Understanding the nature of the transient Universe: A proposed BRICS Astronomy Programme

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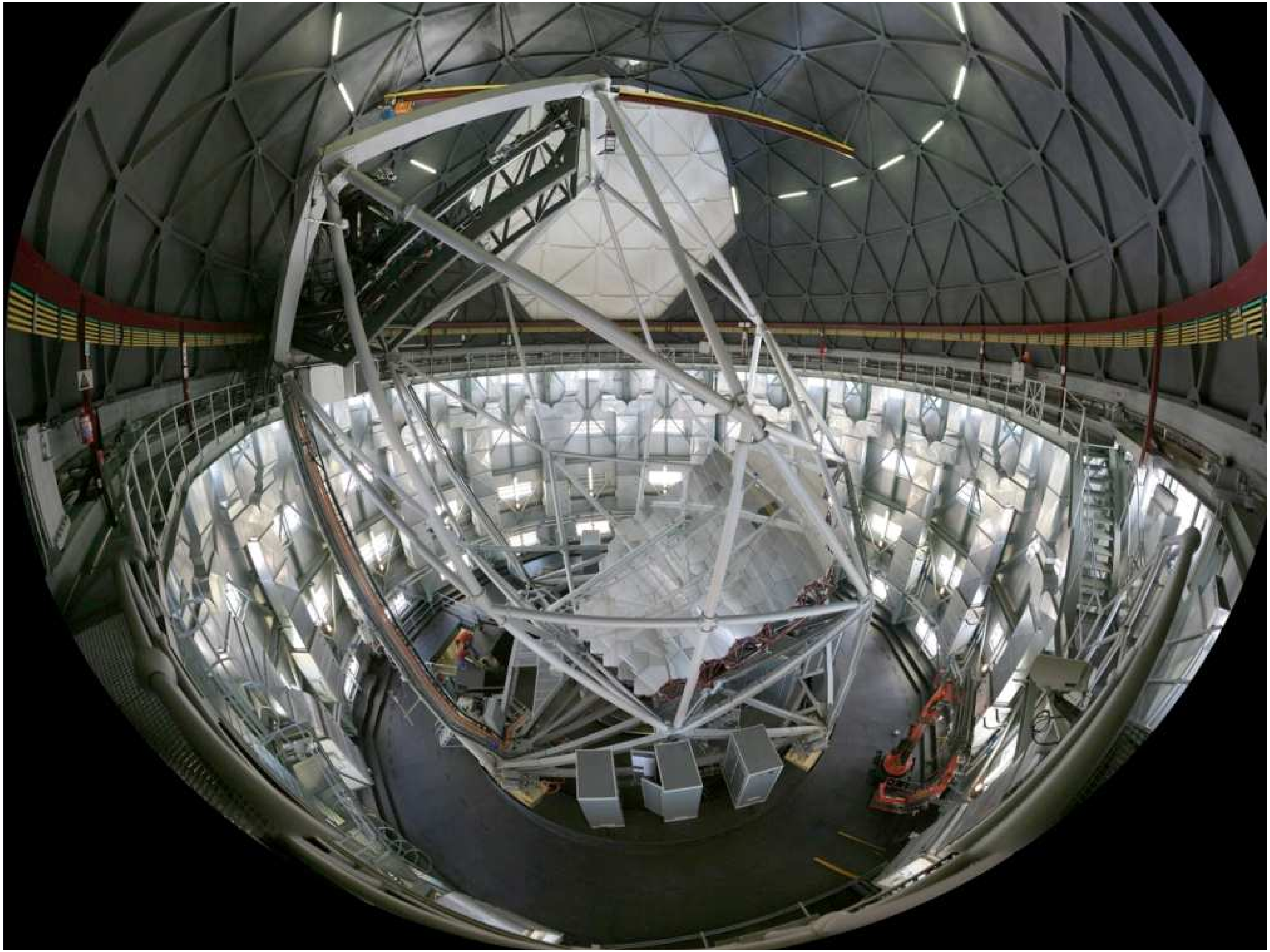
BRICS Astronomy Goals

- Common aspirations for scientific and technological development
- Enhanced human capital development
- In 2015 South Africa is secretariat for BRICS Astronomy Programme
- Leveraging facilities in South(ern) Africa
  - SALT: the largest optical telescope in the southern hemisphere (2005)
  - MeerKAT: will be the most sensitive radio telescope array (2018)
  - HESS: the Cherenkov TeV gamma ray array (2004)

