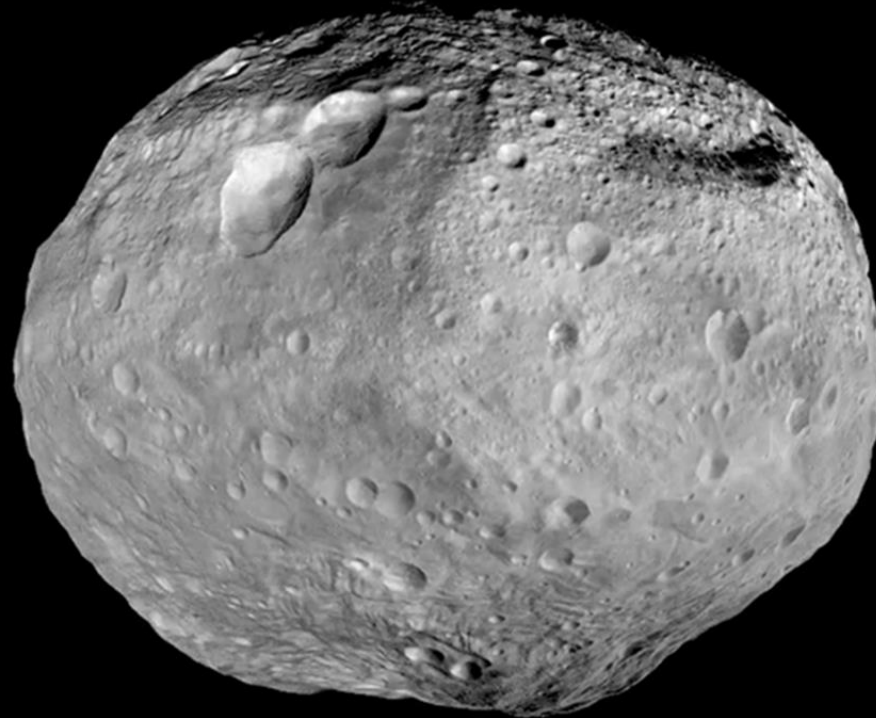


From Vesta to the Kalahari: tracing meteorites from asteroid 2018 LA



Tim Cooper

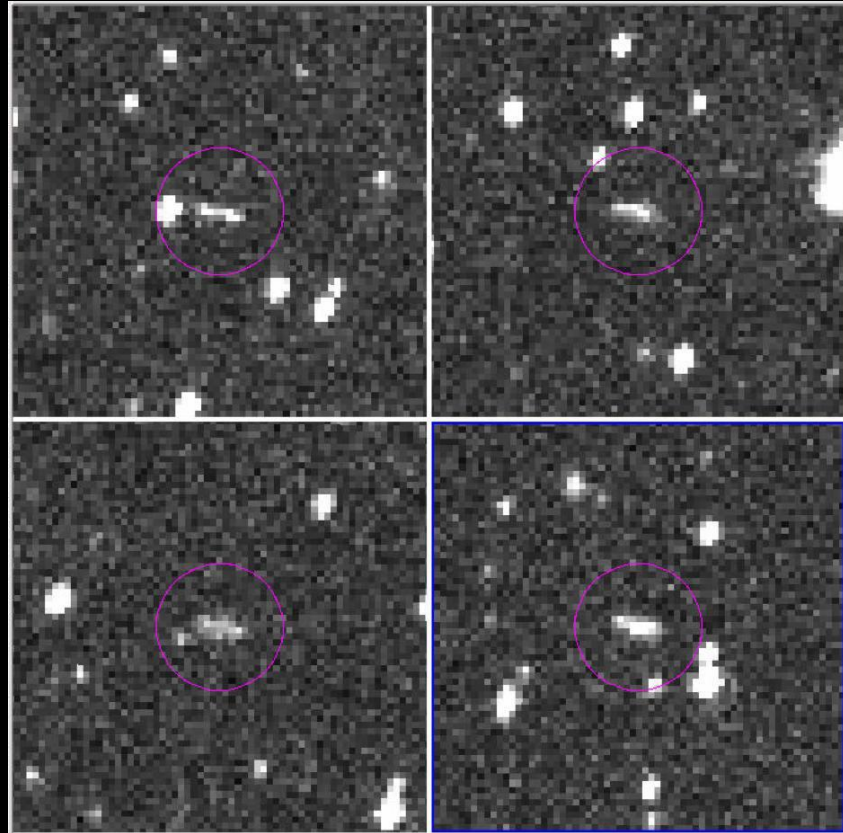
ASSA Shallow Sky Section

Timeline

- ~22.8 Ma fragment ejected in collision that formed Rubria crater.
- 2018 June 2, 08h16 UT, asteroid 2018 LA detected in space.
- 2018 June 2, 16h44 UT, bolide from asteroid 2018 LA.
- 2018 June 7-11, calibration of video images.
- 2018 June 23, first meteorite found, MP-01 weighing 17.92g.
- 2018 July-September, three further expeditions made no more finds.
- 2018 October 8-12 - 5th expedition team finds 22 more fragments.
- 2021 April 21, publication of MAPS paper, 66 authors (2018 LA Consortium).
