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Large-Scale Shining Chains on the Solar Disk: Nobeyama Radioheliograph Data

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Abstract

Consideration of the Nobeyama radioheliograms at 17 GHz with a restricted range of the brightness temperature ($T_b \approx (5-20) \times 10^3$ K) revealed a novel phenomenon of the large-scale solar activity: long-living (days) and transient (hours) microwave shining chains of characteristic sizes comparable with the solar disk diameter and consisting of 30–60″ blobs.

Key words: Sun: large-scale activity — radio emission — soft X-ray emission — EUV emission

1. Introduction

The outstanding characteristics of the Nobeyama Radioheliograph (NRH) (Nakajima et al. 1994) allow us to study a variety of solar phenomena from small-scale features and local activity to global structures and transient events (e.g., Enome and Hirayama 1994; see also this issue). In this paper we outline and illustrate a novel manifestation of the large-scale solar activity: existence of extended (comparable with the solar diameter) blob chains shining at microwaves. These chains were discovered with NRH (Chertok 1997,1998a,b; Chertok and Shibasaki 1998) due to consideration of the radioheliograms with a restricted range of the brightness temperature (for example, of $T_b \approx (5-20) \times 10^3$ K). On such heliograms, the most intense sources are suppressed and the relatively faint features, as the chains, become pronounced (Figure 1). In all figures of this paper, the gray scale NRH images are presented in a negative (inverted) form, i.e. bright sources look as dark, and absorption features (radio filaments, in particular) look as light ones. It belongs also to the Yohkoh/SXT (Tsuneta et al. 1991) and SOHO/EIT (Delaboudinière et al. 1991) heliograms shown below.

2. Features of Microwave Chains

The chains consist of numerous blobs with angular sizes of 30–60″ and $T_b \sim (11-15) \times 10^3$ K. The undisturbed background Sun at 17 GHz has $T_b \sim (10.3-10.8) \times 10^3$ K. At least two types of the microwave chains should be distinguished. In the paper of Chertok and Shibasaki (1998), these chains were illustrated by the November 1-3, 1993 event. Here the events of October 30-31, 1992, May 11-13, 1993, and August 22-23, 1996 are given as illustrations.

The so-called *long-living chains* (Figure 2) exist and keep their general form for many days, have a global character, can cross the solar equator, stretch from one active region to other remote active regions/plages and rotate together with other features on the disk. The preliminary comparison with other solar images and maps gives clear examples in which the form and location of such long-living microwave chains coincide with sharp trans-equatorial boundaries of coronal holes (CH), observed with Yohkoh/SXT. They may outline also footpoint lines of some large X-ray arcades and correspond to the general picture of large-scale magnetic fields and filaments. In the latter case, the chains repeat the form of the corresponding filaments but are located at considerable distance from them. It means that the microwave chains are not counterparts of the inversion polarity lines of the large-scale magnetic fields.

The *short-living (transient) chains* (Figure 3) with a characteristic time scales of several hours are associated very closely with coronal mass ejections (CME) and post-CME energy release in the corona that are revealed, in particular, by long-duration events (LDE) in the soft X-ray and microwave ranges. In some cases, such LDEs are accompanied by strong changes of the form and location of the pre-existing long-living chains, especially near the LDE source. In other cases, new chains, extending of several tens of heliodegrees, arise also in an extended region near the LDE source. The transient chains appear to outline the large-scale structures involved in the processes of CMEs and post-eruption energy release.

