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Automatic Detection of Sunspots Size and Activity using Matlab

Noor Alhuda Kamel*, Ahmed Abdul-Razzaq Selman
Department of Astronomy and Space, College of Science, University of Baghdad, Baghdad, Iraq

Abstract

A study is made about the size and dynamic activity of sunspot using automatically detecting Matlab code "mySS .m" written for this purpose which mainly finds a good estimate about Sunspot diameter (in km). Theory of the Sunspot size has been described using equations, where the growth and decay phases and the area of Sunspot could be calculated. Two types of images, namely H-alpha and HMI magnetograms, have been implemented. The results are divided into four main parts. The first part is sunspot size automatic detection by the Matlab program. The second part is numerical calculations of Sunspot growth and decay phases. The third part is the calculation of Sunspot area. The final part is to explain the Sunspot activity during the end of 24^{th} solar cycle. The relationship between the number of Sunspot and the time evolution describe solar surface activity. Calculations made in this work focused on the period from 2010 till 2018. Results indicated that growth rate is found from the fitting velocity of Sunspots radius variation due to the time of Sunspots evolution. The Sunspots decayed in the period time (17-27 Aug 2011) and (14-25 Nov 2010) when using H-alpha images more than other years of the study, and the little variation in the size of the Sunspots happened in (03-14 Sep 2016) when using H-alpha images. Results of the third part showed Sunspots continued changing during the time of study. The explanation was that more spots appear at the beginning and the magnetic field is strong when the area of observed sunspots increased with time, and vice versa. Results of the fourth part showed that the Sun in 2018 was the least active in that period, and in 2014 it was at highest activity.

Keywords: solar physics, Sunspots, solar magnetic field, Sunspots activity.

الكشف التلقائي عن حجم ونشاط البقع الشمسية باستعمال الماتلاب

نورالهدى كامل حسين*، احمدعبدالرزاق سلمان
قسم الفلك والفضاء، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

تم إجراء دراسة حول حجم و نشاط البقعة الشمسية باستخدام الكشف التلقائي عن كود " Matlab mySS .m " المكتوب لهذا الغرض والذي وجد بشكل أساسي تقديرًا جيدًا لقطر للبقعة الشمسية (بالكيلومتر). تم وصف نظرية حجم البقع الشمسية باستخدام المعادلات ، حيث يمكن حساب مراحل النمو والاضمحلال ومساحة البقع الشمسية. تم تنفيذ نوعين من الصور ، وهما H-alpha و HMI magnetograms. يتم تقسيم النتائج إلى أربعة أجزاء رئيسية. الجزء الأول هو الكشف التلقائي لحجم البقع الشمسية بواسطة برنامج Matlab. الجزء الثاني هو الحسابات العددية لنمو البقع الشمسية ومراحل الاضمحلال. الجزء الثالث هو حساب منطقة البقع الشمسية. الجزء الأخير هو شرح نشاط البقع الشمسية خلال نهاية الدورة الشمسية الرابعة والعشرين. العلاقة بين عدد من البقع الشمسية وتطور الوقت تصف نشاط السطح الشمسي. ركزت الحسابات

*Email: noornoorkamel1994@yahoo.com

التي أجريت في هذا العمل على الفترة من عام 2010 حتى عام 2018. وأشارت النتائج إلى أن معدل النمو تم العثور عليه من سرعة تركيب تنوع الشعاع البقع الشمسية بسبب وقت تطور البقع الشمسية . تلاشت البقع الشمسية في الفترة الزمنية (17-27 أغسطس 2011) و (14-25 نوفمبر 2010) عند استخدام صور H-alpha أكثر من سنوات الدراسة الأخرى ، وحدث التباين الصغير في حجم البقع الشمسية في (03 -14 سبتمبر 2016) عند استخدام صور H-alpha. وأظهرت نتائج الجزء الثالث تغير البقع الشمسية أثناء وقت الدراسة. كان التفسير هو أن المزيد من البقع تظهر في البداية والحقل المغنطيسي قوي عندما تزداد مساحة البقع الشمسية المرصودة بمرور الوقت ، والعكس صحيح. أظهرت نتائج الجزء الرابع أن الشمس في عام 2018 كانت الأقل نشاطًا في تلك الفترة ، وفي 2014 كانت في أعلى نشاط.

1. Introduction

Sunspots are cooler active regions on the photosphere that emits a lower intensity of light in all directions. When concentrated magnetic field lines start to emerge from the photosphere directed outward toward the solar corona the sunspots developed. The isolating of the plasma within these field lines remained from the surrounding solar surface due to a condition called ‘frozen-in’ magnetic field [1]. The solar convection below the flux tube hampered by the orientation and force of the local magnetic field, resulting in fewer plasma particles within this region. Both pressure and temperature within the flux tube decrease while magnetic pressure keeps the flux tube from collapsing inward [2]. There is relation between the sun cycle and the number of the sun spots which the number of sun spots called 'The international sunspot number ' or 'Zürich number'. The number of sun spots is a quantity to measure the number of sunspot in the photosphere of the sun and there are groups of sun spots on the surface of sun. There is a relation between the solar cycle and the appearance of sun spots on the sun. The suns magnetic poles reverse every 22 years. This polar reversal is known as the solar activity so two sun spots occur at 11year intervals within each solar [3]. There is a relation between the sunspots and the flares, a solar flare is an intense burst of radiation coming from the release of magnetic energy associated with sunspots. Flares are our solar system largest explosive events. They are seen as bright areas on the sun and last from more minutes to several hours. Sunspots are regions of the suns photosphere caused by the solar magnetic disturbance while the flare is an eruption of plasma from the chromospheres of the sun that is caused by instance magnetic activity[4]. Sunspots are magnetic structures that appear dark on the solar surface. Each sunspot is characterized by a dark core called the umbra and a less dark halo called the penumbra. The presence of a penumbra is important to distinguish sunspots from the usually smaller pores. The sunspots has two parts the central dark part of the sunspots is the umbra and the outer part is the penumbra. The granular convection cells are the surrounding bright cells with dark boundaries [5].

Sunspots harbor magnetic fields which inhibit at least partially convection energy transport leading to the darker appearance of the umbra. The most strong plasma flow is observed in the penumbra dominated by the flow which is interpreted as a horizontal outflow pattern with velocities roughly in the range 2-6 km/sec. The magnetic field is almost vertical in the umbra. Forced by the exponential decrease of density and flux conservation the field lines spread out with height giving rise to a magnetic canopy[5].

The penumbra carries a significant of the total magnetic flux which makes it a deep structure as opposed to a shallow structure. Besides its large-scale structure that is stable on the time scale of days to weeks. The penumbra and umbra of sunspots appears to be organized on very small dynamic scales (0.1arcsec). We can assume that the magnetic field and its interaction with plasma flows are the main actors in producing and organizing this fine structure [1]. The sunspots sometimes are biggest to see them by telescope, and they only that recorded in an ancient times. To see those spots must be larger than about 5×10^4 km in diameter (four times than the size of the Earth). Most of this spot called naked eye sunspots are groups of spots that look like one large spot.

Sunspots display a large size distribution. Very large sunspots can often reach diameters of 6×10^4 km or more. Mainly large sunspots (or tight groups of smaller ones) are visible to the naked eye under clement conditions (just before sunset on a cloudy day) or when the brightness of the solar disc is reduced with the help of filters. The smallest sunspots are roughly 35×10^2 km in diameter making them smaller than the largest pores, whose diameters can be as large as 7 mm[3].