- 2021 April 26-30, poster paper presented at IAA Planetary Defense Conference, Vienna.
- 2021 June, publication of ASSA account in MNASSA.

First images of 2018 LA

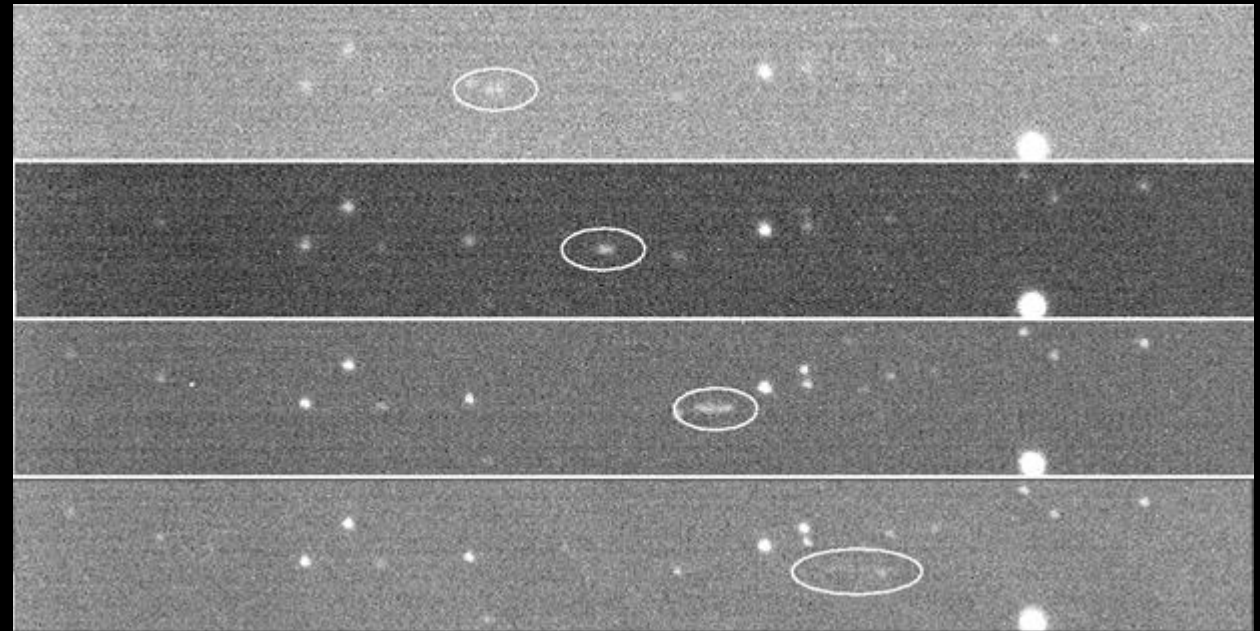
2018 June 2.3443



Catalina Sky Survey discovery images of 2018 LA

Image credit: Catalina Sky Survey
<https://www.jpl.nasa.gov/images/asteroid-2018-la>

Absolute magnitude	= 31.1
Albedo	= 0.25
Diameter	= 156 cm
Spin rate	= 244 sec
Geocentric velocity	= 17 km/s



SkyMapper Southern Survey g,r,i, and z colour bands
(Wolf et al. 2018)

Meteoriet

By my pale op plaas kamera naby Ottosdal.

Die meteoriet het naby deelpan geval volgens ooggetuies.

