Liverpool Telescope 2: A new robotic facility for 2020+

Chris Copperwheat

Liverpool Telescope group:
Iain Steele, Chris Davis, Rob Barnsley, Stuart Bates, Neil Clay, Steve Fraser, Jon Marchant, Chris Mottram, Robert Smith, Mike Tomlinson

The Liverpool Telescope

- The Liverpool Telescope is a robotic 2m alt-az telescope currently in operation on La Palma
- Not 'remote controlled' – operated autonomously without night-time supervision
- 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 work
- High-impact science
  - 36 citations/paper average (for papers > 3yr old)
  - 14 publications in Nature/Science (86 citations on average)

Liverpool Telescope 2

- The Liverpool Telescope is now a mature facility which is expected to stay competitive until at least 2020
- LJMU has committed £200,000 to fund a 2-year feasibility study for a successor 'Liverpool Telescope 2' facility, to come into operation ~2020 - we are now 9 months into that process
- No real preconceptions, but important to understand the key operational strengths of the LT:
  - Low operational cost (robotic observing): 10.5 staff, £500k/year or £10k/paper
  - Rapid response to transient alerts due to robotic observer and telescope design. GRB follow-up a science highlight
  - Instrumentation: diverse suite, instrument changes within the night, rapid deployment of new concepts

Transients

- Transients (of various types) a key interest for LJMU, and many groups worldwide
- Synoptic surveys such as PTF, Pan-STARRS, Skymapper provide large numbers of transients detected at early times
- Spectroscopic follow-up is the bottleneck
  - PTF estimate ~10% of their detections get a spectral classification
- The need for flexible follow-up will be even more keenly felt with the advent of the next generation surveys such as LSST (science first light ~2021)

- Programmes like PESSTO are showing that large scale optical follow-up of transients with 4m class telescopes can be very productive. A dedicated telescope with the speed and flexibility of robotic operations would be a powerful tool

Supernovae

- LSST (and other synoptic surveys) will provide
  - Large, unbiased and statistically complete samples
  - Very early detections (many objects like SN2011fe). New parameter space
  - CC SNe: progenitors (pre-explosion imaging), relative frequencies of rare subtypes, unusual environments
  - Potentially new types of stellar explosions (combined with radio, high energy, GW, neutrino detections)

SN2011fe
(Fulton/LCOGT/PTF)

Supernovae follow-up

- The requirements for a follow-up telescope are driven by what the synoptic surveys will *not* provide
  - Photometry optimised to the SN light curve: LSST 3-4 days between visits (even longer for same filter)
  - High cadence observations at early time and over peak
  - Spectroscopy.
    - Low resolution (R~few hundred) for classification
    - Intermediate resolution for science
      - high velocity features in early time SN Ia spectra
      - Deflagration/detonation models
      - Single/double degenerate progenitor
      - Spectral evolution of exotic SNe subclasses

Gamma-ray bursts

- Robotic telescopes are well suited to GRB science
- GRB science 2020:
  - 4m class facilities can effectively follow-up low to intermediate z bursts
    - GRB-supernova associations
    - Prompt phase – particle acceleration, radiation processes, internal shocks
    - Short GRBs – nature of the binary merger components
- With fast fading transients like GRBs, response time is at least as important as aperture
- LT is on target and taking data within 1-2min of receiving trigger. Can we better this?
- Instrument: perhaps a multiband imager like GROND. Opt/IR for SED
- Will require a Swift successor like SVOM to provide triggers

Variability across the EM spectrum

- **X-ray**: LOFT is a ESA M3 candidate (launch ~2022) X-ray timing mission
- Two instruments, no optical telescope
  - Larger Area Detector: compact objects and bright AGN
  - Wide Field Monitor: X-ray transient detections and triggers
    - 2-50keV energy range
    - Observes 50% of available sky
    - Point source location accuracy (10σ) ~ 1'

- **Optical**: Gaia final catalogue will be published in 2020
- 1e9 stars with accurate positions and distances, limited photometry and very limited spectroscopy
- Millions of variables and binaries. Statistically complete samples, rare subclasses...

