Observing the Planets with Color Filters

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INTRODUCTION

A set of photo-visual color filters is an important observing aid that every planetary astronomer should have. Color filters help overcome image deterioration caused by atmospheric scattering of light, permits separation of light from different levels in a planetary atmosphere, increases hue contrast between areas of differing color, and reduces irradiation within the observer's eye. All of these factors increase the sharpness of details in the atmospheres that are seen on the planets Venus, Mars, Jupiter, Saturn, Uranus and Neptune, and on the surface of the Moon and Mars.

Planetary observers work endlessly to improve the definition of telescopic images of the Moon and planets. While using filters will not eliminate optical defects in the telescope, they will help improve image definition even in a bad system.

IMAGE definition in a telescope is dependent upon resolving power, contrast, and sharpness. ***Resolving power*** is primarily a function of aperture; however, optical quality, collimation, tube currents, etc., can have great effects. ***IMAGE sharpness*** is a factor of "astronomical seeing," atmospheric scattering, irradiation in the eye, and the condition of observer's eye. ***Contrast*** is the difference in brightness between areas of an image. Each of these factors can be improved upon by the use of color filters at the telescope.

The Moon and some planets are brighter than deep sky objects and surface details are often lost in the glare. Filters cut down the intensity of the brighter planets and increase the contrast of the features in the process. For example, the Moon is very bright, so, a neutral density filter used in conjunction with a green filter or "Moon" filter will cut down the tremendous glare and greatly increase contrast in Lunar surface details.

In addition to image contrast, ***color contrast*** is important to the planetary observer. Differences in color hues between features on a planet can lead to strange perceptions and confusion about true nature of the planet in study. This is primarily a function of the human eye; however, some optical systems with chromatic aberrations shift certain colors too. To help explain this we must look at some of the properties of the human eye and how we perceive colors. *Color Contrast* is affected by sharpness of boundaries and by differences in color and shade.

SOME EFFECT OF COLORS IN THE HUMAN EYE

The human eye contains two light sensing elements or nerve ends: *cones and rods*. Rods respond to different intensities of light and not to color stimuli. Three types of color sensations are produced by a composite response of red, green, and blue color-sensitive cones. The smaller cones are 0.0015 mm in diameter and are called fovea. In order to stimulate two cone nerve ends the subtended diameter of the light beam has to be larger than 12.4 seconds of arc. The eye is sensitive to wavelengths ranging from deep violet 390 nanometers (nm) to 710nm (deep red). Maximum sensitivity is around 550nm at normal illumination. With decreasing light levels this sensitivity shifts toward the blue. Cones do not function at light levels below 0.03-candle power per square meter (cd/m²):

Scotcptic (night) vision and **photoptic** vision (below 0.03 cd/m²) are subject to ***Purkinje effect***, which causes objects to appear bluer to us in very low light conditions.

In some lighting conditions yellow-green or reddish-orange objects appear more yellow than they really are. The size, or angular extent, of the object may even effect our color perception, i.e., very small reddish features on Mars may appear gray or blue-green. Brightness ranges from 0.5 to 50 cd/m², above the Purkinje effect, referred to as the ***Bezold-Brucke phenomenon***. This renders red, yellow, green, and blue light to remain the same hue, with decreasing intensities the yellow- greens colors begin to look more yellow and violet and blue-green appear bluer. At high surface brightness colors tend to lose saturation. While increasing the angular extent of an object colors begin to increase in saturation, especially with violet, blue, and green.

While increasing the angular extent of an object colors begin to increase saturation, especially with violet, blue, and green. ***Tritanomalous vision*** is when violet and yellow-green colors begin to appear gray and other colors look more reddish- orange or blue-green [***Dobbins et al***, 1987].

If we consider the color of Mars is predominately RED, with a mix of features displaying dark gray-orange and brown hues, it becomes interesting when attempting to describe Martian dust clouds as "yellow." When we observe bright Mars against the dark nighttime sky, the planet's color hues are often perceived as complementary to the dark background sky. This effect is known as "***simultaneous contrast***" [***Hartmann***, 1989].

