

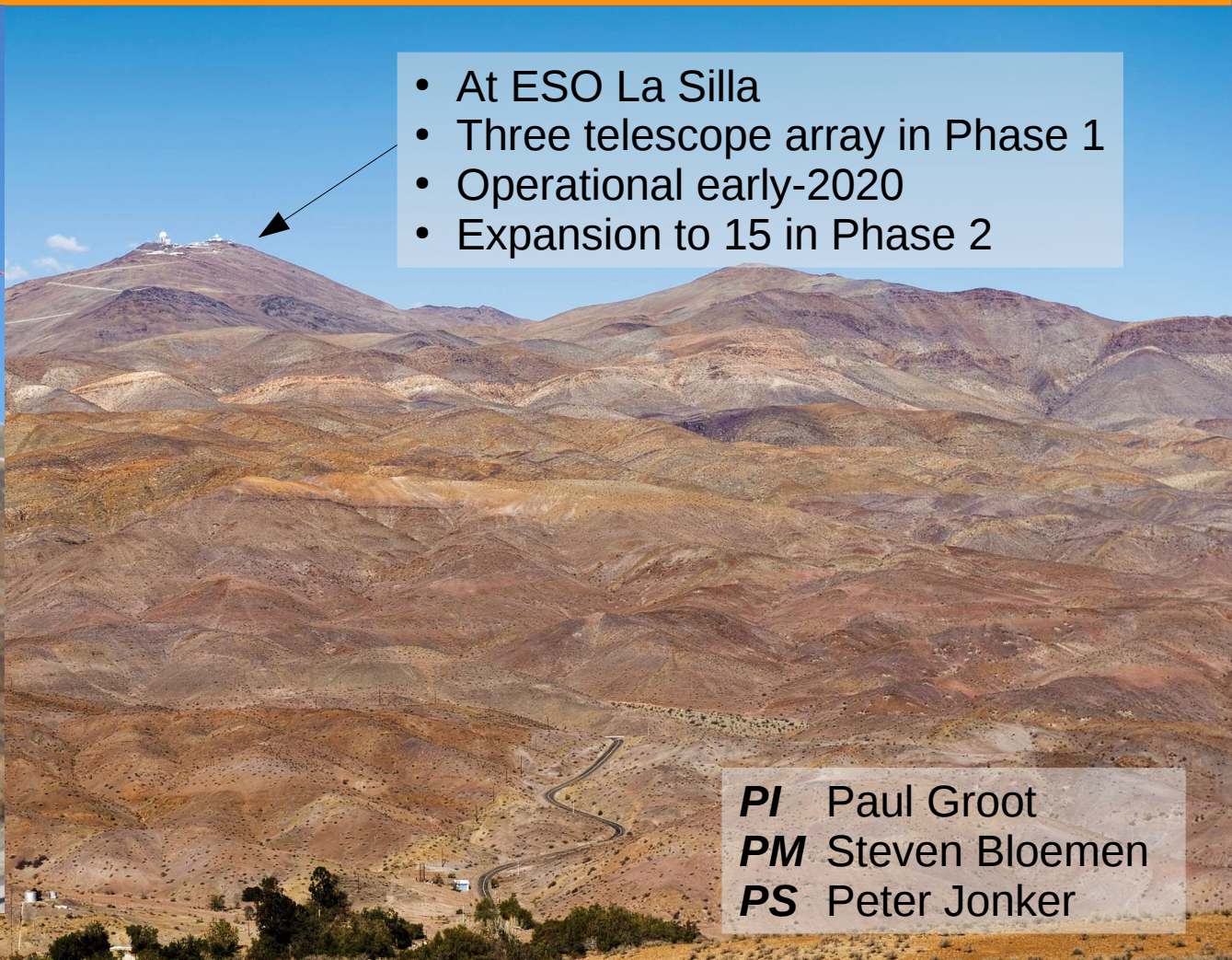


BlackGEM Telescope array



Second BlackGEM telescope
Being installed at La Silla

- At ESO La Silla
- Three telescope array in Phase 1
- Operational early-2020
- Expansion to 15 in Phase 2



PI Paul Groot
PM Steven Bloemen
PS Peter Jonker



Radboud University





BlackGEM

Science:

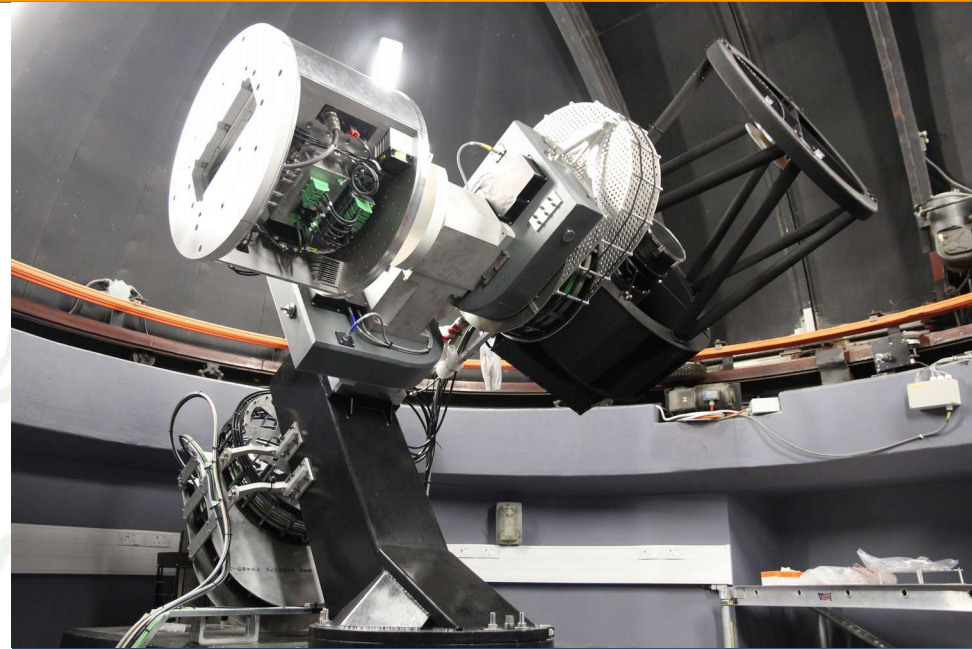
- **Gravitational wave counterparts**
- Southern All Sky Survey
- Fast Transients & Variables
- Nearby Universe Survey

Phase 1:

- 3 wide field telescopes (8.1 square degr. total)
- Primary mirror: 65cm diameter
- Sensitivity: $q=23$ in 5 minutes
- Location: ESO La Silla
- Optical quality: seeing limited, 0.9" median
- Camera: 1 CCD, 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 Team & Consortium

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., TexasTech University, UC Davis, Weizmann, Hebrew U, Potsdam, Danish Technical University, Trinity College Dublin, committed at PI-level
Chilean participation: U Valparaiso + 1 tbd.

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)

→ Institute Level combinations with in-kind (e.g. follow-up telescope time) possible

