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DASCH DISCOVERY OF LARGE AMPLITUDE ∼10–100 YEAR VARIABILITY IN K GIANTS

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ABSTRACT

Here we present the discovery of three unusual long-term variables found in the Digital Access to a Sky Century at Harvard project, with ∼1 mag variations in their light curves on ∼10–100 year timescales. They are all spectroscopically identified as K2III giant stars, probably in the thick disk. Their light curves do not match those previously measured for known types of variable stars, or any theoretical model reported for red giants, and instead suggest a new dust formation mechanism or the first direct observation of "short" timescale evolution-driven variability. More theoretical work on the lithium flash near the red giant branch bump and the helium shell ignition in the lower asymptotic giant branch, as well as long-term monitoring of K2III thick-disk stars is needed.

Key words: methods: data analysis – stars: evolution – stars: variables: general – techniques: photometric

Online-only material: color figures

1. INTRODUCTION

The time domain, especially on 10–100 year timescales, is poorly explored despite its astrophysical importance. The Harvard College Observatory (HCO) maintains a collection of more than 500,000 glass astrophotographic plates from the 1880s to 1980s, constituting the only continuous record of the whole sky in existence. Every point on the sky has been observed between 500 and 1000 times. This 100 year coverage is a unique resource for studying temporal variations in the universe on ∼10–100 year timescales. The Digital Access to a Sky Century at Harvard (DASCH) collaboration has developed an ultra-high-speed digital plate scanner (Simcoe et al. 2006), and will ultimately enable the full Harvard plate collection to be digitized. We have developed the astrometry and photometry pipeline, and scanned 7000 plates in six different fields. An overview of the DASCH project is presented in paper I (J. Grindlay et al. 2010, in preparation; see also Grindlay et al. 2009), and the photometry and astrometry pipelines are described in paper II (Laycock et al. 2010) and paper III (S. Tang et al. 2010a, in preparation).

Here we present the discovery of three unusual long-term variables found in the DASCH scans near open cluster M44, which showed ∼1 mag dimmings and recoveries on ∼10–100 year timescales in their light curves. Such variations are very unusual and have not been seen in any other common classes. We present their light curves and spectra in Section 2. Discussion on individual objects is given in Section 3 and a summary is given in Section 4.

2. DISCOVERY OF THREE UNUSUAL VARIABLES

2.1. *Candidate Selection*

Three unusual long-term variables presented here were found from ∼400 variables found on ∼1200 M44 plates by their peculiar long-term variabilities. These plates cover 5°–25° on a side with typical limiting magnitudes 14–15 mag (Laycock et al. 2010). There are $\sim 1.2 \times 10^5$ objects with more than 100 mag measurements. Details of our variable selection procedure and general properties of variables found in DASCH scans near M44 are described in S. Tang et al. (2010b, in preparation).

2.2. *DASCH Light Curves*

These variables showed unusual ∼1 mag dimmings on timescales from 10 to 100 years in their light curves, as shown in black dots in Figure 1. DASCH J083038.5+140713 (hereafter J0830; named by its equatorial coordinate in J2000; GSC2.3.2 catalog name N2313102243) declined for 1 mag in a century. It is classified as a "MISC" variable in the All Sky Automated Survey (ASAS) (ASAS J083038+1407.3; Pojmanski 2002) since it became 0.3 mag brighter in V gradually from 2003 to 2007, and then became 0.1 mag fainter from 2008 to 2009. DASCH J075445.9+164141 (hereafter J0754; GSC2.3.2 name N2211330177; ASAS J075446+1641.7) showed a sharp decrease around 1930, and then slowly recovered in 10 years. Another dip was shown around 1892, but unfortunately we cannot constrain the light-curve profile of the dip due to the lack of data. DASCH J073606.5+211411 (hereafter J0736; GSC2.3.2 name N2230030699; ASAS J073607+2114.2) showed a 1 mag dip from 1930s to 1950s. Both J0754 and J0736 are new variables found with DASCH.

