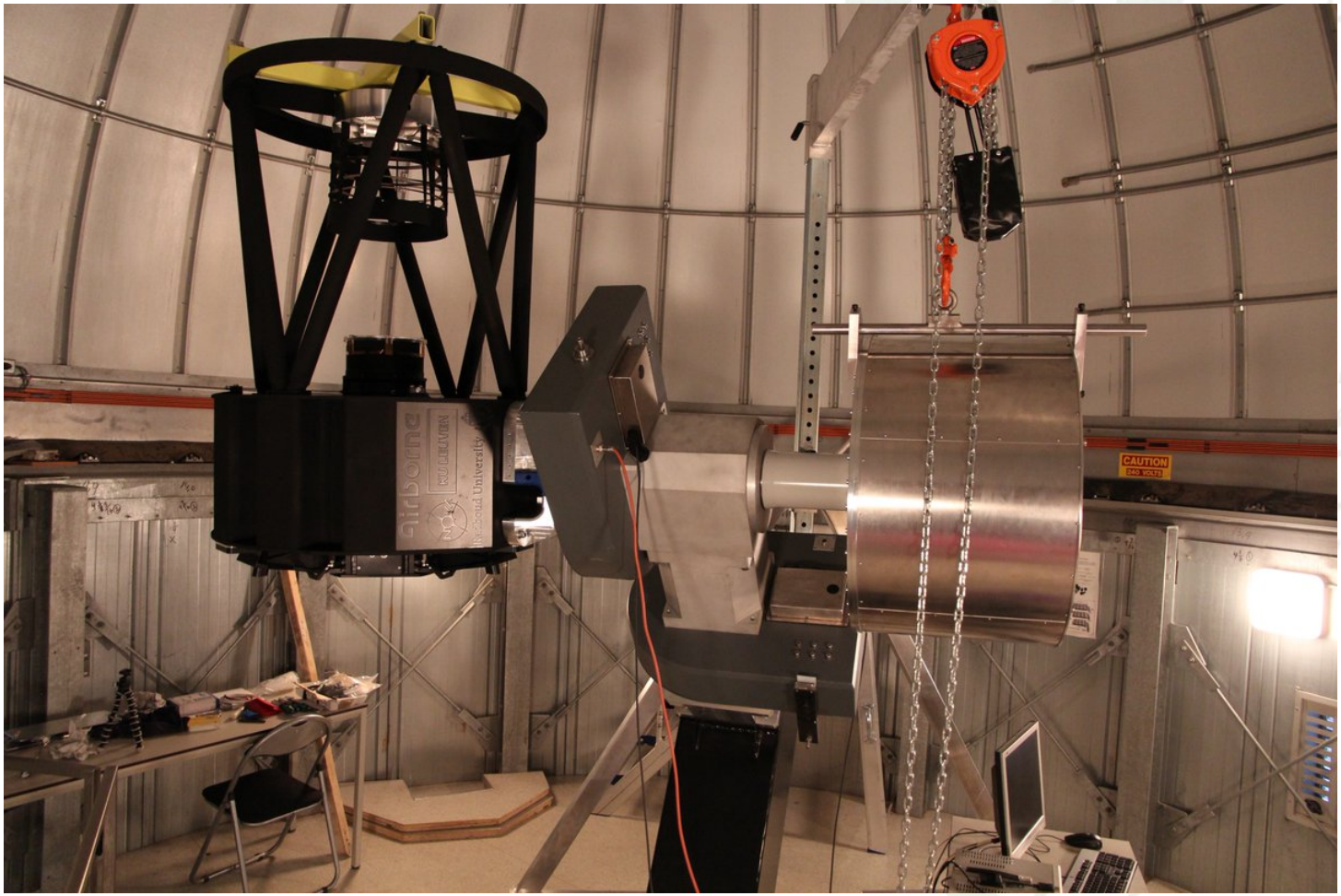
BlackGEM Telescope array



Prototype system installed in dome @Radboud University

Paul Groot
Radboud University & NOVA

Radboud University

BlackGEM

Science:

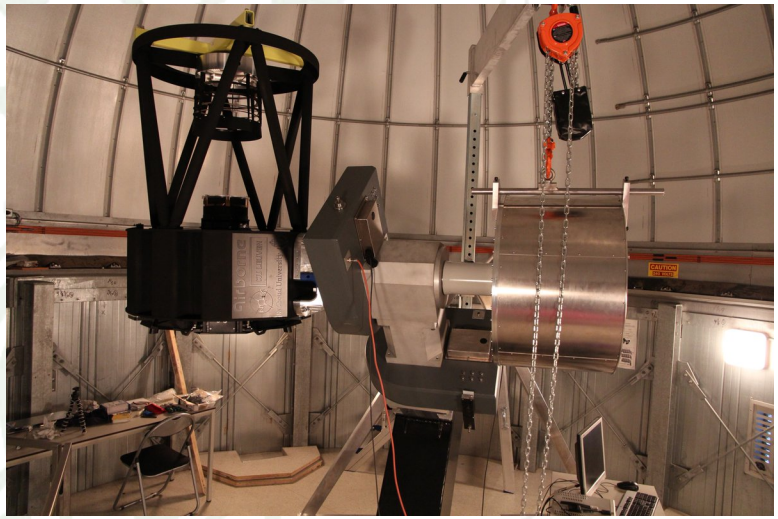
- ***Gravitational wave counterparts***
- Southern All Sky Survey
- Fast Transients & Variables
- Nearby Universe Survey

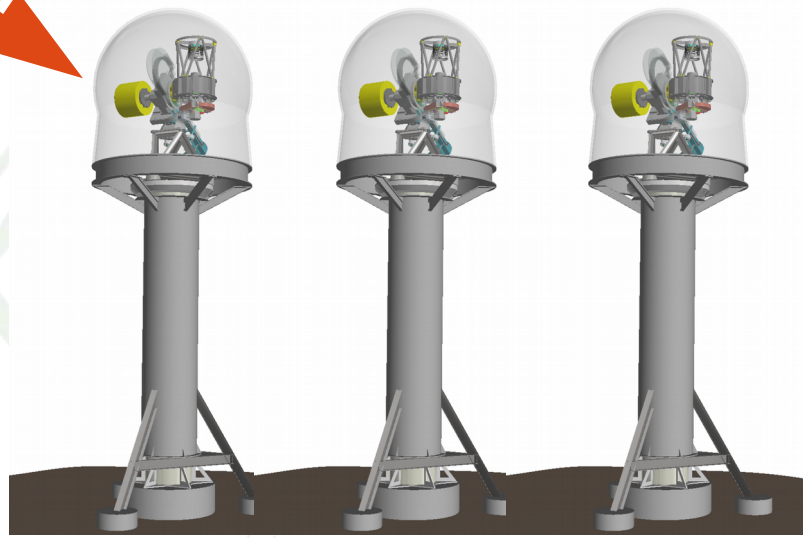
Phase 1:

- 3 wide field telescopes (8.1 square degr. total)
- Primary mirror: 65cm diameter
- Sensitivity: *g=23 in 5 minutes*
- Location: ESO La Silla
- Seeing limited: 0.9” median
- Camera: 1 CCD/telescope, 0.56”/pixel
- *u,g,q,r,i,z* filter set

