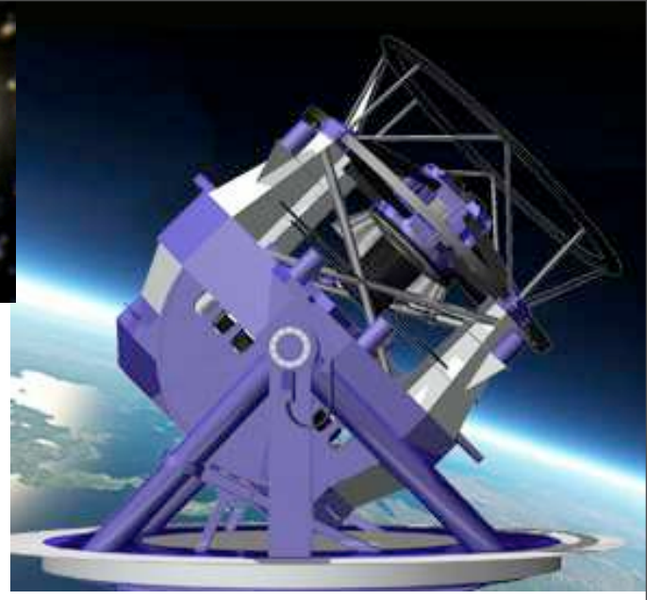
Shotgun session

1. LSST LVC
2. GOTO
3. Wise-GECO
4. SVOM
5. TAROT
6. Leceister
7. Japan Coordinated Network
8. Maxi
9. CALET
10. HESS
11. LOFAR
12. eROSITA
13. Master
14. BlackGEM
15. Apertif
16. Liverpool
17. INAF
18. PIRATE
19. UF group
20. HTRU
21. BOOTES, etc
22. Pi of the sky

Large Synoptic Survey Telescope

the widest, fastest, deepest eye of the new digital age



LSST EM/GW group (16+ members)

Part of LSST transients collaboration (~70) chaired by A. Mahabal and L. Walkowicz.

Independent MoU.

LSST: 8.4m, 9.6 sq. deg, r ~ 24.5, Chile (3π sky),
6 bands (0.3 - 1.1 microns), 1000 visits over 10 years, 2021.

ToO time fraction yet to be finalized, but definite possibility.

Tools enabled: deep sky, galaxy catalogs, false positive vetting.

Gravitational-wave Optical Transient Observer – GOTO

A dedicated GWEM observatory

Don Pollacco on behalf of Warwick/Sheffield Team

- GOTO will detect GWEM candidates for confirmation with larger existing facilities. Limiting magnitude selected to allow spectroscopic characterisation.
- Based on SuperWASP and NGTS technology – modular design: multiple telescopes + detectors on a single mount. Use SWASP infrastructure.
- Based on existing technology – rapid construction. Good GW localisation on La Palma. Existing infrastructure.
- Limited positional control of individual telescopes allowing mimicking of GW error ellipses.
- Rapid slewing etc, continuous all sky survey (aim: whole sky per night).

- Performance – currently 2 models (white(ish) light):

1) System 1: fov >50 square deg, 330sec for V=20.5 (but poor bright time performance)

2) System 2: fov ~ 30 square deg, 350sec for V=22 (V=20.5 in bright time)

Discussion in science team about final specs.

Preparing STFC bid – on sky (limited functionality) start of 2015

Cost < 1m euro

Wise GECO: The Wise Observatory GW EM Counterpart Observations

- 0.46, 0.71, and 1m apertures.
- 1 deg^2 imagers.
- Low and high res spectrographs.
- Soon – fiber bundle IFU: point-and-shoot.

Dovi Poznanski
Dan Maoz
Ehud Behar
Shai Kaspi
Ehud Nakar

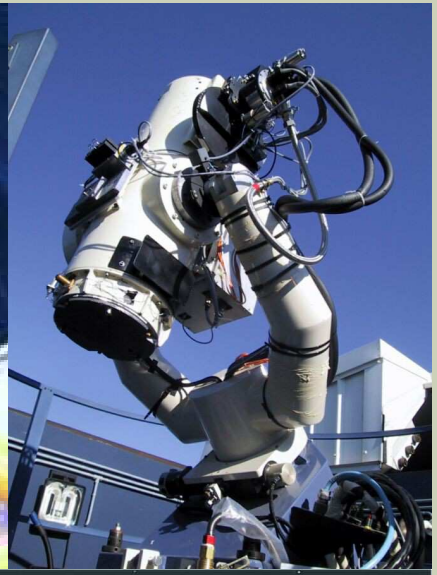
Image credit – I. Arcavi

SVOM Consortium

- Main missions : GRB alerts – events follow-up
- 1 space segment – 1 ground segment
- Space segment (not before 2017) :
  - GRM: γ-ray spectrometer - 30 keV to 1000 keV- fov 4.1 sr
  - ECLAIR: 2D mask imager - 4 to 150 keV – fov 2 sr – 10 ‘
  - MXT: X-ray telescope - 0.3 to 10 keV – fov 1.1 deg. – 10 ‘’
  - VT: 40 cm visible telescope – fov 26’x26’ - 1’’
- Ground segment :
  - GWAC: ~5000 sq.deg - 450-900nm – mag.=16 in 10s – follow ECLAIR FoV – prototype already available
  - GFT-C: 1 m visible telescope – 26’x26’ – mag.= 21 in 300s – will be available for 2015
  - GFT-F: 1 m NIR and visible telescope - fov = 30’ - mag.NIR = 18.8 and mag.vis = 21.8 in 300 s – available in 2017
- Consortium composed mainly by China (CNSA/CAS/IHEP) and France (CEA/CNES/CNRS) with participation from UK, Germany and Mexico
- Final decision this fall

TAROT-ZADKO

- Network, 3 telescopes
  - Calern-France, 25cm, 2deg fov, 2s to target, mag 16 in 10s, continuous light curves
  - ESO-Chile (La Silla), same characteristics
  - Zadko-Gingin-Australia, 1m, 20arcmin fov, mag 22 in 30s
- Both central and distributed scheduling, processing, and archiving (CADOR system)
- Responded already to S6 and various alerts BATSE, HETE2, Swift, and ANTARES (neutrinos)
- Extension foreseen in France and Australia to 20sq. deg., 30cm, and Algeria (60cm)
- Adjunction of IR capability under testing



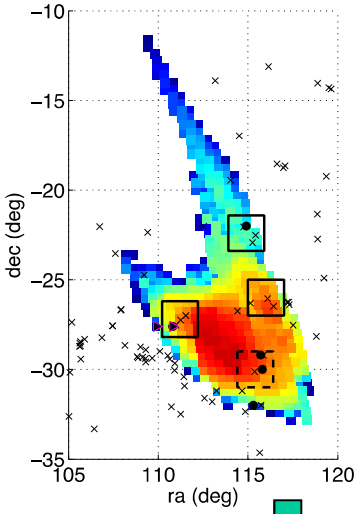
Find and characterise GW sources

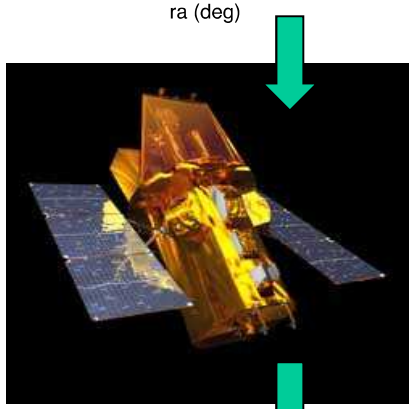
Paul O'Brien, Nial Tanvir & Julian Osborne (on behalf of a lager collaboration)

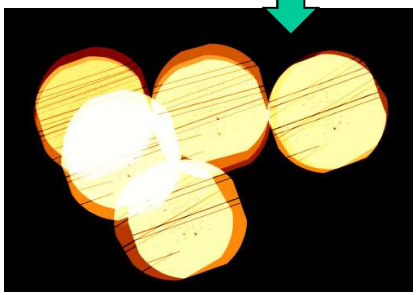
University of Leicester

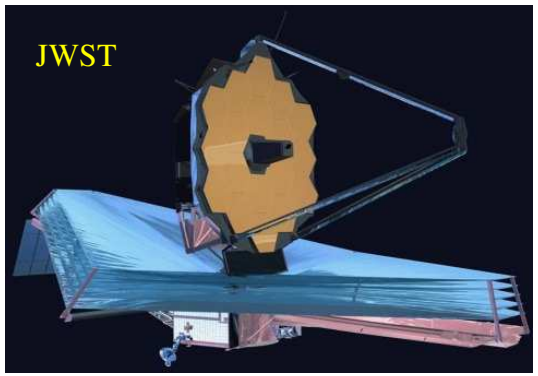
We play a key role in many high-energy transient missions and have a large, on-going multi-wavelength follow-up program

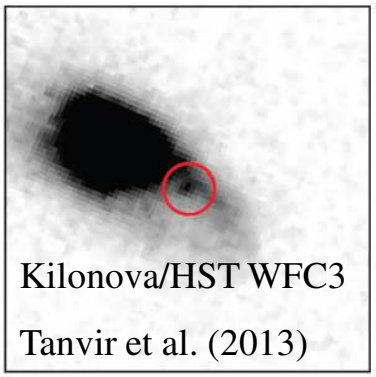
- We lead X-ray searches with Swift for GW counterparts
- We are PI/co-I on numerous ground/space facilities with time to observe transients (e.g. HST, VLT, AAT, XMM-Newton…)
- We lead more novel approaches, e.g. kilonova search
- We produce the XMM-Newton and Swift X-ray serendipitous source catalogues
- We are co-Is on numerous future projects (e.g., SVOM, Einstein Probe, ASTROSAT, CTA, JWST, NGTS)





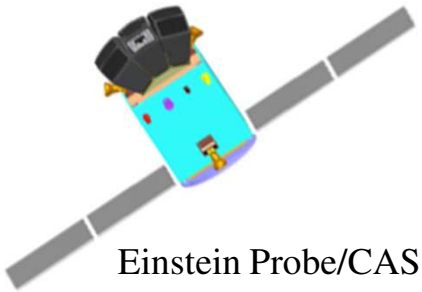






Kilonova/HST WFC3

Tanvir et al. (2013)



Einstein Probe/CAS

Soft X-ray monitor

Japan Coordinated network for transients observation

M. Yoshida (Hiroshima Univ.)

A part of the project “Multi-messenger Observations of GW sources” (2013-2017)
* collaborating with the KAGRA data analysis team
* science cases: GRBs, supernovae, blazars, etc.

