Observations with a Celestron 8'' telescope from Cibolo, Texas

A new small impact in Jupiter in August 7th, 2019

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Agustín Sánchez-Lavega (UPV/EHU)

Ramanakumar Sankar (FIT)
Csaba Palotai (FIT)

Jon Juaristi-Campillo (UPV/EHU & Heidelberg University)

& The Impact Recovery Team

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SAF

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Small impacts in Jupiter - Common phenomena but frequency unknown

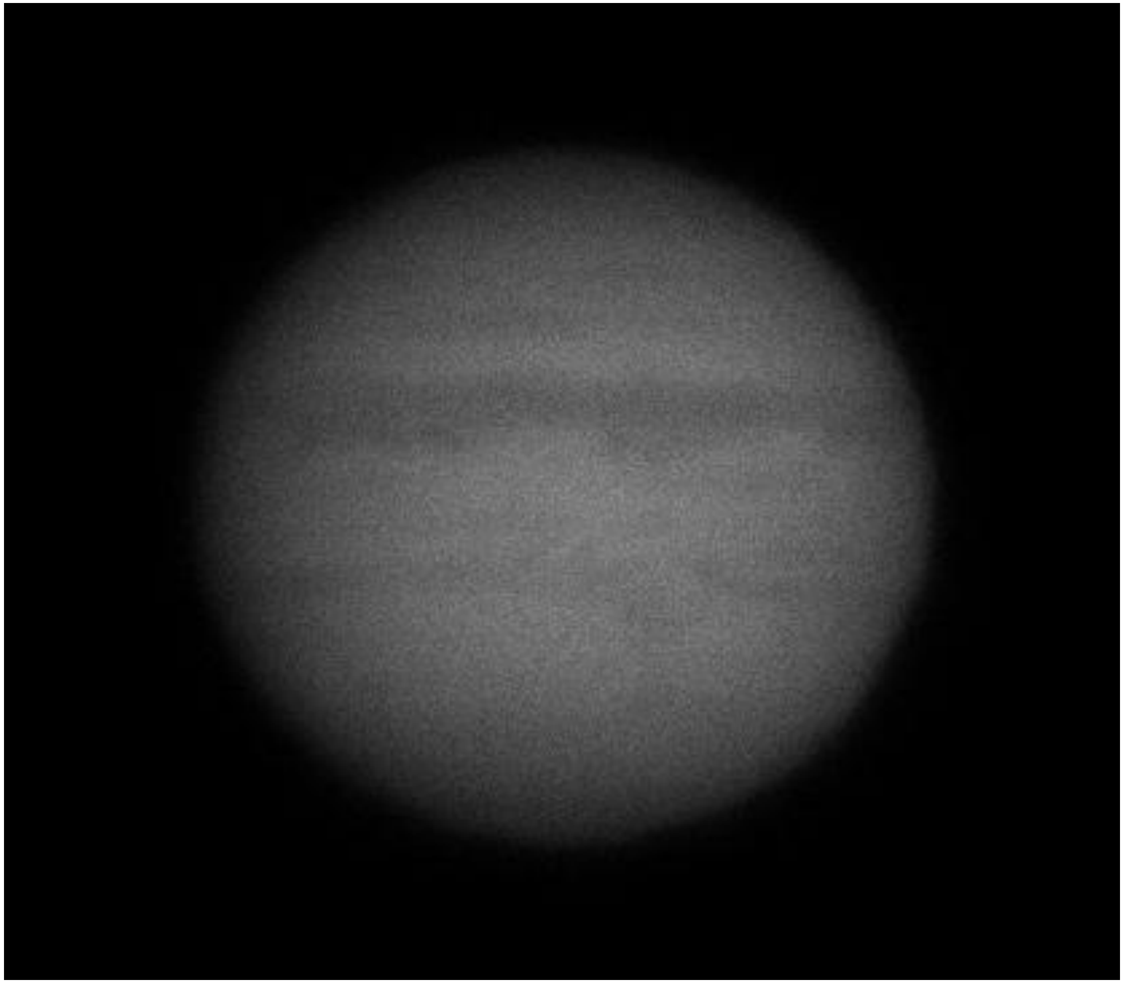
6th Impact "flash" found in Jupiter since 2010

(2 flashes in 2010, 1 in 2012, 1 in 2016, 1 in 2017)

Hueso et al. ApJ, 2010, Hueso et al. A&A, 2013

Hueso et al. A&A, 2018: "Small impacts in the Giant planet Jupiter" A report of all previous flash impacts in Jupiter.

Impact rate predicted: low (10–65 impacts per year) with only 4–25 observable impacts per year



First impact found by software and not the observer. The impact was found using DeTeCt (software by M. Delcroix, J. Juaristi & R. Hueso)

The 2019 impact: Very clear signal ! Bigger than the impact in 2010 and smaller than the brightest flash in 2012

