The atmospheric dispersion corrector

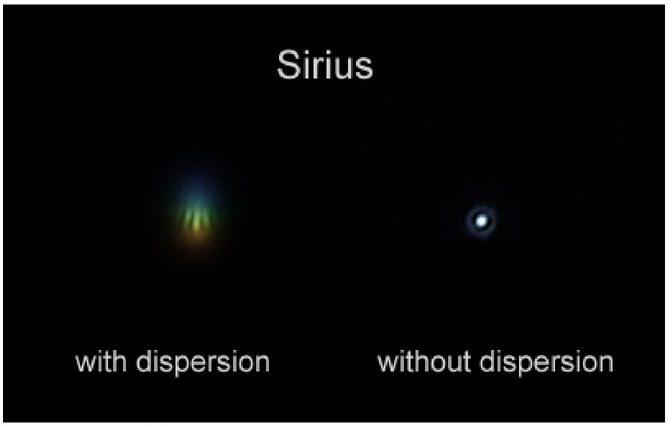
When objects outside the Earth's atmosphere are observed, a phenomenon called atmospheric dispersion is distortion the image. This effect, especially visible when the object of choice is situated near the horizon, manifests itself as a red 'rim' under and a blue rim above an object. It is particularly interfering with high resolution observations of the moon and planets, because it decreases the resolution of such objects and distorts fine detail. An atmospheric dispersion corrector, as described below, corrects for this interference.

Theory

When light of any object (a star or planet) passes through the atmosphere of the Earth, it will be refracted because the refractive index of the air is not equal to the vacuum of space. The difference in refractivity is only small, but nevertheless it causes the light to pass through the atmosphere at a small angle rather than a straight line. The object of interest therefore appears at a slightly different position than it would appear without an interfering atmosphere. Refraction is strongest near the horizon, because the light has to pass a longer path through the atmosphere. There is no or almost no refraction the Zenit.

The refractive index of air is different for different wavelengths of light. Shorter wavelengths are more strongly refracted than longer wavelengths. Since red light has a longer wavelength than blue light, it follows that red light is not refracted in exactly the same way as blue light, causing the two to diverge. Therefore, the red image of an object is not observed at the exact same position as the blue image. This effect makes the colours of the object to be dispersed somewhat, with red and blue displaced with respect to each other. This is called atmospheric dispersion. It is more strongly observed near the horizon.

Figure 2 illustrates this with an image of the star Sirius near the horizon. This image shows the light of star to be dispersed like a miniature spectrum. Red light is less refracted than blue light, causing the blue image of the star to move away from the horizon when compared to the red image.



The image of Sirius also illustrates the problems that occur when high resolution imaging is attempted without compensating for the dispersion. The different dispersion causes multiple images of an object which are displaced with respect to each other. This causes a serious decrease in resolution and loss of fine detail.

Correction for the dispersion

Most medium to large sized amateur telescopes can reach a resolution of up to 0.2" to 0.4" and the effect is a real problem when the dispersion of the different colours is larger than the resolution of the telescope. In practice, objects that are located below 60º altitude suffer from noticeable dispersion. Since planetary or lunar objects rarely reach this altitude (at least in countries situated at higher latitudes), compensation is needed to avoid loss of resolution. When observing objects near the horizon, dispersion can increase to values of 1 or 2", making high resolution imaging almost impossible.

The problem can be controlled by limiting the wavelength range with the use of filters. In general, a RGB filter set can be use to restrict the wavelength range and therefore to limit the dispersion in each of the three colour channels.

It is also possible to use filters that transmit in the near IR, where dispersion effects are far less pronounced. Restricting the wavelength area using filters therefore offers a good way of dealing with dispersion. As long as objects aren't observed at extremely low altitudes, the effects of dispersion can be suppressed. Since RGB filters are already used to make colour images, they simply offer this extra advantage.

Yet there are disadvantages as well. Filters limit the amount of light that reaches the eye or CCD detector. In the case of RGB filters, the signal strength of an object is cut by a factor of three.
Imaging the fainter planets like Saturn and Jupiter is therefore more difficult in comparison with bright objects like the moon or Venus. A lower surface brightness means longer exposures for a CCD camera, and less compensation for seeing effects. Using filters restricts the amount of light even further, requiring even longer exposures.