Main features:
5 deg^2 opt. imaging w/ 1m
1 deg^2 NIR imaging w/ 1m
opt-NIR spectroscopy w/ 1 – 8 m
opt-NIR polarimetry

- 1m Kiso Schmidt telescope
  5 deg^2 camera ➔ 30 deg^2
- 1.5m Kanata telescope
- 50cm MITSuME
- 91cm W-F NIR camera of NAOJ
  1 deg^2 NIR camera
- Yamaguchi 32m radio telescope

50cm telescope
(Hiroshima Univ. 2014)

3.8m telescope
(Kyoto Univ. 2015)

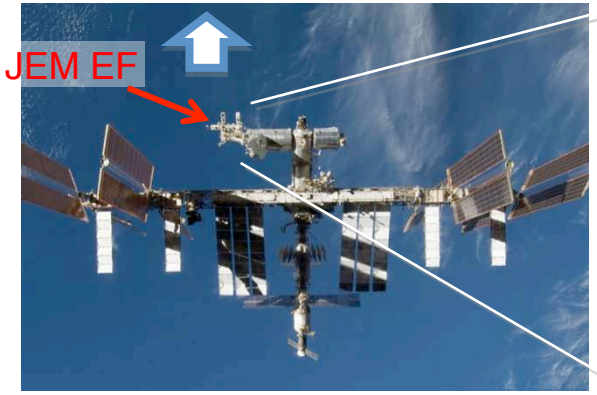
Subaru @Hawaii

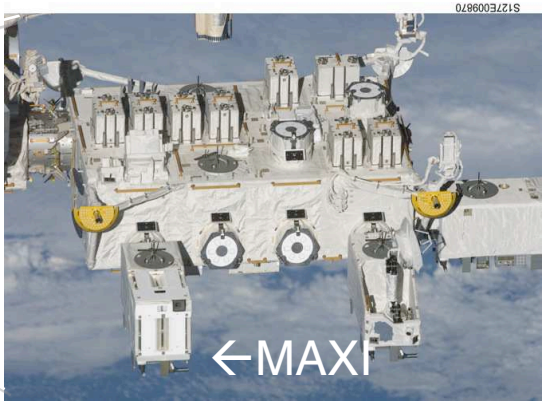
IRSF (Nagoya Univ.)
@ South Africa

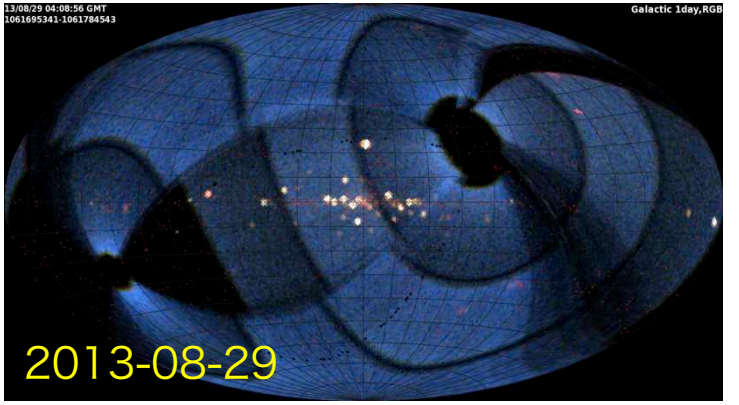
miniTAO (Tokyo Univ.)
@ Chile

MAXI (Monitor of All-sky X-ray Image) on ISS

N. Kawai (Tokyo Tech) for the MAXI Team
RIKEN, JAXA, Tokyo Tech, Osaka U., AGU, Nihon U. Kyoto U. Chuo U. Miyazaki U.





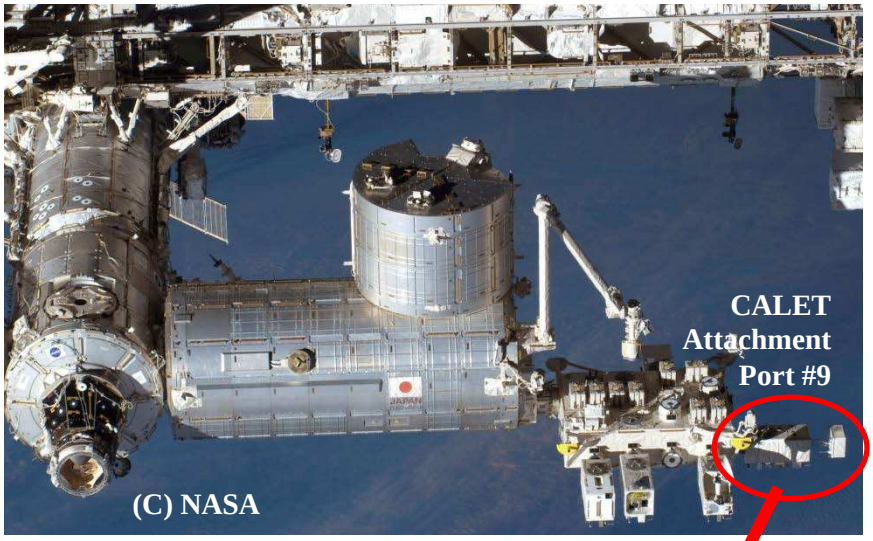


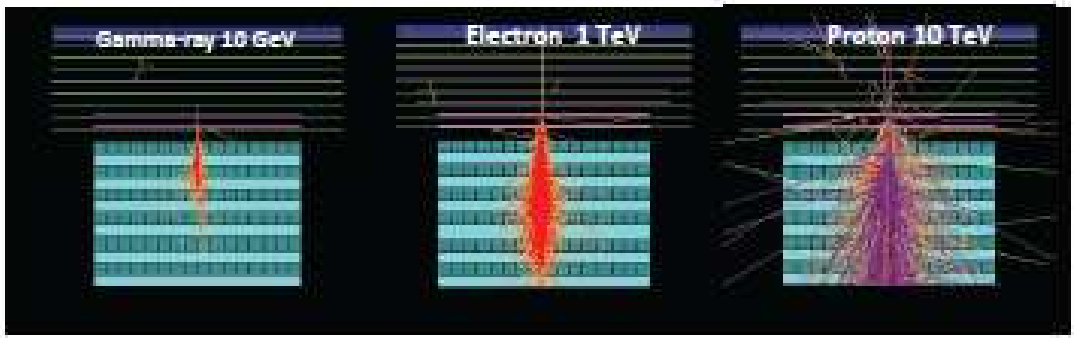
	GSC (X-ray Gas Camera)	SSC (X-ray CCD Camera)
Detector	Gas(Xe) proportional counter	CCD 16 chips
Energy range (Q.E.>10%)	2－30 keV	0.7－12 keV
duty cycle	40 % (x 0.7 real time)	20 % (x 0.7 real time)
Instantaneous sky coverage	2 % of the sky (160 deg x 3 deg x 2 sets)	1.4% of the sky (90 deg x 3 deg x 2 sets)
sensitivity	70 mCrab (single scan)	100 mCrab (single scan)
observing mode	Slit scan with 92 min period	
PSF / localization	1.5 deg / >0.1 deg	
deliverable data product	location, X-ray flux, detection time	

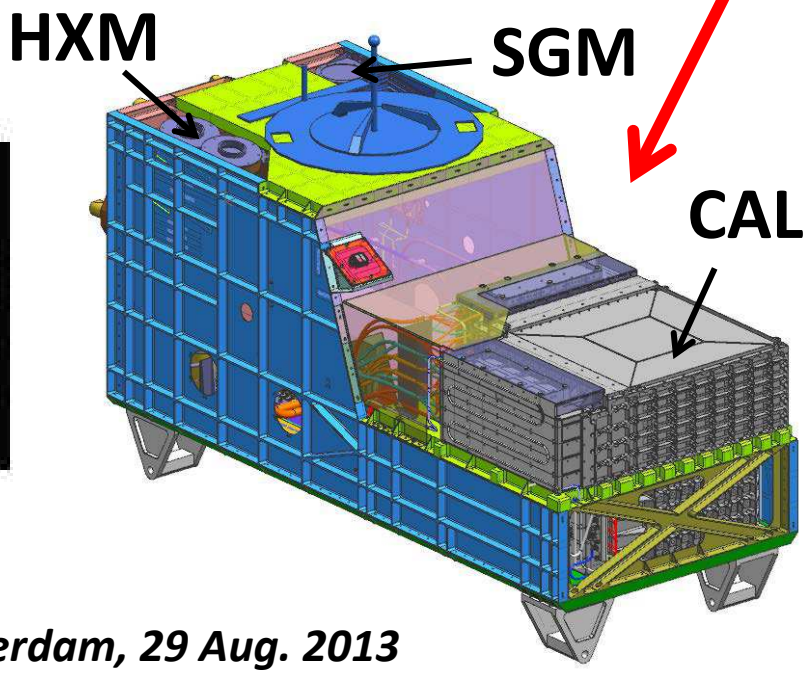
CALET: CALorimetric Electron Telescope

- JAXA(Japan), NASA(US), ASI(Italy).
  - On ISS from JFY 2014. Currently in PFM phase.
- Gamma-ray Burst Monitor (CGBM)
  - Hard X-ray Monitor (**HXM**): $LaBr_3(Ce)$ + PMT.
  - Soft Gamma-ray Monitor (**SGM**): BGO + PMT.