Impact discovery image

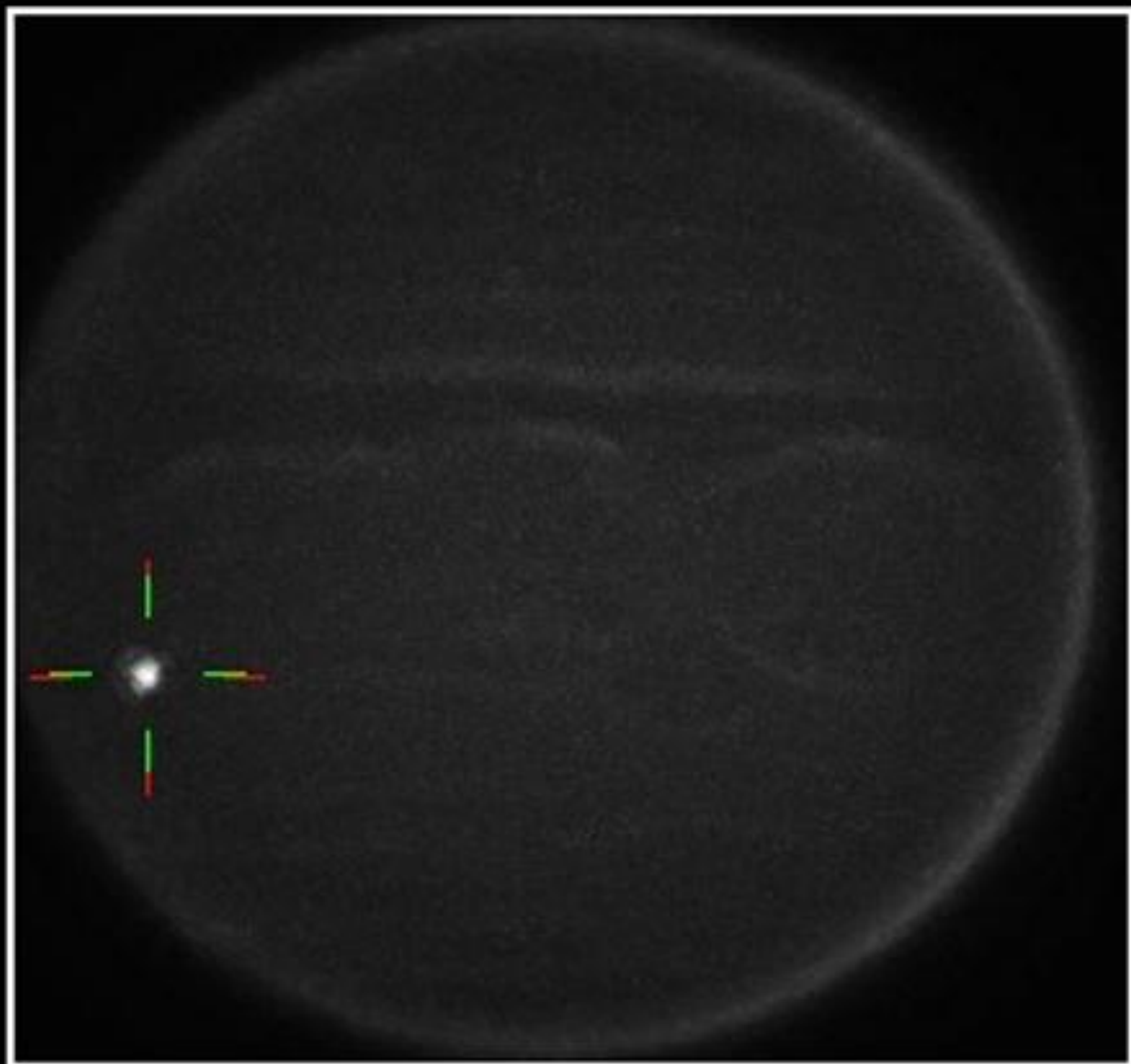
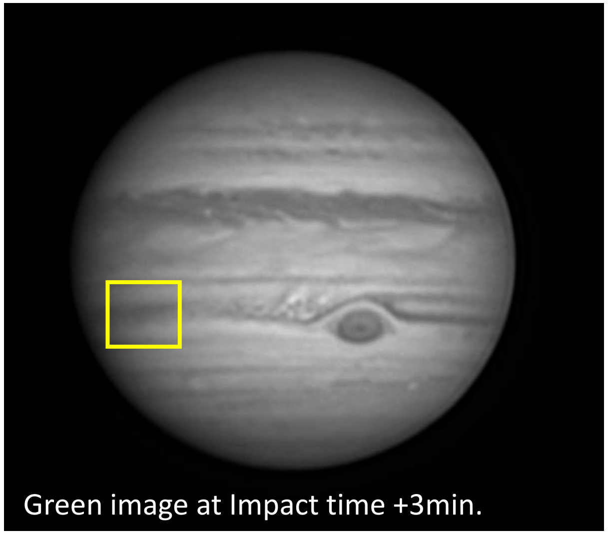
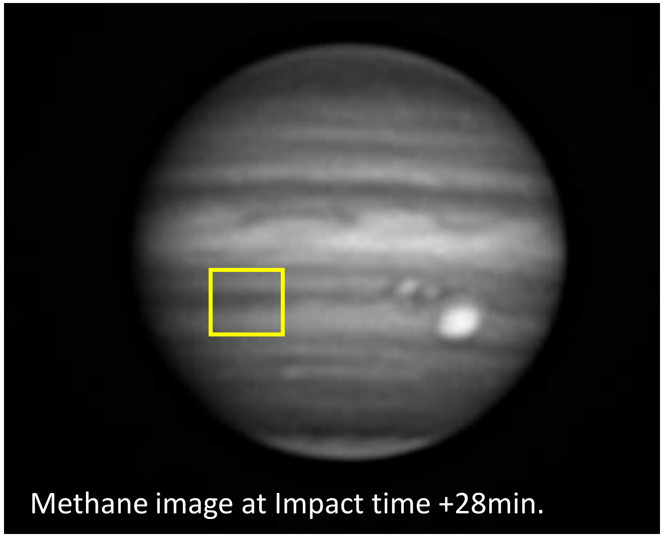


