Lunar Geminid Campaign

1. What is a LIF?
2. LUMIO
3. Why we need amateur astronomers
4. The Web Site
5. Observing Lunar Impact Flashes
6. Statistics
7. Some Results
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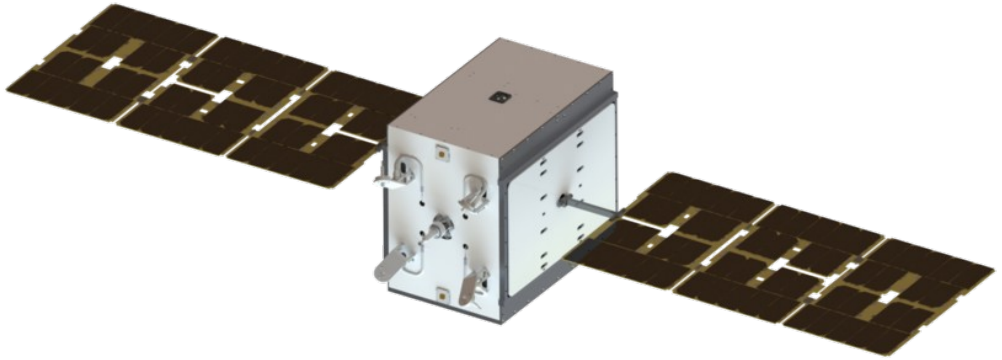
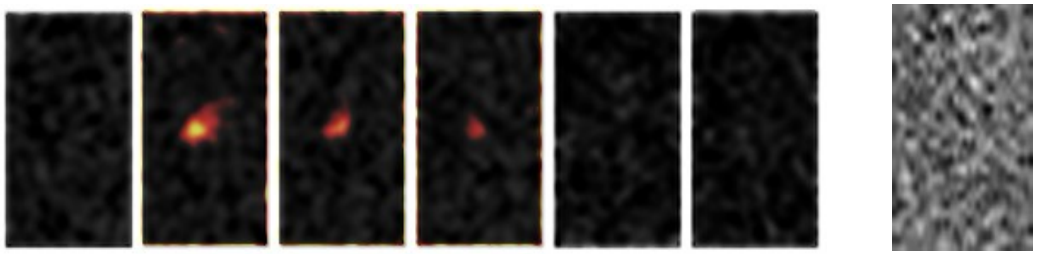


