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Millimeter-radio, SOHO/EIT 171 Å features and the polar faculae in the polar zones of the Sun

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Abstract. In this work we study different manifestations of activity in the polar zones of the Sun in order to gain understanding on the phenomenon of enhanced radio temperature regions (ETR) at high solar latitudes. We have obtained simultaneous radio and optical data during 9 days in 1997. The radio data from the Metsähovi radio telescope, Finland, consisted of 37 GHz and 87 GHz solar maps. White light observations at the Kislovodsk solar mountain station in Russia were used to measure the coordinates of polar faculae groups and diffuse bright structures. We also compared our data with the 171 Å EUV SOHO/EIT images for the same time periods. We find the ETRs in general coincide with the relatively dark areas seen in the SOHO/EIT images. Bright structures in the SOHO/EIT maps are, in general, encircled by the polar faculae groups and diffuse bright structures visible in white light. Some of the EUV bright structures appear to be bases of solar plumes. Connections between ETRs and polar faculae are complicated; sometimes polar faculae groups and diffuse bright structures are situated around the ETR maxima or at their borders, sometimes we see the polar faculae groups distributed over the whole ETR area. Some faint ETRs appear to have no associated polar faculae. However, in general there is a correlation between the ETRs, the polar faculae groups, and the bright structures (bases of the plumes and some other features), indicating that they are different manifestations of the same underlying activity. It is possible that magnetic loops in the active areas, traced by the polar faculae, are responsible for the observed radio enhancements.

Key words. Sun: radio radiation; UV radiation; activity; faculae, plages

1. Introduction

Enhanced temperature regions (ETRs) in the radio emission from the polar zones of the Sun were discovered in the 1970's by Babin et al. (1976) and Efanov et al. (1980). In millimeter-wave maps the ETRs appear as extended regions superficially similar to the radio brightenings associated with sunspots and active areas of the Sun. However, the ETRs occur at high latitudes where no sunspots are seen. No one-to-one correlation with other solar activity has been found, and the problem of the polar brightenings is still unresolved. At cm- and mm- wavelengths the suggested counterparts have included coronal hole brightenings depending on magnetic field configurations (Kosugi et al. 1986; Gopalswamy et al. 1999), polar plumes (Gopalswamy et al. 1992), microwave enhancements superposed on limb brightenings (Shibasaki et al. 1997), diffuse brightenings, bright points and polar plumes (Pohjolainen et al. 2000); (Pohjolainen 2000).

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Unfortunately, we do not know the ETR emission mechanism, partly because we lack multifrequency observations for determining the radio spectrum. The quiet Sun emission at millimeter wavelengths originates from the chromosphere (Vernazza et al. 1981), and is mostly thermal bremsstrahlung. The enhanced radio emission could also be thermal bremsstrahlung from greater heights if the plasma density and temperature are high enough. However, if there is a correlation between the positions of ETRs and polar faculae, coronal holes, or plumes, with associated magnetic phenomena, nonthermal mechanisms may contribute to, or even dominate, the radio emission.

In our previous work (Riehokainen et al. 1998) we studied possible connections between ETRs and polar faculae. We believe that polar faculae, in some sense, may be considered as tracers of magnetic field structures. They are transient phenomena, detectable at high (40°–90°) latitudes in white light as slightly brighter areas than the rest of the solar photosphere, with sizes about 3–5 arcsec. Not very much is as yet known about their physics or their relationship to other phenomena. The polar faculae have

their own activity cycle; they are most numerous during the years of solar minimum (Waldmeier 1955; Makarov & Makarova 1996). Analyzing observations between 1982–1995, we found that while the yearly number of low latitude ETRs varied with the sunspot cycle, the number of high latitude ETRs peaked during the solar minimum and seemed to correlate with the polar faculae cycle instead. This result supports the suggestion that polar faculae and high latitude ETRs are connected, at least in a statistical sense.

In the present work we extend our study to simultaneous radio, optical and ultraviolet data in search of direct connections between ETRs and other polar activity. We have organized a campaign to obtain the first simultaneous observations of ETRs and polar faculae. The radio observations were done at the Metsähovi radio telescope (Finland), and optical observations at the Kislovodsk solar mountain station (Russia) during June and August 1997. In June 1997 observations at the radio telescope were taken at 37 GHz, and in August 1997 at 87 GHz. We compare the polar ETRs with polar faculae groups and diffuse bright structures. In addition, we use archived simultaneous SOHO/EIT 171 Å images, searching for different bright and dark features. Some of them are polar plumes. The so-called polar plumes are visible as radial structures at the solar limb in the SOHO/EIT images. They originate in unipolar magnetic flux concentrations, which lie on cell boundaries in the chromospheric network (DeForest et al. 1997). Some examples of polar plume identifications are shown in Fig. 1.

2. Observations

We obtained radio observations at the Metsähovi Radio Observatory during June 23–29 1997 at 37 GHz, and August 1–30 1997 at 87 GHz. During the same period polar faculae observations were done at the Kislovodsk solar mountain station. Due to weather, joint observations were obtained only during nine days: June 24, 25 and 27, and August 7, 8, 14, 24, 26 and 29.

The Metsähovi radio telescope has single dish with diameter 13.7 m. The spatial resolution at 37 GHz is 2.4 arcmin, at 87 GHz 1 arcmin. The quiet Sun brightness temperatures have been estimated to be around 7800 K at 37 GHz and around 7200 K at 87 GHz. The solar radio maps were made by scanning the Sun in right ascension, changing declination between the scans. The number of scans is 29. Each scan was divided into 91 points, corresponding to about 1/3 beam resolution. The resulting map thus has (91×29) data points. The resolution in brightness temperature varies between 22 K and 36 K. It can conveniently be expressed as a fraction of the quiet Sun level, which is determined from the A/D converter counts. Setting the quiet Sun level equal to one, the resolution corresponds to about 0.003. The details of the Metsähovi mapping method and error analysis for coordinate determination can be found in Pohjolainen et al. (2000).

Data from radio observations were limited to the latitude interval from 40° to 70° due to artificial limb darkening. We have excluded radio features below the latitude of 40°, which are related to sunspots and other solar activity (cf. Riehokainen et al. 1998). The artificial limb darkening (cf. Pohjolainen et al. 2000) limits our view to below the latitude of about 70° (and correspondingly in longitude). The sizes and the outlines of the ETRs are distorted near the zone of the artificial limb darkening. This must be kept in mind when interpreting the radio maps. For example, in Fig. 5 the Northern edge of the extended ETR complex is mainly defined by the limb darkening effect.

