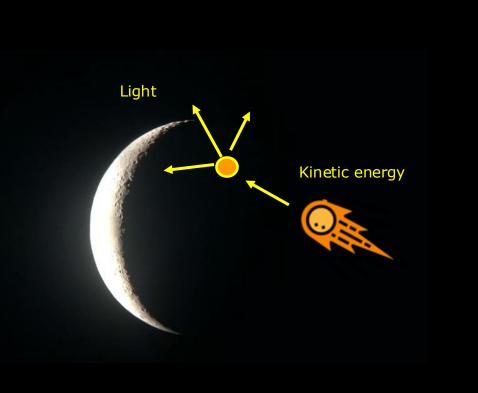
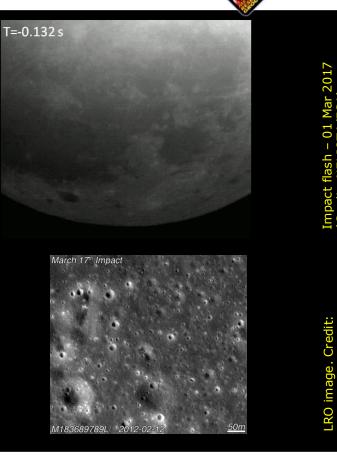
# Lunar Impact Flashes – the how

Detlef Koschny, TU Munich (Germany,) Space Exploration Institute (Switzerland) Detlef.Koschny@tum.de

### What do we see?





Dr. D. Koschny – AMM-HO-046/1.0, 21 Sep 2023

Prof. Dr. Philipp Reiss | Lunar and Planetary Exploration Technologies | Department of Aerospace and Geodesy | Technical University of Munich

ПΠ

#### Cumulative number impacting per vear Grün (1985) Brown (2002) .... Interpolation 1 g Planetary and Space Science HST Solar Arrays Earth De-biased CILBO - New formula Halliday (1996) Suggs (2014) 10Interpolation 100 g NASA (2003) === Silber (2009) $10^{-19} \ 10^{-16} \ 10^{-13} \ 10^{-10} \ 10^{-7} \ 10^{-4} \ 10^{-1} \ 10^{2}$ $10^5 \ 10^8 \ 10^{11}$ Meteoroid mass in kg $10^{-8}$ $10^{-7}$ $10^{-6}$ $10^{-5}$ $10^{-4}$ $10^{-3}$ $10^{-2}$ $10^{-1}$ $10^{0}$ $10^{1}$ $10^{2}$ $10^{3}$ Meteoroid diameter in m

Fig. 10. All used flux density models in one plot including the estimated errors.

# Quick reminder on 'why' – Flux density, impact processes...

Dr. D. Koschny - AMM-HO-046/1.0, 21 Sep 2023

Prof. Dr. Philipp Reiss | Lunar and Planetary Exploration Technologies | Department of Aerospace and Geodesy | Technical University of Munich

and comets

Mass accumulation of earth from interplanetary dust, meteoroids, asteroids



# Multiframe lunar impact flash detected on 7 July 2019



eliota%20fi <u>)tlash%</u>

## **Observing procedure in a nutshell**



- **1.** Take as big a telescope as you have, hopefully with little in-field straylight
- 2. Mount a sensitive camera which can record with high frame rate (10 fps or faster most use video rate) make sure you have some magnitude calibration (see later)
- 3. Point it to the non-sunlit side (henceforth called the 'dark side') of the Moon coordinate with other observers if possible
- 4. Use a detection software and press start or: record on video if you have enough memory space
- 5. If using e.g. the 'Flash Detection Software' (see later) run some scripts over the acquired data, see whether there is a flash be happy!
- 6. If using video use a software that can analyse the data FDS in demo mode, LunarScan, ALFI (again see later)
- 7. Inform Brian Cudnik (ALPO), Tony Cook (BAA), J. Madiedo (MIDAS), post on <u>lunar-impacts@groups.io</u>
- 8. Hope that somebody else has seen it too!

