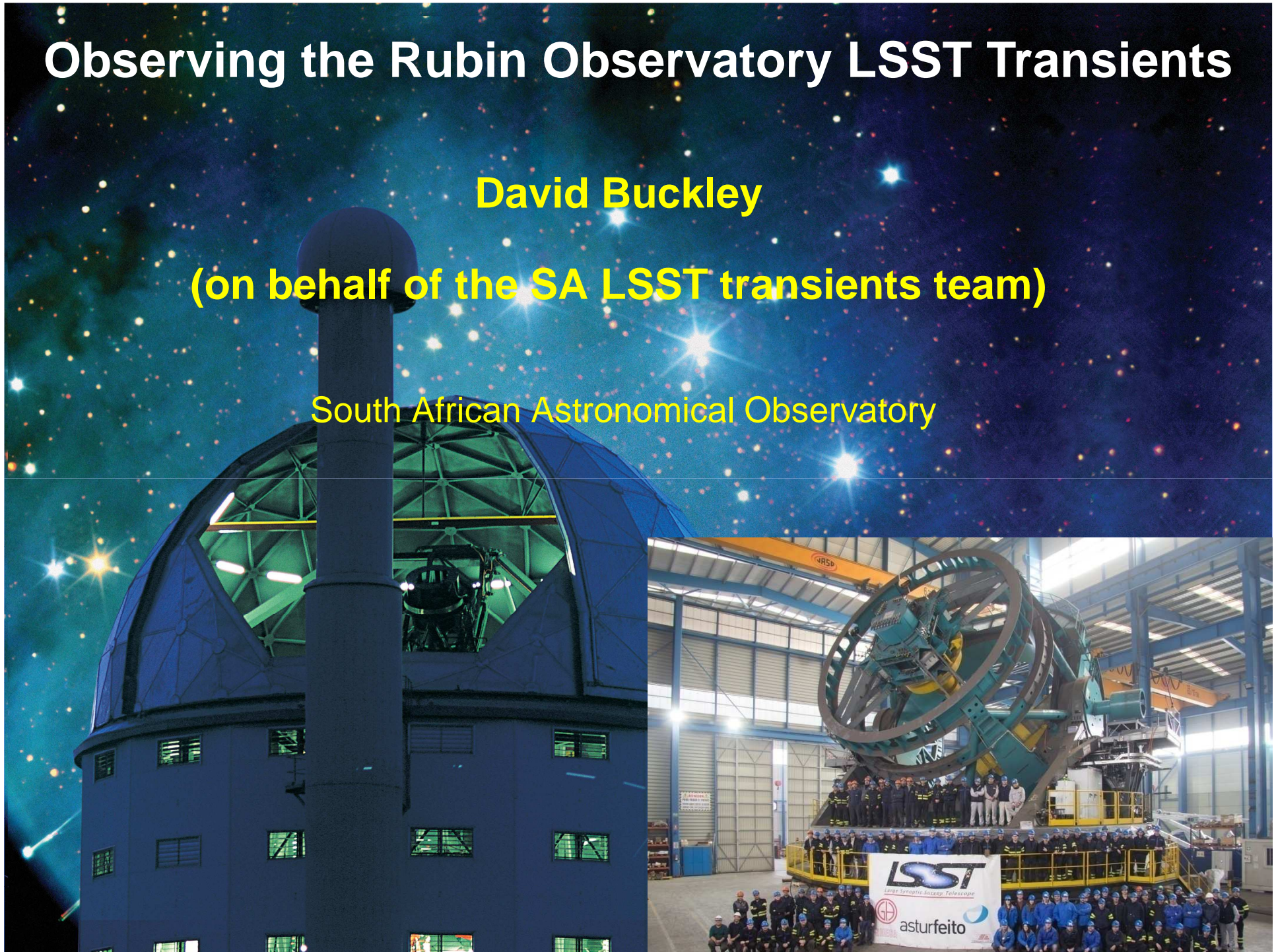


Observing the Rubin Observatory LSST Transients

David Buckley

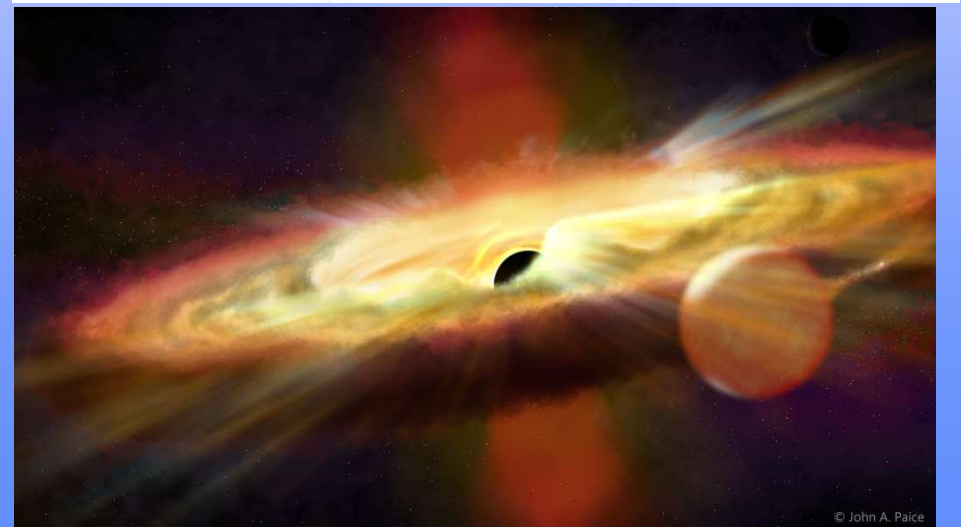
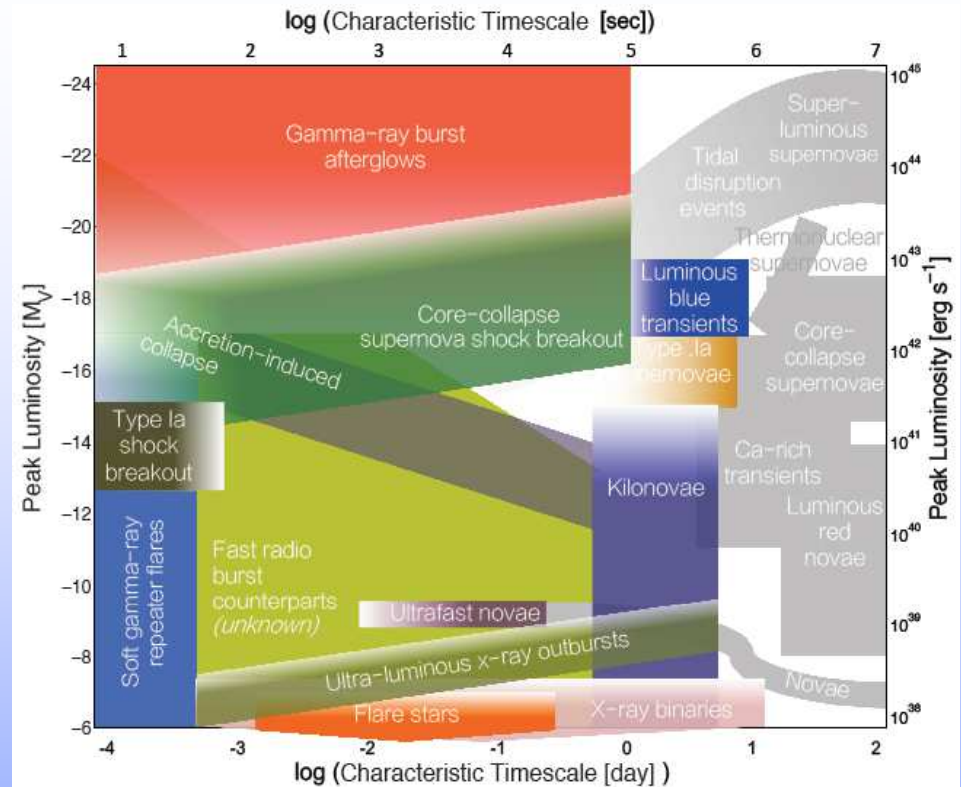
(on behalf of the SA LSST transients team)

South African Astronomical Observatory



Building on existing 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)
 - » From Gaia, OGLE, eROSITA
 - 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)



South African RO-LSST Transient Programme

- One of 3 the current South African programmes which will run initially for 3 years (with expectation of renewal)
- Teams involved will have access to LSST proprietary information (e.g. simulators) and have inputs into the science planning
- Participation in various activities in support of the *Transient & Variable Star* and *Stars, Milky Way and Local Volume* collaborations
- Team of up to 9 individuals of which up to 4 can be students (MSc or PhD)

– PI is DB



– Other astronomers: Patrick Woudt (UCT), Steve Potter (SAAO), Retha Pretorius (SAAO), Enrico Kotze (Postdoc SAAO; to 2020)



– Students: Daniel Egbo (PhD UCT; from 2021) Dante Hewitt (MSc UCT, to 2020), Hanno Marais (PhD UFS)