ESA image

1 What is a Lunar Impact Flash

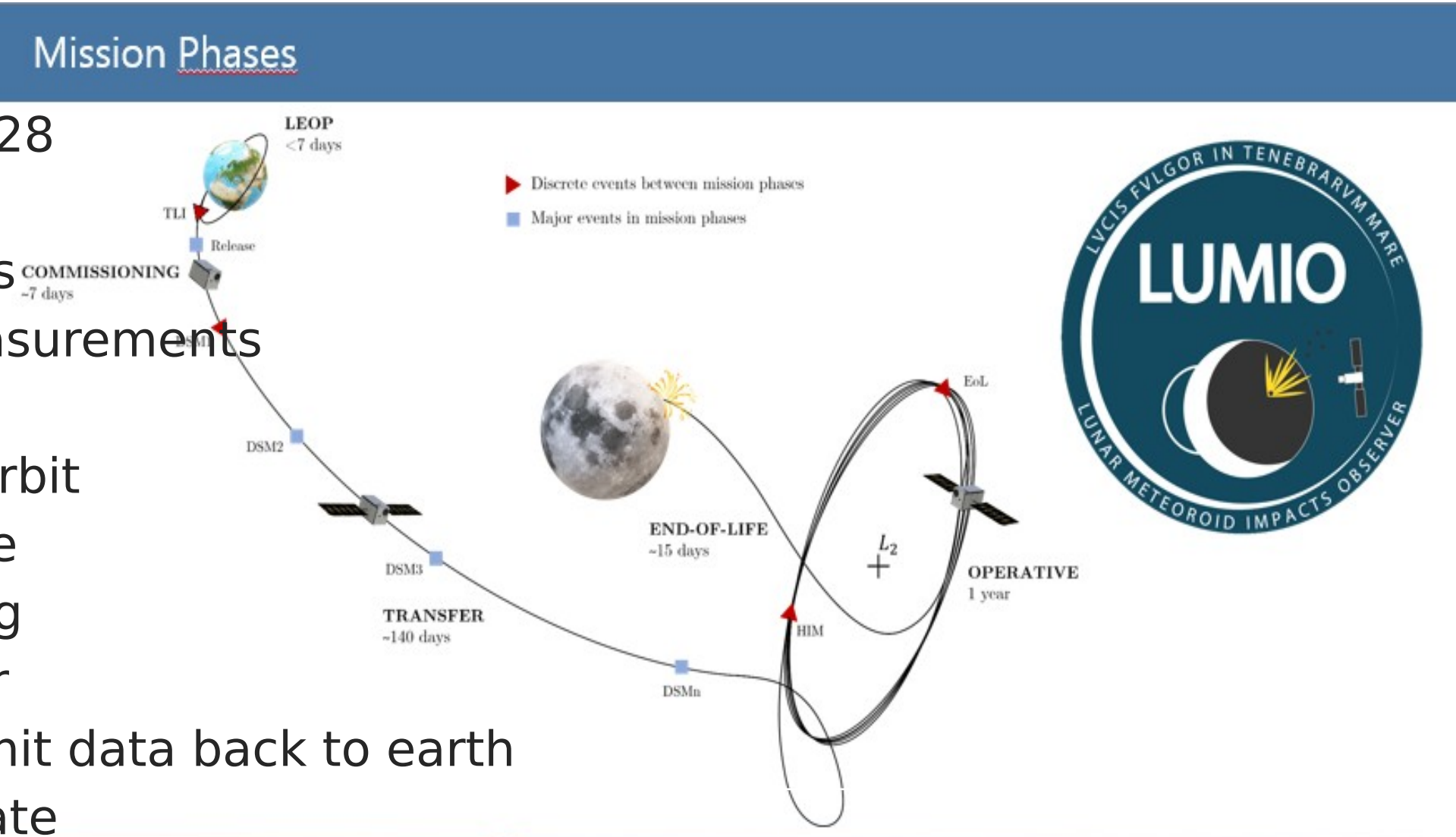


Close up of a 2017 Jan 1st UK videoed impact flash captured from Aberystwyth, UK

1. A LIF is when a meteoroid slams into the Moon
2. The energy involved is Kinetic Energy or simply K.E. = $\frac{1}{2}mv^2$
3. The energy is huge e.g. a 5 gram meteoroid travelling at 20 km/s generates 1 mega joules of K.E.
4. This excavates an instant crater
5. A fraction of a percent of the K.E. gets converted into a flash of light
6. In local vicinity on the lunar surface the flash can be of the order of the Sun's brilliance
7. This can be seen as a tiny flash of light through Earth based telescopes, typically < 0.1s duration
8. Magnitudes are typically in range +3 to +11
9. Brighter flashes are very rare – fainter ones typically one per few hours

1 The LUMIO Mission

- ESA/ASI mission
- Due to launch 2028
- CubeSat
- IR & Red Cameras
- Temperature measurements
- Duration 1y
- L2 : Lunar Halo Orbit
- Far Side Coverage
- 14 days observing
- Last to 1st quarter
- 14 days to transmit data back to earth
- Higher obs flux rate

