

Imaging through a spectroscope

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Abstract

In this article I'll expose my team efforts in order to get narrowband images of the Sun, Moon and some planets by using a spectroscope.

Introduction

The main role of spectroscopy in astrophysics is the study of some properties of the astronomical bodies through the analysis of its light. This may be achieved by inspection of a spectrum acquired with a spectroscope, or by observing narrowband images of the object using narrowband filters. However, spectroscopes may be used for, through an indirect way, assemble narrowband images of extended bright objects, being spectro-heliography the main use of that. Today, at amateur level, spectro-heliography becomes a current practice. The same methods used for the Sun may be applied in other extended objects, such as Moon and planets. The issue here is the low brightness of these objects, and some solutions to overcome this issue will be proposed below. Another issue is what useful information one can obtain from narrowband images of the Moon and planets. The answers to this question are outside the objectives of this article. Yet, the techniques proposed aim the creation of methodology for amateur remote sensing.

Spectro-heliography

Spectro-heliography consist in building an image of the Sun from a specific wavelength of its spectrum. My spectro-heliograph is composed by an 85mm f600mm Apochromatic refractor, diaphragmed to f/10, a Littrow spectrograph with a diffraction grating of 2400 lines per mm, 2 webcams - one for the spectrum and the other to drive the mount, and an equatorial mount. The method is simple: Let the Sun pass perpendicularly through the slit of the spectrograph, by stopping the RA

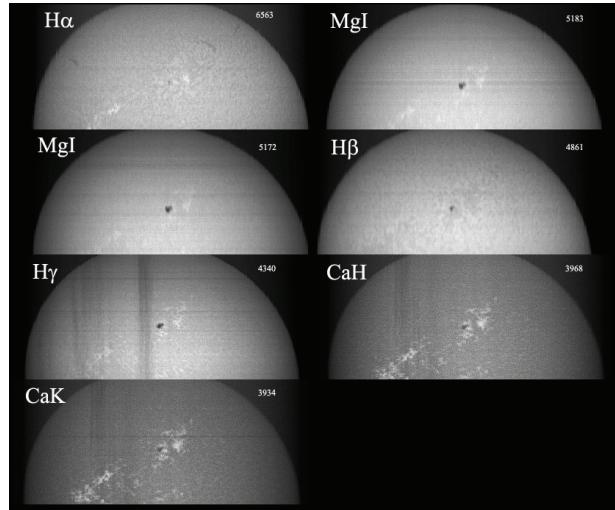


fig.1 multiwavelength solar images

movement of the mount, while recording a film, in my case an AVI. Using the program Iris of Christian Buil, the AVI is decomposed in frames. Next, one must choose the column of pixels corresponding to the wavelength of interest and a SCAN2PIC command is executed. The resulting image suffers from deformation due to the fact that the speed of capture is different from the sidereal speed (not a real drift scan); geometric corrections must be preformed. Although this method

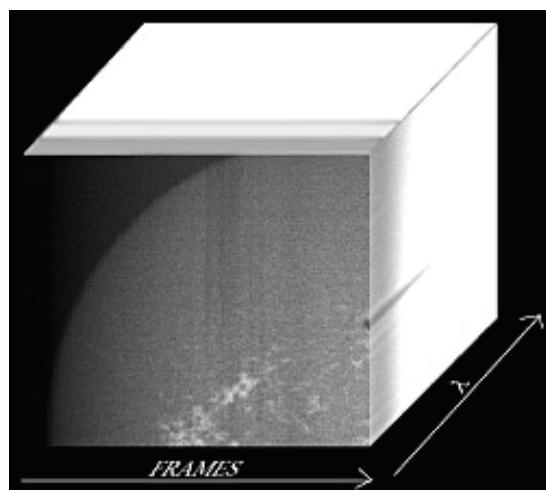


fig.2 image assembling from the spectral line

hardly results in perfect images, it gives us the possibility to study the Sun in all wavelengths in the visible, near IR and near UV (fig. 1).

