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All Known Hot RCB Stars Are Fading Fast Over the Last Century

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ABSTRACT
The R Coronae Borealis (RCB) stars are cool supergiants that display irregular and deep dips in their light curves, caused by dust formation. There are four known hot RCB stars (DY Cen, MV Sgr, V348 Sgr, and HV 2671), with surface temperatures of 15,000–25,000 K, and prior work has suggested that three of these have secular fading in brightness. I have tested this result by measuring century-long light curves in the Johnson B-band with modern comparison star magnitudes, and I have extended this by measuring many magnitudes over a wide time range as well as for the fourth hot RCB star. In all four cases, the B-band magnitude of the maximum light is now fast fading. The fading rates (in units of magnitudes per century) are 2.5 for DY Cen after 1960, 1.3 for MV Sgr, 1.3 for V348 Sgr, and 0.7 for HV 2671. This secular fading is caused by the expected evolution of the star across the top of the HR diagram at constant luminosity, as the temperature rises and the bolometric correction changes. For DY Cen, the brightness at maximum light is rising from 1906 to 1932, and this is caused by the temperature increase from near 5,800 to 7,500 K. Before 1934 DY Cen had frequent dust dips, while after 1934 there are zero dust dips, so there is some apparent connection between the rising temperature and the formation of the dust. Thus, we have watched DY Cen evolve from an ordinary RCB star up to a hot RCB star and now appearing as an extreme helium star, all in under one century.

Key words: stars: AGB and post-AGB – stars: chemically peculiar – stars: individual (V348 Sgr, HV 2671, DY Cen, MV Sgr) – stars: variable: general

1 INTRODUCTION

R Coronae Borealis (RCB) stars are defined by their light curves displaying sudden and large drops in brightness with slower recoveries to the baseline level, with these events occurring randomly in time. These spectacular dips are caused when the star forms dense dust clouds on the line of sight to Earth hiding the star. The RCB stars are all hydrogen deficient supergiants, with various abundance anomalies, including enriched nitrogen and carbon. RCB stars are rare, with only 76 known in our Milky Way. The evolutionary status of RCB stars is that they might be from recent coalescences of a double white dwarf binary or from a final helium shell flash in a born-again asymptotic giant branch (AGB) star. Clayton (1996; 2012) presents full reviews of RCB stars.

Most RCB stars are relatively cool, with surface temperatures of 5,000-7,000 K. However, four of the known RCB stars have a greatly hotter surface temperature, from 15,000-25,000 K, and these are called the 'hot RCB stars'. The four known hot RCB stars are V348 Sgr, MV Sgr, and DY Cen in our Milky Way plus HV 2671 in the Large Magellanic Cloud. DY Cen and MV Sgr are hydrogen deficient (just like the cool RCB stars) and mostly composed of helium, while both have relatively infrequent drops in brightness. V348 Sgr and HV 2671 are very carbon-rich (55% carbon, most of the rest helium), and elemental abundances like in central stars of planetary nebulae, while both have frequent episodes of brightness declines. A plausible idea is that the two greatly different composition indicate two formation mechanisms, with DY Cen and MV Sgr simply being the 'progeny' of the normal RCB stars as they heat up, and with V348 Sgr and HV 2671 being somehow formed during a final helium-shell flash on post-AGB stars. Thus, the birth mechanism of the hot RCB stars could be either from born-again systems or white dwarf mergers. Nevertheless, it is still unclear as to the relationship between the hot RCB stars and the cool RCB stars, as well as to other classes of stars (the born-again stars and the Wolf-Rayet central stars of planetary nebulae). De Marco et al. (2002) present a full review of the hot RCB stars.

The key high-level science question is to understand the

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evolutionary state of the RCB stars, both hot and cold. For this, a critical piece of evidence is to watch them evolve in real time. Like for the born-again post-AGB stars (i.e., V605 Aql, Sakurai's object, and FG Sge), substantial movement across the HR diagram might be seen on time scales of a decade and a century. For this, De Marco et al. (2002) have pointed out that the baseline levels for MV Sgr, V348 Sgr, and DY Cen are apparently fading over the last century, and this would only be from movement from right-to-left across the top of the HR diagram.

These century-long light curves have inevitable big problems for two reasons. The light curves were compiled from magnitudes in the V, m_{vis}, and m_{pg} systems, which makes for large systematic uncertainties between old and new magnitudes, with exactly this able to make apparent systematic declines when none are real. De Marco et al. did attempt to correct for such effects. The big effect not mentioned is that all the old photometry is always systematically in error by from 0.1 to >1.0 mag simply because the old standard stars had these errors. In the days before photoelectric photometers could reach to cover faint sequences (i.e., before the late 1970s), the standard stars and comparison sequences were all calibrated by photographic transfers from the Harvard-Groningen Selected Areas and the North Polar Sequence. These photographic transfers always had problems, due to effects like reciprocity failure, in that claimed magnitudes were always reported systematically different than what we take on the modern magnitude scales. In general, the errors are small for stars brighter than tenth magnitude and start increasing steeply as the stars get fainter. Thorough studies of errors for old standard fields and comparison stars are given by Sandage (2001) and Patat et al. (1997), while I have many examples of poor old calibrations (e.g., Schaefer 1994; 1995; 1996; 1998) The old 'photographic magnitude system' (i.e., m_{pg}) is really just a poorly calibrated B magnitude.

All the early magnitudes of hot RCB stars are photographic magnitudes, all from the Harvard plates, all from old measures, and so there are inevitably possibly-large systematic errors in their long-term light curves. It might be that these systematic errors have created the apparent secular fading of the hot RCB stars, or it might be that the errors are such that the claim of secular fading is still correct.

In this paper, I will solve these problems for the old photometry, and answer the question of whether the hot RCB stars are fading or not. To do this, I visited the Harvard College Observatory (HCO) in October 2015, and remeasured many magnitudes from plates dated 1896 to 1989, all on the modern Johnson B magnitude system. For the modern portions of the light curves, I used a variety of sources from the literature and from the *American Association of Variable Star Observers* (AAVSO), all in the Johnson B magnitude system. My combined light curves, all in a single uniform system, have a larger time range and many more magnitudes than given in De Marco et al. I have further extended their work by adding the B-band light curve for the fourth and last-known hot RCB star, HV 2671.

2 PHOTOMETRY WITH ARCHIVAL PLATES

From around 1890 to the late 1970s, a large part of astronomy was from photometry as based on photographic sky pictures. These pictures were recorded on blue-sensitive emulsion attached to one side of a glass plate, with the plate being exposed to star light in a special holder at the focus of the telescope. The developed emulsion had the sky being nearly transparent, while stars were round black points. Photographic emulsions have only a small dynamic range between the sky and saturation, so star images are almost all completely saturated (i.e., black) in the centers, with only a small annulus of grey in the outer tails of the star profile. With this, essentially, the only change in the star image as the magnitude varies is the diameter of the star image. Given the variability from plate-to-plate and the non-linearity of the emulsion, the only way to calibrate the image-diameter-versus-magnitude relation is to use comparison stars nearby on the plate. The procedure is to make some measure of the image diameter for the target star as well as for a sequence of nearby comparison stars with a tight spacing of magnitudes, both brighter and fainter than the target. With this, the magnitude of the target can be measured by interpolation in the image-diameter-versus-magnitude relation as determined for each plate from the comparison sequence.

