

# Rubin Observatory LSSTによる 激変星の発見と追観測

反保 雄介

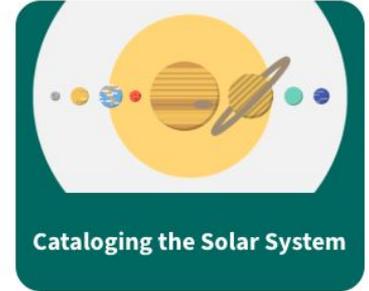
South African Astronomical Observatory /University of Cape Town  
*yusuke@sao.ac.za*

D. Buckley (SAAO), P. Szkody (U. Washington)  
S. Scaringi (Durham U.), M. Motsoaledi (UCT)  
LSST compact binaries WG

Buckley&Tampo et. al. 2025 ApJS – arXiv:2509.07298



# Rubin Observatory LSST & Simonyi tel.



8.4-m telescope@Cerro Pachón  
3.2G pixel CCD  
9.6 deg<sup>2</sup> or 45 full moons  
10M alerts every night  
20TB each night / 60PB in 10 yr  
g~24.0 mag in single visit  
g~27.0 mag in 10 yr

# LSST Timeline

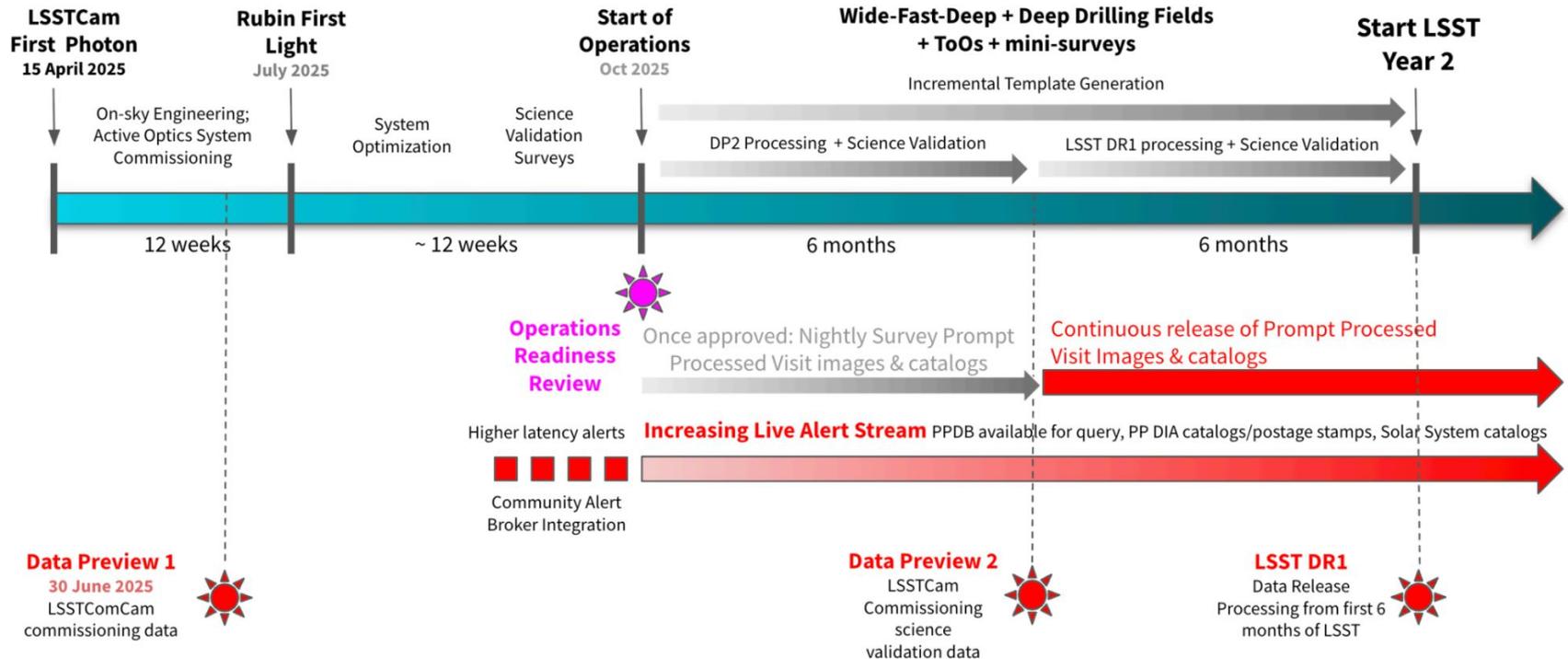
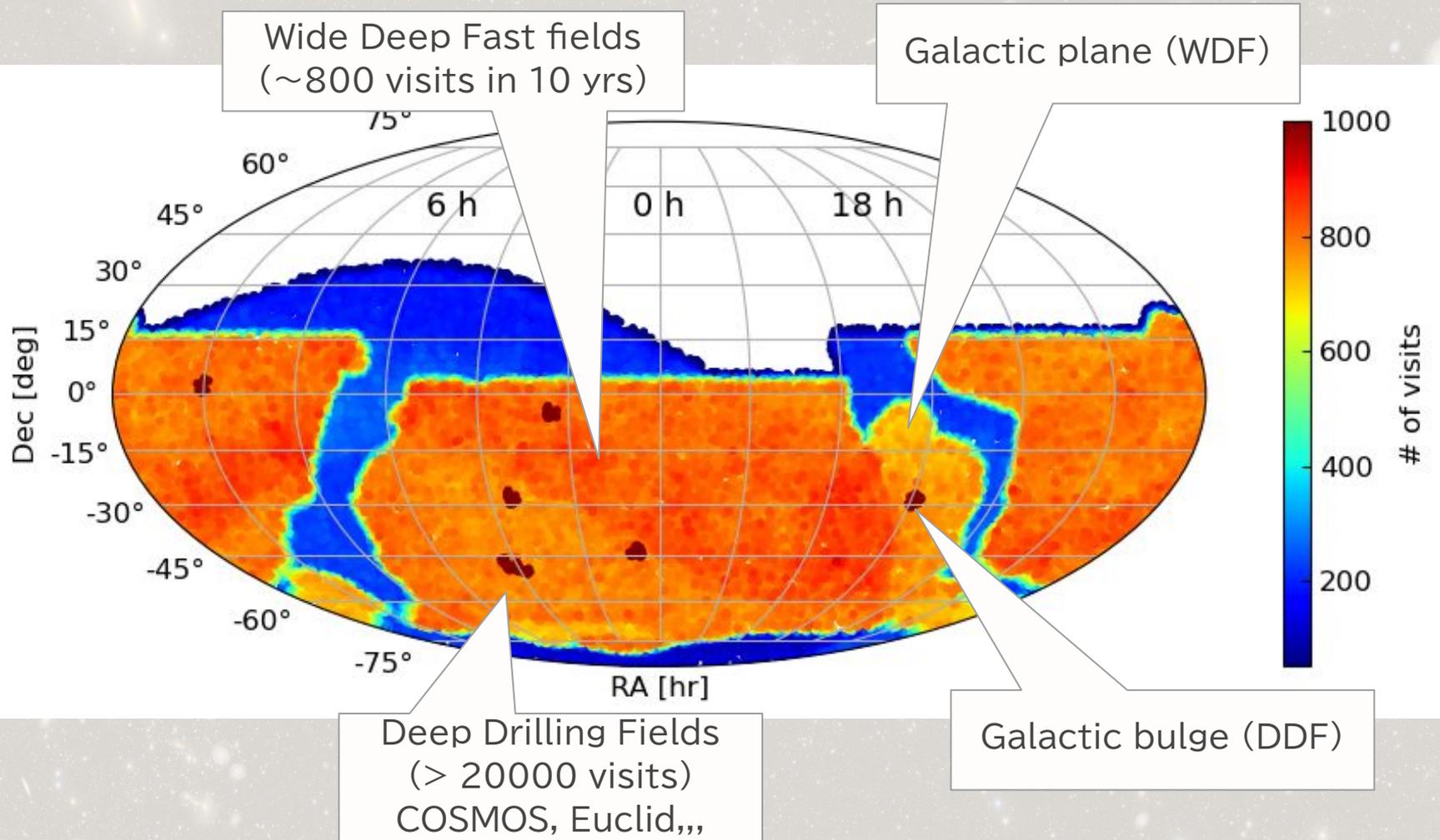
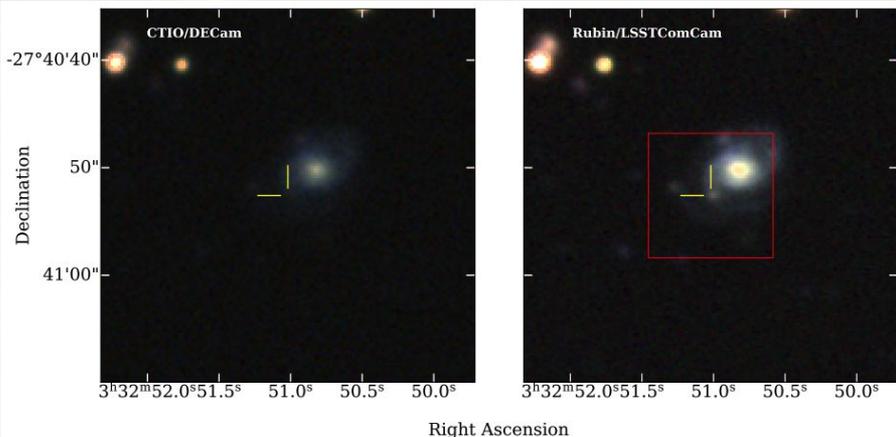


Figure 1: Detailed schedule of commissioning and early science activities relative to Rubin First Light, as of May 2025.

