The solar eclipse and its relation with higree months

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Abstract

The solar eclipse occurs at short time before the crescent birth moment when the moon near any one of moon orbit nodes It is important to determine the synchronic month which is used to find Higree date. The 'rules' of eclipses are:
Y= ± 0.997 of Earth radius , the solar eclipse is central and 0.997 < |Y| < 1.026 the umbra cone touch the surface of the Earth, where Y is the least distance from the axis of the moon's shadow to the center of the Earth in units of the equatorial radius of the Earth.

A new model have been designed, depend on the horizontal coordinates of the sun, moon, the distances Earth-Moon (rm), Earth-sun (rs) and |Y| to determine the date and times of total solar eclipse and the geographical coordinates of spot shadow as well as the shadow diameter and the variations with time.
The results are compared with Almanac and others programs are gets a good agreements and the results show the area of eclipse shadow inversely proportional with rm /rs .The Higree month which must be begin after the solar eclipse and the relation were discussed hear.

Key words
solar eclipse,
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كسوف الشمس وعلاقته بالأشهر الهجرية

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الخلاصة

يحصل كسوف الشمس قبل ولادة الهلال بوقت قصير عندما يكون القمر قريب جدا من إحدى العقدتين لمداره لذلك فهو مهم لتحديد بدايات الأشهر القمرية الاقترانية التي تستخدم لتحديد بدايات الأشهر الهجرية، ويكون كسوف الشمس مركزيا عندما المسافة بين محور الظل ومركز الأرض Y = ± 0.997 بوحدات نصف قطر الأرض ويسقط ظل الكسوف على سطح الأرض عندما 0.997 < |Y| < 1.026.
تم تصميم نموذج جديد يعتمد على الإحداثيات الأفقية للشمس والقمر (الاتجاه والارتفاع الزاوي) كذلك يعتمد على المسافتين أرض - قمر وأرض – شمس التي حسبت بدقة وعلى بعد مخروط الظل عن مركز الأرض Y لنحصل على تواريخ وأوقات الكسوف الكلي للشمس و حساب الإحداثيات الجغرافية لمسقط الظل على سطح الأرض إضافة إلى حساب قطر الظل وتغير كل هذه المعلومات مع الزمن. تم مقارنة النتائج مع المناخ الفلكي وبرامج أخرى وبينت توافق جيد، كذلك استنتجنا من هذا البحث أن مساحة ظل الكسوف تتناسب عكسيا مع rm / rs ، ولوحظ الكسوف دائما قبل بداية الأشهر الهجرية وتمت مناقشة ذلك.

Introduction:

The eclipses occur when the shadows cone of the Moon falling on the Earth's surface. The solar equatorial coordinates have been change through year (The right ascension changes (0 - 360) and the declination change (±23.445 deg.) in the geocentric equatorial system (G.E.S.) while the moon equatorial coordinates change approximately between (0- 360) & (±18, ± 28) through sidereal month (27.53 days) [1,2].

The general important rules of eclipses [4]:
(1) A lunar eclipse can only occur at full Moon and a solar eclipse at new Moon. It does n"t happens every month.
(2) At least two solar eclipses not more than five occur every year, and a maximum of three lunar eclipses in a year.
(3) Eclipses solar-lunar or lunar-solar happen pairs: (two weeks between them).
(4) The eclipses cycles of 18 years 11 days and 8 hours, called 'Saros' cycle.
(5) At the moment of greatest eclipse the Sun and Moon are either in opposition or conjunction. If the angle between the line of nodes and the Sun or Moon is less than 9° a lunar eclipse occur., while if it is less than 15° a solar eclipse occur.
(6) In a lunar eclipse, a maximum time of 1 hour 40 minutes, and the, partial-total-partial, for a maximum time of 3 hours 40 minutes. The maximum time of total solar eclipse (at the equator) is 7 minutes 40 seconds and an annular eclipse can last at most for 12 minutes and 24 seconds.

To determine the solar eclipse; The coordinates of the Sun and the Moon had been calculated for any date and time. There are many astronomers calculate the coordinates of the sun and the moon, the date and time of the new moon as [3-7, 9].

The solar eclipse problem is complicated by the fact that the phases of eclipse are dependent on the observer coordinate, While the lunar eclipse all the observer see the same phase at the same instant. the total solar eclipse is occur at the sun – moon – earth angle (Elongation angle) approach zero when the moon is completely in the node at the syndic moment, the moon shadow maybe touch the Earth surface. When the moon at crescent, phase the Elongation angle is minimum and various between 0, ± 5.2 [5].