2.3. *Possible Color Evolution Derived From Plates*

The light curves of color variations back in time would constrain variable extinction, but it is difficult to derive from DASCH. The majority of the Harvard plate collection are blue sensitive plates, and a small fraction of plates used filters to produce red and yellow sensitive measurements with details of wavelength responses unavailable. In order to generate consistent magnitudes, we did color-term fitting for the plates in annular bins to derive the effective color term C in plates (Laycock et al. 2010), where C of a given plate is defined by

$$m = B + C(B - R),$$

where m is the effective magnitude in the plate, B is the GSC2 B magnitude, and R is the GSC2 R magnitude. We then derive the $(B - R)$ color of a given object by comparing its magnitudes with its neighbor stars (with $B - R$ color from GSC2 catalog) in pairs of blue versus red/yellow plates taken from the same night or very close in time (mostly within a week). Each pair of plates gives a $(B - R)$ color of the object at that time. More details are described in S. Tang et al. (2010a, in preparation).

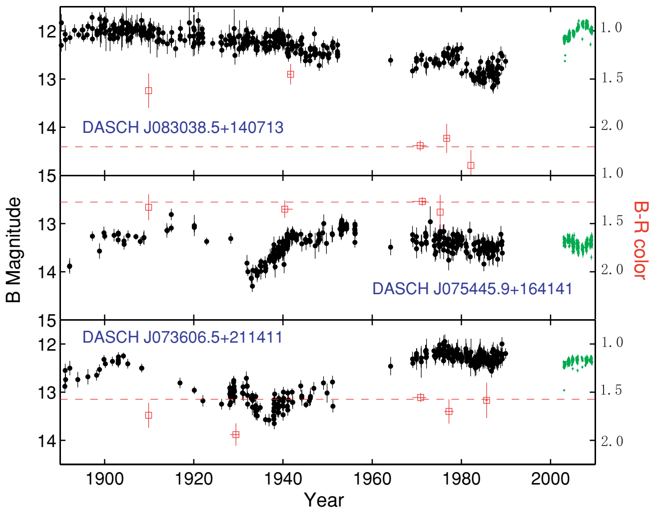

Figure 1. Light curves and color evolution of three unusual long-term variables which were found in DASCH scans near M44. Black dots with error bars are the light curves from DASCH, small green dots are the light curves from ASAS. Since ASAS data are in V band, while DASCH magnitudes are B, we added 1.16 mag to the ASAS V mag in the plots which is the mean $B-V$ value for K2III stars (Cox 2000). Red open squares are the $B-R$ color derived from plates with the y-axis labeled in the right, and red dashed lines mark the weighted mean $B-R$ color values from 1970s to 1980s.

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

We bin some plate pairs close in time, and plot the color evolution of the three variables by the red open squares in Figure 1. The color evolution data are limited mainly by the small number of red and yellow plates usually available. Both J0830 and J0736 are redder when they are fainter at the 7σ and the 3σ level, respectively. We did not detect any color change in J0754, although we do not have red or yellow plates available from during its major dimming phase (1930–1940).

2.4. *Spectroscopic Observations*

Spectra were acquired with FAST spectrograph on the 1.5 m Tillinghast reflector telescope at the F. L. Whipple Observatory (FLWO) and GMOS long-slit spectroscopy blue channel on Gemini North. They are wavelength-calibrated with standard packages, and are shown in Figures 2 and 3. According to their spectra, they are all K2-type stars. By comparing the region between 4900 Å and 5200 Å with FAST spectra of several K2 standards with different luminosity classes, we found all of them are giants (luminosity class III; estimated uncertainties in luminosity class are II–IV. Luminosity classes I and V are ruled out). We estimated metallicities $[\mathrm{Fe/H}] \sim -0.3 \pm 0.3$ for J0830, and $[\mathrm{Fe/H}] \sim -0.9 \pm 0.4$ for J0754 and J0736, by comparing with FAST spectra of several standard K giant stars with known metallicities (Faber et al. 1985). We also found that J0830 and J0754 do not show velocity changes within measurement errors ($\sim$8 km s^{-1}), while J0736 showed significant radial velocity changes in three different epochs, i.e., 11 ± 6 km s^{-1} on 2009 February 4, -18 ± 6 km s^{-1} on February 19, and 22 ± 6 km s^{-1} on April 18, and is then probably in a close binary.

