The zenithal 4-m International Liquid Mirror Telescope : a unique facility for supernova studies

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In order to detect such transients,

- The pointed survey approach
- A specific area survey (LOSS, Pan-STARRS, DES, …)

LMT (Liquid Mirror Telescope)

- Inexpansive technology
- Continuous data flow
- Easy image pre-processing
- Deeper imaging

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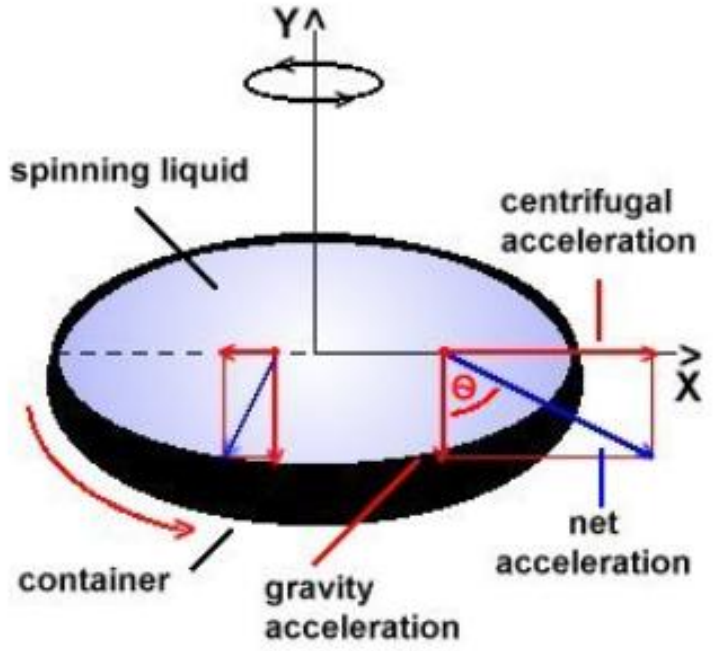

Figure 1: Acting forces on a liquid set in a rotating container

1) http://sci-toys.com/scitoys/scitoys/thermo/liquid_metal/4m%20International%20Liquid%20Mirror%20Telescope%20Project.html

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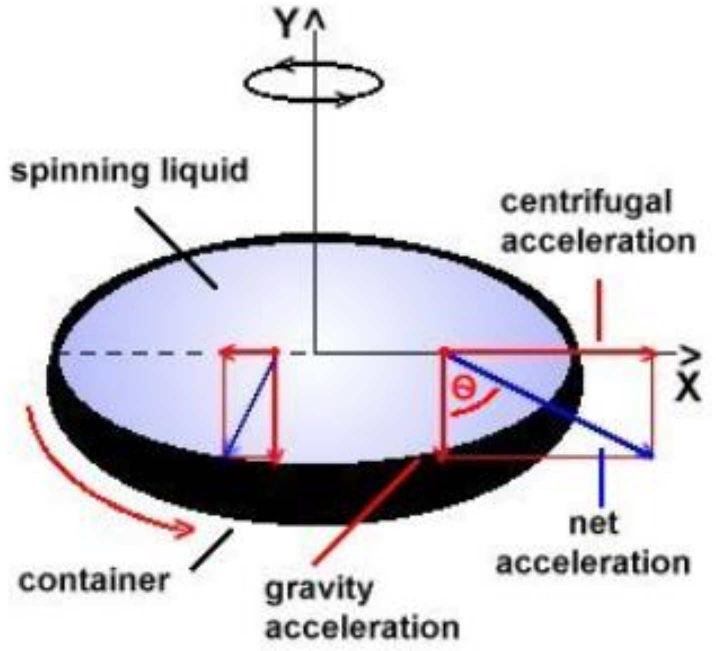

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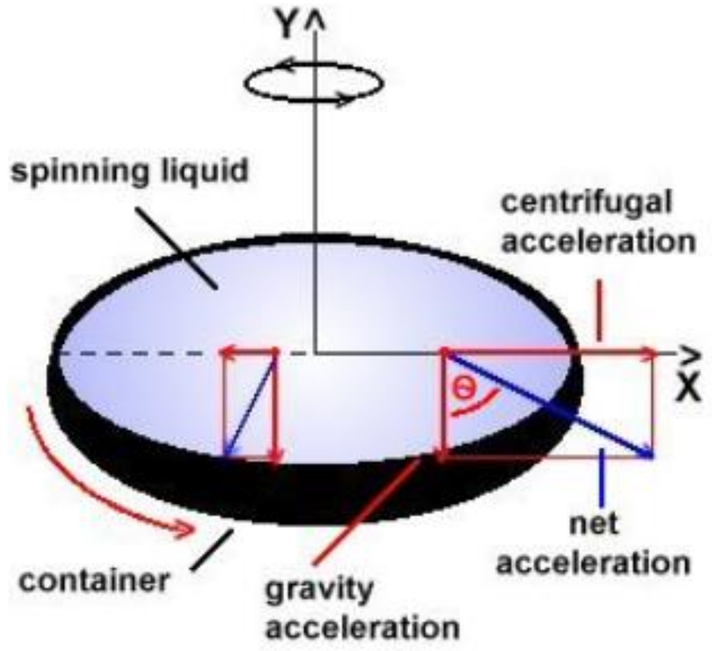

