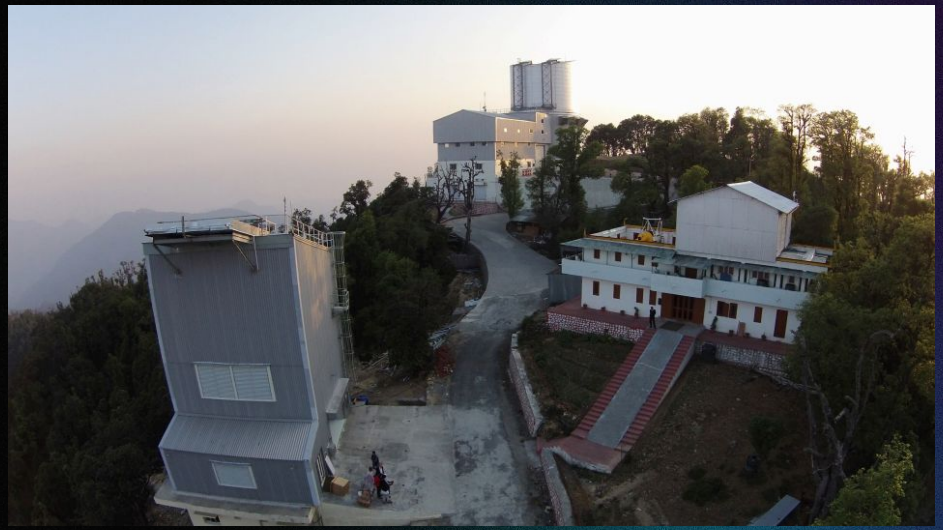
Supernova searches with the 4m International Liquid Mirror Telescope (ILMT)



Located in Devasthal, India

First optical survey telescope in India

First light on 29th April, 2022

Limiting mag ~ 22 mag in single exposure

Naveen Dukiya
on behalf of Kuntal Misra (Indian PI of ILMT)
ARIES Nainital, India

An Extraordinary Journey Into The Transient Sky, Padova, Italy

1 April 2025

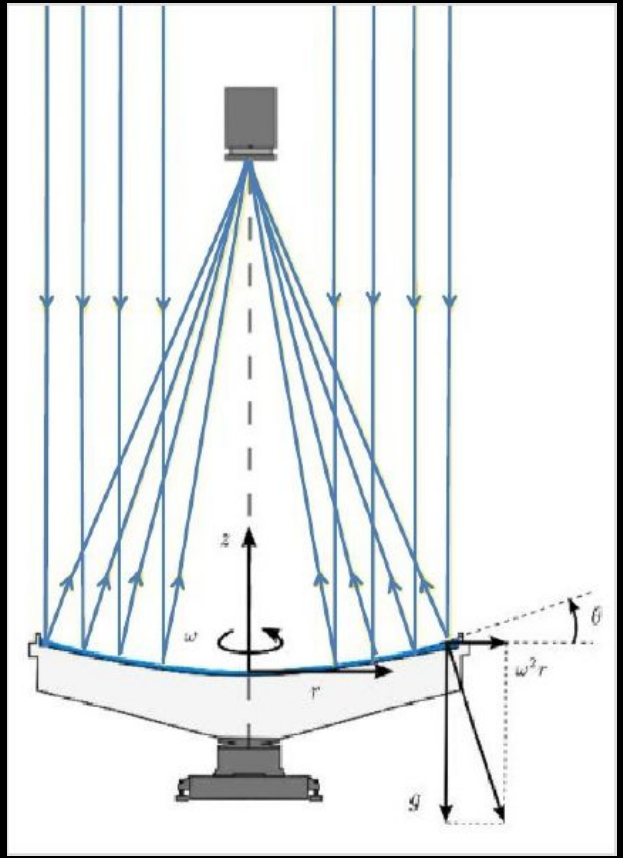
Liquid Mirror Telescopes - Principle

- While rotating at a constant speed the surface of the liquid mirror takes the shape of a parabola under centrifugal force and gravity.

$$\frac{dz}{dr} = tan\theta = \frac{\omega^2 r}{g}$$

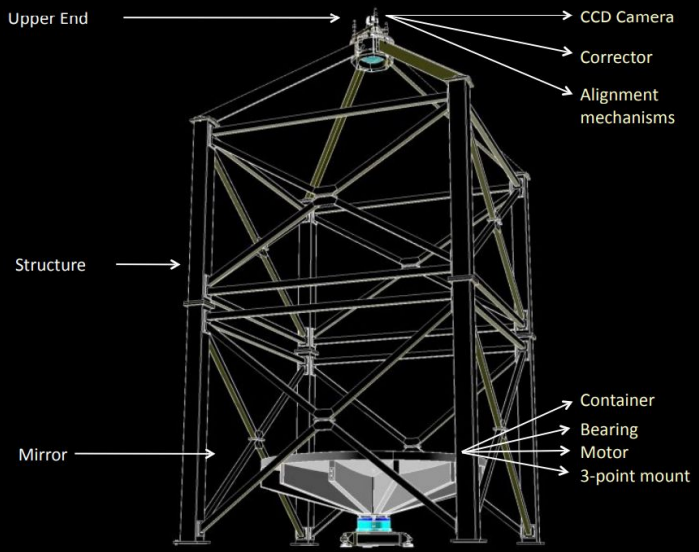
$$z = \frac{\omega^2 r^2}{2g} = \frac{r^2}{4F}$$

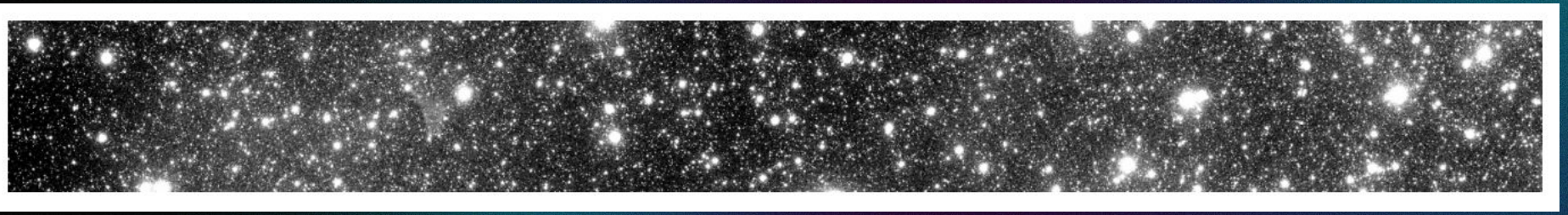
- We can use a thin film of a liquid to behave like a parabolic optical surface.



