THE USE AND ABUSE OF STANDARD STARS

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ABSTRACT. Most systems of classification or quantitative measurement depend on standards. It is of the greatest importance for the user to be aware of the mandate of a particular system. If the mandate is not understood by casual users, a system can be either underutilized or abused.

In the particular case of the MK system of spectral classification, types are defined by the standard stars. They can be calibrated, and the calibration may evolve with time, but the types are relatively stable because they are defined by the standards. The autonomy of this powerful system is crucial to its success, but some astronomers do not understand the importance of this distinction. Recent suggestions to change the spectral type of the Sun show an ignorance of the way the system works.

Precautions in the use of standard stars and the frequency of their use depend on the particular system and on its mandate.

1. INTRODUCTION

The first step in any science is to classify the objects to be studied. In astronomy, as in botany, this is a continuing, complex process because of the number of objects. We can classify stars by brightness, color, position, change of position, line spectrum, variability, or other observable parameters. Once a particular classification scheme has been set up, it is possible to use it to segregate peculiar objects, and thus to gain insight into the processes which generate "normal" objects. Eventually, when there are enough objects in a given "peculiar" class, the definition of "normal" can be extended to include them. Such a system, carefully developed, can be used to infer fundamental stellar quantities, which may be more or less directly related to the quantity measured; sometimes the relationship is very remote or very ambiguous. It is in the determination of this relationship between the measured and fundamental quantities that the calibration

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enters. It is also where the greatest problems arise. This conference has been called to delineate these problems, and possibly to throw some light on them, though I must admit to a certain amount of cynicism about the possibility of solving any of them definitively. Perhaps we can at least clear up some misconceptions.

This introductory talk, by the nature of its title, must necessarily be somewhat philosophical, though I will try to bring in some reality through specific examples drawn mainly from the systems I know best, the MK system of spectral classification and the UBV system of photometric classification. However, most of the statements can be easily translated to apply to other systems.

2. PHILOSOPHICAL CONSIDERATIONS

While it may be more difficult to discuss philosophical approaches to science than to present data and discuss errors or interpretations, it is very important to do so from time to time. The philosophical basis of the MK system has been fully discussed by Morgan et al (1943), Morgan and Keenan (1973), Morgan (1984), Mihalas (1984) and others (see McCarthy, Philip and Coyne 1979 and Garrison 1984).

An important distinction that was made during the 1983 MK workshop held in Toronto is that between the MK Process and the MK System. The MK system of standards may not be applicable to other wavelength regions or other resolutions, but the MK process can be used to set up any classification scheme.

2.1 Definition of Terms

In this talk, the term classification will be used in its broadest sense, including directly measured quantities. For example, the measurement of parallax allows an ordering, or "classification", of stars according to numerical parallax or distance.

Most, but not all, of the classification systems in astronomy use standard stars to a greater or lesser degree. Others use more direct measurements; for example, absolute fluxes may be measured with standard lamps. The latter have their own problems and I will restrict my remarks to the use of standard stars. Laura Pasinetti was going to discuss the relative merits of the two approaches. I believe that they are not competitive, but can both be used in a complementary way; perhaps she would have come to a similar conclusion.

There is, however, some confusion about the meaning of the term "standard star". In a letter to me on this subject, Johannes Andersen made some useful distinctions and outlined several classes of standard stars used for different purposes. In slightly modified form, these are:

a. Standard stars that define a system (e.g. the MK system).

b. Standard stars that are used to transform observations from an instrumental system to a common system (e.g. the UBV system).
c. Standard stars needed for occasional zero point checks (e.g. the radial velocity system).
d. Standard stars that define internal zero point in an instrumental system (e.g. Griffin's system).
e. Standard stars that define a unit of measurement (e.g. the Sun for masses, radii, luminosities, etc.).

As Alan Batten (1985) has said, it is also important to distinguish among primary standards, secondary standards, lists of carefully observed stars, and comparison stars. Variable star comparisons are not the same as systemic standards. Unfortunately, the data centers and the Standard Star Newsletter have not been critical enough in their publication of lists of standard stars. The lists seem to be indiscriminate, yet have the appearance of IAU sanction. While those of us who work in the field may understand, this is a very dangerous trend and it would be good to have some discussion of the problem at this meeting.

