Relationship between CML and Io's phase according to Jupiter's actual radio storms observations

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Abstract

The actual observations for Jupiter radio storm were taken for Hawaii station within multi years from 2001 to 2012. The Central Meridian Longitude (CML_{III}) and Io's phase (γ_{Io}) were calculated for each year from Radio Jove program, the results of CML_{III} for year 2006 was A=(180-300)º,B=(15-239)º, C=(60-280)º, phase was A=(182-260)º,B=(40-109)º, C=(200-260)º, which were close to the theoretical values, longitude was A=(180-300)º, B=(15-240)º, C=(60-280)º and phase was A=(180-260)º,B=(40-110)º and C=(200-260)º.

Key words
Boundaries of Storms from Jupiter, CML, Io's phase.

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العلاقة بين خط الطول المركزي وطور القمر ايو حسب الارصادات الحقيقية للعواصف الراديوية

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الخلاصة

أخذت الارصادات الحقيقية للعواصف الراديوية من كوكب المشتري لموقع هاوي خلال عدة سنوات من سنة (2001-2012)، حسب خط الطول المركزي وطور القمر ايو لكل سنة من برنامج الراديو جوفا ، كانت نتائج خط الطول للعواصف الراديوية لسنة 2006 A=(180- 300) وB= (15-239) وC= (60- 280) الطور A= (182-260) و B= (40- 109) و C= (200- 260) وكانت قريبة للنتائج النظرية ، خط الطول A= (180- 300) و B= (15- 240) و C= (60 - 280) والطور A= (180-260) و B= (40-110) و C=(60- 260).

Introduction

In 1955, scientists found that Jupiter has three rotations, one of them is matching up with radio storm that emitted from it, this system is called system three III or (Central Meridian Longitude of system three for Jupiter CML_{III}), which is defined as the longitude facing the Earth at the time of reception, as shown in Fig.1 with period $9^h55^m29^s$[1]. The CML of system three is not related to the clouds motion, but it is linked to the rotation period of the Jovian magnetic field which is "frozen in" to the interior of the plant, according to CML_{III}, three types of radio storms are determined (A,B and C).

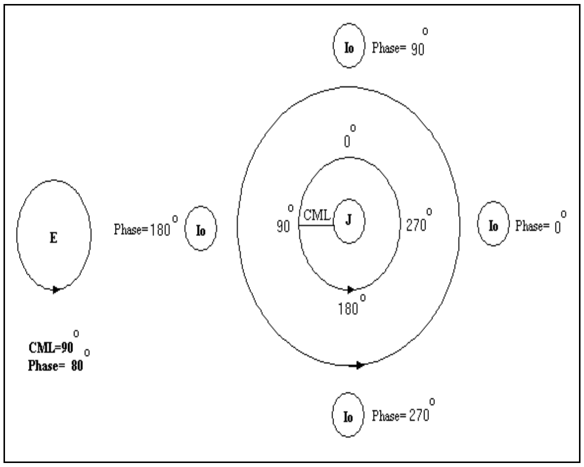


Fig.1: Explains how the CML_{III} of Jupiter and Io's phase are measured with respect to the observer on Earth [1].

In 1964, the location of Io's satellite has been discovered in its orbit influence on the probability of detecting radio storms from Jupiter. This effect combines with the CML_{III} when emissions will be heard on Earth. Io's orbital phase called "phase of Io", which is denoted by (γ_{Io}) and it is measured in degrees from Superior Geocentric Conjunction (SGG), when Io is directly behind the plant, as viewed from Earth, as shown in figure(2)[1].

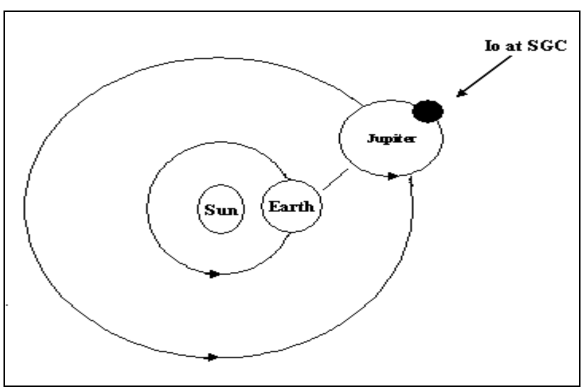


Fig. 2: Explains Io's satellite at SGC[1].