The 4-m International Liquid Mirror Telescope - Structure

- Air bearing: Three-point mounting. Supports a maximum axial load of 1272 Kg.
- Recipient/bowl: The top surface of the dish has a parabolic shape with polyurethane.
- Covered with 1.4μm think mylar film to reduce spiral waves in mercury.
- CCD camera: 4K x 4K pixels with a pixel scale of 0.3 arcseconds. Time Delay Integration (TDI) mode. In TDI mode, the charge from a column of pixels is transferred to the next column at a rate matching the earth's rotation rate.
- Optical corrector: Five lens assembly.
- Pneumatic system

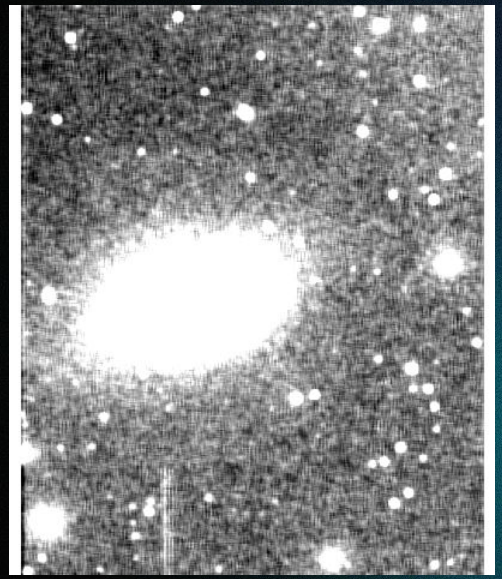




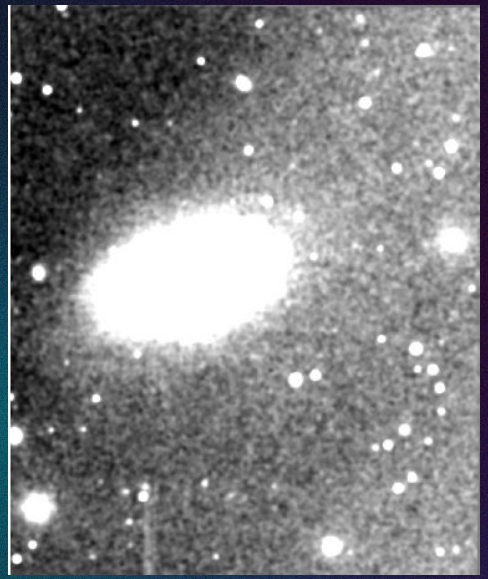
ILMT frame in i′-band of size 22′ along declination and 198′ along RA.
Size of each processed image ~670 MB.

ILMT observes a 22’ wide strip centered at the declination of the +29°21’41”.
It covers 40 sq. degree of area in one night.

