A Photometry Comparison of 41 Henden M67 Comp Star Differences With Five Other Surveys

8/31/2017

	APASS Ave Difference	APASS STDEV	BSM AVE Difference	BSM STDEV	CMC Ave Difference	CMC STDEV	Pan-STARRS Ave Diff	Pan-STARRS STDEV	SDSS Ave Diff	SDSS STDEV
U									.059	.079
B	.029	.033	.018	.021	.087	.104	.097	.030	.039	.063
V	.027	.028	.022	.018	.020	.024	.056	.026	.029	.032
R	.113	.072	.017	.017	.030	.039	022	.026	.023	.031
I	.197	.127	.023	.022			.040	.064	.059	.062

Table 1

Table 1 methodology: The differences in all case are an average for the surveys included stars (see *Table 2*) against the corresponding Henden stars and filters.

No one survey included an equal number of Henden Comps because of their differing ranges of saturation and uncertainties (see notes).

Survey	U Mag Range	# U Comps	B Mag Range	# B Comps	V Mag Range	# V Comps	R Mag Range	# R Comps	I Mag Range	# I Comps
Henden	16.053-19.068	13	9.978-19.511	41	10.040-18.791	41	10.059-18.460	41	10.086-18.197	41
APASS			10.026-16.617	33	10.058-15.663	33	10.164-15.139	33	10.252-14.650	33
BSM			9.980-12.928	14	10.043-12.387	14	10.062-11.624	13	10.095-11.158	13
CMC			10.072-14.746	25	10.048-14.047	25	9.996-13.652	25		
Pan-STARRS			14.800-18.333	14	14.271-19.729	16	13.949-18.383	16	16.637-18.048	16
SDSS	16.054-19.391	12	15.728-18.333	12	14.987-18.732	12	14.563-18.388	12	14.152-18.008	12

Table 2

Survey Notes:

BSM: One comp had no Rc or Ic data.

Pan-STARRS: Because the two faintest B filter comps had unacceptable differences (19.132 & 19.319) they were removed for B filter purposes and ending that sequence with a B = 18.333. Please see the separate section: Efficacy of Pan-STARRS as a BVRI source.

Survey Source Information

Henden: The first 33 comp stars (through V = 15.629) were sourced from the AAVSO's VSP's *Special Chart Option* for the *Standard Field* option centered on the coordinates of M67 (08:51:20+11:47:00):

https://www.aavso.org/apps/vsp/

As that sequence stopped with V = 15.629 the remaining 8 fainter comps were sourced from SeqPlot [NOFS (10)]:

https://www.aavso.org/Seqplot

APASS: These 33 comps were sourced directly from SeqPlot by selecting those comps that matched the Henden coordinates and had reasonable uncertainties. It should be acknowledged that the APASS Rc & Ic data was converted from APASS Sloan filters prior to its inclusion into SeqPlot [Suspect that the conversion was according to Jester et al. (2005)]

BSM: These 14 comps were sourced directly from SeqPlot By selecting those comps that matched the Henden coordinates and had reasonable uncertainties.

CMC: These 25 comps were sourced from VizieR, For this catalog, in their native format of r', J & K, by selecting those comps that matched the Henden coordinates and had an expectation of reasonable uncertainties:

http://vizier.cfa.harvard.edu/viz-bin/VizieR

The conversion to V was accomplished using the formula provided in the paper: *A Method for determining the V magnitude of asteroids from CCD Images*, by Roger Dymock & Richard Miles:

http://www.britastro.org/asteroids/JBAA%20119%20149-156%20Dymock1.pdf

When (10<V<14.2)

V = 0.6278*(J-K)+0.9947*r'

The conversion to B originated from Brian Skiff (no current source for this, except for an old email from a fellow observer).