As shown in Figure 3, all three variables show Ca II K and H emission lines in the absorption core, indicating the presence of active chromospheres. Ca II K and H emission lines are common among cool dwarf and evolved stars, signaling the magnetic dynamo activity in chromospheres (Kraft 1967; Soderblom 1983; Dupree & Smith 1995). Their fluxes correlate with stellar rotational velocities (see Strassmeier et al. 1994; Pasquini et al. 2000, and references therein). Following Linsky et al. (1979), assuming $V - R = 0.84$ for K2III stars (Cox 2000), we calculated the net chromospheric loss in the K lines, which are $\log \mathcal{F}'(K) = 6.35$, 6.13, and 5.98, indicating rotation velocities about 40 km s^{-1}, 25 km s^{-1}, and 16 km s^{-1} (Strassmeier et al. 1994; the uncertainty is large though about 0.5 dex), for J0830, J0754, and J0736, respectively.

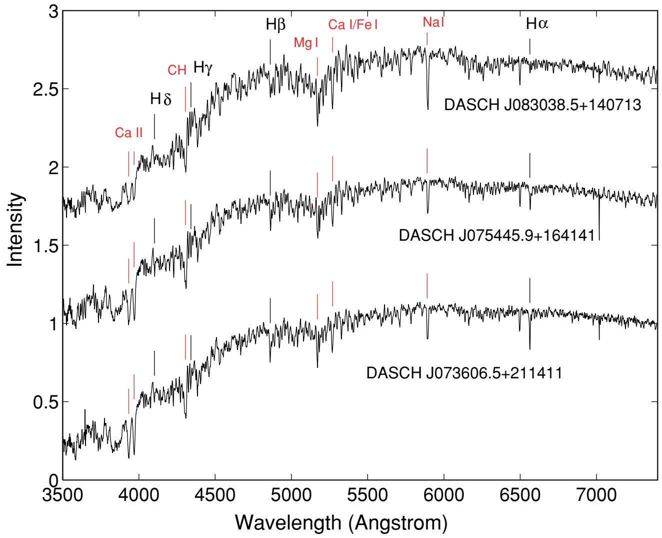

Figure 2. FAST 300 grating spectra of the three erratic variables with light curves shown in Figure 1. All of them are K2III stars. Spectral resolution is about 7 Å.

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

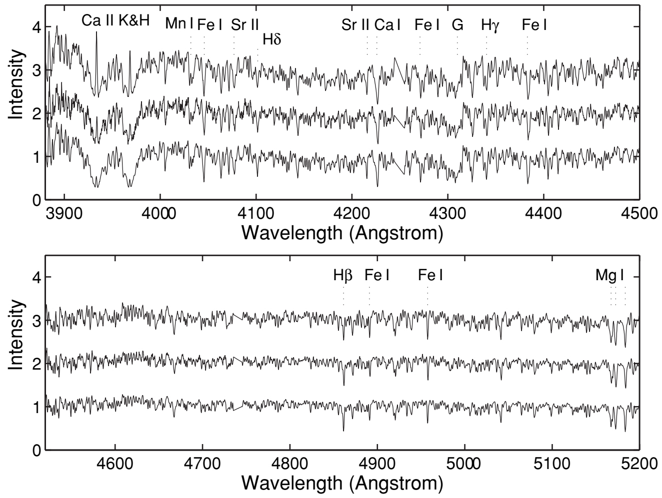

Figure 3. Gemini B1200 grating spectra of the three erratic variables. From top to bottom are spectra of J0830, J0754, and J0736, respectively. The continuum is removed by a sixth-order polynomial fit. Spectral resolution is about 1.2 Å ($R = 3744$).

2.5. *Occurrence Fraction of K2III Long-term Erratic Variables*

The plates we analyzed are centered around the open cluster M44. The coverage decreases when the region is farther away from the center of M44. There is roughly a 40×40 deg^2 region with good coverage (i.e., more than 100 scans). From Keplercam photometry of a 3.2 deg^2 region near M44, we estimate that there are about 4000–6000 stars with $12 < B < 13.5$ and $0.85 < g - r < 1.02$ in this 40×40 deg^2 region. If we assume that objects with $0.85 < g - r < 1.02$ are K2III stars (Covey et al. 2007 and Smith et al. 2002 note that some dwarfs and

