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Solar Intranetwork Magnetic Elements: Evolution and Lifetime

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Abstract Based on *Hinode* SOT/NFI observations with greatly improved spatial and temporal resolution and polarization sensitivity, the lifestory of the intranetwork (IN) magnetic elements are explored in a solar quiet region. A total of 2282 IN elements are followed from their appearance to disappearance and their fluxes measured. By tracing individual IN elements their lifetimes are obtained, which fall in the range from 1 to 20 min. The average lifetime is 2.9 ± 2.0 min. The observed lifetime distribution is well represented by an exponential function. Therefore, the e-fold characteristic lifetime is determined by a least-square fitting to the observations, which is 2.1 ± 0.3 min. The lifetime of IN elements is correlated closely with their flux. The evolution of IN elements is described according to the forms of their birth and disappearance. Based on the lifetime and flux obtained from the new observations, it is estimated that the IN elements have the capacity of heating the corona with a power of 2.1×10^{28} erg s^{-1} for the whole Sun.

Keywords Magnetic fields · Photosphere

1. Introduction

The Sun is a magnetized plasma sphere, whose magnetic fields range from the large-scale sunspots down to the ephemeral regions (Wang *et al.*, 2000) and the small-scale network fields, down to the tiny intranetwork magnetic elements (Livingston and Harvey, 1975; Smithson, 1975). Therefore, an intranetwork magnetic element (IN element, hereafter) may be the ultimate small-scale and weak field structure, which distributes ubiquitously on the

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Sun and is known as ingredients of the "salt and pepper" structure (Wang *et al.*, 2006) and magnetic carpet. Solar surface magnetic fields are believed to determine, to some extent, various levels of solar magnetic activity. IN elements represent an important component of solar magnetism, and their properties are natural keys to understand many forms of solar activity. One wonders how the IN elements distribute spatially and temporally, what their forms are and how fast they evolve on the solar surface and so on. With better understanding of IN elements, it would be possible to disclose the role and contributions of the IN elements to the solar magnetism and activity, and to answer whether or not the IN elements can provide enough energy to heat the corona.

Based on the deep magnetograms from the ground-based observations of the Big Bear Solar Observatory (BBSO), IN elements have previously been studied (Martin, 1984; Zirin, 1985; Wang *et al.*, 1995, 1996). Stokes polarimetry data were analyzed by Keller *et al.* (1994) and Lin (1995). By following hundreds of IN magnetic elements in Big Bear deep magnetograms, Zhang *et al.* (1998b) were able to obtain an average lifetime of IN elements, finding 2.1 h. However, since IN magnetic elements are rapidly evolving, ground-based observations may have a limitation in the sensitivity and resolution in magnetic measurements. With the successful launch of the *Hinode* (Kosugi *et al.*, 2007) satellite on 22 September 2006, the Solar Optical Telescope (SOT, Tsuneta *et al.*, 2008; Suematsu *et al.*, 2008; Ichimoto *et al.*, 2008; Shimizu *et al.*, 2008) provides an unprecedented opportunity to study intranetwork magnetic elements with greatly improved sensitivity, spatial and temporal resolutions. It is natural and necessary to reexamine what the true lifetime of IN elements is and how they appear and disappear as shown in the *Hinode* SOT/Narrow-band Filter Imager (NFI) magnetograms with extremely improved spatial resolution. The reason for choosing the SOT/NFI observations as our database is to maintain as high as possible a temporal resolution and, at the same time, keep a large field of view in observations. This is a way to better determine the lifetime of IN magnetic elements.

In this paper, based on the *Hinode* SOT/NFI observations, we trace 2282 IN elements from their birth to disappearance in a quiet Sun region on 24 June 2007. In Section 2 we describe the data analysis. In Section 3 we present our measurements and results. Then, we estimate the contribution of IN elements in energizing the solar corona, and give discussions of our findings in Section 4.

2. Data Analysis

The Sun on 24 June 2007 is very quiet (see the left panel of Figure 1). A region near the solar disk center is observed by *Hinode* SOT/NFI filtergraph. Since the NFI data suffered a little damage near the observation center from blemishes in the filter, an uninfluenced subset at $\approx$ N02W07 (indicated by the black rectangle in the left panel of Figure 1) that is far from the polluted area is selected for this study. The right panel of Figure 1 is the same region as observed by *Hinode* SOT/NFI with the wavelength of Na I 5896 Å, and the wavelength offset from the line center is -200 mÅ. The data covered two time intervals, *i.e.*, 17:07 – 18:12 UT and 22:03 – 23:08 UT. The two 65 min sequences consist of 66 images each with the time interval of ≈ 1 min. The whole field of view (FOV) is 149×143 arcsec^2 with the resolution of 0.16 arcsec/pixel in the x and y directions. The sequenced NFI data were compensated for the solar rotation and observation error by the method of cross-correlation in this work, and were made into a movie from which the motion and evolution of each magnetic element can be traced.