Status of the SALT Transients Programme

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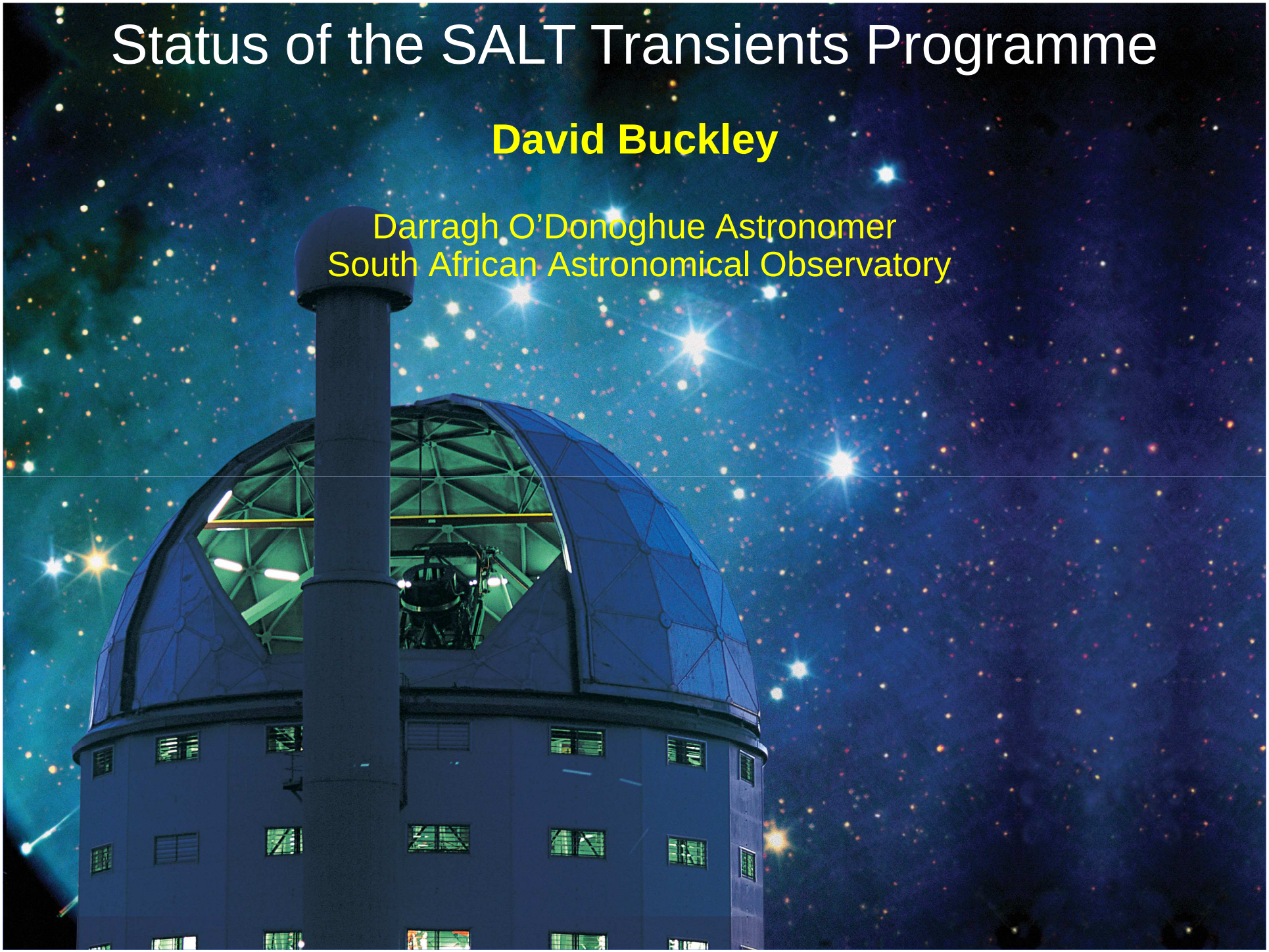
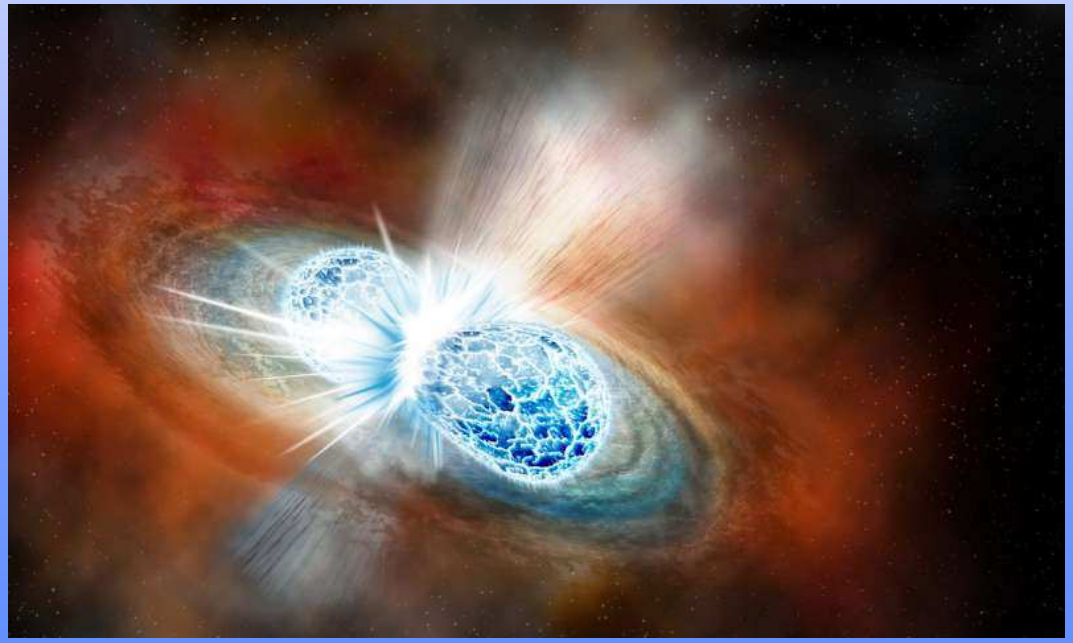


The Transient Universe

- 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

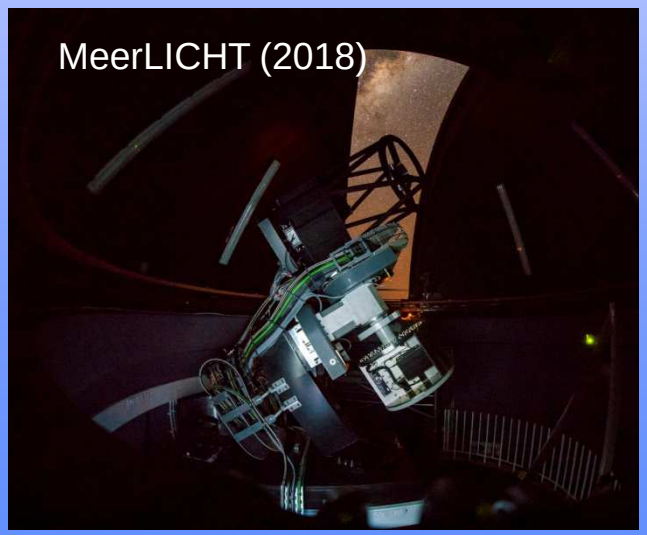


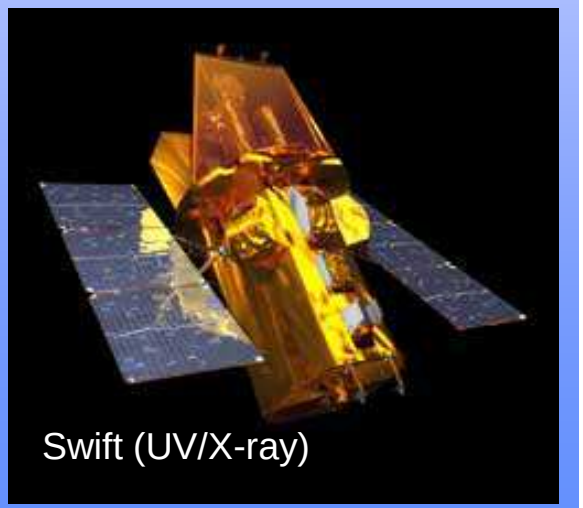
The Transient Universe

- **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

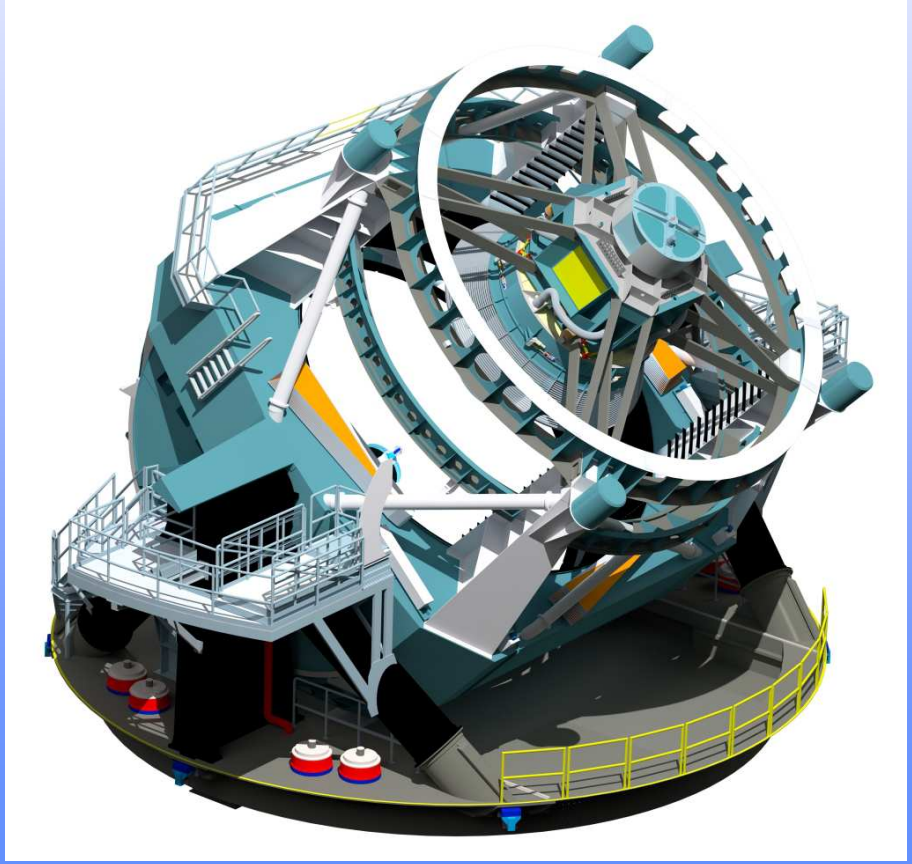
- **Increasing number of facilities and surveys leading to discoveries of transients of all classes**
- **Some dedicated to specific classes of objects (e.g. supernovae)**
- **Others finding many different classes of transients as a by-product of wide-field surveys (e.g. Gaia, OGLE, PanSTARRS, ZTF, TESS)**
- **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**