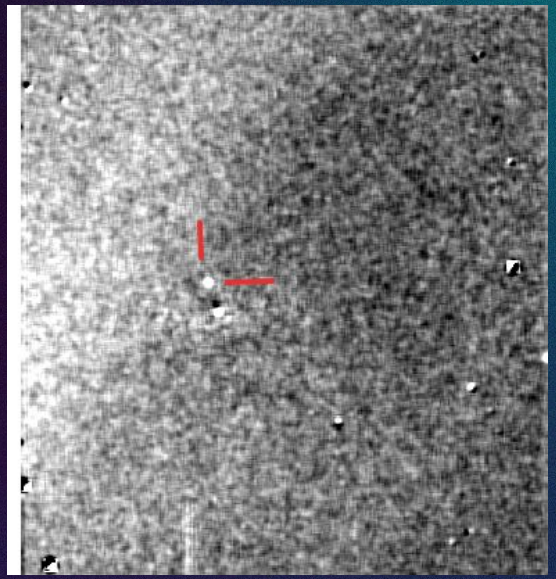
Transient Detection and Classification



Science Image



Reference Image

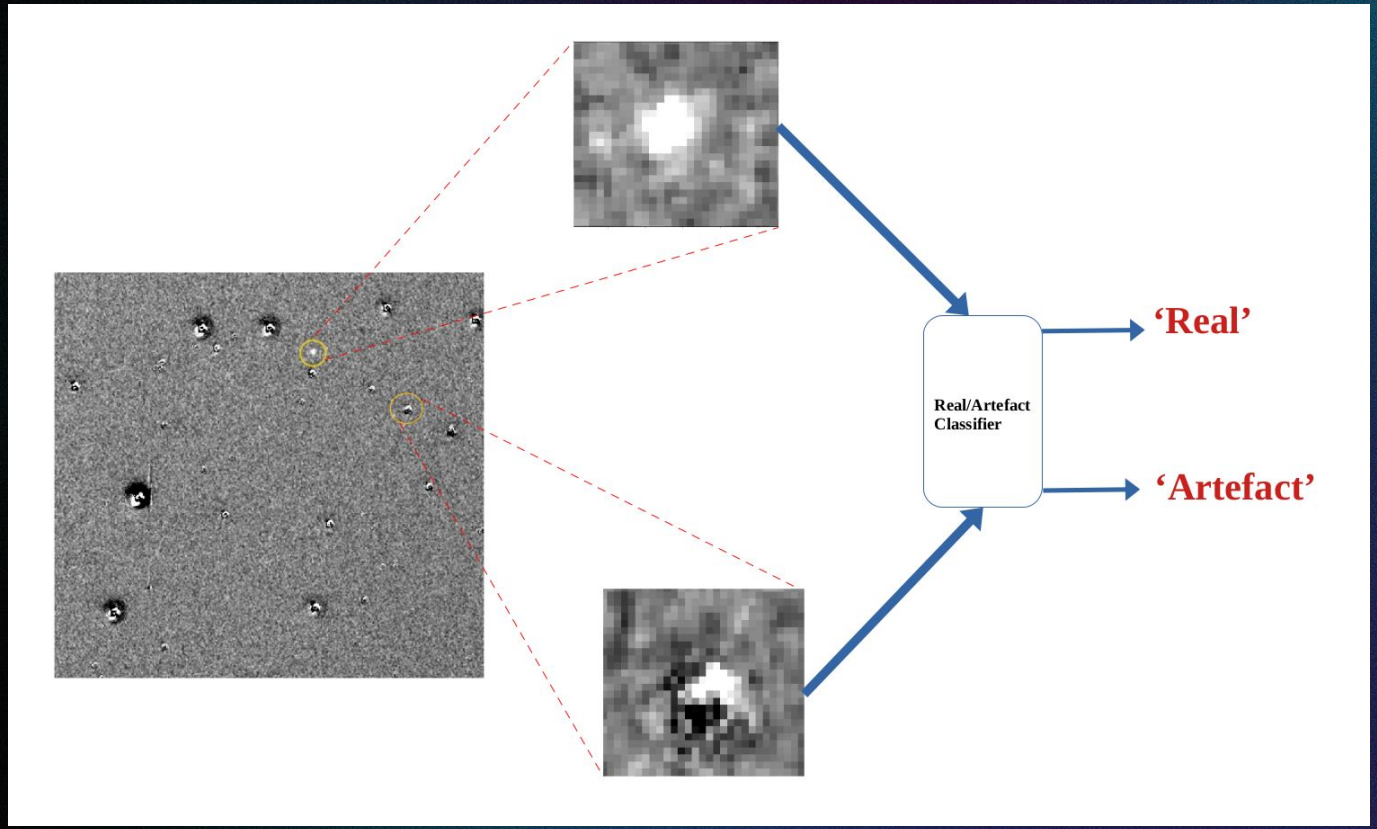


Difference Image

Science & Reference Image → Flux Scaling → PSF Matching → Difference Image

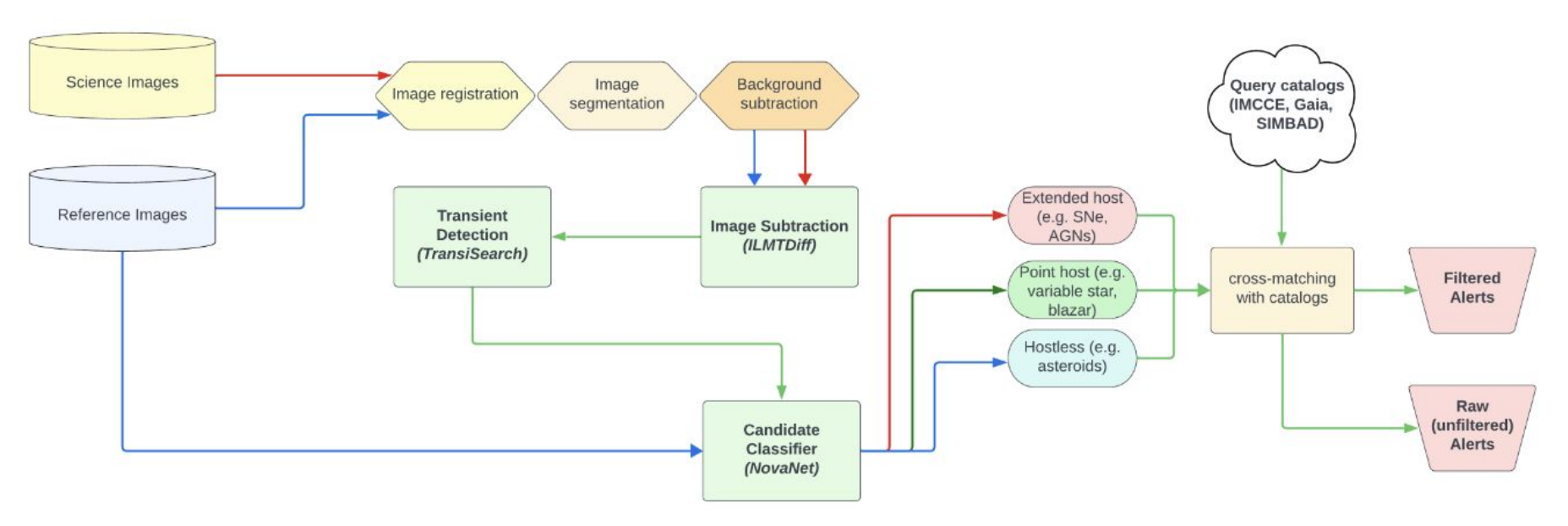
Pranshu, Misra + (2025)

Transient Detection and Classification



Pranshu, Misra + (2025)

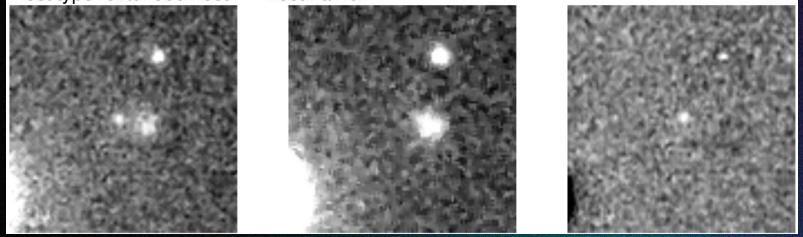
Transient Detection and Classification



Pranshu, Misra + (2025)

Transient discoveries with the ILMT

solar system object: No
confidence score: (0.69497645, 0.9929326)
x-y coordinates of candidate: (3050, 13270)
wcs coordinates of candidate: ('1h 50m 2.9s', '+29d 8m 52s')
host type: extended host host name: ---



AT 2023yjc

RA/DEC (2000)	Type	Redshift
01:50:02.875 +29:08:52.57	**---**	
27.5119796074 +29.1479353184		

