The DADOS spectrograph - a field record

by Sebastian Heß

The DADOS spectrograph

For quite a while, Baader Planetarium has been delivering it's DADOS spectrograph which was developed in cooperation with the Max Planck Institute for Extraterrestrial Physics in Garching, Germany and a group of enthusiastic astronomers at the European Southern Observatory. The DADOS is one of the few complete spectroscopic systems available on the market for amateur astronomers.

The purpose of this report is to provide information on the performance and how this instrument can help amateur astronomers to jump into the world of astrophysical spectroscopy. The report not only sheds light on the handling of the spectrograph but gives insight into new fields of investigation.

Fig. 1: The DADOS spectrograph mounted on a C8 operated by the author

In spanish, "dados" translates to "dice" or "dice-game" which, I believe, perfectly describes the mechanical layout of the spectrograph. Fig. 1: The DADOS spectrograph mounted on a C8 operated by the author.The DADOS consists of two cubic (or dice-like) metal housings one of which contains a mirror/slit system and the other contains a grating. The mirror/slit system is constructed so that most of the light from the source will be reflected into an eyepiece or a guiding-CCD that can be connected to the system and provide a direct view of the positioned object. A fraction of that light will pass through one of the three slits (sized 25, 30, and 50 micron thick) and onto the grating in the other half of the spectrograph. After passing one of the three slits, the light from the object is diffracted into different colors by the reflection grating.

The grating is "blazed" which means that it is manufactured with small tilted mirror surfaces instead of even structures. This has the advantage that the first order diffraction is strongly enhanced, which means little light is wasted. In addition, by switching between the three

different slits or by changing the grating itself (which is done quite easily), the observer experiences the highest possible flexibility concerning the difficult compromise between spectral resolution and integration time.
The spectrograph also features focusing optics which are connected in a 90 degree angle to the spectrometer. The focusing optics can easily be adjusted and fixed in place by a special screw. The angle of the grating can be adjusted with a micrometer and separately fixed in place. In this way a complete observation schedule can be done without the need to refocus or move the grating.

First impression of the instrument
Now we come to the first impression with the instrument. Fig. 2 shows two spectra of the Hα (Balmer) line of hydrogen in the spectroscopic double star β Aurigae with just one day difference. Due to the orbits of both stars, the emitted electromagnetic waves are either redshifted or blueshifted, depending on their velocity as seen on earth. Therefore, the lines split in a periodic way. The lines on the right side are in the infrared and come from oxygen in our atmosphere. Hence they are excluded from the doppler shift.