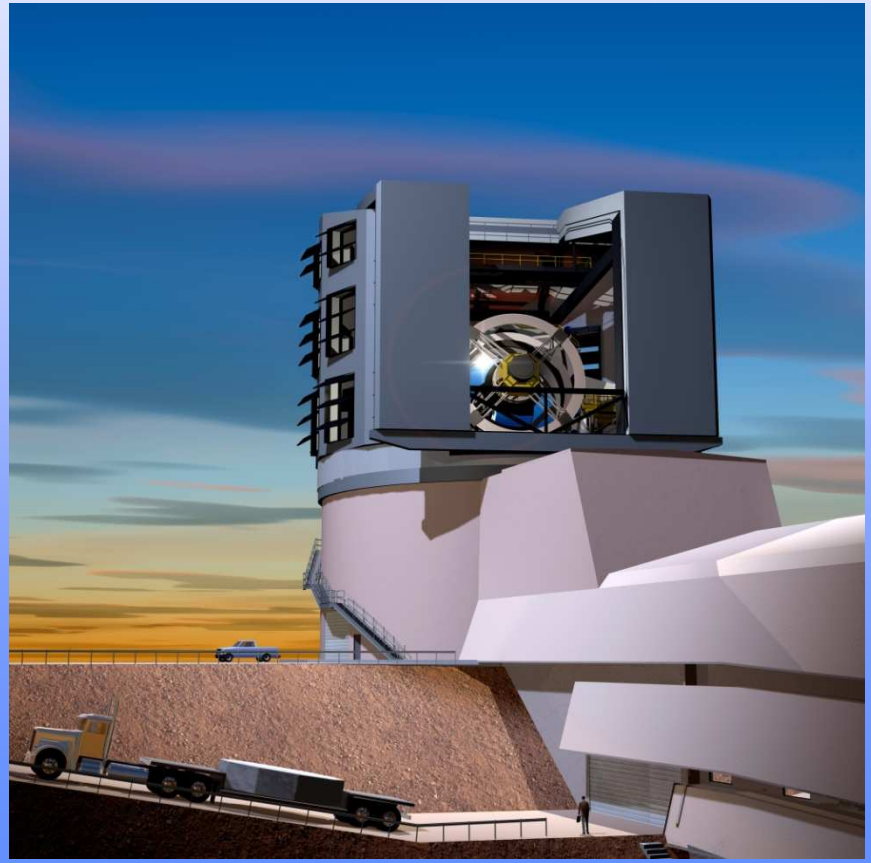




The Large Synoptic Survey Telescope

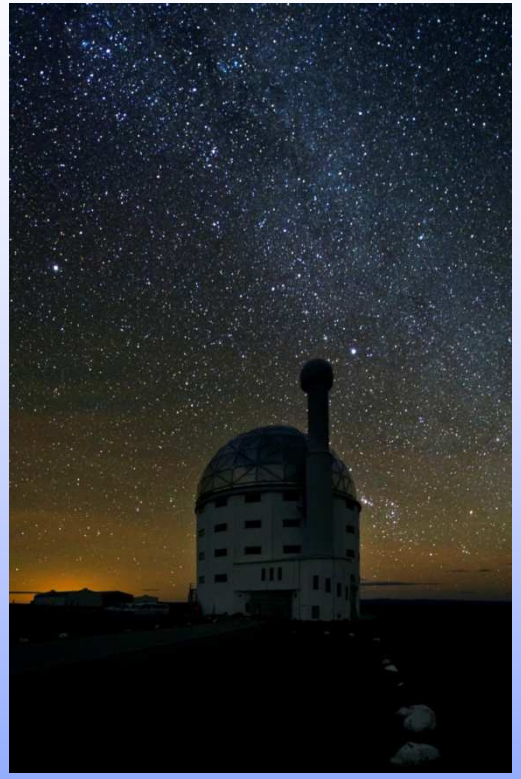
- International project to continuously survey southern sky over 10 year (wide field “video” 30 gigapixel camera)
- Under construction in Chile (completion early 2020s)
- South Africa is becoming involved (funding five PI Affiliates)
- Huge opportunity for transient science

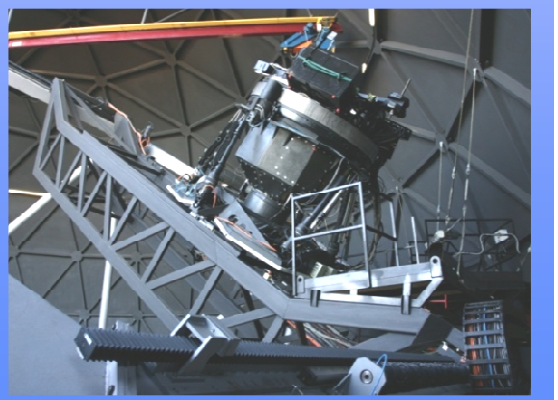




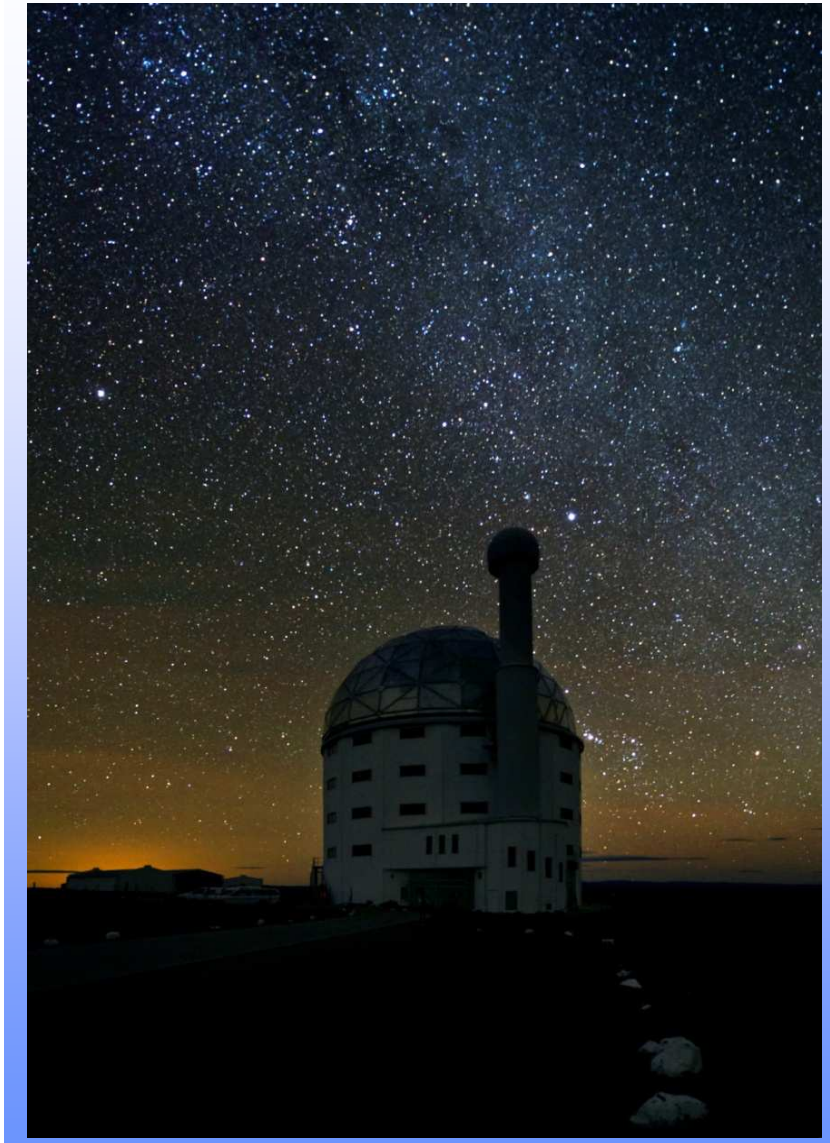
The SALT Transient Programme

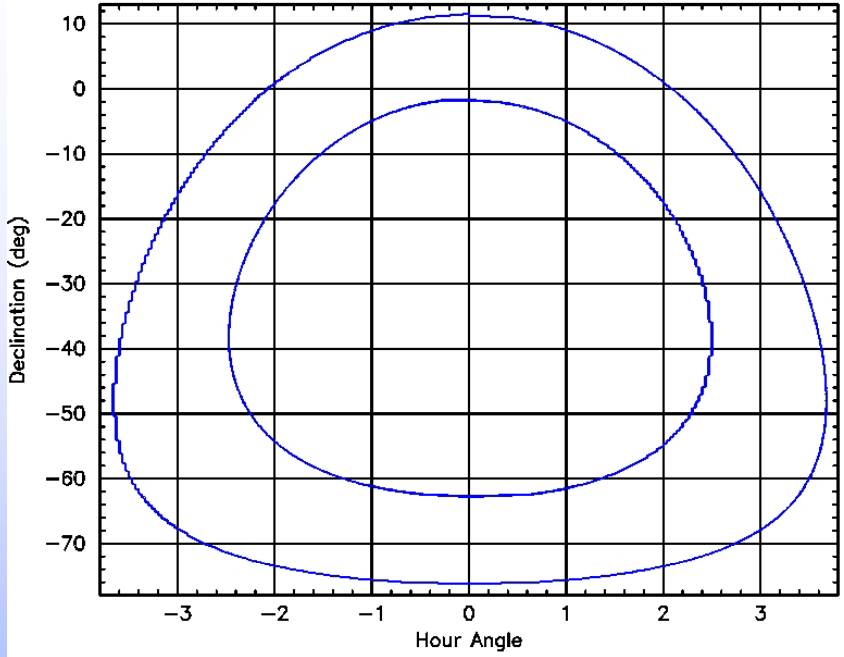
- **SALT Large Program on transients began in May 2016**
  - **Large allocation in highest priority (e.g. ToO) class (P0)**
  - **allows for rapid response to alerts**
  - **Basic pipeline reduced data available in < 12 h (raw data immediately)**
  - ***Recently extended for 3 more years***
- **Multi-institutional/multi-partner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