Finally, there are some areas of research where the concept of "standard stars" has no meaning whatsoever. What is the meaning of a list of "standard" radii, where the measurements are of necessity absolute and vary only according to the measurement technique and errors? If someone uses a better system of measurement, they may get different values from the list of standards, yet there is no reason why they should transform to the list. So, I suggest that the use of the concept of "standard stars" should not apply in the case of fundamental stellar quantities such as mass and radius.

2.2 The Mandate of a System

Every system of classification or measurement in astronomy has been created for a reason. In using the system, it is of the greatest importance to be aware of why it was created, how it was constructed, what its useful limits are, how it has evolved, and what credibility it has achieved in practice. This is what I call the "mandate" of the system.

Astronomers who use a system casually are not always sufficiently aware of the mandate of the system to use it intelligently, and this leads to problems. To properly utilize the UBV system, for example, it is essential to understand that it was the first of the modern systems and was devised to provide a general reference frame. It remains useful as a general reference frame and for observations of very faint stars, but there are people who complain about the lack of precision. High precision is not its present mandate and is probably not achievable because of the broad bands. The standard stars are not defined better than 0.01 or 0.02 magnitudes for all-sky coverage. If high precision is required, some other system, such as the Strömgren system or the Geneva system should be used. When the mandate is misunderstood, the system will be abused by expecting too much of it or by overinterpreting the data. It doesn't matter that Alpha Lyrae is slightly variable in UBV

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because the variations are well below the limit of accuracy of the system. It does matter that it is too bright for most people to observe, however, and it is important to carefully establish secondary standards, but it can still be used as the primary standard.

Similarly, systems are often underutilized because some astronomers do not realize what can be done usefully and do not give the system credit for its value for a particular task. Both of these conditions are deplorable, but can be improved by a correct understanding of the mandate of a system.

It follows from this, in my opinion, that it may not be possible to define a set of standard stars which would be appropriate for all systems, so I will not support such a move at this meeting. However, what we can do is to obtain data in other systems for standard stars used in a particular system; that I will support enthusiastically. For example, MK standard stars may not be appropriate as standards in other systems, but it is very useful to know their values in other systems.

2.3 The MK System Mandate

The mandate of the MK system is to describe the appearance of the blue-violet spectrum of stars at moderate dispersion by reference to a set of standard stars. It is not bound to match the color or the effective temperature or anything else besides the spectrum itself. Though, for convenience, the sequences are ordered roughly by effective temperature, they are not exactly the same as effective temperature and the ultimate test is whether the spectrum matches that of the standard star using exactly the same observing technique for both the standard and the unknown. Thus the MK system depends only on the standard stars and nothing else. There may be small errors in the system of standards, and those must be realized and corrected, but by and large it is a very reliable tool, because it is based on standard stars independently of the calibration.

For a given star, the range of effective temperatures found in the literature is greater than the range of spectral types given by different classifiers. What a mess we would have if the spectral type were changed every time some theoretician came out with a new effective temperature. It is best that the MK system remain autonomous. It has greater value that way, to observers and theoreticians alike.

Similarly, there is not a one-to-one correlation between spectral type and color anywhere in the HR diagram, though the general trends are well correlated. Not all stars with the same color have the same spectrum or vice versa, and it doesn't mean that the type is wrong any more than it means that the color is wrong. They measure different parts of the atmosphere. If they give different values, the confrontation will teach us something. The interface between two autonomous systems produces new information which is not available to either system alone. By ignoring the difference or by assuming automatically that one or the other is wrong, we are throwing away information. That is bad science, in my opinion, and we should be careful not to fall into that trap.

It irritates me to see superficial criticism of the MK system by others who use completely different systems to tell us what we should be seeing. We see what we see and we call it as we see it. It doesn't matter what the photometry says or what high dispersion shows, the comparison of the appearance of the spectrum with that of the standard stars is what determines the type. It is fine for various groups to try to define the colors of the Sun, but it is not okay for them to claim that therefore the MK classification of the Sun is wrong. The appearance of the spectrum of the Sun is halfway between that of Beta CVn at G0 V and Kappa Cet at G5 V, independently of abundance. The three stars form a consistent set of standards and if there are problems with other stars, it is the others that should be changed.