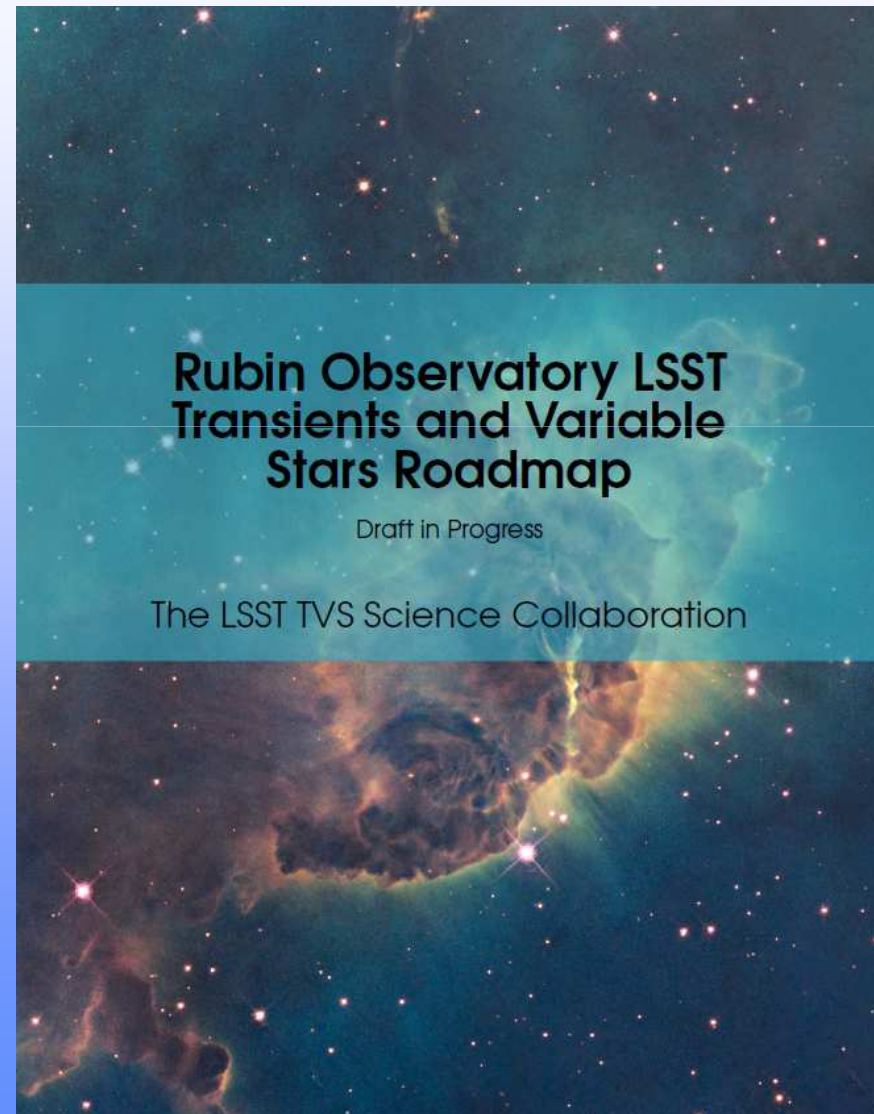
South African LSST Transient Programme

Activities for first ~3 years (prior to survey data):

- **Contribute to SC activities**
- **develop automatic followup systems at SAAO/SALT to react to triggers from LSST observing brokers,**
- **Develop autonomous and intelligent telescope/instrument scheduling systems as part of the SAAO's new "Intelligent Observatory" programme**
- **develop optimal cadencing strategies for Galactic transient from simulations of various compact binaries populations in the Galaxy and Magellanic Clouds,**
- **motivating for various high cadence and deep-drilling programmes, developing and testing simulations and undertaking test observations in support of these,**
- **using data from shallower wide-field transient alert facilities (e.g. MeerLICHT and MASTER) to test automated classification software (e.g. from their light curves) through potential machine learning,**
- **undertaking mini-surveys with facilities like MeerLICHT and KMTNet to test detection algorithms and automated light curve classifications,**
- **Development of in-kind proposal for transient followup with South African optical facilities**

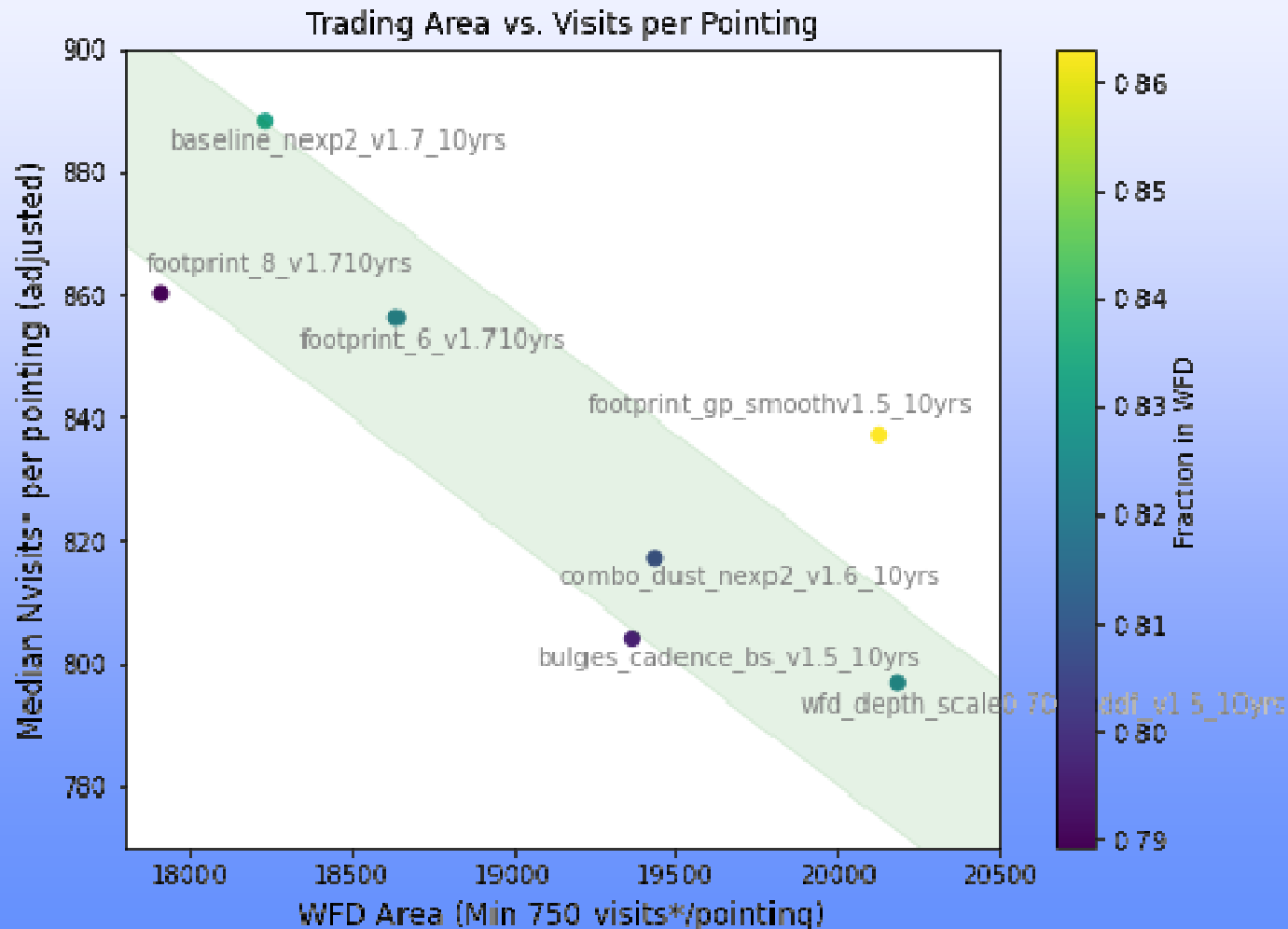
Examples of work done or in progress

- **TVS roadmap: compact binary inputs (2020)**
 - Time critical
 - Non time critical
 - Deep drilling fields
 - Mini-survey