#Meteor #Meteoriet



2018 June 2
18h44 local time

2018/06/02 18:42:18 SAT

2018/06/02 18:42:19 SAT

2018/06/02 18:42:20 SAT

Frame grabs at 1 second intervals
Gaborone video footage, Botswana
Image credit: Beverly Lombard

HIP 44700

HIP 48113

β Gem

γ Uma

α Gem

ι Uma

κ UMa

θ UMa

β Uma

α Uma

JUMCORP

Gaborone video footage
Calibration image taken by Tim Cooper

6/02 18:42:20 SAT



Gaborone video footage
Calibration image taken by Tim Cooper

HIP 44700

HIP 48113

β Gem

γ Uma

α Gem

ι Uma

κ UMa

θ UMa

β Uma

Positions 1-5

Main flash

α Uma

• β Gem

• α Gem

31 Lyn

κ UMa

ι UMa

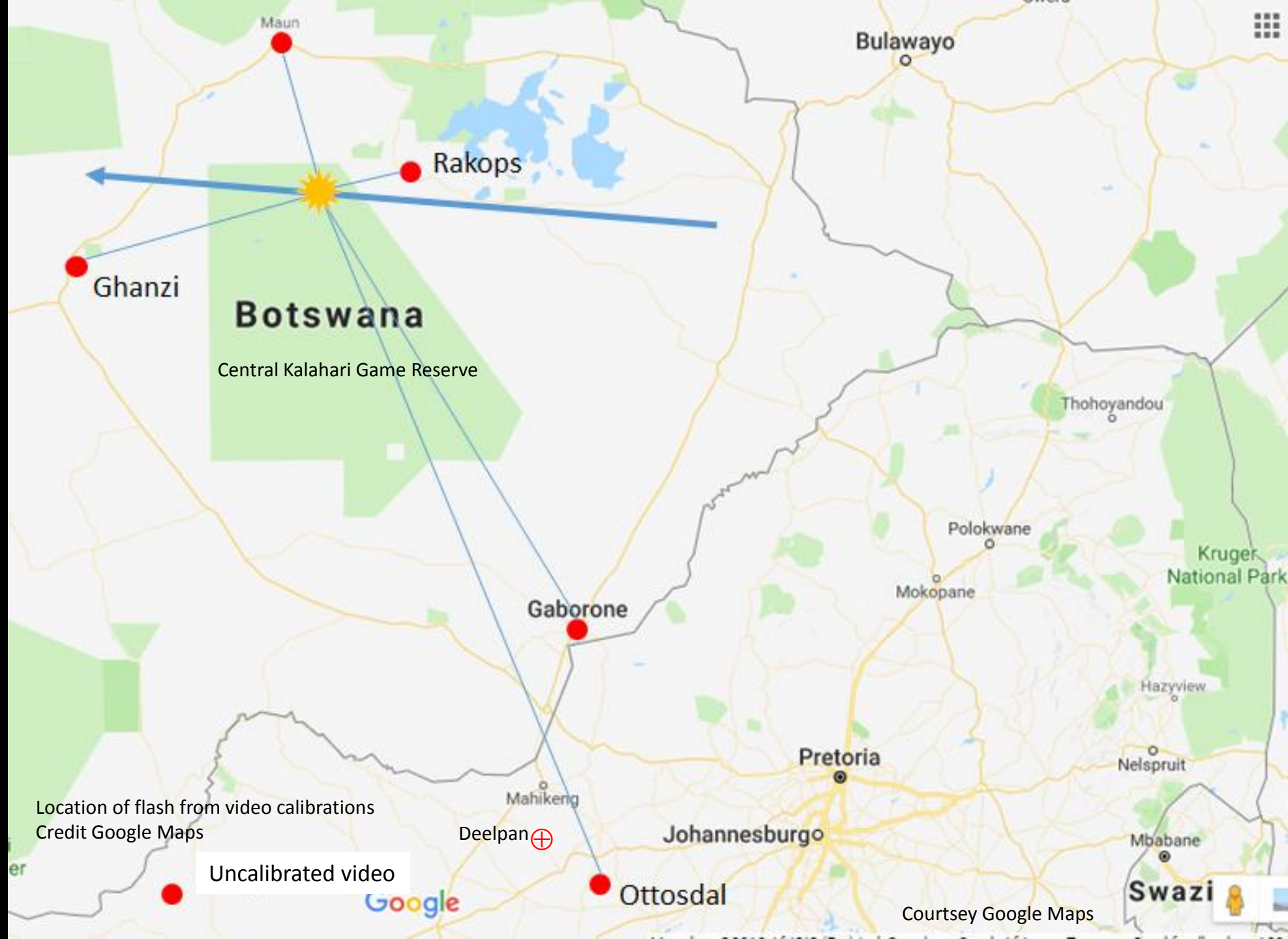
θ UMa



2018 June 8
Image @ 16:41:00 UT
10 seconds

Ottosdal video footage
Calibration image taken by Tim Cooper





Uncalibrated video

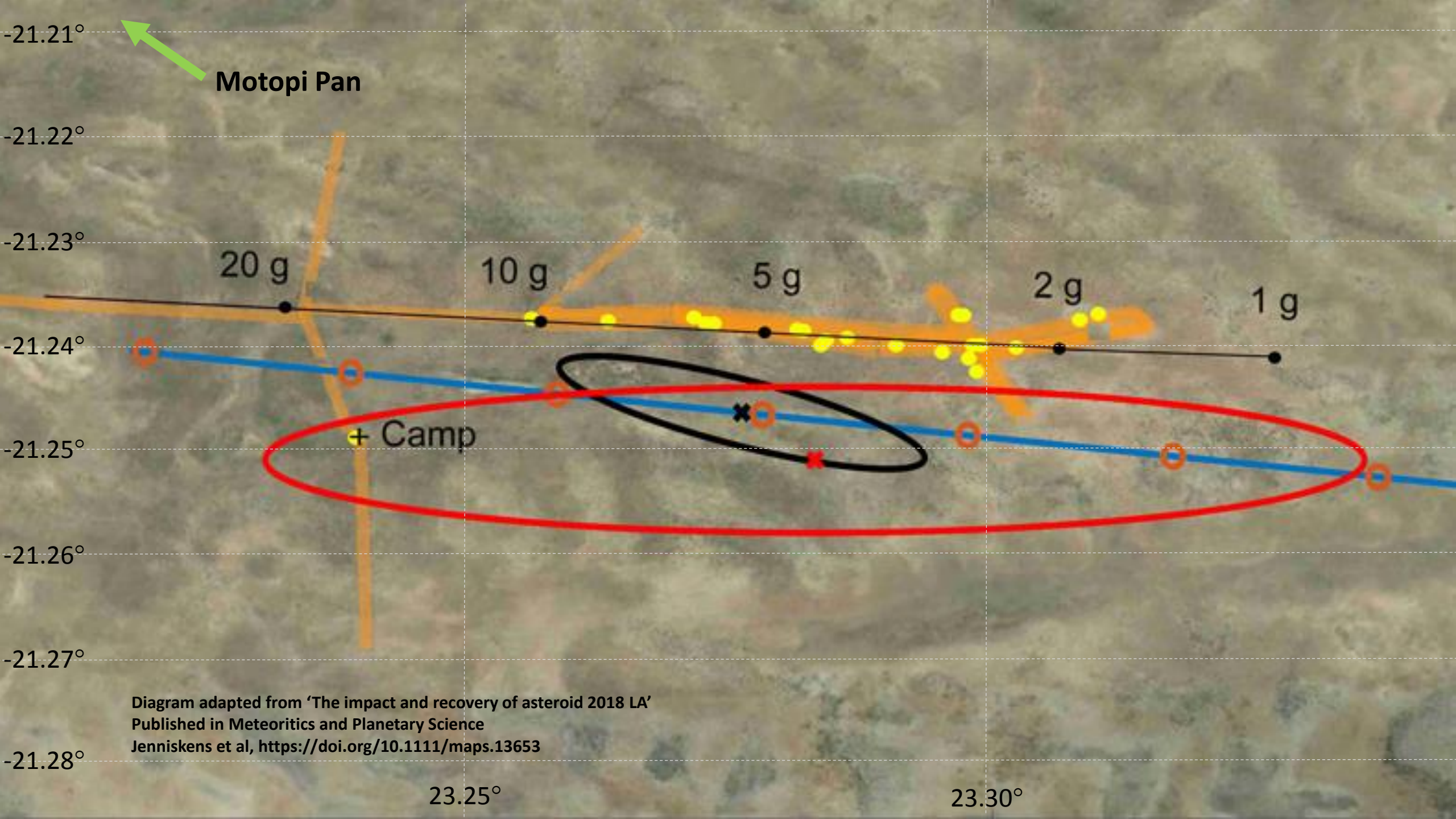
Location of flash from video calibrations
Credit Google Maps

Courtsey Google Maps



2018, July 6 - A fresh-looking 18-g meteorite was found in the Central Kalahari Game Reserve during a search effort dedicated to finding debris from asteroid 2018 LA. The search was guided by Peter Jenniskens and conducted by three Botswana institutes, the Botswana International University of Science and Technology (BIUST), the Botswana Geoscience Institute (BGI) and the University of Botswana at Maun Okavango Research Institute (ORI), and supported by Central Kalahari Game Reserve staff. Peter Jenniskens teamed with Oliver Moses of ORI (to the right in image above) and recovered video security camera footage in Maun and Rakops that helped constrain the disruption point and focus the search. Images were calibrated from star background by Jim Albers. Tim Cooper from ASSA calibrated videos to the south. Jelle Assink and Laslo Evers of the KNMI provided atmospheric wind data. The first meteorite was found by team member Lesedi Seitshiro on Saturday June 23 (center front in photo).