  Sensitivity of CGBM: ~10^{-8} ergs cm^{-2} s^{-1} (1-1000 keV) for 50 s long bursts.
- Calorimeter (**CAL**)
  - Charge detector: plastic scintillator + PMT.
  - Imaging calorimeter (3 X_0): W/SciFi + MA-PMT.
  - Total absorp. calorimeter (27 X_0): PWO + PD/APD.







- Broad energy range (keV - TeV gamma-rays): long/short-duration GRBs, X-ray flashes, GeV GRBs.

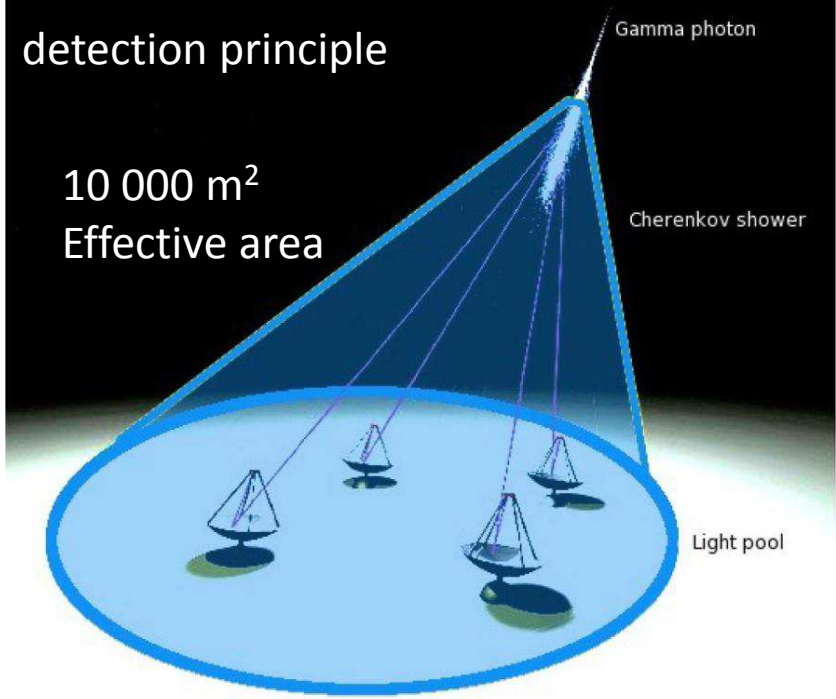
GRB performance and deliverables

Parameters	CAL	CGBM
Energy range	1 GeV - 10 TeV (GRB trigger)	HXM: 7 keV - 1 MeV (goal 3 keV - 3 MeV) SGM: 100 keV - 20 MeV (goal 30 keV - 30 MeV)
Energy resolution	3% (10 GeV)	HXM: ~3% (662 keV) SGM: ~15% (662 keV)
Effective area	~600 cm^2 (10 GeV)	68 cm^2 (2 HXMs), 82 cm^2 (SGM)
Angular resolution	2.5° (1 GeV) 0.35° (10 GeV)	-
Field of view	~45° (~2 sr)	~3 sr (HXM), ~4π sr (SGM)
Dead time	2 ms	40 μs
Time resolution	62.5 μs	GRB trigger: 62.5 μs (event-by-event data) Normal mode: 125 ms with 8 ch, 4 s with 512 ch

- **CALET deliverables to LVC:**
  - Fine time resolution (<250 ms) light curve of GRB from CGBM, within one day.
  - GRB spectral data from CGBM, within few days (if GRB position info available).
  - GRB preliminary data (e.g. position, light curve and spectrum) from CAL (if applicable), within a few days. Completed data will be provided for publication.

H.E.S.S.

H.E.S.S. collaboration



- Array of Cherenkov telescopes
- Sothern hemisphere
- Large effective area (transient searches)
- E > 30 GeV (HESS II)
- Repositioning time: about 1 minute
- Field of view: 5 degrees(HESS I)
- Location accuracy: 0.1 degree
- Moonless nights