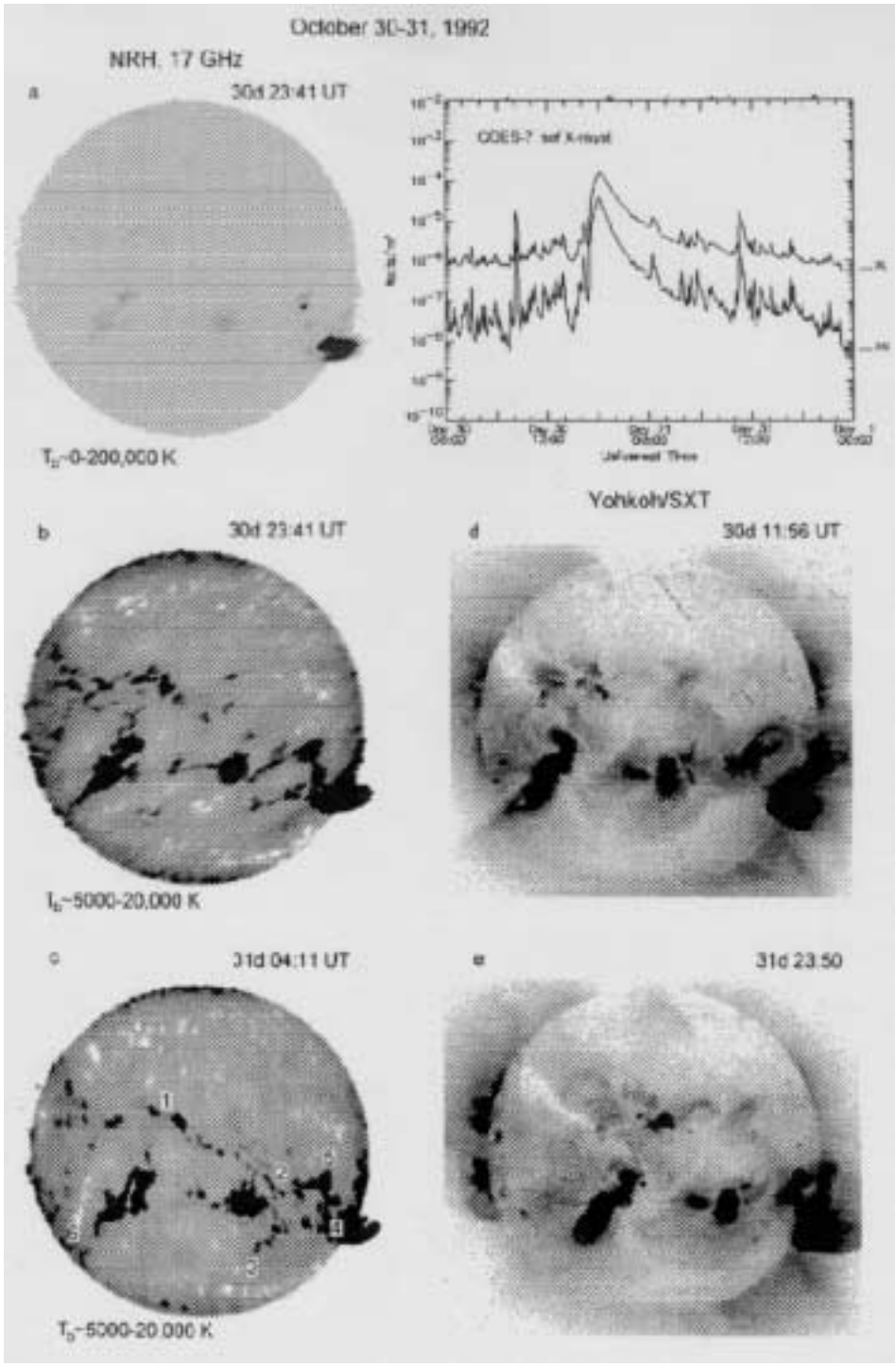

Fig. 1.. The October 30–31, 1992 images illustrating a technique of the revelation of the microwave shining chains. (a) – This NRH image is adapted to show a very bright loop-like source over AR 7321 near the SW-limb identified with the X1.7 soft X-ray LDE peaked on 30d at 17:30 UT (see the GOES-7 soft X-ray plot in the upper right corner). The rest relatively weak regions and features are hardly seen on this radioheliogram. (b) – The same NRH image, but in the restricted range of the brightness temperature of $T_b \sim 5000$–20000 K. This radioheliogram displays the blob groups and chains in the south hemisphere. The brightest sources are saturated. Here and hereafter, the white features are radio filaments. (c) – This modified NRH image shows some large-scale microwave blob chains and structures developing several hours later. The large shining chain 1-2-3 is predominant. A rhombus-like structure, outlined by points 2-3-4-5, evolved near the LDE source. Another large-scale closed blob structure developed later around the filament 6. (d) and (e) – Two Yohkoh/SXT images are presented for comparison.

