



# BlackGEM

**Nadia Blagorodnova**

of behalf of the BlackGEM team:

**PI: Paul Groot**

**Project Manager: Steven Bloemen**

**Project Scientist: Peter Jonker**

**Operations Manager: Paul Vreeswijk**





# BlackGEM

## Science:

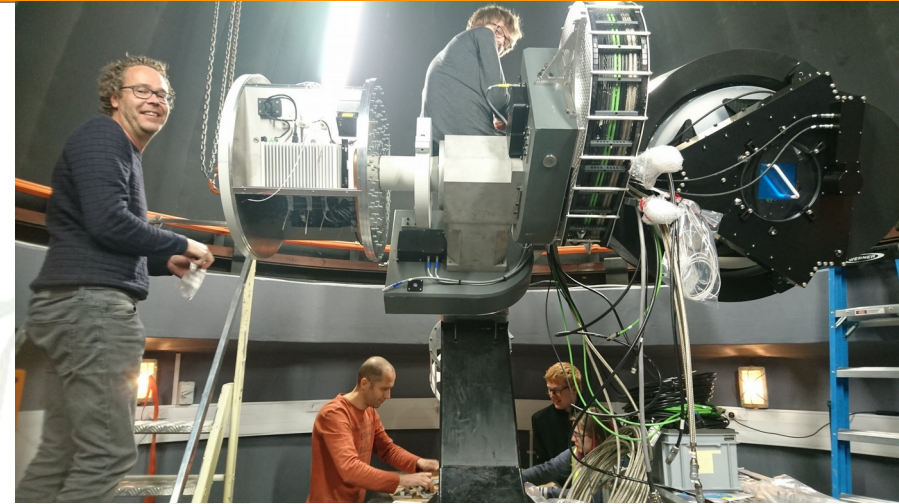
- **Gravitational wave counterparts**
- Southern All Sky Survey
- Fast Transients & Variables
- Nearby Universe Survey

## Phase 1:

- 3 wide field telescopes (8.1 square degr. total)
- Primary mirror: 65cm diameter
- Sensitivity:  $g=23$  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 Surveys

## BlackGEM Southern Sky Survey: '*Southern Sloan*'

- 30 000 sqd down to 22<sup>nd</sup> 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  $q \sim 21.5$***

## • 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  $\sim$ week time scale down to  $g=23$   
(TDEs, SN of all types, Dwarf Novae, SN .Ia, SN Iax, etc. )



# 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., 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](http://www.blackgem.org) ; @BlackGEM\_Array