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

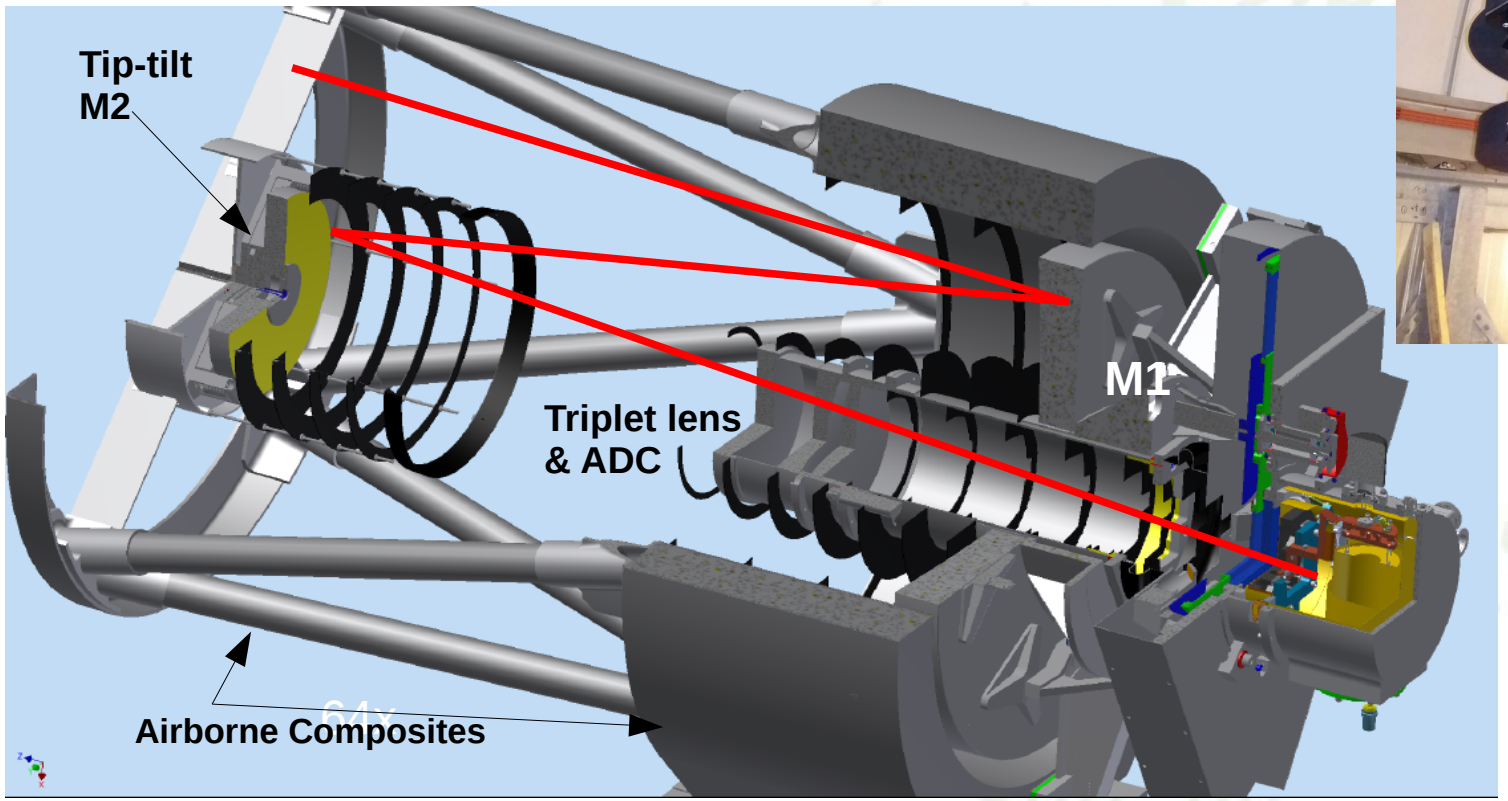




BlackGEM Unit telescope

- Wynn-Harper 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
- Water-cooled electronics

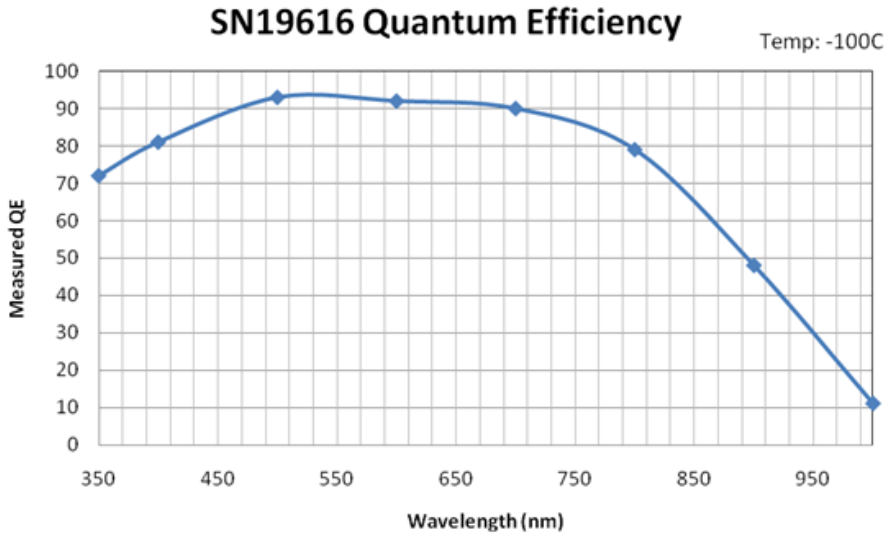
Finished Prototype

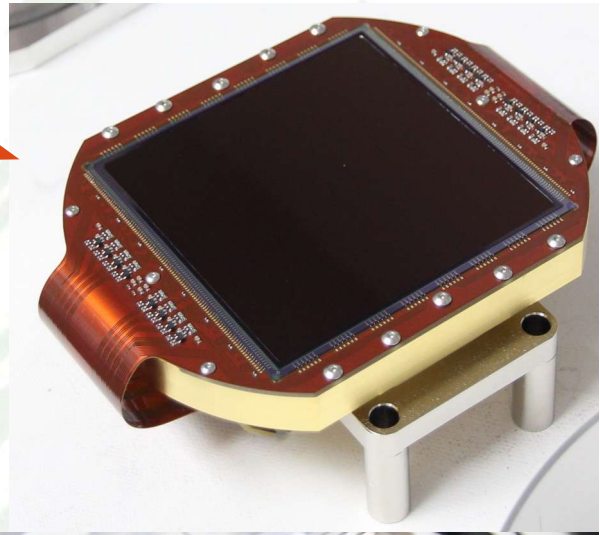


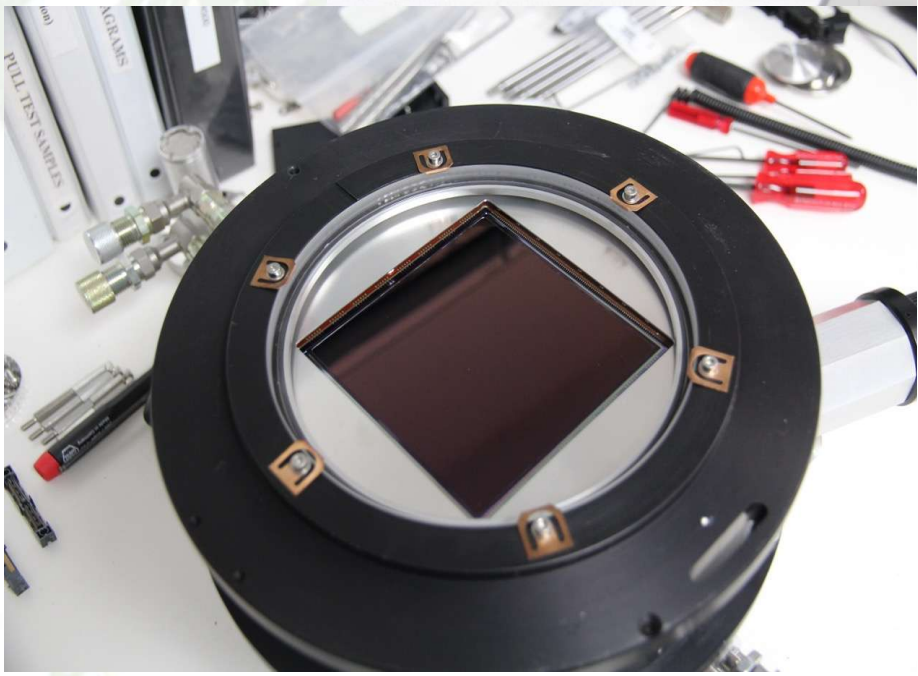
Design

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-
- Status: ***Final, first delivered and integrated in cryostat***



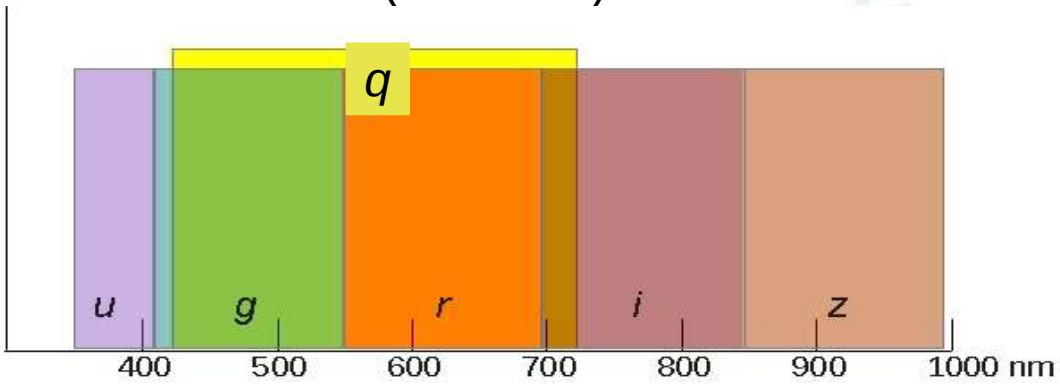




Filters:

