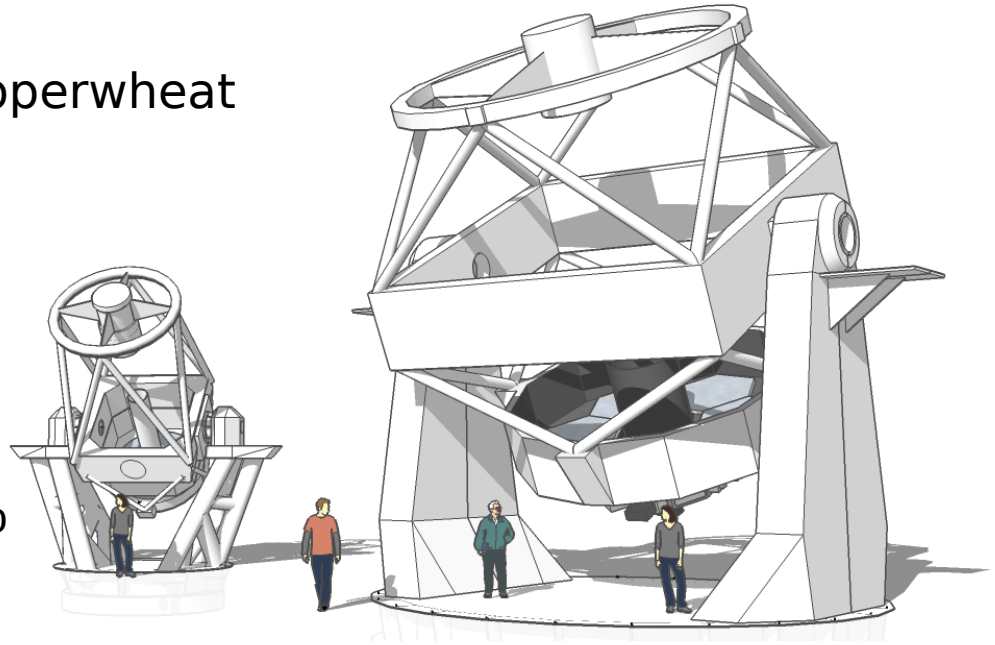
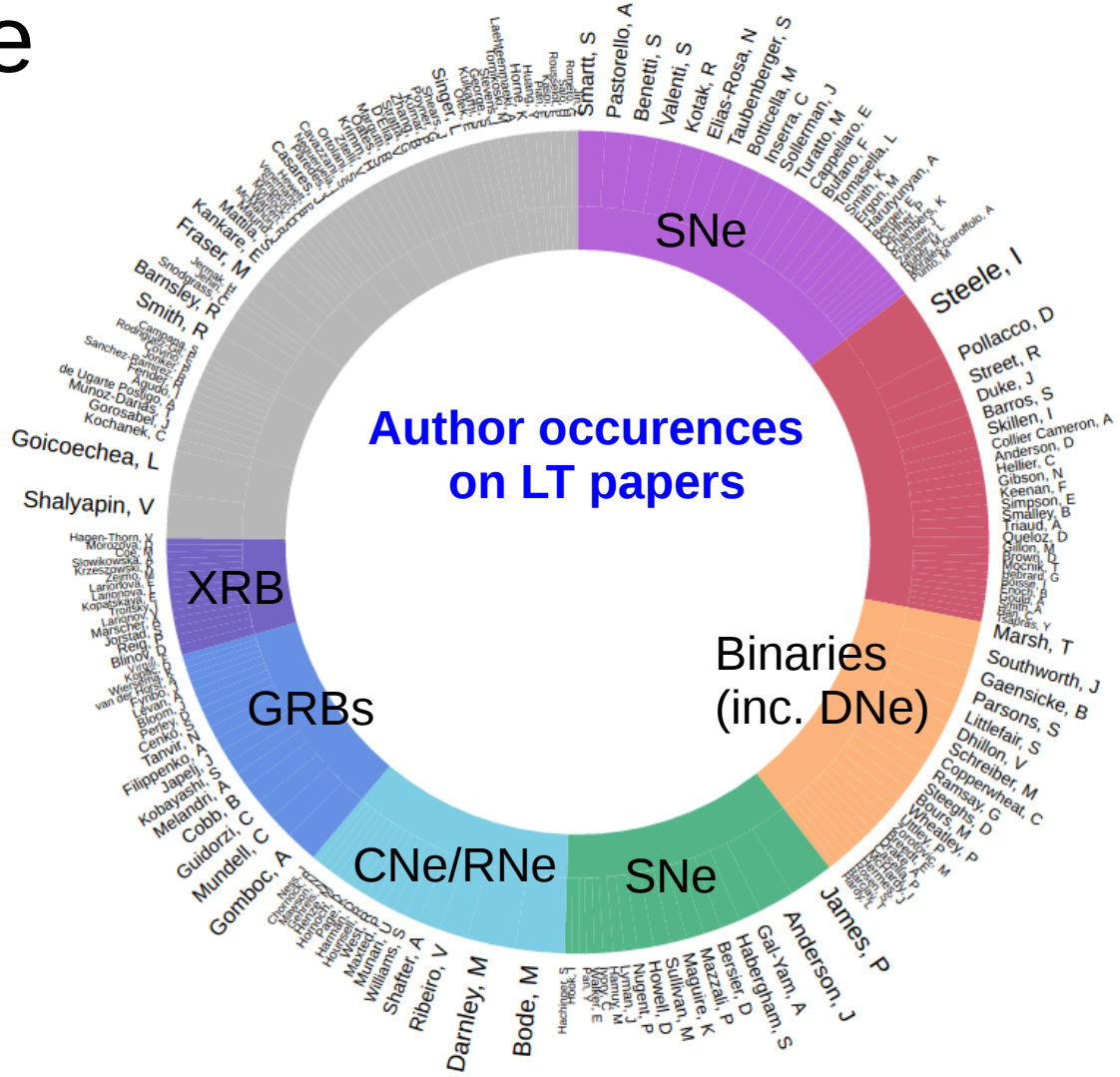
LSST follow-up with the Large Robotic Telescope (Liverpool Telescope 2)