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The 6-m diameter Large Zenithal Telescope (LZT)

The limit of conventional facilities

- The lack of an appropriate TDI corrector and/or large CCD camera and/or location.

1)

The Large Zenith Telescope. Notice the Size compared to the lady in the back.

Location of Large Zenith Telescope

1) https://en.wikipedia.org/wiki/Large_Zenith_Telescope

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Introduction

The ILMT Project

Supernova rate and ILMT

The International Liquid Mirror Telescope (ILMT) project

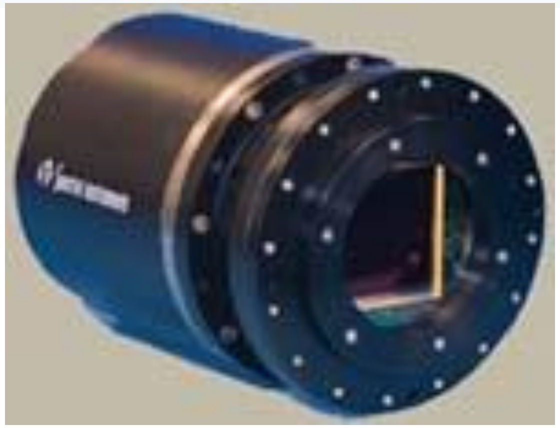
- Belgium, India, Canada and Poland
- Location : Devasthal
  - Altitude : ~2450m
  - Longitude : 79° 41′ 04″
  - East and latitude : 29° 21′ 40″

- A zenithal rotating telescope
  - Time delayed integration mode is used.
  - Shape of the mirror : Paraboloid
  - CCD : 4096 × 4096 pixel

1)

Location of Devasthal Observatory

2)



1) https://en.wikipedia.org/wiki/Devasthal_Observatory
2) http://www.aeos.ulg.ac.be/LMT/instruments.php

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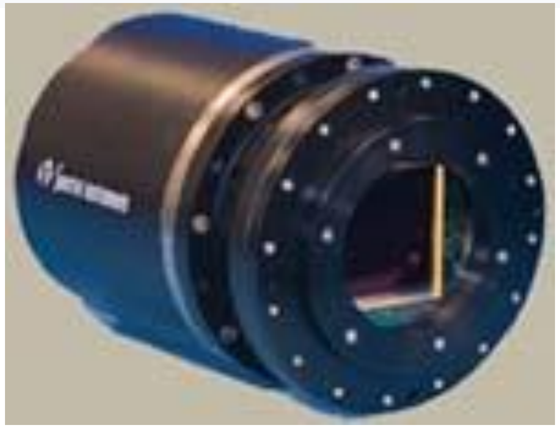

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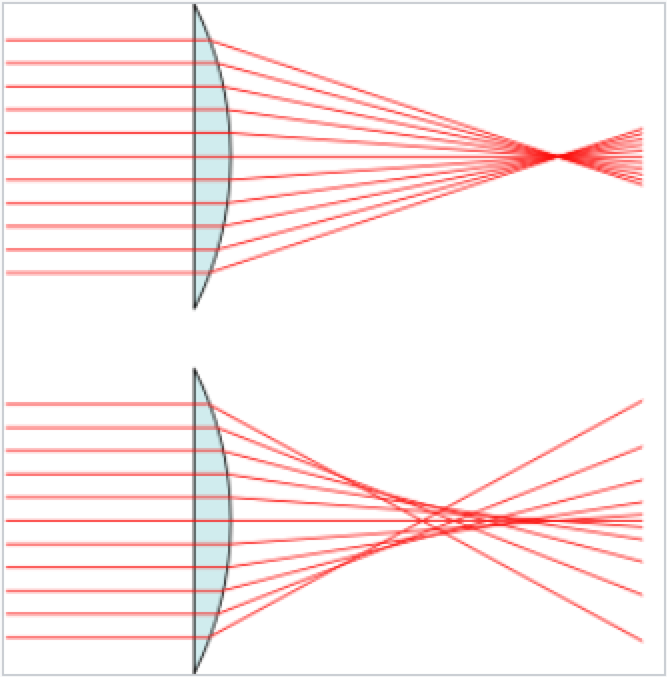
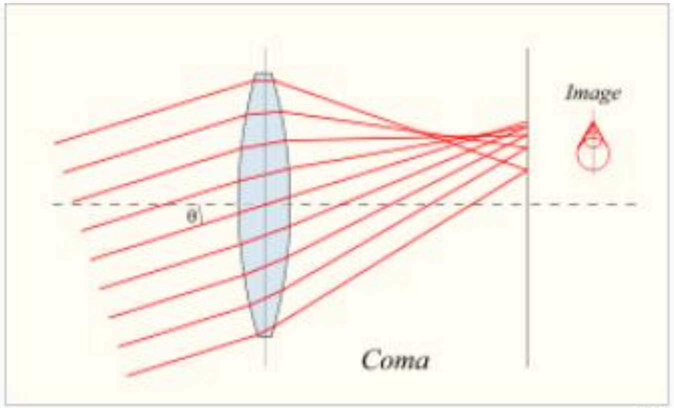
Spheircal aberration

