9/25/2019

Color Guidelines Revisited

In response to an observer(CCD) having some issues while measuring a reddened target another observer pointed out that the comps were possibly part of the reason in that the target had a B-V ~ 1.5 and the comps B-V were no redder than ~ 1.06.

Tim Crawford then raised this issue with team members with the questions:

Should We:

1) Continue with Our previous guidelines
or
2) Matching the Target's Color, whether on the blue or red side, data permitting.
If 2)
Then should we revise our guidelines?

Our Current guidelines:

Sequence Selection and Revision Guidelines (2002)

5. Choose comp stars that range between 0.3<B-V<1.0 , (or its equivalent in the sequence colorindex), with a conscious effort to limit the range to ~0.7.

When revising existing sequences there are additional guidelines:
…….. - Eliminate red stars

Brad Walter:

I think there is good reason for the for the color limits of 0.3 < B-V < 1.0 we use as a general rule in choosing comps. From Section 9.2a of Astronomical Photometry by Henden and Kaitchuck -

"Comparison stars should meet five criteria: (1) less than 1° from the program star, (2) of similar color, (3) equal in magnitude, (4) non varying, and (5) not red in color. Red stars are almost always variable and are quite likely flare stars. Rules 2 and 3 are not rigid, as few stars will be near the variable and be the same brightness and color. But make every effort to enforce rules 1 and 4! Pick a brighter comparison star rather than one which is fainter than the variable, as better statistics can be obtained in a shorter time. "[document creator's emphasis]

Looking at figures 6.3 and 6.4 from John Percy's Understanding Variable Stars, the red side of the instability strip crosses the main sequence at about F0 which corresponds to B-V = 0.3 on the attached table of correspondences between spectral type, temperatures and B-V color index. Also

from Percy, 6.3, the blue side of the instability strip has large regions of instability that lie on, and adjacent to, the main sequence. Kaler makes the point succinctly in Stars and their spectra: "Approximately one third of the main sequence stars between A2V and F0V are low-level pulsators, some with amplitudes of only a few hundredths of a magnitude."

Stars mid K and later on the main sequence have deep convection zones which tends to cause at least low level "flickering" variability in many (probably most) stars and larger amplitude flaring becomes common. Also because of the deeper convection these cooler stars also tend to have large star spots making them more likely to have some level of rotating variability. There are numerous YSOs at these lower surface temps and essentially all have some level of variability whether or not the stars have been classified as T Tauri, FU Orionis, WTTS or some other type of YSO variable. Therefore, B-V = 1.0 which correspond to K3V spectral class is a reasonable red limit. By B-V = 1.15 corresponding to K5V most stars on the main sequence probably has some level of observable variability.

Also from Percy 6.3 and 6.4, most evolved regions with high star concentration above the main sequence are regions of instability at temperatures below about 6500 K which corresponds to spectral class F5 and later (for evolved stars), i.e. cooler than about 6500 K and B-V > 0.5. Therefore, the evolved stars won't be useful, in general, as comps.

Therefore, our comps are going to be primarily main sequence stars and the limitations of B-V 0.3 to 1.0 seem to be reasonable. You might go a bit to the red side of 1.0 but I would not go beyond 1.1.

There is an issue with color limits that I don't know how to resolve concerning interstellar reddening when you are working in fields in the plane of the Milky Way, particularly in directions toward the Galactic center and particularly when you are dealing with fainter comps. Fainter comps are often more distant therefore subject to more reddening I don't know how to assess the effect on observed B-V particularly since we often don't know distance to the star.

One other issue that comes into play is that our sequences are not associated with specific variables. Any comp star in a particular field of view is available for use with any variable in the same field of view and we don't allow duplicate labels in a field. For E and smaller fields there is often no conflict, at least up to this point, except in regions of the sky with high concentrations of variables. However, in some regions with high concentrations of variables for which sequences have been requested, the comp stars on our charts are probably not the best color match available for all variables for which they are used. The best we can do is to pick comps that are in the "well behaved" color range (which we have established currently as 0.3 < B-V < 1.0) where if the error values are reasonably small, we can be reasonably confident that the stars don't have significant undetected variability. In such "crowded" areas the only alternative would be to change to a relational database that can associate sequences with individual variables as well as allowing all variables within the field to be displayed. From a practical standpoint, it would only be possible to make such associations for new sequences that were added after creating the relational database. It would be an unrealistic, manual project to try to associate existing comps in a field with existing variables. Associating existing sequences with existing

variables in a field is something that could be done on a case-by-case, "as resources allow" CHET request basis over a long period of time.

Arne Henden:

Brad's arguments are the ones I used in selecting the 0.3-1.0 color range. I agree that in reddened regions of the sky, you can go significantly redder and still pick non-variable comps; that is what Landolt did when choosing his red standards - they are all reddened main sequence stars. [document creator's emphasis]

There are lots of other decisions that are made in selecting sequences, as you experienced folks know:

- choosing even a 3-night calibrated star does not guard against variability. There are lots of eclipsing binaries, for example, that will yield 3 random constant values. 3 is better than 2, which is better than 1.
- at the millimagnitude level, Kepler found that half of all stars are variable. So someone wanting a sequence for an exoplanet target may need to be very careful in the selection. I tend to do ensembles at first to find as many problem comps as possible.
- as I've said before, my primary emphasis in setting up the sequence team was to create visual sequences.

