The NEO Lunar Impact Monitoring Project NELIOTA*

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National Observatory of Athens

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ESA Contract No. 4000112943/14/NL/JD, 2/2015 to 11/2018, 700K euros

*<u>NE</u>O <u>L</u>unar <u>I</u>mpacts and <u>O</u>ptical <u>T</u>r<u>A</u>nsients

NELIOTA lunar impact project

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neliota

NELIOTA lunar impact project

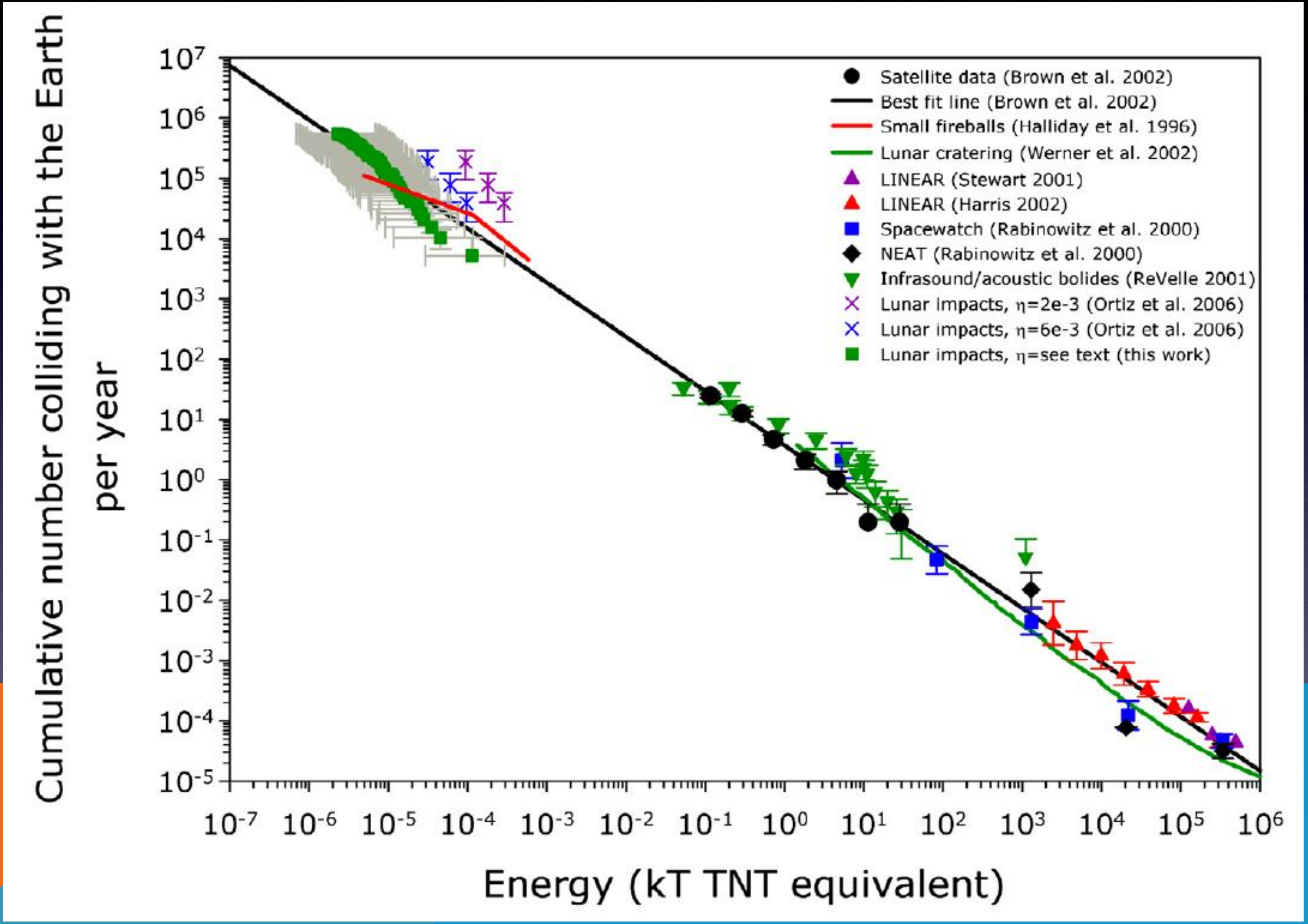
Objective: Determine frequency and distribution of small near-earth objects (NEOs) via lunar monitoring.

Develop a highly automated lunar monitoring system using NOA's 1.2m Kryoneri telescope, and conduct an observing campaign for 2 years. Impact flashes will be available online:

