in the APEXTRACT package.

Wavelength calibration was accomplished using identify, reidentify, and dispcor in the CTIOSLIT package. Once we had carried out the wavelength calibration we could ask the question: To what extent were our two usable nights clear? To do this one can sum up the instrumental counts over some wavelength range, then take $\sim -2.5 \log_{10}$ of the counts to produce instrumental magnitudes. In Figure 3 we show these instrumental magnitudes versus airmass from 27 Sirius spectra obtained on 6 January 2003. We have eliminated the 9 spectra that were the final spectra of the batches of four on this date. For reasons we do not understand the final spectrum of each batch often gave an instrumental magnitude that was about $\sim$0.10 mag fainter than the other three. In Figure 3 the slope is $0.237 \pm 0.009$ mag per airmass. The rms residual of the fit is $\pm 0.018$ mag, which is comparable to CCD photometry on a photometric night. The wavelength range for integrating those spectra was 3600 to 5500 Å. This is somewhat wider than the standard B-band filter. From photometry at Cerro Tololo and Las Campanas we find a mean B-band extinction coefficient of $0.262 \pm 0.007$ mag per airmass. The bottom line is that by using RCSPEC as a photometer, we demonstrated that 2003 January 6 was clear the whole night.

Similar considerations for the spectra taken on 2005 January 21 indicate that this night became non-photometric by 05:27 UT. We will only consider spectra taken on this night prior to this time.

The flux calibration of our spectra was carried out with tasks standard, sensfunc, and calibrate within the CTIOSLIT package. With the calibrate task we applied extinction corrections appropriate for Cerro Tololo (found in file onedstds$ctioextract.dat within IRAF).
For flux calibration of the blue grating spectra obtained on 6 January 2003 we observed the spectrophotometric standards HR 3454 (observed at a mean airmass of 1.201) and HR 4468 (observed at mean airmass 1.154). For red grating spectra obtained on 21 January 2005 we used the standard HR 1544 for the flux calibration. It was observed at a mean airmass of 1.427. The mean airmass values for the observations of our target stars are given in Table 1. Any systematic errors in the flux calibration with IRAF will be equal to the arithmetic difference of the airmass of the standards and the program stars times the arithmetic difference of the true extinction coefficient as a function of wavelength minus the adopted mean values appropriate to CTIO. For photometric sky and observations above an elevation angle of 45 degrees, any systematic error of the flux calibration should be less than 10 percent in the $B$-band and less than 5 percent in the $VRI$ bands. Relative fluxes of our spectra and synthetic photometry have estimated internal random errors of 3 percent or better (see below).

The final step in our reduction was to tie the spectra to a Kurucz model of Sirius. An ASCII version of an $R = 1000$ spectrum of Sirius was kindly provided by Ralph Bohlin. The sampling is at twice the frequency of the resolution. The model spectrum has $T = 9850$ K, $\log g = 4.30$ and metallicity $[\text{Fe/H}] = +0.4$.

The wavelengths of the model spectrum were in nm, so we multiplied by 10 to convert them to Å. We also want wavelengths in air, rather than vacuum wavelengths. For this we used the transformation given at the SDSS Data Release 7 website. Finally, we used a scale factor of $2.7544 \times 10^{-16}$ to

---

Figure 2. $V$-band magnitude of $\alpha$ Ori from 1979 October through 1996 November. Key to data points: blue dots (K. Krisciunas), green squares (D. Fisher), red triangles (K. Luedeke). Data by Fisher were published by Krisciunas & Fisher (1988). Data by Luedeke were published by Krisciunas & Luedeke (1996). (A color version of this figure is available in the online journal.)

---

6 One must use a model spectrum of appropriate resolution. Otherwise the final spectra may contain spurious features such as fictitious P Cygni profiles. A scaled FITS version of the Kurucz model spectrum can be obtained via http://www.stsci.edu/hst/observatory/crds/calspec.html as file sirius_mod_002.fits. A comment in the header of this file indicates that fluxes have been scaled by $2.7544 \times 10^{-16}$. This accounts for the distance to Sirius and its limb-darkened angular diameter.

