Detection and Identification of Asteroids with the 4m ILMT

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Abstract

A very unique strength of the Devasthal Observatory is its capability of detecting optical transients with the 4m International Liquid Mirror Telescope (ILMT) and to rapidly follow them up using the 1.3m Devasthal Fast Optical Telescope (DFOT) and/or the 3.6m Devasthal Optical Telescope (DOT), installed right next to it.
In this context, we have inspected 20 fields observed during 9 consecutive nights in October-November 2022 during the first commissioning phase of the 4m ILMT. Each of these fields has an angular extent of 22' in declination by 9x22' in right ascension. Combining both a visual search for optical transients and an automatic search for optical transients using an image subtraction technique (see the ILMT poster by P. Kumar et al.), we report a total of 232 significant transient candidates. After consulting the Minor Planet Center database of asteroids, we could identify among these 206 positions of known asteroids brighter than V=22 mag. These correspond to the confirmed positions of 75 distinct known asteroids. Analysis of the remaining CCD frames covering 19 more fields (out of 20) should lead to an impressive number of asteroids observed in only 9 nights.
The conclusion is that in order to detect and characterize new supernovae, micro-lensing events, highly variable stars, multiply imaged quasars, quasars … among the ILMT optical transients, we shall first have to identify all known and new asteroids.
Thanks to its large diameter and short focal length (f/D ~2.4), the ILMT turns out to be an excellent asteroid hunter.

Introduction

First light has been obtained with the 4m ILMT on 29 April 2022. The ILMT consists of a high precision photometric and astrometric survey instrument observing at the zenith in the Time Delay Integration (TDI) mode (see the ILMT poster by Surdej et al. for more details). The singly scanned CCD frames correspond to an integration time of 102 sec, i.e. the time an object's image remains within the active area of the detector.
A unique niche for the 4m ILMT is the detection of optical transients for which rapid spectroscopic follow-up observations with the 3.6m DOT or direct imaging with the 1.3m DFOT or 3.6m DOT can be easily carried out.
We were thus very much interested in searching for optical transients in the ILMT observations collected during 9 nights in October-November 2022. They consist of 3 times 3 nights using the g, r and i Sloan spectral filters. Among these, only the i-band observations were obtained during 3 consecutive nights (28-30 October 2022). Our first approach for detecting optical transients has been to start with a visual search for transients (see Fig. 1). These detections were then used to calibrate an automatic search for transients making use of the image subtraction technique. We then noticed that optical transients associated with many triplets showed similar angular separations and orientations. They naturally consisted of good asteroid candidates. This was confirmed after consulting the asteroid database of the Minor Planet Center. We then made use of the optical transients detected in the other spectral bands (g and r) to extend our search for asteroids and other transient candidates.
We present hereafter the observations and a detailed analysis of just one out of the 20 fields imaged with the ILMT in October-November 2022.

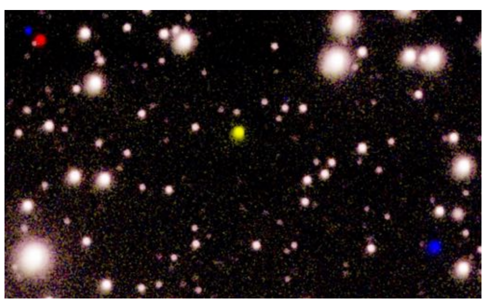
Observations and Detailed Analysis

We have summarized in Table 1 the log of the observations collected with the ILMT in October-November 2022. Under each date (cf. 24/10/2022), are listed the spectral band (cf. r) used on that night, the Local Sidereal Time (cf. 00h:03m) at which the exposure has started and the associated file number (cf. #35). Each field covers a rectangular solid angle of 22' x 198' with its length aligned along the right ascension axis.
Each of these fields has been observed during three consecutive nights with the i filter (i.e. the nights of 28, 29 and 30 October 2022). Defining an optical transient as being a source appearing clearly on only one of the three i-band frames and an asteroid candidate as consisting of three transients detected at the three different epochs, showing similar angular separations while being properly oriented as a function of time, a total of more than 160 asteroid candidates have been visually identified. Furthermore, we report in these same fields 611 additional i-band detections of transients which could be other known or new asteroids, highly variable stars, quasars, supernova candidates, etc.
Concentrating on just one of those 20 fields, i.e. the field with its RA (2022.8) starting at 04h32m, we have visually identified 18 known asteroids reported in the database of the Minor Planet Center. Making use of the automatic identification of transients based upon the image subtraction technique applied to the three g, r and i-band CCD frames covering this same field (see the ILMT poster by P. Kumar et al.), we could identify 57 additional known asteroids reported in the Minor Planet Center database. Furthermore, 39 additional transients have been identified on the basis of the g, r and i-band CCD frames covering this unique field.
Figure 1 illustrates the optical identification of three positions of a same asteroid on the nights of 28 (blue colour), 29 (yellow colour) and 30 October 2022 (red colour).