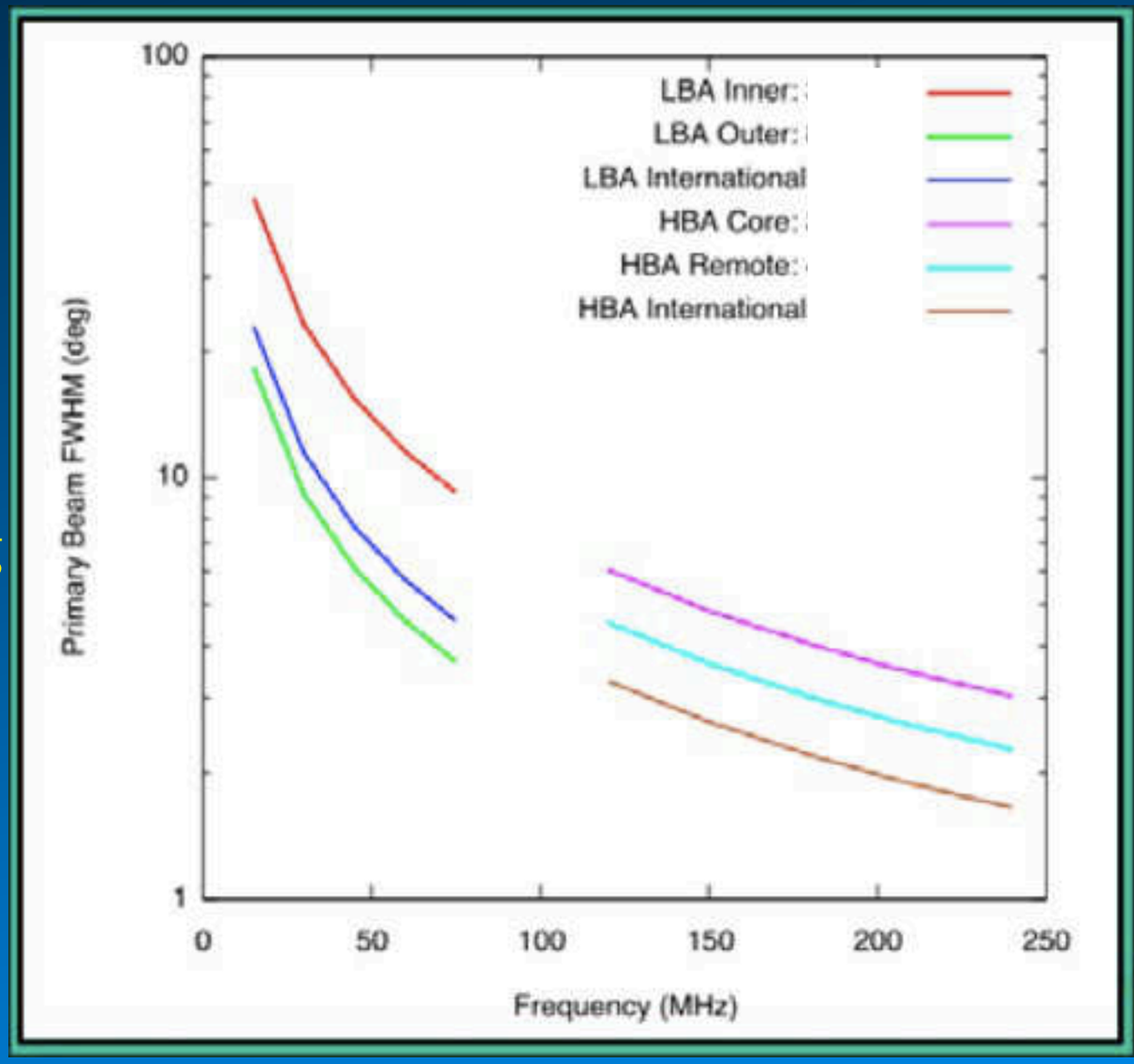
LOFAR Transient Key Science Project

LOFAR

Low band antennae: 30 – 80 MHz

High band tiles:120 – 240 MHz

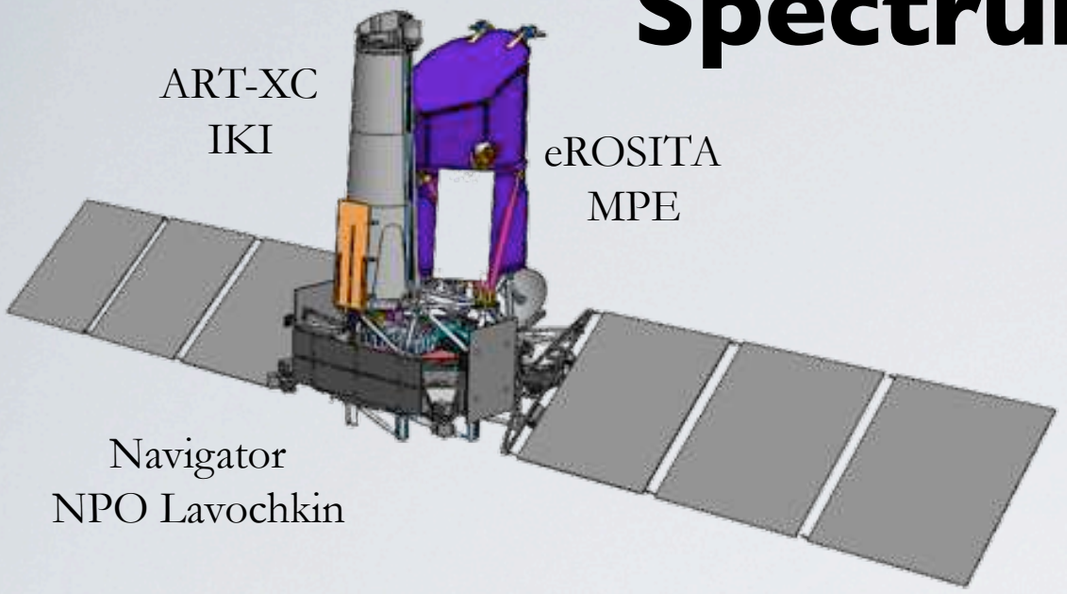
- 38 NL + 8 EU stations of dipoles
- No moving parts: electronic beam steering
- Flexible digital beam forming



Peter Jonker (SRON, RU, CfA)

coordinator of multiwave/messenger follow-up

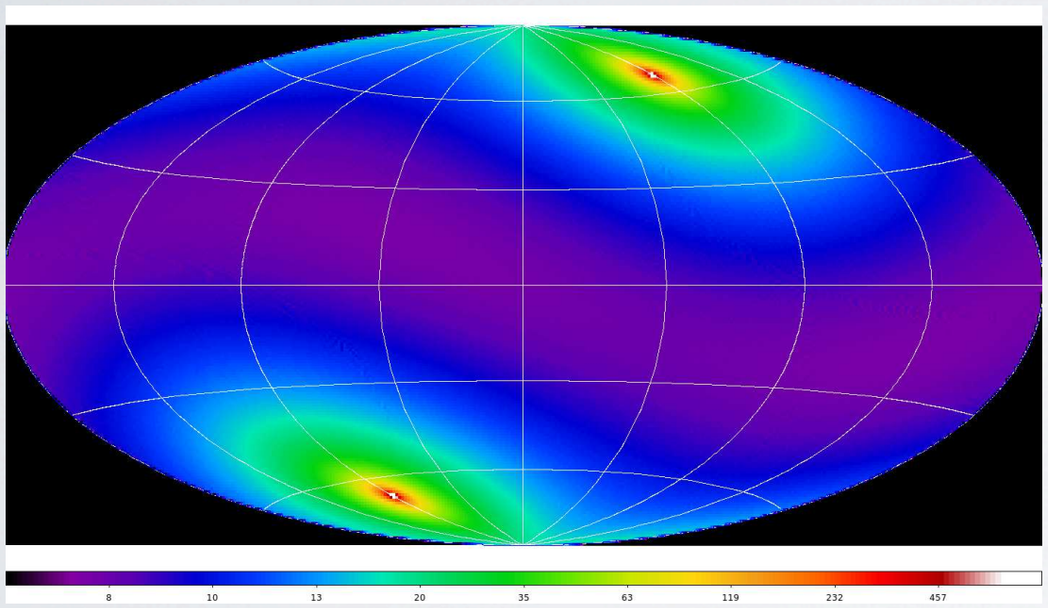
Spectrum-Roentgen-Gamma (SRG)



(to be launched to L2 orbit in Q4 2014 - tbc)

<u>two instruments:</u>

eROSITA: 0.3-10 keV, ~0.8 sqdeg FoV, ~25" ang. res.
ART-XC: 6-30 keV, ~0.2 sqdeg FoV, <1' ang. res.



<u>operation mode:</u>

- first 4 years: all-sky survey every 1/2 year (6 rot. per day, 1 deg advance per day)
- 0.5-2 keV : 20x deeper than ROSAT
- 2-10 keV : unprecedented
- next 3.5 years: pointed observations
- data initially proprietary to SRG team
- eROSITA survey data rights split in German and Russian Hemispheres

<u>relevance for EM search of GW counterparts:</u>

- all-sky survey mode limits SRG response to ToOs
- but: archival eROSITA+ART-XC data will provide unique X-ray all-sky reference frames
- positions, fluxes, timing, spatial, and spectral information for potential candidates inside LVC error region

(presented by A. Rau (MPE) on behalf of the SRG team)

Global MASTER Robotic Net (The Night Watch), Moscow State University Vladimir Lipunov

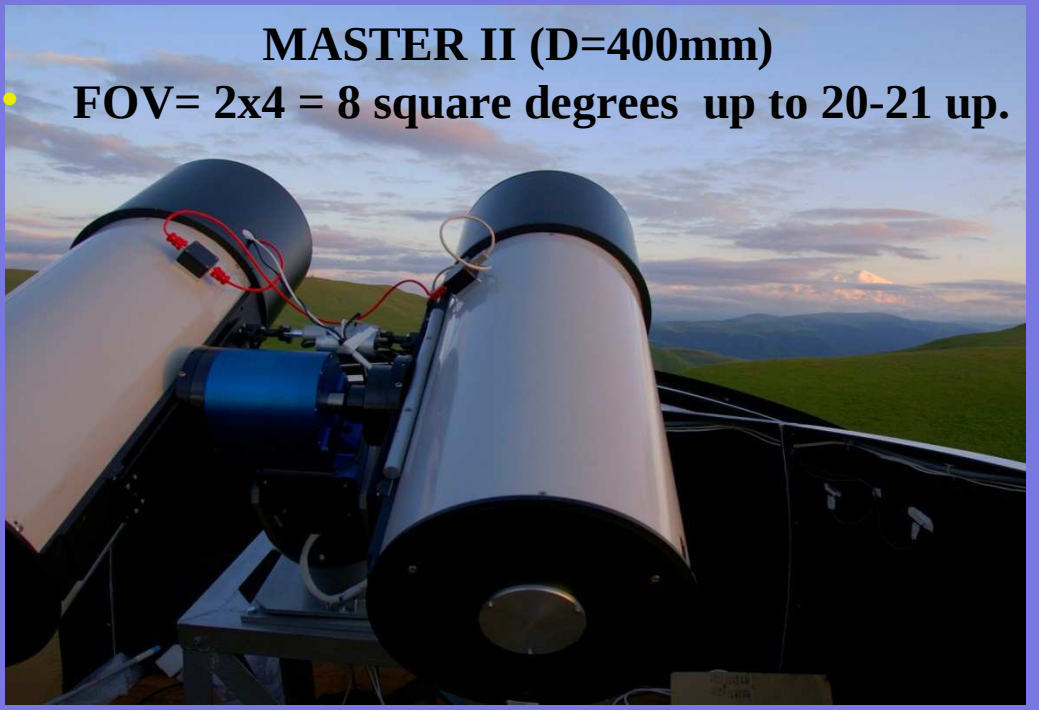
LIGO-Virgo Alert Discussion,
29-30 aug 2013, Amsterdam

- **Very Wide Field Cameras**

MACTEP VWF

- **FOV=400 square degrees up to 12 mag per 1 s.**
- **Time Resolution 150 ms**

- **MASTER II (D=400mm)**
- **FOV= 2x4 = 8 square degrees up to 20-21 up.**

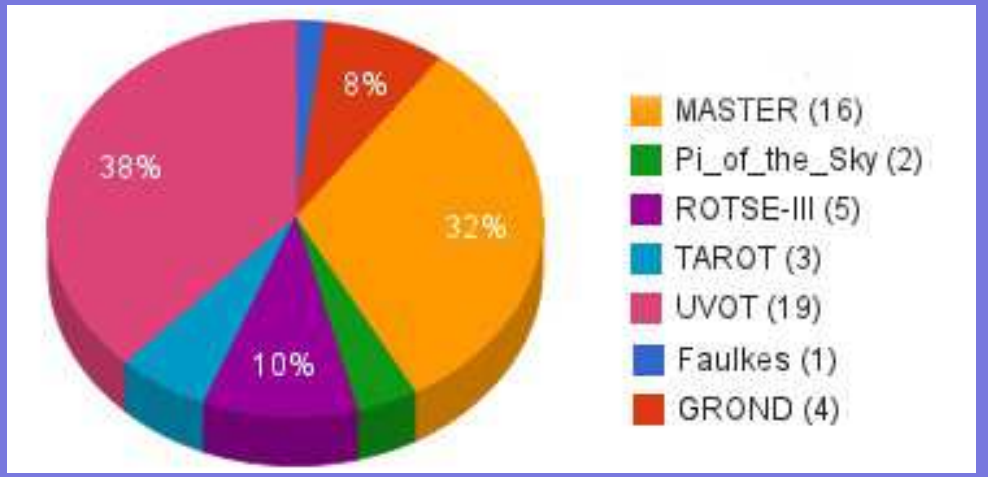


Second Generation Robotic Telescope MASTER II

Wide Field + Color & Polarization & Fast Mount (50degrees/s)

