Occultation of 44 Cap by the Jovian satellite Io on 2021 April 2

Eric Sussenbach & John Sussenbach

The occultation of the star 44 Capricorni (44 Cap) by Io on 2021 April 2 was imaged from Curaçao. Occasional overcast and atmospheric blurring hampered an accurate analysis of the event. The time points of the ingress and egress were derived from analysis of individual frames and photometry. We established the ingress time from the photographic data as 10:19:51.7 UT, and from the photometric data as 10:19:54.1 UT (predicted 10:19:52 UT). The egress was timed at 10:21:05 UT (predicted 10:20:58 UT).

Introduction

On 2021 Apr 2, the magnitude 5.8 star 44 Cap, of spectral type G, was occulted by Jupiter and four Jovian satellites (Io, Amalthea, Thebe and Metis). This is a rare event which happens once a century. We recorded the occultation of 44 Cap by Io.

The predicted track of Io's shadow is shown in Figure 1. This illustrates that the occultation was predominantly visible from South America and Africa.[1]

Eric lives on the Caribbean island of Curaçao, located at the northern side of the track. The coordinates of the observation location are 12° 5′ 37″ N, 68° 52′ 23″ W. For Curaçao, the predicted midpoint of the occultation was calculated to be at 10:20:25 UT and the duration of the occultation 66 seconds (data from the Institut de Mécanique Céleste et de Calcul des Éphémérides (IMCCE)).[2] The event occurred shortly before sunrise. During the occultation, the meteorological circumstances were rather unstable and unfavourable due to frequent cloud passages. The low altitude of Jupiter, at 35°, was also a handicap. However, Eric was nonetheless able to record the occultation.

In this communication, the results of the observation session are presented. It was our main goal to record the phenomenon photographically and to derive from these images the times of the ingress and egress as accurately as possible. Although it is obvious that the photometric approach was the most accurate way to determine these times, we wanted to investigate how well the timing could be established using imaging of the event, compared to results from a photometric analysis. Due to the poor weather conditions, a photometric comparison could only be performed for the ingress.

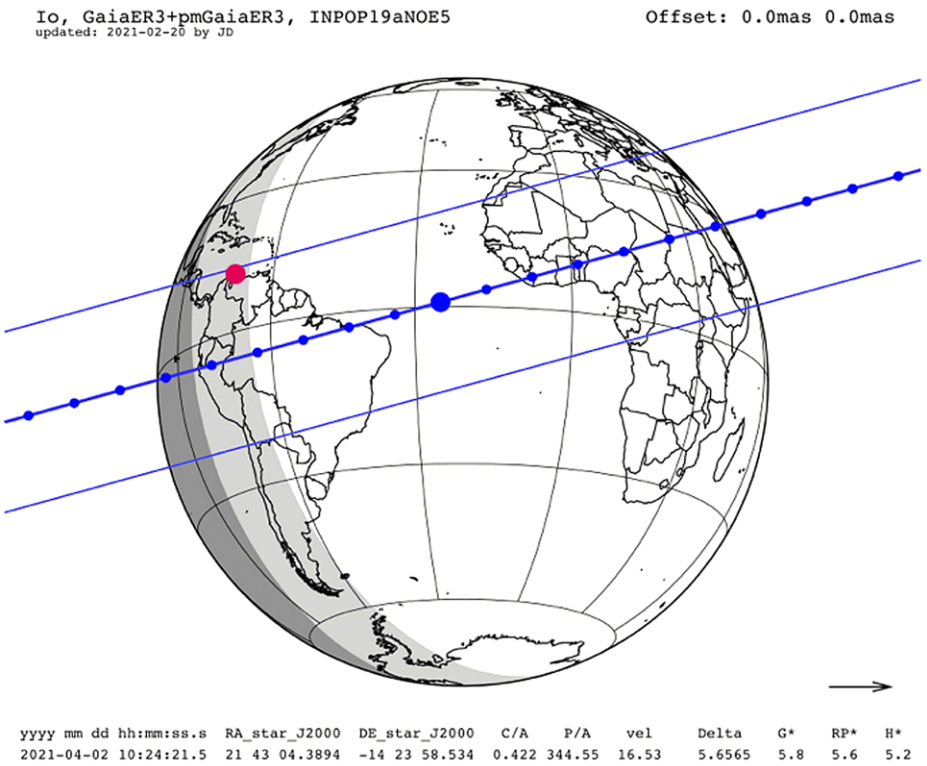

Figure 1. Theoretical track of the shadow of Io on 2021 Apr 2. The position of Curaçao is indicated by the red dot. *(Data from IMCCE)*

