The 4 meter New Robotic Telescope

Carlos M. Gutiérrez

(on behalf of the consortium members in LJMU, IAC and UO)

LIVERPOOL JOHN MOORES UNIVERSITY

Iain Steele (PI NRT Project)
Chris Copperwheat
Helen Jermak
Eamonn Harvey
Adrian McGrath

INSTITUTO DE ASTROFISICA DE CANARIAS · IAC

Carlos M. Gutiérrez (IAC-PI)
Rafael Rebolo
Johan Knapen
Miguel Torres
Asier Oria
Juan J. Sanabria

Universidad de Oviedo

Francisco J. de Cos

IWARA2018, Ollantaytambo, September 2018

NRT TELESCOPE

In a nutshell:

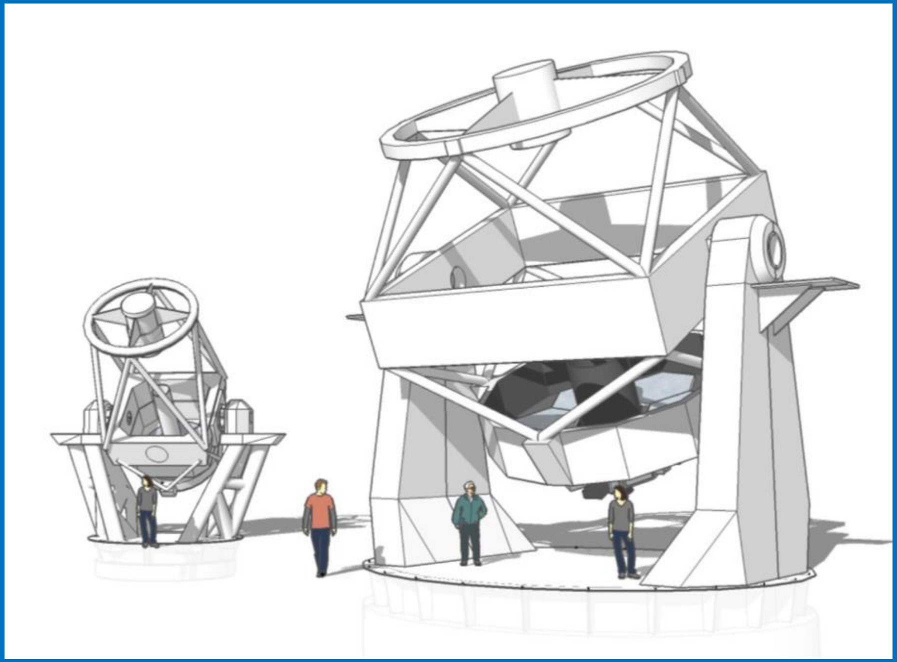
- International collaboration to build in 5 years time the largest (4 m) entirely robotic telescope in the world with a extremely quick response (on target in 30 s)
- Sited at ORM in La Palma
- Based on the success of LT
- Partners:

LJMU (UK) IAC (Spain) UO (Spain)

LIVERPOOL JOHN MOORES UNIVERSITY

INSTITUTO DE ASTROFISICA DE CANARIAS · IAC

Universidad de Oviedo



∅ 2 m ∅ 4 m

Estimated cost 20 M€

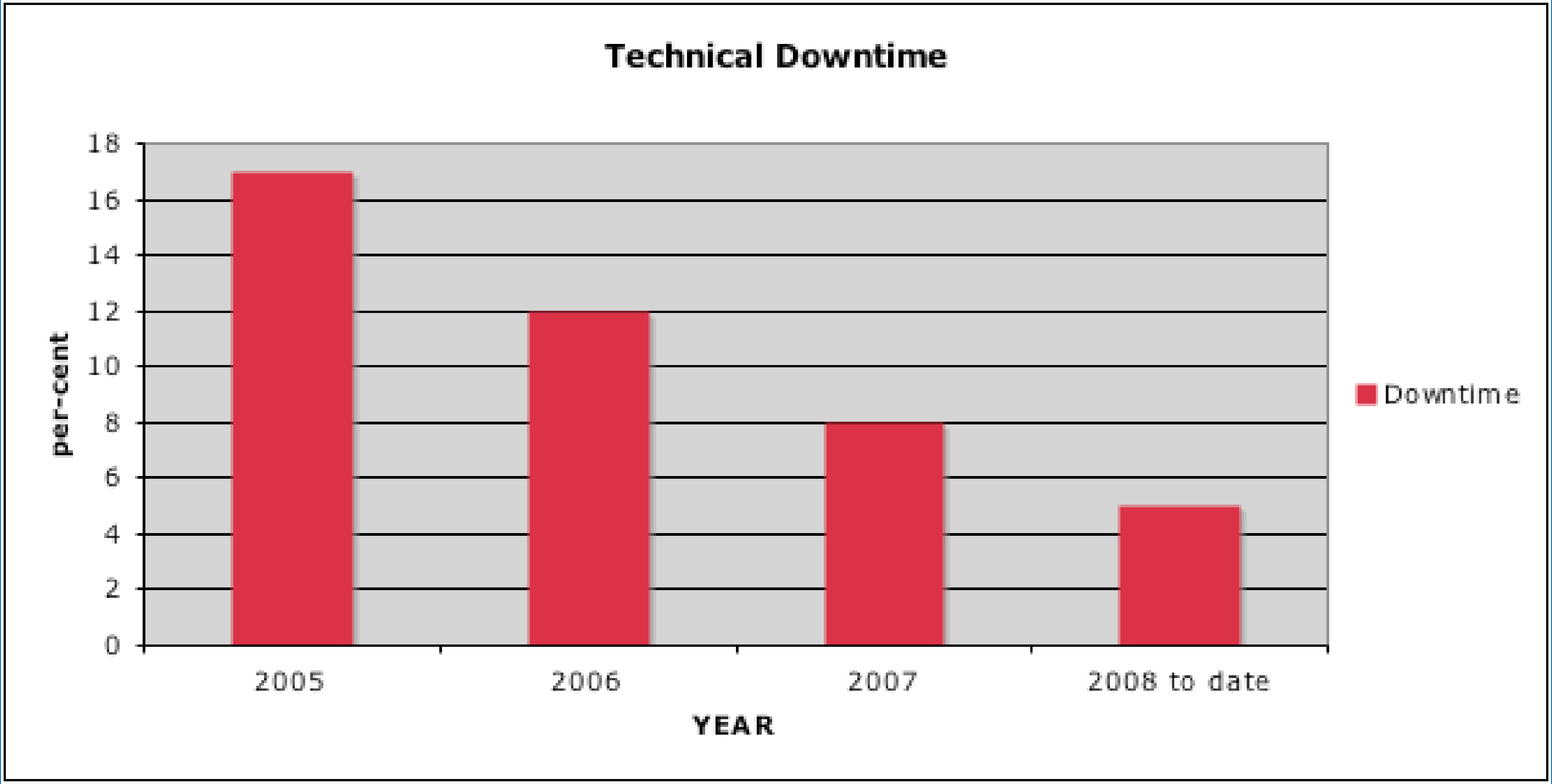
LIVERPOOL TELESCOPE

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

- The Liverpool Telescope is a robotic 2m alt-az telescope (owner LJMU) in operation at ORM (La Palma) since 2004.
- **Not 'remote controlled' – operated autonomously without night-time supervisión**
- Software decides what and how to observe and is responsible for safe operation of telescope throughout the night
- Flexible nature of LT observing modes makes it ideal for time domain astronomy

