The Transient Universe

- Time domain and transient astronomy is a new frontier of discovery space
  - “things that go bump in the night”
- Allows studies of variability over timescales of milliseconds to years
- Observations of transient behaviour for a wide range of objects and timescales
  - From the closest (Solar System) to the furthest
  - Some of the most energetic objects in the Universe
  - Opening the frontiers of time domain multi-messenger astronomy
The Transient Universe

• Time domain astronomy has become increasingly important
• Allows studies over variability over timescales of milliseconds to years
  – Synoptic monitoring of ‘slowly’ varying objects on timescales of days-years (e.g. variable stars of all flavours, AGN)
  – Variability of close binary stars on orbital timescales 10s of minutes to hours (e.g. Cataclysmic Variables, X-ray binaries)
  – High time resolution observations (to sub-sec) of rapidly varying objects (e.g. accretion instabilities in flows and discs)

• Observations of transient behaviour for a wide range of objects and timescales
  – Supernovae and Gamma Ray Bursts
  – AGN
  – X-ray transients (neutron star and black hole binary systems)
  – Novae and related objects; CVs of all types
  – Eruptive variables
  – Microlensing events; Tidal Disruption Events
  – Exoplanet transits
  – Radio transients
  – Gravitational Wave and Neutrino transients
  – Solar System objects (minor planets, comets)
The Transient Universe

• Increasing number of facilities and surveys leading to discoveries of transients of all classes
• Some dedicated to specific classes of objects (e.g. supernovae)
• Others finding many different classes of transients as a by-product of wide-field surveys (e.g. Gaia, OGLE, PanSTARRS, ZTF, TESS)
• Both ground-based and space-based facilities are sources of alerts
• South Africa has developed its own ground-based optical detection facilities
• A SALT large science programme on transients began in 2016
• Paving the way for the next big transient discovery machine: the Large Synoptic Survey Telescope
• Need for machine learning tools based on current experiences

The Large Synoptic Survey Telescope

- International project to continuously survey southern sky over 10 year (wide field “video” 30 gigapixel camera)
- Under construction in Chile (completion early 2020s)
- South Africa is becoming involved (funding five PI Affiliates)
- Huge opportunity for transient science
The SALT Transient Programme

- SALT Large Program on transients began in May 2016
  - Large allocation in highest priority (e.g. ToO) class (P0)
  - allows for rapid response to alerts
  - Basic pipeline reduced data available in < 12 h (raw data immediately)
  - Recently extended for 3 more years

- Multi-institutional/multi-partner program
  - 5 South African institutions (SAAO, UCT, UFS, NWU, UJ)
  - 4 other SALT partners (Poland, IUCAA, UKSC, UW)
  - 32 investigators (incl. many graduate students)
  - Now being expanded to include other international participation (e.g. China, Russia)
Observing Transients With SALT

- 100% queue scheduled service observing
- Variety of instruments/modes
- Rapid instrument changes and mode configurations
- Scheduling allows for synoptic monitoring at different cadences
- Targets of Opportunity can be done at short notice
- Ideal for followup of transients

SALT Viewing Annulus
SALT Transient Program

- Covering wide range in luminosity (& distance)
- Variability on wide range of timescales
  - Sub-seconds domain a new frontier
- Covering many object classes
  - X-ray transients*
  - Cataclysmic Variables
  - Novae*
  - Intermediate luminosity transients
  - Tidal Disruption Events (TDEs)
  - Black Hole microlensing events
  - Flaring Blazars*
  - Unusual supernovae (e.g. Super Luminous Supernovae)
  - Gamma-Ray Bursts (GRBs)
  - Multi-messenger (Gravitational Wave & Neutrino) events
    - *Radio transients with MeerKAT (ThunderKAT programme)

