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Extending the Long Wavelength Limit of the DSS7

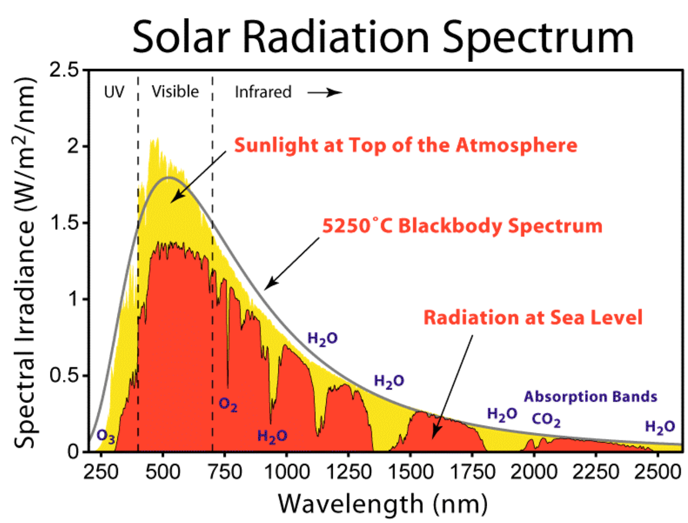
June 15, 2009

Introduction

The DSS7 spectrometer is rated for a wavelength range of approximately 4100A, and is blazed for a peak at about 5000A. The DSS7 would normally operate over the range of about 3500-7600A. Using the DSS7 with the SBIG 402 camera (510x765pixels) has shown that these specifications are actually achieved. However, there are times when one would like to use the DSS7 at longer wavelength. Experiments described here show that simple modifications will allow the DSS7/402 combination to operate out to approximately 5000 to 9000A. Experiments also show that using the 1603 (1020x1530 pixels) the entire range of wavelengths is accessible without modification to the DSS7, i.e., over the range 3500-9000A.

Wavelengths

A brief word on wavelengths: The graph shows the solar spectrum in space and at the surface of the earth. There are major absorption lines at 7640 (Oxygen) and 9400A (water) that will limit sensitivity (and must be corrected for). In addition, the response of the CCD camera itself is dropping fast as one moves toward the infrared (see below). Thus, the most that one could expect would be a limit of about 10000A (1000nm).



The wavelength reference I use is a small battery powered fluorescent lamp. Different lamps produce different mixtures of lines; however, the small battery light is not only cheap and convenient, but has an excellent mixture of lines from 4046 up past 8000A so there are many feasible points of calibration. Most of the wavelength measurements have been made by simply shining the lamp into the DSS7. It should be noted that details of how the calibration is done can change the calibration by up to 20A. Lines are identified using the reference tables in Vspec (see below).

I use MaximDL to operate the camera, take the spectrum, calibrate it (bias and dark), rotate the spectrum to horizontal, crop the desired portion of the spectrum, and save the image. The spectral results discussed here have been done using freeware Vspec. While very convenient to use if one follows a rigid procedure, Vspec is very prone to crashing if one attempts anything out of the ordinary. In addition, erratic behavior can occur that can only be stopped by closing and restarting the program. An alternative I frequently use is a simple spreadsheet analysis program that I developed. However, Vspec includes a library of reference spectral curves useful in measuring instrument sensitivity, as well as tables of line emissions that enable calibration of fluorescent lamp lines.

Using the 402/DSS7 Combination.

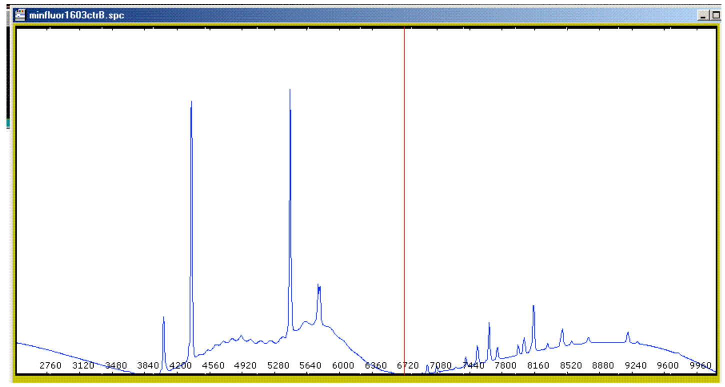
The DSS7 mates to the 402 camera using a pair of aluminum plates. The plates are held together with three thumbscrews in very loose holes. One loosens the thumbscrews, and adjusts the relative position of the DSS7 and camera by about +/-2mm or so to achieve the correct wavelength range and the positioning of the spectra approximately through the middle of the image. While crude, this process is easy to do and once adjusted, is stable.