The image radii vary such that the square of the radii or the logarithm of the radii are linear with the magnitude, depending on the brightness of the star (Schaefer 1981). In general, the full calibration curve (image radius versus magnitude) is nonlinear with either magnitude or flux. This condition violates one of the requirements ingrained in observers with CCDs, because then magnitudes cannot be calculated from any application of the magnitude equation with one comparison star. The long-standing traditional solution is to use a whole sequence of comparison stars, strung out over a wide range of brightnesses, so that the radius-versus-magnitude relation is empirically determined for the brightness of the target star.

The image diameters can be measured with machines called 'iris diaphragm photometers' (first developed in the 1930s) and with photoelectric scanners (first developed in the 1970s). From the earliest days, the dominant method for measuring image diameters was simply for a trained observer to make size comparisons between the diameter of the target star and the diameters of nearby comparison stars. The human eye is remarkably accurate at side-by-side comparisons of the sizes of round objects. The procedure is to view the glass plate on a light table through a loupe or a low-power microscope, compare the target's size to the size of nearby stars, and judge by-eye the relative placement of the target star's diameter. To give a specific and typical example, if the target is judged to be halfway between two comparison stars of magnitude 12.2 and 12.6, then the target has a magnitude of 12.4. In practice, an inexperienced worker can produce magnitudes with an accuracy of 0.3 mag or so, while an experienced worker can produce magnitudes with a one-sigma uncertainty of 0.1 mag. For many situations, where magnitudes from many plates can be averaged together, the real accuracy of the light curves can be 0.02 mag or better. For an experienced worker, the by-eye method provides equal or better accuracy as compared to iris diaphragm photometers or scanning. The by-eye method is very simple, cheap, and fast, whereas the instrumented methods are always complex, slow, and costly.

Harvard College Observatory has a collection of roughly 500,000 glass plates recording the entire sky from 1889 to 1989. (There are few plates from 1954 to 1969 due to the notorious 'Menzel Gap'.) These are almost all blue-sensitive emulsion on glass plates 8×10 inch in size, stored in paper envelopes, and placed on shelves in time order. The plates were taken with a wide variety of telescope, from essentially camera lenses up to 24-inch apertures, with the plate sizes covering widths from 5° to 42°. The limiting magnitudes for the normal-quality plates vary from B=12 to deeper than B=18. The Harvard plates have 1000-4000 plates covering any given position on the sky. Harvard has about half the existing archival plates in the world, and is nearly the only source for targets in the southern skies.

Historically, from 1890 to 1960, the Harvard plates dominated the world of variable stars for anything fainter than about eleventh magnitude. To take an example of the hot RCB stars, all four were discovered with the Harvard plates, and the only published information of any type from before the 1950s is the Harvard light curves. For many questions of modern astrophysics, light curves with 0.1 mag or 0.02 mag accuracy are more than adequate, so the accuracy attainable with CCDs is completely irrelevant. In the world of variable stars, the stars are displaying phenomena on all time scales. Modern studies can cover variable star phenomena on time scales faster than the duration of a single telescope run, and multiple telescope runs can be pasted together to get a picture of phenomena up to a decade in time scale. But to measure phenomena on time scales from a decade to a century, the only means is to use archival data. For most stars, the only source of archival information older than a decade or two is from archival photographic plates, and that largely means the Harvard plates. For the hot RCB stars, in looking for any secular trend (as associated with the evolution of the stars), the only solution is to get fully calibrated light curves from Harvard.

Historically, the Harvard plates were the predecessor of the Johnson B system through the North Polar Sequence. In modern times, the native magnitudes of the Harvard blue plates have always been found to have a near-zero color term with respect to the Johnson B system. This means that as long as the comparison star magnitudes are on the Johnson B system, then the resultant magnitudes are exactly in the Johnson B system.

For my measures of the Harvard plates, I have taken all my comparison star magnitudes from the B-band measures of the AAVSO Photometric All-Sky Survey (*APASS*, Henden & Munari 2014). These magnitudes are tied to the Johnson B magnitudes with high accuracy (Munari et al. 2014), as calibrated from the standard stars of Landolt (2009). Thus, my modern measures of the Harvard plates are accurately in the Johnson B system.

Critically, both the very extensive *DASCH* program (Grindlay et al. 2012) and my own extensive measures prove that long term light curves from Harvard of normal (i.e., constant) stars do *not* produce any measurable slope or trend (i.e., typically <0.05 magnitude per century) over the last century. Further, these check star magnitudes are consistent with the modern measures. This is the proof that any observed secular trend is not some data or analysis artifact.

3 CENTURY-LONG LIGHT CURVES FOR HOT RCB STARS

The goal of this paper is to get the century-long light curves for all four known hot RCB stars so as to test for any secular fading in the maximum light. For this, the only way to get the old data is from Harvard, and these are only in the Johnson B-band. To minimize the mixing of bands, I will take the AAVSO and literature magnitudes for the B-band.

The Johnson B magnitudes for the four Hot RCB stars are listed in Table 1. These do not include the magnitudes where the star was substantially fainter than the maximum brightness.

The archived magnitudes from the AAVSO are freely available on-line. The AAVSO B-band measures are all taken with CCDs, with photometric uncertainties of 0.03 mag or better. Observers are designated with a three-letter designation, with HMB being Dr. Franz-Josef Hambsch in Belgium, DSI being Giorgio di Scala in Australia, and SXN being Michael Simonson in the United States. These are all calibrated with APASS comparison stars, and are thus in the Johnson B system.

I have also pulled a variety of magnitudes from the literature, and these are all CCD measures. (The one exception is the single magnitude from Herbig in 1964 for MV Sgr.) These have been calibrated ultimately from the Landolt fields, and thus are also in the Johnson B system. Intercomparison of modern published B magnitudes always shows that different sources disagree with each other up to ∼0.1 mag, even for known-constant stars and for effectively simultaneous measures of slow variable stars. This is likely being due to different color terms and calibrations between observers. Within each literature source, the quoted error bars are usually ∼0.01 mag, but these are always measurement errors and do not include systematic errors that will appear as a constant offset for each source. Fortunately, the hot RCB stars show variations that are greatly larger than these usual calibration problems, so the existence and slope of the trends remain unaffected. In all, to within the normal errors, all the literature magnitudes are on the modern Johnson B system.

The archival magnitudes in the literature (Hoffleit 1930; 1958; 1959; Woods 1928) are not used, because all have big photometric differences from the modern B magnitude system due to problems with the comparison star sequences, as was universal for the era. I have examined the exact same plates at Harvard, plus many more, all on the modern Johnson B system, so my magnitudes now supersede the old ones in the literature.

