ANALYSIS OF HIPPKE et al. (2016) and LUND et al. (2016)

--M. Hippke, D. Angerhausen, M. Lund, J. Pepper, & K. Stassun 2016, arXiv:1601.07314v4
--M. Lund, J. Pepper, K. Stassun, M. Hippke, & D. Angerhausen, 2016, arXiv:1605.02760v1

Hippke and Lund have made two blunders:

(1) The first blunder is to use crowded check stars, where some check stars have another random star nearby, such that on some plate series the two stars are overlapped and the DASCH SExtractor photometry will return a *combined* magnitude. With the distributions of these known-errors being strongly structured in time, the apparent light curve will not appear flat. In particular, if crowded check stars are selected, then often the Damon plates will be reported as being unusually bright, and since the post-Menzel-gap magnitudes are exclusively from the Damons, there will appear to be a jump across the Menzel gap. Such effects will also lead to apparent non-flat slopes. But the jumps and slopes are purely an artifact of a nearby crowding star. KIC 8462852 is not crowded. So the use-of or comparison-to crowded check stars is bad. Hippke and Lund make this blunder many times.

(2) The second blunder is to use the 'KIC calibration' instead of the correct 'APASS calibration'. For historical reasons, before the release of the APASS survey to serve as comparison stars, the KIC '*g*' magnitudes were used to calibrate the stars in the Kepler field. This is known to be poor, due to variations in color terms that change with the plate series and stars involved. When the APASS 'B' magnitudes came out in ~2011, the DASCH team started using this calibration exclusively, and their strong recommendations (stated on their web page, in their journal articles, at conferences, and in private) is to only use the APASS calibration. And it actually matters, as simply changing the source for the calibration will change a perfectly flat light curve with APASS into an apparent slope with a jump in the light curve with the KIC calibration. It turns out that both Hippke and Lund have primarily used the KIC calibration. This is a mistake. The resultant light curves have apparent jumps and slopes caused only by a bad use of the DASCH data. They have fooled themselves into seeing jumps and non-flat light curves only because they have abused their data source.

THE EXTENT OF HIPPKE'S and LUND'S MISTAKES

Most of the stars selected and reported by both Hippke and Lund have one or two of the analysis mistakes.

Let me show the cases for Hippke's stars. In the body of his paper, Hippke only specifies the IDs for three stars, one of which is Tabby's star. The first two are the only ones that Hippke highlights as specific examples in the body of the text:

KIC ID #	Claimed Slope (mag/cen)	Crowding Star?	Calibration	Comments
6366512	-0.45	Yes!	KIC	Slope & jump entirely from crowding star
9909362	+0.12	No	KIC	KIC calibration, not APASS as labeled

That is, Hippke's primary examples of DASCH light curves only serve to illustrate his two blunders.

Now let us look at the stars in the Appendix, for which Hippke specifies by star name, quotes his claimed slope, and presents a plot of the DASCH light curve. Let me show the results for just the first six, with all the rest showing similar conclusions:

KIC ID #	Claimed Slope (mag/cen)	Crowding Star?	Calibration	Comments
8863278	-0.19	Yes!	KIC	Slope & jump entirely from crowding star
8864316	+0.070	No	KIC	APASS has similar slope
8864877	+0.031	No	KIC	APASS has flat light curve
8864911	-0.16	No	KIC	APASS has flat light curve
8864923	+0.159	No	KIC	APASS has flat light curve (large uncertainty)
8831931	+0.054	...	...	Hippke's star ID is wrong

What we see is that all of Hippke's appendix stars have mistakes. When correct slopes are found for uncrowded check stars, the average slope is near zero with an RMS of under 0.05 mag/century.