NASA press release, 2018 July 6



Motopi Pan

20 g

10 g

5 g

2 g

1 g

+ Camp

Diagram adapted from 'The impact and recovery of asteroid 2018 LA'
Published in Meteoritics and Planetary Science
Jenniskens et al, <https://doi.org/10.1111/maps.13653>

23.25°

23.30°

Members of the expedition which found 22 fragments, October 9-12, 2018



Standing left to right Tim Cooper (ASSA), Oliver Moses (ORI), Mohutsiwe Gabadirwe (BGI), Thebe Kemosedile (ORI), Sarah Tsenene (DWNP), Kabelo Dikole (BGI), Mosarwa Babutsi (Botswana National Museum, Gaborone), kneeling Kagiso Kgetse (DWNP) and Peter Jenniskens (SETI Institute). Photo by team member Odirile Sempfo.

Fragments of meteorite Motopi Pan

MP-#	Latitude (°S)	Longitude (°E)	Alt. (m)	Date (2018)	Time (UTC)	Finder	Affil. †	Mass (g)
01*	21.24848	23.23866	1002	6/23	07:00	Lesedi Seitshiro	BIUST	17.92
02	21.23612	23.25528	1004	10/9	10:50	Mohutsiwa Gabadirwe	BGI	4.28
03	21.23696	23.27134	1001	10/10	13:00	Oliver Moses	ORI	10.08
04*	21.23880	23.28254	989	10/10	14:26	Thebe Kemosedile	ORI	13.16
05	21.23959	23.29484	991	10/11	07:28	Mohutsiwa Gabadirwe	BGI	2.59
06*	21.23887	23.29740	994	10/11	07:54	Peter Jenniskens	ORI	8.55
07	21.23888	23.29785	994	10/11	08:00	Sarah M. Tsenene	DWNP	0.51
08	21.23862	23.29811	996	10/11	08:24	Kagiso Kgetse	DWNP	3.95
09*	21.23689	23.30645	996	10/11	09:10	Kagiso Kgetse	DWNP	4.96
10	21.23633	23.30866	997	10/11	09:45	Kagiso Kgetse	DWNP	0.89
11	21.23968	23.30086	991	10/11	12:45	Sara M. Tsenene	DWNP	4.51
12	21.23979	23.29714	990	10/11	14:10	Mohutsiwa Gabadirwe	BGI	3.60
13*	21.23708	23.27264	998	10/12	07:14	Kagiso Kgetse	DWNP	3.76
14*	21.23629	23.29703	996	10/12	09:06	Kabelo Dikole	BGI	4.35
15	21.23626	23.29700	995	10/12	09:10	Oliver Moses	ORI	2.71
16	21.24087	23.29789	994	10/12	09:45	Peter Jenniskens	ORI	1.35
17*	21.23889	23.29038	1005	10/12	12:50	Kagiso Kgetse	DWNP	4.93
18*	21.23765	23.28587	997	10/12	13:20	Mohutsiwa Gabadirwe	BGI	0.90
19*	21.23812	23.28381	996	10/12	13:38	Tim Cooper	ASSA	6.19
20	21.23758	23.28099	994	10/12	13:53	Peter Jenniskens	ORI	1.85
21	21.23743	23.28025	992	10/12	14:04	Mohutsiwa Gabadirwe	BGI	7.60
22	21.23619	23.27041	997	10/12	15:07	Peter Jenniskens	ORI	4.73
23	21.23646	23.26306	991	10/12	15:37	Mohutsiwa Gabadirwe	BGI	8.85

Fragments of meteorite Motopi Pan

Images credit Peter Jenniskens, adapted from 'The impact and recovery of asteroid 2018 LA'
Published in Meteoritics and Planetary Science, Jenniskens et al, <https://doi.org/10.1111/maps.13653>



MP-01 17.92g



MP-02 4.28g



MP-03 10.08g



MP-04 13.16g



MP-05 2.59g



MP-06 8.55g



MP-07 0.51g



MP-08 3.95g



MP-09 4.96g



MP-10 0.89g



MP-11 4.51g



MP-12 3.60g



MP-13 3.76g



MP-14 4.35g



MP-15 2.71g



MP-16 1.35g



MP-17 4.93g



MP-18 0.90g



MP-19 6.19g



MP-20 1.85g



MP-21 7.60g



MP-22 4.73g



MP-23 8.85g

Examples of finds which were not meteorites;
 MP-not 1 is a piece of charcoal from recent bush fire
 MP-also not 1 is a Gemsbok dropping.
 Meteorite images courtesy Peter Jenniskens
 Non-meteorite images by Tim Cooper