A substantial problem is to select out the magnitudes taken when the star is at maximum light. Part of the problem is that the brightness recovery from a decline is only asymptotic, so all magnitudes will still have some residual dust to varying degrees. This is illustrated in Fig. 1, where V348 Sgr never quite recovers completely to some dust-free maximum brightness. An adequate solution is simply that this effect should be the same for old and new magnitudes, so there should be negligible effect on any trends. The biggest part of the problem is that most of the magnitudes are isolated in time, so we cannot recognize whether the star is at maximum or is in a dip. Magnitudes greatly fainter than some maximum are easily recognized and rejected, but mag-

Table 1. B Magnitudes from Harvard Plates.

Star	Julian Date	B (mag)	Plate
DY Cen	2415898	12.7	B29838
DY Cen	2416255	13.0	B31827
DY Cen	2416959	13.3	AM3470
DY Cen	2417257	12.6	AM4107
DY Cen	2418405	12.8	B40009
DY Cen	2418428	12.6	AK286
DY Cen	2418437	12.6	AM6102
DY Cen	2418507	12.7	AM6372
DY Cen	2418869	13.3	B41635
DY Cen	2420960	12.2	AM11620
DY Cen	2421024	12.2	AM11923
DY Cen	2421315	12.2	AM12906
DY Cen	2421333	12.2	AM12992
DY Cen	2421333	12.7	AM13003
DY Cen	2421338	13.0	AM13037
DY Cen	2421342	12.7	AM13047
DY Cen	2422073	12.8	AM14631
DY Cen	2422130	12.8	AM14775
DY Cen	2422137	12.7	AM14806
DY Cen	2422162	12.5	AM14853
DY Cen	2422172	12.6	AM14878
DY Cen	2422176	12.1	AM14889
DY Cen	2422436	12.5	AM15123
DY Cen	2422437	12.4	AM15127
DY Cen	2422456	12.5	AM15165
DY Cen	2422483	12.1	AM15231
DY Cen	2422493	12.1	AM15255
DY Cen	2422517	12.0	AM15292
DY Cen	2422544	12.8	AM15382
DY Cen	2423180	12.5	AM15747
DY Cen	2426470	12.5	RB1688
DY Cen	2426480	12.4	RB1729
DY Cen	2426490	12.7	RB1798
DY Cen	2426497	11.9	RB1821
DY Cen	2426531	12.0	RB1900
DY Cen	2426546	12.8	RB1935
DY Cen	2426771	12.0	RB2507
DY Cen	2426843	12.0	RB2753
DY Cen	2426899	12.7	RB3075
DY Cen	2431904	12.0	RB14293
DY Cen	2431950	12.7	RB14385
DY Cen	2432011	12.3	RB14552
DY Cen	2432328	12.5	RB15102
DY Cen	2432648	12.5	RB15596
DY Cen	2432681	11.9	RB15654
DY Cen	2432758	12.5	RB15795
DY Cen	2433054	12.5	RB16284
DY Cen	2445490	13.8	DSB1047
DY Cen	2445813	13.5	DSB1286
DY Cen	2445848	13.5	DSB1325
DY Cen	2445872	13.1	DSB1359
DY Cen	2445900	13.3	DSB1388
DY Cen	2446243	13.5	DSB1708
DY Cen	2446257	13.6	DSB1711
DY Cen	2446291	13.5	DSB1736
DY Cen	2446497	13.5	DSB1903
DY Cen	2446527	13.2	DSB1932
DY Cen	2446827	13.7	DSB2153
DY Cen	2446945	13.5	DSB2227
DY Cen	2447002	13.8	DSB2300
DY Cen	2447022	13.8	DSB2334
DY Cen	2447241	13.4	DSB2493
DY Cen	2447267	13.3	DSB2541
DY Cen	2447298	13.7	DSB2574
DY Cen	2447322	13.5	DSB2588
DY Cen	2447357	13.3	DSB2630
DY Cen	2447380	13.6	DSB2653
DY Cen	2447590	13.5	DSB2794
DY Cen	2447682	13.6	DSB2827
DY Cen	2447761	13.6	DSB2863
MV Sgr	2417077	12.6	AM3801
MV Sgr	2422605	13.3	MC16930
MV Sgr	2422606	13.0	MC16931
MV Sgr	2425746	12.7	RB334
MV Sgr	2425751	12.7	RB345
MV Sgr	2425778	12.7	RB402
MV Sgr	2428306	13.0	MA5360
MV Sgr	2428672	12.9	MA6375
MV Sgr	2429080	12.7	MA7302
MV Sgr	2429429	12.1	RB8838
MV Sgr	2429435	12.5	RB8861
MV Sgr	2429441	12.6	RB8891
MV Sgr	2429485	12.3	RB9039
MV Sgr	2429547	12.0	RB9181
MV Sgr	2429732	12.4	RB9488
MV Sgr	2429793	12.4	RB9691
MV Sgr	2429808	12.5	RB9732
MV Sgr	2429811	12.4	RB9755
MV Sgr	2429869	12.4	RB9967
MV Sgr	2443616	13.5	DSB512
MV Sgr	2444165	13.5	DSB644
MV Sgr	2444821	13.5	DSB769
MV Sgr	2445140	13.3	DSB911
MV Sgr	2445173	13.3	DSB919
MV Sgr	2445551	13.2	DSB1087
MV Sgr	2445801	13.5	DSB1274
MV Sgr	2445824	13.5	DSB1305
MV Sgr	2445858	13.0	DSB1346
MV Sgr	2445908	13.5	DSB1408
MV Sgr	2446210	13.6	DSB1672
MV Sgr	2446233	13.3	DSB1702
MV Sgr	2446294	13.3	DSB1755
MV Sgr	2446624	13.0	DSB2022
V348 Sgr	2413724	12.1	A1837
V348 Sgr	2415533	12.0	AM808
V348 Sgr	2415576	11.7	AM907
V348 Sgr	2415633	11.6	AM1028
V348 Sgr	2415635	11.6	AM1043
V348 Sgr	2417704	11.9	AM4804
V348 Sgr	2417748	11.7	AM4931
V348 Sgr	2417759	12.0	AM4954
V348 Sgr	2417788	11.6	AM5024
V348 Sgr	2417814	11.8	AM5090
V348 Sgr	2417821	11.8	AM5114
V348 Sgr	2418028	11.8	AM5340
V348 Sgr	2418043	11.8	AM5390
V348 Sgr	2418070	11.6	AM5444
V348 Sgr	2418396	11.7	AM6011
V348 Sgr	2418429	11.4	AK288
V348 Sgr	2418439	11.6	AM6114
V348 Sgr	2418454	11.7	AM6170
V348 Sgr	2418502	11.8	AM6347
V348 Sgr	2418532	11.7	AM6454
V348 Sgr	2418822	11.8	AM6952
V348 Sgr	2418849	11.8	AM7033
V348 Sgr	2418856	11.6	AM7063

Table 1 – *continued* B Magnitudes from Harvard Plates.