2. Details of Present a Matlab Code

A Matlab computer code was written in this paper with the help of the supervisor in order to automatically calculate the size of sunspot. The code name is "mySS .m". It uses three parts:

1-The function my-sun-spot.m, which is a modified function from the original Matlab example file ipexradius.m. It is used to determine the solar radius from the image automatically. The actual sun radius is 6.94×10^7 km as shown in Figure-1.

2-The function dri.m which determines the region of interest where the sunspot exists from the image.

3-The main program which determines the sunspot region's area. Figure the size of sunspot is given in pixels and kilometers as shown in Figure-2.

The size of sunspot is found from a simple arithmetic procedure. The solar size is used to find the coefficient P which is the ratio between the radius of the real sun in km units to radius of the real sun in pixels. Then:

$$\boldsymbol{P} = \frac{\boldsymbol{Radius\ of\ the\ real\ sun\ in}\ (\boldsymbol{km})}{\boldsymbol{Number\ of\ pixels\ in\ the\ image\ of\ the\ sun}} \quad \ldots\ldots\ldots\ldots\ldots..(\mathbf{1})$$

After calculating the radius of the sunspot K from the image in pixels, the radius of the sunspots in km is:

$$\boldsymbol{R_{sunspot}} = \boldsymbol{P} * \boldsymbol{K} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(\mathbf{2})$$

$\mathrm{R_{sunspot}} =$ The radius of sunspot in in km.

P= the ratio between the radius of the real sun in km units to the radius of the real sun in pixels.

$K =$ The radius of the sunspot from the image in pixels

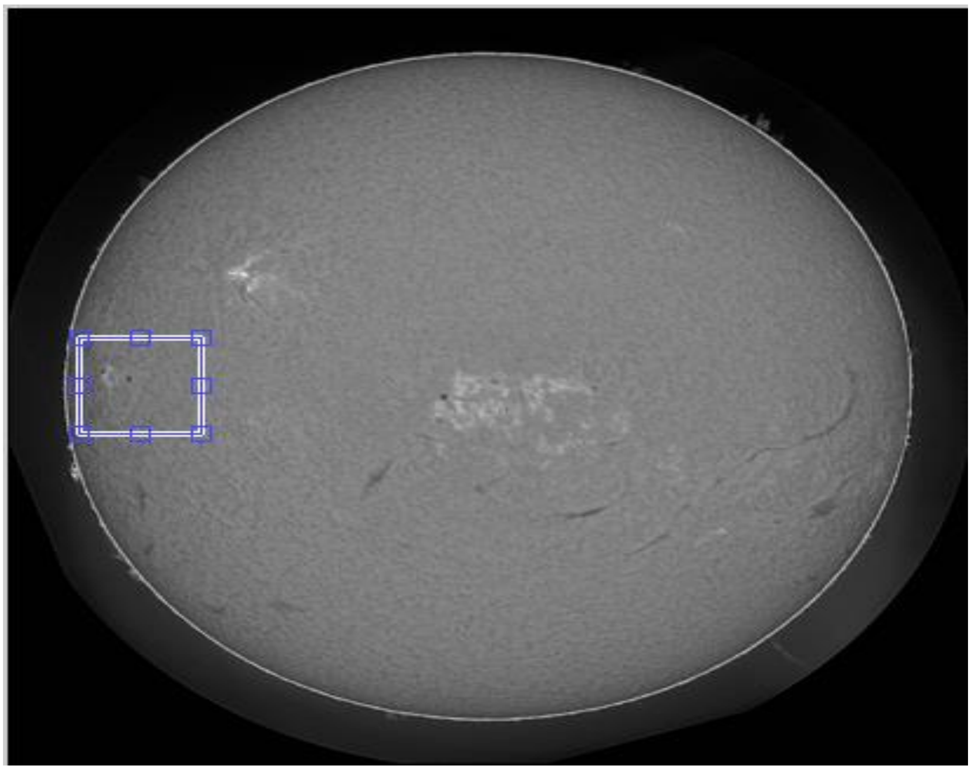

Figure 1-The result of my-sun-spot.m function . The solid frame is selected by the user to determine the region of interest in the image.

Figure 2-The result of "mySS.m" code. This is the detected sunspots on 2014-2-21 at 04:16:54 ,which is shown to have many sunspots.

3. The Sunspots Activity

The activity of Sunspots which is given by potted the relation between the number of Sunspots that appear on the surface of the Sun with time of Sunspot evolution in (sec). The number of Sunspot that appears on the surface of the Sun changes from year to year. The rise and fall in Sunspot counts is a cycle. When few Sunspots appear on the surface of sun the time is called a solar minimum The solar activity shows a clear increase of sunspots and their locations across the tropical circle of the sun. The number of sunspots that used in the program of Matlab to plotted the relationship between the number of sunspots and the time of sunspot evolution, are taken from (http://www.sidc.be/sislo/inforsndtot).

4. Results and Discussion

1- Sunspots Evolution

The behavior of the size of sunspots calculated through 9 years (2010-2018) using two types of images (H-alpha and HMI magnetogram).The HMI Magnetogram can only measure the component of the solar magnetic field parallel to the observer's line of sight. It's used to track variations in the solar magnetic field at the photosphere. Also referred to as a line-of-sight magnetogram in order to distinguish from vector magnetograms. Typically, magnetograms are gray scale images with white shaded regions implying outward directed magnetic field lines and black representing inward directed magnetic field lines. Shades of gray denote no net line-of-sight magnetic field. HMI Magnetogram images use the Zeeman splitting of the 6173 Å spectral line to measure then Stokes parameters and determine the magnetic polarity of solar active region. The results were plotted in Figure-3(a) to Figure- 3(r).

When compared between the results of sunspots for 2010, 2011 and the results for 2012 respectively, as shows in the below figures the right images are H-alpha and the left images are the HMI magnetogram images. We noticed that the first coefficient (slop) for the fitting equation for data of 2010 its larger than the first coefficient (slop) for the data of 2010 and 2011 for H-alpha images this mean that the variation of radius of sunspots to the variation of time is very large .So the radius of sunspots increase therefore the size of sunspots larger than the size of sunspots for the time period (17-27 Aug 2011) and (02-11 June 2012). This difference between the outputs of research code is caused by the different between the two images that used in this research.

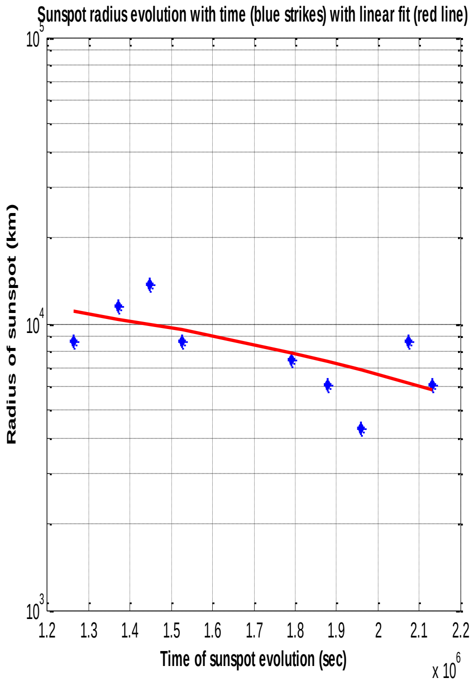

Figure 3(a)-Behavior of sunspots evolution using H-alpha images for the period of time (14-25 Nov 2010).

