FAULKES TELESCOPE

Colour Imaging

Colour in Astronomical Images

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Socrates

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Introduction

Are the colours in deep-sky astronomical images "real"?

Are they "accurate"?

Answering this involves several different questions-- how do we define colours, how do we perceive them, and how do we record them.

Light itself is "out there" in the real world and can be measured and quantified objectively and defined by its wavelength. But colour, and its perception by humans, is subjective because of its interpretation by the brain. Its "accurate" recording in images is complicated because of the combination of these two considerations.

Normal Photography

In normal daylight photography, we can get pretty close to accurately reproducing the colours in nature in a photograph. The proof would seem to be simple, we can take a photo under controlled conditions, and then compare it to the original objects. The photograph on the right, shows a typical outdoor scene.

To be really critical though, it is, in fact, nearly impossible to perfectly record all of the colours in a scene because of the problems of the limitations of the recording medium, colour spaces, and other things too complicated to go into here. So even in this simple example, it is impossible to be completely accurate in colour reproduction. If you want to test this for yourself, take an image of some light blue flowers, bluebells for instance, you might find a significant different between what you see and what you camera sees as the camera and film are more sensitive to ultra-violet light.

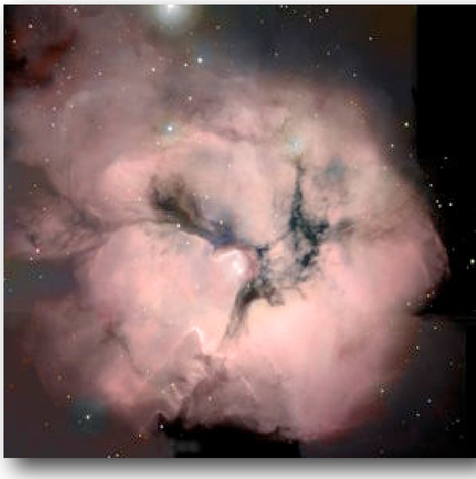
The question of the accuracy of visually observed colours is even more complicated because the eye / brain combination. In some sense, our perception of colours can even be considered an "illusion".

For instance, consider Edwin Land's (inventor of Polaroid photography) famous example where he photographed a scene as two black and white images, one with a red filter, and one with a green filter. Then he simultaneously projected the resulting images in register, the first through a red filter, but the second with ordinary white light, unfiltered. Amazingly this produces the perception of a full colour image.

Our perception is also very adaptive to the colour of the light the subject is viewed under. For instance, consider scenes illuminated by different light sources, such as florescent, tungsten, and daylight. Most florescent lights are quite greenish, tungsten is very red, and daylight, normal. But our eye / brain compensates, and all of these scenes look perfectly normal and natural. Recorded on film, these scenes will have the colour bias of the light source, which, if considered objectively, we would have to say is correct. But viewed in a photograph, which is subjective, we would consider the lighting in such scenes as wrong.

To quote from Oliver Sacks, clinical neurologist, in his book An Anthropologist on Mars, these illusions "demonstrated a neurological truth - that colours are not 'out there in the world', nor (as classical theory held) an automatic correlate of wavelength, but rather, are constructed by the brain."

Astrophotography



But what about the question of colours in astronomical objects?

Experienced amateur astronomers realize that very few objects will show any colour at all visually, even in the largest telescopes. This is because most objects are just not bright enough to stimulate the eye's cone cells in the center of the retina in the fovea centralis. The cones are the light sensitive cells we use in the daytime when there is plenty of light and they give us our sharp direct vision, and they also see colours.

The eye also has other cells called rods that are more sensitive to very faint light. They are located around the periphery of the fovea centralis and are very sensitive to motion, but they cannot detect any colour . They are the cells amateur astronomers use during the trick of "averted vision", that is, when faint objects are intentionally looked at indirectly, slightly off-axis. Much fainter objects can be seen this way, especially if the scope is jiggled slightly during the observation.