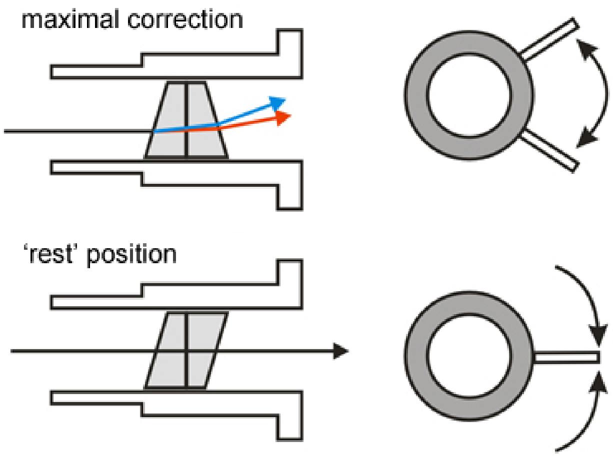
A second disadvantage, although less pressing, is that filters only restrict the dispersion, but do not compensate for it. Especially the blue to violet part of the spectrum is more sensitive to dispersion effects, and at low altitude, the dispersion between blue and violet wavelengths may be a factor even when a blue filter is used. UV imaging of Venus may be even more sensitive, although to what extent this is problematic (UV imaging usually yields less resolution due to seeing effects) remains to be seen.

the dispersion corrector

Professional astronomers compensate for seeing effects with so-called dispersion correctors. Now, for the amateur, a simple corrector exist as well

The dispersion corrector is a relatively simple instrument that is designed to correct for the effects of the atmospheric dispersion. The optics cause a controllable refraction that is opposite in direction to the atmospheric dispersion. It is therefore capable of compensating for the effect rather than restricting it, which makes it possible to view or record an object without being hindered by dispersion effects.

The corrector consists of 2 round prisms that are placed with the plane sides facing each other. In resting position, both prisms are placed in such a way that each prism forms the half of a window with parallel facing surfaces (see figure below). It acts like a window in the light path without any effects on the dispersion. To correct for the dispersion, the prisms must be rotated with respect to each other. When they are maximally rotated, they form a large prism that causes any light beam that passes through it to be refracted like a normal prism would. This effect is used to counter the effects of the atmospheric dispersion. By changing the positions of the levers, the amount of refraction can be fine-tuned to match the atmospheric dispersion of the object of interest, and cancel out the dispersion effect observed in the telescope.



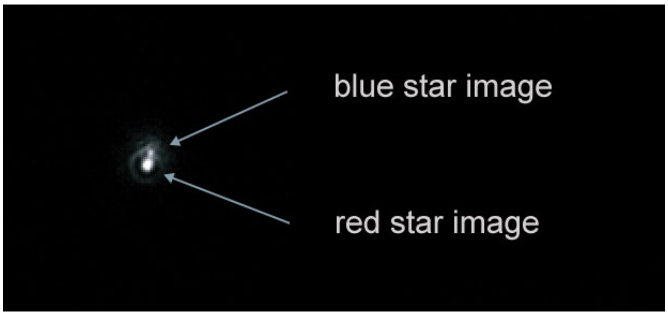
Using the corrector this way it is possible to correct very accurately for the dispersion. For colour camera's this means that the blue and red rim in images of the moon and planets will disappear. For monochrome camera's there is no reason to use filters to limit the amount of dispersion using filters, and a bright Luminance can be used which requires far shorter exposures, offering a new tool for high resolution imaging. Seeing effects can be suppressed with greater effectiveness.
Especially for dim Saturn this creates a big advantage, because the increased luminosity makes it far more easy to image the planet.

Practical use of the Dispersion corrector

The dispersion corrector is placed behind a Barlow. A Barlow is highly recommended because the corrector works most efficient at high focal ratio's (f/30-f/40). Always place the corrector between the Barlow and they eyepiece/CCD camera.

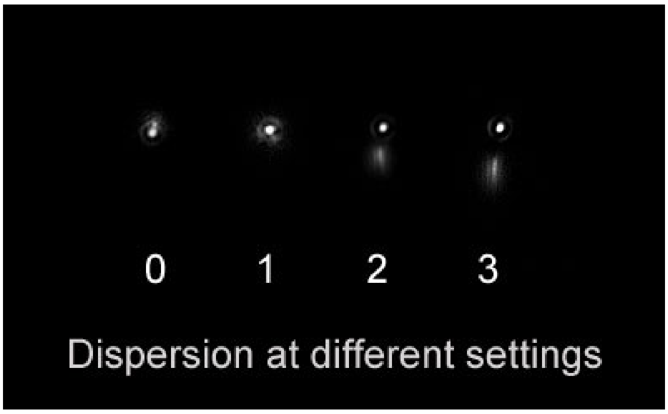
The dispersion can be corrected by positioning the levers in such a way that the dispersion is compensated. In 'resting' position, the two levers must be parallel to the horizon. Also, when correcting for the dispersion, the two lever positions must mirror themselves in the horizon. So an angle of 30 degrees with the horizon for the upper lever must be accompanied by a angle of –30 degrees with the horizon for the lower lever. In other words, the angle the two levers make must always be cut in equal parts by the horizon.