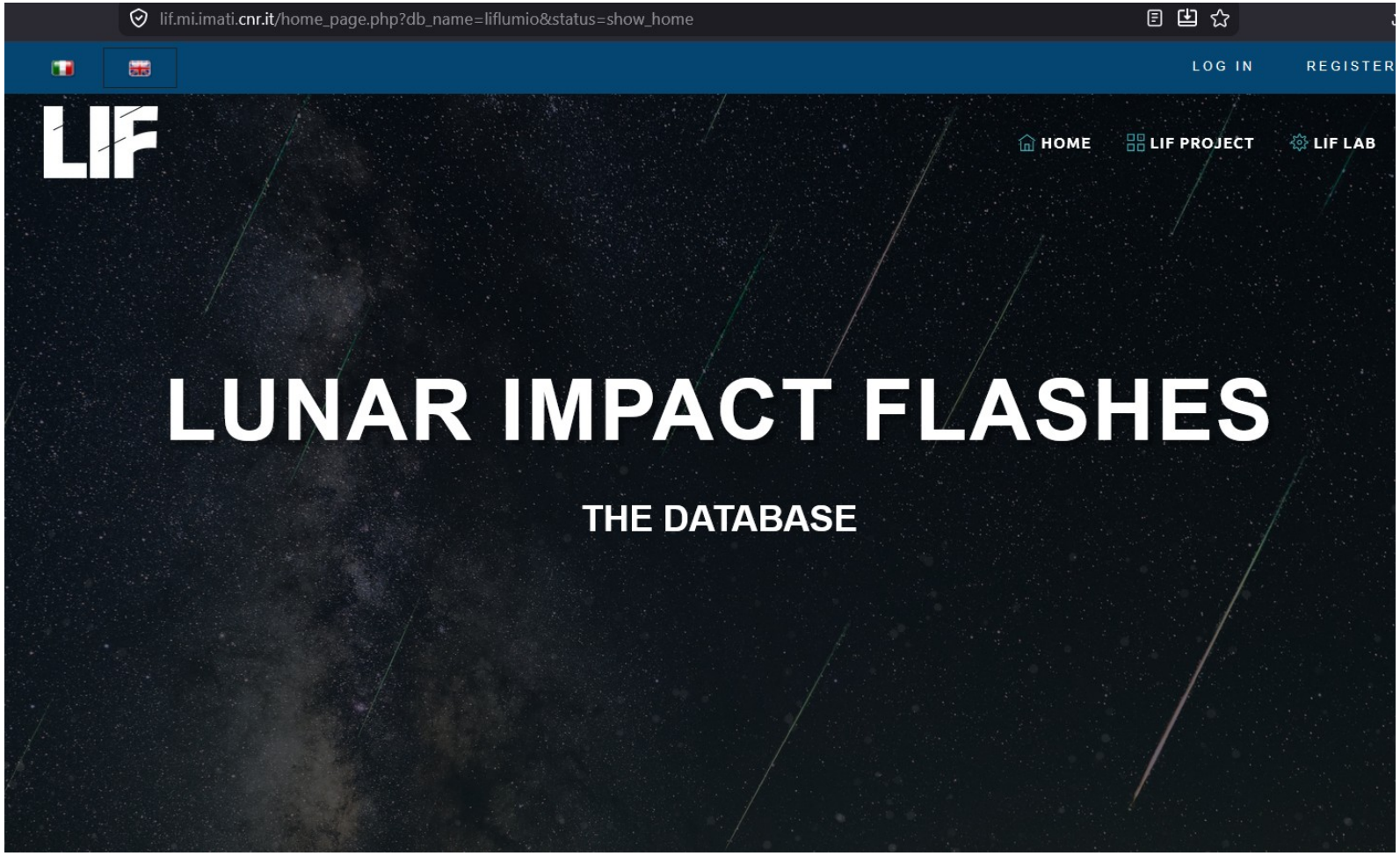


2 Why We Need Amateur Astronomers?

- Need to compare far side rates with nearside
- Maybe some overlap regions near Limb – is the absolute magnitude of the LIF the same from the two vantage points?
- A few big professionally funded telescopes observing e.g. NELIOTA (Greece), Spain, NASA Marshall Space Flight Center, TILT (France etc.) etc. – so coverage restricted
- Weather can prevent observing at these professionally dedicated sites
- Professionals can only observe when funded
- Seeing conditions can interfere with light curves at professional sites – amateurs can confirm/refute unusual details seen in light curves
- Amateurs can experiment with new techniques/filters e.g. LWIR cameras, low res diffraction gratings, Na filters etc.

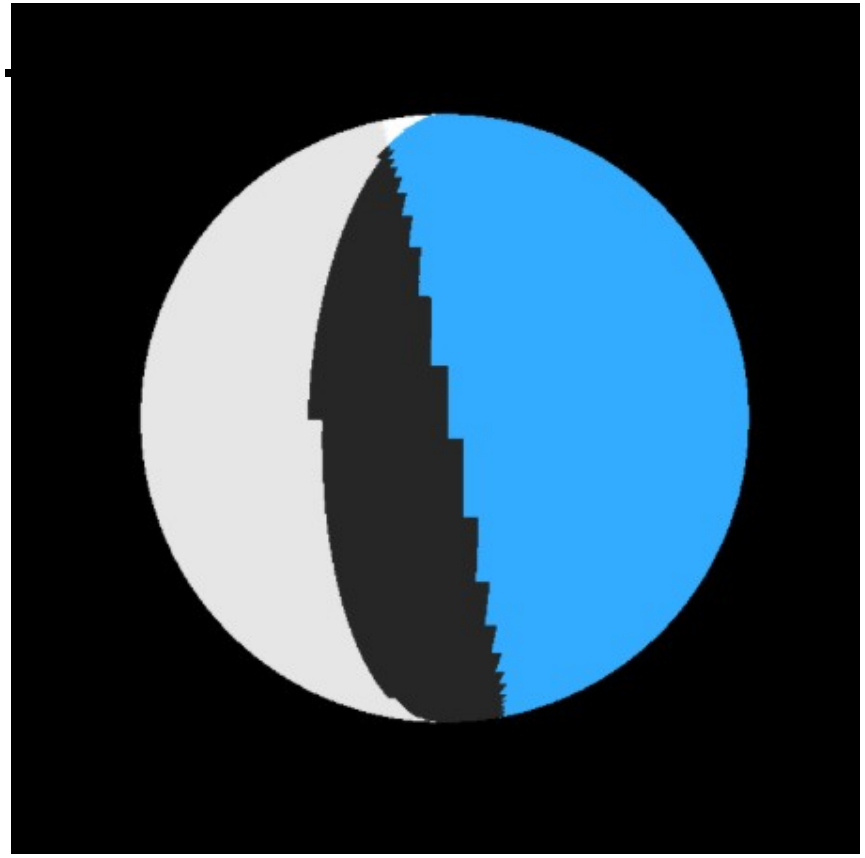
3 The Web Site

- An observing campaign web site was been set up:
- You can register on: https://lif.mi.imati.cnr.it
- You can upload your observations to this
- All raw observations submitted are available for anybody who has registered on the site.
- Another impact flash campaign site has been/is set up by the NELIOTA observatory team: https://neliota.astro.noa.gr/