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Star	Julian Date	B (mag)	Plate
V348 Sgr	2419205	11.4	AM7457
V348 Sgr	2419205	11.5	AM7458
V348 Sgr	2419234	11.9	AM7549
V348 Sgr	2419562	12.0	AM8301
V348 Sgr	2419563	12.0	AM8307
V348 Sgr	2419594	11.8	AM8423
V348 Sgr	2419605	12.1	AM8492
V348 Sgr	2419618	11.9	AM8522
V348 Sgr	2419633	11.6	AM8559
V348 Sgr	2422084	12.1	AM14682
V348 Sgr	2422152	12.1	MC16930
V348 Sgr	2422152	12.0	MC16931
V348 Sgr	2422515	12.2	MC16838
V348 Sgr	2422517	11.8	AM15294
V348 Sgr	2422581	11.9	AM15486
V348 Sgr	2422582	11.5	MF07104
V348 Sgr	2423179	11.8	AM15745
V348 Sgr	2423182	11.6	AM15767
V348 Sgr	2423192	11.9	A11979
V348 Sgr	2423195	11.8	AM15795
V348 Sgr	2423210	11.5	AM15842
V348 Sgr	2423223	11.7	AM15869
V348 Sgr	2423236	11.8	AM15909
V348 Sgr	2423248	11.5	AM15931
V348 Sgr	2423249	11.6	AM15934
V348 Sgr	2423347	11.9	AM16120
V348 Sgr	2423663	11.5	AM16382
V348 Sgr	2425706	12.0	RB228
V348 Sgr	2425746	12.1	RB334
V348 Sgr	2425751	11.9	RB345
V348 Sgr	2425778	11.9	RB402
V348 Sgr	2425798	11.9	RB434
V348 Sgr	2426802	11.7	RB2554
V348 Sgr	2426810	11.9	RB2611
V348 Sgr	2426871	11.8	RB2851
V348 Sgr	2426872	11.8	RB2869
V348 Sgr	2427901	12.1	RB6045
V348 Sgr	2428013	11.7	RB6313
V348 Sgr	2428035	11.9	AM17031
V348 Sgr	2428041	11.6	AM17056
V348 Sgr	2429485	11.9	RB9039
V348 Sgr	2429732	12.0	RB9488
V348 Sgr	2430095	11.8	RB10453
V348 Sgr	2430107	11.9	AM21531
V348 Sgr	2430110	12.1	AM21549
V348 Sgr	2430111	11.8	RB10532
V348 Sgr	2430111	12.0	RB10534
V348 Sgr	2430111	11.8	RB10535
V348 Sgr	2430111	11.7	RB10540
V348 Sgr	2430113	11.9	RB10560
V348 Sgr	2430113	11.8	RB10566
V348 Sgr	2430113	11.6	RB10568
V348 Sgr	2430118	11.8	RB10585
V348 Sgr	2430120	11.8	RB10593
V348 Sgr	2430121	12.1	RB10598
V348 Sgr	2430136	11.9	RB10666
V348 Sgr	2430137	11.5	RB10668
V348 Sgr	2430139	11.7	RB10680
V348 Sgr	2430140	11.9	RB10692
V348 Sgr	2430141	11.4	RB10698
V348 Sgr	2430141	11.6	RB10699
V348 Sgr	2430153	12.0	RB10768
V348 Sgr	2430162	11.6	RB10827
V348 Sgr	2430163	11.8	RB10828

Table 1 – *continued* B Magnitudes from Harvard Plates.

Star	Julian Date	B (mag)	Plate
V348 Sgr	2430163	11.7	RB10829
V348 Sgr	2430220	11.7	AM21975
V348 Sgr	2430221	11.9	AX4088
V348 Sgr	2430299	11.9	RB11123
V348 Sgr	2431158	12.1	RB12537
V348 Sgr	2431172	11.6	AM23552
HV 2671	2413878	16.2	A2172
HV 2671	2414253	15.4	B20843
HV 2671	2416398	15.4	B32728
HV 2671	2416817	16.0	A7098
HV 2671	2423466	16.3	A12286
HV 2671	2423487	16.1	A12288
HV 2671	2423683	16.2	A12699
HV 2671	2423684	15.8	A12700
HV 2671	2423707	16.1	A12788
HV 2671	2423733	16.0	A12830
HV 2671	2423735	16.1	A12834
HV 2671	2423738	16.1	A12848
HV 2671	2423739	16.2	A12851
HV 2671	2423741	15.5	A12855
HV 2671	2423753	16.2	A12865
HV 2671	2425941	16.3	A14366
HV 2671	2426309	16.0	A15041
HV 2671	2426309	15.5	MF15038
HV 2671	2426322	16.3	A15064
HV 2671	2426328	15.9	A15075
HV 2671	2426335	16.1	A15087
HV 2671	2426410	16.1	A15233
HV 2671	2426412	15.9	A15250
HV 2671	2426413	16.1	A15254
HV 2671	2426414	16.2	A15256
HV 2671	2426421	16.1	A15264
HV 2671	2426426	16.1	A15266
HV 2671	2426441	16.1	A15278
HV 2671	2426444	16.2	A15287
HV 2671	2426452	16.3	A15293
HV 2671	2426453	16.1	A15298
HV 2671	2426454	15.9	A15303
HV 2671	2426455	16.1	A15308
HV 2671	2426456	16.3	A15314
HV 2671	2426566	16.3	A15631
HV 2671	2426568	16.4	A15651
HV 2671	2426569	16.3	A15661
HV 2671	2426572	16.4	A15680
HV 2671	2426573	16.2	A15686
HV 2671	2426578	16.4	A15703
HV 2671	2426606	15.2	MF16077
HV 2671	2426608	15.3	MF16082
HV 2671	2426636	16.4	A15806
HV 2671	2426657	15.7	MF16170
HV 2671	2426679	16.4	A15838
HV 2671	2426680	15.6	MF16250
HV 2671	2426684	16.3	A15847
HV 2671	2426687	16.0	A15851
HV 2671	2426687	15.7	MF16282
HV 2671	2426690	16.2	A15858
HV 2671	2426710	16.3	A15872
HV 2671	2426710	15.5	MF16324
HV 2671	2426720	15.4	MF16389
HV 2671	2426802	15.6	MF16591
HV 2671	2426931	15.3	B56513
HV 2671	2426946	15.6	B56559
HV 2671	2426947	16.2	A16203
HV 2671	2426950	15.7	B56593

Table 1 – *continued* B Magnitudes from Harvard Plates.

