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RESEARCH ARTICLE

Statistical Investigation of the Solar Eclipses During Four Centuries (1601 – 2000).

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Abstract

The Solar eclipses have been incorporated in diverse ways into the myths, beliefs, and customs of cultures through many centuries. The solar eclipse occurs when the moon passes between the sun and the earth, so that the sun is fully or partially covered. The Least Square Method was used to investigate the statistical study of the solar eclipses during four centuries (1600 – 2000). We found that the percentage ratio for partial solar eclipse is 35.707%, while the percentage ratio for the annular solar eclipse is 31.166%, and the percentage ratio for total and hybrid solar eclipses are 26.522% and 6.605% respectively. The General Linear Trend formula for predicting the types of the future eclipses was obtained and determined for every solar eclipse during next 100 years (2001-2100). Our results are in a good agreement with that published by NASA.

Introduction:-

The total eclipse of the sun is truly a remarkable event not only because of the fact that the beautiful corona, prominences and all other associated phenomena are rendered visible, due to the hiding by the moon of the disc of the sun or the photosphere as it is called, but mainly because it enables astronomers to study these parts of the sun which are always invisible during bright sunshine.

There are four types of solar eclipse:-

1. **Partial solar eclipse** occurs when the Moon's penumbral shadow strikes Earth, we see a partial eclipse of the sun from that region.
2. **Annular solar eclipse** *o*ccurs when the three bodies are not perfectly aligned; the Moon's Umbra fails to reach the Earth's surface leaving a run of Sun still visible around the Moon.
3. **Total solar eclipse** occurs when all of the sun is hidden or eclipsed by the Moon. When the Moon's shadow sweeps across Earth's surface, then a total eclipse of the Sun is seen.
4. **Hybrid solar eclipse** is a unique type of central eclipse where parts of **t**he path are annular while other parts are total.

According to statistics, the earth witnesses about 238 eclipses on average in each century nearly 65% of them are central solar eclipses, including total, annular, and total-annular (hybrid) solar eclipses (Han and Qiao 2009). With the scientific revolution of the 16th century, eclipses were studied systematically, but one cannot forget the work carried out by astronomers during earlier centuries (Vaquero &Vazquez 2009).

Marzouk (2013) showed that the historical eclipses and different predictions during Babylonian, Ptolemy, Mediaeval Arabic and Chinese ancients.

In the present work, the frequency distributions of each type of solar eclipses during one century as well as during four centuries are obtained. After that we used the least squares method to find the general linear trend formula for each type of solar eclipse.

Data and method of analysis:-

We used the selected data to find the formula for total number of every type of solar eclipse from NASA system through its principle center at "http://eclipse.gsfc.nasa.gov/SEatlas/SEatlas.html#2CE ", this site contain the solar and lunar eclipses for the past and future.

There are several methods to find the general trend for all types of solar eclipses, but we used the Least Squares method to find the general trend, we used the time as "Independent Variable" and found series for all eclipse numbers, and each type of solar eclipse.

The general linear trend equation is:-

$$\hat{y} = \hat{a} + \hat{b}x \qquad (1)$$

Where: $\hat{a}$ is the cute distance from horizontal axis, $\hat{b}$ is the slope, and $\hat{y}$ is the estimated value for phenomena trend, *x* is the time (where x=1 for first series, x=2 for second series….etc, every series = 25 years). The first from 1600-1625 , the 2nd from 1625 to 1650 , …, and so on.

Applying the Least Squares method in equation (1) we can get:-

$$\hat{b} = \frac{\sum xy - n\bar{x}\bar{\bar{y}}}{\sum x^2 - n\bar{\bar{x}}^2} \qquad (2)$$

$$\hat{a} = \bar{\bar{y}} - \hat{b}x \qquad (3)$$

From equations (2) and (3) we can find the estimation values for $\hat{a}$, $\hat{b}$ then substitute in equation (1) to get the future values for every type of solar eclipse.

Results and Discussions:-

As we showed, we used the Least Squares method to find the general trend. Before applying this method we calculated the frequency distribution of all types of solar eclipses during 1600-2000. Table (1.1) shows the frequency distribution of partial eclipse during four centuries, while Table (1.2) shows the frequency distribution of annular eclipse during the four centuries, the frequency distribution of total eclipse during the four centuries is shown in Table (1.3), the frequency distribution of hybrid eclipse during the four centuries is shown in Table (1.4) and finally the frequency distribution of all eclipses during the four centuries is shown in Table (1.5).