Image generated with DeTeCt

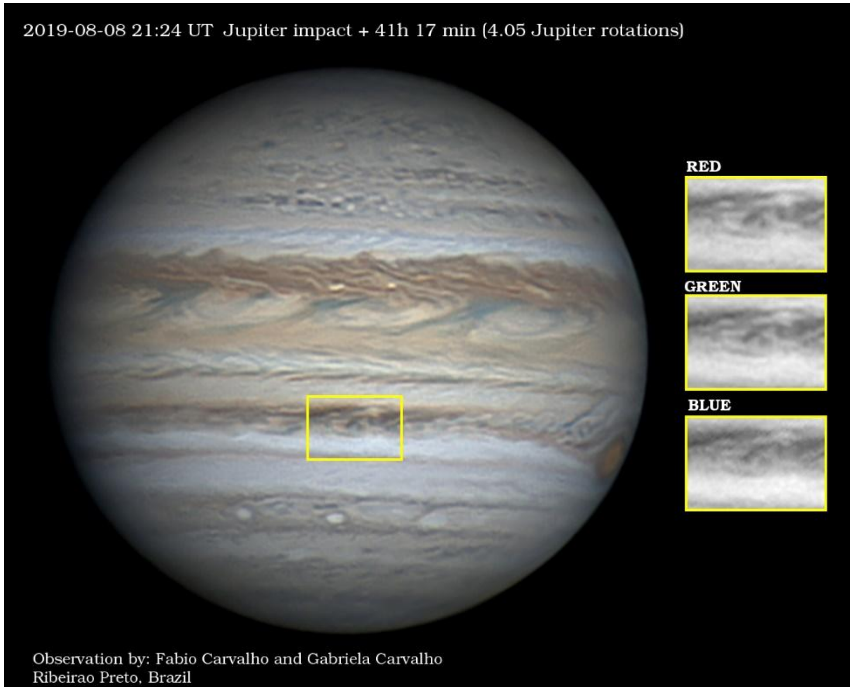
Absence of debris on amateur images

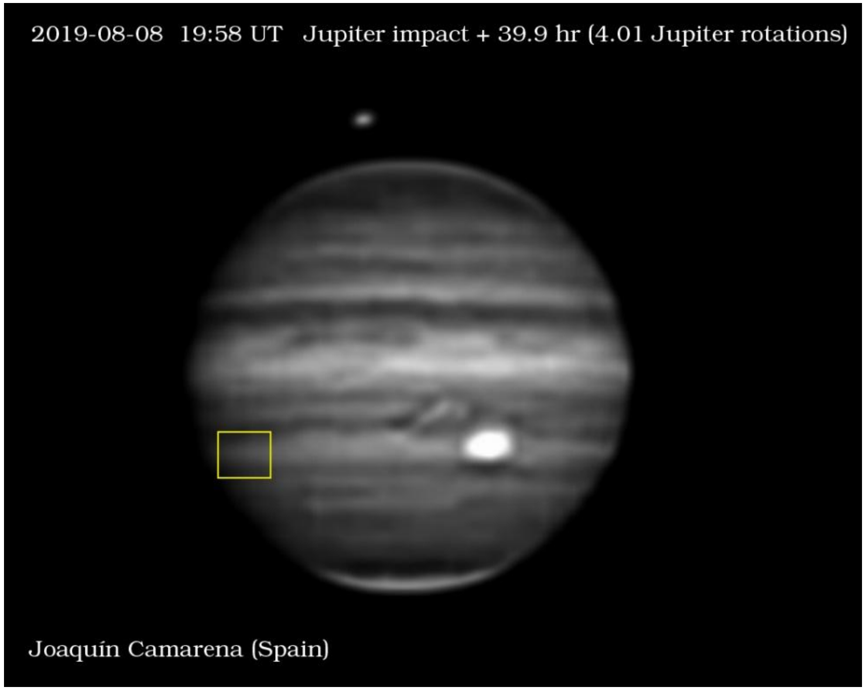
Impact Time=2019-08-07T04:07:30 UT





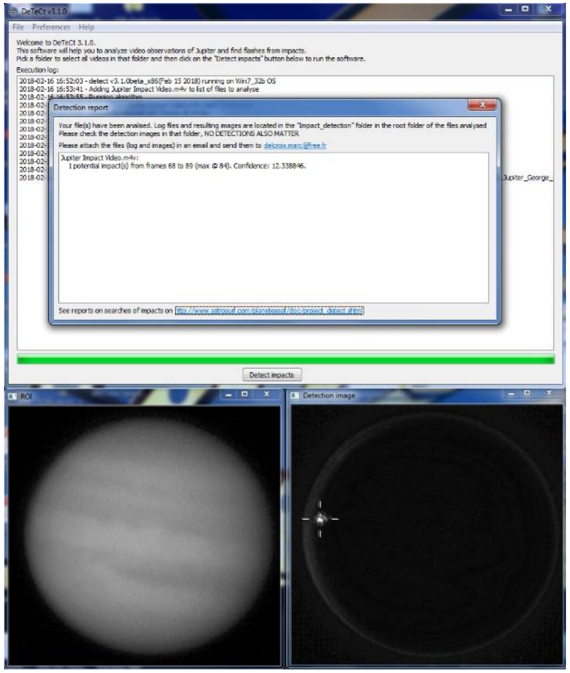
Many other images acquired by Ethan Chappel between these two images. None of them shows any possible debris.



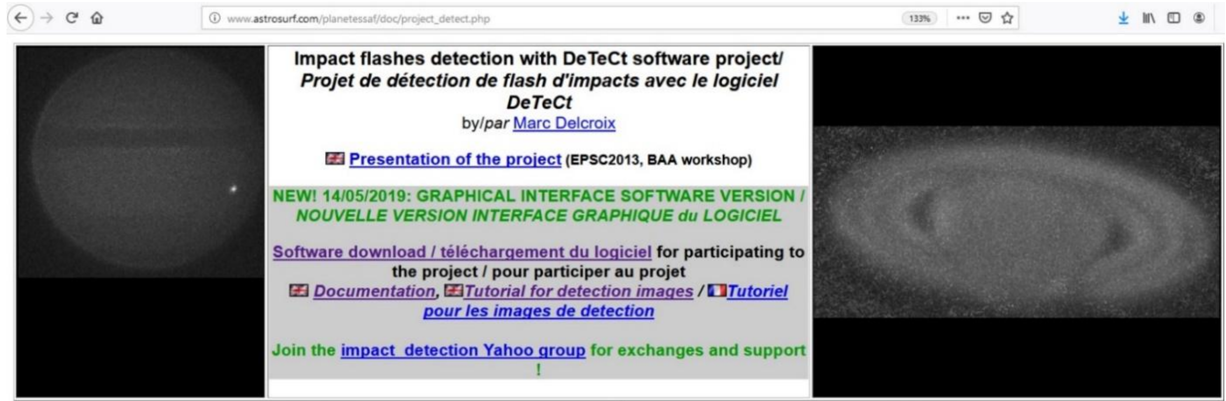


DeTeCt: A software tool in windows to automatically analyze videos of Jupiter

EPSC-DPS2019-970 : Jupiter and Saturn impact detection project, Delcroix et al., Monday 14:25



More than 125,000 videos analyzed!



Jupiter
estimation of 8,6 impacts per year
total excludes 7,355 days of simultaneous observations

Observer	Duration	Number of videos	Date range
Total : 96 observers	**127.214 days**	**113839 videos**	**2004/02/29 - 2019/09/04**
Zac Pujic (Australia)	19.101 days	7764	2005/02/22 - 2019/07/29
Michel Jacquesson (France)	15.758 days	9384	2014/03/12 - 2019/08/07
Benito Loyola (USA)	15.514 days	14832	2018/02/17 - 2019/09/04
Paul Rolet (France)	14.481 days	11932	2012/09/07 - 2019/09/02
Manos Kardasis (Greece)	8.642 days	7288	2004/02/29 - 2018/09/07
Thomas Ashcraft (USA)	4.969 days	5886	2013/10/09 - 2016/11/30
Bernd Gaehrken (Germany)	4.098 days	5682	2016/03/06 - 2018/06/24
Alan Coffelt (USA)	3.593 days	2605	2013/10/04 - 2018/05/14
Marc Delcroix (France)	3.208 days	2601	2006/04/13 - 2019/06/17
Clyde Foster (South Africa)	3.087 days	3836	2018/05/03 - 2019/08/18
Christophe Pellier (France)	2.374 days	906	2012/02/20 - 2019/07/28
Agapios Elia (Cyprus)	2.197 days	2605	2013/11/09 - 2019/08/15
Sauveur Pedranghelu (France)	2.157 days	2640	2017/05/26 - 2019/07/29
Xavier Dupont (France)	2.062 days	1867	2012/08/16 - 2015/04/25
Hampton University Sayanagi Group (USA)	2.028 days	1543	2018/03/23 - 2019/03/29

Saturn
estimation of less than 24,2 impacts per year
total excludes 0,018 days of simultaneous observations

Observer	Duration	Number of videos	Date range
Total : 29 observers	**15.121 days**	**7046 videos**	**2005/02/04 - 2019/09/03**
Zac Pujic (Australia)	5.252 days	2131	2005/02/04 - 2018/04/21
Marc Delcroix (France)	2.561 days	1104	2007/01/20 - 2019/06/16
Paul Rolet (France)	1.966 day	544	2015/05/12 - 2019/08/30
Manos Kardasis (Greece)	1.069 day	713	2008/03/10 - 2018/10/27
Sauveur Pedranghelu (France)	0.681 day	289	2019/06/03 - 2019/07/29
Benito Loyola (USA)	0.497 day	567	2018/07/11 - 2019/07/30
Oleg Zaharciuc (Moldova)	0.466 day	224	2016/05/22 - 2018/07/06
Pic du Midi (Colas/Delcroix/Dauvergne /Sylla) (France)	0.454 day	434	2012/08/06 - 2019/08/15
Grant Blair (USA)	0.445 day	255	2014/03/14 - 2016/04/24
Arnaud Claisse (France)	0.260 day	62	2015/05/21 - 2016/05/04
Philippe Chatelain (France)	0.251 day	26	2017/05/21 - 2019/05/31
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