www.blackgem.org ; @BlackGEM_Array

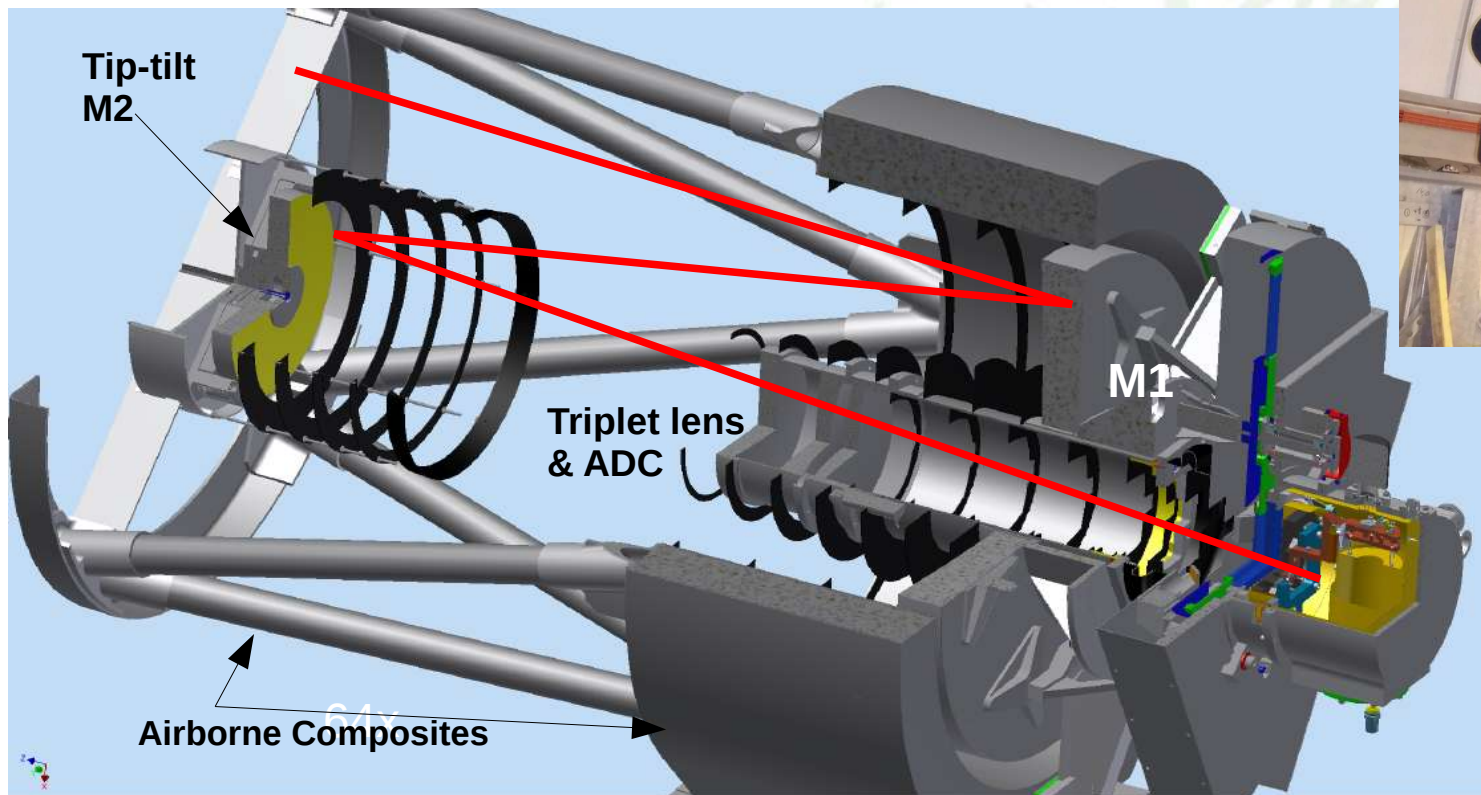


BlackGEM Unit telescope

- Harmer-Wynne design incl. M2 on tip-tilt piezo stage
- 110 Mpix camera (1 STA 1600 chip)
- **2.7 square degree field-of-view @ 0.56"/pix sampling**
- 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



Finished Prototype

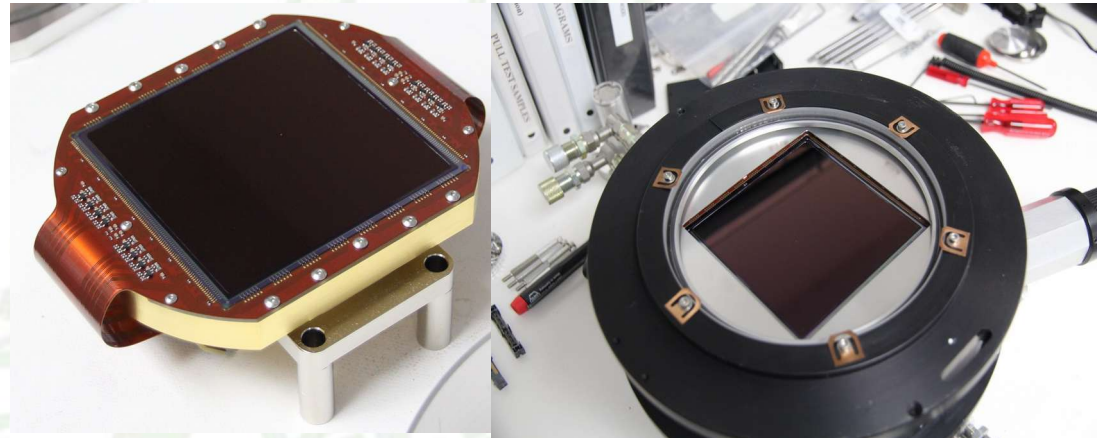
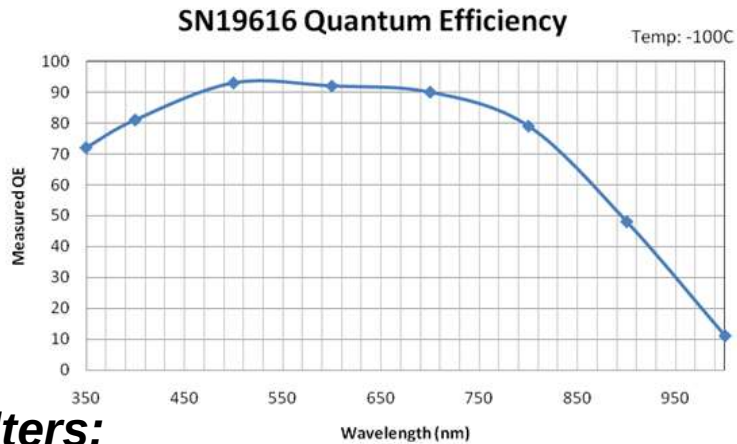


Design



CCD, Filters, Coatings

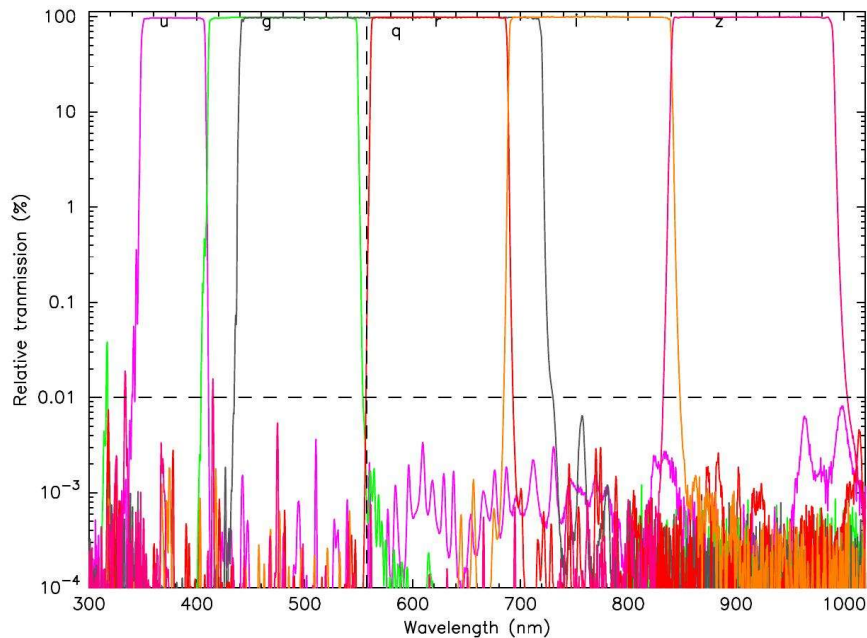
- STA1600, 10.5k x 10.5k CCD, 9 μ pixel : 110 Mpixel chip
- Scale on sky: 0.56"/pix, total field of view: 2.7 sqd/telescope
- Readout time: 7 seconds (at 1 MHz on 16 ports), RON: 5.5 e-



Filters:

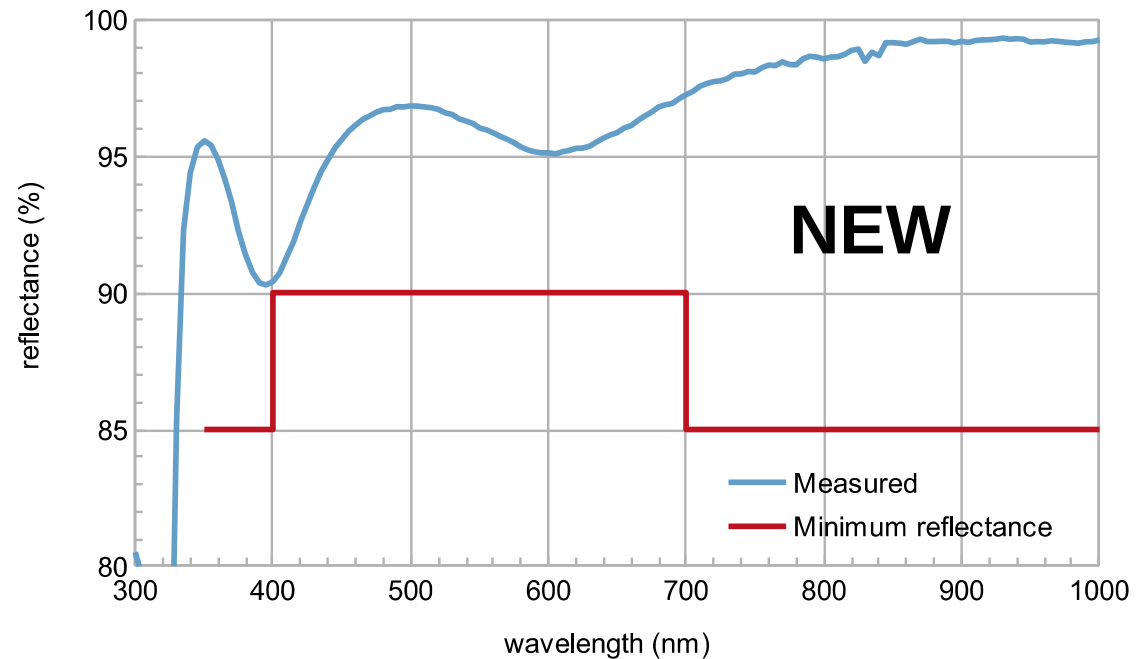
Sloan filters plus broad-band q (440-720nm)

Astrodon BlackGEM set (BG-u,BG-g,BG-r,BG-i,BG-z and BG-vr (=q))