Examples of work done or in progress

- Inputs to Cadence Notes exercise (2021)
- Utilizing latest OpSims (observing simulations) and MAF (metrics analysis framework)



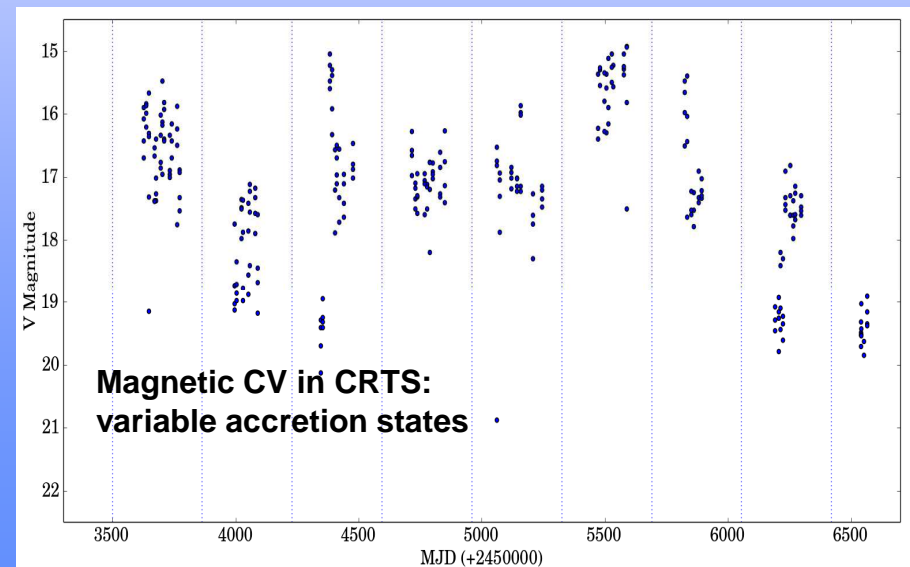
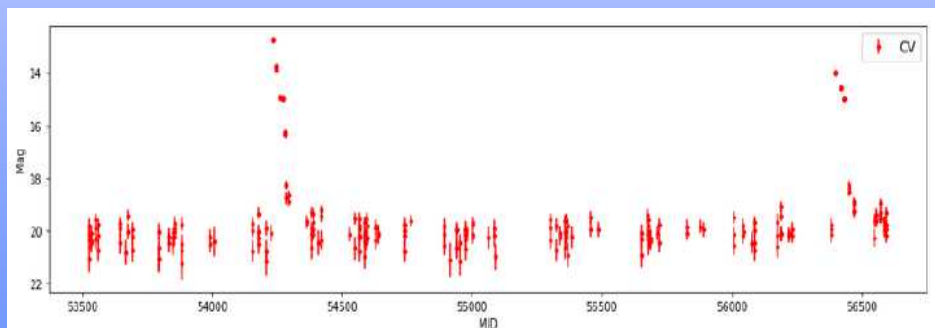
Examples of work done or in progress

LSST Cadence Note for Accreting Binaries

David Buckley, JP Marais, Stephen Potter, Retha Pretorius, Mokhine Motsoaledi; SAAO
Paula Szkody, U of Washington
Peshak Gandhi, U of Southampton

April 16, 2021

- **Inputs are actual light curves (e.g. Catalina Real Time Survey)**
- **Metrics include:**
 - **chance of discovery (amplitude/colour/ timescale)**
 - **early (first year(s) vs. later (1/2 way through WDF survey) discovery & classification**
 - **ability to determine periods (orbital, super-orbital, other)**
 - **ability to detect short periods (AM CVns)**
 - **ability to find objects in the plane**

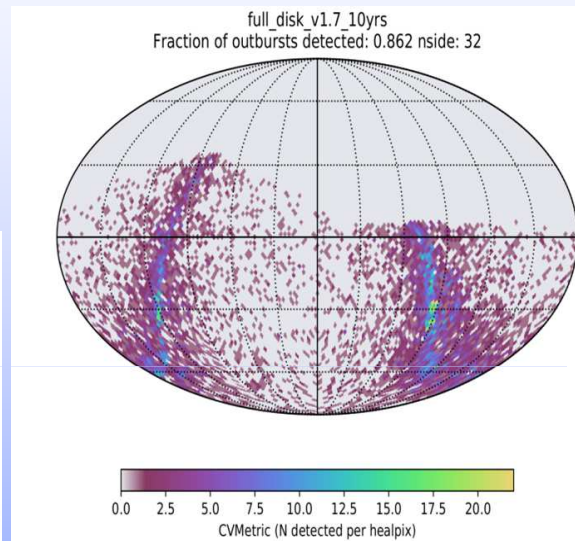
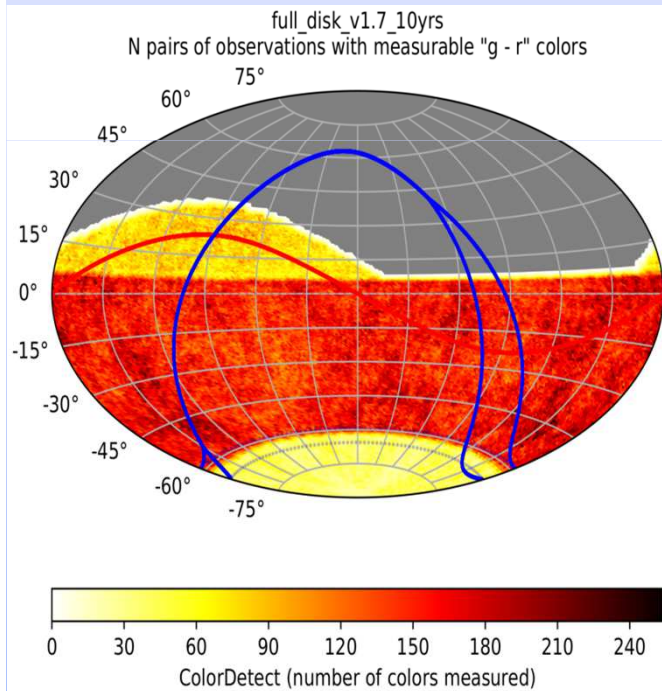


