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ScienceDirect
Advances in Space Research 45 (2010) 537–540
ADVANCES IN SPACE RESEARCH (a COSPAR publication)
www.elsevier.com/locate/asr

Statistical study of twist values of transequatorial loops and the relationship with flares

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Received 28 April 2009; received in revised form 6 October 2009; accepted 7 October 2009

Abstract

In this paper, the twist values of 'S'-shape transequatorial loops (TLs) from 1991 to 2001 are calculated, GOES soft X-ray flares dataset of the active regions connected by these TLs are investigated. The result shows the twist value of the TLs has a weak relation with the flare flux. There is no clear correlation between the twist value and the distance between the footpoint of TLs and location of flare in the corresponding active regions.

Keywords: Sun: activity; Sun: transequatorial loops; Sun: flare

1. Introduction

Sigmoid structure indicates the non-potentiality of active region, Canfield et al. (1999) investigated sigmoid structures and studied the association between sigmoid/non-sigmoid shape and the tendency toward eruption, they found that sigmoidal regions are more likely to erupt than non-sigmoidal ones. There are two methods which are used to calculate the non-potentiality of the sigmoid structure: Rust and Kumar (1996) modeled sigmoidal structures as helically kinked flux ropes; Pevtsov et al. (1997) modeled the projection of three-dimensional constant-α force-free fields of a simple bipole.

Transequatorial loops demonstrate large-scale structure, its properties and its correlation with flares and CMEs were studied recently in several papers (Fárník et al., 1999, 2001; Pevtsov, 2000; Khan and Hudson, 2000; Glover et al., 2003; Chen et al., 2006, 2007). The non-potentiality of transequatorial loops is considered using constant-α force-free fields by Fárník et al. (1999) and Chen et al. (2007), but it is too complicate to study the large sample data through this method. We apply a simple method to consider the twist of TLs. Some of TLs are rooted in active regions. The flare in these active regions maybe has relation with the twist of TL. Glover et al. (2003) have already studied whether the evolution of TL induces CME, we only investigate the relation between the twist of TL and flare in this paper. In Section 2, we introduce data analysis. The statistical results are shown in Section 3. In Section 4, we show the conclusion.

2. Data analysis

2.1. Calculation of twist values of TLs

Chen et al. (2006) identified 356 transequatorial loops using *Yohkoh* soft X-ray dataset from 1991 to 2001. Some of the TLs connect two active regions, some of them connect two quiet regions, others connect one active region and one quiet region. For these TLs, there are 'S'-shape and non-'S'-shape structures (Pevtsov, 2004). Only TLs which are 'S'-shape and connect two active regions are

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doi:10.1016/j.asr.2009.10.005

selected in this study. For the selected TLs, we calculate the twist values using the following formula:

$$Tw = \frac{L}{D}, \qquad (1)$$

where Tw is the twist value, L is the length and D is the distance between the two footpoints of TL.

Considering two-dimensional structures of 'S'-shape TLs, two twist values on both edges for every TLs are calculated. For each edge of TL, we select nine points, then we use spline interpolation to plot the shape of TL and calculate the length of TLs. The distance of the two footpoints represents the distance of TLs. The mean value of the two twist values is the twist value of these TLs. A case in Fig. 1 is given to demonstrate how we calculate the twist value of TL.

Fig. 1 is a *Yohkoh* soft X-ray image which demonstrates a transequatorial loop. In order to calculate the twist value of TL accurately, we find the two footpoints of the TL, mark them and calculate the distance of the two points (D) firstly. Second, we mark the other seven points along the TL between the footpoints. Third, we make spline interpolation for the nine points, and calculate the length of the TL (L_1) in the left side. Fourth, we repeat the second and third steps on the right side of TL, the length of the TL in the right side is L_2. Fifth, the twist value of TL is computed using $Tw = (L_1 + L_2)/2D$.

2.2. Data selection

For the selected 'S'-shape transequatorial loops described in Section 2.1, we get the corresponding international number of the active regions. Then we find the flare