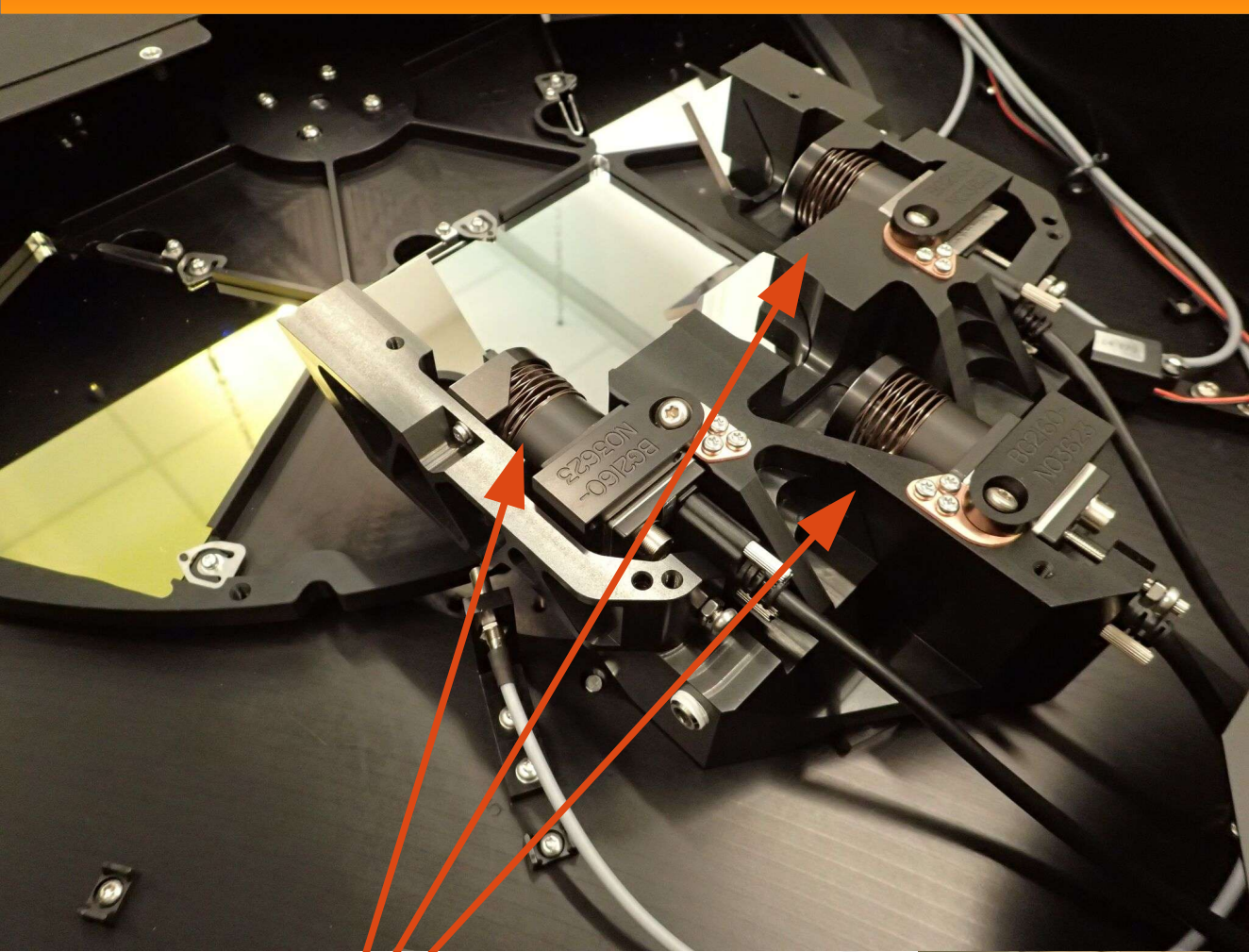
Coatings:

TNO protected silver coatings M1 & M2





Guide cameras & Filters



3 Guide cameras

Filter wheel



Dome & Tower

5m clam-shell dome

5m high

Raster floor

Outer tube holds dome

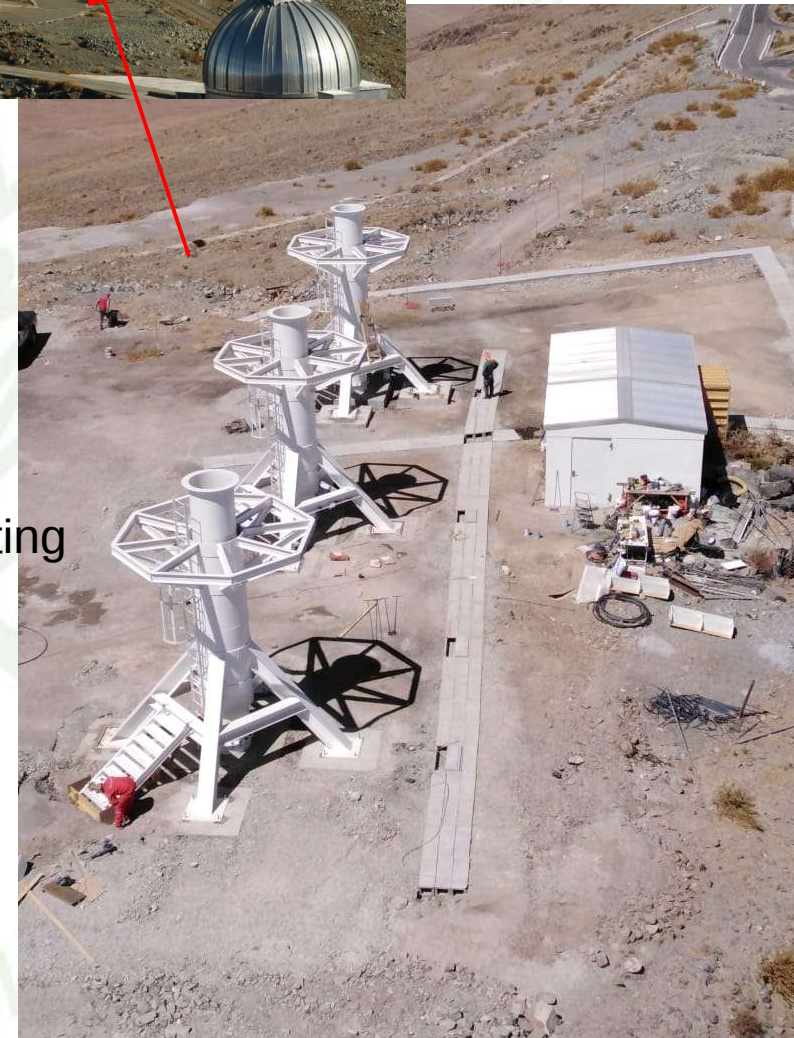
Inner tube holds the telescope

Ventilation openings

TiO coating on outside to prevent daytime heating

Separate foundations

White ground

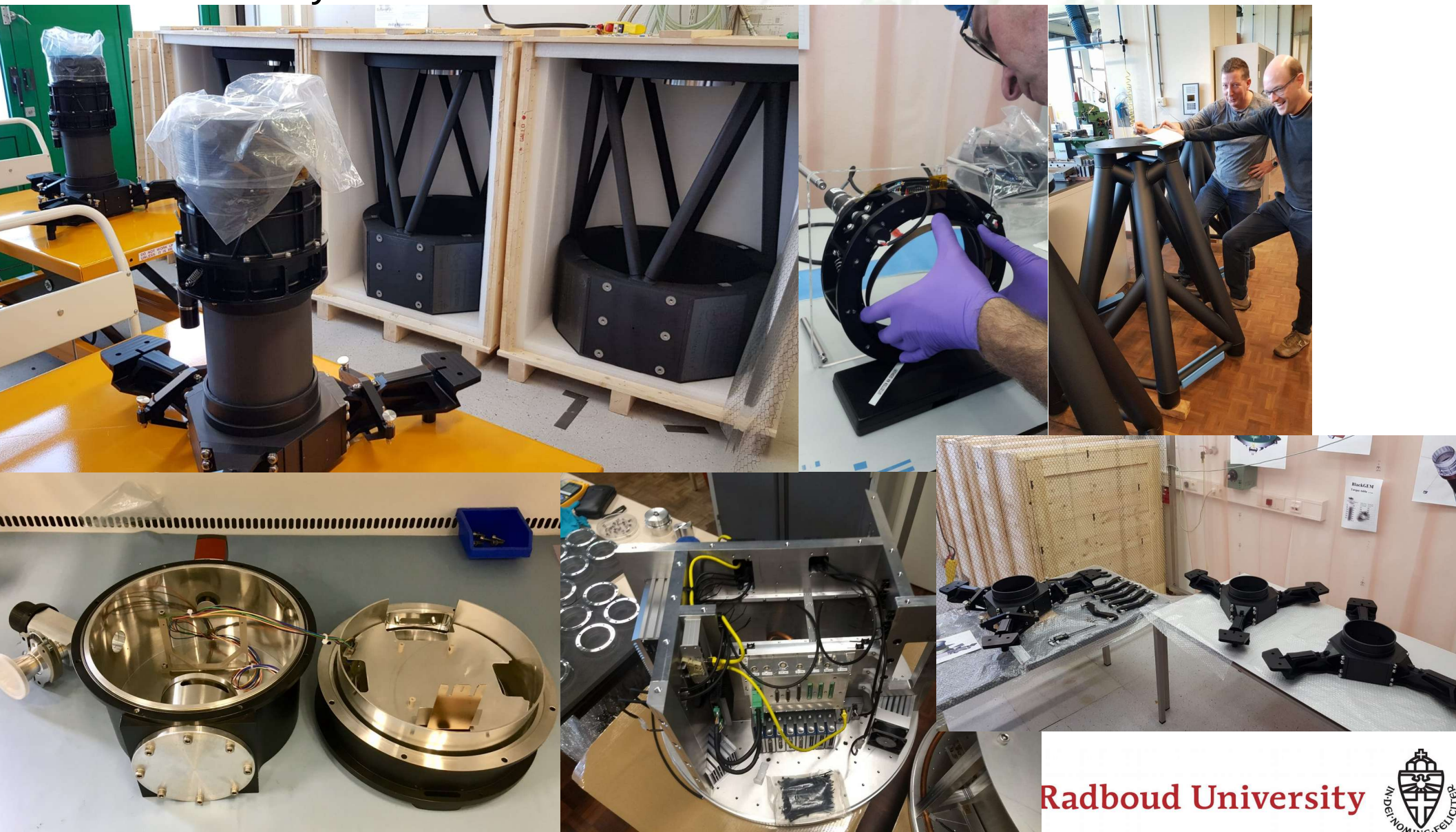




BlackGEM



Three telescopes assembled in Nijmegen/Groningen/Leuven, shipped to La Silla in May 2019