Boundaries of Storms

The study of radio storms from Jupiter and Io was based on a limited frequency of 18 MHz from the data that was obtained at Gainesville station from Florida's radio observatory during the apparition of 1962. This investigation extended to 1963 and 1964 including the 18, MHz data from not only the Gainesvilla station, but also the observatory's southern hemisphere field station near Maipu Chile. The data indicated the boundaries of CML_{III} for B and C storms between (110-200)° and (310-360)° respectively[2]. Another study during the period of 1964 to 1968 indicated that the CML_{III} for B storm was (150-270)°, which was picked up at frequency 22 MHz[3]. The spectrograph of Colorado's university in Boulder, picked up at the same frequency, three storms A, B and C, their CML_{III} were (210-330)°, (10-200)° and (45-300)° respectively and their phases were (210-270)°, (60-120)° and (210-270)° respectively[4]. During the same period and at same frequency the CML_{III} of the three storms (A, B and C) was equal to (240-270)°, (110-190)° and (20-260)° respectively and their phases equal to (220-260)°, (65-105)° and (220-260)° respectively[5]. The period between 1960-1967 at frequency 22.2 MHz the CML_{III} of these storms was (190-280)°, (70-190)° and (280-360)° respectively and their phase equal to (220-260)°, (70-110)° and (220-260)° respectively[6]. Between 1963-1976 Synoptic spectral observations indicated to only two storms their CML_{III} were (70-90) ° for B storm and (230-240) ° for C storm, the two storms picked up at frequency between (20-23) MHz[7]. At the same year pioneer11 indicted to three storms A,B and C, picked up at frequency 22 MHz the CML_{III} was 240°,145° and 325° respectively[8], also other observations at the same frequency indicated that the two storms CML_{III} were (210-260)° for A and (60-110) for B[9]. France Nancay observatory allowed to distinguish three storms in the period between 1978-1979, which were picked up at frequency 22.2MHz, the CML_{III} was (135-147)° for A, (91-94)° for B, and their phase (234-240)° for A and (301-302)° for

B[10], while the observations made by Voyager1 and Voyager2 in 1979 at frequency 20MHz, which observed only one subsidiary storm that is B its CML_{III} was between $(60\text{-}100)^o$[11]. In 1986 Nancay's observatory studies indicated to only one storm, which was C, its CML_{III} between $(60\text{-}280)^o$ and its phase 240^o, this storm was picked up at frequency 25 MHz[12]. Statistical studies were made by Nancay's array and waves experiment aboard wind spacecraft in 1997 at frequency 22MHz, which were observed two storms A and C and their CML_{III} were $(170\text{-}360)^o$ and $(180\text{-}340)^o$ respectively[13]. Finally, the long based observations indicated to three storms the CML_{III} of these storms were A $(180^o\text{-}300^o)$,B $(15^o\text{-}240^o)$ and C $(60^o\text{-}280^o)$ and their phase were $(180^o\text{-}260^o)$,$(40^o\text{-}110^o)$ and $(200^o\text{-}260^o)$ respectively picked up at frequency 22.2MHz, the exact location and magnitude of these storms varied slowly depending on the frequency range. Spacecrafts observations of this transition storm were limited, the Voygare Planetary Radio Astronomy (VPRA) experiment had a good coverage for frequency between (50KHz-40MHz), but suffered from internal spacecrafts interference in the frequencies near 5MHz , also the data was limited since Voygare flew by quickly and only observed Jupiter only from very limited sectors[14].

Radio Jove Software

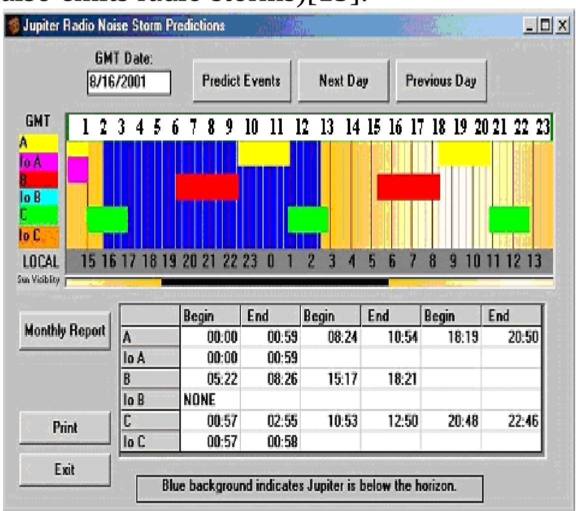
It is an educational/public outreach program involving scientists and educators from NASA space data operations center at the Goddard space flight center, the University of Florida, and the Florida space flight grant consortium. Radio Jove engages users in making analyzing observations of the natural radio emissions of Jupiter's plant and the Sun. Details of this exciting program can be obtained from the website of NASA: http://radiojove.nasa.gov. This website serves as a focal point for users and participants[15]. The purpose of the outreach program is to educate users about the bases of radio astronomy with respect to Jupiter and the Sun, to provide an opportunity to experience the scientific process, to create a worldwide net of observers connected through the internet, and facilitate the exchange of the idea for researchers at different locations. The program provides relatively affordable kits to observers complete with a receiver, antenna and software. The equipment provided through the Radio Jove program is used to study Jupiter and the Sun at a frequency of 21 MHz, three phenomenons can be regularly observed at this frequency[15]:

- Solar Flare Bursts.
- Coronal Mass Ejections.
- Jovian Decametric Emissions.

The Radio Jove Software is specifically designed to meet the needs of Jupiter radio observer. The program includes the following features useful for predicating noise storms, planning observations, and tracking the motions of Jupiter and Io, this software consists of [15]:

- Jupiter radio noise storm predications.
- Epheremeris.
- Yearly visibility schedule.
- Jupiter altitude vs. azimuth display.
- Sky map.
- CML-Io planning.
- Observer location.
- Jove declination.

This software gives us the CML_{III} and Phase, after input a specific date (year, month and day). From CML_{III} and phase, we can get the radio storm, because it is determined by the CML_{III} and phase, in our research we used the window of "Jupiter Radio Noise Storm Predications" to get their type (A, B and C), there are two parameters are important to predict the radio storms, Jupiter is in front of the antenna beam and the ionosphere is settling based upon the position of the Sun. As a part of the software, the observer enters (latitude, longitude and the time zone of Hawaii location). The user can run the software for any date, Fig.3 shows a 24 – hour of view of a both (Io and none-Io) predicated noise storms, both GMT and local time of the selected city are displayed, the storms that occurred at the daylight is neglected, because of the interference pattern (the Sun also emits radio storms)[15].