Liverpool Telescope

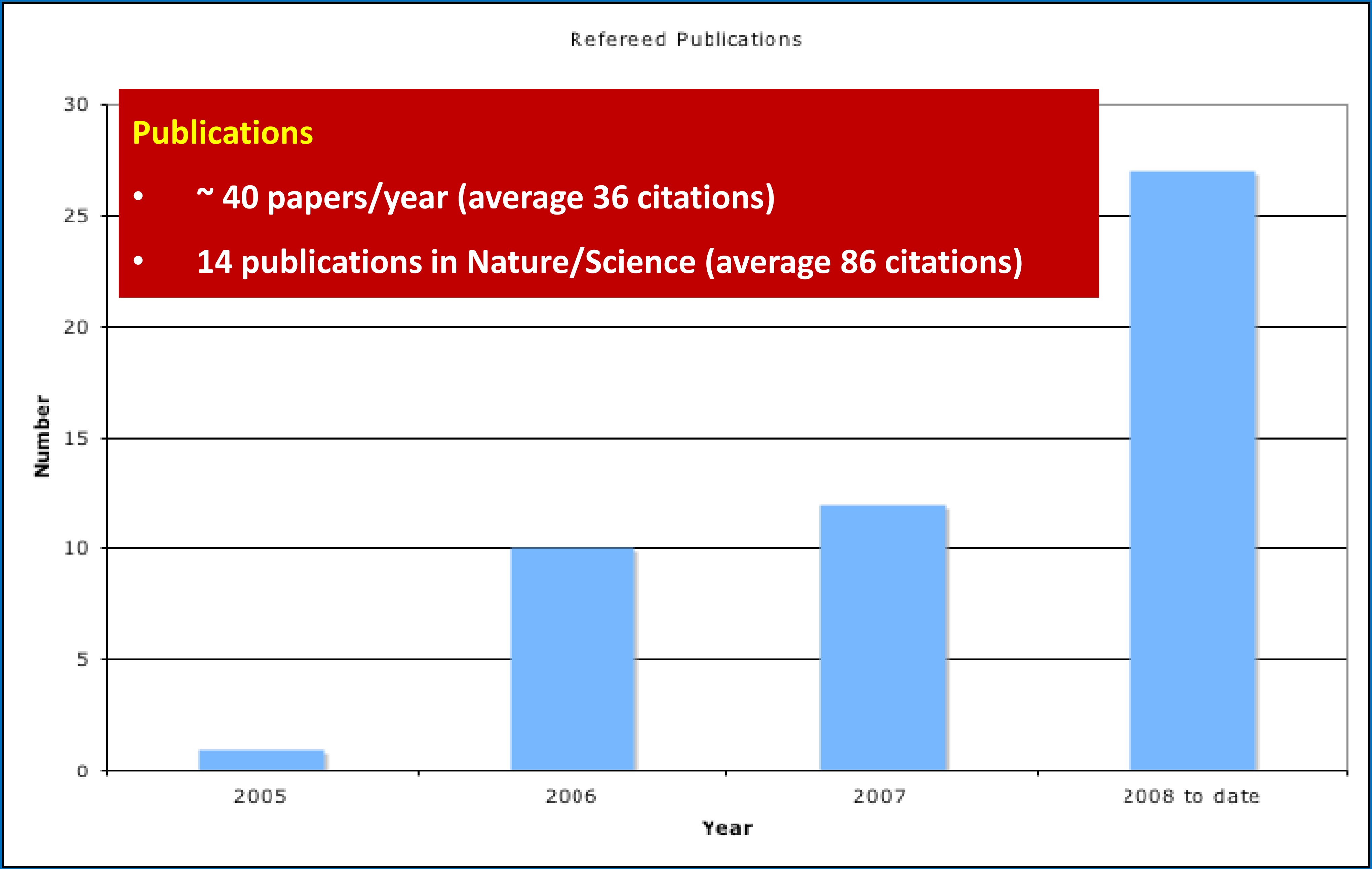
Credits: I. Steele



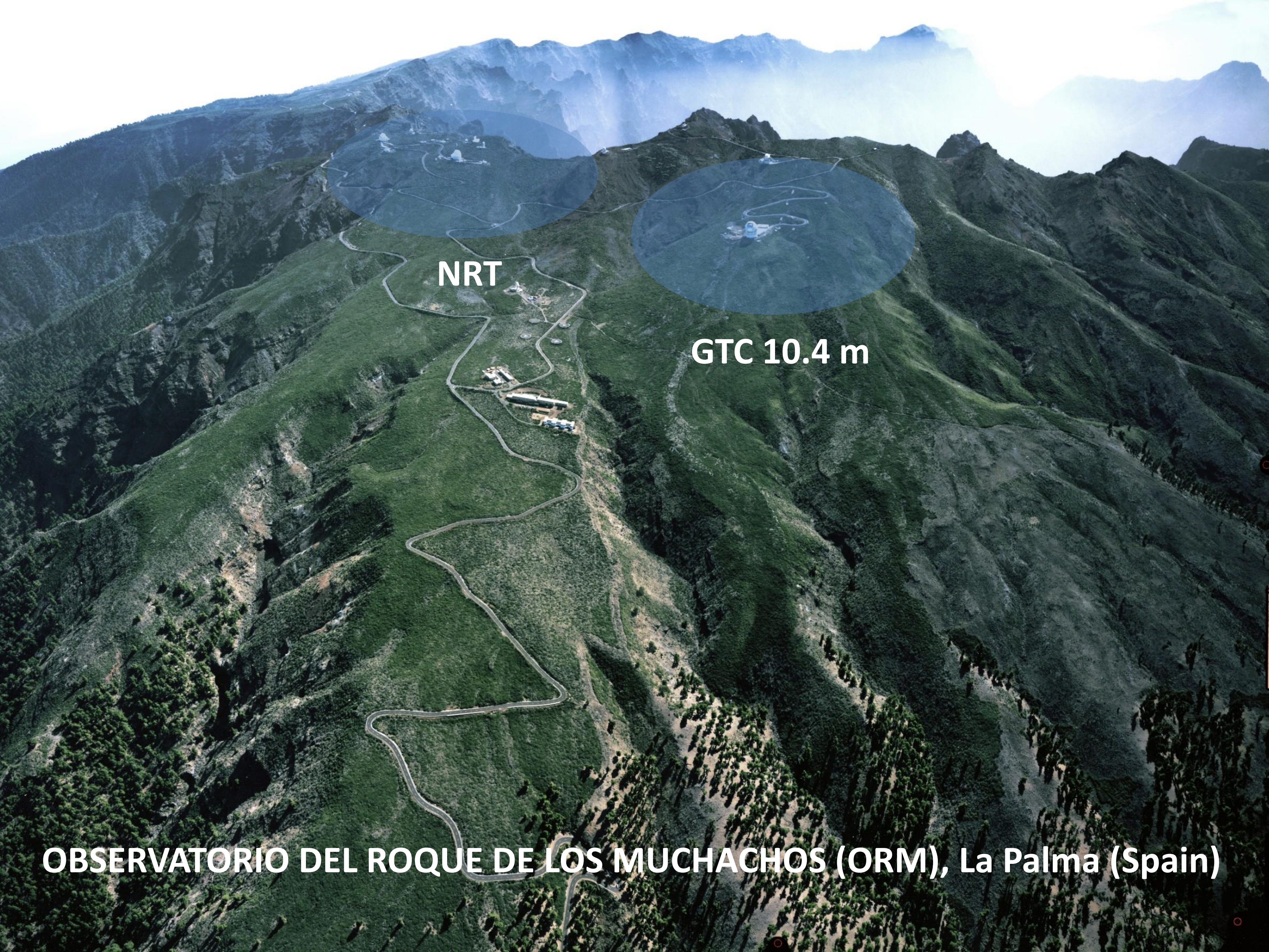
LIVERPOOL TELESCOPE IMPACT

Publications

- ~ 40 papers/year (average 36 citations)
- 14 publications in Nature/Science (average 86 citations)