https://neliota.astro.noa.gr/

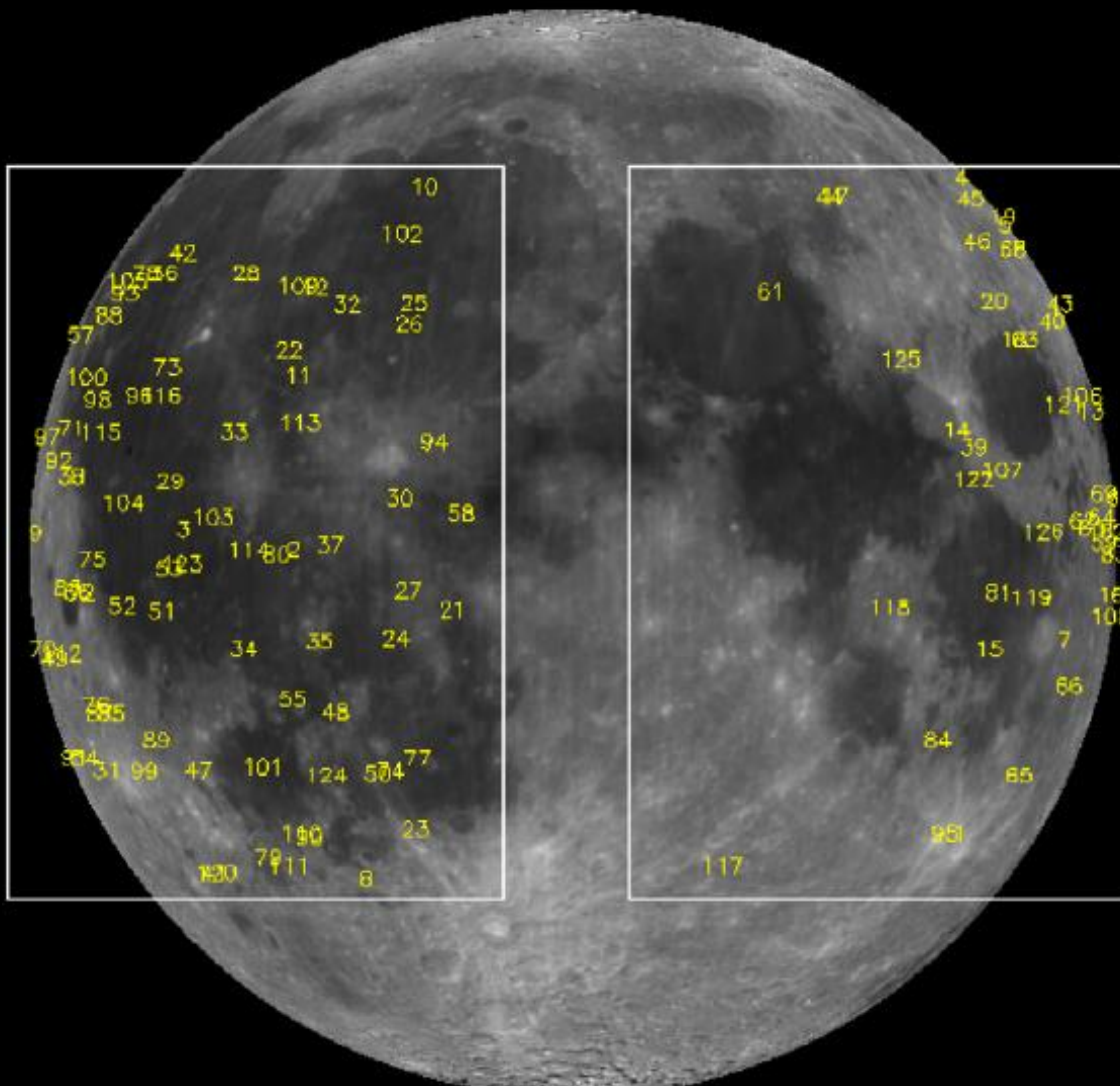
neliota

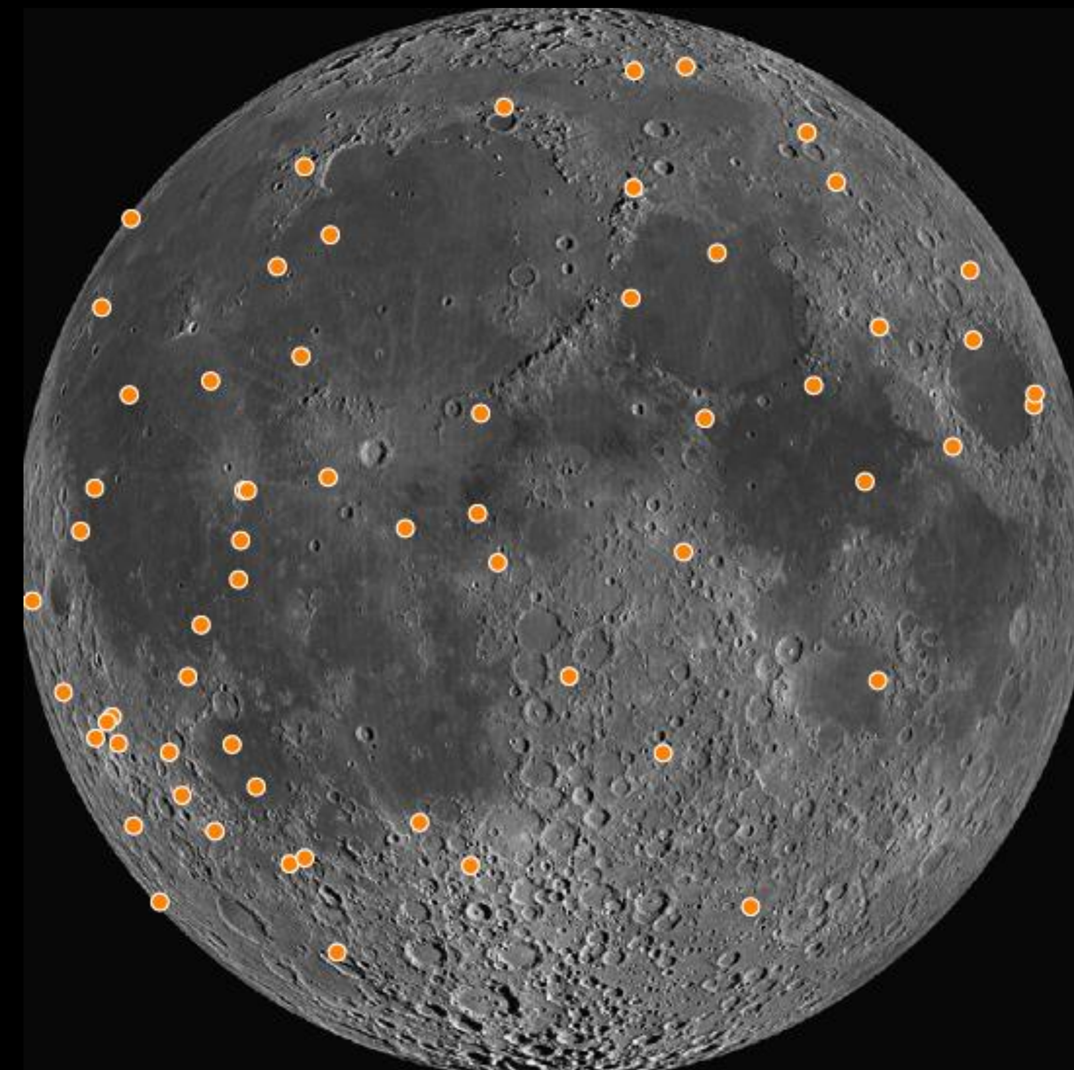
Motivation



Suggs et al. (2014)

Other Lunar monitoring projects





NASA Marshall Center - USA
(Suggs et al. 2014)

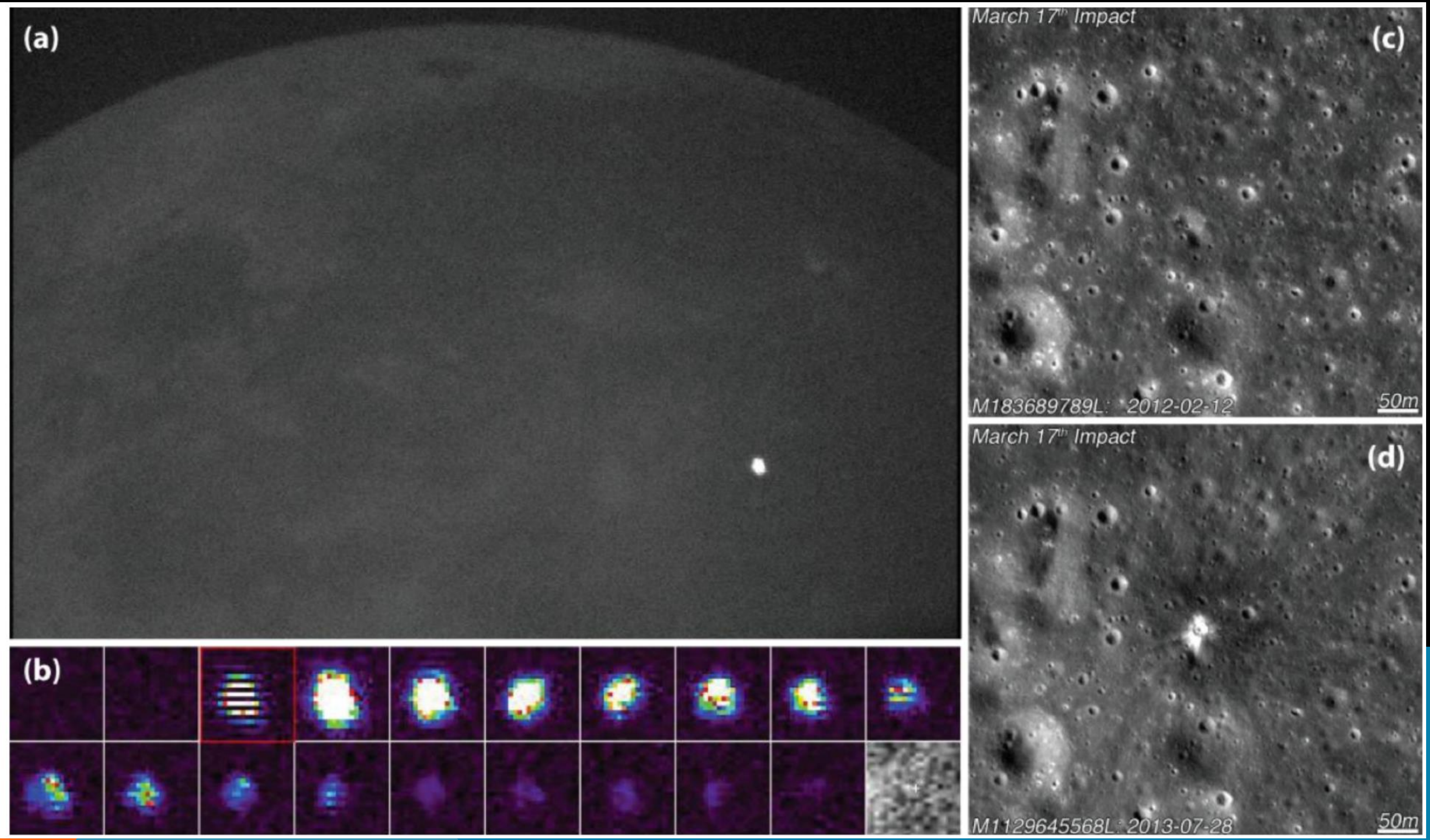
New Mexico State - USA
(Rembold & Ryan 2015)

MIDAS Project - Spain
(Madiedo et al. 2014, 2015)

ILIAD Network - Morocco
(Ait Mouley Larbi et al. 2015)

Lunar Impact of March 17, 2013

(R= 3.0 ± 0.4 mag, ~1 sec, 16 kg)