Star	Julian Date	B (mag)	Plate
HV 2671	2426956	16.2	B56627
HV 2671	2426957	15.7	B56637
HV 2671	2426978	16.2	A16254
HV 2671	2427311	15.9	A16561
HV 2671	2427749	16.3	A17232
HV 2671	2427777	16.0	A17258
HV 2671	2427800	16.4	A17287
HV 2671	2427800	16.3	A17288
HV 2671	2427800	16.2	A17289
HV 2671	2427800	16.2	A17290
HV 2671	2427800	16.3	A17291
HV 2671	2427801	16.3	A17295
HV 2671	2427802	15.8	A17298
HV 2671	2427807	16.2	A17302
HV 2671	2427807	16.2	A17303
HV 2671	2427808	16.1	A17307
HV 2671	2427808	16.4	A17308
HV 2671	2427808	16.4	A17309
HV 2671	2427808	16.0	A17311
HV 2671	2427811	16.2	A17315
HV 2671	2429584	16.5	A21491
HV 2671	2429606	16.2	B65009
HV 2671	2429671	16.1	B65083
HV 2671	2429674	16.3	A21606
HV 2671	2429690	16.2	A21621
HV 2671	2429879	15.9	B65919
HV 2671	2429905	16.0	A22207
HV 2671	2429934	16.3	A22269
HV 2671	2429939	16.1	A22277
HV 2671	2429956	16.2	A22305
HV 2671	2429970	16.1	A22330
HV 2671	2429994	16.0	A22340
HV 2671	2430023	16.0	B66141
HV 2671	2430045	15.7	MF28653
HV 2671	2430057	16.2	MF22404
HV 2671	2430058	16.2	A22409
HV 2671	2430080	15.9	B66300
HV 2671	2430101	15.7	MF28870
HV 2671	2430110	15.8	MF28953
HV 2671	2430111	16.3	MF28967
HV 2671	2430112	16.2	MF28976
HV 2671	2430240	16.1	B67078
HV 2671	2430264	15.7	B67149
HV 2671	2430314	16.2	A22980
HV 2671	2430314	16.0	B67253
HV 2671	2430315	16.3	A22987
HV 2671	2430318	16.0	A22992
HV 2671	2430318	16.2	A22994
HV 2671	2430319	16.1	A22995
HV 2671	2430320	16.3	A23002
HV 2671	2430322	16.1	A23007
HV 2671	2430323	16.1	A23008
HV 2671	2430324	16.0	A23011
HV 2671	2430325	16.0	A23017
HV 2671	2430328	16.1	A23020
HV 2671	2430372	16.0	B67322
HV 2671	2430373	16.2	A23044
HV 2671	2430373	15.9	B67325
HV 2671	2430373	16.0	B67327
HV 2671	2430373	16.2	A23046
HV 2671	2430373	16.0	A23047
HV 2671	2430375	15.8	B67328
HV 2671	2430375	15.7	B67330
HV 2671	2430586	16.1	A23415

Table 1 – *continued* B Magnitudes from Harvard Plates.

Star	Julian Date	B (mag)	Plate
HV 2671	2430591	16.1	A23424
HV 2671	2430591	15.9	B67968
HV 2671	2430594	16.0	A23427
HV 2671	2430606	16.2	A23430
HV 2671	2430621	16.1	A23450
HV 2671	2430621	15.8	B68040
HV 2671	2430625	16.1	A23453
HV 2671	2430640	16.3	A23458
HV 2671	2430641	16.3	A23462
HV 2671	2430642	16.0	A23466
HV 2671	2430648	16.1	A23471
HV 2671	2430666	16.1	A23485
HV 2671	2430673	16.2	A23490
HV 2671	2430696	16.3	A23502
HV 2671	2430713	16.2	A23513
HV 2671	2430749	15.9	A23528
HV 2671	2430750	16.2	A23530
HV 2671	2430766	15.4	MF31282
HV 2671	2430767	16.2	A23570
HV 2671	2430782	15.6	MF31352
HV 2671	2430791	15.1	MF31364
HV 2671	2430792	15.3	MF31381
HV 2671	2430793	15.5	MF31390
HV 2671	2430809	15.7	B68351
HV 2671	2431804	16.3	A25189
HV 2671	2431814	15.5	B71365
HV 2671	2431817	15.8	MF35012
HV 2671	2431823	16.1	A25194
HV 2671	2431873	16.2	A25218
HV 2671	2431874	16.0	B71427
HV 2671	2432070	16.3	B72205
HV 2671	2432070	16.3	A25565
HV 2671	2432940	15.6	A26696
HV 2671	2433161	15.9	A26976
HV 2671	2433181	16.2	A26998

nitudes from the start or end of a dip, with the brightness only somewhat below the true maximum, can be included, resulting in an apparent fainter maximum. The inclusion of more or fewer in-decline magnitudes will make the star's maximum appear to be fainter or brighter. Fortunately, this problem is minimized by several means. First, dips are deep with fast drop offs, so there will be only a small fraction of the time during which the star will be close-but-below maximum light. That is, contaminated magnitudes must be rare and statistically negligible. Second, for DY Cen and MV Sgr, the dips are rare, so there is little opportunity for contamination. Third, I have rejected plates taken near times of known dips, whether or not the plate shows the star near a maximum. Fourth, for the AAVSO light curves, there are a high density of observations so that dips can be easily recognized (e.g., see Fig. 1) and avoided. Fifth, in generating a light curve at maximum, the effect of including magnitudes in dips) will only matter for measuring secular fading if the early and late measures have different inclusion fractions for dip-magnitudes, and this does not seem plausible. In general, operationally, when I have no additional information, I have tossed out magnitudes if they are more than a magnitude fainter than the maximum for that star and decade. There is a plausible chance that inclusion of the initial and

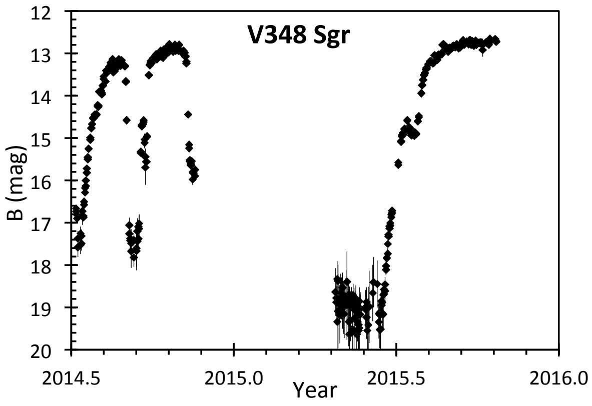


Figure 1. V348 Sgr in B from AAVSO in 2014-2015. The observer was Dr. Franz-Josef Hambsch, in Belgium with a 14-inch telescope. This Johnson B light curve has 483 points, for which 164 magnitudes have been selected as representing the star at maximum light, while Hambsch also has Johnson V magnitudes on all the same nights. This light curve illustrates that the complete recovery from a dip only asymptotically approaches some presumably-dust-free maximum. It also illustrates that the time duration when the star is in the dip but just below maximum is a very small fraction of the time. A further point is that we can confidently measure the magnitudes at maximum to better accuracy than the maximum can be defined. The main point of this figure is that the recent maximum of V348 Sgr is close to B=12.93, whereas the Harvard plates show a maximum light around B=11.8 over a century earlier, with this being proof of a secular decline.

final parts of dips has slightly lowered some of the averages over time. In general, the problem is likely to be minimal in the averages, and certainly the effect is smaller than the trends observed. Thus, I conclude that this problem is not a significant contributor to the observed trends for any of the hot RCB stars.