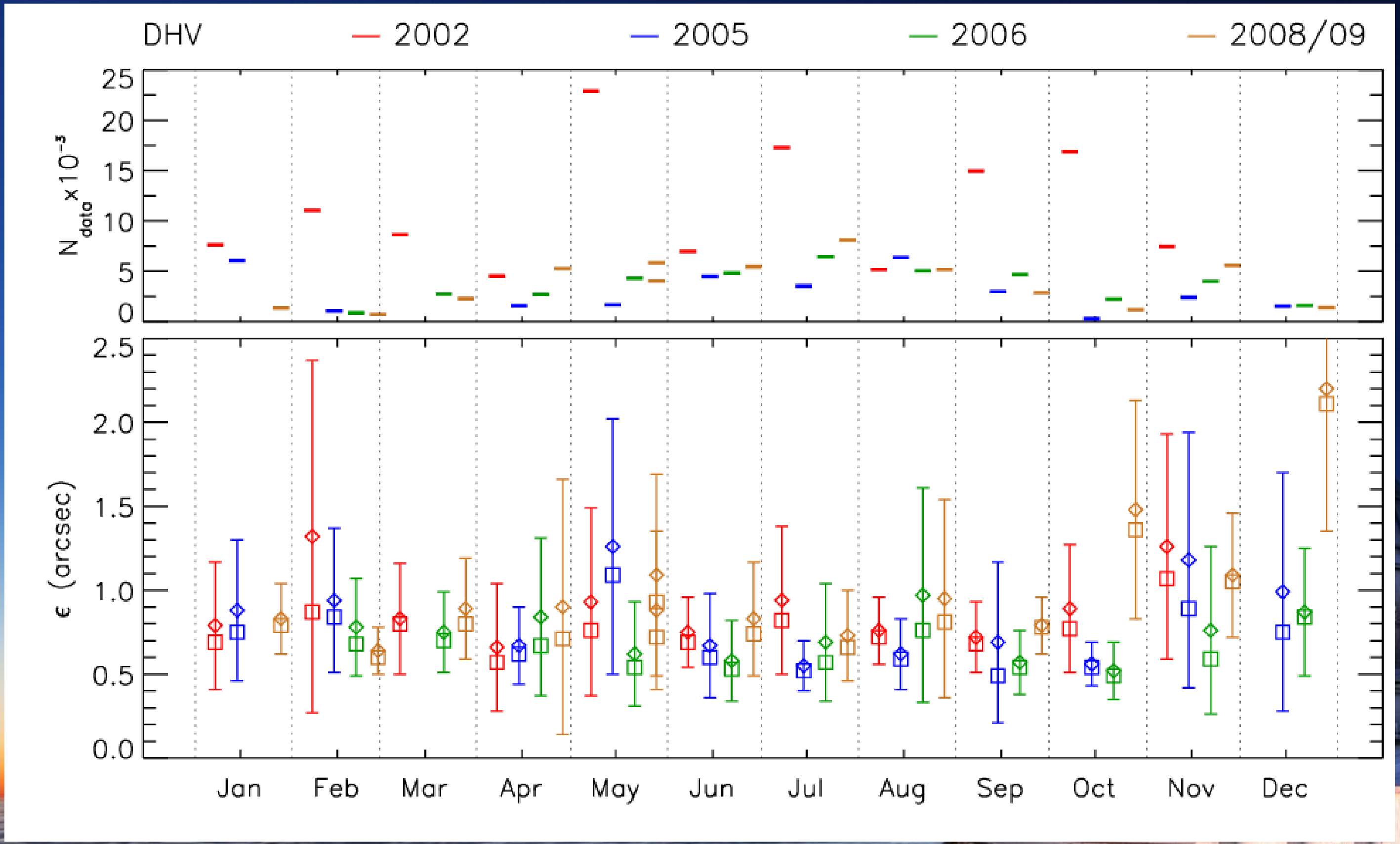



OBSERVATORIO DEL ROQUE DE LOS MUCHACHOS (ORM), La Palma (Spain)


NRT
GTC 10.4 m
OBSERVATORIO DEL ROQUE DE LOS MUCHACHOS (ORM), La Palma (Spain)

ORM seeing

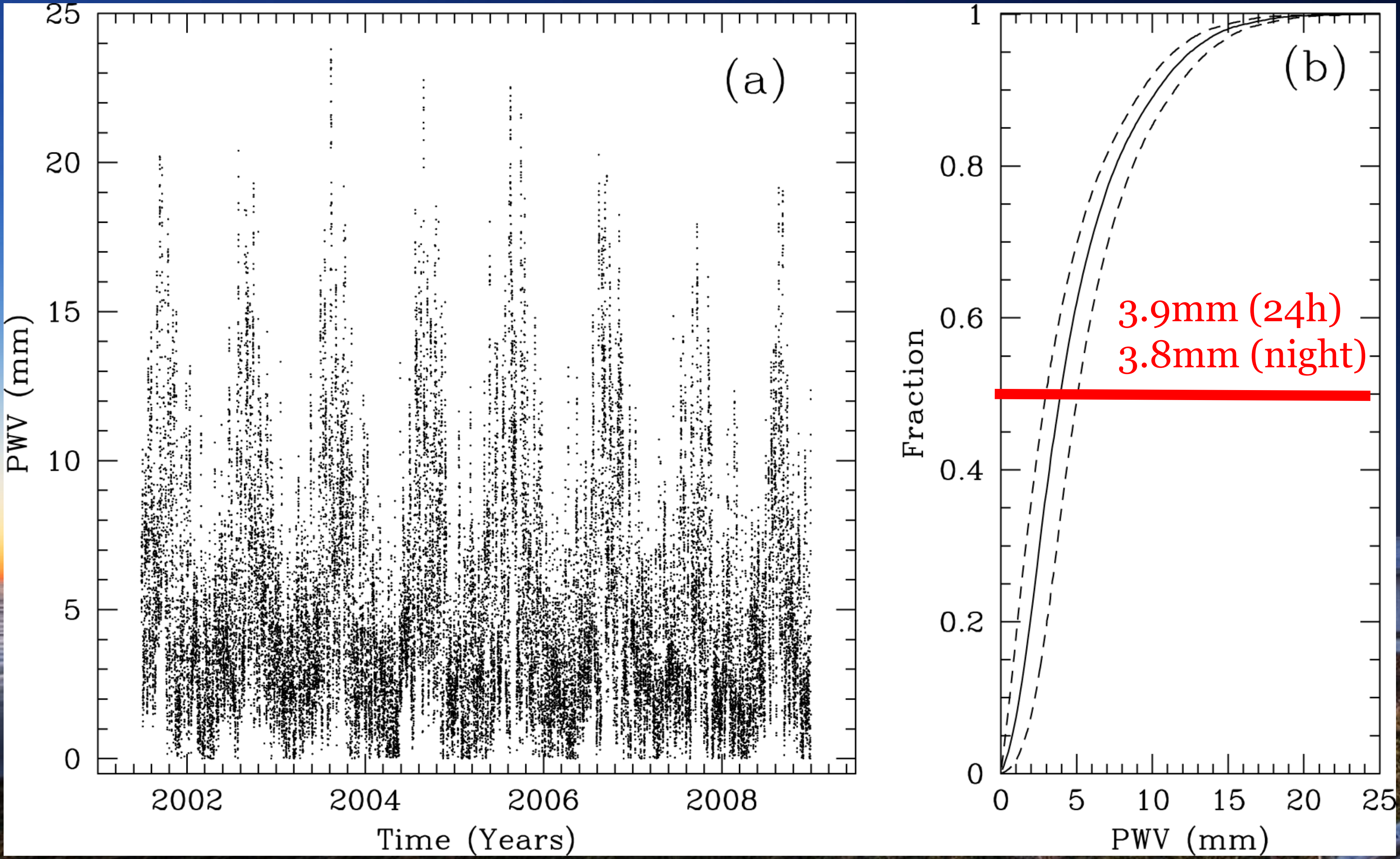
Measurements since 1995 (Vernin & Muñoz-Tuñón 1995, PASP, 107, 265)



Mean = 0.76" (< 0.3" 7%)
Median = 0.64" (0.54" in summer)
Stdev. = 0.17"

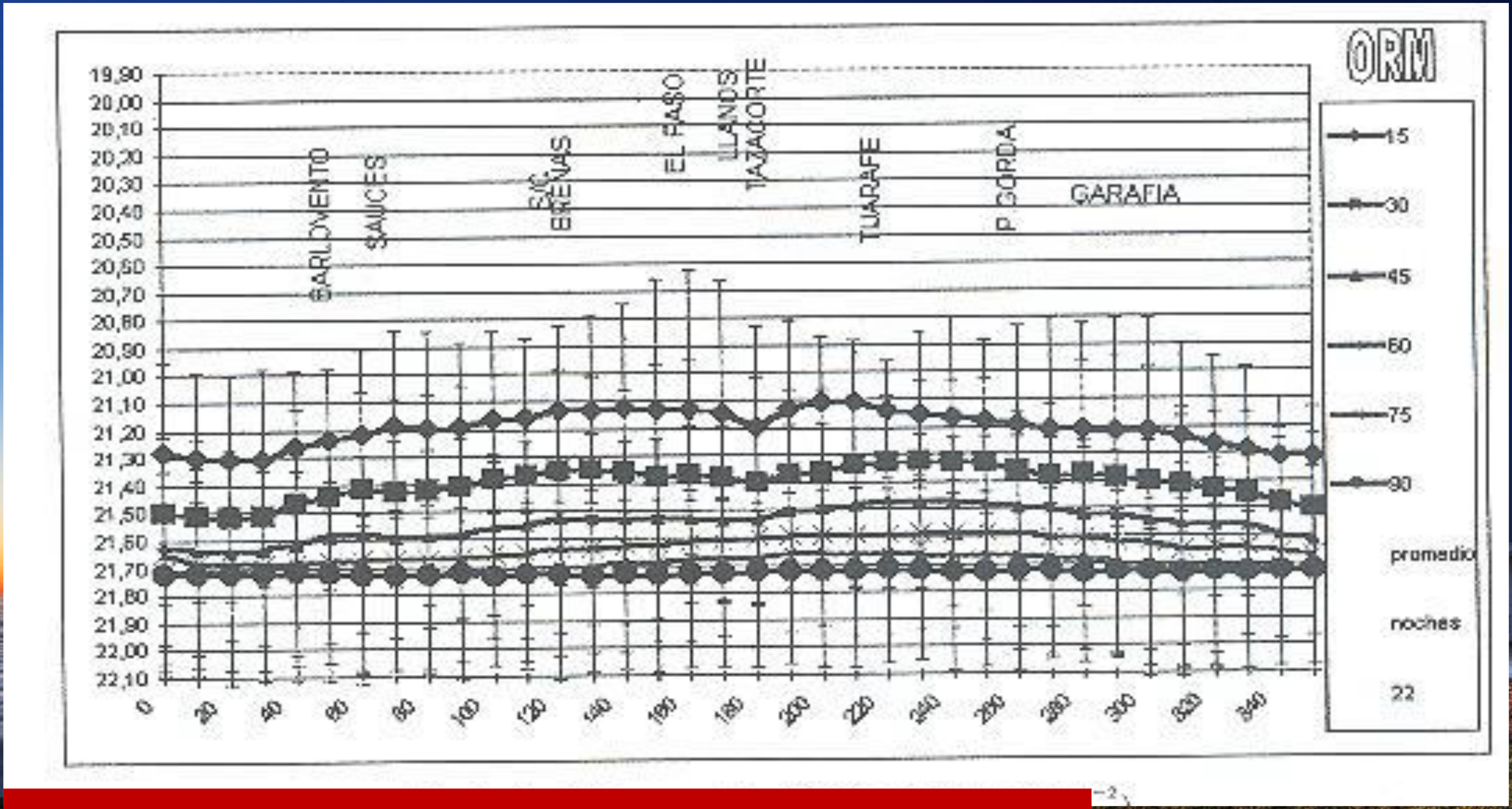
ORM: Site testing (PWV)

