ACTIVE REGION 9612 EVOLUTION

LILIANA DUMITRU, CRISTIANA DUMITRACHE

Astronomical Institute of the Romanian Academy
Str. Cuţitul de Argint 5, 040557 Bucharest, Romania
E-mail: lyly@aira.astro.ro, crisd@aira.astro.ro

Abstract. The active region 9612 was observed between 6 and 17 September 2001. Situated in the Northern hemisphere of the Sun, this region is closely linked to a filament evolution, forming together an interesting magnetic topology. We analyze the evolution of this active region and the explosive events that occurred during this period: the flares on 13 and 16 September, and a CME on 15 September 2001. We use ground-based observations and data from space (SOHO, Yohkoh).

Key words: Sun – active regions – filaments – magnetic fields – CMEs.

1. INTRODUCTION

Active regions are the main source of solar activity phenomena and are located in places with strong bipolar magnetic field intensity. Active regions include sunspots, faculae at the photosphere level, but they extend upwards to solar atmosphere layers where many other activity features, like flares or prominences, appear. Filaments or prominences could form inside the active region or in their neighborhood, to trace the polarity inversion line on the solar surface.

The active region NOAA 9612 (AR9612) was observed between 6 and 17 September 2001. It was situated in the Northern hemisphere (N22E40) and was closely linked to a complex sigmoid filament that evolved in its neighborhood (Fig. 1).

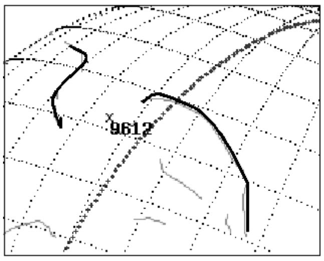

Fig. 1 – Position of the active region NOAA 9612 and a double sigmoid filament, on 6 September 2001.

Rom. Astron. J., Vol. **20**, No. 1, p. 27–34, Bucharest, 2010

2. THE ACTIVE REGION EVOLUTION

AR9612 is part of solar cycle 23, cycle that began in May 1996 and reached its peak in April 2000. This active region appeared after the maximum of the solar cycle and after the general magnetic field polarity reversal. We analyzed its evolution, along with the events occurred in this period: flares on 13 and 16 September, and a CME on 15 September 2001. In our investigation we have used observations from space (MDI/SOHO and EIT/SOHO for the period 7–16 September 2001) and ground based observations (H_α images from BBSO, for the period 6–17 September 2001). Fig. 2 displays the magnetic evolution of the active region as revealed by MDI magnetograms.