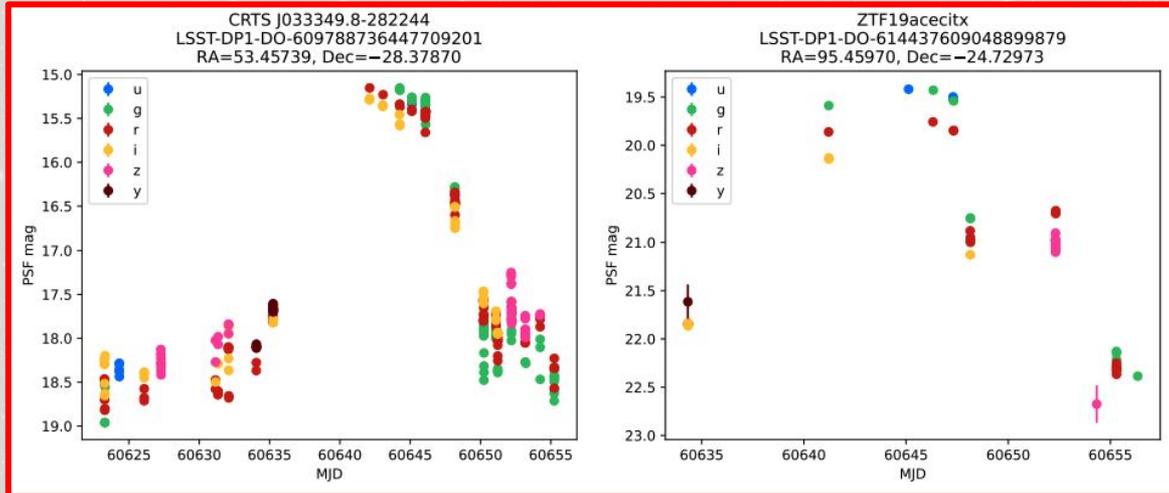
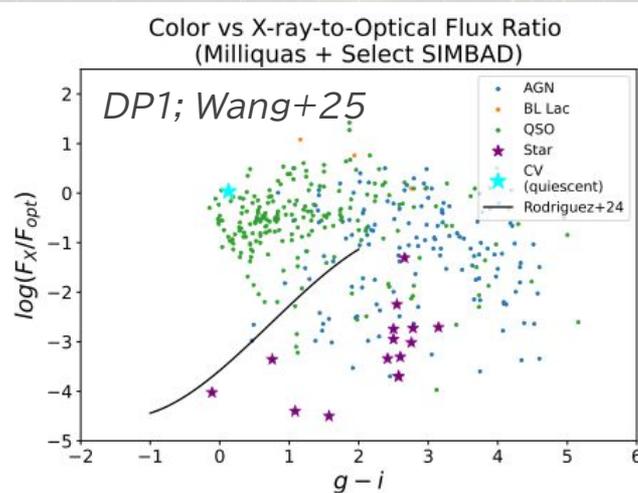
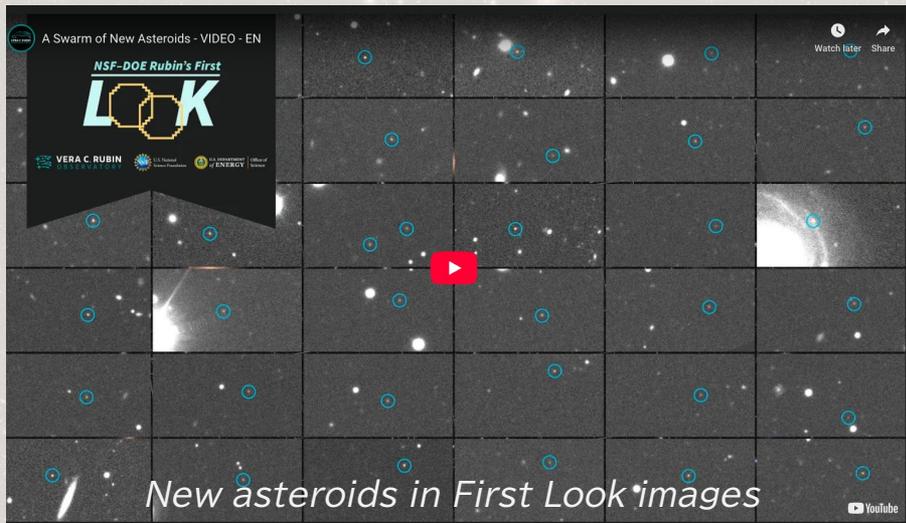
# LSST footprints - on sky



# LSST DP1 / First look high lights



↑ SN from LSST DP1; *Freeburn+25*



↑ CVs from LSST DP1; *Malanchev+25*

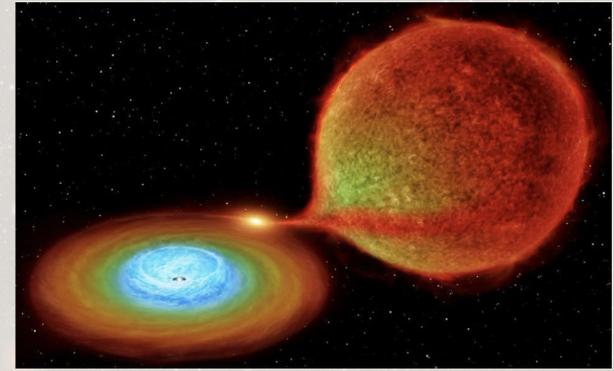
# Cataclysmic variables with various scales

Close binary of white dwarf + secondary

- accretion disk around non-magnetic WD
- accretion column onto magnetic WD

The largest population of Galactic variables (in CRTS)

	<i>Amplitude</i>	<i>Timescale</i>
Classical nova	7 – 15 mag	weeks – years
Dwarf nova	2–9 mag	weeks
High/low states	1–5 mag	days – decades
Micronovae	1–3 mag	hours
Orbital	0 – 1 mag	hours – days
WD spin	0.01 – 1 mag	minutes – hours
QPOs / flickering	0.01 – 0.5 mag	seconds – minutes



