# The Large Array Survey Telescope

**Ruslan Konno**
On behalf of the LAST collaboration

Astro-COLIBRI workshop, Orly

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www.weizmann.ac.il/wao

# Designing a cost effective survey instrument

- **What is a survey instrument supposed to do?**
- One useful measure – the grasp
  - Volume per unit time in which a standard candle is detectable

$$G = \Omega A^{3/4} \sigma^{-3/2} \frac{t_E^{3/4}}{t_E + t_D}$$

Ofek & Ben-Ami, PASP 132, 2020

$\Omega$… FoV
$A$… effective area
$\sigma$… seeing or pixel-size
$t_E$… exposure time
$t_D$… dead time

- Dependency on $A$ is to the power of < 1
  - Cost of a telescope is relative to $A$ to the power of > 1

# Designing a cost effective survey instrument

- *N* smaller telescopes will be more cost-effective than a larger telescope with the same grasp
  - Nothing new, claim also holds when using étendue

- How small can the telescopes be?
  - Aperture > 20-cm; otherwise telescope is diffraction limited

- However**!** Larger FoV on smaller telescopes requires shorter focal lengths

  → Resolution suffers, PSF may no longer be Nyquist sampled

  - e.g. a 30-cm f/2 telescope requires 3 μm pixels for 1” pix$^{-1}$
  - <4 μm pixel cameras only started entering the commercial market in ~2019