The dispersion corrector can be calibrated as well. The casing of the corrector is marked with different settings, so the levers can be accurately set and the settings for each session can be recorded.
To calibrate the corrector, it is necessary to measure the dispersion correction for a given altitude of an object above the horizon. Once the amount of dispersion is known, the levers can be set to the same configuration each time an object is observed at the same altitude. The best way to do this is by making use of Wratten 47 filter. This filter blocks a large part of the visual spectrum, and only transmits in the deep violet and NIR (>700 nm). These two wavelength ranges are maximally dispersed by the atmospheric dispersion. When a star is imaged at a given altitude, the dispersion effects are more accurately visualized and offer the opportunity to actually measure the extent of the dispersion as well as the correct setting of compensating for it. For a given star, at a certain altitude, the dispersion causes the light to be dispersed into the different colours of the spectrum. Because the W47 filter only passes violet and NIR light, two different images of the same star appear, offset by a certain distance, caused by the dispersion. The star image can be recorded, and the distances measured.



In the image above an image is shown of a single magnitude 2 star. The blue-violet image of the star (dimmer because of the lower transmission of violet through the filter and because it was a red star) is noticeably displace with respect to the lower red image. This distance can easily be measured once an image is made. The blue image can be distinguished from the red one by looking at the size of the airy disc and first diffraction ring, which are noticeable smaller in the blue image.

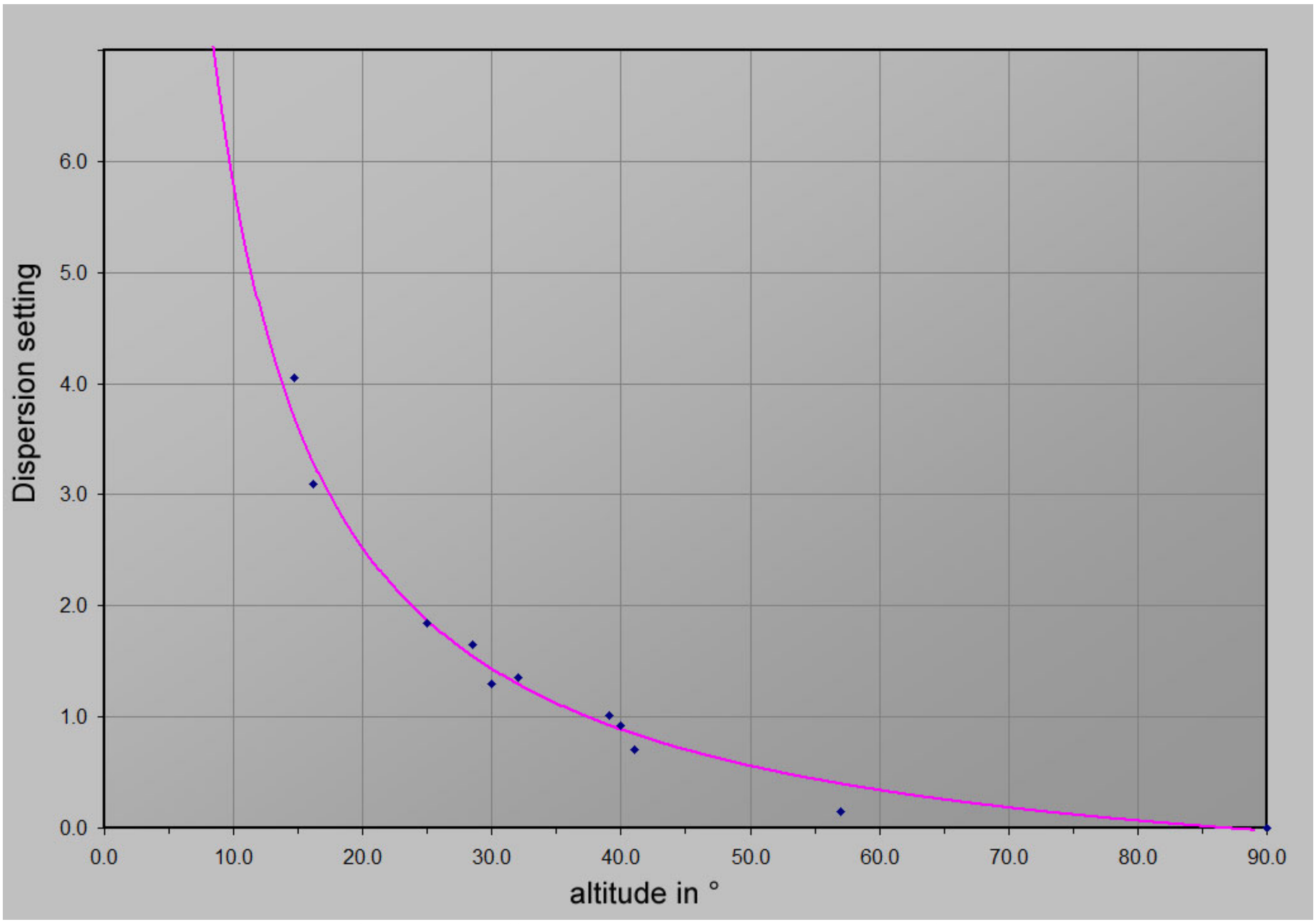
With the dispersion corrector, the star can be imaged at different settings with the dispersion corrector. This way the right setting for matching the dispersion can be obtained. The altitude of the star can be determined using the time and date of the recording and making use of an astronomical reference.