Table 1
List of the Three Unusual Long-term Variables Found in DASCH

DASCH Name	Gal.	Coord.	GSC[a]	GSC[a]	ASAS[b]		2MASS[c]		[Fe/H]	PMRA[d]	PMDec[d]	v_r[e]	D[f]	u[g]	v[g]	w[g]
	l	b	B	$B-R$	V	J	H	K		(mas yr^{-1})	(mas yr^{-1})	(km s^{-1})	(kpc)			
J083038.5+140713	211	28	12.90	1.40	10.85	8.82	8.20	7.93	-0.3 ± 0.3	9.0	−10.8	0 ± 8	1.8	−82	−79	37
J075445.9+164141	205	21	13.30	1.61	12.24	10.42	9.83	9.70	-0.9 ± 0.4	−3.0	−10.2	22 ± 8	2.1	−2	−81	−48
J073606.5+211411	198	19	12.66	1.29	11.19	9.30	8.78	8.67	-0.9 ± 0.4	−1.8	−2.3	⋯ [e]	1.6	⋯	⋯	⋯

Notes.

[a] From GSC2.3.2 catalog (Lasker et al. 1990).

[b] Median ASAS *V* magnitudes (Pojmanski 2002).

[c] 2MASS *J*, *H,* and *K* magnitudes with typical uncertainty about 0.02 mag (Skrutskie et al. 2006).

[d] Proper motion in right ascension (R.A.) and declination (decl.), from *Tycho*-2 catalog with typical uncertainty about 2 mas yr^{-1} (Hog et al. 2000).

[e] Radial velocity. The radial velocity of J0736 is variable.

[f] Distances of the objects assuming absolute *B* magnitude of 1.66 for K2III stars (Cox 2000).

[g] Galactic space velocity in km s^{-1}, corrected to the local standard of rest. u: positive toward the Galactic anti-center; v: positive in the direction of Galactic rotation; w: positive toward the North Galactic Pole. We did not estimate the Galactic space velocity for J0736, due to the uncertain nature of its radial velocity and its small proper motion velocity which is consistent with zero within uncertainty.

supergiants are also included, but there are many more giants than supergiants, and at 12–13 mag, we are seeing more giants than dwarfs), then the event ratio of such long-term variables among K2III stars is about $3/5000 \sim 0.06\%$.

3. DISCUSSION ON INDIVIDUAL OBJECTS

Table 1 lists the galactic coordinates, GSC2.3.2 $B-R$ colors, GSC *B*, ASAS *V,* and Two Micron All Sky Survey (2MASS) *JHK* magnitudes, [Fe/H], proper motions, radial velocities, distances, and galactic velocities for the three variables. J0830 and J0754 have high proper motions (>10 mas yr^{-1}), while J0736 has no proper motion within its error of 2 mas yr^{-1}. These three stars are about 500–800 pc above the galactic plane. J0830 and J0754 have velocities about 100 km s^{-1}, while J0736 probably has smaller velocity <30 km s^{-1}. Our spectra indicate metallicities [Fe/H] ~ -1 to 0. They are most probably thick-disk giants (Carollo et al. 2010). The 2MASS $H-K$ color of J0830 is 0.27, which is redder than $H - K = 0.04$ expected for a K2 giant (Covey et al. 2007). Note that J0830 also showed large reddening in the 1970s and 1980s in our plates during its dimming, as shown in Figure 1. As K2III stars with [Fe/H] ~ -1 to 0, the three erratic variables could be on the red giant branch (RGB), but not near the tip, on the horizontal branch (HB), or early asymptotic giant branch (AGB).

Timescales of 10–100 years are too long to be pulsations driven by ionization (Percy 2007), or convective instabilities which have timescales in the order of a year for a K giant (Prialnik 2000). The light curves of these three erratic variables look somewhat like R Coronae Borealis (RCB) stars. RCB stars are rare, hydrogen deficient, carbon-rich supergiants which undergo large amplitude (3–8 mag) fading events lasting weeks to a few years as dust condensates to block the light along the line of sight (Clayton 1996). Our variables share some of these typical RCB light-curve features, and the light curve of J0830 is similar to some hot ($T \sim 20{,}000$ K) RCB stars (De Marco et al. 2002). Dust obscuration events have also been observed in some other carbon-rich stars. Whitelock et al. (2006) found about one-third of the carbon-rich Mira variables, and other AGB stars undergo dimming episodes.