Stars which cannot be matched with the standards of the MK system can still be usefully described in terms of the system. Two examples come to mind. The Am stars, which are now given both a hydrogen type and a metallic-line type (e.g. A5mF2), can be described accurately by the new designations. The late-type population II stars are described in terms of the closest type and then an abundance parameter is given for outstanding anomalies (e.g. G8 III Fe-1,CN-2). In other words, if a star doesn't fit, describe how it doesn't fit. That is part of the power of the system.

3. PRACTICAL CONSIDERATIONS

Most of the problems are with users, not systems! It has been my experience that most of the differences among observers using a given system are not due to problems with the system itself, but are due to lack of proper attention to careful standardization, through use of standard techniques and standard stars. It is not surprising to me that an observer who uses high dispersion, unwidened, overexposed radial velocity plates for spectral classification or who uses a different filter set for photometry, might get a different result from others using the standard techniques. In some systems, the standard technique is more important than the standard stars. However, since this is a discussion of the use of standard stars, it will be assumed that the standard techniques recommended for the systems will be used.

I will not try to outline in detail all of the precautions that should be observed in all the systems of measurement being discussed at this meeting, since they depend on the mandate of the system. However, I would like to mention some key areas where I think there are problems and while I may mention particular systems, some of these difficulties apply to more than one system.

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3.1 Precautions in the Use of Standard Stars

When using a system of standard stars, it should be obvious that the standards should be taken under the same conditions as the unknowns, but some astronomers still violate this basic rule. The use of large telescopes has actually increased the temptation, since telescope time is at such a premium and since the new detectors are too sensitive to be used on stars brighter than 10th or 12th magnitude. Thus there is a danger that the use of poor secondary standards, and fewer observations of them, will increase in the future.

As discussed in the 1983 MK workshop, it is important to carefully transfer the MK system to fainter stars using the traditional photographic techniques. Then, the carefully established faint secondary standards can be used with modern detectors. This is being done using the classification spectrographs on small University of Toronto telescopes in Chile and Canada, in conjunction with the prime focus MK spectrograph on the 3.6 meter Canada-France-Hawaii telescope. With the former, secondary standards will be established near 10th magnitude around the equatorial zone, and with the latter these will be extended to 15th magnitude. Thus, in a few years, there will be good standards for use with large telescopes and new detectors if time is made available. For the UBV system, this process is already underway (e.g. Landolt, 1983).

A good grid of MK standards is essential to good quality classifications, but how are these to be established for large telescopes? It is too expensive for individuals to each have their own set. Thus, it may be that libraries of standards taken with the new detectors will have to be set up so that observers can plug into the library by taking only a few standards as a check that the conditions are the same as those under which the more extensive grid was taken.

Another possibility is to use a smaller telescope of the same f-ratio with the same spectrograph. I have used the f/3.8 CFHT-MK spectrograph at the DDO 1.88 meter Newtonian focus, as well as at the DDO 60 cm Cassegrain focus with an f/15 to f/3.8 focal reducer. It is also possible to design a 15 or 25 cm telescope to mount on the spectrograph for use with a dedicated drive unit. With a minimum time for standards with the big telescope, it is thus possible to tie into a much larger grid of standards if proper precautions were taken. This is not the ideal way to do classification, but we have no choice with big telescopes, if we want to get time for classification work.

Taking data indiscriminately from the literature and treating it as standard is unfortunately an all too common practice. This is a problem for all systems. Most astronomers are becoming aware that, because of inadequate standardization on the part of some astronomers doing classification work, MK types given in the literature are not of uniformly high quality. Because photometric observations are given numerically, they are considered to be accurate, even though they may suffer from all sorts of errors. I call this the "deification of quantization" and most scientists suffer from it. However, compilations of UBV data gathered by the Strasbourg Data Center show that even for well-observed, non-variable stars the values for B-V differ by more than 0.03 or 0.04 magnitudes and for some it is as much as 0.10! Yet astronomers like Hardorp (e.g. 1982) pretend to be able to distinguish between B-V=0.63 and 0.67 for the solar analogs, taking UBV values (as well as MK types) indiscriminately from the literature. For such critical work, it is essential to use the very best values possible or to determine them on a uniform system.