(*see other talks at this meeting)
<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cataclysmic Variables (mostly dwarf novae)</td>
<td>19.5%</td>
</tr>
<tr>
<td>Gaia, OGLE, ASASSN, ATLAS transients (TDE, nuclear, some SNe, microlensing events)</td>
<td>24.1%</td>
</tr>
<tr>
<td>Supernovae (Super Luminous, core collapse)</td>
<td>10.6%</td>
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<tr>
<td>GRB</td>
<td>1.4%</td>
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<tr>
<td>Swift transients</td>
<td>1.2%</td>
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<tr>
<td>AGN (mostly blazars)</td>
<td>9.9%</td>
</tr>
<tr>
<td>X-ray Transients (LMXBs, HMXBs)</td>
<td>23.8%</td>
</tr>
<tr>
<td>Novae</td>
<td>9.5%</td>
</tr>
</tbody>
</table>
Cataclysmic Variables

- Alerts from MASTER, ASASSN, OGLE, Gaia
  - Mostly Dwarf Novae
  - Some AM CVn candidates
  - Some magnetic CV candidates

![Graph showing spectral lines](image-url)
Cataclysmic Variables

- Alerts from MASTER, ASASSN, OGLE, Gaia
  - Mostly Dwarf Novae
  - Some AM CVn candidates
  - Some magnetic CV candidates
Cataclysmic Variables

- Alerts from MASTER, ASASSN, OGLE, Gaia
  - Some anti-dwarf novae (VY Scl)
  - Combined ASASSN / MASTER light curve
Cataclysmic Variables

- Alerts from MASTER, ASASSN, OGLE, Gaia
  - Some anti-dwarf novae (VY Scl)
  - Some oddities
Papers: Wyrzykowski et al. (prep, Gaia transients), Hamanowicz et al. (prep, OGLE transients), Gromadzki et al. (submitted, OGLE17aaj), Gromadzki et al. (prep, OGLE17jei) and Sokolovsky et al. (prep, ASASSN-17gs).
Microlensing events from Gaia

Kruszynska et al. (prep)
Spectra allows for classification and estimation spectro-photometric distance
Event first thought to be a microlensing event turned out to be a brightening AGN at $z = 2$
Supernovae

- Spectroscopic classifications of few SNe – ASASSN-17pr, ASASSN-17rj, ASASSN-18vo
Super-Luminous Supernovae

- Class only recognized in last ~decade
- 10-100 x more luminous than usual SNe
- Rare (1 in 1000)
- Closest one to date (z = 0.027)
- 12 epochs of SALT spectroscopy (from -5 to 107 days w.r.t. Peak brightness)
Program led by UFS and NWU (van Soelen, Britto, Boettcher)

- Alerts from X-ray satellites (e.g. Fermi LAT)
- Utilizing spectropolarimetric modes for SALT
- Investigate the position angle variations during flares
Recent X-ray Transient Result

**New Super Soft Source: ASASSN-16oh**

- discovery of a new Super Soft Source in the SMC on 15 Dec 2016
- Followup SALT RSS spectroscopy
  - Strong HeII 4686
  - Small R.V. variations
- Followup LCO photometry (DDT)
  - ~2 nights over X-mas period 2016
- OGLE photometry
  - Symmetrical and long-lived (~200 d) outburst
  - Evidence of previous lower amplitude ones
- Swift/ASTROSAT observations
  - Very soft X-ray spectrum
  - Outburst from hot (~900,000 K) spreading layer on white dwarf
  - *Not* a thermonuclear ignition event
Another Super Soft Source?

New transient OGLE17nif

- Followup SALT RSS spectroscopy
  - Strong HeII 4686
  - Similar to ASASSN-16oh
  - Light curve also show symmetrical slow rise/decay
CONCLUSIONS & REMARKS

• SALT is well suited follow-up of transients (optical, X-ray, gamma ray, radio), including SNe, GRBs (when caught early enough), CVs, eruptive variables, TDEs, BH microlenses, AGN/blazar flares, X-ray transients and multi-messenger events (gravitational waves and neutrinos)

• New transient detections systems at Sutherland (MASTER-SAAO & now MeerLICHT)

• New follow-up robotic facilities at SAAO, including LCO, 1-m Lesedi (robotic at some point), MONET, MASTER, plus auto-alert/followup scheduling systems

• Development of integrated network of automated telescopes at SAAO, eventually linking to global facilities

• Multi-wavelength opportunities (e.g. now with: HESS, X-ray missions; future with: MeerKAT, HESS, ... SKA, CTA...)