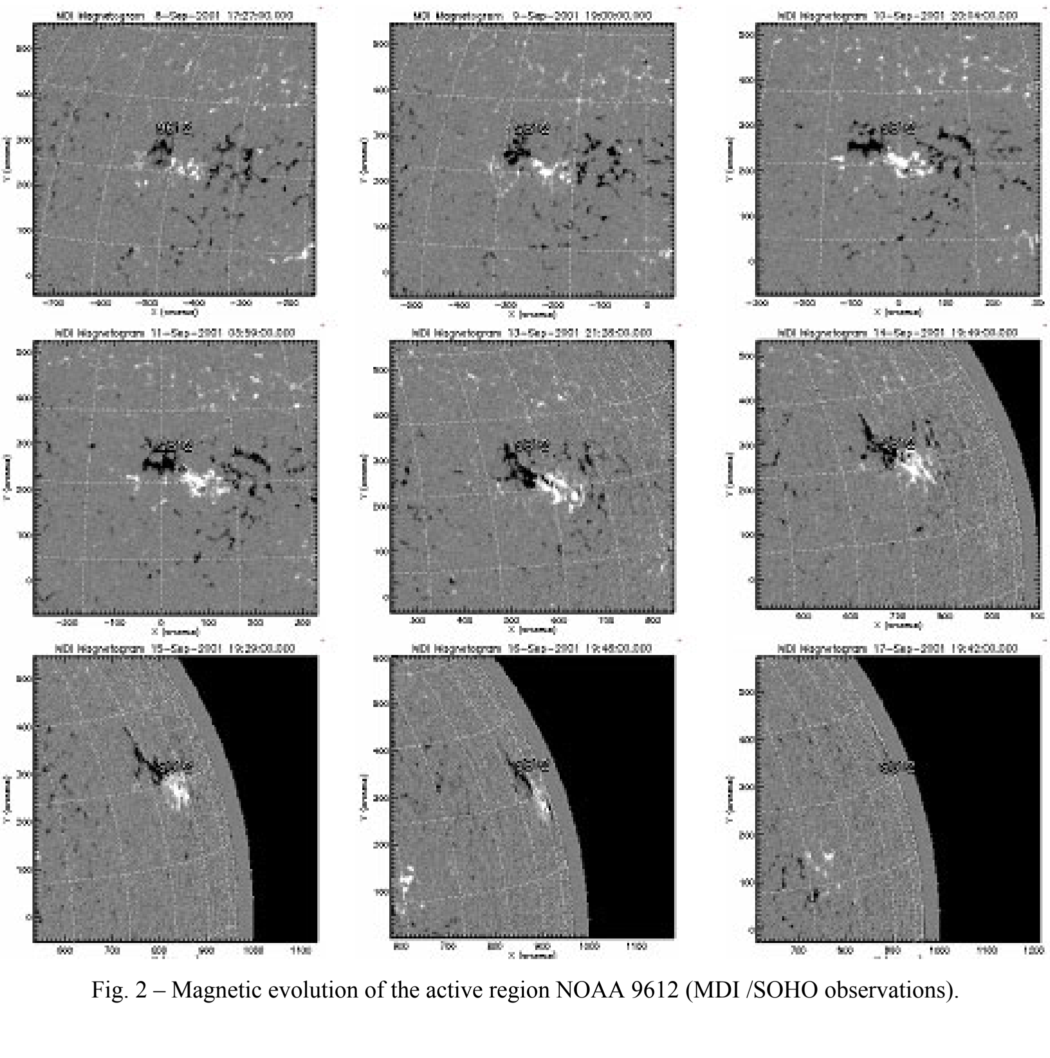

Fig. 2 – Magnetic evolution of the active region NOAA 9612 (MDI /SOHO observations).

We summarize below the AR9612 photospheric evolution:

– 6 September: Active region appears;
– 7 September: Beta region with some small sunspots;
– 8 September: Day when topology changes;
– 9 September: Beta region with some small sunspots;
– 10 September: Small beta region;
– 12 September: Medium-sized bi-polar region/beta sunspot group;
– 14 September: Small beta region;
– 13 September: Simple decaying beta region and the first day of the flare;
– 15 September: Small decaying beta region and day of CME;
– 16 September: Decaying beta region nearing the West limb and the next day of the flare;
– 17 September: Active region disappears.

To get a clearer idea of the evolution of the active region, in Fig. 3 we plotted the H_α chromospheric observations registered between 6 and 17 September 2001 at BBSO. We are therefore able to observe, on each separate day, all the stages that the active region is passing through, the strong link between the filament and the active region, and their position on the solar disk.

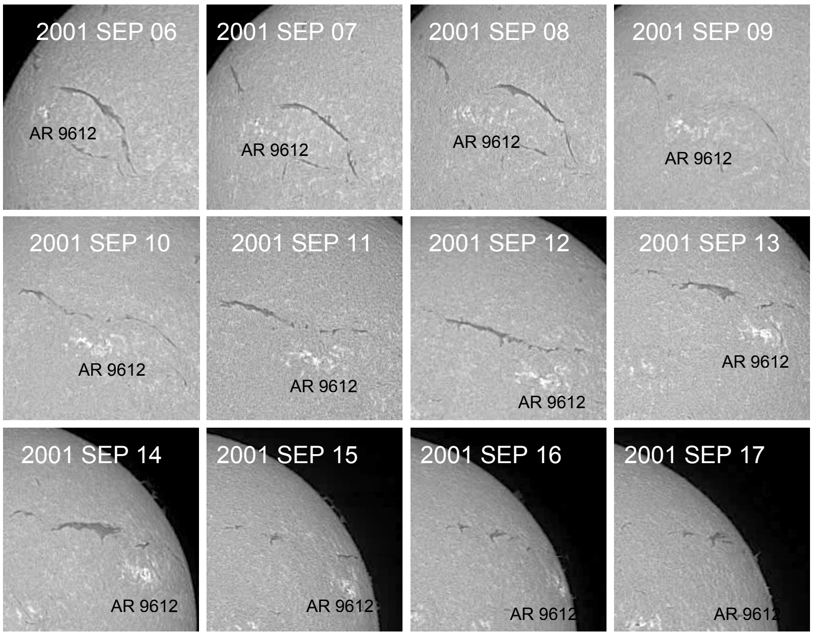

Fig. 3 – H_α observations between 6 and 17 September 2001.