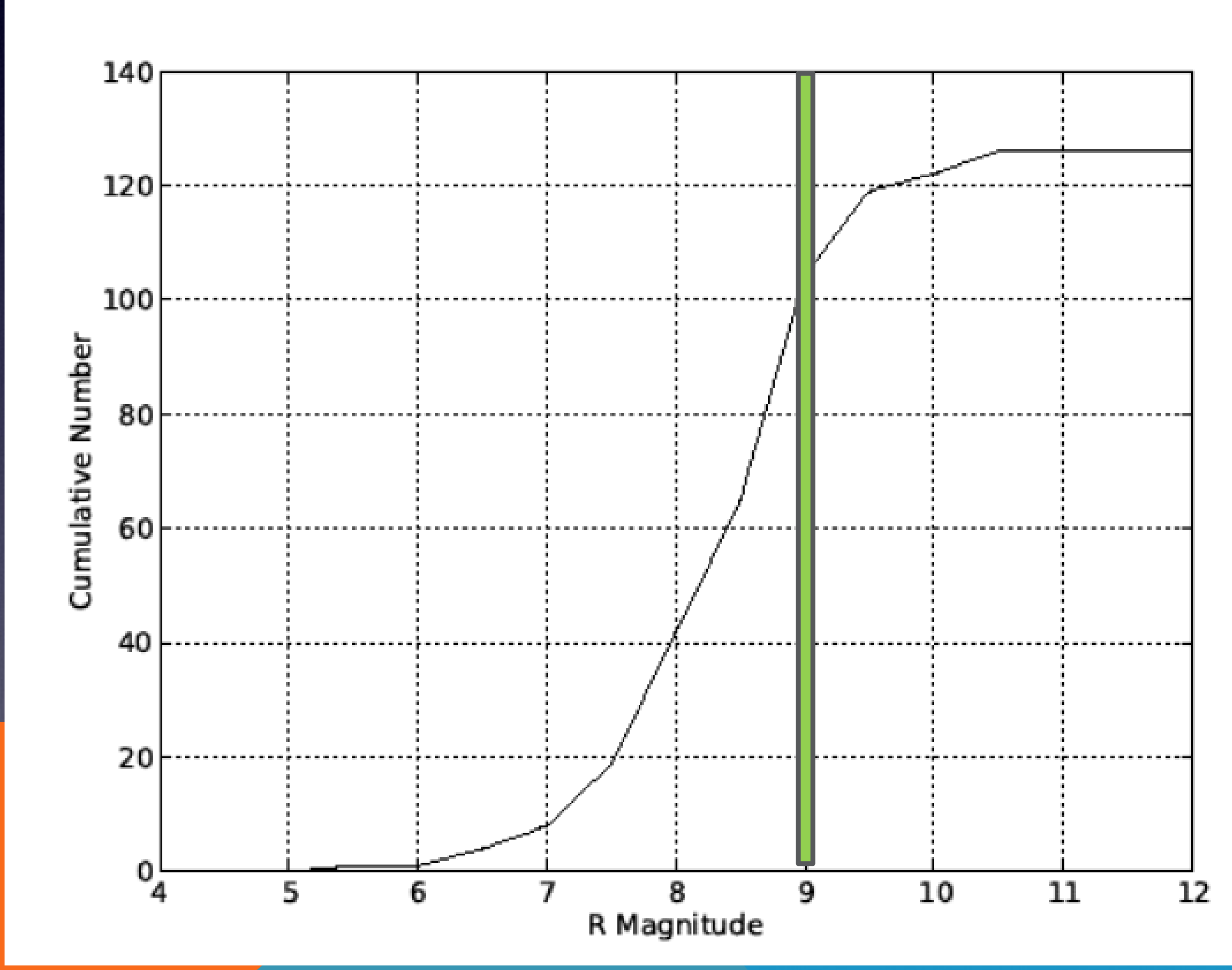


Suggs et al. (2014)

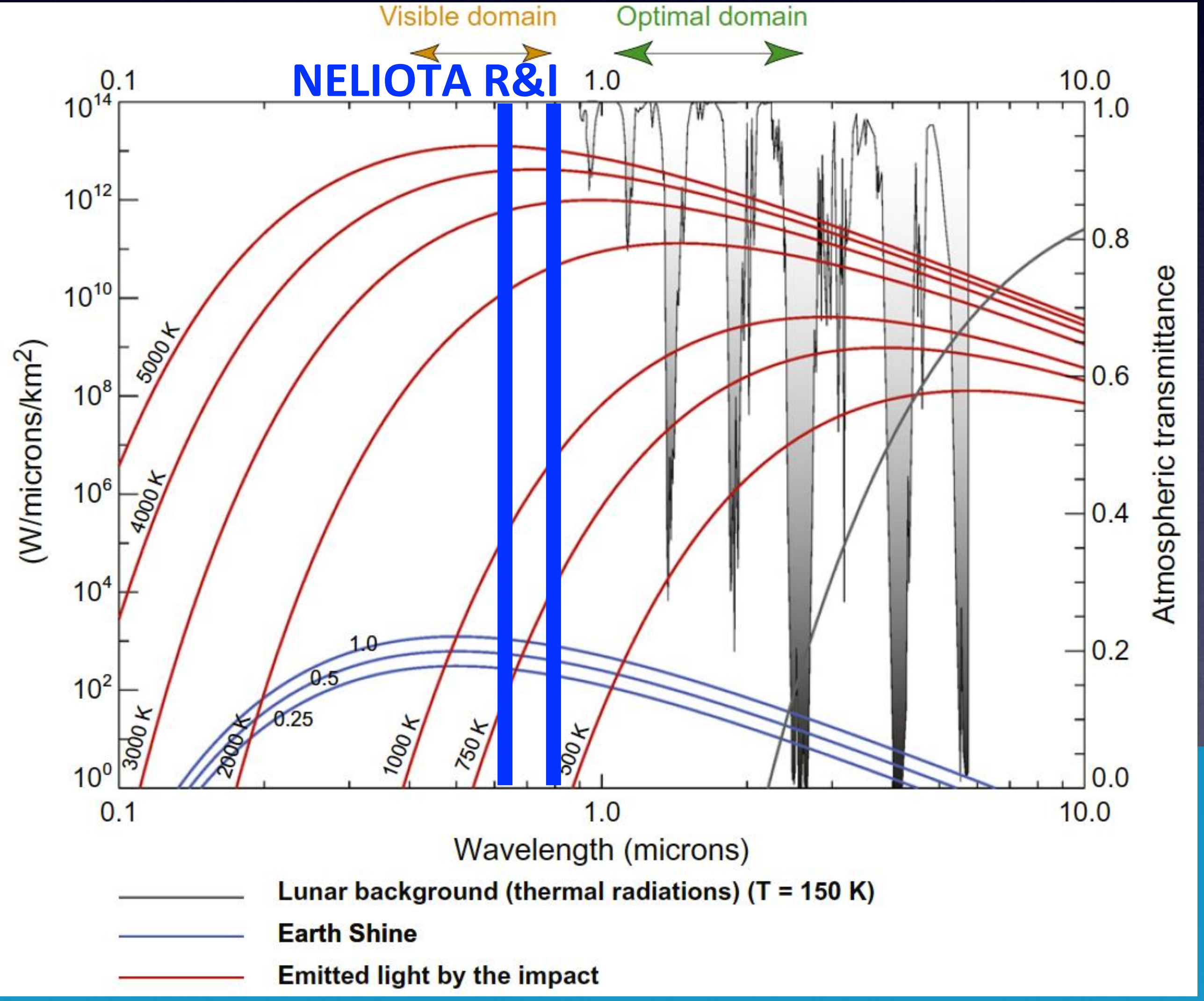
New crater observed by the Lunar Reconnaissance Orbiter

NELIOTA Scope & Objective

- Detect faint impact flashes of small NEOs beyond the current completeness level of ~9 mag.
- Calculate the temperatures of the impacts



Suggs et al. (2014)



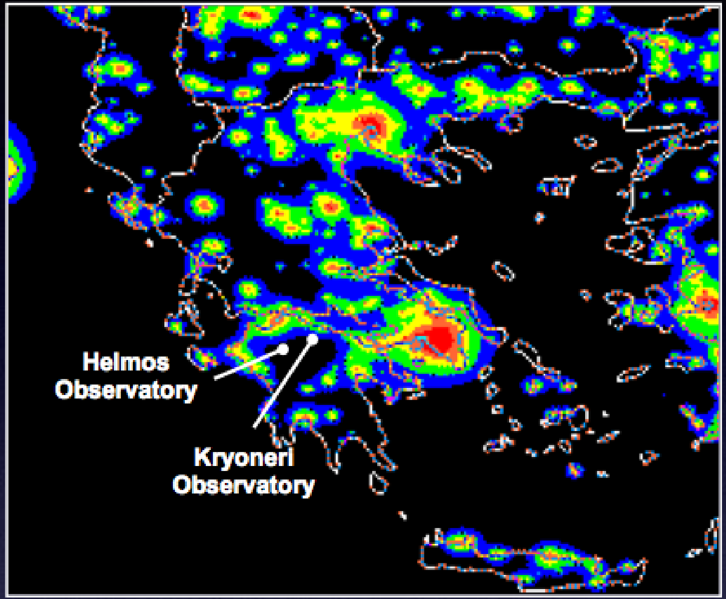
Bouley et al. (2012)

