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Small impacts on the giant planet Jupiter: the March 2016 and May 2017 impacts

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Abstract: Video observations of Jupiter obtained by amateur astronomers over the last eight years have shown five flashes of light with durations of 1-2 s, each one observed at least by 2 observers. These events have to be very energetic to be observed with small telescopes and are considered to be caused by the impact of small objects of 5-20 m in diameter. When they collide with Jupiter they can release energies comparable to superbolides on Earth similar to the one that caused the Chelyabinsk airburst in 2013. The last two of these events occurred on 17 March 2016 and 26 May 2017 and have been analyzed as part of the Planetary and Space Weather activities.
An observational report of these two impacts presents an analysis of the light curves of the impacts characterizing the energy, masses and sizes of the objects impacting with Jupiter. We conclude that the impacting objects had masses on the order of 400-800 Tn for the impact in March 2016 and 75-130 Tn in the May 2017 impact. These masses correspond to objects with sizes from 7.3-19 m in diameter for the first case and 4.1-10 m for the second case for a range of possible densities. The May 2017 impact is the lowest energetic observed for the planet. This report of the two impacts in 2016 and 2017 is a summary of a detailed study submitted to Astronomy & Astrophysics ("Small impacts on the Giant planet Jupiter", Hueso et al., 2018, *Astronomy & Astrophysics*, submitted).

1. Introduction

Because of its large size and mass Jupiter is the planet that receives the largest number of impacts in the Solar System (at least one thousand times more often than the Earth; Hueso et al., 2013). Impacts in Jupiter from objects of about 10-m in diameter release enough energy to be observable from the Earth with small telescopes. These impacts produce brief flashes of light and 5 of these impacts have been detected by amateur astronomers in telescopic observations of Jupiter since the year 2010. Three of these impacts have been previously analyzed in the scientific literature (Hueso et al. 2010, 2013) and two more have occurred since then. Each of these impacts has been detected simultaneously by more than one observer demonstrating they are real events not caused by the electronics of the different cameras used by each observer. All in all 12 observers have recorded 11 video acquisitions of a total 5 impacts over the last 8 years in Jupiter. This report constitutes a summary of a detailed analysis of these events presented in Hueso et al. (2018) in which the two impacts are also compared with previous impacts in Jupiter towards a better knowledge of the current impact rate on Jupiter and the role these impacts may have in the supply of exogenous chemical species in the stratosphere of the planet.

2. The March 2017 and May 2017 impacts

In March 17, 2016 Gerrit Kernbauer, an Austrian amateur astronomer discovered a bright flash of light in a regular observation of Jupiter. The flash detection was announced 10 days after the observation because the relatively bad seeing of that night made the observer to delay his initial analysis of the video from that night. The flash occurred close to the planet's East limb. News of the flash arrived to John McKeon, an amateur astronomer in Ireland, who had been observing the planet the same night. His video observation of the planet confirmed the finding with better image quality since he was observing with a better atmospheric seeing. The flash generated significant interest in amateur astronomy journals and was covered by several amateur astronomy journals (see for instance: http://pvol2.ehu.eus/psws/jovian_impacts/science_background.html). The next year, on May 26, 2017, another impact on Jupiter was found by Sauveur Pedranghelu, an amateur astronomer from Corsica (France) and announced on several astronomy forums the same day. The impact was quickly confirmed by two German observers, Thomas Riessler and Andre Fleckstein, both after reading news of the impact. Figure 1 shows the location of both impacts on the planet and is based on a combination of data from the five video observations. Details about the observations are summarized on Table 1.