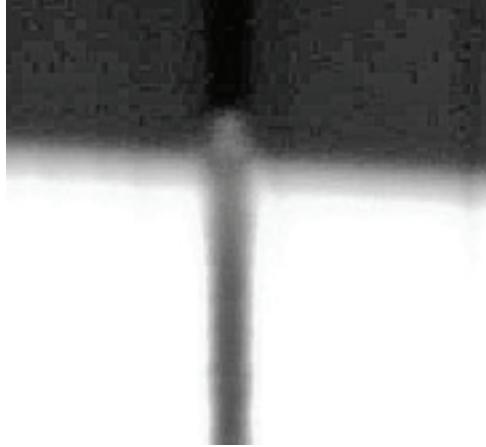


fig.3 hotter chromosphere above photosphere

Figure 2 shows how the solar image is assembled from the frames: Each column of adjacent spectra is stacked to form the image. The line represented corresponds to the CaH; the black horizontal trace in the spectrum side corresponds to the solar spot.

In figure 3 one can see the H α line due to the chromosphere. This line seems of absorption at the solar disk but of emission at the solar limb, where a prominence is seen. However, the absorption line is due essentially to the colder external layer of the photosphere. As the chromosphere is hotter than the photosphere, an emission of H α take place, weaker, overlaid to the absorption line.

The Moon: spectro-selenography

Spectro-selenography consists in assembling a lunar image from a line of its spectrum. As in spectro-heliography, the Moon is forced to pass in front of the spectrograph's slit while an AVI or an image sequence is recorded. Due to the Moon's brightness being much inferior than Sun's brightness, some of the procedures are necessarily different. First, a higher aperture telescope is used, in this case a 9.25" Schmidt-Cassegrain. The spectral resolution of the spectrograph is also reduced in order to gain light. In our

case we use a diffraction grating of 300 lines per millimetre. If a webcam is used with a 5.6μ pixel, a dispersion of $1\text{\AA}/\text{pixel}$ is obtained. Although with this setup some image detail is achieved, due to the lack of light the signal-to-noise ratio (SNR) is

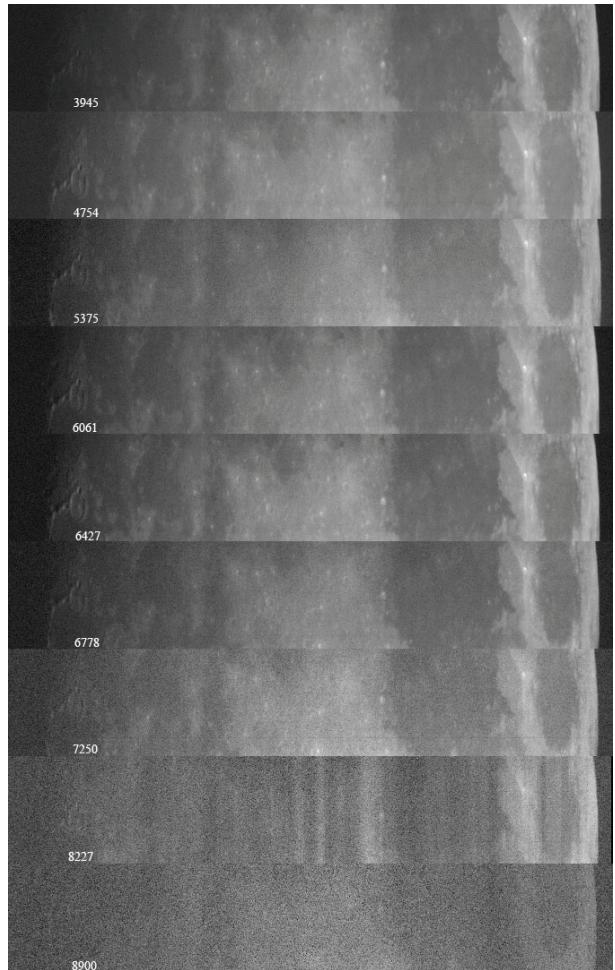


fig.4 webcam lunar results

very low, not allowing the visualisation of eventual different detail of images with different wavelengths. The dynamics of an 8 bit image doesn't allow big manipulations, either. Figure 4 shows a set of narrowband images of the Moon, from Mare Crisium to Gassendi, assembled from a set of spectra captured by a webcam. This image, the first that I captured with this process, has a bandwidth of 1\AA in the H α zone. Many images were obtained with this process, but the method was abandoned due to the reasons above exposed. From now on, the work contained in this article was

performed by me, Filipe Alves and Alberto Fernando. We opted to use a CCD, in this case a KAF3200. The main

sidereal movement, or $0.5''/\text{s}$. Maintaining the mount at sidereal rate and letting the Moon pass over the slit at its lunar rate, is