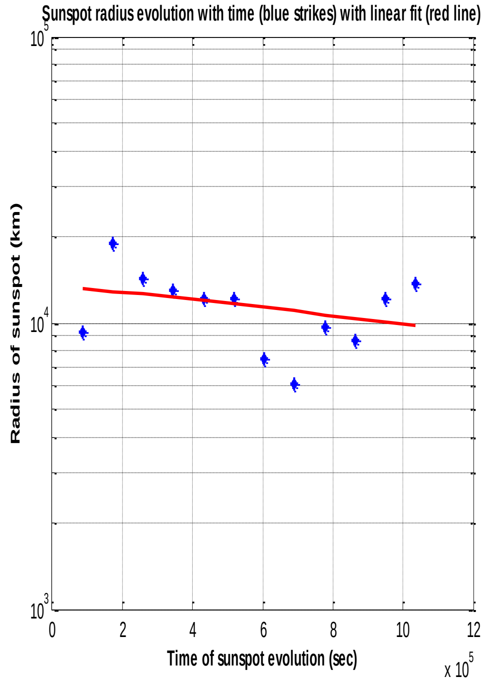

Figure 3(b)-Behavior of sunspots images for evolution using HMI for the period of time (14-25 Nov 2010).

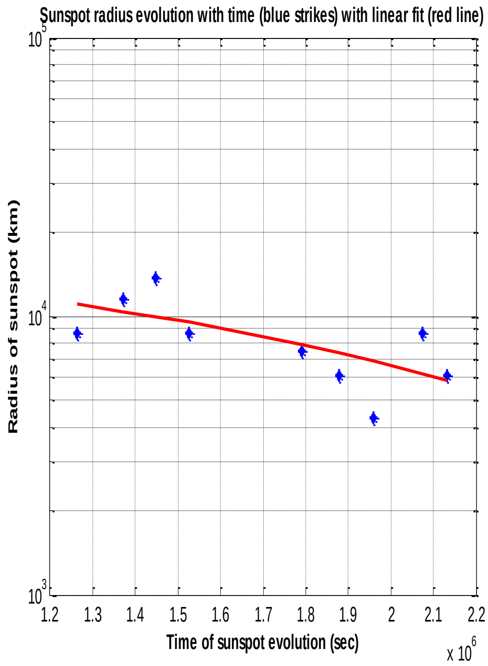

Figure 3(c)-Behavior of sunspots evolution using H-alpha the period of time (17-27 Aug 2011).

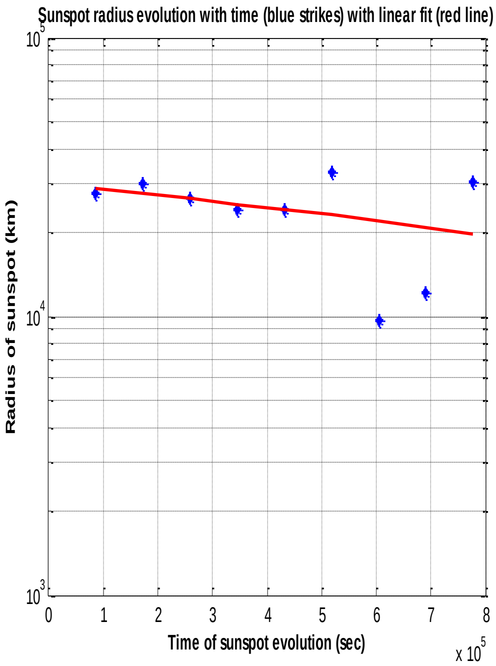

Figure 3(d)-Behavior of sunspots images for evolution using HMI images for the period of time (17-27 Aug 2011).

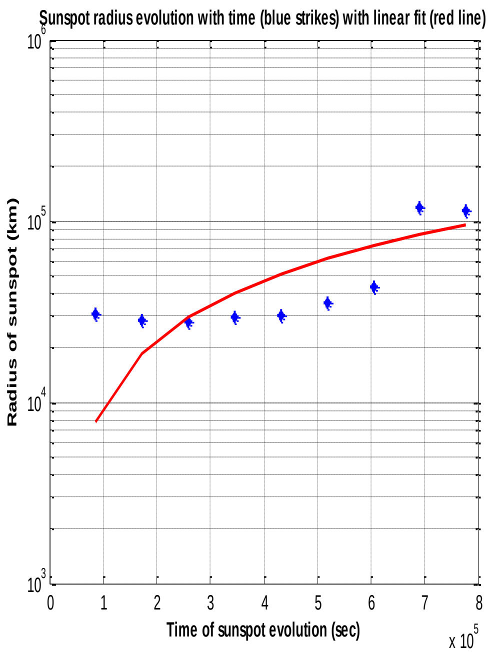

Figure 3(e)-Behavior of sunspots evolution using H-alpha for the period of time (02-11 June 2012).

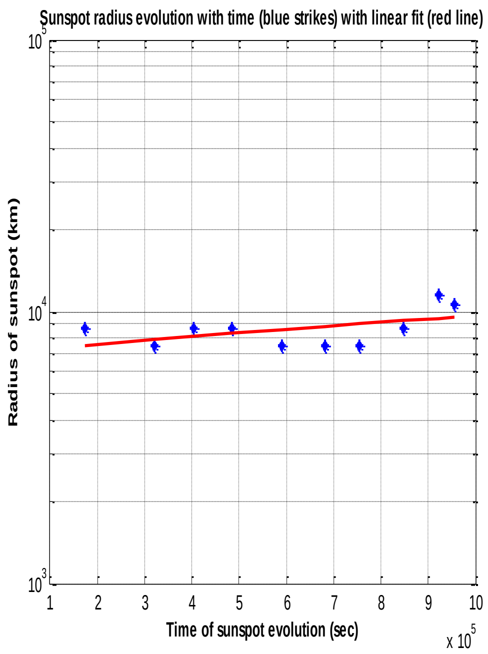

Figure 3f)-Behavior of sunspots images evolution using HMI images for the period of time (02-11 June 2012).

When compared between the results of sunspots for the 6 years (2013, 2014, 2015, 2016, 2017,and 2018) respectively , as shows in the below figures.

We noticed that the radius of sunspot in 2014 still on the average 33167 km in HMI larger than that on the H-alpha image. The size of sunspot is increase with time when using HMI magnetogram images. The radius of sunspots when using HMI magnetogram images are changed more than that when using H-alpha images. The slop of the fit line for HMI magnetogram image is equal to -0.0065, which is larger than that of H-alpha image that equal to -0.0125, but the y-intercept of H-alpha image of value 21036 km is larger than that of HMI magnetogram image of value 15927 km. These values mean the size of sunspots is still on average 21036 km lager than previous one. The largest value of slop is 0.0266 for time period from 13 to 23 Dec 2015 using H-alpha images, this value mean that the radius of the sunspot rise and fall from day to day, and its larger than that when used HMI magnetogram images for the same time. So the variation in the size of sunspots in H-alpha images is larger than that of HMI magnetogram images, and this value of slop is larger than that for the other years, So the variation in the radius in 2015 is larger than that of 2016,2017 and 2018. The largest value of y-intercept is 98748 km for time period from 13 to 23 Dec 2015 using HMI magnetogram images. This value means that the radiuses of Sunspots are still on the average of 98748 km larger than that on the H-alpha images, and its larger than that for the other values of 2016,2107 and 2018. This means that the sizes of sunspots for 2015 are larger than that for 2016, 2017 and 2018.