# Location





# Dome & Tower

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





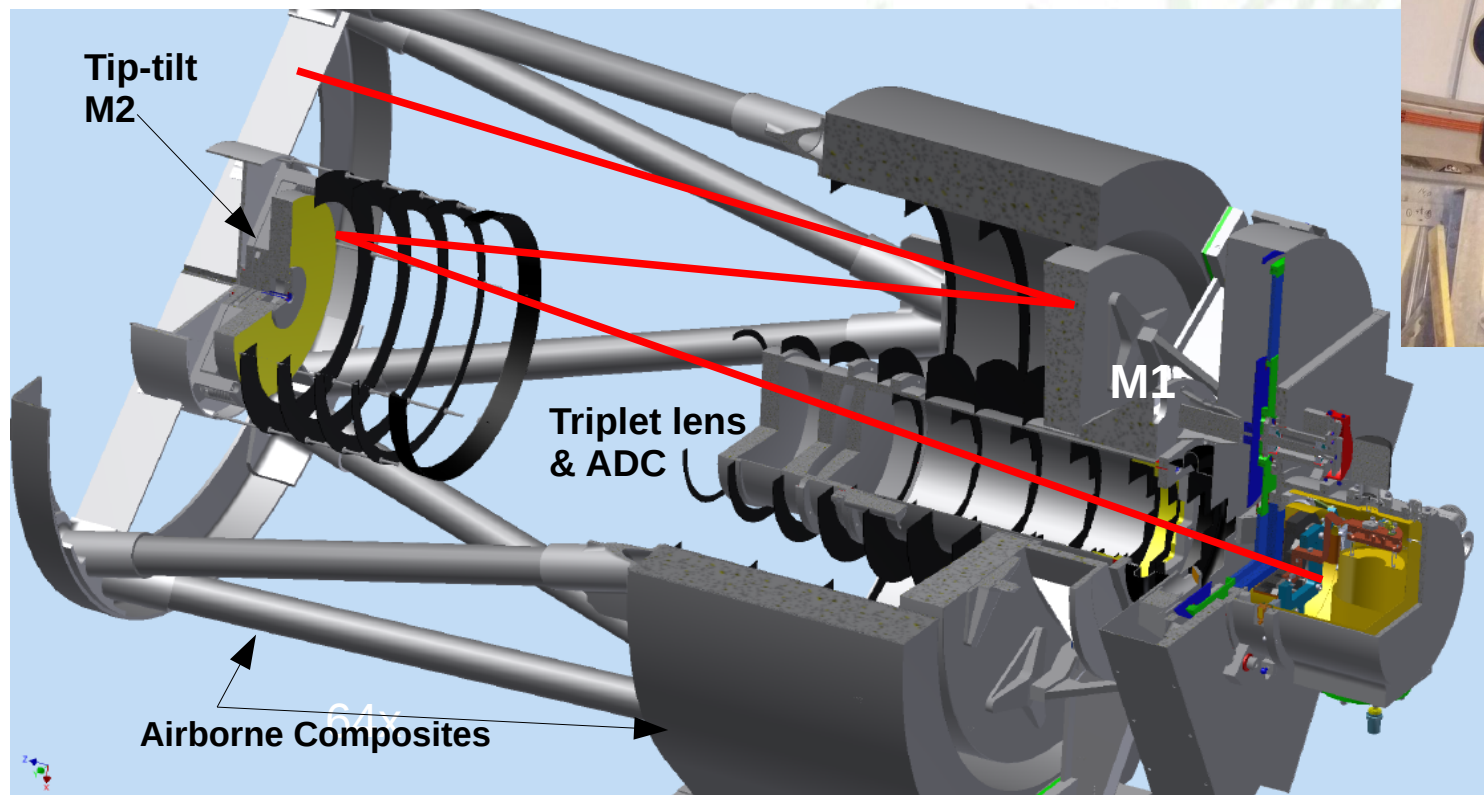


# BlackGEM Unit telescope

- 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



*Finished Prototype*

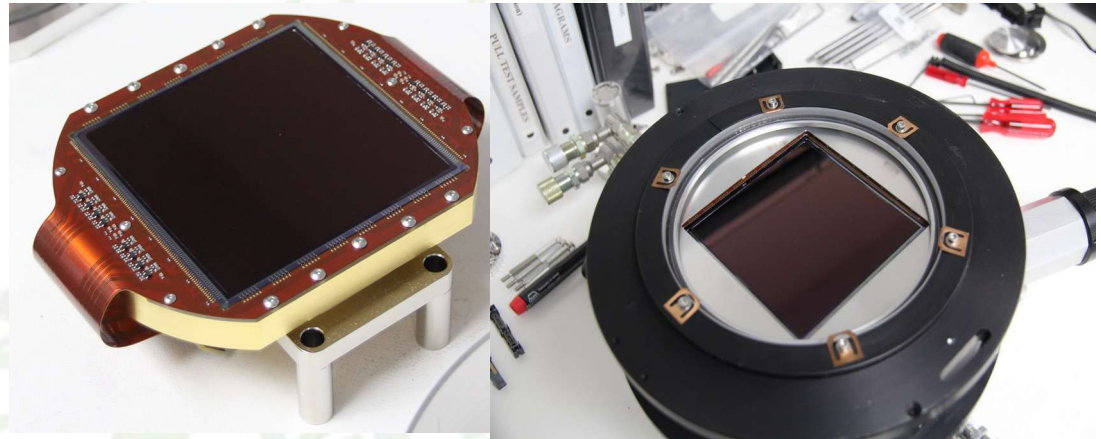
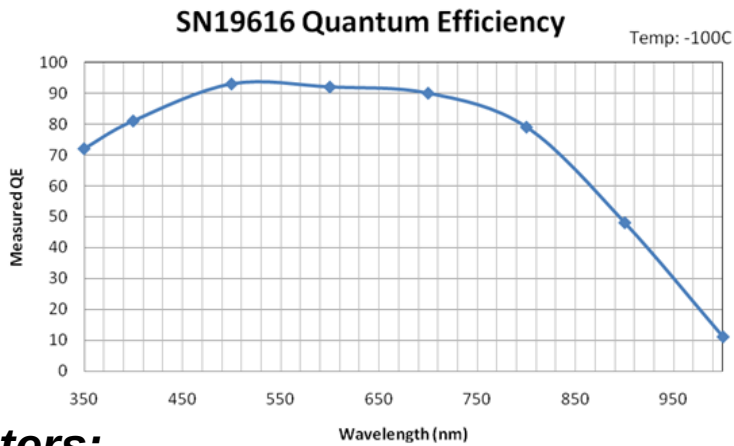