MP-not 1



MP-also not 1



MP-01 17.92g



MP-02 4.28g



MP-03 10.08g



MP-04 13.16g



MP-05 2.59g



MP-06 8.55g



MP-07 0.51g



MP-08 3.95g



MP-09 4.96g



MP-10 0.89g



MP-11 4.51g



MP-12 3.60g



MP-13 3.76g



MP-14 4.35g



MP-15 2.71g



MP-16 1.35g



MP-17 4.93g



MP-18 0.90g



MP-19 6.19g



MP-20 1.85g



MP-21 7.60g



MP-22 4.73g



MP-23 8.85g

6/02 18:42:20 SAT



D

C

B

A

Gaborone video, calibration of lamp brightness
Calibration image taken by Tim Cooper

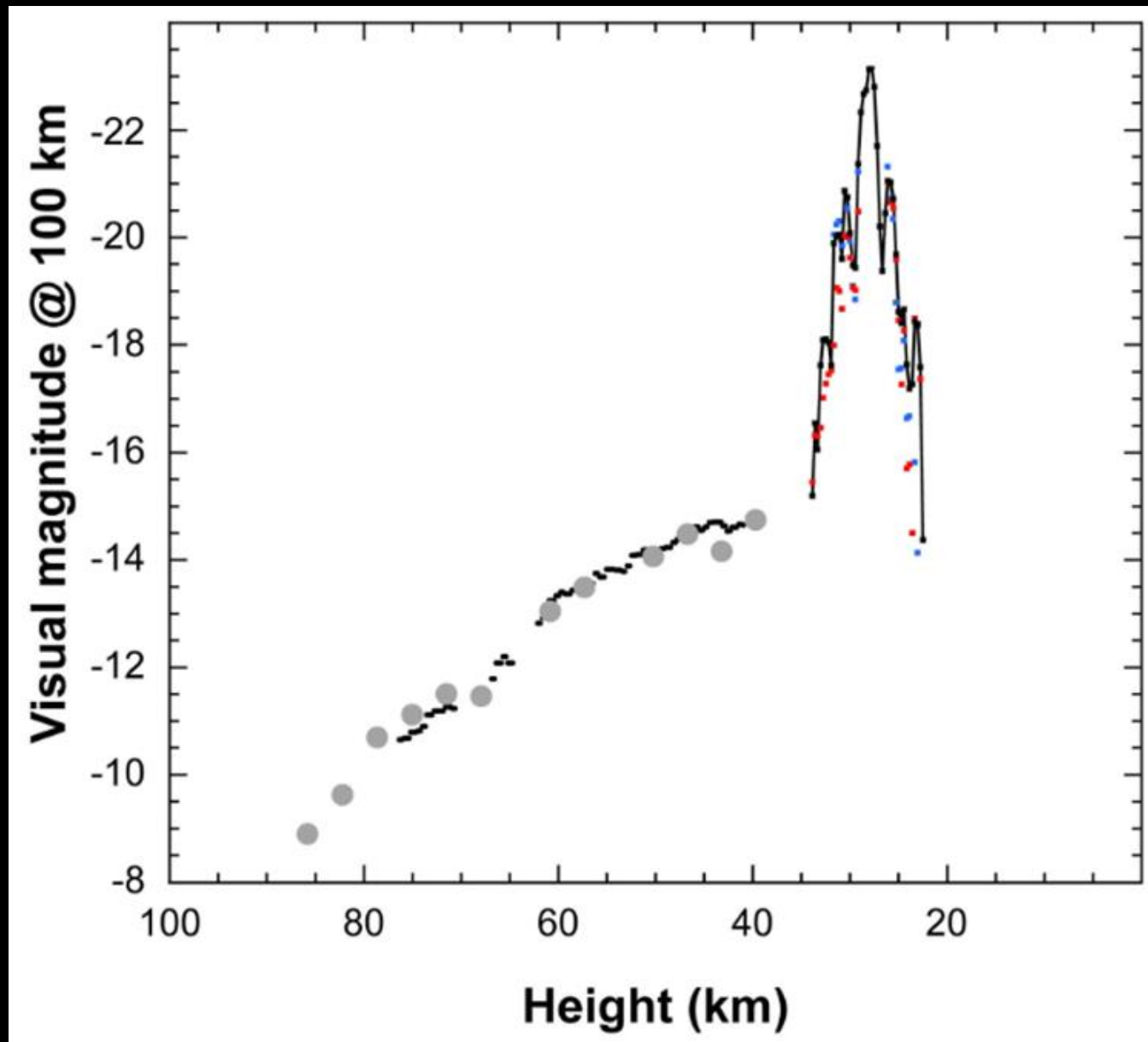


Diagram adapted from 'The impact and recovery of asteroid 2018 LA', Published in Meteoritics and Planetary Science, Jenniskens et al, <https://doi.org/10.1111/maps.13653>