Chris Copperwheat



Liverpool Telescope group:
Stuart Bates, Neil Clay, Helen Jermak, Marco Lam, Jon Marchant, Chris Mottram, Andrzej Piascik, Robert Smith, Iain Steele

Robotic telescopes powerful tools for transient science

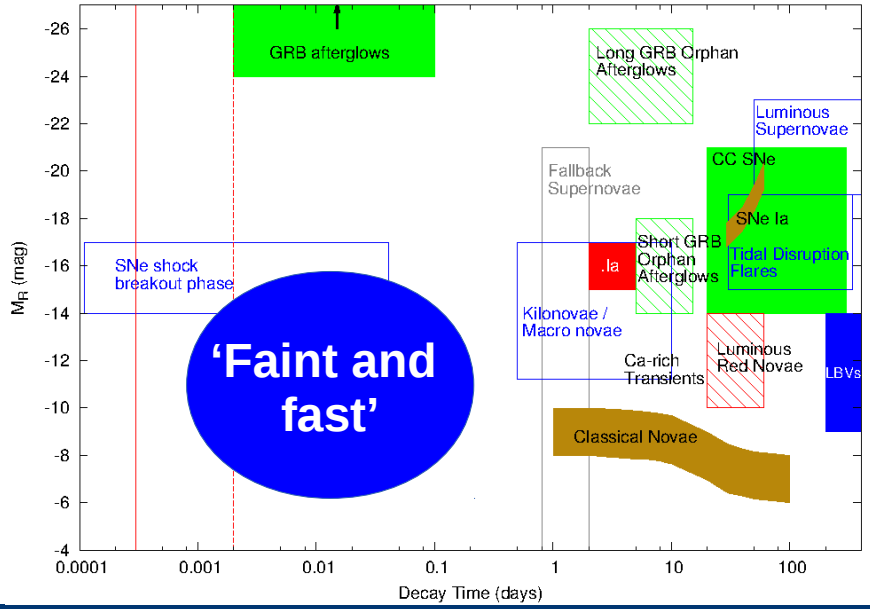


Transient science and the ‘follow-up gap’

