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Calculation of the Time Interval of Radio Storm Emitted from Jupiter

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Abstract

A program in Visual Basic language was designed to calculate the time interval of radio storm by predict their type at specific Local Time (LT) from Baghdad location, such storms result from the Central Meridian Longitude (CML) of system III for Jupiter and phase of Io's satellite (Φ_{Io}). These storms are related to position of Io (Io- A,B,C,D). The input parameters for this program were the observer's location (longitude), year, month and day. The output program results in form of tables provide the observer information about the date and the LT of beginning and end of each type of emitted storm. The year 2011 was taken to apply the results within twelve month; the results of the time interval of radio storm were between (0.08^h-5.41^h) hours. The obtained results reveal a good agreement as compared with the results of (**Radio Jove**) software.

Keywords: Jupiter, Storms of Jupiter, Io-Storm, non-Io-Storm.

حساب الوقت الذي تستغرقة العاصفة الراديوية المنبعثة من كوكب المشتري

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الخلاصة

صمم برنامج بلغة الفيجوال بيسك لحساب الوقت المستغرق للعاصفة الراديوية من خلال التنبؤ بتوقيتها المحلي من مدينه بغداد، مثل هذا النوع من العواصف ينتج من النظام المركزي الثالث لكوكب المشتري وحركه القمر ايو حول المشتري. هذه العواصف هي (Io– A,B,C,D). معاملات الادخال للبرنامج هي موقع الراصد (خط الطول) و السنه والشهر واليوم. كانت النتائج المستخرجه بشكل جداول تجهز الراصد بمعلومات حول تاريخ والتوقيت المحلي لبداية ونهاية العاصفه الراديويه المنبعثه من كوكب المشتري من مدينه بغداد. اخذت سنه 2011 لعرض النتائج شهريا حيث استغرقت العاصفة الراديويه بين (0.08–5.41) ساعه. اشارت النتائج المستخرجه الى توافق جيد عندما قورنت مع برنامج الراديو جوفا.

Introduction

The emission mechanism that determines the Φ_{Io} and CML_{III} does not depend only on the detailed emission process, but also on the propagation characteristics within the Jovian ionosphere and magnetosphere. The orbital phase controls in terms of an emission mechanism, that determines the radiation within a small range of angles with respect to the magnetic field direction, and the CML, with respect to Jupiter, from this the storms are determined, as shown in Figure-1 [1, 2], when the probability of reception, as well as the overall energy of the signals received from Jupiter are higher than the average, there is a probability of existence of these storms [3]. All the radio signals from Jupiter are divided into two types "storm" and "non-Io-storm" events [4, 5]. Each storm consists of Io-related and Io-unrelated (non-Io) component according to Io's position has a strong, weak or non existence influence respectively, as shown in Figure-2 [4]. These storms are main (Io-A), early (Io-B), weak (Io-C) and fourth storm (Io-D) [6, 7]. The Earth based observations showed that the exact

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location varies slowly depending on frequency, these observations from above Earth were continued by the spacecrafts, but the transition in CML_{III} and Φ_{Io} are limited by the interference in frequency and the speed of the spacecraft. The probability of observing (non-Io) from Nancy was shown to be high variable, and there are the same storm regions in Jovian magnetosphere. Data from the United Radio and Plasma Wave (URAPW) experiment were used to determine the angular size and the direction of the radio storms. The URAPW observations of Jovian radio radiations greatly improved the determination of storm locations [8,9]. The ranges of the storms that depend on the program to obtain the results of radio storms from Jupiter are given in Table-1 [3,5].

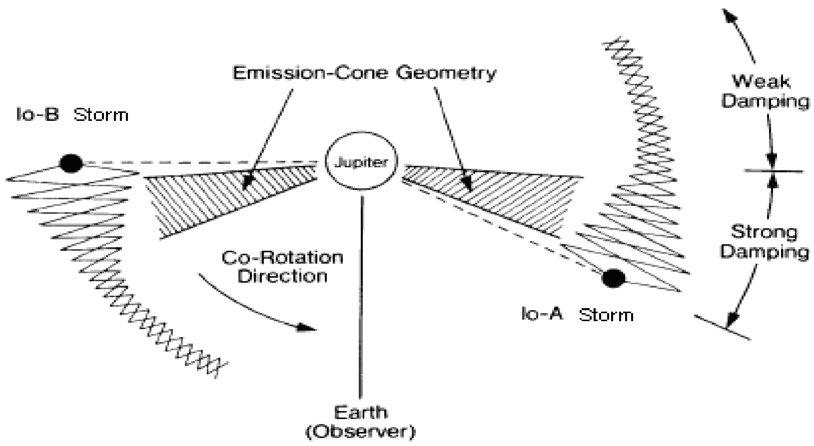


Figure 1- Explains the strong and weak radiation are affected by the position of Io [4].