Table 1. Times covered by images in Figure 2

Frame	*Start*	*End*	*Average*
1	09:57:33.4	09:58:46.5	09:58:10.1
2	10:05:38.3	10:07:33.3	10:06:30.9
3	10:09:30.5	10:10:27.9	10:09:59.2
4	10:14:22.7	10:16:16.6	10:15:18.7
5	10:16:59.9	10:18:37.4	10:17:48:7
6	10:18:40.0	10:20:40.1	10:19:40.1
7	10:20:45.4	10:22:22.2	10:21:33.8
8	10:28:03.5	10:30:03.5	10:29:03.5
9	10:31:09.5	10:33:09.6	10:32:09.6

All times are given in UT. Frame 1 = topmost in Figure 2 (overleaf).

Methods

Using a Celestron C11 (28cm Schmidt–Cassegrain telescope) in its primary focus, with an ASI 462MC camera plus an 889nm methane-band filter to reduce the glare of the planet, short videos (SER format) were captured of two minutes duration, at a frame rate of 10fps. Due to passing cloud there were several interruptions in the sequence, in particular around the egress. The system time of the computer was synchronised with an atomic clock and each frame received a time stamp.

Each SER file was centred with the *PIPP* program; 25% of frames from the full SER files were stacked with *Autostakkert 2.6* and sharpened with the wavelet function of *Registax.* Final processing was performed with *Photoshop CS2*. For a photometric analysis of the SER file of the ingress, we employed *Tangra 3.6* software.

Results

Ingress

The time course of the changing angular distance of 44 Cap and Io from the western limb of Jupiter is shown in Figure 2. Average stacks of nine individual SER files, each spanning a period of two minutes (about 1,200 frames), are presented and indicated by their average time point. This time series clearly shows how Io (brighter dot) and 44 Cap (fainter dot) approached each other, and that in the SER files 10:19:40.118 and 10:21:33.839 UT, Io and 44 Cap overlap. Table 1 indicates the time intervals covered by each SER file.