- Comprehensive and systematic programmes of spectroscopic follow-up (PESSTO) have been shown to add a huge amount of value to the big transient surveys

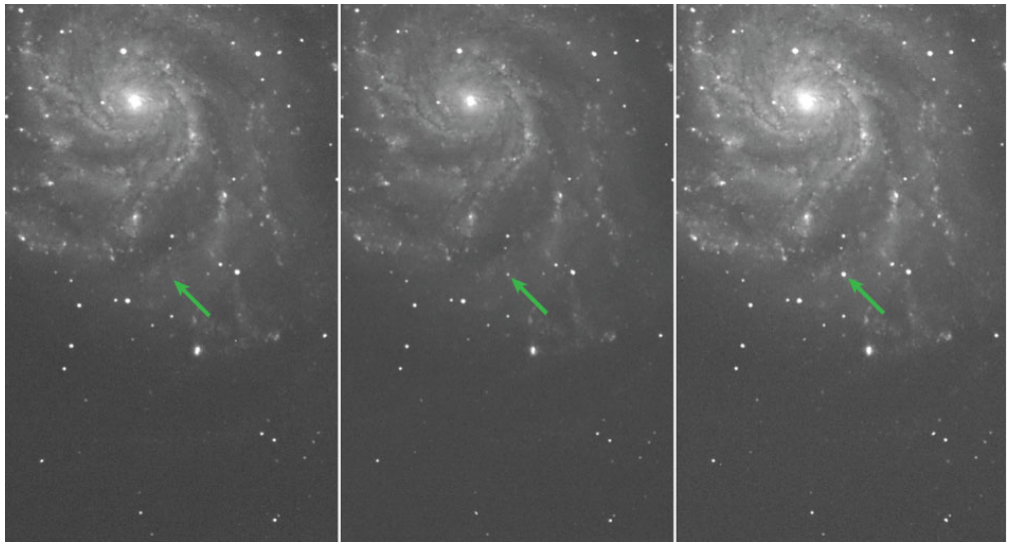
- However there is a big capacity gap for follow-up: only ~10% of iPTF transients received a spectroscopic *classification*

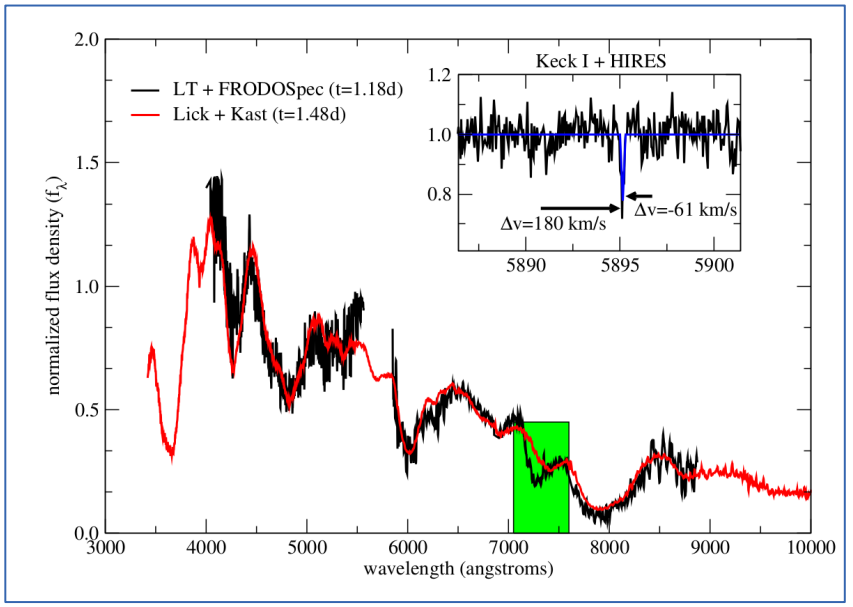
- An even greater problem in the LSST era: significant risk that the transient science potential of the survey will not be fully realised



(Adapted from LSST science book)

The importance of fast follow-up





- Catching targets at very early times: spectral diagnostics of progenitors
- Fast evolving, early time features (shock breakout phase)
- New transient phenomena in ‘fast and faint’ discovery space

SN 2011fe: Nugent et al. (Nature, 2011)

Multi-object spectroscopy?