García-Lorenzo et al. , 2010, MNRAS 405, 2683–2696, (data from 2001 to 2008)



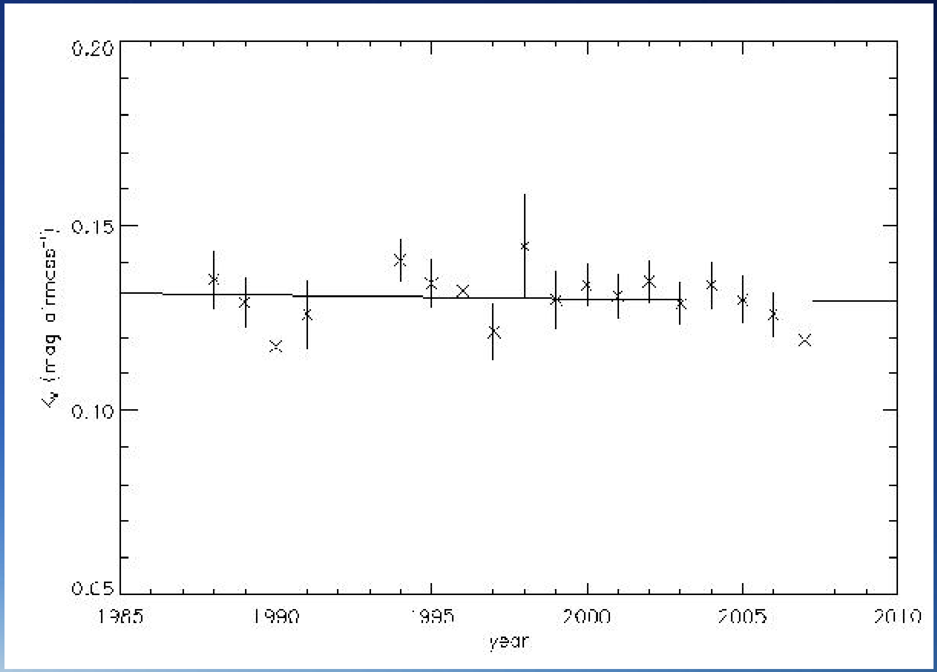
ORM: Brightness of the sky

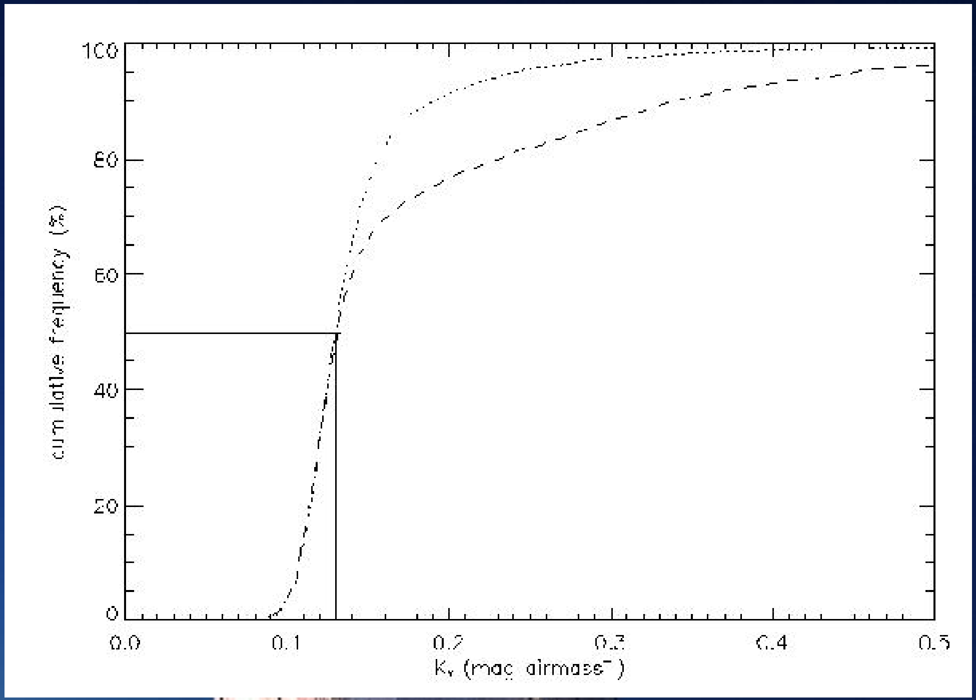
N E S W



New Astronomy Reviews, 509-513, 42 (1998), F. J. Díaz-Castro

ORM Atmospheric extinction





K_V (yearly median fit) = 0.13 mag

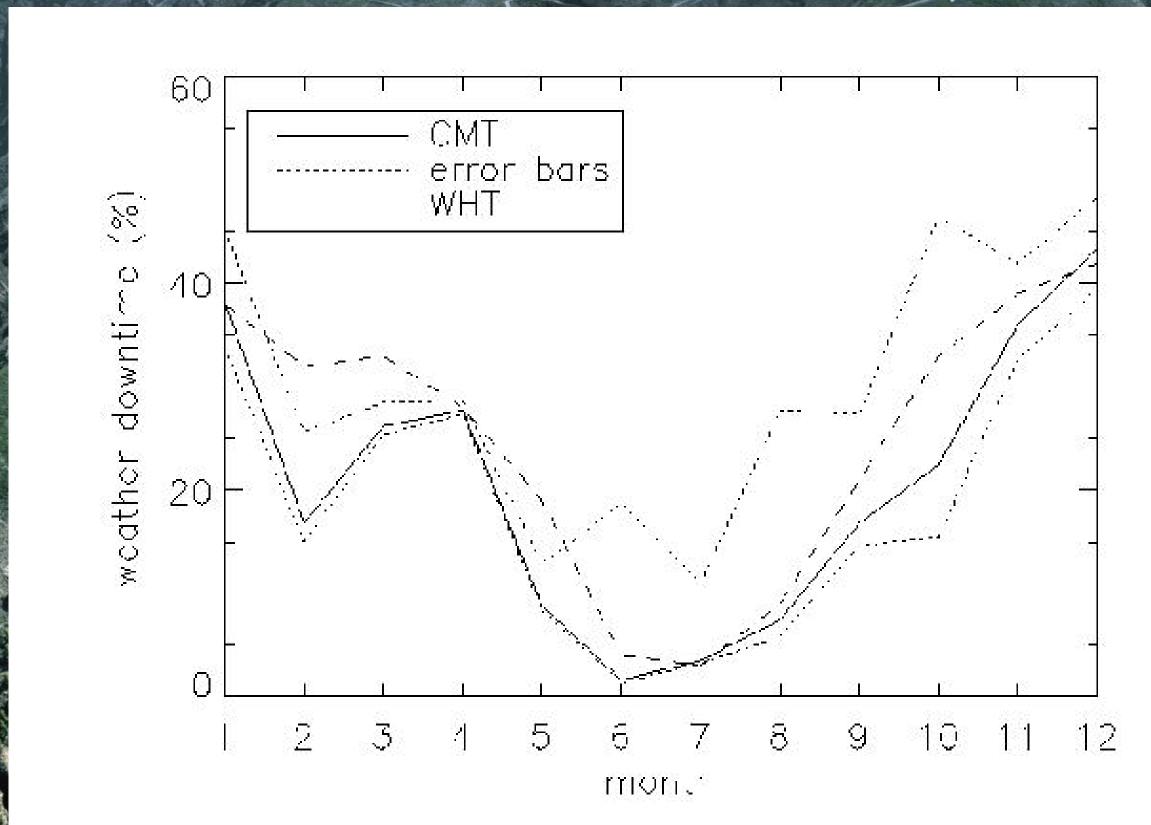
García-Gil, Muñoz-Tuñón & Varela, PASP, 122 , 1109 (2010)

- **Oct-May: 90 % dust free nights (i.e. extinction < 0.15 mag/airmass)**
- **Jun-Aug: 75 %**

Photometric nights (%)

	ORM	PARANAL	TOLOLO	MAUNA KEA	M.GRAHAM
January	53	72	78	64	48
February	62	85	83	54	39
March	70	83	75	61	43
April	64	77	62	52	58
May	67	65	39	51	42
June	78	71	38	49	56
July	81	73	40	47	17
August	82	70	47	49	13
September	82	81	54	36	35
October	78	83	58	20	30
November	77	82	68	37	44
December	37	75	79	44	49

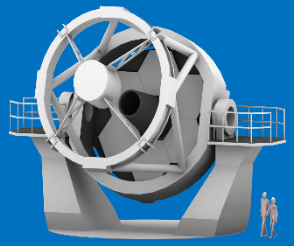
ORM: Weather downtime



Average weather downtime : 23% (from a sample of 21 years)

García-Gil, Muñoz-Tuñón & Varela, PASP, 122 , 1109 (2010)- 20 yr database baseline

NRT project: timeline



2014 – 2016

- Feasibility study, development of science case (Copperwheat et al. 2015).
- Forming consortium.