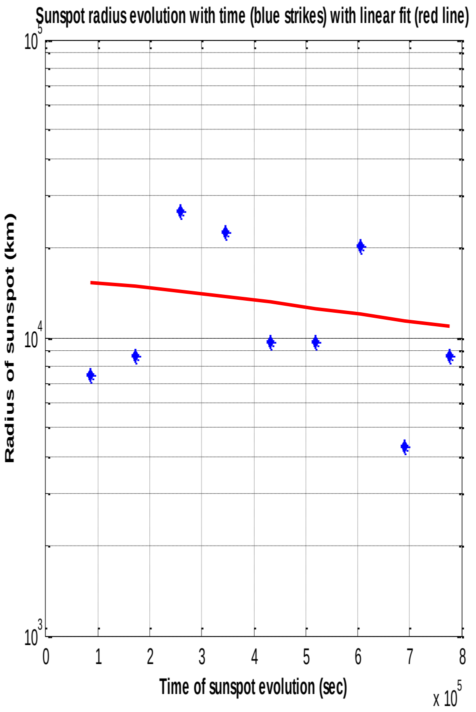

Figure 3(g)-Behavior of sunspots evolution using for the H-alpha period of time (02-11 April 2013). of time

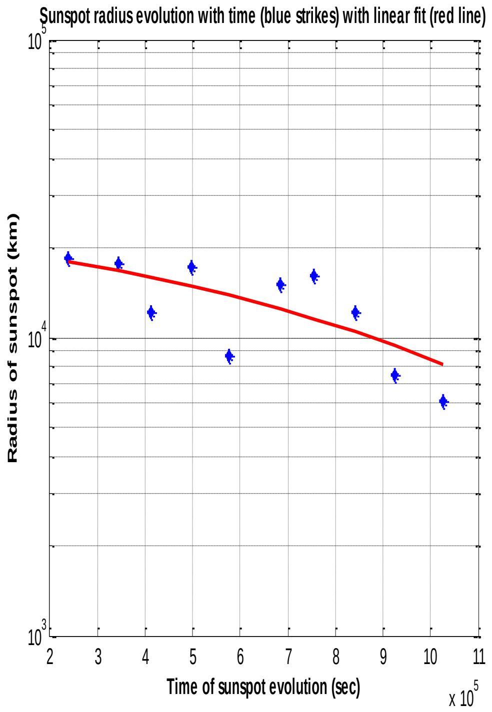

Figure 3(h)-Behavior of sunspots images evolution using HMI images for the period (02-11 April 2013).

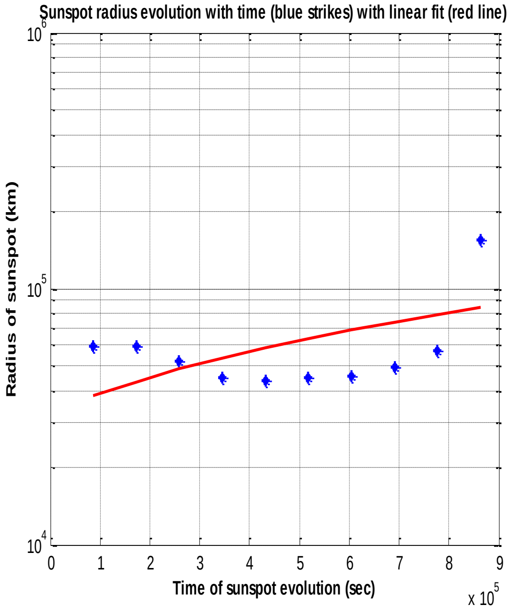

Figure 3(i)-Behavior of sunspots evolution using the period H-alpha of time (10-20 Feb 2014).

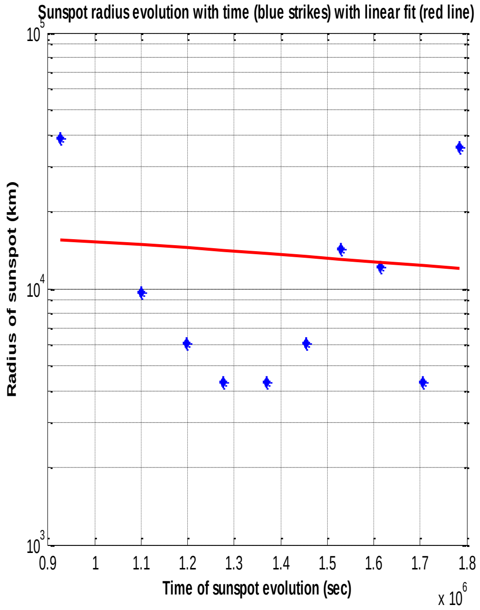

Figure 3(j)-Behavior of sunspots images for evolution using HMI images for the period of time (10-20 Feb 2014).

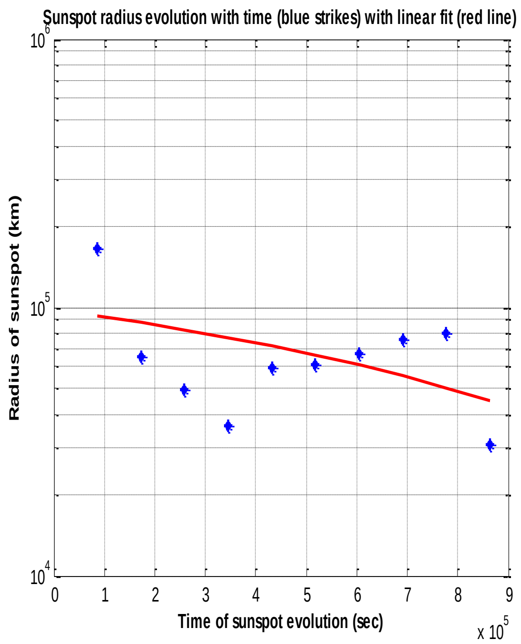

Figure 3(k)-Behavior of sunspots evolution using the period of time (13-23 Dec 2015).

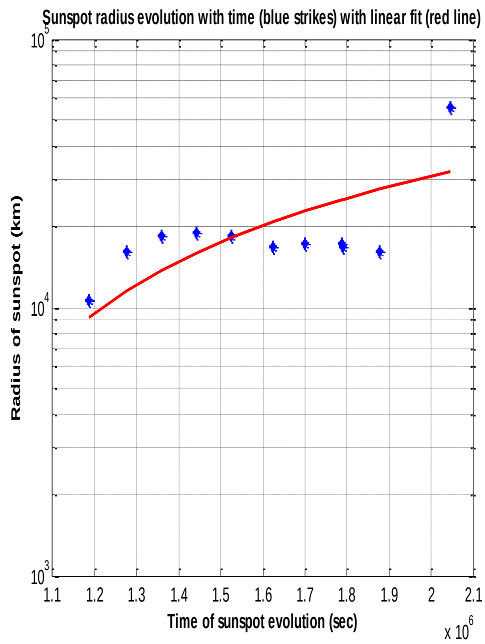

Figure 3(l)-Behavior of sunspots images for evolution using HMI images for the period of time (13-23 Dec 2015).

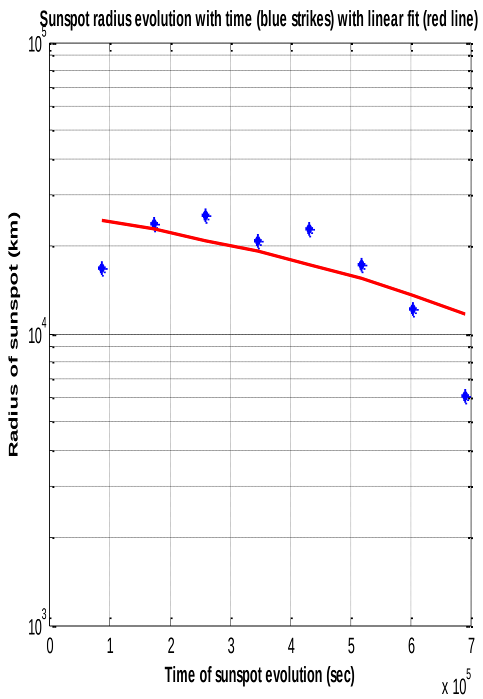

Figure 3(m)-Behavior of sunspots evolution using H-alpha period of time (03-14 Sep 2016).