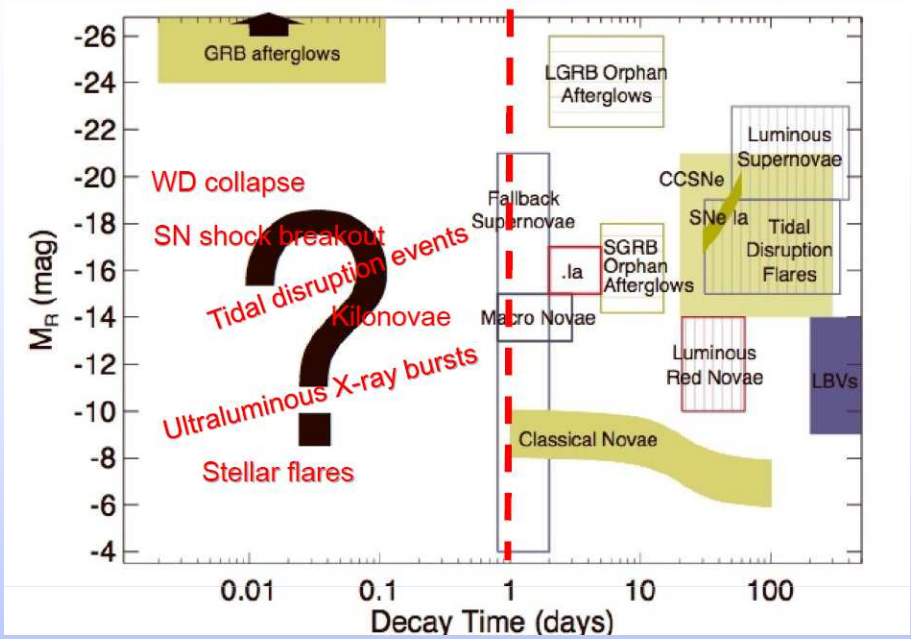
SALT Viewing Annulus

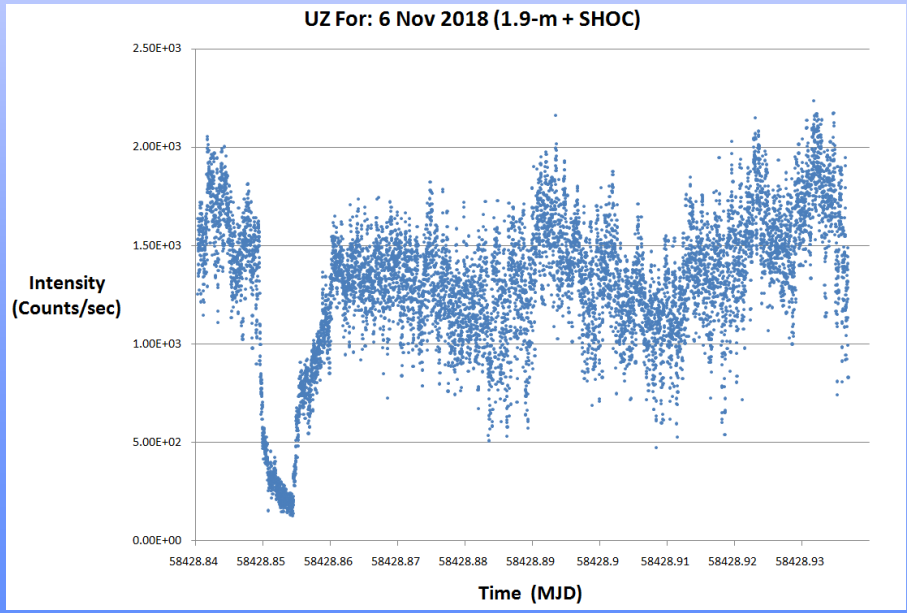
- 100% queue scheduled service observing
- Variety of instruments/modes
- Rapid instrument changes and mode configurations
- Scheduling allows for synoptic monitoring at difference cadences
- Targets of Opportunity can be done at short notice
- Ideal for followup of transients

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)



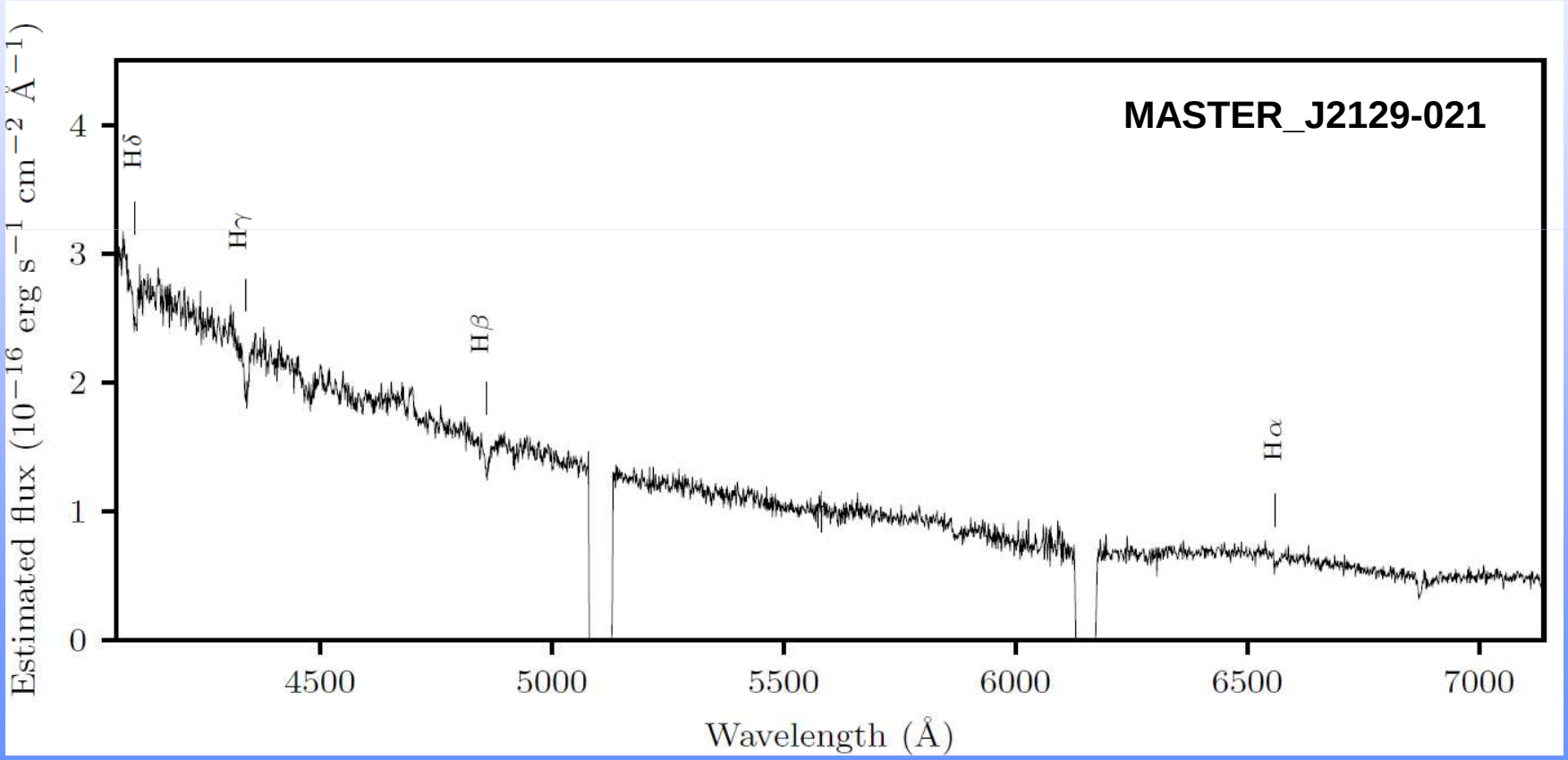


Breakdown of Observations to date (2016 – 2018)

• Cataclysmic Variables (mostly dwarf novae)	19.5%
• Gaia, OGLE, ASASSN, ATLAS transients (TDE, nuclear, some SNe, microlensing events	24.1%
• Supernovae (Super Luminous, core collapse)	10.6%
• GRB	1.4%
• Swift transients	1.2%
• AGN (mostly blazars)	9.9%
• X-ray Transients (LMXBs, HMXBs)	23.8%
• Novae	9.5%