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At La Silla towers installed in
Early 2019



Radboud University





August 23, 2019



Radboud University





August 28, 2019



Radboud University





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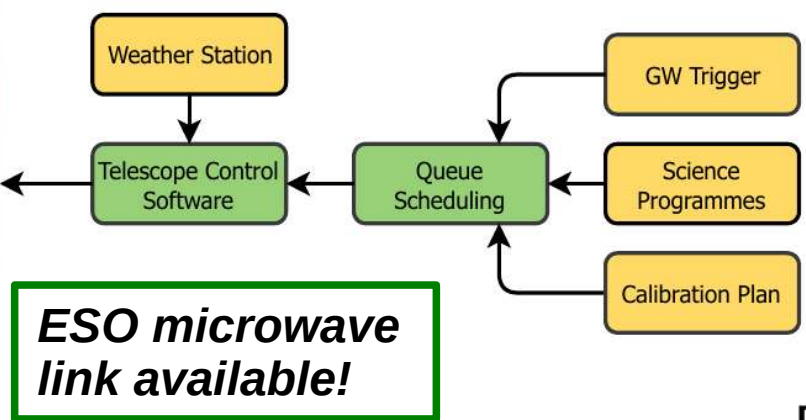


First two telescopes installed in August 2019 @ La Silla
Third telescope to come in November (awaiting dome)
Commissioning until end 2019
Start Science Verification in early 2020



Radboud University

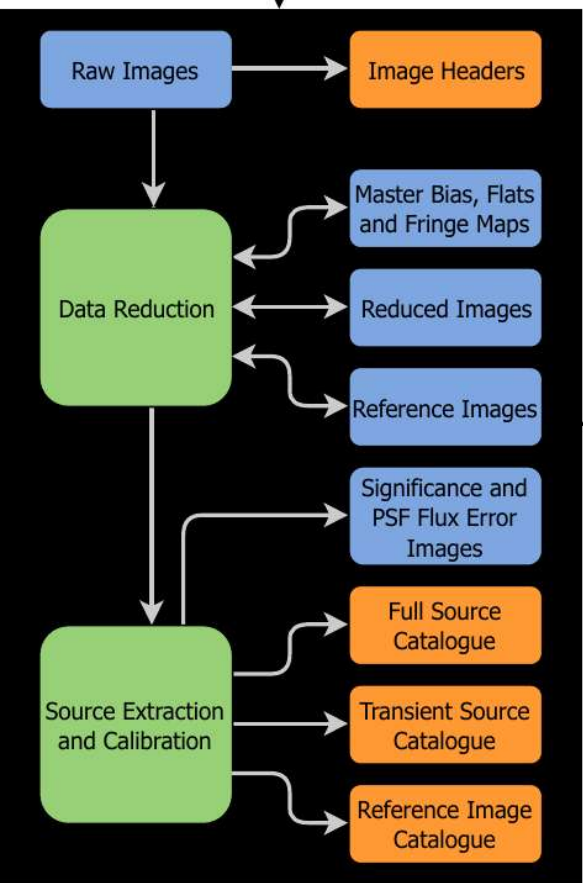




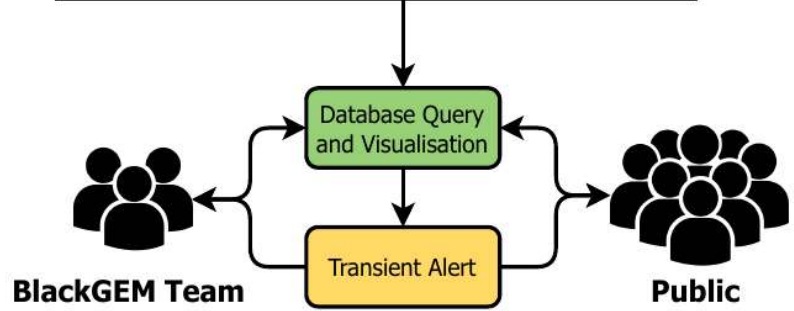
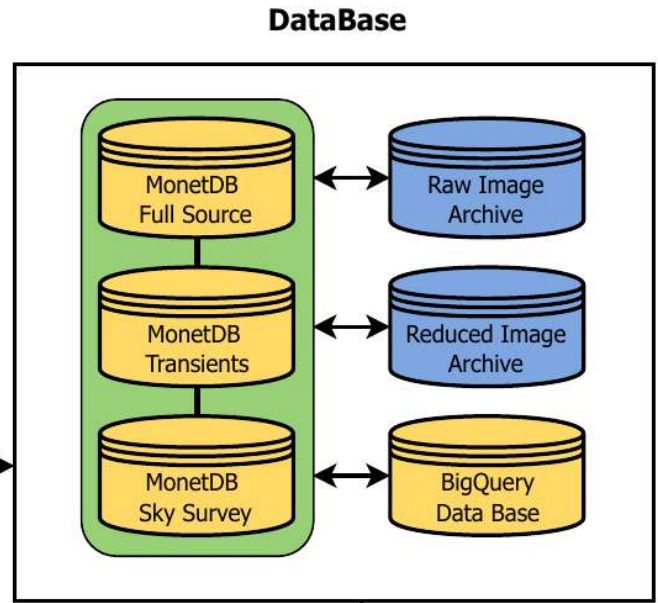
ESO microwave link available!



BlackGEM Data Flow



BlackBOX



Data available within 15 minutes from taking

MUNMEEGEN · 2019



BlackGEM Programs

- **BlackGEM Trigger Mode: 'Transients Galore'**
 - GW error box coverage in multiple colours (u, q, i)
 - 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.)
- **BlackGEM Southern Sky Survey: 'Southern Sloan', in collaboration with ESO**
 - 30 000 sqd down to 22nd 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 ~5000 sqd every 2nd night, down to $q \sim 21.5$**
- **BlackGEM Fast Synoptic Survey: 'Kepler on steroids'**
 - High cadence (1 min), multi-colour (u, q, i), 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 Local Transient Program**
 - Every twilight and every 3 hrs Local Universe galaxies in 3 bands (u, q, i)
(incl. SMC/LMC, Fornax Cluster, Cen A/M83 group, etc.). 50 square degrees, selected





BlackGEM GW counterparts

BlackGEM covers 100 square degrees in 2 hours in 1 filter down to $q=23$

- Use **ranked tiling** for selection area on sky (see Ghosh, S., et al., 2016)
- No priority-ranking on galaxies. For $d > 100$ Mpc: $\Sigma_{\text{gal},100\text{Mpc}} > 1 \text{ sqd}^{-1}$
- Transients announced like normal transients (i.e. public in 15 minutes)
- Will follow the location in the sky of ~ 1 week
- Multi-band observations require **smaller area/lower cadence/shallower/more telescopes**