*Design*



# CCD & Filters

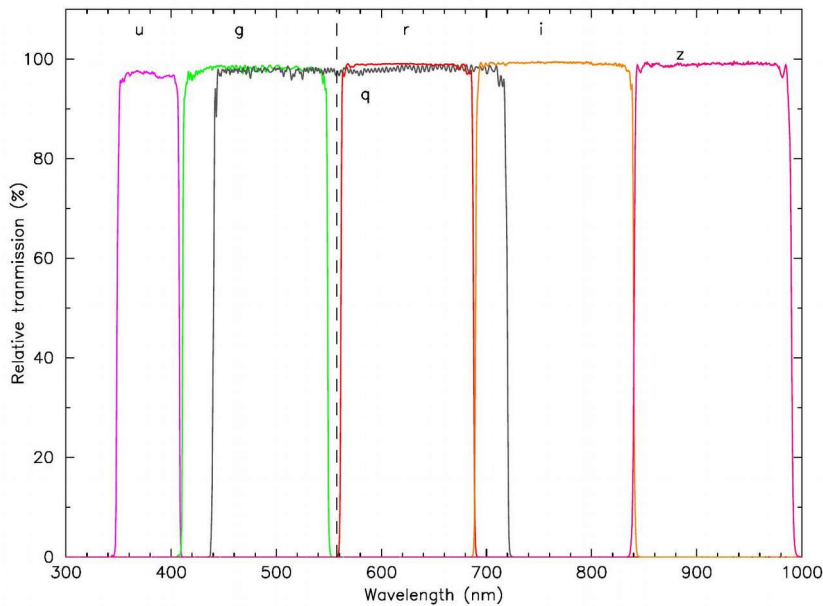
- STA1600, 10.5k x 10.5k CCD, 9  $\mu$  pixel : 110 Mpixel chip
- Scale on sky: 0.562"/pix, total field of view: 2.7 sqd/telescope
- Readout time: 7 seconds (at 1 MHz on 16 ports), RON: 5.5 e<sup>-</sup>



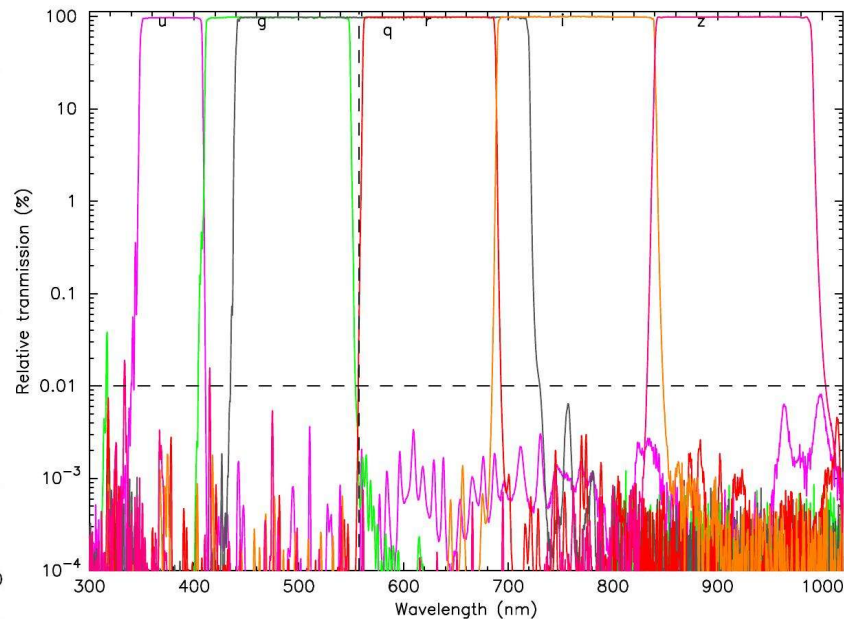
## Filters:

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

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



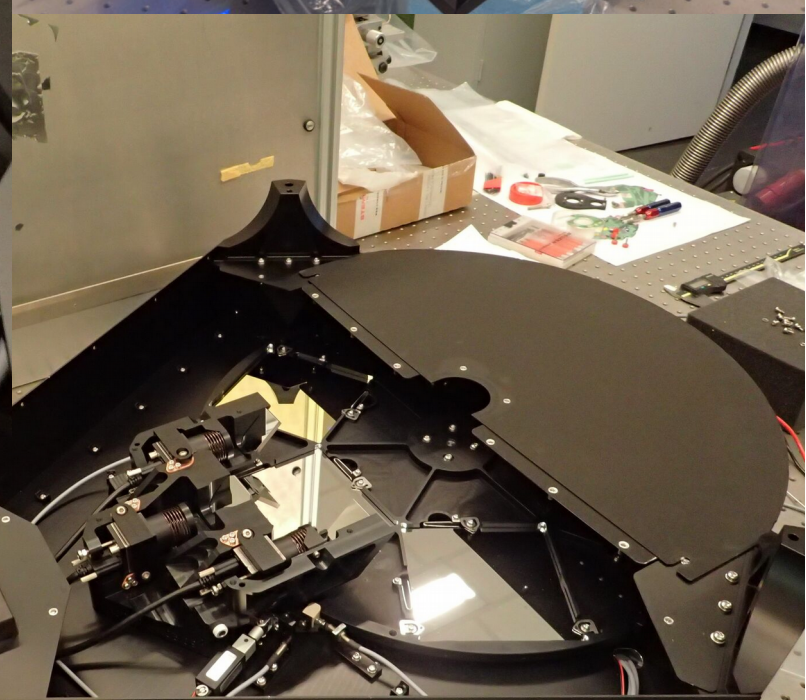
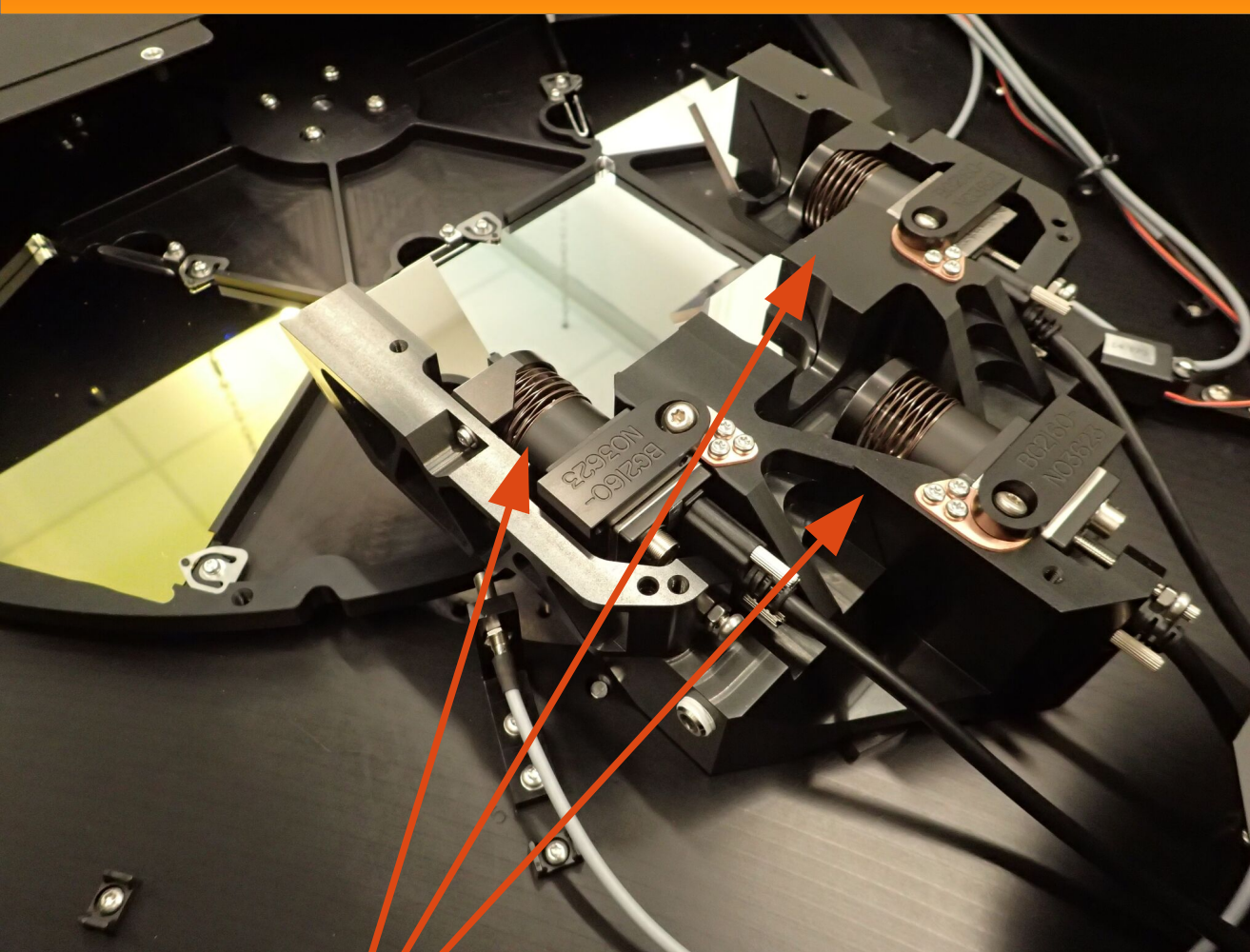
Astrodon BlackGEM set (BG-u,BG-g,BG-r,BG-i,BG-z and BG-vr (=q))







