Available online at www.sciencedirect.com

ScienceDirect

Advances in Space Research 52 (2013) 2122–2131

ADVANCES IN SPACE RESEARCH (a COSPAR publication)

www.elsevier.com/locate/asr

Investigation of N–S asymmetry of solar differential rotation by various patterns for solar cycles 20 and 21

M.Sh. Gigolashvili *, D.R. Japaridze, T.G. Mdzinarishvili

E.K. Kharadze Abastumani Astrophysical Observatory at Ilia State University, Kakutsa Cholokashvili Ave 3/5, Tbilisi 0162, Georgia

Received 30 March 2013; received in revised form 21 September 2013; accepted 25 September 2013
Available online 16 October 2013

Abstract

For solar cycles 20 and 21 the latitudinal variations of the solar rotation rates are found using data of the H_α filaments and the long-lived magnetic features of negative and positive polarities. Analysis of the data showed that: (a) there is N–S asymmetry in the equatorial rotation of the H_α filaments and the long-lived magnetic features; (b) for both solar cycles the long-lived magnetic features of both polarities have similar behavior; (c) in the solar cycle 20 the long-lived magnetic features of both polarities vary in phase to each other but show some difference during cycle 21. For the long-lived magnetic features of positive polarity the confidence level is lower than for those of negative one.

Keywords: Sun; Filaments; Magnetic patterns; Differential rotation; N–S asymmetry

1. Introduction

Investigations of the differential rotation of the solar atmospheric layers yield information on solar activity. Although there have been many studies of this phenomenon, the solar differential rotation is still unexplained. Data on the rotation velocities differ both for different solar structures, and given objects.

It is possible to explain the differences in the rotation velocity of solar structures by the action of different factors in various layers of the solar atmosphere. As for the disagreement among the data for the same kind of objects, this can be explained by the complexity of the phenomenon, and especially by the comparatively small difference in velocities, as well as the high noise level. In this regard, it is most important to use homogeneous data obtained over a sufficiently long period.

The N–S asymmetry in the solar rotation, as well as the temporal variation of solar differential rotation attracted the interest of scientists during last two decades. The N–S asymmetry in the formation of various structures on the solar surface has been studied in greatest detail for sunspots (Temmer et al. 2006), for sunspot areas (Chang 2007, 2008, 2009; Li et al. 2009a) and the whole solar activity (Li 2009; Li et al., 2009b, 2010b). North-south asymmetries in the distribution of H_α filaments, flares, solar faculae, the polar magnetic field, and coronal bright points on the solar surface have also been studied (Georgieva et al. 2005; Ataç and Özgüç, 2006; Brajša et al. 2005; Badalyan et al., 2008; Giordano and Mancuso 2008; Liu and Zhao 2009; Li et al. 2009a, c, 2010a, b).

There have been reports of the existence of N–S asymmetry in the solar differential rotation (Gilman and Howard 1984; Sheeley et al., 1987; Antonucci et al., 1990; Javaraiah and Komm, 1999; Gigolashvili et al, 2005a, b; Brajša et al. 2005; Badalyan et al., 2008; Sokoloff et al. 2008). However, these results sometimes differ and occasionally are contradictory.

* Corresponding author. Tel.: +995 32 223 10 26; fax: +995 32 223 40 21.
E-mail address: marina.gigolashvili@iliauni.edu.ge (M.Sh. Gigolashvili).

0273-1177/$36.00 © 2013 COSPAR. Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.asr.2013.09.032

Joshi et al. (2009) presented the results of a study of the spatial distribution and asymmetry of solar active prominences for the period 1996 through 2007. Their statistical study shows that the N–S asymmetry is more significant than the E–W asymmetry.

N–S asymmetry in three indices of solar activity has been found over five solar cycles (1945–2001). The reliability of these data has been confirmed by numerical tests conducted by sampling different numerical values of the parameters used (Sykora and Rybak, 2010).

The variations of solar rotation of the northern and southern hemispheres are in anticorrelation. Suggested period of these variations is 10–12 solar cycles (Zhang et al., 2011).