Variability across the EM spectrum

- **Radio**: SKA full science operations 2020 (phase 1), 2024 (phase 2)
- Transient science:
  - Pulsars, RRATs, AXPs, SGRs
  - NS-NS / NS-BH binaries. Mergers.
  - Synchrotron emission in jets from CVs, XRBs, SNe and GRBs
  - Coherent emission from flare stars, brown dwarfs, hot Jupiters

- **High energies**: Cherenkov Telescope Array begins construction ~2018
- Energy range 10s of GeV – 100 TeV, 5 – 10 improvement in sensitivity over HESS, MAGIC, VERITAS
- Northern site: AGN, GRBs, clusters
- Southern site:Galactic centre, SNR, pulsars, SFR, XRBs

GW electromagnetic counterparts

- Detection of counterpart is important for both validation of the detection and elucidation of the source. ALIGO full sensitivity ~2022
- The main complications are localisation of the GW detection (very poor) and the rapidly fading nature of the prompt emission

- For an NS-NS or NS-BH merger, counterpart consists of
  - sGRB - prompt emission and afterglow, harder to detect further off axis
  - 'kilonova' - SN like, isotropic component powered by radioactive decay of heavy elements synthesised in ejecta (Observed in GRB080503, Perley et al. 2009)?
  - Non-thermal radio afterglow. Long time delay

Metzger and Berger (2012)

Exoplanet science 2020+

- Kepler host stars typically $14.5 > m_V > 13.5$
- New facilities will concentrate on brighter ($m_V \sim 8$ - 13) stars to maximise follow-up potential
  - Millions of stars surveyed, tens of thousands of transiting planets
  - Neptunes / super-Earths / Earths
- NGTS (2014-12018) to start construction this year at Paranal
- TESS approved by NASA for a 2017 launch
- PLATO potential ESA M3 mission (~2022) decision this year
- Secondary eclipses? Transmission spectroscopy for water, biomarkers?

From http://www.ngtransits.org/

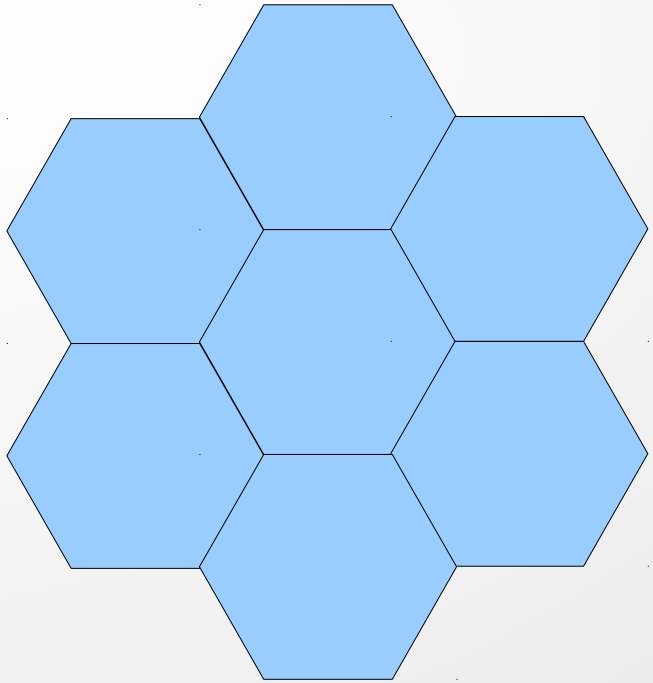
Site

- Northern and southern sites both viable for our science: synoptic surveys cover both hemispheres, targets from space facilities, GW/neutrino detections over whole sky, etc.
- Some important infrastructure will be in the south, but LSST for example will cover the sky up to +15 in dec, so northern telescopes will still have a significant follow-up role.

- At this stage our preferred site is La Palma, and we are developing this option in close collaboration with the IAC

Telescope Design

- The key elements of our current concept are
  - 4m class facility gives us the S/N to obtain spectroscopy for large numbers of SNe and more exotic transients
  - Main instrument will be an intermediate dispersion spectrograph, optical/ infrared to at least J-band
  - Ideally we would like to maintain the instrumental diversity of the LT
  - Extremely fast response for rapidly fading transients like GRB afterglows, GW counterparts and 'the unknown'
- What does a fast-slewing 4m telescope look like? Thin, segmented mirror? All instruments on Nasmyth stations? We are currently in the process of commissioning a preliminary design.



Novel instrumentation

- EM (electron multiplying) CCDs are seeing increasing use at various observatories
  - Effectively zero read noise
  - Spectroscopic format chips imminent
- CMOS detectors
  - Very fast. QE historically a problem, things now improving
- MKIDS: Microwave Kinetic Inductance Detectors
  - Surface impedance of superconductor changed by incident photon through kinetic inductance effect
  - Photon counting with spectral information
  - Largish arrays now possible, although energy resolution still poor (R~10-15)
  - As you go to larger arrays the key challenges are computational and cooling

Summary

- We intend to build a new 4m class telescope to come into operation at the beginning of the next decade
- Our preferred site is the ORM on La Palma
- Telescope will be fully robotic with all the versatility that entails
- Time domain science with a focus on transients
- Rapid response for fast-fading transients
- Spectroscopy, but hopefully a diverse instrument suite

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

Later this year: preliminary design and science white paper