4 Observing Lunar Impact Flashes -

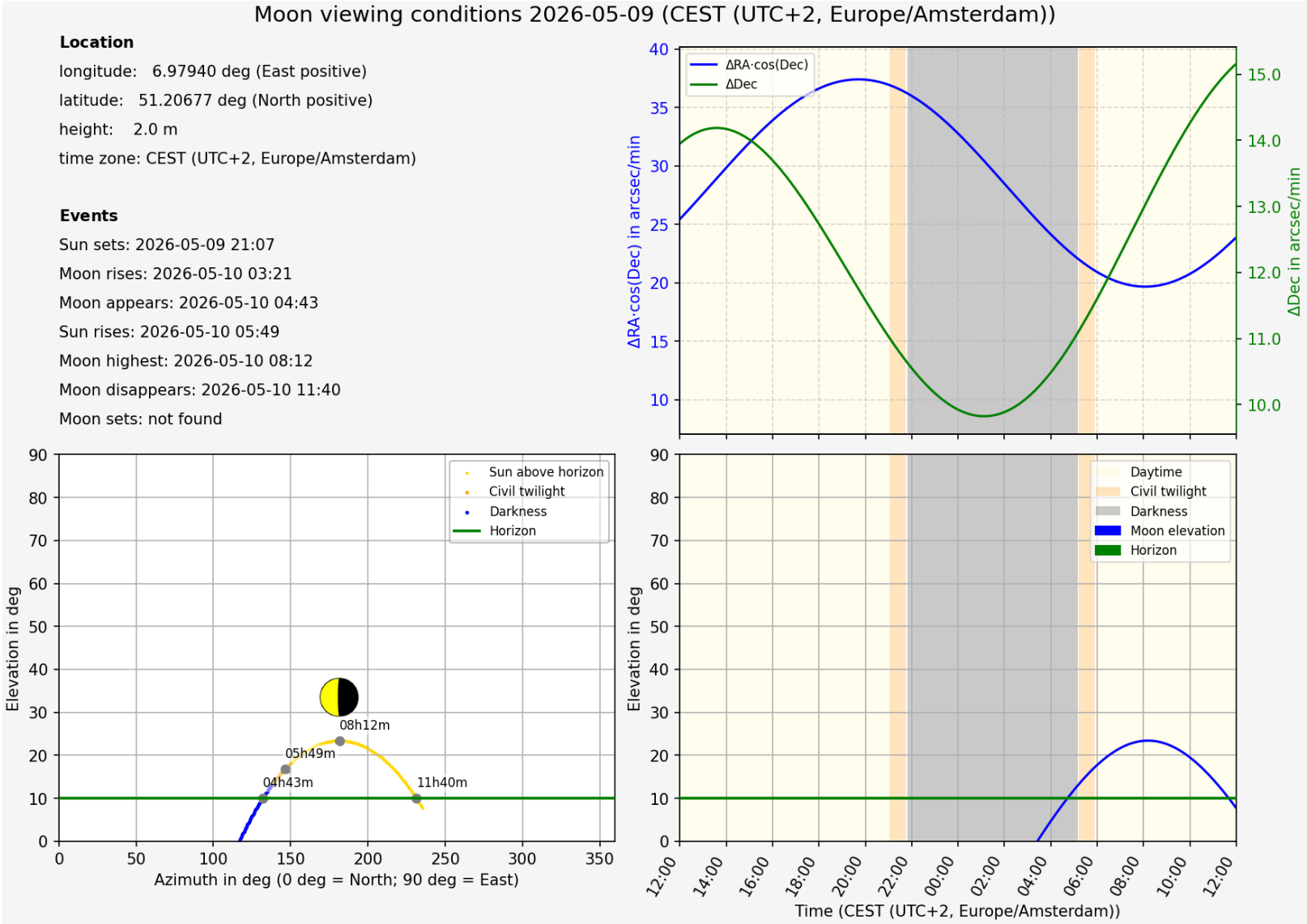
- Scopes and monochrome cameras capable of attaining mag 9 -11 stars in real time at 15fps or faster
- Use monochrome camera with no filter
- Have as large FOV as possible
- Cover as much earthshine as possible
- Keep sunlit areas out of FOV if possible
- Occasionally calibrate/video on nearby stars in M45
- Advised to do multiple recording of just a few min in case computer crashes – to avoid major loss of observational data
- Important to note start and end UTC or have an embedded clock in the video
- Suggested observing dates/UTCs on: https://users.aber.ac.uk/atc/lunar_schedule.htm



Geminid 2025 lunar distribution against the Moon- from Detlef Koschny's Software see: https://www.asg.ed.tum.de/lpe/forschung/mondeinschlagsblitze/meteoroid-stream-geometry/