At total solar eclipse the solar and lunar equatorial coordinate must be the same and the umbra passes on the observer when the solar horizontal coordinates equal the lunar horizontal coordinate.

The moon's umbra shadow is about 371000 km.in length and the earth moon distance which varies between 336000-420000 km [5,10] that mean the moon's umbra maybe not reached the earth's surface, The total eclipses could never seen but for annular solar eclipse some of the sun disc can seen. The moons shadow diameter depend on the sun distance rs and the Earth Moon rm, which varies always with time, period through year and the shadow diameter velocity depend on moon-earth distance which varies throughout the syndic month. The moons shadow sweep across the earth depend on the moon orbital speed as a domain factor and the earth rotate as secondary factor, the shadow can be seen from a spot on the earth for the total eclipse only 2-3 minutes, A typical eclipse sweeps out a path about 10000 km. long and about 150 km wide [2].
This number is 50% depend on the distances rm and rs. In the present work new model have been used to determine the date and time of the total solar eclipse, eclipse shadow center coordinate and shadow area on the earth surface.

Calculating a total solar eclipse

A solar eclipse is more difficult to calculate than a lunar eclipse. If the solar eclipse looked in the Astronomical Almanac a map of the world shows the path and duration of the eclipse at each point.

The solar eclipse is total when the moon disc passes on the earth –sun line this case happen only when the new moon in one of the two nodes. The solar eclipse occurs when the Earth passes the night side of Moon and the Moon shadow cone touch the Earth surface.

The solar eclipse characteristic known from the least distance from the axis of the moon's shadow to the center of the Earth in units of the equatorial radius of the Earth(Y) [4]. Smith P.D. see that Y= ±0.9972 the solar eclipse is central and 0.9972 < |Y| < 1.026 the umbra cone touch the surface of the Earth [5]. Others references depend on the elongation angle (the Earth-Sun – Moon angle) must be less than 1 degree, in this work the elongation less than 1 degree and the observer – sun – moon angle is minimum than any other observers and the shadow area is more than zero.

The programs for our model are designed in Q-basic language in this big work all the years and months are chosen to limit the new Moon days, the solar eclipse type, shadow spot diameter and its geographical coordinates as the following steps:

1- Find the Julian Date (J.D.) for the new Moon with concluded all the perturbation effect on the Moon orbit [4].
2- From the J.D. compute the Julian century (T)
   T= J.D.- 2451545 / 36525 (1)
3- T used to compute the ecliptic coordinates (β, λ) for the Sun and Moon [4] or as in [14] take the similar results and compute the obliquity angle ε

$\varepsilon = \pm 23.4512 - 0.00256 \cos [259.18 + 1934.142T + 0.00207T^2]$ (2)

4- Convert the ecliptic coordinate to equatorial (α , δ) for the new Moon, as in the following formula:

$\sin \delta = \sin \beta \cos \varepsilon + \cos \beta \sin \varepsilon \sin \lambda$ (3)

$\tan \alpha = (\sin \lambda \cos \varepsilon - \tan \beta \sin \varepsilon) / \cos \lambda$. (4)

$H = LST - \alpha$. (5)

$LST = GST - L / 15 - ((\gamma /60)/24)$. (6)

LST,GST: Are the local and universal sidereal time respectively.

L, φ the observer geographical coordinate (longitude and latitude).

4- Convert the equatorial coordinate to horizontal (a , A) for the new Moon, as in the following formula:

$\sin a = \sin \delta \sin \varphi + \cos \delta \cos \varphi \cos H$ (7)

$\cos A = (\sin \delta - \sin \varphi \sin a) / (\cos \varphi \cos a)$ (8)

5- Calculate the Sun and Moon mean anomaly M, M' and the Moon mean argument of latitude F as the following formula [14]:

M = 375.5256 + 35999.049 T }
M' = 134.96292 + 477198.86753 T} (9)
F = 93.27283 + 483202.01873 T }

6- Calculate the Earth – Moon and Earth – Sun distances at the instate time as in the following formula [14] :

rs = [149.619 – 2.499 cos(M) – 0.21 cos(2M)] 10^6 km. (10)

rm = 385000 – 20905 cos(M') – 3699 cos (2D-M')-2956 cos(2D) -570 cos(2M') +246 cos(2M'-2D) + 205 cos (M-2D) – 171 cos(M'+2D) – 152 cos (M'+M-2D) km. (11)

where D is the difference between the mean longitudes of the Sun and the Moon.