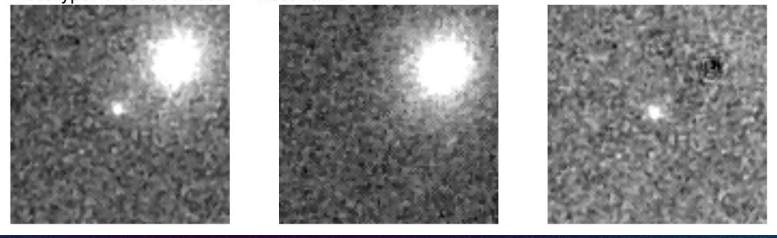
Discovery Report

Reporting Group	Discovering Data Source	Discovery Date	TNS AT	Public	Discovery Mag
ILMT	**ILMT**	**2023-11-13 16:57:44.000**	**Y**	**Y**	**21.55**

Filter
r-Sloan

Reporter/s
Kumar Pranshu, Kuntal Misra, Bhavya Ailawadhi, Monalisa Dubey, Naveen Dukiya, Vibhore Negi, Arun S (ARIES, Nainital), Jean Surdej (Institute of Astrophysics and Geophysics, University of Liège), Paul Hickson(Department of Physics and Astronomy, University of British Columbia)

solar system object: No
confidence score: (0.90179276, 0.9997066)
x-y coordinates of candidate: (3054, 24222)
wcs coordinates of candidate: ('14h 13m 49.6s', '+29d 23m 32s')
host type: extended host host name: ---



AT 2024fxn

RA/DEC (2000)	Type	Redshift
14:13:49.576 +29:23:32.40	**---**	
213.4565659 +29.3923328		

Discovery Report

Reporting Group	Discovering Data Source	Discovery Date	TNS AT	Public	Discovery Mag
ILMT	**ILMT**	**2024-04-05 00:00:00.000**	**Y**	**Y**	**19.74**

Filter
r-Sloan

Reporter/s
Kumar Pranshu, Kuntal Misra, Bhavya Ailawadhi, Manisha Kharayat, Monalisa Dubey, Naveen Dukiya (ARIES, Nainital), Vibhore Negi (IUCAA, Pune), Jean Surdej, Sara Filali (Institute of Astrophysics and Geophysics, University of Liège), Paul Hickson (Department of Physics and Astronomy, University of British Columbia)

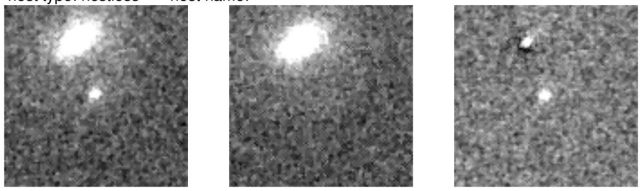
Transient discoveries with the ILMT

solar system object: No
confidence score: (0.9108355, 0.9999958)
x-y coordinates of candidate: (369, 25835)
wcs coordinates of candidate: ('22h 19m 30.4s', '+29d 23m 18s')
host type: extended host host name: UGC 11985 (GiP)

SN2023wuk

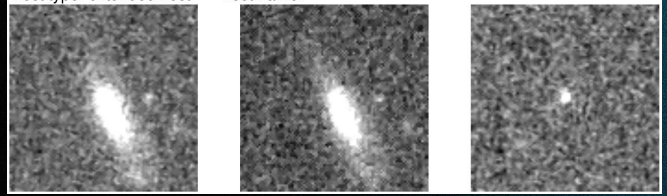
solar system object: No
confidence score: (0.49907178, 0.9997798)
x-y coordinates of candidate: (704, 30517)
wcs coordinates of candidate: ('15h 28m 31.7s', '+29d 34m 36s')
host type: hostless host name: ---

AT2024fpx



solar system object: No
confidence score: (0.9326213, 0.9999288)
x-y coordinates of candidate: (1747, 29081)
wcs coordinates of candidate: ('9h 11m 27.5s', '+29d 29m 36s')
host type: extended host host name: ---

AT2024cjb



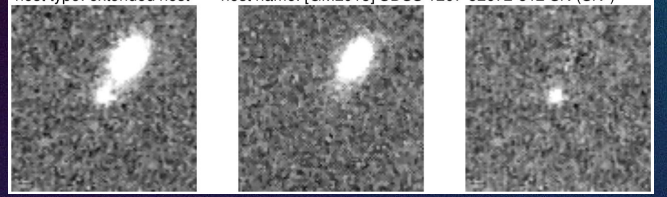
Reported routinely in the Transient Name Server (TNS)

solar system object: No
confidence score: (0.86799586, 0.99998236)
x-y coordinates of candidate: (351, 27477)
wcs coordinates of candidate: ('23h 56m 5.9s', '+29d 22m 41s')
host type: extended host host name: UGC 12850 (GiG)

SN2023vcg

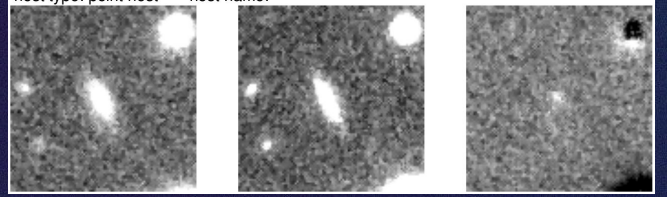
solar system object: No
confidence score: (0.9667067, 0.99964356)
x-y coordinates of candidate: (182, 8423)
wcs coordinates of candidate: ('8h 24m 49.5s', '+29d 36m 49s')
host type: extended host host name: [GM2013] SDSS 1207-52672-512 SN (SN*)