LSST Cadence Note 2021 Simulations

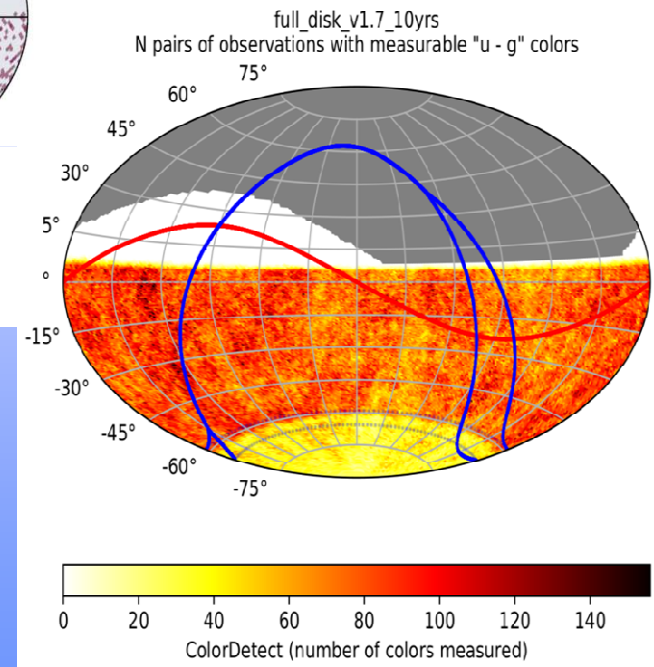
MAF Simulations For Cataclysmic Variables (Hanno Marais)

- 10 K simulated outbursts
- $2 < \Delta m_g < 8$
- Decay time 1 week – 1 month
- ~86% detection

Evenly distributed observations over deeper observations preferred



**Blue colours (g-r)
preferred for
galactic outbursts**



A population study will require increased observations in the galactic plane over that proposed with WFD.

Machine Learning

PhD topic of Hanno Marais (UFS, expected completion in 2022)

Goals

- Use neural networks to classify (ANN) and detect anomalies (AutoEncoder) in transient lightcurves
- Detect new transient types and anomalies within 7 days of first detection
- Predict future flux for existing classes in order to more accurately detect deviations

Method

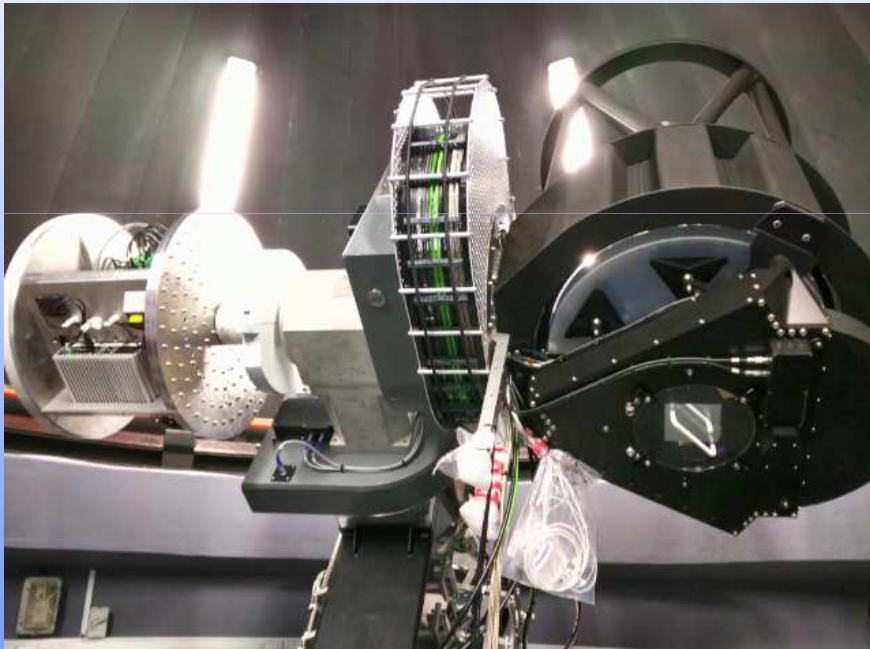
- Use PLAsTiCC (simulation) transient model (Supernova, AGN etc)
- Using the updated LSST cadences (OpSim 1.7)
- Look at the effects of different cadence families
- Simulate observations
- Use real data examples (e.g. ZTF & MeerLICHT)

Progress

- 75 - 80% accuracy on common network types
- 85 - 95 % Using AutoEncoder features to enhance classification accuracy
- AutoEncoder able to distinguish between known class anomalies and novel unseen classes