Table 1: Log of observations collected in October-November 2022 with the 4m ILMT (see text).

24/10/22	25/10/22	26/10/22	27/10/22	28/10/22	29/10/22	30/10/22	31/10/22	1/11/22
r band	r band	g band	g band	i band	i band	i band	g band	r band
00:03 #35	00:03:00 #22			00:03 #30	00:03 #27	00:03 #27	00:03 #21	00:03 #23
00:24 #36	00:24:00 #23	00:25 #33		00:24 #31	00:24 #28	00:24 #28	00:24 #22	00:24 #24
00:42 #37	00:44 #24	00:42:10 #34		00:42 #32	00:42 #29	00:42 #29	00:42 #23	00:42 #25
01:08 #38	01:08 #25	01:08 #35		01:08 #33	01:08 #30	01:08 #30	01:08 #24	01:08 #26
01:26 #39	01:26 #26	01:26 #36	01:26 #31	01:26 #34	01:26 #31	01:26 #31	01:26 #25	01:26 #27
01:45 #40		01:45 #37	01:45 #32	01:45 #35	01:45 #32	01:45 #32	01:45 #26	01:45 #28
02:03 #41	02:03 #27	02:03 #38	02:03 #33	02:03 #36	02:03 #33	02:03 #33	02:03 #27	02:03 #29
02:21 #42	02:21 #28	02:21 #39	02:21 #34	02:21 #37	02:21 #34	02:21 #34	02:21 #28	
02:39 #43	02:39 #29	02:39 #40	02:39 #35	02:39 #38	02:39 #35	02:39 #35	02:39 #29	02:39 #31
03:54 #53	03:54 #39	03:54 #50	03:56 #43	03:54 #50	03:54 #46	03:54 #45		03:54 #40
04:12 #54	04:12 #40	04:12 #51	04:12 #44	04:12 #51	04:12 #47	04:12 #46	04:12 #44	04:12 #41
04:32 #55	04:32 #41	04:32 #52	04:32 #45	04:32 #52	04:32 #48	04:43 #47	04:32 #45	04:32 #42
04:50 #56	04:50 #42	04:50 #53	04:50 #46	04:50 #53	04:50 #49	04:50 #48	04:50 #46	04:50 #43
05:08 #57	05:08 #43	05:08 #54	05:08 #47	05:08 #54	05:08 #50	05:08 #49	05:08 #47	05:08 #44
05:26 #58	05:26 #44	05:26 #55	05:26 #48	05:26 #55	05:26 #51	05:26 #50	05:26 #48	05:26 #45
05:44 #59	05:44 #45	05:44 #56	05:44 #49	05:44 #56	05:44 #52	05:44 #51	05:44 #49	05:44 #46
06:02 #60	06:02 #46	06:02 #57	06:02 #50	06:02 #57	06:02 #53	06:02 #52	06:02 #50	06:02 #47
06:20 #61	06:20 #47	06:20 #58	06:20 #51	06:20 #58	06:20 #54	06:20 #53	06:20 #51	06:20 #48
06:38 #62	06:38 #48	06:38 #59	06:38 #52	06:38 #59	06:38 #55	06:38 #54	06:38 #52	06:38 #49
06:56 #63	06:56 #49	06:56 #60	06:56 #53	06:56 #60	06:56 #56	06:56 #55	06:56 #53	06:56 #50

Fig. 1: Excerpt of a RGB-like composite picture consisting of the superposition of three i-band CCD frames recorded with the ILMT on the nights of 28 (blue dot), 29 (yellow dot) and 30 (red dot) October 2022. Near the red dot, an additional blue one is visible corresponding to another optical transient detected on 28 October. Most of the stars which are present on the three frames appear white-like on this picture. Visual inspection of such frames easily leads to the identification of optical transients.