- 100,000 genuine explosive transients per night?
- 500 fields per night, so 200 transients per field

Observation Properties:

Visits per night = "about a 1000"

Alert Production:

Real-time alert latency = 60 seconds

Average number of alerts per night= "about 10 million"

Optical System:

Field of View = 3.5 degrees (9.6 square degrees)

Primary mirror diameter = 8.4 m

However, spectroscopic visit longer than LSST visit

- Assume 15 min per visit, 10 hour night, → 40 targets per night
- So even if MOS FoV matches LSST, only 8 per cent of fields get same night spectra

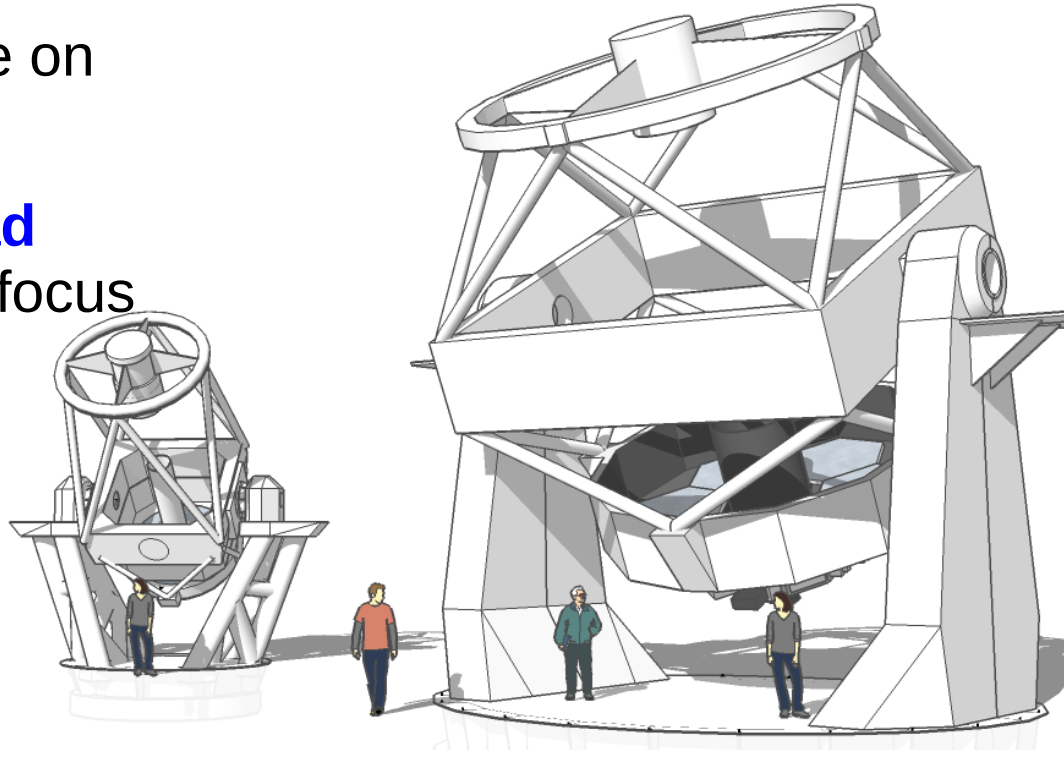
- In practice, rapid follow-up will involve choosing the best 50 candidates based on LSST broker
- Fairly low odds of a single spectroscopic pointing containing multiple best candidates...

Target selection

- Intelligent, automated selection of most interesting candidates the hardest part of the new transient astronomy era
- Available photometric information, cross matching with other catalogues
- Scale of the challenge very much appreciated, work underway...