Flash no.	Date (UT)	Time (UT)	Solar long (°)	N	Lunar lat (°)	Lunar long (°)	Air mas	Peak R mag	eak lum. energy (J)
1	16 September 2006	09:52:54	173.3082	2	−32.0	57.0	1.40	8.5 ± 0.2	2.14×10^4
2	28 September 2006	00:42:57	184.6750	2	−0.5	−30.8	4.00	8.1 ± 0.4	3.14×10^4
3	29 October 2006	01:18:43	215.3898	2	1.7	−45.7	2.61	7.6 ± 0.3	4.98×10^4
4	17 November 2006	10:46:26	234.8499	2	42.6	76.7	3.38	8.9 ± 0.3	1.56×10^4
5	17 November 2006	10:56:33	234.8570	2	36.1	80.3	3.04	7.0 ± 0.3	8.58×10^4
6	17 November 2006	11:02:29	234.8611	2	5.0	85.5	2.91	7.6 ± 0.3	5.17×10^4
7	17 November 2006	11:09:10	234.8658	2	−10.0	66.8	2.75	8.6 ± 0.3	1.93×10^4
8	24 November 2006	23:58:12	242.4758	2	−37.8	−28.7	3.40	7.8 ± 0.3	4.11×10^4
9	25 November 2006	00:55:54	242.5163	2	1.3	−80.8	6.18	7.9 ± 0.5	3.78×10^4
10	26 November 2006	00:59:16	243.5303	2	41.3	−21.2	3.05	7.5 ± 0.3	5.67×10^4
85	03 December 2008	00:30:58	251.0915	3	−18.0	−63.0	2.47	10.1 ± 0.3	5.08×10^3
86	03 December 2008	02:09:04	251.1606	2	−4.5	−68.5	6.45	7.9 ± 0.6	3.68×10^4
87	01 February 2009	01:40:26	312.2038	3	−18.0	−66.0	1.71	9.4 ± 0.2	9.67×10^3
88	01 February 2009	02:04:46	312.2210	3	25.0	−70.0	1.94	8.9 ± 0.3	1.49×10^4
89	02 February 2009	02:45:43	313.2647	3	−21.0	−55.0	1.73	8.8 ± 0.2	1.62×10^4
90	03 March 2009	02:51:43	342.5371	3	−32.5	−35.0	1.77	9.2 ± 0.2	1.09×10^4

Flash no.	Shower ID	V (km/s)	$\eta = 5 \times 10^{-4}$		$\eta = 1.5 \times 10^{-3} \exp(-9.3^2/V^2)$				$\eta = 5 \times 10^{-3}$	
			Kinetic energy (J)	Mass (g)	η (V)	Kinetic energy (J)	Mass (g)	Imp.diam.(cm)	inetic energy (J)	Mass (g)
1		24.00	4.27×10^7	148.3	1.29×10^{-3}	1.65×10^7	57.5	4.79	4.27×10^6	14.8
2	STA	27.71	6.29×10^7	163.8	1.34×10^{-3}	2.35×10^7	61.1	4.89	6.29×10^6	16.4
3	ORI	66.66	9.97×10^7	44.9	1.47×10^{-3}	3.39×10^7	15.3	3.08	9.97×10^6	4.5
4	LEO	69.95	3.12×10^7	12.8	1.47×10^{-3}	1.06×10^7	4.3	2.02	3.12×10^6	1.3
5	LEO	69.94	1.72×10^8	70.2	1.47×10^{-3}	5.82×10^7	23.8	3.57	1.72×10^7	7.0
6	LEO	69.94	1.03×10^8	42.3	1.47×10^{-3}	3.51×10^7	14.3	3.01	1.03×10^7	4.2
7	LEO	69.94	3.86×10^7	15.8	1.47×10^{-3}	1.31×10^7	5.4	2.17	3.86×10^6	1.6
8	NTA	29.91	8.22×10^7	183.7	1.36×10^{-3}	3.02×10^7	67.4	5.05	8.22×10^6	18.4
9	NTA	29.92	7.56×10^7	168.9	1.36×10^{-3}	2.78×10^7	62.0	4.91	7.56×10^6	16.9
10		24.00	1.13×10^8	393.8	1.29×10^{-3}	4.39×10^7	152.5	6.63	1.13×10^7	39.4
85	MON	42.98	1.02×10^7	11.0	1.43×10^{-3}	3.55×10^6	3.8	1.94	1.02×10^6	1.1
86	MON	42.99	7.36×10^7	79.6	1.43×10^{-3}	2.57×10^7	27.8	3.76	7.36×10^6	8.0
87		24.00	1.93×10^7	67.2	1.29×10^{-3}	7.49×10^6	26.0	3.68	1.93×10^6	6.7
88		24.00	2.98×10^7	103.6	1.29×10^{-3}	1.16×10^7	40.1	4.25	2.98×10^6	10.4
89		24.00	3.24×10^7	112.5	1.29×10^{-3}	1.26×10^7	43.6	4.37	3.24×10^6	11.3
90		24.00	2.18×10^7	75.7	1.29×10^{-3}	8.45×10^6	29.3	3.83	2.18×10^6	7.6

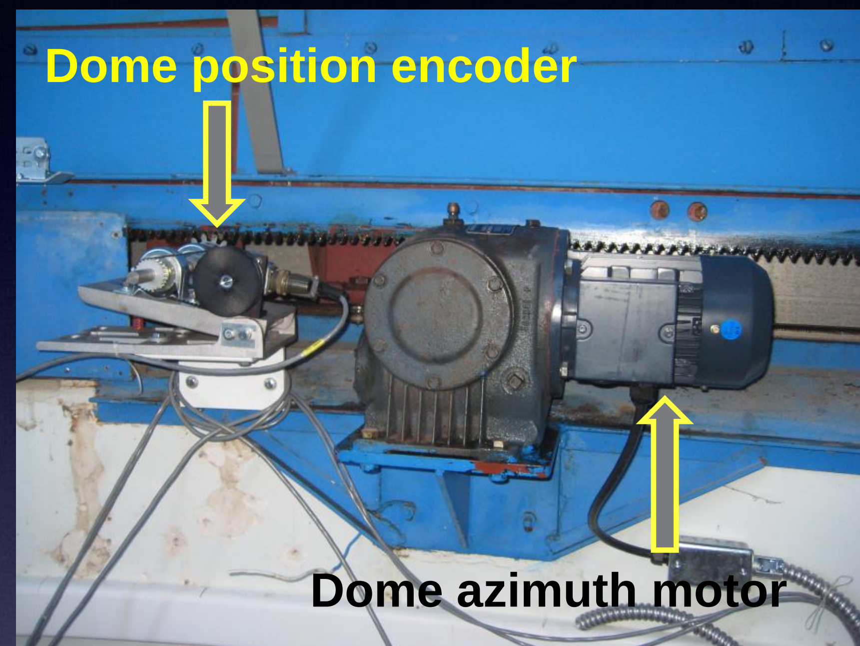
NELIOTA: 1.2m Kryoneri telescope

- 1.2m Cassegrain reflector at Kryoneri Observatory (930 m altitude)
- 1975: Grubb Parsons, Co., Newcastle