Interaction of MASTER OTs with the large telescopes in the World

Number of first pointing on Swift GRB from 1 september 2010 to 1 june 2011

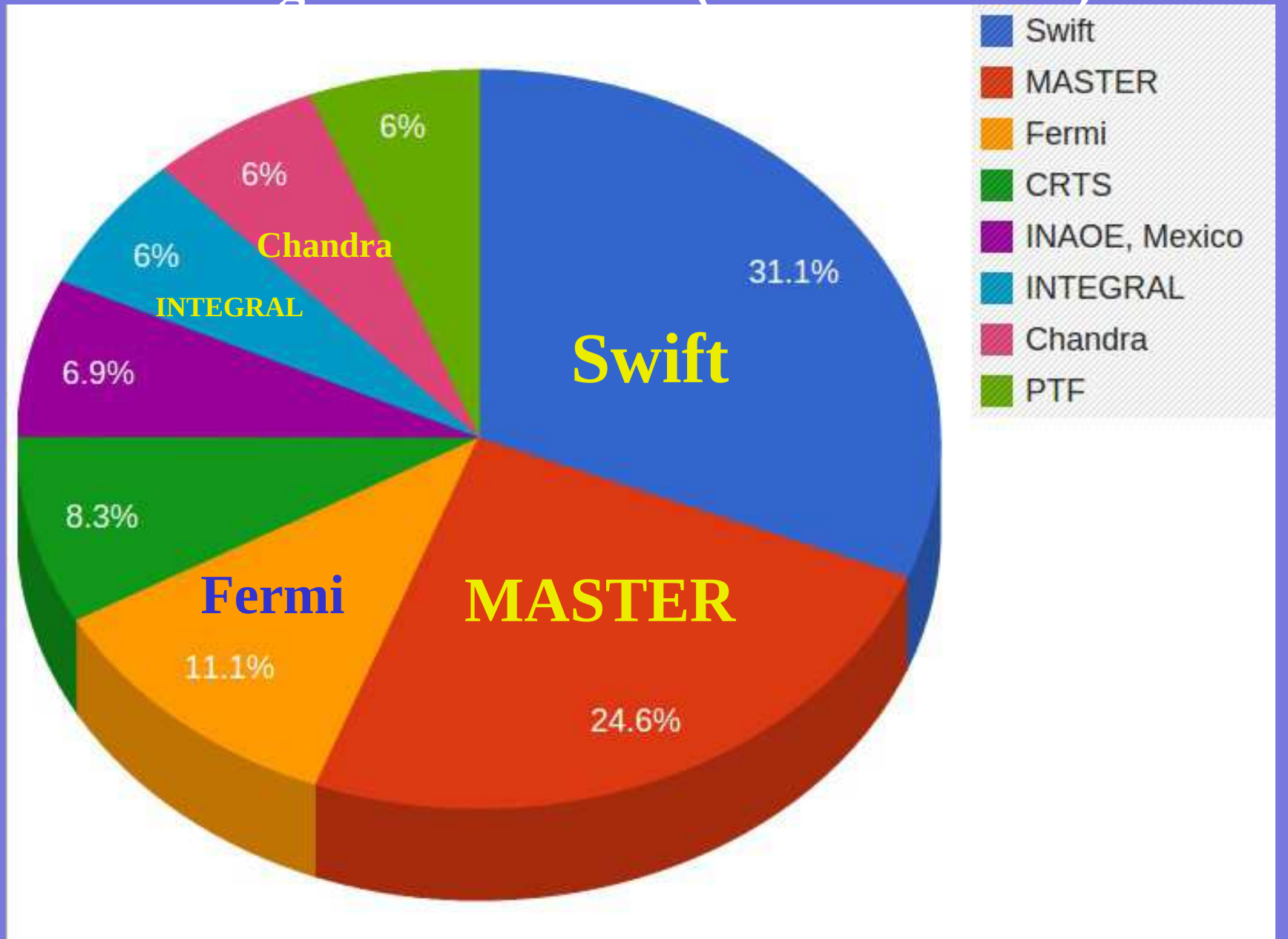


Common FOV = 38 square degrees up to 21mag
Common FOV = 4800 square degrees up to 14 mag
Reaction Time 10-20 sec

Information Flow

MACTEP II 4x15Gb = 60Gb/night
MACTEP VWF
12 x950 Gb/night =10Tb/night

MASTER INPUT to Astronomer telegrams 2011-2012 (>300 transients)



BlackGEM Array

Dedicated, optical telescope array for GW events (2015+).

- 20 telescopes with 65cm, 2.2 square degree *each*
- Spatial resolution: 0.51-0.57″ / pixel (i.e. seeing limited)

- Flexible: fish-eye, combi-mode, full zoom, @ ESO La Silla
- Robotically, remote-controlled, triggered by Virgo/LIGO
- *Dedicated to GW events!*
- Open for external partners to extend array

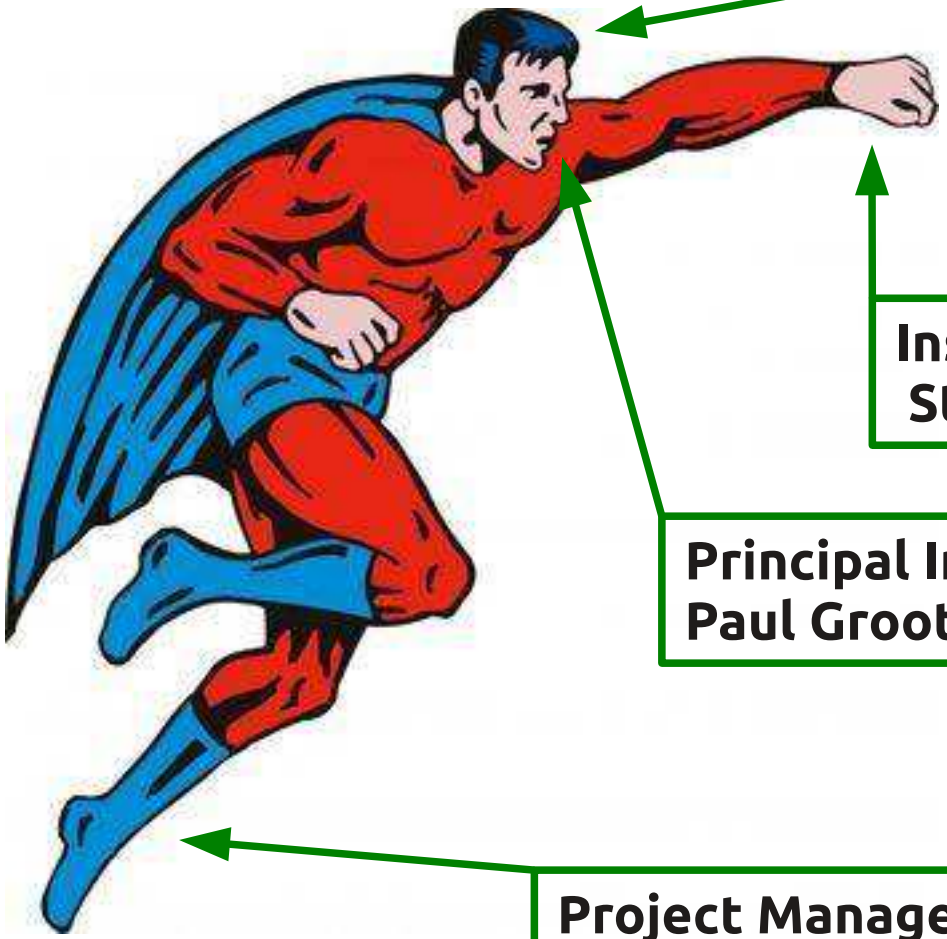
- *Follow-up with VLT, WHT, ALMA, SALT, MeerKAT, HST, XMM, Chandra*