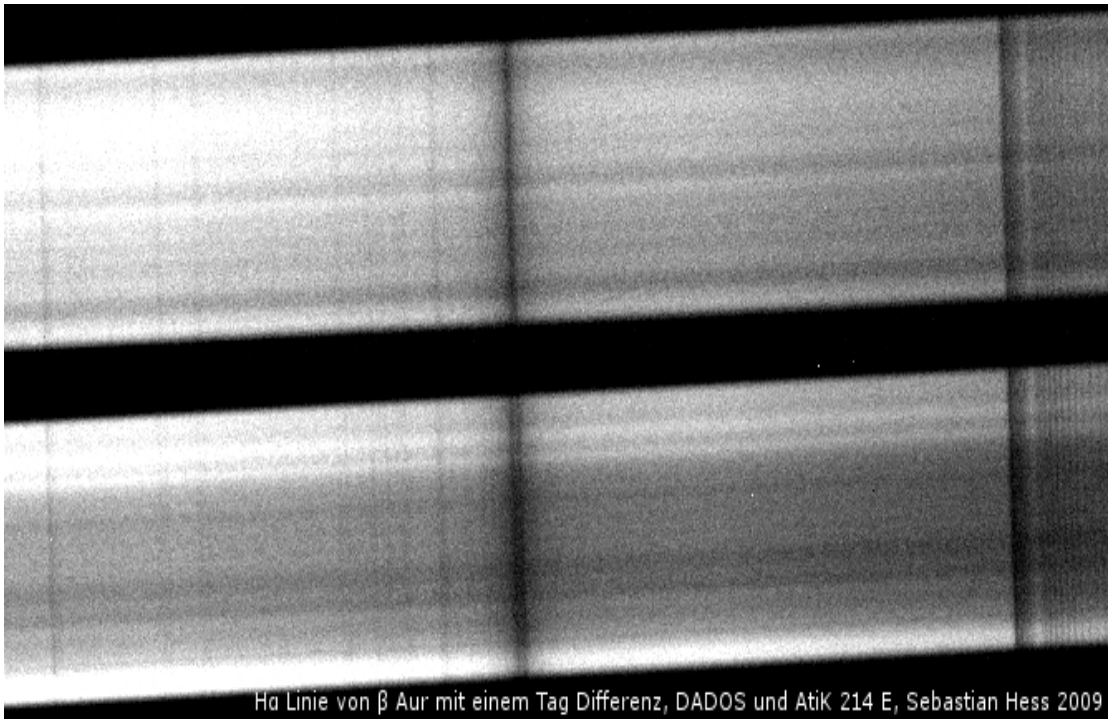

Fig.2: The Hα-line of the spectroscopic double star β Aurigae

This image was taken over the course of two Northern European nights ;-) with the DADOS spectrograph, an off the shelf CCD (Atik 214 E), and a reasonably aligned telescope mount. This illustrates what can easily be done with the DADOS spectrograph and equipment that is readily available to the amateur astronomer. To emphasize: To do spectroscopy of a bright spectroscopic double-star like β Aurigae (~1.9m), it is sufficient to use moderate equipment and 20 minutes of clear sky. However a lightweight (due to the 90 degree angle of the focusing optics) and cooled CCD like the Atik 214 seems to be crucial to receive highly resolved spectra.

Unfortunately, the system cannot be focused perfectly in a fast way due to optical aberrations occurring by the combination of the 90 deg geometry and the grating. This effect is increased with the higher resolution grating (the 900 Lines/mm). However, by investing some time and effort the aberrations can be cancelled by a very exact focusing. One idea to deal with the problem is to leave the system composed and fixed once exactly focused. Or one uses the dovetail, also delivered by Baader Planetarium to switch between camera systems and eyepieces.

Especially if using DSLR camera systems it is most useful to buy a focusing eyepiece - since exact focusing on the small screen is most painfull. It makes perfect sense to buy a 20mm (1.25") eyepiece, a second dove tail and a prolongiation adapter for the eyepiece. Here the astronomer has to play with the given possibilities. For focusing by eyepiece the moon or any other bright and extended lightsource with sharp linefeatures in it's spectrum is optimal. If there is no moon, the Neon lightbulb does a good job, but has the disadvantage of a necessary removal of the spectrometer from the telescope.