We are interested in obtaining information from all the solar atmosphere layers. Therefore we have also investigated the coronal EIT/SOHO observations (they are displayed in Fig. 4).

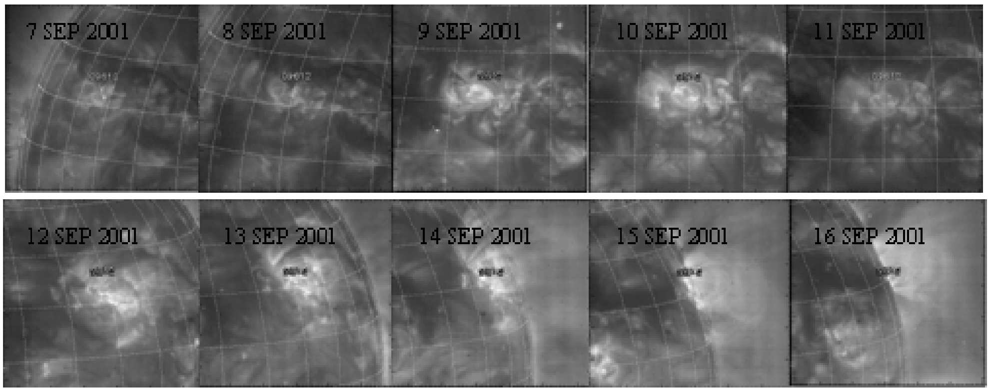

Fig. 4 – EIT/SOHO observations between 7 and 16 September 2001.

We note the occurrence of four flare events in AR9612. They are presented in Table 1, and outline the days 13 and 16 September 2001 as being important in the active region evolution.

Table 1

List of flares occurred in AR9612

2001 September 13						
Event	Begin	Max	End	Obs	Type	Loc/Frq
3590+	13:45	13:45	13:54	SVI	FLA	N19W36
3610	14:33	14:34	14:43	RAM	FLA	N20W36
2001 September 16						
4560	21:26	21:27	21:32	HOL	FLA	N19W80
4560	21:30	////	21:30	CUL	RSP	57-100

Another explosive event occurred on 15 September 2001, when a small coronal mass ejection was registered by LASCO/SOHO coronagraph. The images of this CME are presented in Fig. 5.

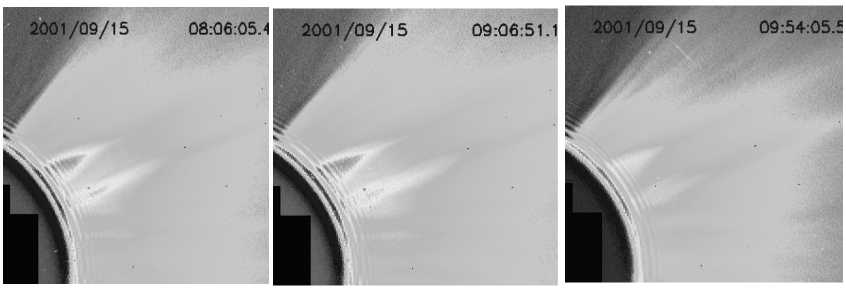

Fig. 5 – LASCO C2 images of the CME occurred in AR9612.

3. THE FILAMENT – ACTIVE REGION INTERACTION

The appearance of AR9612 is not spectacular, but what is noticeable concerns the magnetic topologies drawn by this active region and a neighborhood complex filament. The filament having a double sigmoid shape changed the position relative to AR9612 when one of its components erupted on 8 September 2001 and another one underwent a spectacular activation, as well as plasma flows, on 9 September 2001 (Dumitrache and Dumitru 2009).

Three parts compose the complex double-sigmoid filament: the lateral ends (denoted by A and B in Fig. 7 below) are polar filaments, and they form a complex together with a small active region filament (denoted by C in Fig.7). Filament C had a shape of a decumbent "3", surrounding AR9612. This complex could not remain stable and that it was. On 8 September 2001, the C filament component erupted, allowing the other two to rejoin and form a polar filament above AR9612. In order to understand the filament – active region interaction, we have studied the dynamics of the filament during the whole period. We have computed the filament dynamics expressed by the variations of the differential velocity values (w_i), tilt angle (u_i) and length (L_i). These variations are plotted in Fig. 6.

