DeTeCt3.1.: A software tool to detect impacts of small objects in video observations of Jupiter obtained by amateur astronomers

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Abstract: Impacts of small size objects (7-20 m in diameter) with Jupiter atmosphere result in **luminous superbolides that can be observed from the Earth with small size telescopes (12-40 cm)**. **Impacts of this kind have been observed five times** by amateur astronomers since July 2010. Although the probability of observing one of these events by an individual observer is very small, the accumulated probability of finding impacts by the large community of amateur astronomers is much higher. Amateur astronomers observe Jupiter using fast video cameras that record thousands of frames during a few minutes which combine into a single image that generally results in a high-resolution image. Flashes are brief, faint and often lost by image reconstruction software. We present major upgrades in a software tool DeTeCt and our current project to maximize the chances of detecting more of these impacts in Jupiter.

Fireballs in Jupiter atmosphere

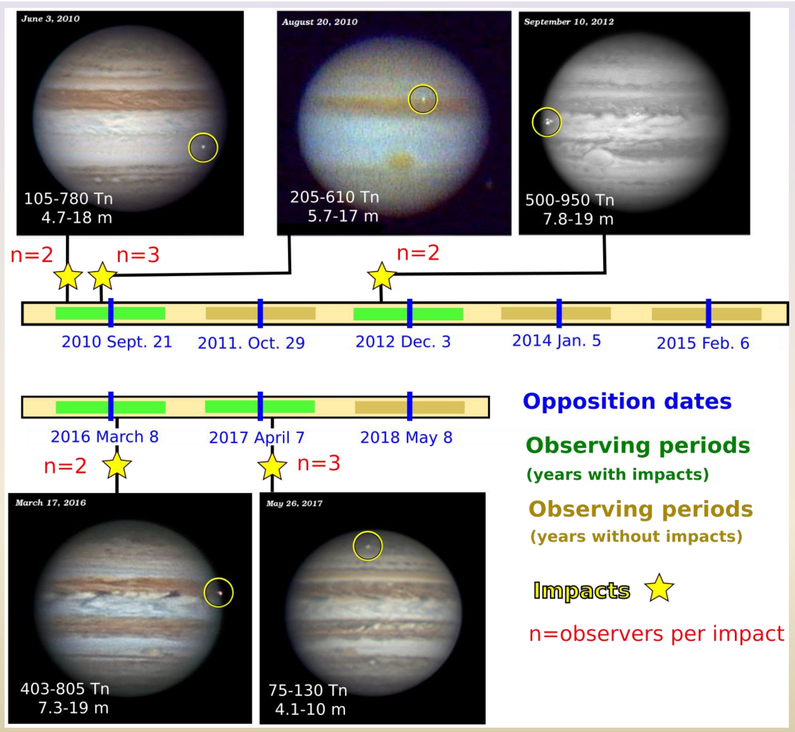
On June 3, 2010 amateur astronomers Anthony Wesley from Murrumbateman, Australia and Christopher Go from Cebu, Philippines recorded a short flash of light on Jupiter while taking video observations of Jupiter. The observed **flash lasted about two seconds** and a scientific analysis of its light resulted in the conclusion that it was caused by an object of 8-13 meters impacting on Jupiter's atmosphere and producing a giant fireball in a superbolide event [1].

Other events have been found later with similar characteristics (see lower box and refs 2&3). In all cases an observed raised the alarm to the amateur community after visually observing the impact flash on the video recording with later confirmations coming from observers who had been taking data at the right time but didn't see the flash when it produced. In all cases the regions suffering the impacts did not show any trace of the bolide material.

These events can therefore only be discovered if spotted on the few seconds each impact produces a bright fireball observable from ground-based telescopes but some of them are so faint that might be missing by an observer looking at its video data or not observing the video file while being acquired.