# Large Array Survey Telescope (LAST)

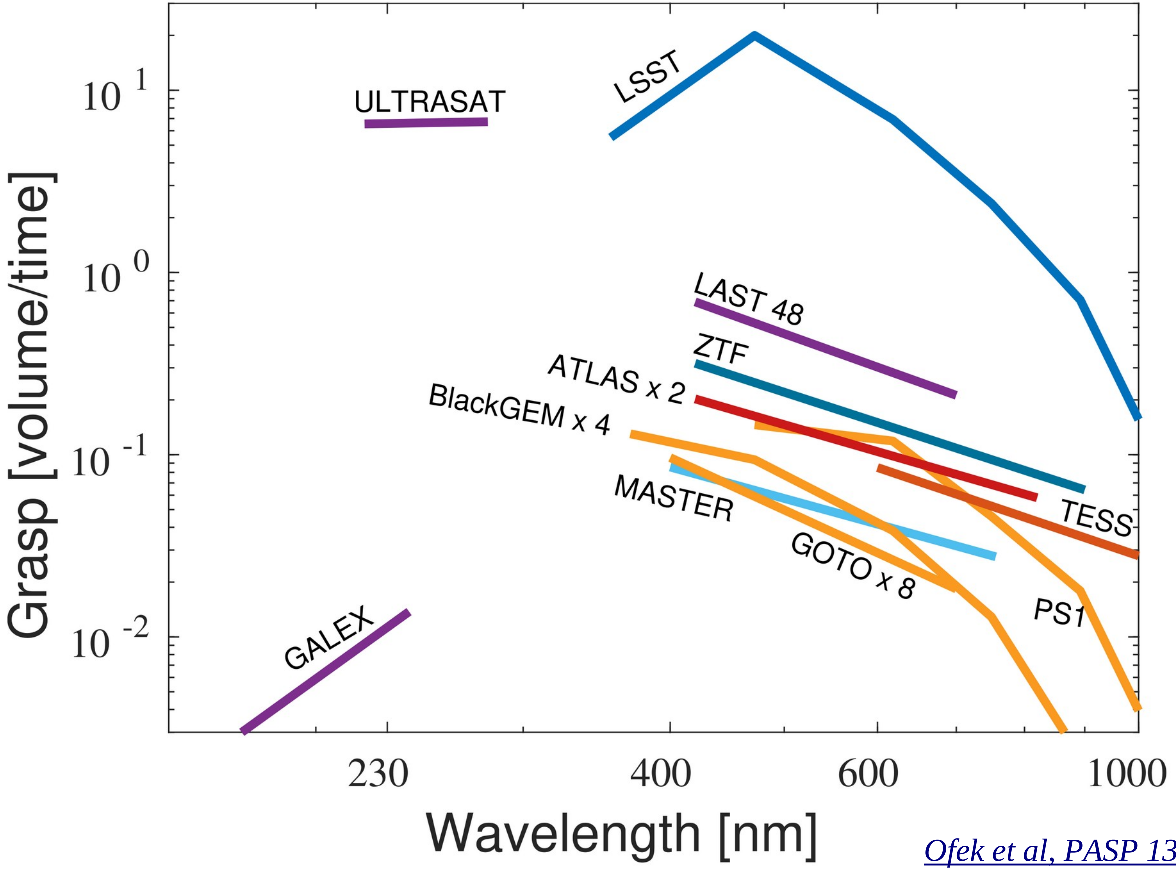

- Optical survey instrument
- Array of small telescopes with small pixels and wide FoV
  - 28-cm f/2.2
  - 3.6 μm pixels
    → 1.”25 $pix^{-1}$
  - 61 Mpix (9600x6400)
    → 7.4 $deg^2$ FoV
- 4 telescopes per unit
  - (Mostly) commercial parts


QHY600

# Large Array Survey Telescope (LAST)

- First node being constructed in Israeli Negev Desert
- Envisioned to consist of 48 telescopes (12 units)
  - Total FoV of 355 deg$^2$
  - 32 are deployed and operational
- Total node cost at $1.5M
  - All hardware and construction

# Grasp of survey instruments




[Ofek et al, PASP 135, 2023]

# Advantages and disadvantages

- Modular and scalable
- Off-the-shell components are cheap
- Easy to modify (e.g. filters, polarizers)
- Failure points generally isolated

**But!**

- Many failure points (several computers, cameras, focusers,…)
- High data rate
  - 8640 images per hour → 2.2 Gbit/s (large chip, small pixels)

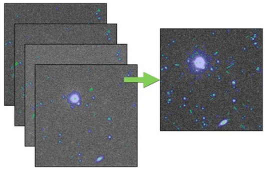
    → Need for highly efficient procedure and pipeline

    → Existing code too slow; in-house software - AstroPack

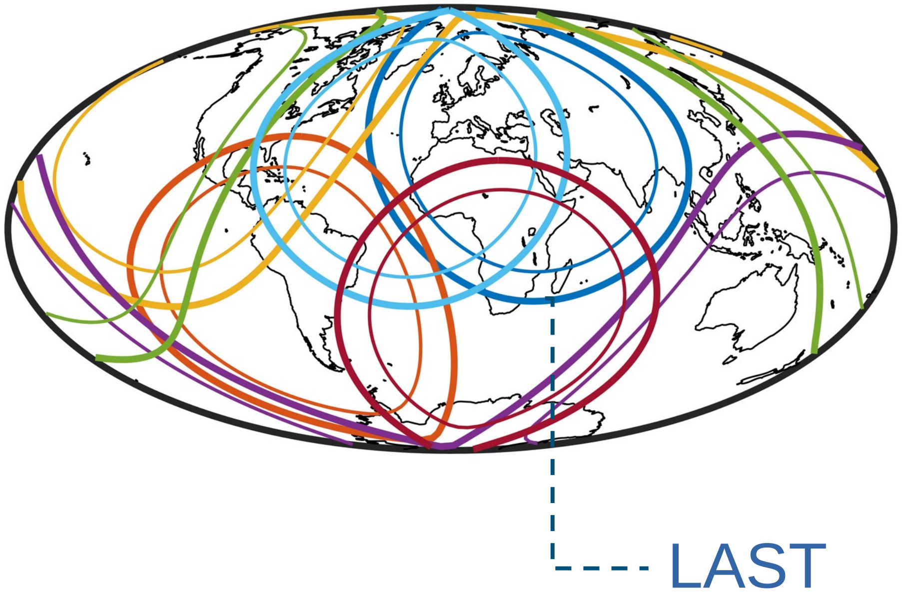

AstroHaven

# LAST survey mode

- Scan the sky in visits
  - 20x20 s exposures per visit
  - Images are coadded



- Limiting magnitude of 19.6 (20.8) mag in 20 (20x20) s exposure
- With a wide FoV of 355 $deg^2$
  - → scanning speed of 17,640 $deg^2$ per night
  - → cadence of visible sky every 1.4 days
- Covers the Asiatic gap
- No filter (clear), AB system