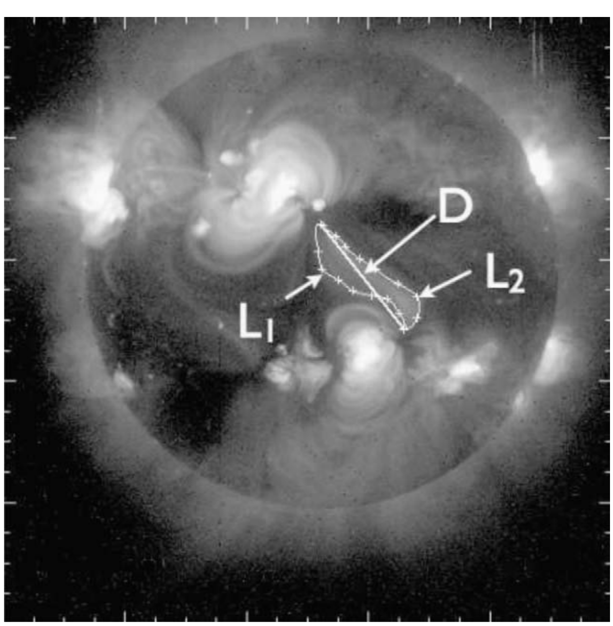

Fig. 1. A *Yohkoh* soft X-ray image presents a transequatorial loop on November 30, 1998. L_1 and L_2 represent the two lengths of TL which are plotted using interpolation. D shows the distance of TL.

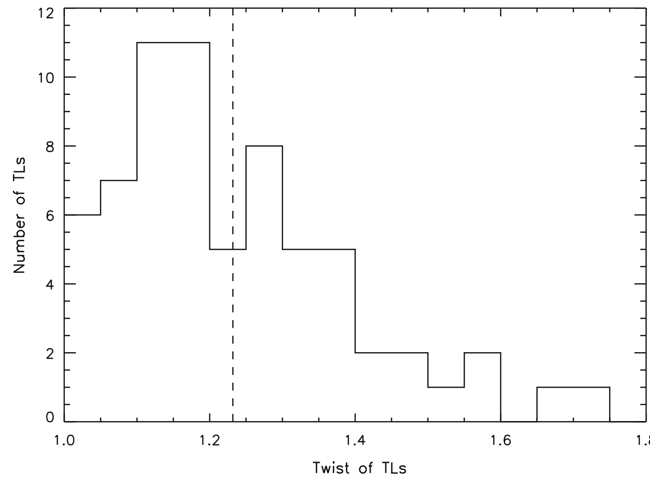

Fig. 2. Distribution of the twist value of TLs, the dashed line show the average value.

period for these active regions through surveying GOES soft X-ray flare database. Considering B-class flares are small, the flares above C-class are included. After that, we investigate the total *Yohkoh* SXT full-disk dataset and select the soft X-ray data during the flare period. According to these processes, 68 TLs are found finally.

3. Statistical results

In this section, we introduce the statistical results of the distribution of the twist values of TLs, the distribution of soft X-ray flux of flares in different twist values, the relation between the twist value and the distance between the flare and TL-footpoint, the variation of soft X-ray flux of the flares following solar cycle.

Fig. 2 shows the distribution of twist values of TLs. From this figure, we can see the average twist value of these TLs is about 1.23, the twist values of these TLs are almost focused on 1.15.

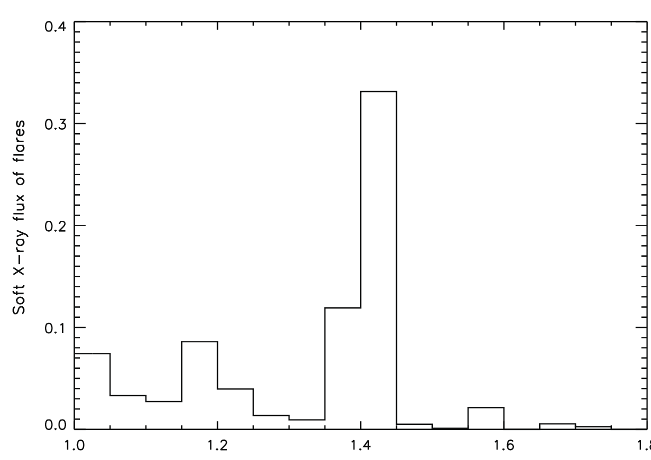

Fig. 3. Relationship between the twist value of TLs and GOES soft X-ray flare flux, the unit of flux is erg cm^{-2} s^{-1}.