# Guide cameras & Filters



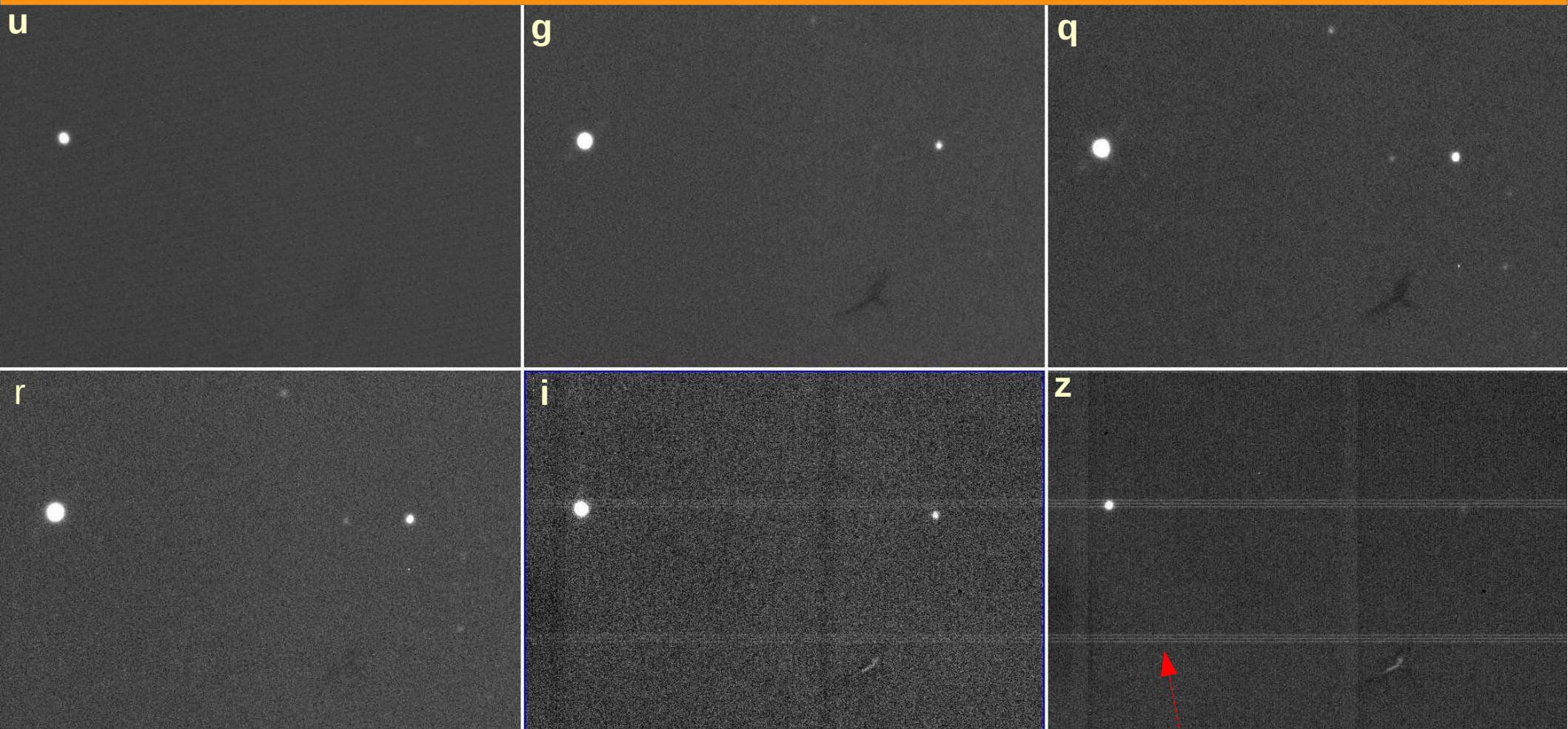
3 Guide cameras

Filter wheel





# Filter performance



All exposures 5 seconds, unguided, on Pole

Reflection on backing structure CCD

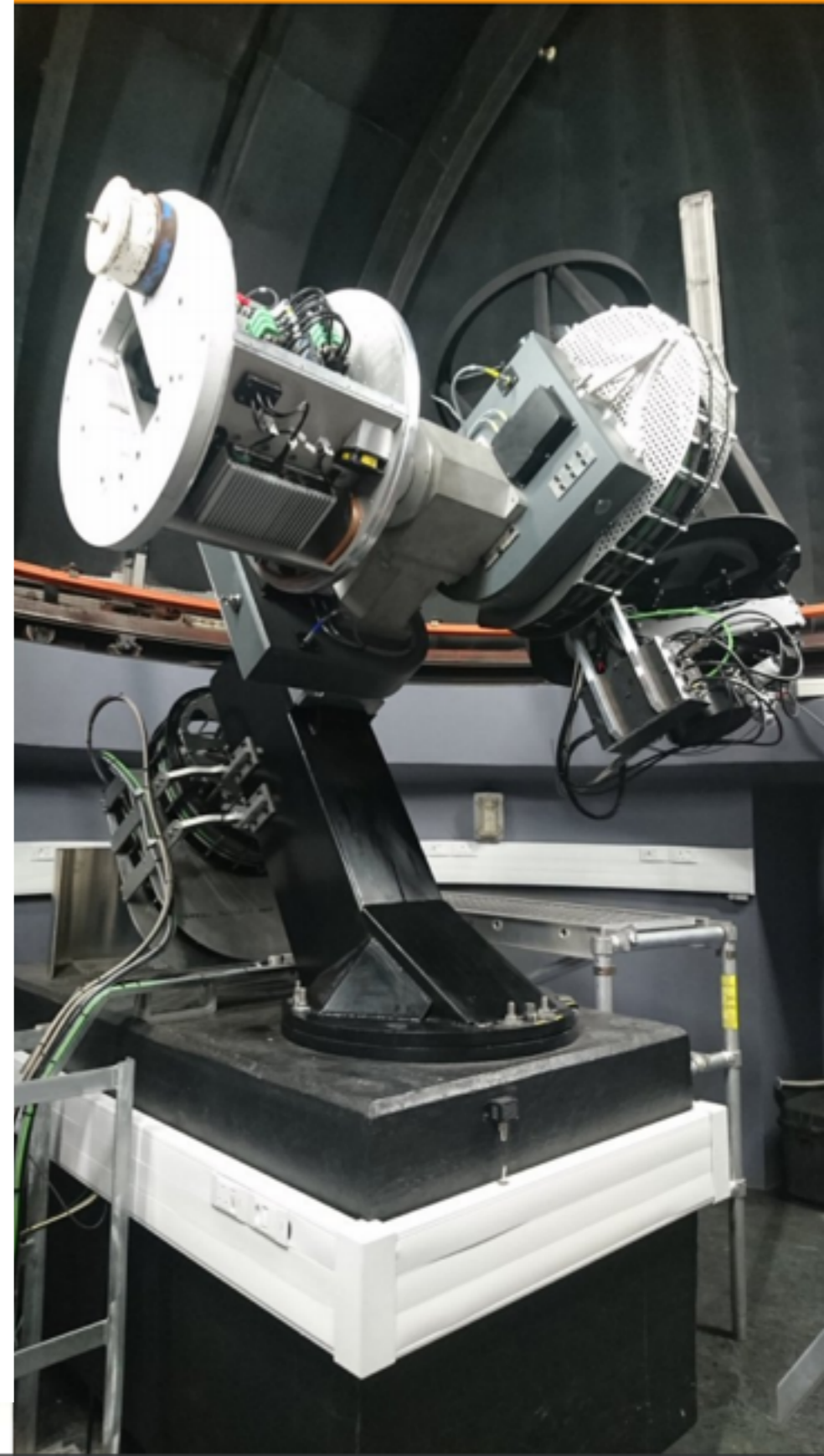






# MeerLICHT Prototype

- **Inaugurated on 25 May 2018** in South African Astronomical Observatory (SAAO).
- Strongly linked to the ThunderKAT and TRAPUM MeerKAT (inaugurated on 18 July 2018) Large Survey Projects.
- **Simultaneous radio and optical** multi-band observations
- Short time-scale **radio-optical correlations** in astrophysical transients: dwarf novae, novae, X-ray binaries, pulsars, fast radio bursts, supernovae, gamma-ray bursts, AGN, gravitational wave events and sources yet unknown.
- MeerLICHT hardware and software is used as a prototype for BlackGEM.