The "tyranny of the mean" has been criticized before, in many fields but it needs mentioning here. It is not good enough to take photometry or spectral types for stars or groups of stars randomly from the literature, average them, and use that value as "standard". Because of systematic effects, it is not enough to take the average of random radial velocity data for a star from the literature and use that as "standard", no matter how many thousands of measures are included. It is not enough to use photometric measures of a random star, no matter how many there are, as standard unless it is part of a well-defined system using standard stars and standard techniques. These statements may seem obvious, but systems are very often abused even today in these very ways.

There are many other precautions which could be listed, but they all reduce to one basic caution; think about the data being used and how it has been obtained, and if you are doing the work, do it with an extreme amount of care.

3.2 Frequency of Use of Standard Stars

The frequency of observation of standard stars depends very much on the system of measurement being used and its mandate. All too often, shortcuts are taken when observing and in some cases (e.g. large telescopes) there is no alternative; however, if too many shortcuts are taken the observations have less value and might as well not be made, so some compromise must be reached.

It has been said of photometry that the only way to adequately determine the extinction and transformation coefficients is to observe nothing but standards all night every night. Obviously that is not practical and it has been found that well-determined mean coefficients can safely be used with occasional checks during the night. This procedure obviously favors the dedicated observer over the casual observer because the former will have a more secure foundation over a longer time period. It also means that large telescopes are almost doomed to lower accuracy because nobody will be given time to adequately determine mean coefficients. There may be no solution except to observe as carefully as possible within the constraints. It is still necessary to observe some standard stars each night. Fernie, at the David Dunlap Observatory, has devised a promising technique using twin photometers on two different telescopes, one of them dedicated to extinction determination.

The frequency of observations of standard stars for radial velocity is somewhat less critical, but it is nonetheless important and depends to a certain extent on the stability of the equipment.

For MK classification, it is not necessary to observe standards every night, because the equipment is usually sufficiently stable to allow comparison with a grid of previously observed standards. That is a big advantage. At the DDO in Toronto, there is a complete grid of MK standards taken with each spectrograph, and for each dispersion, developer, slit width, and slit length combination. Then, for each observing run, the most important standards are re-observed and at least one standard is observed each night, just as a check on the stability of the equipment and processing techniques. Because of very careful attention to standardization of techniques, differences have only rarely been detected. This is an example of how standard observing and reduction techniques are important in the use of standard stars. Classification is not a black art, as some have claimed, but can be successfully done by anyone who is willing to do the work carefully. Most of the differences in spectral type for a given star found in the literature are due to the use of non-standard techniques or inadequate attention to standard stars.

4. EXAMPLES

4.1 The Use of Standard Stars

The MK system, combined with photometry and absolute magnitude calibrations, has enabled astronomers to determine spectroscopic distances to a wide variety of objects, including black holes, Cepheids, and external galaxies, thus extending the system of parallaxes for nearby stars to the farthest reaches of space. Our knowledge of the structure of the Milky Way Galaxy was determined in 1951 by the careful use of standard stars, and it has since been extended by the complementary use of several different techniques. These advances were possible because the system was set up carefully, using standard stars, and because it is autonomous, yet can be calibrated in terms of fundamental quantities. One can even argue that the spectrum, color, position and motion are the real fundamental quantities, in the existentialist sense, because they are directly observable; however, not at this meeting.

The mandate of the MK system is to describe the appearance of the spectrum in terms of a set of standard stars, and not necessarily to give mass, radius and abundance. However, the accurate description of the spectrum allows astronomers to isolate interesting stars for more detailed observations to determine these fundamental quantities. In a similar way, photometric standard stars can be used to isolate stars with interesting colors and radial velocity standards can be used to isolate binaries or stars with extremely large motions. All of this can be used in a complementary way to learn more about the universe in which we live. The usefulness of the various systems depends partly on their autonomy and partly on their complementarity.

4.2 The Abuse of Standard Stars

Several references to the abuse of standards have been made in the comments above. Most problems can be avoided by a proper understanding of the mandate of a system and by careful observations and reductions. The controversy over the spectral type of the Sun is a case in point.