3 impacts in 127 days of accumulated data: 8.6 "detectable" impacts per year
in the visible side of Jupiter or ~ 20 impacts per year counting impacts in the rest of the planet

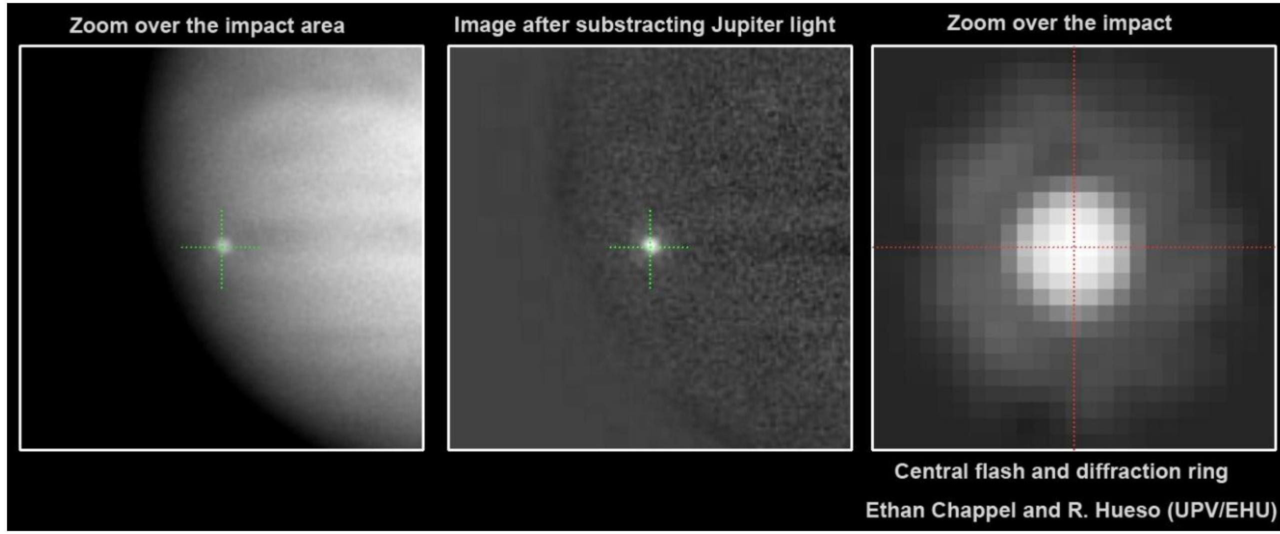
This number does not consider problems related with seeing or video quality and the real number should be larger

We can increase our last estimation of impact rate in Jupiter from 10-65 to 20-65 impacts per year.

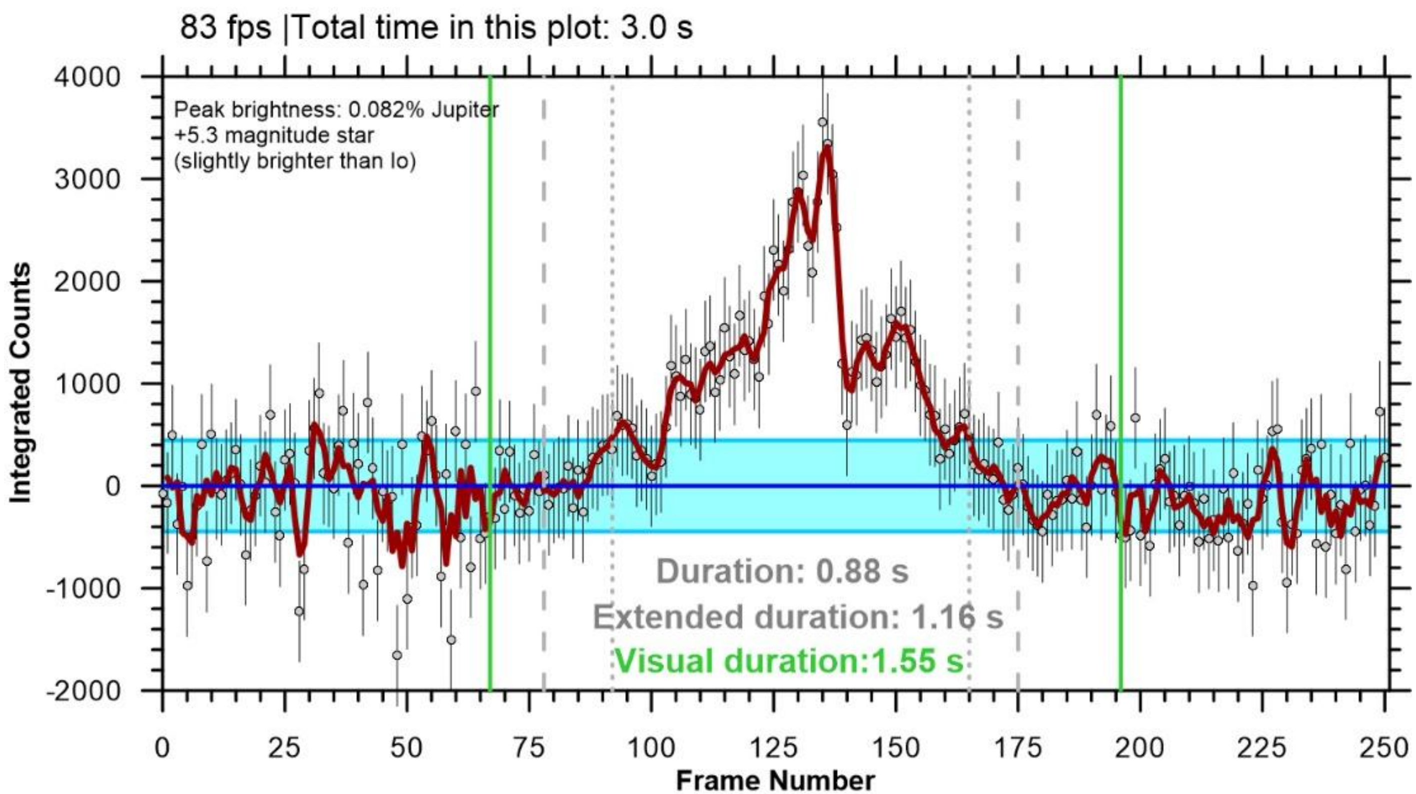
DeTeCt project goals: (1) That observers run DeTeCt after their observing sessions regularly
(2) That prominent observers with dozens of Terabytes of data stored in their hard-drives use the software to find "past" impacts. Kind support of Clyde Foster (South Africa) and others