Table 1- Ranges of storms according to Jupiter and Io angles [5].

Type of Storm	CML (Degrees)	Φ_{Io} (Degrees)
Io-A	180 -300	180-260
Io-B	15-240	40-110
Io-C	60-280	200-260
Io-D	0-200	95-130

Date and Time

It is often convenient in making astronomical calculations to use UT to deduce the LT in hours by the following equation [10]:

$$LT = UT + \left(\frac{\lambda_{City}}{15^\circ}\right) \quad \textbf{(1)}$$

Where:

UT: is the universal time measured in hours, λ_{City}: is the longitude of the city measured in degrees (example: Baghdad location longitude=45° and latitude=33°, www.google earth.com). The CML_{III} and phase change for each instant so it is necessary to express them in terms of Julian Date (JD) and UT for each instant. The Julian Date can be defined, as the interval of time in days and fractions of a day since January 1st 4713 B.C. That is midday, as measured on the Greenwich meridian [10].

- The Julian date was calculated for all the year, which is specific case by following equation [11]:

$$JD = INT(365.25 \times Y) + INT(30.6001(M+1)) + D + B + 1720994.5 \quad \textbf{(2)}$$

Where:
B: is Gregorian calendar.
Y: is the year.
M: is the month.
D: is the day.

- The number of days is given by [11]:

$$d = JD - 2435108 \quad \textbf{(3)}$$

The Orbital Elements of Jupiter

The motion of the planets around the Sun and of the satellites around their planets, are controlled by the action of the gravity that is by mutual force of attraction between masses. Orbital elements are the parameters required to uniquely identify a specific orbit. In celestial mechanics these elements are generally considered in classical two body systems. The CML of Jupiter is change for each instant during the year, which can be found from several astronomical elements [11].

- Argument (V_J) for the long - period term in the motion of Jupiter is given by [11]:

$$V_J = 157.0456 + 0.0011159d \quad \textbf{(4)}$$

- Mean anomaly for Earth (M_E), and Jupiter (N_J) is given by [11]:

$$M_E = 357.2148 + 0.9856003d \quad \textbf{(5)}$$

$$N_J = 94.3455 + 0.0830853d + 0.33 \, \text{Sin}\,(V_J) \quad \textbf{(6)}$$

- Difference (J) between the mean heliocentric longitude of Earth and Jupiter by [11]:

$$J = 351.4266 + 0.9025179d + 0.33 \, \text{Sin}\,(V_J) \quad \textbf{(7)}$$

Where:

V_J, M_E, N_J, and J are expressed in degrees.

- Equations of center of Earth (A_E), and Jupiter (B_J), they are also expressed in degrees, are given by [11]:

$$A_E = 1.916 \, \text{Sin}\,(M_E) + 0.020 \, \text{Sin}\,(2M_E) \quad \textbf{(8)}$$

$$B_J = 5.552 \, \text{Sin}\,(N_J) + 0.167 \, \text{Sin}\,(2N_J) \quad \textbf{(9)}$$

- And use another relation to link them as [11]:

$$K = J + A_E - B_J \quad \textbf{(10)}$$

- Radius vector for Earth (R_E) and Jupiter (R_J) are given by [11]:

$$R_E = 1.00014 - 0.01672 \, \text{Cos}\,(M_E) - 0.00014 \, \text{Cos}\,(2M_E) \quad \textbf{(11)}$$

$$R_J = 5.20867 - 0.25192 \, \text{Cos}\,(N_J) - 0.00610 \, \text{Cos}\,(2N_J) \quad \textbf{(12)}$$

- Distance (Δ) from Earth to Jupiter by [11]:

$$\Delta = \sqrt{(R_J)^2 + (R_E)^2 - 2 R_J R_E \text{Cos}\,(K)} \quad \textbf{(13)}$$

R_J, R_E, and Δ are expressed in Astronomical Units (AU), and the distance from Earth to Jupiter (Δ) always be positive.