The Sun is an important standard for most astronomical systems because of its availability for detailed study. However, the very property which makes it so fundamental - its proximity - also renders it difficult to observe as a star. It is an extended source, is 30 magnitudes too bright, and cannot be observed at night; in most systems it is therefore impossible to observe with the same equipment at the same time as other standard stars unless an intermediate step in used.

Therefore Hardorp (1978), with good intentions, set out to find a solar analog among the stars. However, he used non-standard techniques and because of his misunderstanding of the mandates of the UBV and MK systems, he has muddied the waters considerably. Some of the problems were discussed at the Vatican Conference in 1978 (Garrison, 1979). Hardorp has also softened his approach recently.

In dealing with suggestions like this, it is useful to be aware of two dangerous effects, which I will call the "bandwagon effect" and the "don't rock the boat" effect. The first refers to the tendency for observers to ascribe differences in the observations to a fashionable interpretation, even when such leaps are not justified. The solution to this problem is to just "watch the parade" for awhile before carefully choosing a path. The second effect refers to the tendency of the "old guard" to try to keep the status quo. The solution is to rock the boat only when necessary and then VERY carefully, making sure that you understand the "mandate" of the system; otherwise you may be "all wet".

The idea of a search for solar analogs in all systems is a good one, but for the MK system it must be done using line spectra of comparable resolution to that used in MK classification because that is where the symbols G2 V originate. To use those symbols for another system is to abuse the MK system of standard stars. The biggest mistake made by Hardorp and others who have jumped on his bandwagon is to use non-standard techniques to infer results in the MK system. The Sun is G2 V by definition and other stars with the same classification have line spectra in the blue-violet region at moderate resolution that very closely resemble that of the Sun. It doesn't matter what B-V they have or what effective temperature someone thinks they have. It only matters that the spectra match. That is the test in MK terms. Hardorp has not made that test so he can say nothing about the MK type of the Sun except to suggest that we look at the spectra again. That is being done now.

One good result is that I have been stimulated to look for a solar analog using standard MK techniques. To this end, I have taken spectra on a homogeneous system of all the analogs suggested by Hardorp (1982),

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Reitsema (1977) and others. The total comes to about 400 stars, which includes other G stars brighter than 5th magnitude. We are not yet in a position to publish definitive results, but already there are some interesting classifications. The Cayrels suggested that HR 1318 B might be a solar analog. Corbally and I find that it is G5 V, Fe-2 and does not resemble the Sun at all, either at 120 Å/mm or at 67 Å/mm. To be sure to avoid the "don't rock the boat" effect, I have tried to look at the problem as carefully as I can and will be doing the classifications blindly to make sure that I am at the mercy of the data. I hope that my complaint is understood. I am not upset that there may be some misclassifications of early G stars in the literature, but that the MK types have been criticized by people who have not looked at classification spectra, and have in fact used much poorer data than was used for the original types. That is a complete abuse of the MK system of standard stars.

5. CONCLUSIONS

The conclusion of this paper is obvious. Classification of any kind is a fragile process and great care must be taken to use standard techniques and observe standard stars. New systems can and will be presented and if they are good, they will eventually be acknowledged. The MK Process, using an autonomous system of standards, which can then be calibrated and recalibrated without changing the system, is very powerful. It can be applied to other classification systems with great value. The confrontation and complementary use of such autonomous systems yields information which neither contains in isolation.

To paraphrase a famous American president, "Ask not what astronomy can do for your system of standard stars, but what your system can do for astronomy."

6. ACKNOWLEDGEMENTS

It is a great pleasure to acknowledge with warm gratitude the hospitality of the Danish astronomical community at Brorfelde during a month spent there just before this meeting. Their stimulating discussions helped to focus my thoughts on this difficult subject. The generous support of the IAU and the Natural Sciences and Engineering Council of Canada is also gratefully acknowledged. Without their support, such meetings could not be held so successfully.

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DISCUSSION

HECK: Bob, I am very happy to hear your comments on the dangers of averaging photometric data and would like to call the attention of the audience to the papers on this matter by Manfroid, and Manfroid and myself which are displayed as poster papers.

LYNGÅ: What has been referred to earlier as peculiarities in the MK system, now often takes the shape of more specific comments, letters. etc. Is this a third dimension being introduced and does it change the mandate of the system as you see it?

