Observation Study of Major Solar Flares in AR 10720

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Abstract: In this project, we study the process before, during and after major solar flares in active region AR 10720 using EIT 195Å and Magnetogram spectrum from SOHO data set. Solar flares in AR 10720 showed recurrent or homologous flares, which were X class solar flares X1.2, X2.6, X3.8, X1.3 and X7.1. Images were analyzed and interpreted using ImageJ and Helio Viewer. EIT 195Å images showed that all major flares were preceded by sigmoidal shaped brightening that later transformed into magnetic arcades after the flare maximum. Through magnetogram images, we saw formations of magnetic flux rope (MFR) before and after major solar flares. By comparing both image filters we found the sigmoidal shape and arcade formation were laid above the MFR.

Keywords: The Sun**,** Solar Flares, Sigmoidal Shape, Magnetic Flux Rope

I. INTRODUCTION

Solar flares are very spectacular solar activity that occurs above active region in the due to dissipation at many tangential discontinuities arising spontaneously in the bipolar magnetic fields. Solar flares release very strong energy emission in the broad frequency range from microwave to hard X-ray [1][2]. Solar flares blast gives out very energetic particles into space with energies of several hundred MeV to several GeV into space. Magnetic field loops at active regions can reach maximum heights of up to 15% the solar radius during a flare [3]. Our Earth is protected by its magnetosphere from solar activities, but under extreme conditions like a major solar flare, charged particles can penetrate into the terrestrial environment and cause magnetospheric disturbances leading to geomagnetic storms [4, 5]. Generally, researcher around the world accepted that solar flares and CMEs are the major drivers in space weather and there is a great interest from astrophysical and practical economic point of view to understand this phenomenon.

Many fundamental questions related to the physics of how and why solar flares occur have received much attention and debate. CSHKP model is the most accepted model to explained solar flares because it is able to explain the phases during the solar flares process. CSHKP model was named after the scientists (H. Carmichael, P. Sturrock, T. Hirayama, R.Kopp, and J. Pneuman) who contributed to this model. The model suggests flares are driven by magnetic reconnection in the solar corona [6-9]. Many researchers attempted to test this model, but it is complicated by the fact that we cannot observe the build-up energy and energy release directly.

One of the interesting observations is the sigmoidal (S or reverse S) shape before the flares/pre-flares. Rust in 1996 examined the soft X-ray images of large flares and found that there were many sigmoidal shaped brightening at active regions [10]. He suggested that the magnetic field associated with x-ray emissions were twisted. This led to the idea that flares erupt because of magnetohydrodynamics (MHD) helical kink instabilities. Hence, the active regions with sigmoidal shape possessed higher probabilities for eruption [11, 12].

II. DATA COLLECTION AND ANALYSIS

In this paper, we choose active region AR 10720 to study the changes in morphology of magnetic flux rope (MFR) in magnetogram images and sigmoidal shape in EIT 195 Å images. The time and date of the flares are mentions in figure 1. This AR had a series of major recurrent or homologous flares. Some studies attribute this to a continuous emergence of new magnetic flux lines in the active region[13][14]. AR 10720 displayed of 5 major X-class flares, namely X1.2, X2.6, X3.8, X1.3 and X7.1. Of this solar flare, X7.1 cannot be discussed due to its limb position on the solar surface. All data were obtained from the SOHO website in FITS format (https://sohowww.nascom.nasa.gov/data/archive/). The images were viewed and processed using ImageJ followed by measurements of the MFR, sigmoidal shapes and arcades formations. Figure 1 shows the images in EIT 195Å and magnetogram.

III. DISCUSSION

Base on figure 1, the emergence of sigmoidal shape just prior to major flare events (pre-flares) is clearly seen in all the images. During the impulsive (peak flare) phase, the CCD camera became saturated and bleeding. Later, the magnetic arcade was formed. The intensity of major solar flares is independent of the length of sigmoidal shapes. MFR has seen magnetogram images, during flare burst. However, there is no significant change to the MFR morphology before and after the flares. By comparing both filters, we find the magnetic sigmoidal shapes and arcade formation is laid above MFR locations, indicating magnetic flux rope as the main location for flares. The existence of MFR is approximately 2 hours prior to major flares. This becomes a suitable indicator for an upcoming major flare, hence assisting space weather monitoring and prediction.

All the processes in figure 1 are best explained by the CSHKP model. Solar flares begin when magnetic field lines are stretched or expanded, driven by current sheets produced by moving layers of plasma. Magnetic field lines become twisted. Magnetic reconnection occurs when the magnetic fields lines are diffuse through the current sheet. Top of magnetic loops is sharply cusped. It is then retracted downward due to cooling process and forms a potential-field arcade [8, 9]. At the reconnection site, the plasma is heated by the annihilation of the magnetic field and arcade formation. The energy release from reconnection causes the plasma to heat, creating a bulk kinetic energy release and wave generation. The question of how the energy is stored and partitioned between the processes is still unclear [15, 16].