AT2024aeb

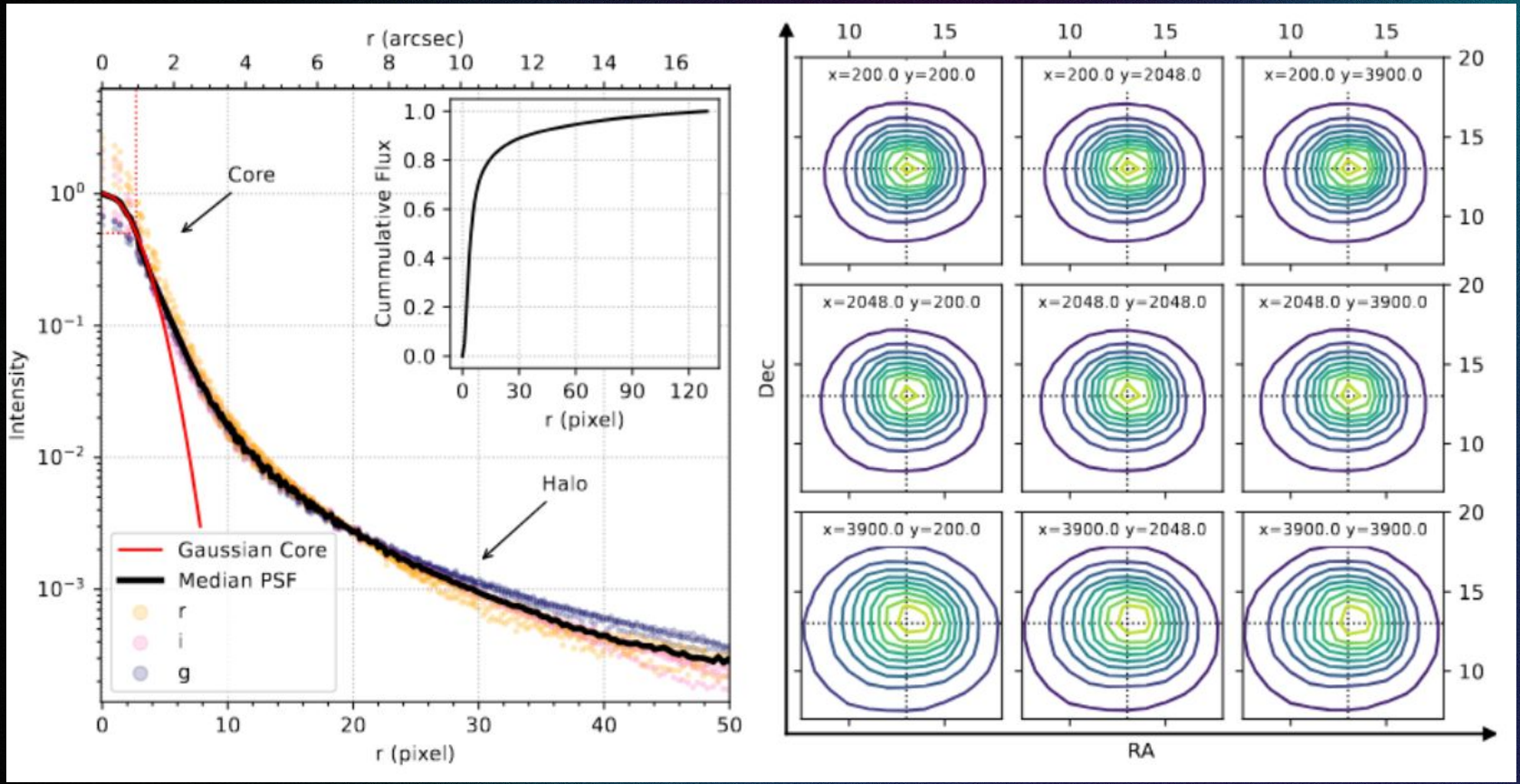


solar system object: No
confidence score: (0.28310207, 0.99362606)
x-y coordinates of candidate: (978, 29428)
wcs coordinates of candidate: ('6h 45m 29.1s', '+29d 29m 15s')
host type: point host host name: ---

AT2024ccg

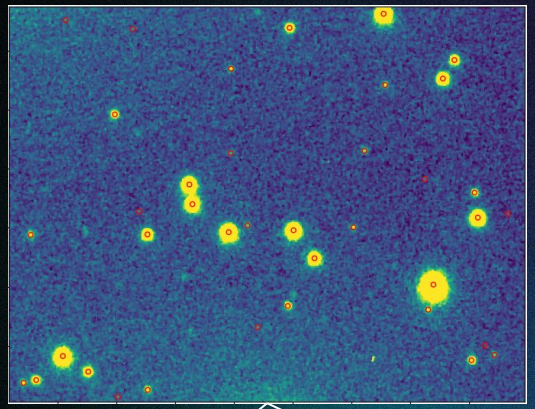


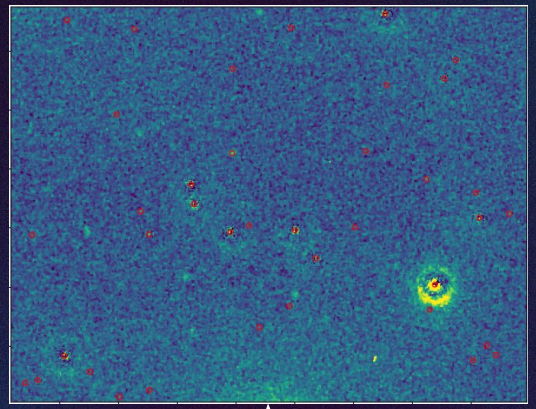
Transient and field photometry



Ailawadhi, Dukiya, Misra + (in prep.)