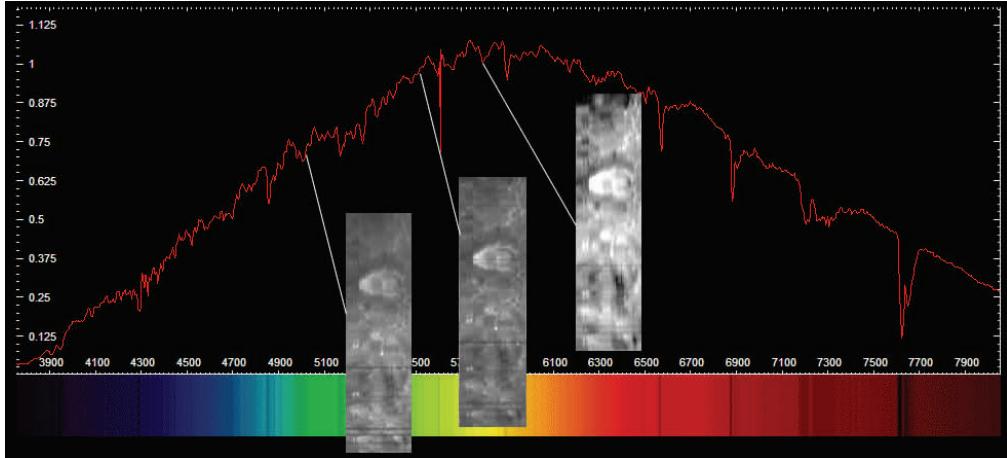


fig.5 Kaf 3200 lunar results

obstacle to this choice is the read time for this CCD: the Moon doesn't stop between CCD readings. The solution

enough to achieve results. Related to this, if a 3×3 binning is used, the reading time of the CCD is reduced, in the case of a KAF3200 USB from 8s to 1s. With this

configuration a lower spectral resolution is attained, of $3.4\text{\AA}/\text{pixel}$, but on the other hand, an excellent SNR and 16 bit dynamics is obtained. Another advantage of this CCD is its size, allowing the coverage of the entire visible spectrum only in two grating positions. Another major improvement was the method of assembling the image from the spectral line. Filipe developed a routine working in the 3D program Softimage, which automatically assembles the image at any wavelength. From now on, we are able to inspect instantly the narrowband images through the entire spectral domain. Figure 5 represents the visible spectrum of the Moon covered by the CCD in two positions of the diffraction grid, as well as some images of Tycho obtained with this method. Interesting to note that the continuum obtained is the solar continuum reflected by the Moon.

The Moon has colour (fig. 6). From literature, some of the colours of the Moon were already related to soil properties. For instance, the blue colour of maria reveal concentration of TiO_2 , brown is related with Iron oxide, and orange with



fig.6 the coloured Moon

found was to reduce the speed of the Moon's pass over the slit, by taking advantage of the difference between sidereal and lunar speeds. Moon travels its diameter in one hour relative to the