It turns out that the limited movement of the aluminum plates allowed by the thumbscrew holes is the primary limitation on the long wavelength limit. That is, increasing the ability to move the camera relative to the DSS7 will allow extension of the long wavelength limit. I therefore machined the holes to allow an increase of about +/-3mm in the forward/back direction. The plate attached to the camera then struck a ledge on the bottom of the DSS7 that prevented full movement in the new slots, so I cut approximately 2-3mm off the offending plate. All this work can be carried out with hand tools or machine tools, and none is critical, and none interferes with use of the DSS7 in its normal range.

Using the 1603/DSS7 Combination

The experiments with the 402 camera showed that the wavelength limit was largely set by the physical placement of the CCD chip. Therefore, using the much bigger chip in the 1603 allowed the camera/DSS7 to be centered on the alignment plates, and the full range of the spectrum achieved. Most of the spectra shown were taken with the 1603/DSS7 combination.

Results

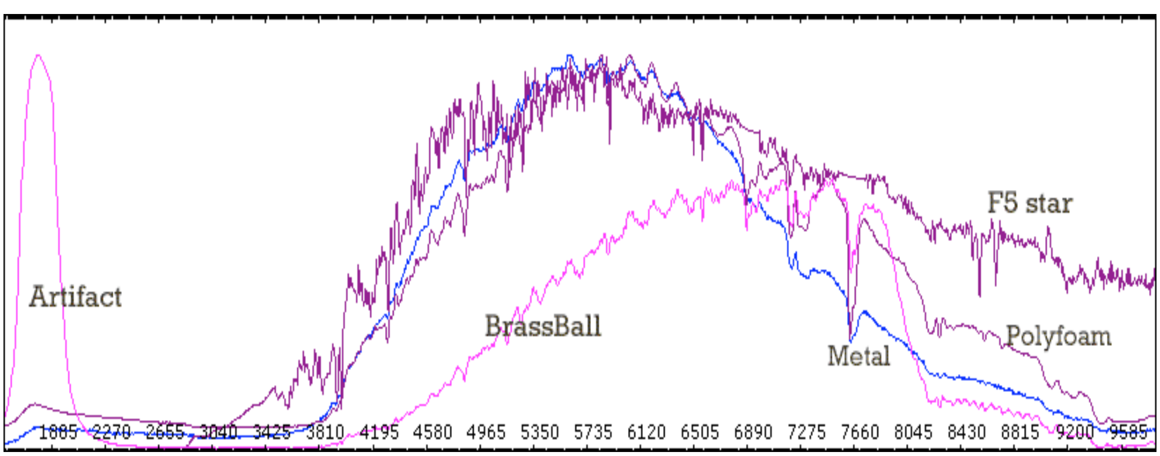


A typical calibration spectrum using the battery fluorescent lamp is shown in the figure. The wavelength scale was applied using the 4046 and 7635 lines. One can see that the spectrum includes some lines past 8000A.