*To identify dormant CVs in ZTF  
See e.g. van Roestel+22  
Galiullin+24*

## Remaining questions on cataclysmic variables

- **Count the accurate number of CVs in our galaxy**
  - discrepancy in volume density b/w models vs observations – *Pala+20*
  - inactive and faint CV populations – *Muñoz-Giraldo+24, Inight+25*
  - CV subtypes(s) to be a progenitor of SNe Ia
- **Understand background physics in CVs**
  - disk & binary model in different metallicity / age – *Belloni+16*
  - behaviour/evolution in deep quiescence/low-state – *YT+20*
- **And any new exciting (non-)accreting WD systems?**

**WHAT will be the discovery  
space of CVs in LSST?**

**→ Mock observation simulation w/ LSST  
(NOT how to identify/classify)**

# Simulator – Opsim environment

## rubin\_sim

Scheduler, survey strategy analysis, and other simulation tools for Rubin Observatory.

pypi v2.3.0 conda-forge v2.3.0

Run CI passing Build and Upload Docs passing codecov 58%

DOI 10.5281/zenodo.17081503

## rubin\_sim

The [Legacy Survey of Space and Time](#) (LSST) is anticipated to encompass around 2 a decade, averaging 800 visits per night. The `rubin_sim` package was built to help performance of the LSST.

The `rubin_sim` package contains the following main modules:

- `phot_utils` - provides synthetic photometry using provided throughput curves performance.
- `skybrightness` incorporates the ESO sky model, modified to match measured site, including an addition of a model for twilight skybrightness. This is used to skybrightness data used in [rubin\\_scheduler.skybrightness\\_pre](#).
- `moving_objects` provides a way to generate synthetic observations of moving would appear in pointing databases ("opsims") created by [rubin\\_scheduler](#).
- `maf` the Metrics Analysis Framework, enabling efficient and scientifically varied strategy and progress by providing a framework to enable these metrics to run in opsim outputs.

More documentation for `rubin_sim` is available at <https://rubin-sim.lsst.io>, including

*Delgado+14,16, Reuter+16*  
[https://github.com/lsst/rubin\\_sim](https://github.com/lsst/rubin_sim)

AGN_N_qsos.ipynb	agn notebooks	3 years ago
AGN_structurefunction.ipynb	agn notebooks	3 years ago
AGN_time_lags.ipynb	agn time lags	3 years ago
Bulge Distances.ipynb	Update to v3.4	last year
Demo_for_SSO.ipynb	updating notebooks to v1.0	3 years ago
FilterPairsMetric.ipynb	Update to v3.4	last year
GalacticPlaneMetrics.ipynb	updating notebooks to v1.0	3 years ago
GalacticPlaneMetrics__oo.ipynb	Update to v3.4	last year
KNeMetric.ipynb	updating notebooks to v1.0	3 years ago
Local_Volume_Dwarfs_Metric.ipynb	maf notebooks	3 years ago
Microlensing Metric.ipynb	maf notebooks	3 years ago

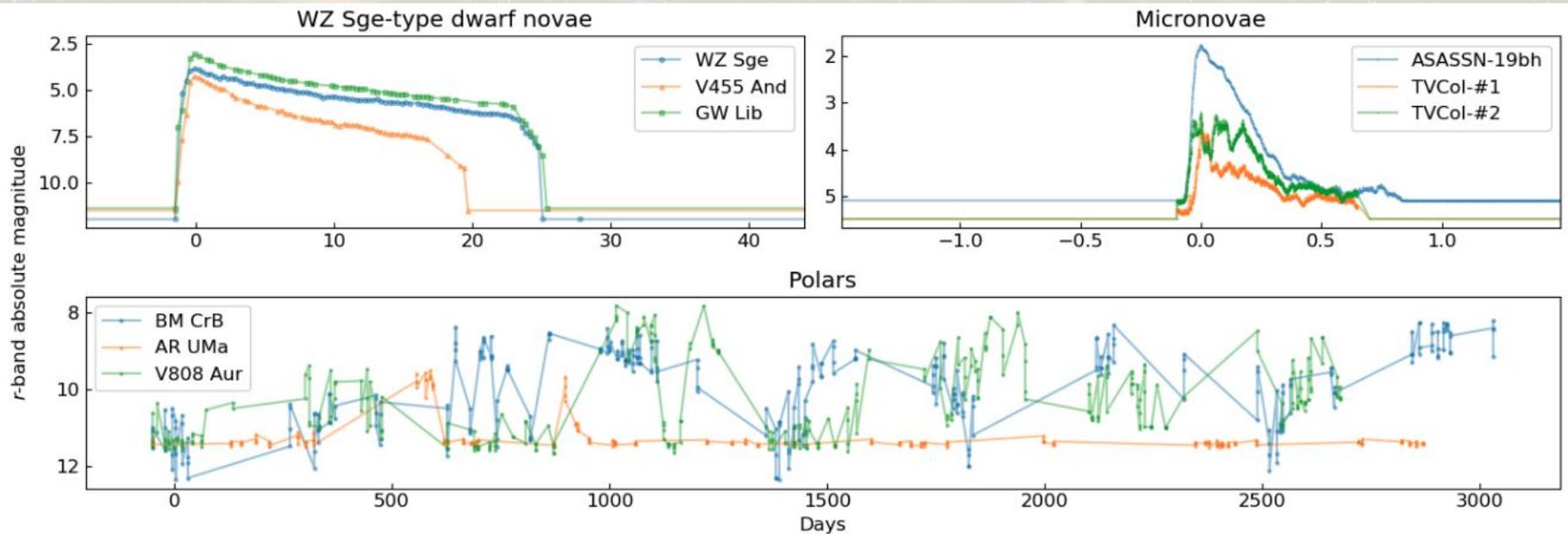
# Simulation samples – cover various timescales and brightness

