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THE RED COLOR OF MARS FROM OPTICAL SPECTRA

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ABSTRACT

Colors have been derived from the observed optical spectrum of Mars and Jupiter. It is known that the planets and the Moon emit reflected sunlight and thus their spectra are similar to the spectrum of solar radiation. The question was then why is the color of Mars different from that of other planets, i.e. red, although it would share the same spectrum of reflected sunlight. Can one derive color from the spectrum? Therefore, we observed the optical spectra of the scattered sunlight in day time for the Moon and Mars using a 1-D array spectrograph on the 12-inch reflecting telescope in the Korea Science Academy of KAIST in Busan, Korea. We adopted the International Commission on Illumination (CIE) in 1931 of three spectral sensitivity peaks for the human eye in short, medium and long wavelengths in visible light. The observed spectra were imposed on CIE sensitivities and the color detected by the human eye was derived. The Mars spectrum represents red color and the Moon white. It is a similar color to that which a human would see. This result means that color is easily derived from astronomical spectra. The appearance of the planets surface can be determined for Mars, which is the result of iron oxide.

Key words: Spectroscopy; Bolometric Color; Mars; CIE

1. INTRODUCTION

Planets reflect sunlight and their spectra would therefore be similar to the solar spectrum. Mars in the night sky shows a red color due to iron oxide on its surface. The question has been raised whether one can derive the bolometric color from spectra. A newly applied spectroscopic device can make this examination possible because of its ability to detect continuous emission over a wide range of visible wavelengths (Song, 2015).

The International Commission on Illumination (CIE) in 1931 has been used for bolometric color estimation (Guild, 1932). It provides the spectral sensitivity of the human eye as a function of visible wavelength. The human eye has three kinds of cone cells and it provides three functions. The CIE standard observer color matching functions are shown in Fig 1.

The spectra of the Sun, Moon, Jupiter and Mars were obtained because they are brightest objects in the sky. Their bolometric colors are derived. The Mars spectrum shows a red color and the Jupiter olive. This means that color can be derived from astronomical spectra.

2. DATA

The Spectroscopic device, SV2100R, has been used to obtain spectra of the Sun, Moon, Jupiter and Mars. Scattered solar radiation was obtained as is without any telescopic facilities. The spectrum of the Moon was detected using a 5-inch refractor and one of planets acquired using a 12-inch reflecting telescope in an astronomical observatory. The exposure times for the planets are 1000 msec and dark current has been subtracted.

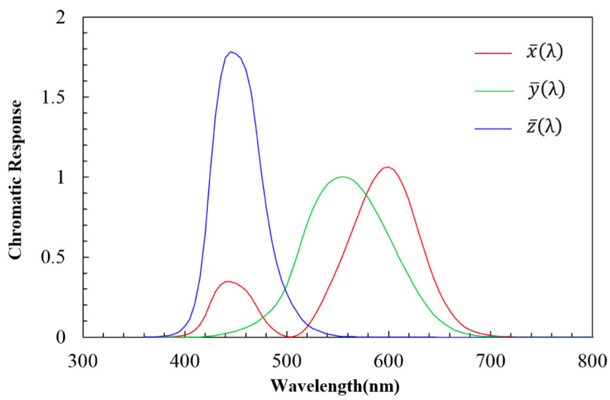

Figure 1. The CIE standard observer color matching functions (Guild, 1932)

3. BOLOMETRIC COLOR

Color matching functions of R, G and B components ($\bar{x}(\lambda)$, $\bar{y}(\lambda)$ and $\bar{z}(\lambda)$ in Fig. 1) have been applied to derive bolometric colors from the observed astronomical spectra. This method is described in Harris and Weatherall (1990). When electromagnetic radiation comes into human eye, the chromatic response can be