Using the sun as a source of light, one can get a rough measure of the sensitivity of the system. The problem is that the sun is too bright simply to point the spectrometer, while the light from the blue sky or clouds will already be color biased. Working outside, I set up several small reflective targets about 10in. from the DSS7. I then shadowed the whole system, except for a spot of light that I could allow to strike at the target. The figure shows four spectra:

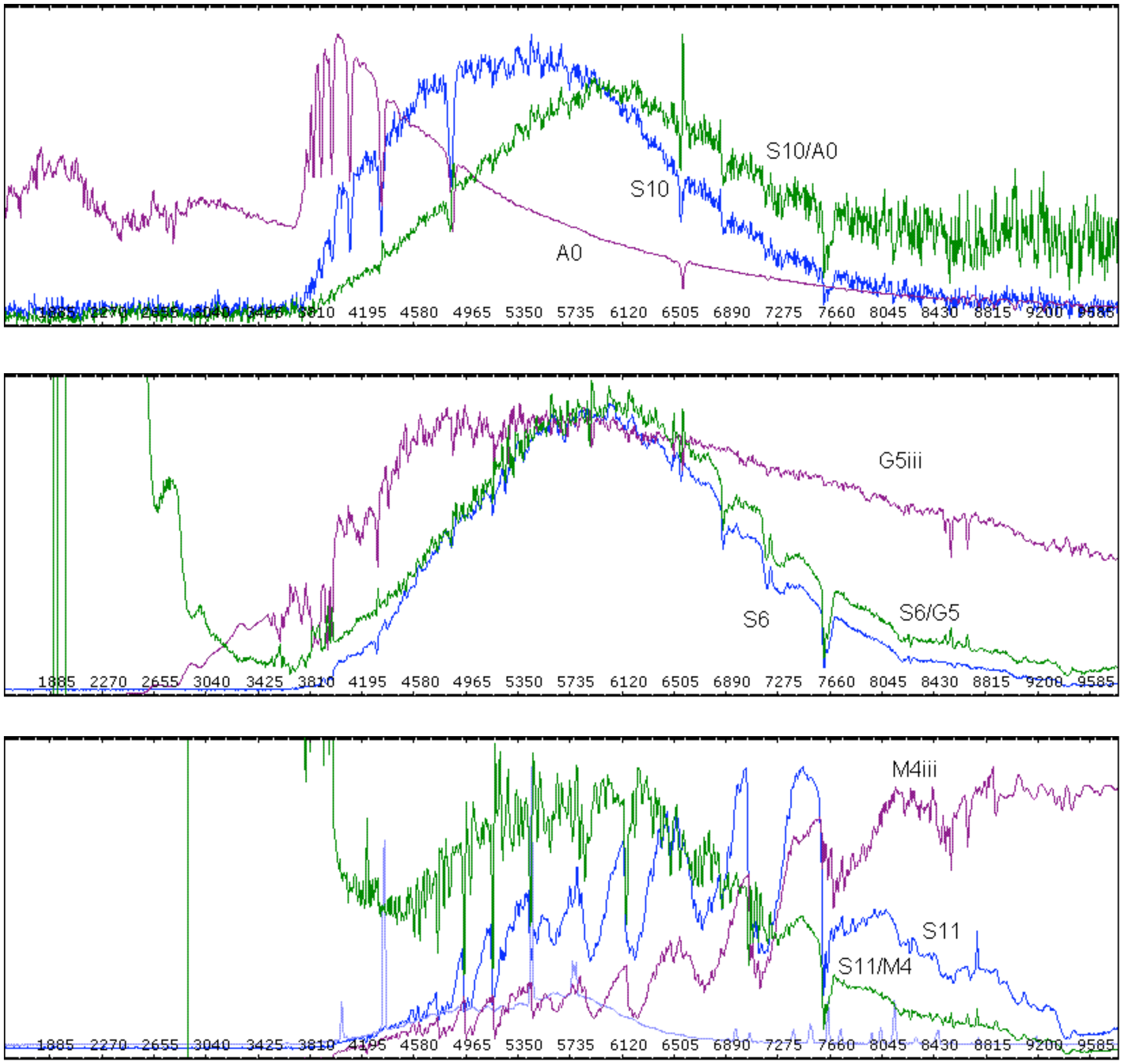
- An G5 (not F5 as labeled) reference top-of-the-atmosphere spectrum from Vspec
- Solar reflection from a small cat food can disc
- Solar reflection from a small polyethylene foam disc
- Solar reflection from a shiny brass spherical doorknob

It is obvious that the spectral response is dropping fast past 8000A, but there is still response remaining at 9400. The dip at about 7600 is due to atmospheric O2. There is a major difference among the samples in their reflectivity in the red to near Infrared regions. However, the polyfoam sample appears to show that there is as much as 40% remaining sensitivity at 8000 (vs6000), and 30% at 9000, roughly consistent with the CCD sensitivity shown below.