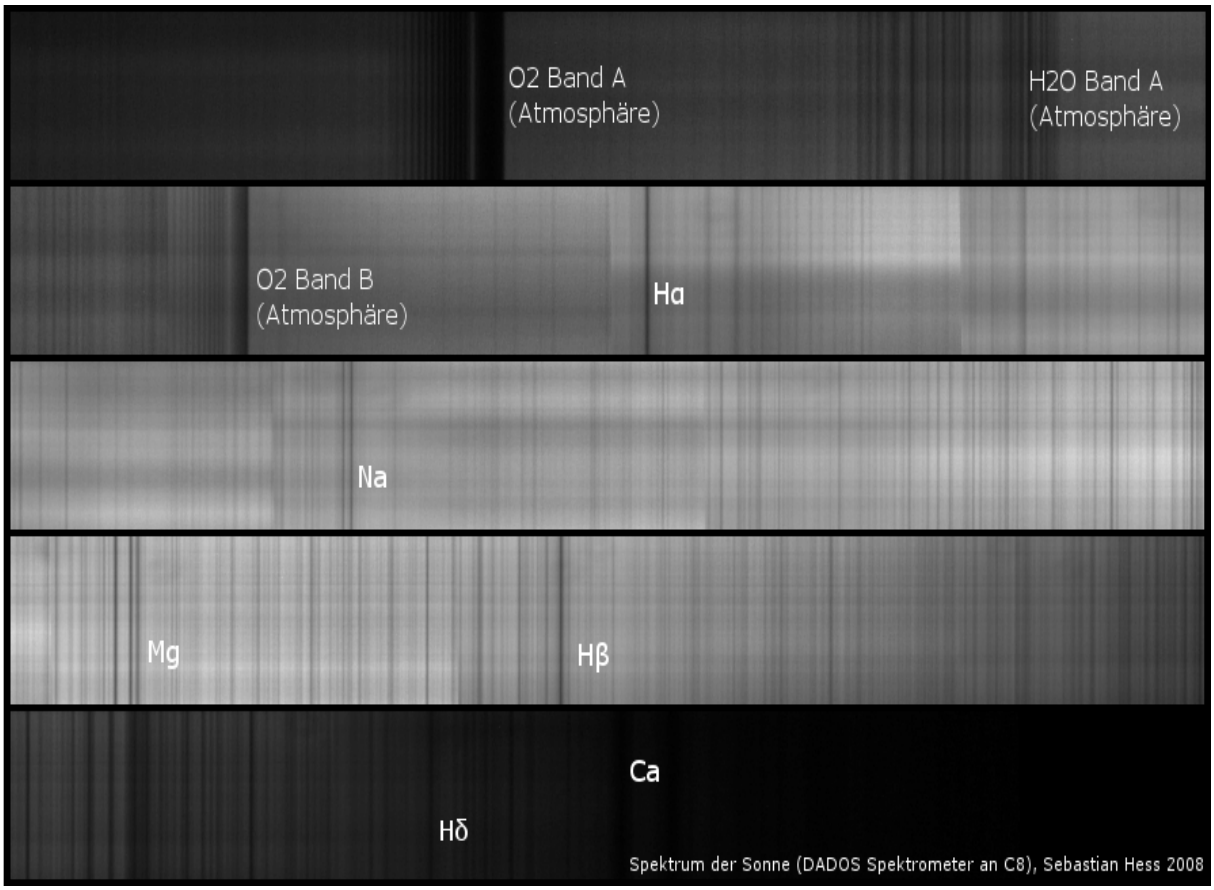

Fig.3: The spectrum of sunlight reflected on the moons surface shows distinct Fraunhofer absorbtion lines.