D = 297.85027 + 445267.11135T (12)

The Earth-Moon distance also can be calculated as in [4] that is

$r_c = 6378.16 / \sin \pi_c$. (13)

where π_c: The Moon parallax.

7- To find the characteristic of eclipse calculate Y the least distance from the axis of the moon's shadow to the center of the Earth in units of the equatorial radius of the Earth. as the following [4]:

S = 5.19595 – 0.0048 cos M +0.002 cos 2M – 0.3283cos M' -0.006cos (M+M') + 0.0041cos(M-M') (14)

C= 0.207sin M+0.0024sin 2M – 0.039 sin M' + 0.115 sin 2M' – 0.0073 sin (M+M') - 0.0067sin(M-M') + 0.0117 sin 2F (15)

Y = S sin F + C cos F (16)

Now at Y= ± 0.9972 the solar eclipse is central (+ north of earth- south of earth) at

0.9972 < |Y| < 1.026 the umbral cone touch the surface of the Earth.

8- Calculate U factor as in [4].

U = 0.0059 + 0.0046 cos M – 0.0182 cos M' +0.0004cos2M'–0.0005cos(M+M') (17)

where U: denotes the radius of the Moons umbra cone in the Earth fundamental plane, In this work if U=+ve.

The shadow diameter (d) in the fundamental plane of Earth surface can calculate from the two large and medium triangles get:

Rm / Rs = (X+ rm / (X+ rs) (18)

or

X = (rs Rm – rm Rs) / (Rs-Rm) (19)

where Rm, Rs the actual radius of the Moon and the Sun are 1738 Km, 696000 Km.

From the other triangles medium and small get the eclipse shadow diameter d which full down on the fundamental plane:

d = X Rm / (X+rm) (20)

9- Determine the best agreement of the equatorial and horizontal coordinate for the Sun and the Moon for the entire geographical coordinate in step 4 and print the results.

10-Return to calculate all the above steps (2 to 9) at other time (t= t+15 min) or JD= JD+ 15/(60*24) to calculate the geographical coordinate of shadow spot and it's area.

Results and Discussion

The programs which designed for this model are get the Julian date for the new Moon with concluded all the perturbation effect on the Moon orbit. The elliptical, equatorial, horizontal coordinate and the distance for the Sun and the Moon are calculated to find the date and time of total solar eclipse and position of shadow spot on the earth surface. The distances rm, rs are computed to limit the eclipse type and shadow diameter.

These results are shown in Tables (1 -11) for the years1995, 1997, 1998, 1999, 2001, 2004, 2005, 2006, 2007, 2008, 2009 and the variation of all above information with time as well as its variation with geographical coordinate, the center of shadow at best agree of coordinate, these tables contain the eclipse type, date and universal time for mid eclipse must of these results agree with Astronomical Almanac 2010 [15] that meaning our programs are right.

Table 12 shows information about some eclipses happen at the last years and comparison with other reference it's have a good agreement and some of this eclipse iare agree with observation.

Table 13 and Fig. 2 shows the variation of shadow spot diameter on the earth surface with rm/rs for some above years. It's shows that its linear inversely proportional relation this expect relation, and because rs is slow variation but rm varies through month than the shadow area is inversely proportional with rm when the Earth position before the shadow cone end but rm proportion with shadow area when the Earth after see Fig. 1.

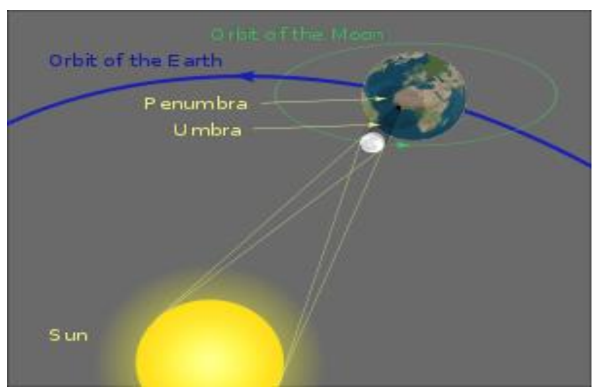

Fig. 1: The Moon shadow cone on the Earth surface and moved easterly[9].

During a central eclipse, the Moon's umbra (or ant umbra, in the case of an annular eclipse) moves rapidly from west to east across the Earth. The Earth is also rotating from west to east, but the umbra always moves faster than any given point on the Earth's surface, so it almost always appears to move in a roughly easterly direction across a map of the Earth see Fig.1.