Table (1.1): The frequency distribution of Partial eclipse for 4 centuries

Centuries	Frequency (Partial)	Percentage Frequency	Relative Frequency
1601 - 1700	89.00	25.723	0.25723
1701 – 1800	92.00	26.59	0.2659
1801 – 1900	87.00	25.145	0.25145
1901 - 2000	78.00	22.543	0.22543
SUM	346	100	1.00

Table (1.2): The frequency distribution of Annular eclipse for 4 centuries

Centuries	Frequency (Annular)	Percentage Frequency	Relative Frequency
1601 - 1700	74.00	24.503	0.24503
1701 – 1800	78.00	25.828	0.25828
1801 – 1900	77.00	25.497	0.25497
1901 - 2000	73.00	24.172	0.24172
SUM	302	100	1.00

Table (1.3): The frequency distribution of Total eclipse for 4 centuries

Centuries	frequency (Total)	Percentage Frequency	Relative Frequency
1601 - 1700	61.00	23.735	0.23735
1701 – 1800	62.00	24.125	0.24125
1801 – 1900	63.00	24.514	0.24514
1901 - 2000	71.00	27.626	0.27626
SUM	257	100	1.00

Table (1.4): The frequency distribution of Hybrids eclipse for 4 centuries

Centuries	Frequency (Hybrids)	Percentage Frequency	Relative Frequency
1601 – 1700	24.00	37.5	0.375
1701 – 1800	19.00	29.688	0.29688
1801 – 1900	15.00	23.438	0.23438
1901 – 2000	6.00	9.375	0.09375
SUM	64	100	1.00

Table (1.5): The frequency distribution of all eclipse for 4 centuries

Type of eclipse	frequencies	Percentage Frequency	Relative Frequency
Partial	346	35.707	0.35707
Annular	302	31.166	0.31166
Total	257	26.522	0.26522
Hybrids	64	6.605	0.06605
SUM	969	100	1.00

After applying the least squares method to equation (1), we find the estimation values for $\hat{a}$, $\hat{b}$ and by substitution in equation (1) we can find the future values for every type of solar eclipse as following:

a. For Partial solar eclipse we can use the next equation to find the number of future partial eclipses.

P = 23.775 – 0.253 x

To find the number of future partial eclipses during 25 years (2001-2025) we put x =17 then, we find P = 19; to find the number of future partial eclipses during 25 years (2026-2050) we put x=18 then we find P=19, and P=19,19 for x=19, 20 respectively.

b. For Annular solar eclipse we can use the next equation to find the number of future Annular eclipses.

A = 19.125 – 0.029 x

To find the number of future partial eclipses number during 25 years (2001-2025) we put x=17 then we find A=18; A=17, 21, 20 for x=18, 19, 20 respectively.

c. For total solar eclipse we can use the following equation to find the number of future total solar eclipses.
T = 14.45 + 0.19 x
As we did in (a) and (b) we find T=17, 17, 18, 18 for x=17, 18, 19, 20 respectively.
(d) For hybrid eclipses we can use the following equation to find the future hybrid eclipses.
H = 6.975 + 0.19 x

As we did in (a) , (b) and (c) we find H=1, 1, 0, 0 for x=17, 18, 19, 20 respectively.

After estimating the future values for all types of the solar eclipses we compared our results with published NASA results for one century (2001-2100).

Table (2.1) shows the comparison between our results and NASA results for one century for all types of the solar eclipses.

Table (2.1): the comparison between our results and NASA results for one century:-

Date	Partial		Annular		Total		Hybrid	
	Our results	NASA	Our results	NASA	Our results	NASA	Our results	NASA
2001-2025	19	18	18	18	17	15	1	3
2026-2050	19	17	18	19	17	17	1	3
2051-2075	19	21	18	16	18	17	0	1
2076-2100	19	20	18	19	18	19	0	0
total	76	76	72	72	70	68	2	7

The comparison of our results with NASA results for partial eclipse during 100 years is shown in figure (1), while the comparison of our results with NASA results for Annular eclipse during 100 years is shown in figure (2), the comparison of our results with NASA results for total eclipse during 100 years is shown in figure (3), finally the comparison of our results with NASA results for hybrid eclipse during 100 years is shown in figure (4).