Cataclysmic Variables

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



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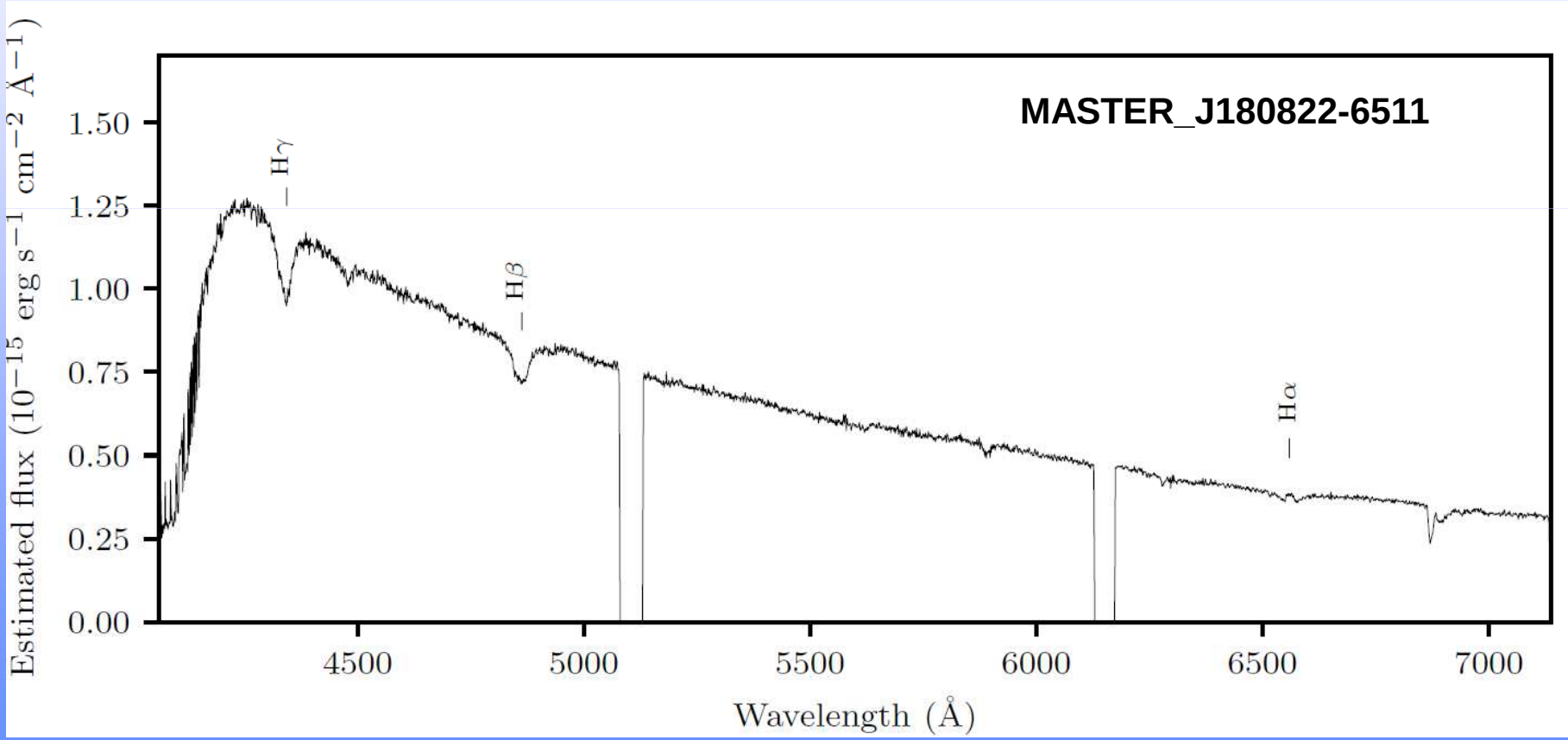
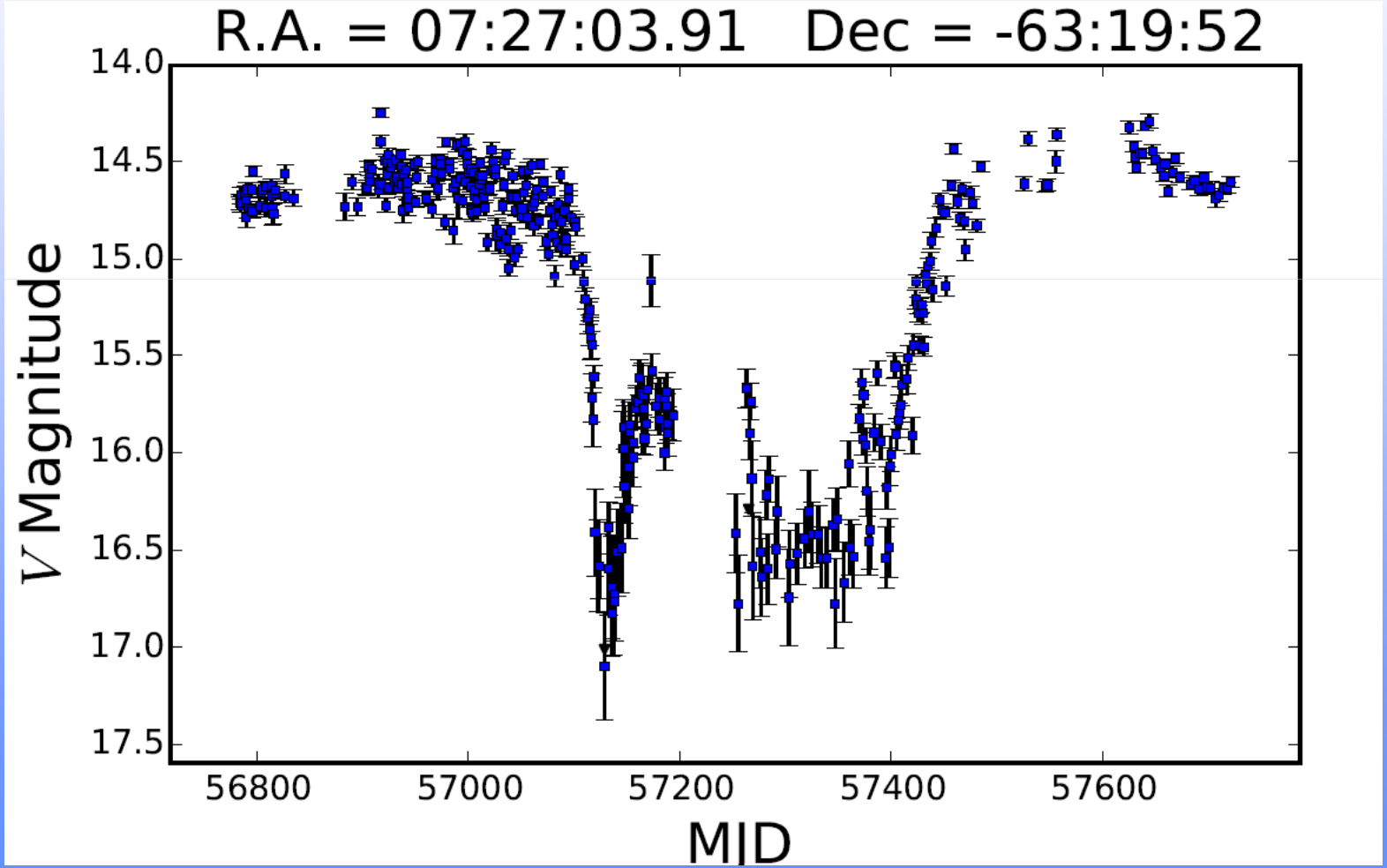