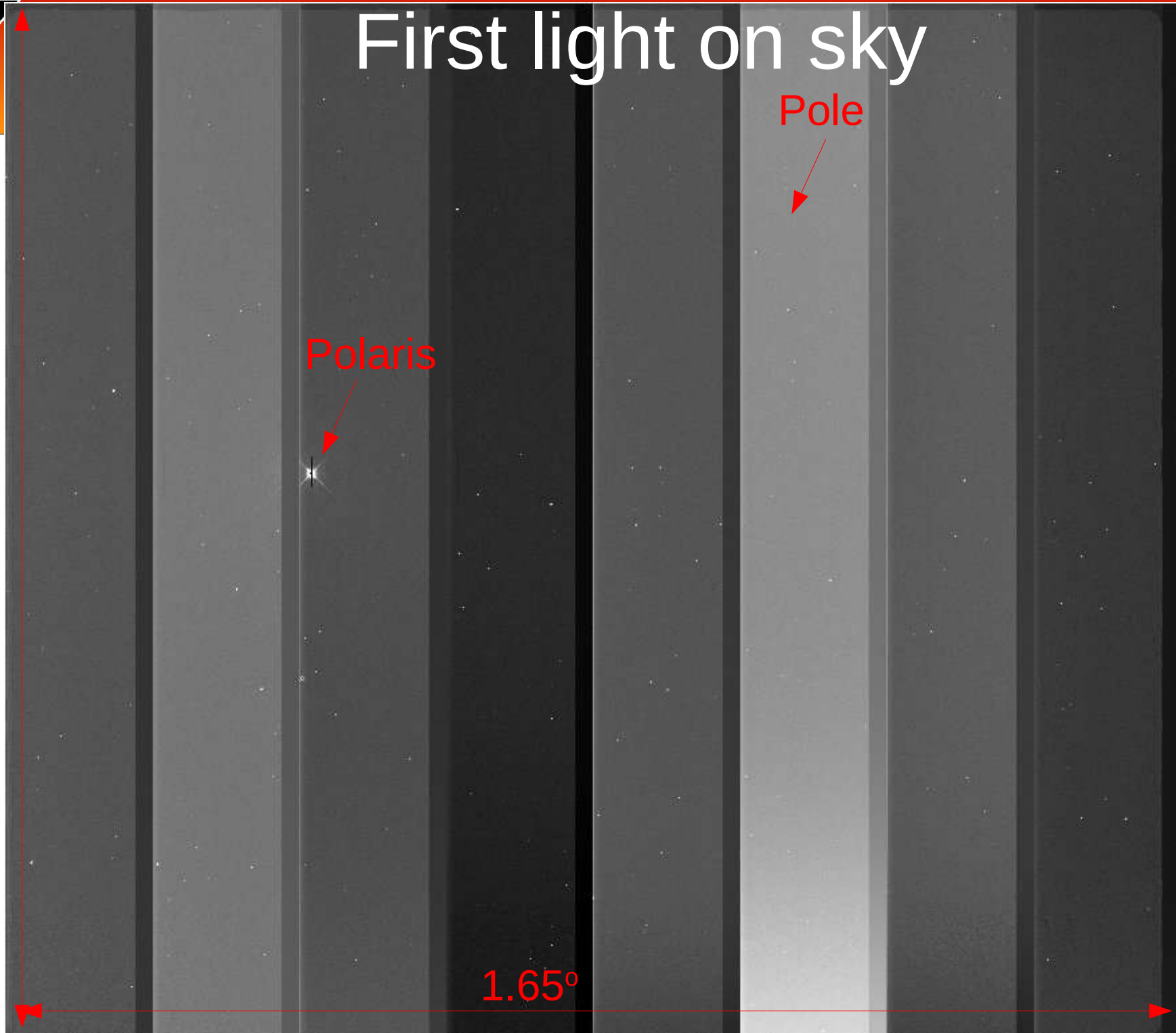
# First light on sky

1.65°

Polaris

Pole

1.65°





# MeerLICHT image of LMC







# BlackCloud: A cloud solution



- 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)



# Pipelines and calibration

- Data reduction software: **BlackBOX**: optimal image subtraction (Zackay, Ofek & Gal-Yam 2016) for the detection of transients
- **Photometric calibration** based on **stellar template fitting** of a combination of Gaia DR2/SDSS/PS1/SkyMapper/GALEX NUV and 2MASS J-band photometry
- Catalog with tens of millions of sources
  - 100 - 1000 stars per field in the BlackGEM photometric system
  - Ready to calibrate any image



# Schedule BlackGEM

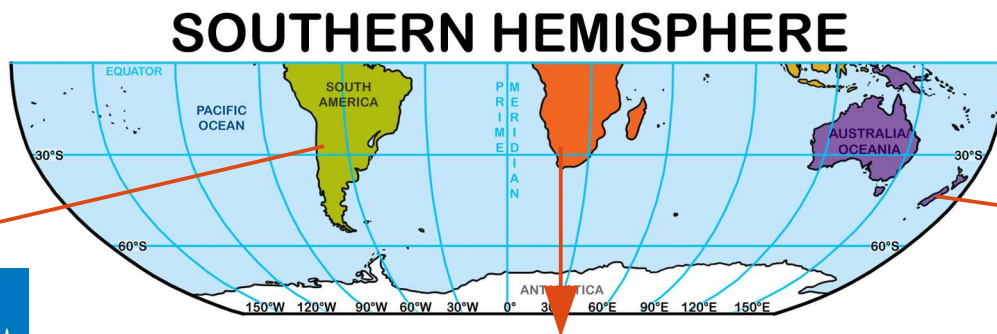