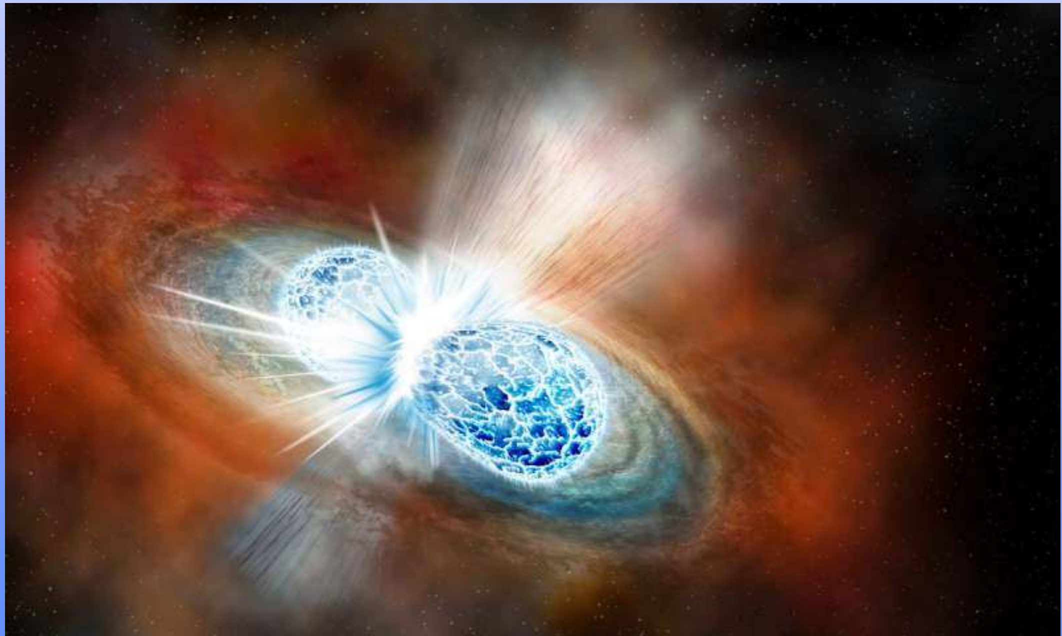


BRICS Astronomy Goals

- **Synergies with other astronomical facilities in BRICS countries**
  - **Brazil: access to 4.0-m SOAR optical telescope and European Southern Observatory**
  - **Russia: access to many optical telescopes (1 to 6-m) and RATAN radio telescope**
  - **India: 3.5-m ARIES and smaller optical telescope; GMRT radio array**
  - **China: FAST radio dish (largest in the world) plus 1 & 2-m optical telescope**
  - **South Africa: future host of the Square Kilometer Array (SKA)**
- **Telescope distributed in longitude and latitude**
  - **Allow access to a wide area of sky continuously**

The Transient Universe

- **Time domain and transient astronomy is 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**