$Rc = V-0.508*(B-V)-0.040$
$B-V = (V-Rc-0.04)/.508$

The conversion to Rc was accomplished using the formula provided in the paper: Red Magnitudes, by John Greaves:

http://www.aerith.net/astro/color_conversion/JG/redmags.pdf

$Rc = 0.984r'$

Pan-STARRS:

These 16 comp stars were sourced directly from a Pan-STARRS catalog search url, centered on the M67 coordinates:

http://archive.stsci.edu/panstarrs/search.php

using the mean aperture magnitudes for the g,r & I filters (i.e, gMeanAPMag)

The conversions to BVRI were accomplished with the use of transformations suggested by Jester et al. (2005) as sourced through SDSS:

http://www.sdss3.org/dr8/algorithms/sdssUBVRITransform.php

When $Rc-Ic < 1.15$

$B-V = 0.98*(g-r)+0.22$
$V-R = 1.09*(r-i)+0.22$
$Rc-Ic = 1.00*(r-i)+0.21$
$B = g+0.39*(g-r)+0.21$
$V = g-0.59*(g-r)-0.01$

SDSS

These 12 comps were sourced directly from a SDSS url, using the inserted search language, as provided below between the --- lines (see below instructions):

http://skyserver.sdss.org/dr12/en/tools/search/sql.aspx

1. (a) Delete the existing copy from the SQL Search Box(white area).

2. Copy & Paste in the following query(between lines) into the SQL Search Box (white area). Replace "W" with the RA (decimal degrees), "X" with declination, "Y" with the radius (5th line from bottom-radius is in arcmin; suggest “6” as a starting point) and "Z" with the magnitude of the variable we are making a sequence for (last line).

```
-----------------------------------------------------------------
select
  s.objid,
  s.ra,
  dbo.fHMS(s.ra) as HMSra,
  s.dec,
  dbo.fDMS(s.dec) as DMSdec,
  (s.u - 0.0316*(s.u - s.g) - 0.7487) as U,
  (s.u - 0.8116*(s.u - s.g) + 0.1313) as B,
  (s.g - 0.5784*(s.g - s.r) - 0.0038) as V,
  (s.r - 0.1837*(s.g - s.r) - 0.0971) as R,
  (s.r - 1.2444*(s.r - s.i) - 0.3820) as I,
  ((s.g - 0.5784*(s.g - s.r) - 0.0038) - 16) as VmagDifference
from star s, dbo.fGetNearbyObjEq(W,X,Y) f
where s.objid = f.objid
  and (0.1884*s.u + 0.39*s.g - 0.5784*s.r + 0.1351) between 0.3 and 1
  and (s.g - 0.5784*(s.g - s.r) - 0.0038) < 19
order by ((s.g - 0.5784*(s.g - s.r) - 0.0038) - Z)
----------------------------------------------------------------
```

The results will be in the form of a nice HTML table with RA and Dec in both sexigesimal and decimal degrees and UBVRI. The photometry equations are from: The U band comes from Jester and the BVRI from Lupton. Arne Henden chose the specific equations to use (which can be seen in the SQL query), in 2007.

The stars listed are those with 0.3 < B-V < 1.0 and cutoff at 19th magnitude (change the 19 in the equation for a different cutoff).

Efficacy of Pan-STARRS as a BVRI source

A goal of this survey was to also see if it were possible to demonstrate the efficacy of Pan-STARRS as a BVRI source using the best magnitude option and best conversion algorithm. The other surveys, herein covered, are all already being used as an AAVSO sequence source.

After examining the V filter data (V = g-0.59*(g-r)-0.01)using both the Mean aperture column data (I,e, gMeanApMag) and the maximum PSF magnitude column (i.e., gMeanPSFMagMax) I concluded that the Mean aperture column provided the best results; then it was just a question of whether the Jester conversion formulas or the Lupton conversion formulas would be the best choice; table 3 shows the differences with both sources against Henden data.

	Lupton Ave Difference	Lupton STDEV	Jester Ave Difference	Jester STDEV
B	.117	.037	.097	.030
V	.044	.025	.056	.026
R	.024	.026	.022	.026
I	.039	.054	.040	.064

Table 3

The differences are relatively comparative, IMO, and I elected to use Jester for this purpose. In either event, the data shows that Pan-STARRS is an acceptable source for fainter data for use in AAVSO Sequences.

Note To Sequence Team Members Regarding Uncertainty values for CMC, Pan-STARRS and SDSS Surveys.

CMC Uncertainties: Historically, we have Inserted .05 for V, NA for B and .139 for R. Based upon this data I would be comfortable in leaving the V uncertainty as is; changing the B uncertainty from NA to .2 and the R uncertainty from .139 to .09.

Pan-STARRS Uncertainties: Add the appropriate Sloan filter error values in quadrature.

SDSS Uncertainties: Historically we have inserted .05 uncertainty for each filter, BVRI and this data suggests that is a reasonable option.