	Begin	End	Begin	End	Begin	End
A	00:00	00:59	08:24	10:54	18:19	20:50
Io A	00:00	00:59				
B	05:22	08:26	15:17	18:21		
Io B	NONE					
C	00:57	02:55	10:53	12:50	20:48	22:46
Io C	00:57	00:58				

Fig.3: Radio noise storm prediction screen of radio Jupiter software[15].

Aim of Research and Results

In this research, Hawaii location was selected to determine the boundaries of storms, by input these parameters (Lat. = 21.30°N, Long. =157.58°E and time zone=-10). The CML_{III} of Jupiter and phase of Io were obtained from the radio jove software at specific observing day. The type of radio storm also predicated by the same software, as explained in window of "Jupiter Radio Noise Storm Predications", as Fig.3. Multi years were taken to determine the actual boundaries from year (2001 to 2012) for the same location, three types of storms that are related to Io's position (Io-A,B and C) were taken to determine the boundaries at specific angles. In one day there is a probability to occur more than one type, this depends on the motion of Jupiter with respect to Earth and motion of Io with respect to Jupiter, the value of CML_{III} and phase were calculated for each day within these years, the results of year 2006 were given, because a large number of storms occurred in this year, as Tables 1, 2 and 3, the maximum and the minimum values for CML_{III} and phase were determined for three types of storms as explained. Table 1 gave CML_{III} and phase for Io-A region, the maximum value for CML_{III}=300° and phase=258°, and the minimum value was CML_{III}=180° and phase=182°, for Io-B region the maximum value for CML_{III}=109° and phase=239°, the minimum value was CML_{III}=15° and phase=42°, as Table2. Finally, for Io-C region, the maximum value for CML_{III}=355° and phase=260°, and the minimum value was CML_{III}=61° and phase=200°, as Table 3. The same work had done for the other years to notice the difference in values of CML_{III} and phase, which were not change too much. Table 4 explains the boundaries for multi years. The theoretical boundaries were given in Table5, the results indicated that some boundaries were identical to the theoretical, while others were not. The results in Table4 were also plotted to determine the difference in the values of CML_{III} and phase, as regions (Io-A, B, C), as explained from Figs.4-15 to compare them with Fig.16, which represents the theoretical values, not all the boundaries of storms were plotted, the difference boundaries were plotted only, as explained in figures to determine the change at these regions. The frequency that required to determine the boundaries from the radio jove software was 21 MHz, which was not effect on them, the motion of Earth, Jupiter and Io in the solar system effect on these boundaries, the observer can determine the boundaries of storms from any location by the radio jove software, not only for Hawaii location, but this is not effect on the boundaries.

Table1: Io-A for year (2006).

Month	Phase Max. (Deg.)	Phase Min. (Deg.)	CML_{III} Max. (Deg.)	CML_{III} Min. (Deg.)
1	250	184	298	189
2	**258**	182	**300**	191
3	256	183	277	**182**
4	256	197	295	185
5	247	188	295	186
6	256	193	299	183
7	236	**180**	255	192
8	247	184	297	188
9	258	195	292	183
10	239	203	300	190
11	242	183	298	188
12	253	188	295	185

Table2: Io-B for year(2006).

Month	Phase Max. (Deg.)	Phase Min. (Deg.)	CML_{III} Max. (Deg.)	CML_{III} Min. (Deg.)
1	**109**	47	234	17
2	103	44	237	**15**
3	86	44	**239**	19
4	107	44	239	19
5	107	44	234	15
6	105	**42**	237	30
7	102	52	226	22
8	94	47	238	18
9	107	43	229	26
10	98	51	236	17
11	95	49	234	15
12	106	45	231	29

Table3: Io-C for year (2006).

Month	Phase Max. (Deg.)	Phase Min. (Deg.)	CML_{III} Max. (Deg.)	CML_{III} Min. (Deg.)
1	242	204	**355**	**61**
2	256	224	338	87
3	**260**	201	314	159
4	243	208	324	181
5	252	201	335	87
6	254	208	338	159
7	259	**200**	345	94
8	245	209	333	79
9	255	219	354	88
10	255	232	345	94
11	252	208	354	73
12	242	204	333	65

