BlackGEM Telescope array

- Gravitational wave counterparts
- Six-band Southern All Sky Survey
- Three-band Synoptic Survey
- Nearby Universe monitoring program

At ESO La Silla
- Three telescope array in Phase 1
- Operational end 2018
- Expansion to 15 in Phase 2

PI  Paul Groot
PM  Steven Bloemen
PS  Peter Jonker
Science:
- **Gravitational wave counterparts**
- Southern All Sky Survey
- Fast Transients & Variables
- Nearby Universe Survey

Phase 1:
- 3 wide field telescopes (8.1 square degr. total)
- Primary mirror: 65cm diameter
- Sensitivity: \( g=23 \) in 5 minutes
- Location: ESO La Silla
- Optical quality: seeing limited, 0.9” median
- Camera: 1 CCD/telescope, 10k x 10k, 0.56”/pixel
- Filters: \( u,g,q,r,i,z \) filter set, change in 3s

Phase 2:
- Expansion to 15 telescopes
- 40 square degrees total field of view (@ 0.56”/pix)
- Location: ESO La Silla; or combi ESO, NZ and SA
BlackGEM Unit telescope

- Wynn-Harmer design incl. M2 on tip-tilt piezo stage
- 110 Mpix camera (1 STA 1600 chip)
- 2.7 square degree field-of-view
- 10 second readout + filter change + repointing
- Carbon-fibre structure
- Atmospheric Dispersion Corrector in triplet lens barrel
- Fornax 200 mount
- Fully robotic
- Cooled electronics, in counterweight
CCD & Filters

- STA1600, 10.5k x 10.5k CCD, 9 μ pixel : 110 Mpixel chip
- Scale on sky: 0.562”/pix, total field of view: 2.7 sqd/telescope
- Readout time: 7 seconds (at 1 MHz on 16 ports), RON: 5.5 e-

Filters:
Sloan u,g,r,i,z filters plus broad-band q (440-720nm)

SN19616 Quantum Efficiency

![SN19616 Quantum Efficiency](image)

![Filters Graph](image)
4.5m Clam-shell dome

7m high

Raster floor

Outer tube holds dome

Inner tube holds the telescope

Ventilation openings

TiO coating on outside to prevent daytime heating

Separate foundations

Will replace GPO Building @ESO La Silla
BlackGEM Surveys

BlackGEM Southern Sky Survey: ‘Southern Sloan’

→ 30 000 sqd down to 22$^{nd}$ mag in $u,g,q,r,i,z$ at 1” median seeing
→ By itself a fantastic resource for all kinds of science:
  (galactic streams/structure, dwarf galaxies, stellar populations, 'gems',
   quasars, weak lensing, high-z galaxies, etc.)
→ Includes a 1-minute integration q-band scan of available Southern Sky (10000 sqd)
  every two weeks, down to q~21.5

• BlackGEM Fast Synoptic Survey: 'Kepler on steroids'
  → High cadence (1 min), multi-colour (simultaneous), wide-field
  → Kepler Short Cadence-type sampling on millions of objects
  → Deep drilling fields: thousands of exposures over weeks time-scale
  → Flexibility for experiments: continuous read-out, six filters, etc.
  (fast transients, asteroids, KBOs, early SN, interacting binaries, eclipses etc.)

• BlackGEM Twilight Program
  → Every twilight (30 minutes) Local Universe galaxies in 3 bands ($u,q,z$) for new transients
    (incl. SMC/LMC, Fornax Cluster, Cen A/M83 group, etc.). Fifteen fields (120sqd) per twilight.

• BlackGEM Trigger Mode: 'Transients Galore'
  → GW error box coverage in multiple colours
  → 100s of sqd in multiple times over ~week time scale down to $g=23$
    (TDEs, SN of all types, Dwarf Novae, SN .Ia, SN Iax, etc.)
BlackCloud: A cloud solution

- Data flow pipeline based on *subpipe* data reduction flow SkyMapper

- Aim is to make all BlackGEM data instantly accessible:
  - A live database of any transient is maintained 'on the fly', live processing of 'previous' image during the night, instant alerts (T+5min)
  - All images kept on (spinning) disk for re-reductions and target photometry at any time
  - A live database of all sources, including variability.

- Complete set-up ideal for *cloud solution* on compute, database, storage BlackGEM data: the *BlackCloud*.

- 1.8 Pb of data storage, 150 Tbyte of live database (3 telescopes)
Principal Investigator: Paul Groot (Radboud University)
Project Scientist: Peter Jonker (SRON/Radboud University)
Project Manager: Steven Bloemen (Radboud University)

Consortium Institute Partners in Phase 1:

NOVA = Amsterdam, Leiden, Groningen, Radboud

Radboud Universiteit

KU Leuven

Manchester U., Tel Aviv U., U Canterbury, UC Davis, Weizmann, Hebrew U, Northwestern committed at PI-level

Possibility for new partners (for 5 year operation):
• 150 kEuro to join at PI-level (one faculty member + PDRAs/PhDs)
  (all data, science team, lead science case)
• 1 MEuro to join at Institute level (full institute)
  (all data, science team, lead science case, consortium board)

→ Combinations with in-kind contributions (e.g. follow-up telescope time) possible

www.blackgem.org ; @BlackGEM_Array
Operational at SAAO Sutherland

See @MeerLICHT_ZA on Twitter and www.meerlicht.org for more pictures
Guide cameras & Filters

- 3 Guide cameras
- Filter wheel
Filter performance

All exposures 5 seconds, unguided, on Pole

Reflection on backing structure CCD
First light on sky

Polaris

1.65°

Pole
M16 / Eagle Nebula

Full frame colour composite of M16/Eagle nebula

1.6d x 1.6d field-of-view
<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prototype testing @Radboud</td>
<td>February 2017</td>
</tr>
<tr>
<td>Shipment MeerLICHT prototype → ZA</td>
<td>June 2017</td>
</tr>
<tr>
<td>Commissioning MeerLICHT @SAAO</td>
<td>August-December 2017</td>
</tr>
<tr>
<td>Start operations MeerLICHT</td>
<td>January 2018</td>
</tr>
<tr>
<td>Final Design Review BlackGEM</td>
<td>March 23/24, 2017</td>
</tr>
<tr>
<td>Manufacturing BlackGEM-Phase1</td>
<td>March 2017 – March 2018</td>
</tr>
<tr>
<td>Shipment BlackGEM → Chile</td>
<td>May 2018</td>
</tr>
<tr>
<td>Commissioning BlackGEM-Phase1</td>
<td>Sept-Nov 2018</td>
</tr>
<tr>
<td>Start operations Phase1</td>
<td>December 2018</td>
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Future plans

- Expansion of BlackGEM to 15 telescopes (requires additional 15 MEuro)
- Chile, or NZ and/or Southern Africa
- Development/addition of low-cost spectroscopic telescopes