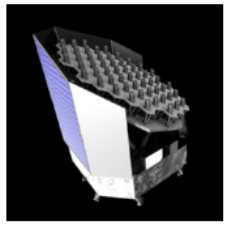
Large Robotic Telescope (“LT2”)

- A new, **4-metre class robotic telescope** for rapid follow-up of astrophysical transients. Largest robotic telescope in the world
- To be co-located with the LT on **La Palma**
- **First light ~2022** to capitalise on new discovery facilities
- **Versatile instrument payload** opt/NIR spectroscopy a core focus (X-shooter type instrument)
- **World-leading response time** for fast fading / fast evolving transients, efficient programmes

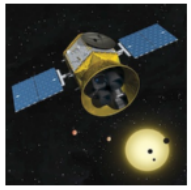


Time Domain: strategic fit

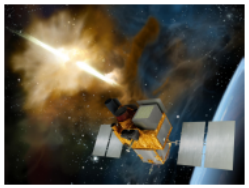
- The next decade will see the advent of many new major facilities: most (all?) have a 'time domain' component
- Much of the science gain from these 'discovery' facilities will be realised via support from follow-up facilities: long term monitoring, lightcurves, spectroscopic classification, etc.



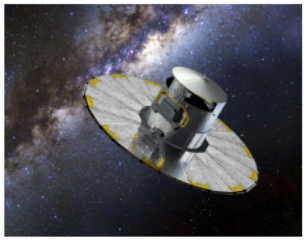
PLATO: launch 2022



TESS: launch 2017



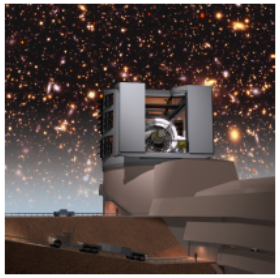
SVOM: launch 2021



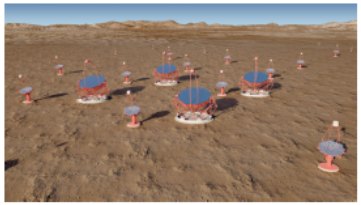
Gaia catalogue published 2020

ALIGO/aVirgo full sensitivity 2022

LT2 (~2022)