Timeline of Jupiter impacts detected

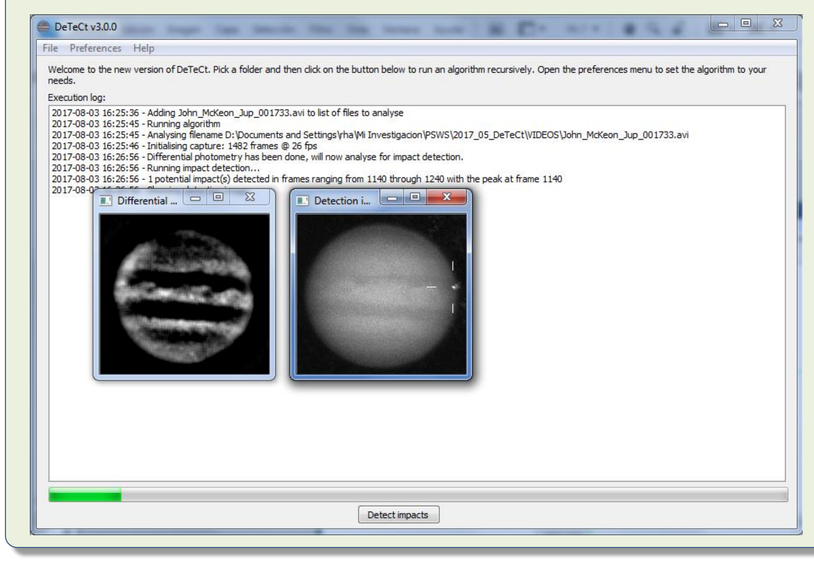
- ***June 3, 2010 | Observers:*** *Anthony Wesley (Australia) and Christopher Go (Philippines). Possible characteristics: 4.7-18 m size object (105-780 Tn in mass; Energy 46-340 kTn)*
- ***August 22, 2010 | Observers:*** *Masayuki Tachikawa, Kazuo Aoki, Masayuki Ishimaru (Japan). Possible characteristics: 5.8-17 m size object (205-610 Tn in mass; Energy 88-260 kTn)*
- ***Sept. 10, 2012 | Observers:*** *Dan Petersen (visual observation and alarm; USA) & George Hall (USA). Possible characteristics: 7.8-19 m size object (500-950 Tn in mass; Energy 215-405 kTn)*
- ***March 17, 2016 | Observers:*** *Gerrit Kernbauer (Austria) and John McKeon (Ireland).*
- ***May 26, 2017 | Observers:*** *Sauveur Pedranghelu (France), Thomas Riessler (Germany) & Andre Fleckstein (Germany).*



Sizes and energies from references [1&2]. Latest analysis in reference [3].

DeTeCt 3.1

*As part of the "**Planetary and Space Weather Services**" (http://planetaryspaceweather-europlanet.irap.omp.eu/) Europlanet 2020-RI has funded the development of **DeTeCt3.1** and further research on impacts in Giant planets. DeTeCt3.1 is an open-source software developed for Windows operative system and incorporates a graphic user interface and some characteristics to find faint impacts. The software is **based in the popular DeTeCt software written by Marc Delcroix**. The new version has many innovations including a Graphical User Interface that makes much easier to use the tool. The main window shows a console view with text messages and a progress bar. The user can select to show the videos as they are processed with a variety of options including the visualization of differential photometry images. **The software produces log files, allows visualization of the detection steps and finally builds detection images that the user can visually inspect**. Batch mode is available for the analysis of large sets of videos. The software can be retrieved from: http://pvol2.ehu.eus/psws/jovian_impacts/*



DeTeCt3.1 console view with a differential photometry image and the detection image

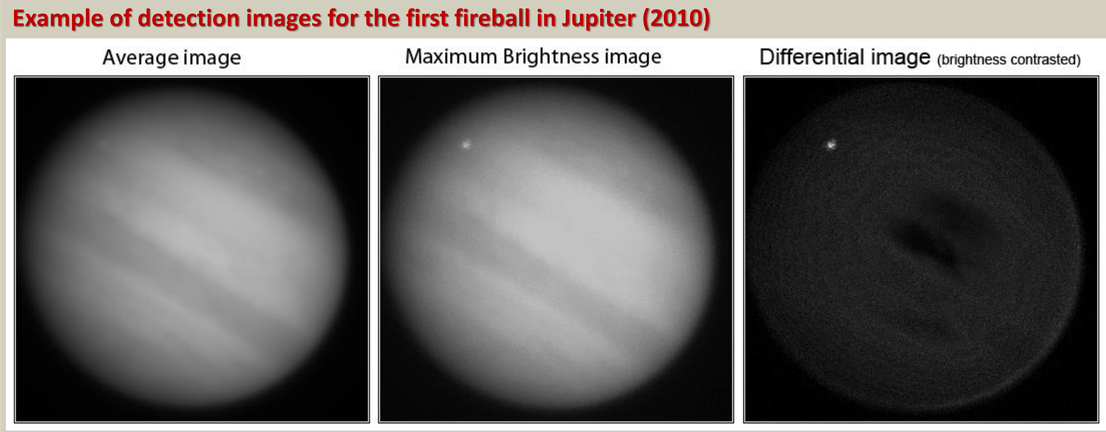
Please note *that you when you run the software you should send to Marc Delcroix (delcroix.marc@free.fr) the DeTeCt.log files for statistical analysis.*