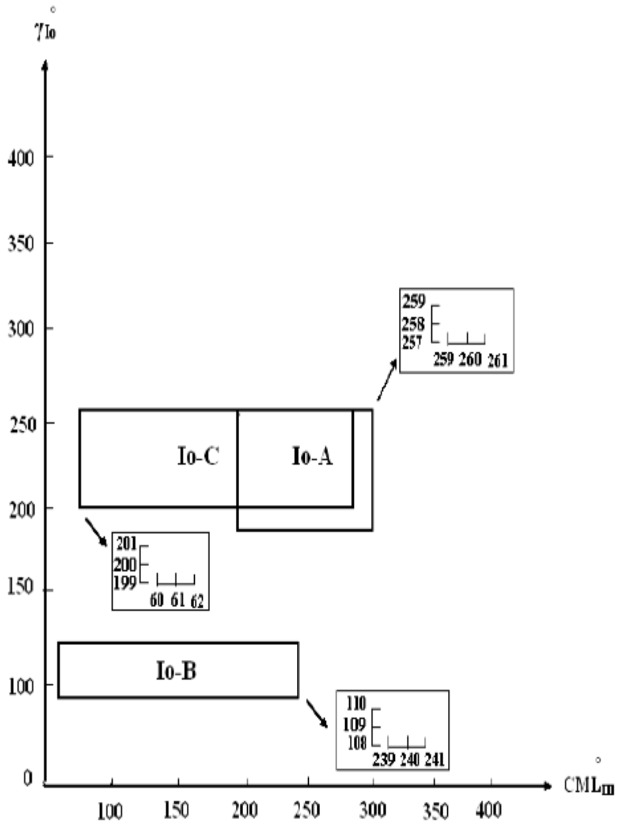
Table4: The boundaries for multi years from the observations.

Year	Type of storm	CML_{III} (Deg.)	Phase (Deg.)
2001	Io-A	180-300	180-260
	Io-B	15-240	40-109
	Io-C	61-280	200-260
2002	Io-A	180-300	181-258
	Io-B	15-240	42-110
	Io-C	61-280	200-260
2003	Io-A	180-300	181-258
	Io-B	15-240	40-110
	Io-C	60-280	200-260
2004	Io-A	180-300	182-260
	Io-B	15-239	42-109
	Io-C	61-280	200-260
2005	Io-A	180-300	182-260
	Io-B	15-239	40-109
	Io-C	60-280	200-260
2006	Io-A	180-300	182-260
	Io-B	15-239	40-109
	Io-C	60-280	200-260

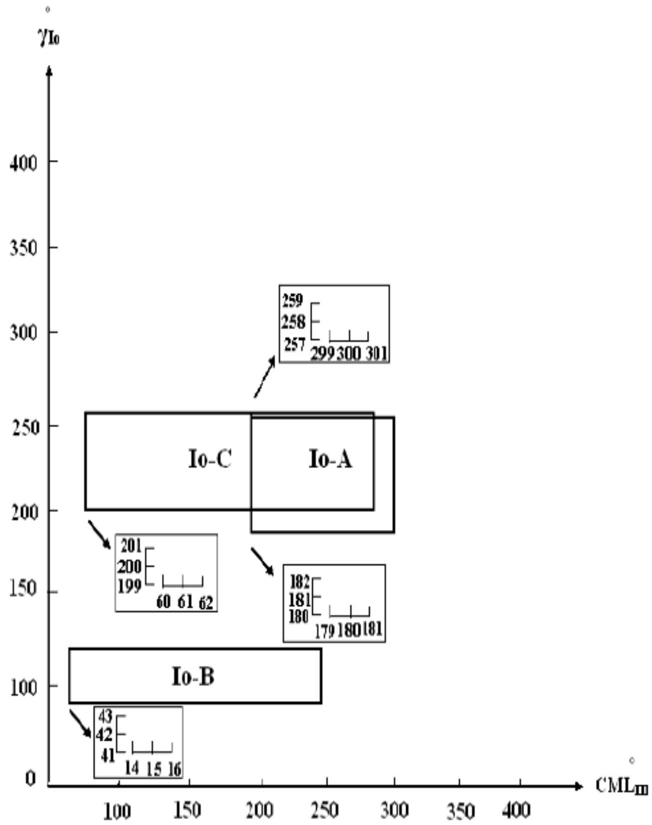
Year	Type of storm	CML_{III} (Deg.)	Phase (Deg.)
2007	Io-A	180-300	182-260
	Io-B	15-240	42-109
	Io-C	61-280	200-260
2008	Io-A	180-300	182-260
	Io-B	15-240	40-109
	Io-C	61-280	200-260
2009	Io-A	180-300	182-260
	Io-B	15-240	40-109
	Io-C	60-280	200-260
2010	Io-A	180-300	180-260
	Io-B	15-239	40-109
	Io-C	61-280	200-260
2011	Io-A	180-300	181-258
	Io-B	15-239	42-110
	Io-C	60-280	200-260
2012	Io-A	180-300	181-258
	Io-B	15-239	40-110
	Io-C	60-280	200-260

Table5: The theoretical boundaries[14].

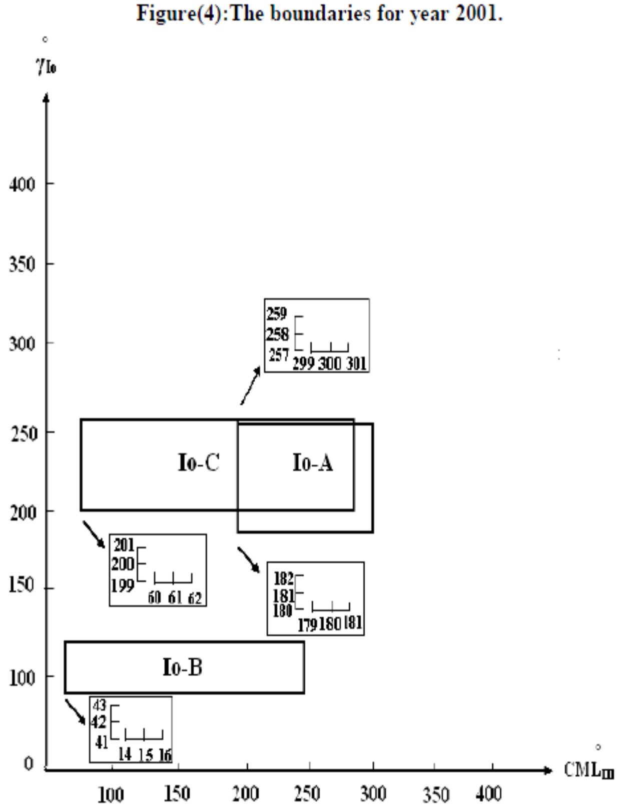
Type of Storm	CML_{III} (Deg.)	Phase (Deg.)
Io-A	180-300	180-260
Io-B	15-240	40-110
Io-C	60-280	200-260