- Phase angle of Jupiter (Ψ_J), which is the angle in phase with Jupiter with respect to the observer on the Earth is given by [11]:

$$\text{Sin}\,\Psi_J = \left(\frac{R_J}{\Delta}\right) \text{Sin}\,(K) \quad \textbf{(14)}$$

As mentioned, the CML, and phase are change for each instant, so the equations of CML of the three systems (system I, II and III) of Jupiter are given by [10]:

$$CML_{I,II} = 150.4529\left(d - \frac{\Delta}{173}\right) + 870.4529\left(d - \frac{\Delta}{173}\right) \quad \textbf{(15)}$$

$$CML_{III} = 274.319 + \Psi_J - B_J + CML_{I,II} \quad \textbf{(16)}$$

Where:

$\frac{\Delta}{173}$: is the correction for the light time, expressed in days, and the denominator 173 results from the fact, that the light time for unit distance is 1/173 day. The CML of Jupiter should be reduced to the interval (0-360)°. The angles of the Io satellite are measured from the inferior conjunction with Jupiter, so that U=0° corresponds to satellite's inferior conjunction, U=90° with its greatest western elongation, U=180° with the superior conjunction, and U=270° with the greatest western elongation the angles of Io's satellite are given by [11]:

$$U_1 = 101.5265 + 203.405863\left(d - \frac{\Delta}{173}\right) + \Psi_J - B_J \quad \textbf{(17)}$$

$$U_2 = 67.81114 + 101.291632\,(d - \frac{\Delta}{173}) + \Psi_J - B_J \tag{18}$$

- The equation of the phase is given by [11]:

$$\Phi_{Io} = 0.472\,\text{Sin}\,[\,2\,(U_1 - U_2\,)] \tag{19}$$

Where: U1, U2 and Φ_{Io} should be reduced to the interval (0-360)°. Figure-2, which represents the CML of Jupiter and orbital motion of Io's satellite around Jupiter.

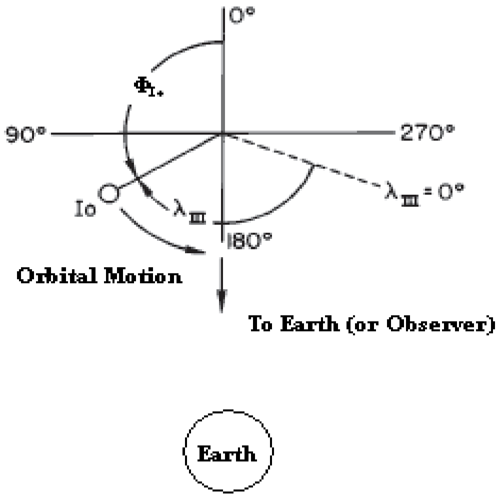
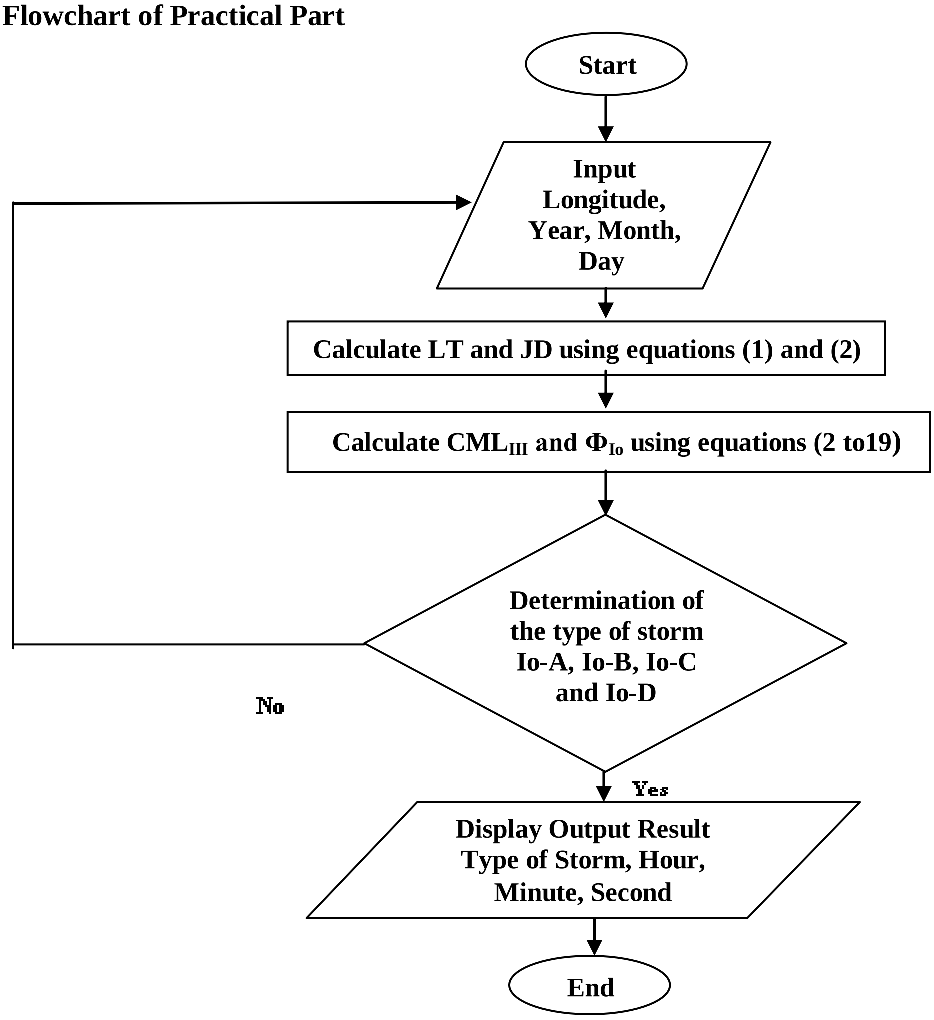