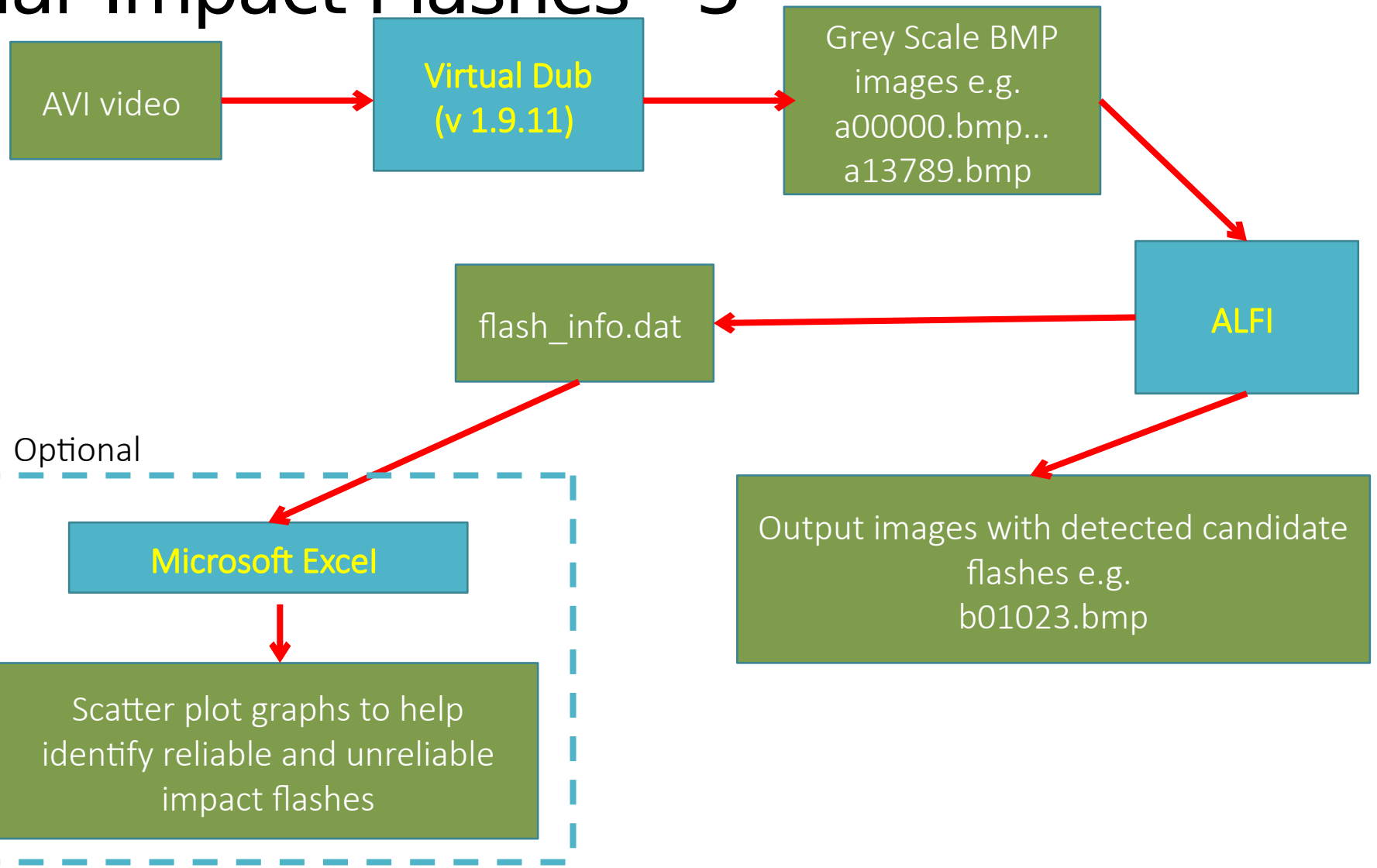
4 Observing Lunar Impact Flashes - 2

- One of the worst things that can happen is to get up early in the morning to find that the Moon is blocked by a tree or its already twilight.
- The following tool was designed to help observers plan ahead: https://moon-planner.koschny.eu



4 Observing Lunar Impact Flashes - 3

- After observing, amateur astronomers were invited to put their videos (AVI) into ALFI software to do the detections
- Alternatively, to use Lunarscan and FDS
- ALFI is clunky but is the most robust out of the software available



4 Observing Lunar Impact Flashes - 4

- This is the interface for ALFI
- Most people used default settings
- If you had a time clock present in the video it's important to increase the border mask region to cover this up
- Most detections were due to noise or cosmic rays or scintillating sunlit peaks
- Some people wrote their own algorithms
- No one LIF detection software is perfect !

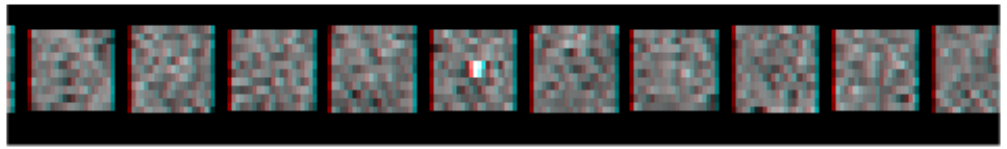
```
****************
*** A L F I ***
****************

NS=640 NL=480


 Current Detection Parameters:
(1) Multiple flashes No. (lower limit): 1
(2) Multiple flash No. (upper limit): 5
(3) Multiple flash separation standard deviation threshold: 20.000000
(4) No. of s.d. above neighbour pixels threshold: 3.000000
(5) No. of s.d. in time domain threshold: 5.000000
(6) Minimum s.d. 1 threshold: 4.000000
(7) Minimum s.d. 2 threshold: 4.000000
(8) Left Border (Pixels): 10
(9) Right Border (Pixels): 10
(10) Top Border (Pixels): 10
(11) Bottom Border (Pixels): 10
(12) Peak Killer Threshold: 0.000000
(13) De-interlace: Odd then Even
(14) No. of Images in Buffer: 60
(15) Load/Save Settings
(16) Information About ALFI
If OK press 0, else select a parameter between 1 and 16:
```

5 Statistics - Geminids

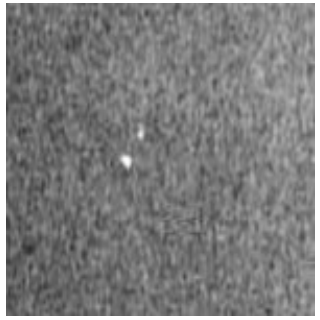
- 27 observers participated
- ~60h of earthshine observations made
- ~10h of this were overlapping observations
- **N.B.** Once we had people's candidate LIF dates and UTCs we emailed people to check manually to help eliminate false detections from cosmic rays, noise, Mt peaks, sun glint from satellites etc.
- 17 Confirmed LIFs were detected between 13th and 14th Dec
- This approximates to 1 Geminid every 35 min
- Mostly European observers but we had others in China, Australia, USA, Canada, New Zealand etc.