7 http://classic.sdss.org/dr7/products/spectra/vacwavelength.html
convert the Kurucz model flux to that of Sirius, so that it is measured in erg cm\(^{-2}\) s\(^{-1}\) Å\(^{-1}\).

In the top panel of Figure 4, we see the Kurucz model spectrum. The middle panel is the average of 18 blue grating spectra of Sirius (taken at airmass less than 1.3), and 16 red grating spectra, as processed with IRAF. We have stitched together the blue grating spectra and the red grating spectra at 6000 Å, which produces a small discontinuity at that wavelength. The bottom panel of Figure 4 is the ratio of the Kurucz spectrum and our mean Sirius spectrum. We call that ratio the “flux function” or “spectral flat”. All our other spectra are then multiplied by the flux function to place them on a system tied to the Kurucz model of Sirius. This largely, but not entirely, takes out the discontinuity at 6000 Å and also takes out telluric features such as the Fraunhofer B-, A-, and Z-lines at 6867, 7594 and 8227 Å, which are due to atmospheric O\(_2\).

The identity of a feature at \(\sim\)3680 Å evident in many of our spectra is uncertain; it too is largely taken out by the spectral flat.

The average value of the flux function shown in the bottom panel of Figure 4 is 0.990, which is close enough to 1.000 to give us confidence that the flux calibration of our coadded spectra of Sirius, obtained with IRAF, is consistent with the scaling of the model of Sirius to the flux density of the star. Our ultimate filter by filter zeropoints are the values of the \(BVRI\) magnitudes of Sirius given in Table 1, which come from Cousins (1971, 1980).

Fully reduced spectra, transformed to the “Sirius system” and ranging from 3300 to 10,000 Å, are shown in Figure 5. Spectra taken with only the blue grating are shown in Figure 6.

Some line identifications are given in the last panel of Figure 5. In spectra of stars hotter than the Sun we clearly see the Balmer lines at 6563, 4861, 4340, 4102 Å and shorter wavelengths. Cooler stars such as HR 3307 (\(\alpha\) Ori) and HR 2061 (\(\alpha\) Ori) show the infrared Ca\(^+\) triplet (8498, 8542, and 8662 Å) and the blended Na D lines (5890 and 5896 Å). \(\zeta\) Ori and early B-type stars, such as HR 1790 (\(\gamma\) Ori), HR 2294 (\(\beta\) CMa), HR 2618 (\(\epsilon\) CMa), and HR 4853 (\(\beta\) Cru), show He I absorption at 4471 and 5876 Å, though it is difficult to see given the scale of the spectra shown in Figures 5 and 6.

\(^8\) FITS and ASCII spectra are available via http://people.physics.tamu.edu/krisciunas/spec.tar.gz and from the online version of this paper.
higher resolution spectrum of ζ Ori A from 3980 to 4940 Å, including line identifications, is shown in Figure 14 of Soto et al. (2011). One thing to note in our reduced spectra is the strength of the Balmer jump in early-type main sequence stars. This is due to ionization of atomic hydrogen from the first excited state, producing strong absorption shortward of the Balmer limit at 3646 Å. This results in fainter U-band magnitudes of such stars. A much weaker Balmer jump is seen in hot giant and supergiant stars. Thus, the Balmer jump gives us a photometric tool to measure a combination of the luminosity class and the local acceleration of gravity of hot stars (log g). For example, an A2 V star is 0.30 mag redder in the U-B color index than an A2 III star (Drilling & Landolt 2000, pp. 388–389). Kaler (1962) points out that one also needs the rotation rates of the stars to do this properly.

4. Synthetic Photometry

The filter prescriptions originally given by Bessell (1990) have been slightly modified by Bessell & Murphy (2012). We have adopted the latter. In Figure 7 we show their filter prescriptions, multiplied by an atmospheric extinction function appropriate to Cerro Tololo, and also multiplied by a function which accounts for the principal atmospheric extinction lines. This is noticeable in the R- and I-band functions.