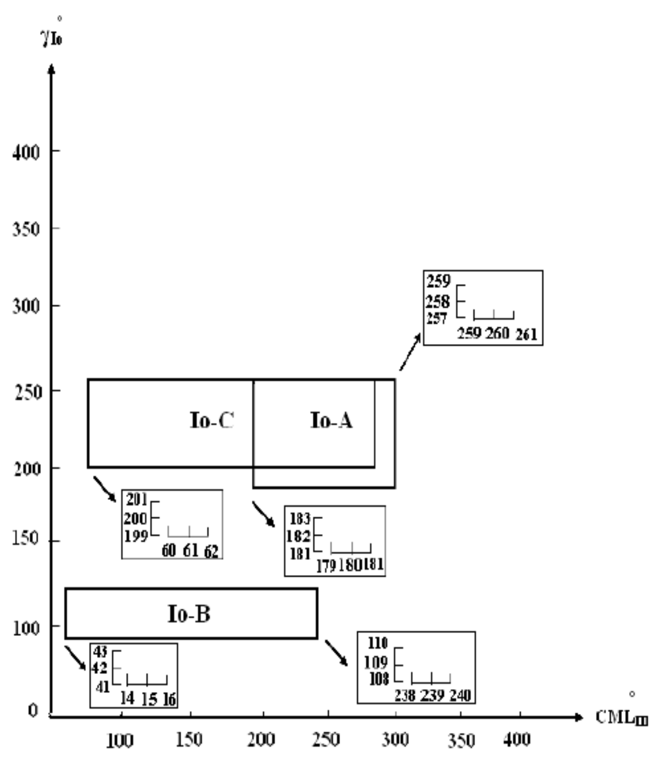
Figure(4):The boundaries for year 2001.



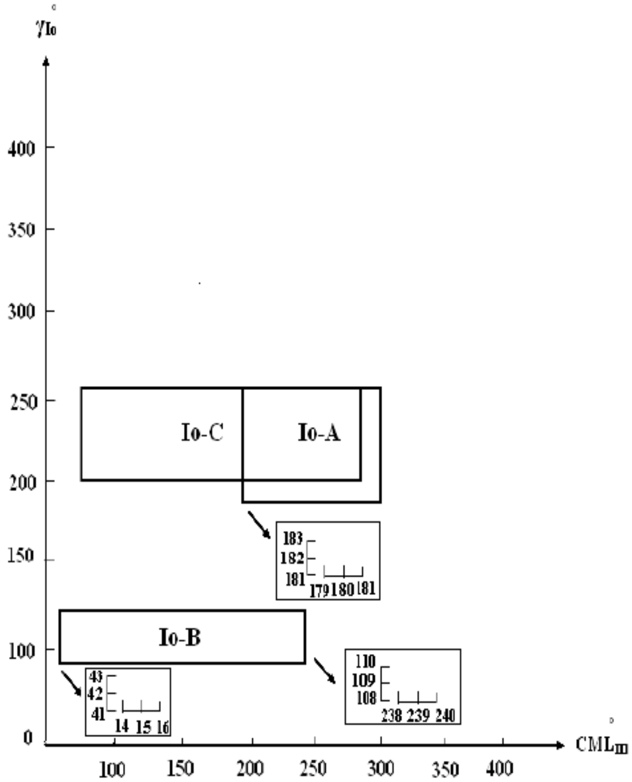
Figure(5):The boundaries for year 2002.



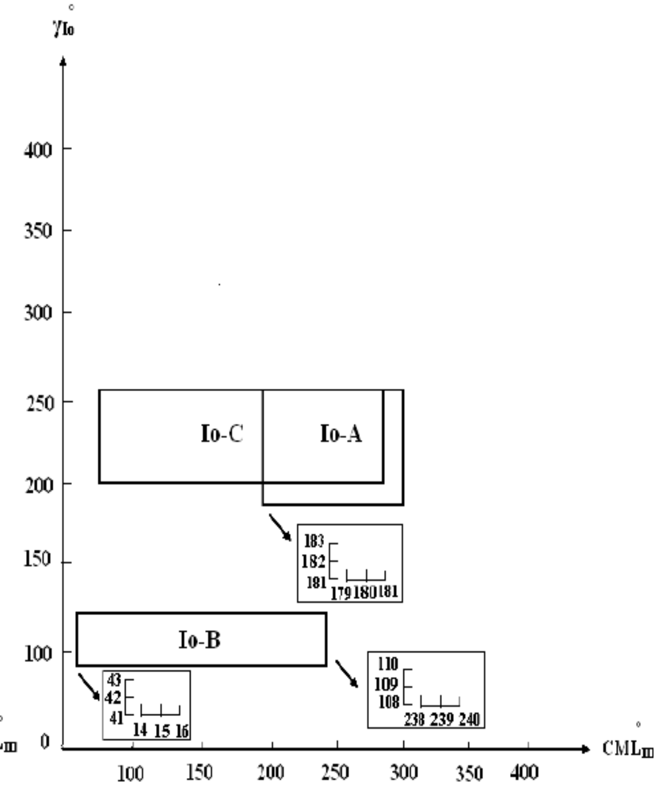
Figure(6): The boundaries for year 2003.