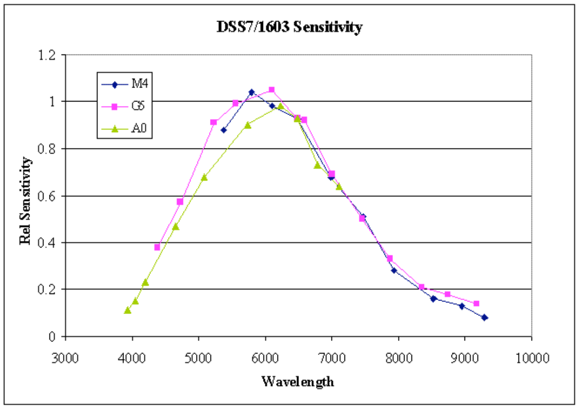
Star Results

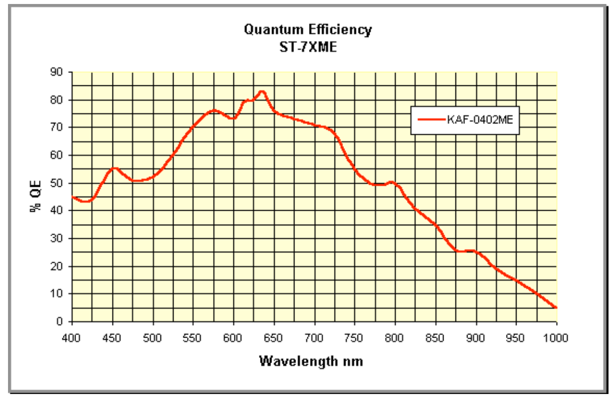
To gain a more realistic measure of the instrumental sensitivity, I took the spectra of several stars as shown in the figure.



The telescope was a C11 at f/10, and the observing conditions were poor with variable clouds. The stars were in the 5-7 mag range, altitude about 60deg, AirMass about 1.1-1.2. The three spectra in blue are of an A0, G5 (solar), and M4 star, and each shows a red Vspec library spectrum for that spectral type. In each graph, I have shown the raw spectrum divided by the reference spectrum as the green line, which thus shows the approximate relative wavelength sensitivity (atmospheric lines were not removed from spectra).

For each of the three spectra, I normalized the spectrum at about 6489A and prepared an instrumental sensitivity curve as shown below. As one can see, there is reasonable agreement from the different spectra. While the sensitivity is clearly dropping fast above 7500A, there is still usable sensitivity even beyond 9000A.





Sensitivity Limitation

A major limitation on the long wavelength sensitivity appears to be in the response of the CCD camera itself. The figure above right shows the response curve for the ST7/402 cameras, which is virtually identical to the ST8/1603. From 7000 to 9000A, the response drops by almost 2/3, and is clearly a major part of the system decrease in sensitivity to long wavelengths.