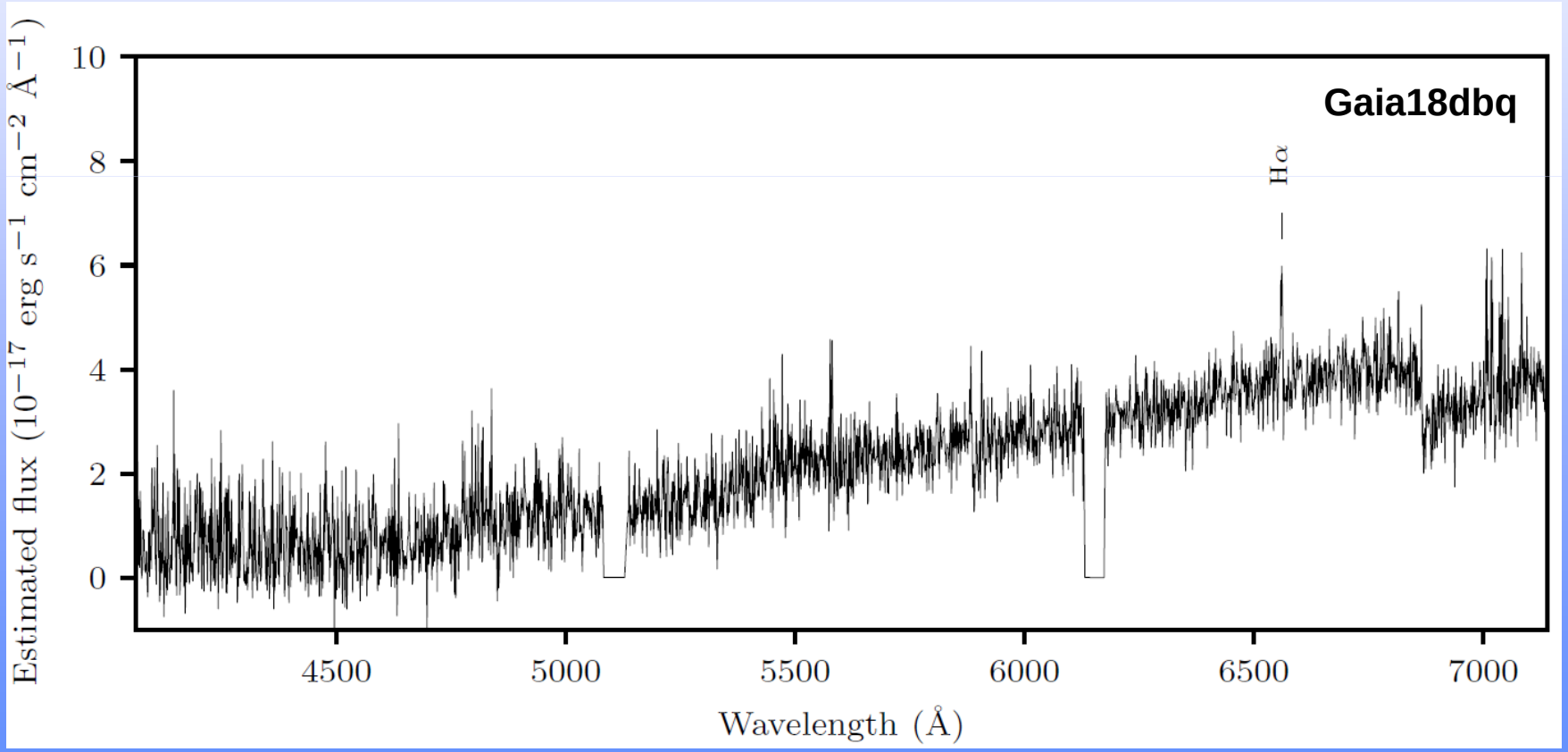
Cataclysmic Variables

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



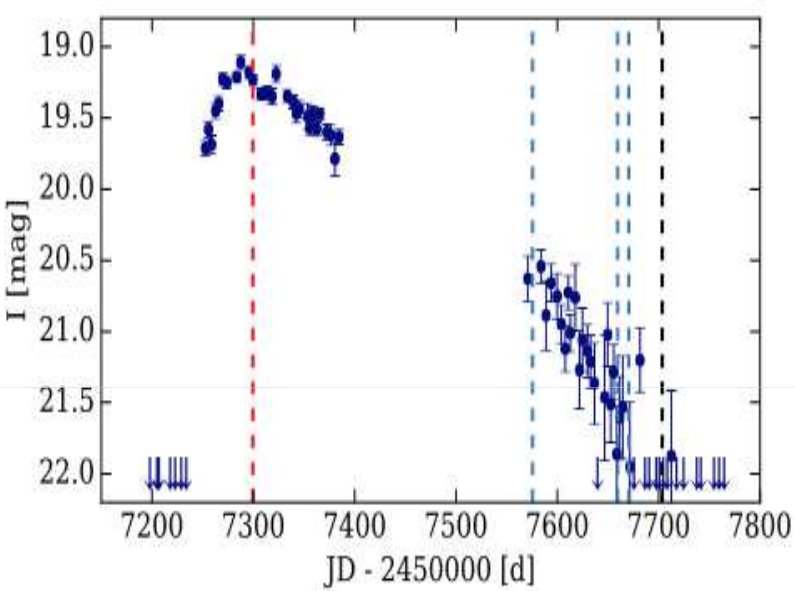
Cataclysmic Variables

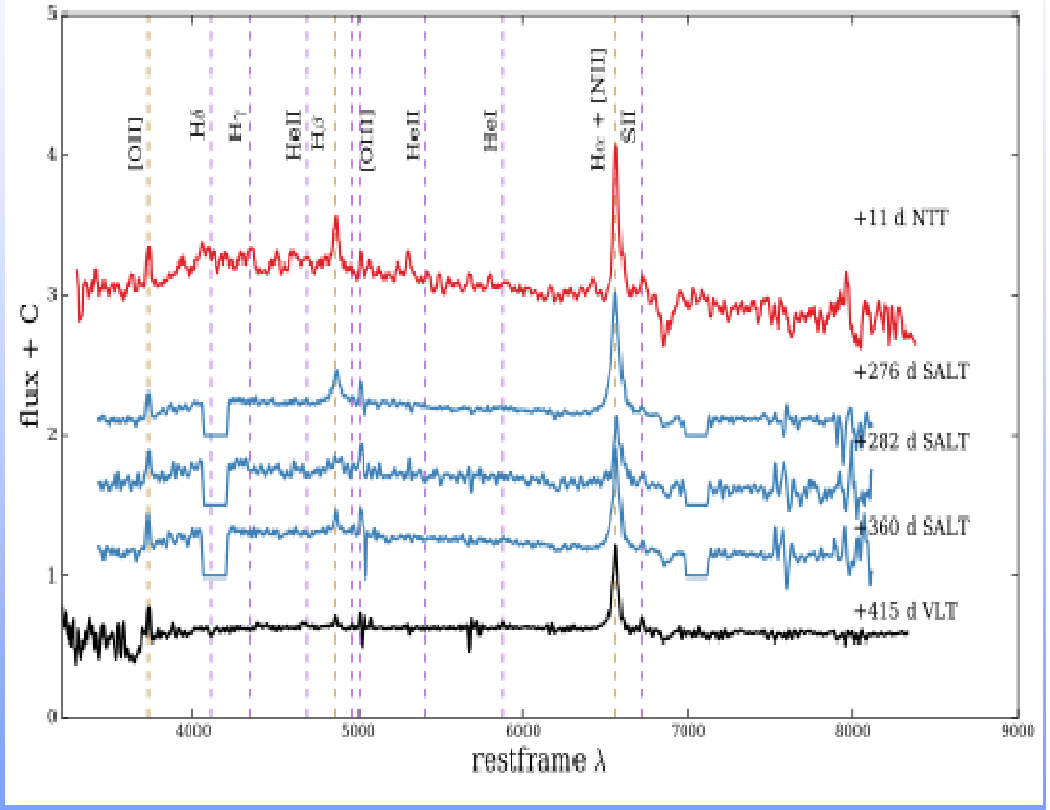
- **Alerts from MASTER, ASASSN, OGLE, Gaia**
  - **Some anti-dwarf novae (VY Scl)**
  - **Some oddities**



Nuclear transients from OGLE and Gaia surveys

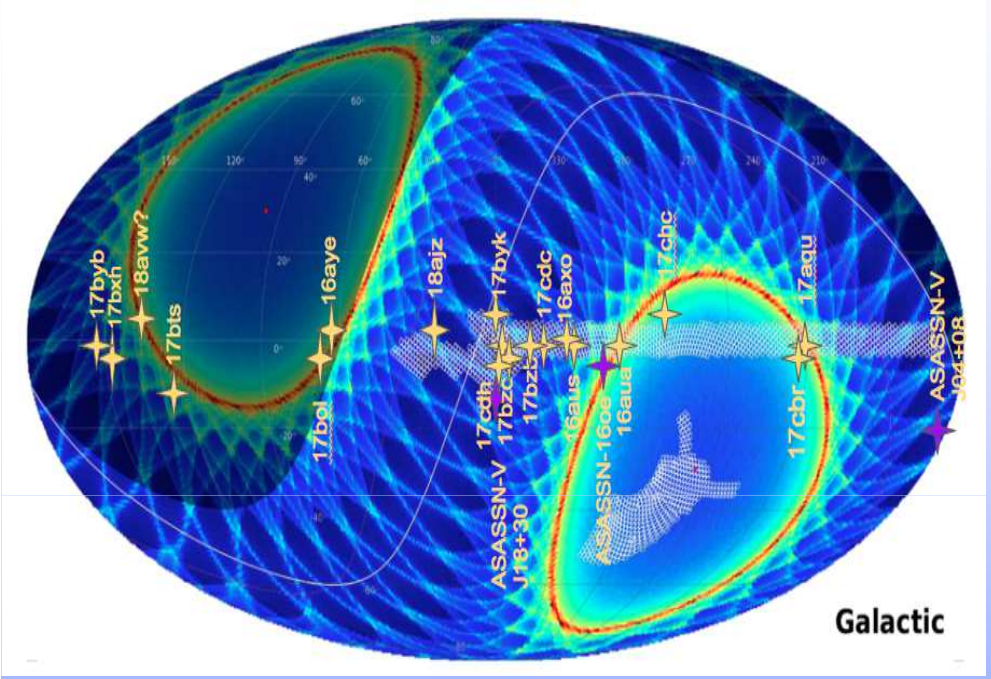
OGLE15gt:

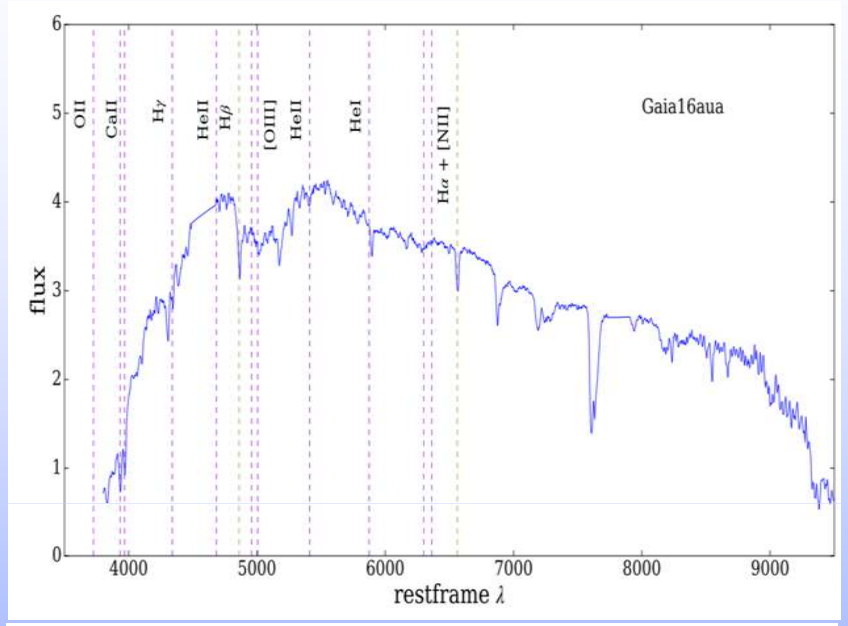




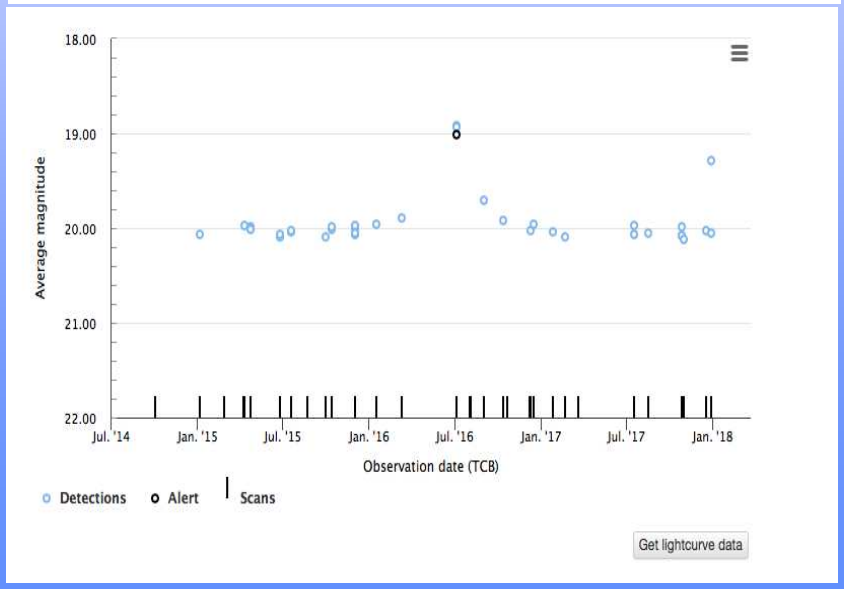
Papers: Wyrzykowski et al. (prep, Gaia transients), Hamanowicz et al. (prep, OGLE transients),
Gromadzki et al. (submitted, OGLE17aaj), Gromadzki et al. (prep, OGLE17jei) and Sokolovsky et al. (prep, ASASSN-17gs).