2017 – 2018

- Funding.
- Complete consortium.
- Conceptual design.

2019 – 2020

- Preliminary design.

2021 – 2022

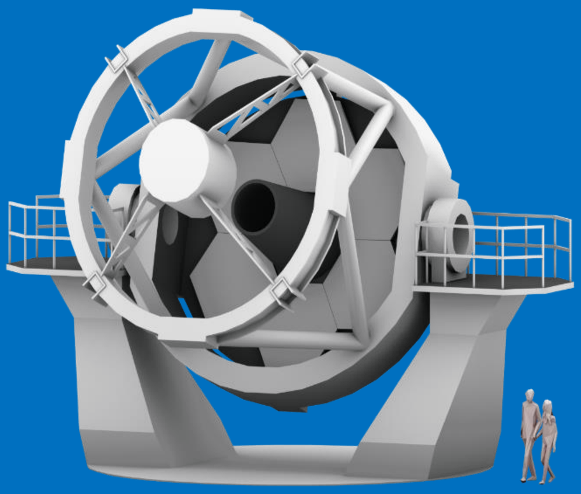
- Detailed design.
- Construction of the telescope and first light instrumentation.

2023

- Integration, first light and commissioning.

NRT estimation cost

Description	M€
Project office	3.0
Telescope design	2.8
Telescope construction	9.5
Instrumentation	2.4
LT upgrade	1.8
Commissioning	0.5
Total	20.0



NRT consortium

LIVERPOOL JOHN MOORES UNIVERSITY

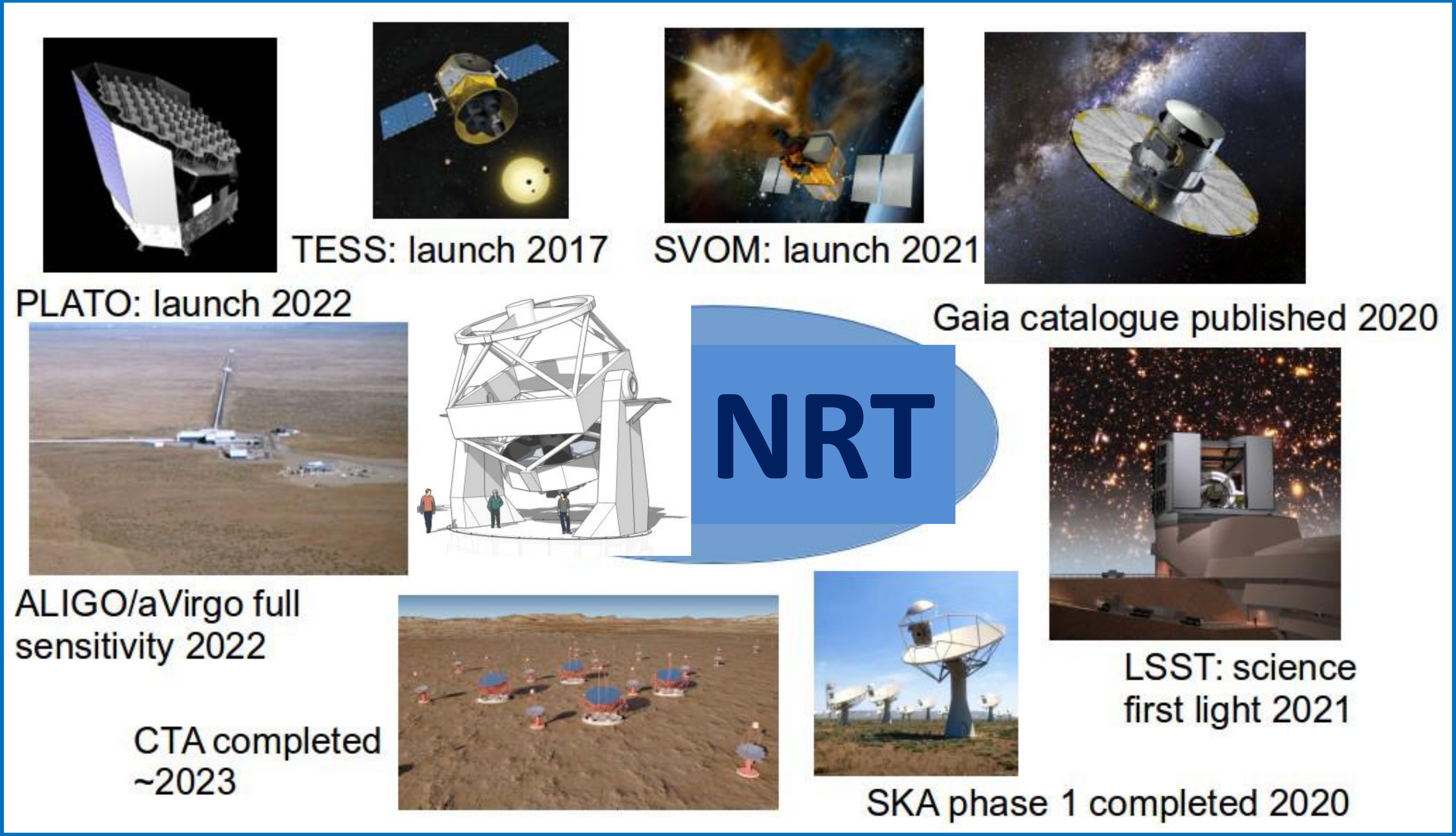
INSTITUTO DE ASTROFISICA DE CANARIAS · IAC ·

Universidad de Oviedo

Partners	Contribution (%)
LJMU (UK)	~50
IAC (Spain)	~20
UO (Spain)	~10

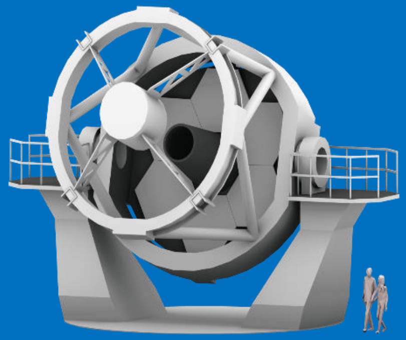
NRT opportunity

- Around 2020's there will be an advent of many new major facilities having a 'time domain' component: **new era of time domain science**
- Much of the science from these *discovery* facilities will be obtained from support from follow-up facilities.



NRT scientific case: Variability across the spectrum

Copperwheat et al. (2015)

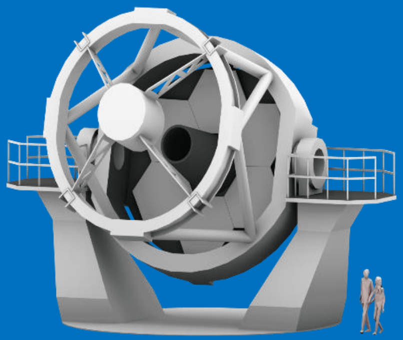


- **X-ray**: LOFT is a ESA M3 candidate (launch ~2025). Wide Field Monitor: X-ray transient detections and triggers
- **Optical**: Gaia final catalogue will be published in 2020: 1 billion of stars with accurate positions and distances. Millions of variables and binaries. Statistically complete samples, rare subclases . . .
- **Radio**: SKA science operations 2020 (phase 1), 2024 (phase 2). Pulsars, radio-bursts, synchrotron emission from jets, coherent emission from flare stars, . . .
- **High energies**: Cherenkov Telescope Array begins construction ~2018

  -Northern site: AGN, GRBs, clusters

  -Southern site: Galactic centre, SNR, pulsars, . . .

