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A STATISTICAL STUDY OF TRANSEQUATORIAL LOOPS

JIE CHEN, SHUDONG BAO and HONGQI ZHANG
National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, China
(e-mail: chj@sun10.bao.ac.cn)

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Abstract. We identify 356 transequatorial loops (TLs) from the data set of *Yohkoh* Soft X-Ray Telescope (SXT) in the period of solar cycles 22 and 23. The classification of the TLs can be made on two bases. One is according to the magnetic polarities of the footpoints of TLs, and the other is according to the number of TLs in the same region. Based on the first criterion, TLs fall into two categories: PTLs in which the magnetic polarities of the footpoints are the same as the preceding polarities and FTLs in which the footpoint polarities are the same as the following polarities of active regions, respectively. It is found that PTLs have a preference; about 66% of the TLs are PTLs, and this preference of PTLs is independent of the solar cycle. The percentage of FTLs is about 34%. Based on the second criterion, TLs are also divided into two categories: the number of TLs in a region is either single (STLs) or multiple (MTLs). In addition, we find that the number of TLs, PTLs, and FTLs have good correlations with solar cycle indices. By comparing the number of TLs and the number of active regions in each year, we obtain the ratio between them. The separation of footpoints and their yearly variations are calculated, and we find that our result is consistent with spörer's law.

1. Introduction

Transequatorial loops are one type of coronal structures which connect different regions in the opposite hemispheres. The first direct evidence of TLs was observed by Skylab (Chase *et al*., 1976; Švestka *et al*., 1977). A TL is not an occasional phenomenon; it was found by Pevtsov (2000) that as many as one-third of all active regions exhibit TLs in soft X-ray images. The regions connected by TLs tend to have the same chirality. Canfield, Pevtsov, and McClymont (1996) studied the chirality of active regions on the opposite sides of the equator and found that the regions with the same chirality form transequatorial loops, but those with the opposite chirality do not. This was further confirmed by Fárník *et al*. (1999) and Pevtsov (2000).

Chase *et al*. (1976) identified 100 interconnecting loops using the data from Skylab and found that the average length of the loops is about 20° with the longest loop of 37°. They supposed that this was the real maximum of interconnecting loops on the sun. Recently, Fárník *et al*. (1999) found two long transequatorial loops (with lengths of 47 and 61 heliographic degrees) from *Yohkoh* SXT data. They provided evidence that the upper limit in length of 37° was only determined during the period of Skylab observations. Pevtsov (2000) studied 87 TLs and showed the average footpoint separation of them to be approximately 30° with a maximum of 75°.

The origin of transequatorial loops is thought to be reconnection of field lines. Švestka *et al.* (1977) studied the life history of one TL and concluded that the TL was most probably born via reconnection of magnetic field lines. Tsuneta (1996) studied an X-shaped transequatorial loop and provided a strong evidence that magnetic reconnection is responsible for the TL formation. Fárník *et al.* (1999) and Harra *et al.* (2003) also gave several observational facts to support that magnetic reconnection forms TLs.

The eruption, disappearance, and brightening of transequatorial loops may be related to flares and coronal mass ejections (CMEs). Khan and Hudson (2000) found that a sequence of homologous disappearance of TLs were associated with a major flare and CME. They suggested that flare-generated shock waves may cause the eruption of transequatorial loops and estimated the masses of the X-ray loops which are similar to CME masses. Glover *et al.* (2003) looked for a sample of 18 TLs to investigate the association of TLs with flaring and CME activity. They found that the eruption of TLs leading to soft X-ray brightening equivalent in temperature to a B-class flare is equally as common as dimming in the corona. Harra *et al.* (2003) found an evidence of flaring in one TL. Moon *et al.* (2002) studied sympathetic flares and found that transequatorial loops more likely produce sympathetic flares than other interconnecting loops.

Transequatorial loops exhibit magnetic structures of solar coronal atmosphere. They connect regions of opposite magnetic polarities. Krieger *et al.* (1971) compared X-ray emitting structure in the corona to the magnetic field distribution measured by photospheric longitudinal magnetograms and found that the TLs appear to originate over areas of preceding polarities, while Švestka *et al.* (1981) observed that some TLs connect the following polarities. Here a question is raised: Do the footpoints of TLs connect preceding polarities or following polarities more easily? This has motivated us to make a statistical study on the magnetic polarities of the footpoints of TLs.