Phase1 = 4 telescopes has now started *(NOVA, RU, FOM, NWO)*

www.blackgem.eu and **@BlackGEM_Array**

BlackGEM Array Team

Project Scientist ('brains'): Gijs Nelemans

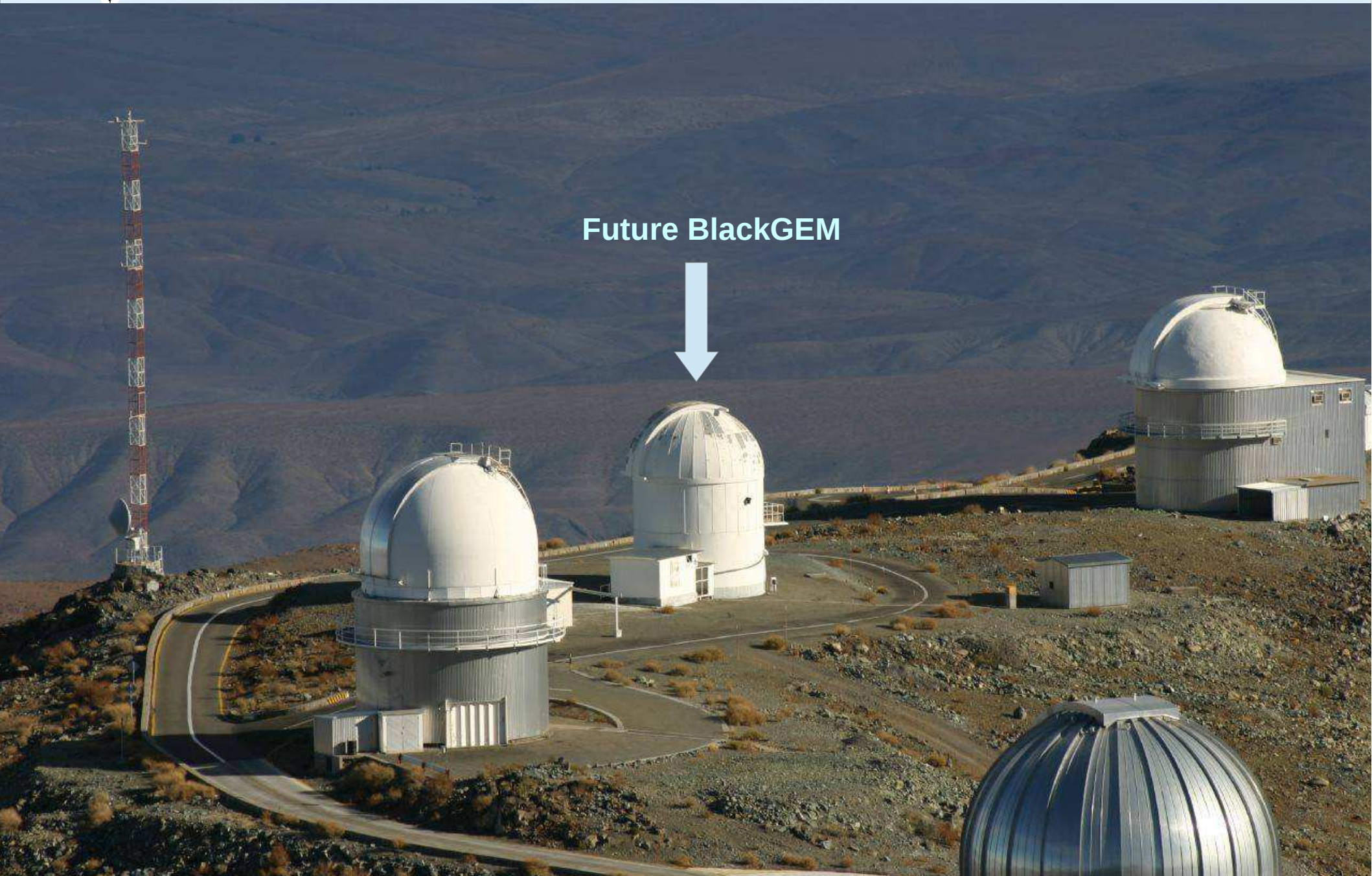


Instrument Scientist ('golden hands'): Steven Bloemen

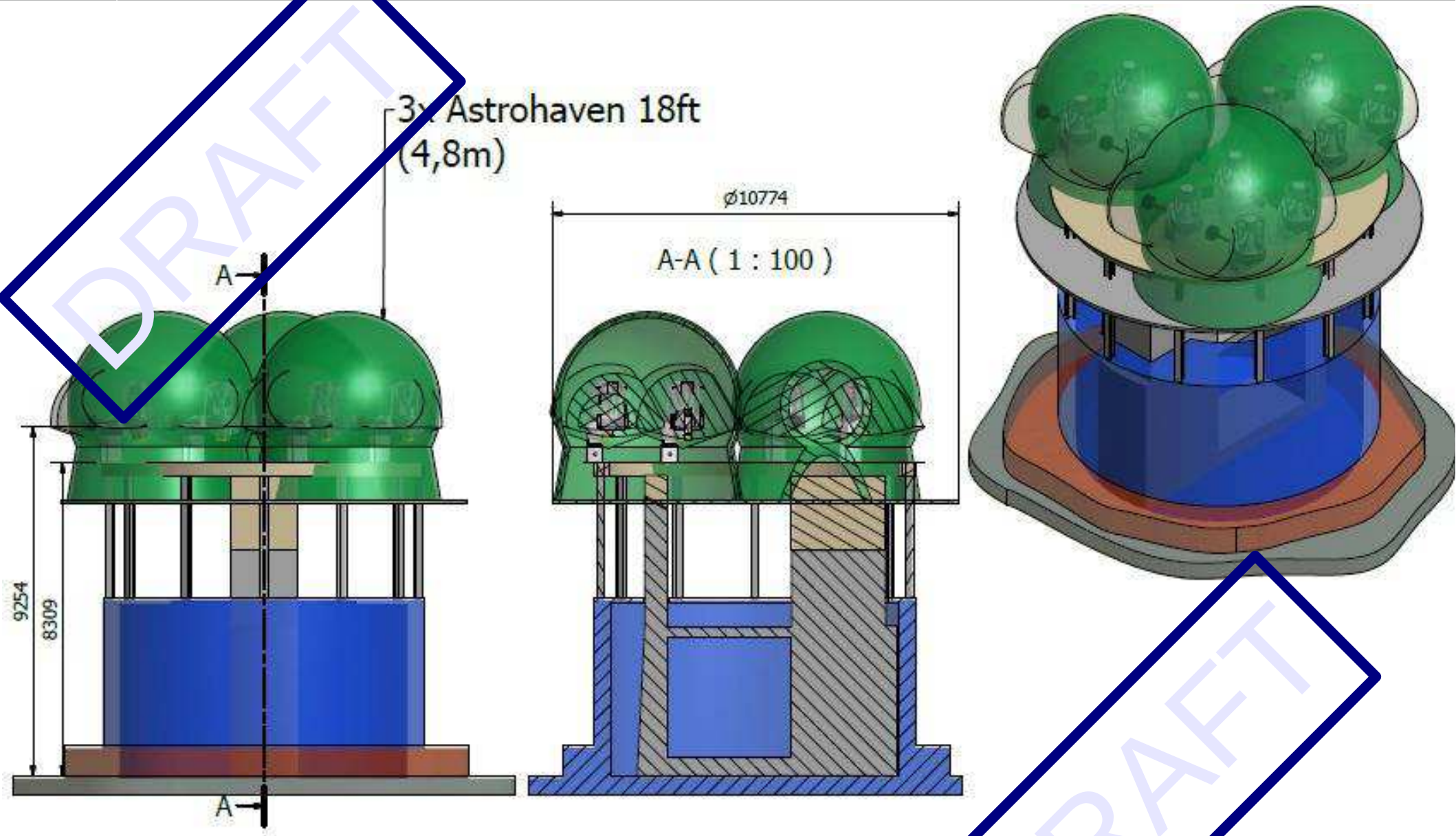
Principal Investigator ('mouth'): Paul Groot