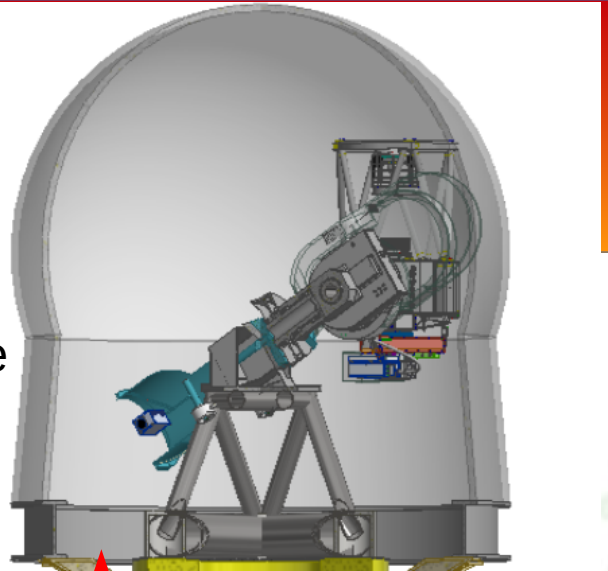
Sloan u,g,r,i,z filters plus broad-band q (440-720nm)

Status: delivered (Astrodon)



Dome & Tower

Baader 3.5m
Clam-shell dome



7m high

Raster floor

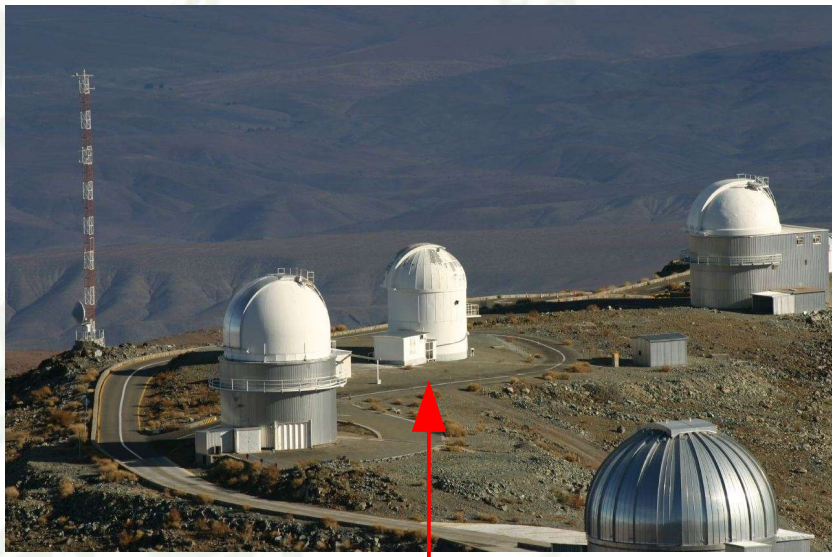
Outer tube
holds dome

Inner tube holds the
telescope

Ventilation
openings

TiO coating on outside
to prevent daytime heating

Separate
foundations



Will replace GPO
Building @ESO La Silla

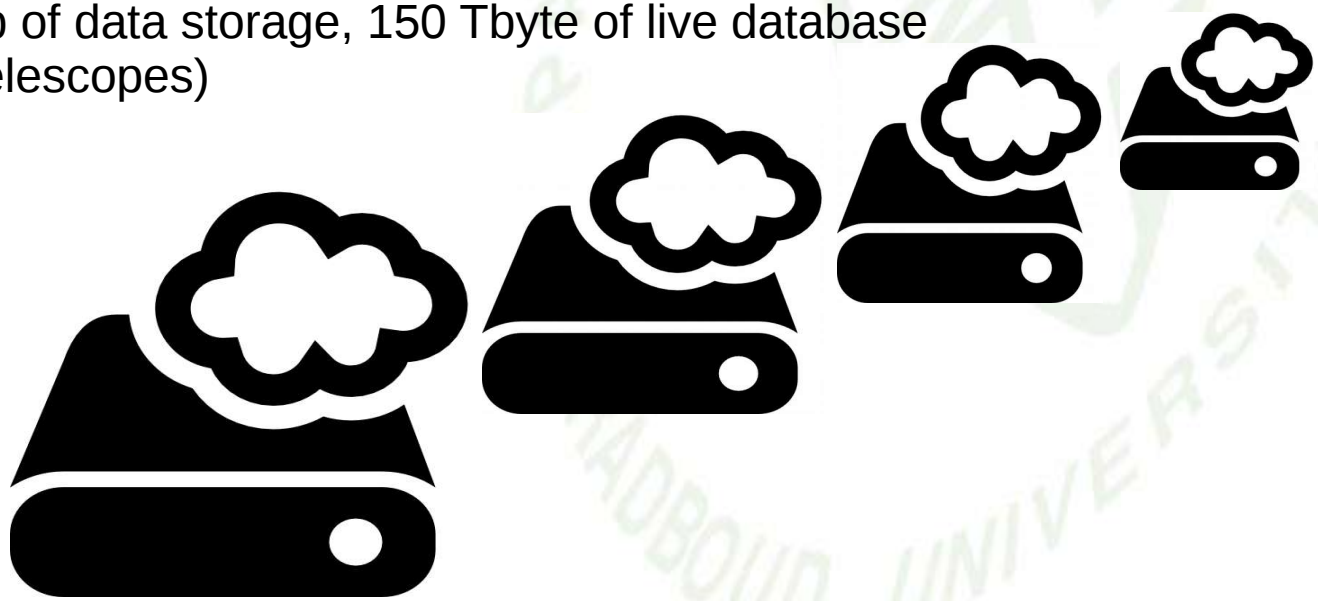
BlackCloud: A cloud solution

- 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
  - → 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 Pb of data storage, 150 Tbyte of live database (3 telescopes)



BlackGEM Team & Consortium

Principal Investigator: Paul Groot (Radboud University)
Project Scientist: Gijs Nelemans (Radboud University/Leuven)
Project Manager: Steven Bloemen (Radboud University)

Consortium Institute Partners in Phase 1:

NOVA

Radboud Universiteit

KU Leuven

NOVA = Amsterdam, Leiden, Groningen, Radboud

Manchester University & Tel Aviv University & U Canterbury committed at PI-level

Possibility for new partners (for 5 year operation):

- 100 kEuro to join at PI-level (one faculty member + PDRAs/PhDs)
  (all data, science team, lead science case)
- 750 kEuro to join at Institute level (full institute)
  (all data, science team, lead science case, consortium board)

→ Will go up to 150 k€ and 1 M€ after start operation MeerLICHT

www.blackgem.org ; **@BlackGEM_Array**

BlackGEM Surveys

To properly facilitate GW searches, BlackGEM survey programs:

- **BlackGEM Southern All Sky Survey**: ***'Southern Sloan'***
  → 30 000 sqd down to 22nd mag in u,g,q,r,i,z at 1” median seeing
  →Reference frame for GW searches, but stand-alone science:
  (galactic streams/structure, dwarf galaxies, stellar populations, 'gems', quasars, weak lensing, high-z galaxies, etc.)

- **BlackGEM q-band Scan:** ***‘What was there yesterday?’***
  → Visible 10 000 square degrees in q-band every 14 days
  → Itself a fantastic resource for finding SN, TDE, Novae, etc.