The shadow diameter is plot with the ratio rm/rs in Fig.2 it shows a linear relation and inversely proportion that means the shadow is grater at perigee of the Moon and the beginning of lunar month is more clearly.

Table 1: YY = .3710349801 Total CENTRAL ECLPSE
J.D NEW MOON 2450014.691681355 24/10/ 1995 4h 33min

Time	Rmoon	Rsun	Sh.dim. (Km.)
3h 48m 59.9	346495.0	148802122.1	147
4h 3m 59.9	346464.3	148801695.1	147
4h 18m 59.9	346434.1	148801268.1	147
4h 33m 59.9	346404.5	148800841.1	147
4h 48m 59.9	346375.4	148800414.1	147
5h 3m 59.9	346346.9	148799987.2	148
5h 18m 59.9	346318.9	148799560.3	148
5h 33m 59.9	346291.5	148799133.4	148
5h 48m 59.9	346264.6	148798706.5	148
6h 3m 59.9	346238.3	148798279.7	148

Table 2: YY = .934365429 Total CENTRAL ECLPSE
J.D NEW MOON 2450516.55302816 9/ 3/ 1997SUNDAY 1h 14 min

Time	R moon	R sun	Sh.dim.(Km.)
0h 29m 18.5	358083.2	148541022	90
0h 44m 18.5	358096.8	148541957.6	90
0h 59m 18.5	358110.6	148542366.8	89
1h 14m 18.5	358124.6	148542776.0	89
1h 29m 18.5	358138.8	148543185.3	89
1h 44m 18.5	358153.2	148543594.6	89
1h 59m 18.5	358167.8	148544003.9	89
2h 14m 18.5	358182.7	148544413.2	89
2h 29m 18.5	358182.7	148544413.2	88

Table 3 : YY = .2163553301 Total CENTRAL ECLPSE
J.D NEW MOON 2450871.227450439 26/ 2/ 1998THURSDAY17h 25min

Time	Rmoon	Rsun	G .sh. p. def . Eq. coord.	Dim,(Km)
16h 40m 27.3	360020.1	148145957.6	50 -20 0.262 68.77 19.90	77
16h 55m 27.3	359999.3	148146326.1		77
17h 10m 27.3	359978.6	148146694.6		77
17h 25m 27.3	359958.2	148147063.2		77
17h 40m 27.3	359937.9	148147431.8	-80 -10 0.273 42.19 7.92	77
17h 55m 27.3	359917.9	148147800.5	-70 0 0.298 50.74 6.82	77
18h 10m 27.3	359898.0	148148169.2	-60 40 0.277 34.78 4.78	77
18h 25m 27.3	359878.3	148148538.0	-50 60 0.328 19.89 18.96	77
18h 40m 27.3	359858.8	148148906.8		77
18h 55m 27.3	359839.5	148149275.7		77

Table 4: YY = .5053345262 Total CENTRAL ECLPSE
J.D NEW MOON 2451401.965079836 11/ 8/ 1999 WEDNES 11h 7min

Time	R moon	R sun	G .sh. p. def . Eq. coord	Sh.dim (Km)
10h 22m 36.5	372903.0	151614561.2	80 10 0.501 22.51 257.6	55
10h 37m 36.5	372941.8	151614299.5	-90 20 0.498 33.6 264.72	55
10h 52m 36.5	372980.7	151614037.8	-90 20 0.497 33.60 264.7	55
11h 7m 36.5	373019.7	151613776.	-90 30 0.497 33.93 271.4	54
11h 22m 36.5	373058.8	151613514.1	-90 40 0.476 33.09 278.	54
11h 37m 36.5	373098.0	151613252.1	-90 50 0.481 31.15 284.2	54
11h 52m 36.5	373137.3	151612990.1	-80 50 0.460 24.81 275.9	54
12h 7m 36.5	373176.7	151612728.1	-60 60 0.486 13.43 262.9	54
12h 22m 36.5	373216.2	151612465.9	-60 10 0.542 3.28 255.2	53
12h 37m 36.5	373255.8	151612203.7	-70 -10 0.538 7.55 253	53

Table 5: YY = .555508236 Total CENTRAL ECLPSE
J.D NEW MOON 2452081.999582159 21/ 6/ 2001 11h 57min