Closing Remarks

It is to be recognized that the number of comps involved are a very small sample. Other fov's with differing number of observations and seeing will probably produce different data.

While this has been a very time consuming project (10 spread sheets) and I have endeavored to be accurate, there always remains the potential for errors. Please feel free to point out any errors or omissions

At the end of this I have also included the BVRI Magnitudes for all the comps, extracted from the original spread sheets used, with the coordinates being from Henden (NOFS) data.

Tim R Crawford, CTX
AAVSO Sequence Team
tcarchcape@yahoo.com

RA	m	s	Dec	m	s	Henden B	APASS B	CMC B	BSM B	SDSS B	Pan-STARRS B
8	51	11.82	11	45	22	9.978	10.026	10.072	9.980		
8	51	17.12	11	48	16	11.553	11.554	11.362	11.547		
8	51	22.83	11	48	2	11.562	11.571	11.353	11.601		
8	51	26.87	11	48	41	11.064	11.094	11.063	11.097		
8	51	12.71	11	52	43	11.617	11.629	11.501	11.625		
8	51	43.58	11	44	27	11.898	11.894	11.761	11.889		
8	51	27.04	11	51	53	11.042	11.058	11.209	11.061		
8	51	26.46	11	43	51	11.391	11.402	11.499	11.401		
8	51	42.39	11	51	23	12.342	12.357	12.216	12.352		
8	51	21.78	11	52	38	11.911	11.952	11.857	11.933		
8	51	3.54	11	45	3	11.604	11.587	11.657	11.625		
8	51	7.84	11	48	9.5	11.949	11.972	12.033	11.962		
8	51	19.93	11	47	0.7	12.572	12.591	12.532	NA		
8	51	39.41	11	51	46	13.138	13.165	13.042	13.156		
8	51	13.63	11	50	38	12.883	12.896	12.820	NA		
8	51	42.7	11	46	37	12.971	12.961	13.058	12.928		
8	51	25.4	11	47	35	13.129	13.158	13.154	NA		
8	51	3.28	11	45	48	13.263	13.263	13.198			
8	51	1.08	11	50	11	13.468	13.493	13.452			
8	51	24.11	11	48	22	13.386	13.410	13.332			
8	51	30.16	11	43	50	13.714	13.749	13.721			
8	51	1.59	11	47	50	14.101	14.078	14.227			
8	51	5.27	11	49	34	14.321	14.289	14.409			
8	51	4.95	11	52	26	14.423	14.449	14.456			
8	51	31.94	11	51	17	14.618	14.688	14.746			
8	51	13.75	11	49	59	14.851	14.854				14.800
8	51	21.86	11	43	18	15.157	15.205				15.070
8	51	24.7	11	43	6.5	15.448	15.510				15.363
8	51	3.02	11	52	26	15.746	15.859			15.728	15.636
8	51	12.25	11	47	15	15.901	15.861			15.953	15.801
8	51	35.2	11	51	40	16.129	16.110				15.999
8	51	31.78	11	45	9.1	16.347	16.389			16.342	16.214
8	51	6.99	11	41	49	16.531	16.617			16.522	16.417
8	51	18.31	11	41	30	16.851				16.831	16.705
8	51	43.94	11	45	38	17.073				17.056	16.948
8	51	27.29	11	41	59	17.214				17.203	17.137
8	51	45.55	11	42	10	17.717				17.726	17.653
8	51	22.21	11	44	39	18.190				18.193	18.121
8	51	29.29	11	42	48	18.403				18.394	18.333
8	51	18	11	52	26	19.346				19.212	19.132
8	51	22.58	11	43	36	19.511				19.334	19.319