Project Managers ('kicking feet'): Marc Klein Wolt & Arno Engels

BlackGEM on ESO La Silla

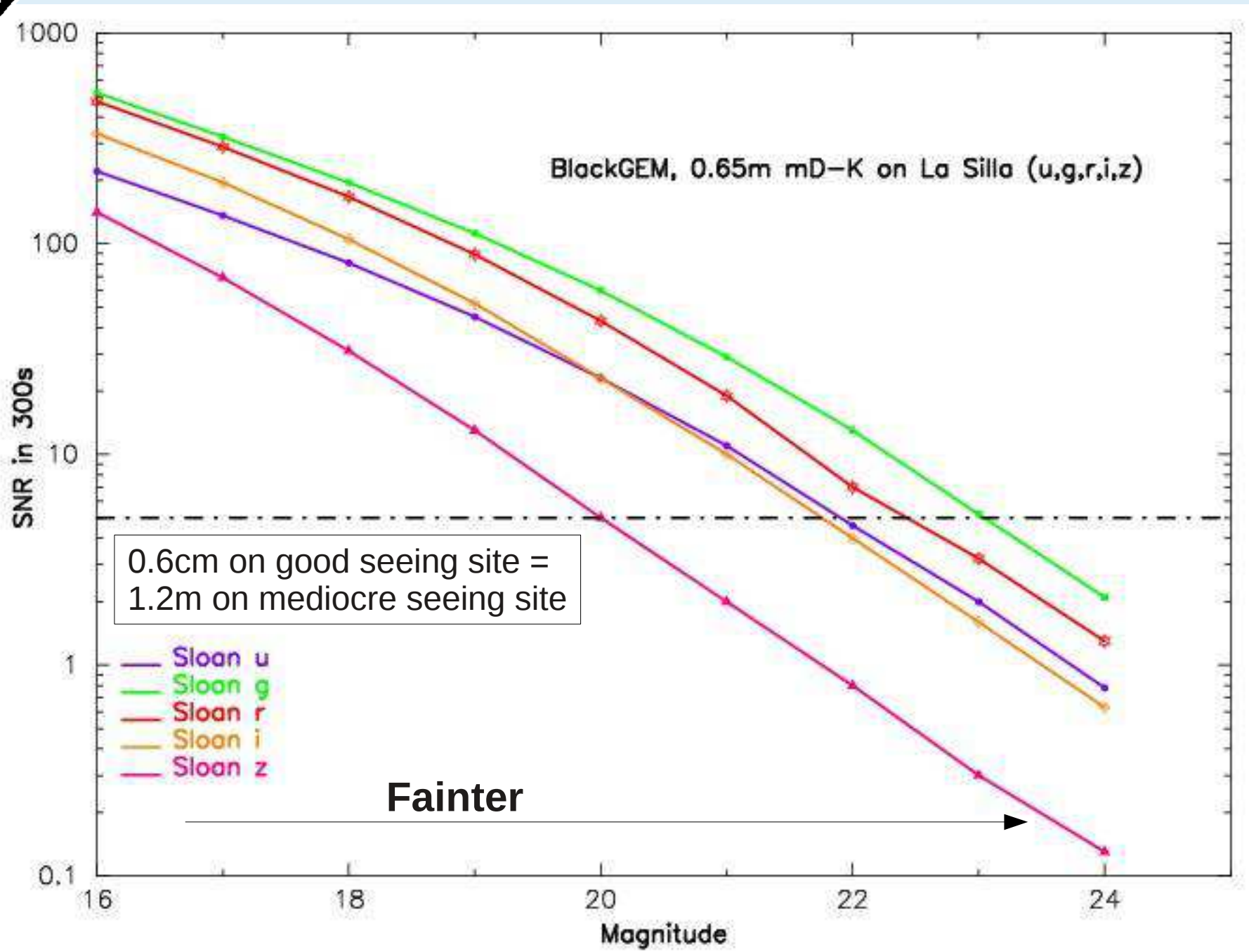


Reusing the GPO/Marly dome



St.Nr.	Aant.	Benamin		Materiaal	Tek. Nr.	Opmerking
Ontw.		Schaal		Ruwheid	Maattolerantie	Vorm en Plaatstol.

Performance



Aim and Schedules

Phase 0: (8 sqd, 2015 – 2016) **All Sky Survey**

Full Southern Sky in u,g,r,i,z down to ~22nd mag

Phase 1: (8 sqd, 2015 – 2016) **Survey Phase**

Rates : $N_{candidates}(l,b,\tau,mag,colour)$ $(degr^{-2}\,hr^{-1}\,mag^{-1})$

- Number of fiducial fields: ~200 square degrees
- Cadence: once every 5-30 minutes, in 4 bands (u,g,r,i)
- Time per sqd: 7 nights

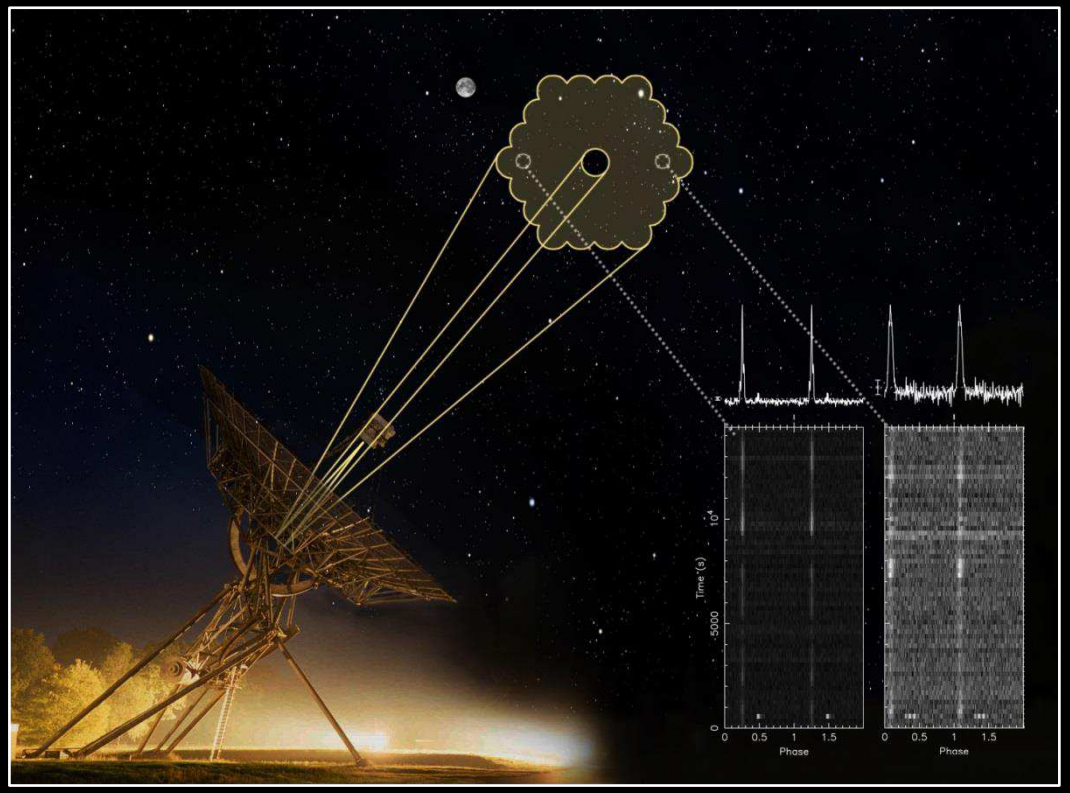
Phase 2: (8-40 sqd, 2017+) **Trigger Phase**

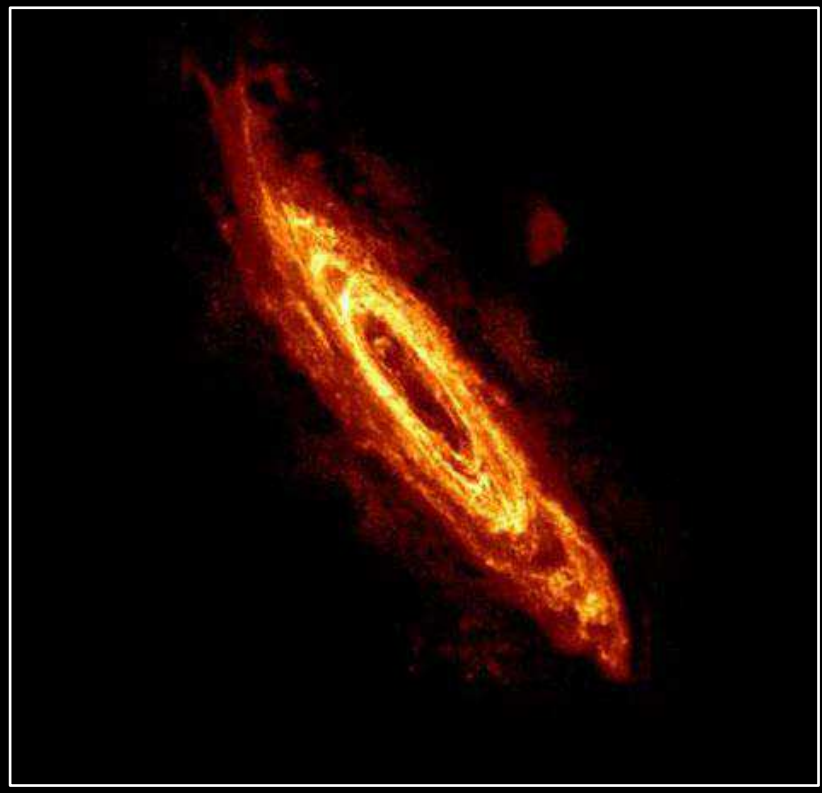
GW events

- Follow-up on Virgo/LIGO detections
- Cover the error boxes in a tiling pattern (Fly's Eye Mode)
- Follow late-term afterglows (Zoom Mode)

van Leeuwen, Paragi, Bell, Hessels, Fender, Stappers, ..