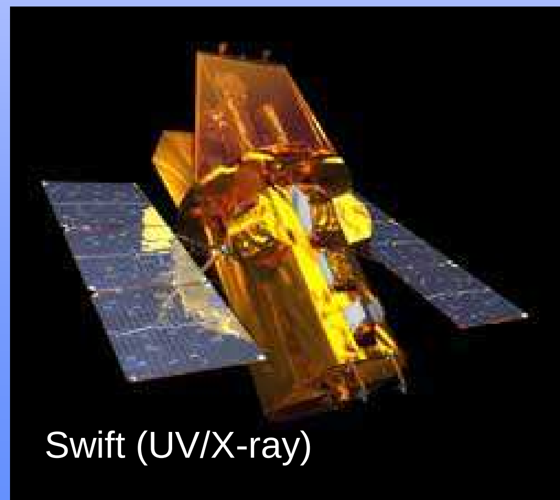


The Transient Universe

- 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

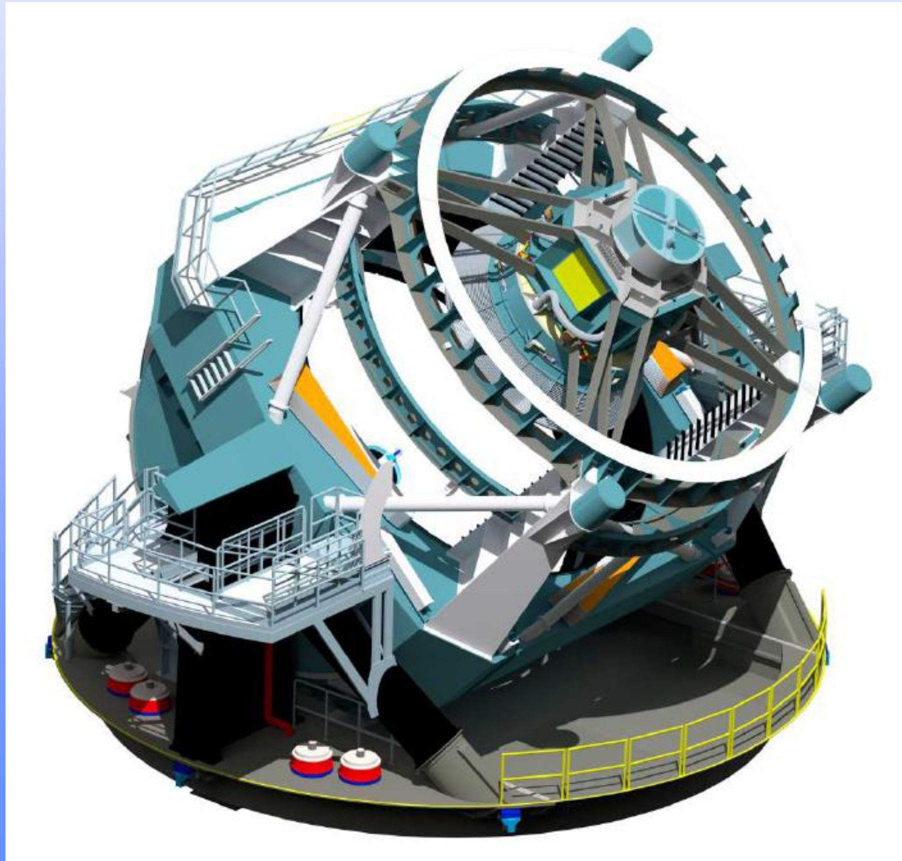

MeerLICHT (2018)

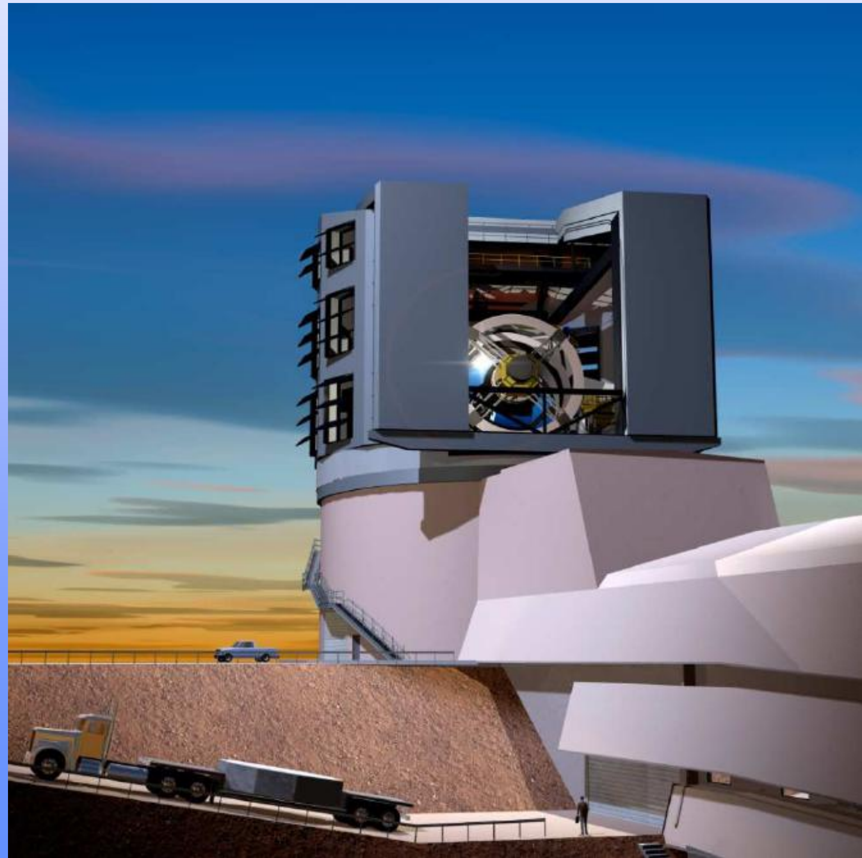
MASTER-SAAO (2015)