In this paper, by analyzing the *Yohkoh* SXT images and the full disk longitudinal magnetograms, we classify TLs according to the magnetic polarities of the footpoints, and the number of TLs in one region. In addition, we study the relation between the numbers of TLs and active regions, and analyze the variation in number of TLs in different solar cycles. The footpoints separation, tilt angle, and latitudinal asymmetry of TLs are also studied.

2. Observations and Data Reduction

The *Yohkoh* satellite was launched in 1991 and has observed the solar atmosphere in X-ray radiation continuously for about ten years. The SXT (Tsuneta *et al.*, 1991) is a grazing-incidence reflection telescope with a CCD detector (1024×1024). It can provide both full- and partial-frame images which cover the whole sun and only a region of interest. In order to study transequatorial loops, we use the full-frame soft X-ray images having a spatial resolution of 4.9″ per pixel and the images were taken using the A1.1 and AlMg filters. The data set from the beginning of the mission (1991 October) to its end (2001 December) is considered. 356 TLs are identified from about ten years data. We select the images with the best appearance of TLs when they were located near to the central meridian. We use the same data set and employ a similar data analysis approach as in Pevtsov (2004), but the number of TLs is different: Pevtsov (2004) found only 226 TLs. The reason is that the approach we used is different from Pevtsov (2004). We classify TLs by their footpoint polarity. In our approach, if a pair of active regions has two TLs, we would count them twice. In a similar situation, Pevtsov (2004) would count this system as one TL.

Then SOHO Michelson and Doppler Instrument (MDI) longitudinal magnetograms are used. The observation of MDI consists of full-disk longitudinal magnetograms taken with a time cadence of 96 minutes, and during some short periods with a cadence of one minutes. The spatial resolution is 1.96″ (Scherrer *et al.*, 1995). We choose the MDI magnetograms with a time cadence of 96 minutes which are close (in time) to the SXT images previously selected. MDI provides data from 1996, and there are gaps from 1998 June to October and from 1999 January to February. Not all SXT images have the corresponding MDI full-disk magnetograms, and the missing magnetograms are replaced by the data of the National Solar Observatory at Kitt Peak.

Through co-aligning the soft X-ray images and full-disk longitudinal magnetograms, the magnetic polarities of TL footpoints can be identified. After the footpoint polarities of TLs are ascertained, the magnetic flux-weighted centers of the same polarities are calculated, and we transform them to heliographic coordinates. Using the positions of these flux systems, we compute the footpoint separation, tilt angle, and latitudinal asymmetry of TLs.

3. Results

3.1. Classification

In solar cycle 22, the preceding polarities of most bipolar groups are negative in the northern hemisphere and positive in the southern. In solar cycle 23, magnetic polarity is reversed, *i.e.*, most preceding polarities are positive in the northern and negative in the southern hemisphere. The whole data base of SXT includes the data of solar cycles 22 and 23. Transequatorial loops may develop between mature active regions or between an active region and a quiet region of the Sun (Fárník *et al.*, 2001; Pevtsov, 2000). The footpoint of TLs may belong to an active region or to a quiet region of the Sun.

Different from the classification of Pevtsov (2000) according to configuration, we classify TLs according to the magnetic polarity of TL footpoints. Without