Chang (2011) found that distributions of sunspots can well be represented by the double Gaussian function for 1845–2009. When the northern (southern) hemisphere is dominant the width of the secondary component of the double Gaussian function in the northern (southern) hemisphere is about twice as wide as that in the southern (northern) hemisphere.

Hemispherical asymmetry is found in the intensity of heliospheric magnetic field and the location of the heliospheric current sheet. The received results well coincide with the earlier ones obtained by the Ulysses and Earth satellites (Mursula and Virtanen, 2012).

Identical variation trend in N–S asymmetry of the rotational cycle length and solar activity were found for 1945–2010 period (Xie et al., 2012).

Chandra et al. (2009) have shown that the solar corona rotates less differentially than the photosphere and chromosphere with a small gradient in the rotation rate.

Wöhl et al. measured the solar differential rotation by tracing small bright coronal structures (SBCS) in SOHO-EIT images. A more differential rotation profile of SBCS than that of sunspots and sunspot groups was found. The north-south rotational asymmetry of SBCS was interpreted with a model of the relationship between solar rotation and activity (Wöhl et al., 2010).

Rotation rates measured for the white light solar corona in the period 1996–2010 show large variations, which can vary considerably between latitudes, even between neighboring ones. Furthermore, for certain latitudes the periods are revealed when the movement is dominated by rapid structural reconfiguration without a coherent rotation (Morgan, 2011). On the other hand the angular rotation velocity of the solar corona measured by images of the AIA 094 SDO satellite appears dependent on heliographic latitude and it is a function of time also (Lorenc et al., 2012).

Javaraiah (2013) compared the solar cycle variations in the equatorial rotation rates of different features of various layers of the solar atmosphere. He obtained, that the coronal rotation is strongly connected to the rotational motion of the surface magnetic features. There is an agreement between the variation in the equatorial rotation rates of the sunspot-group and the plasma. The equatorial-rate variations determined from the Doppler-velocity data differs from those determined from the sunspot group.

The existence of a north–south asymmetry in the rotation of H_α filaments has been confirmed statistically (Gigolashvili et al., 2003). Changes in the solar differential rotation in the northern and southern hemispheres can be interpreted as oscillations with a 22-year magnetic period (Gigolashvili et al, 2005a; Japaridze et al., 2007; Vats and Chandra 2011). This kind of behavior has been discovered in compact magnetic features with negative and positive polarities except the time of polarity reversal on the solar surface (Japaridze et al., 2009). The variations of the equatorial rotation rates (A) and the latitude gradient coefficient (B) for $H\alpha$ filaments and the long-lived magnetic features with the negative and positive polarities were presented for the Solar Cycles 20 and 21 (Gigolashvili et al., 2013). It is possible to see that Hα filaments and the long-lived magnetic features reveal asymmetry in rotation rate for investigated period (1966–1985). We decided that the N–S asymmetry of rotation rates of the long-lived magnetic features with the negative and positive polarities needs further studies and it is the subject of our present investigations, carried out by improved statistical methods, than we used for $H\alpha$ filaments in earlier works (Gigolashvili et al., 2005b; 2007).

This article is a continuation of a study of the solar differential rotation for the purpose of investigating details of its temporal and spatial variations. This is done by means of a statistical analysis of data for different objects on the solar surface in order to discover a north-south asymmetry in the solar rotation.

2. Observational investigated data and results

In order to estimate the difference in the rotational velocities of different objects in the solar atmosphere, we compared data on H_α filaments (usually lying along neutral lines of the magnetic fields) and long-lived magnetic features during solar activity cycles 20 (1966–1975) and 21 (1976–1985).

2.1. Investigation of the H_α filaments

For studying the solar differential rotation we examined H_α filaments from the collection of H_α spectrograms at the Abastumani Astrophysical Observatory.

We selected relatively stable H_α filaments which did not change shape significantly and for which individual fragments could be identified. The quiet H_α filaments that we choose existed for more than 3 days and were not directly connected with active regions. The H_α filaments with the lifetime less than 3 days had not been measured because measurements of the differential rotations rate need at least three independent measurements of coordinates for subsequent few days. Measurements were carried out near the central meridian to avoid additional distortions of forms of filaments during the projection effects on the Sun's disk,