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Evolution of a Filament/CH/Magnetic Field Complex

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Abstract. SOHO and YOHKOH images, as well as Hα filtergrams and magnetograms from IZMIRAN have been used to analyze the evolution of the related solar phenomena – filament, active region, and accompanying pair of coronal holes – during six solar rotations, with an emphasis on the events observed during August–September, 1996. The whole complex has been considered against the large–scale magnetic fields calculated under the potential approximation. A peculiar point has been found along the changing filament. It is shown that the phenomena under investigation (filament, active region, and coronal hole) form a single complex connected with the magnetic field structure.

As shown by Mogilevsky et al. (1997), the large–scale magnetic field (LSMF), the related active regions (AR), and the coronal holes (CH) nearby form a single complex, united by the magnetic field. This result arises from observations, obtained in 1991, when the activity level was still high. In the present paper, the same complex is considered during a deep cycle minimum in the second half of 1996, when it was naturally isolated from the neighbouring active regions. As a rule, the evolution of an active region affects the structure and stability of an Hα filament, that represents the AR magnetic field topology. Most authors usually consider the formation, stability and decay of Hα filaments on relatively short time scales (e.g., Priest 1982, 1989). Since the lifetimes of LSMF+AR+CH complexes are sometimes several solar rotations, it would be interesting to analyze the evolution of the filament over such a long time interval both inside and outside the AR.

The AR complex under investigation (L=266, ϕ=10S) formed in early August, 1996 and existed during 4 solar rotations until it finally decayed in November, 1996. The analysis is based on solar images in different wavelength ranges from the SOHO and YOHKOH space missions, as well as from ground–based observations, obtained through the Internet. We have also used magnetic field and Hα data, obtained with the solar tower telescope at IZMIRAN.

The view of the complex on August 28 when the AR was at the center of the disk is shown in Figure 1. One can see an active region, Hα filaments, and two coronal holes. One of the holes (the Western CH) is well pronounced and extends far towards the North pole. The Eastern CH is less pronounced and extends towards the South pole. According to our concept, the complex in question consists of the above–mentioned AR, the filaments and the two coronal holes, united by the large–scale magnetic field. The Western CH persisted for only 4 solar rotations, whereas the Eastern one was more stable.

Figure 2 illustrates the large–scale radial magnetic field structure, calculated from the Stanford data (3 arc-min spatial resolution) for 6 successive solar

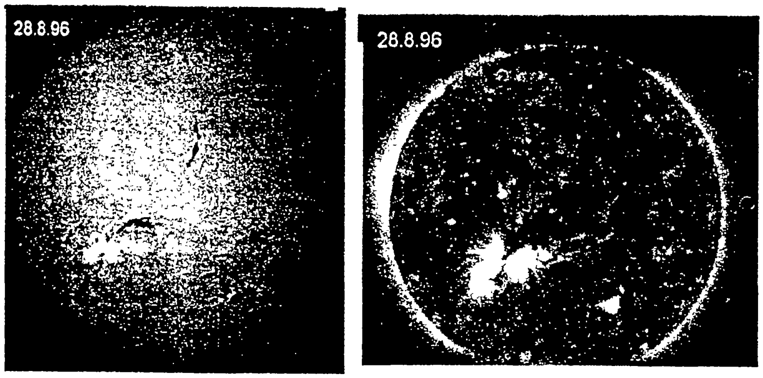

Figure 1. The August 28, 1966 complex: an Hα filtergram from Big Bear Observatory (left) and a solar image in FeXII 195Å from the SOHO EIT (right).

rotations. The maps are centered on the days corresponding to the passage of the complex near the central meridian. Circles mark the ends of the field lines calculated under the potential approximation and connecting the source surface at $2.5R_{\odot}$ with the inner sphere of unit radius (i.e., the photosphere surface). The calculation method is described in the literature (e.g., Hoeksema and Scherrer 1986 and Mogilevsky et al. 1997). Starting from the source surface, where the field lines are open by definition and the grid points are evenly spaced, we have traced every field line down to the photosphere and have found the coordinates of its intersection with the photosphere surface. The ends of the field lines at this level are not evenly spaced, but are clustered, determining the open configuration regions.

One can see that the ends of the open field lines in the photosphere are clustered at the locations of both coronal holes. In July, when the Western CH is not yet completely shaped, the open field lines end only at the Eastern CH. The same situation is observed in November, when the Western CH has already decayed and the Eastern one still exists. In Figure 3, we can see the configuration of the calculated open field lines for August 30.

Now, let us consider briefly the structure of Hα filaments and note some peculiarities connected with the evolution of the large–scale magnetic field and other active phenomena in the Sun.