Swift (UV/X-ray)

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, Brazil and potential BRICS involvement





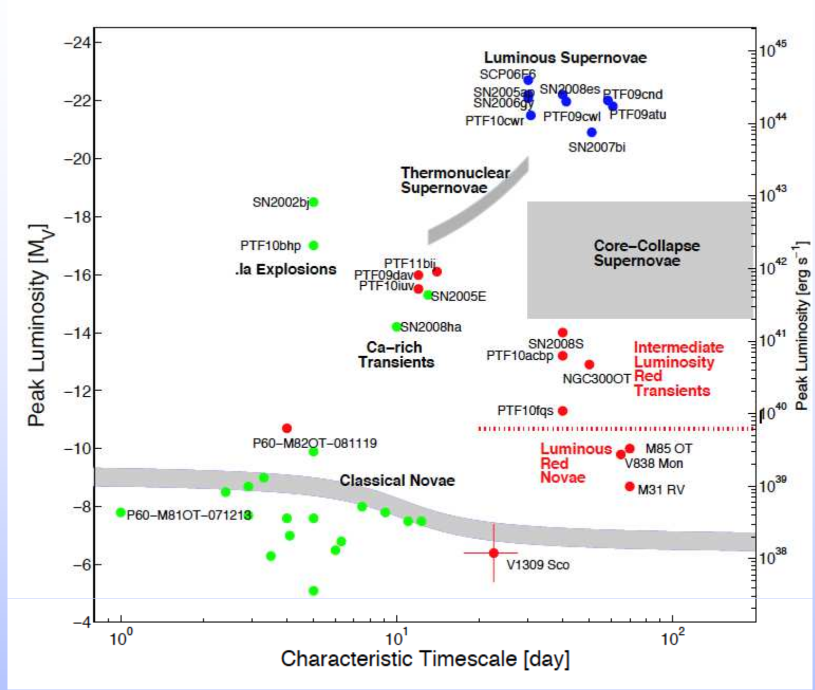
Building on Success: The SALT/SAAO Transient Programme

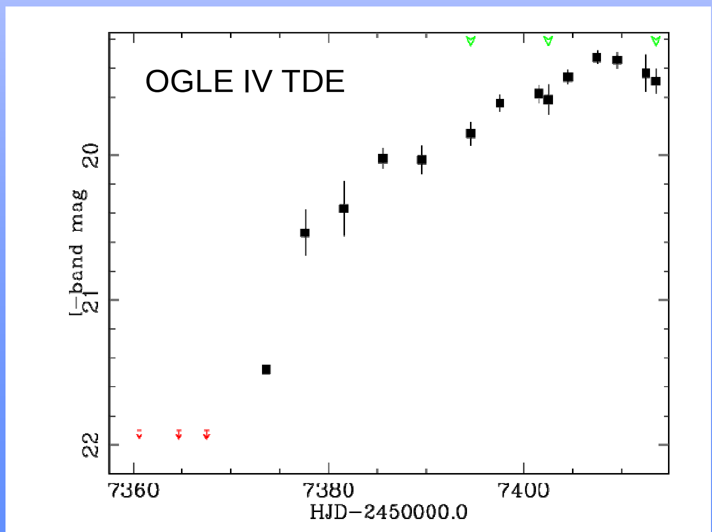
- **SALT Large Program on transients began in May 2016**
  - **60% allocated in highest priority (override) class (P0)**
  - **allows for rapid response to alerts**
  - **Basic pipeline reduced data available in < 12 h (raw data immediately)**
  - ***Recently extended for 3 more years***