## Dwarf nova outbursts of non-magnetic CVs

- especially WZ Sge-type = most energetic disk outburst.
- 7–9 mag / 20–30 d / > 10 yr recurrence time

Polars in magnetic CVs – erratic state changes. 2–4 mag

Micronova eruptions – fast localized thermonuclear burst(?). 1–3 mag / < 1 d



## Input distributions

On-sky positions following Pretorius+07

- **smooth Galactic thin disk**, w/o thick disk, bulge, arms, clusters, halos
- vertical scale height: 260 pc (120 pc for MNe)
- radial scale height: 3 kpc
- Sun / Earth at (7620, 0, 0) pc
- 3D extinction in Opsim

$$\rho(z) \propto \exp -|z|/H_z$$

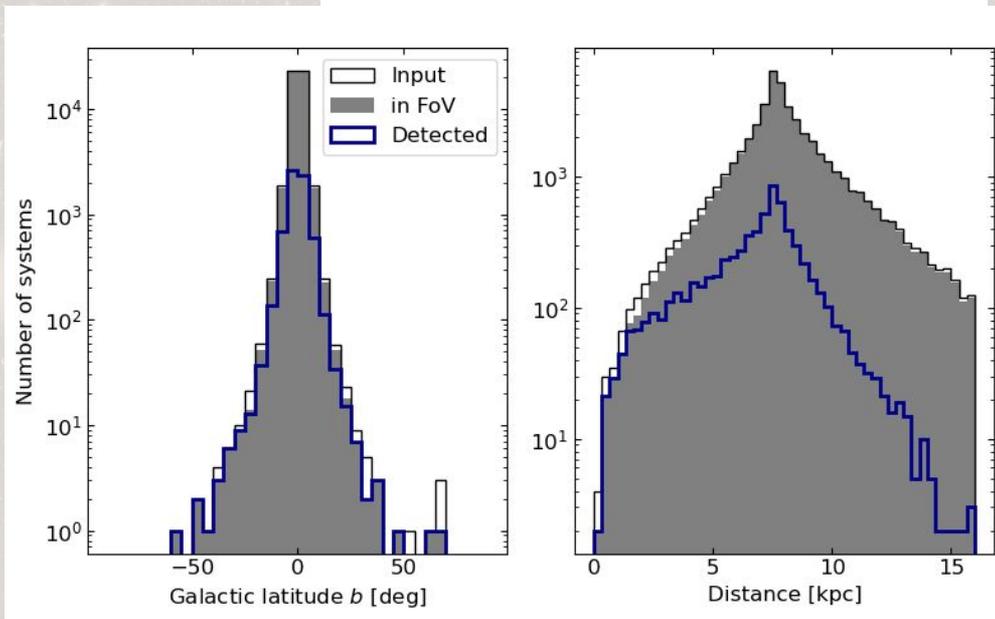
$$\rho(r) \propto \exp -r/H_r$$

Outburst in first two years of LSST

Baseline file v4.3.1 (latest)

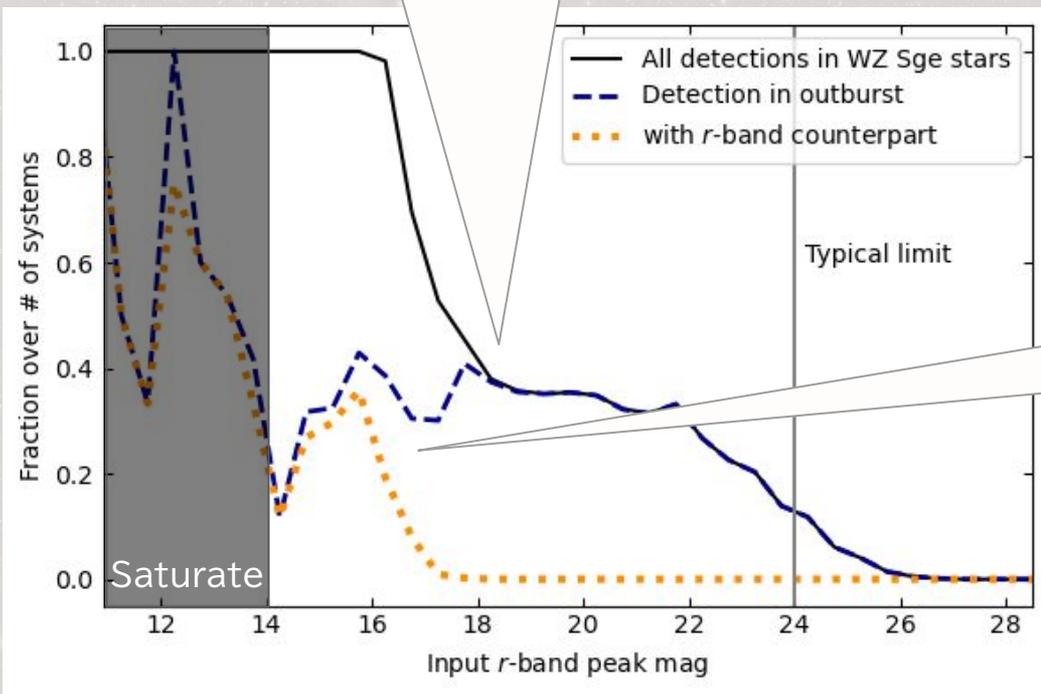
- cadence
- depth
- weather factor
- simulated ToO