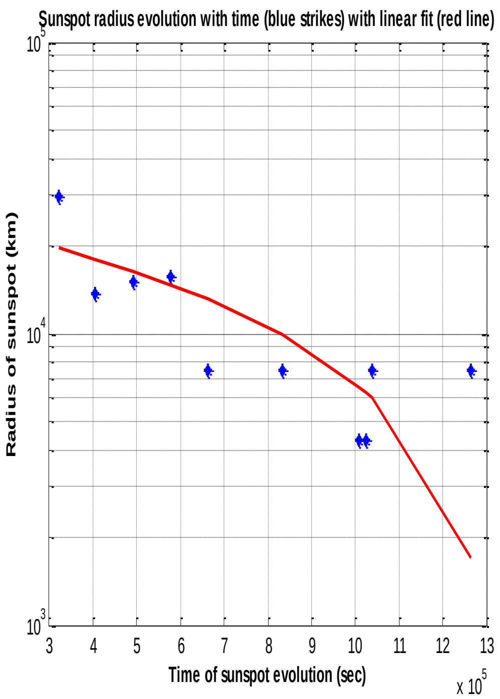

Figure 3(n)-Behavior of sunspots images for the evolution using HMI images for the period of time (03-14 Sep 2016).

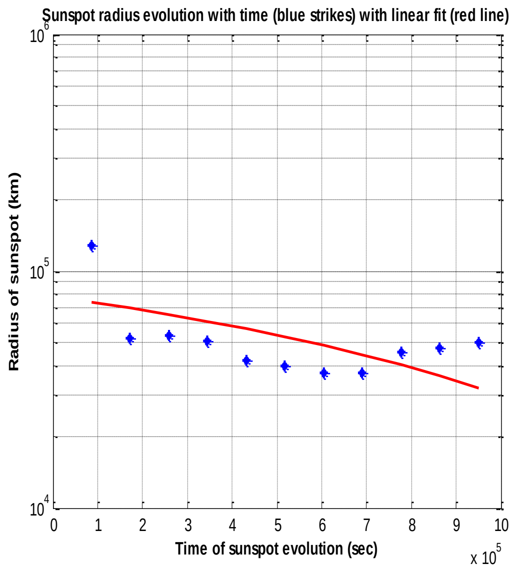

Figure 3(o)-Behavior of sunspots evolution using H-alpha of time (01-12 Aug 2017).

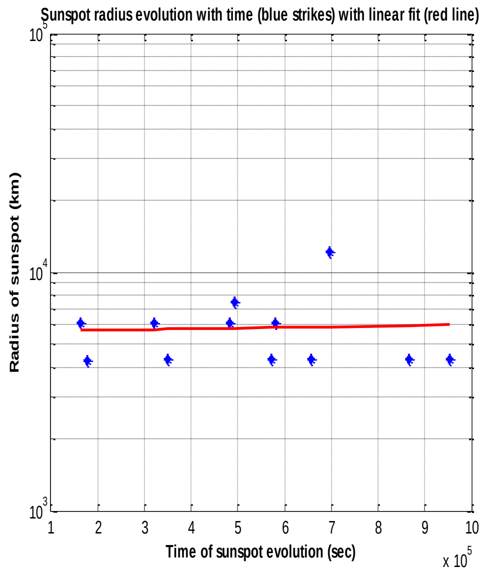

Figure 3(p)-Behavior of sunspots images for the period evolution using HMI images for the period of time (01-12 Aug 2017).

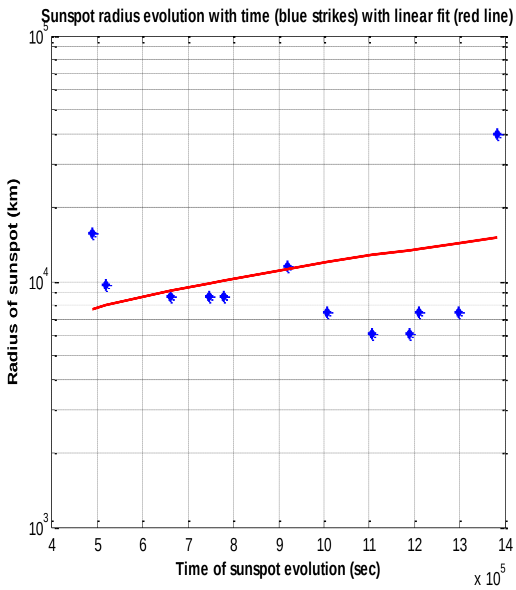

Figure 3(q)-Behavior of sunspots evolution using H-alpha period of time (05-16 Feb 2018).

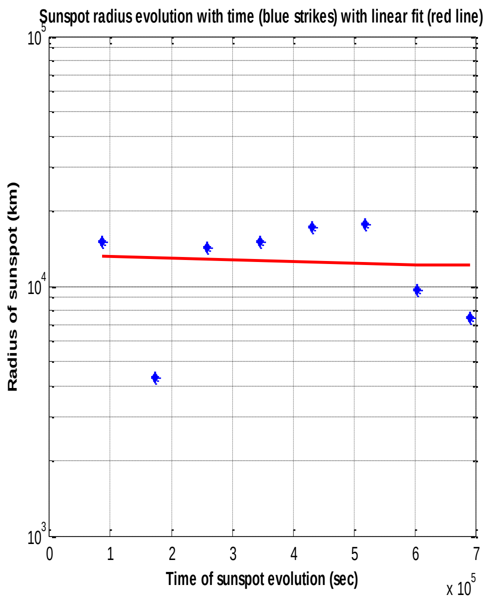

Figure 3(r)-Behavior of sunspots images for the evolution using HMI images for the period (05-16 Feb 2018).

2-The Sunspots Activity (The Relation Between The Number of Sunspots and The Time of Sunspots Evolution)

In this section the relationship between the number of Sunspots that we are get it from SIDC and the time of Sunspots evolution in sec. Figures-(4(a),4(b),4(c),4(d),4(e),4(f),4(g),4(h),4(i)) show the relation between the number of Sunspots and the time of Sunspots evolution in (sec) for 9 years (2010-2011-2012-2013-2014-2015-2016-2017 and 2018).

The period (14-25 Nov 2010) considered as a solar minimum because the number of Sunspots decreased and when the average of number of Sunspots is little the sun is inactivity. While the period (17-27 Aug 2011) considered as a solar maximum because the number of Sunspots increase and when the average of number of Sunspots is large the Sun is activity.

The year 2011 is more active than the year 2010 because there are many Sunspots on the surface of the sun than that in 2010. This means that there are periodic changes in the properties of the Sun is coupled with hurricanes of hot gases and changes in their magnetic field. When compared between the results of the years 2010, 2011 and 2012 the number of Sunspots on the surface of the sun in 2012 is more than the number of Sunspots that appear on the surface of Sun in the years 2010 and 2011. This means that the Sun in 2012 is more activity than that in 2010 and 2011. Then when compared between the results of the years 2010, 2011, 2012, 2013, 2014, 2015 and 2016, the number of Sunspots on the surface of the Sun in 2016 is less than the number of Sunspots that appear on the surface of Sun in the years 2011,2012,2013and 2015 but more than that in 2010. This means that the Sun in 2016 is less activity than that in 2011 and 2015. The year 2017 is less activity than that in 2011 and 2016.
When compared between the results of the year's 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017 and 2018 the number of Sunspots on the surface of the Sun in 2018 is less than the number of Sunspots that appear on the surface of Sun in the years (2011, 2012, 2013, 2014, 2015 2017 and 2018). This means that the Sun in 2018 is less activity than that in (2011, 2012, 2013, 2014, 2015, 2016 and 2017). From the figures the trend of Sunspot number throughout a solar cycle is well known and generally rises rapidly at the start of a solar cycle before a slower decrease towards the end of the cycle.