Microlensing events from Gaia



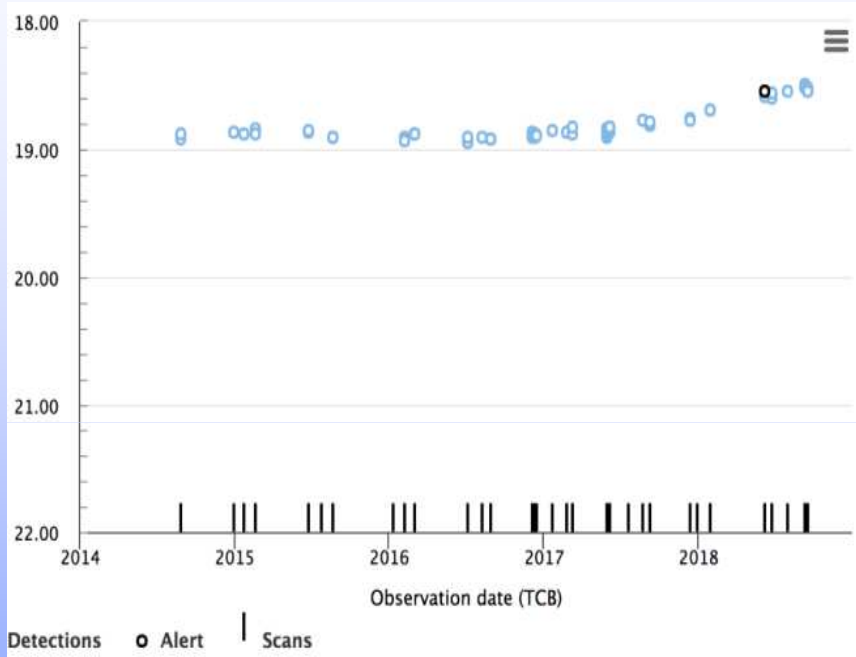


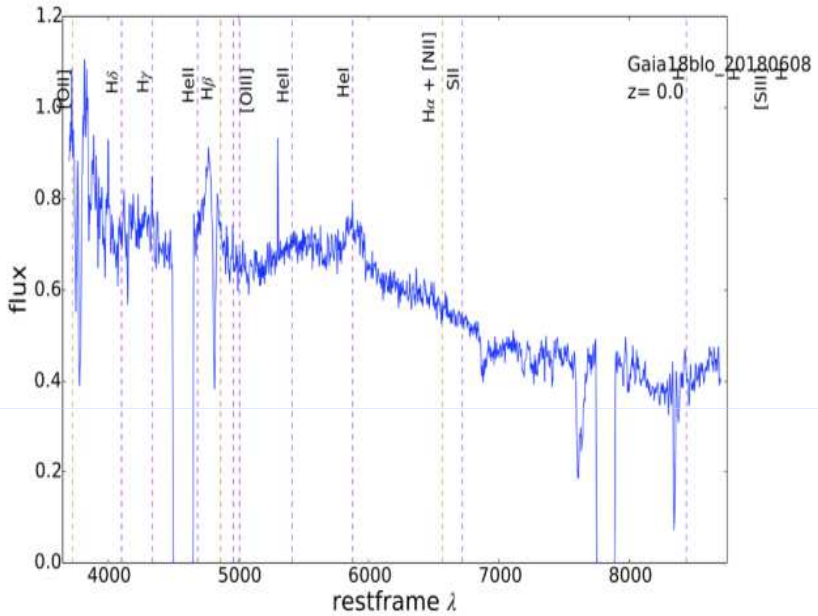
Kruszynska et al. (prep)
Spectra allows for classification and estimation spectro-photometric distance



Microlensing events from Gaia

Gaia18blo

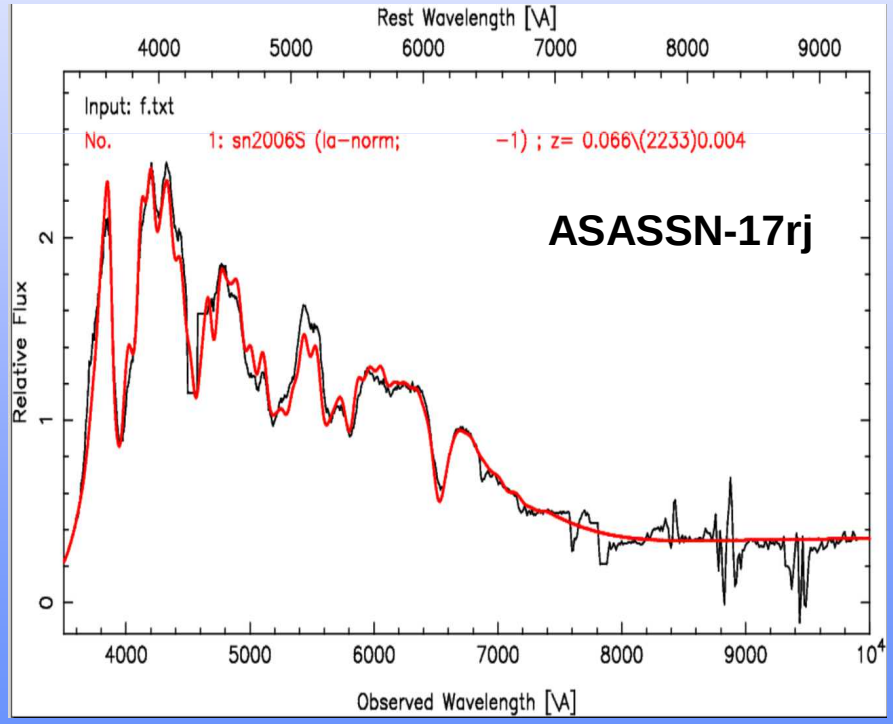


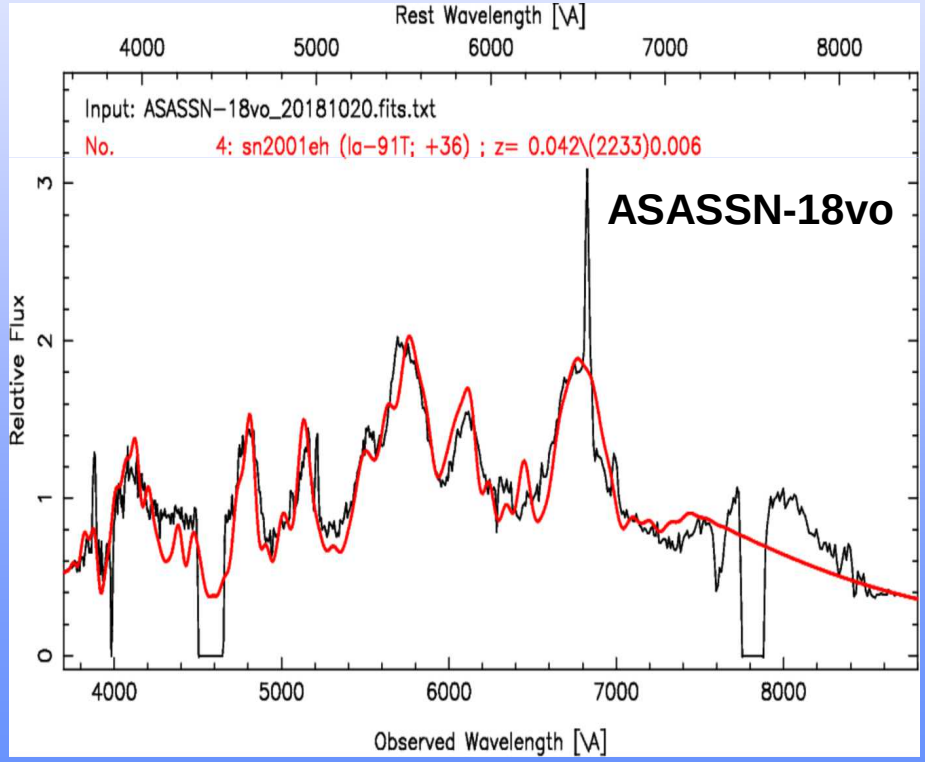


Event first thought to be a microlensing event turned out to be a brightening AGN at z = 2

Supernovae

- **Spectroscopic classifications of few SNe – ASASSN-17pr, ASASSN-17rj, ASASSN-18vo**