NELIOTA: 1.2m Kryoneri telescope

- Telescope upgraded (2016) by DFM Engineering

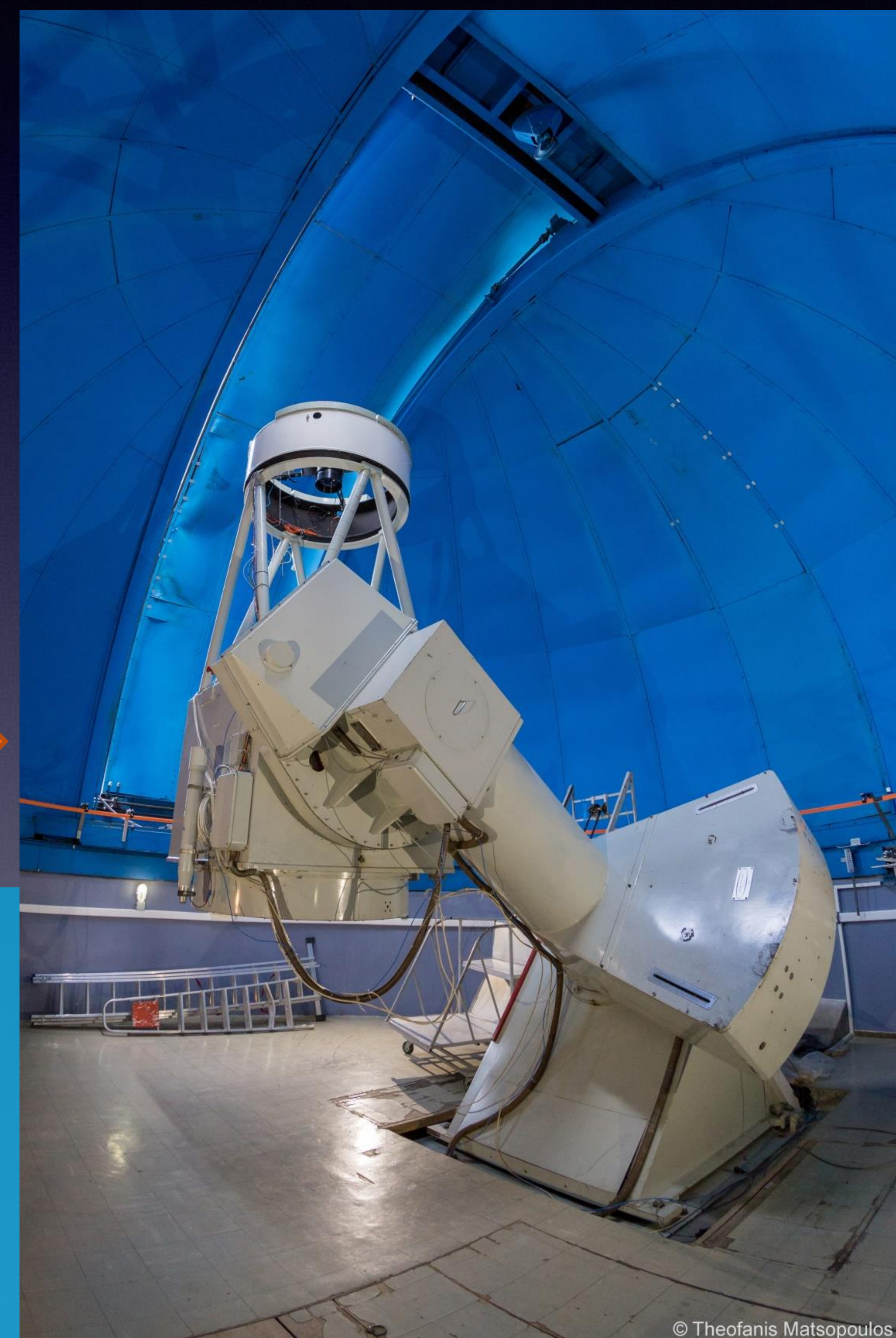


NELIOTA: 1.2m Kryoneri telescope

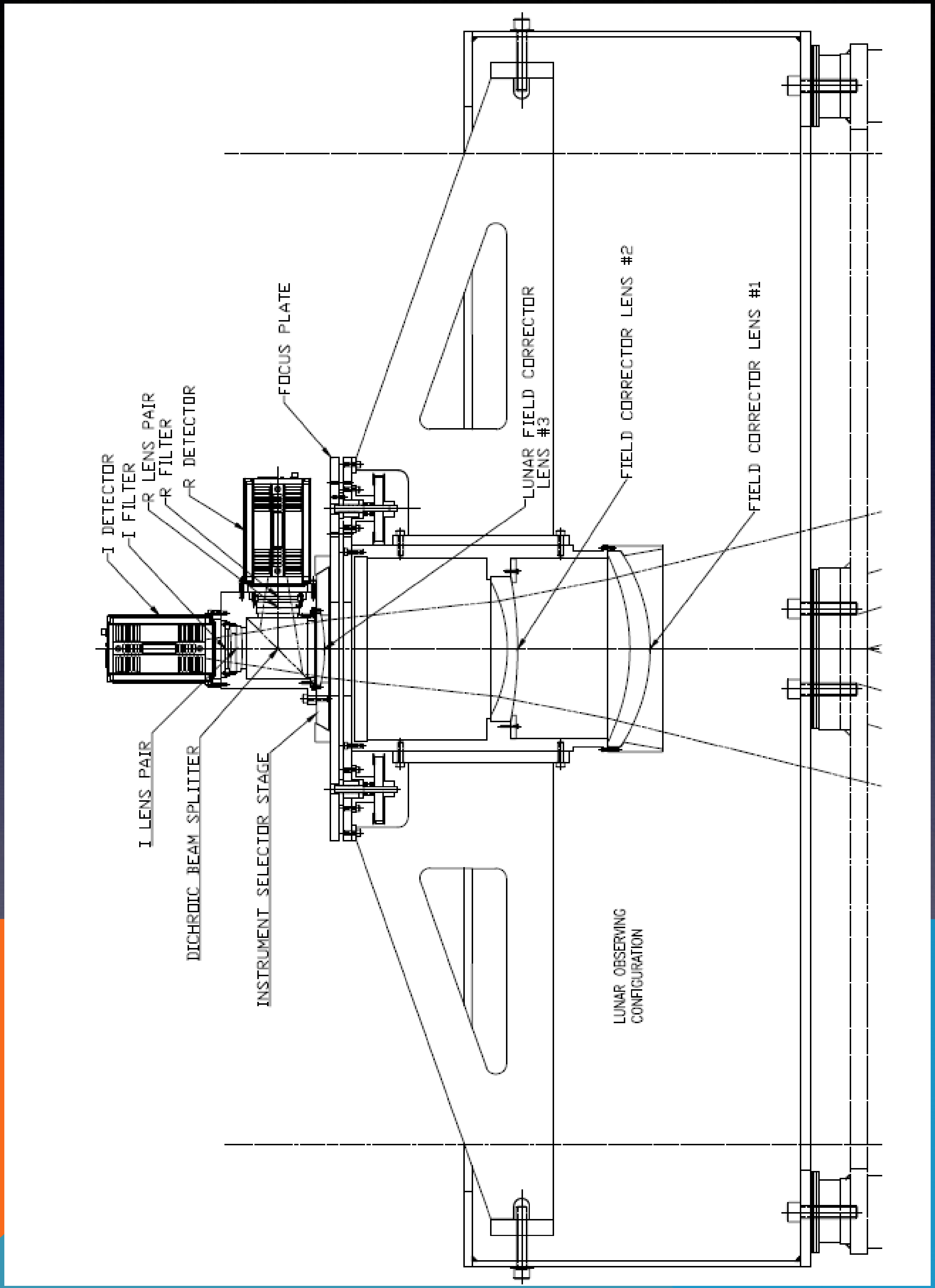
- Telescope upgraded (2016) by DFM Engineering

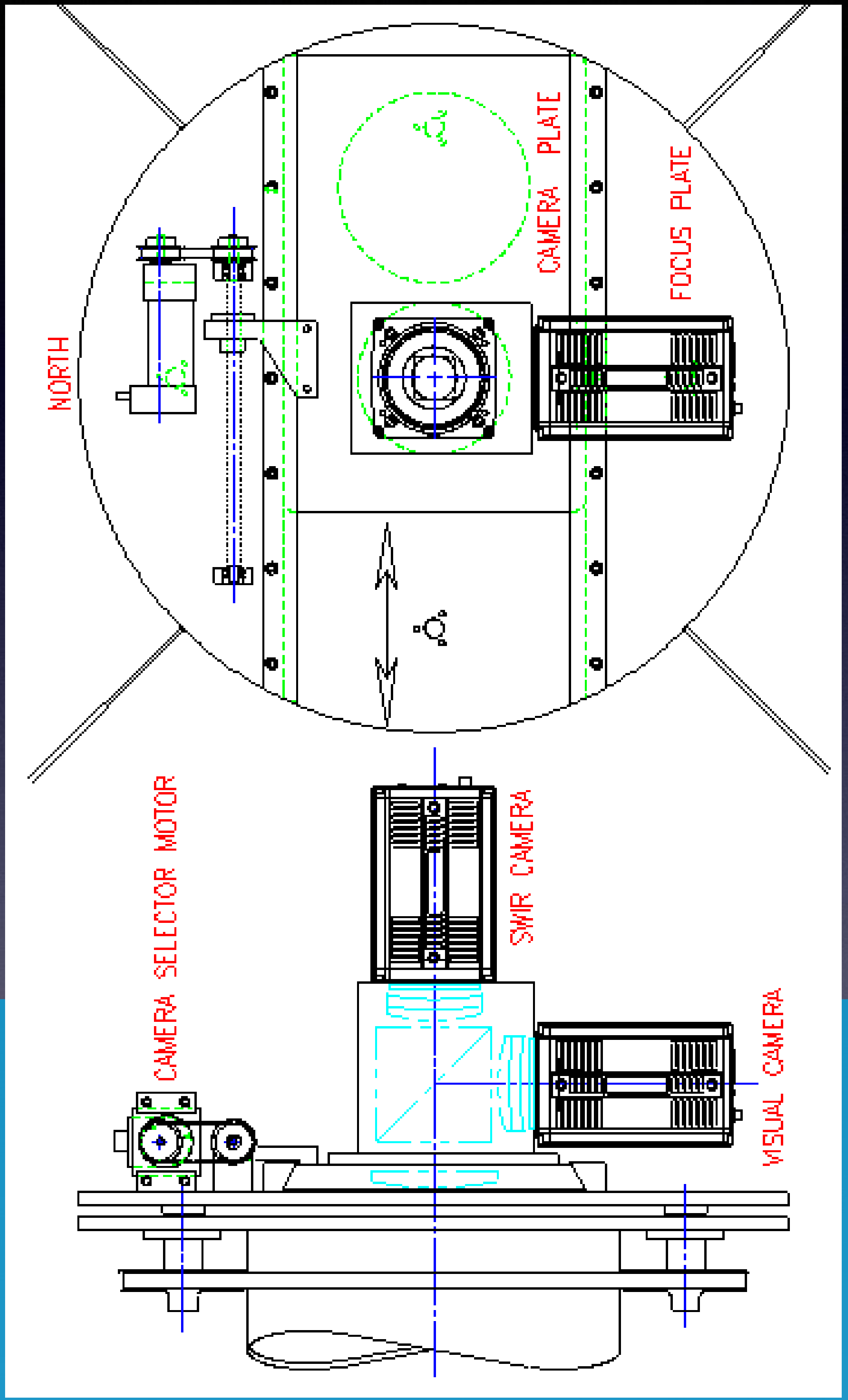
NELIOTA: 1.2m Kryoneri telescope

- 2016: Upgrade and retrofit of mechanical and electronic parts of telescope, dome automation by DFM Engineering, Inc.
- Focal ratio f/13 → f/2.8