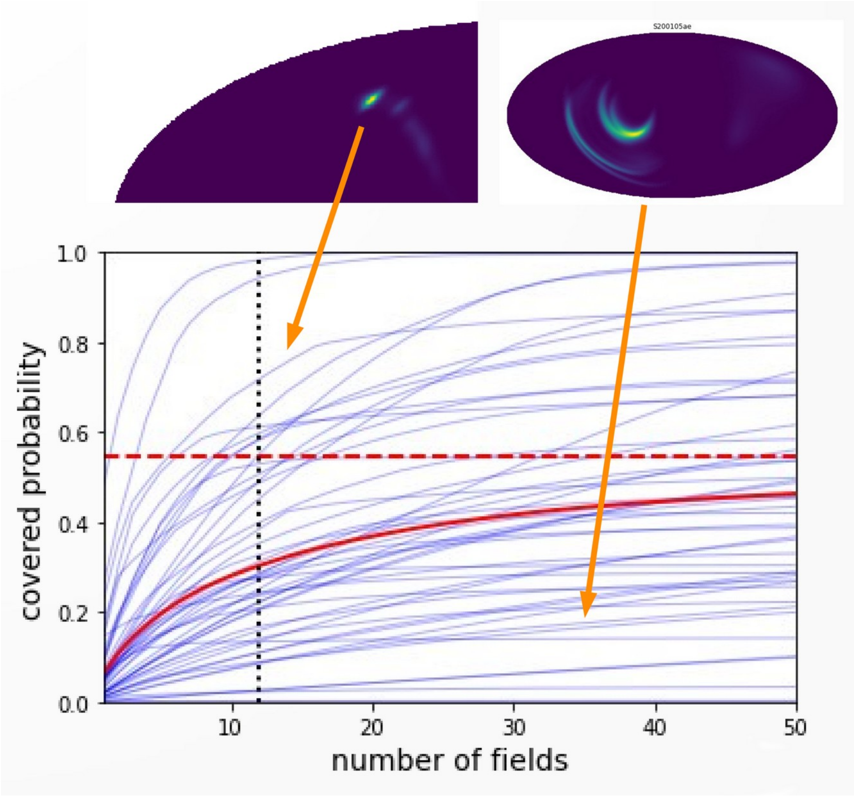


# Science goals

- Primarily transients detection via survey mode
- Follow-up
  - GWs, SNe, GRBs, flares,…
- Cosmology (lensing and time delays)
- Exoplanet, stellar activity, stellar systems
- Solar system + Oort cloud
- Strength: short time scales

# Localization large uncertainty areas (GWs,GRBs,..)

- 12 unit fields can cover 355 deg$^2$ at once
- Error regions of O3 alerts
  - 355 deg$^2$ corresponds to ~55% of observable error region for average alert
- 24 fields: 70%; 36 fields: 78% …
- Up to 648 fields per night observable



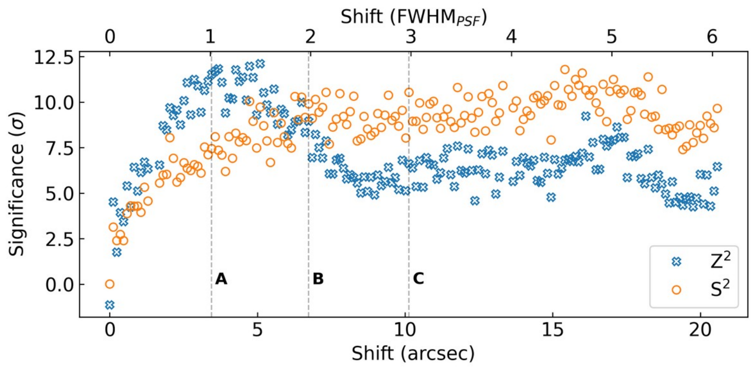

Credit: Nora Linn Strotjohann

# Transients search

- Transients search via proper subtraction (ZOGY) [*Zackay, Ofek & Gal-Yam, ApJ 830, 2016*]
- Aim to identify real transients without machine learning
  - Using either hypothesis tests or heuristic methods
    - Example: registration errors