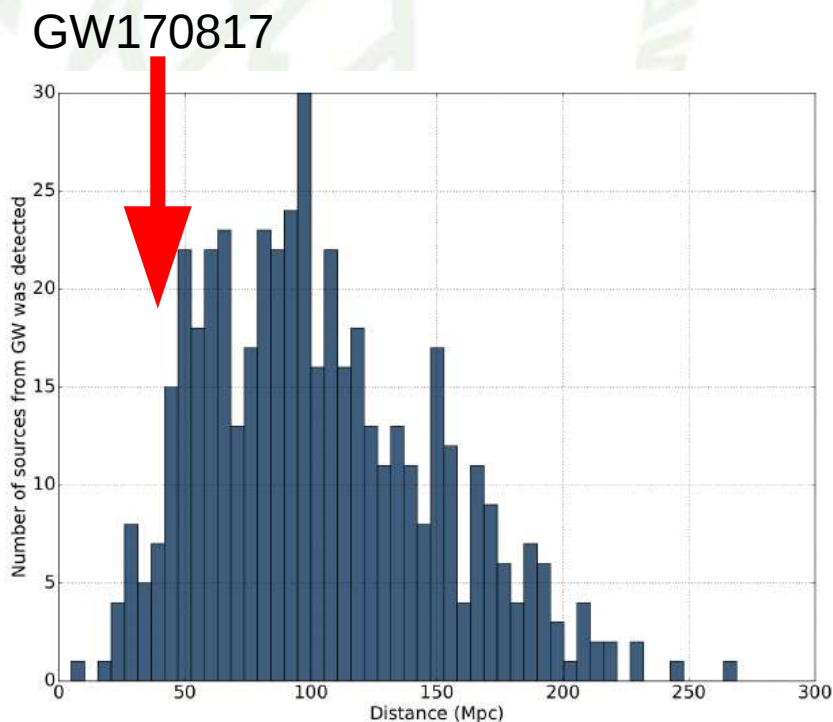
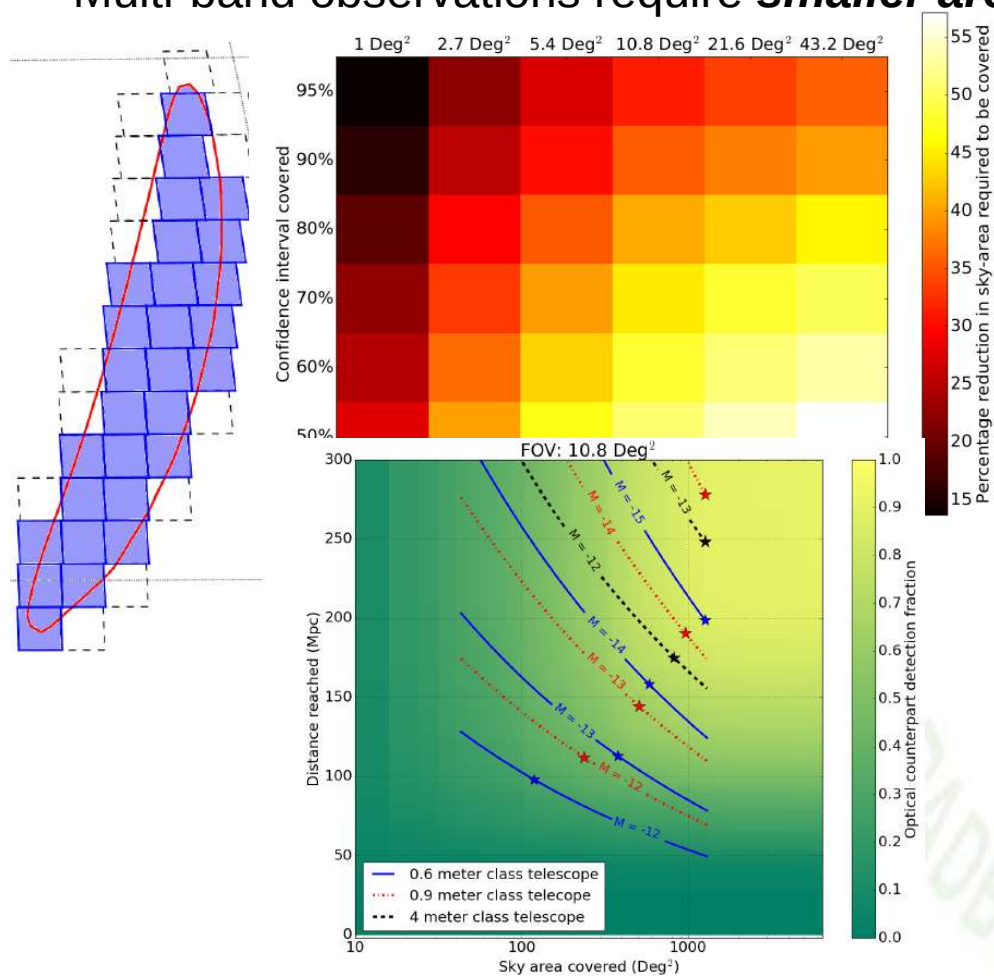
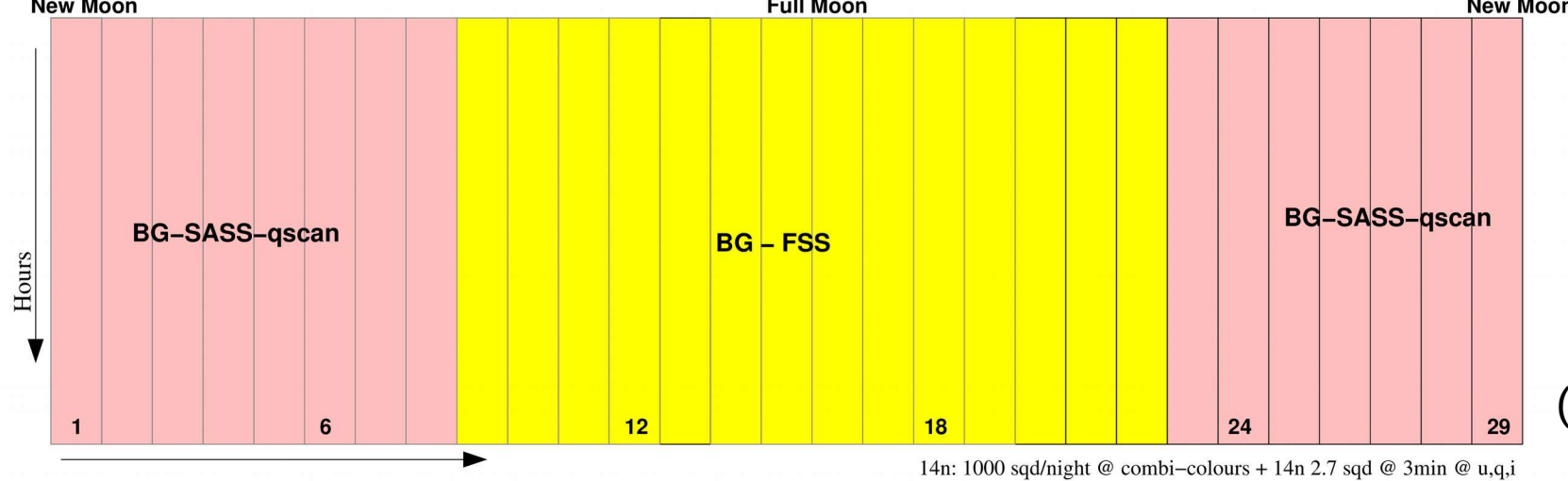
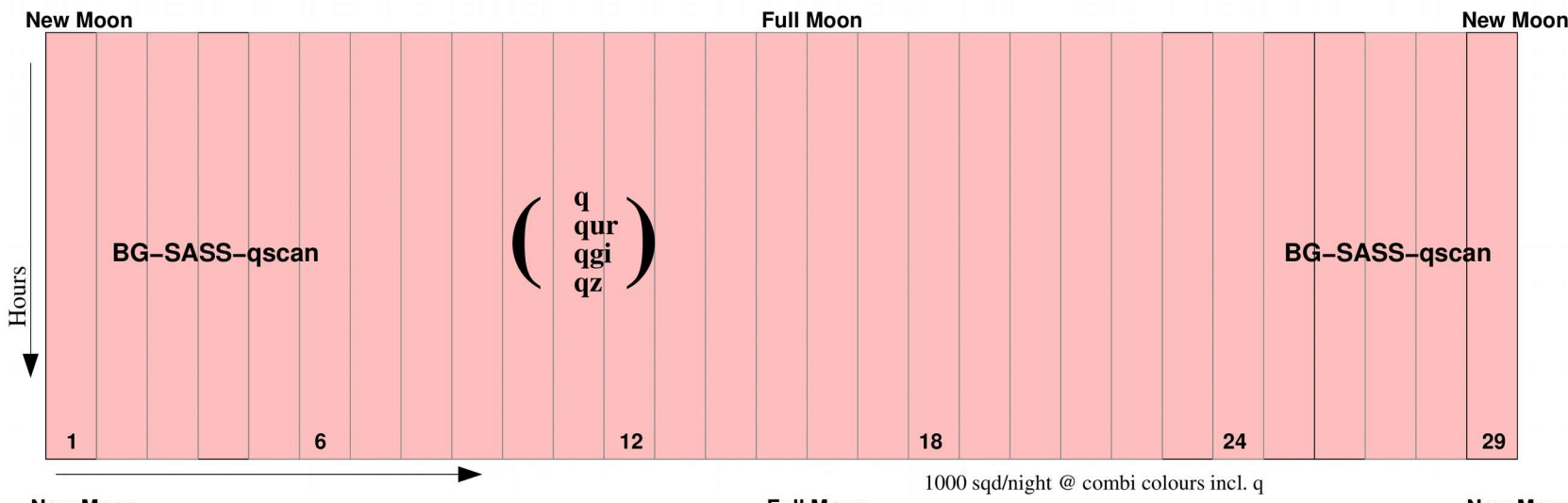
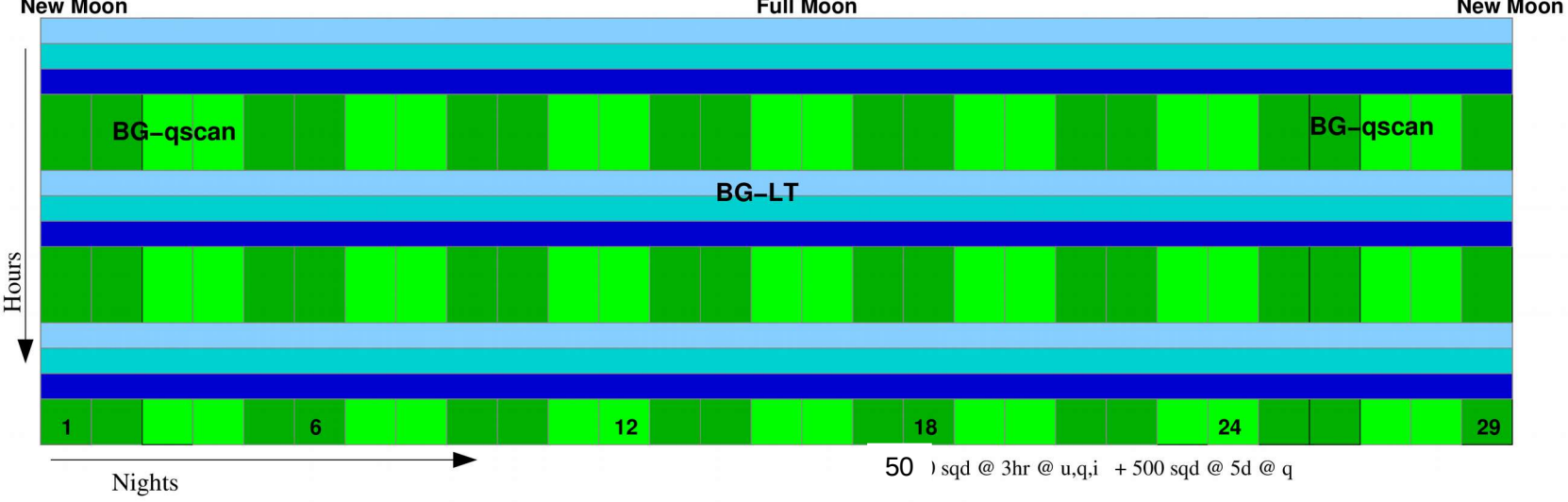
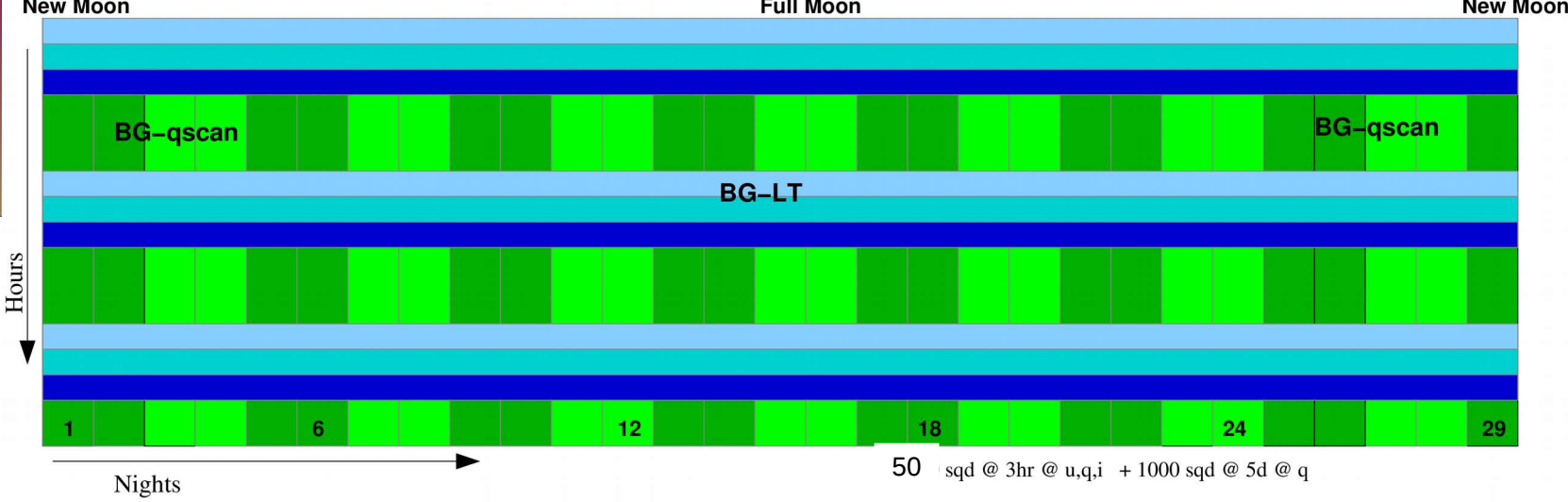