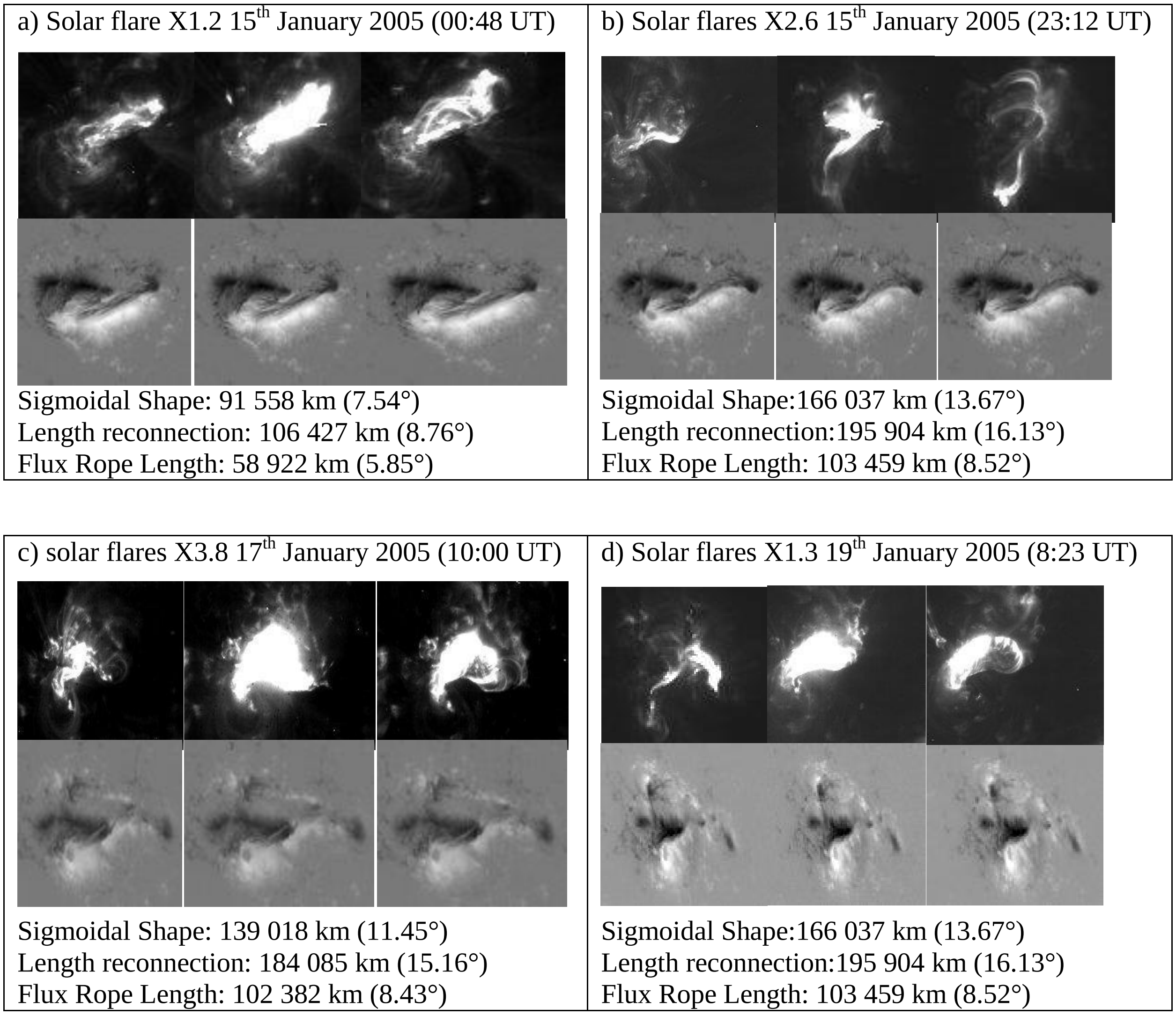

FIGURE 1: Images from SOHO EIT 195Å and Magnetogram filter. Box (a) Solar flares X1.2, (b) solar flare X2.6, (c) solar flare X3.8, (d) solar flare X1.3. The top rows are images from EIT 195Å while the bottom rows are magnetogram images. The images are ordered according to pre-flares, impulsive flares and arcade formation (post flares) phases.

An early sign of sigmoidal shape is due to the twisted magnetic field. It is, therefore, the main suspect for solar flares and CMEs generation. It may appear as S-shape or reverse S in soft X-ray and in EUV images [12, 17]. By referring figure 1, sigmoidal shape loop structure developed prior to the flares and re-formed into arcade structure after the flares [18, 19]. Generally, the sigmoidal shape is dependent on active region size. Sigmoidal appearance in a large active region often signals an upcoming eruption. For the largest active regions of more than 200 millionth hemisphere, we will get an eruption, sigmoidal or non-sigmoidal [12].

IV. CONCLUSION

This research concludes major solar flares are associated with the prior emergence of sigmoidal shape within a fairly large active region as seen in EIT 195Å. Magnetogram images indicated that MFR instability as responsible for X-class solar flares.

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