The optical observations in Kislovodsk were done with a refractor with a diameter of 10 cm. Observations of polar faculae were made at wavelength 4100 ± 250 Å. The solar disk diameter in the photographic plates is 8 cm. The resolution is 2–3 arcsec. From these observations we obtain the size of the polar faculae: a single polar facula has a typical size of 3–5 arcsec, while the polar faculae groups and diffuse bright structures have typical sizes of 5–20 arcsec. We measured the coordinates of the polar faculae groups and diffuse bright structures and the number of polar faculae in each group. We have focused on polar faculae groups instead of individual faculae, since the groups have sizes more comparable to the radio telescope beam size. We cannot exclude the possibility that the observed enhanced radio emission could be related to just one of the faculae within the radio beam; however, the best available indicator of activity in the scale of the radio resolution is the number of faculae.

It is important to notice that the polar faculae and diffuse bright structure data is also incomplete, especially at lower solar latitudes (40°–50°). Due to their relative weakness, as compared with the rest of the solar surface, these features are difficult to observe. They are most easily detected near the solar limb in the polar zones, outside the borders of our radio maps.

We also used images obtained from the SOHO/EIT instrument (Extreme ultraviolet Imaging Telescope) at 171 Å (Fe IX,X temperature 1.3 10^6). The EIT images were selected as close as possible to the radio observations. All EIT images were taken with filter Clear or Al+1. The EIT pixel resolution is 2.6 arcsec. In our study we have used 1024×1024 (full resolution) or 512×512 (half resolution) full Sun images. The EIT instrument is described in more detail in Delaboudiniere et al. (1996).

The time difference between the polar faculae observations, the radio observations, and the EIT 171 Å images was at most a few hours. During this time, the visible distribution of the polar faculae and diffuse bright structures may in some cases change considerably (due to relatively small lifetimes of the individual polar faculae). This is true for ETRs, too. The actual times for the different observations for each day are given in the figure captions. The positions of the various features have been corrected for solar rotation if the time difference to the EIT map exceeds one hour.

3. Correlations between different polar features

In this paper we concentrate on the features corresponding to ETRs in the northern solar hemisphere, as the north pole was more in view during our observing time. We found altogether 46 ETRs in the north polar zone, 7 ETRs at 37 GHz and 39 ETRs at 87 GHz. The difference between 37 GHz and 87 GHz results from a combination of three facts. 1) In June (37 GHz) we had only 3 days of joint observations, as compared to 6 in August (87 GHz). 2) The heliographic latitude B_0 in August is larger than in June, and therefore we could observe the north polar zone better. 3) The beam size of our radiotelescope at 87 GHz is less than at 37 GHz, and smaller radio structures can be detected.

The features seen in SOHO/EIT 171 Å images were classified as follows:

- DA — a dark area, smallest visible brightness, black in the figures;
- RD — a relatively dark area, grey in the figures;
- RD/DA — an intermediate case between DA and RD, consisting of DA and RD elements;
- BA — a bright area, white or quasi-white in the figures;
- RD/BA — an intermediate case between RD and BA, consisting of RD and BA elements.

This classification is based on the the visual ability of the human eye to separate areas with different brightness. We think that this classification is good enough for the comparison between the positions of the polar faculae groups, diffuse bright structures (white light), ETRs in radio, and areas of different brightness in the EIT 171 Å images. We have defined the border of an ETR as the contour at 0.5 of the peak value. For complicated radio structures with several maxima, the border between two ETRs is taken to be at the minimum level between the maxima.

3.1. June 24, 1997

Figure 1 shows that the polar faculae groups (the number indicates how many polar faculae form the group) and diffuse bright structures ("O") are located near or between the local bright areas (BA inside the relatively dark (RD) areas of the EIT 171 Å. The polar faculae and diffuse bright structures appear to avoid the dark areas (DA), and also do not coincide with the local bright areas (BA). As can be seen near the solar limb, the polar faculae groups and the diffuse bright structures are situated in the vicinity or between the bases of plumes.

The radio observations were done at 37 GHz. Only one ETR is present near the pole. It is relatively weak. Its maximum coincides with a dark area (DA) in the EIT image. The boundaries of this ETR partially coincide with the positions of the local bright features (BA).

At the boundary of the ETR we see a single polar facula.

3.2. June 25, 1997

The polar faculae groups and diffuse bright structures (Fig. 2) are near the local bright features (BA) of the EIT 171 Å image, but do not coincide with them. As a rule, they are situated in the relatively dark (RD) areas of the same image but avoid the dark areas (DA). The polar faculae groups and diffuse bright structures are located near or between the bases of the polar plumes, but do not coincide with them.

The radio observations were done at 37 GHz. Of the four ETRs, one (C) coincides with a RD/DA area and three (A, B, D) with RD areas. Each ETR appears to be either completely (B, D) or partially (A, C) surrounded by bright areas (BA).

In the case of B and C ETRs, we can see that there are some polar faculae groups and diffuse bright structures near their boundaries.

3.3. June 27, 1997

Figure 3 shows that the positions of the polar faculae groups and diffuse bright structures coincide with the relatively dark (RD) areas. They are situated near the bright features (BA), but do not coincide with them and also do not coincide with the the dark areas (DA) of the EIT image. Often, it is possible to notice that the polar faculae groups and diffuse bright structures are located near or between the bases of the polar plumes.

The radio observations were done at 37 GHz. We can see 2 ETRs (A, B). The maximum of the A feature is situated in the RD area of the EIT image, surrounded by more bright features (BA). B coincides with a RD/BA area, again surrounded by brighter features (BA).

Polar faculae groups and diffuse bright structures are found near the maxima of both ETRs.

3.4. August 7, 1997

In Fig. 4 we can see that the polar faculae groups and diffuse bright structures are located between the bright and the dark structures in the EIT 171 Å image. They are practically absent in the dark areas (DA), and do not coincide with the local brightenings (BA) of the EIT image. In the vicinity of the solar limb polar faculae and diffuse bright structures are found around the bases of the plumes or between them.

The radio observations were done at 87 GHz. We can see 5 ETRs (A, B, C, D, E) above 40° latitude. In each case the maxima of the ETRs coincide with the relative dark (RD) areas. The borders of the ETRs coincide with local brightenings (BA) of the EIT image.

Some polar faculae and diffuse bright structures are seen at the borders of the ETRs.