- Prototype testing @Radboud — February 2017
  - Shipment MeerLICHT prototype → ZA — June 2017
  - Commissioning MeerLICHT @SAAO — August-December 2017
  - **Inauguration MeerLICHT — May 2018**
  - Final Design Review BlackGEM — March, 2017
  - Manufacturing BlackGEM-Phase1 2017 – 2018
  - Testing BlackGEM telescopes in Groningen — 2018
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- Shipment BlackGEM → Chile — Early 2019
  - **Commissioning BlackGEM-Phase1 — March 2019**
  - Start operations Phase1 — April 2019
- now



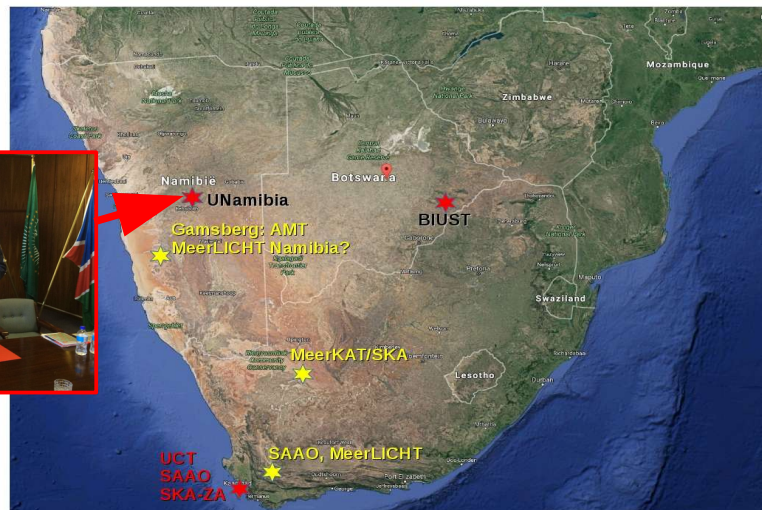


# Future plans

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



South Africa or Namibia



Mt. John  
U. of Canterbury  
Christchurch