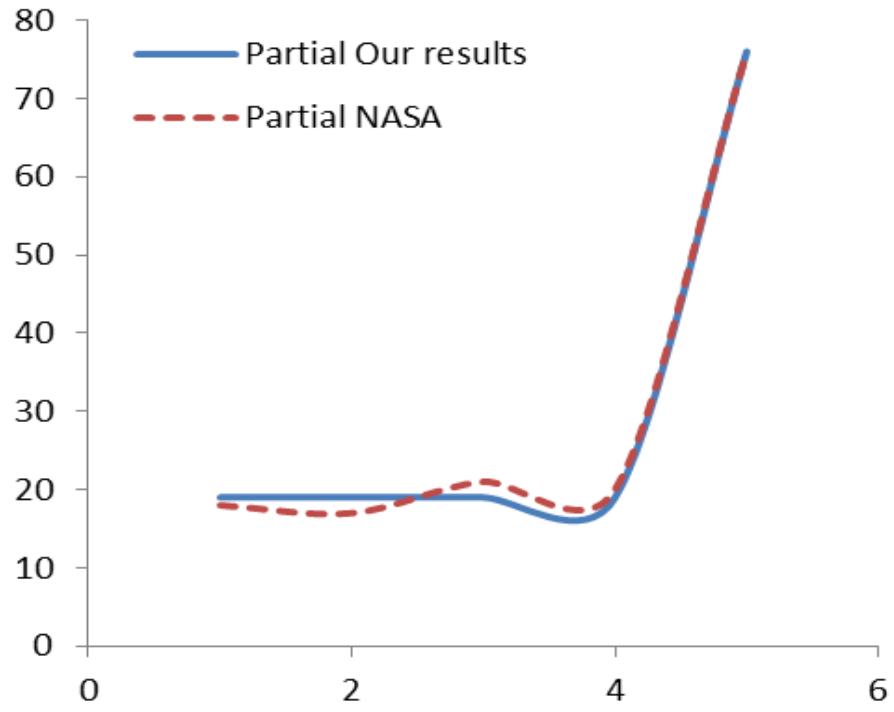

Figure (1): Comparison between our results and NASA results for the partial eclipse.

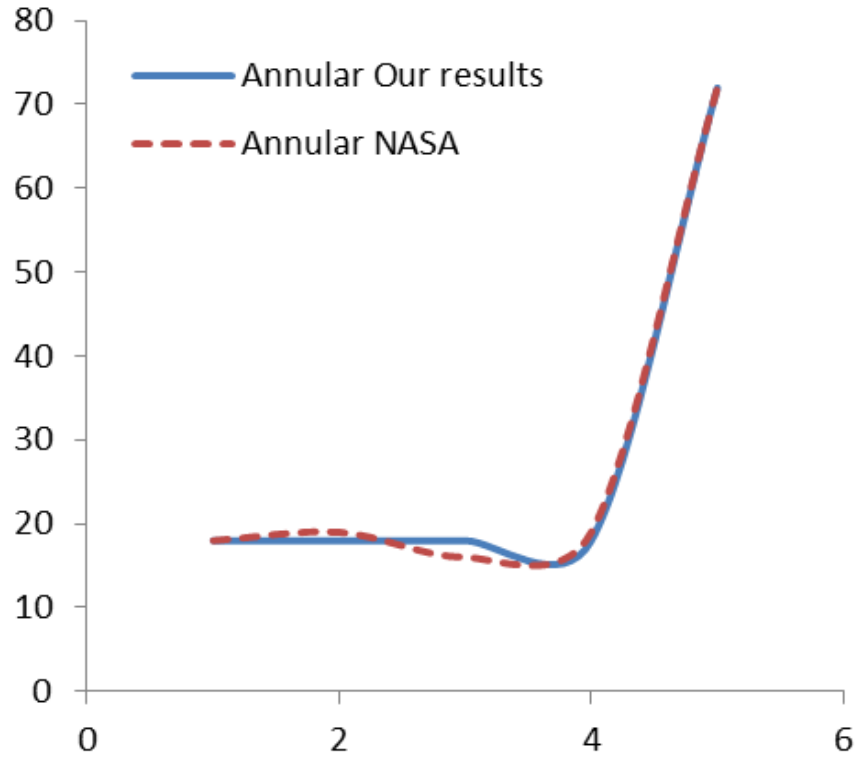

Figure (2): Comparison between our results and NASA results for the annular eclipse.