20000 light curves in each class



# WZ Sge-type dwarf novae – I

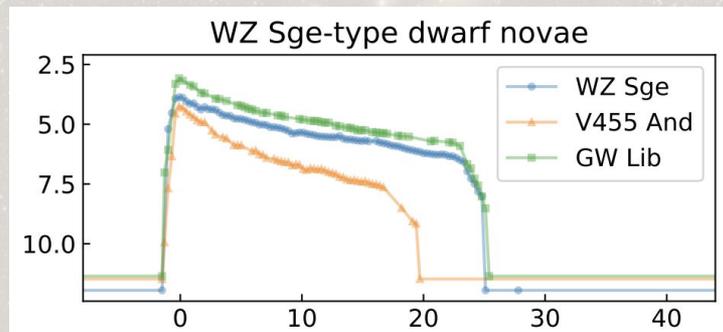
~40% of outbursts detected  
 – purely due to LSST cadence



\*\*\*Note small number of nearby systems in simulation

	#
Simulated	20000
In LSST FoV	19419
<b>Detection</b>	<b>4014</b>
<b>Detection in outburst</b>	<b>3917</b>
<b>With counterpart</b>	<b>43</b>

Counterpart up to 17 mag  
 – outburst amplitude  
 → classification



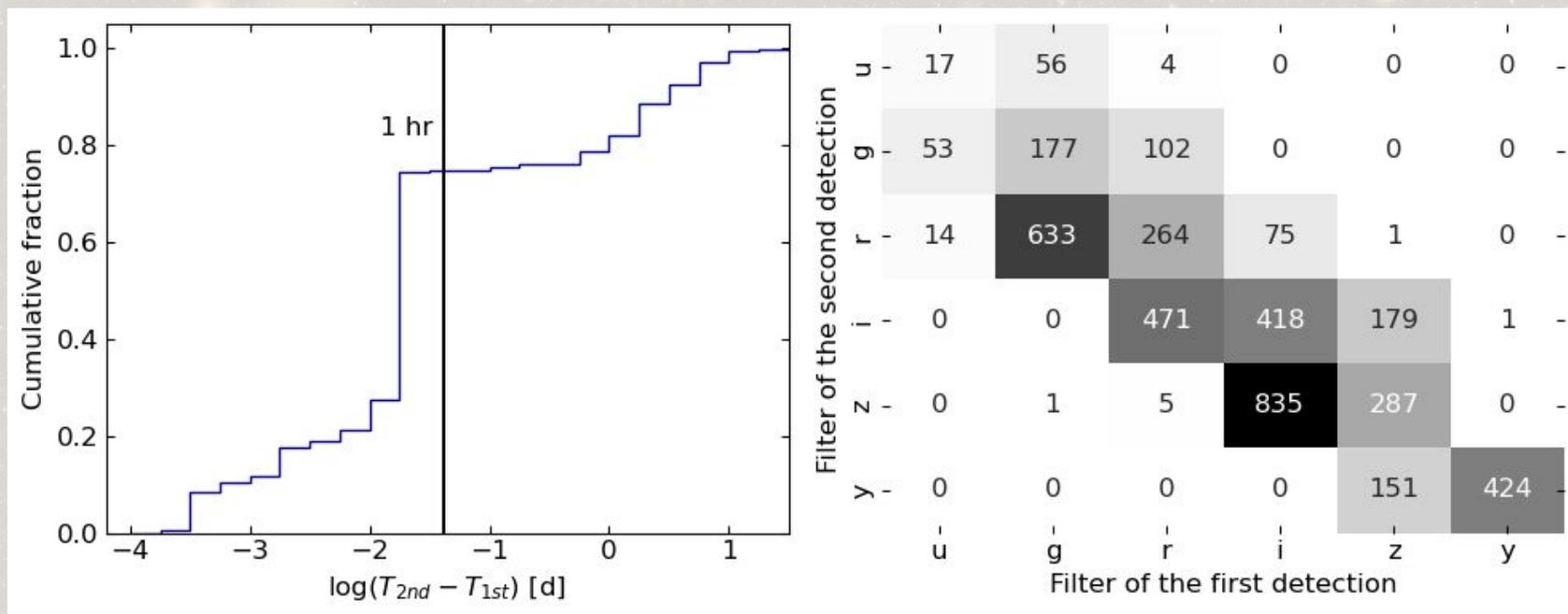
## WZ Sge-type dwarf novae – II

### Second detection of ~80% outbursts within 1 hour

- affordable in events with timescales of a few days or longer
- exclude bogus events / moving objects