However, all of the three variables presented here are very different from normal RCB stars in the following aspects, and therefore are not RCB stars (or any other type of carbon-rich AGB stars): they are not post-AGB supergiants like RCB stars (Alcock et al. 2001), much cooler than most RCBs, have much longer variability timescales and much smaller amplitudes than average RCB stars, have no strong carbon absorption bands, and have strong hydrogen absorption lines. J0830 has weaker Hα absorption which might be due to the chromospheric emission in the core, since the Ca II emission lines are very strong in J0830, and Hα emission is usually strongly correlated with Ca II lines (Cincunegui et al. 2007).

Some symbiotic stars also show irregular long-term variations (see, e.g., Sokoloski et al. 2006; Skopal 2008). However, there is no symbiotic signature in our variables, such as nebula emission lines or combination spectra. There is no common model that works well for these three erratic variables, as we discuss below.

3.1. J0830[3]

The first possible model is dimming caused by obscuration of dust shells ejected from the star, which is consistent with our observation that the object became redder when it was fainter and its redder 2MASS $H-K$ color. However, how to produce and maintain the dust for such a long time is not clear. For RGB stars, significant mass loss occurs only at the very tip (Origlia et al. 2002), which is much too luminous for the three erratic variables. Bedding et al. (2002) found a five-year dimming event in the oxygen-rich, Mira-like variable L_2 Pup, likely due to absorption by a dust shell containing silicates. L_2 Pup is located near the tip of the AGB, and thus has a high mass-loss rate ($5 \times 10^{-7}\, M_\odot$ yr^{-1}), which if applied to our K2III stars would require that they have low metallicity and be halo stars. Tsuji (2009) found excess absorption in CO lines of Arcturus (K1.5III), and proposed it might be caused by the formation of molecular clouds in the outer atmosphere. Arcturus only shows low-amplitude optical variations of a few percent (Bedding 2000) and thus the absorption due to such molecular clouds is not enough to account for the 1 mag dimming events in the three erratic variables.

A second possible model is the lithium flash near the RGB luminosity bump (Palacios et al. 2001), which proposed that rotation-induced mixing leads to a thin and unstable lithium burning shell, which leads to an increase of nuclear luminosity, and mass loss which might account for the formation of a dust shell around the star and thus the reddening of the star. All of our three variables are chromospherically active and probably fast rotators, which fit to this model. However, the variation

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[3] Some of the models in this subsection may also apply to J0754 and J0736.

timescale and amplitude of surface luminosity in this model are unknown.

A third possible model, which may be the most plausible one, is the evolution phase when the star is leaving the HB and beginning to ascend the AGB, at the point that helium is exhausted in the core and helium burning is ignited in a surrounding shell. This could apply to the point L in Figures 2 and 4 of Sackmann et al. (1993). We plotted the evolutionary tracks for $[Z = 0.008, Y = 0.25]$ ([Fe/H] ~ -0.4 if we assume the same composition as the Sun) from Girardi et al. (2000), and found stars with mass 0.8–1.2 $M_\odot$ are crossing this evolutionary phase near $T \sim 4400$ K and $L \sim 10^{2.2}\, L_\odot$ (which is the temperature and luminosity for K2III stars; Cox 2000). The ignition of the helium-burning shell causes expansion and makes the hydrogen-burning shell expand and cool, which makes the surface luminosity decline and the color redden, and then recover later. If this process is similar to thermal pulses in the He-burning shell of later AGB stars, then first the surface luminosity decreases by a factor of 2 over 50–100 years, and then increases by a factor of 2 over 200 years (Mowlavi 1999), which is roughly consistent with J0830 and J0736. More theoretical study and simulations of this evolution phase may clarify the nature of our variables.