After-images are seen as a ghost image in your eye after staring at some object for a long time. The after image takes on the complimentary color from the object, that is, it will appear as a ghost image but is of the opposite color of the image you stare at.

IMAGE CONTRAST

Contrast, as measured by our eye, is the difference in brightness or intensity between various parts of the telescopic image, i.e., a star against the background sky. In planetary work contrast efficiency of our telescopes is very important because a planet's surface or atmosphere is composed of various materials that reflect different levels of Sunlight. IMAGE contrast can effect our color perceptions, especially while observing the planets using larger aperture telescopes.

If we scatter stray light throughout the image it makes the dark areas of the object brighter and the bright areas darker, so, we loose contrast. Mars might display very fine surface details during perfect seeing in a telescope with 12% secondary obstruction and barely any detail in one with 35% obstruction, even though the limbs (edges) of the planet are sharp and well defined in both scopes. A quality refractor is an example of a high contrast instrument, but suffers from other problems, such as chromatic aberration, not found in reflecting telescopes. We will try to design our Newtonian to deliver near refractor like contrast without the color problems.

This also applies to extended deep sky objects such as galaxies or nebula. These images are made up of varying intensities from bright wisps with dark lanes to dim fuzzy globs. Contrast is calculated by a simple formula:

$$c = (b2 - b1) / b2$$

where **b1** and **b2** are the brightness of each of two areas of the object and **c** is the contrast. If we measure brightness in candle power/meter squared (cd/m²) the Earth's daylight sky brightness is about 8000 cd/m².

For example, Jupiter has a surface brightness of around 600 cd/m² for light areas. If we compare a dark belt of 300 cd/m², then the contrast between these areas would be:

$$c = (600 - 300)/600 = 0.5 \text{ or } 50\%$$

If we scatter light from the bright area, say 50 cd/m² and add it to the dark belt then the contrast between the two becomes:

$$c = (550 - 350)/550 \text{ or } 0.36 \text{ or } 36\%$$

A relatively small amount of scatter may cause a significant decrease in image contrast.

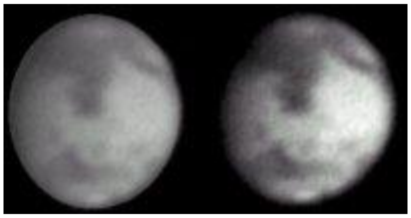

Figure 1. Two images of Mars taken with same CCD camera but with different contrast levels. The image on the left was taken without a red filter and right image with red filter. Contrast difference is readily apparent. Images by D.C. Parker.

THE ATMOSPHERIC AND PHYSICAL EFFECTS

Several atmospheric conditions and physical effects are modified by the use of color filters at the telescope:

Scattering interposes a luminous veil between the observer and his/her subject. Scientists have shown that for particles in a planet's atmosphere of a given size, the scattering is inversely proportional to the fourth power of the wavelength of the light. Hence, violet light of 400 nm is scattered about 16 times more than deep red light of 800 nm; Earth's daytime sky is blue as a result of this property. The Martian atmosphere scatters light in the same manner and thus allows us to observe Martian aerosols at the different relative atmospheric depths.

<u>Prismatic dispersion</u> by our atmosphere is most evident when a star or planet is seen near the horizon. It results from refraction being less for the longer wavelengths where the red appears nearer the horizon and violet toward the zenith.

<u>Color Contrast</u> is controlled to some extent by filters. Light yellow and orange filters are useful in judging the colors of the low-hue cloud belts and zones of Jupiter and Saturn. To bring out a white area on a reddish background, a green filter is useful.

<u>Atmospheric penetration</u>. To explore an atmosphere similar to Earth's to various depths, molecular scattering can be exploited. Since the shorter wave lengths are scattered more, it follows that ultra violet light scarcely penetrates an atmosphere at all, violet light penetrates to some depth, blue still deeper, while blue-green may reach the solid surface.

<u>Irradiation</u> occurs between adjoining areas of unequal brightness. The amount the bright area appears to encroach upon the fainter one is approximately proportional to their intensity difference. This is evidently a physiological effect, originating within the eye itself. A deep red or orange filter reduces this effect while observing.

