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RELATIONSHIP BETWEEN DISTRIBUTION OF MAGNETIC DECAY INDEX AND FILAMENT ERUPTIONS

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ABSTRACT

The decay index n of a horizontal magnetic field is considered to be an important parameter in judging the stability of a flux rope. However, the spatial distribution of this parameter has not been extensively explored so far. In this paper, we present a delineative study of the three-dimensional maps of n for two eruptive events, in which filaments underwent asymmetrical eruptions. The corresponding n-distributions are both found to show that the filaments tend to erupt at abnormal regions (dubbed ABN regions) of n. These ABN regions appear to be divided into two subregions, with larger and smaller n. Moreover, an analysis of the magnetic topological configuration of the ABN regions has been also performed. The results indicate that these ABN regions are associated with a kind of special quasi-separatrix layer across which the connectivity of magnetic field is discontinuous. The presented observations and analyses strongly suggest that the torus instability in ABN regions may play a crucial role for the triggering of an asymmetrical eruption. Additionally, our investigation can provide a way of forecasting how a filament might erupt, and predicting the location for an asymmetrically eruptive filament to be split through analyzing the spatial structure of n.

Key words: Sun: activity – Sun: filaments, prominences – Sun: magnetic fields

1. INTRODUCTION

Solar filaments, as some of the most common structures in the coronal atmosphere, are often observed suspended in the hot and tenuous solar atmosphere for a long period (usually a few days to a few weeks; Parenti 2014). In a stable situation, they are generally considered as dense and cool plasmas supported by the coronal magnetic field, and are also observational evidence of magnetic flux ropes extending into the corona. Most filaments also manifest in more dynamical processes, namely filament eruptions. These fierce phenomena, with their intimate connection with flares and coronal mass ejections (see Low 1996), have been extensively studied over the last two decades (Forbes 2000; Lin & Forbes 2000; Zhang 2002; Hudson et al. 2006). In these studies, three phenomena are suggested to originate from the same physical process, which involves the reconnection of the magnetic field and the release of magnetic energy (Forbes 2000; Priest & Forbes 2002).

Filaments can erupt in different ways, including symmetric and asymmetric eruption, distinguishable by whether they exhibit a symmetric form during the eruptions or not. Eruptive filaments often show an asymmetric process of eruption, in which the filament splits away from one leg, with the other leg remaining fixed to the photosphere (Tripathi et al. 2006; Liu et al. 2009a). These observational characteristics of asymmetric eruptive filaments make them suitable and relevant for testing the validity of the eruptive models and the corresponding triggering mechanisms (Liu et al. 2009b).

Concerning the triggering mechanisms of filament eruptions, both theoretical and numerical studies indicate kink and torus instabilities as two possible candidates (Török & Kliem 2005; Kliem & Török 2006; Fan & Gibson 2007). Beyond that, it is also suggested that the magnetic decay index n (Bateman 1978), a gradient of the horizontal magnetic field decreasing versus the height, is crucial to ascertain whether the background magnetic field is vulnerable to a torus instability and whether a kink instability might develop into a filament eruption. According to the analyses of Bateman (1978) and Kliem & Török (2006), a critical index may be between 1.5 and 2, so we will take the middle value, i.e., 1.75, as the critical index in the present study. Observationally, many studies also indicate that n can be used to estimate the probability of the occurrence of a filament eruption (Liu 2008; Filippov et al. 2014). Recently, Zuccarello et al. (2014) reported an eruption initiated when the filament reached a critical height where the decay index had a larger value. However, the spatial distribution of this parameter has never been given adequate attention. Evidently, the spatial distribution of n is inhomogeneous because of the complex structure of the coronal magnetic field, which most likely has some influence on filament eruptions, especially the asymmetric ones.

In this paper, we investigate two asymmetric filament eruptions and carefully examine the spatial distribution of the decay index n over them. In order to have a clear understanding of the relationship between the spatial distribution of n and the studied filament eruptions, the topological configuration of the magnetic field has also been explored, and a model is proposed for this type of eruptive event. Our data and method are shown in the next section. The analysis is given in Section 3. Finally, a discussion and conclusions are presented in Section 4.

2. OBSERVATIONS

In order to probe the eruptive processes of filaments, we exploit images from the Atmospheric Imaging Assembly (AIA; Lemen et al. 2012) on board the *Solar Dynamics Observatory* (*SDO*; Pesnell et al. 2012). The AIA observations are taken at 12 s temporal cadence with a spatial resolution of 0.″6. In addition, images from the Extreme Ultraviolet Imager (EUVI; Wuelser et al. 2004) on board the twin *Solar Terrestrial Relations Observatory* (*STEREO*; Kaiser et al. 2008) spacecraft