6 Example Results – Fake LIF Detections

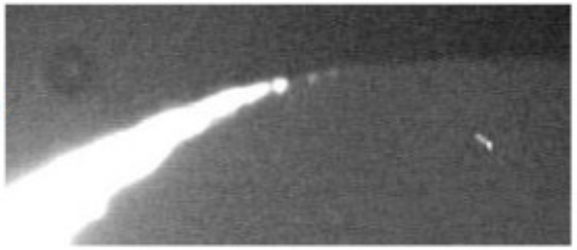
Here are some flashes that can trick Lunarscan / ALFI / FDS:

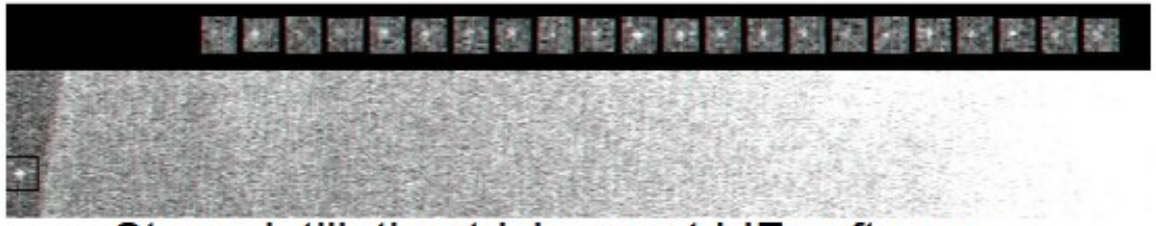


Cosmic ray – a single blip and not seeing blurred as a real flash or star would be



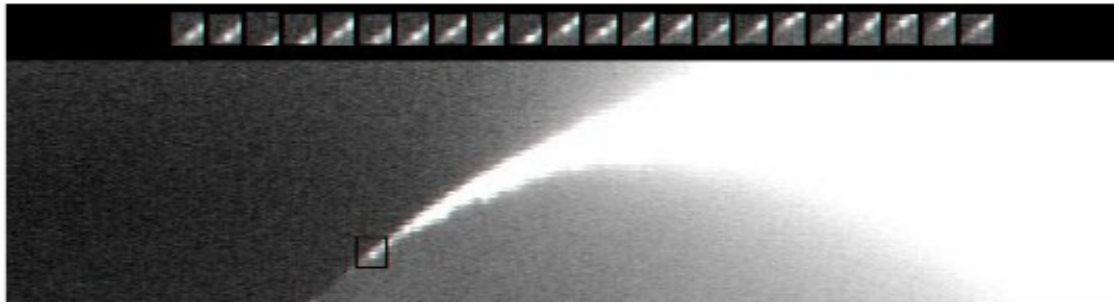
Cosmic rays are sometimes two or more blips in the image or even a streak