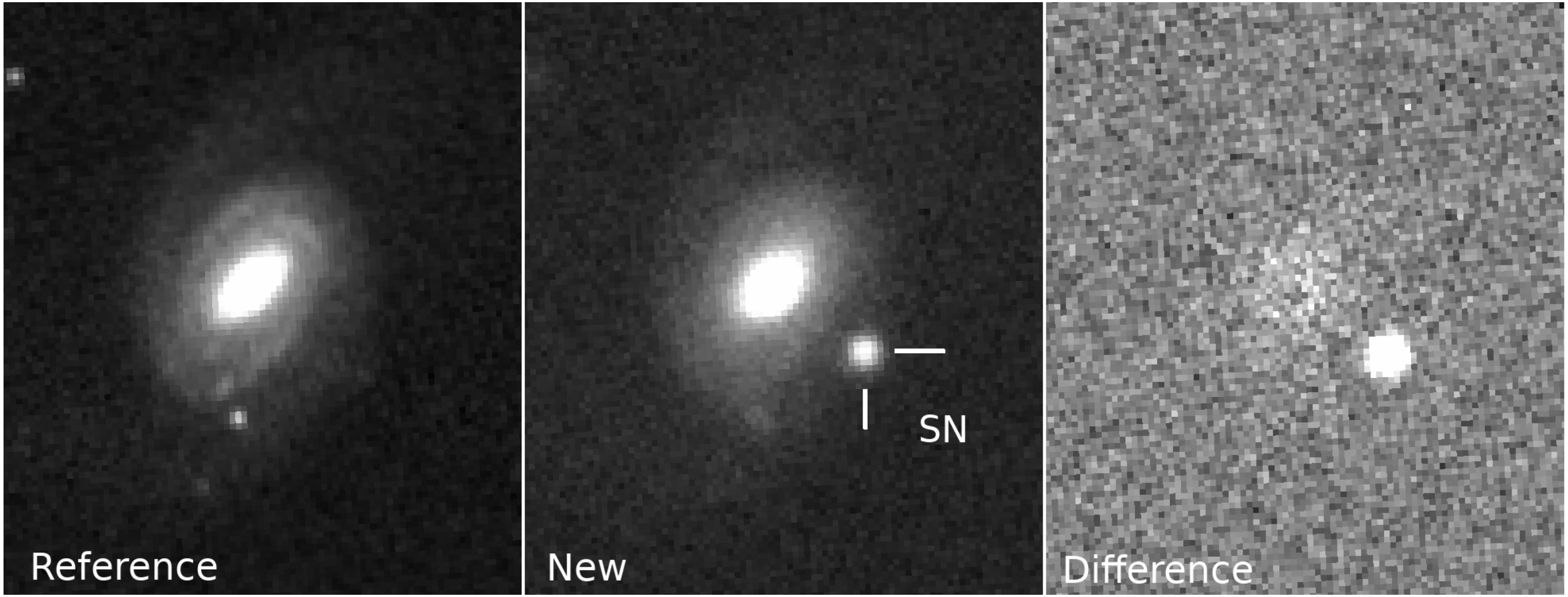
      → New vs moving source statistic (*translient*)