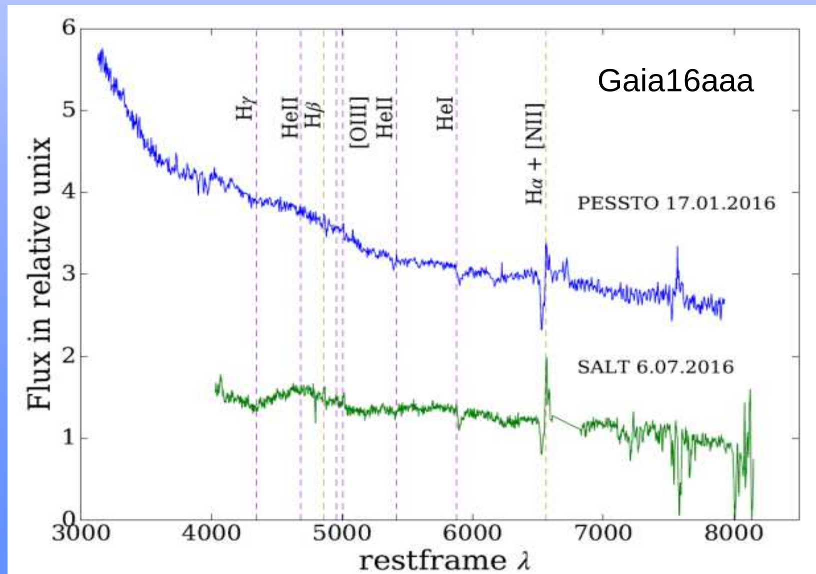
- **Multi-institutional/multi-partner program**
  - **5 South African institutions (SAAO, UCT, UFS, NWU, UJ)**
  - **4 other SALT partners (Poland, IUCAA, UKSC, USA)**
  - **32 investigators (incl. many graduate students)**
  - **Now being expanded to include BRICS participation**
- **First South African BRICS astronomy project**
  - **Involving Russia, India & China**
  - **Focus on highly energetic phenomena**
  - **Leveraging national facilities**

SALT Transient Program

- **Covering many object classes**
  - **X-ray transients**
  - **Dwarf Novae**
  - **Novae**
  - **Intermediate luminosity transients**
  - **Tidal Disruption Events (TDEs)**
  - **Black Hole microlensing events**
  - **Flaring Blazars**
  - **Gamma-Ray Bursts (GRBs)**
  - **Gravitational Wave events**
  - ***Radio transients (from 2018 with MeerKAT)***