GARRISON: There is no simple third dimension and most people do not realize this. The remarks, notes and additional symbols used by Keenan and Morgan are the best we can offer for now. It is not a simple problem. The mandate has changed in the sense that these symbols and notes are more accepted, but has not changed in the sense that our task is to describe the spectrum as consistently and completely as possible.

JASCHEK: Two comments. You referred to the "mandate" of a system. I guess this is an average of what the author said and what the colleagues thought of it ten years after. I hope that at this meeting we arrive at a better set of standards; the "Centre de Données Stellaires" has deliberately tried to get available lists published. They are scattered all over the literature and they should be published, assembled and critically discussed at the same place so that astronomers may use them more easily.

GARRISON: It is not the simple average, but as I mentioned, it does

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include the definition as well as the evolution of the system.

BIANCHI: When good standards are not available (e.g. in the case of faint stars of late spectral type in the Strömgren system) and brightness limits are set by the instrument, one is left with two possibilities; either to give up matching the colors of the star, or to observe a very large number of "non reliable" standards (i.e. for which very few measurements exist), hoping that the "bad" ones can be recognized and eliminated afterwards during the reduction. This is very dangerous and time consuming. Do you have any suggestion for what a wise criterion would be?

GARRISON: There is a third possibility which you did not mention; that is to establish carefully secondary standards yourself. People too often rely on others to do the really hard, unexciting work, but it is an essential step in doing the more exciting stuff like cosmology. Many theoreticians have become observers because of a similar problem. Why do you think they have done so? It is because they became frustrated with the data available and could not get anyone else to do what they needed in the way they wanted. You may just have to do the preliminary work on setting up standards before you can do the more interesting work on faint stars.

BESSELL: Mandates evolve with time. The UBVRI system in the E regions in the southern hemisphere has errors less than 0.01 magnitude. Also one should not ask what your system can do for astronomy but what system best provides the astrophysical parameter one requires.

GARRISON: Obviously, if your choose the best system for your astrophysical application, you will automatically do well for astronomy! That was implicit in my remarks. In my definition of "mandate" the evolution of the system was included, as well as credibility.

HECK: The problem you just raised, i.e. getting time on large telescopes for observing photometric standards is a very important one and also a more general one. We have also encountered difficulties in getting time on IUE for our low-dispersion reference atlas. Maybe we should think about some action in the course of this meeting for calling the attention of the various allocation committees to this problem. I definitely hope that this meeting will have an impact in this sense.

GARRISON: I agree. The same problem was discussed at length last summer at the MK Workshop in Toronto, as you will remember. Perhaps a letter to the directors of large observatories is in order.

SCARFE: You suggested that large-telescope time is too precious to use on standards. But earlier in your talk you pointed out that this condemns large telescope results to a lower accuracy than the best from smaller telescopes. Surely this means that we cannot afford not to use large telescope time for observing standards, to get the best use of these instruments.

GARRISON: Ah, that is precisely the problem. I do not know the solution except to put pressure on the large observatories.

POPPER: With respect to the search for a "solar analog" it is my impression that a purpose of the search is to a large extent to determine quantities difficult to observe for the Sun, such as (B-V), in order to be able to fit the Sun with its well established properties, into the stellar systems, rather than to re-evaluate the solar spectral type.

GARRISON: That is the reason for doing it, and (B-V) has been chosen as the interface, even though it is relatively insensitive and one could question the choice. The idea is a good one, but it must be done carefully.

CAYREL: I agree with Dr. Garrison that for an observer who is writing a program for a given research problem (in my case finding out the best solar analogs) it is much easier to observe a sample of stars already proposed for such a research by somebody else. Unhappily it may happen that the results are deceiving and that the stars of the chosen sample do not have the physical properties we wanted them to have.

Is 16 Cyg B similar to the Sun in type?

GARRISON: Not really. It is slightly later. Dr. Keenan and I agreed in November on G3 V for 16 Cyg B. I wanted it slightly later.

KEENAN: Dr. Garrison's type of G3 V is in agreement with mine, but I am not absolutely sure that Kap Cet remains constant at G5 V! That is the reason that I do not like to rely on individual stars, but prefer to use a cloud of standards.

GARRISON: You and Bill Morgan differ somewhat in your approach. He has been moving in the direction of single standards for "dagger" types and you prefer a cloud.

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