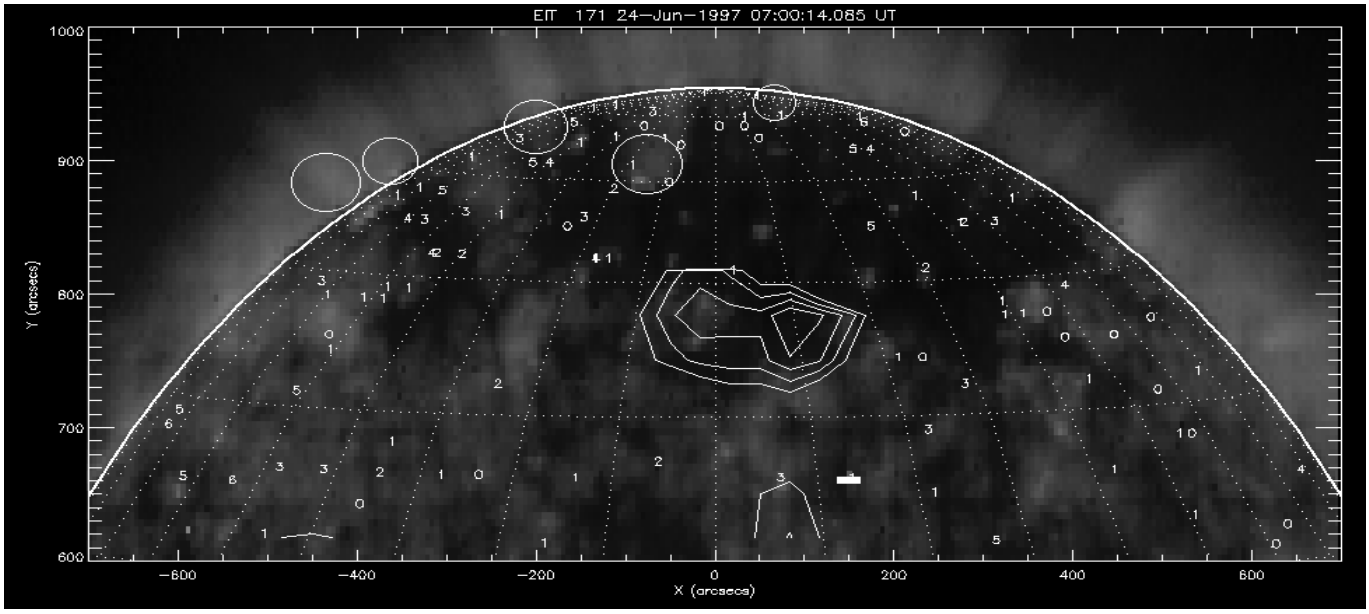

Fig. 1. The EIT 171 Å image at 07:00 UT on June 24, 1997. The superposed 37 GHz radio map at 08:00 UT has contours 1.0, 1.001, 1.002, 1.003 and 1.004 above the quiet Sun level (3770.0 A/D converter units). The polar faculae group positions (the numbers indicate how many polar faculae are in each group, with "O" indicating a bright diffuse structure) were observed at 08:49 UT

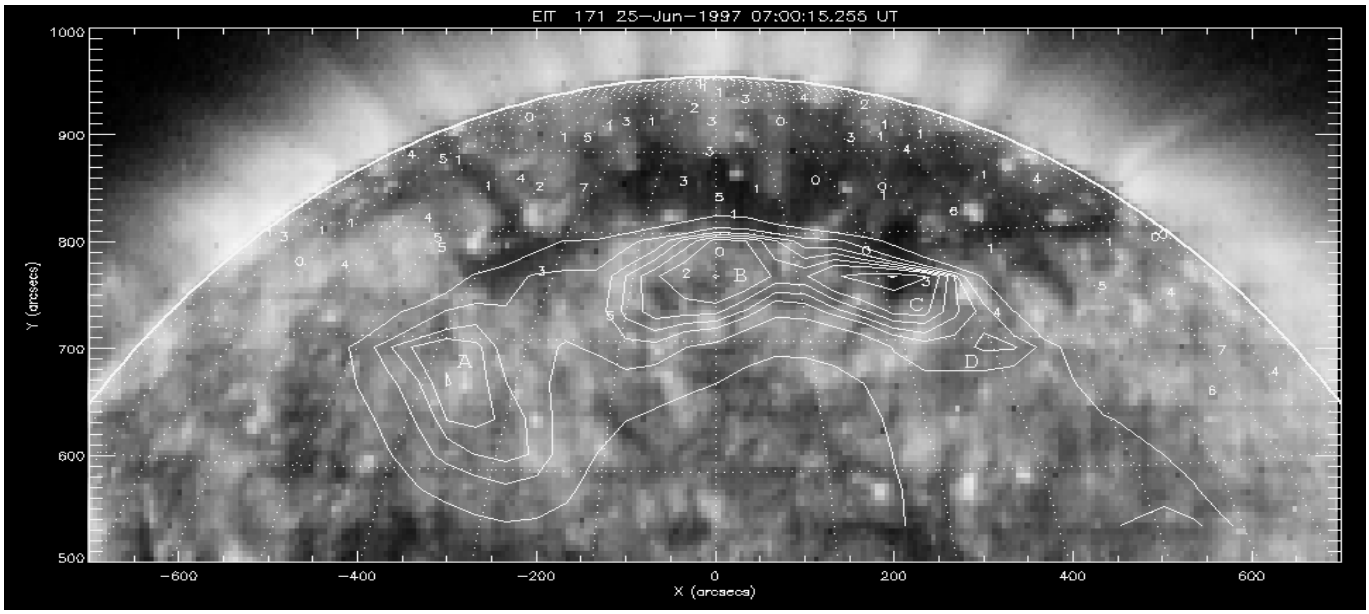

Fig. 2. The EIT 171 Å image at 07:00 UT on June 25, 1997. The superposed 37 GHz radio map at 10:26 UT has contours 1.0, 1.005, 1.007, 1.008, 1.009, 1.010, 1.012 and 1.013 above the quiet Sun level (3970.0 A/D converter units). The polar faculae group positions (the numbers indicate how many polar faculae are in each group, with "O" indicating a bright diffuse structure) were observed at 07:01 UT

3.5. August 8, 1997

Figure 5 shows that the polar faculae and diffuse bright structures are situated near the local bright (BA) or between the bright (BA) and dark (DA) areas of the EIT image. Usually they are in relatively dark(RD) areas. As in previous days, the polar faculae and diffuse bright structures are practically absent in the dark areas (DA), and do not coincide with the local brightenings (BA). Again, near the limb they occur in the vicinity of the plumes, but do not coincide with them.