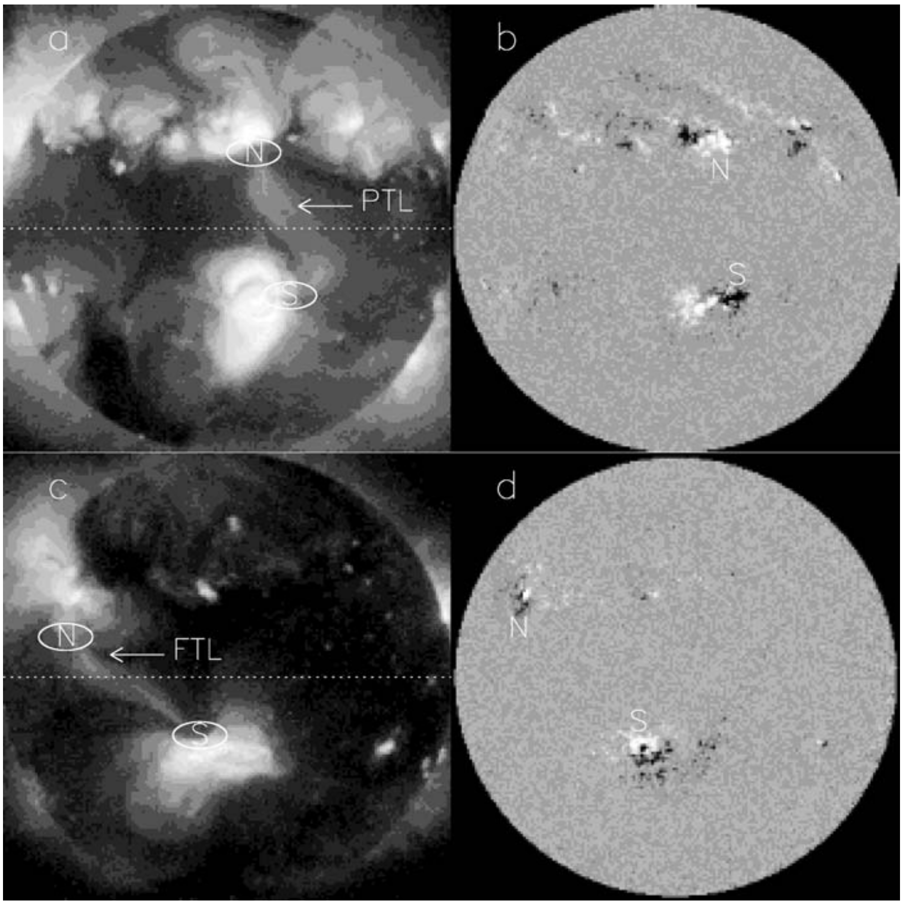

Figure 1. (a) A soft X-ray image showing PTL (SPTL). N and S represent the footpoints in the northern and southern hemispheres, respectively. The *circles* show the footpoint positions. (b) The corresponding full-disk longitudinal magnetogram of PTL (SPTL). The characters show the footpoint polarities. (c) A soft X-ray image showing FTL (SFTL). (d) The corresponding full-disk longitudinal magnetogram of FTL(SFTL).

considering which solar cycle it belongs and no matter whether it connects active regions or quiet regions, if the magnetic polarities of the footpoints of a TL are the same as the preceding polarity of bipolar groups, it is called PTL. If the polarities of the footpoints are similar to the following polarity, it is called FTL. So according to the magnetic polarities of footpoints, TLs are classified into two categories: one is PTL, and the other is FTL. Some examples are shown in Figure 1.

Figures 1a and 1c are soft X-ray images having transequatorial loops. The footpoints of TLs are plotted using white circles. Characters N and S represent the footpoints in the northern and southern hemispheres, respectively. Figures 1b and 1d are the corresponding longitudinal magnetograms. Characters N and S show the magnetic polarities of footpoints.

Figure 1a shows an example of PTL. It is an image in 1999 belonging to solar cycle 23, and the magnetic polarity of the footpoint is positive in the northern hemisphere and negative in the southern. Both of them are preceding polarities in bipolar groups. One example of FTL in 1997 belonging to solar cycle 23 is shown in Figure 1c, in which the footpoint polarity is positive in the southern hemisphere. From the magnetogram, we cannot define whether this positive polarity belongs to the preceding polarity or following polarity. We have mentioned that the most following polarities of bipolar groups are positive in the southern hemisphere in solar cycle 23. The footpoint of this TL in the northern hemisphere is located in the following polarity of a bipolar group and the magnetic polarity of the footpoint in the southern hemisphere is the same as the following polarity, so it is called FTL.

TLs are also classified according to the number of TLs in the same region. If both of the regions that TLs connect have only one TL, it is called STL. If one of the regions hosts two or three TLs, this transequatorial loop system is called MTLs. Further, STLs and MTLs are classified into several sub-categories according to the magnetic polarities of footpoints. For STL, if the magnetic polarities of the footpoints are the same as the preceding polarities, it is called SPTL. If the polarities of the footpoints are the same as the following polarities, it is called SFTL. For MTLs, if one TL is PTL and another one is FTL, the transequatorial loop system is called MTL-PF; if all of TLs are PTLs, the system is called MPTL; if all of TLs are FTLs, it is called MFTL. Examples are shown in Figures 1 and 2.

Figures 1a and 1c show STLs. According to the sub-classification, the TL in Figure 1a is SPTL and the one in Figure 1c is SFTL. Figures 2a,c, and e show the transequatorial loop system of MTLs; the images are selected from soft X-ray data. Figures 2b, d, and f give the corresponding full-disk longitudinal magnetograms. In Figure 2, the notations and characters have the same meaning as in Figure 1.