Figure 2- Explains the CML of Jupiter and orbital motion of Io [12].

Flowchart of Practical Part



Results and Discussion

A program in visual basic language was used to predict the type of radio storms that emitted from Jupiter at specific LT by determining (the observer's location, year, month and day), the observations in Table-1, which are according to the CML and phase of Io, are also used in the program, Baghdad location was chosen to apply the results. These results provide the observer information about the date of beginning and end of each type of predicated storm and their LT, these results are also indicated that the observer on the Earth in some days cannot receive any type of storm, while in other days he receives one type or more than one type, as shown in Table-2, which gave the results for Baghdad location for January 2011. The ranges of radio storm is not constant it is change due to the observations by the spacecrafts (**Voyager1 and Voyager2**). The program is also calculating the time interval of radio storm, the difference of beginning and end of the storm for the first month in the year 2011 was taken to find the time interval of continuity of storm, as equation (20).

Time interval= Begin of Storm – End of Storm **(20)**

This equation is applied for any type of storm regardless of their type and the location of the observer. Figure-2 which explain the time interval of storm as a function of number of days, the maximum time interval of storm is 5.41^h in the sixth day, while the minimum time interval is 0.15^h in the twenty-fourth day. The difference between the two values refers to the motion of Jupiter and Io which produces the type of storm. In a maximum value of time interval Jupiter and Io start with motion at the same time (the motion of Jupiter and Io covered all the ranges of CML_{III} and phase). The minimum value means that there is some delay in the motion of Jupiter or the motion of Io around Jupiter, so there is some missing amount in the ranges of CML_{III} and phase. As result of this, there is a difference between the maximum and the minimum value. The same behavior is also appeared for other months in the same year; regardless of the location, this means the time interval of continuity of storm is different along the year, as Figure-4. The obtained results reveal a good agreement as compared with the other results, that predict the type of radio storm that emitted from Jupiter at specific Local Time (LT) from two different Iraqi locations (Baghdad and Basra), such storms result from the Central Meridian Longitude (CML) of system III for Jupiter and phase of Io's satellite (Φ_{Io}) [13].

Table 2- Prediction of radio storms

Date		***Local Time***						***Type of Storm***
		Begin			***End***			
Day	***Month***	***HH***	***MM***	***SS***	***HH***	***MM***	***SS***	
1	1	11	38	23	17	49	9	Io-B
2	1	3	31	41	5	23	57	Io-A
3	1	5	24	7	9	21	35	Io-B
4	1	3	45	19	7	2	10	Io-A
5	1	8	4	4	10	3	38	Io-D
	1	5	45	17	8	3	6	Io-B
6	1	20	41	34	1	33	20	Io-B
7	1	11	10	28	14	27	18	Io-A
8	1	21	55	29	23	25	53	Io-D
9	1	9	30	6	12	48	50	Io-C
10	1	7	22	35	10	17	33	Io-B
11	1	4	31	20	7	48	10	Io-A
12	1	/	/	/	/	/	/	no storm
13	1	2	56	21	3	28	0	Io-D
14	1	3	38	35	5	17	49	Io-A
15	1	/	/	/	/	/	/	no storm
16	1	10	16	19	13	34	48	Io-C
17	1	9	21	50	11	3	47	Io-B
18	1	4	21	9	5	17	18	Io-C
19	1	6	31	17	12	2	58	Io-B
20	1	3	37	6	5	47	59	Io-C
	1	14	51	46	19	21	3	Io-B
21	1	22	38	32	0	18	44	Io-A
22	1	16	51	27	20	7	31	Io-B
23	1	14	21	3	17	37	53	Io-A
24	1	11	21	34	11	32	1	Io-B
25	1	12	40	52	13	18	17	Io-C
26	1	7	17	50	13	28	22	Io-B
27	1	4	23	23	7	42	10	Io-C
28	1	20	6	11	23	24	41	Io-C
29	1	18	51	57	20	53	42	Io-B
30	1	15	7	30	18	24	21	Io-A
31	1	16	21	30	21	33	56	Io-B