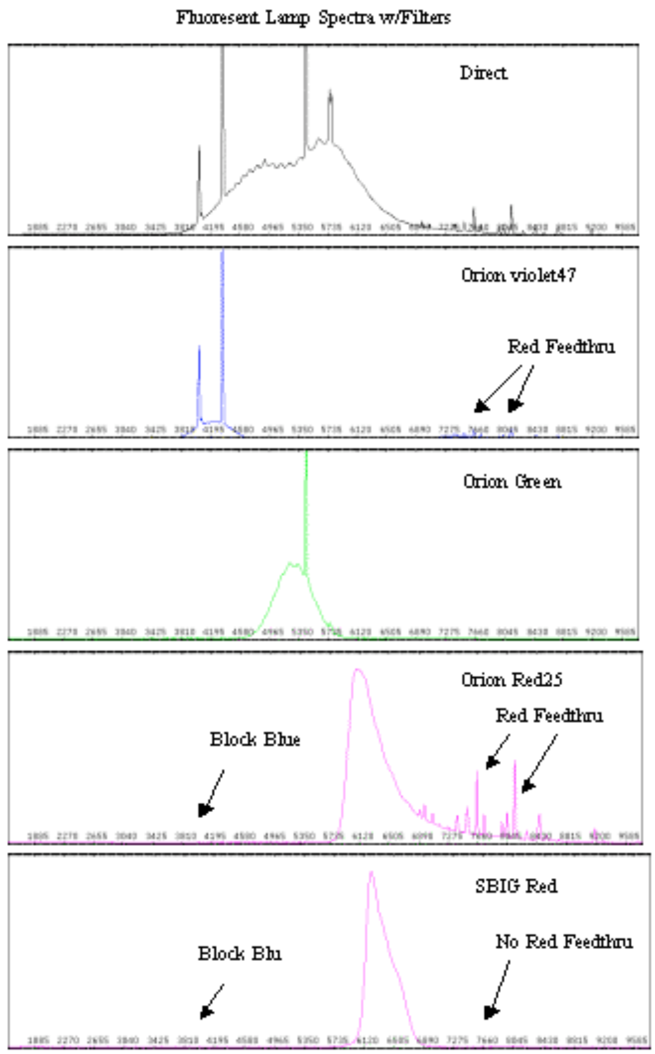
Higher Order Contamination

A diffraction grating spectrometer can allow higher orders of diffraction of a signal to show as a spurious signal. Thus, if one is looking far into the red on a grating designed to be used in the mid-visual range, a short wavelength line can also appear far toward the red in the spectrum, albeit at a reduced level. One can use a filter to block the bluer wavelengths; however, the question is whether such higher order effects are occurring in this setup even without a filter.

This problem can be investigated by using filters to pass and block various wavelength regimes. If a filter were used to block all wavelengths shorter than, say 6000A and pass all those higher, then the result should show that the longer wave lines are essentially unchanged, even though all the short waves are blocked. This would demonstrate no significant higher order contamination.

However, although not having such a filter, I was still able to rule out higher order contamination using a series of filters at hand. See the attached figure showing five spectra of the same fluorescent lamp:

- First is the spectrum of the direct (unfiltered) lamp.
- Second shows an Orion Violet (visual) filter showing the blue lines plus red lines showing it is not blocking red (or it is all blue feeding through as higher order)
- Third shows Orion Green (visual) which blocks blue. The red lines also go away--though it could be blocking red or it could by blocking blue could be blocking blue showing as higher order in the red.
- Fourth is Orion Red 25 (visual), which clearly blocks blue and passes red way out to 9000. Therefore, the undiminished structure past 7000 must not be related to the blue or green lines from the lamp, shifted to higher orders
- Fifth is SBIG Red (I think an LRGB filter, it is dichroic) which passes red only, all else is blocked.



Taking all these together, there is little or no apparent feed through to higher order of the blue and green structure from the lamp. Obviously, one can search for more sensitivity in the results; however, this work shows that there is little if any contamination of the signal beyond 8000, at least for this source. The Orion Red25 would be a good filter to use if substantial higher order contamination is suspected.

System Wavelength Non-Linearity

The fluorescent lamp source produces a wide range of wavelengths, mostly due to Hg and Ar. The program Vspec provides a table of wavelengths and intensities that allow one to identify the various lines. In calibrating a spectrum, one normally uses a linear wavelength calibration based on the known wavelengths of two known lines--in the case of this reference lamp, the lines at 4046 and 7635. While the wavelengths in between are always valid to within approximately one resolution width (about 7A), the longer wavelength lines show longer wave length than actual. The error is roughly proportionate to the wavelength above 7635, with a maximum error of about 75A at an indicated 9657A. Calibrating at 4058 and 9657 results in errors more than 7A for the intermediate wavelengths, so is not desirable.

The present work did not allow determination of the source of the non-linearity, but it is likely within the DSS7 lens system. However, the results make it clear that for accurate wavelength calibrations over this full range of wavelength, a non-linear wavelength calibration process is necessary.