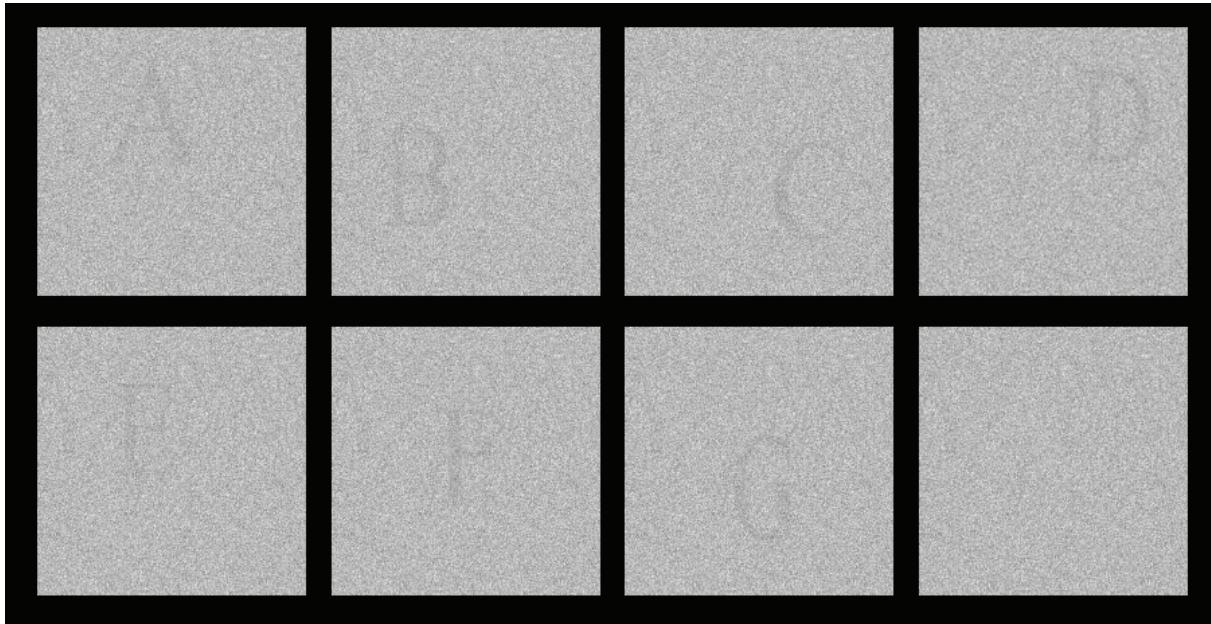


fig.7 a narrowband example

pyroclastic lava. The aim of spectro-selenography is the acquisition of lunar narrowband images.

By inspection of those images try to obtain information about the formation and geologic evolution of our natural satellite. After developing the method for the acquisition of narrowband images of the Moon with enough

fig.8 the broadband result

resolution and a good signal-to-noise ratio, procedures must be found for the interpretation of the results. A probable method advanced by Filipe Alves, consist in the determination of the ratio between two images, one corresponding to a spectro-selenogram of

a precise wavelength (narrowband image) and the other the result of the average of all spectro-selenograms contained in the acquired spectra (broadband image). In order to better understand the aim of the method, let's see the follow example:

Figure 7 simulates a series of

"narrowband" images all different in some details, in this case represented by letters. The image at bellow-right contains a white "A" nearly at the same position of the black "A" in the upper-left corner. The average of these images results in an image without the details of each individual image (fig. 8). The image corresponds to a "broadband" image containing all the contributions of the acquired spectra. Performing a ratio between each "narrowband" image and the "broadband" image, one manages to show the differences of the two images,

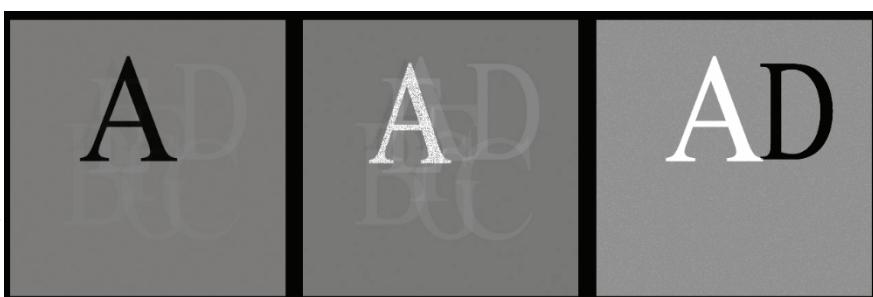


fig.9 left and middle images, narrowband / broadband ratio. Right image, D/A ratio (colour index)

nullifying the common parts (fig. 9). In the figure, the left image corresponds to the ratio between the black "A" and the average, the central image corresponds to the ratio between the white "A" and the average, and the left image corresponds to the ratio between the black D and the