## How many do we expect?

**Brighter than 8 mag:** 

**Brighter than 9 mag:** 

48 in 271 hours

=> 1 / 5.6 hours

119 in 271 hours

=> 1 / 2.3 hours

Note: More during

sporadics only

(10" to 12"

aperture?)

p.6

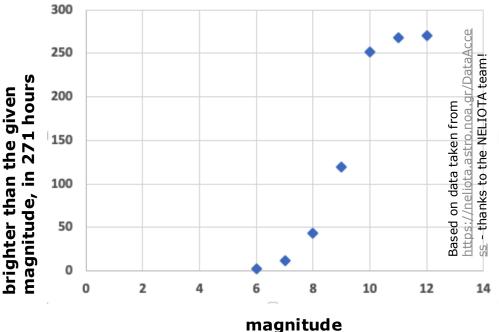
showers, less during

Prof. Dr. Philipp Reiss | Lunar and Planetary Exploration Technologies | Department of Aerospace and Geodesy | Technical University of Munich

umber of events

Cumulati

Observed flashes by NELIOTA in 271 hours



# ТШ

# My setups - 10" Newton, later 12"



Pror. Dr. Philipp Reiss | Lunar and Planetary Exploration Technologies | Department of Aerospace and Geodesy | Technical University of Munich

### Test setup – 13 cm Refraktor



And the camera: QHY 174 1920 x 1200 px, 5.86 um 11.3 mm \* 7.0 mm





Prof. Dr. Philipp Reiss | Lunar and Planetary Exploration Technologies | Department of Aerospace and Geodesy | Technical University of Munich

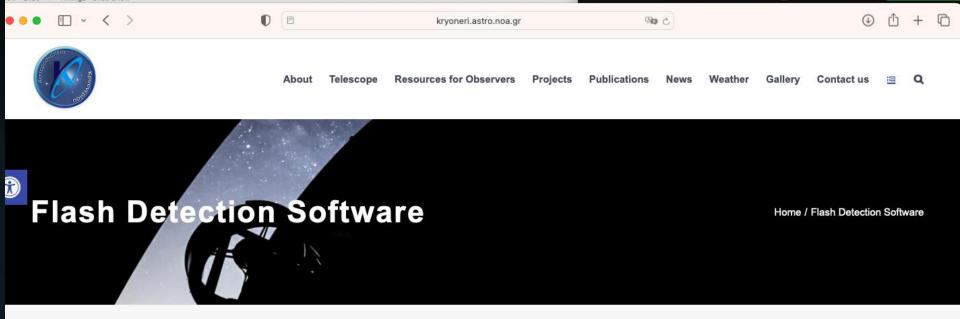
## Test setup – 6" Refraktor



Dr. D. Koschny – AMM-HO-046/1.0, 21 Sep 2023 Prof. Dr. Philipp Reiss | Lunar and Planetary Exploration Technologies | Department of Aerospace



# **Detection software**



The Flash Detection Software (FDS) is a tool for detecting impact flashes on the Moon. This software can be used by any amateur or professional astronomer performing planetary observations with video cameras or fast-frame CMOS/CCDs for data processing and flagging all potential flash events. The ultimate goal is to encourage and increase the observations of impact flashes from both professional and amateur astronomers and to enable verification of impact flashes from multiple sites. The software was developed and tested for lunar impact flash observations, however, its use on planets (e.g. Jupiter, Mars) is encouraged.

#### https://kryoneri.astro.noa.gr/en/flash-detection-software/

Flash Detection Software	Detection Standalone Tool
"Real-time" quick and dirty detection	Choose the operation you would like to perform
	Event Detection Event Localization
Important     Important       Important	Edit Parameters mage for Calibration (Optional) No directory chosen ange for Calibration (Optional) Modification (Optional) Modificati
Specify	Select Directory No directory chosen ROI Dimension (Optional) 30 The select Directory and position determination

Dr. D. Koschny – AMM-HO-046/1.0, 21 Sep 2023

Prof. Dr. Philipp Reiss | Lunar and Planetary Exploration Technologies | Department of Aerospace and Geodesy | Technical University of Munich

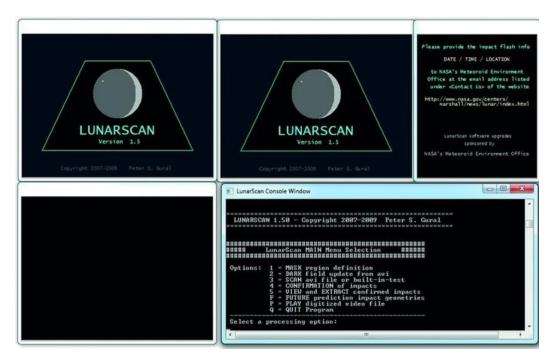
#### **LunarScan**

# ПШ

### DOS-based software to analyse video up to 720 px x 576 px

- http://www.lunarimpacts.com /lunarscan15.zip
- Note: "The software is free under the condition that you provide impact flash observations (date/time/location) to NASA's Meteoroid Environment Office at the e-mail address listed under "Contact Us" at <u>http://www.nasa.gov/centers/mars</u>