Now let us look at the stars in the Lund et al. paper. In particular, let us look at the stars highlighted in Lund's Table 1 as "Stars with Significant (5sigma) Long-Term Photometric Trends":

TYC or KIC ID #	Claimed Slope (mag/cen)	Crowding Star?	Calibration	Comments
6727-524	+0.121	No	APASS	
6174-949	-0.215	Yes!	KIC	Slope & jump entirely from crowding star
5531-1038	-0.169	Yes!	KIC	Slope & jump entirely from crowding star
5554-1593	-0.023	Yes!	APASS	Crowding star affects mags on RB series
6178-821	-0.088	Yes!	APASS	Crowding star affects mags on RB & Damons
6749-508	+0.126	Yes!	APASS	Crowding star affects mags on RB & Damons
6160-274	+0.111	No	APASS	
5554-1017	-0.022	Yes (2)	APASS	Crowding star affects mags on RB & Damons
6165-1434	+0.096	No	APASS	
3868420	-0.571	Yes!	KIC	Slope & jump entirely from crowding star
11802860	+0.452	No	KIC	Large amplitude RR Lyr *, =AW Dra, APASS LC has few mags, slope is random

So most of Lund's stars also have errors.

But there are three stars with slope ~0.1 mag which do *not* suffer for Lund's Mistakes #1 and #2. So what about these? Well, Lund says that he examined 644 stars. Out of all these, he found the three highest slopes to be 0.096-0.121. At the 3/644 = 0.5% level, we expect to get such random variations in the slope up to the 2.8-sigma level. We independently have my measures of the RMS=0.044 for the slope with the same magnitude and color all within ~22 arc-min from Tabby's star. With this, we expect 99.73% to be within 3-simga = 0.134 for the slope, which is to say that we expect roughly 2 stars (out of Lund's 644 stars) to have a slope of >0.134, whereas Lund sees zero. So, Lund's statistics is merely confirming that the RMS slope of constant stars on the Harvard plates is ~0.04 mag/century.

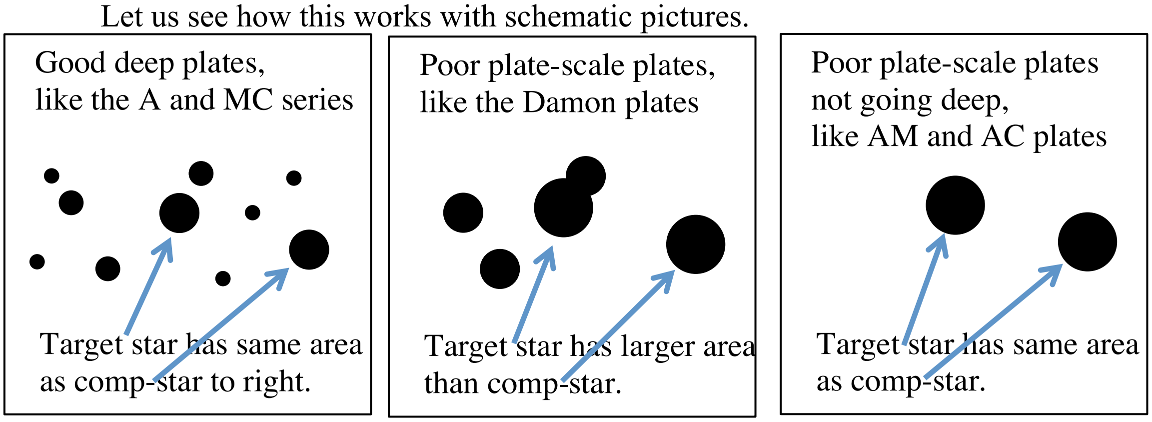
MISTAKE #1: NEARBY CROWDING STARS

Some stars in the sky have other crowding stars nearby, and if they overlap, then the photometry will certainly have systematic errors. These systematic errors will depend on the Harvard plate series (because the limiting magnitude and plate scales vary greatly with the series), and the series are confined to specific range of years within 1890-1989. So when a crowded-check-star is involved, we always will have one time interval being bright, leading to an apparent jump in the DASCH light curve and an apparent long term slope. That is, if a crowded-check-star is used, then a false high-slope will be reported.

OK, so if someone uses crowded check stars (like both Hippke and Lund do), then they will produce spurious slopes and jumps. Without experience or knowledge, they claim that the DASCH light curves are bad, when all it really is that they have bad choices of check stars. Critically, KIC 8462852 (i.e., Tabby's star) does *not* have any crowding. So any use of crowded check stars is a mistake. Many of Hippke's and Lund's check stars are crowded, and so they are fooling themselves with Mistake #1.