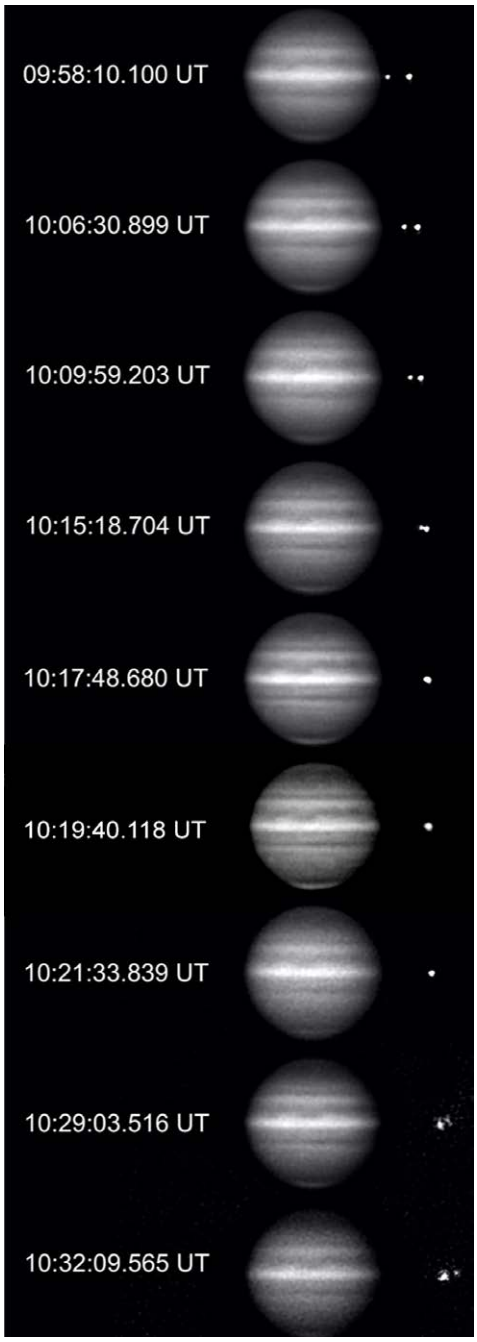

Figure 2. Compilation of stacks of frames captured during the occultation by Io of 44 Cap on 2021 Apr 2.

To analyse further the two-minute SER file encompassing the ingress of the occultation, file 10:19:40.118 UT was subdivided into groups of 50 frames, each covering a period of five seconds. Unfortunately, no smaller groups could be used, because with so few frames no decent image of the event could be obtained. Subsequently, the frames of each group were stacked with *Autostakkert 2.6* and sharpened with *Photoshop.*

Stacking the frames of each group of 50 yielded an image showing 44 Cap and Io. The stacks showing Io and 44 Cap around ingress are presented in Figure 3. Table 2 indicates the time periods covered by each stack shown. Based on the images, we conclude that the ingress took place between 10:19:50.0 and 10:19:53.4 UT (average 10:19:51.7 UT).

Using Tangra 3.6, we performed a photometric analysis of the combined images of 44 Cap and Io in the frames of SER file 10:19:40.118 UT. The brightness of Europa was used as a reference. The result is shown in Figure 4. From these data, we derive that the midpoint of the ingress was at 10:19:54.1 UT. According to IMCCE, the theoretical time of ingress for Curaçao was calculated to be 10:19:52 UT.

Egress

The time course of the egress is presented in Figure 5. For time details, see Table 3. Unfortunately, during that event, scattered clouds and atmospheric blurring of the images interfered with the possibility of an accurate timing. In addition, imaging was close to sunrise at 10:31 UT, which also hampered high-quality results.

In this case, groups of 100 frames were stacked and analysed. From Figure 5, it was concluded that the time point of egress was between 10:20:55 and 10:21:15 UT (average 10:21:05 UT). According to IMCCE, the theoretical time of egress for Curaçao was calculated to be 10:20:58 UT.

Discussion

We have recorded the rare occultation of 44 Cap by Io on 2021 Apr 2 by digital imaging. This phenomenon was predicted to be observable in South America and Africa. The island of Curaçao was located at the northern border of the occultation path. Despite poor meteorological conditions on the island, the ingress of the occultation was recorded reasonably well, using imaging and photometry of relevant frames. However, the accuracy of the analysis suffered from the poor seeing and blurring of the images. From the photographic analysis, we established the ingress to have been at

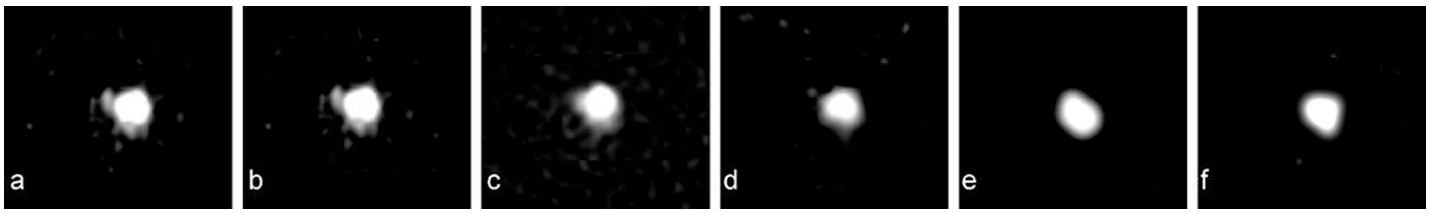

Figure 3. Analysis of the SER file obtained at 10:19:40.1 UT, covering the ingress. The frames were stacked in groups of 50 and processed. The time intervals covered by each image are indicated in Table 2.