Colour can be seen in some bright astronomical objects, such as stars, and bright planetary nebulae. However, very few gaseous emission nebulae or reflection nebulae will show any colour at all visually because the are so faint. One of the few that does is M42, the Orion Nebula. Because it is so bright, greens and some pink/red/magenta can be seen in large telescopes by experienced observers.

Yellow - green is seen first because if an object is bright enough to stimulate the eye's cones, this is the wavelength that the cones are most sensitive to. When we see green colour in an object such as the Trapezium area of M42, it is primarily due to O III emissions at 500.7 nanometers exciting our eye's cones at the lower end of their colour sensitivity. Any red seen in such nebulae is coming from the Hydrogen-alpha emission line at 656.3 nanometers, which lies at the other extreme end of the cones sensitivity. But these lines must be very strong to be bright enough to excite the eye's cone cells.

The problem with faint nebulae is that they never get bright enough to stimulate the eye's cones, so they must be viewed with the rods, and the rods cannot see colour at all. So if your definition of "correct" colour is the colour that the eye sees, then only black and white photos would be accurate based on this limited interpretation.

Colour in Astronomical Images

However, just because we cannot see the colour does not mean it cannot be recorded by other means such as photography.

Long exposure photographs can reveal colour in objects that is too faint to be seen visually. Continuum sources such as stars and galaxies can be recorded accurately. But, even with objects we think we know exactly what colour they should be, such as sun-like stars, the colour can be changed by intervening dust and nebulosity.

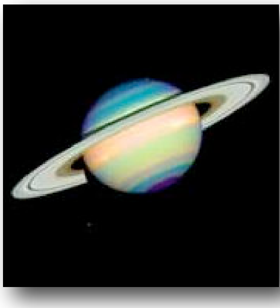
To briefly summarize, there are many difficulties, some possibly insurmountable with present-day film and filter technology, in perfectly and accurately recording colours in objects such as emission nebulae.

However, it is possible to record colour fairly accurately in other deep-sky astronomical objects. For instance, tri-colour photography on both Kodak Technical Pan film, and CCDs, if carefully calibrated, can accurately record colour . But even these techniques have problems with things such as uneven spectral response in Tech Pan, and low transmission at critical spectral wavelengths in filters.

Recording accurate colours is much more problematic with colour film emulsions due to problems such as the differential effects of reciprocity failure in the film's different colour recording layers, and gaps or relative insensitivity of these layers to prominent spectral lines in the objects photographed.

Also, colour from pure spectral lines can change when their light is mixed with light from other spectral emission lines in the same object or changed by absorption by dust along the line of sight between the object and observer.

Deliberate False Colour and Natural Colour



Sometimes colour is added to images to enhance certain features and making it look “natural” is not the main aim. For example, the image of Saturn opposite is made up of three colours (red, green and blue) but each image was in fact taken through a different infra-red filter, and the light used to produce t he image is in fact invisible to human eyes.

In other cases colour images are produced that represent different shades of a colour. In the image of the Cat’s Eye Nebula on the left, there are again three colours, red, green and blue. However, this time each of those colours represents a different shade of just one colour, red in this case. The different shades of red correspond to emissions from different atoms. In this case, light from hydrogen atoms is red, oxygen atoms is blue and nitrogen atoms are green.

The image of Mars to the right was produced to show a more natural colouring. Again, the colours red, green and blue are used, but this time they really were used to represent light from filters that are red, green and blue. This is probably the closest that you can get to natural colour.

So in conclusion, you have to know what you are looking at when you see astronomical images in books, magazines and on TV or the Internet because what you are looking at may not be what it at first seems. It could be that the image is trying to present a natural colour, or it could be that some enhanced or false colour is being used to highlight certain features. This all makes the world of astroimaging quite complex, but also opens up lots of opportunities for us to experiment with our own images.

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We are grateful to Jerry Lodriguss for allowing us to reproduce some of the text from his website. You can visit Jerry’s website at http://www.astropix.com/HTML/I_ASTROP/TOC_AP.HTM