DY Cen has had no minimum from 1960 to 2016, as shown by the densely-sampled light curves from the Royal Astronomical Society of New Zealand and from the AAVSO (De Marco et al. 2002). With the Harvard plates, I can extend this back to 1935, although the interval from 1954 to 1960 is poorly covered due to the Menzel Gap. Before 1930, Hoffleit (1930) identified four dust dips with the Harvard plates, while I have added further dips. The known dips are in 1897, 1901, 1904.4, 1906.3-1908.5, 1914.5, 1915.3, 1918.5, 1924.1-1924.6, 1929.2-1929.5, 1931.2, 1932.6 and 1934.2. The coverage of the dips is patchy, but it appears that durations are a few months, other than the cases noted. Further dips are likely to have occurred, mainly during the part of the year when DY Cen is the closest to the Sun. We are left with a stark situation where DY Cen has many dust dips from 1895 to 1934, but none from 1935 to 2016.

With this, I have constructed a maximum light curve for each of the hot RCB stars with Harvard, AAVSO, and literature magnitudes, all in the Johnson B system. A simple plot of all these magnitudes shows the usual scatter, with this somewhat hiding secular trends. To solve this, I have averaged the magnitudes by source and time interval. The one-sigma uncertainty is taken to be the RMS scatter in the magnitudes divided by the square root of the number of magnitudes. These averages are presented in Table 2 and Fig. 2.

We see that all four hot RCB stars have an obvious secular decline of roughly one magnitude per century. This then provides the direct confirmation of the result in De Marco et al. (2002). The light curves show roughly linear declines. There is substantial scatter around these linear declines, with it being unclear whether this is due to real variation in the star's maximum light, due to inclusion of magnitudes just below maximum, or due to measurement error. The secular decline need not be linear or even monotonic. We can quantify the secular decline by an average decline rate, derived from a linear fit.

I have made chi-square fits for the light curves in Table 1 for a linear decline. The resultant fits have reduced chi-square values that are much greater than unity, pointing to the variations around the simple straight line being much larger than the nominal error bars. As such, the formal one-sigma error bars from the chi-square fits for the slope are not meaningful. The fitted slopes are 1.15 for DY Cen, 1.29 for MV Sgr, 1.29 for V348 Sgr, and 0.73 for HV 2671, all in units of magnitudes per century. For these four slopes, the average is 1.11 magnitude per century, with an RMS of 0.26 magnitude per century. The calculation of an averaged linear slope is making no implication that any of the stars has a constant linear slope, nor that the stars all have the same linear slope. Indeed, for DY Cen, the light curve appears to be more of a parabola than a line. Further, the Hot RCB stars are apparently a diverse class, so an average decline rate will be some sort of a mixture of rates for stars with different histories and masses. Still, the average fade rate of 1.11±0.26 magnitude per century has utility in expressing the typical decline rate and its variations, in quantitatively showing that the Hot RCB stars are fast fading, and in providing a representative rate for model calculations.

While still with only one band, the AAVSO visual light curves are long enough and with enough accuracy that we can get an independent measure of the secular fading rate. For DY Cen, 6438 visual magnitudes cover the time from April 1978 to October 2015 with no dips, with an average decline rate of 1.87 magnitudes per century. For V348 Sgr, the frequent dips make it harder to pick out a decline by eye from the full visual light curve, yet the maximum magnitudes are around 11.5 in the 1950's and around 12.2 for the last decade, for a decline rate of approximately 1.3 magnitudes per century.

4 DISCUSSION

In essence, I have merely confirmed and extended the conclusion of De Marco et al. (2002) that the hot RCB stars are secularly fading. My improvements have been to use a single photometric system all with modern comparison stars, to collect many more magnitudes over a much wider time range, as well as to measure the decline rate for the fourth hot RCB star.

De Marco et al. (2002) have interpreted these secular

Table 2. Hot RCB star light curves.

Star	Years	⟨B⟩ (mag)	Source
DY Cen	1902–1910	12.84 ± 0.10	HCO (9 plates)
DY Cen	1916–1922	12.46 ± 0.06	HCO (21 plates)
DY Cen	1931–1932	12.33 ± 0.12	HCO (9 plates)
DY Cen	1946–1949	12.36 ± 0.10	HCO (8 plates)
DY Cen	1970	12.62 ± 0.03	Marino & Walker (1971)
DY Cen	1972	12.70 ± 0.03	Sherwood (1975)[a]
DY Cen	1983–1989	13.51 ± 0.04	HCO (23 plates)
DY Cen	1983	12.96 ± 0.02	Kilkenny et al. (1985)
DY Cen	1985	13.03 ± 0.02	Goldsmith et al. (1990)
DY Cen	1987	13.11 ± 0.02	Pollacco & Hill (1991)
DY Cen	1988	13.22 ± 0.04	Jones et al. (1989)
DY Cen	2006–2007	13.45 ± 0.01	AAVSO (DSI, 38 mags)
DY Cen	2013–2015	13.82 ± 0.09	AAVSO (SXN, 25 mags)
MV Sgr	1905	12.60 ± 0.20	HCO (1 plate)
MV Sgr	1920	13.15 ± 0.20	HCO (2 plates)
MV Sgr	1929	12.70 ± 0.20	HCO (3 plates)
MV Sgr	1934-1940	12.48 ± 0.08	HCO (13 plates)
MV Sgr	1963	12.96 ± 0.10	Herbig (1964)
MV Sgr	1978–1986	13.36 ± 0.05	HCO (14 plates)
MV Sgr	1985	13.62 ± 0.03	Goldsmith et al. (1990)
MV Sgr	2006–2014	13.59 ± 0.01	AAVSO (DSI, 76 mags)
MV Sgr	2011–2015	13.90 ± 0.01	AAVSO (SXN, 71 mags)
V348 Sgr	1896–1901	11.80 ± 0.09	HCO (5 plates)
V348 Sgr	1907–1912	11.75 ± 0.03	HCO (27 plates)
V348 Sgr	1919–1923	11.79 ± 0.04	HCO (18 plates)
V348 Sgr	1929–1935	11.87 ± 0.03	HCO (13 plates)
V348 Sgr	1939–1944	11.81 ± 0.03	HCO (30 plates)
V348 Sgr	1970	12.50 ± 0.10	Heck et al. (1985)
V348 Sgr	1972–1974	12.78 ± 0.28	Heck et al. (1985)
V348 Sgr	1981	12.78 ± 0.01	Heck et al. (1985)
V348 Sgr	2014–2015	12.93 ± 0.02	AAVSO (HMB, 164 mags)
HV 2671	1896–1904	15.76 ± 0.26	HCO (4 plates)
HV 2671	1923	16.05 ± 0.10	HCO (11 plates)
HV 2671	1929–1935	16.07 ± 0.04	HCO (63 plates)
HV 2671	1939–1943	16.02 ± 0.03	HCO (68 plates)
HV 2671	1945–1949	16.02 ± 0.08	HCO (11 plates)
HV 2671	1993–1999	16.75 ± 0.1	Alcock et al. (1996)
HV 2671	2001–2009	16.41 ± 0.1	Soszynski et al. (2009)