Figure 2a shows an example of MTL-PF. It presents two TLs, and now we see the two footpoints of these two TLs in the northern hemisphere from Figures 2a and b. They are associated with one active region (in the northern hemisphere), that is to say, one active region hosts two TLs. No matter whether the other footpoints exist in one active region or two active regions, this TLs system is called MTLs. About these two TLs, one TL is PTL, and the other is FTL. So it is called MTL-PF. From Figure 2c, we can see that one active region in the southern hemisphere hosts two TLs. Figure 2e also shows that one region hosts two TLs in the south. They are also called MTLs. The two TLs in Figures 2c and d are PTLs, and the system is called MPTL. An example of MFTL is shown in Figure 2e, where the two TLs are FTLs.

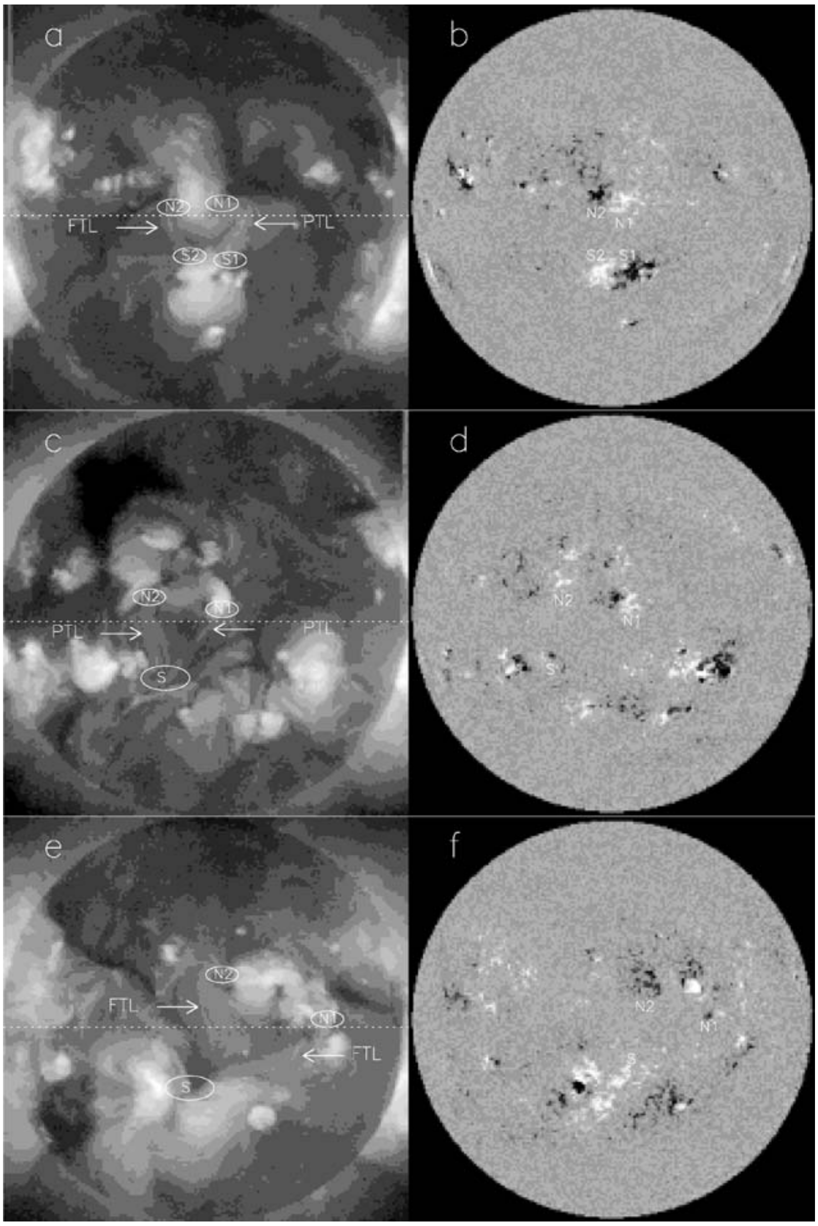

Figure 2. (a) A soft X-ray image showing MTL-PF. ‘N1’ and ‘N2’ represent the footpoints in the northern hemisphere and ‘S1’ and ‘S2’ represent the footpoints in the southern hemisphere. The *circles* show the footpoint positions (b) The corresponding full-disk longitudinal magnetogram of MTL-PF. The characters show the magnetic polarities of the footpoints. (c) A soft X-ray image showing MPTL. (d) The corresponding full-disk longitudinal magnetogram of MPTL. (e) A soft X-ray image showing MFTL. (f) The corresponding full-disk longitudinal magnetogram of MFTL.

TABLE I
Classification of transequatorial loops according to the magnetic polarities of the footpoints.

Category	Number	Fraction
PTL	229	66%
FTL	127	34%

TABLE II
Classification of transequatorial loops according to the TL number and magnetic polarities of the footpoints.