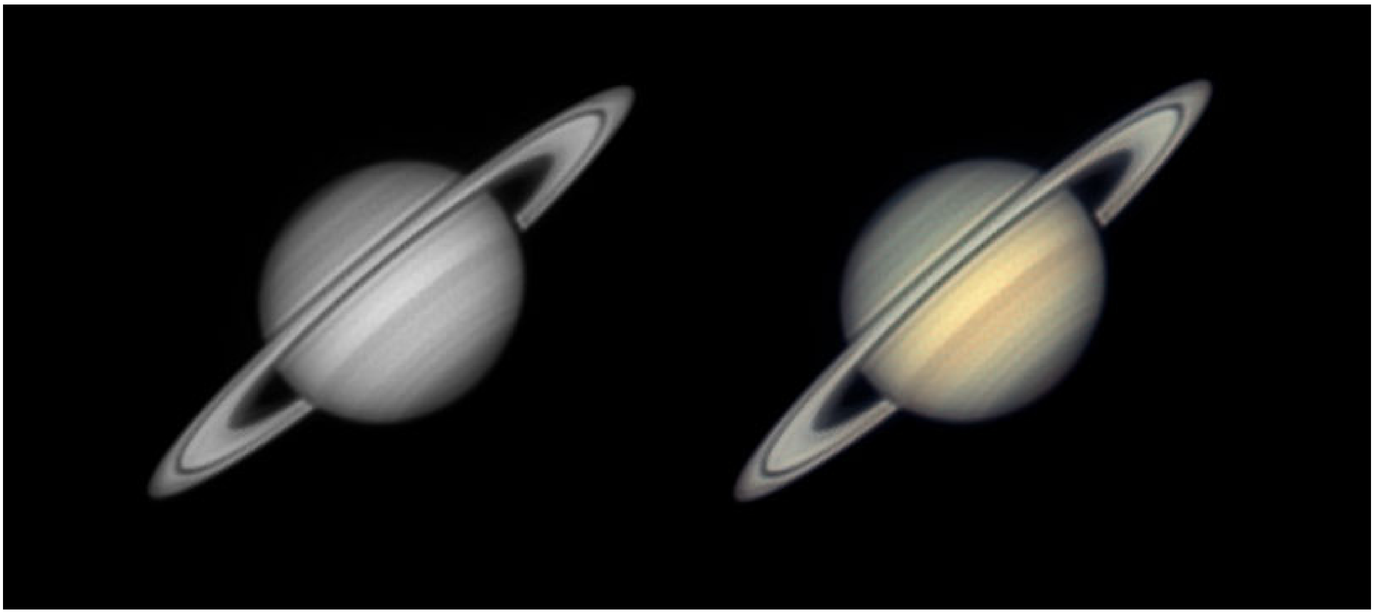
At a certain point, the dispersion corrector exactly compensates for the dispersion of the air. Compensating more will only disperse the two star images in opposite direction. This causes the blue-violet image to be distorted (most likely due to the fact that blue light is more affected by dispersion and the wavelength differences in the filter ranges start to show dispersion differences as well NIR light is never distorted in this way). In the above case, setting number 1 is the correct setting.

This can be done for various altitudes obtaining the right settings for a range of different altitudes. Once a certain list of measurements has been completed, they can be plotted in a graph. Using the graph will make it possible to determine the right settings by determining the altitude of the targeted object.

The curve is dependent on the type of telescope and Barlow used and the same configuration of telescope, Barlow and corrector has to be used if such a calibration will be applied.



A dispersion curve, calculated from many different measurements over a period of time. This way it was possible to determine the right setting for any object at a given altitude*. The below image of Saturn was made this way. The Luminance to the left is build op of several images made without filter and with a broadband yellow filter. The right image was coloured using a low resolution RGB.



---

* the atmospheric dispersion is not completely constant and is influenced by air humidity. However, these differences seem small compared to the total dispersion and could be ignored.