~65% in different bands (e.g. g+r, r+i, i+z)

- color information



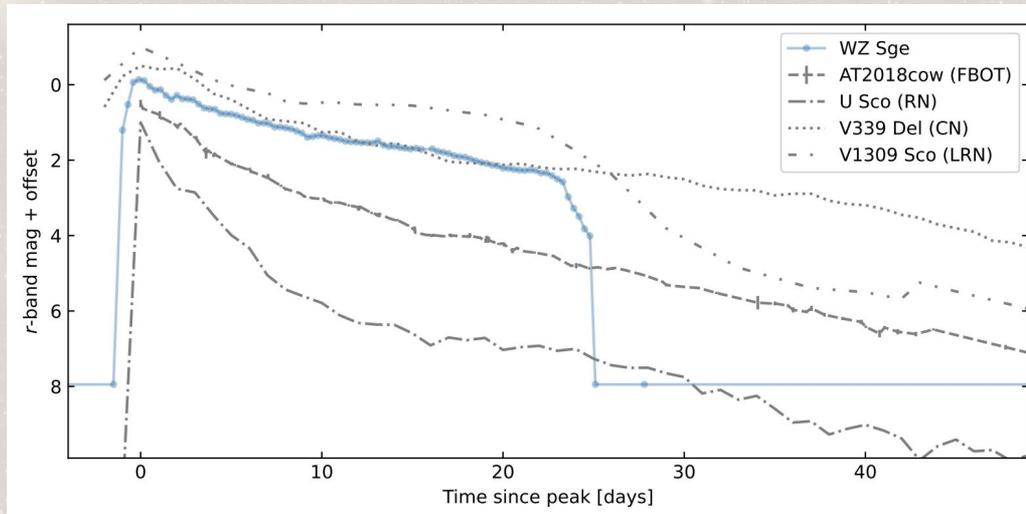
# So how many will be discovered?

## WZ Sge stars

- : ~350 are registered in AAVSO Variable Star Index
- : ~10 WZ Sge stars brighter than 15 mag in outburst in ZTF
  - a few every night & >1000 per year by LSST!
  - challenge is HOW to identify them as a CV (and subtype) in 10M alerts

## Applications of our results to...

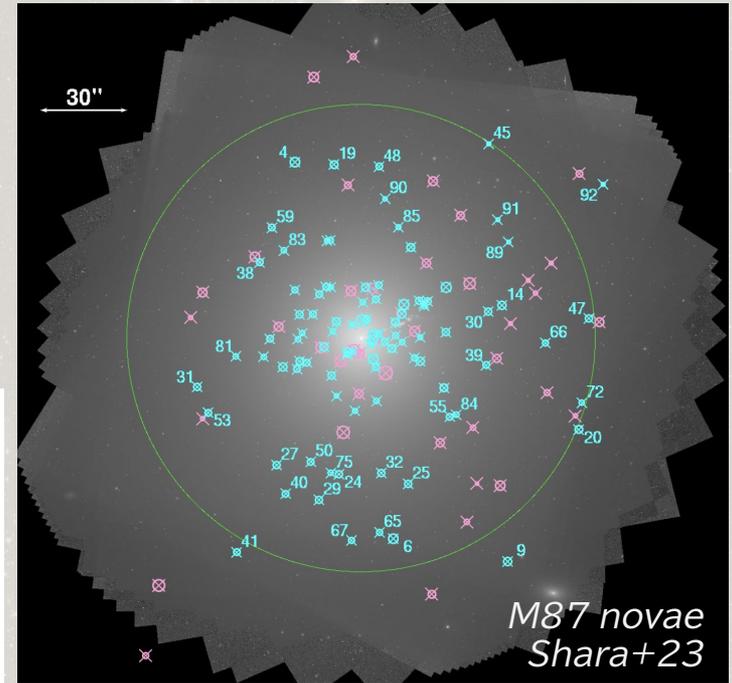
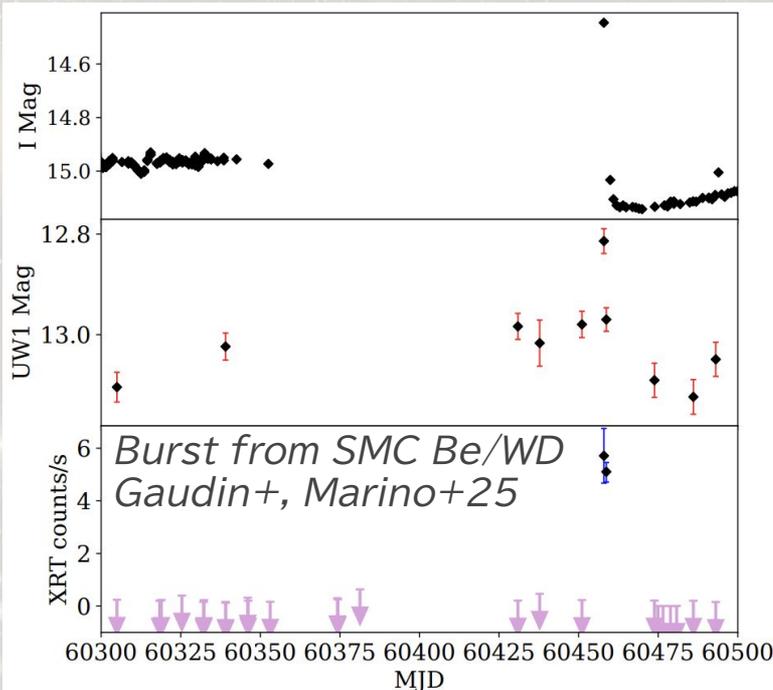
- novae, AM CVn outbursts (possible SNe Ia progenitors), extragalactic rapid transients, luminous red novae