We then calculated synthetic BVRI magnitudes of our target stars using an IRAF script written by one of us (N. B. S.). This script uses an arbitrary zero point for each filter. We adjusted the BVRI zeropoints to given synthetic magnitudes of the scaled Sirius model spectrum that match those of Cousins (1971, 1980). If the reader chooses to adopt different BVRI magnitudes of Sirius than those given in Table 1, then the synthetic magnitudes of the other stars given in the table must be adjusted up or down accordingly.

Bessell and Murphy’s V-band filter prescription extends to 7400 Å, while our blue grating spectra stop at ~6400 Å. We cannot obtain synthetic V-band magnitudes for the cooler stars observed only with the blue grating. However, we can obtain approximate V-band magnitudes for the hot stars HR 2618,
3485, 4853, and 4963 by extrapolating the spectra using the Rayleigh–Jeans approximation.

Table 1 gives our synthetic $BVR_I$ photometry. Figure 8 shows the differences of our synthetic photometry and the values of Cousins (1971) and Cousins (1980), as a function $B - V$ (for $B$ and $V$), $V - R$ (for $R$), and $V - I$ (for $I$). There is no color term for the $R$-band differences, but there are non-zero colors terms for $B$, $V$, and $I$. At zero color there is no offset between our $V$-band magnitudes and those of Cousins, but in $B$, $R$, and $I$ ours are 0.02 to 0.03 mag fainter.

From the AAVSO online light curve calculator we find that the $V$-band brightness of $\alpha$ Ori was $V = 0.398$ on 2 January 2003, and $V = 0.384$ on 7 January. The mean is $V = 0.391$, which is comparable to our synthetic $V$-band magnitude of 0.398 from spectra taken on 6 January 2003. This is a good sanity check. On 21 January 2005, when we took the
red grating spectra, Betelgeuse’s brightness was $V = 0.436$, according to the AAVSO.

The spectra presented here and the associated synthetic photometry can function as a Sirius-based anchor for Galactic as well as extragalactic observational astronomy.

This study made use of the SIMBAD database, operated at CDS, Strasbourg, France. We thank the AAVSO for the $V$-band photometry of Betelgeuse obtained from their database. Kenneth Luedeke and Raymond Thompson measured Betelgeuse closest to the times we took spectra. We thank Ralph Bohlin for providing an ASCII version of the Kurucz spectrum of Sirius used for the calibration, and for useful comments. We also thank James Kaler and Jesus Maíz Apellániz for comments and references.

Figure 5. (Continued.)

Figure 6. Spectra of program stars observed with the blue grating only.
Figure 7. Fractional transmission of Bessell & Murphy (2012) filters, multiplied by an atmospheric extinction model appropriate to Cerro Tololo, and also multiplied by a function that accounts for principal terrestrial atmospheric features. As our spectra are not useful shortward of 3300 Å, designated here by a vertical dashed line, we cannot easily obtain $U$-band synthetic photometry of our program stars.

(A color version of this figure is available in the online journal.)

Figure 8. Differences of photometry in the sense “our synthetic photometry” minus “photometry of Cousins”. The slope is also known as the “color term”. 

(A color version of this figure is available in the online journal.)
Note added in press. As part of this project, we also obtained blue grating spectra of HR 5056 (alpha Vir) and HR 5267 (beta Cen). The flux calibration was anomalous. We believe this occurred as a result of a misalignment of the dome slit and the telescope. Under non-photometric conditions, we obtained red grating spectra of HR 3454 (eta Hya), HR 4210 (eta Car), HR 4216 (mu Vel), and HR 4450 (xi Hya). Except for eta Carinae, these spectra can be scaled appropriately using photometry of Cousins (1971, 1980). These additional spectra can be obtained from the lead author.