NRT transient science



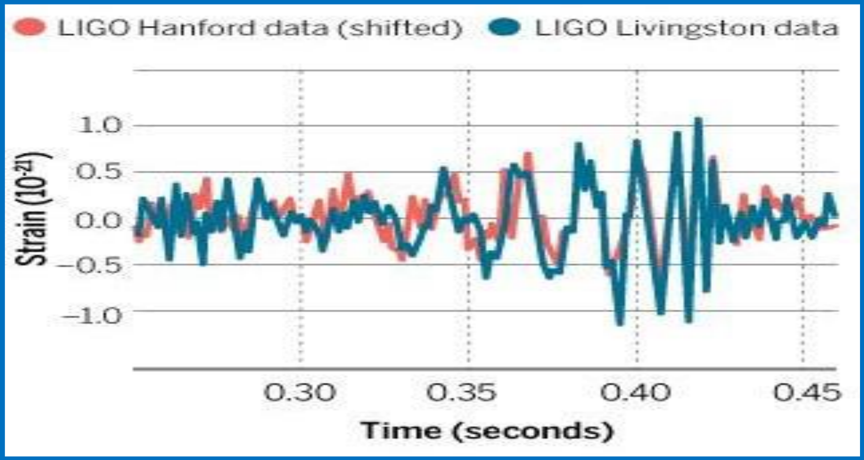
Copperwheat et al. (2015)

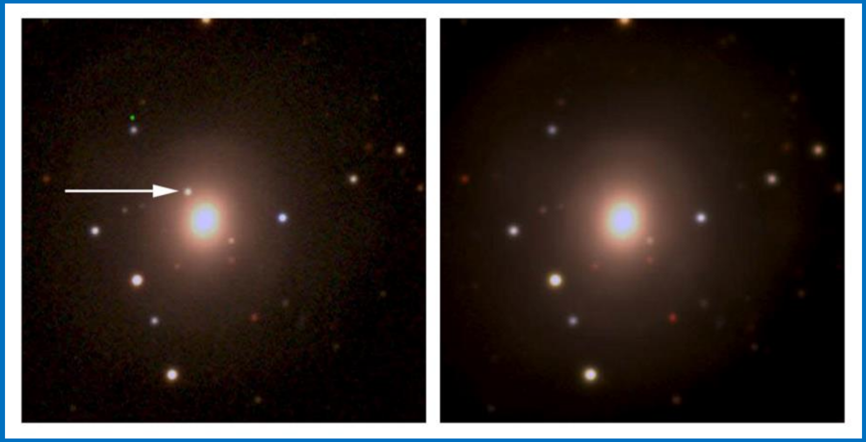
Response time	Transient phenomena
< 1 min after trigger	• GRB afterglows • Fast radio phenomena • Neutrino events • High energy transients (CTA)
< 1 hour after trigger	• Early time SNe
~hours	• Novae • SNe
~days	• GW • Tidal disruption events

NRT scientific case: I. GW counterparts

- Already first detection
- ALIGO full sensitivity 2022. Key issues for detection of GW electromagnetic counterparts:

- Expected discovery rate 10 – 100 transients per year
- Extremely difficult location (uncertainty ~a few degrees)
- Prompt emission from merger rapidly fades





Identification and follow-up requirements

- Wide FoV search capability.
- Rapid response.
- Efficient spectroscopic classification of large numbers of candidates.

Soares-Santos et al. and DES collaboration

NRT scientific case: II. Exoplanets

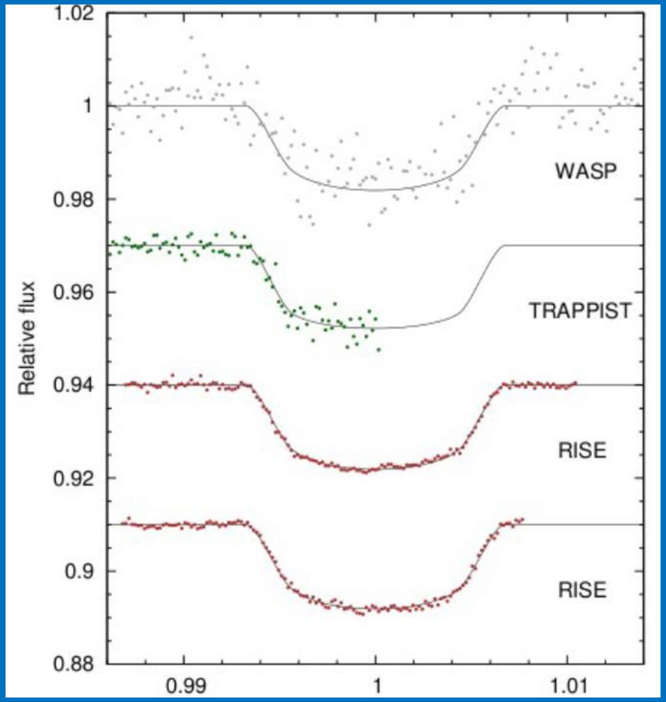
Gaia:

- operational lifetime of 5 years, final catalogue published in ~2020
- >1 billion of stars with accurate positions and distances, but little photometry and very little spectroscopy

NGTS 12 x20 cm telescopes in Paranal
TESS NASA mission (2018)
PLATO ESA M3 misión (~2026)

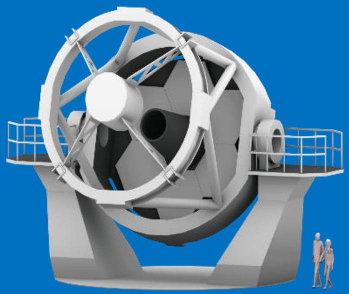
Follow-up with NRT, some examples:

- Planetary formation and evolution
- Atmospheres
- Rings, moons, binary planets
- Jupiters, Neptunes, super-Earths, Earths)
- Stellar systems rather than individual objects



Transit light-curves from WASP, TRAPPIST, and RISE on the LT

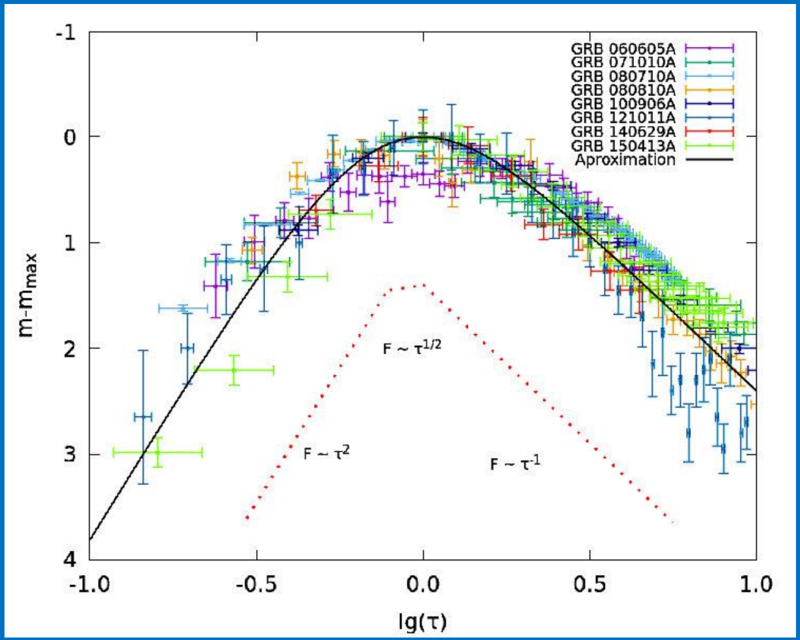
NRT scientific case: III. GRBs



- Scientific interest: first stars, structure/evolution of universe...)
- Detected by space-based facilities (now: Swift, future: SVOM,. . .), follow-up by ground based telescopes.
- Key point: fast fading afterglows (current facilities ~1 min, **NRT~30 s**)
- Important LT science highlight, but much still to do in post-Swift era (esp. short GRBs)

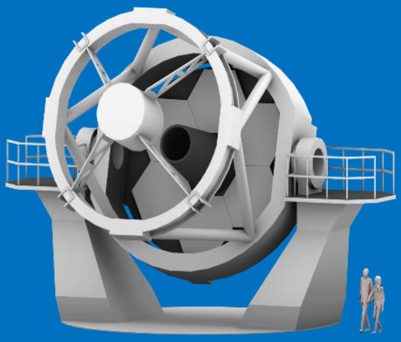
Follow-up requirements:

- Extremely rapid response (more important than aperture).
- Instrumental capability – photometry multiband, spectroscopy (perhaps better suited for 8 m telescopes), polarimetry... high time resolution (EMCCD) spectra of fast spikes would be useful



MASTER Global Robotic Net telescopes (MSU)