Two other interesting observations might be related to the three erratic variables. Edmonds & Gilliland (1996; hereafter EG96) found a new class of variable stars in K giants with amplitudes 5–15 mmag and periods of days clumped in the color–magnitude diagram with $B - V = 1.1$–1.2, which is the location of K2III stars. They lie on both the AGB and the RGB. Bedin et al. (2000) found a “heap” in the luminosity function which is about 1.4 mag brighter than the RGB bump, and in the case of 47 Tuc, the heap is in a similar location on the RGB to the variables found by EG96. The heap and the new class variables are not well understood yet (see, e.g., Salaris et al. 2002), and it is surprising that they have a similar color and luminosity class as our erratic variables, which show much longer timescales and larger amplitude variations. There might be some intrinsic link between the objects in the three independent observations. In Figure 4 of Sackmann et al. (1993), the location of the He-shell ignition is just about 0.6 dex, i.e., 1.5 mag, brighter than the RGB bump, consistent with the luminosity of K giant variables in EG96.

3.2. J0754

This star is not yet included in any known variable catalogs. The sharper decline and slower recovery are similar to what is seen in RCB stars. It might be puffing off outer layers at irregular intervals, which blocks the light from the star.

3.3. J0736

This variable is probably a binary. Given its possible orbital period of $\sim \leqslant 15$ days ($\sim$30 km s^{-1} change in radial velocities from February 4 to February 19) and its Ca K and H line emission, it might share some properties in common with RS CVn systems. It is not yet included in any known variable catalogs. Similar to J0830 and J0736, it might be puffing off out layers which blocks the light from the star, as supported by the measured reddening during dimming; it might also be lithium flash near the RGB bump, or the He-shell ignition in the lower AGB, as discussed in Section 3.1.

4. SUMMARY

We have found three very interesting long-term variables, which do not resemble known classes of variables previously reported. We found no model reported for red giants which could explain both their timescales and amplitudes. The underlying causes of their 10–100 year variations might be related to evolutionary nuclear shell-burning instability and/or variable dust obscuration. Higher resolution spectra and infrared observations in the future are needed to constrain surface gravity, mass, and possible dust properties. More theoretical work on the lithium flash near the RGB bump and the helium-shell ignition in the AGB, including surface luminosity variation and possible dust formation, will be helpful to understand their nature. As probable thick disk stars with [Fe/H] ~ -0.9 to -0.3, they are likely to have ages 8–16 Gyr (Bensby et al. 2004), and therefore likely to be $\sim$0.8–1.1 $M_\odot$ (Girardi et al. 2000). If all three stars are $\sim$1 $M_\odot$ for which the RGB is nearly vertical, their similar spectral type is expected. The evolutionary timescales of variations in models 2 and 3 (Section 3.1) are both in the range $\sim$200–1000 years. A $\sim 1\, M_\odot$ star with $Z = 0.004$ to 0.008 ([Fe/H] ~ -0.7 to -0.4) spends $\sim 10^{7.2}$ yr during the RGB and $\sim 10^{6.4}$ yr during the AGB phases as a K2 giant ($T \sim 4300$–4500 K, Cox 2000; Girardi et al. 2000). Therefore the predicted rate of such erratic variables among K2 giants is $\sim 600/10^{7.2} \sim 0.004\%$. This is $\sim$15 times smaller than our estimated occurance fraction of our K2III variables (0.06%), indicating other mechanisms beyond the evolutionary models we discussed might be relevant.

We did a general search for long-term variables, and it turned out surprisingly that the three most interesting objects with drops in timescales $\sim$10–100 years are all K2 giants. Is this a coincidence, or are thick-disk K2 giants special? Due to the small size of the sample, we cannot answer the question for sure yet. We are working on a larger sample of similar long-term variables over more plates, and hopefully we will have more knowledge about the demographic very soon. We note that $\sim$1200 plates covering the M44 field are only $\sim$0.2% of the whole Harvard plate collection, and there is huge potential to find more interesting objects and new classes of variables.

Stellar evolution proceeds on astronomical, not human, timescales (except for pulsations and eruptive events). However, evolution-driven changes on $\sim$100 year timescales, such as shell-burning flashes and core helium flash in giants, are rare but can be observed with the DASCH database with both long-term data coverage and very large stellar samples. Note that AAVSO also provides invaluable long-term data, but mostly for a few thousand much brighter sources; see http://www.aavso.org. Instead of waiting for another century to gather data to study 100 year variability, we could make it available for bright objects ($B < 15$ mag) in several years from DASCH, provided support for this full digitization scanning can be found.