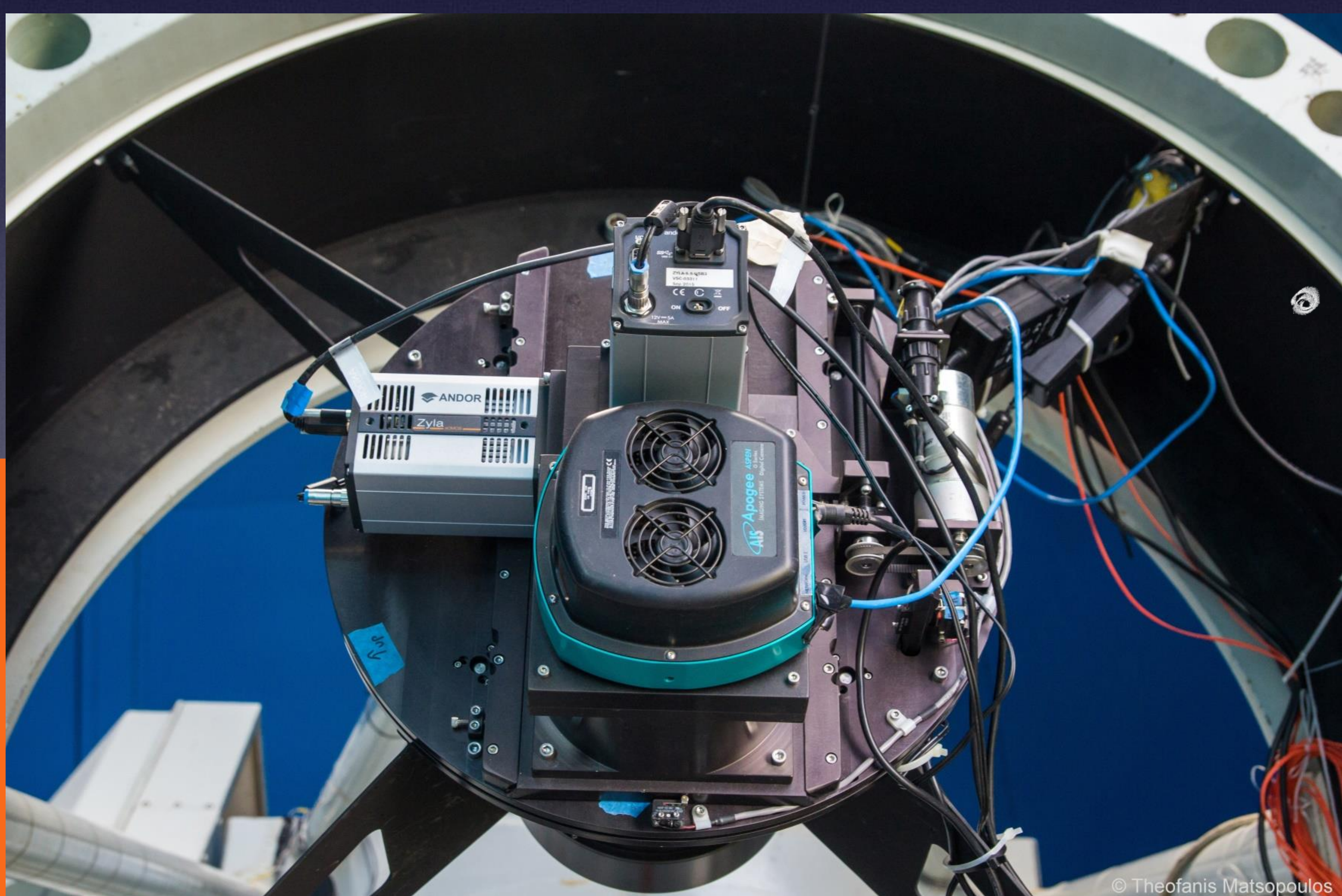
NELIOTA: Lunar Imager Optical Path





NELIOTA: Lunar Imager

Prime focus Lunar Imager
- Andor Zyla 5.5 sCMOS cameras @30 fps
- Dichroic beam splitter at 730 μm
- R & I filters
- Pixel scale: 0.39 arcsec/pixel
- Field of view: 16.0’ x 14.4’
  (25160 x 2160 pixels)



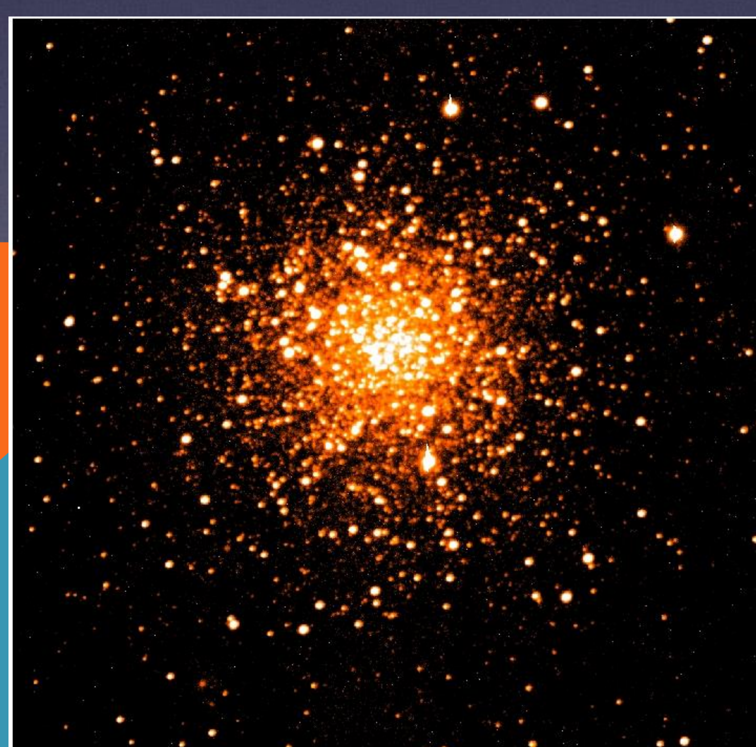
- Prime focus Science Camera
  - Apogee Aspen
  - Clear filter
  - Pixel scale: 0.72 arcsec/pixel
  - Field of view: 12.3’ x 12.3’
    (1024 x 1024 pixels)