The radio observations were done at 87 GHz. We can observe altogether 13 ETRs (A, B, C, D, E, F, G, H, I, J, K, L, M) above 40 degrees. The ETRs E, G, J, and L are weak. The peaks C, D, F, H, I, and K form a complicated structure. The ETRs A, C, K, E, and G coincide with relatively dark (RD) areas. D, H, and I coincide with dark

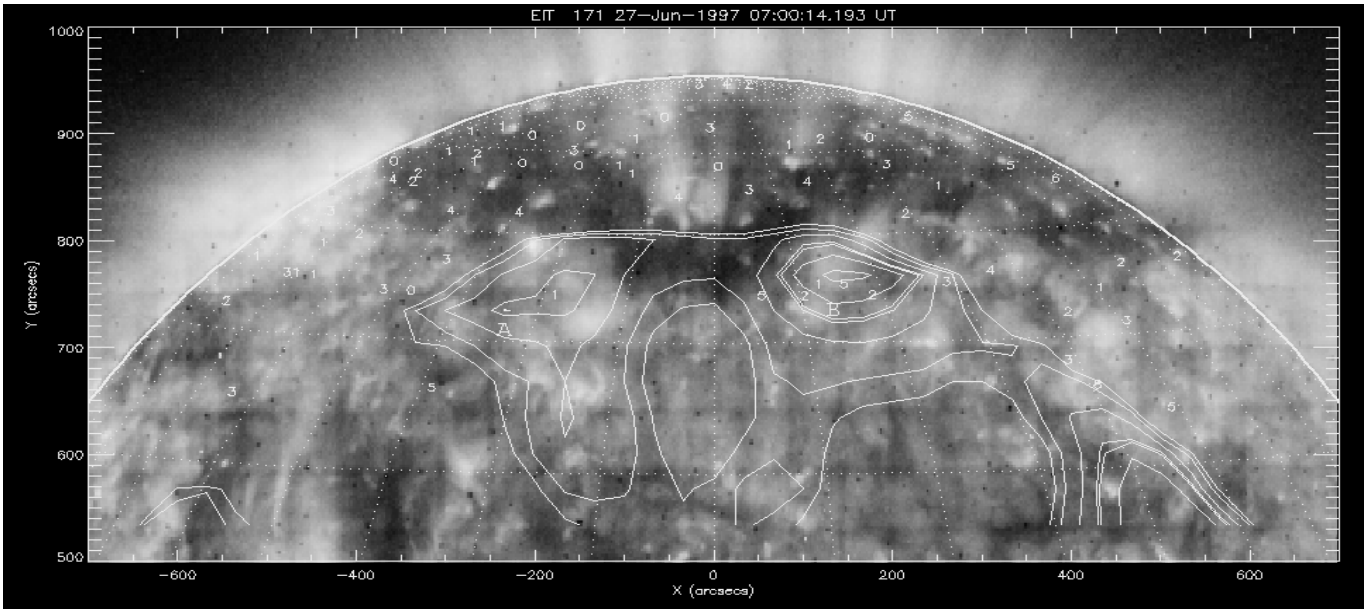

Fig. 3. EIT 171 Å UT 07:00 on June 27, 1997. The superposed 37 GHz radiomap at 08:00 UT has contours 1.0, 1.002, 1.005, 1.0075, 1.008, 1.01, 1.013 above the quiet Sun level (3980.0 A/D converter units). The polar faculae group positions (the numbers indicate how many polar faculae are in each group, with "O" indicating a bright diffuse structure) were observed at 03:07 UT

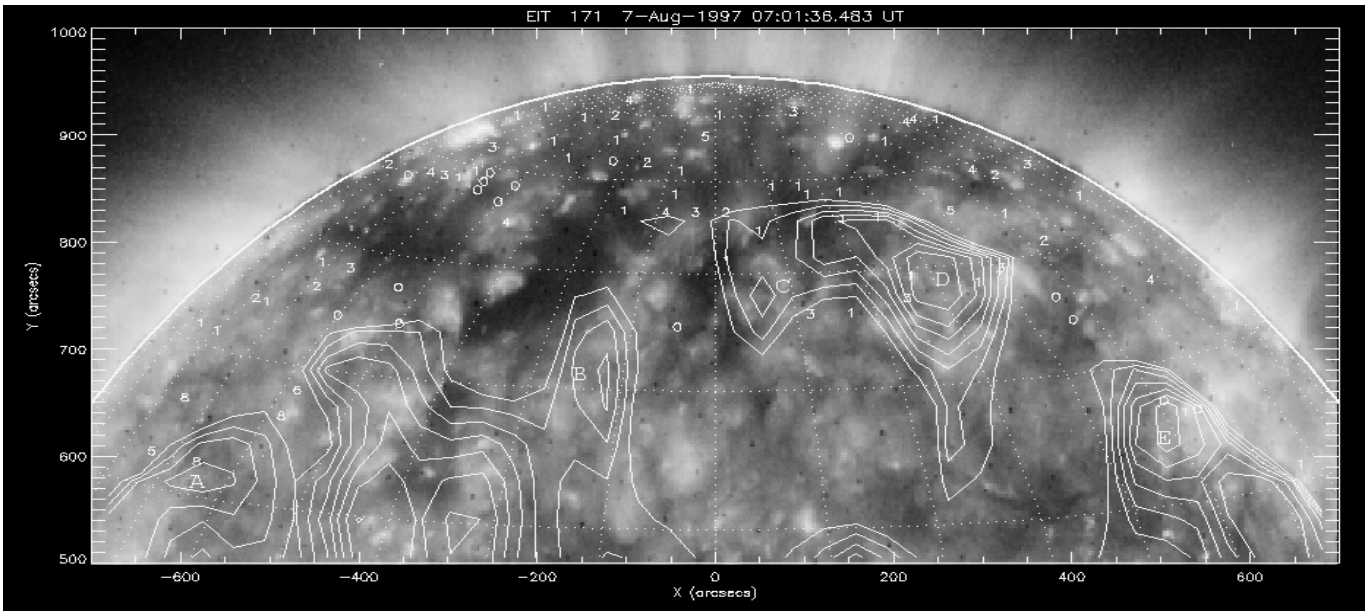

Fig. 4. The EIT 171 Å image at 07:01 UT on August 7, 1997. The superposed 87 GHz radio map at 08:30 UT has contours 1.0, 1.002, 1.004, 1.006, 1.008, 1.01, 1.0125 above the quiet Sun level (5460.0 A/D converter units). The polar faculae group positions (the numbers indicate how many polar faculae are in each group, with "O" indicating a bright diffuse structure) were observed at 03:11 UT

areas, and F, J, and M with RD/DA areas. L coincides with a RD/BA and B with a BA.

Polar faculae groups and bright diffuse structures are found near the borders of the extended ETR structure.

3.6. August 14, 1997

As Fig. 6 shows, the polar faculae groups and diffuse bright structures are found near bright features (BA), usually in the relatively dark areas (RD) of the EIT image. We do not observe polar faculae groups and diffuse bright structures in the dark (DA) or bright (BA) areas. Near the solar limb the polar faculae and diffuse bright structures are in the vicinity of the bases of plumes or between them.