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REFERENCES

Alcock, C., et al. 2001, ApJ, 554, 296
Bedding, T. R. 2000, in 3rd MONS Workshop, Science Preparation and Target Selection, ed. T. C. Texiera & T. R. Bedding (Aarhus: Aarhus Univ.), 97
Bedding, T. R., Zijlstra, A. A., Jones, A., Marang, F., Matsuura, M., Retter, A., Whitelock, P. A., & Yamamura, I. 2002, MNRAS, 337, 79
Bedin, L. R., Piotto, G., Zoccali, M., Stetson, P. B., Saviane, I., Cassisi, S., & Bono, G. 2000, A&A, 363, 159
Bensby, T., Feltzing, S., & Lundstrom, I. 2004, A&A, 421, 969
Carollo, D., et al. 2010, ApJ, submitted (arXiv:0909.3019)
Cincunegui, C., Diaz, R. F., & Mauas, P. J. D. 2007, A&A, 469, 309
Clayton, G. C. 1996, PASP, 108, 225
Covey, K. R., et al. 2007, AJ, 134, 2396
Cox, A. N. 2000, Allen's Astrophysical Quantities (New York: Springer)
De Marco, O., et al. 2002, AJ, 123, 3387
Dupree, A. K., & Smith, G. H. 1995, AJ, 110, 405
Edmonds, P. D., & Gilliland, R. L. 1996, ApJ, 464, 157 (EG96)
Faber, S. M., Friel, E. D., Burstein, D., & Gaskell, C. M. 1985, ApJS, 57, 711
Girardi, L., Bressan, A., Bertelli, & Chiosi, C. 2000, A&AS, 141, 371
Grindlay, J., Tang, S., Simcoe, R., Laycock, S., Los, E., Mink, D., Doane, A., & Champine, G. 2009, in ASP Conf. Ser. 410, Preserving Astronomy's Photographic Legacy: Current State and the Future of North American Astronomical Plates, ed. W. Osborn & L. Robbins (San Francisco, CA: ASP), 101
Hog, E., et al. 2000, A&A, 355, 27
Kraft, R. P. 1967, ApJ, 150, 551
Lasker, B. M., Sturch, C. R., McLean, B. J., Russell, J. L., Jenker, H., & Shara, M. M. 1990, AJ, 99, 2019
Laycock, S., Tang, S., Grindlay, J., Los, E., Simcoe, R., & Mink, D. 2010, AJ, submitted (arXiv:0811.2005) (paper II)
Linsky, J. L., Worden, S. P., McClintock, W., & Robertson, R. M. 1979, ApJS, 41, 47
Mowlavi, N. 1999, A&A, 344, 617
Origlia, L., Ferraro, F. R., Pecci, F. F., & Rood, R. T. 2002, ApJ, 571, 458
Palacios, A., Charbonnel, C., & Forestini, M. 2001, A&A, 375, 9
Pasquini, L., de Medeiros, J. R., & Girardi, L. 2000, A&A, 361, 1011
Percy, J. R. 2007, Understanding Variable Stars (Cambridge: Cambridge Univ. Press)
Pojmanski, G. 2002, Acta Astron., 52, 397
Prialnik, D. 2000, An Introduction to the Theory of Stellar Structure and Evolution (Cambridge: Cambridge Univ. Press)
Sackmann, I.-J., Boothroyd, A. I., & Kraemer, K. E. 1993, ApJ, 418, 457
Salaris, M., Cassisi, S., & Weiss, A. 2002, PASP, 114, 375
Simcoe, R. J., Grindlay., J. E., Los, E. J., Doane, A., Laycock, S., Mink, D. J., Champine, G., & Sliski, A. 2006, Proc. SPIE 6312, 631217
Skopal, A. 2008, J. Am. Assoc. Var. Star Obs., 36, 9
Skrutskie, M. F., et al. 2006, AJ, 131, 1163
Smith, J. A., et al. 2002, AJ, 123, 2121
Soderblom, D. R. 1983, ApJS, 53, 1
Sokoloski, J. L., et al. 2006, ApJ, 636, 1002
Strassmeier, K. G., Handler, G., Paunzen, E., & Rauth, M. 1994, A&A, 281, 855
Tsuji, T. 2009, A&A, 504, 543
Whitelock, P. A., Feast, M. W., Marang, F., & Groenewegen, M. A. T. 2006, MNRAS, 369, 751