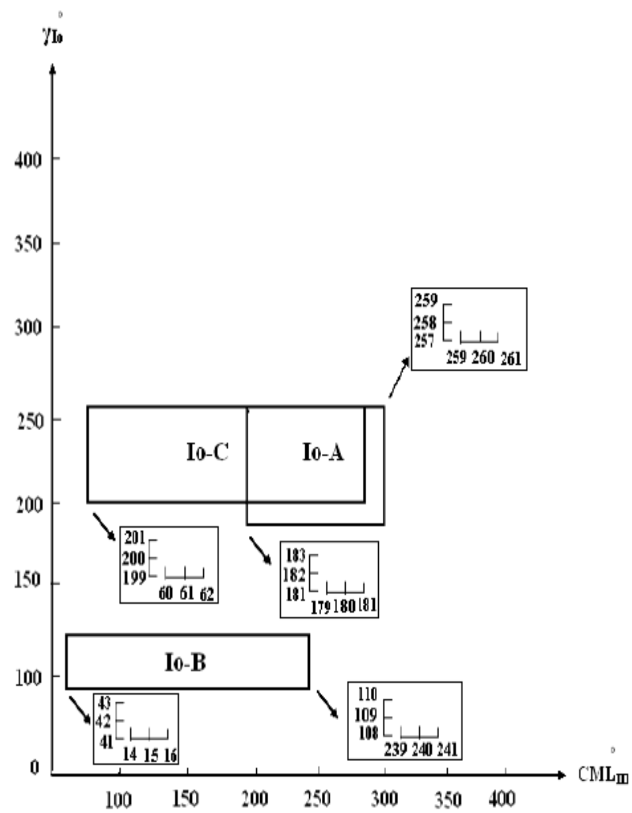
Figure(7): The boundaries for year 2004.



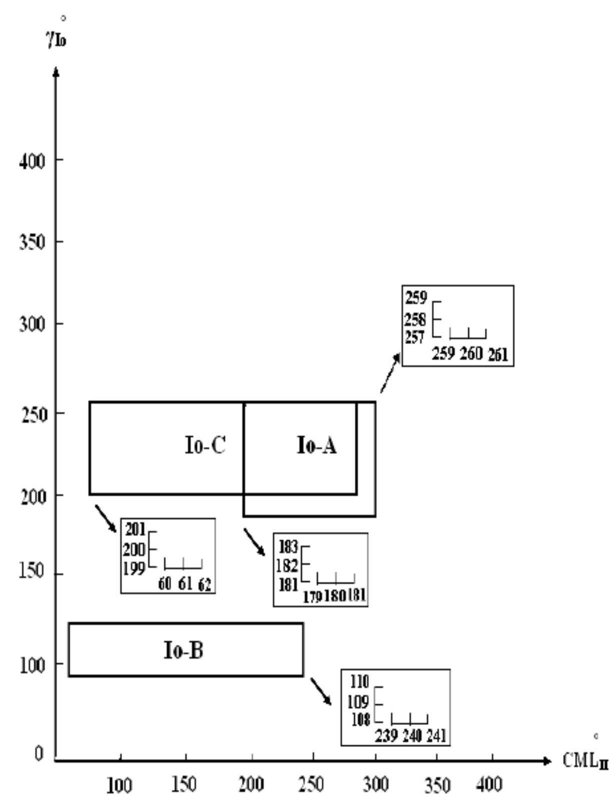
Figure(8): The boundaries for year 2005.



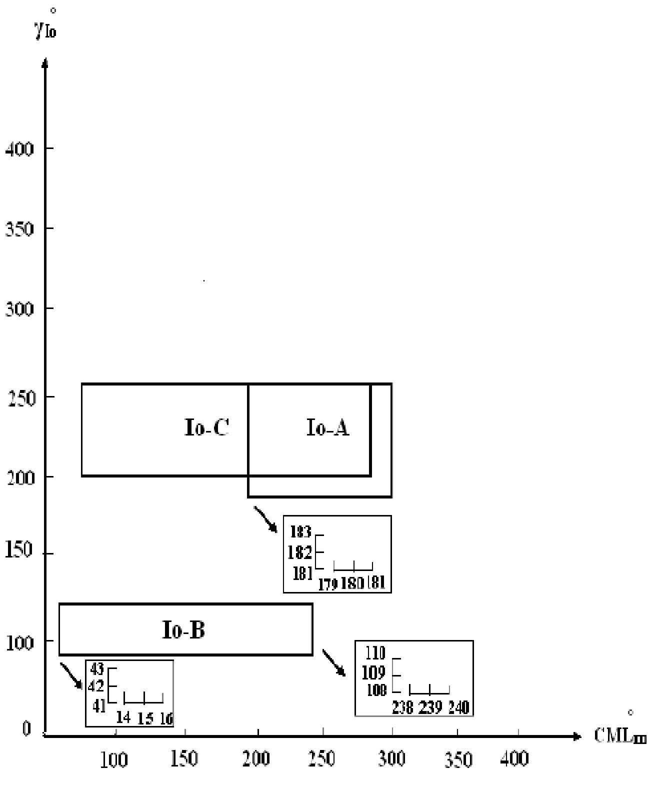
Figure(9): The boundaries for year 2006.