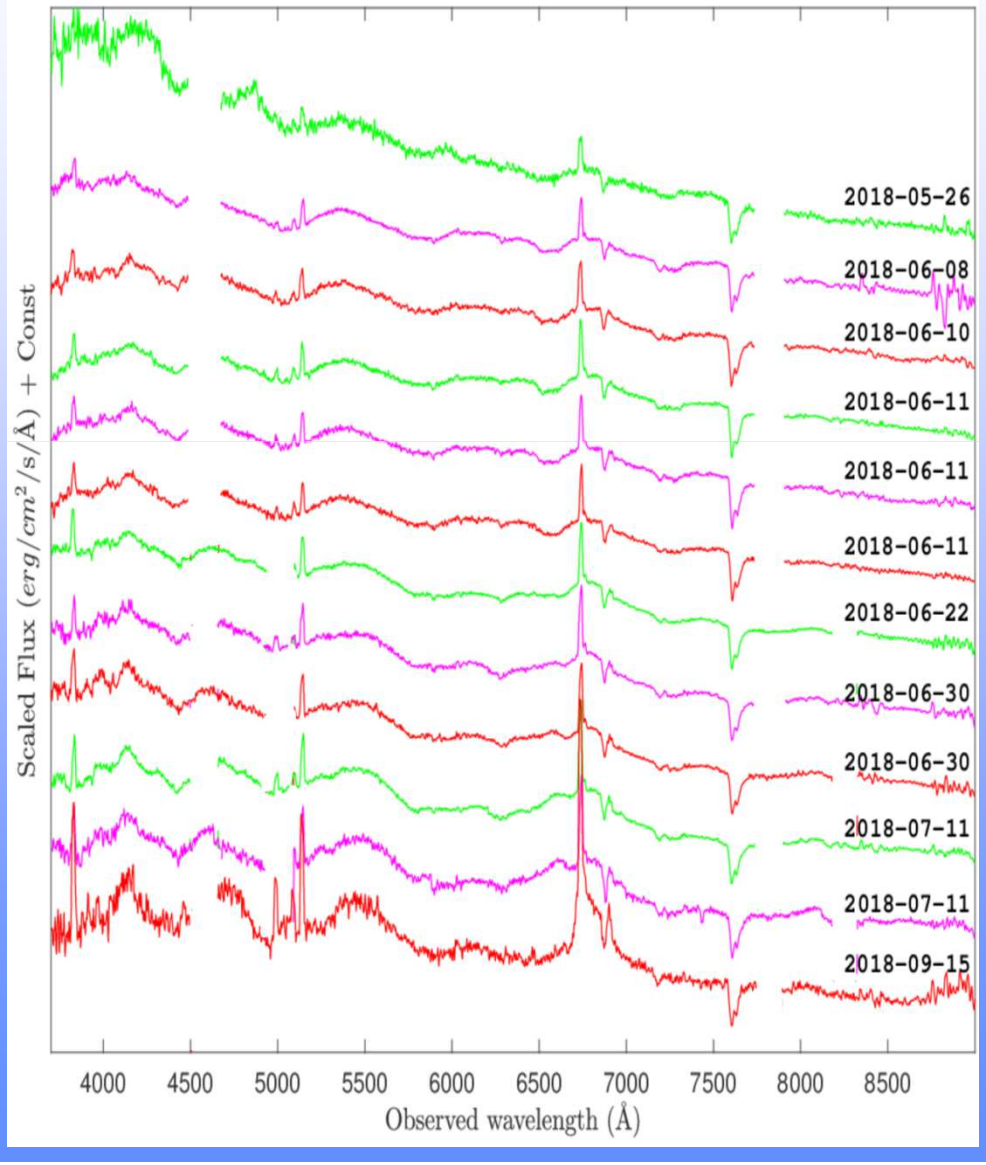




Super-Luminous Supernovae

- 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)

ASASSN-18km

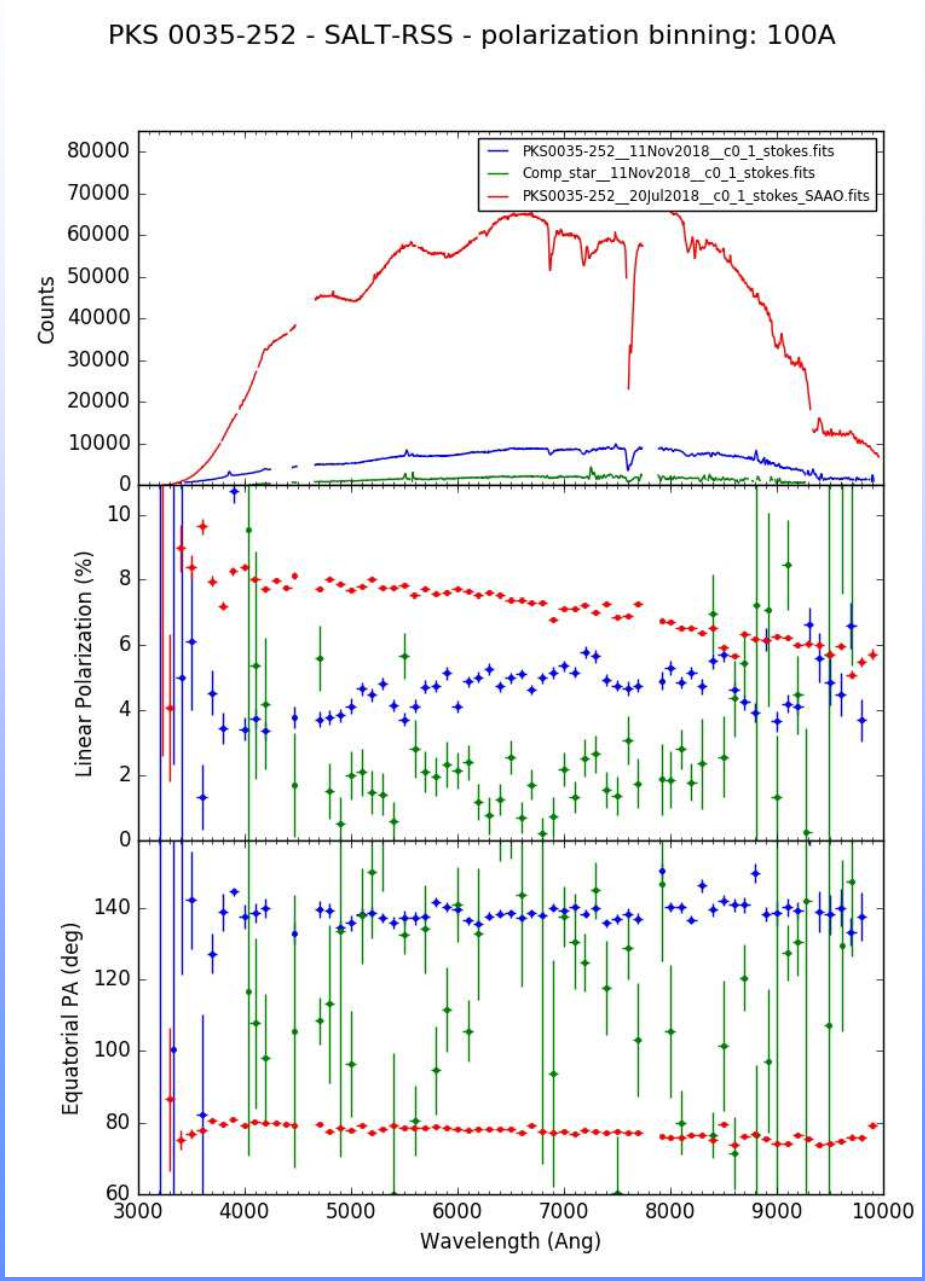


Spectropolarimetry of Flaring Blazars

Program led by UFS and NWU (van Soelen, Britto, Boettcher)

- **Alerts from X-ray satellites (e.g. Fermi LAT)**
-
- **Utilizing spectropolarimetric modes for SALT**

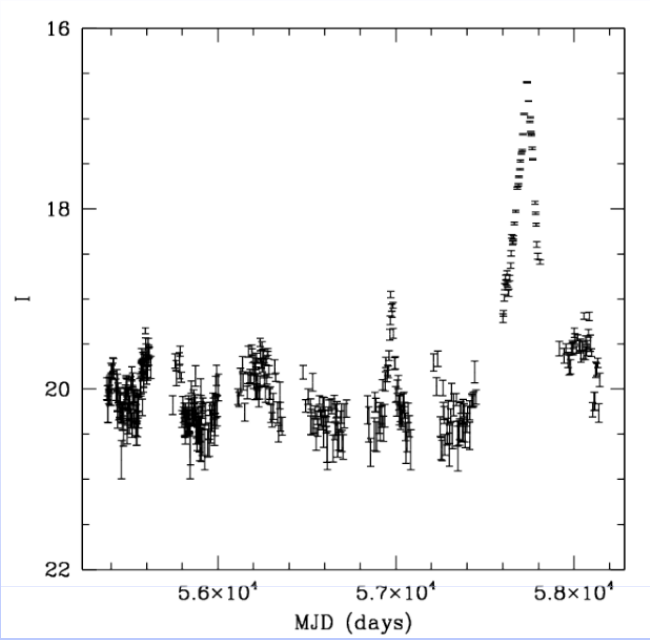
- **Investigate the position angle variations during flares**