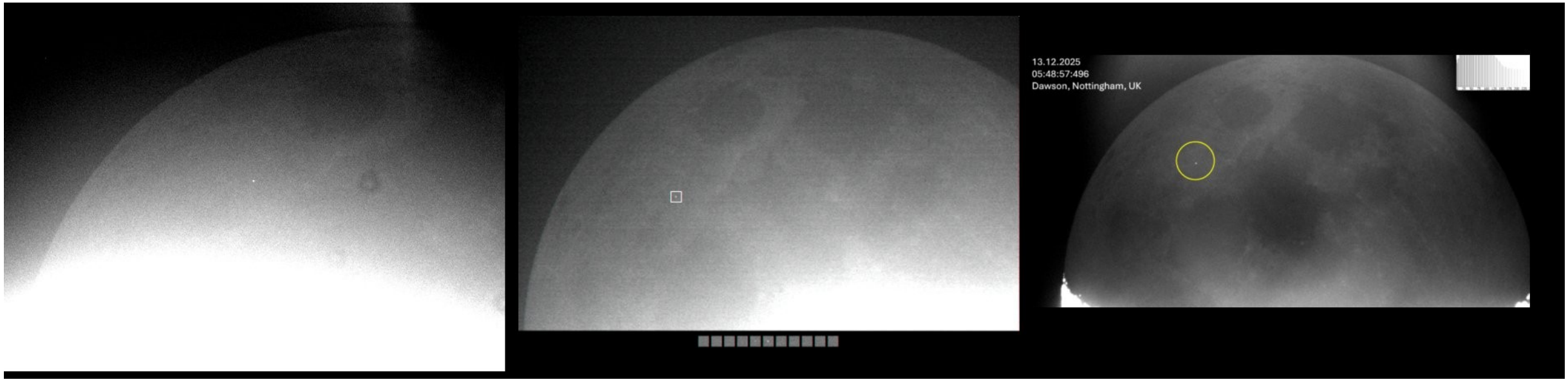


Star scintillation tricks most LIF software

So do sunlit peaks

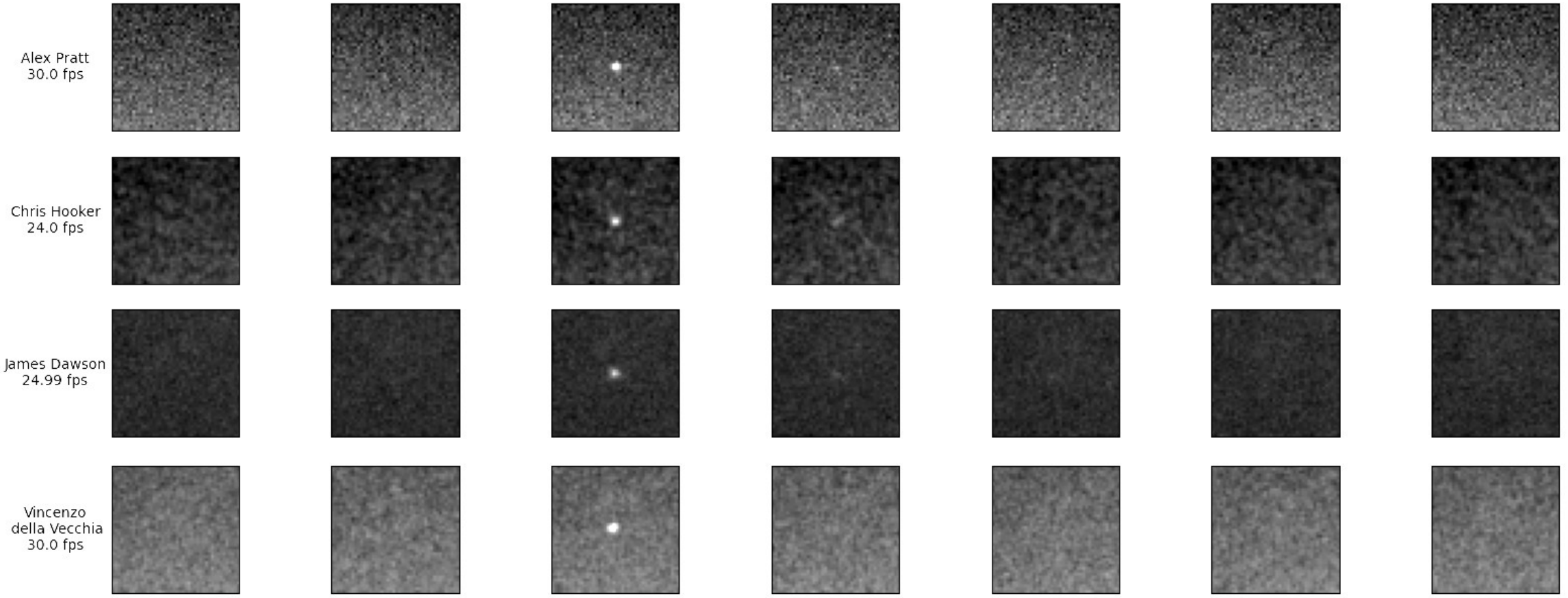


6 Example Results – Real Confirmed LIFs – from Geminid Campaign



The 2025 Dec 13 UTC 05:48:56 Lunar Impact Flash as imaged by (Left) Alex Pratt, (Centre) Chris Hooker, (Right) James Dawson. This event was seen by 5 observers (see next slide)

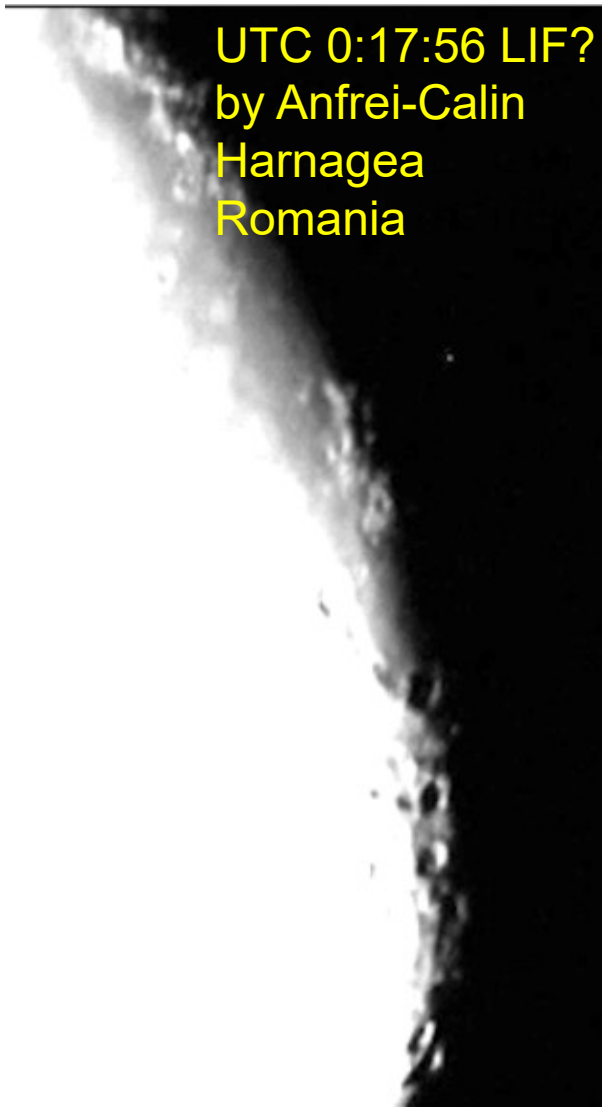
6 Example Results – Real Confirmed LIFs – from Geminid Campaign