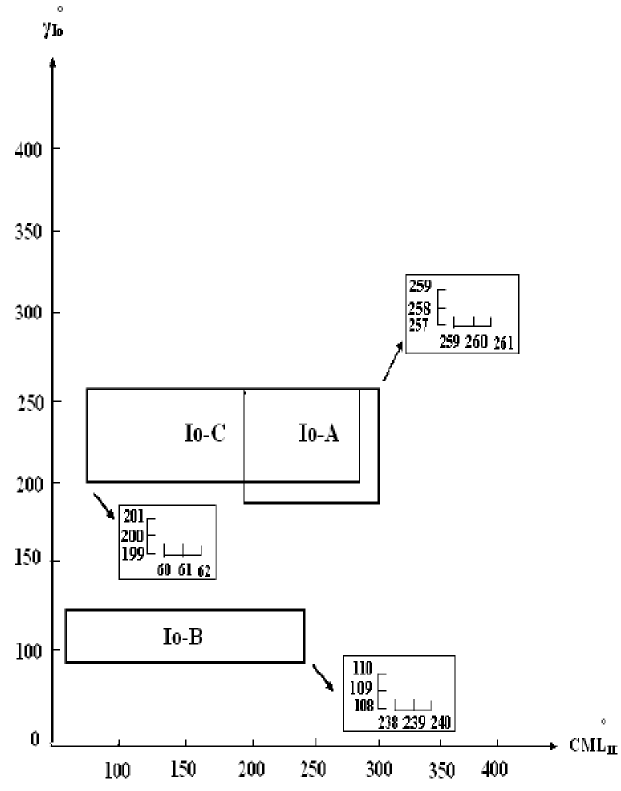
Figure(10): The boundaries for year 2007.



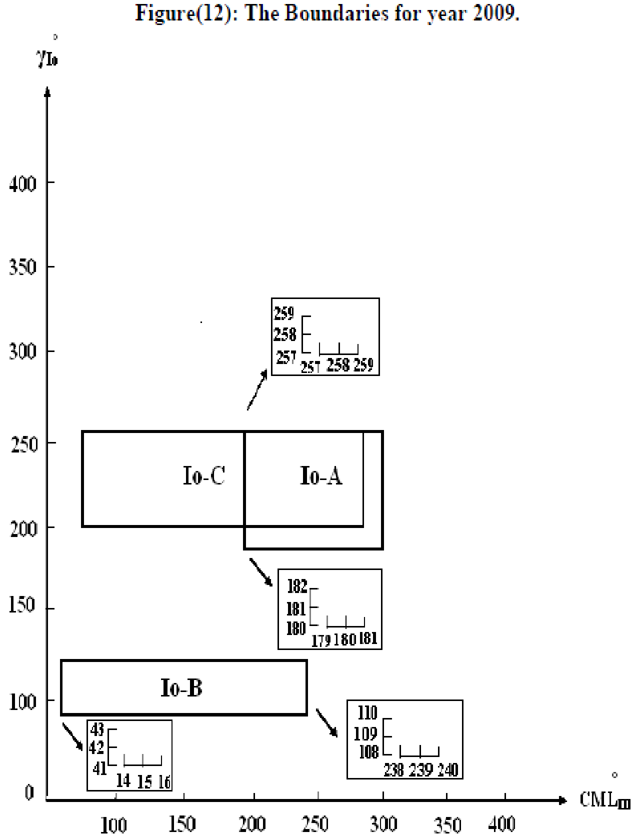
Figure(11): The boundaries for year 2008.



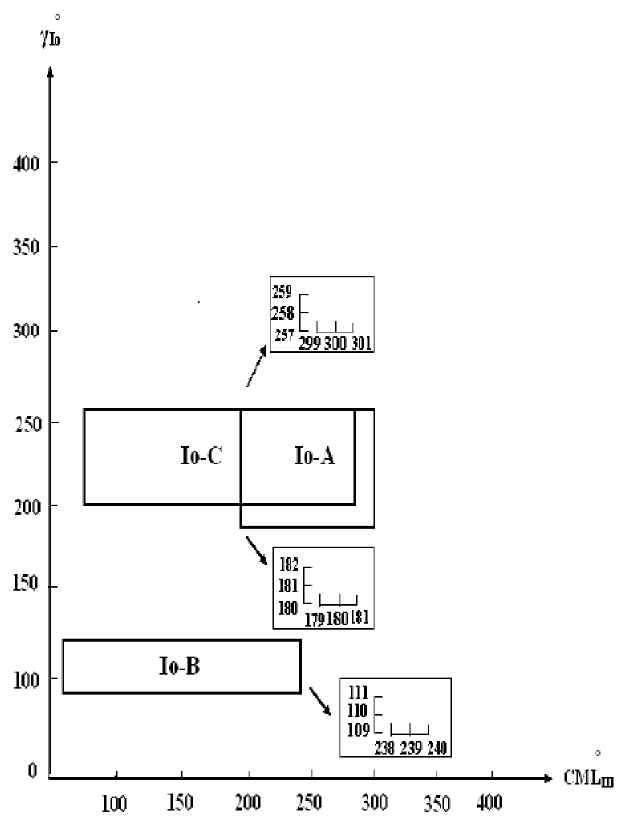
Figure(12): The Boundaries for year 2009.