Fig. 9. Simulation of the distance distribution of the detected events from 2016.

Ghosh, S., et al., 2016

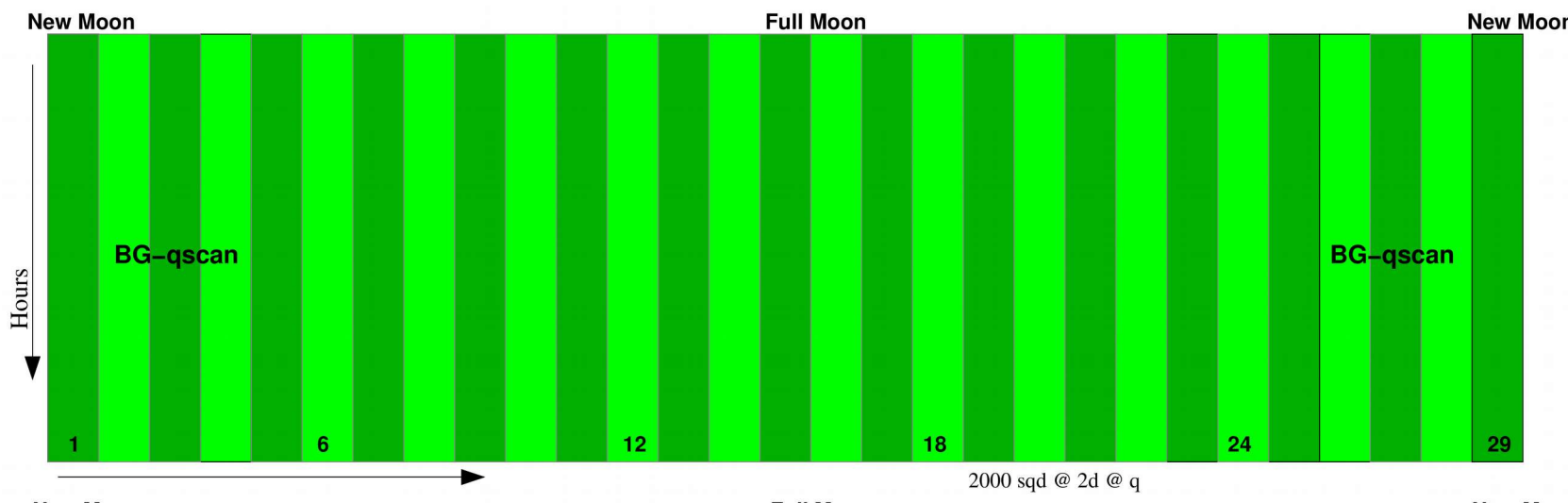


(one typical month)