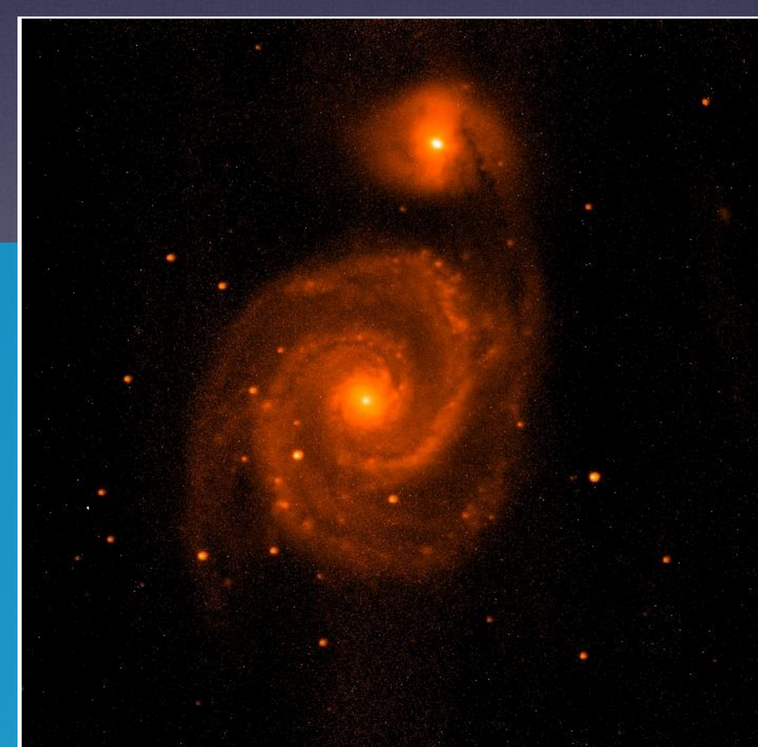
Lunar imager

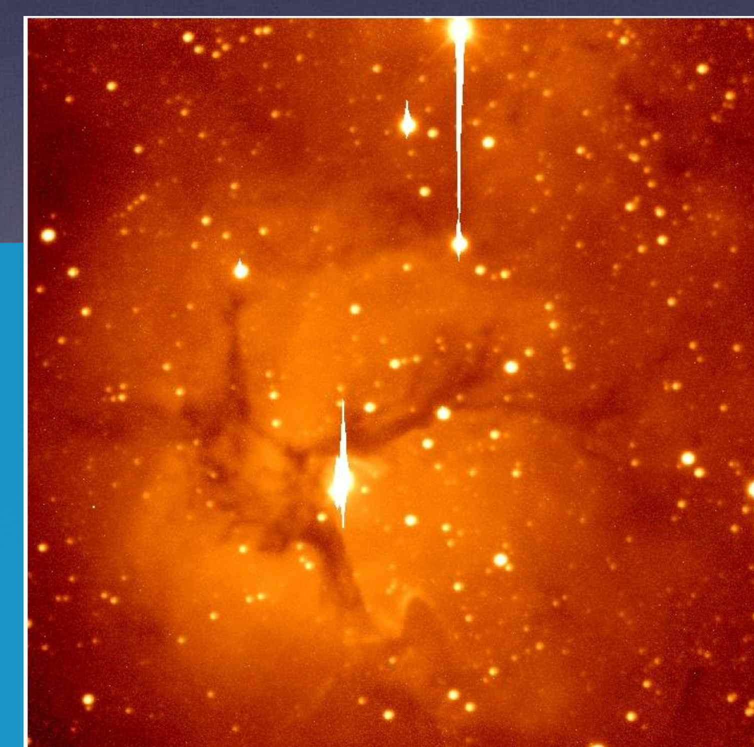
R-band

I-band

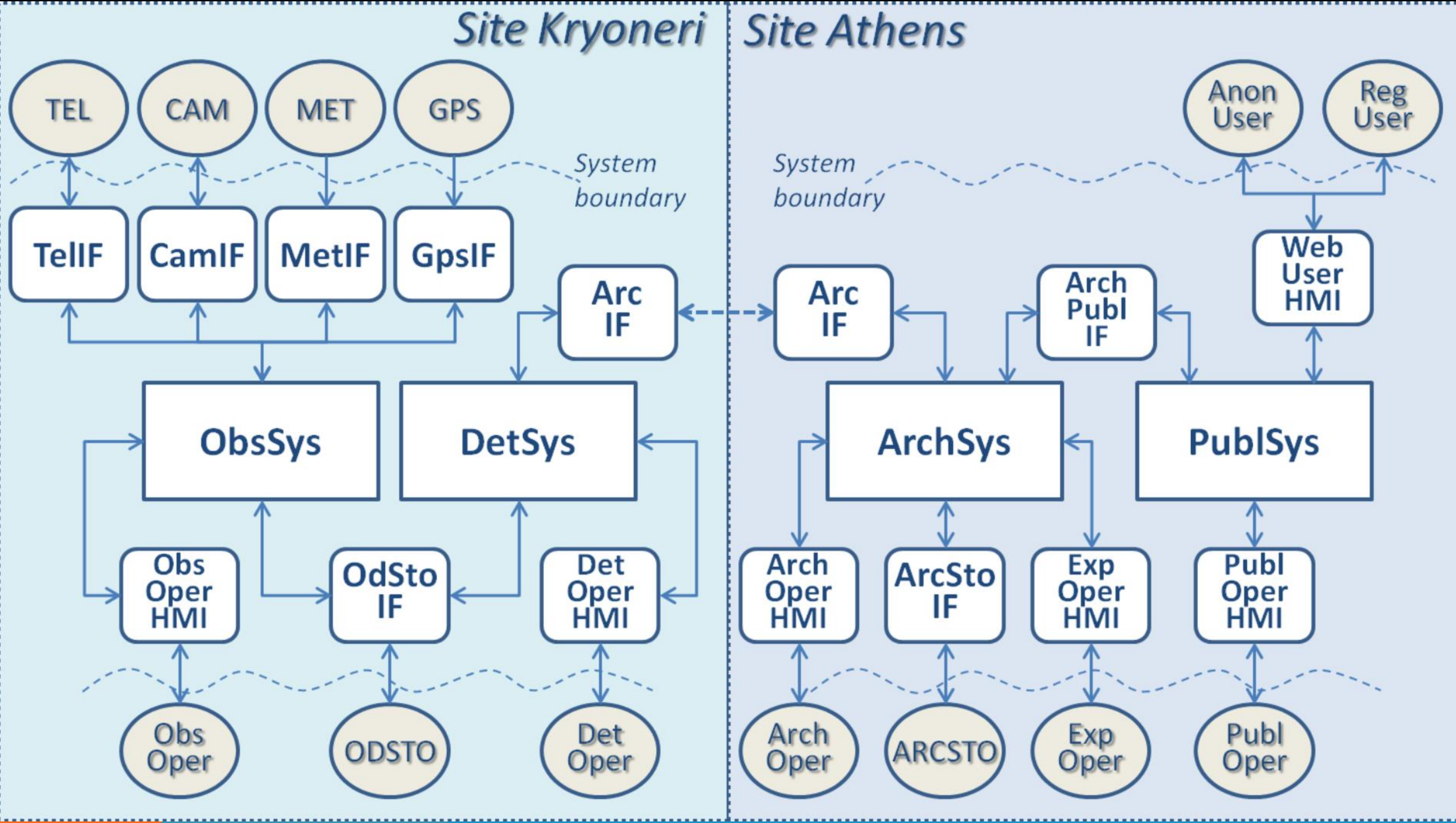
Science camera







NELIOTA System



Impacts are detected, characterized and uploaded to the web site (https://neliota.astro.noa.gr) within 24 hours

NELIOTA Hardware

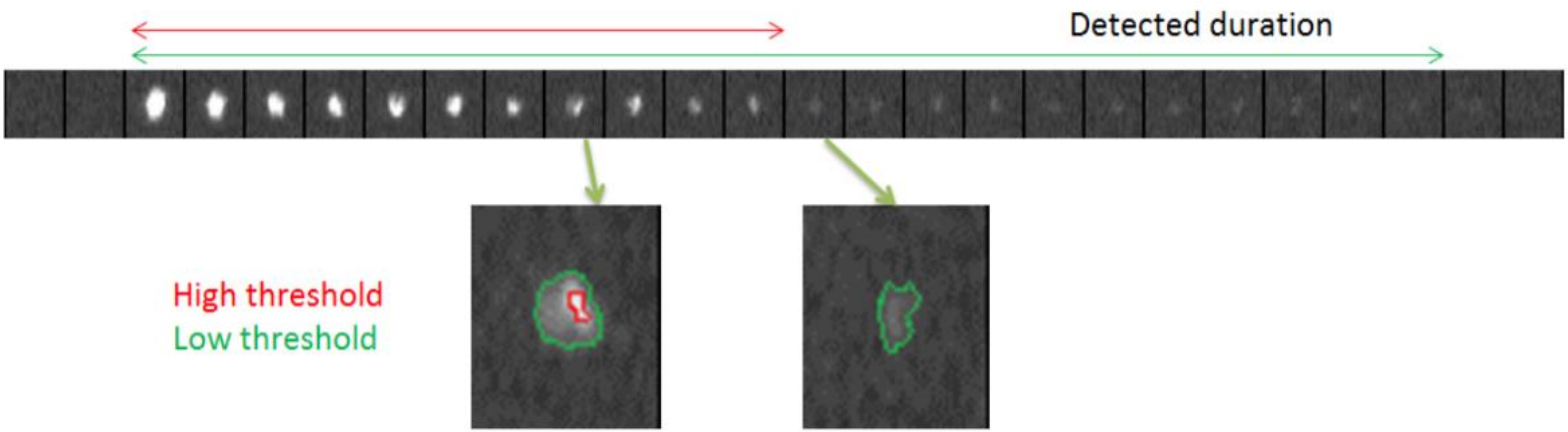
The Cluster System consists of:

- Two (2) nodes HP DL380 Gen9 Servers.
- A storage Subsystem of an HP MSA 2040 SAN DC SFF Storage with an additional HP D2700 Disk Enclosure. The Storage Subsystem is populated with 32xHP 1.2TB 6GB SAS 10K SFF DP ENT HDDs, providing total RAW capacity 38.4TB.