The size and energy of the 2019 impact

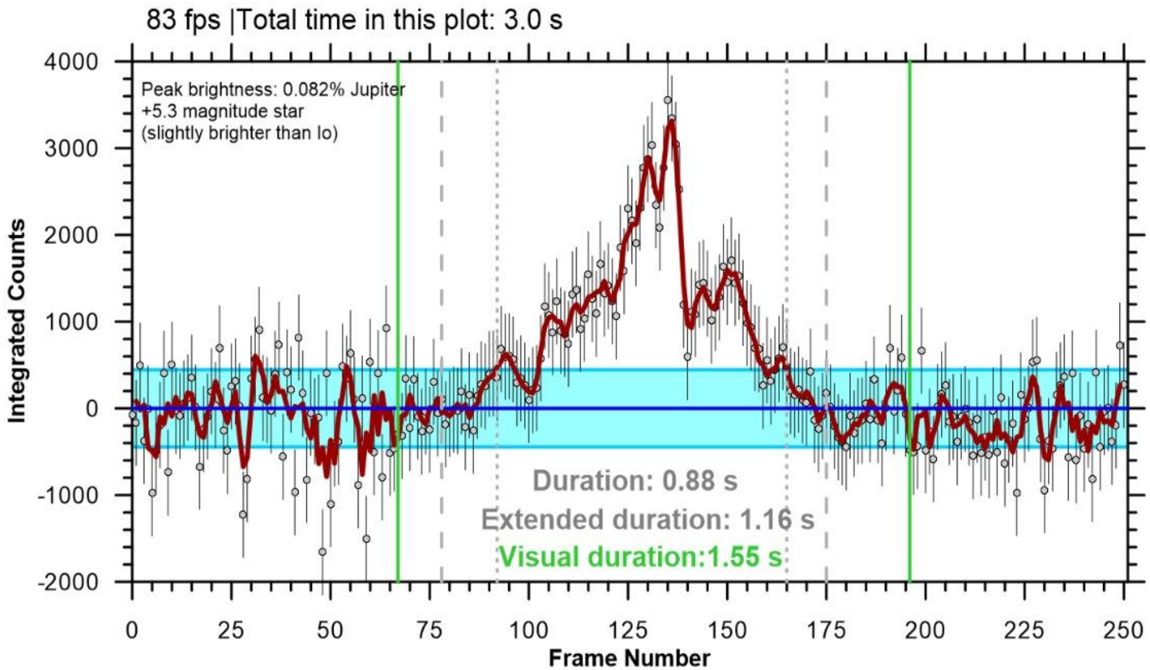
Automatic pipeline analysis using correlation of images and aperture photometry masks



Good evidence in this light-curve and visual inspection of the video of fragmentation of the object in Jupiter's atmosphere

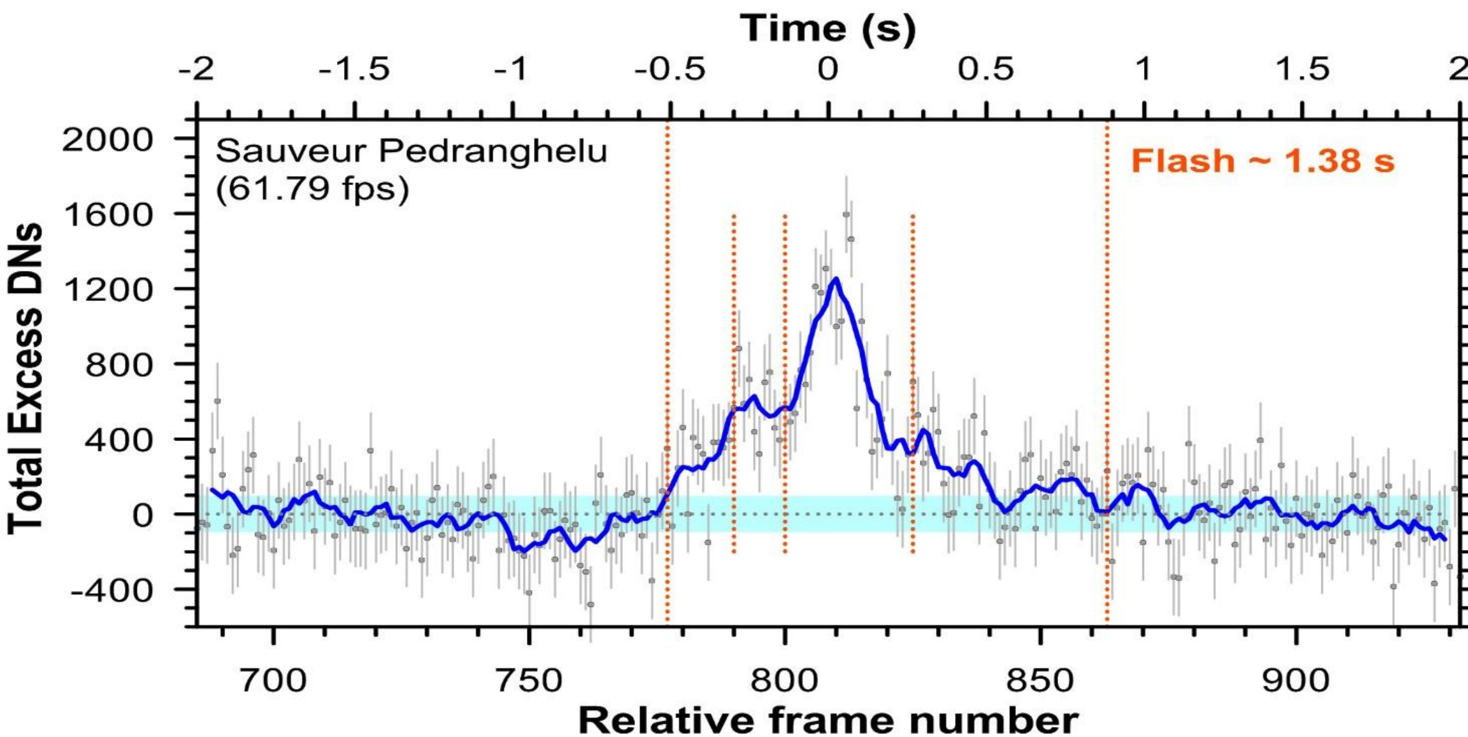


Not the first case with fragmentation but the first one we try to model!