Team members responsible for securing and calibrating video footage from 2018 LA bolide and shadows:
Left to right Tim Cooper (ASSA), Dr Oliver Moses (ORI) and Dr Peter Jenniskens (SETI Institute and NASA Ames)

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Volume 56

Number 4

2021 April



Motopi Pan MP-04 was the fourth recovered fragment of asteroid 2018 LA in the Central Kalahari Game Reserve.

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Wiley Online Library

Scientific results by 66 authors (2018 LA Consortium)
published in Meteoritics and Planetary Science, Vol. 56, 844-893

Impact and recovery of asteroid 2018 LA

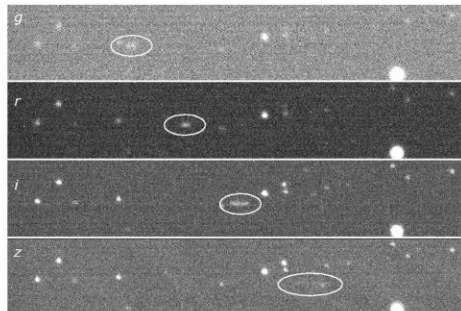
Peter Jenniskens [1,2], Mohutsiwa Gabadirwe [3], Qing-zhu Yin [4], Alexander Proyer [5], Oliver Moses [6], Tomas Kohout [7,8], Fulvio Franchi [8], Roger L. Gibson [9] and **the 2018 LA Consortium**

[1] SETI Institute; [2] NASA Ames Research Center; [3] Botswana Geoscience Institute; [4] University of California at Davis; [5] Botswana International University of Science and Technology (BIUST); [6] University of Botswana, Okavango Research Institute; [7] Department of Geosciences and Geography, University of Helsinki; [8] Ursa Finnish Fireball Network; [9] School of Geosciences, University of the Witwatersrand; Email: Petrus.M.Jenniskens@nasa.gov



Asteroid 2018 LA

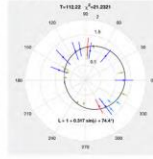
Contributions from Richard Kowalski, Eric J. Christensen, Alex R. Gibbs, Aren Heinze, Larry Denneau, Davide Farnocchia, Paul W. Chodas, William Gray, Marco Micheli, Nick Moskovitz, Christopher A. Onken, Christian Wolf, Hadrien A. R. Devillepoix, Qianzhi Ye, Darrel K. Robertson, Peter Brown



New detection: asteroid 2018 LA in SkyMapper Survey data.

On June 2, 2018, asteroid 2018 LA was detected by the Catalina Sky Survey on an impact trajectory, 8 hours before possible impact. A video security camera in Ottosdal, South Africa, recorded a bolide over Botswana. ATLAS survey data extended the observing arc. Here, we report on additional detections in the SkyMapper Survey data that extend the observing arc to 5.4h, improve the orbit and enable an approximate determination of the asteroid's spin period and shape.

Asteroid brightness as function of phase in spin period:



Best sinusoidal fit to the lightcurve for triaxial ellipsoid $c/b = 0.58$.

Spin period = 224 ± 40 s.

Combining astronomical brightness data with data from meteorite analysis shows most likely size = 156 cm diameter, V-class spectrum with 25% reflectivity, and no opposition effect.

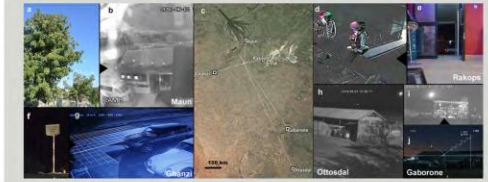


Motopi Pan #2

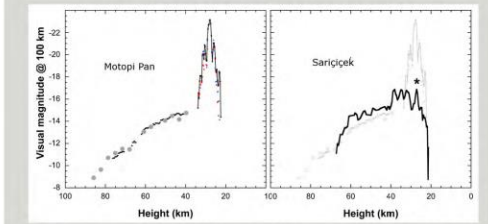
#2! Mohutsiwa Gabadirwe of the Botswana Geoscience Institute recovers the second Motopi Pan meteorite. This is also the second recovered fall from a small observed asteroid, after 2008 TC3 ten years earlier. From left to right: Peter Jenniskens, Tim Cooper, Mohutsiwa Gabadirwe, Kabelo Dikole, and Thebe Kemosedile.