The radio observations were done at 87 GHz. The single ETR in the northern hemisphere coincides with a RD/BA between two bright areas of the EIT image.

Along the border of the ETR we can see some polar faculae groups and bright diffuse structures.

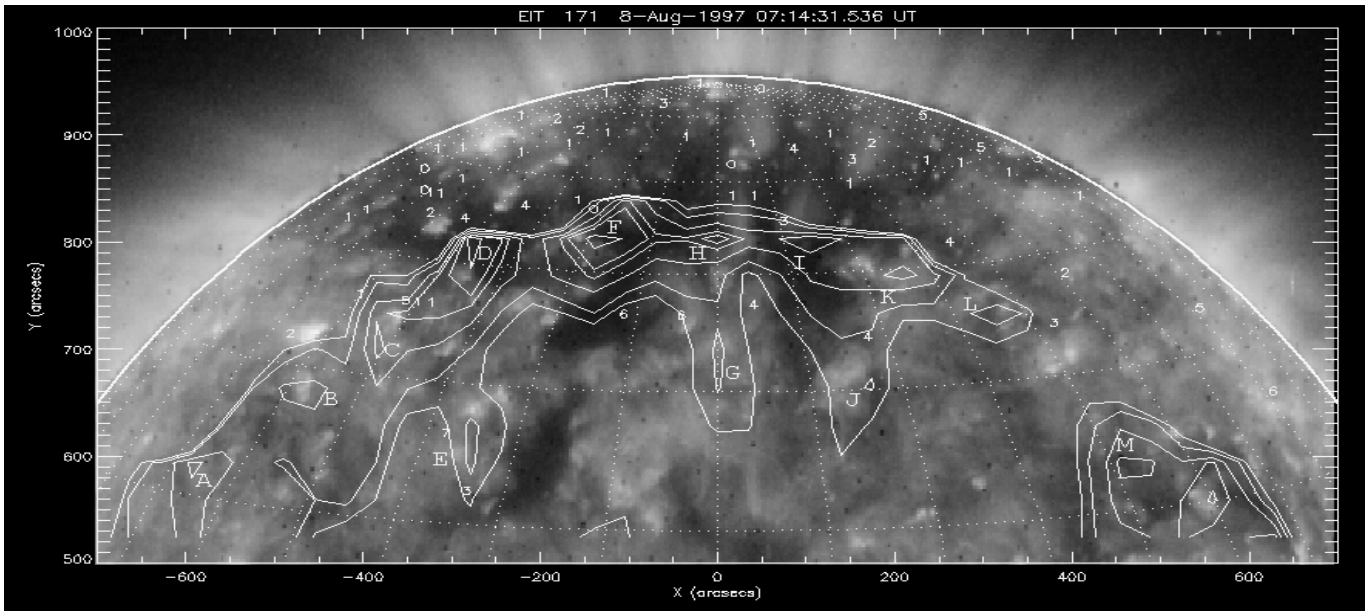

Fig. 5. The EIT 171 Å image at 07:14 UT on August 8,1997. The superposed 87 GHz radio map at 07:08 UT has contours 1.0, 1.002, 1.005, 1.007, 1.008, 1.01 above the quiet Sun level (5135.0 A/D converter units). The polar faculae group positions (the numbers indicate how many polar faculae are in each group, with "O" indicating a bright diffuse structure) were observed at 04:13 UT

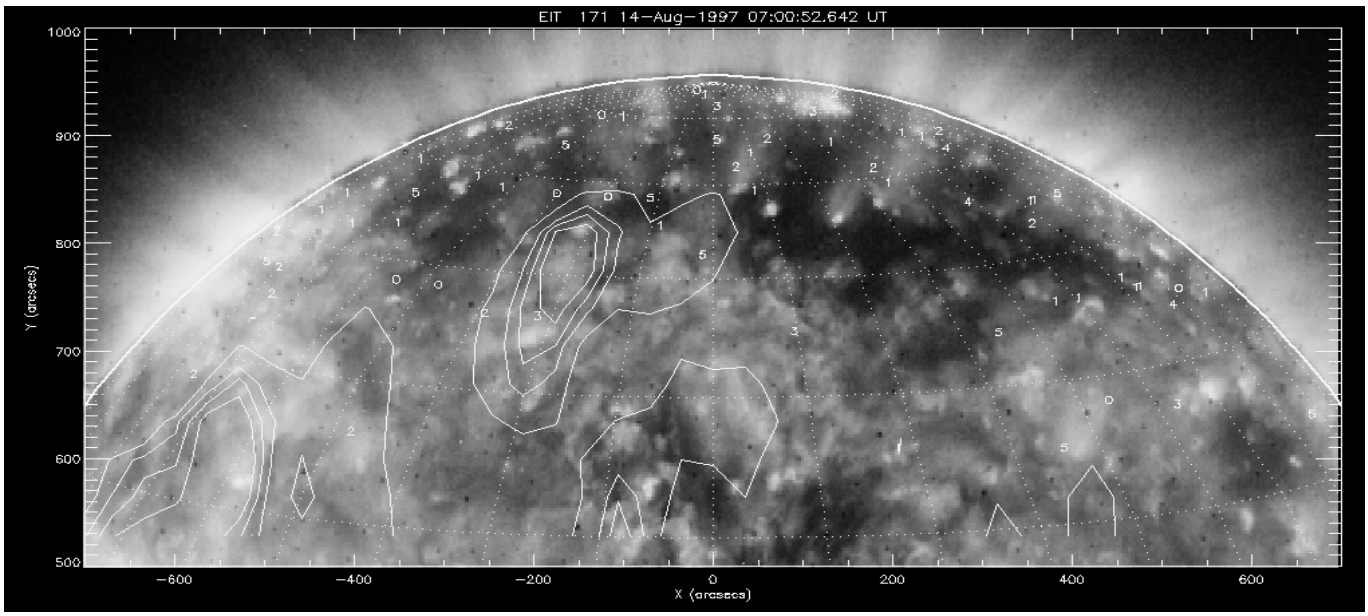

Fig. 6. The EIT 171 Å image at 07:00 UT on August 14, 1997. The superposed 87 GHz radio map at 07:41 has contours 1.0, 1.005, 1.0075, 1.01, 1.015, 1.02 above the quiet Sun level (5990.0 A/D converter units). The polar faculae group positions (the numbers indicate how many polar faculae are in each group, with "O" indicating a bright diffuse structure) were observed at 03:54 UT

3.7. August 24, 1997

In Fig. 7 we can see that the polar faculae groups and bright diffuse structures are situated near the local bright areas (BA) or between them, inside the relatively dark areas (RD) of the EIT 171 Å image. Near the solar limb the polar faculae groups and diffuse bright structures are located in the vicinity of the plumes or between them. The polar faculae and diffuse bright structures avoid both the dark and the bright areas.