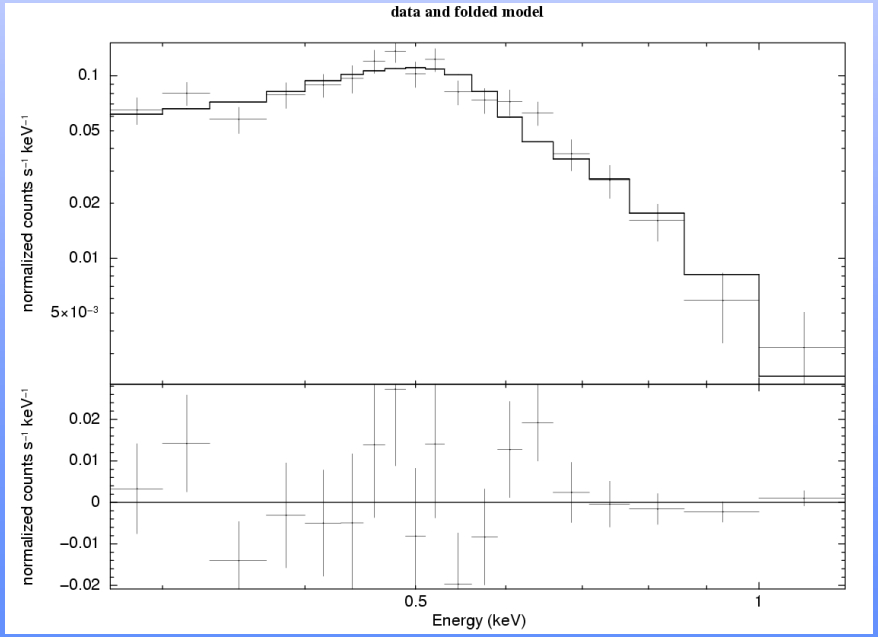


Recent X-ray Transient Result

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

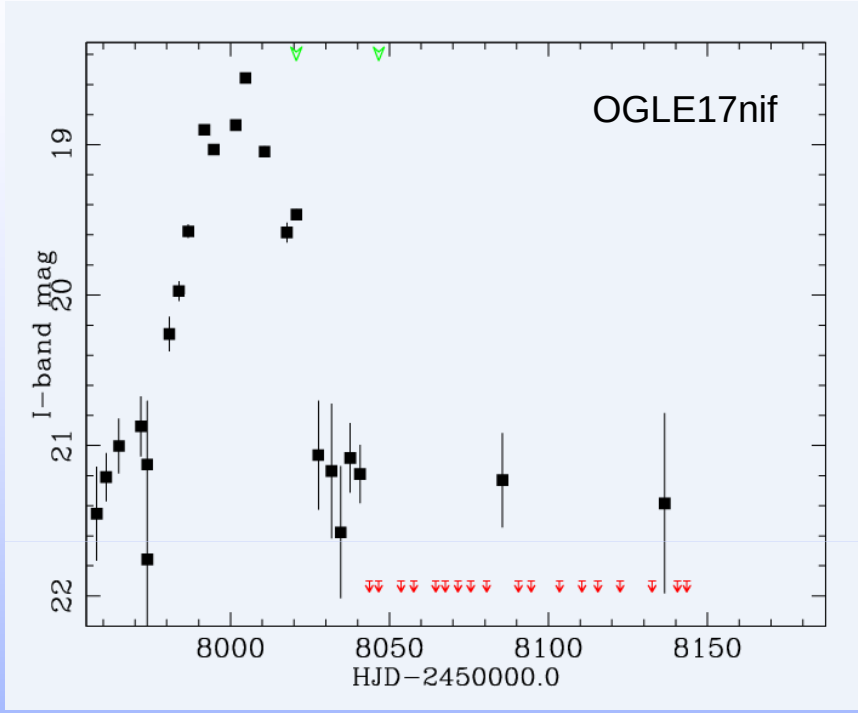


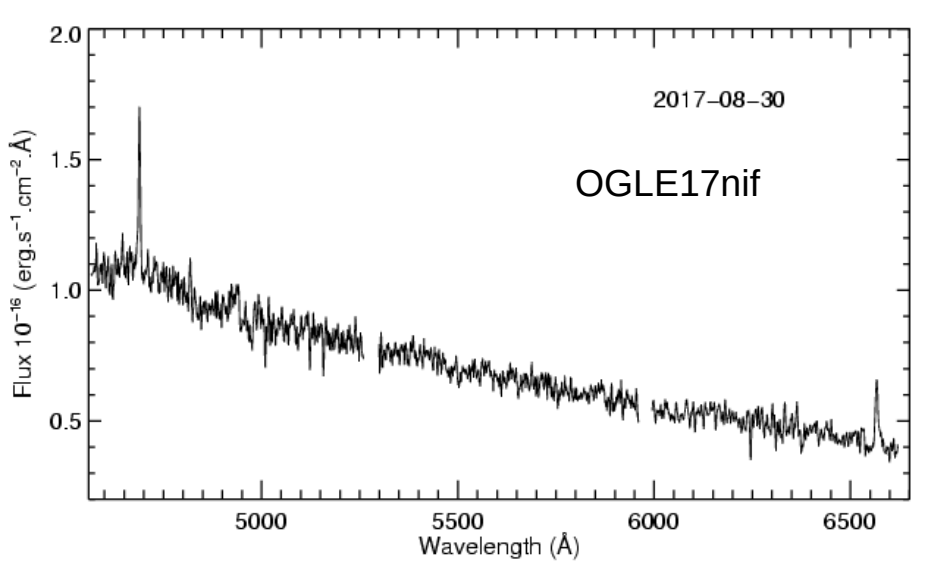


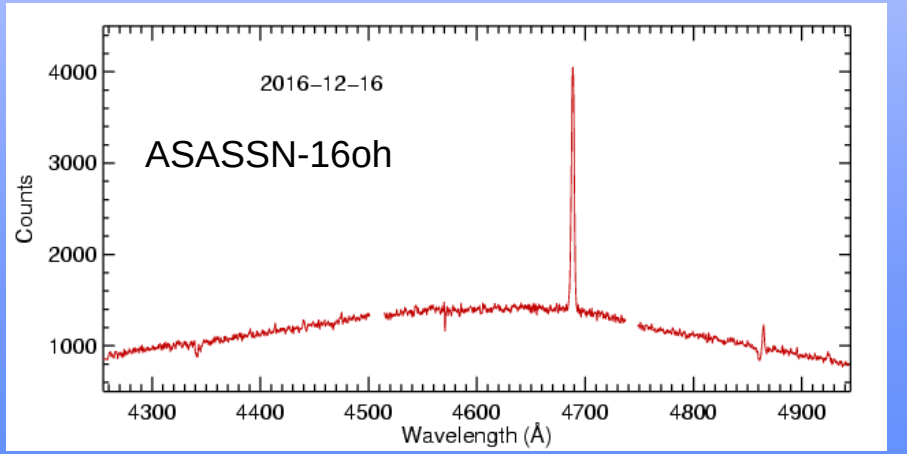
Another Super Soft Source?

New transient OGLE17nif

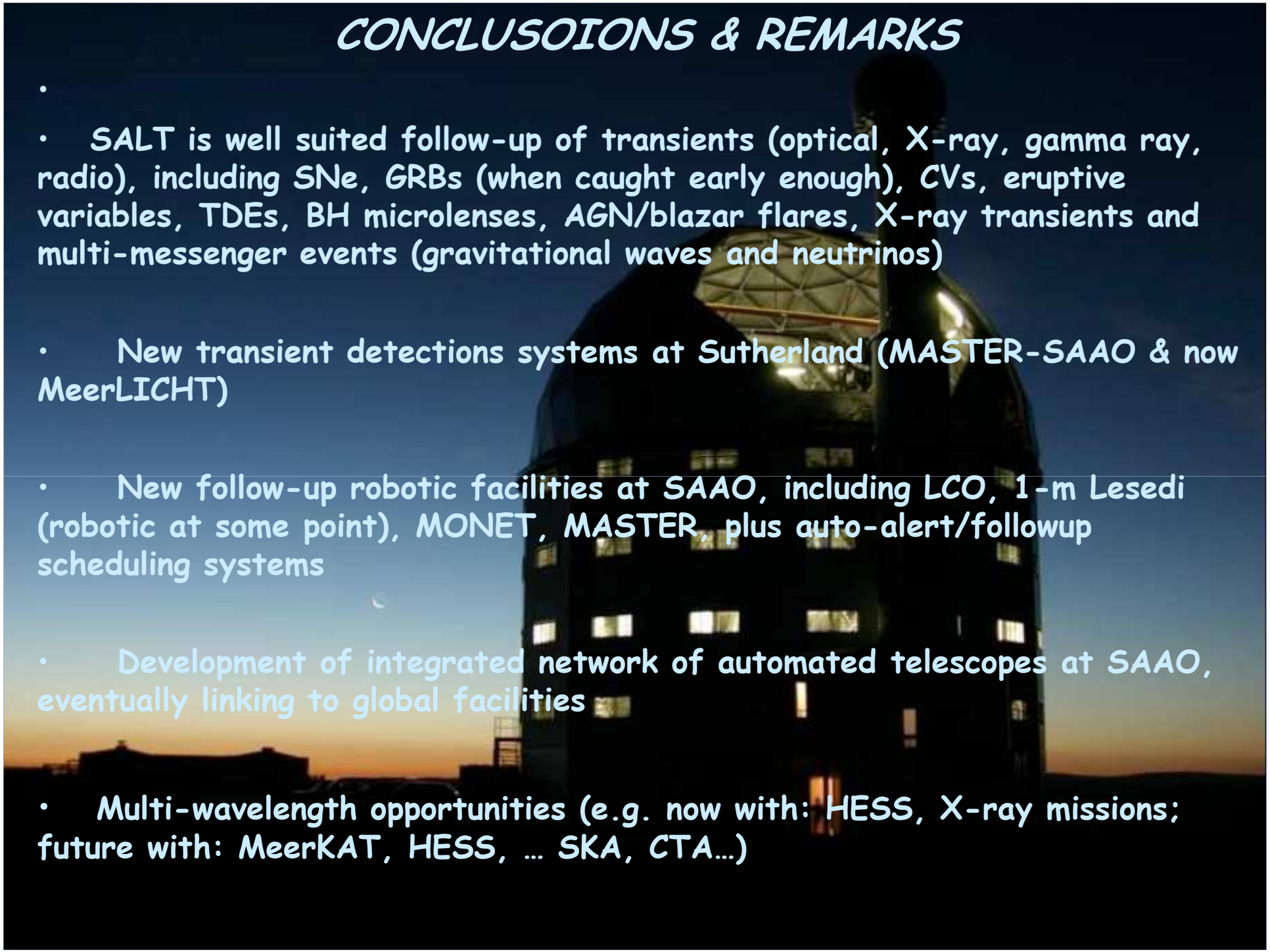
- **Followup SALT RSS spectroscopy**
  - **Strong HeII 4686**
  - **Similar to ASASSN-16oh**
  - **Light curve also show symmetrical slow rise/decay**







CONCLUSOIONS & 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…)