- **BlackGEM Fast Synoptic Survey**: ***'Kepler on steroids' : what else goes bang?***
  → High cadence (1 min), multi-colour (simultaneous), wide-field
  → Deep drilling fields: thousands of exposures over weeks time-scale

- **BlackGEM Twilight Program:** ***‘Local Universe transients’***
  → Every twilight (30 minutes) scan Local Universe galaxies in 2 bands for new transients (incl. SMC/LMC, Fornax Cluster, Cen A/M83 group, etc.). Fifteen fields 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

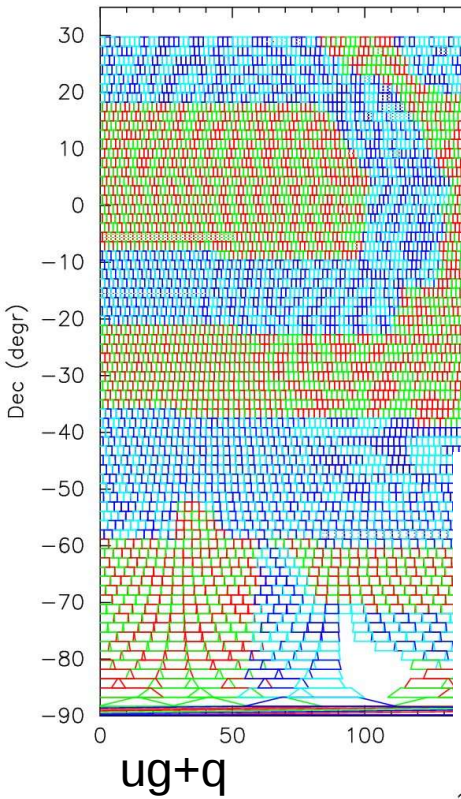
BG-SASS & BG-FSS Planning

BlackGEM Southern All Sky Survey and Fast Synoptic Survey Planning
Start of operations + 15 months

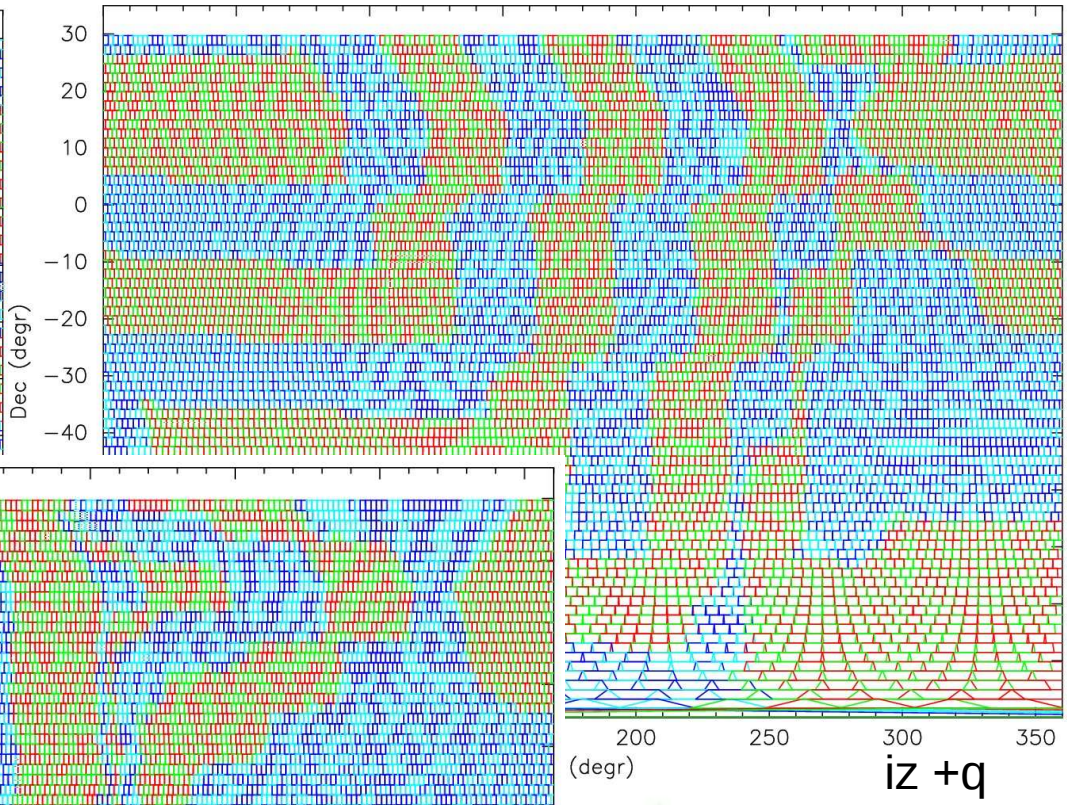
●	○	●	○	●	○
qr 18 nights	iz 11 nights	qr 18 nights	iz 11 nights	qr 18 nights	iz 11 nights
qr 3n	ug 15 nights	iz 11 nights	qr 3n	ug 15 nights	iz 11 nights	qr 3n	ug 12 nights	qr 3n	iz 11 nights
qr 3n	ug 12 nights	qr 3n	iz 11 nights	qr 18 nights	iz 5nights	qr 3n	qscan 6n	ug 15 nights	q scan	iz 5nights	qr 3n
ug 18 nights	iz 11 nights	q scan	ug 6nights	FSS 9n	iz 11 nights	q scan	ug 6nights	FSS 9n	q scan	FSS 7n	iz 1
q scan	ug 6nights	FSS 9n	q scan	FSS 8n	q scan	ug 6nights	FSS 9n	q scan	FSS 8n	q scan	ug 6nights	FSS 9n	q scan	FSS 8n

qr: 18n, 18n, 18n, 3n, 3n, 6n, 6n, 18n, 6n
iz+q:7x11, 5n, 5n, 11n, 11n, 1n
ug+q: 15n,15n,12n,12,0n,12n,18n, 5x6n

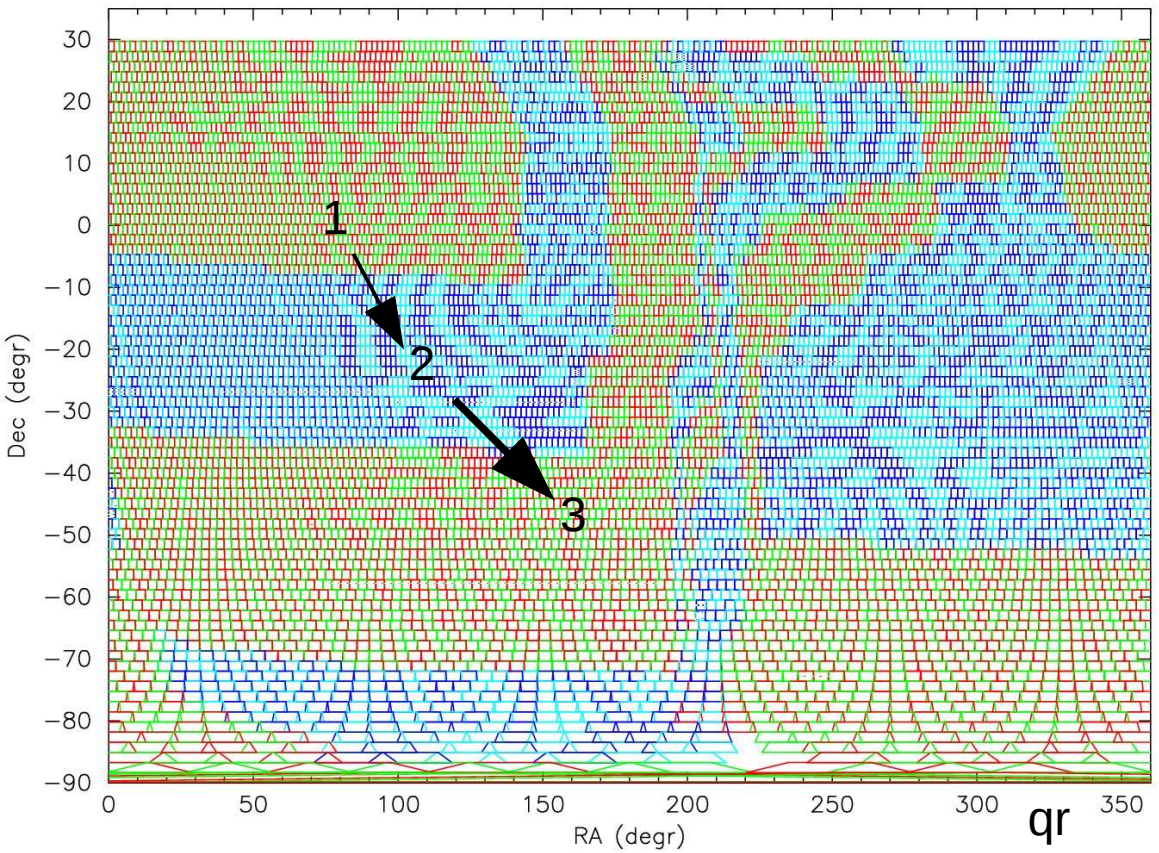
BlackGEM Southern All Sky Survey



ug+q



iz +q



qr

Month by month coverage *(green/red and blue/blue are subsequent months*) using planning of previous slide