The radio observations were done at 87 GHz. We see 8 ETRs (A, B, C, D, E, F, G, H) above 40°. The ETRs C, D, E, and G are weak. A coincides with a BA area. H and D coincide with RD/BA features. B, G, and E coincide with RD areas, C with a RD/DA area and F coincide with a dark area (DA) of the EIT image. A few polar

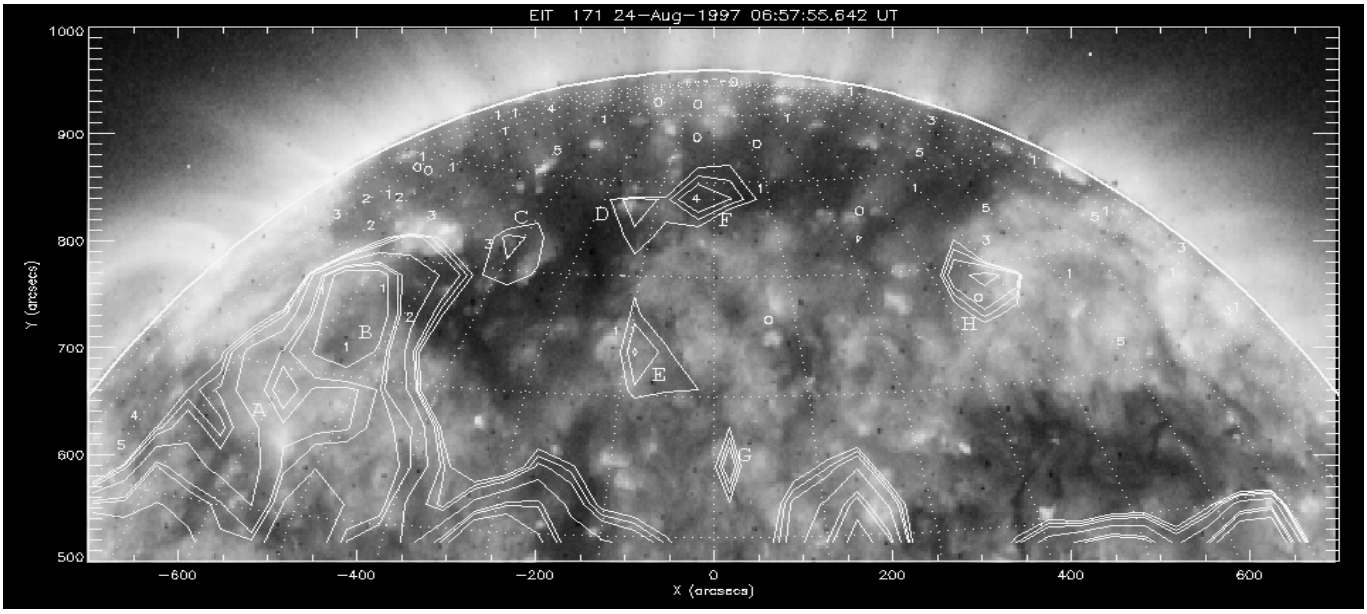

Fig. 7. The EIT 171 Å image at 06:57 UT on August 24, 1997. The superposed 87 GHz radio map at 08:13 has contours 1.0, 1.001, 1.002, 1.005, 1.009, 1.01, 1.0125 above the quiet Sun level (4730.0 A/D converter units). The polar faculae group positions (the numbers indicate how many polar faculae are in each group, with "O" indicating a bright diffuse structure) were observed at 05:31 UT

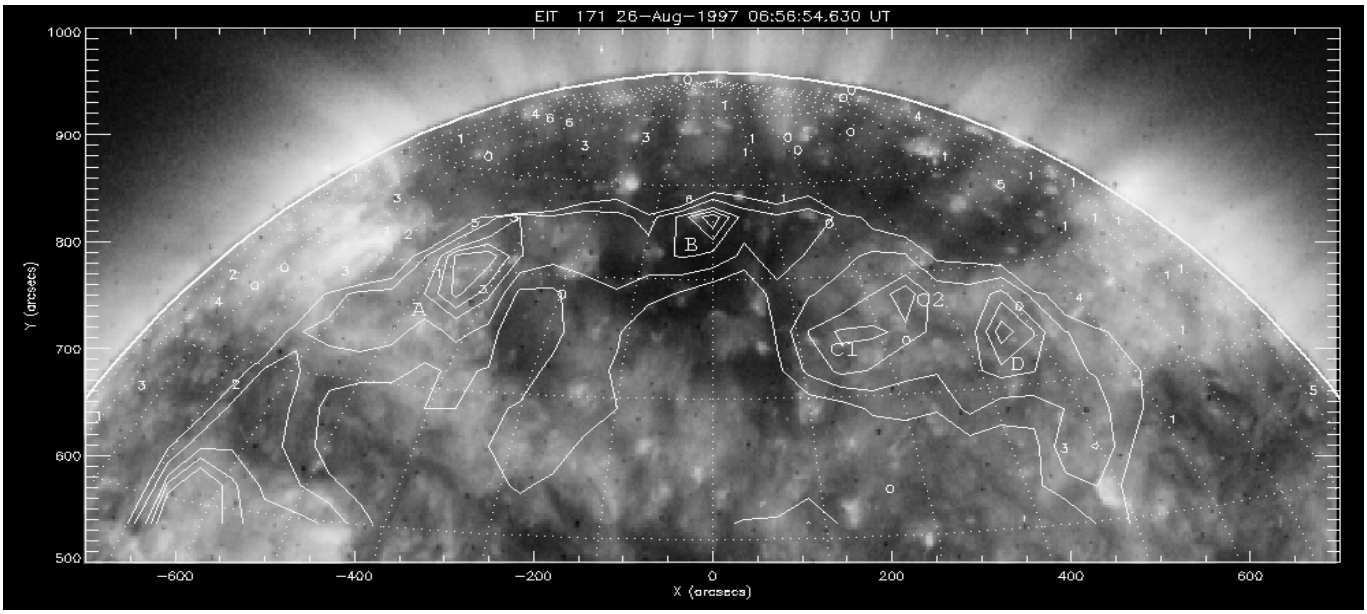

Fig. 8. The EIT 171 Å image at 06:56 UT on August 26, 1997. The superposed 87 GHz radio map at 06:50 has contours 1.0, 1.004, 1.008, 1.01, 1.012, 1.02 above the quiet Sun level (4120.0 A/D converter units). The polar faculae group positions (the numbers indicate how many polar faculae are in each group, with "O" indicating a bright diffuse structure) were observed at 04:12 UT

faculae groups and diffuse bright structures are seen near the borders of some ETRs.

