Prominence measurement of total solar eclipse: March 9th 2016, Ternate, Indonesia

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Abstract. Prominence is a hot gas that consists of electrically charged particles, which is propelled outward Solar surface. It can happen when the activity of sunspot rising up. Ground-based observation of prominence is rather difficult due to the brightness of the Sun, which it needs appropriate method. During total solar eclipse (TSE), prominence is easier to observe. In Ternate, Maluku islands (0°46'32.0"N 127°23'05.7"E), we observed solar prominence in visual and infrared spectra performed by using regular-DSLR camera for visual wavelength and modified-DSLR (IR-cut filter removal) for infrared wavelength, respectively. Next, we calculated the length of prominence from TSE images, and found that the real minimum length of prominence in red is 1.05 times longer than green and blue ones. And, the real maximum length of prominence is 1.08 times longer than blue and 1.04 times longer than green. The intensity of red is brighter 1.37 times to green and 1.23 times to blue. The causes of the results due to the different temperatures of the prominences and the radiation from H-alpha emission. We succeeded to observe directly the prominence with simple cameras and measured its length and brightness.

1. Introduction

One of the most exotic features that we can observe during Total Solar Eclipse (TSE) is solar prominence. Solar prominence is a most common part of the solar atmosphere, which can be seen in large region of corona. The term of prominence is refer to long-lived cool and dense plasma curtain in the hot and rarefied outer solar atmosphere [1]. Prominence has one hundred times temperature lower but denser than that of corona. It means that it is thermally isolated from their surrounding regions [2]. Generally, there are two ways to classify prominence: based on its location in solar surface and based on its dynamics [3]. Classification by the location is divided into two types: quiescent and plage (active region) prominences. Whereas, classification by dynamics are filament and active prominences. Solar prominence activity could be seen when TSE is happened. Fortunately, we could detected two major parts of prominence from images of TSE which occurred in March 9th 2016. Main path of the TSE is through 12 cities in Indonesia and the longest duration of TSE is about 3m 7s. We observed The TSE in Ternate, Indonesia. Ternate was one of the best place where we could observed the TSE clearly and the period of the TSE was about 2m 45s. Prominence can be observed in wide wavelength range, but its image clarity depends on microparticle temperature and surrounding atmospheric regions. Visual limb-prominence can be observed even by amateur astronomers using a coronagraph, or at total solar eclipse. Whereas, filaments are rather different where they will be easily found and observed through a Hα filter.
at regular time (not only TSE). In H-alpha band, we can easily distinguish prominence from whole solar disk. In fact, Hα filter blocks all wavelength from the Sun except the wavelength, which is emitted by the excited hydrogen atom at particular energy on 6563 Å wavelength. This hydrogen emission is responsible for the special characteristic of color appearance of prominence and chromosphere. The duration of TSE is very short comparing to the existence period of the prominences that is for days to weeks. Thus, in this work, we tried to measure the size and brightness of the prominence from the images captured by simple cameras.

1.1. The characteristic of solar prominence
Prominence is propelled as one effect of magnetic dynamic and thermal activity in solar atmosphere. Prominences are frequently found inside coronal cavities, which are tunnel-like elliptical dark regions [4] at the solar limb, with up to 40% density depletion [5], around the prominences. Regarding to the prominence scale, we consider two selections: large-scale structure and fine-structure prominence. In case of quiescent prominence, large-scale structure is unchanged while the fine-structure is changed rapidly [6]. There are three types of quiescent prominences based on the location of figuration prominence [3]. Those are type A which is associated with active region in solar surface, type B which is related to the region between two active regions, and type C which spans over polar crown neutral line and near an expanding active regions. The dynamics of prominence can be understood as a contribution of magnetic-force resistance to gravitational attraction of interior and solar surface. They typically have a length of \(6 \times 10^4\) m to \(6 \times 10^5\) m, a height spanning from \(1.5 \times 10^4\) m to \(1 \times 10^5\) m above chromosphere and a width ranging from \(5 \times 10^3\) m to \(1 \times 10^4\) m. The temperature range is about 4300-8500 K [7, 8].

2. Method
Prominence was observed by using three DSLR cameras. For obtaining infrared (IR) spectrum, we used modified Canon EOS 550D camera. Modification was made by removing IR-cut filter, which blocked infrared spectrum, from front of camera then the camera could observed the wavelength from visible to infra-red. Furthermore, the filter that was hampered visible light was used to obtain infrared spectra. In order to obtain visible light, we used Canon EOS 5D Mark II and Canon EOS 700 D cameras. In collecting image data using Canon 550 D (IR) and 700 D (visible), the cameras were used in video mode 8-bit standard compression. For Canon 5D mark II, 14-bit raw-video was used. The prominence images were taken by using frames of videos. Moreover, the frames were separated into Red (R), Green (G) and Blue (B) channels for next further analysis: calculating the brightness and dimensions of prominences.

3. Results and discussion
Figure 1 shows results from frames of videos in multiple channel. Figure 1a shows the red channel, it can be seen that the prominence is brighter and longer than in other channels: green (figure 1b) and blue (figure 1c). In red channel, there are some saturation of images, and the two prominences are indistinguishable because of its bright intensity and it is different from green and blue spectra in which two prominences are observed clearly. Images from IR (figure 1d) shows that the prominence and corona are not emitting IR wavelength, only, we observed some radiation in range red to near-infrared from the Sun.

Figure 2 is a plot (intensity profile) of the brightness vs pixel position of prominences, representing intensity profile from photosphere to the near edge of prominence. Only in red channel (figure 2b), there are saturation in pixel 1 and in pixel 4 to pixel 16. Because we just concern in measuring the dimensions of prominences, only pixels in edge of prominences are taken into account, and no saturation in those pixels. Figure 2a shows how to calculate the intensity profile from images to enumerate intensity for each channel in each pixels in order to estimate the real length of prominences.
Figure 1. Images of solar prominence in (a) red (b) green (c) blue (d) infrared spectra.

Figure 2. The intensity profile of prominence (a) in red (b) green (c) and blue (d).
Table 1. Pixel length and its real length of prominence.

| Spectra            | Minimum Length Pixel (px) | Real Minimum Length (km) | Maximum Length Pixel (px) | Real Maximum Length (km) |
|--------------------|---------------------------|--------------------------|---------------------------|--------------------------|
| Red (6200-7500 Å)  | 20                        | 28958.66819              | 26                        | 37646.26897              |
| Green (4950-5700 Å)| 19                        | 27510.73475              | 25                        | 36198.33549              |
| Blue (4500-4950 Å)| 19                        | 27510.73475              | 24                        | 34750.40202              |
| Infrared (> 7200 Å)| 0                         | 0                        | 0                         | 0                        |

The pixel length of prominence is calculated to the pixel where the intensity drops drastically. Due to unclear edge of prominences, the pixel length of prominence is calculated in ranges (minimum length and maximum length). Tabulation of pixel length and its transformation to real length of prominence is showed in table 1. From intensity profile in figure 2 and results in table 1, it is observed clearly that the red wavelength is brighter and longer than that of other wavelength and it confirmed that the main-radiation sources of prominence is H-alpha [9].

4. Conclusion
Based from our observation and calculation (figure 2 and table 1), we found that the intensity in red wavelength is brighter than that of blue and green, 1.37 times to green and 1.23 times to blue. The real minimum length of prominence in red is 1.05 times longer than green and blue ones. And, the real maximum length of prominence is 1.08 times longer than blue and 1.04 times longer than green. These results are due to the different temperatures of the prominences and the radiation from H-alpha emission.

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