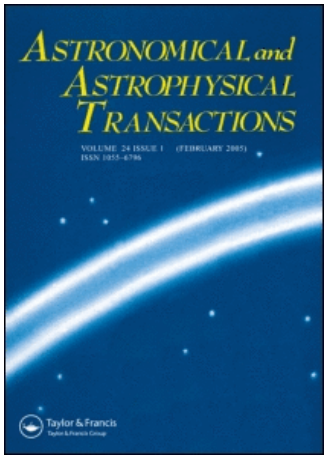

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Solar large-scale emitting chains: Preliminary remarks on the cycle variability

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SOLAR LARGE-SCALE EMITTING CHAINS: PRELIMINARY REMARKS ON THE CYCLE VARIABILITY

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Preliminary remarks on the solar cycle phase variability of the microwave and EUV large-scale chains are outlined briefly based on the Nobeyama Radioheliograph and SOHO/EIT data. The observed complication of the chains in the course of the cycle appears to reflect the corresponding complication of the global solar magnetosphere.

KEY WORDS Solar activity, large-scale structures, chains

1 INTRODUCTION

Large-scale emitting chains with a characteristic length comparable with the solar disk radius or even diameter were detected recently in the microwave, soft X-ray, EUV, and other ranges due to consideration of the modified Nobeyama Radioheliograph (NRH), Yohkoh/SXT, SOHO/EIT, TRACE and other images (e.g., Chertok (1998, 1999), Chertok and Shibasaki (2000); see also the web page http://helios.izmiran.troitsk.ru/lars/Chertok). There are grounds to suppose that these chains light up separators or quasi-separatrix layers between different interacting and reconnecting large-scale magnetic flux systems in the global solar magnetosphere.

In this paper, some preliminary remarks on the cycle phase variability of the microwave and EUV chains are given based on the NRH (Nakajima *et al.*, 1994) and SOHO/EIT (Delaboudiniere *et al.*, 1995) observations starting in June 1992 and January 1996 respectively. At the same time, some features of the chains and their relations to other large-scale structures particularly to coronal holes (CHs) are illustrated.

It should be kept in mind that the SOHO/EIT images in the Fe IX/X (171 Å) and Fe XII (195 Å) spectral lines are sensitive to the coronal plasma with a temperature of $T_e \approx 1.1$ and 1.5 MK). The NRH maps are calibrated in brightness

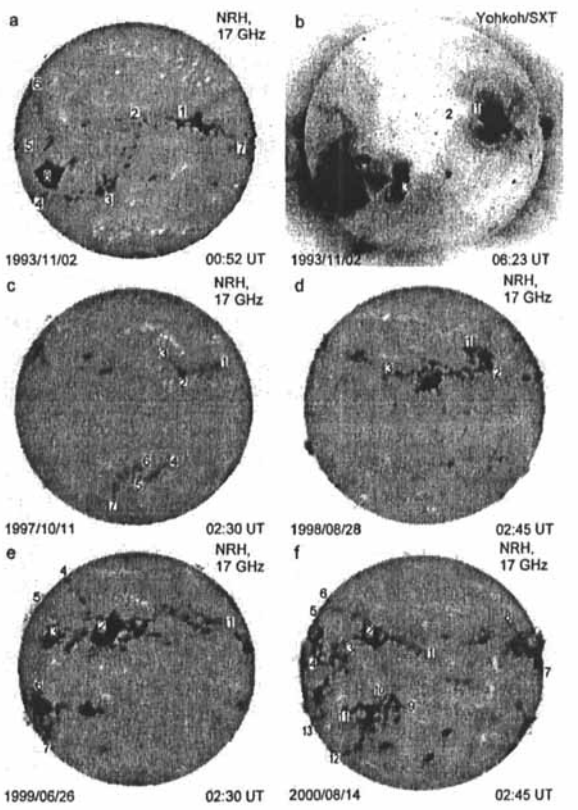

Figure 1 Inverted modified 17 GHz NRH images illustrating emitting microwave chains typical for the descending phase of the 23nd cycle (*a*), the minimum (*c*), the ascending (*d*, *e*) and maximum (*f*) phases of the 23rd cycle. The light elements are radio filaments visible in absorption. The Yohkoh/SXT image (*b*) displays a CH whose SW boundary is lighted up by a microwave chain shown in frame (*a*).

temperature that for the optically thin thermal free–free radio emission can be much less than the electron temperature. The chains are studied on the modified images with a restricted range of intensities. On such images, the most intense sources are suppressed (saturated) and the relatively faint features, such as the chains, become more pronounced. All images are presented here in an inverted (negative) form, i.e. emitting sources look dark, and absorption features appear light.