STL		MTLs		
SPTL	SFTL	MTL-PF	MPTL	MFTL
120	32	70(145)	20(41)	8(18)
79%	21%	71%	20%	9%
152		98(204)		
61%(43%)		39%(57%)		

3.2. Statistical results

We identifiy 356 TLs from *Yohkoh* Soft X-ray images. Table I lists the result according to the classification of footpoint polarity of TLs. It shows that the total number of PTLs is 229 and has a percentage of 66%. The number of FTL is 127 and its percentage is 34%. The PTLs are preferred in number.

Table II lists the TLs in term of detailed classification according to the TL number and footpoint polarities. The number of STL is 152 and the number of MTL systems is 98 including 204 transequatorial loops. For STL, the number of SPTL is 120 having a percentage of 79%; the number of SFTL is 32 and its percentage is only 21%. From this table, we can see that SPTL has an obvious preference in STLs. For MTLs, the number of MTL-PF system is 70 including 145 TLs and the percentage is 71%. The number of MPTL system is 20 including 41 TLs and the percentage is 20%. The number of MFTL system is 8 including 18 TLs having the percentage of 9%. For MTLs, MTL-PF has an obvious preference.

Table III lists the percentage of PTLs and FTLs in different solar cycles. In solar cycle 22, the percentage of PTLs is about 61%: In solar cycle 23, the percentage of PTLs is about 66%. The preference of PTL is independent of the solar cycle.

TABLE III
The TLs in solar cycles 22 and 23.

Solar Cycle 22			Solar Cycle 23		
Category	148	100%	Category	208	100%
PTL	91	61%	PTL	138	66%
FTL	57	39%	FTL	70	34%

3.3. Relation with solar cycle

Solar activity is usually associated with an eleven-year sunspot cycle, such as the variations in the flare count, the total magnetic flux, the 10cm radio flux and even the evolution of the large-scale field patterns. Transequatorial loops also show the eleven-year solar cycle (Pevtsov, 2000, 2004). Figure 3a confirms Pevtsov's result. Figures 3c and d show that the numbers of PTLs and FTLs change with the solar cycle.

Figure 3a shows the number of TLs in different years. In the declining phase of the solar cycle, the number of TLs decreases; in the rising phase, it increases. The number of TLs is large in high solar activity (1992, 2000), and is small in low activity (1996, 1997). The relation between the numbers of TLs and of active regions in each year is shown in Figure 3b. The dotted line shows that the average value of the ratio is only about 10%, which is different from Pevtsov's (2000) result (about 30%). We obtain the number of active regions in each year by calculating the NOAA region number of the last day of the year minus the region number of the first day of the year. The SXT data are incomplete in 1991 and 2001; in these two years the active region numbers are calculated only during the period in which SXT had observations. Pevtsov (2000, 2004) normalized the number of transequatorial loops by the annual sunspot numbers. One TL is usually associated with two active regions. If this is taken into consideration, when we normalize the number of TLs by the number of active regions, the number of NOAA active regions should be divided by two. This will bring the fraction of active regions having TLs to about 20%. Not all the TLs are connected to a pair of active regions, considering the fact that some TLs are associated with quiet Sun areas, and therefore the fraction of active regions having TLs should be less than 20%. Figures 3c and d show the changes in number of PTLs and FTLs following the solar cycle. They have the same trend as the number of TLs.

3.4. Three parameters of TLs

In Section 2, we have introduced the method of calculating the footpoint positions of TLs. Using the footpoint positions, three parameters of TLs are computed;