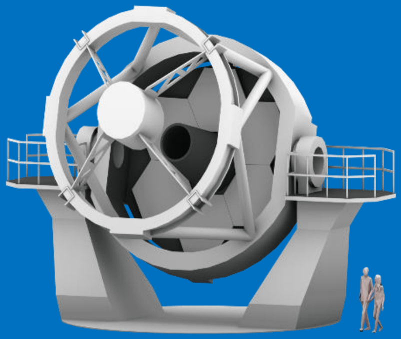
NRT design



General considerations

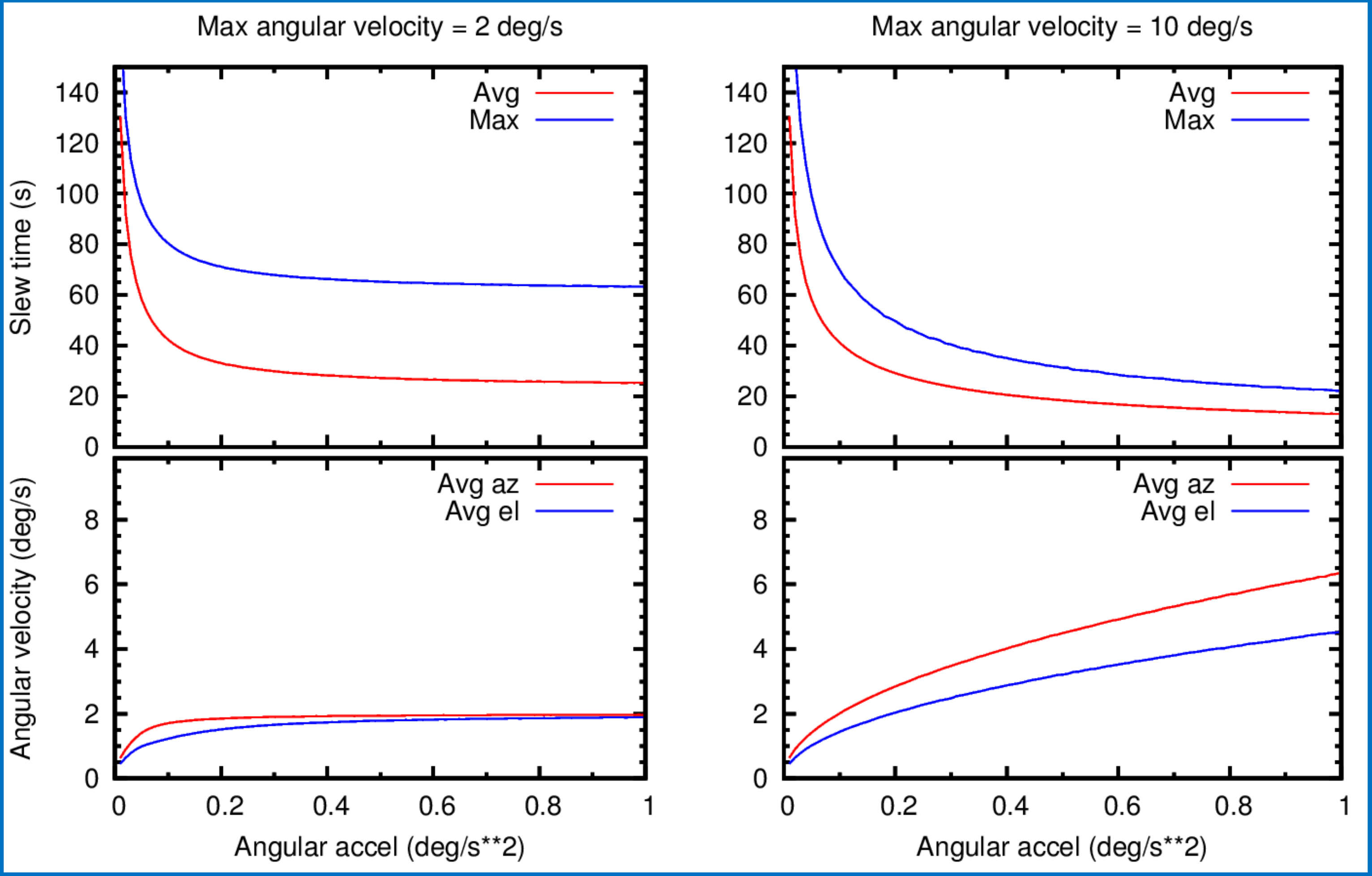
- A 4 m aperture diameter, robotic mode, 30 s on target
- A Ritchey–Chretien design
- Fast slewing requirement means a very lightweight structure
- Light materials (carbon fibre?)
- Rapid response necessitates fully-open enclosure, like the LT's clamshell.
- FoV ~ 15' diameter
- Full optical and near IR ranges
- Focal stations for five instruments
- Image elongation no greater than 0.2'' in ten minutes
- Optimal image quality at times of median seeing (~0.7'') in La Palma

NRT slewing



Simulations

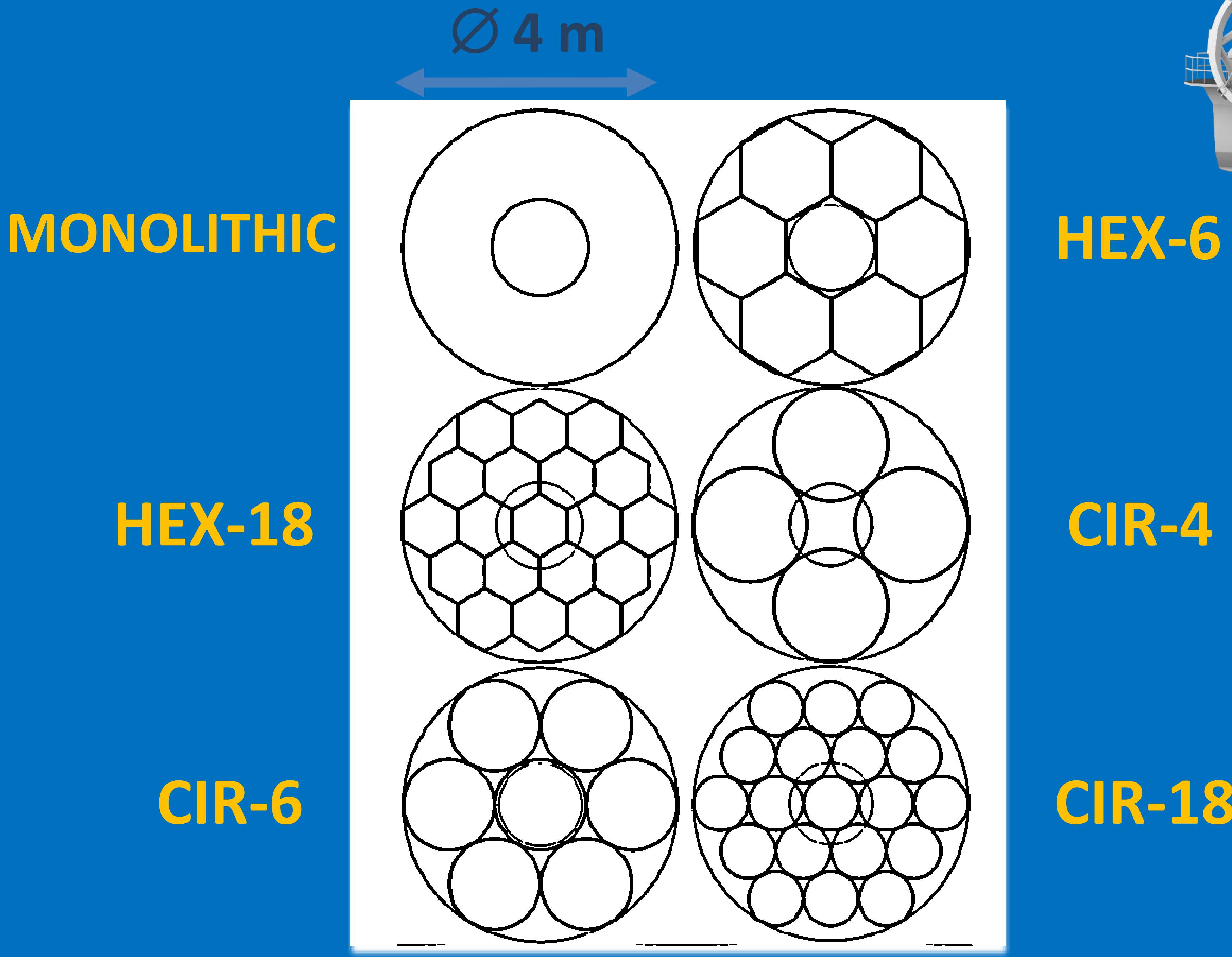
Copperwheat et al. (2015)