1)



Coma aberration

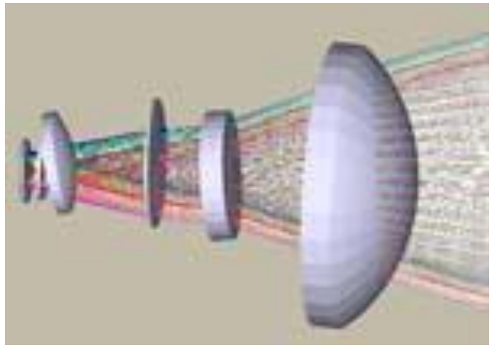
2)



Coma of a single lens

TDI corrector

3)



1) https://en.wikipedia.org/wiki/Spherical_aberration 2) https://en.wikipedia.org/wiki/Coma_(optics)
3) http://www.aeos.ulg.ac.be/LMT/instruments.php

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Introduction

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Supernova rate and ILMT

Figure 1. Left panel: Panoramic view of the ILMT site. The 1.3-m *DFOT* and the 4-m ILMT are in the middle and right side, respectively in this image. Right panel: Major components of the ILMT. Here, the container is gray, the air bearing is red, the three-point mount (white) sits below the air bearing and the vertical steel frames (white) hold the corrector and the CCD camera at the top. The tentative size and other parameters of the telescope are listed in Table 1. Note the nice view on the Himalayan chain in the background of the left photograph.

Figure 2. Fish eye view of the present status of the ILMT. To protect from the dust, the air bearing and the three-point mount are covered with a wooden box (blue colour). Four safety pillars (yellow colour) are also visible near the parabolic container to prevent any mercury spill.

Table 1. Different parameters used to calculate the ILMT limiting magnitude. See also Finet (2013).

Diameter	4.0-m
Fraction of reflecting area	0.95
Reflectivity	0.77
Mylar transmission	0.80
Corrector transmission	0.85
FWHM	$1.5''$
CCD pixel size	$0.4''$/pixel
CCD dark noise	0.00083 e^-/pixel/sec
CCD readout noise	5.0 e^-
CCD gain	4.0 e^-/ADU
Wavelength (g', r', i')	4750, 6250, 7630 Å
Wavelength FWHM (g', r', i')	1450, 1500, 1500 Å
Extinction ($\sim g'$,$\sim r'$,$\sim i'$)	0.21, 0.13, 0.08 mag
Sky mag ($\sim g'$,$\sim r'$,$\sim i'$)	21.3, 20.5, 18.9 mag/arcsec^2
CCD quantum efficiency (g', r', i')	0.70, 0.91, 0.91
Filter transmission (g', r', i')	0.92, 0.95, 0.95
System efficiency, η (g', r', i')	0.55, 0.74, 0.74

- ILMT limiting magnitudes

$$N_{\mathrm{e}} = 3.95 \times 10^{11} \, D^2 \, \lambda_{\mathrm{n}} \, \Delta\lambda_{\mathrm{n}} \, F_0^{\mathrm{n}} \, 10^{-0.4\mathrm{m}} A_{\mathrm{F}} \, \eta$$

$$N = \sqrt{(N_{\mathrm{e}} \, e_{\mathrm{t}} + S_{\mathrm{e}} \, e_{\mathrm{t}} \, n_{\mathrm{p}} + D_{\mathrm{c}} \, e_{\mathrm{t}} \, n_{\mathrm{p}} + R_{\mathrm{n}}^2 \, n_{\mathrm{p}})}$$