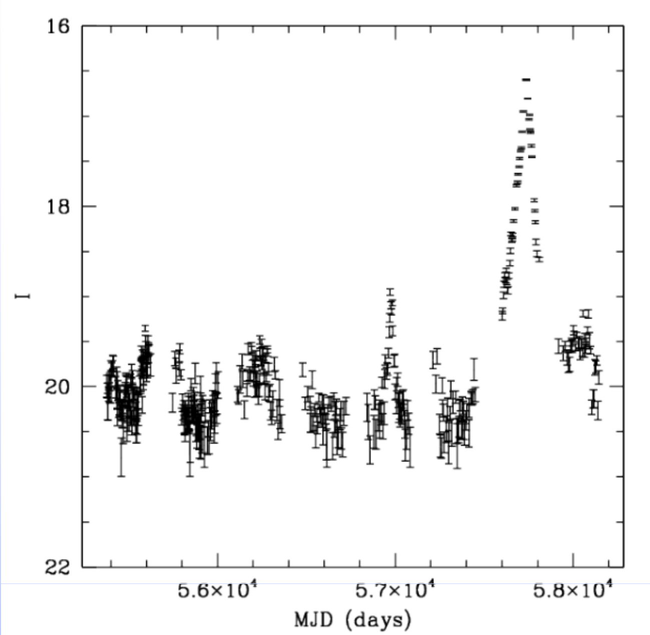


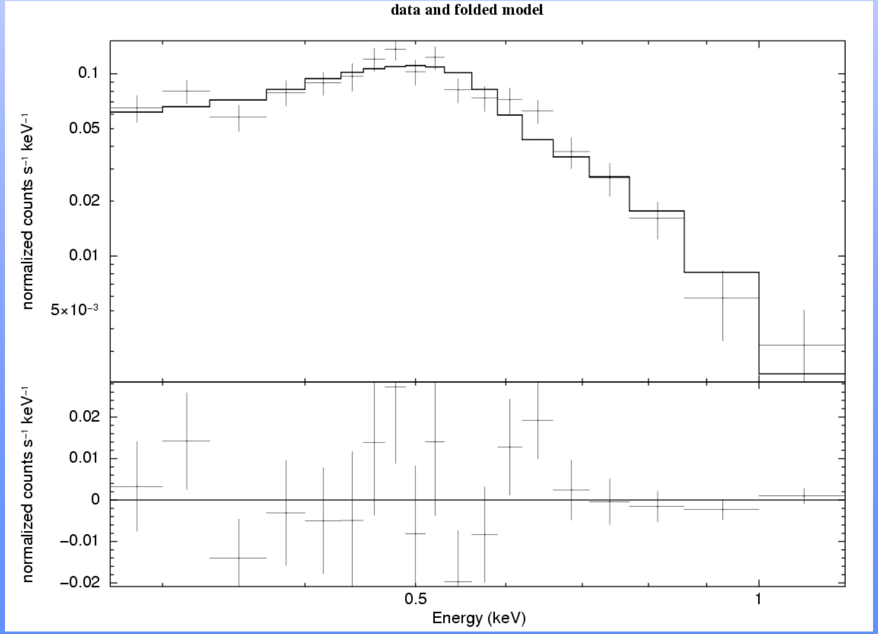


Examples of recent results

1. 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
- Paper in *Nature Astronomy* (in press)
  - Outburst from hot (~900,000 K) spreading layer on white dwarf
  - *Not* a thermonuclear ignition event





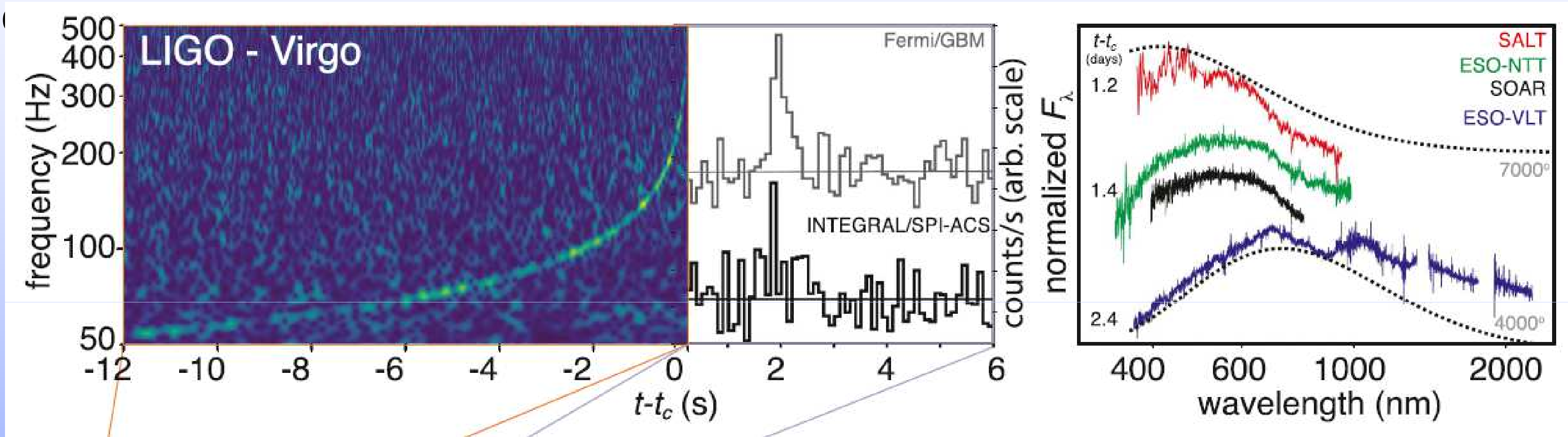
Examples of recent results

2. GW170817: the first electromagnetic counterpart to a GW event: South African follow-up

- first opportunity was on 18 Aug (1.2 d after GW event) once the optical counterpart was identified
- only visible early in the earley evening for a short time (<20 min)
- observations done with 4 telescopes at SAAO:
  - SALT spectroscopy (on 18 & 19 Aug)
  - Optical photometry (MASTER-SAAO and 1-m)
  - Infrared photometry (Japanese IRSF telescope)

GW170817 results

- 84 papers appeared on arXiv on 16 Oct (embargo date; 2 months after detection)
- SALT & SAAO results have appeared in 9 refereed papers (including *Nature* and *Science*)
- SALT spectra featured in a massive (3,677 author) “multi-messenger” paper
- SALT/SAAO led paper helped to build a consistent model for neutron star mergers and resulting kil



Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS 474, L71–L75 (2018) doi:10.1093/mnrasl/slx196
Advance Access publication 2017 December 4