Recovery

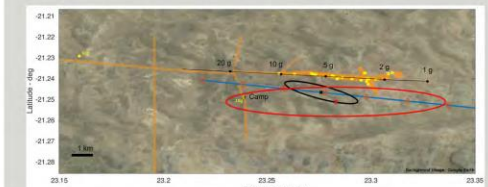
Contributions by: Peter Jenniskens, Alexander Proyer, Mohutsiwa Gabadirwe, Oliver Moses, Tomas Kohout, Fulvio Franchi, Esko Lytinen, Jarmo Moilanen, Jim Albers, Tim Cooper, Jelle Assink, Láslo Evers, Panu Lahtinen, and Lesedi Setshiro



Video security camera footage from Ottosdal, Gaborone, Maun, Rakops and Ghanzi was calibrated to triangulate the fireball disruption. From that position, using wind model data, the fall area was calculated. First meteorite found on June 23, 2018 by Lesedi Setshiro of BIUST.



Fireball lightcurve showed a prominent flare, much stronger than seen in Sariçiçek. Same disruption altitude: 27.8 ± 0.9 km.

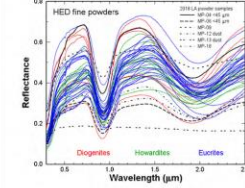


Fall area in Central Kalahari Game Reserve in central Botswana. Red ellipse is the position of the flare estimated by video triangulation. Black ellipse is the position of the flare after taking into account the asteroid astrometry. Blue line shows the ground-projected path, with orange circles marking 10-km steps in altitude. Thin black line is the calculated fall line. Orange areas were searched, yellow dots are finds.

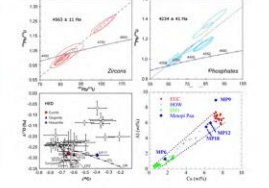
Planetary Defense

Contributions from: Matthias Laubenstein, Ngigé Wanto, Phero Moleje, Joseph Maritinkole, Heikki Suhonen, Michael E. Zolensky, Roger L. Gibson, Lewis Ashwal, Takahiro Hirai, Derek W. Sears, Alexander Sehlke, Alessandro Matunili, Qing-zhu Yin, Matthew E. Sanborn, Magdolena H. Huyskens, Supratim Dey, Karen Ziegler, Henner Busemann, My G. I. Riebe, Matthias H. M. Meier, Kees C. Welton, Marc W. Caffee, Qin Zhou, Qiu-Li Li, Xian-Hua Li, Yu Liu, Guo-Qiang Tang, Hannah L. McLain, Jason P. Dworkin, Daniel P. Gaultin, Philippe Schmitt-Kopplin, Hassan Sabbah, Christine Joblin, Mikael Granvik, Babutsi Mosarwa, and Koketso Botsepe.

Reflectance spectra:

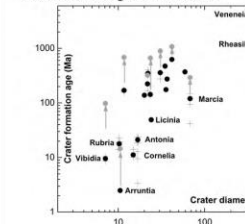


Isotopic & elemental compositions:

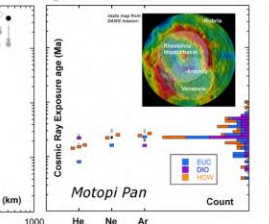


Analysis of 7 meteorites showed these were part of a HED polymict breccia derived from howardite, cumulate and basaltic eucrite, and diogenite lithologies. Some similarities and some differences with howardite Sariçiçek were noticed.

Vesta crater age versus size:



Age distribution of known HED:



Orbit of 2018 LA is consistent with origin at Vesta (small a , low i). Cosmic ray exposure age is 23 ± 4 Ma, similar to HED Sariçiçek (thought to have originated at the Antonia impact crater). Unlike Sariçiçek, Motopi Pan experienced a heating event 4234 ± 41 Ma ago, possibly from formation of Veneneia impact basin. Later formation of Rhesalvia spread this material around. On top of Rhesalvia ejecta is 10-km sized crater Rubria, a good candidate for the origin crater.

Acknowledgements & further reading:

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In this issue:

Award of Overbeek Medal to Magda Streicher and Clyde Foster

**Asteroid 2018 LA
(Observed in space and recovered on the ground)**

The Eta Aquariids in 2021

Visit to SAAO Carnarvon