$$\mathrm{SNR} = \left(\frac{N_e \times e_t}{N}\right).$$

$$\sigma_{mag} = 2.5 \times log_{10}[1 + 1/\mathrm{SNR}].$$

ILMT limiting magnitudes

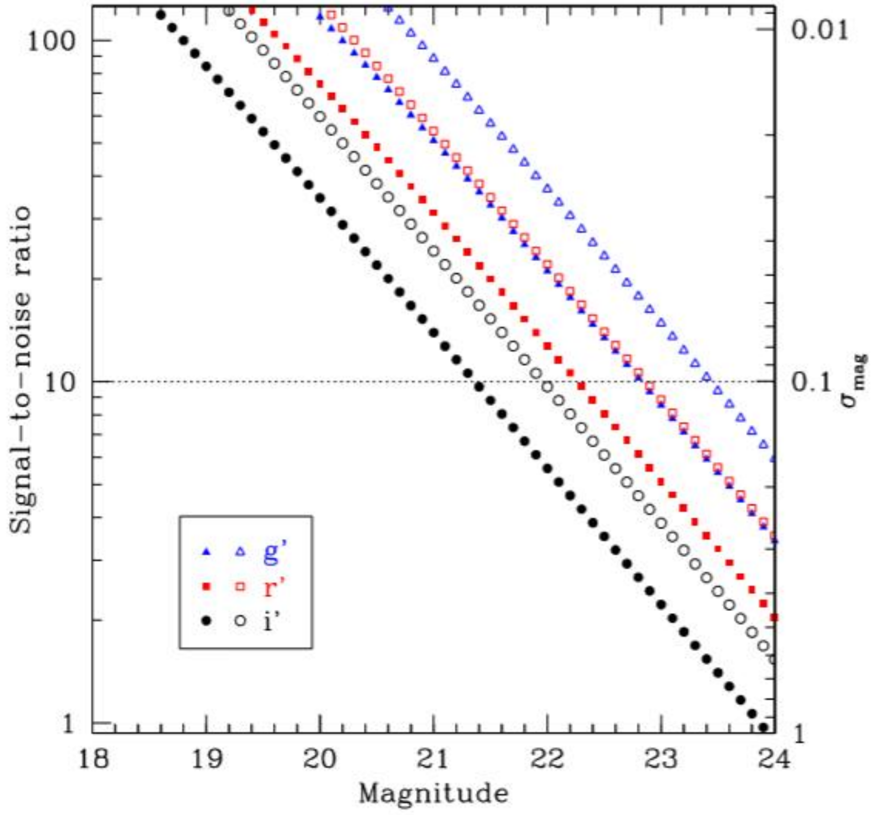

Figure 3. The ILMT limiting magnitudes for the g', r' and i' filters are shown with different symbols. The X-axis represents the limiting magnitude and the Y-axis represents the SNR and the corresponding error in magnitude. The filled and open symbols represent the results for the exposure of a single scan (102 sec) and three scans (306 sec), respectively (see Section 3 for details). The dotted horizontal line is indicative for a SNR of 10 and an uncertainty of 0.1 mag. Approximately 0.5 mag is gained once we stack images taken over three nights in any single filter.

Single scan (102sec)

g' ~ 22.8
r' ~ 22.3
i' ~ 21.4

Three scan (306sec)

g' ~ 23.4
r' ~ 22.8
i' ~ 22.0

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Supernova rate and ILMT

$$(1+z)^{\beta}$$

The supernova detection rate per unit redshift per unit solid angle in a filter band x can be expressed as follows,

$$\frac{dN_{SN,obs,x}}{dt_{obs}dzd\Omega} = R_{\rm SN}(z)\ f_{detect}(z; m^{\rm SN}_{lim,x})\ \frac{r(z)^2}{1+z}\frac{dr}{dz} \qquad (5)$$

where $r(z)$ is the co-moving distance, $R_{SN}(z)$ is the cosmic SN rate which can be written as

$$R_{\rm SN}(z) = \frac{X_{\rm SN}}{\langle m\rangle_{\rm SN}}\ \dot{\rho}_{\star}(z) \qquad (6)$$

where X_{SN} is the fraction of stellar mass which results in supernovae $(=\int_{SN} M\xi(M)dM \big/ \int M\ \xi(M)dM)$, $\langle m\rangle_{\rm SN}$ is the average supernova progenitor mass $(=\int_{SN} M\ \xi(M)dM \big/ \int \xi(M)dM)$ and $\dot{\rho}_{\star}(z)$ is the star formation rate. $\xi(M)$ represents the stellar initial mass function (IMF).

Supernova rate and ILMT

Table 2. SN detection rates with the ILMT. 1_N, 3_N and 6_N indicate the number of SNe for the limiting magnitudes of single, and co-added images of 3 and 6 nights, respectively. Total number of SNe (columns 6, 7 and 8) are the redshift integrated events in a year (only 160 photometric nights of the site and an average 8 hours of observing time each night have been accounted for).

SN Type	Filter	SNe/deg^2/year			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