A comparison between SALT/SAAO observations and kilonova models for AT 2017gfo: the first electromagnetic counterpart of a gravitational wave transient – GW170817

David A. H. Buckley,[1,2★] Igor Andreoni,[3,4,5] Sudhanshu Barway,[1] Jeff Cooke,[3,4,6] Steven M. Crawford,[1,2] Evgeny Gorbovskoy,[7] Mariusz Gromadzki,[8] Vladimir Lipunov,[9,7] Jirong Mao,[10,11,12] Stephen B. Potter,[1] Magaretha L. Pretorius,[13,1] Tyler A. Pritchard,[3] Encarni Romero-Colmenero,[1,2] Michael M. Shara,[14,15] Petri Väisänen[1,2] and Ted B. Williams[1]

New SAAO Transient Followup Opportunities

Follow-up selected objects with robotic facilities and SALT

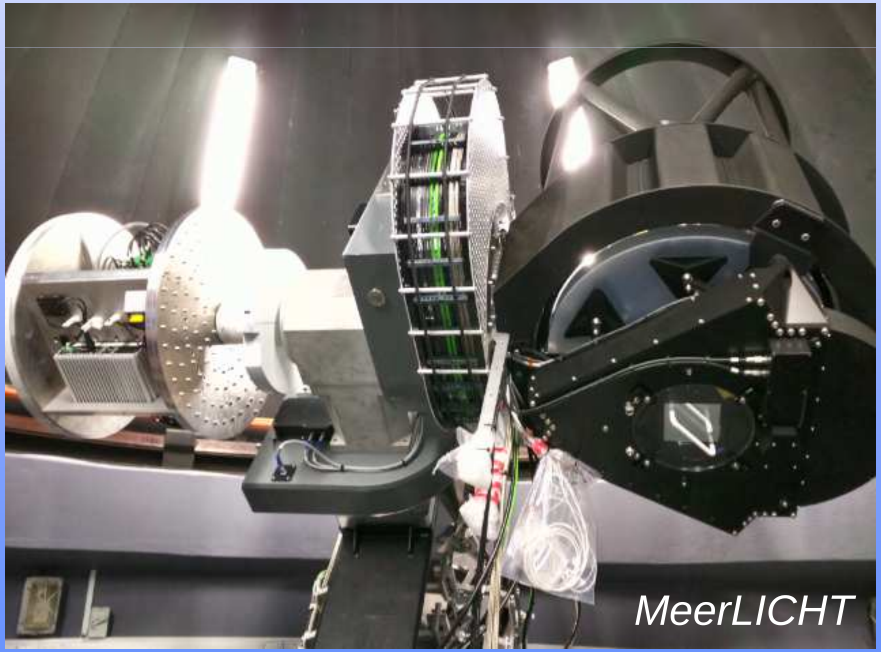
Photometric monitoring (orbital periods):

- **LCOGT 1.0-m (+ other longitudes)**
- **MONET 1.2m**
- **new SAAO 1.0 m robotic telescope (*Lesedi*)**
- **instruments including CCD and high speed EM-CCD cameras and spectrograph(s)**