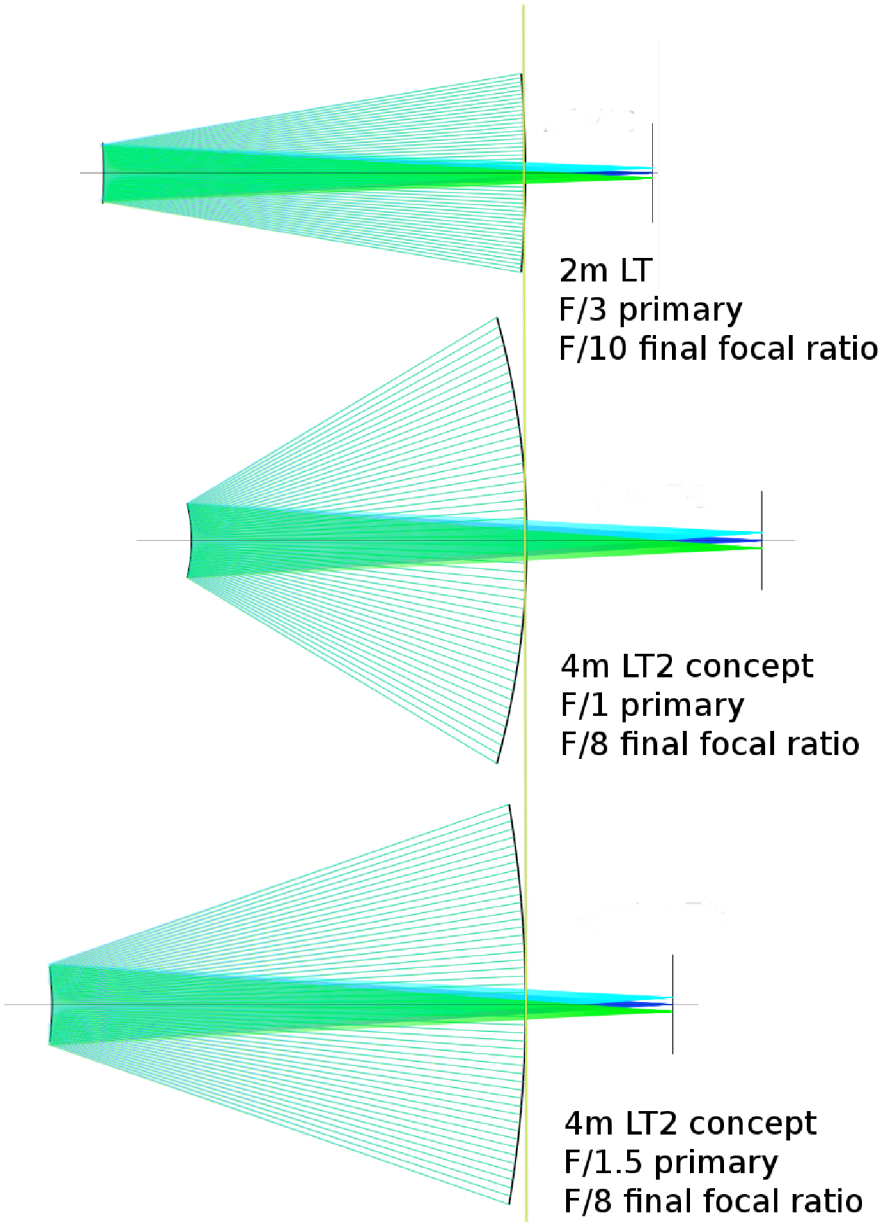
LSST: science first light 2021



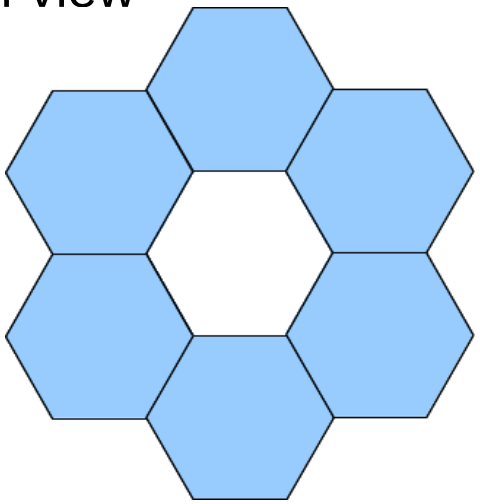
CTA completed ~2023

SKA phase 1 completed 2020

Design

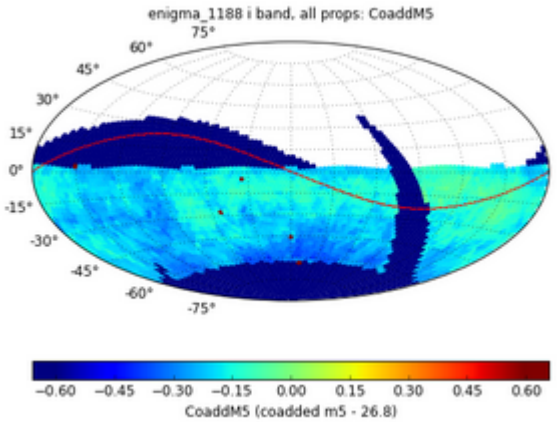


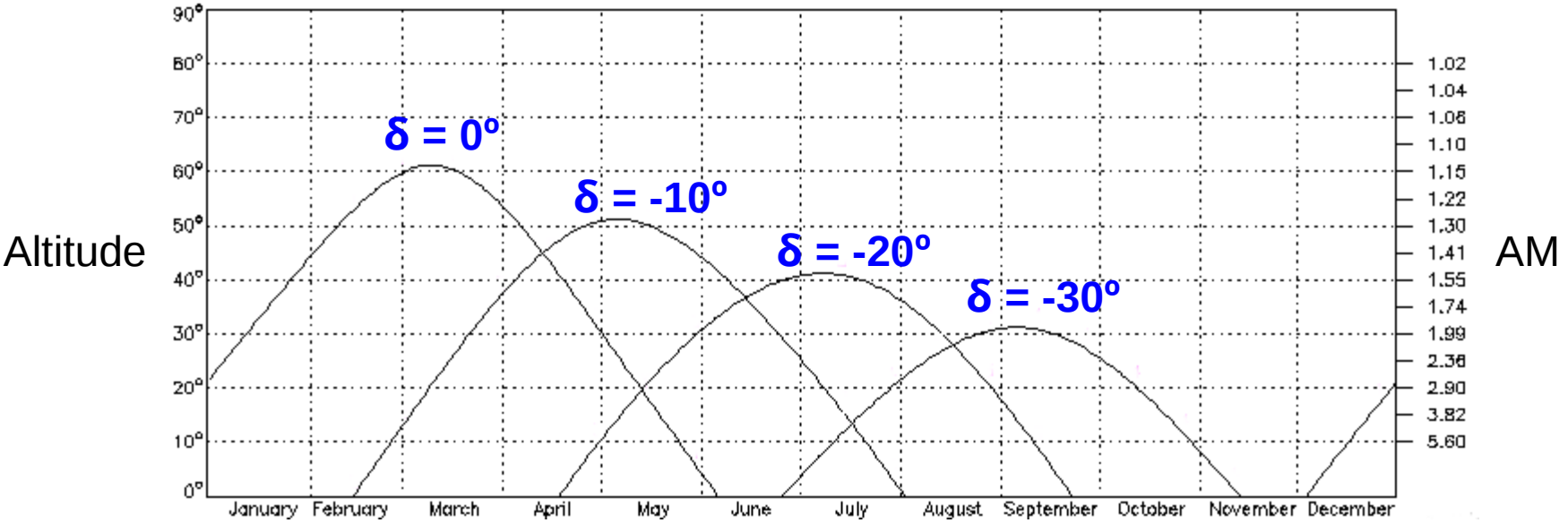
- Lightweight design for fast slewing, low overhead
- Ritchey–Chrétien optics, with fast (f/1.5?) primary mirror
- Segmented primary. 6 segments same size as GTC segments an attractive option from a logistical point of view



Site: ORM on La Palma (342ºE, 29ºN)

- Excellent conditions, well know site for us, simplifies logistics
- Run two telescopes as a single facility
- Northern site still provides excellent access to a large fraction of the LSST field





Project cost and existing partners

Description	Cost	
Project Office	£	2,575,000
Telescope Design	£	2,400,000
Telescope Construction	£	8,000,000
Instrumentation	£	2,000,000
LT Upgrade	£	1,500,000
Commissioning	£	300,000
Total	**£**	**16,775,000**

Total 6.25 year cost (including 10% contingency) for the delivery of the LT2 project, including LT upgrade.