Using the DSS7 Conveniently

The SBIG software that comes with the DSS7 is useful, but awkward to use. The biggest problem is that one has to place a target on the slit, and be able easily to check between exposures that the target is still on the slit. Remember that there are three modes of operation in the DSS7 (selected by sending selected "guide corrections" to the camera). These are

- **Slit**. For giving an image of the slit, so that you know where it is on the image field (i.e., is the object image on the slit?)
- **Direction**. This yields a fair quality sky image through the system and shows you the position in the field of where the various objects (stars, comet) are. The problem is to place the object on the slit by moving the telescope. My software allows me to superimpose an outline of the slit onto the direction image to make this easier.
- **Spectrum**. This mode takes a spectrum of whatever is on the slit.

My freeware DSS7CP program connects MaximDL to the SBIG spectrometer DSS7. DSS7CP provides for changing the mode of the spectrometer. It also provides the ability to convert an image of the slit into an outline of the slit, and then allows the user to superimpose this outline onto any subsequent image. This allows the user to direct the telescope to center the object on the slit.

Installation

Install the program as any other. Put in Program Files\DSS7CP folder.

When ready to use, execute the program. This will show a small control panel. You may set the **PulseDur**ations for the DSS7 motor drives. We recommend a minimum value to save the battery, usually between 0.1 and 0.2 sec. Note that most buttons have built-in reminders of how to use them.

Operation

The system will allow spectra to be taken in imaging or Focus mode, and any binning. These instructions assume you are in Binning=3 Focus mode (useful with slow download cameras), and that you are set up properly and able to take test spectra using the SBIG software.

First step is to verify that everything works with Maxim and DSS7CP. For example, select and take images using **ShowSlit**, **Direction**, and **Spectrum** to be sure you can see the slit, see the image field in the direction you want, and obtain a spectrum. The biggest operational challenge is to put the object of interest on the slit. For slow download cameras, use of MaximDL Binning=3 Focus mode allows quick trials of settings that makes this process go much faster. The ability to flip back and forth between trial images is important because the system as provided does not allow you to see the slit superimposed on the direction.

Slit Image Preparation

Take an image of the slit. You want the slit pattern to be VERY clear and bright (pixel readings over 10000), so use long exposures or a bright light source: you can even wave a flashlight (or use the battery fluorescent lamps if you use one for wavelength calibration) into the telescope. When you have a good slit image save it; it will be good until you modify the camera/DSS7 setup. While you are at it, do one for Binning=1, too.

Now, select (click on) the center of the narrowest slit image, and then click **SlitOutline**. You should get an image showing the outline of the entire slit. When you get a good image, save this, too. Again, this will be good until you modify the camera/DSS7 setup, i.e., you can use it in later observing sessions.

Click on an appropriate slit outline image (as taken above) in Maxim. Then click on the **ChooseSOL** button, thus choosing the SlitOutLine desired (you might have several on the screen at different binning). You do not need to ChooseSOL again unless you need a different SlitOutLIne.

Setting scope on Target

Direct the telescope to the target using the Direction mode to image the field. Aim the scope so the target is about on the slit (using your remembered positions). Remember, the directions of the image in the DSS7 are rotated from those of normal imaging.

Click on the direction image, and click **PasteSlit**. This will paste the previously selected SlitOutLine onto the DSS7 direction image. You may need to readjust the screen stretch settings. You can switch back to the non-superimposed image using the Edit/Undo menu (if selected in Files/Settings). Judge how far to move the scope, and use your scope software or controls accordingly. Repeat the direction image and slot outline pasting until the scope is aimed as desired. You will likely find movements of 5-30 a-sec as being all that are needed once the target is close to the slit.

Now select **Spectrum** on DSS7CP and take your image. At this point, the spectrum you take can be either Bin=3 or Bin=1 as desired.

If the telescope does not track well enough to keep the object on the slit, you will either have to make short exposures (with re-aiming each time), or use an external guider, or other means to obtain the needed tracking accuracy.