# CVs beyond local population (>1 kpc)

“Special” CVs are known beyond disk populations

- novae in magellanic clouds, M31, M87,,
- Super-soft X-ray source, Be/WD binary
- heavily-redded novae in bulge
- OV Boo as a halo CV



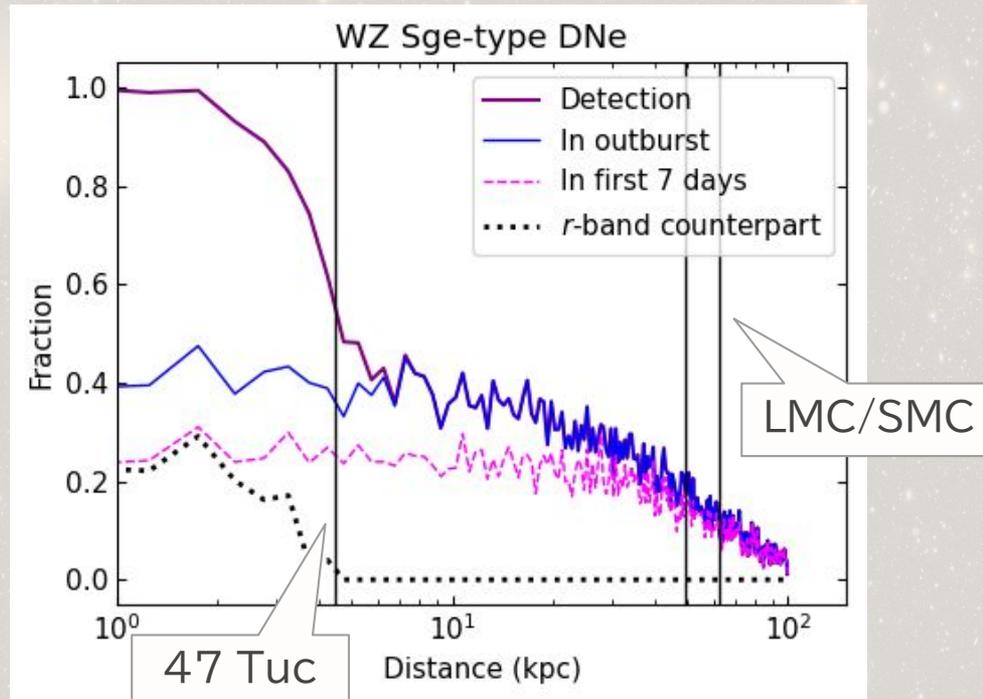
# Discovery rate of uniform distribution as a function of distance

Disk-bright CVs in globular clusters and magellanic clouds

: CVs in GCs must be old – WZ Sge stars (*Belloni+16*)

: Binary population & disk instability dependence in metallicity, age,,

Enable study of “normal” CVs in distant populations



# LSST follow-up in South Africa

PI	Institution	Program Title
David Buckley	SAAO	Observing the Transient Universe with the Rubin Observatory LSST
Matt Hilton	Wits/UKZN	Tracing the evolution of galaxy clusters using Rubin Observatory and radio surveys
Sthabile Kolwa	UNISA	Unraveling cosmic dawn: early galaxy formation with Rubin/LSST-SKA
Michelle Lochner	UWC/SARAO	Unlocking LSST-SKA Synergies with Machine Intelligence
Yin-Zhe Ma	US	Probing Cosmic Structure Formation with Rubin Observatory and multi-wavelength surveys
Lucia Marchetti	UCT	Multi-wavelength approaches to galaxy evolution
John McKean	UP	Unveiling the dark Universe with LSST-SKA and next generation VLBI surveys
Kavilan Moodley	UKZN	Synergistic cosmology with Rubin-LSST and HIRAX
Mario Santos	UWC	Multi-tracer Cosmology with MeerKAT/SKAO and LSST
Kshitij Thorat	UP	Next-generation multi-wavelength astrophysics in the Southern Sky



**Transient follow-up w/ SALT, IRSF, PRIME, and others**  
 – IRSF is unique for Opt-IR 5-band coverage

**Synergy w/ MeerKAT & SKA**

## Summary

The Rubin Observatory LSST will start its operation by the end of this year.

- 10 deg<sup>2</sup> FoV, 24.0 limiting mag, and 10M alerts per night

Tons of CVs, the largest population of Galactic variable stars, must be detected

WZ Sge-type dwarf novae

- ~40% of outbursts, no counterpart for >17 mag at peak
- two or more scans per night with different bands

CVs in clusters and Magellanic clouds

- opportunities to study “normal” CVs on age / metallicity / population

**Any collaboration using SA telescopes are welcome!**