[a] As quoted in Rao et al. (1993)

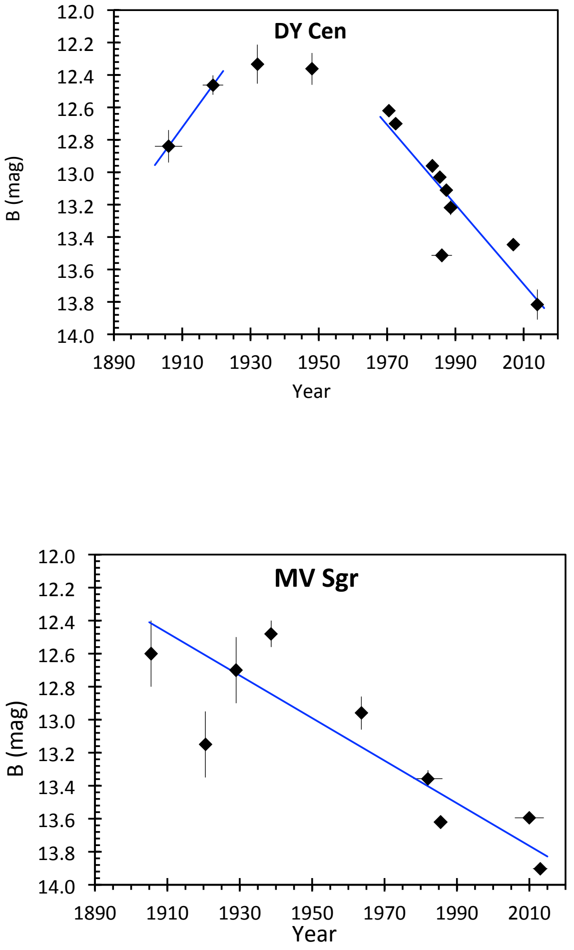
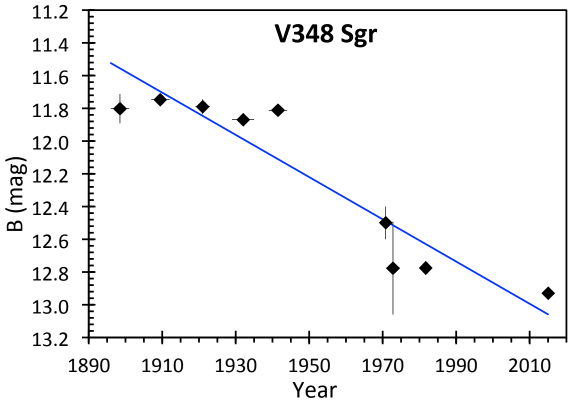
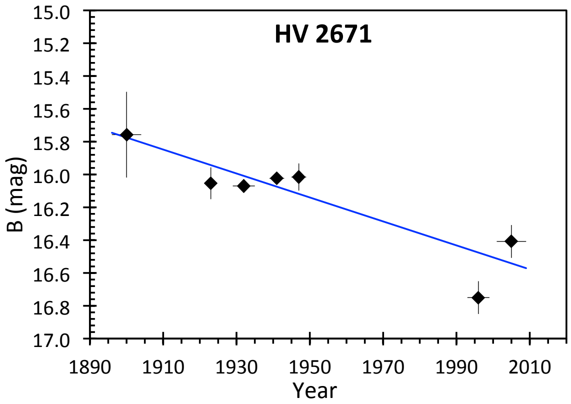


Figure 2. Century-long Johnson B light curves for all four known hot RCB stars. The main point of this figure and this paper is that all four known hot RCB stars have obvious and significant secular declines. The thick lines are from the formal chi-square fit, which represent the average secular fading of the stars. The scatter around these best fits is much larger than the nominal error bars, and it is not clear whether this is due to the intrinsic variations of the maximum brightness, the inclusion of just-below-maximum in-dip magnitudes, or ordinary photometric errors. The four panels are for DY Cen, MV Sgr, V348 Sgr, and HV 2671. The fading of DY Cen is apparent only since 1960 or so, whereas the star was *brightening* before the 1930s.

declines as being due to the star evolving to hotter temperature at constant luminosity, such that the bolometric correction to the optical band makes for an apparent dimming. (The only other plausible explanation is some sort of general increase in the circumstellar dust density, but such would lead to color changes that are not observed in the cases of DY Cen and MV Sgr.) This interpretation matches with the general idea that the hot RCB stars are moving horizontally across the top of the HR diagram as part of their normal and fast evolution. Pandey et al. (2014) have explicitly tested this interpretation for DY Cen, where archival spectra give surface temperatures of 19,400±400 K in 1987, 23,000±300 K in 2002, and 24,800±600 K in 2010. This is 5,400 K in 23 years, or 23,500 K per century. This increase in the stellar temperature is confirmed and reflected in the dramatic change in the excitation of the nebula around DY Cen (Rao et al. 2013).

We can translate this rate of temperature change for DY Cen into a magnitude decline rate. The calculation of the change in bolometric corrections and the change of B-V color is presented in Fig. 1 of Pandey et al. (2014) for the relevant conditions. For a temperature of 19,400 K, they give V=12.78 and B-V=-0.80 (with an arbitrary zero point), for B=11.98. For a temperature of 24,800 K, they give V=13.38 and B-V=-0.85 (with the same arbitrary zero point), for B=12.53. Thus, the observed temperature decline in 23 years corresponds to a fading by 0.55 mag, for a decline rate of 2.39 magnitudes per century. This is close to the average decline rate for the years 1983 to 2015 (see Fig. 2a). So the observed temperature change is consistent with the observed decline rate.





For the evolution of DY Cen going back in time, the temperature must be relatively low in old times, resulting in a large bolometric correction. A simple extrapolation back to 1905 puts the temperature to near zero, so the temperature changes cannot be linear with time. Nevertheless, the temperature back in 1905 should be relatively quite cold. The bolometric correction for the B band is minimized for a stellar temperature of 7,500 K, so that for evolution at constant luminosity, the B magnitude will be brightest at that temperature and dimmer as the temperature departs from this value to both hotter and colder temperatures. So we then have a ready interpretation of the long-term trend in the maximum magnitude (Fig. 2a), with DY Cen starting in 1906 out colder than 7,500 K, heating up to 7,500 K in 1932 when the star was at its brightest, then continuing heating of the star makes it dim over the next decades. The correction from a constant luminosity to the B band can be taken from Table 15.7 of Cox et al. (2000), where the minimum correction is at 7,500 K, and where the corrections of 0.6 mag are for temperatures of 5,800 K and 11,000 K. With this, DY Cen had temperatures of 5,800 K around 1906, 7,500 K around 1932, and 11,000 K around the 1970s. So we now have a simple explanation for why the DY Cen maxima back around 1906 was substantially dimmer than around in 1932. In all, a continuous temperature increase from 5,800 K in 1905 to 24,800 K in 2010 can account for both the observed change in maximum magnitudes and the observed changes in the temperature.