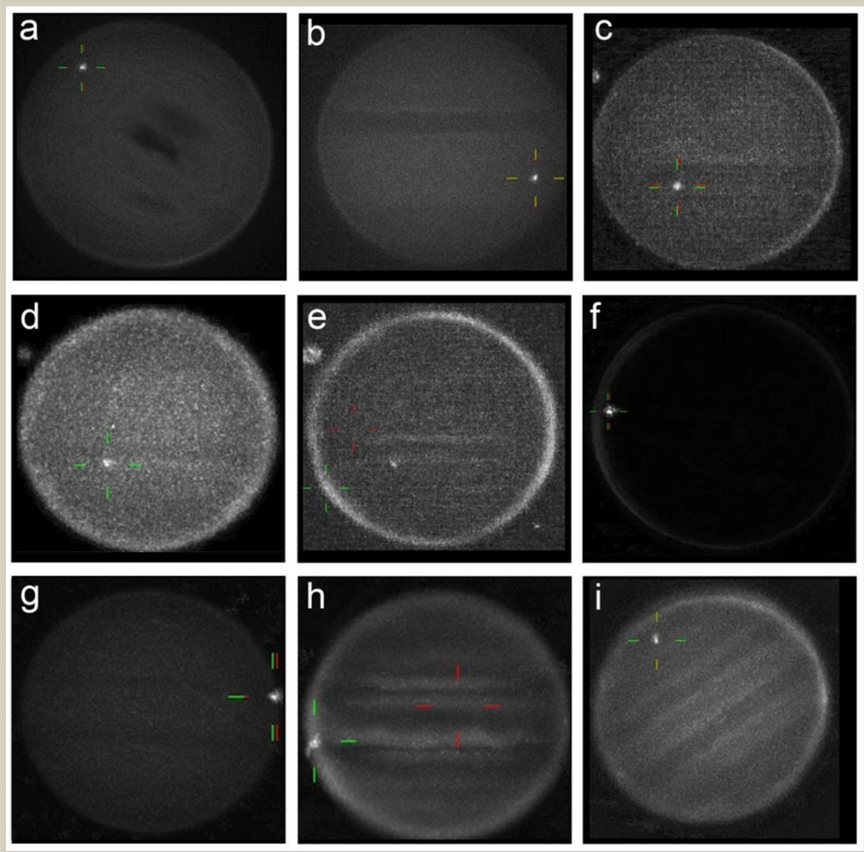
Negative detections are also important to constraint the flux of impacts in Jupiter. If you have a positive detection please also send the detection image.

DeTection images (since DeTeCt2.1)

Besides automatic results both versions of DeTeCt incorporate the capability to build a "detection image". This image is computed from the maximum brightness minus the average brightness for each pixel in the planet and in many cases offers a very high potential for an instantaneous view of the impact. The detection image can filter-out spurious results at the limb of the planet from bad seeing or from flickering images of Jupiter's satellites.

Example of detection images for the first fireball in Jupiter (2010)



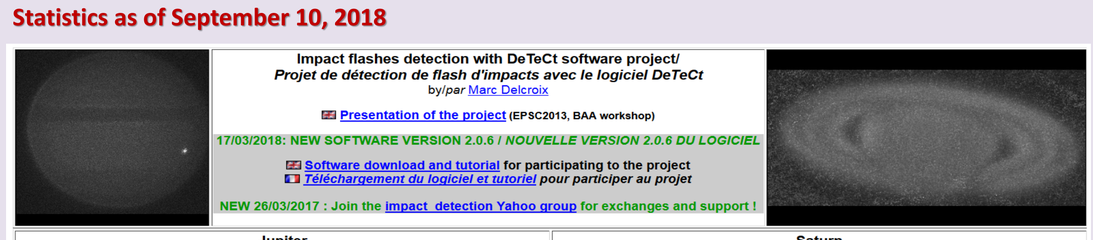


Sample of detection images produced by the software in analyses of 9 different videos of previous impact flashes in Jupiter.

DeTeCt 3.1

DeTeCt is an open source Linux/Windows application developed by Marc Delcroix that allows to search for impacts in Jupiter videos. The software has been used regularly by dozens of observers examining data equivalent to about 99 days of observations distributed unevenly over the last few years. The software and statistical analysis of its results can be accessed at: http://www.astrosurf.com/planetessaf/doc/project_detect.shtml

Statistics as of September 10, 2018



Jupiter
estimation of 3,7 impacts per year (0,3 per month)
total excludes 5,002 days of simultaneous observations