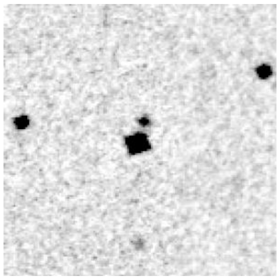
To work out how it goes, we have to see how photographic photometry works and how DASCH photometry works. A key point is that photographs have all the star images (brighter than about one magnitude above the plate limit) saturated in the core. This immediately means that the usual experience from CCD photometry is of no use. The star images have only a small radius range where the photographic density is grey, outside of the black saturated body of the image, and inside the background region. So for photographic photometry, the measure of the magnitude is largely just the radius of the image. For visual examination of the plate, the human eye does a very good job in comparing nearby images to evaluate the relative radii. For the common case where Harvard plates have trailing or non-circular PSFs, the radius is not well defined, so the real measure is the area of the image. And that is what the SExtractor algorithm does. From Laycock et al. (2010, AJ, 140, 1062), we read "The instrumental magnitude is then derived from the summation of pixel values belonging to the star." With most of the image being saturated, this is basically the area of the image above some isophotal level. Now the next question is how SExtractor handles crowding stars nearby the target of interest. If the stars are far enough apart, then the contiguous area will have a saddle point and DASCH will split the flux. But if the star is too faint, then there will not be a saddle point, and SExtractor will attribute the area in the crowding star to the brightness of the target star. Or if the two stars are sufficiently close that the saturated cores overlap, then there will be no saddle point (and no two peaks), so then SExtractor will measure a larger area and attribute it all to the target star, resulting it in an erroneous bright magnitude.

Let us see how this works with schematic pictures.



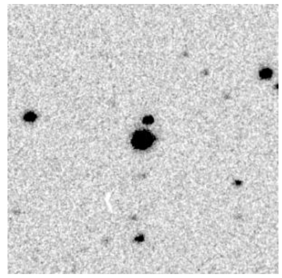
OK, now let us see how this works with one of Lund's stars, TYC 5531-1038-1, with the real DASCH postage stamp images. The target star has a nearby crowding star that is something like two mags fainter. On some plates, this crowding star is well separated and does not contribute any area to the SExtractor instrumental magnitude. This is usually the case for plates in the MC, MF, B, I, and A series:

RB 5161

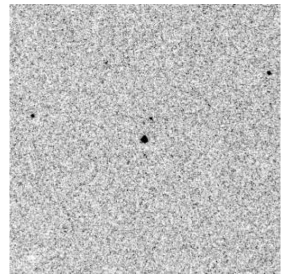


B 74846

MF 37226

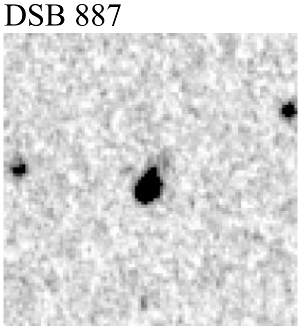


MC 12826

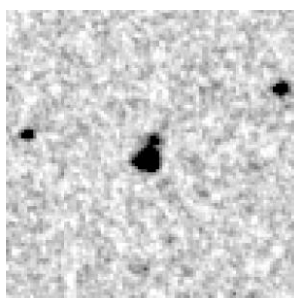


But for series with a poor plate scale (like the Damons and the AM and AC series), all the image sizes are large enough such that the target star image joins with the crowding-star image, resulting in DASCH seeing the combined light as one too-bright star. For this particular example from Lund's paper, nearly all of the Damon plates are crowded. And since the post-Menzel-gap plates are only from the Damons, which are erroneously bright due to crowding, it looks like the target star is brighter after 1960 than before. This shows how Hippke's and Lund's bad choice of check stars makes for apparent jumps and slopes - all as an artifact of their bad choices:

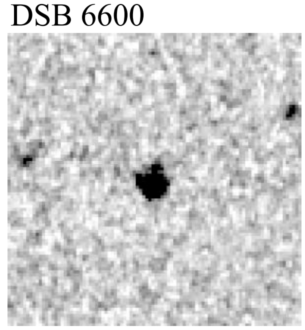
DSB 887



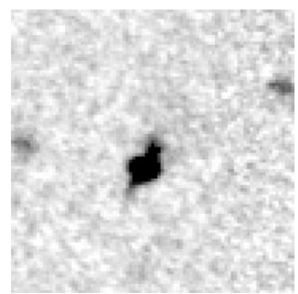
DSB 2189



DSB 6600

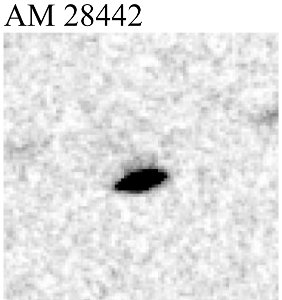


AM 28183

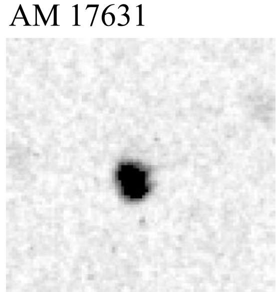


Sometimes, the plate limiting magnitude does not go deep enough, so the crowding star does not appear (above the isophotal threshold for SExtractor), so there is no effect on the derived magnitude of the target star. And sometimes the plate has poor enough of a focus so that the target star largely covers the crowding star, so most of the flux of the crowded star simply is lost in an already saturated place, again with no significant affect on the derived magnitude of the target star. Here are some examples for Lund's star:

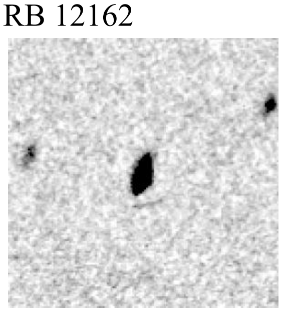
AM 28442



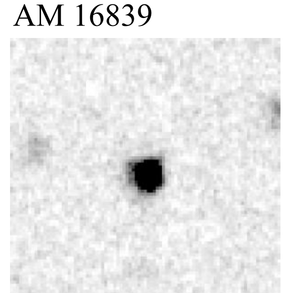
AM 17631



RB 12162



AM 16839



OK, there is one more ingredient that needs to get put in, and that is the time distribution of the various Harvard plate series. Critically, the Damon plates often have exactly these crowding troubles, and all of the Damon plates are after the Menzel gap of 1953-1969, and essentially *only* the Damon plates are after the Menzel gap. This means that the pre-Menzel-gap light curves of crowded-check-stars will be often without corrections needed (being composed with many good plates series, or of plate series that do not go deep enough to record the crowding star). This also means that the post-Menzel-gap plates almost always erroneously appear bright due to the crowding that affects the Damon plates. That is, any person who choses a crowded-check-star will get a known bad result. Both Hippke and Lund have chosen many crowded-check-stars.

The effects can be more complicated than simply having a jump to brighter magnitudes across the Menzel gap. The details depend on the closeness and the relative magnitude of the crowding star. Here is a short summary of the Harvard plate series, along with their characteristics:

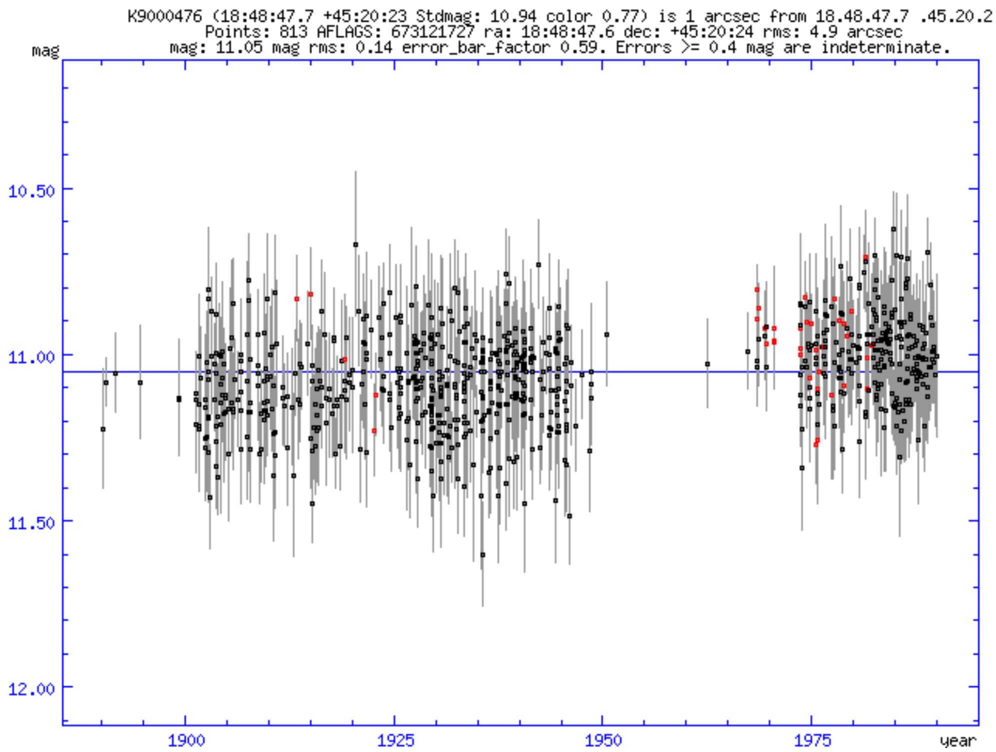
SERIES	YEAR RANGE	CHARACTERISTICS
Damons	1969-1989	Poor plate scale but goes deep
AM, AC	1898-1953	Poor plate scale, does not go deep
A	1893-1950	Very good plate scale, goes very deep
MC, MF	1910-1953	Good plate scale, goes very deep
B, I	1889-1953	Middle plate scale, sometimes goes moderately deep
RH, RB	1928-1953	Middle plate scale, sometimes goes moderately deep

The point is that the plate series all have individual time distributions, and with a crowded-check-star making for a combined magnitude preferentially bright for only some particular series, with the result that the apparent light curve will show false jumps and false overall-slopes. But this is due to Hippke and Lund selecting bad-check stars, and not having the experience to recognize their errors.

MISTAKE #2: USING THE KIC CALIBRATION

Before the advent of the AAVSO Photometry All-Sky Survey (APASS), the Kepler field was calibrated in DASCH with the Kepler Input Catalog (KIC). The use of the KIC calibration was problematic because color corrections are required to go from the KIC *griz* magnitudes to the DASCH native B-magnitude system. With the availability of the APASS, with its native B magnitudes, this becomes the default. Grindlay advertises this in conferences and in person. Tang et al. (2013, PASP, 125, 857) points to the APASS calibration as the default. The prime DASCH web page states "The APASS calibration gives the best photometric accuracy over the entire sky." The point is that the use of the KIC calibration is a mistake.

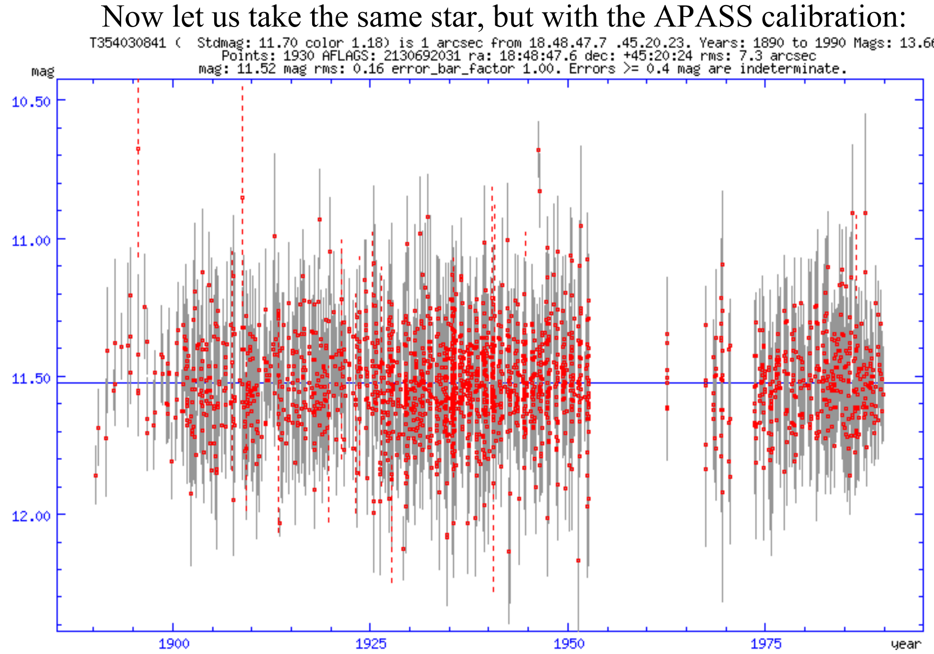
And this actually matters. We can see this by comparing the DASCH light curves for one of Hippke's stars with both the KIC and APASS calibration. For KIC 9000476, here is the DASCH light curve with the KIC calibration:



We see that Hippke is right, that there is an apparent jump in brightness after 1960. That is, the average magnitude before 1960 is a bit below the average line, while the average magnitude after 1960 is about 0.1 mag brighter than the average line.

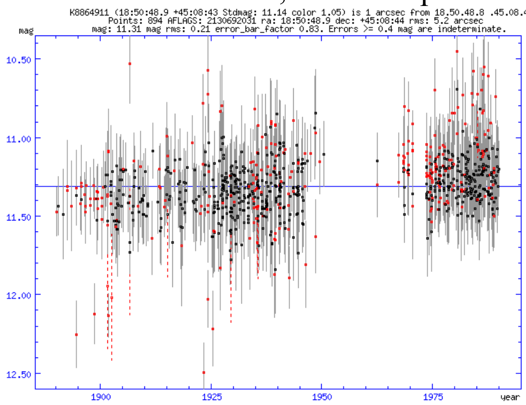
Note that the KIC calibration returns an average magnitude of 11.05, whereas Arlo Landolt's measured magnitudes are B=11.518 (and V=10.451). This shows that the KIC calibration has troubles. The KIC calibration is not returning B magnitudes. The APASS calibration gives a magnitude (see below) that has an average of B=11.52, which is just perfect. This shows in one way that it is a mistake to use the KIC calibration.

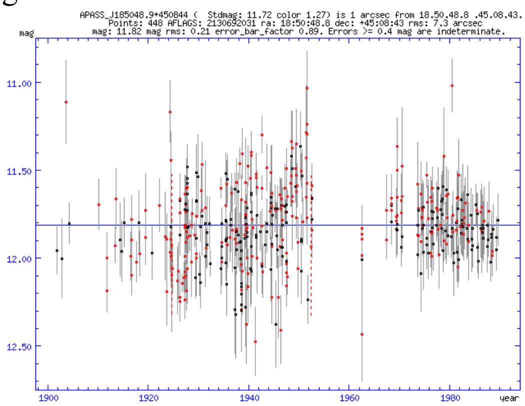
Now let us take the same star, but with the APASS calibration:



Suddenly, we see that the jump across 1960 has gone away. We see a perfectly flat light curve, with the usual scatter. The point is that the KIC light curve has an artificial jump superposed. The APASS calibration shows a constant star, while the KIC calibration introduced the exact error that Hippke has picked out.

Let us look at smaller images for another Hippke star; KIC 8864911. The plot on the left is the KIC calibration, while the plot on the right is the APASS calibration:





Again, we see that the KIC calibration has a systematic jump across 1960. Again we see that this goes away with the correct APASS calibration. This shows another case where the Hippke methodology (using the KIC calibration) knowing produces wrong-jumps and wrong-slopes., whereas the DASCH light curves are nice and flat with the correct procedures.

This exact same pattern is seen for star after star in Hippke's paper. Hippke is concluding that DASCH photometry has systematic errors, but all he has found is that the (non-recommended) KIC calibration has systematic errors. But if you use DASCH as recommended, the check stars have flat light curves. Many of Hippke's claimed check-stars-with-large-apparent-slope are simple blunders because he made Mistake #2.