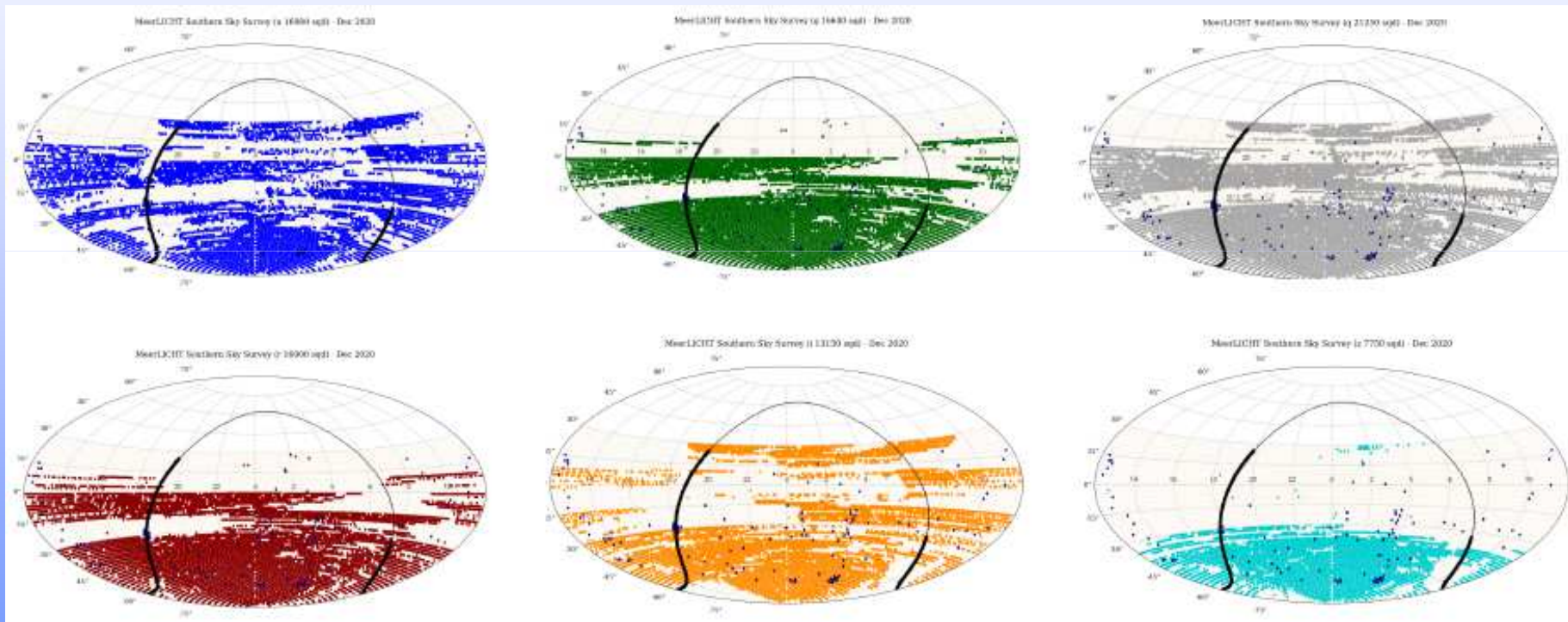
SAAO's wide field facilities & synergies

- **Use to test LSST software systems**
 - Pilot programmes for transient detection/followup (e.g. for mini-surveys)
 - e.g. MeerLICHT high cadence survey of Magellanic Clouds
 - » Patrick Woudt leading this



MeerLICHT Survey

- Multi-filter survey (*u,g,r,i,z, broad*)
- Synergy with KMTNet KS4 survey (*U,B,V,R,I*)