I have made a crude model that accounts for the stellar temperature and maximum magnitude as a function of time. From the models of Saio (1988), I take the logarithm of the temperature to be linear with time, with this being approximately right for a given star under hot RCB conditions. I then set the linear relation by using the observed temperature in 2010 plus the 7,500 K condition for 1932. With these temperatures, I get the bolometric corrections and B-V colors for supergiants from Cox et al. (2000), and add a constant to get the B-band magnitude outside of a decline. This model light curve is displayed in Fig. 3. This model result is not perfect, with the worst problem being that the bolometric correction for 24,800 K should make DY Cen close to 2.0 mag fainter in 2010 than in 1932, whereas it is observed to be more like 1.3 mag fainter. This problem is easily solved if there is extra light in the DY Cen system, perhaps from a wide binary companion or from the circumstellar material. Nevertheless, it is clear that the model captures the essence of a normal RCB stars heating up from around 5,800 K in 1906 to 24,800 K in 2010.

So we have actually watched DY Cen start out as an ordinary RCB star (with temperature around 5,800 K), and then heat up to become a hot RCB star, and now appear as an extreme helium star with no dust dips. This evolution has taken close to one century. So we have a real measure of the duration of the hot RCB stage, and it is about one century. This is a very fast phase of evolution. This explains why so few hot RCB stars have been seen in our Milky Way galaxy, despite them being supergiant stars.

The heating up of DY Cen is also associated with a sharp drop off in the frequency of dips. De Marco et al. (2002) note that DY Cen had only four knowns dips from 1897 to 1927, and zero known dips since 1960. With the Harvard plates, I have identified eight additional dips, all from 1904 to 1934. Apparently, the heating of the star's surface temperature is connected with the turn off of the dust formation, perhaps caused by a stoppage of pulsations as the star leaves some instability strip. We realize that there is only a narrow time window over which the hot RCB phenomenon can be recognized, with only a few decades from the time when DY Cen was sufficiently hotter than the upper limit for normal RCB stars up until the time when the dust dips turn off.

We can translate the typical decline rate of 1.11 magnitude per century into a temperature change rate. For a case with effective surface temperature of 15,000 K, Pandey et al. (2014) give V=12.15 and B-V=-0.75 (with the same arbitrary zero point), for B=11.40. For a temperature of 20,000 K, they give V=12.88 and B-V=-0.79, for B=12.09. For a 5,000 K temperature change over the range for hot RCB stars, the B magnitude changes by 0.69 magnitudes. If this change happens over 62 years, then the B magnitude will fade at the rate of 1.11 magnitude per century.

DY Cen is similar to extreme helium stars (supergiants composed mostly of helium with near one percent carbon and temperatures 9000-35,000 K). Jeffery et al. (2001) found

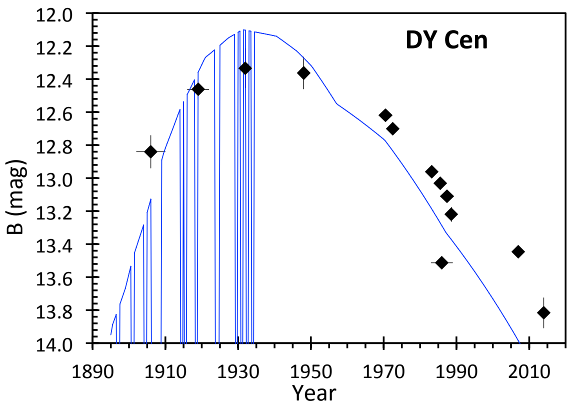


Figure 3. DY Cen evolution from normal RCB to hot RCB to an extreme helium star. Over the last century, the maximum brightness has first brightened, come to a peak round 1932, then started a secular decline continuing to today. The temperature is observed to go from 19,400 K in 1987 to 24,800 K in 2010. This is all consistent with the expected evolution from right to left across the HR diagram at constant luminosity. DY Cen started in 1906 with a temperature of near 5,800 K as a normal RCB star, and rapidly heated up. As it heated up, the bolometric correction lessened, making the star appear brighter, until around 1932 when the bolometric correction is its smallest for a temperature near 7,500 K. As the star kept heating up, the bolometric correction got larger, making the maximum magnitude dim, with this continuing to today. A crude model of this is shown here, with the logarithm of the temperature assumed to change linearly with time, for comparison with the observed peak magnitude. The frequency of RCB dips has also change, with many known dips before 1934, but none known after 1934. All known dips are shown displayed onto the model light curve.

that four out of twelve extreme helium stars are heating up with rates from 20 to 120 degrees K per year. (A useful program would be to search for B-band brightness changes from the 1890s to the present with the Harvard plates for the two stars with the fastest temperature changes; HD 160641 and BD -1°3438.) Such surface temperature changes are expected from models of extreme helium stars with masses of $\sim$0.9 $M_\odot$ (Saio 1988). The majority of stars with no measured change in surface temperature are presumably less massive, perhaps $\sim$0.7 $M_\odot$. DY Cen is changing at a rate of 235 K per year from 1987 to 2010. If the models of Saio (1988) are applicable to DY Cen, then this star would be $\sim$1.0 $M_\odot$.

With the realization as to how some 'cold' RCB stars should evolve on a time scale of a century, we can look for the same changes amongst the known normal RCB stars. That is, the normal RCB stars are heating up, having their maximum magnitudes getting brighter, and their frequency of declines falling to near zero. But such changes have never been seen for any star that is now a 'cold' RCB star. A small number of cold RCB stars have century-long light curves with no apparent change in their brightness at maximum, while R CrB itself has a 230 year record of unchanging peaks. So the heating up of the cold RCB stars must usually be too slow to produce observable effects. Still, some fraction of the now-cold RCB stars might be like DY Cen a century ago. Perhaps only the most-massive cold RCB stars will be evolving fast enough for the changes to be detectable.

A practical plan to search for fast evolving cold RCB stars is to construct a century-long light curve for many of them. This could show secular changes in the magnitude at maximum as well as in the frequencies of declines. In practice, the primary sources are archival data from AAVSO and Harvard. In any such study, care must be used to place all magnitudes onto a consistent magnitude system. (For example, old AAVSO magnitudes will require corrections for changes in the comparison sequences, and these can only be gotten from old charts archived at AAVSO Headquarters.) A substantial problem in seeking changes in the decline-frequency will be to adjust for the variations in time-coverage over the decades. With this, we have a plan for someone to make a systematic survey of century-long light curves for normal RCB stars so as to measure their evolution across the HR diagram.

In general, stars evolve on such slow time scales that astronomers have not been able to see the changes over time. Other than for supernovae, evolutionary changes have only been seen for a few post-AGB stars, including the born-again stars and the Stingray (Schaefer & Edwards 2015). Now, we can add the four hot RCB stars, with observed temperature rises of 8,000 K or more over the last century.

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