Transient Observation Opportunities

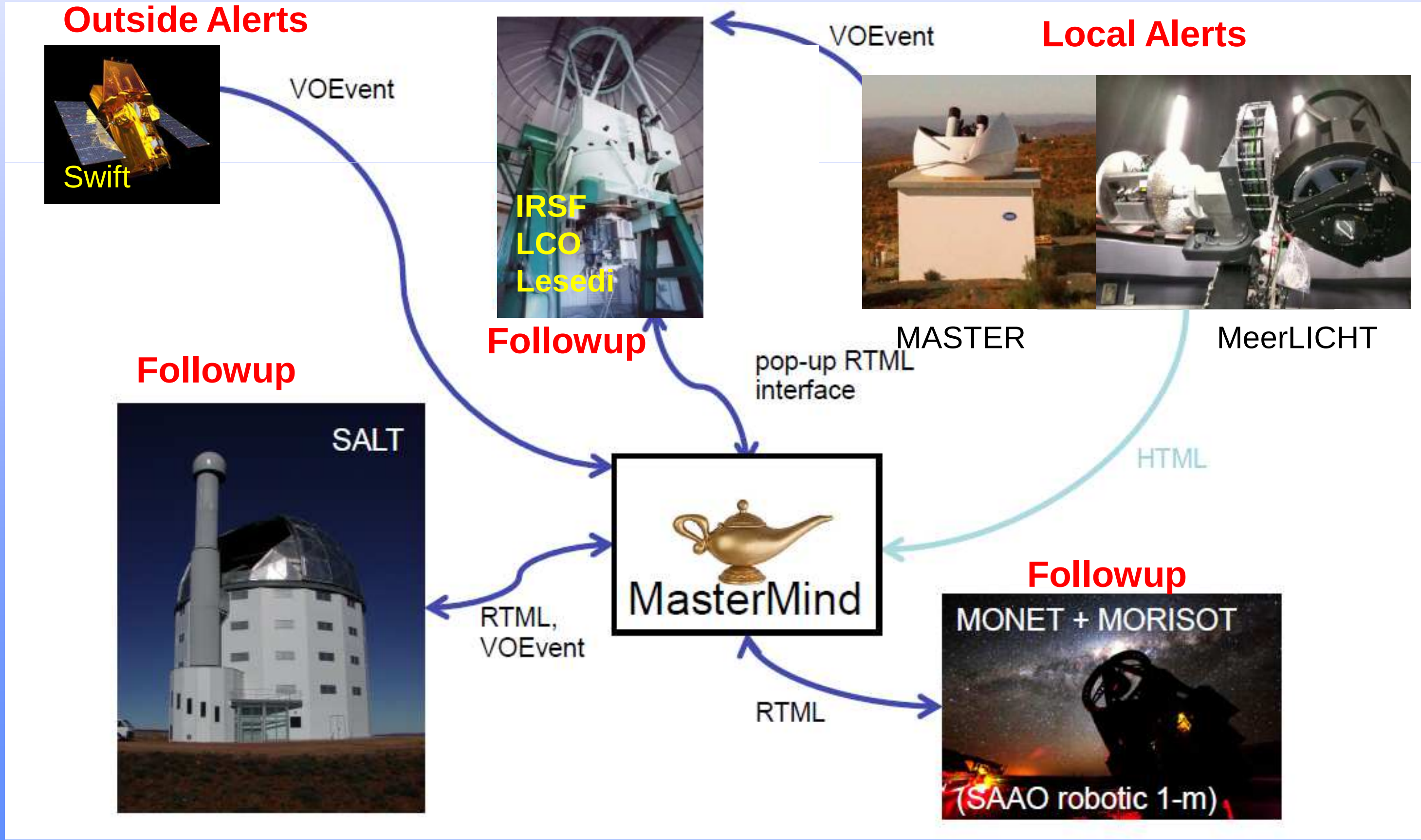
New optical telescope just opened: *MeerLICHT* (0.65 m; 2 sq ° FoV)

- **Joint Dutch-UK-SAAO venture**
- **Optical monitoring of *MeerKAT* radio source**
- **Correlate with *radio transients* to identify optical counterparts**
  - **- chance to see FRB optical counterparts for the first time (if they exist!)**



Automated Transient Followup Project

- Trigger automated requests for followup observations from alert triggers
- Will allow for the automated selection of telescopes, instruments & modes and appropriate observation setup and scheduling
- GCN socket, VOEvents, APIs for robotic & queue-scheduled telescopes
- Efforts are underway in developing toolkits for automated scheduling, e.g. Target & Observation Manager (TOM) and Astronomical Event Observatory Network (AEON), used to coordinate observing requests across multiple participating facilities (LCO initiatives)



SAAO Sutherland plateau:
An Intelligent Transient Observatory

Future aspirations at SAAO: make the whole Sutherland site an integrated intelligent machine for transient followup

This work is beginning now with several recent initiatives:

- funding for a new highly efficient spectrograph for SALT (point & shoot)
- resources being provided to allow development of SW scheduling tools in collaboration with other groups (e.g. LCO)
- South African participation in LSST

A BRICS Transient Followup Programme

- **Develop a BRICS key astronomy programme on transients**
- **A global multi-site, multi-wavelength approach**
- **Programme could involve:**
  - **Automating networks of telescopes within BRICS countries**
  - **Developing new dedicated telescopes, instruments, software (scheduling, data pipelines & analysis)**
  - **Chinese *Sitian* network (see Prof Shen's talk) could be part of this (?)**

The End