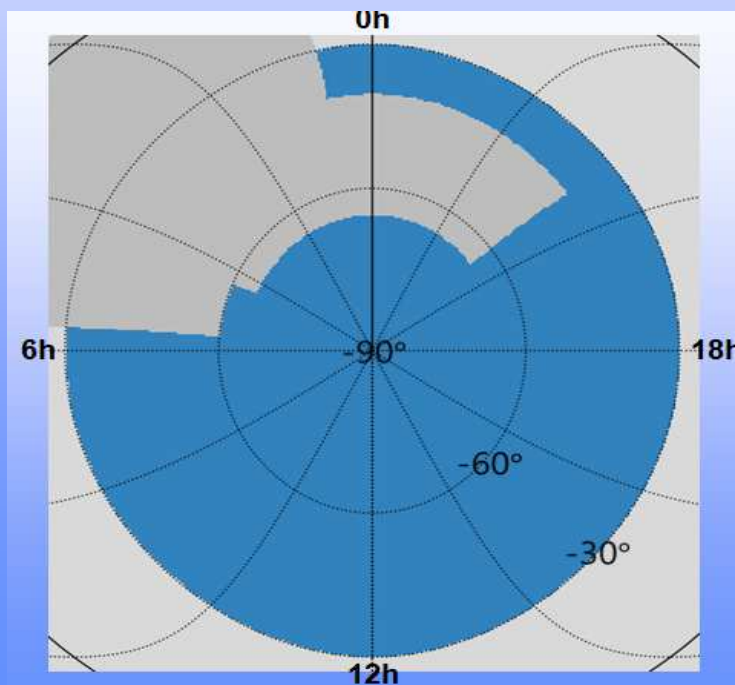
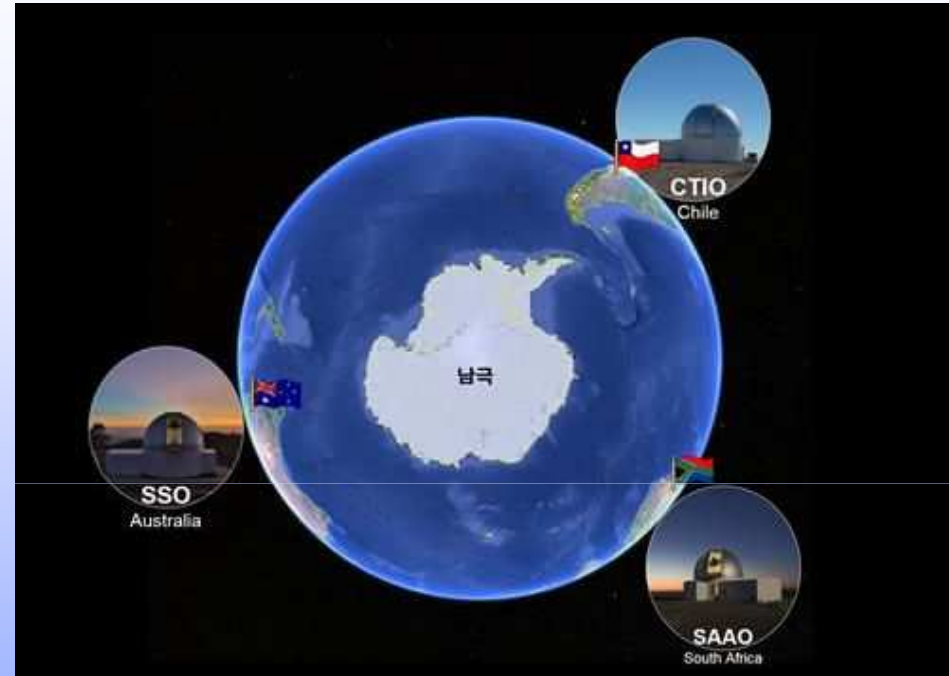


SAAO's wide field facilities & synergies

KMTNet Southern Synoptic Sky Survey (KS4)

(David Buckley, Co-I)

- Three 1.6m telescopes on three sites
 - Australia, Chile, South Africa
- Large field of view
 - 2 deg x 2 deg
- BVRI filters

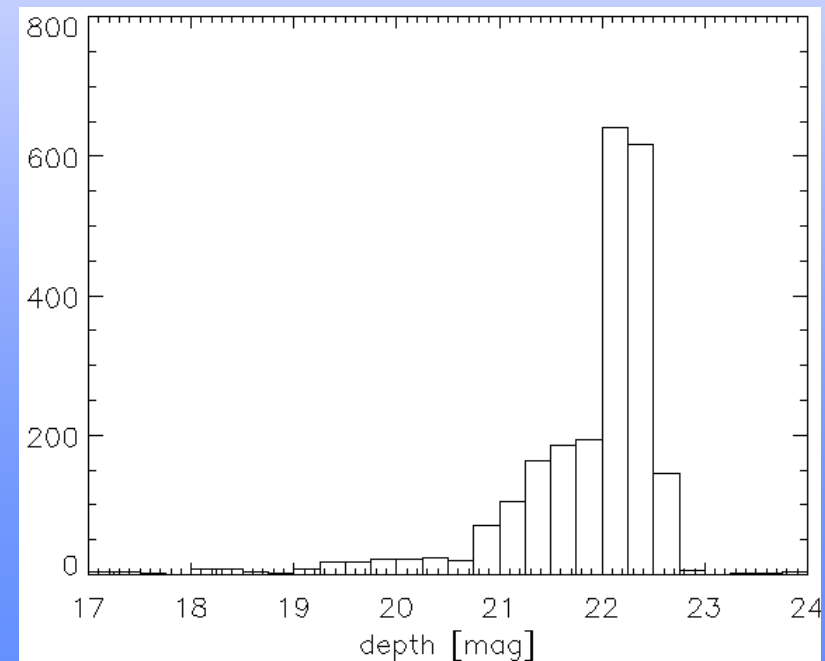
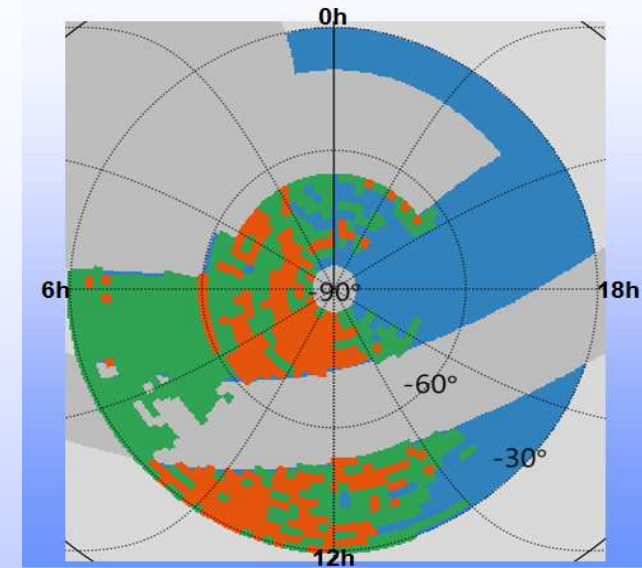


- 7000 deg^2
 - Dec < -30
 - No DES and VSTATLAS
 - Higher l > 10
- ~ 2023 Sep.
- BVRI filters
- 23 mag depth
- 2 arcsec seeing