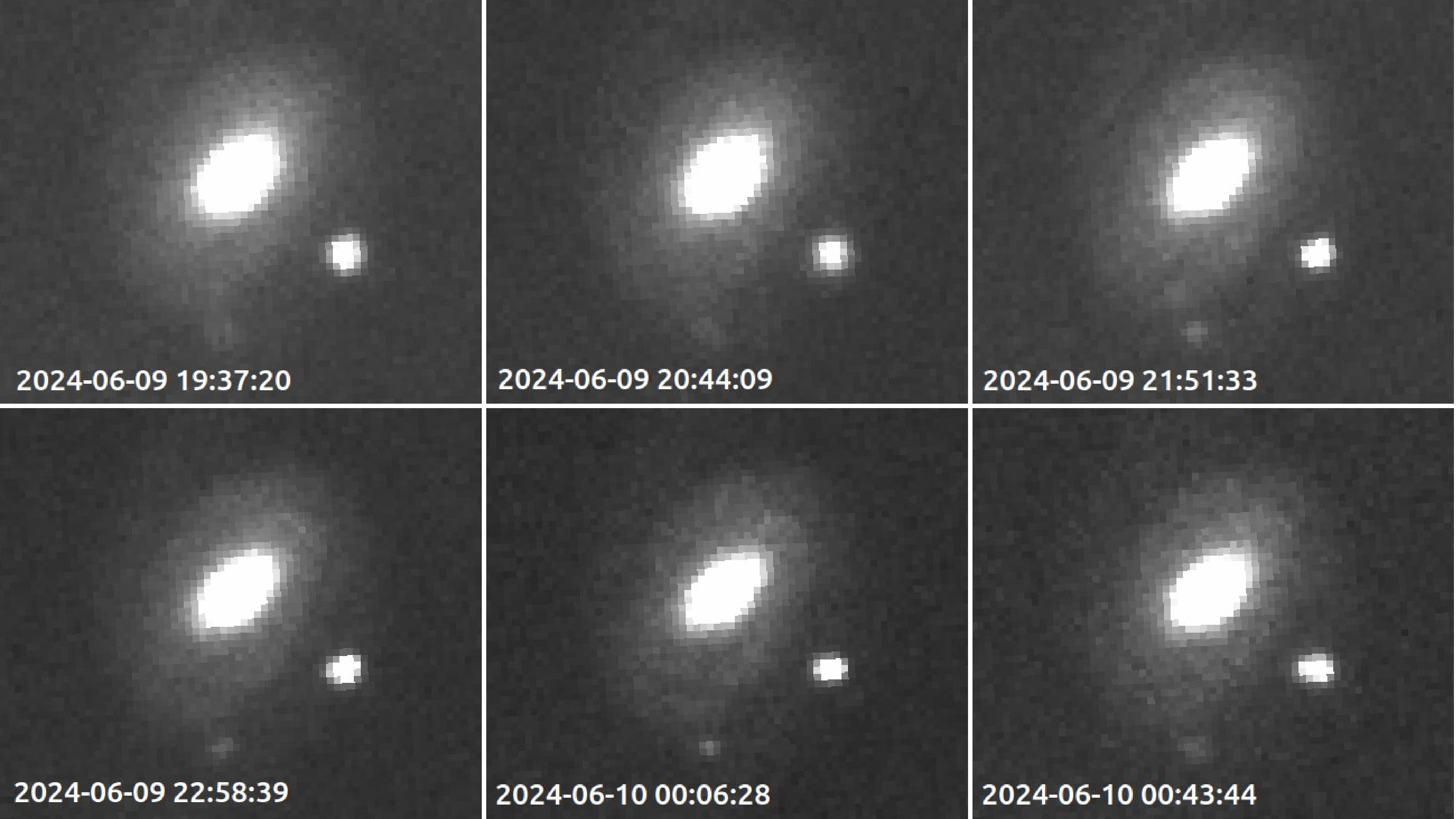
      [*Springer et al., AJ 167, 2024*]




  - Estimated efficiency of > 80% and purity of > 90%
- First four weeks of survey observations; 28 transients reported to TNS

# Transients search

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2024-06-09 20:44:09
2024-06-09 21:51:33
2024-06-09 22:58:39
2024-06-10 00:06:28
2024-06-10 00:43:44

# Current status

- Construction of a new enclosure which will be able to house 72 telescopes
  - Full array by Q4/2025
  - Additional enclosures for further instruments
    - Multi-Aperture Spectroscopic Telescope (MAST): Spectroscope fed by several 60-cm telescopes via optical fibers
    - Panchromatic Survey Telescope (PAST): Array of 35-cm telescopes with 8 broad overlapping wavebands

- LAST in general running from data taking to alert production.
  - However, still in engineering phase and not ready for full automatization.

# Summary

- LAST is an under construction cost-effective optical sky survey
- Will study the unexplored phase space of fast transients
    - High FoV – up to 355 $deg^2$
    - High cadence – 1.4 d cadence for visible sky
- Will be part of a larger facility with follow-up instruments, MAST and PAST

The First LAST Node System's Parameters

| Property | Value |
|---|---|
| Number of telescopes (planned; 2023 June) | 48 |
| Number of telescopes (2023 March) | 32 |
| Telescopes per mount | 4 |
| Telescope aperture | 279.4 mm |
| System equivalent aperture | 1.9 m ($\cong 0.28\sqrt{48}$) |
| Telescope focal length | 620 mm |
| Pixel scale | $1\farcs25$ $pix^{-1}$ |
| Telescope FoV | $2.2 \times 3.3$ deg $\cong 7.4$ $deg^2$ |
| System FoV | 355 $deg^2$ |
| Total number of pixels | $\cong 2.9 \times 10^9$ |
| $B_p$ Limiting magnitude ($5\sigma$ in 20 s) | $\approx$19.6 mag |
| $B_p$ Limiting magnitude ($5\sigma$ in $20 \times 20$ s) | $\approx$21.0 mag |
| Location | Neot-Smadar, Israel |
| Longitude (WGS84) | 35.0407331deg E |
| Latitude (WGS84) | 30.0529838deg N |
| Height (WGS84) | 415 m |

# Backup