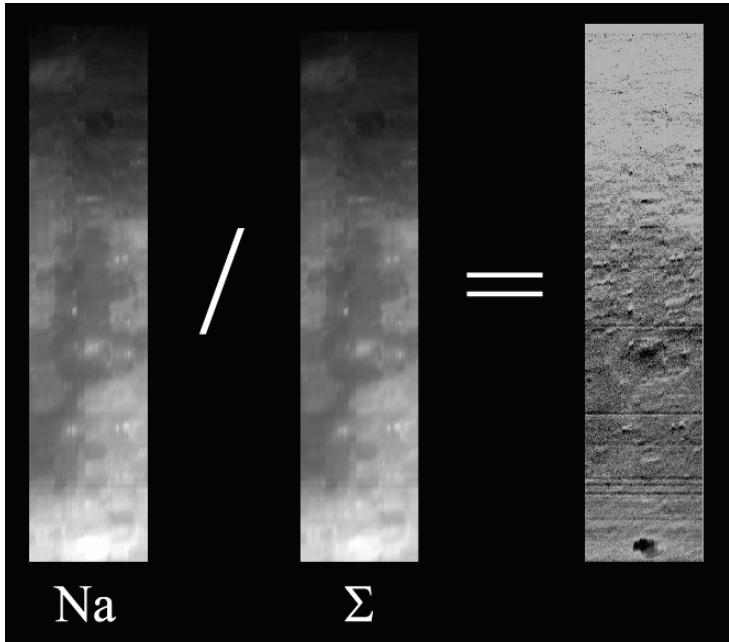


fig.10 a practical example of the ratio method

black A (useful for colour-index). The "narrowband" image details become evident.

between the other two. In the right image, zones without detail correspond to zones without differences between the narrowband and the broadband images. The dark spot below show a difference, in this case, by defect of the colour corresponding to the wavelength centred at 5893 Å. This method may be interesting in the study of colour-index as an image, such as the C(0.42/0.55μm) to estimate the TiO₂ abundance (Charette et al., 1974) (fig. 11). The colour image of the zone is included for comparison.

Probably, the correlation of the composition of the lunar samples with the narrowband images of the places from they where taken, may be extrapolated to other lunar regions not directly explored by spacecraft.