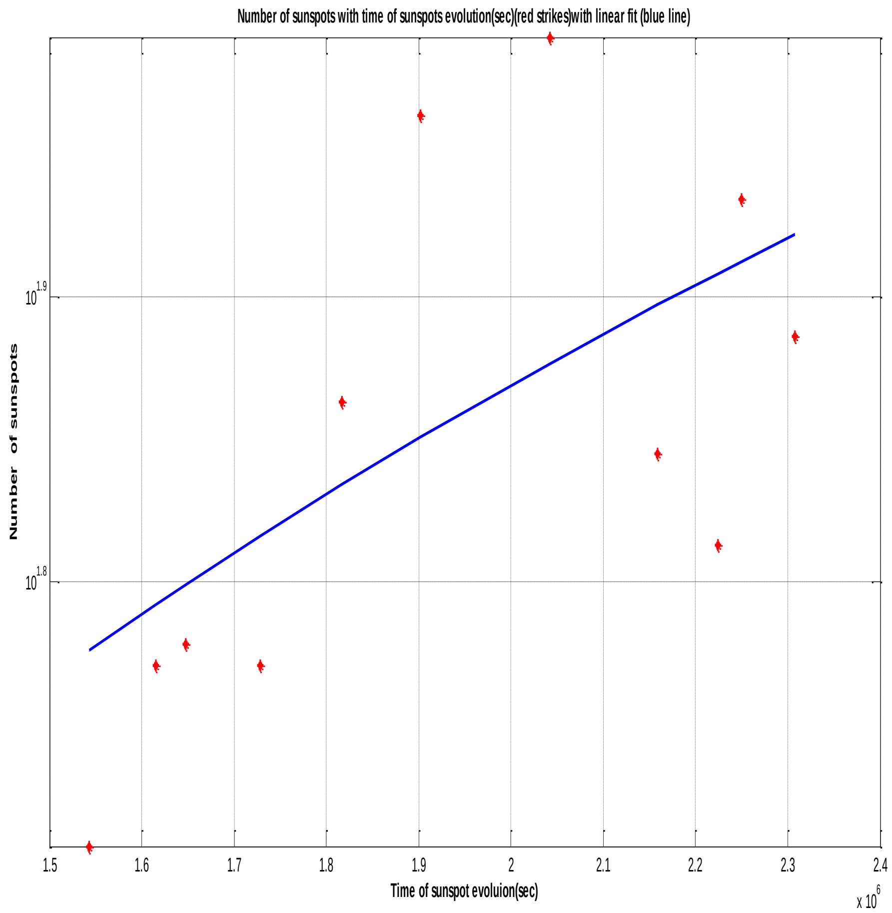

Figure 4(a)-Relation between the number of sunspots and the time of sunspots evolution in (sec) for the period of time (14-25 Nov 2010).

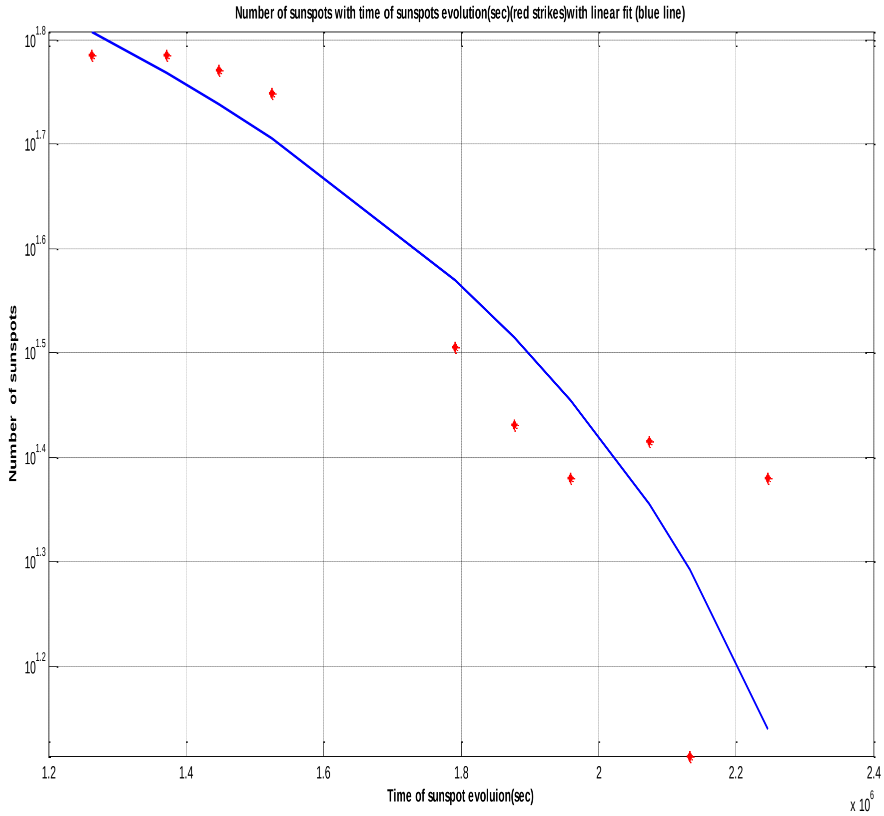

Figure 4(b)-Relation between the number of sunspots and the time of sunspots evolution for the period of time (17-27 Aug 2011).

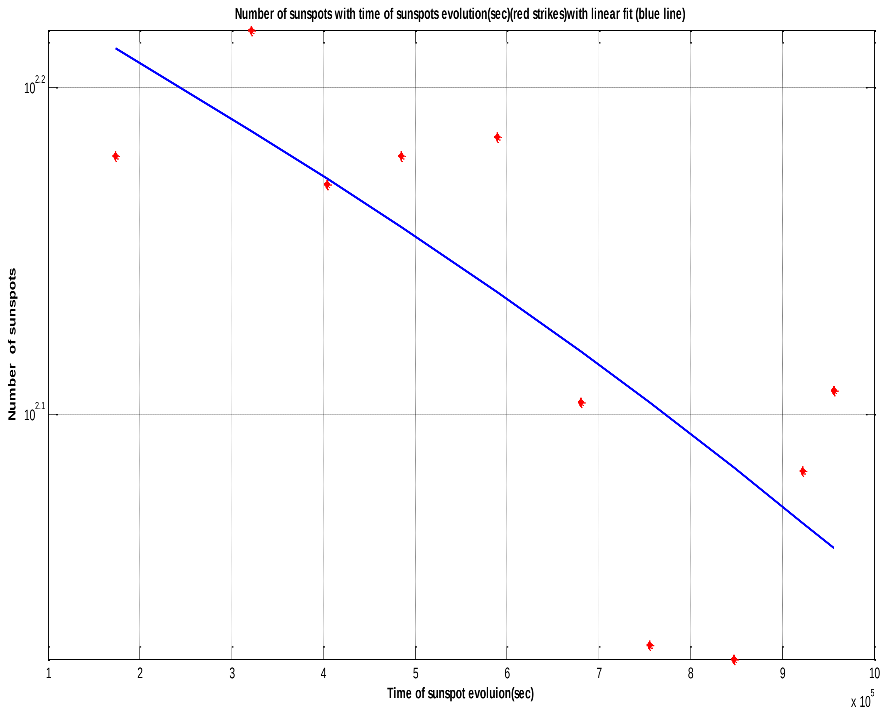

Figure 4(c)-Relation between the number of sunspots and the time of sunspots evolution in (sec) for the period of time (02-11 June 2012).