Transient and field photometry





SExtractor + PSFEx

PSF

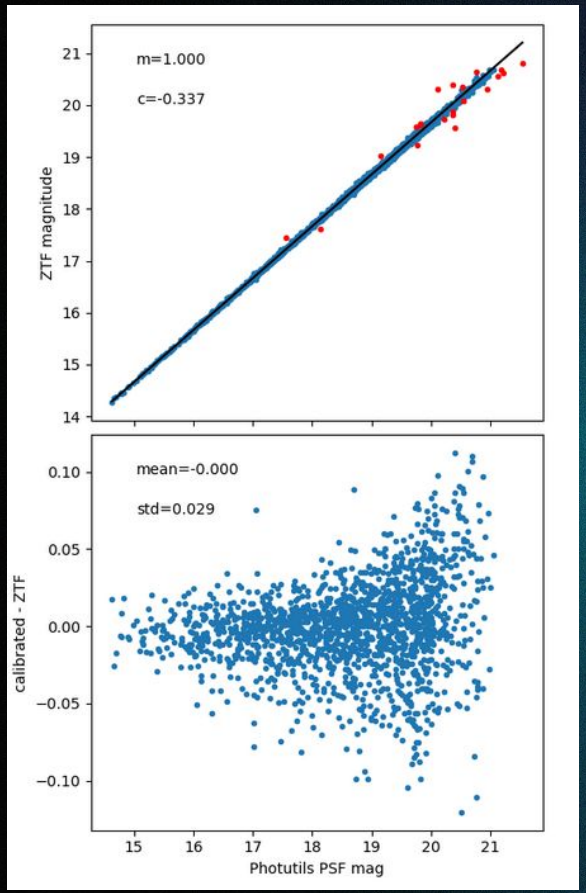
photutils
An Astropy Package for Photometry

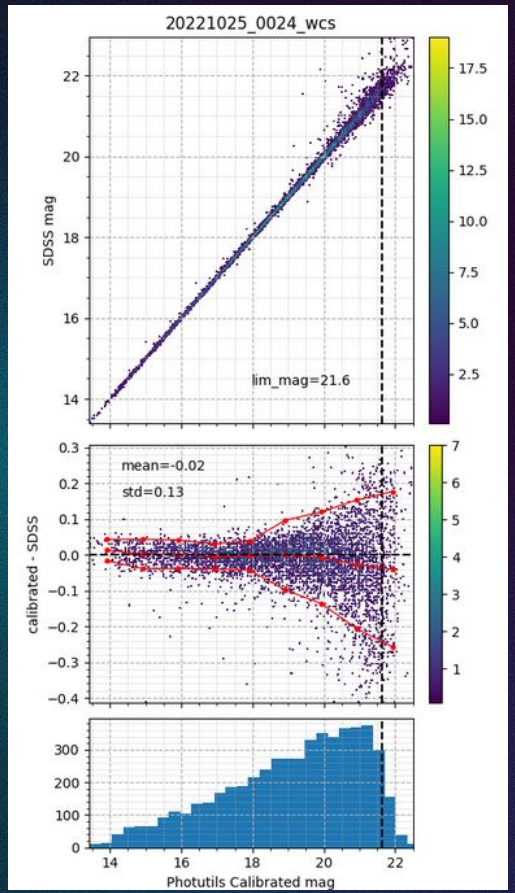
- Detection
- Aperture Photometry
- PSF fitting

Field Photometry

Ailawadhi, Dukiya, Misra + (in prep.)