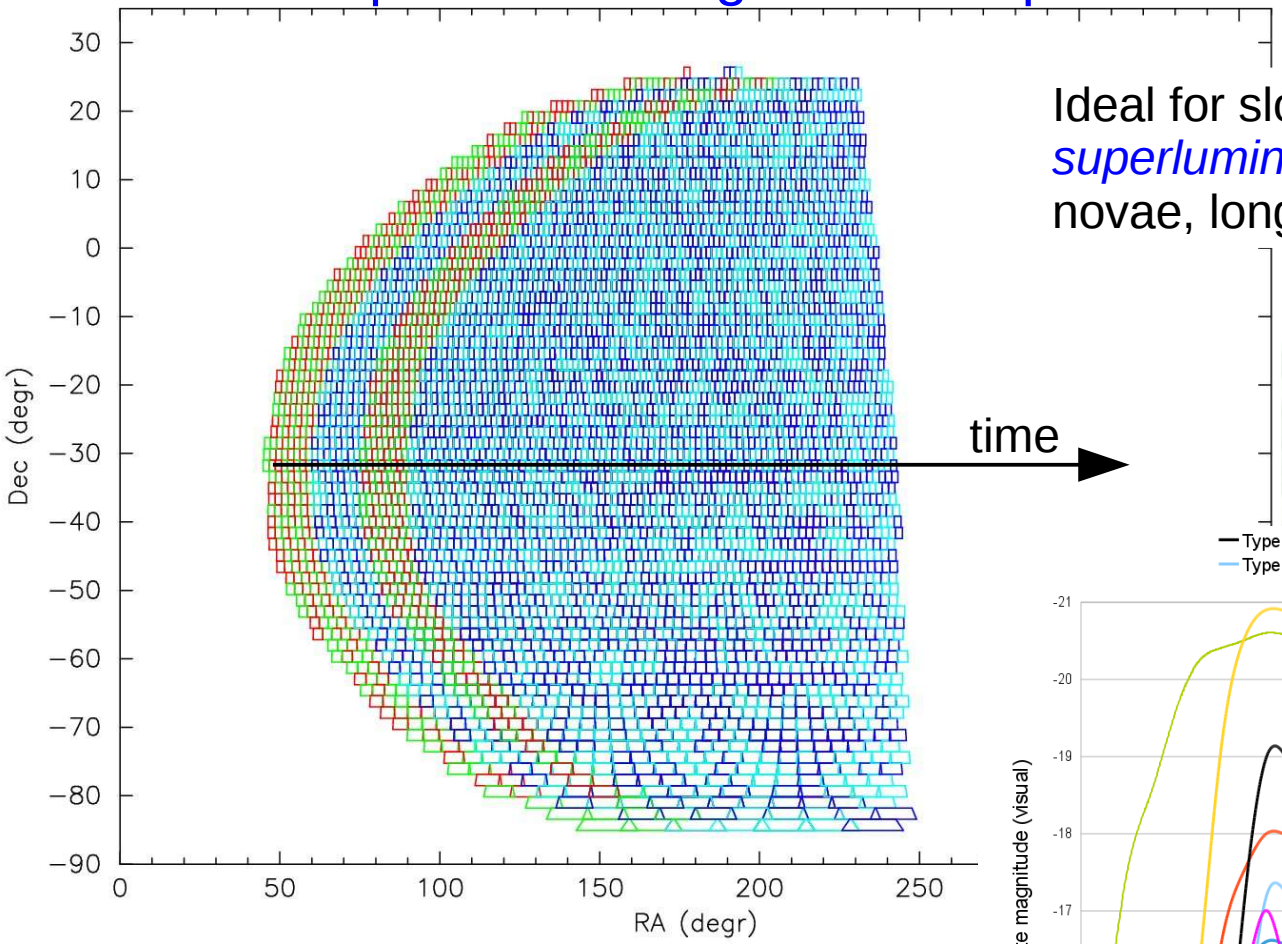
Two bands,
5x 60s each.

Alternating:
q,r,q,r,q,r,q,r,q,r
= 700 sec total,

good for asteroid detection/removal

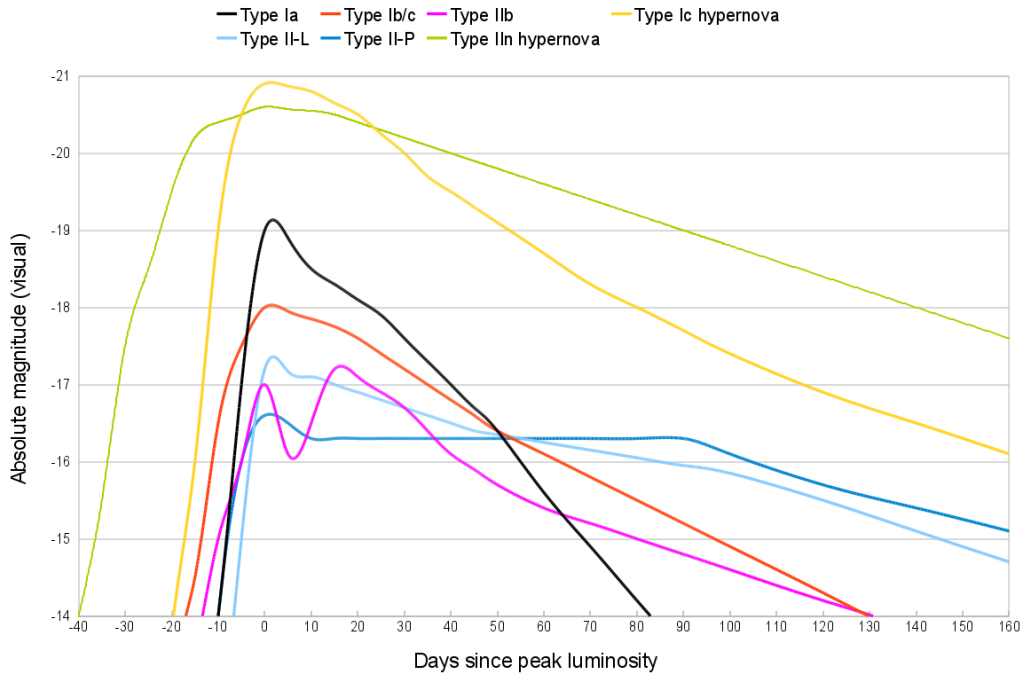
BlackGEM Bi-Weekly q-scan

Every two weeks 3 nights will be used to scan the available sky:
10000 sqd. in 60s integrations in q-band