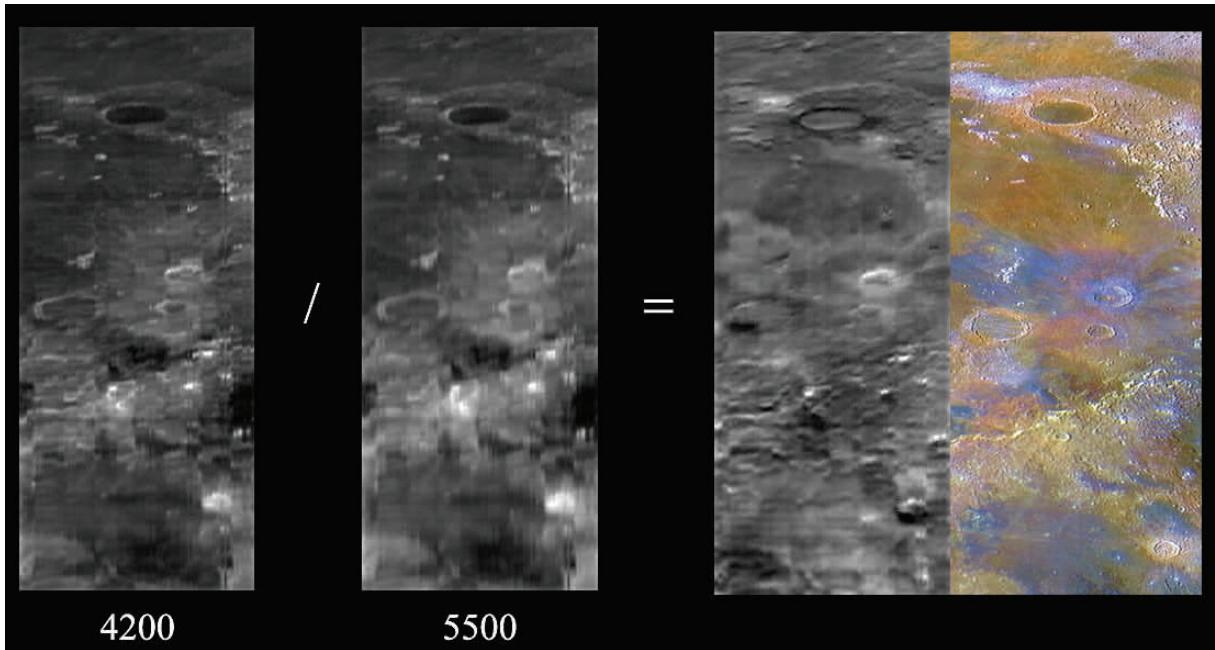


fig.11 a comparison between a colour-index image and the colour image for TiO₂

The lunar zone represented in (fig. 10) goes from Lalande to near Pitatus, passing by Birt. The left image correspond to a wavelength centred in the Sodium doublet and have a bandwidth of 3.4 Å. The central image result from the average of all acquired wavelengths (broadband image), and the right one is the ratio

The planets

Here, we are really doing our first steps. The basic method is the same as for lunar spectrography, described above. The big issues here are the guiding and the atmospheric turbulence. First, we attempted to drive the mount by hand,

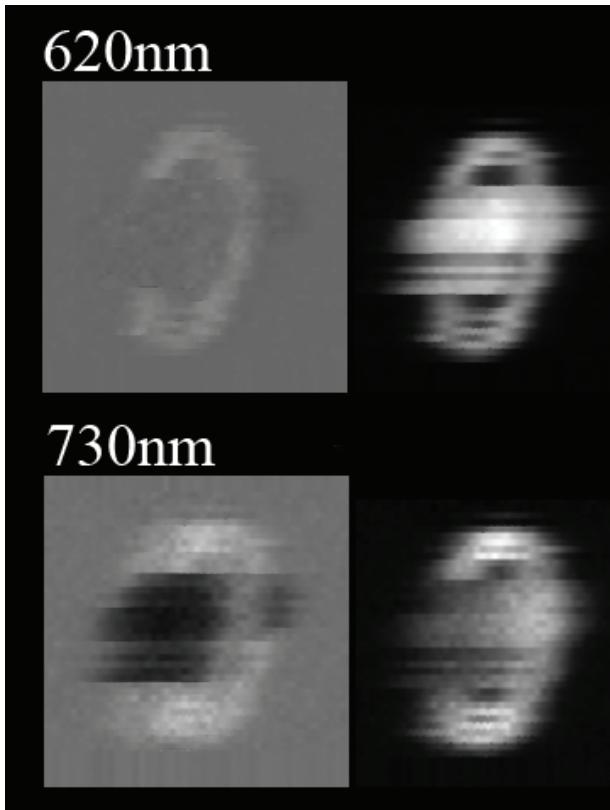


fig.12 At Methane's wavelengths Saturn's disk absorbs the solar light but the rings don't.

doing the geometric corrections later. I must say that it resulted, at least on Saturn and Jupiter. Later, we tried to follow Mars at sidereal speed, which at its position at the date of acquisition took ten minutes for the disk to pass the slit. The major issue here was the atmospheric turbulence that jeopardized completely the resulting images. One interesting result obtained so far is the narrowband image of Saturn at the wavelengths 620nm and 730nm corresponding to methane absorption. The disk vanishes, while the rings maintain its brightness (fig. 12). Saturn images at right are the narrowband images as they were assembled, and the Saturn images at left are the ratios between the narrowband images and the broadband image, as explained above. Much work is yet to be done in this area.

Conclusion

Spectroscopy in the visible has its limitations on solids. However, the study of colour and of the spectral albedo gives

useful information on the geologic and chemical properties. The use of modest spectrometers as ours, make remote-sensing of our solar system at the reach of amateur astronomers. If issues on the Sun and Moon are almost overcome, there are a lot of improvements to perform on planetary narrowband acquisition methods. Autoguiding on a star is crucial for planetary work. The atmospheric turbulence is in my opinion the main problem. With the development of technology applied to amateur astronomy, perhaps in a near future we can have adaptive optics in our telescopes (they exist already for guiding).

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