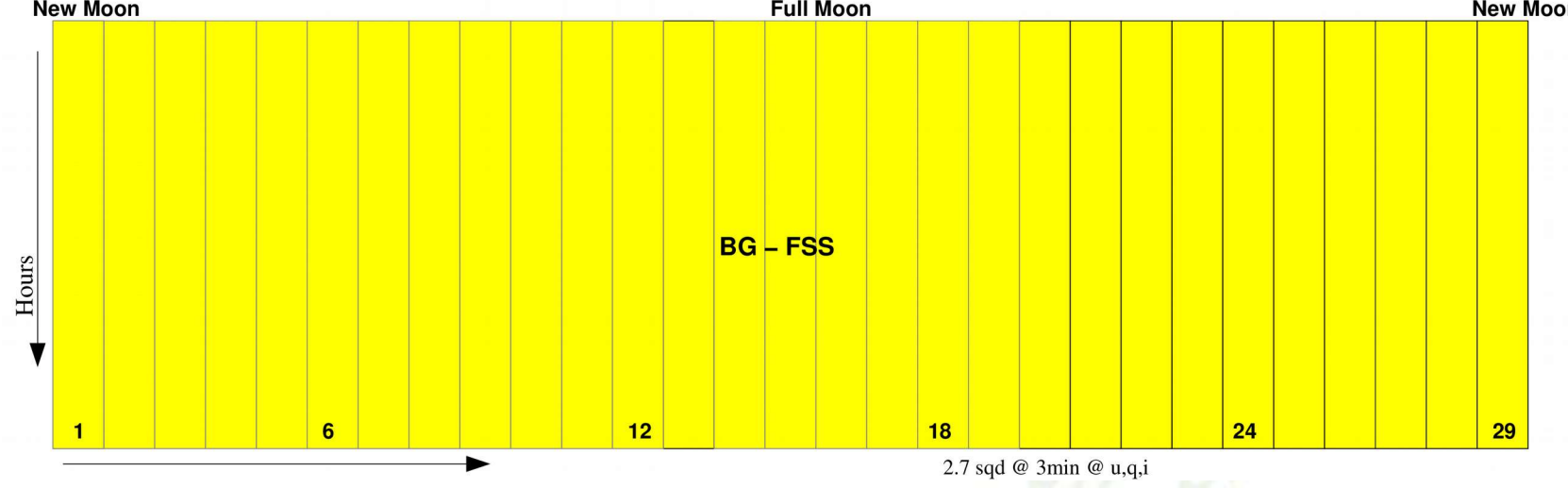


Surveys 2nd + year

Tel. 1



Tel. 2



Tel. 3



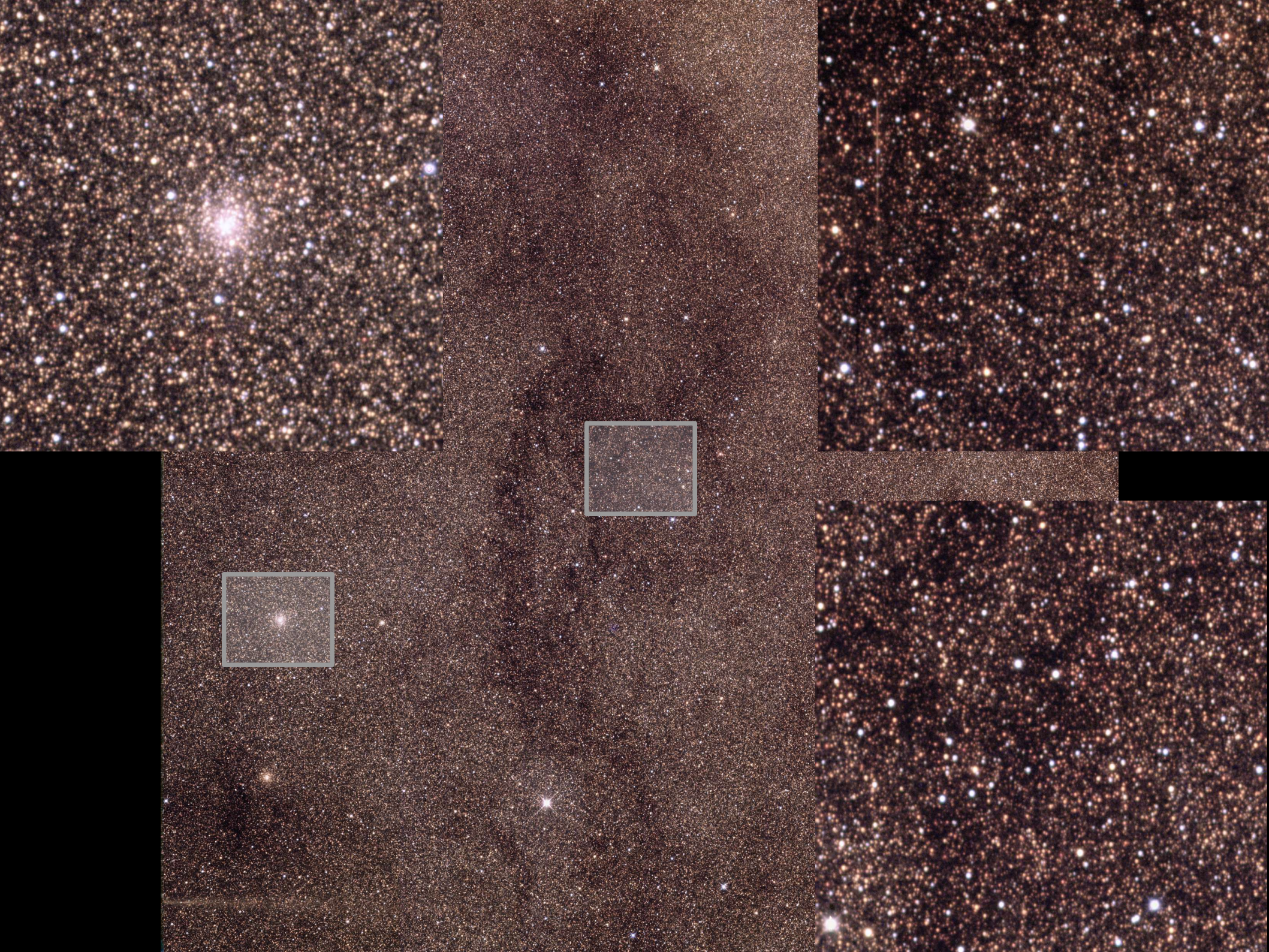
MeerLICHT Prototype

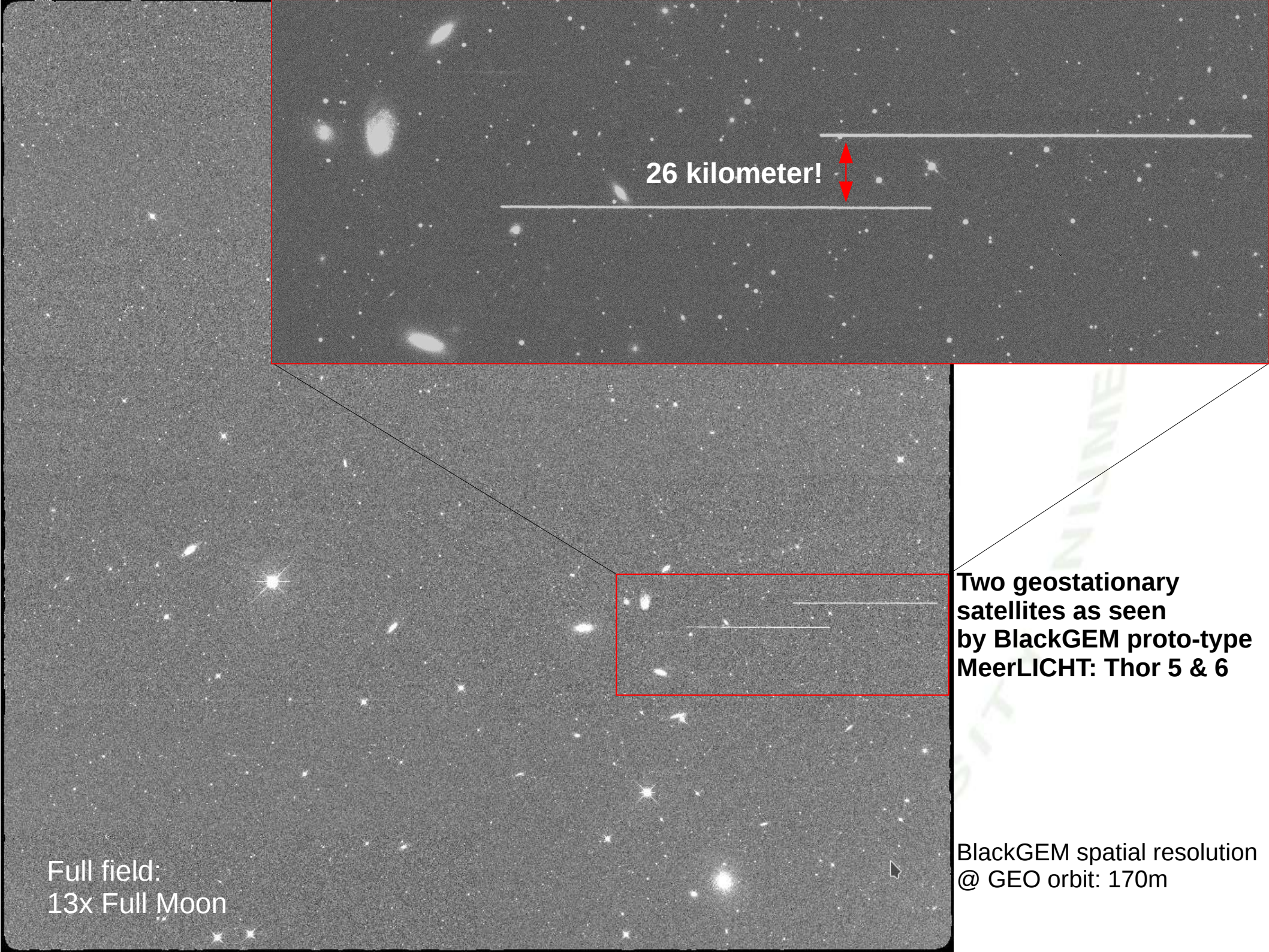


Operational at SAAO Sutherland

See [@MeerLICHT_ZA](#) on Twitter and www.meerlicht.org for more pictures

Science: Follow MeerKAT around to get optical-radio





26 kilometer!