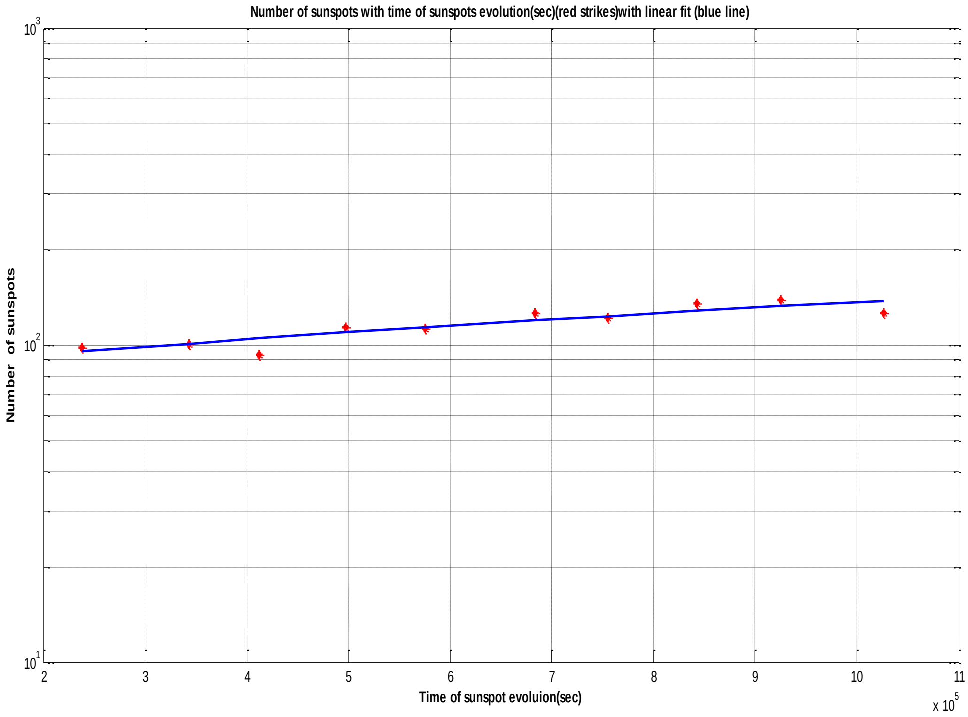

Figure 4(d)-Relation between the number of sunspots and the time of sunspots evolution in (sec) for the period of time (02-11 April 2013).

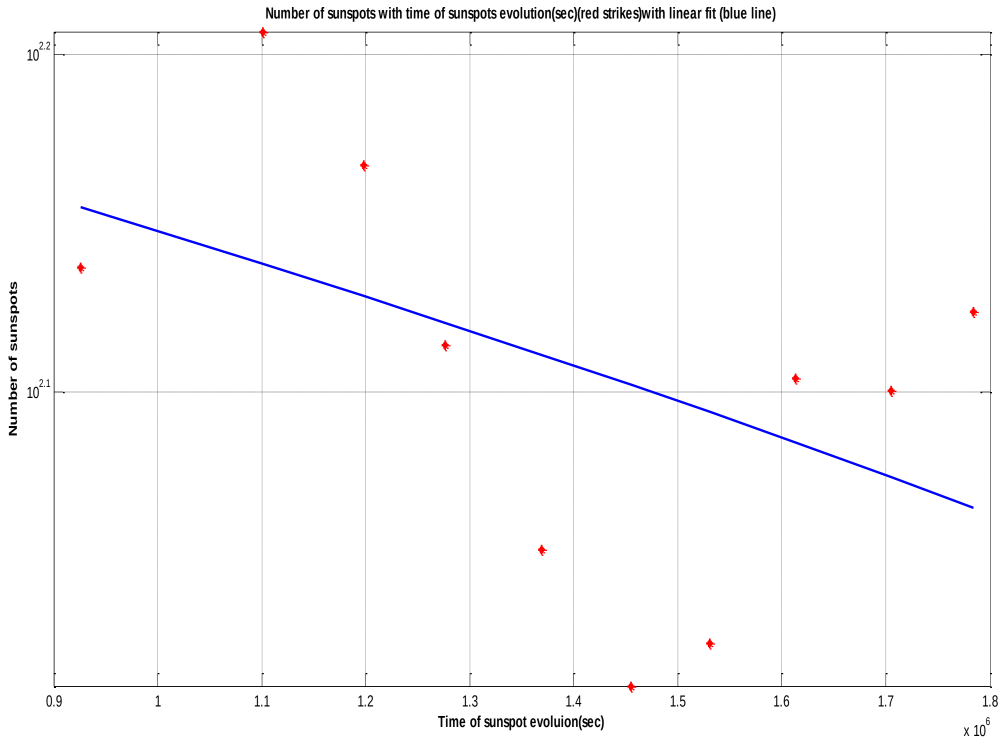

Figure 4(e)-Relation between the number of sunspots and the time of sunspots evolution in (sec) for the period of time (10-20 Feb 2014).

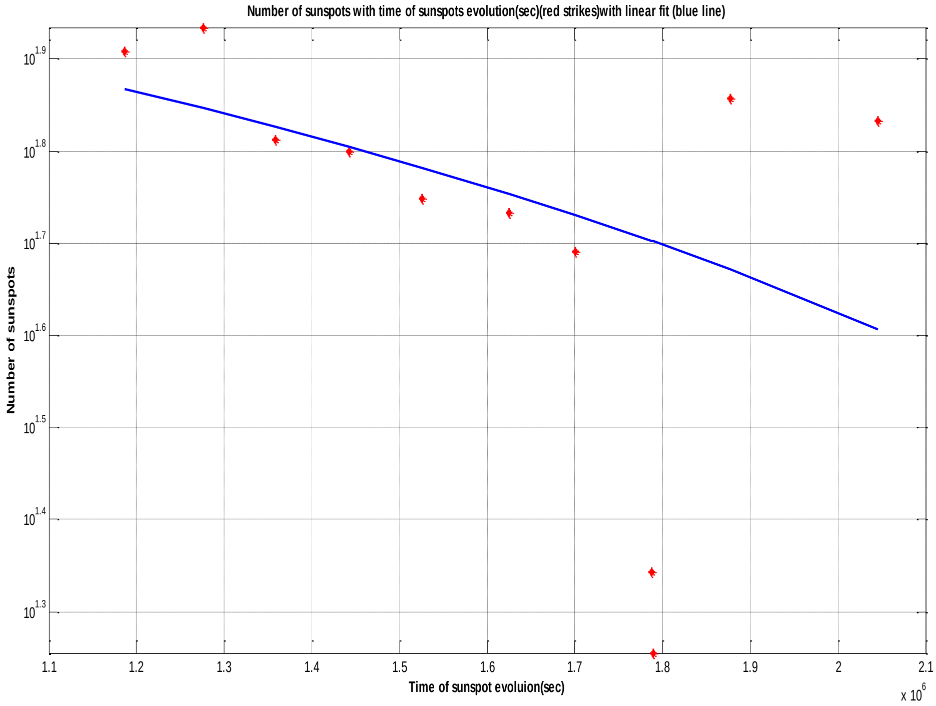

Figure 4(f)-Relation between the number of sunspots and the time of sunspots evolution in (sec) for the period of time (13-23 December 2015).