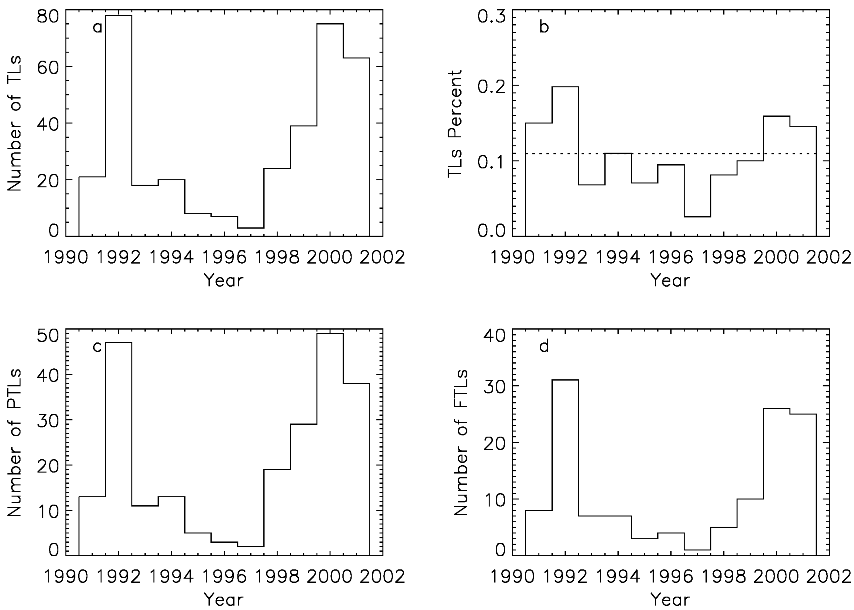

Figure 3. (a) The number of TLs in different years. (b) The ratio in number of TLs to active regions in each year. The dotted line shows the average value. (c) The number of PTLs in different years. (d) The number of FTLs in different years. Years 1991–1996 belong to solar cycle 22 and years 1996–2001 belong to solar cycle 23.

separation of footpoints, tilt angle, and asymmetry in latitude. Figures 4a, 5a, and 6a show the distribution of TLs in terms of these three parameters. The curves show the polynomial fit, and the dotted lines indicate the average values of these parameters. Figures 4b, 5b, and 6b show the variations of these parameters in different years. They also show an error at 1σ level.

3.4.1. *Separation of Footpoints*

The separation of footpoints means the distance between the two footpoints of TLs. From Figure 4, we can see that the average value of separation is about 27°, which is close to Pevtsov (2000)'s result and different from Chase *et al.* (1976) value of about 20°. Pevtsov (2000) also used *Yohkoh* SXT data and the analyzed period is between 1991 and 1998, but Chase *et al.* (1976) used Skylab data only having the relatively short 9 month period.

The period of 1991–1995 is the declining phase of solar cycle 22 and the period of 1997–2001 is the increasing branch of solar cycle 23. From Figure 4b we can see that the mean value of separation decreases gradually year by year from 1991 to 1995 and it also decreases from 1997 to 2001. The mean value of separation in solar cycles 22 and 23 are also calculated. In solar cycle 22, the mean value is about 22°; in solar cycle 23, the mean value is about 31°. In 1996, a change of magnetic

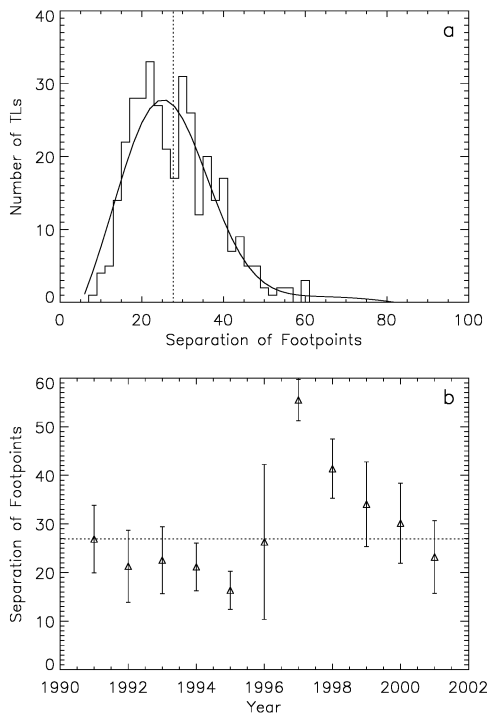

Figure 4. Separation of TLs. (a) The number distribution of footpoint separation. The *curve* shows a polynomial fit. The *dotted line* shows the mean value. (b) The separation in different years. The *triangle* shows the average value in each year. The error bar is for 1σ interval. The *dotted line* shows the overall average value.

polarity took place happened, but the mean value of separation for this year is near to the average value of the whole TLs. Spörer's law shows the solar latitude at which new sunspots appear gradually decreases, from high latitudes at the beginning of a solar cycle to low latitudes at the end of the cycle. The footpoint separation of TLs is consistent with Spörer's law from Figure 4b. It decreases following the solar cycle and the mean value is lower in the declining phase (1991–1995) than in the ascending part (1997–2001).