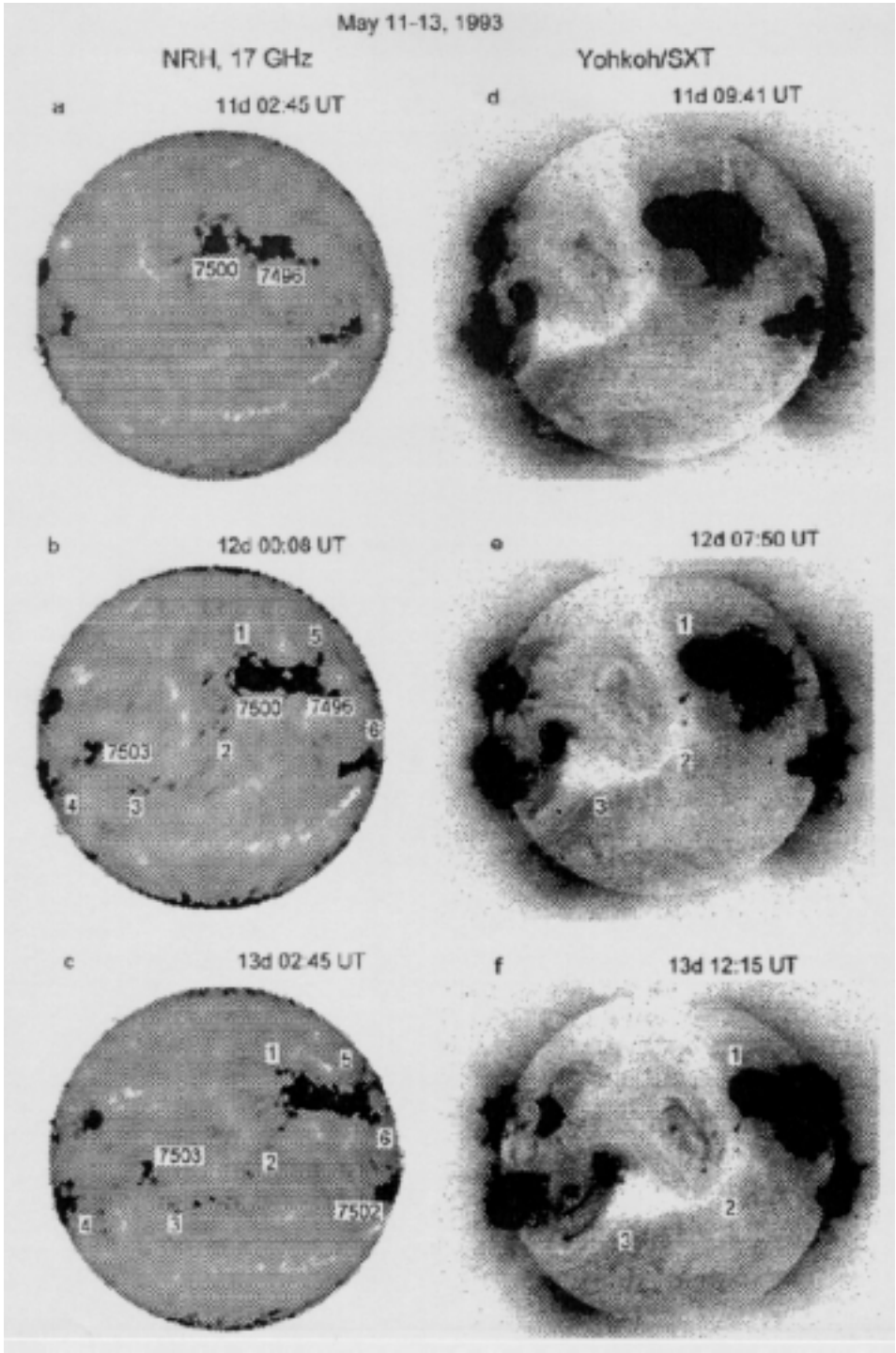

Fig. 2.. Appearance of the trans-equatorial long-living microwave chain of May 11-13, 1993. On 11 May (a), only some blobs and small chain fragments are present near the complex of ARs 7496 and 7500 located westward from the trans-equatorial coronal hole observed with the Yohkoh/SXT (d). On 12 May, after the C2.1 soft X-ray LDE event, peaked on May 11 at 21:52 UT in AR 7500 (see Figure 2), a trans-equatorial microwave chain 1-2-3 is being developed (b) along the narrow part of the coronal hole (e). The chain seems to go also from AR 7496 to the west limb (point 5) and then to AR 7502, as well as from point 3 through AR 7503 to point 4 near the south-east limb. This extended microwave chain, coinciding with the coronal hole (f), is clearly seen also on May 13 (c), as well as on May 14 and 15 (Chertok, 1998b).