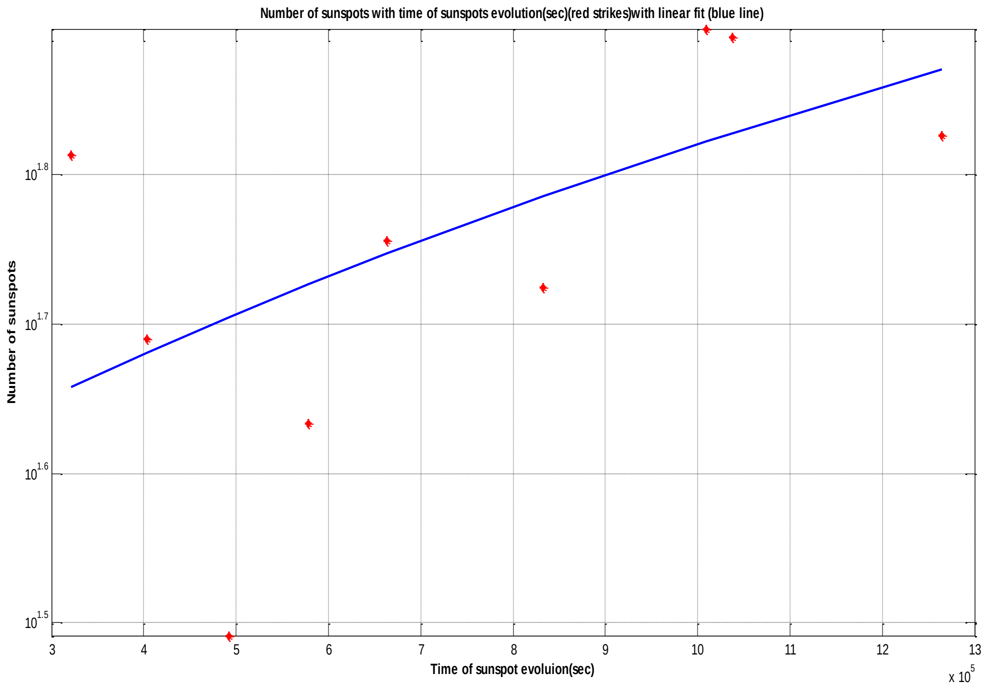

Figure 4(g)-Relation between the number of sunspots and the time of sunspots evolution in (sec) for the period of time (03-14 Sep 2016)

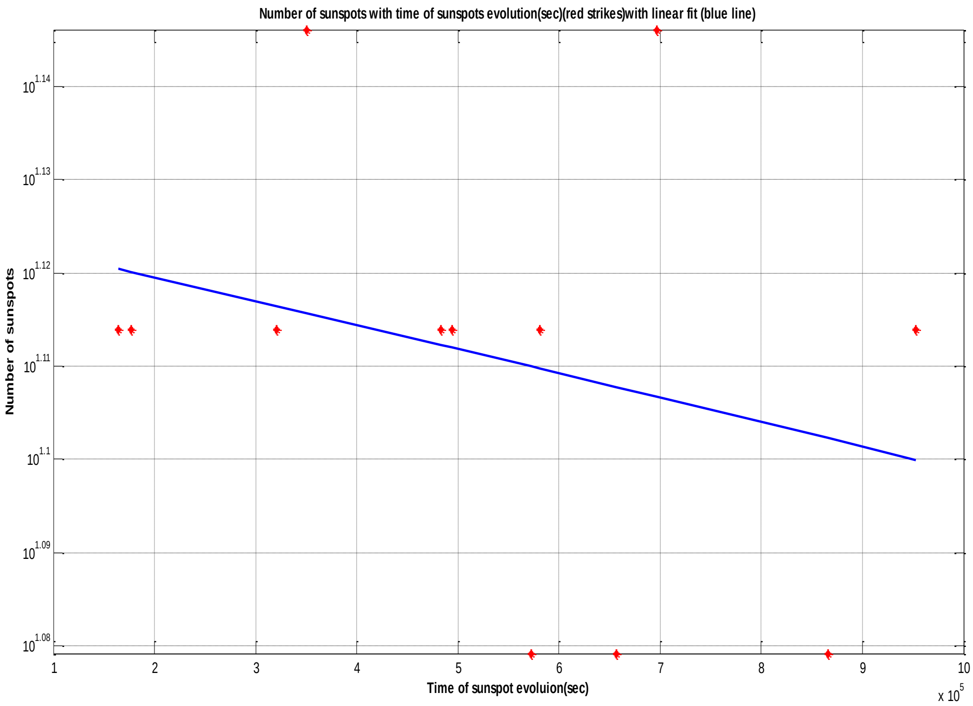

Figure 4(h)-Relation between the number of sunspots and the time of sunspots evolution in (sec) for the period of time (01-12 Aug 2017).

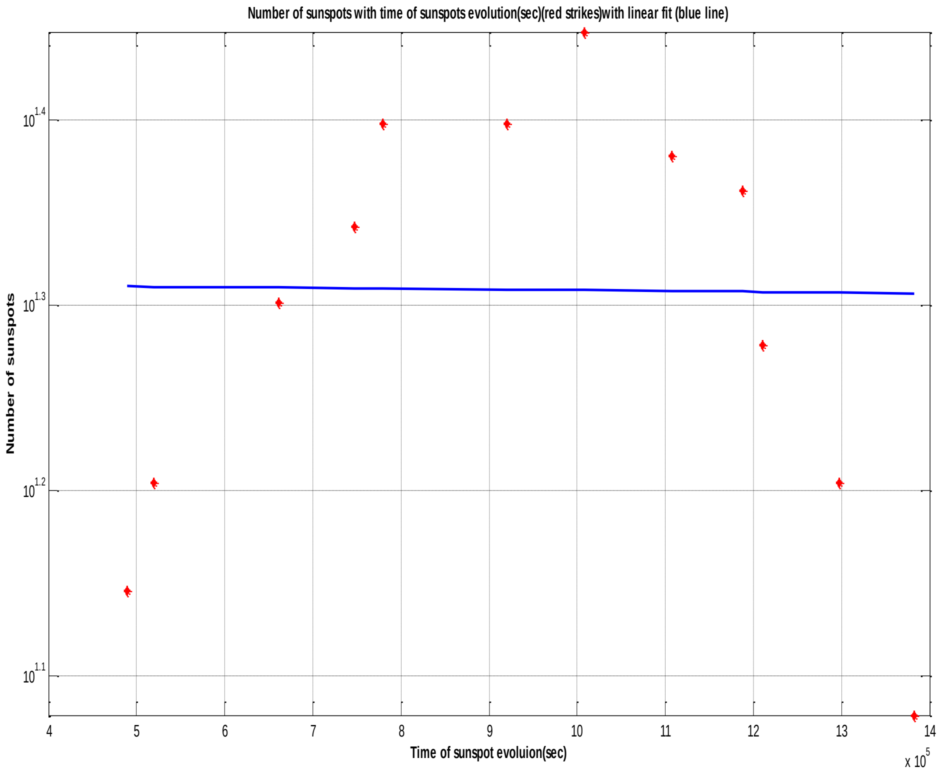

Figure 4(i)-Relation between the number of sunspots and the time of sunspots evolution in (sec) for the period of time (05-16 Feb 2018).

7. Conclusion

The largest sunspots appear in 2015 more than the other years that have been studied using HMI magnetograms images, but the largest sunspots appear in 2012 when using H-alpha images. This difference in the results caused by the differences between the images that have been used and the differences between the data sources. There are more spots beginning to appear and the magnetic field is strong when the area of observed Sunspots increased with time , but there are spots beginning to appear but the spot magnetic fields are still weak when the area of observed Sunspots decreased with time. The sunspots in 2014 are more active than 2010, 2011, 2012, 2013, 2015, 2016, 2017 and 2018, and the sunspots in 2018 are less active than 2010,2011,2012,2013,2014,2015,2016 and 2017.

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