3.4.2. *Tilt Angle*

A tilt angle is defined as the angle between a transequatorial loop and the equator. We can obtain the tangent value of the tilt angle using the difference in footpoint latitudes divided by the difference in footpoint longitudes. When the northern footpoint is to the west of the southern footpoint, the tilt angle is defined to be less than 90° (acute angle). On the contrary, if the northern footpoint is to the east of the southern footpoint, the tilt angle is defined to be more than 90° (obtuse angle). Figure 5a shows TLs numbers distribution in different tilt angles. The average value is near

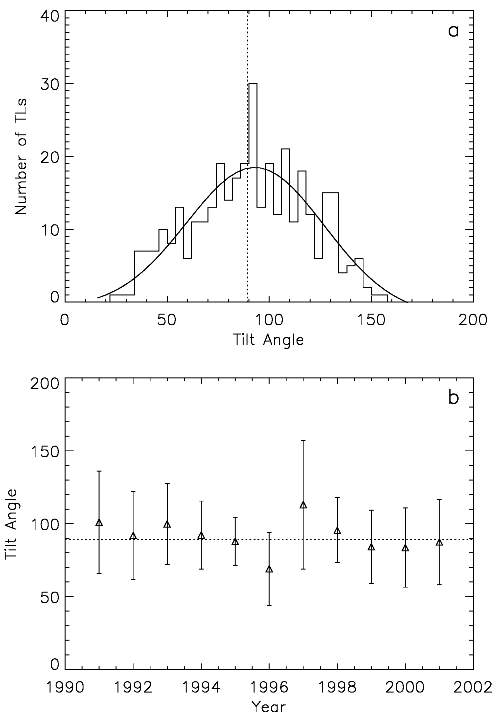

Figure 5. Tilt angle of TLs. (a) The number distribution of tilt angles. The *curve* shows a polynomial fit. The *dotted line* shows the mean value. (b) The tilt angle in different years. The *triangle* shows the average value in each year. The error bar is for 1σ interval. The *dotted line* shows the overall average value.

to 90°. Figure 5b shows the the tilt angles in different years. The error bar is for 1σ interval. In Figure 5b, no obvious changes following the solar cycle is seen. It is similar to Pevtsov (2004)'s result.

3.4.3. *Asymmetry in Latitude*

The asymmetry here is defined as the latitude of the northern footpoint subtracted by the absolute value of the latitude of the southern footpoint. If the latitude value of the northern footpoint is larger (smaller) than that of the southern footpoint, the result is positive (negative), respectively. We found that the mean value of asymmetry in latitude is near to 0°, namely, the transequatorial loops are almost symmetry in latitude. Figure 6b presents the latitude asymmetry in different years. The average value in each year is also $\sim 0°$. We see no obvious difference of the TLs asymmetry in latitude in different years and no obvious difference in the asymmetry in different years, nor in the decreasing phase of solar cycle 22 and in the ascending phase of solar cycle 23.

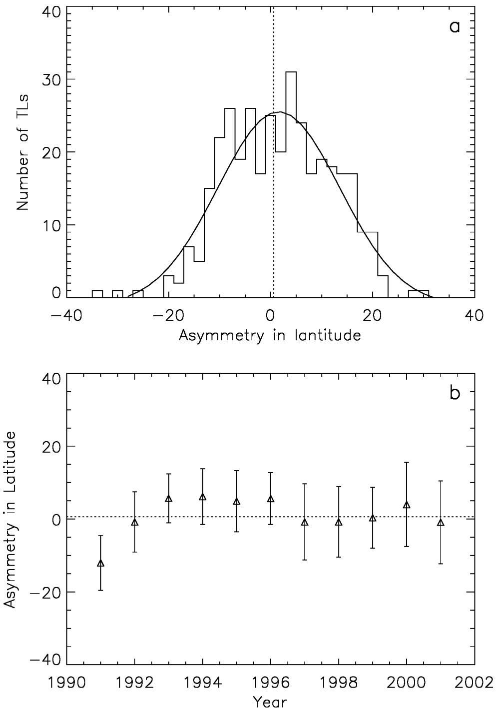

Figure 6. Asymmetry in latitude of TLs. (a) The number distribution in asymmetry. The *curve* shows a polynomial fit. The *dotted line* shows the mean value. (b) Asymmetry in different years. The *triangle* shows the average value in each year. The error bar is for 1σ interval. The *dotted line* shows the overall average value.

4. Conclusion and Discussion

Using *Yohkoh* SXT images, we identified 356 transequatorial loops. Through the statistical study of TLs, we obtained the following results:

1. For all of the transequatorial loops that are surveyed about 66% of them that the footpoints have the same magnetic polarities to the preceding polarities (PTLs) and about 34% the magnetic polarities of footpoints are the same as the following polarities (FTLs) of bipolar active regions. This relation is independent of the solar cycle. The predominance of PTLs can be explained using the well-known asymmetries between the preceding and the following polarities of a bipolar active region, namely, that the leading polarity of an active region is more compact, and has a longer life time than does the following polarity (see, *e.g.*, Bray and Loughhead 1979, p. 226). So the preceding polarity is expected to form TLs more easily than the following polarity. For STLs, the preference is more obvious. When there are two mature active regions, then the following polarity has the same probability as the leading polarity to form TLs, and therefore MTL-PF has a larger ratio among MTLs.