CCD observers have different needs (for example, more similar-magnitude comps rather than covering the variable's entire range), and can often get by with wide color differences with transformation. [document creator's emphasis]

I could probably think of a bunch more reasons/guidelines. The main point is that guidelines help in the generic selection of comp stars, but guidelines are just that - you can violate them at times when needed. [document creator's emphasis]

Brad Walter (in response to Arne's remarks):

Thanks for the response. My problem with reddening is I have no way to evaluate how much B-V shifts since it depends on the distance and direction. I have assumed that I don't need to worry about it for comp stars away from the plane of the Milky Way. But in the plane, particularly toward the Galactic center reddening is likely to be an issue when selecting comps. Looking at reddening effects have made me question whether it is appropriate to ignore them away from the galactic plane.

I only have a superficial knowledge about reddening. I have read that in the solar neighborhood $A_V/E_{(B-V)} \approx 3.05$ as a rough average and A_V on the average is "typically" somewhere in the range of 0.7 – 1.0 mag/kpc. However, If I am calculating correctly, that amounts to about 0.22 to 0.33 mag shift in B-V due to reddening per kpc on average. That could mean that some comps (particularly faint ones) that appear significantly redder than B-V >1.0 are significantly reddened and lie within our default range while similarly distant ones that appear to be in the default range may be too blue. However, since we don't have distance information for comp stars, we have no

way of calculating the intrinsic B-V value of comps even if my assumption away from the Galactic plane is invalid.

I agree picking comps for exoplanet transit use requires a much deeper investigation than the sequence team can do. Essentially one needs to follow the procedures in Dennis Conti's instructions for exoplanet observing to weed out field stars that are noisy or variable typically at millimag levels. That requires a series of observations over a significant period of time and is far beyond the scope of the sequence team.

Michael Poxon:

I think that most, if not all, of the reasoning behind the non-use of red stars as comparisons is that they were susceptible to some variation themselves, which surely is of as much relevance to visual observers as to those using CCDs.

The guidelines quoted may well be built upon previous directions where the majority of stars on the observational programme were Miras / SR types; but with the more recent trend towards observing non-red variables such as YSOs (Yay!) and CVs this tendency for comps to be similar in colour to the target may not be such an issue. Also, I am assuming (sorry Tim, I know you don't like assumption!) that those 'old' Mira stars are mainly observed by visual observers, which is fine. Taking an example at random, the change in period (and type) of T UMi was discovered purely as a result of visual observation, so… horses for courses.

Thomas Bretl:

I have always tried to follow the 2002 guideline. Was told when I joined the team that it was okay to choose comps with B-V>1 just as long as the variation was reasonable. Depending on what's available in the field, I sometimes do that for red variables. In my opinion, comparing a very red variable with a much bluer comp is not easy!

As a visual observer, I have also tried to avoid back and forth jumps of less than 0.7 between successive comps (example: 0.4, 1.0, 0.4 B-V values for comps with V = 9.5, 9.8, and 10.2). I used to deal with lots of CHETs from Bob Stine concerning the difficulty many visual observers (me included) experience when sequences include lots of color variation. Is that not an issue for CCD observers?

Thomas Bretl After All the Above Remarks:

So if visual and CCD observers have different needs, doesn't that suggest that they need different sequences? Or do we just supply photometry for a wide variety of potential comps, and let individual observers choose what is appropriate for them? Seems to me that 2nd option might work okay for CCD observers but not so well for visual observers. As I recall, this question has been raised in the past; maybe it deserves to be revisited.

Tim Crawford:

Tom (& all),

I have prepared a document to post to our team website**, Color Guidelines Revisited**, which contains everyone's remarks on this topic.

I am somewhat stuck, however, with what I was going to write as a "conclusion," if any, in as much as I am pondering the same issues you just raised and thinking about how we might re-word our existing guidelines, if at all.

I think the general consenses is that the guidelines are well constructed with "scientific" support; with some recognition that they tend to favor visual observers, but not exclusively, and that CCD observers, under some conditions, may require a broader range of comps with some justification.

As you realize and point out, many of the targets are favorable for both visual and CCD observers and expansion of the guide lines for any specific target may not be a compatible option.

Brad, has been pointing out for some time that sequences, especially in wider FOV's are universal and not target specific; while I am not an enthusiastic supporter of this, especially given that we create our sequences for specific targets, I do grasp the concept of what Brad keeps reminding us. [speaking of Brad, he did do a great job of researching and presenting the issue]

My inclination, for my own actions, is to continue doing what I have been. With CCD requests for red stars and occasionally really blue stars, to try and include some of the comps that are closer in color to the target, if data permits, otherwise to conform to our existing guidelines. As Arne stated: "The main point is that guidelines help in the generic selection of comp stars, but guidelines are just that - you can violate them at times when needed."

As sequencers we are always left to our own experience and judgment as to how we best resolve sequence issues regarding a specific fov and I think each of us manage to accomplish this task rather well with the majority of our efforts.

I am still seeking the "Wisdom of Solomon," in a manner of speaking, to finalize this issue, from all of our blended perspectives.

Also, and most importantly, ultimately, in addition, the observer has to have some responsibility has to how they select comps and how they process or judge the veracity of resultant measurements.

It just occurred to me, after writing this, that just possibly my own words herein potentially could be the finial perspective for the document.

Having said this a further thought occurs to me that we might add the following to our guidelines: [ ]

5.Choose comp stars that range between 0.3<B-V<1.0 , (or its equivalent in the sequence color index), with a conscious effort to limit the range to ~0.7 [for further discussion, see the pdf: Color Guidelines Revisited]