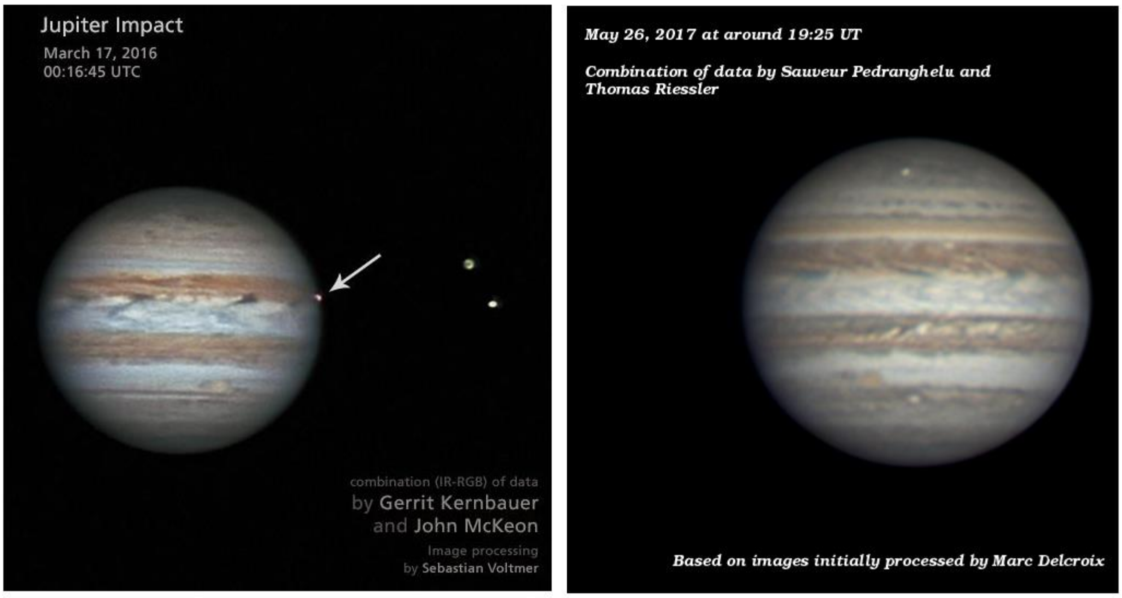

Figure 1: Images of the March 2016 and May 2017 impacts. Each image is based on the combination of data from the different video observations of each impact.

Table 1: Summary of the observational characteristics of the March 2016 and May 2017 impacts.

Date (yyyy-mm-dd) Time (hh:mm:ss)	**Observers (and locations)**	**Telescope diameter** (cm)	**Detector**	**Filters**	**Sampling rate** (fps)	**Impact coordinates** (System III longitude and planetographic latitude)
2016-03-17 00:18:39 UT	G. Kernbauer (Austria	20	QHY5LII	Bayer RGB	47	Lon=310, Lat=+12
	J. McKeon (Ireland)	28	ASI120MM	IR742	26	
2017-05-26 19:24:50 UT	S. Pedranghelu (France)	20.3	ASI224MC	Bayer RGB	61.79	Lon=296, Lat=+51.2
	T. Riessler (Germany)	20.3	ASI120MC	Bayer RGB	30.78	
	A. Fleckstein (Germany)	28	ASI120MM	IR742	30	

3. Image analysis and energy calculation

The energy of the impact can be computed from a quantification of the light in the flash. We transformed each video into a sequence of frames that were analyzed with a software tool written in IDL (Interactive Data Language). The software coregisters the sequence of observations to correct from image displacements caused by the atmospheric seeing. Once the images are coregistered, differential aperture photometry over the impact location can be obtained frame by frame. In order to obtain the differential photometry a reference image without the impact was used to substract from each frame and the light from the impact location was computed using aperture photometry techniques with a radius large enough to cover the impact location. The overall technique is described in detail in Hueso et al. (2013, 2018).

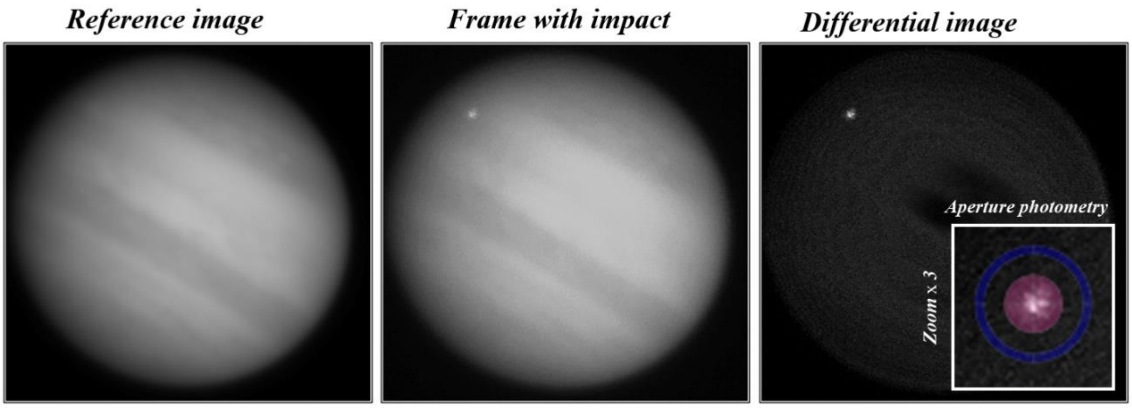

Figure 2: Example of the analysis pipeline showing a reference image (left), the energetic flash on one frame (center) and the difference between both images (right). An inset showing a zoom of the impact area and the aperture photometry mask is also shown. The full light from the magenta region is integrated and the light from an outer blue ring is used to compute the baseline brightness from that region.

Figure 3 presents light curves of both impacts and are based on data from J. McKeon (first impact) and S. Pedranghelu (second impact) and adapted from Hueso et al. (2018).