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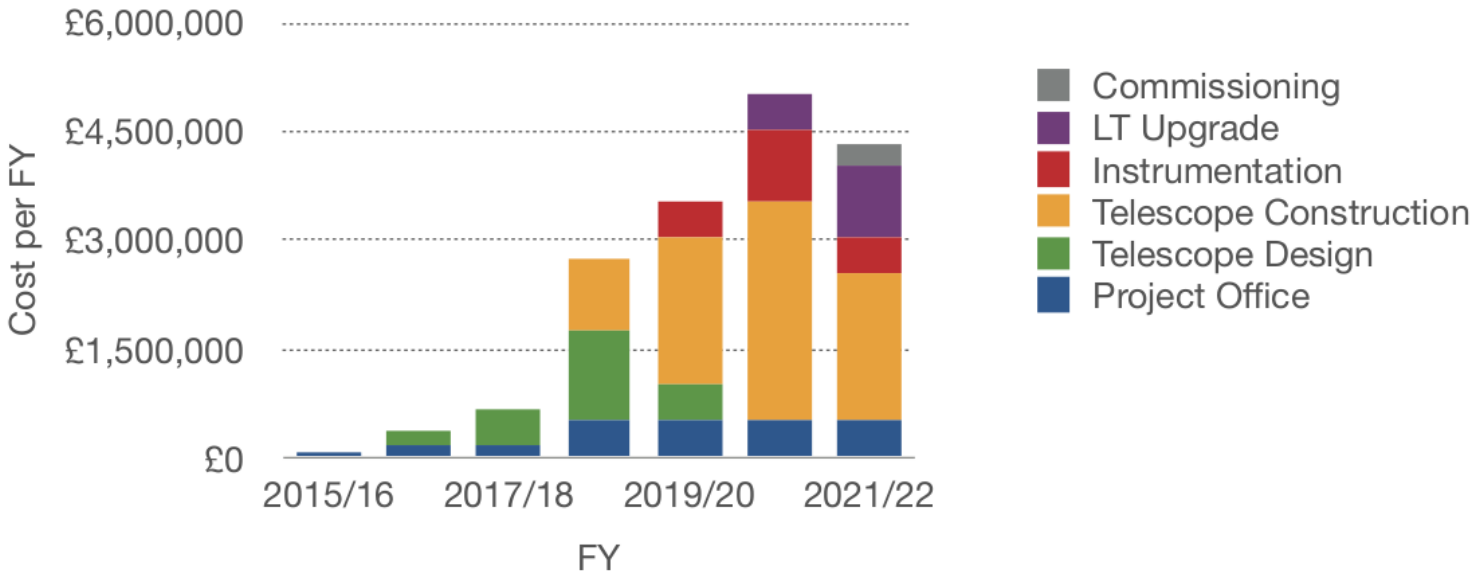
- Project receiving strong support within LJMU, with VC taking the personal lead. Anticipate >50% of construction cost
- IAC have already raised 10 per cent of project cost and intend to raise more. Appointed engineering staff

Project cost and funding consortium



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- We have enough serious expressions of interest to complete the funding consortium for construction
- Intention is to continue to request STFC support for Liverpool Telescopes operations costs → UK access

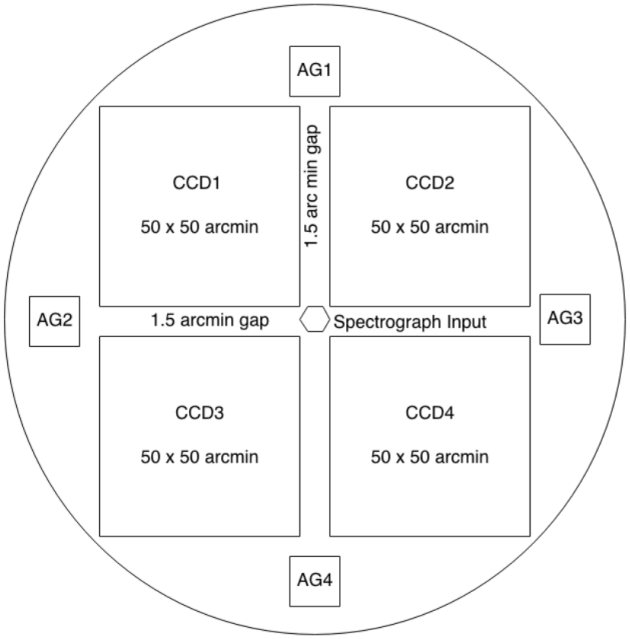
Summary

- Comprehensive spectroscopic follow-up vital for full exploitation of the new era of transient science
- A clear role for targeted, rapid response follow-up for objects of particular interest
- We intend to build a new 4m class telescope to come into operation on La Palma ~2022
- Telescope will be fully robotic with all the versatility that entails.
- Intermediate resolution spectroscopy, but provision for a diverse array of simultaneously mounted instrumentation

Science paper: Copperwheat et al. (2015) ExA 39,119
arXiv:1410.1732

LT2 website: **http://telescope.livjm.ac.uk/lt2/**

A new role for the LT



- We aim to keep LT running but move the majority of staff effort to LRT:
  - Requires simplification of LT operations, reduction in operational costs.
- We propose to replace current instrument suite with single prime focus imager
  - 2x2 deg field for surveys, gravitational wave counterpart searches...
  - Cost ~10% of overall project budget