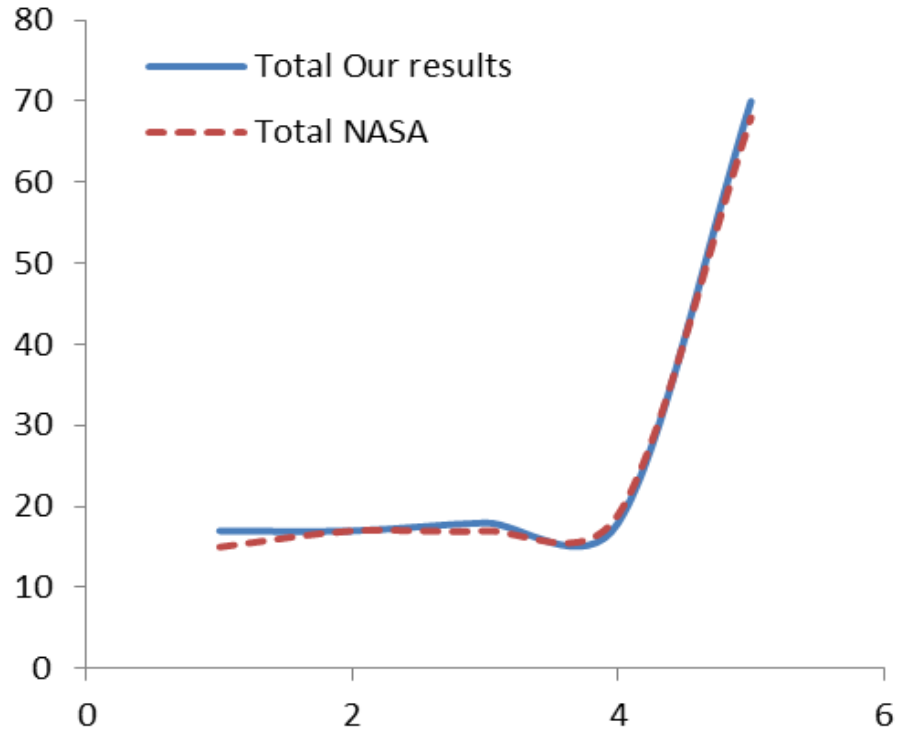

Figure (3): Comparison between our results and NASA results for the total eclipse.

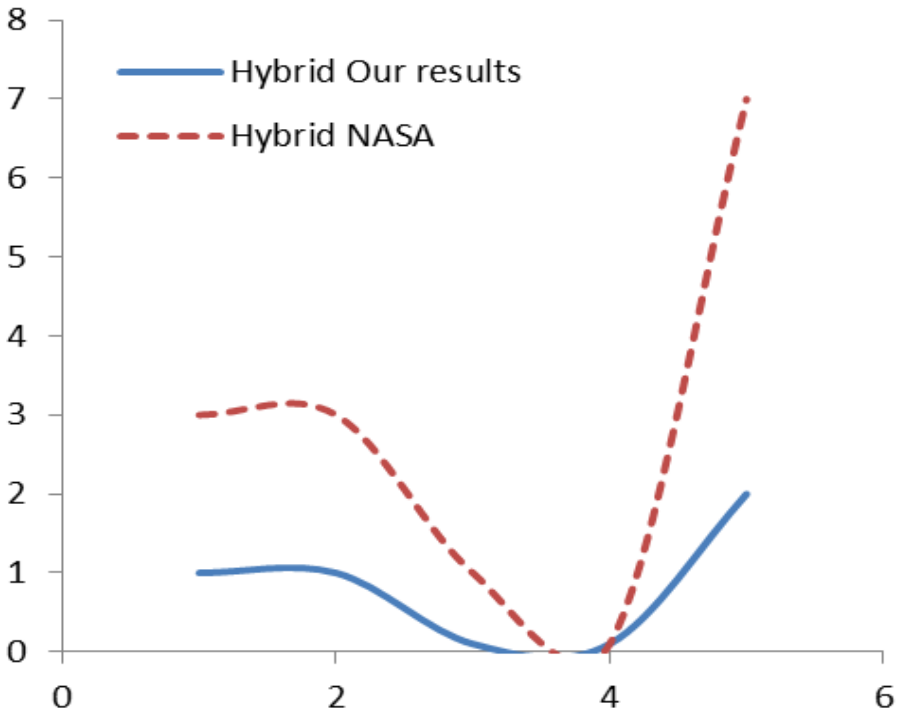

Figure (4): Comparison between our results and NASA results for the hybrid eclipse.

As we see from figures our results for partial eclipse are in a good agreement with published NASA results (see figure 1), consistent with published NASA results for annular eclipse (see figure 2) and give the same values for partial and annular eclipses (76 for partial and 72 for annular) during one century (2001-2100). For total solar eclipse we find that our results are in a good agreement with that published by NASA (see figure 3), finally our results for hybrid eclipses are not completely in agreement with published results by NASA (see figure 4), we attributed this difference to the rare occurrence of this type of the solar eclipses

Conclusions:-

We have a new formula for predicting the future values of all types of the solar eclipse types (partial, annular, total and hybrid). Our results for partial eclipse are in a good agreement with published NASA results and we have the same values of sum partial eclipses during one century. Our results for annular solar eclipses are in a good agreement with published NASA results and we have the same values of sum annular eclipses during 100 years (2001-2100). For the total solar eclipse, our results are in a good coincident with NASA results during 100 years (2001-2100). For the hybrid solar eclipse, there is a small difference with NASA results during 100 years (2001-2100), this difference attributed to the rare occurrence of this type of the solar eclipses**.**

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