On the Difficulty of Observing the Sun as a Star

Robert F. Garrison
University of Toronto
garrison@astro.utoronto.edu

I think we're beginning to converge already, as I find myself in agreement with the first two speakers.

I'm in favor of using all the information available. I don't like having one technique dominate. It is too tempting then to say, "This is the most important thing, and everything that doesn't agree with this is wrong."

I also believe that the information I use really should depend on what use I'm going to make of it. For example, if I want to study the history of the Sun, and archive it, then I wouldn't want to choose stars that have the same activity level as the Sun. I'd want to let that be a free parameter. So I'd look at stars that have one solar mass, but are much younger, with the same mass. What I decide upon as my sample of solar analogs, therefore, really depends on what I'm going to do with the information. In other words, I consider all the information in a complementary way. *Complementarity* is a basic principle that I refer to often in my classification work.

It's unfortunate that the Sun was chosen as a standard for the MK system, because it is a devilishly difficult star to observe. An extended source such as the Sun cannot be observed easily with the same equipment as a star. Not only that, but an additional problem is that we can't observe the Sun at night, at least not directly. So we have a disk to observe, we have extended sources to observe, like twilight, sky, the Moon, and the planets, and we can't observe it at night. These are big problems, and it is because we decided to call the Sun G2 V in the first place. On the other hand, we can know the Sun in much more detail than any other star. So it does have advantages; for example, even theoreticians can pick it out in the sky. [laughter].

White: Sometimes [laughter].

Anyway, this problem of having an extended source to observe is not the only one. When we look at a star, we get an integrated spectrum. With the Sun, that's very hard to do without looking at the Moon or at twilight. So Linda Zimmerman and I did an experiment: we used a heliostat to produce a large image of the Sun in the lab and placed a moderate resolution spectrograph so that we could put a slit at different places on the disk. As you can see [referring to slide; see paper by Garrison and Zimmerman 1983 in JRASC 77, 78-86] there are substantial differences in the spectrum from one point on the disk to the next. This of course is because as we moved across the disk we were looking at different angles and therefore different layers of the atmosphere. When the slit is placed at the center of the Sun, we see a type of about G0; at 99.5closer to K0, but is very peculiar and looks quite veiled. Thus it is difficult to classify any single part of the Sun's disk as a star, so again, it is difficult to integrate the spectra of different parts of the Sun to compare with a stellar spectrum.

Many of the problems that people have encountered have been the result of having made some bad choices. This diagram [David Gray's famous $B-V$ plot showing the outrageous spread in that index for the Sun, determined indirectly by a variety of methods] was shown yesterday and was included in our registration package. Presumably, $B-V$ is something we can measure quite accurately, so why do we have such a range, from 0.62 to 0.69, in $B-V$? It's quantitative, just measured, but very different results are obtained, depending on how it is measured. So the choice of any one parameter as a bellwether is very tricky, and should not be used to discount the other parameters.

So how can we measure the Sun? In the blue-violet, I personally prefer the asteroids, because there's no mineral signature in the blue-violet spectra, but they wouldn't be good for the ultraviolet or the infrared. I'm not sure what to suggest for those regions.

An ideal solution would be to put an aluminum ball up in geosynchronous orbit, calibrate it from the ground, calibrate it from orbit using the Hubble and other Space Telescopes, then observe it at night as a star; about tenth magnitude would be just right. If we could do that, we'd get a lot better handle on the $B-V$ of the Sun, as well as on the Solar Irradiance, and on nearly every other parameter that we might want to measure.

Another serious problem is poor resolution. Hardorp, who started all this business about solar analogs and solar twins, made the mistake of observing the twilight sky with only a 200 Å bandpass, and about 20 Å resolution. That is fraught with all kinds of difficulties, but he used these observations anyway to discount all the other measurements that had ever been made. That was not a wise conclusion. There is often new and interesting information at the interface of different techniques; we lose that information if we assume that everyone else has been wrong.

One of the other big mistakes people make is to take data indiscriminately from the literature. There may be many very high-accuracy measurements, such as $B-V$, and if you stick to one person and one set of observations, and if that person is careful, a nice relative ranking can be found, even if the absolute accuracy is off. If data is taken randomly from the literature, the results can be a mess. That includes $B-V$, it includes [Fe/H], it includes T_{eff}. If you look at Cayrel's table of [Fe/H], and look at their choices for a given star, for *one star*, you'll find that T_{eff} has a larger range in the literature than the range of MK types, even though the former has higher resolution. So taking data from the literature indiscriminately is rather bad practice.

The mandate of the MK system is simply to describe the blue-violet spectrum in terms of moderate-resolution spectra. If the MK type is used as a reality check, as Derek suggested, that's probably the best use of that system. I have a sample of about 800 G-dwarfs. I have classified them once; I haven't gone back through them yet to check for consistency. When I finish that, I'll have at least a good sample regarding what the MK system says about the description of the spectrum in the blue-violet. Combining that in a complementary way with other data, we can then see what we come up with as a good sample of Solar analogs or twins, rather than a single star.