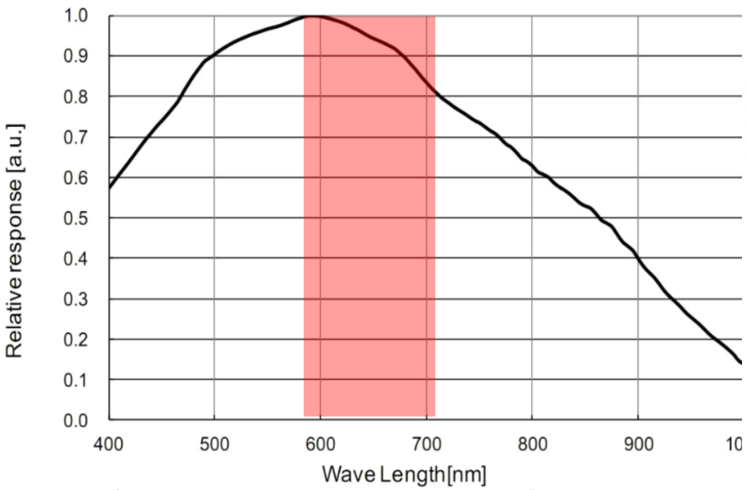
Less clear fragmentation in the light-curve of the 2017 impact

Hueso et al. *A&A* (2018)



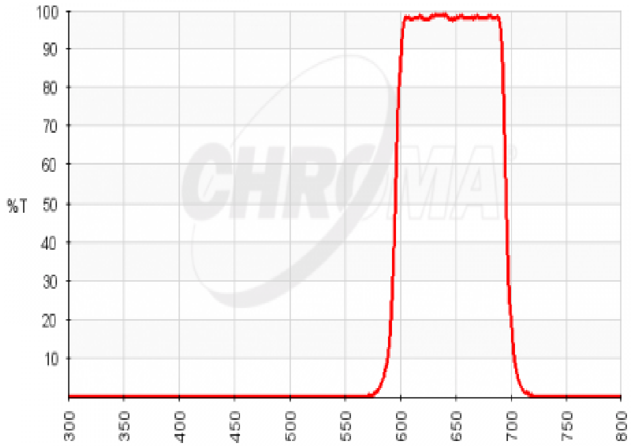
The size and energy of the 7th August 2019 impact

Camera: ASI=ZWO ASI290MM



(fps=83.31 gain=290 exp=12.00 ms)

Filter: Chroma red



Astro-Physics Advanced Convertible Barlow (considered negligible)

Calculation of kinetic energy by Ramanakumar Sankar (Florida Institute of Technology)

From light-curve: 8.9×10^{12} J in red
From black-body temperature~6500 K→ ~ 8.6×10^{13} J total luminous.
Luminous efficiency ~ 8.5%

Total energy ~ 1.0×10^{15} J (240 kT) 50% of the Chelyabinsk meteor impact in 2013

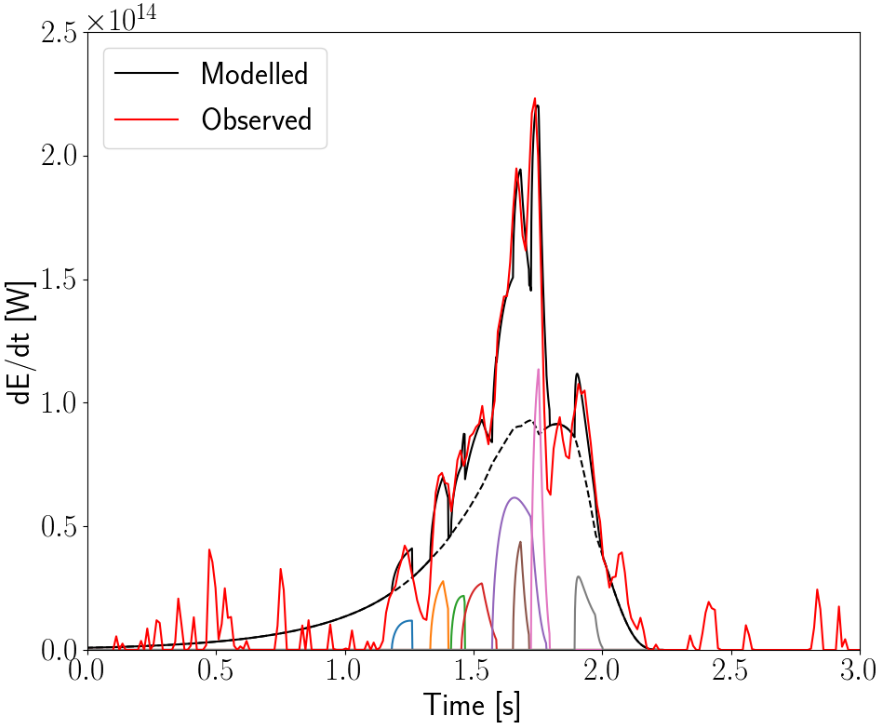
Almost exactly the same energy as estimated from a scale comparison with the 2012 impact by R. Hueso

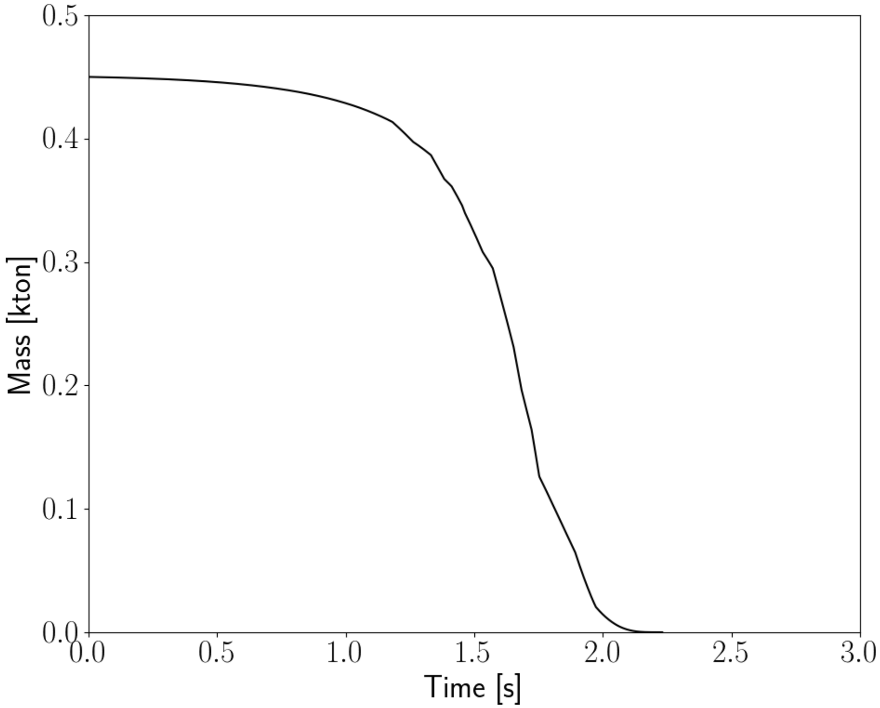
Estimated mass ~4.4 - 5.5×10^{6} kg Maximum diameter: 16 m (if cometary density ρ=0.25 kg/m3)

Not large enough to leave a traceable debris
(largest SL9 fragment with a debris SL9-N had an estimated size of 47 m, 25 times more massive)

This object is slightly smaller than the biggest flash observed in Jupiter (the September 2012 impact) which partially saturated the detector and had a maximum mass of 1000 Tn and a maximum size estimate of 20 m in diameter.