1. Two filaments were observed inside the complex under investigation: one (in the Southern hemisphere) was obviously connected with the AR and another (in the Northern hemisphere) lay nearly parallel with the Northern part of the Western CH and, as suggested by the analysis of solar images, its behaviour was closely connected with that of the respective CH. The North filament disappeared at the end of the August rotation. The South filament existed during all six solar rotations, but in some periods in August and September it was very unstable, especially inside the AR. This instability is probably accounted for by CME activity (on the Eastern limb on August 22 and on the solar disk on September 25).

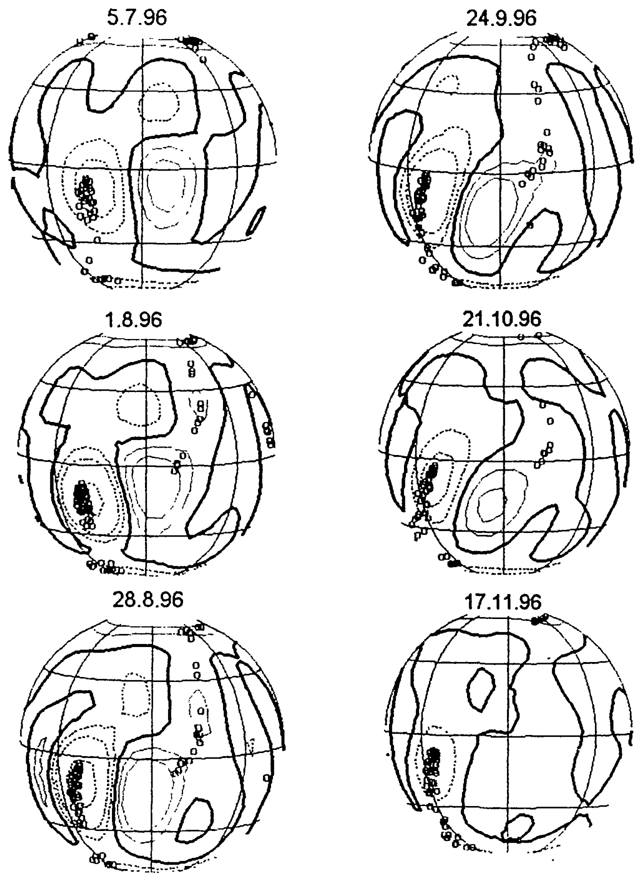

Figure 2. Large–scale radial magnetic field, calculated from the Stanford data for 6 successive solar rotations. The circles mark the ends of the open field lines.

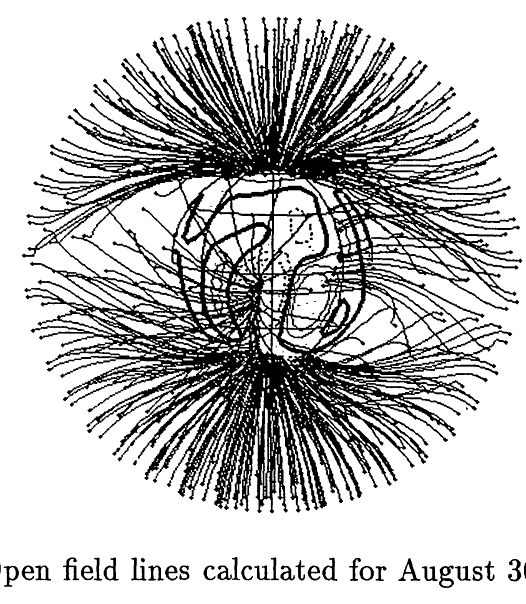

Figure 3. Open field lines calculated for August 30, 1996.

2. From the beginning of August to the end of October (3 solar rotations), the neutral line of the large–scale magnetic field near AR turned clockwise at an angle of about 45°, and so did the filament aligned with the neutral line. This rotation occurred about a certain part of the filament, rotating with a period of 27 days. We presumed it to be a region of solid–body rotation — the Pivot Point. The existence of such points was established by Mouradian et al. (1987). This hypothesis is corroborated by the Hα filtergrams for August 28–30. One can see a point of enhanced brightness at the filament discontinuity, that exists for 3 days, probably indicating the site of energy supply from subphotospheric layers.

3. The comparison between the Hα filtergrams and SOHO EIT images of the Sun in Fe XII shows that the quiet Northern part of the filament matches the region of reduced EUV radiation, whereas the active part of the Southern filament near the AR coincides with the strip of enhanced EUV radiation.

4. A comparison of the Hα filtergrams and the radio images of the Sun at 17 GHz from the Nobeyama Observatory shows that the stable parts of Hα filaments coincide with radio absorption regions.

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