3.8. August 26, 1997

Figure 8 shows that the polar faculae groups and diffuse bright structures are situated near or between the local bright areas (BA) of the EIT image. Usually they are inside the relatively dark areas or at local depressions of brighter areas of the EIT image. As in previous days, we do not see them in the dark or bright areas. The polar faculae and bright diffuse structures are near or between the bases of the plumes.

The radio observations were done at 87 GHz. We can see 5 ETRs (A, B, C1, C2, D). Together they form a very large complicated structure of radio enhancement. A, C1, C2, and D coincide with relatively dark (RD) areas of the

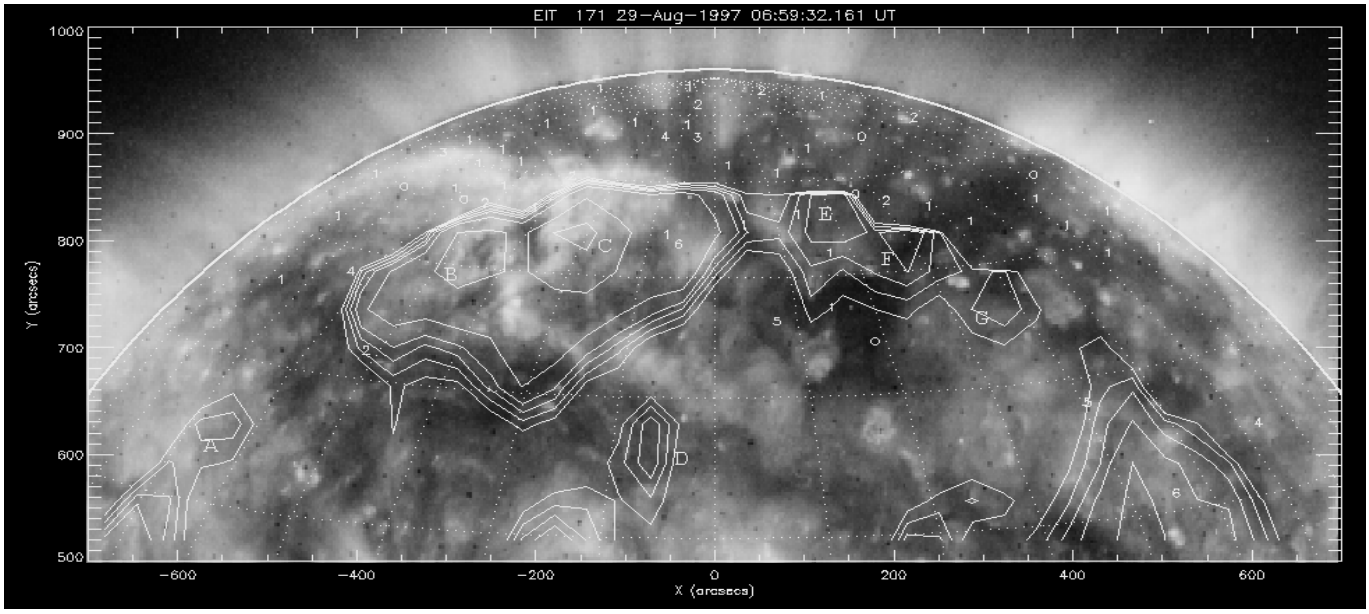

Fig. 9. The EIT 171 Å image at 06:59 UT on August 29, 1997. The superposed 87 GHz radio map at 07:04 has contours 1.0, 1.002, 1.004, 1.006, 1.01, 1.02, 1.03 above the quiet Sun level (3970.0 A/D converter count units). The polar faculae group positions (the numbers indicate how many polar faculae are in each group, with "O" indicating a bright diffuse structure) were observed at 04:40 UT

EIT image. B coincides with a RD/BA area. Between C1 and C2 we can see slightly brighter areas.

Near the borders of each ETR we can see polar faculae groups or diffuse bright structures.

3.9. August 29, 1997

As Fig. 9 shows, the polar faculae groups and diffuse bright structures are in general located around the bases of plumes in the relatively dark (RD) areas near the solar limb. On the solar disc they are located in the vicinity of local bright features (BA) inside the relatively dark areas. They are hardly ever seen in the dark areas, and also do not coincide with the local bright areas (BA). Even when we observe them in the relatively bright area (B and C), they are located in areas with local brightness depressions.

The radio observations were done at 87 GHz. We can observe 7 ETRs (A, B, C, D, E, F, G). A and G are weak. A, D, E and G coincide with RD areas. D and E coincide with RD areas, surrounded by slightly brighter features. The peak of B coincides with a RD/DA, but it is also surrounded with bright features. C includes areas of different brightness, but the maximum coincides with a RD/BA area. Between B and C we see an extended bright area. F coincides with a DA. Between F and E we can also see a slightly brighter area.

Near the borders of the ETRs some polar faculae groups and diffuse bright structures are seen.

4. Results

Here we summarize the results of our study of the enhanced temperature regions in the millimeter radio regime (8 mm/37 GHz and 3.5 mm/87 GHz), the features visible in the SOHO/EIT 171 Å images, and the white light polar faculae and diffuse bright structure positions during nine days in June and August 1997. It is always difficult to compare data with different resolutions and with additional other limitations (as described in Sect. 2), and any interpretation of the data for a single active area may be challenged. However, considering all the data from the nine days of observations, presented in Figs. 1–9, a consistent picture of the relationships between the radio, optical and EUV phenomena at high solar latitudes seems to emerge. The four observational main results are as follows.

1) At both 37 GHz and 87 GHz, the maxima of the mm-wave radio brightenings are mainly found in the relatively dark (RD) areas of the EIT 171 Å images. They tend to avoid both dark (DA) and bright (BA) areas. However, the ETR maxima are often completely or partially surrounded by bright features (BA) in the EIT image. Using the simple classification introduced earlier, the 46 ETRs found during the nine days were distributed as follows:

6 ETRs — dark areas (DA);

6 ETRs — intermediate (RD/DA);

25 ETRs — relatively dark areas (RD);

7 ETRs — intermediate (RD/BA);

2 ETRs — bright areas (BA).

2) In many cases the ETRs contain polar faculae groups and diffuse bright structures, or they are situated close to the ETR boundaries.

3) The polar faculae groups and diffuse bright structures are found near the bright features (BA) or between them at the relatively dark (RD) areas in the EIT 171 Å images.