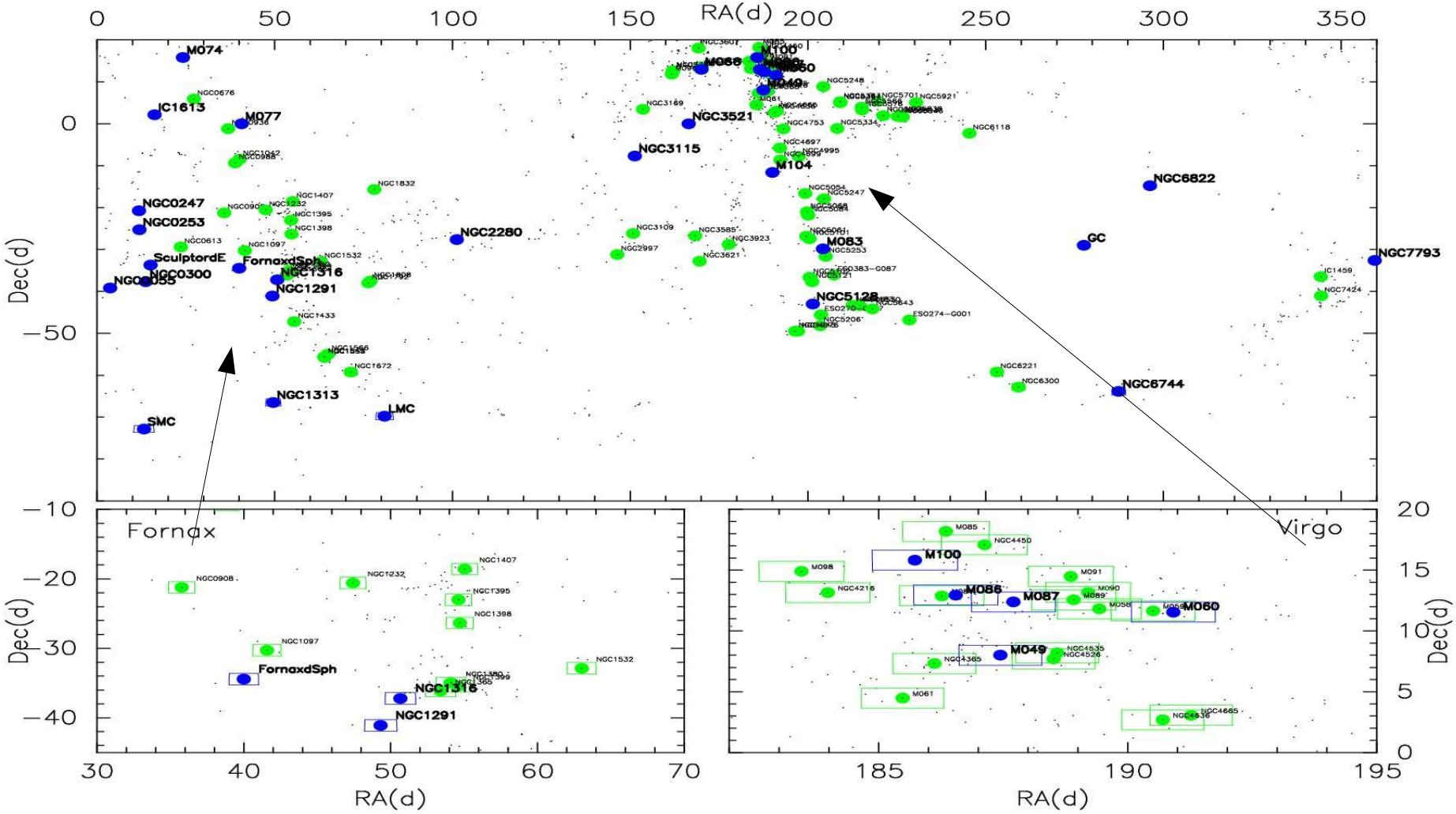
time

Ideal for slower transients/variables: *superluminous supernovae;* TDEs, novae, long-period variables, etc



BlackGEM Twilight Survey

- Every twilight a 30-min window @ end/start twilight calibs and start/stop main data-taking
- In this window: 15x3 fields (2.7 sqd each) in two bands: *u* and *r*
- N*earby Universe galaxies* with high integrated brightness profiles (incl. Gal.Cen. and Ω Cen)

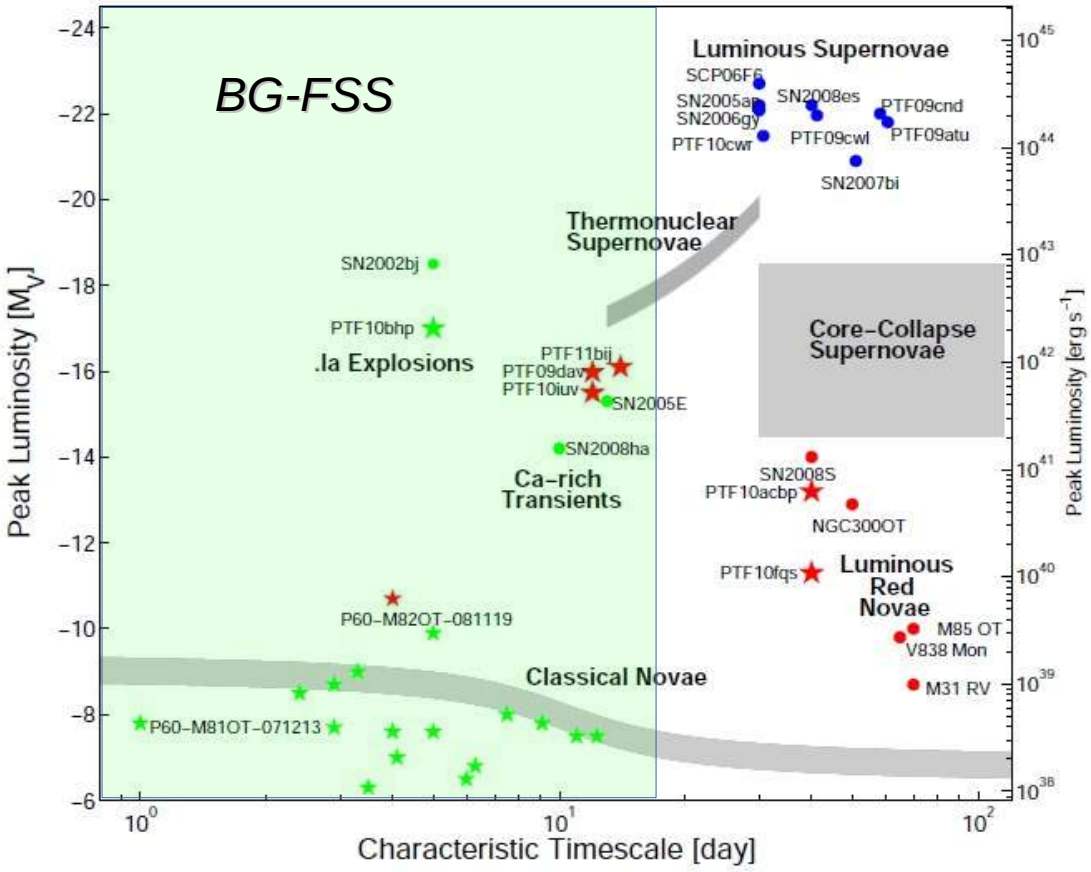


Points: d< 30 Mpc & B<14 mag; green: 120 brightest, blue 30 brightest

BlackGEM Fast Synoptic Survey

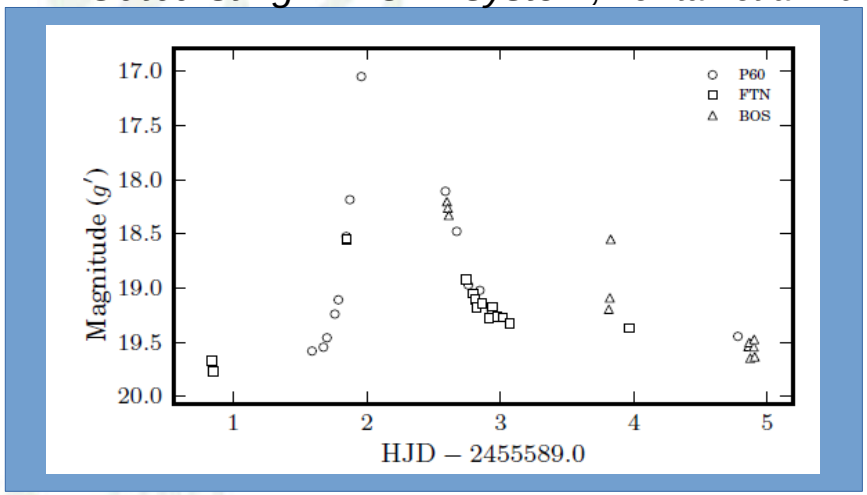
High Cadence survey to characterize fast transient phase space:
"What goes 'bang'- 'bang' in the night?"

→ 60s integrations, 2 bands (qr alternating), continuous for 2 weeks
i.e. 2800 q-band & 2800 r-band observations, 140s effective cadence