References

Bessell, M. S. 1990, PASP, 102, 1181
Bessell, M. S., & Murphy, S. 2012, PASP, 124, 140
Bohlin, R. C. 2014, AJ, 147, 127
Bohlin, R. C., Gordon, K. D., & Tremblay, P.-E. 2014, PASP, 126, 711
Bohlin, R. C., & Landolt, A. U. 2015, AJ, 149, 122
Butkovskaya, V. V. 2014, BCAO, 110, 80
Cousins, A. W. J. 1971, ROAn, 7, 1
Cousins, A. W. J. 1980, SAAOC, 1, 234
Drilling, J. S., & Landolt, A. U. 2000, in Allen’s Astrophysical Quantities, ed. A. N. Cox (4th ed.; Berlin, New York: Springer)
Fukugita, M., Ichikawa, T., Gunn, J. E., et al. 1996, AJ, 111, 1748
Hamuy, M., Suntzeff, N. B., Heathcote, S. R., et al. 1994, PASP, 106, 566
Hamuy, M., Walker, A. R., Suntzeff, N. B., et al. 1992, PASP, 104, 533
Hayes, D. S., & Latham, D. W. 1975, ApJ, 197, 593
Hearnshaw, J. B. 1996, The Measurement of Starlight: Two Centuries of Astronomical Photometry (Cambridge: Cambridge Univ. Press)
Hearnshaw, J. B. 2014, The Analysis of Starlight: Two Centuries of Astronomical Spectroscopy (2nd ed.; Cambridge: Cambridge Univ. Press)
Johnson, H. L., & Morgan, W. W. 1953, ApJ, 117, 313
Kaler, J. 1962, ZA, 56, 150
Krisciunas, K. 1982, IBVS, 2104
Krisciunas, K. 1990, IBVS, 3477
Krisciunas, K., & Fisher, D. 1988, IBVS, 3227
Krisciunas, K., & Luedeke, K. D. 1996, IBVS, 4355
Massey, P., Valdes, F., & Barnes, J. 1992, A User’s Guide to Reducing Slit Spectra with IRAF (Tucson, AZ: National Optical Astronomy Observatory)
Soto, A., Maíz Apellániz, J., Walborn, N. R., et al. 2011, ApJS, 193, 24
Stritzinger, M., Suntzeff, N. B., Hamuy, M., et al. 2005, PASP, 117, 810
Su, K. Y. L., Rieke, G. H., Malhotra, R., et al. 2013, ApJ, 763, 118
Su, K. Y. L., Rieke, G. H., Misselt, K. A., et al. 2005, ApJ, 628, 487
Tompkin, J. 1998, S&T, 95, 59

Cousins, A. W. J. 1980, SAAOC, 1, 234
Drilling, J. S., & Landolt, A. U. 2000, in Allen’s Astrophysical Quantities, ed. A. N. Cox (4th ed.; Berlin, New York: Springer)
Fukugita, M., Ichikawa, T., Gunn, J. E., et al. 1996, AJ, 111, 1748
Hamuy, M., Suntzeff, N. B., Heathcote, S. R., et al. 1994, PASP, 106, 566
Hamuy, M., Walker, A. R., Suntzeff, N. B., et al. 1992, PASP, 104, 533
Hayes, D. S., & Latham, D. W. 1975, ApJ, 197, 593
Hearnshaw, J. B. 1996, The Measurement of Starlight: Two Centuries of Astronomical Photometry (Cambridge: Cambridge Univ. Press)
Hearnshaw, J. B. 2014, The Analysis of Starlight: Two Centuries of Astronomical Spectroscopy (2nd ed.; Cambridge: Cambridge Univ. Press)
Johnson, H. L., & Morgan, W. W. 1953, ApJ, 117, 313
Kaler, J. 1962, ZA, 56, 150
Krisciunas, K. 1982, IBVS, 2104
Krisciunas, K. 1990, IBVS, 3477
Krisciunas, K., & Fisher, D. 1988, IBVS, 3227
Krisciunas, K., & Luedeke, K. D. 1996, IBVS, 4355
Massey, P., Valdes, F., & Barnes, J. 1992, A User’s Guide to Reducing Slit Spectra with IRAF (Tucson, AZ: National Optical Astronomy Observatory)
Soto, A., Maíz Apellániz, J., Walborn, N. R., et al. 2011, ApJS, 193, 24
Stritzinger, M., Suntzeff, N. B., Hamuy, M., et al. 2005, PASP, 117, 810
Su, K. Y. L., Rieke, G. H., Malhotra, R., et al. 2013, ApJ, 763, 118
Su, K. Y. L., Rieke, G. H., Misselt, K. A., et al. 2005, ApJ, 628, 487
Tompkin, J. 1998, S&T, 95, 59