Change of gratings and first tests with a DSLR camera

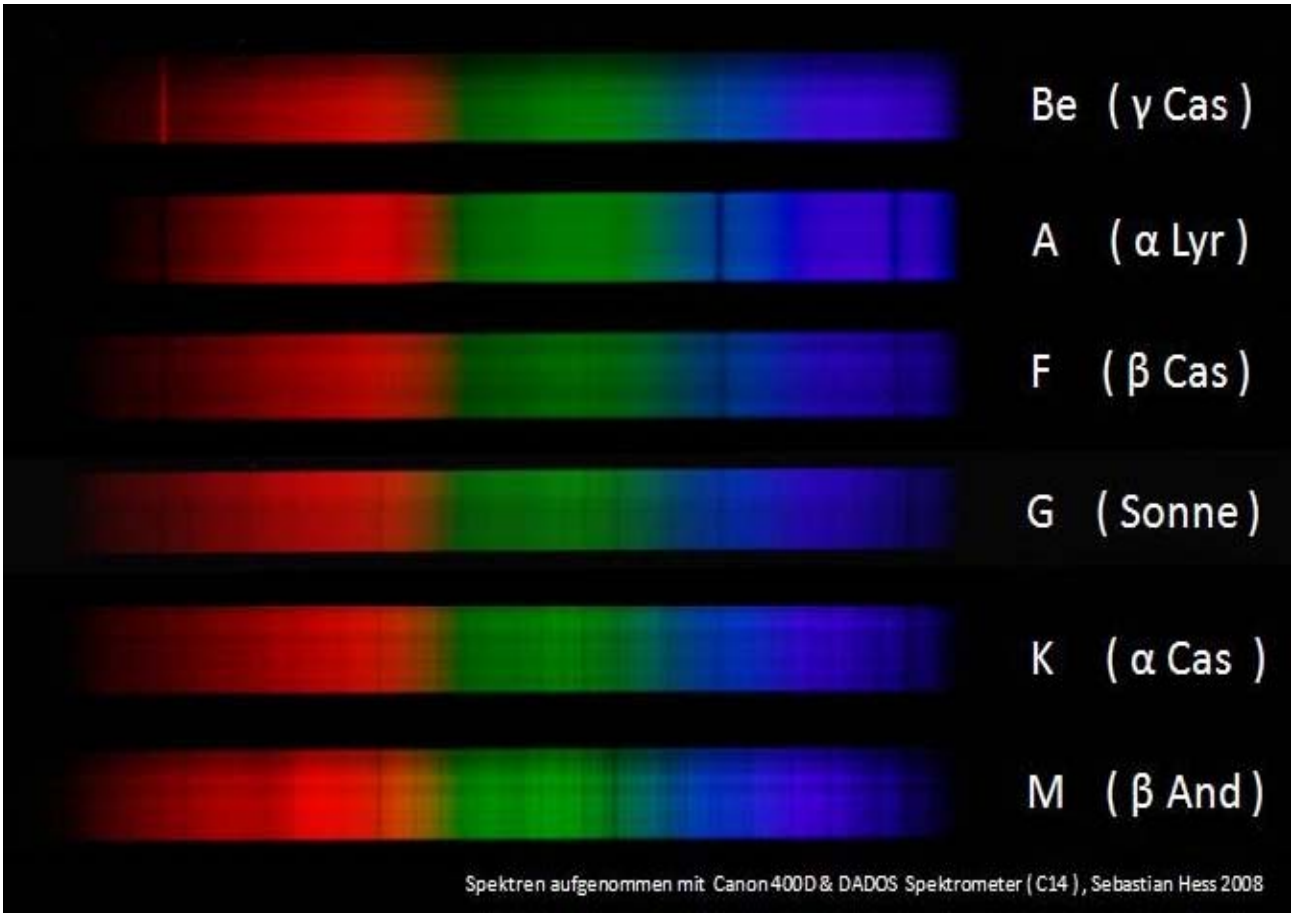

Fig.4: Stars of different spectral class realized with the 200L/mm grating and a Canon 400D DSLR camera system.

Even if the seduction to always use the highest spectral resolution is big, it makes perfect sense to use the lower resolution grating (200 L/mm) for darker objects or just to cover the complete visible range in just one single shot. For this work it is useful to prepare a clean working environment and to know the necessary steps in advance. In this way the danger of a destruction of one the gratings can be held as small as possible. With some training the process is inproblematic and can performed in less than 10 minutest.

First, the mikrometer has to be unlocked. Then the second cube has to be opened and the old grating has to be unscrewed. Then the new grating can be inserted into the right position which is marked for both gratings individualy. They are different since the diffraction angle differs with the number of lines per mm. Even for higher resolution gratings (1200L/mm ...) there are already marks prepared. Before starting the new observation session it is useful to find the new focus and to put the right part of the spectrum into the middle of the field of view. This can save a lot of time!

Already with the standard 200 lines / mm grating, the DADOS spectrograph can be used to visualize the dominant features in the different spectral classes. The classes O,B,A,F,G,K;M

have developed historically and refer in this (modern) order to the surface temperature of the stars. That is why in the image, the hotter stars are on the top and the cooler stars are on the bottom. Hotter stars show other lines than the cooler ones.

One reason for the different absorbtion line features at different temperatures is the appearence or absence of special excited or ionized states of the observed elements, which are described in detail by the field of plasma physics. In sloppy words: If all the hydrogen is ionized, there will be no H alpha absorbtion line due to the absence of any electron. But since the (Balmer series) H? line refers to an electron transition beween the second and the third main quantum number (orbit), the temperature of the star can also be too cool, since there must be enough excited hydrogen with electrons in the second orbit. Another reason is the existence of molecules at very low temperatures (see the many absorbtion line features a the M-Star).

Preliminary Conclusion

As a preliminary conclusion one might state that with the DADOS one gets good quality for the money. Especially for newcomers to spectroscopy the DADOS opens up the possibility for a fast but nonetheless deep jump into the field. Here details such as the integrated possibility for the positioning of guiding CCD's or eyepieces as well as the dove - tail system help a lot. But also the advanced amateur can have fun with these details, possibly with the higher resolution 900 L/mm grating.

At this point it should be mentioned that there are systems on the market which provide a higher spectral resolution, but are much more expensive. Up to now I do not regret my decision for the DADOS. It is "Plug and Play!" - A long awaited dream coming true! How could the beginning be nicer?

Outlook

For those under you, awaiting the holy grale of high resolution spectroscopy: It must be mentioned that Baader Planetarium will soon provide us with a new spectrometer which has been developed by the same group of people. It is called the BACHES echelle spectrograph. The visitors of the ATT spectroscopy meeting 2009 in Essen were able to have closer look onto their prototype. And I must say: Wow! Without promising too much: This spectrometer is a big hit.

For the first time, amateurs will be provided with a complete affordable Echelle spectrograph system with an up to now amateur unreached spectral resolution. The complete visual spectral range in just one shot and a resolution of ?? / &lambda of up to 20000. That is a revolution. For reasons of comparison: Slit - Spectrographs on the market - also the DADOS - have a resolution of about ?? / &lambda ~ 4000. Following the keynote at the ATT spectroscopy meeting, the BACHES will cost about 6000 EUR and might be available starting this year. This will open up new possibilities, such as only few people worldwide have right now ...