Time	R moon	R sun	Sh.dim.(Km.)
11h 12m 15.1	341496.7	152038653.3	204
11h 27m 15.1	341477.5	152038750.0	204
11h 42m 15.1	341458.8	152038846.5	204
11h 57m 15.1	341440.7	152038943.	204
12h 12m 15.1	341423.2	152039039.4	204
12h 27m 15.1	341406.1	152039135.8	204
12h 42m 15.1	341389.6	152039232.	204
12h 57m 15.1	341373.7	152039328.2	204
13h 12m 15.1	341358.3	152039424.3	203
13h 27m 15.1	341343.4	152039520.4	203

Table 6: YY = 1.03890571
J.D NEW MOON 2453292.6164 14/10/ 2004 2h 45min

Time	R moon	R sun	Sh.dim.(Km.)
2h 0m 28.3	347866.5	149189626.0	145
2h 15m 28.3	347833.8	149189182.8	145
2h 30m 28.3	347801.7	149188739.6	145
2h 45m 28.3	347770.1	149188296.4	145
3h 0m 28.3	347739.1	149187853.2	145
3h 15m 28.3	347708.5	149187410.0	146
3h 30m 28.3	347678.5	149186966.8	146
3h 45m 28.3	347649.0	149186523.6	146
4h 0m 28.3	347620.0	149186080.5	

Table 7: YY = .352106190 Total CENTRAL ECLPSE
J.D NEW MOON 2453646.935928283 3/10/ 2005 10h 25min

Time	R moon	R sun	Sh.dim. (Km.)
9h 55m 29.6	364967.9	149657702.8	70
10h 10m 29.6	364943.3	149657255.0	70
10h 25m 29.6	364919.2	149656807.2	70
10h 40m 29.6	364895.5	149656359.5	70
10h 55m 29.6	364872.4	149655911.7	70
11h 10m 29.6	364849.7	149655464.0	71
11h 25m 29	364827.5	149655016.2	71
11h 40m 29	364805.9	149654568.4	71
11h 55m 29.6	364784.7	149654120.6	71

Table 8: YY = .3929685 Total CENTRAL ECLPSE
J.D NEW MOON 2454000.99 22/ 9/ 2006 11h 43min

Time	R moon	R sun	Sh.dim.(Km)
11h 13m 31.6	375621.2	150133366.5	26
11h 28m 31.6	375611.1	150132930.4	26
11h 43m 31.6	375601.6	150132494.3	26
11h 58m 31.6	375592.5	150132058.1	26
12h 13m 31.6	375583.9	150131621.9	26
12h 43m 31.6	375575.9	150131185.7	26
12h 58m 31.6	375568.3	150130749.5	26
13h 13m 31.6	375561.3	150130313.2	26

Table 9: YY = 1.123586
J.D NEW MOON 2454355.031 11/ 9/ 2007 12h 43min

Time	R moon	R sun	Sh.dim.(Km.)
11h 58m 8.7	370812.9	150589761.6	53
12h 13m 8.7	370816.7	150589352.9	53
12h 28m 8.7	370821.0	150588944.2	53
12h 43m 8.7	370825.7	150588535.5	53
12h 58m 8.7	370830.9	150588126.7	53
13h 13m 8.7	370836.6	150587717.9	53
13h 28m 8.7	370842.9	150587309.1	53
13h 43m 8.7	370849.6	150586900.2	53
13h 58m 8.7	370856.8	150586491.3	53
14h 13m 8.7	370864.5	150586082.4	53

Table 10: YY = .971495462 total CENTRAL ECLPSE
J.D NEW MOON 2454503.65626 7/ 2/ 2008 3h 42min

Time	R moon	R sun	Sh.dim (Km.)
2h 57m 43.6	353750.1	147538467.4	99
3h 12m 43.6	353731.4	147538725.1	99
3h 27m 43.6	353713.1	147538982.9	99
3h 57m 43.6	353695.4	147539240.8	99
4h 12m 43.6	353678.2	147539498.8	99
4h 27m 43.6	353661.5	147539756.8	99
4h 42m 43.6	353645.2	147540014.9	100
4h 57m 43.6	353629.5	147540273.0	100
5h 12m 43.6	353614.2	147540531.3	100

Table (11-a): YY = .305644197 CENTRAL ECLPSE
J.D NEW MOON 2454857.830658545 26/ 1/ 2009 7h 53min