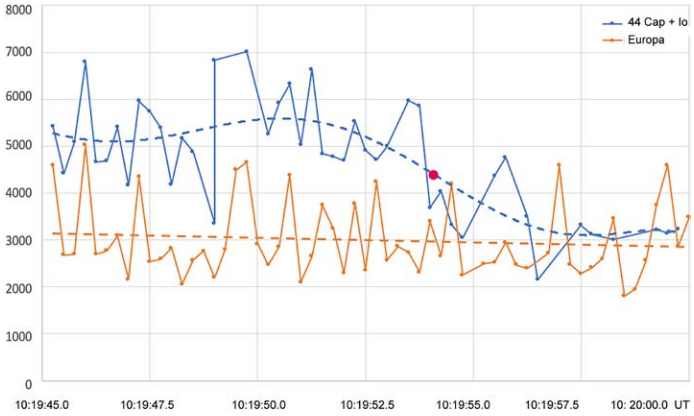

Figure 4. Photometric analysis of the combination of Io and 44 Cap (blue dots) and Europa (yellow dots) on 2021 Apr 2, from 10:19:45.0 UT till 10:20:00.0 UT. Produced using the software *Tangra 3.6*.

10:19:51.7 UT, with an estimated error range of ±5s, whereas the photometric analysis yielded a time of 10:19:54.1 UT with an estimated error range of ±2s. These values fit reasonably well with the predicted time of 10:19:52 UT.

The imaging of the egress was hampered by scattered clouds and photometry was also not possible only 10 minutes before sunrise. Analysis of the available frames revealed that the egress took place between 10:20:55.0 and 10:21:15 UT (average 10:21:05 UT). The predicted time was 10:20:58 UT. The error is larger than for the ingress, but that is no surprise considering the imaging conditions.

From our data, it is obvious that photometry is a more accurate way to establish ingress and egress times. Unfortunately, due to poor seeing, photometry did not yield accurate time measurement on this occasion. Nevertheless, the recording of a rare event like this, happening once in a century, is always satisfying.

Addresses: ES – Willemstad, Curaçao. **JS:** Houten, the Netherlands *[john@jsussenbach.nl]*

Table 2. Times covered by images in Figure 3

Frame	*Start*	*End*	*Average*
a	10:19:37.7	10:19:40.1	10:19:38.9
b	10:19:40.1	10:19:45.0	10:19:42.6
c	10:19:45.0	10:19:50.0	10:19:47.5
d	10:19:50.0	10:19:53.4	10:19:51.7
e	10:19:56.2	10:20:00.1	10:19:58.1
f	10:20:00.1	10:20:05.4	10:20:02.7

All times are given in UT.

Table 3. Times covered by images in Figure 5

Frame	*Start*	*End*	*Average*
a	10:20:45	10:20:55	10:20:50
b	10:20:55	10:21:05	10:21:00
c	10:21:05	10:21:15	10:21:10
d	10:21:26	10:21:36	10:21:31

All times are given in UT.

References

1 Desmars J., 'Quadruple occultation of 44 Cap (2021-04-02)', online: **http://josselin.desmars.free.fr/occ/20210402/** (accessed 2021 April)
2 Institut de Mécanique Céleste et de Calcul des Éphémérides (IMCCE): **https://ssp.imcce.fr/forms** (accessed 2021 April)

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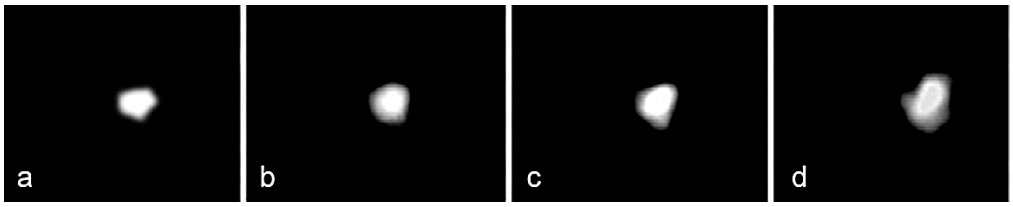

Figure 5. Analysis of the SER file obtained at 10:21:33.5 UT. Sets of 100 frames were stacked. The time intervals covered are shown in Table 3.