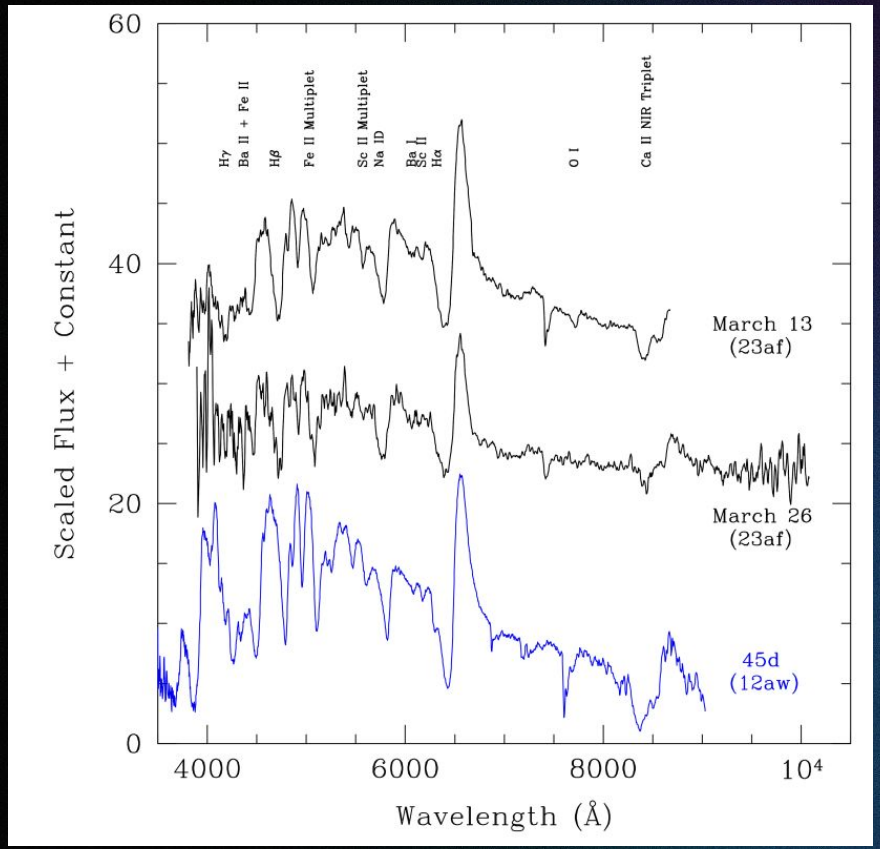
Transient and field photometry

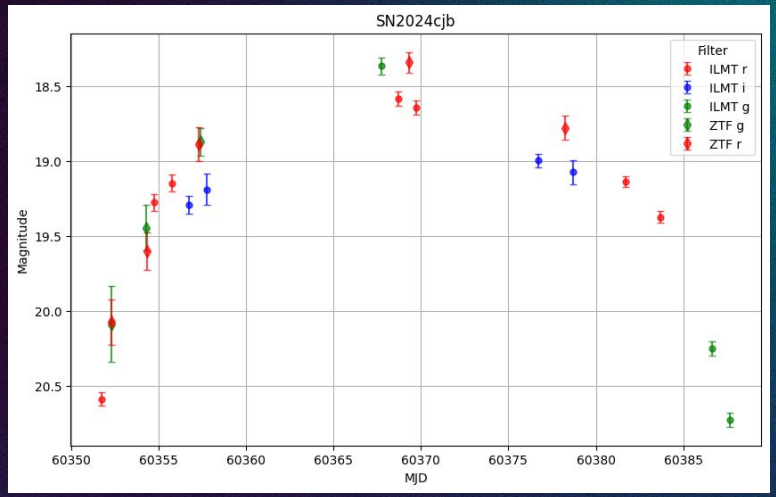


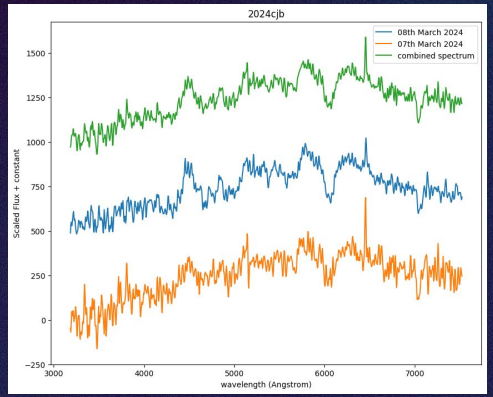


Ailawadhi, Dukiya, Misra + (in prep.)

Follow-up of the detected transients





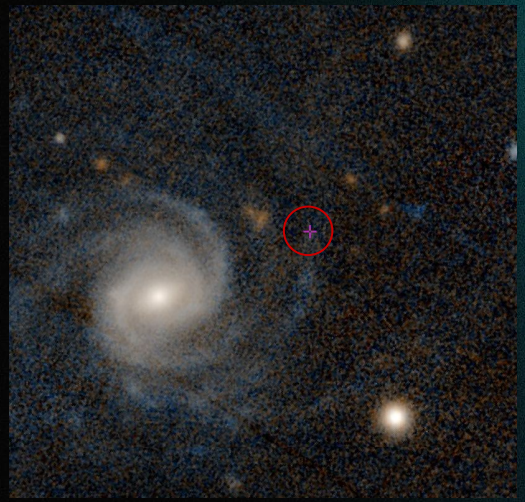


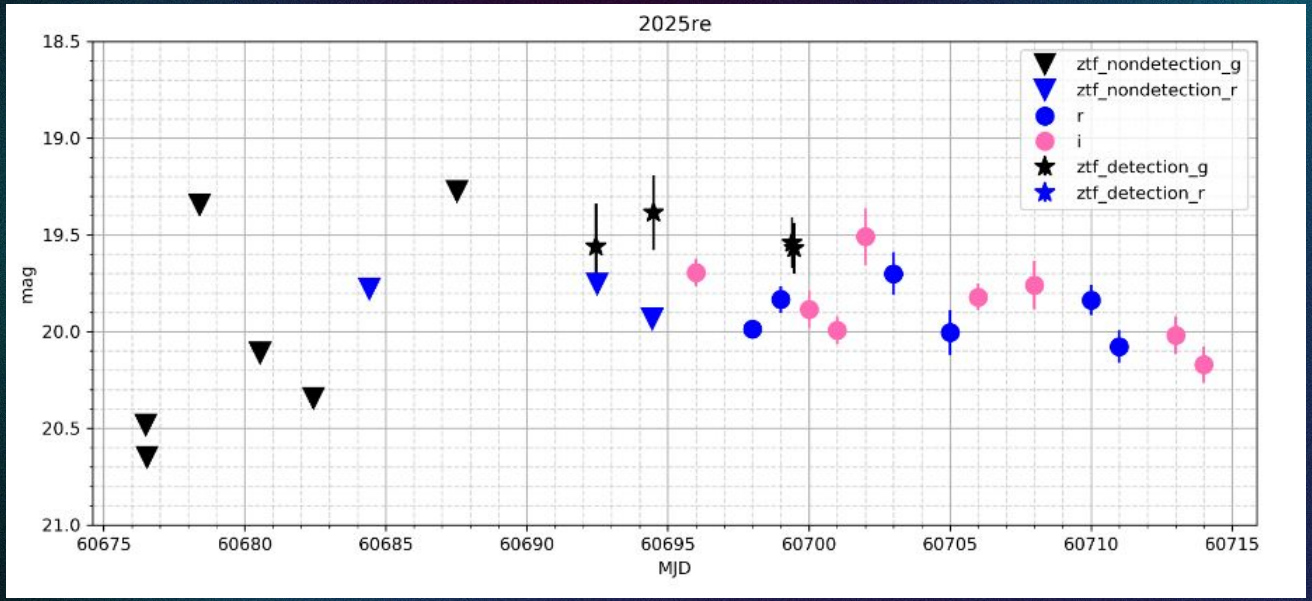
Kumar + (2024)

Follow-up of the detected transients

AT 2025re

RA/DEC (2000)	Type
13:31:15.557 +29:22:16.30	---
202.814820871 +29.3711957589	





SN rates

SN type	Filter	SNe (deg^{-2} yr^{-1})			Total SNe in a year		
		1_N	3_N	6_N	1_N	3_N	6_N
Ia	g'	63	89	115	1299	1835	2371
	r'	155	274	426	3196	5649	8783
	i'	28	71	174	577	1464	3588
CC	g'	50	97	177	1031	2000	3649
	r'	20	43	87	412	887	1794
	i'	3	8	19	62	165	392