RA	m	s	Dec	m	s	Henden V	APASS V	CMC V	BSM V	SDSS V	Pan-STARRS V
8	51	11.82	11	45	21.7	10.040	10.058	10.048	10.043		
8	51	17.12	11	48	16.4	10.289	10.314	10.299	10.308		
8	51	22.83	11	48	2	10.453	10.473	10.455	10.486		
8	51	26.87	11	48	40.7	10.489	10.515	10.500	10.519		
8	51	12.71	11	52	42.6	10.524	10.542	10.532	10.535		
8	51	43.58	11	44	26.7	10.763	10.777	10.785	10.789		
8	51	27.04	11	51	52.8	10.946	10.975	11.000	11.000		
8	51	26.46	11	43	51	11.263	11.273	11.304	11.287		
8	51	42.39	11	51	23.3	11.266	11.298	11.273	11.284		
8	51	21.78	11	52	38.1	11.305	11.325	11.274	11.310		
8	51	3.54	11	45	3	11.314	11.327	11.332	11.339		
8	51	7.84	11	48	9.5	11.544	11.571	11.570	11.560		
8	51	19.93	11	47	0.7	12.116	12.147	12.093	NA		
8	51	39.41	11	51	45.9	12.138	12.178	12.146	12.164		
8	51	13.63	11	50	38.3	12.213	12.171	12.186	NA		
8	51	42.7	11	46	36.9	12.410	12.408	12.436	12.387		
8	51	25.4	11	47	34.5	12.540	12.568	12.556	NA		
8	51	3.28	11	45	47.6	12.652	12.663	12.637			
8	51	1.08	11	50	11.1	12.731	12.755	12.735			
8	51	24.11	11	48	22.2	12.815	12.853	12.771			
8	51	30.16	11	43	50.2	13.133	13.153	13.134			
8	51	1.59	11	47	50.4	13.509	13.488	13.554			
8	51	5.27	11	49	34.3	13.750	13.680	13.750			
8	51	4.95	11	52	26.3	13.850	13.830	13.848			
8	51	31.94	11	51	16.9	14.016	14.068	14.047			
8	51	13.75	11	49	59.1	14.302	14.292				14.271
8	51	21.86	11	43	18	14.492	14.516				14.461
8	51	24.7	11	43	6.5	14.698	14.717				14.656
8	51	3.02	11	52	25.9	14.994	14.984			14.987	14.941
8	51	12.25	11	47	15.1	15.177	15.118			15.146	15.076
8	51	35.2	11	51	39.7	15.308	15.324				15.254
8	51	31.78	11	45	9.1	15.479	15.532			15.485	15.443
8	51	6.99	11	41	49.2	15.629	15.663			15.595	15.544
8	51	18.31	11	41	29.9	15.921				15.889	15.846
8	51	43.94	11	45	37.5	16.228				16.238	16.190
8	51	27.29	11	41	59.1	16.646				16.616	16.588
8	51	45.55	11	42	10.4	17.140				17.119	17.084
8	51	22.21	11	44	39.3	17.452				17.441	17.421
8	51	29.29	11	42	47.5	17.764				17.764	17.736
8	51	18	11	52	25.8	18.448				18.344	18.336
8	51	22.58	11	43	36	18.791				18.732	18.729

RA	m	s	Dec	m	s	Henden R	APASS R	CMC R	BSM R	SDSS R	Pan-STARRS R
8	51	11.82	11	45	21.7	10.059	10.164	9.996	10.062		
8	51	17.12	11	48	16.4	9.626	9.572	9.719	9.65		
8	51	22.83	11	48	2	9.886	10.101	9.959	9.909		
8	51	26.87	11	48	40.7	10.149	10.244	10.174	10.17		
8	51	12.71	11	52	42.6	9.961	10.215	10.000	9.964		
8	51	43.58	11	44	26.7	10.185	10.269	10.249	10.204		
8	51	27.04	11	51	52.8	10.902	11.015	10.854	10.964		
8	51	26.46	11	43	51	11.215	11.310	11.165	11.224		
8	51	42.39	11	51	23.3	10.697	10.810	10.754	10.716		
8	51	21.78	11	52	38.1	10.945	11.019	10.938	10.941		
8	51	3.54	11	45	3	11.149	11.273	11.127	11.161		
8	51	7.84	11	48	9.5	11.293	11.423	11.295	11.291		
8	51	19.93	11	47	0.7	11.835	11.946	11.830	NA		
8	51	39.41	11	51	45.9	11.602	11.732	11.651	11.624		
8	51	13.63	11	50	38.3	11.830	11.810	11.824			
8	51	42.7	11	46	36.9	12.069	12.107	12.080			
8	51	25.4	11	47	34.5	12.194	12.312	12.212			
8	51	3.28	11	45	47.6	12.299	12.425	12.312			
8	51	1.08	11	50	11.1	12.311	12.459	12.331			
8	51	24.11	11	48	22.2	12.478	12.567	12.446			
8	51	30.16	11	43	50.2	12.796	12.858	12.796			
8	51	1.59	11	47	50.4	13.162	13.276	13.172			
8	51	5.27	11	49	34.3	13.412	13.425	13.375			
8	51	4.95	11	52	26.3	13.509	13.595	13.499			
8	51	31.94	11	51	16.9	13.653	13.762	13.652			
8	51	13.75	11	49	59.1	13.973	14.066				13.949
8	51	21.86	11	43	18	14.115	14.260				14.111
8	51	24.7	11	43	6.5	14.257	14.392				14.249
8	51	3.02	11	52	25.9	14.566	14.613			14.563	14.569
8	51	12.25	11	47	15.1	14.682	14.772			14.671	14.656
8	51	35.2	11	51	39.7	14.846	15.149			NA	14.858
8	51	31.78	11	45	9.1	14.997	15.243			14.991	15.012
8	51	6.99	11	41	49.2	15.089	15.139			15.045	15.046
8	51	18.31	11	41	29.9	15.402				15.338	15.394
8	51	43.94	11	45	37.5	15.770				15.753	15.776
8	51	27.29	11	41	59.1	16.288				16.287	16.247
8	51	45.55	11	42	10.4	16.770				16.768	16.755
8	51	22.21	11	44	39.3	16.998				17.000	16.999
8	51	29.29	11	42	47.5	17.415				17.395	17.373
8	51	18	11	52	25.8	17.803				17.843	17.825
8	51	22.58	11	43	36	18.460				18.388	18.383