Time	R moon	R sun	Sh.dim.(Km.)
7h 8m 49.8	368961	147304455.5	24
7h 23m 49.8	368953.9	147304636.8	24
7h 38m 49.8	368947.4	147304818.3	24
7h 53m 49.8	368941.3	147304999.7	24
8h 8m 49.8	368935.7	147305181.3	24
8h 23m 49.8	368930.6	147305363	24
8h 38m 49.8	368926	147305544.7	24
8h 53m 49.8	368921.9	147305726.5	24
9h 8m 49.8	368918.2	147305908.3	25
9h 23m 49.8	368915.1	147306090.3	25

Table (11-b): YY = 0.077345662990 Total CENTRAL ECLPSE
J.D NEW MOON 2455034.607968499 22/ 7/ 2009 2h 33 min

Time	R moon	R sun	Sh.dim.(Km.)
1h 48m 8.7	336918.7	151989181.6	224
2h 3m 8.7	336916.8	151989052.0	224
2h 18m 8.7	336915.5	151988922.3	224
2h 33m 8.7	336914.8	151988792.6	224
2h 48m 8.7	336914.7	151988662.8	224
3h 3m 8.7	336915.2	151988532.9	224
3h 18m 8.7	336916.2	151988402.9	224
3h 33m 8.7	336917.8	151988272.9	224
3h 48m 8.7	336920.1	151988142.8	223
4h 3m 8.7	336922.9	151988012.6	223

Table 12: total solar eclipse information

Date d m y	Time(U.T) h. min.	Shadow G. coordinate	Sh. iam. Km.	YY Re	Notes
24-10-1995	4 33	60N,130E -130w	147	.371	*In ocean*
9 - 3 -1997	1 14	60W - 10E	90	.934	
26- 2- 1998	17 25	20S,30W - 80E			
11- 8-1999	11 7	50N,10W - 90E	55	.505	*Show from Iraq*
21- 6-2001	11 57	18S,40E – 140E	204	.555	
14-10-2004	2 45			1.02	*annular*
3 -10-2005	10 25	130E -150W	70	.352	*In Ocean*
11-9 -2007	12 43	100W -20E		1.12	*Annular*
7 - 2 -2008	3 42				
26-1 -2009	7 53	130W -80W	24	.305	*In ocean*
22-7 -2009	2 33	40E - 150E	224	.077	

Table 13: Shadow area variation with rm/rs

JD > (days)	rm /rs	sh. Dim (km)
2451401.95	2.4561	55
2451401.97	2.4566	54
2451402.03	2.4619	53
2454503.63	2.3977	99
2454503.67	2.3972	99.5
2454503.71	2.3967	100
2453646.9	2.4388	70
2453647	2.4375	71
2453292.6	2.3315	145
2453292.64	2.3307	145.5
2453292.68	2.3299	146

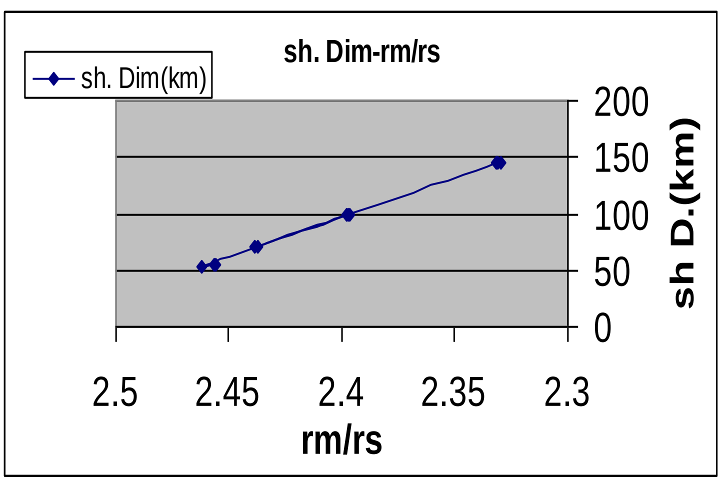

Fig.2: Shadow diameter variation with ratio rm/rs.

Conclusions

It was noted from the figures that the eclipse was total. Comparison of our results (calculated times) with those deduced from the maps and tables of the Astronomical Ephemeris [15] shows that we are within about a quarter of an hour of the correct solar eclipse times. Even our comparatively simple method allows us to make quite accurate predictions of phenomenon. We are think this program is the big first step about the eclipse in Iraq astronomer groups.

The solar eclipse can used to determine the Hegree month where the solar eclipse moment point to the beginning of the syndic month from top centric observer, which can be used to determined Hegree month which begin at sun set after solar eclipse because this event can see from all people [2,9].

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