EFFECTS OF FILTERS ON THE MOON AND PLANETS

In general, "astronomical seeing" is improved by using filters. Red filters improve seeing the greatest and is followed by orange, then yellow, and so on. Each color filter will pass their characteristic color of light and block their complimentary colors. Red objects will appear very dark in a blue or green filter and bright in a red filter. Green features will be bright in green light, dark in blue or red light. Blue is bright in blue light and dark in red or green and yellow. Many A.L.P.O. members recommend Eastman Kodak Wratten Color Filter for observing the planets. Listed below are the filter reactions on the planets:

Mercury: Usually observed from twilight to nearly full daylight. Filters help reduce light scattering, improves seeing and contrast of surface features. This planet usually appears very bright pinkish with light gray markings. Very difficult to observe. Use<u>red (W25, W29)</u>, <u>orange (W21, W23A)</u>, <u>yellow (W15)</u> and <u>green (W57).</u>

Venus: Devoid of markings this planet requires color filters to increase image contrast. A <u>deep blue filter (W46, W47)</u> is useful to reveal the very low contrast shadings in its atmosphere. Since Venus is extremely bright a filter is necessary to cut down on its intensity and reduce irradiation in the observers eye. Venus is often observed in the daytime a red filter is used to darken the blue background sky and increase contrast as well.

The Moon: A <u>green filter (W57)</u> used in conjunction with a neutral density filter is a great way to increase lunar surface features and reduce its excessive glare. Special Moon filters are also available and are usually very dense and green in color.

Mars: Observed both at night and in twilight hours. Difficult to observe due to bright surface. Mars is similar to Earth because the surface and its atmosphere can been seen.

Yellow (W12, W15) to brighten desert regions, darkens bluish and brownish features.

Orange (W21, W23A) further increases contrast between light and dark features, penetrates hazes and most clouds, and limited detection of dust clouds.

Red (W25, W29) gives maximum contrast of surface features, enhances fine surface details, dust clouds boundaries, and polar cap boundaries.

Green (W57) darkens red and blue features, enhances frost patches, surface fogs, and polar projections.

Blue-Green (W64) helps detect ice-fogs and polar hazes.

Blue (W80A, W38, W38A) and deep blue (W46, W47) shows atmospheric clouds, discrete white clouds, and limb hazes, equatorial cloud bands, polar cloud hoods, and darkens reddish features.

Magenta (W30, W32) will enhance red and blue features and darkens green ones. Improves polar region features and some Martian clouds.

Jupiter: This bright gaseous planet is a very interesting object to study in different colors of light. Using a light blue filter (W38A), W80A) enhances the contrast within the bright zones on this planet and sharpens boundaries of faint cloud currents. Since Jupiter's belts are brown both the green (W57) and blue (W47) filters will darken them. A yellow (W12, W15) filter will darken the blue festoons that appear near the North Equatorial Belts south edge and equatorial zone. A magenta (W30) filter is great to brighten and enhance those white ovals seen in the South Temperate Belts and Zone.

Saturn: A most interesting planet to observe. It has bright and dark cloud bands similar to Jupiter, but, are less distinct than the larger planet. The brighter zones appear off-white and slate-gray or yellowish at times. On the other hand, Saturn's belts exhibit bluish-gray, brown and reddish colors easily seen using the same filters as for Jupiter. Brighter patches sometimes appear on this ringed planet and are best seen on green or blue-green light. The rings are highlighted using a light green (W57) filter and at times a magenta filter (W30).

Uranus and ***Neptune***: Yellow-green (W12), green (W57), and magenta (W30) filters are recommended on these bluish and greenish planets. Because both planets are much dimmer than the others in the telescope it suggests the Purkinje, Bezold-Brucke, Tritanomalous vision effects may be at work here. Observing these planets is difficult and their blue-greenish color begins to change to a bright blue using moderate to large aperture telescope (12- to 24-inches).

COLORS OF MARS

What color is Mars through a telescope? This question has been asked by astronomers for at least three centuries and is a subject of debate even today. Observers even report certain dark features on Mars grow darker and even change color during seasonal transitions. This has led to some startling conclusions, some of which has brought the wrath of the scientific community down on a few very prominent astronomers.