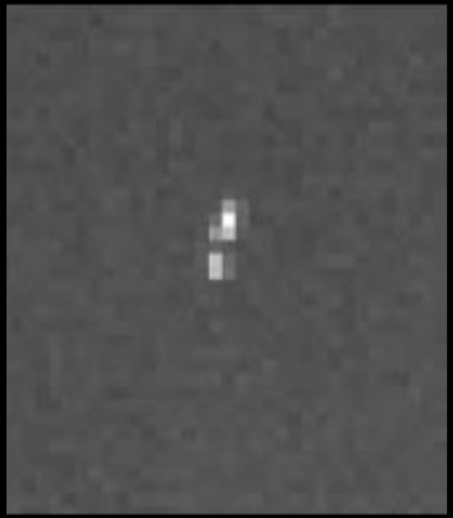
CMOS frame (16bit) pixels	Base 2560x2160	Binned 1280x1080
Frame size [MB]	11	2.8
Rate (30 fps) [MB/s]	330	83
Cams (x2) [MB/s]	660	166
Single PC input rate [Gbps]	*5.28*	*1.33*
Chunk (10min) [GB]	396	100
Daily (6h) [TB]	**14.3**	**3.6**

NELIOTA Detection Algorithm

- Adaptive background subtraction
- Thresholding using a high and low threshold
- Extraction of connected components
- Detection of cosmic rays, moving objects
- Identification of candidate events



Artifacts




NELIOTA Results - Event #2

NELIOTA Website

https://neliota.astro.noa.gr

neliota

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News & Highlights

ESA press release: New NELIOTA project detects flashes from lunar impacts

Using a system developed under an ESA contract, the Greek NELIOTA project has begun to detect flashes of light caused by small pieces of rock striking the Moon's surface. NELIOTA is the first system that can determine the temperature of these impact flashes.

"Its large telescope aperture enables NELIOTA to detect fainter flashes than other lunar monitoring surveys and provides precise colour information not currently available from other projects," says Alceste Bonanos, the Principal Investigator for NELIOTA.

Read the whole press release here.

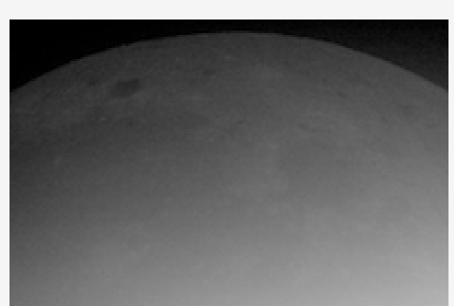
[24 May 2017]

First lunar flashes detected by NELIOTA

We are proud to announce that NELIOTA has so far detected 5 lunar flashes. Parameters of all flashes are available via the Data Access page of the NELIOTA website. The brightest flash detected so far peaked at 6.7 mag in R and 6.0 mag in I and had a duration of 0.13 seconds, while the faintest flash peaked at 10.0 mag in R and 8.7 mag in I and lasted 0.03 seconds.

[20 April 2017]

NELIOTA commissioning phase completed



The NELIOTA project has completed its 2-month commissioning phase, which started in January 2017. The lunar observations are being used to validate the performance of the software and fine-tune the detection algorithm. The 22-month observational campaign will begin on March 8, 2017. An image of the non-illuminated side of the Moon obtained by NELIOTA on February 1, 2017 is shown.

NELIOTA Status

150 days since start of observations
20.8 hours of lunar observations
16.37 TB of lunar images
7 NEO lunar impact events

Asteroid Day 2017

ASTEROID DAY 30 JUNE

Upcoming Events

13th Hellenic Astronomical Conference (July 2-6, 2017)

Researchers' Night (September 29, 2017)

Near-Earth Objects: Properties, Detection, Resources, Impacts and Defending Earth (May 14 - June 8, 2018, Munich, Germany)

NELIOTA Website

https://neliota.astro.noa.gr

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NELIOTA Archive

The NELIOTA Archive is automatically updated with new suspected and validated flashes within 24 hours of the actual observations. Scientists may obtain full access to the NELIOTA Archive by registering here. If you are already registered, please login by clicking here.

The table below lists the UT date and time of the start of the validated events, their duration, peak R and I magnitude, as well as their lunar coordinates, altitute, azimuth and airmass. Registered users can also view the suspected events, i.e. events which cannot be validated.

Registered users have access to the FITS data cube files for each event, which are provided separately for the R and I filter. These include:

- the reduced (bias-subtracted and flatfielded) images
- the background image (running average of previous reduced images)
- the difference images (between the reduced image and the background)

The reduced image files include 7 frames before and 7 frames after the frames that contain the event. The difference image files include the frames that contain the event and 7 subsequent frames.

If you plan to scientifically exploit data from the NELIOTA Archive, please inform us in advance and include the following acknowledgement in your publications:

This work has made use of data from the European Space Agency (ESA) NELIOTA project.

Validated NEO Lunar Impact Events

UT Date (DD/MM/YYYY)	UT Time	Duration (sec)	R (mag)	I (mag)	Validated	Size (MB)	Details
27/06/2017	18:58:27.680	0.066	10.3 ± 0.0	9.2 ± 0.0	✓	87	See >>
01/05/2017	20:31:01.137	0.066	9.7 ± 0.0	8.5 ± 0.0	✓	97	See >>
01/04/2017	19:45:51.653	0.033	10.0 ± 0.1	8.7 ± 0.1	✓	92	See >>
04/03/2017	20:51:33.853	0.033	9.7 ± 0.1	8.8 ± 0.1	✓	94	See >>
01/03/2017	17:13:19.360	0.033	9.2 ± 0.1	8.1 ± 0.1	✓	84	See >>
01/03/2017	17:08:48.573	0.133	6.7 ± 0.1	6.0 ± 0.1	✓	98	See >>
01/02/2017	17:13:57.863	0.033	9.8 ± 0.1	8.9 ± 0.1	✓	91	See >>

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NELIOTA milestones

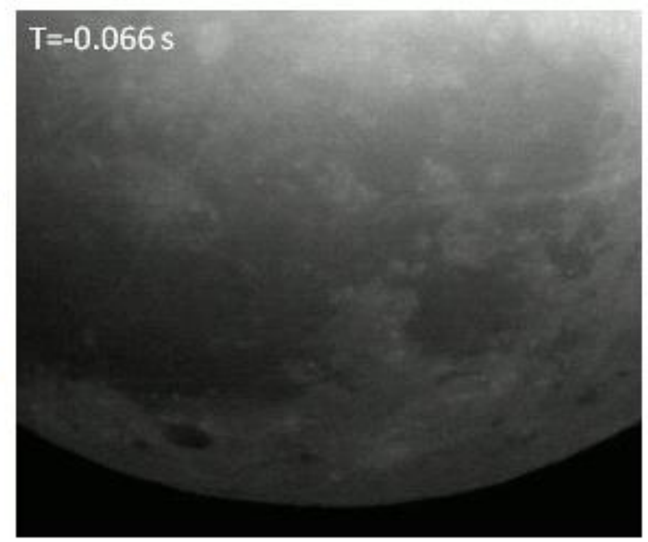
- NELIOTA Kick-off meeting (February 2015)
- NELIOTA first light (June 2016)
- NELIOTA passes 1st acceptance test (October 2016)
- NELIOTA enters operational phase (November 2016)
- NELIOTA test campaign in January-February 2017
- NELIOTA discovers first lunar impact flash (February 1st, 2017)
- NELIOTA passes 2nd acceptance test (March 8th, 2017)
- NELIOTA 22-month campaign began in March 2017

NEW NELIOTA PROJECT DETECTS FLASHES FROM LUNAR IMPACTS

24 May 2017

Using a system developed under an ESA contract, the Greek NELIOTA project has begun to detect flashes of light caused by small pieces of rock striking the Moon's surface. NELIOTA is the first system that can determine the temperature of these impact flashes.

Studies such as NELIOTA are important because Earth and its Moon are constantly bombarded by natural space debris. Most of this material ranges in size from dust particles to small pebbles, although larger objects can appear, unexpectedly, from time to time. This was the case when an object almost 20 m in diameter disintegrated above the Russian city of Chelyabinsk in February 2013. The resultant explosion, caught on camera, caused considerable damage, although, fortunately, no one was killed.



Lunar impact flash. *Credit: NELIOTA project*

Particles only millimetres across usually appear several times per hour on any clear dark night in the form of meteors or 'shooting stars'. However, the number of incoming objects in the size range from decimetres to metres is not well known. Too small to be detected directly with telescopes, they are rarely captured by cameras when they enter Earth's atmosphere.

One way to determine the number of larger impactors and the potential impact threat to Earth is to observe the Moon, in particular the dark area not illuminated by the Sun. When small asteroids strike the lunar surface at high speed, they burn up on impact, generating a brief flash of light, which can be visible from Earth. Assuming a typical velocity and density, the size and mass of the object can be estimated from the brightness of the event.

A new campaign to study these lunar flashes is being undertaken by the NELIOTA (Near-Earth

Search here

23-Jun-2017 13:14 UT

Shortcut URL
http://sci.esa.int/jump.cfm?oid=59165

Images And Videos

- Kryoneri Observatory, Greece
- Lunar impact flash
- Lunar impact flash

Related Links
- NELIOTA website
- Kryoneri Observatory
- Asteroid Day
- Space Situational Awareness at ESA
- NEO Coordination Centre at ESA