Models of impact fragmentation (also courtesy of Ramanakumar Sankar and Csaba Palotai at FIT)





Simulations based on **Borovicka et al. (2007) fragmentation model**.

The code starts with initial conditions of the object (mass, velocity, angle, height) and a prescription of the points of fragmentation (time and duration in the light-curve, total mass loss in each fragment and number of fragments. Inputs include the type of material (ablation coefficient, shape density coefficient).

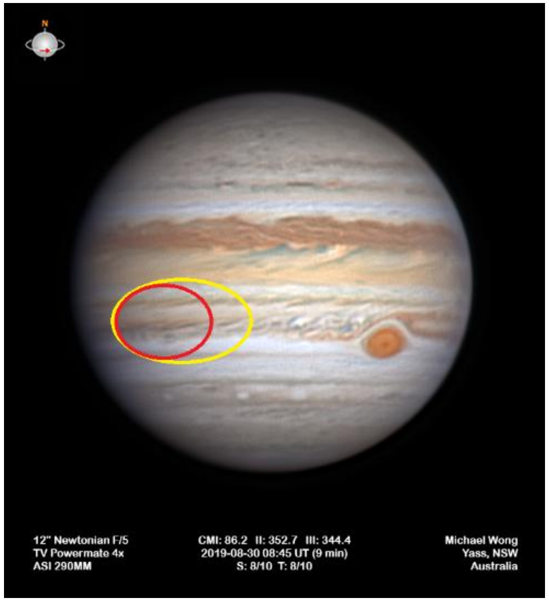
Simulation above: **0.45 kTon object impacting at 69 km/s with an angle of 25º.**
This fit of the light-curve requires **high density** (4.5 g/cm3; **stony-iron meteor**).
Terminal depth ~ 15 km below the point the bolide ignites (possibly at z=110-120 km)
Terminal depth ~ z=95-105 km or ~6-8 mbar
Diameter of this stony-iron object: 12.5 m

Non-unique solution. Currently the team at FIT is exploring the space of parameters to rule out a possible cometary impact.

Another impact alert in 2019: August 30 (Netherlands) | Visual observation

Visual observation of a flash in Jupiter near sunset with Jupiter at 15º elevation.
Telescope: C14, most convincing report so far (except the one by William Petersen in 2012 that led to the discovery of the September 2012 impact by George Hall both in USA) of the characteristics of an impact flash,

Only information available: ***August 30 18:15-18:30 UT) &***
Location over Jupiter (SEB)

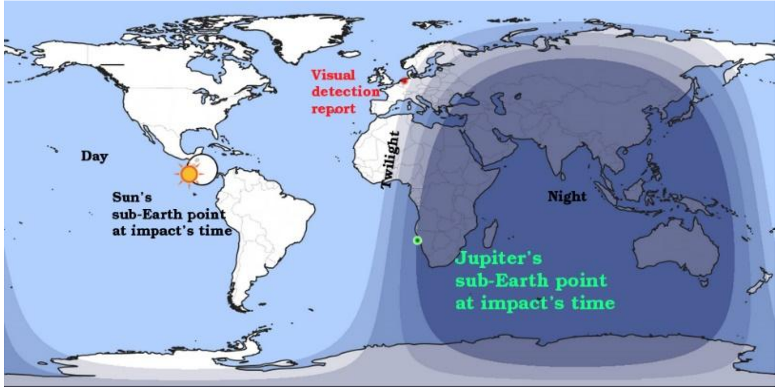


An Impact Recovery Team

Observers close in time: Michel Jacquesson, (France)	18:52-19:37 UT	
Armando Vaccaro (Italy)	18:59-19:22 UT	
Javier Beltrán Jovani (Spain)	19:36 UT	

Observational alert in Italy, Malta, **Greece**, Romania & **South Africa** (Jupiter at their peak elevation around 18-19 UT)

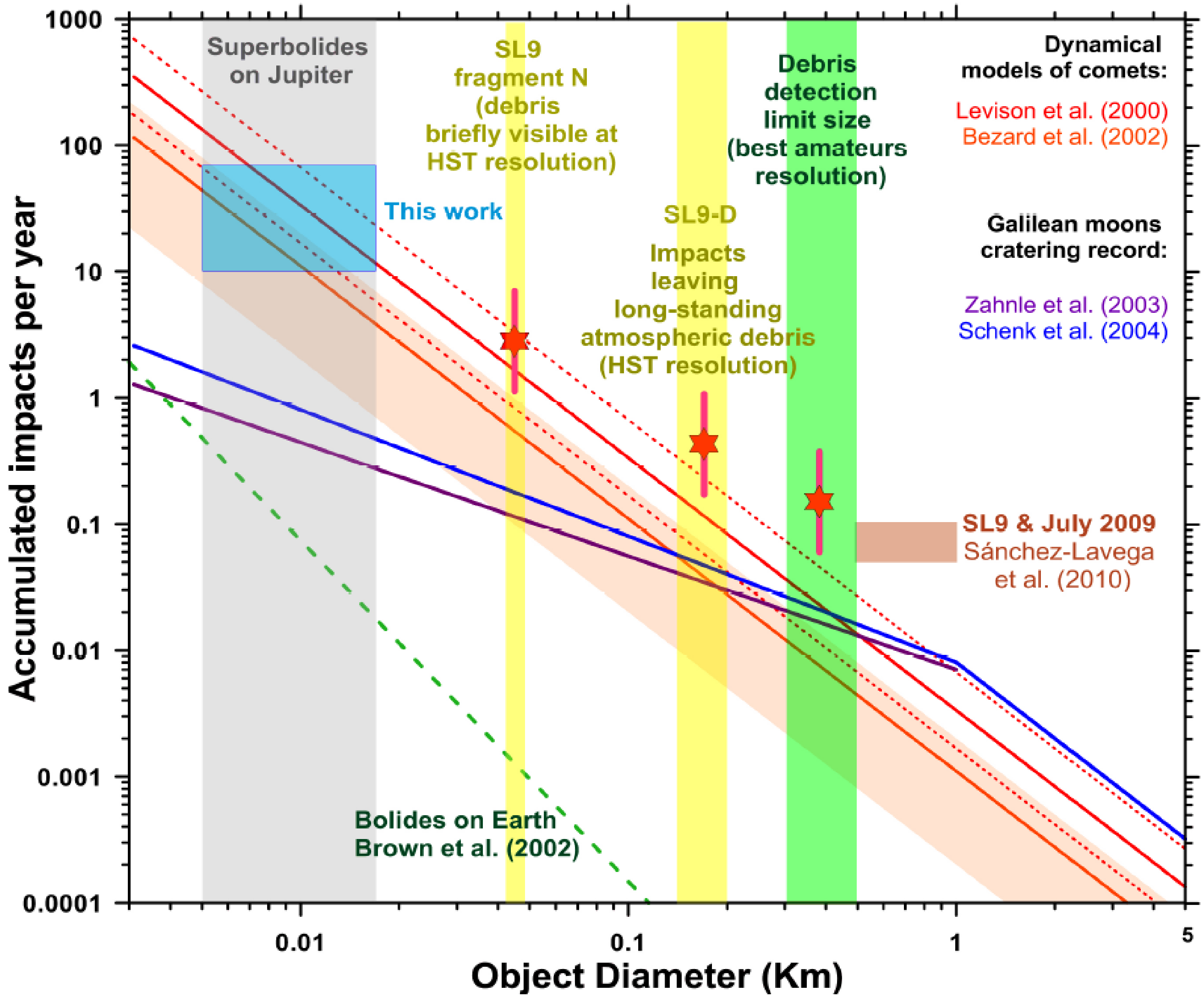
Help from ***M. Vedovato, Manos Kardasis, Ioannis Bouhras, Constantin Sprianu , Clyde Foster and Alexei Pace***



No success in finding a video observation of the planet close to the right time.
Larger alert released on Sept. 9 to observers in African countries with help of Salma Sylla and Clyde Foster.
No impact scar on Jupiter in images obtained the same and later nights.