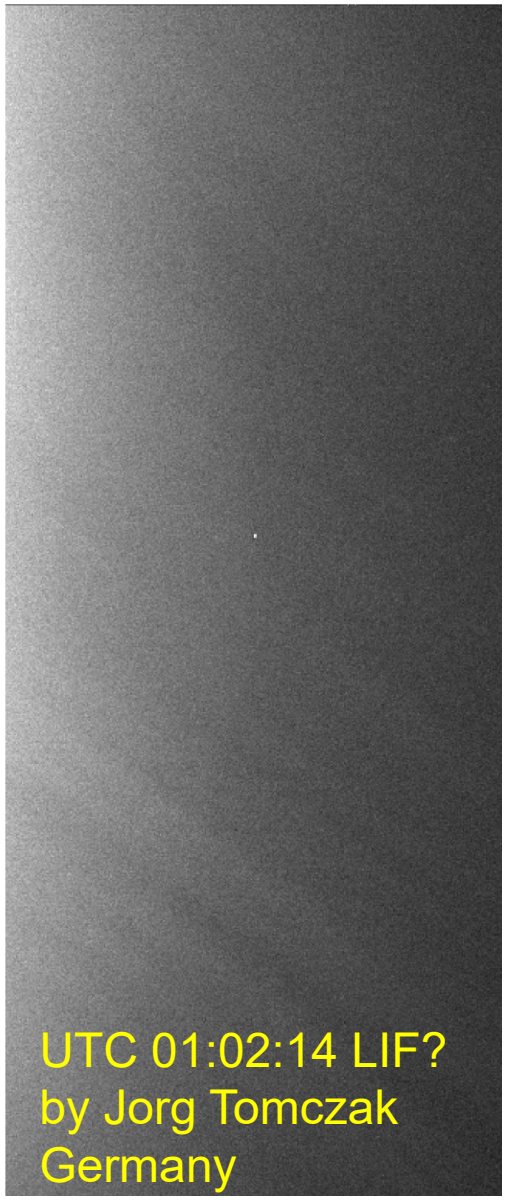


Close up of the 2025 Dec 13 UTC 05:48:56 Lunar Impact Flash seen by 4 different observers– note frame rates differ slightly. 5th observer results not shown here as they have gone into a MNRAS publication submission by Dr Daniel Sheward

6 Example Results – Candidate LIFs – from Artemis II campaign

- During the Artemis II flyby of the lunar far side (at 6745 km closest) Earth based observers looked for LIFs in the near and far side/night overlap region
- Observers from France, Italy, UK, Romania, Germany, Poland contributed
- Artemis II astronauts reported flashes seen on the far side & night area of the Moon
- Our campaign resulted in 2 candidate LIFS
- We won't learn about how many, or when the crew saw, flashes until a NASA science meeting in Oct





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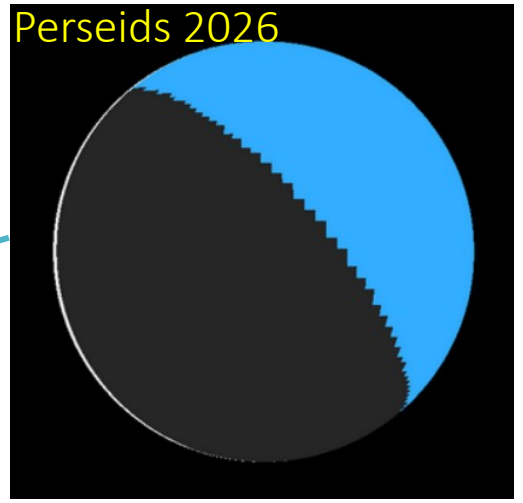
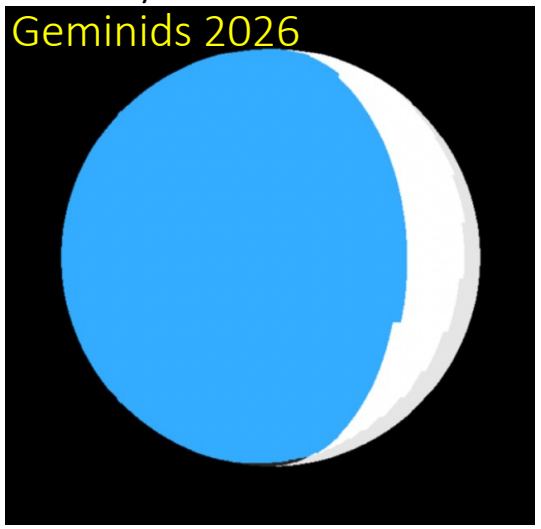
7 Future Campaigns

1. Space X Falcon 9 Rocket due to crash into NW limb of Moon 2026 Aug 05 UTC 06:44
   - This is not a conventional LIF and if anything seen it might just be a dust cloud over the NW limb, near Einstein crater – its daylight in Europe at that time
2. Solar Eclipse 2026 Aug 12 - during Perseid shower:
   - We don't plan a campaign & people should enjoy the eclipse, but as the eclipse path is 2h long (each observer sees though just approx. 2 min) – there is a good chance an impact flash(es) will be recorded somewhere along the eclipse path
3. Almost Total Eclipse of Moon on 2026 Aug 28 UTC 02:34-max(04:13)-05:52
   - Alas there is no major shower on
   - Moon sets during eclipse from Europe
4. Geminids at a more social hour (evening) 2026 Dec 12-15 Max 14th 09 to 14h UTC ZHR=120



Above & Below from Detlef Koschny's Software



Link to the software can be found here::
https://www.asg.ed.tum.de/lpe/forschung/mondeinschlagsblitze/meteoroid-stream-geometry/

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