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The flux of impacts in Jupiter: From superbolides to large-scale collisions

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Abstract

Observations of Jupiter by a large number of amateurs have resulted in the discovery of three fireballs in its atmosphere produced by the impacts of small objects. The fireballs were detected on June 3, 2010, August 20, 2010 and September 10, 2012. The light-curves of these atmospheric airbursts provide a measure of the masses and sizes of the impacting objects and the statistical significance of the three events can be examined from knowledge of the large pool of Jupiter observations by the global community of amateur astronomers. These objects are in the category of 5-20 m sizes depending on their density and release energies comparable to the recent Chelyabinsk airburst. Current biases in observations of Jupiter suggest a rate of similar impacts of 18-160 per year.

1. Introduction

Direct observation of collisions on solar system objects outside Earth constitutes a rare event that has been directly observed only a few times. Because of its mass and large size Jupiter is the only solar system body where impacts of very different sizes have been observed: from small 10 kg [1] objects, superbolides [4], 500 m single object [2, 5] to the several fragments of the Shoemaker-Levy 9 comet [3]. Here we focus on impacts in Jupiter produced by small-size objects causing short-lived light flashes observable from Earth.

2. Jovian fireballs

Amateur astronomers regularly obtain high-resolution observations of the planets capturing video sequences of several hundreds to a few thousands frames that are used to build a final image whose resolution can approach the diffraction-limit of the telescope. The popularity of this technique over the last decade has resulted in an accumulation of thousands of hours of Jupiter video observations. Direct visual inspection of some of them has revealed three intense flashes of light visible for 1 to 2 seconds. All three flashes have been observed by more than one single observer. The basic characteristics of these observations are summarized in Table 1.

Date	Observers	Telescope diameter	Sampling rate (fps)
June 3, 2010 20:31:20 UT	A. Wesley	37 cm	60
	C. Go	28 cm	55
Aug. 20, 2010 18:21:56 UT	M. Tachikawa	15 cm	30
	K. Aoki	23,5 cm	15
	M. Ichimaru	12,5 cm	30
Sept.10, 2012 11:35:30 UT	D. Petersen	30,5 cm	---
	G. Hall	30,5 cm	15

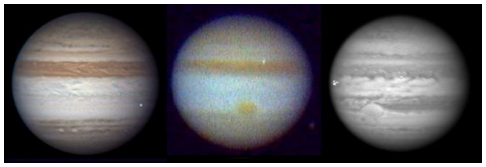

Figure 1: Images of the three bolides observed in Jupiter. Left to right: June 3, 2010, August 20, 2010 and September 10, 2010. Each image has been built from several frames and the impact has been added from an image stacked with the frames where the impact was visible.

2. Searches for atmospheric debris

We obtained observations of Jupiter following each of the impacts with professional telescopes on the next few Jupiter rotations. The best set of observations were obtained for the first impact in June 2010 which created the expectancy of finding atmospheric debris that could be used to constrain the size of the impactor and that should behave similarly to the dark features produced by the SL9 and the 2009 impact. Among other first-class facilities, observations from the HST, VLT and Keck telescope were obtained. Example images of the impact area are presented on figure 2. None of these observations in any of the impacts showed any debris feature indicating a small size for the impactors.

3. Analysis

We calibrated the original images and extracted light-curves from the video observations. The brightness temperature of the bolide is slightly constrained by the observations of the first bolide by A. Wesley and C. Go observing with red and blue filters respectively. We conclude that these objects have size of 5-20 m for different values of assumed densities and release about 100-750 kilotons of TNT energy similar to the recent Chelyabinsk airburst.

3 Conclusions

Based on the frequency Jupiter is observed and the databases of images acquired by amateur astronomers we estimate that Jupiter could be impacted by similar objects 18-160 times per year. More detections are needed to further constrain this range. Additionally, a closer examination of video observations obtained by amateurs could detect more of these objects. We have developed software tools able to perform this task and information for amateurs is provided on the following link: http://www.pvol.ehu.es/software/

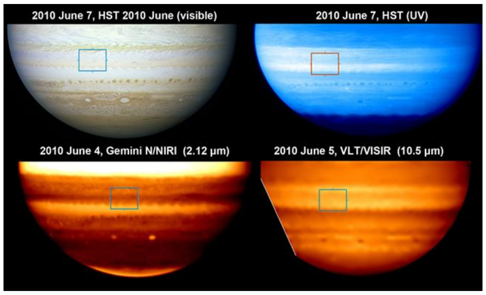

Figure 2: Subset of observations obtained a few Jupiter rotations after the June 2010 impact. The impact area is marked with a box. Observations with the Keck telescope and the NASA IRTF after the second and third fireballs in August 2010 and September 2012 did not show debris features, either.

Acknowledgements

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