Observer	Duration	Number of videos	Date range
Total : 79 observers	99,001 days	84401 videos	2004/02/29 - 2030/06/18
Zac Pujic (Australia)	15.557 days	6372	2005/02/22 - 2018/06/05
Michel Jacquesson (France)	12.509 days	8276	2014/03/12 - 2030/06/18
Paul Rolet (France)	12.184 days	9836	2012/09/07 - 2018/09/02
Benito Loyola (USA)	7.134 days	3131	2018/02/17 - 2018/09/05
Manos Kardasis (Greece)	6.993 days	5668	2004/02/29 - 2017/09/12
Thomas Ashcraft (USA)	4.969 days	5886	2013/10/09 - 2016/11/30
Bernd Gaehrken (Germany)	4.095 days	5673	2016/03/06 - 2018/06/24
Alan Coffelt (USA)	3.593 days	2605	2013/10/04 - 2018/05/14
Marc Delcroix (France)	2.859 days	2220	2006/04/13 - 2018/07/18
Xavier Dupont (France)	2.062 days	1867	2012/08/16 - 2015/04/25
Grant Blair (USA)	1.988 day	1874	2013/08/20 - 2016/04/21
Hampton University Sayanagi Group (USA)	1.912 day	1396	2018/03/23 - 2018/06/19
Agapios Elia (Cyprus)	1.772 day	1978	2013/11/09 - 2018/07/10
Trevor Barry (Australia)	1.612 day	2421	2009/07/06 - 2012/12/30
Christophe Pellier (France)	1.530 day	739	2012/02/20 - 2015/02/12
David Domine (France)	1.460 day	907	2016/02/25 - 2017/04/10
Pascal Bayle (France)	1.390 day	1697	2012/11/30 - 2015/05/10
Torsten Mellenthin (Germany)	1.218 day	1416	2016/01/28 - 2017/06/24
Lammertus de Vries (Spain)	1.171 day	635	2009/08/03 - 2015/05/08
Jocelyn Serot (France)	1.139 day	863	2014/01/10 - 2018/07/17
Stephane Gonzales (France)	1.131 day	1243	2013/12/20 - 2018/06/03
Arnaud Claisse (France)	0.941 day	842	2014/01/19 - 2016/05/03

Saturn
estimation of less than 29,6 impacts per year (2,5 per month)
no simultaneous observations

Observer	Duration	Number of videos	Date range
Total : 19 observers	12,337 days	5421 videos	2005/02/04 - 2018/09/02
Zac Pujic (Australia)	5.155 days	2103	2005/02/04 - 2018/04/21
Marc Delcroix (France)	2.231 days	977	2007/01/20 - 2018/07/19
Paul Rolet (France)	1.656 day	474	2015/05/12 - 2018/09/02
Manos Kardasis (Greece)	0.791 day	398	2008/03/10 - 2017/03/25
Grant Blair (USA)	0.445 day	255	2014/03/14 - 2016/04/24
Oleg Zaharciuc (Moldova)	0.443 day	213	2016/05/22 - 2018/07/06
Pic du Midi (Delcroix/Dauvergne) (France)	0.305 day	345	2012/08/06 - 2018/07/15
Arnaud Claisse (France)	0.260 day	62	2015/05/21 - 2016/05/04
Societe Astronomique de Touraine (France)	0.223 day	92	2014/03/14 - 2016/07/16
Stephane Gonzales (France)	0.195 day	89	2015/05/23 - 2017/06/05
David Domine (France)	0.171 day	35	2016/04/23 - 2017/04/08
Alan Coffelt (USA)	0.150 day	56	2015/05/03 - 2017/04/26
Matic Smrekar (Slovenia)	0.089 day	85	2011/06/27 - 2016/06/06
Charles Galdies (Malta)	0.077 day	81	2014/06/08 - 2015/07/17
Blake Estes (USA)	0.055 day	79	2016/05/08 - 2016/05/13
Benito Loyola (USA)	0.042 day	40	2018/07/11 - 2018/08/28
Adrien Marezac (France)	0.022 day	18	2017/06/11 - 2017/06/11
Michel Legrand (France)	0.011 day	8	2018/07/16 - 2018/08/03
Torsten Mellenthin (Germany)	0.006 day	11	2017/04/01 - 2017/06/23

Probability of finding an impact

*Based on the current detections, detectable impacts in Jupiter could be **frequent (4-25 per year;** reference 3) or **very rare (3.7 per year, see statistics of the use of Detect above**). However more detections are needed to explore this. **Jupiter impacts have been found close to Jupiter opposition when the planet is more observed by amateurs**. We expect new impact detections as more explore their video observations of Jupiter and the planet's opposition moves towards summer in the north hemisphere where the highest density of observers live and as Jupiter's declination increases favoring observations from the North hemisphere. Additionally, **frequent observations by larger telescopes (1-m) using filters where the planet is dark (blue or methane)** could seed light in the impact flux by finding impacts of smaller objects not observable with amateur means. These smaller impacts should be more frequent.*

References

[1] Hueso et al.: First Earth-based detection of a superbolide on Jupiter, *The Astrophysical Journal* (2010).
[2] Hueso et al.: Impact flux on Jupiter: From superbolides to large-scale collisions. *A&A* (2013).
[3] Hueso et al.: Small impacts on the giant planet Jupiter, A&A, 2018. Also on astro-ph at https://arxiv.org/abs/1804.03006

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