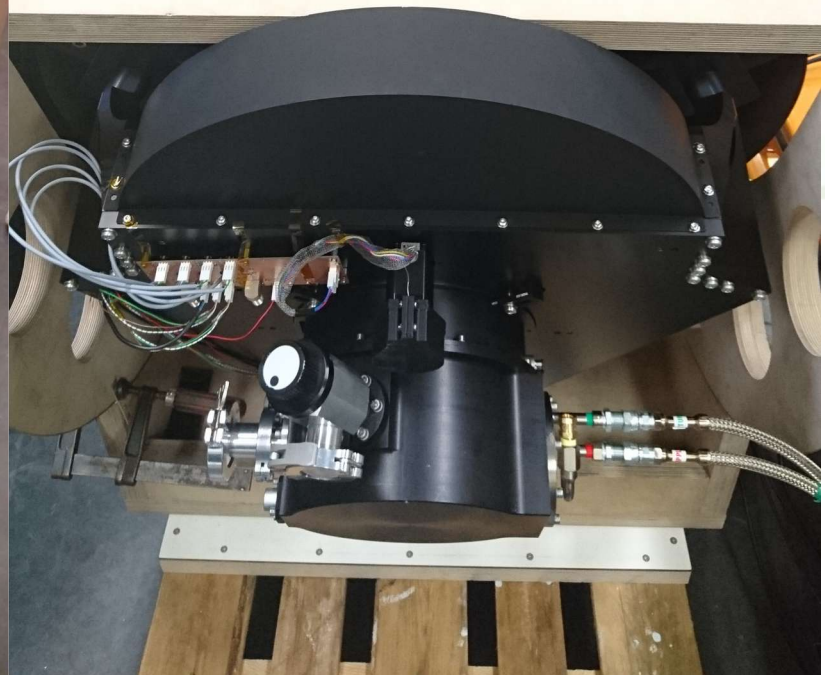


- Fast transients
- Short-period variables
- Fast-moving objects

Outbursting AM CVn system; Levitan et al. 2012

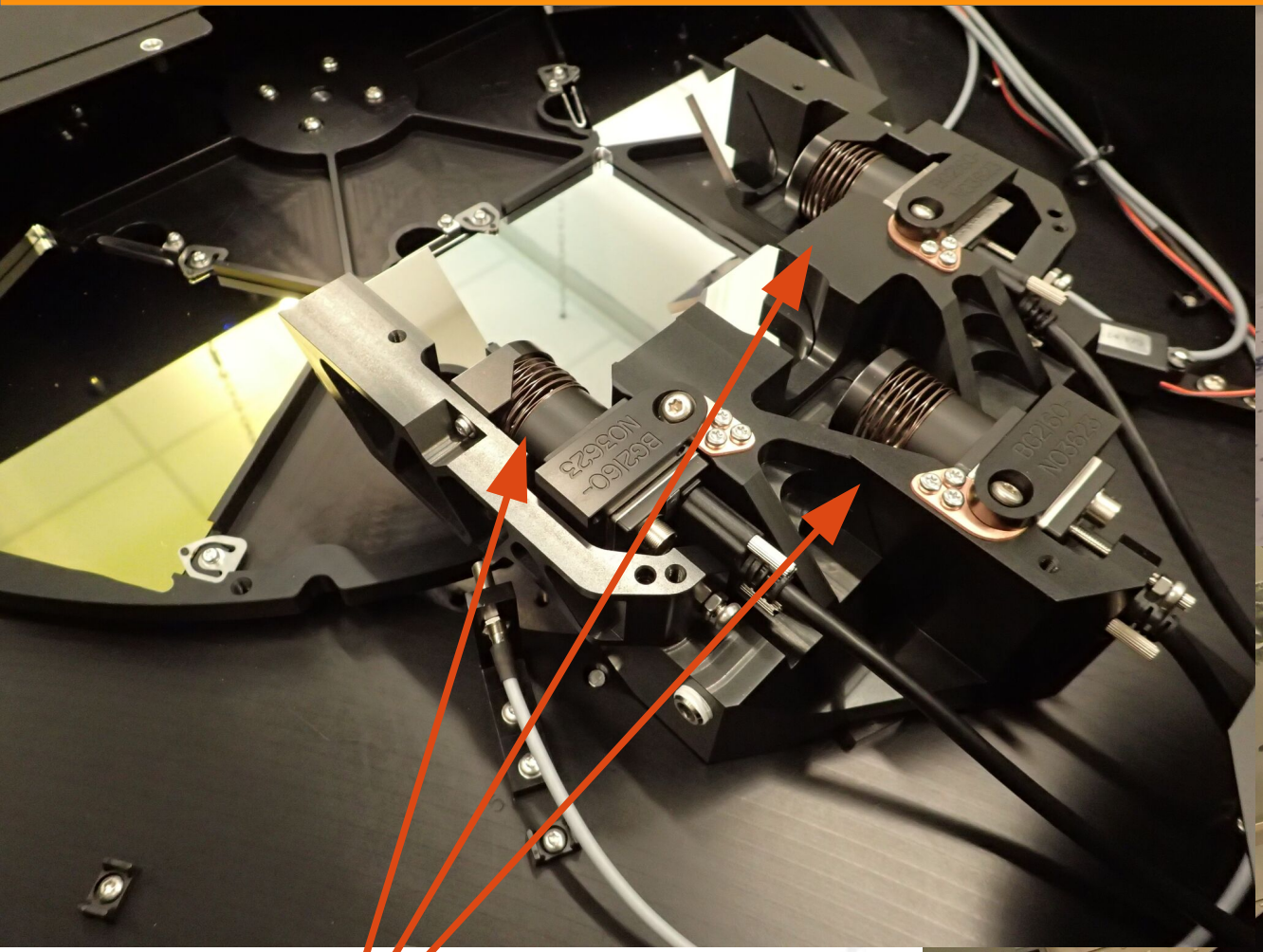


Prototype

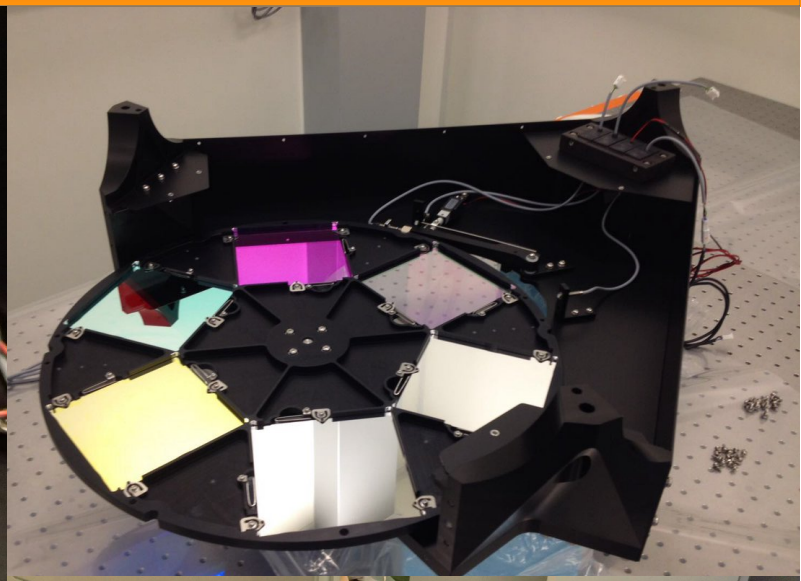


Sept. 2016
in NOVA OIR lab, on temporary Dobsonian mount

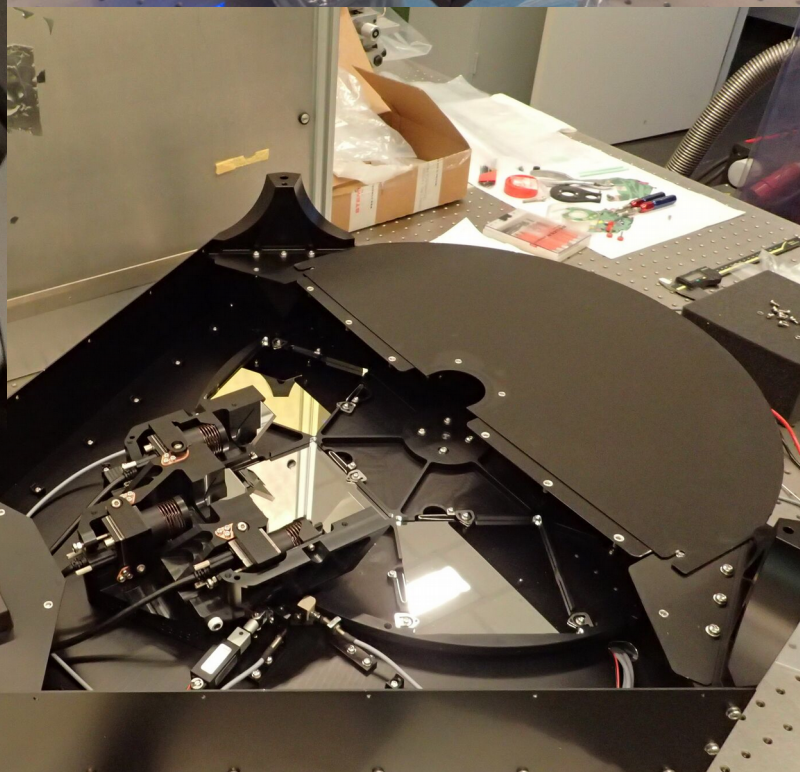
Guide cameras & Filters



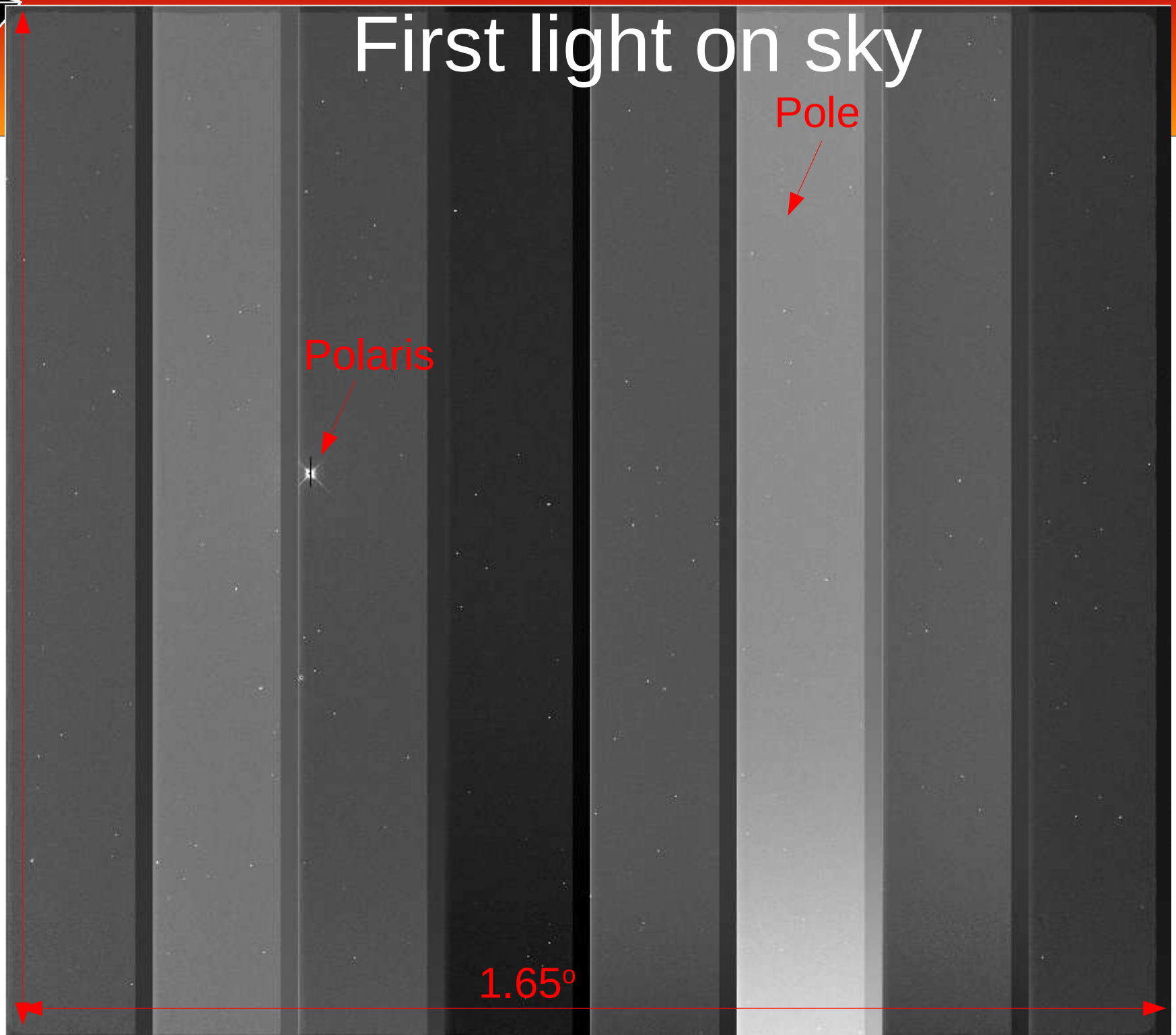
3 Guide cameras



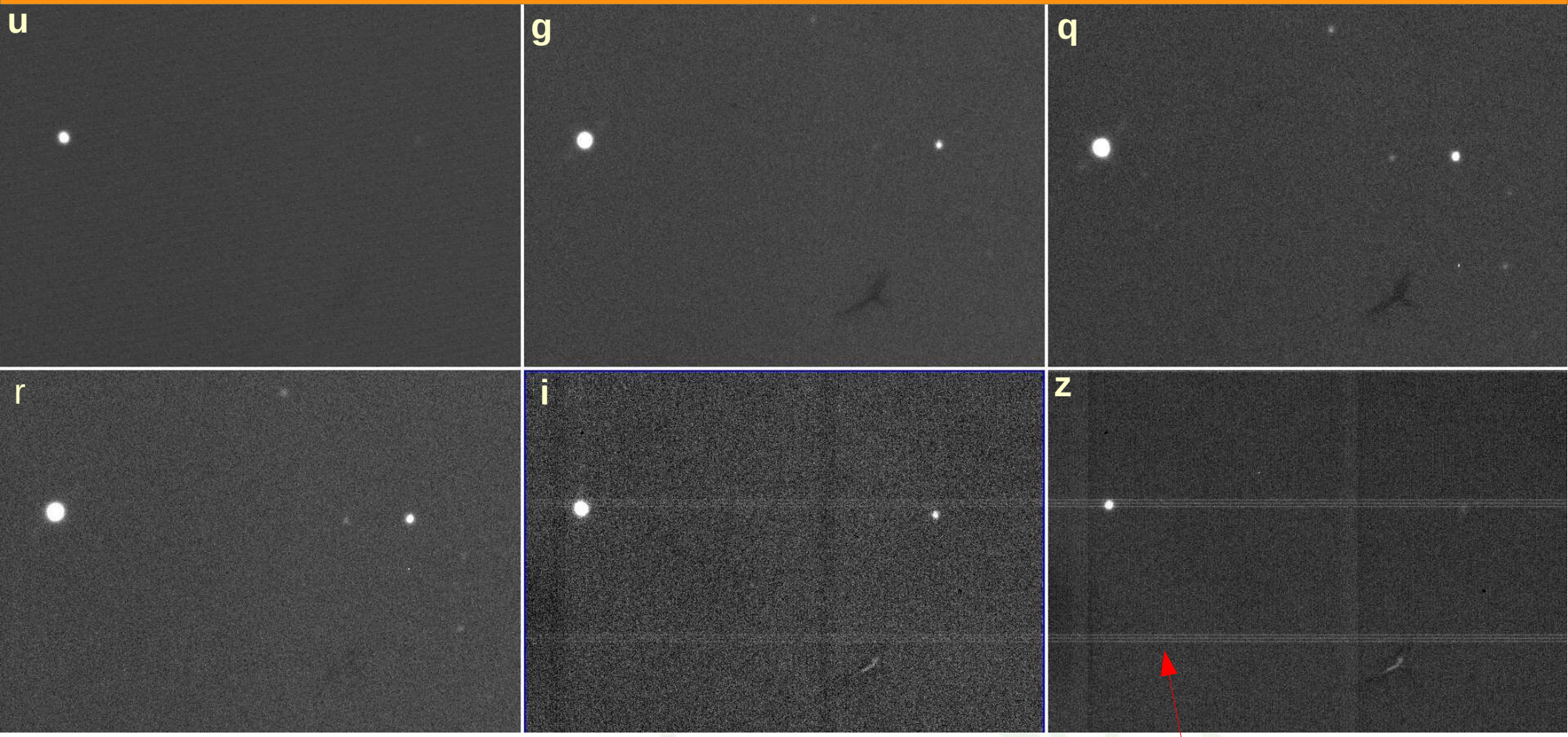
Filter wheel



First light on sky



Filter performance



All exposures 5 seconds, unguided, on Pole

Reflection on backing structure CCD

First light CCD: 22/9/2016

File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help

File ML_12000x10600_73.fits
Object
Value 4765
WCS
Physical X 6406.000 Y 8598.000
Image X 6406.000 Y 8598.000
Frame 12 x 1.000 0.000 °

Taken from backlot of NOVA-OIR building in 2.5” seeing

file edit view frame bin zoom scale color region wcs help
- + to fit zoom 1/8 zoom 1/4 zoom 1/2 zoom 1 zoom 2 zoom 4 zoom 8

POSS2-Blue

DSS2 Galactic Pole
Blue plate

BlackGEM prototype
20s q-band, unguided

Image quality and depth approaching POSS2 plates in 20 seconds (in 2.5” seeing in NL)

Schedule

• Prototype testing @Radboud:	February 2017
• Shipment MeerLICHT prototype → ZA	Early April 2017 (by plane)
• Commissioning MeerLICHT @SAAO	Mid-March – May 2017
• Start operations MeerLICHT	June/July 2017
• Final Design Review BlackGEM	March 23/24, 2017
• Manufacturing BlackGEM-Phase1	March 2017 – March 2018
• Shipment BlackGEM → Chile	May 2018
• Commissioning BlackGEM-Phase1	July/August 2018
• Start operations Phase1	September 2018.