2. The number of TLs varies in accordance with the sunspots number during solar cycles 22 and 23. The number of TLs is large in high solar activity (1992, 2000), and is small in low activity (1996, 1997). Both PTLs and FTLs change similarly following the solar cycle.

3. We calculated three parameters characterizing TLs; separation, tilt angle, and asymmetry in latitude. The separation of TLs varies following the solar cycle. At the beginning of a cycle, the separation value has a maximum. The separation decreases in the course of the solar cycle. This behavior is closely linked with Spörer's law of sunspot activity. According to the results by Stenflo (1988), the radial component of the Sun's large-scale magnetic field has a branch which drifts equatorwards (accompanied with a branch drifting toward the poles at higher latitudes) that starts at a latitude of $\sim 30^\circ$. The branch drifting equatorwards is also found in some dynamo models (Kitchatinov 1993). Obridko and Shelting (2003), on the other hand, claim that the radial component of the large-scale magnetic field of the Sun has only one branch which starts to drift from the equator toward the poles. If we assume that a TL is a magnetic configuration reflecting the large-scale structure of the poloidal component of the Suns magnetic fields, then our findings are in favor of Stenflo (1988) and against Obridko and Shelting (2003). The tilt angle and asymmetry in latitude do not have obvious variations following the solar cycle and show no significant difference in the declining phase of solar cycle 22 and in the ascending branch of solar cycle 23. The average value of the tilt angle is $\sim 90^\circ$ and the TLs are symmetric in latitude.

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References

Bray, R. and Loughhead, R.: 1979, *Sunspots*, Dover Publications Inc., New York, p. 226.

Canfield, R., Pevtsov, A., and McClymont, A.: 1996, in R. D. Bentley and J. T. Mariska (eds.), *Magnetic Reconnection in the Solar Atmosphere*, *ASP Conf. Ser.* **111**, 341.

Chase, R., Krieger, A., Švestka, Z., and Vaiana, G.: 1976, in *Space Research* XVI, Akademie-Verlag, Berlin, p. 917.
Fárník, M., Karlicky, M., and Švestka, Z.: 1999, *Solar Phys.* **187**, 33.
Fárník, M., Karlicky, M., and Švestka, Z.: 2001, *Solar Phys.* **202**, 81.
Glover, A., Harra, L.K., Matthews, S.A. and Foley, C.A.: 2003, *Astron. Astrophys*. **400**, 759.
Harra, L., Matthews, S., and van Driel-Gesztelyi, L.: 2003, *Astrophys. J.* **598**, L59.
Khan, J. and Hudson, H.: 2000, *Geophys. Res. Lett.* **27**, 1083.
Kitchatinov, L. L.: 1993, in F. Krause, K.H. Rädler and G. Rüdiger (eds.), *The Cosmic Dynamo*, *IAU Symp.* **157**, 13.
Krieger, A., Vaiana, G., and Van Speybroeck, L.: 1971, in R. Howard (ed.), *Solar Magnetic Fields*, *IAU Symp.* **43**, 397.
Moon, Y. *et al.*: 2002, *Astrophys. J.* **574**, 434.
Obridko, V.N. and Shelting, B.D.: 2003, *Astronomy Rep.* **47**, 333.
Pevtsov, A.: 2000, *Astrophys. J.* **531**, 553.
Pevtsov, A.: 2004, in A.V. Stepanov, E.E. Benevolenskaya, and A.G. Kosovichev (eds.), *Multi-Wavelength Investigations of Solar Activity, IAU Symp.* **223**, 521.
Scherrer, P.H. *et al.*: 1995, *Solar Phys.* **162**, 129.
Švestka, Z., Krieger, A.S., Chase, R.C., and Howard, R.: 1977, *Solar Phys.* **52**, 69.
Švestka, Z. and Howard, R.: 1981, *Solar Phys.* **71**, 349.
Stenflo, J.O.: 1988, *Astrophys. Space Sci.* **144**, 321.
Tsuneta, S. *et al.*: 1991, *Solar Phys*. **136**, 37.
Tsuneta, S.: 1996, *Astrophys. J.* **456**, L63.