Besides the light curves we obtained integrated photometry of the planet Jupiter. A comparison of the flash light with the total brightness of Jupiter allows computing a conversion factor between digital numbers in the video recording and energy. This conversion factor depends on the camera and filters used, electronics settings and camera frame rate. The detailed procedure and calibration of the images is described in Hueso et al. (2018). The integrated light curves and the conversion factors result in an estimation of the total energy associated to each video observation. The calculation can be done for each video observation but the videos with lower quality result in lower estimates of energy and we present results only for the best observations. Results of these calculations are given in Table 2. The range of energies released by these objects on their impact with Jupiter are comparable to the most energetic superbolides on Earth and are similar to the one that caused the Chelyabinsk airburst in 2013 (Brown et al., 2013) which was estimated to lie around 450 KTn of energy (1KTn= 4.185x10^{12} J).

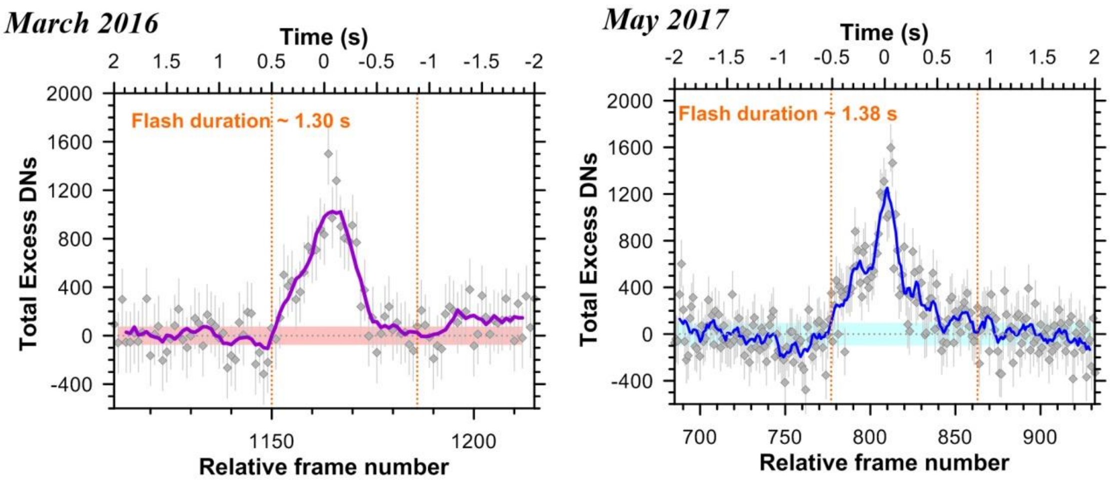

Figure 3: Light-curves for the March 2016 and May 2017 impact. Symbols represent data for individual frames, magenta and blue line represent fits to the light curves. Uncertainties are given for the individual frames (grey error bars). The flashes duration is very similar in both cases. The light curves are based on the best video observation in each case. In the March 2016 this is the light curve from J.McKeon’s data. In the May 2017 the light curve comes from the video obtained by S. Pedranghelu. Significant structure is found in the May 2017 light curve. Digital Numbers (DNs) depend also on the electronics setting of each camera and is only by chance that are similar in both panels.

Table 2: Summary of the energies released and masses and sizes of the impact objects.

Date (yr-mm-dd)	**Energy (J)**	**Energy (ktn)**	**Mass (Tn)**	**Diameter (m)** (ρ=2.0 gcm^{-3})	**Diameter (m)** (ρ=0.6 gcm^{-3})	**Diameter (m)** (ρ=0.25 gcm^{-3})
2016-03-17	7.3-14.6x10^{14}	175-350	403-805	7.3-9.2	10.9-13.7	14-19
2017-05-21	1.3-2.3x10^{14}	32-55	75-130	4.1-5.0	6.1-7.4	8.3-10

(*) Energies are given in Joules and in kilotons (ktn). 1 ktn=4.185x10^{12} J.
(**) Densities from 0.25 to 2.0 gcm^{-3} are used to infer the possible range of sizes of the impact objects

5. Conclusions & further work

The impacts in March 2016 and May 2017 are similar to previous impacts reported on Jupiter by amateur astronomers. The May 2017 impact is the lowest energetic impact ever observed in Jupiter, while the March 2016 is similar to previous flashes detected by amateur astronomers. The serendipitous discovery of these events provides information about the current rate of impacts oin Jupiter. From these and previous impacts on the planet, Hueso et al. (2018) offer an estimated flux of impacts of about 10-70 impacts per year with 4-25 of them being potentially detectable from the Earth. The Planetary & Space Weather Services is working on developing software tools capable of analyzing amateur video observations so that more impacts like these could be detected by the amateur astronomy community (André et al., 2018). We expect that more of these events will be found in the near future improving the known rate of impacts and allowing a better characterization of these objects.

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