Two geostationary satellites as seen by BlackGEM proto-type MeerLICHT: Thor 5 & 6

Full field:
13x Full Moon

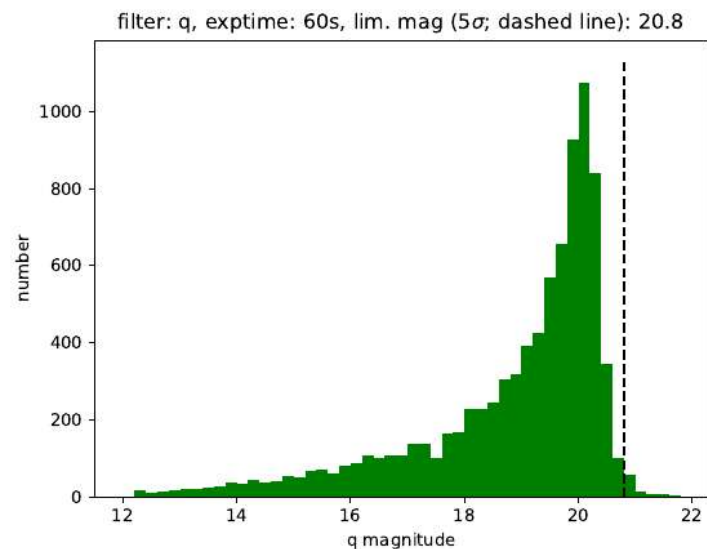
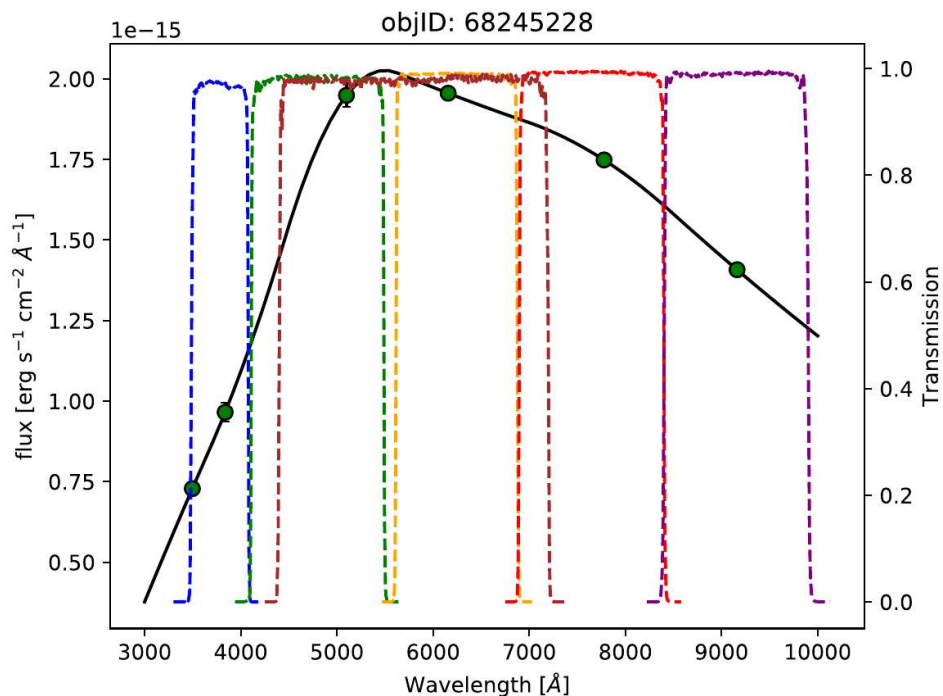
BlackGEM spatial resolution
@ GEO orbit: 170m



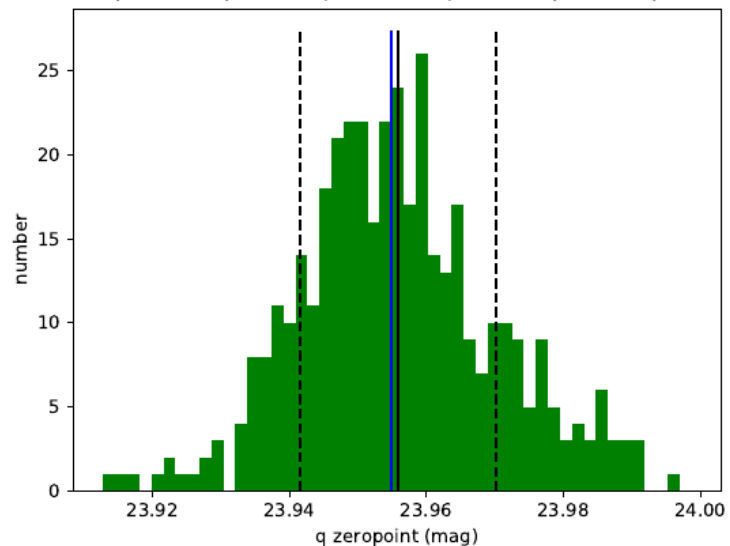
Science Verification



- Instantaneous Photometric calibration using SDSS/PanStarrs/SkyMapper/Gaia/2MASS/Galex



mean (black line): 23.956, std: 0.014, median (blue line): 23.955



Zeropoint (1 e/s) : MeerLICHT

Detected $q_0 = 23.95$ mag

Expected for BlackGEM:

Zero-point $q_0 = 24.2$ mag

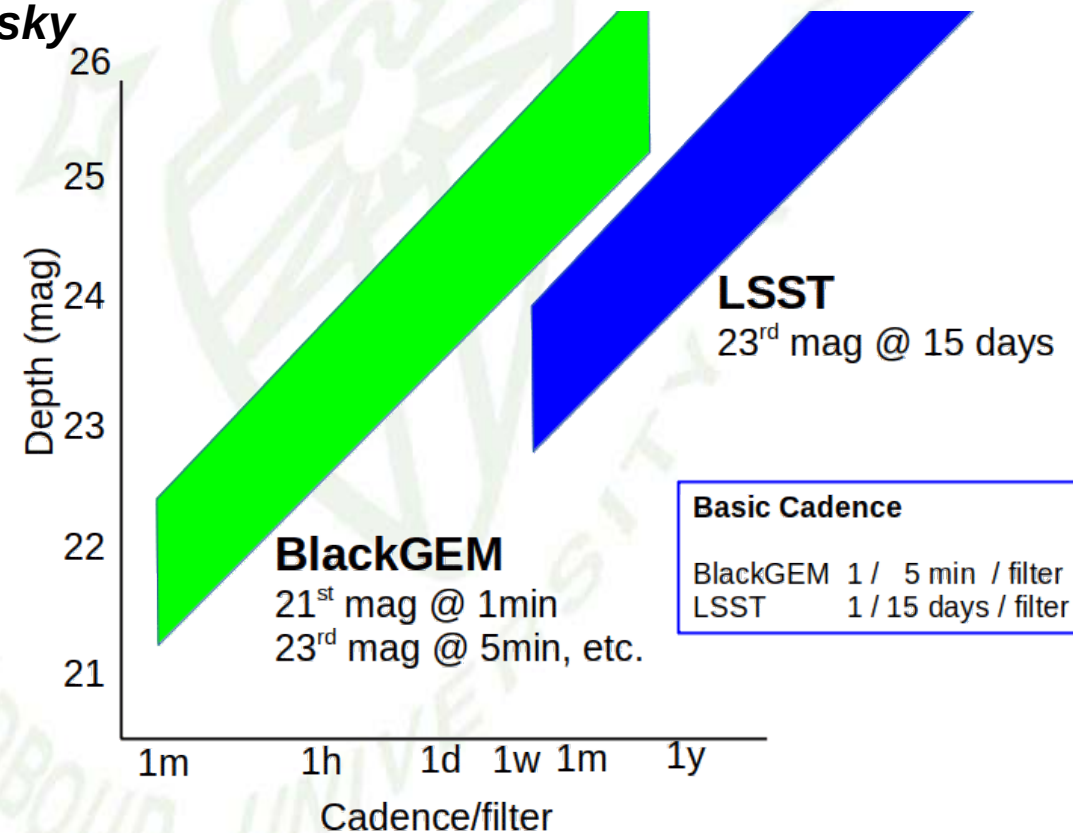
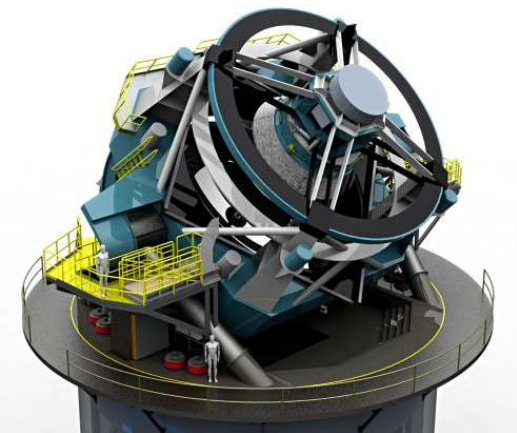
→ $q=23$ in five minutes integration
@ 1" & dark sky



BlackGEM & LSST

Projects highly complementary

- Different parts of synoptic parameter space (min-hours → days vs. weeks)
- Different parts of magnitude range (23rd vs. 26th)
- Different science case, but....
- Three years earlier (2020 vs. 2023)
- Identical **type** of data; same **field-of-view**
- Highly similar **quality** of data
- Similar **location**, same **sky**



**BlackGEM closest to LSST,
until the LSST itself**



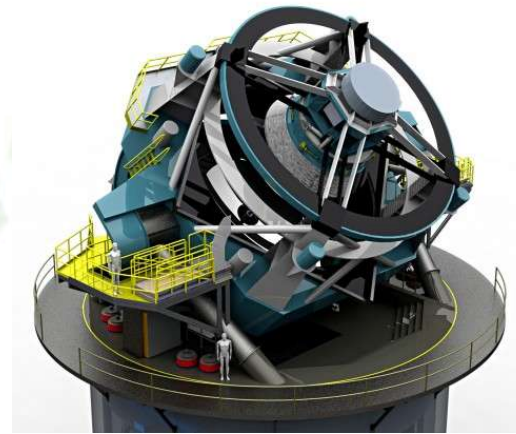
Cerro Pachon from La Silla



Soar

Gemini

LSST





BlackGEM Phase 1 commissioning now
Survey operations start Jan 2020
Runs for 5 years
Possibilities to join

Phase 2 = 15 telescopes, on La Silla.



***Gem in the night,
No place to hide!***