APERTIF – EVN





Liverpool John Moores University, UK

I.Steele, S.Kobayashi, C.Collins, C.Copperwheat, C.Mundell

- The Liverpool Telescope is a 2.0m fully robotic alt-az telescope at the ORM, La Palma
  - Rapid response to ToOs – time to target typically ~180s
  - Software triggered override systems, flexible response pipeline
  - Diverse instrument suite: FoVs 10' or less
  - SkyCams: R~12 over 20deg^2, R~18 over 1deg^2

- Liverpool Telescope 2 is a planned 4m class successor telescope for 2020+
  - Preferred site is La Palma
  - Transient science, extremely rapid response – taking data within 30sec of receipt of trigger
  - Opt/IR intermediate resolution spectroscopy, but imaging capability as well: FoV > 15'

http://telescope.livjm.ac.uk/lt2

The Italian Istituto Nazionale di Astrofisica

expresses the intent to provide Italian observational resources for the advanced gravitational-wave detector era EM-follow-up:

*The **"2.6m VLT survey telescope"** able to optimally cover wide-field with deep-sensitivity, high-resolution and multi-color observations*

→ **corrected FOV 1 deg x 1 deg, pixel scale of 0.21"/pixel**

→ **V-limiting magnitude of 25.5** AB mag arcsec^{-2} for **30 min** exposure

→ it takes about **1 hour to cover a sky area of 10 sq. deg. in u', g' and r'** reaching a **magnitude of about 23**

→in 2016 the **INAF-Guaranteed Time Observation** will increase to up to **15% of the total observing VST time**

*The **"Campo Imperatore Transient Experiment"** is a project to develop an innovative **wide-field camera of 8.8 sq. deg. FOV** able to scan large GW skymaps **within few hours** from the GW alert up to **V ~21mag***

→ **If funded**, the camera will be **installed and tested at the *60cm Schmidt telescope*,** in view of its application in a new generation of robotic wide field telescopes and at better sites

→ At the CI site there is an operating ***near-IR telescope, AZT-24*** with **limiting magnitudes** of **J=17.7, H=16.9** and **K=16.2 mag for 1 min exposure** and a **FoV** of **4.4x4.4 arcmin^2**

*These facilities could be coupled with other INAF facilities with high resolution power and large collecting area (e.g. **TNG, LBT**), near-IR (e.g. **REM**) or radio facilities (e.g. **SRT**)*

Working Group

The 29 scientists are organized in four operative units:

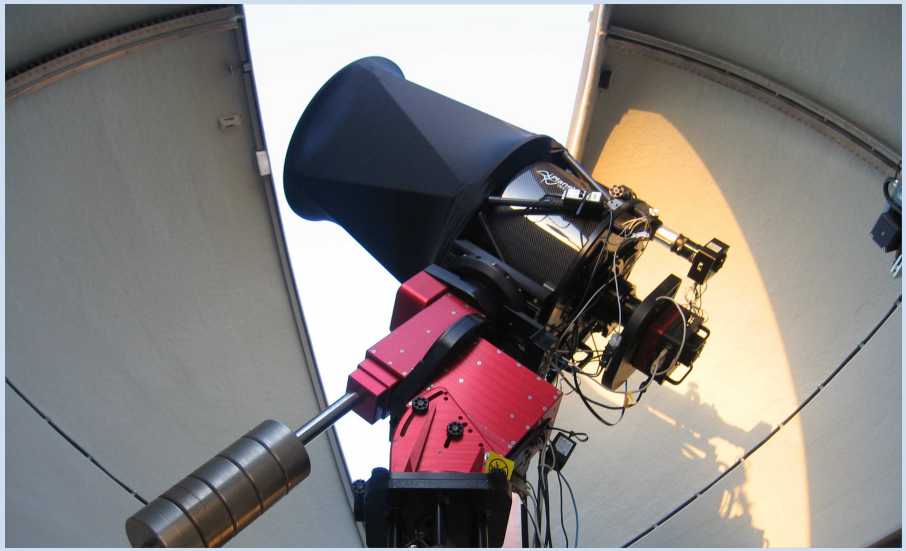
Unit 1) VST and CITE follow-up of GW transient events **-** M.T. Botticella, M. Dall'Ora, M. Della Valle, A. Grado, M. Marconi, N. R. Napolitano, V. Ripepi (Osservatorio Astronomico di Capodimonte, INAF); M. Branchesi (Universitá di Urbino); E. Brocato, V. Testa (OA di Roma, INAF); M. Capaccioli, M. Paolillo (Universitá di Napoli Federico II); E. Cappellaro (OA di Padova, INAF)

Unit 2) Radio, optical and X–ray follow-up of counterpart candidates and archival data studies - A. Caccianiga, S. Campana, S. Covino, R. Della Ceca, A. Moretti, P. Severgnini (OA di Brera); E. Palazzi, E. Pian (Istituto di Astrofisica Spaziale e Fisica Cosmica - Bologna, INAF) , L. Piro (Istituto Astrofisica e Planetologia Spaziali, INAF)

Unit 3) Compact object theory and study of local galaxies - D. Guetta, F. Fiore, L. Stella (OA di Roma, INAF), F. Mannucci (OA di Arcetri, INAF), M. Mapelli (OA di Padova, INAF)

Unit 4) Technological development and management of optical facilities
A. Di Paola (OA di Roma, INAF), P. Schipani (OA di Capodimonte, INAF)

Ulrich Kolb, The Open University



PIRATE Mark 2:

- PlaneWave CDK17 0.42m
- SBIG STX-16803 (4k x 4k 9μ pixels)
- *ƒ*/6.8
- F.O.V 43’ x 43’
- Plate scale: 0.64’’ pixel^{-1}
- seeing 2”
- limiting magnitude V=19

30% teaching, 70% research

- SuperWASP candidate winnowing
- transient follow-up – set up for automated follow-up of Gaia transient alerts (reaction within minutes)
- periodic varibables

PIRATE site

- Observatori Astronomic de Mallorca (OAM)
- hosts OU astronomy field trip

Longitude E 2° 57' 06"
Latitude N 39° 38' 38"
Altitude 203 m

PIRATE published

http://pirate.open.ac.uk/

- 2013, ATel with Gaia Science Alert team
- Maxted et al 2013, MNRAS, submitted (EL CVn-type binaries)
- Faedi et al 2013, A&A, 551, 73 (new planets WASP-54b, 56b, 57b)
- Faillace et al 2013, JBAA 123 (2), 100 (near-contact binary)
- Rodda et al 2013, JBAA, in press (chromospherically active binary)
- Haswell et al 2012, ApJ 760, 70 (second HST visit of WASP-12)
- Bloom et al 2012, ApJ Letters,744, L17 (**supernova SN2011fe**)
- **Holmes et al 2011, PASP 123,1177, (PIRATE commissioning)**
- Lucas & Kolb 2011, JBAA 121, 265 (software architecture)
- Fossati et al 2010 ApJL (HST visit of WASP-12)

- 8 ATel or CBET notes (M31 novae)

PIRATE

UF Group – EM Followup LOIs

- **Planned proposals:**
  - DECam (south): 2.2-deg FOV @CTIO 4m; r=23 mag in <30s; 100 sq.deg. <0.5hr
  - WIYN/ODI (north): 0.75-deg FOV @WIYN 3.5m; r=23 mag in 30s; 100 sq.deg. <2hr
- **Team:**
  - Steve Eikenberry (UF, LVC)
  - Sergey Klimenko (UF, LVC)
  - Kendall Ackley (UF grad student, LVC)
  - Ian Dell'Antonio (Brown, ODI commissioning scientist)
  - Possible merger with other proposing groups for DECam and WIYN/ODI (??)

High Time Resolution Universe surveys

PI: David Champion

- Full sky survey for pulsars using multi-beam receivers. Northern hemisphere covered by Effelsberg (100-m), Southern hemisphere covered by Parkes (64-m).
- Unprecedented time and frequency resolution used to detect pulsars but also extra-Galactic bursts (in realtime).
- Hardware is continually developed to improve sensitivity and triggers.
- Effelsberg is privately owned by MPIfR and can respond very quickly.
- This collaboration has been extremely successful in obtaining time at Parkes and can follow-up as part of the continuing survey (potentially with ToO component).
- Processing of follow-up data would be quasi-realtime.
- HTRU - Collaboration between pulsar groups in UK (Uni. Manchester), Australia (Swinburne/CASS), Germany (MPIfR-Bonn), Italy (Cagliari) – experienced in multi-wavelength follow-up – many members also work in GWs

Riding Shotgun

People

Nicholas James Rattenbury, Alberto J. Castro-Tirado, Richard Easther, Phil Yock, Bill Allen, Grant Christie, Fumio Abe.

Facilities

- **BOOTES-1, 2** are in Spain. FoV: 30'x20', 10'x10', 5° x 5°.
- **BOOTES-3**, South Island of New Zealand. FoV: 10'x10'.
- **BOOTES-4**, Yunnan province of China. FoV: 10'x10'.
- **Auckland Observatory**, New Zealand. FoV: 34'x 27'.
- **Mount John Observatory**, South Island, New Zealand.
- Proposed 1-m LCOGT telescope, Auckland, New Zealand.

Pi of the Sky

- a search for short optical transients

- Two sites
  - **Pi of the Sky North (INTA, Spain)** – since 2010, extended 2013
    - **4 telescopes, 4 cameras each (total FOV 76° x 76°)**
    - **Covering most sensitive part of Swift's FOV**
    - Limiting magnitude 11.5 mag (or 12.5 mag for 20 stacked frames)
    - High time resolution (10s exposition + 2s readout)
  - **Pi of the Sky South (San Pedro de Atacama, Chile)** – since 2011 (previously at LCO, Chile)
    - **1 telescope with two cameras working in coincidence (FOV 20° x 20°)**
    - Limiting magnitude 12 mag (or 13 mag for 20 stacked frames)
    - High time resolution (10s exposition + 2s readout)
  - Possibility of observation using parallax (Chile-Spain, 8500 km)
- Custom designed hardware and software solutions for efficient and autonomous transient detection
- Currently developing new device with larger aperture, very fast parallactic mount (30 deg/s) and higher time resolution
- The team
  - Center for Theoretical of Physics Polish Academy of Sciences
  - Faculty of Physics, University of Warsaw
  - National Centre for Nuclear Research
- The team took part in the Looc-Up project