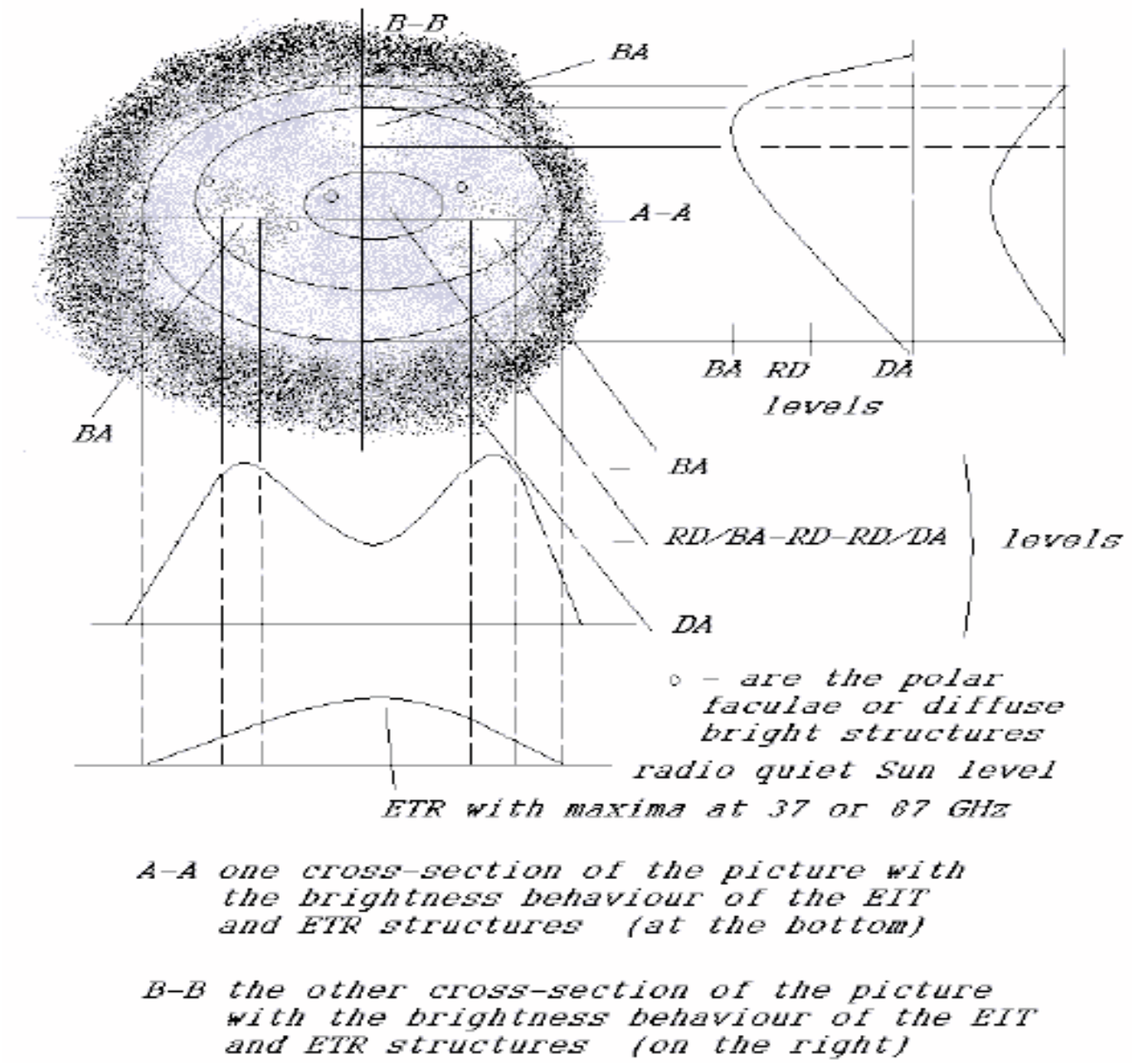

Fig. 10. A possible configuration for the polar faculae, diffuse bright structures, ETRs and different EIT 171 Å brightness features. The small circles mark the polar faculae or diffuse bright structures. Two cross sections (A–A and B–B) across the active area are shown, with the corresponding EIT brightness levels from BA to DA

4) Data from close to the solar limb shows that polar faculae and diffuse bright structures tend to be located near or between the bases of the plumes, visible as bright features (BA) in the EIT maps. Consequently, we can suppose that at least some of the bright features seen away from the limb also correspond to the bases of plumes.

A possible configuration for polar faculae groups, diffuse bright structures, polar plumes, ETRs, and different brightness EIT areas, consistent with the observed trends, is presented schematically in Fig. 10. According to our observations, at least some brightest areas in the EIT 171 Å images correspond to plumes, surrounded by polar faculae. The polar faculae and diffuse bright structures are inside or at the borders of the ETRs, and on the other hand they are located mainly in the relatively dark areas of the EIT images. The plumes or bright areas (BA) coincide with the ETR areas, but in general not with their maxima.

Our observations at millimeter wavelengths do not provide any direct evidence for either a thermal or a non-thermal origin for the ETR emission. However, inside and between the polar faculae groups complicated magnetic structures such as magnetic loops are likely to exist. The magnetic fields in polar faculae may reach kilogauss strengths (Homman et al. 1997). The existence of moderate or strong magnetic fields in the same area where ETRs

are located gives hints that ETRs are powered by gyrosynchrotron emission. If that is the case then the brightness of ETR is directly related to the strength of the magnetic field. As was shown by Nesterov et al. (1995), the parameters of the radio emission from local sources at 8–13.5 mm wavelenghts depend on the intensity of the magnetic field.

Our data, as sketched in Fig. 10, also indicates that the polar faculae groups and diffuse bright structures occur around the bases of the plumes or some other bright structures (BA). These phenomena must therefore be somehow connected to each other, but the physical mechanisms are as yet unknown.

Several of our maps give the impression that ETRs tend to occur at the southern edge of polar coronal holes. However, it must be kept in mind that due to artificial limb darkening we could not obtain radio data from the main polar coronal hole region above 70°, and the polar coronal holes did not cover much of the lower latitudes during the observing period. One therefore must be careful in drawing conclusions about the possible relationship between ETRs and coronal holes. A previous study (Pohjolainen et al. 2000) has found that millimeter-wave radio brightenings inside coronal holes are rare.

In summary, it seems likely that observed phenomena with a wide range of physical scales, such as polar faculae and plumes, result from complicated magnetic field structures. Magnetic field loops within these structures are plausible candidates for the observed radio temperature enhancements.

In order to form a more detailed picture of the polar zone active regions and to understand how the magnetic field structures cause the observed phenomena, we must obtain more polar faculae and millimeter radio data, supplemented by magnetic field SOHO/MDI and other SOHO/EIT line data, such as He II 304 Å and CaII K line data.

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