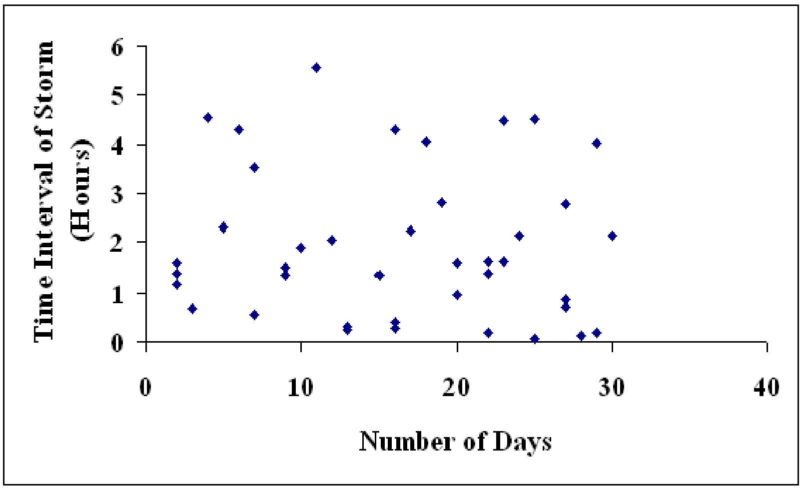


Figure 3- Time interval as a function of number of days for first month.

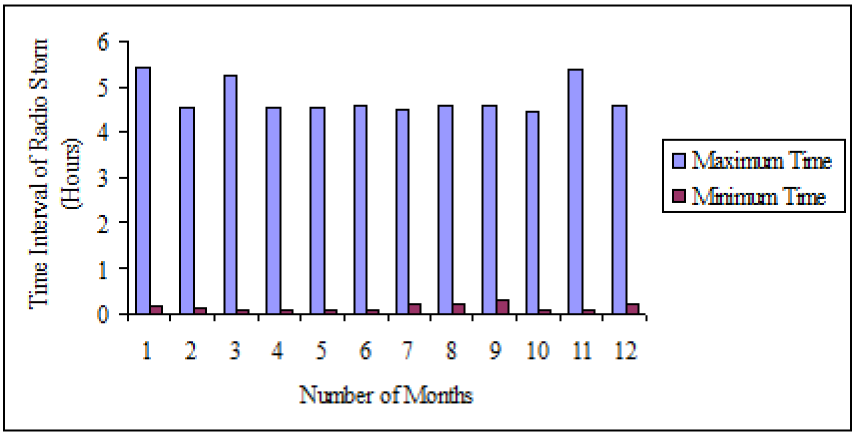


Figure 4-Time interval as a function of number of days for first month.

Conclusions

The time interval of radio storm lasts from few minutes to several hours within the day. The calculation of this time depends on the motion of Jupiter and Io, according to the geometry of the CML and phase of Io and there is a probability for the observer on the Earth to receive during the day one or more than one storm. This means that the number of storms is also not a constant, which is the reason of difference in average values. The longitude of the location does not effect on the time interval of radio storm, because the radio storm is occurred on the solar system with respect to the observer on the Earth, so is there time. Two different assumptions can accounted for (Earth-Jupiter-Io) geometry:

a. The radiation comes from Jupiter in specific ranges when Jupiter interacts with Io's satellite. From this many types of storms that related and unrelated to the position of Io are seen. This mechanism is responsible for the generation and the escape of this radiation from Jupiter, when different angular sizes or bandwidths are taken for these storms. They are located at large distance from CML of Jupiter and come from the northern hemisphere of the planet. The main and early storms occur near the edge of the plasma torus. A wide range of longitude, perhaps all longitudes, is excited by Io, but the radiation is beamed (either at the emission point or during the propagation) and is received only when the Earth crosses the radiation beam.

b. The difference in Io Flux Tube (IFT) means variation in plasma torus density and source region. Such variation will affect the orientation of the radiation of the emission as it is generated, or affect the escape of radiation after propagation through the Jovian plasma. These variations are caused by the strength of Io interaction at a certain point along its orbits.

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