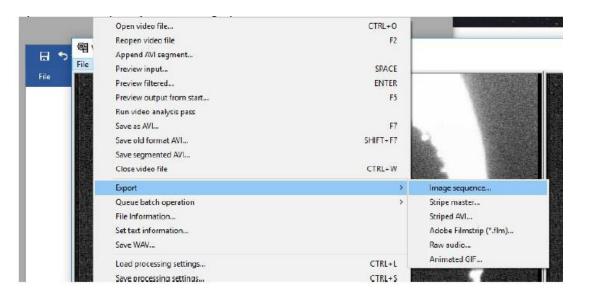
hall/news/lunar/index.html."



### ALFI



Windows software, requires data as sequence of bmp files
 https://users.aber.ac.uk/atc/alfi.htm



Prof. Dr. Philipp Reiss | Lunar and Planetary Exploration Technologies | Department of Aerospace and Geodesy | Technical University of Munich

### MIDAS

ТШТ

Windows-based
 Used by Spanish
 team

Not freely available (when I last asked)

Moon statut       Video stream         Moon data       Video stream         Moon data       Fige data         Fige data       Fige data         Fige data       Fige data	×
Moon statut         Video stream           Moon data         Video stream	
Moon dats           RA (deg 1 356.47 DEC (deg 1 405 Prese (1) 1231	
RA(deg) 356.47 DEC(deg) 405 Phase (3) 12.31	
Earth Moon distance (km) 404803.67 Events detected Total events detected	
Event identifier         Video size(Mb)         XPos         Y           O6/02/11         19:27:58         0957.6           Current fixine:         13         Total frames:         45001         Elapsed time:         0         Wideo rate Tpot3         25         Detection as           Observing station:         Observing station:         Moor cellstration:         Y         Use inage mask.         I///           Video size(Mb)         Station:         Servite         Station:         Servite         I//         I//	1996

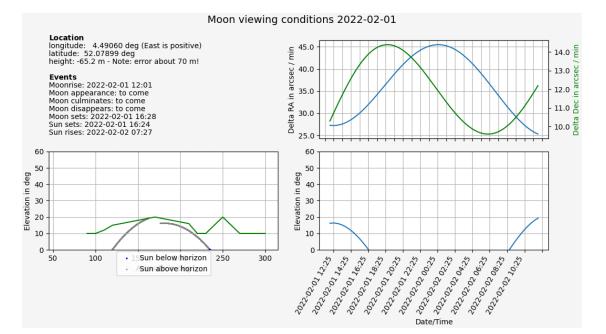
Prof. Dr. Philipp Reiss | Lunar and Planetary Exploration Technologies | Department of Aerospace and Geodesy | Technical University of Munich

# Scheduling, tracking (guiding?)

# Dark sky / away from full Moon / elevation...

# ТШ

### A (still quite draft) Python script to visualize all this is here: https://gitlab.com/dkoschny/moon



Dr. D. Koschny - AMM-HO-046/1.0, 21 Sep 2023

Prof. Dr. Philipp Reiss | Lunar and Planetary Exploration Technologies | Department of Aerospace and Geodesy | Technical University of Munich

# **Tracking or guiding**

- Software to track the Moon exists

   e.g. N.I.N.A., SkyTrack
   (https://heavenscape.com/).
- I wrote a Python script for ASCOM mounts <u>https://gitlab.com/dkoschny/moo</u> <u>n</u>
- Tracking should work for well aligned mount