RA	m	s	Dec	m	s	Hendon I	APASS I	CMC I	BSM I	SDSS I	Pan-STARRS I
8	51	11.82	11	45	21.7	10.086	10.252	NA	10.095		
8	51	17.12	11	48	16.4	9.063	8.884		9.078		
8	51	22.83	11	48	2	9.386	9.752		9.412		
8	51	26.87	11	48	40.7	9.822	9.988		9.855		
8	51	12.71	11	52	42.6	9.471	9.906		9.461		
8	51	43.58	11	44	26.7	9.657	9.795		9.688		
8	51	27.04	11	51	52.8	10.844	11.043		10.916		
8	51	26.46	11	43	51	11.146	11.335		11.165		
8	51	42.39	11	51	23.3	10.187	10.354		10.218		
8	51	21.78	11	52	38.1	10.609	10.73		10.605		
8	51	3.54	11	45	3	10.988	11.215		11.002		
8	51	7.84	11	48	9.5	11.05	11.28		11.046		
8	51	19.93	11	47	0.7	11.566	11.754				
8	51	39.41	11	51	45.9	11.122	11.315		11.158		
8	51	13.63	11	50	38.3	11.477	11.47				
8	51	42.7	11	46	36.9	11.716	11.823				
8	51	25.4	11	47	34.5	11.86	12.07				
8	51	3.28	11	45	47.6	11.975	12.199				
8	51	1.08	11	50	11.1	11.945	12.18				
8	51	24.11	11	48	22.2	12.155	12.297				
8	51	30.16	11	43	50.2	12.468	12.58				
8	51	1.59	11	47	50.4	12.847	13.073				
8	51	5.27	11	49	13.627	13.1	13.183				
8	51	4.95	11	52	26.3	13.206	13.371				
8	51	31.94	11	51	16.9	13.302	13.473				
8	51	13.75	11	49	59.1	13.663	13.851				13.637
8	51	21.86	11	43	18	13.776	14.017				13.772
8	51	24.7	11	43	6.5	13.858	14.085				13.857
8	51	3.02	11	52	25.9	14.202	14.265			14.152	14.209
8	51	12.25	11	47	15.1	14.285	14.446			14.248	14.251
8	51	35.2	11	51	39.7	14.434	14.981			NA	14.475
8	51	31.78	11	45	9.1	14.589	14.969			14.572	14.596
8	51	6.99	11	41	49.2	14.608	14.65			14.565	14.568
8	51	18.31	11	41	29.9	14.967				14.907	14.958
8	51	43.94	11	45	37.5	15.318				15.344	15.376
8	51	27.29	11	41	59.1	15.915				15.907	15.917
8	51	45.55	11	42	10.4	16.460				16.387	16.436
8	51	22.21	11	44	39.3	16.614				16.575	16.592
8	51	29.29	11	42	47.5	16.999				17.013	17.022
8	51	18	11	52	25.8	17.528				17.380	17.336
8	51	22.58	11	43	36	18.197				18.008	18.048