Confusion over the colors of Mars is nothing new. Reports of green or even blue features on Mars are common from ground-based observers. In the early 20th century, some astronomers saw the apparent greening of Martian maria, during spring and early summer, as proof that vegetation it was the cause. We have since found that the human eye is subject to a variety of illusionary perceptions, one being the inability for us to correctly identify colors in low light conditions. We may have a good idea of what the average human response to a particular color might be on Mars; however, observers often describe the planet's colors completely different even while using the same telescope.

A layer of volcanic ash and rock covers the surface of Mars, at least in the smooth areas where the United States landed two spacecraft during the 1970's. Using the robotics arms on each of the two Viking Landers the nearby surface was sampled and the results suggested a surface of ash-like material was saturated by water vapor. When similar materials on Earth are saturated to water vapor it tends to darken and/or change color hues. Also, during the colder Martian seasons its surface has been observed covered with frost or snow like condensates that tend to brighten some areas and make adjacent dark areas appear darker that they really are.

Hoar frost in Earth's surface tends to clump ash-like and sandy materials into mounds or irregular piles, which will appear darker, especially when accompanied with long shadows. However, when viewed from certain incident angles, these same piles may appear brighter.

Using the proper color filters one can determine colors of Martian features, usually red; however, we have found that certain atmospheric clouds display blue-to-blue white color at times [***Beish et al,*** 1988]. Even without filters there are a few clouds that appear bluish, such as the "Capen Blue Syrtis Cloud." This cloud shows up often during Martian northern spring (southern autumn) and will appear blue-white visually. In photographs taken with color film and tri-color CCD images this cloud is a vivid blue. To prove this the observer can use a yellow filter on Mars to see this particular blue cloud turn greenish in the filtered image. It is usually brighter in blue color, that is while observing Mars with a blue filter, and darker in red light.

Dust clouds often appear bright yellow in the telescope without observing with filters. They are usually brightest in red light, but can be also bright in yellow light. Dust clouds will be blurry or hazy in yellow light. A blue filter will not brighten the dust cloud and often will make the dust cloud appear to vanish. However, we have found that white-yellowish clouds can accompany dust clouds so the observer should watch for these phenomena. Look for a dusty polar cap following any dust clouds they show up in red and green light.

Since Mars is red in color it will be brightest in red or orange filters. While observing Mars using a deep blue or violet filter the surface features will most often disappear and only a dull bluish haze will been seen. Occasionally surface features will appear dark in deep blue light, a phenomenon not well understood.

NEAT FILTER HOLDER

An excellent method to use color filters while observing at the telescope it to hold them between the eye and the eyepiece. You can use the glass screw-in types that fit into the eyepiece barrel or tape several different colored gelatin sheets into a slide holder or frame. It is best to select a film slide frame with plastic windows and use transparent tape to attach the ends to the inside frame and hand held between the eye and the eyepiece. (See Figure 2).

A.L.P.O. observers usually obtain slide frames or holders with a clear plastic window and avoid those holders with the so-called "anti-Newton Ring" glass windows.

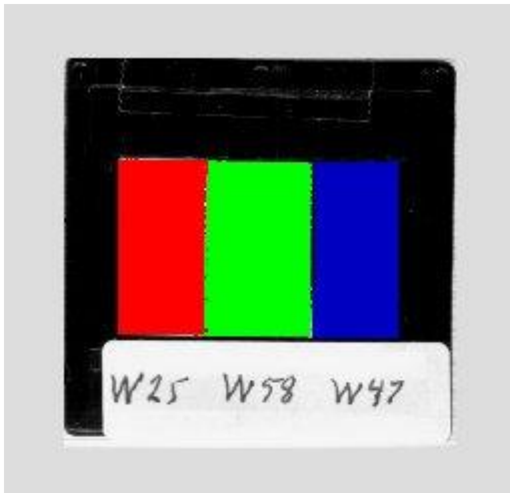

Figure 2. Slide frame with plastic windows with four 1/4-inch colored gelatin filter sheets taped inside. Use until they deteriorate and replace filter strips. Also, clear plastic window can be cleaned. A Don Parker invention.

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