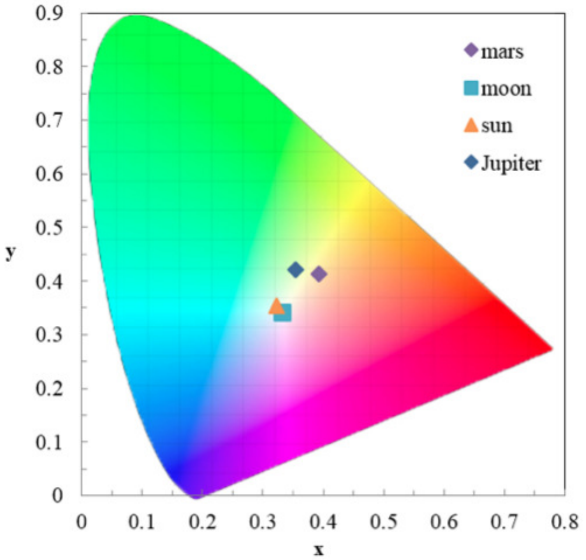

Figure 2. Obtained bolometric colors of Sun, Moon, Mars and Jupiter are shown in CIE 1931 color space chromaticity diagram (Smith and Pokorny, 1975).

represented by multipying by the color matching function. The spectral sensitivity functions of three light detectors yielding the X, Y and Z value are shown and they are called the CIE tristimulus values.

$$X = \int_0^\infty I(\lambda)\bar{x}(\lambda)d\lambda \quad (1)$$

$$Y = \int_0^\infty I(\lambda)\bar{y}(\lambda)d\lambda \quad (2)$$

$$Z = \int_0^\infty I(\lambda)\bar{z}(\lambda)d\lambda \quad (3)$$

$I(\lambda)$ is the spectral power distribution as a function of wavelength. In this work, the observed spectra have been summed over $I(\lambda)$. These X,Y and Z values indicate the sum of teh chromatic response over whole spectrum that our brain can perceive.

The CIE color space (Fig. 2) describes the chromaticity of a color specified by the two derived parameters x and y. They are normalized values from the three normalised values.

$$x = \frac{X}{X+Y+Z} \quad (4)$$

$$y = \frac{Y}{X+Y+Z} \quad (5)$$

$$z = \frac{Z}{X+Y+Z} = 1-(x+y) \quad (6)$$

4. RESULTS

Derived bolometric color from each spectrum of stellar objects are shown in Fig. 2. Colors of the Sun and Moon are similar to a white-ish color. The intensity

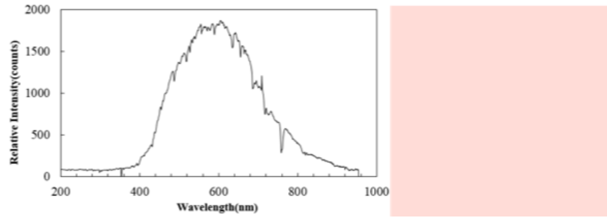

Figure 3. Mars spectrum and its color in CIE frame: red-ish color

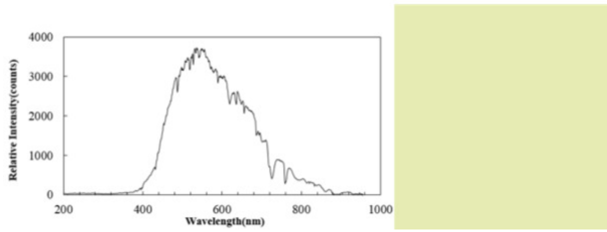

Figure 4. Jupiter spectrum and its color in CIE frame: olive-ish color

Table 1
CALCULATED X, Y, Z VALUES IN CIE COLOR SPACE

Objects	x	y	z
Sun	0.323	0.354	0.323
Moon	0.332	0.343	0.325
Mars	0.392	0.414	0.194
Jupiter	0.355	0.422	0.223

integrations are done between 360nm and 830nm. The colors of Mars and Jupiter are distinct from the solar one. It is assumed that the surface of planets absorbs specific wavelength ranges and it appears in different colors as a result. The value of x,y, z are shown in Table 1

In Fig. 3 and 4, the observed spectra are shown of Mars and Jupiter respectively. Colors derived in CIE space are shown as well.

5. SUMMARY

Low resolution spectroscopy can be detected in a wide range of wavelengths and it allows us to derive bolometric over in CIE space. In the future, the intensity calibration of observed spectra will be required in order to obtain more reliable results. Also the air-mass will affect bolometric color and it should be considered in the future.

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