2 THE DESCENDING PHASE OF THE 22nd CYCLE (1992–1995)

The NRH data allow us to start with the descending phase of the 22nd cycle. At this stage, the microwave chains were fairly numerous and extended. Transequatorial chains connecting remote active regions in the different hemispheres were present,

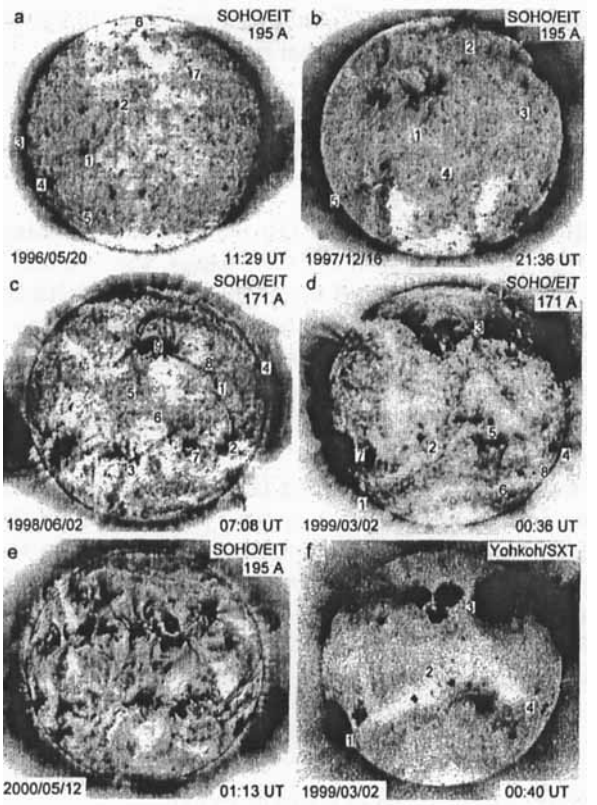

Figure 2 Inverted modified 171 and 195 Å SOHO/EIT images showing examples of the EUV chains observed during the minimum (*a*), the ascending (*b*–*d*) and maximum (*e*) phases of the 23rd cycle. The Yohkoh/SXT image (*f*) displays a CH outlined by a microwave chain presented in frame (*d*).

sometimes coinciding with the CH boundaries. In Figure 1*a*, such a long-living transequatorial chain 1-2-3 outlines the SW boundary of a large CH visible on the Yohkoh soft X-ray image (*b*). Several transient chain branches 3–4, 2–5, 5–6 appeared around the SE region 8 after a C3.2 long-decay event being a significant proxy of a CME. The global character of this transient activity also displays itself in the simultaneous appearance of a west branch 1–7.

3 THE MINIMUM PHASE (1996)

During the minimum, microwave chains were observed highly rarely, located in general at high latitudes and of comparatively small size (see the chains 1–2–3, 4–5, 6–7 in Figure 1*c*). In the EUV range, a few chains were low-contrast and associated mainly with numerous bright points which predominated at this stage.

Nevertheless, some of the chains crossed the helioequator. In Figure 2*a*, such typical EUV chains as 2–3, 4–1–2, 3–4–5, 6–7 can be distinguished.

4 THE ASCENDING PHASE OF THE 23rd CYCLE (1997–1999)

A gradual complication and increase of the number of the chains is characteristic of this phase of the cycle. In the microwave range, the longitudinal (i.e. located inside the active zones in the N and S hemispheres) chains with some high-latitude branches predominate. Transequatorial branches are very rare. Figure 1*d* shows a rather extended longitudinal chain 2–3 with a northward branch 2–1. The still larger and more complicated longitudinal microwave chain 1–2–3 combined with two high-latitude branches 2–4, 3–5 is shown in Figure 1*e*. The southward chains 6–7 are also present in the S hemisphere.

At the same time, the sufficiently long (including transequatorial) EUV chains connecting remote active regions on a large area in all sectors of the disk are visible. At first these chains are relatively 'simple' and can look like the one 1–2–3–4–5 presented in Figure 1*c*. Then a whole system of long and cross chains appears. In Figure 1*c* such a system consists particularly of the chains 3–1–4, 6–7–2, 5–1–2, 1–8–9. Shown in Figure 1*d* is a pronounced transequatorial inverted V-shaped chain 1–2–3–4 outlining a corresponding soft X-ray CH (Figure 1*f*) and crossed by chains 8–2, 5–6–7.

5 THE MAXIMUM OF THE 23rd CYCLE (2000)

At this phase of the cycle, the most complicated chain systems are observed both in the microwave and EUV ranges. However, the microwave chains are mainly longitudinal as before. The transequatorial microwave chains are present rather rarely in contrast to the EUV chains. In Figure 1*f*, one can see some quasi-longitudinal microwave chains 1–2–3–4, 9–11, quasi-meridian high-latitude chain branches 2–6, 4–5, 7–8, 10–12 and a not too long transequatorial chain 3–13. The system of EUV chains, shown in Figure 2*e*, extends throughout the whole disk, includes various chains and is so complicated that it is unreasonable and very difficult to mark concrete chains.

6 CONCLUSIONS

The analysis shows that the EUV chains and partly the microwave chains appear to be present in one or another form almost always at all phases of the solar cycle and to change their configuration and/or character of emission over the course of the cycle.

If one accepts the suggestion that the chains light up separators and quasi-separatrix layers in the global solar magnetosphere, the observed complication of the chains during the ascending and maximum phases of the present cycle is a signature and indicator of the corresponding complication of the global solar magnetosphere.

The differences between the cycle variability of the EUV and microwave chains, in particular concerning transequatorial and longitudinal chains, appears to be a consequence of different emission conditions and mechanisms responsible for the excitation of the EUV lines and generation of the optically thin centimetre radio emission.

It is clear that more detailed studies of chains are necessary.

Acknowledgments

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