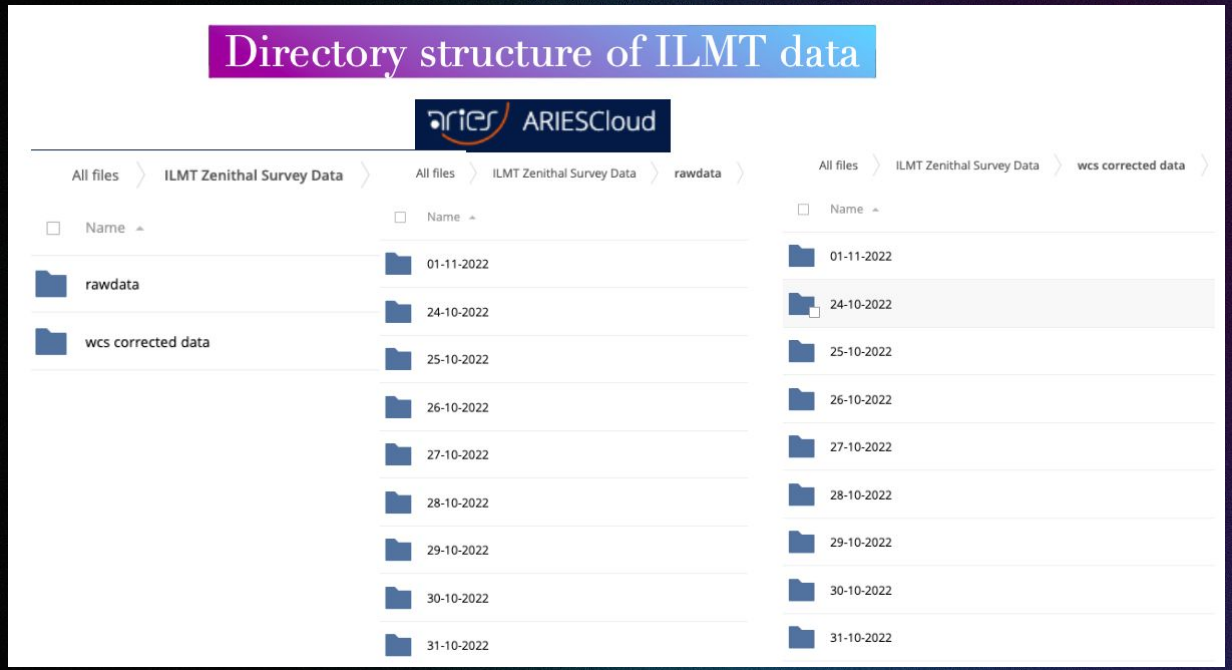
- 47 sq degree FoV

- Derived from redshift integrated rates

- 160 photometric nights with 8h of observations

Kumar + (2018)

Accessibility of the ILMT survey data



Publicly available

ILMT DR1 and DR2 released

Contact: kuntal@aries.res.in

First Papers!

[34] arXiv:2502.00556 [pdf, html, other]

PyLMT: A transient detection pipeline for the 4-m International Liquid Mirror Telescope

Kumar Pranshu, Kuntal Misra, Bhavya Ailawadhi, Monalisa Dubey, Naveen Dukiya, Sara Filali, Paul Hickson, Brajesh Kumar, Vibhore Negi, Jean Surdej

Comments: 21 pages, 26 figures, accepted for publication in MNRAS

Subjects: **Instrumentation and Methods for Astrophysics (astro-ph.IM)**; High Energy Astrophysical Phenomena (astro-ph.HE)

The International Liquid Mirror Telescope (ILMT) is a 4-m aperture, zenith-pointing telescope with a field-of-view of 22', situated in the foothills of the Himalayas. The telescope operates in continuous survey mode, making it a useful instrument for time-domain astronomy, particularly for detecting transients, variable stars, active galactic nuclei variability, and asteroids. This paper presents the PyLMT transient detection pipeline to detect such transient/varying sources in the ILMT images. The pipeline utilises the image subtraction technique to compare a pair of images from the same field, identifying such sources in subtracted images with the help of convolutional neural networks (CNN) based real/bogus classifiers. The test accuracies determined for the real/bogus classifiers ranged from 94% to 98%. The resulting precision of the pipeline calculated over candidate alerts in the ILMT frames is 0.91. It also houses a CNN-aided transient candidate classifier that classifies the transient/variable candidates based on host morphology. The test accuracy of the candidate classifier is 98.6%. It has the provision to identify catalogued asteroids and other solar system objects using public databases. The median execution time of the pipeline is approximately 29 minutes per image of 17 minutes exposure. Relevant CNNs have been trained on data acquired with the ILMT during the cycle of October-November 2022. Subsequent tests on those images have confirmed the detection of numerous catalogued asteroids, variable stars, and other uncatalogued sources. The pipeline has been operational and has detected 12 extragalactic transients, including 2 new discoveries in the November 2023-May 2024 observation cycle.

[35] arXiv:2502.00564 [pdf, html, other]

The 4m International Liquid Mirror Telescope: Construction, operation, and science

Jean Surdej, Paul Hickson, Kuntal Misra, Dipankar Banerjee, Bhavya Ailawadhi, Talat Akhunov, Ermanno Borra, Monalisa Dubey, Naveen Dukiya, Sara Filali, Joschua Hellemeier, Manisha Kharayat, Brajesh Kumar, Hitesh Kumar, Mukesh Kumar, T.S. Kumar, Priyanshi Kumari, Vibhore Negi, Anna Pospieszalska-Surdej, Sarath Prabhavu, Bikram Pradhan, Kumar Pranshu, Himanshu Rawat, B.Krishna Reddy, Arun Sasidharan Pillai, Khushal Singh, Suzanne Tremblay, Saakshi Turakhia, Sahaana Vijay

Comments: 12 pages, 18 figures, accepted for publication in Astronomy & Astrophysics

Subjects: **Instrumentation and Methods for Astrophysics (astro-ph.IM)**

The International Liquid Mirror Telescope (ILMT) project was motivated by the need for an inexpensive 4 metre diameter optical telescope that could be devoted entirely to astronomical surveys. Its scientific programmes include the detection and study of transients, variable objects, asteroids, comets, space debris and low surface brightness galaxies. To this end, a collaboration was formed between the Institute of Astrophysics and Geophysics (Liège University, Belgium), several Canadian universities (University of British Columbia, Laval University, University of Montreal, University of Toronto, York University, University of Victoria) and the Aryabhatta Research Institute of Observational Sciences (ARIES, India). After several years of design work in Belgium and construction in India on the ARIES Devasthal site, the telescope saw its first light on 29 April 2022. Its commissioning phase lasted from May 2022 until June 2023 (beginning of the monsoon). The ILMT was inaugurated on 21 March 2023 and has been in regular operation since October 2023. The telescope continuously observes the sky passing at the zenith using the SDSS g', r', and i' filters. This paper describes the ILMT, its operation, performance and shows some initial results.

Thanks!