40552554.86	Satellite Tracking Satellite Transits					
A 10h52m54.8s EC +10°42'24.4"	Deep Sky   Bright Stars   Double				sking	Find Dark Period
z 168°25'49.0"	JPL Ephemeris Files (Downloade	d) Download JPL	Major Bodies   Down	load by JPL ID		Start Search from 2023-07-21
T +51°29'14.1"	Name	JPLID	Date from	Date to	File	Moon Illumination
т 10:23:43	Euclid (spacecraft) Moon		Jul 21 2023 12:41 Jul 21 2023 12:41	Jul 23 2023 23:59 Jul 23 2023 23:59	2023-07-21_ 2023-07-21	Dark for 1 hr
Tracking: Custom	MOON	501	30121202312.41	Jul 23 2023 23.35	2023-07-21_	Dark for
Slewing						Search for Next Dark Period
STOP MOUNT						Sun < -18° and Moon < -8° elevation Result displays in 'Calculation Date and Time'
king						Calculation Date and Time
dereal Y Set Off	Delete Ephemeris File 🗆 Dele	rte all F	efresh Ephemeris Li	t View JPL Eph	emeris Data	<ul> <li>Now (computer time)</li> </ul>
ting Model		C:\SkyT	ackUPL\2023-07-21_JF	PL301.txt		2023-07-21 = 12:41:39
	ASCOM Custom Tracking PHE	2 Guiding with Cus	tom Rates			Set time to astronomical dusk
	F Enable custom tracking rate		Object/Mount Ser	paration (arcsecs)	29.48	
W Target Nudge	Lock current framing of e			cension (arcsecs)	-29.97	Refresh All Lists
Right Ascension	<ul> <li>enabling custom tracking</li> </ul>			ination (arcsecs)	1.33	Calculated for Jul 21 2023 @ 14:08:06.
0 h 52 m 55 s	Offset: RA 00h00m00s	Dec +00°00'00"	RA P	ate (arcsecs/sec)	-0.297609	Target Object
Declination 10 * 42 * 43 *	□ Use 'ArcSec/Sec' for Right	Ascension Rate	Dec F	ate (arcsecs/sec)	0.212858	Moon [JPL]
10 * 42 * 43 *	P Open loop tracking when se	paration <= 10	arcsecs	pen loop tracking.		Magnitude: -7.569 Size: N/A
w to Target Graph	Closed loop tracking is used	to close the delta R	A and Dec (separatio	n) between the obiec	tand	
Topocentric C J2000	mount. Some mounts will qu time RA/Dec position in whic	eue the mount posit	ion coordinates inste	ad of responding with	n a real	- J2000 RA: 10h51m42.7s
	time RA/Dec position in whic	n case open loop in	acking may produce t	etter results.		Dec: +10°49'54.6"
COM Legacy	Flauntine on Texas, Mana LIDU 1					- Topcentric RA: 10h52m56.8s
COM.Simulator.Telescop	Elevation vs Time - Moon [JPL]					Dec: +10°42'23.0"
Choose Driver ?	76' .			Dark Moonik	Below limit Moon light	- Other Designations
Continuous Tracking	60° - 45° -			Telight	Transit	Sure Designations
Disconnect Mount	w.			Sunit		
	15' -			1		Google Image Search Astrobin Search

Prof. Dr. Philipp Reiss | Lunar and Planetary Exploration Technologies | Department of Aerospace and Geodesy | Technical University of Munich

# **Magnitude calibration**

# Magnitude calibration



# Magnitude calibration





### More on magnitude calibration

- ПΠ
- NELIOTA uses photometric standard stars but also uses two cameras with different filters to derive temperatures
- Might be overkill for single camera observations. The previous example was the summer beehive cluster; in winter I would use M45, Hyades...
- A standard list for targets is not (yet) there

# Additional resources (from IMC 2023 presentation)

# (Some) ongoing activities and web resources

- Four workshops related to the topic (and others) took place, funded via EuroPlanet (EU funding), see here: <u>https://www.europlanet-society.org/europlanet-workshop-series-on-fireballs-and-their-detection/</u> presentations are available there
- The ESA-funded NELIOTA project (<u>https://neliota.astro.noa.gr</u>) has been observing impact flashes for >6 years but: funding has stopped a few months ago
- The ESA/ASI space mission LUMIO has just started science working groups one is about citizen science, lead by Tony Cook, Aberysthwith University (no official web page yet, but see e.g. <u>https://dart.polimi.it/lumio-call/</u>)
- Detection s/w (plugin for FireCapture) is available for download (<u>https://kryoneri.astro.noa.gr/en/flash-detection-software/</u> - not yet perfect, talk to me)
- A simulation tool developed by a Master's student at Univ. Oldenburg is available (<u>https://gitlab.com/dkoschny/lif\_simulation</u>)
- A 'lunar guider' is under development at TU Munich, based on a Raspberry PI, controlling the ST-4 guide port available on most telescope mounts