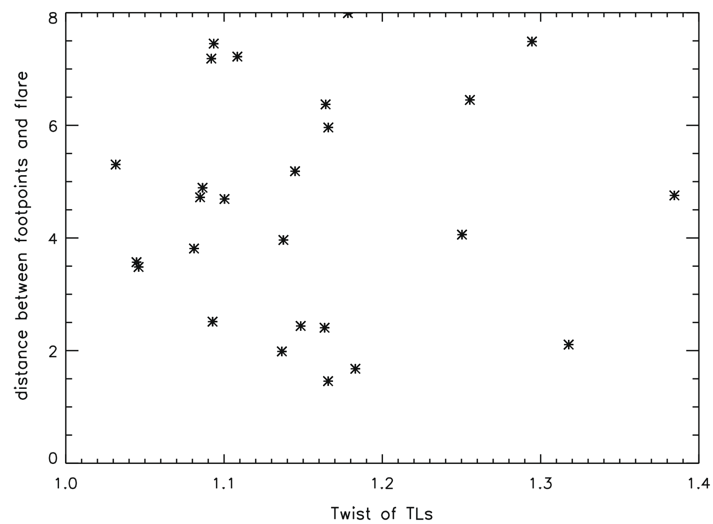

Fig. 4. Relation between twist of TL and distance between flare and TL-footpoint, the unit of distance is heliospheric degree.

The distribution of GOES soft X-ray flare flux in different twist values of TLs are shown in Fig. 3. We obtain GOES soft X-ray flare flux through calculating the total flux of different types. The flux is computed using the following formula:

$$\mathrm{Flux_{tot}} = 1.0 \times 10^{-3}\sum C + 1.0 \times 10^{-2}\sum M + 1.0 \times 10^{-1}\sum X. \quad (2)$$

Fig. 3 views the total flare flux of GOES soft X-ray has a high value during the twist value is between 1.35 and 1.45. This twist value is a little higher than the mean value of all the TLs.

For the selected TLs in Section 2.2, we investigate SOHO/MDI dataset and select the closest longitudinal magnetogram field in 1 h, 27 magnetograms are found. Among these magnetograms, one image, the active region is close to the east limb with the absolute longitude degree >50°, is removed, 26 active regions are left. We make projection correction for the MDI magnetograms, and calculate weighted center of the magnetic polarity region (the region has the same magnetic polarity in one active region) which represents the footpoint of TL.

Then we compute the distance between flare and TL-footpoint using the formula of great-circle distance, it is as following:

$$\theta = \arccos(\sin\phi_f \sin\phi_t + \cos\phi_f \cos\phi_t \cos\Delta\lambda), \quad (3)$$

where θ represents the distance. ϕ_f, λ_f, ϕ_t, λ_t are the geographical latitude and longitude of the flare location and TL-footpoint, respectively. $\Delta\lambda$ is the difference of the longitudinal degree. From Fig. 4, we can see the distance is from 1° to 8°. The relation between twist value of TL and distance between flare and TL-footpoint are demonstrated in Fig. 4. The Pearson correlation coefficient for the twist value and distance is 0.01, it shows there is no relation.

The flare flux variations for the active regions which are related with the selected TLs in different years are also studied. In the years of 1992 and 1999, they are high in solar activity. In 1996, it is low in solar activity. From Fig. 5, we can see that the flare flux variation following solar cycle, during the period of high solar activity, the flare flux is large, during the period of low solar activity, the flare flux is small.

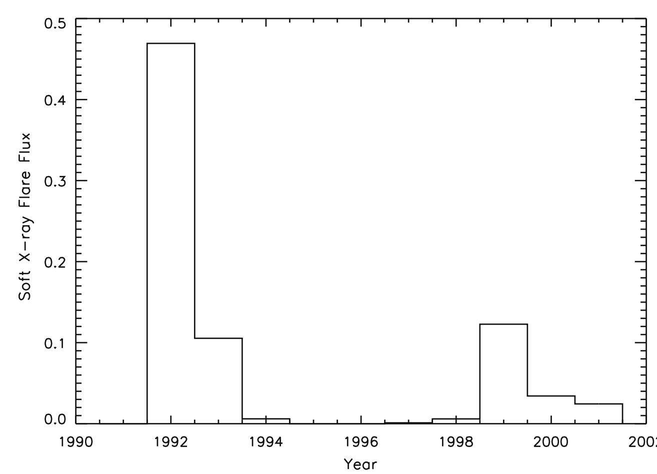

Fig. 5. Variation of soft X-ray flare flux following solar cycle (for the active regions which are corresponding to the selected 68 TLs).

4. Conclusion

The twist values of 68 transequatorial loops are calculated. There is a weak correlation between GOES soft X-ray flare flux and the twist value of TLs: the twist value for the flare flux peak is bigger than the average twist value of TL. We cannot see clear relation between the twist value and the distance between flare and TL-footpoint.

Acknowledgements

One of the authors J. Chen thanks A. Nindos for his discussion and P. Wintoft for his suggestion. This work is supported by Swedish National Space Board. It is also supported by National Natural Science Foundation of China 10733020 and the Youth Foundation of National Astronomical Observatories of China. *Yohkoh* is a mission of ISAS (Japan) with participation from the US and UK.

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