The sudden variations of these parameters indicate signatures of magnetic reconnections in the zone, as well as the structures destabilization. We computed the length and inclination on the solar parallel with the formulae (Dumitrache 1997):

$$L = \arccos(\sin\varphi 1 \cdot \sin\varphi 2 + \cos\varphi 1 \cdot \cos\varphi 2 \cdot \cos(L1 - L2))\,;$$

$$u = \arcsin\left(\frac{\sin\varphi 1 - \sin\varphi 2 \cdot \cos L}{\cos\varphi 2 \cdot \sin L}\right),$$

where ($\varphi 1, L1$) and ($\varphi 2, L2$) are the coordinates of the ends of the filament, while L represents the length of the filament computed as a great circle on a sphere and u is the angle made by the filament with the solar parallel. A necessary condition is that $L1 > L2$. It was noted that for $u < 0$ the filament is dextral and for $u > 0$ is sinistral.

Fig. 6, representing the filament parameters variations, indicates major changes occurred in the days of the year (DOY) 251, 253, 256, and 259, corresponding to 8, 10, 13 and 16 September 2001, respectively, i.e., the days of the magnetic topology changes between AR9612 and the filament and also the days when flares were observed. The differential rotation velocity of the filament underwent also variations on 15 September (DOY 258), when a CME occurred.

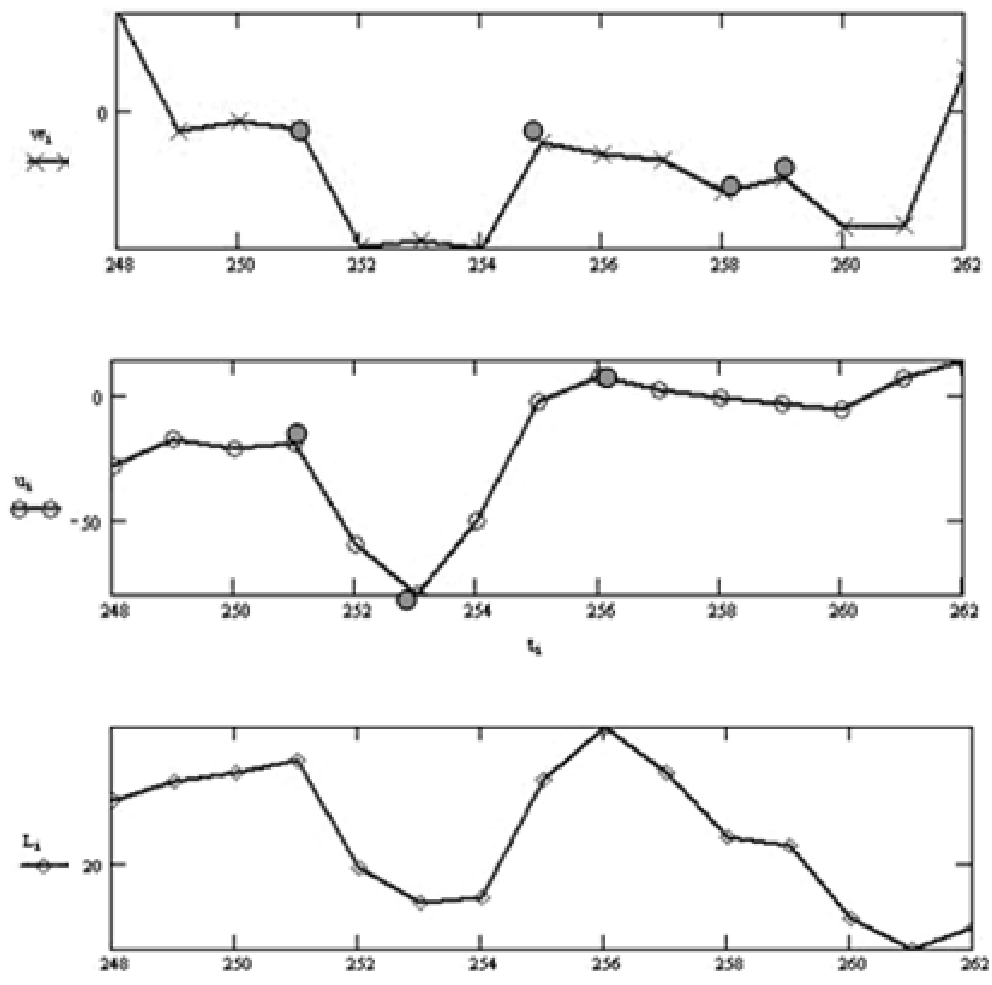

Fig. 6 – Variations of the differential velocity values (w_i), tilt angle (u_i) and length (L_i) of the filament. Circles mark the days when important events were registered.