# (Some) other ongoing activities and web resources

ПΠ

- NASA has been operating an impact flash observing programme since many years (https://www.nasa.gov/offices/meo/environments/lunar\_detail.html)
- Additional activities within one of ESA's observational programme Spain (<u>http://www.meteoroides.net</u>), Polish-led activities in preparation
- B. Cudnik from ALPO has set up an email group here: <u>https://groups.io/g/lunar-impacts</u>
- Obs. Nice is active testing short-wave IR cameras, linking flashes to craters, more (<u>https://sitweb.obs-nice.fr/fr/home-flash</u>)
- British Astronomical Association (Anthony Cook): <u>https://britastro.org/section\_information\_/lunar-section-overview/lunar-section-obserview/lunar-section-observing-lunar-impact-flashes</u>
- Unione Astrofili Italy (Antonio Mercatali): <u>http://luna.uai.it/index.php/Lunar\_Impacts\_Research\_-\_theory\_for\_observation</u>
- ALPO, USA (Brian Cudnik): <u>https://alpo-astronomy.org/lunarupload/lunimpacts.htm</u>

Date: Name:

#### Before starting, check the following:

#### Mount is aligned

U

V

1

0

G

- Mount set such that no pier flip will be needed during the observing run
- Mount has enough battery power, or is connected to power
- Cables routed such that over the full expected recording time they don't block the tracking
- Dew protection in place
- Recording computer has enough free disk space
- Recording computer has enough battery power (or is connected to power)
- No unnecessary processes are running in the background
- Computer clock is synchronized to some time server. Time zone (UTC preferred): \_\_\_\_\_
- Telescope is aligned
- Telescope is in focus
- A recent magnitude calibration is existing

#### Configuration of this night

Camera	Make/type	Pixel size	IR-block filter on camera?	Extra filter?	Comments (e.g., cover glass removed)
Telescope	Make/type	R = Refractor, N = Newton, SC = Schmidt Cassegrain, O = other [specify]	Aperture in mm	Focal length in mm	Correctors, barlow?
Mount	Make/type		Azimuthal / equatorial	Guiding	
Software	Make/type		Version		
		1			
Recording	Frames/s	Exp. time in mg.	Gain		
Begin time (UTC)					
End time (UTC)					
Transparency		(Scale: tbd)			
Seeing		(Scale: tbd)			

Dr. D. Koschny - AMM-HO-046/1.0, 21 Sep 2023

Prof. Dr. Philipp Reiss | Lunar and Planetary Exploration Technologies | Department of Aerospace and Geodesy | Technical University of Munich

#### Lunar Impact Flash observing log

Name:

ervers)

obse

p. 26

Π

П

Λ

ίì

Sketch Moon with illuminated part, N-S and E-W orientation, and the field of the camera as seen on the monitor.

#### Record of events

Slews (note times, or say roughly how often)	
Clouds in front of Moon (note time slots, from - to)	
Other events (note times)	

+ Derived values		
Total recorded time (end – begin –		
interruptions due		
to clouds or other)		
Comments:		

# Some open points as presented by me at a Europlanet workshop in Feb 2022

# Lunar impact flashes – what needs to be done?





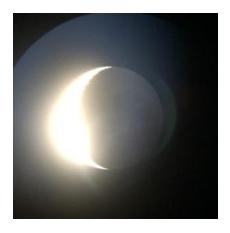
p. 28

**Issues I found when trying it myself - #02:** 

□ Settings of camera – gain, exposure time – guidelines would be useful.

Straylight

- With my setup: up to two days after 50 % illumination seems ok – with refractor even longer!
- NELIOTA stops before 50 %.
- Don't use open truss systems.
- Try "re-imaging" system, coronagraph-type optics. Proposed e.g. by Koschny (2005), Groundbased monitoring of Venus fireballs, Comp. meteor studies on terrestrial planets, 11-12 Nov 2005, Graz, Austria – and others.... – for the future



- Coma corrector introduced straylight and strange shadow effects
  - Should we use one or not? Not clear to me.

Dr. D. Roschny **Magnitude calibration must be done – needs procedure (e.g. point to open clusters)** Prof. Dr. Philipp Reiss | Lunar and Planetary Exploration Technologies | Department of Aerospace and Geodesy | Technical University of Munich



# Straylight due to corrector lens system



Post on Facebook, G. Palten: https://www.facebook.com/photo.php?fbid=6624084130958504&set=p.6624084130958504&type=3