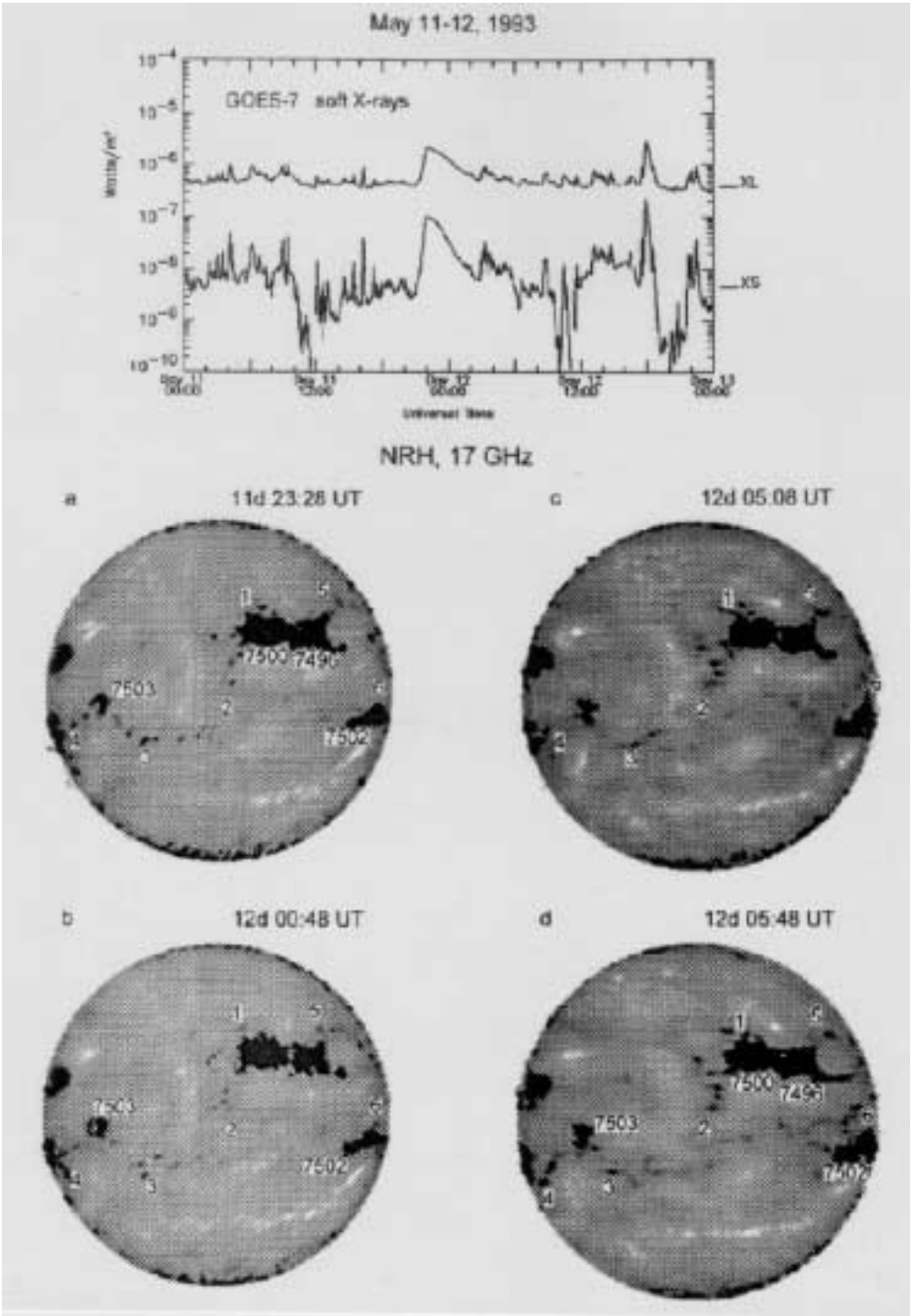

Fig. 3.. The transient microwave chain of May 11–12, 1993. The GOES-7 soft X-ray plot with the C2.1 LDE in the complex of ARs 7496 and 7500 (top). (a)-(d) – The chain 1-2-3-AR 7503-4 remains. An additional part of the chain is being developed from point 1a in the west and south directions to point 5 and AR 7502 (a,b). Several hours later (c,d), a new diffuse fragment of the chain, going directly from the south-west (5) to the south-east (4) limbs through points 2 and 3 can be seen.

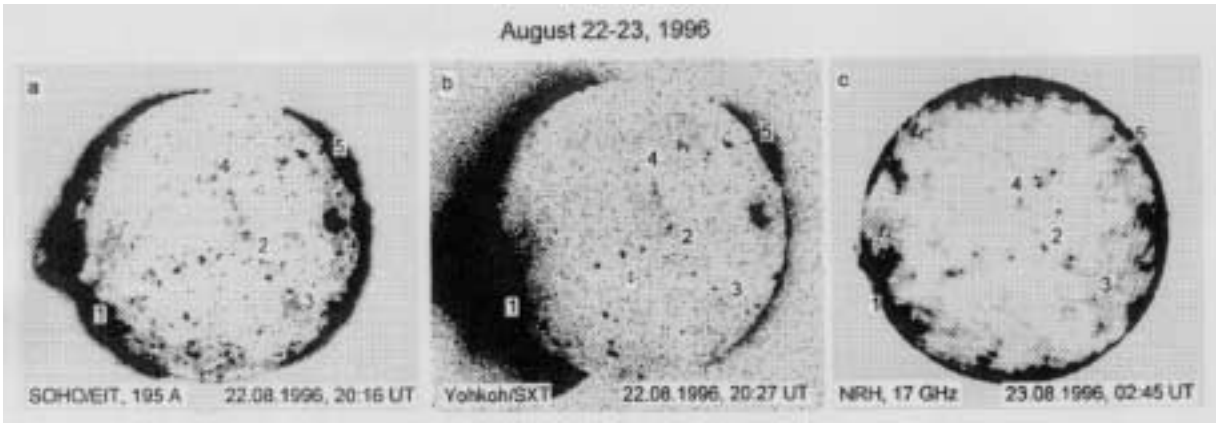

Fig. 4.. The Yohkoh/SXT (a), SOHO/EIT (b), and NRH (c) modified images of August 22 and 23, 1996 showing coinciding large-scale shining bright point chains 1-2-4-5 and 1-2-3 (see Chertok 1997,1998a,b). These chains appeared in several hours after a large loop-like CME observed with all three SOHO/LASCO coronagraphs above the east/east-south limb. The accompanying activity included the C3.6/1N LDE in the near-the-limb active region AR 7986 (point 1). Note that the NRH map belongs to the moment which is more than 6 hours later than the Yohkoh/SXT and SOHO/EIT images.

3. Concluding Remarks

The features of the microwave chains outlined above mean that some large-scale structures shine at microwaves as a result of energy release associated either with the long-term evolution of the large-scale magnetic fields or with disturbances identified with the CME/LDE events. In particular, some long-living chains can be identified with boundaries between open and closed magnetic structures. In the transient chains, the bright blobs perhaps are due to hot footpoints of the large post-CME arcades of loops. The most probable mechanism of the shine of the microwave blobs forming these chains is a thermal free-free emission.

The further analysis showed that the described large-scale shining chains are characteristic not only of the microwave range but of other ranges as well. The similar extended chains (and threads as well) have been found also on the modified images of the SOHO/EIT, Yohkoh/SXT, TRACE, and other space and ground-based telescopes (Chertok, 1997, 1998a,b,c) (see Figure 4). In particular, in the EUV (especially) and soft X-ray ranges, they appear to be still more typical and pronounced than at microwaves.

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