Figure(13): The Boundaries for year 2010.



Figure(14): The Boundaries for year 2011.



Figure(15): The Boundaries for year 2012.

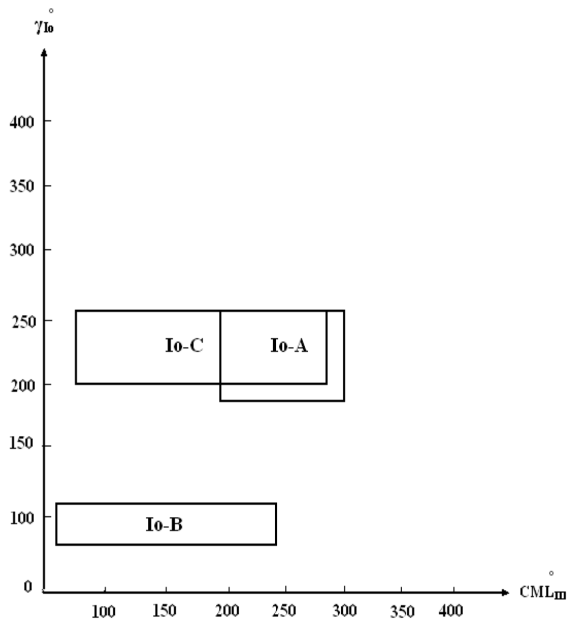


Fig.16: The theoretical boundaries[14].

Discussion and Conclusions

The boundaries of radio storms that emitted from Jupiter change due to the CML_{III} of Jupiter, which represent the rotation of Jupiter around itself and phase of Io's satellite around Jupiter and at specific regions the radio storms occurred with respect to the observer on Earth, during the rotation of Io, Jupiter's planet completes approximately four cycles with respect to Io; therefore the boundaries formed the storms according to CML_{III} were larger than the boundaries of phase. The boundaries of radio storm do not depend on the frequency of the receiver that is picked up the storm, which is different (the stations are set up at multiple frequencies such as (18 MHz, 21MHz, 22MHz), Radio Jove software predicated the storms (Io-A,B and C) for any observing day at specific frequency that is 21MHz, this indicates that the boundaries were not affected by the frequency. Multi years from 2001-2012 were taken, which gave a different values for CML_{III} and phase with a little difference in the boundaries, as Table(4), these results were close to the theoretical values that given in Table(5). This means that the boundaries of storms were depending on the motion of Jupiter and Io, the observer on Earth determines their type, according to the boundaries and intensities during the observations. Figs 4-15 are divided to subsidiary regions each region represent a type of radio storm. The values of CML_{III} and phase were different for each year, the boundaries for our results were close to the boundaries of theoretical results as Fig.16, because they are depend on the motion in the solar system and do not effect by the location of the observer, the observer can determine the boundaries from any location or any planet in the solar system.

References

[1] Th.Jim, H.Chuck, G.Leonard,P.Bill, L.Paul and D.Albie,"Radio Educational Activities and Lesson Plans", NASA, (2001), pp5-9.

[2] C. N. Olsson and G. S.Alex, , Science, 153, 3733 (2001) 289-290.

[3] W. W.James, and A.George, Dulk, Astroph. J., 19, 172(1970) 175-192.

[4]A.Lecacheux, Astro. and Astroph. J., 37, 20 (1974) 301-304.

[5]Z.Pokorny, Astro. Ins. of Czechoslovakia, Bulletin, 27, 3(1976) 137-143.

[6]M.George Gruber, Astroph. and Spa. Sci., 37 (1975) 169-172.

[7] J. R.Jorma, Astroph. and Spa. Sci.,. 51, 2 (1977) 363-383.

[8] A. J. Dessler and T. W.Hill, Astroph. J., 227(1979) 664-675.

[9] J. R.Jorma, Astro. and Astroph. J., 78(1979) L363-L383.

[10] F.Genova, M.G. Aubier and A.Lecacheux, , Astro. and Astroph. J., 104 (1981) 229-239.

[11] C. H.Barrow, Astro. and Astroph. Supp. Ser., 46(1981) 111-114.

[12] M. Y.Boudjada, H. O. Rucker and H. P.Ladreiter, Astro. and Astroph. J., 303(1995) 255-264.

[13]A.Aubier, M.Y.Boudjada, P. Moreau, P.H.M.Galopeau, A.Lecacheux, and

H.O.Rucker, Astro. and Astroph. J., 354(2000) 1101-1109.
[14]S.K.Bose, S. Sarkar, and A.B.Bhattacharyya, Ind. J. of Rad. and Spa. Phys., 37 (2008) 77-108.
[15]Flagg R.S., "Listening to Jupiter:A Guide for the Amateur Radio Astronomer, Radio-Sky publishing(2000),NASA, pp1-7.