Estimated impact rate in Jupiter

Hueso et al. A&A 2018



The new impact increases slightly the lower limit of the estimated impact rate of superbolides but does not change things significantly.

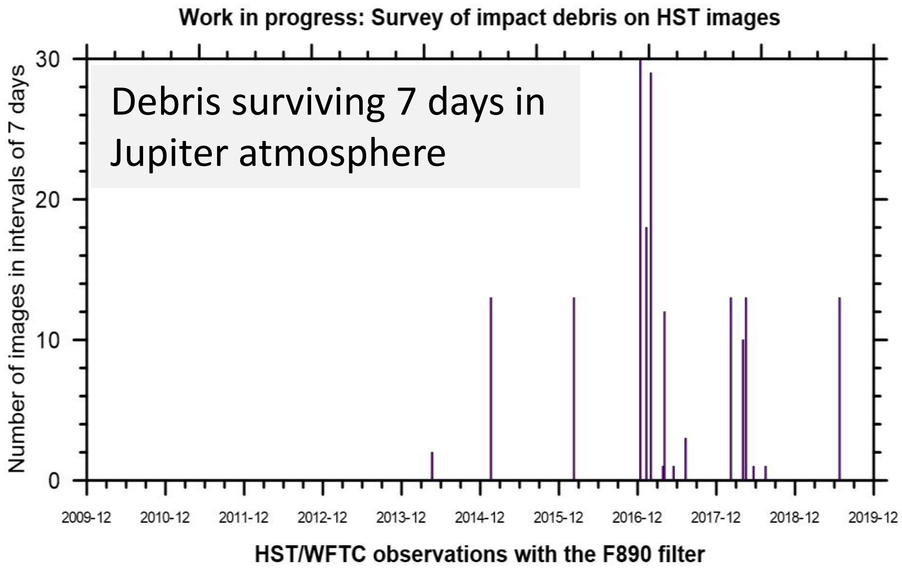
WHAT DO WE NEED?

1) Better estimate of objects masses.
Requires better knowledge of flash brightness temperature, a new flash observed simultaneously with two filters

2) Better understanding of the more frequent impact rate of smaller objects
Requires dedicated observing programs with professional telescopes

3) Better understanding of the less frequent impact rate of larger objects
Examen of accumulated observations on telescopes such as HST.

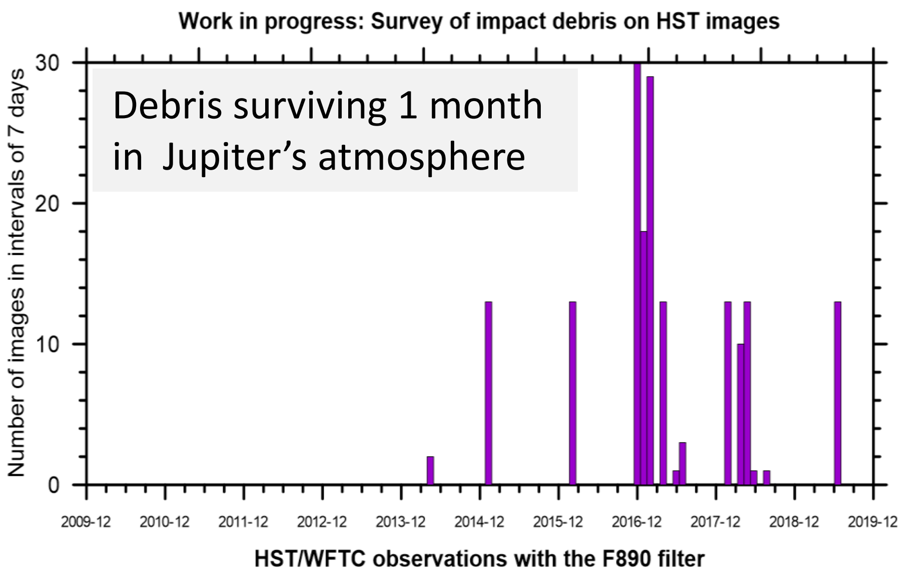
Survey efficiency for HST and amateur searches of impacts



Efficiency to discover a SL-9 N-like debris field (47-m object) by random chance over HST images: ~3%.

Need at least an impact rate of 7 objects per year of this size to produce a high probability of discovery.

Estimates in Hueso et al. (2018) are 1-3 objects per year of this size. It would be very difficult to find impact debris on HST images by chance.



Efficiency to discover a 2009 impact debris field (~150 m object) by random chance over HST images: ~13%.

Need at least an impact rate of 1-2 objects per year of this size to produce a high probability of discovery.

Estimates in Hueso et al. (2018) are 0.2-0.4 objects per year of this size.

Observational surveys for small and big impacts at:

Hampton University (Kunio Sayanagi & Benito Loyola)
~300 hrs per year of observations with 8-14" telescopes

Senegal (Salma Sylla)
Excellent near equatorial location with the capability to provide long observing sessions

Pic du Midi, France (François Colas)
~ A few tens of hours 15-50? per year with a 1m telescope in a site with excellent seeing and optics

Calar Alto Observatory, Spain (R. Hueso & A. Sánchez-Lavega)
~ 15 hrs per year at a 2.2 m telescope with two simultaneous cameras

Several surveys by amateurs:
Most dedicated amateurs (A.Wesley, C. Foster, …) can observe Jupiter ~300 hrs per year

Jupiter System Dynamics Observatory at Sun-Jupiter Lagrangian Point One
(PI:H.W. Hsu, University of Colorado)
Dedicated instrument in the mission proposal. **Mission concept** proposal under study at NASA

Targeting impact scars caused by bigger impacts:
One every 4-10 years an object could leave a traceable debris in Jupiter's atmosphere

- ✓ **HST Cycle 27 ToO proposal accepted** (PI: Imke de Pater)
- ✓ **Possibility to detect stratospheric exogenous species with ALMA from "small" impacts**
- ✓ **JWST Cycle 1 opportunities**