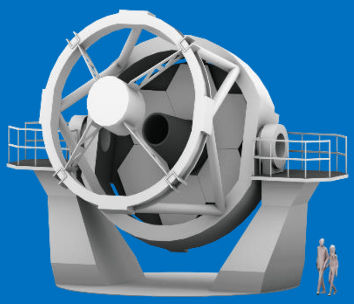


LT

NRT

NRT possible primary mirror configurations

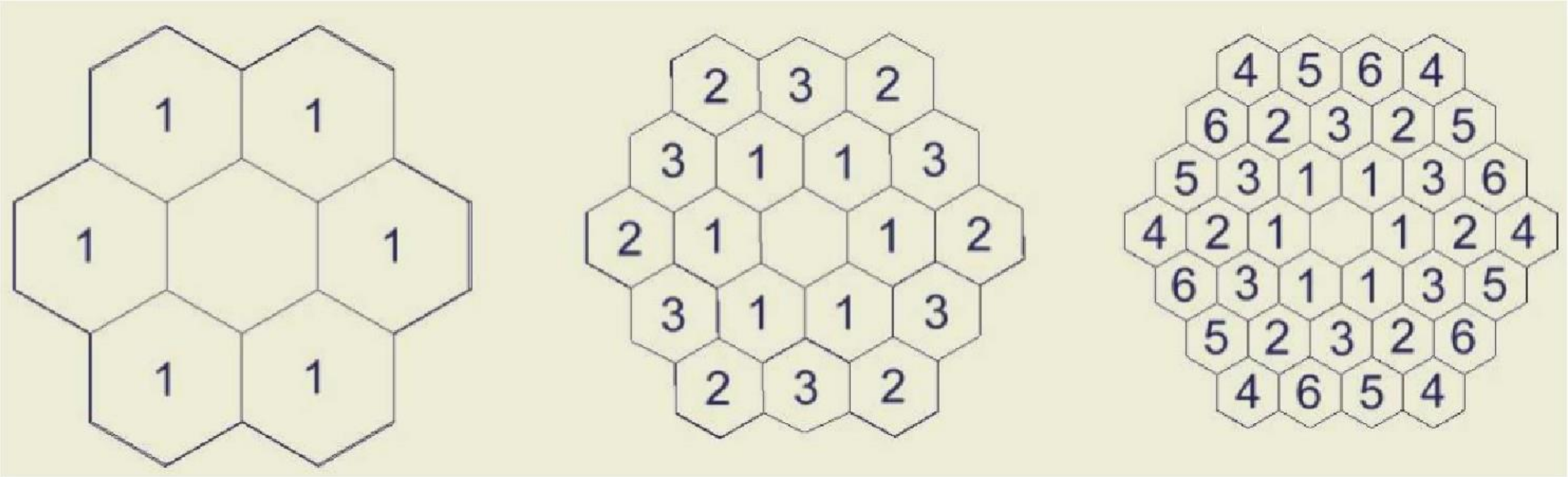




NRT primary mirror design design

- Much of the mass of a telescope is concentrated in the primary mirror (MONOLITHIC ~5,500 kg)
- That can be largely reduced by constructing it out of hexagonal segments (the segments can be much thinner)

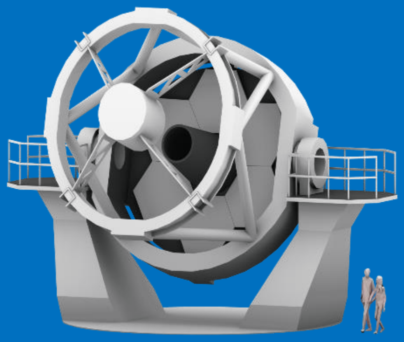
HEX-6 ~2,700 kg **HEX-18 ~900 kg** **HEX-36**



HEX-6 same segment size as used in the 10.4 m GTC, i. e.

- mirror support structure for segments of this size already designed
- recoating tank for segments of this size already exists at the observatory

NRT instrumentation



Use the experience gained with LT:

- simple, versatile and robust instruments
- quick changes
- diversity

First light instruments

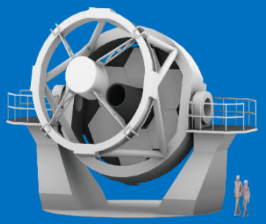
- **optical and infrared intermediate resolution spectrograph (R < 10,000)**
- **high cadence imager, polarimetry...**

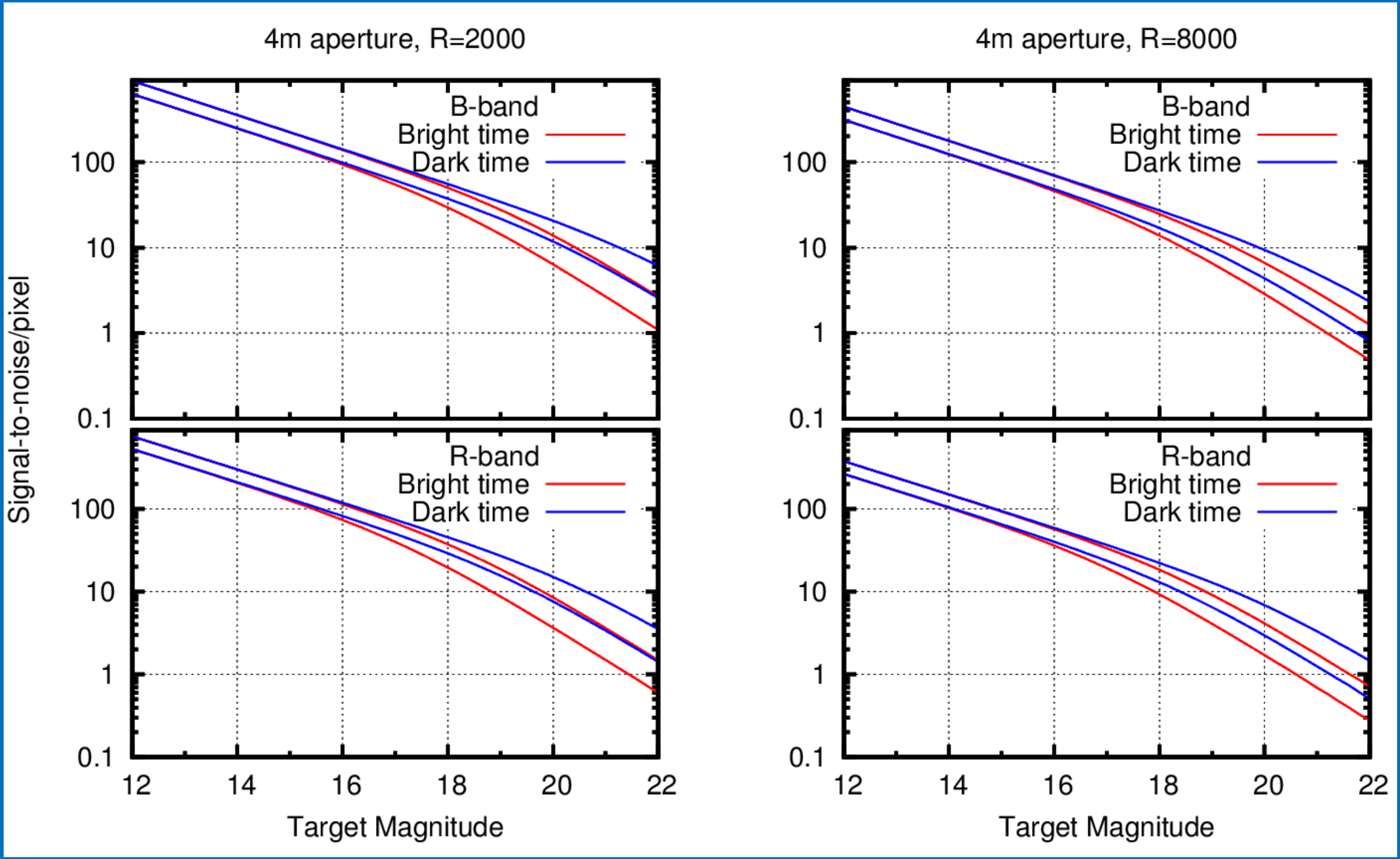
Use of new detector technologies to properly exploit the rapid reaction capability of the telescope:

- EM (electron multiplying) CCDs now fairly common.
- CMOS detectors. Very fast. QE now improving
- MKIDS: Microwave Kinetic Inductance Detectors
- . . .

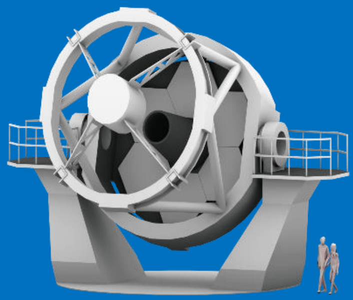
NRT spectroscopy

1800 sec observations





Summary NRT



1. Key astronomical facility (power: 4 m and quick response: 30 s) for the new era of time domain astronomy.
2. Current partners (LJMU, IAC and UO) with huge experience building and operating large telescopes and instrumentation.
3. Opportunity to develop and implement new technologies in control, detectors, light materials, etc.
4. Sited at ORM with superb atmospheric conditions.
5. Standard for a future generation of large robotic telescopes.
6. Open to educational programmes.