SAAO's wide field facilities & synergies

KMTNet Southern Sky Survey (KS4) status

- **Coverage**
 - 2019 Oct. ~ 2021 Jun.
- **Blue field**
 - No data yet
- **Orange field**
 - Survey finished
 - BVRI & 4 dither
- **Green field**
 - Need more data
 - < 4 filter or < 4 dither
- **42 % completeness**



Expected wider KS4 results

- **Identification of GW EM counterparts**
 - ~6 events per year
- **High-z quasars**
 - 1? at $z=8$, ~3 at $z=7$, ~30 at $z=6$, +more
 - With IR surveys (VHS, WISE, SPHEREx, Euclid)
- **Galaxy clusters**
 - ~17,000 at $z > \sim 1$
 - With X-ray (eROSITA), IR surveys
- **Magellanic stream, satellite galaxies, our galaxy, solar system, ...**
- **Public release for astronomical community**
 - 1 – 2 years? after observation (2022?~)

Automated Transient Followup SAAO Intelligent Observatory (Steve Potter leading this)

Make the whole Sutherland site an integrated intelligent machine for transient followup

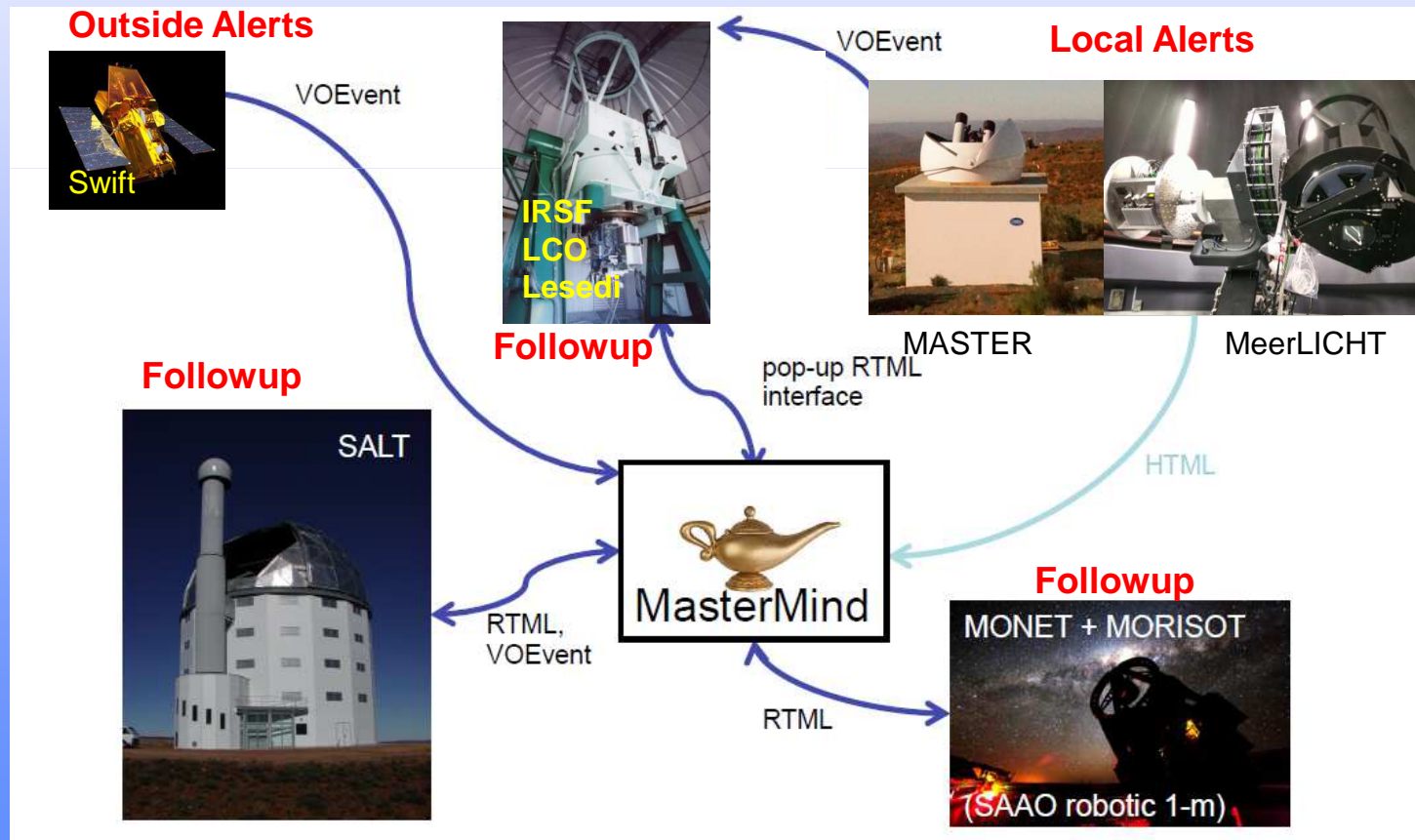
This work began as an SAAO project in 2020

- resources being provided to allow development of SW scheduling tools in collaboration with other groups (e.g. LCO)
- part of South Africa's in-kind contribution
- includes SALT & other SAAO telescopes (including hosted facilities)



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)



Future Potential Synergies



“BRICS Intelligent Telescope and Data Network”

- **Adopted at Rio meeting of BRICS Astronomy Working Group (Oct 2019)**
- **Merger of the two top-ranked flagship proposals, which have natural synergy:**
 - **Transients (David Buckley)**
 - **Big Data (Russ Taylor, IDIA/UWC/UCT)**
- **Targeting transient, time domain & survey science (LSST & SKA) with Big Data/Compute**
- **Funding provided in 2020 by DSI to begin (including for SW systems for transient followup)**

Fin