Results and conclusions

Concentrating on the 22' x 198' field taken at the Local Sidereal Time 4h 22m, we report a total of 232 optical transient candidates. After consulting the Minor Planet Center database of asteroids, we have found that 206 of these optical transients correspond to the positions of 75 known asteroids brighter than V=22 mag.
Among these, we find that 1 (resp. 1, 3, 2, 6, 11, 6, 19, 26) asteroids have been detected on 9 (resp. 8, 7, 6, 5, 4, 3, 2, 1) nights (see Table 2 and Figs. 2 and 3).
Analysis of the remaining CCD frames covering 19 more fields (out of 20) should lead to an impressive number of asteroids observed in just 9 nights. The ILMT turns out to be an excellent asteroid hunter.

Table 2: List of the 78 asteroids detected with the ILMT during 9 consecutive nights in October-November 2022. # indicates their label displayed in Fig. 2. The last column indicates the number of nights they were observed.

#	Asteroid	Nights	#	Asteroid	Nights	#	Asteroid	Nights
1	(287600) 2003 FH133	1	27	(285615) 2000 QB233	5	53	(251579) 2009 FZ47	2
2	(398791) 2013 AR133	2	28	(351463) 2005 NH30	7	54	(290252) 2005 SC110	1
3	(583720) 2016 NL66	1	29	(449883) 2015 MW84	5	55	(568319) 2003 UN386	2
4	(72368) 2001 CT2	2	30	(475809) 2006 YH27	4	56	(66305) 1999 JD38	2
5	(7377) Pizzarello	2	31	2011 EK46	8	57	2005 UB252	1
6	(121771) 2000 AN3	2	32	(585743) 2019 BQ6	1	58	2016 EL276	1
7	2009 UD159	1	33	(243494) 2009 UF74	9	59	(290365) 2005 SV266	3
8	(528498) 2008 UO72	2	34	(488998) 2005 UR468	3	60	(599255) 2009 UD168	1
9	(574664) 2010 TV179	1	35	(54958) 2001 PK8	2	61	2013 HS101	1
10	(271811) 2004 TV106	1	36	(59790) 1999 NR56	7	62	(349593) 2008 TG61	1
11	2022 SX245	1	37	(232625) 2003 UQ177	4	63	(356264) 2009 VE25	6
12	(38733) 2000 QF141	4	38	2005 UY125	1	64	(65781) 1995 TT1	1
13	(147247) 2002 XA80	7	39	(350968) 2003 CH14	2	65	(351688) 2006 BQ46	2
14	2011 WM162	4	40	(140914) 2001 VH60	1	66	(101033) 1998 QR82	3
15	(25526) 1999 XV115	5	41	2022 UQ89	2	67	(224216) 2005 SY35	4
16	2017 QL25	2	42	(270512) 2002 FD30	1	68	(222288) 2000 SJ130	4
17	(87719) 2000 SL45	4	43	(39161) 2000 WH117	2	69	(166170) 2002 EP52	4
18	(595633) 2003 SC300	5	44		0	70	(89412) 2001 WV16	4
19	(261417) 2005 UJ489	3	45	(91818) 1999 TU267	4	71	(402103) 2003 WM109	1
20	(273964) 2007 KS7	5	46	(594949) 2000 BZ11	1	72	(398828) 2013 BV80	5
21	(423552) 2005 UK313	2	47	(98222) 2000 SL144	4	73	2022 UM108	1
22	(130440) 2000 QW18	2	48	(568302) 2003 UV344	1	74	2001 YP31	3
23	(149624) 2004 EC37	2	49	2005 UF171	1	75	(125328) 2001 VC46	3
24		0	50		0	76	(250774) Syosset	2
25	2019 NX78	1	51	(304478) 2006 UV88	2	77	(363975) 2005 UU154	1
26	(37765) 1997 GF11	6	52	(169617) 2002 GC128	1	78	(568211) 2003 SM444	1

Fig. 2: Paths of the 75 asteroids detected with the 4m ILMT in the 04h 32m LST field during 9 consecutive nights in October-November 2022. The horizontal and vertical axes represent respectively RA cos(Dec) and Dec in degree, where RA is the right ascension and Dec the declination of the asteroids for the 2000 epoch. The numbers refer to the asteroids listed in Table 2. The different coloured symbols correspond to the asteroid positions observed during the different nights.