On 8 September the active region changed its position with part of the complex filament, after the middle of this one erupted in a CME observable in EIT images. Initially the active region was located above the middle of the filament. Fig. 7 shows the filament, with a double sigmoid shape, surrounding AR9612. The middle of the filament channel (denoted by C in Fig. 7) was located under the active region, but after 19:12:30 UT a plasma movement occurred as result of the filament activation. After the CME the filament lateral sides jumped over the active region and reconnect to form a new polar filament. The arrows displayed in Fig. 7 indicate first the filament C, and then the point of re-binding of A and B filament components. We have discussed this phenomenon in detail in Dumitrache and Dumitru (2009).

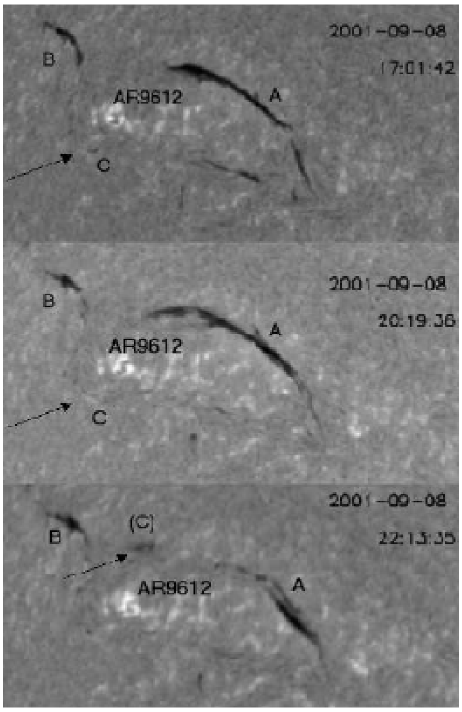

Fig. 7 – Active Region is above the filament channel (see text for details).

4. CONCLUSIONS

An unusual magnetic topology characterizes the evolution of AR9612 and the double-sigmoid complex filament: first, the active region is located above the C component of the filament and after a spectacular CME occurred on 8 September 2001 and then a plasma movement registered in the filament on 8 and 9 September, the active region shifted under the A+B complex filament. The phenomenon of filament junction, split, and re-junction, forming so-called “complex filaments”, is described by many authors (Dumitrache 1998; Schmieder et al. 2004; Aulanier et al. 2006).

Few flares occurred in AR9612 are registered after the large-scale magnetic reconnection, as well as a new small CME occurred on 15 September 2001. All these eruptive events could be seen in the dynamics of the filament (variations of its differential rotation, tilt angle with the solar parallel, and its length), proving that the filament evolution is very sensitive to the large-scale magnetic reconnections.

Acknowledgments. This research is carried out under the ESA-PECS Contract C98055. SOHO is a project of international cooperation between ESA and NASA. This paper was presented at the International Workshop "Recent Insights into Our Universe", Bucharest, 28–29 October 2009.

REFERENCES

Aulanier, G., DeVore, C. R., Antiochos, S. K.: 2006, *Astrophys. J.*, **646**, 1349.
Dumitrache, C.: 1997, *Solar Phys.*, **173**, 281.
Dumitrache, C.: 1998, in D. F. Webb, B. Schmieder, D. M. Rust (eds), *New Perspectives on Solar Prominences*, Astron. Soc. Pacific Conference Series, **150**, p. 221.
Dumitrache, C., Dumitru, L.: 2009, *Publ. Astron .Obs. Belgrade* (to appear).
Schmieder, B., Mein, N., Deng, Y., Dumitrache, C., Malherbe, J. M., Staiger, J., Deluca, E. E.: 2004, *Solar Phys.*, **223**, 119.

Received on 29 January 2010