Imaging and spectroscopic observations of the 9 March 2016 Total Solar Eclipse in Palangkaraya

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Abstract. The March 9th 2016 total solar eclipse observation was carried out at Universitas Palangkaraya, Central Kalimantan. Time-resolved imaging of the Sun has been conducted before, after, and during totality of eclipse while optical spectroscopic observation has been carried out only at the totality. The imaging observation in white light was done to take high resolution images of solar corona. The images were taken with a DSLR camera that is attached to a refractor telescope (d=66 mm, f/5.9). Despite cloudy weather during the eclipse moments, we managed to obtain the images with lower signal-to-noise ratio, including identifiable diamond ring, prominence and coronal structure. The images were processed using standard reduction procedure to increase the signal-to-noise ratio and to enhance the corona. Then, the coronal structure is determined and compared with ultraviolet data from SOHO to analyze the correlation between visual and ultraviolet corona. The spectroscopic observation was conducted using a slit-less spectrograph and a DSLR camera to obtain solar flash spectra. The flash spectra taken during the eclipse show emissions of H 4861 Å, He I 5876 Å, and H 6563 Å. The Fe XIV 5303 Å and Fe X 6374 Å lines are hardly detected due to low signal-to-noise ratio. Spectral reduction and analysis are conducted to derive the emission lines intensity relative to continuum intensity. We use the measured parameters to determine the temperature of solar chromosphere.

1. Introduction
We conducted imaging and spectroscopic observation before, after and during totality. We intended to observe the coronal structure up to two solar radii that is not observed by Solar Heliospheric Observatory (SOHO). Using visual image combined with other wavelength such as extreme ultraviolet (EUV) and X-ray, we can determine more detailed coronal structure.

The spectroscopic observation can be used to determine the coronal electron temperature. E-corona in visual wavelength contains Fe XIV line (5303 Å - ionization potential 355 eV) and Fe X line (6374 Å - ionization potential 235 eV), where intensity ratio of Fe XIV and Fe X is sensitive to temperature of solar corona.

The observation was conducted at Universitas Palangkaraya in Palangkaraya, Central Kalimantan. The weather was rainy at the early morning and thick cloud covered the Sun at the time of totality. However, we managed to get some images of the corona and the flash spectrum with low signal-to-noise ratio.
Our goal is to determine the temperature of the solar chromosphere and to complete the ultraviolet data with our visual result to get the correlation between solar corona and the solar activity. However, due to poor quality of images which are contaminated with high noise from the clouds, we only focus on the spectroscopic analysis in determining the temperature of the solar chromosphere.

2. Method
On March 9th 2016, we observed Total Solar Eclipse in Palangkaraya (2°12′36″ S, 113°55′12″ E). Total Solar Eclipse in that location was occurred at 00:28:56 until 00:31:26 (UT) or lasted 2 minutes and 30 seconds (http://xjubier.free.fr/en/site_pages/SolarEclipseCalc_Diagram.html). In imaging observation we used instrument configuration: (1) William-Optics telescope with diameter 66 mm, f/5.9, (2) Neutral Density 5 filter, (3) DSLR Canon EOS 500D. On the other hand, we used instrument configuration: (1) Star analyzer SA-100 (100 grooves/mm, R~100) transmission grating, (2) DSLR Canon EOS 1100D in spectroscopy observation. Those observations used EOS Utility 2 as remote camera.

Imaging observation was conducted by taking a number of images of the Sun from the first contact until the fourth contact. At the time of the second contact to the third contact we conducted video recording observation in order to obtain the dynamics of the corona and get the image more than the usual image acquisition. Spectroscopic observation was conducted by taking a number of images of the Sun on a few seconds before the second contact and few seconds after the third contact so we got flash spectrum and Corona spectrum as the result.

3. Result

3.1. The corona image
Instead of 2 minutes and 30 seconds of totality, we just recorded the totality in 30 seconds before 3rd contact with video mode. After that, we stacked the video in a picture and enhanced it. The image result is shown in figure 1.

![Corona Image](image1.png)

Figure 1. Left: image of original stacked and enhanced 30 s totality video. Right: inverted image.

3.2. The flash spectrum
The data were taken during third contact phase of total solar eclipse. Due to cloudy weather, we only managed to obtain the spectrum with low signal-to-noise ratio. Figure 2 shows the flash spectrum shows strong emission lines from Hβ (4861 Å), He I (5876 Å), and Hα (6563 Å). These lines are emitted from solar chromosphere with large height range. The Fe XIV (5303 Å) and Fe X (6374 Å) lines, which are produced by solar corona, are hardly detected due to low signal-to-noise ratio.
The local continuum underneath each line was fitted by interpolating the continuum windows around the line to measure $I_c$. We fitted each line using a single Gaussian function to measure $I_\lambda$. We measured the relative intensity of each emission line using the equation $I = (I_\lambda - I_c)/I_c$ where $I_\lambda$ is the integrated intensity underneath the line profiles and $I_c$ is the corresponding continuum intensity of the continuum background. We detected 3-4 emission lines only in 3 images. The relative intensities of the observed lines are tabulated in Table 1.

### Table 1. Relative intensity of the observed lines in the flash spectrum.

| Line | Relative Intensity | Error | Time (local) |
|------|-------------------|-------|--------------|
| Hβ   | 4.73              | 0.03  | 7:31:20      |
| He I | 10.26             | 0.12  |              |
| Hα   | 17.05             | 0.17  |              |
| Fe X | 2.90              | 0.11  |              |
| Hβ   | 1.17              | 0.01  | 7:31:21      |
| He I | 1.65              | 0.03  |              |
| Hα   | 11.47             | 0.06  |              |
| Hβ   | 0.09              | 0.01  | 7:31:22      |
| He I | 0.52              | 0.02  |              |
| Hα   | 9.06              | 0.05  |              |

### 4. Analysis

#### 4.1. Imaging

The coronal structure in our image cannot be seen clearly because the solar disk was covered by clouds. Two images in Extreme Ultraviolet (EUV) 193 Å and 304 Å that were taken from SDO AIA are shown in Figure 3. Image of 193 Å represents the lower solar corona and the image of 304 Å represents the solar chromosphere. We detected a prominence in 193 Å and 304 Å. However, coronal structure in 193 Å and chromosphere activities in 304 Å could not be detected in our visual image. So, our visual observation cannot be combined with these two EUV images and the correlation that shows solar activity cannot be determined.
Figure 3. Left: Image in Extreme Ultraviolet (EUV) 193 Å from SDO AIA. Center: Image in Extreme Ultraviolet (EUV) 304 Å from SDO AIA. Right: Combined observed image with EUV images cannot be used to find a correlation of solar activity.

4.2. Spectroscopy
We only observed Fe X in our spectrum, while Fe XIV is not detected due to low signal-to-noise ratio. Therefore, we cannot determine the ratio of Fe XIV and Fe X to determine the temperature of the corona by using [1]. However, the detected Fe X still gives us information that the minimum temperature of the corona is $1.2 \times 10^6$ K because minimum temperature that is needed to produce Fe X is above that value[2].

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