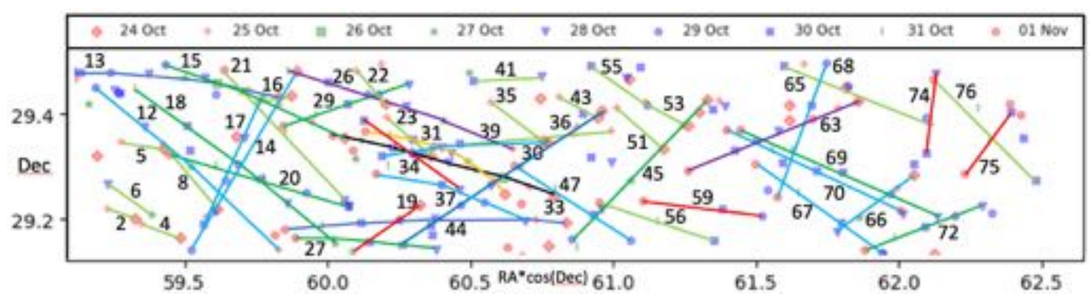
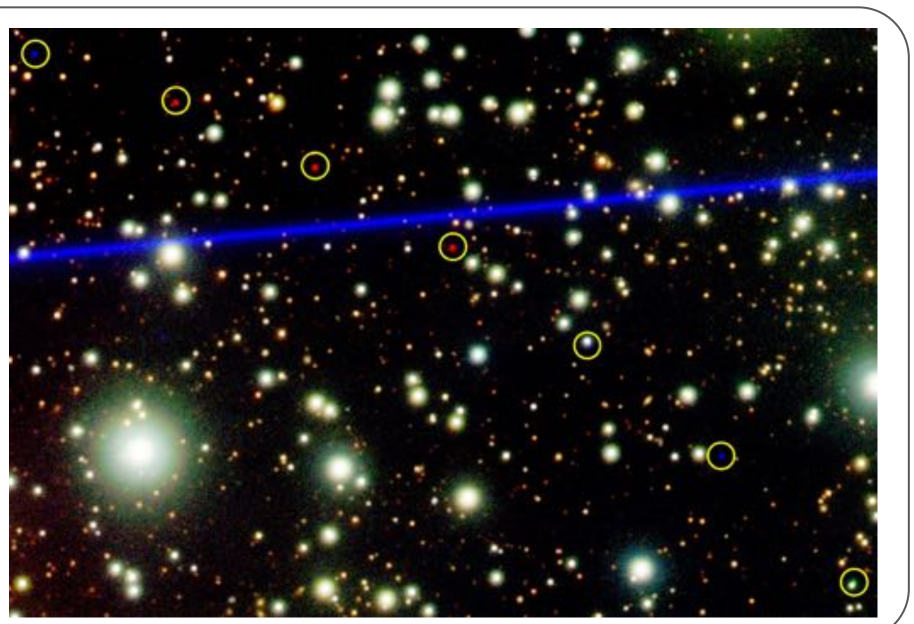


Fig. 3:

Example of an asteroid (3548 Eurybates) observed with the 4m ILMT on 7 consecutive nights in October 2022 using the g, r and i Sloan filters. The blue streak is the signature of a passing space debris.



Acknowledgements

The 4m International Liquid Mirror Telescope (ILMT) project results from a collaboration between the Institute of Astrophysics and Geophysics (University of Liège, Belgium), the Universities of British Columbia, Laval, Montreal, Toronto, Victoria and York University, and Aryabhatta Research Institute of Observational Sciences (ARIES, India), The authors thank Hitesh Kumar, Himanshu Rawat and Khushal Singh for their assistance at the telescope and JS and AP-S thank ARIES for hospitality during their numerous visits to Devasthal and Nainital. This research has made use of data provided by the International Astronomical Union's Minor Planet Center.