LGWA Meeting 2026
University of Liège

LSST and the role in the identification of LGWA counterparts

Silvia Piranomonte
INAF-OAR



Rubin: the Legacy Survey of Space and Time has started



six filters: u g r i z y
Southern optical sky sampled to 27 mag

optical wide-fast-deep imaging, real-time alerts, time-domain, Solar System, Milky Way, cosmology

Ivezic et al. (2019)

KEY NUMBERS



10-year survey started (30 Jun 2026) !

8.4 m telescope · 9.6 deg² field · 3.2-Gpixel camera

Whole southern sky every 3-4 nights - r ≈ 24.5 per visit - ~800 visits per field over 10 yr

Up to ~7 million alerts every night · public since Feb 2026

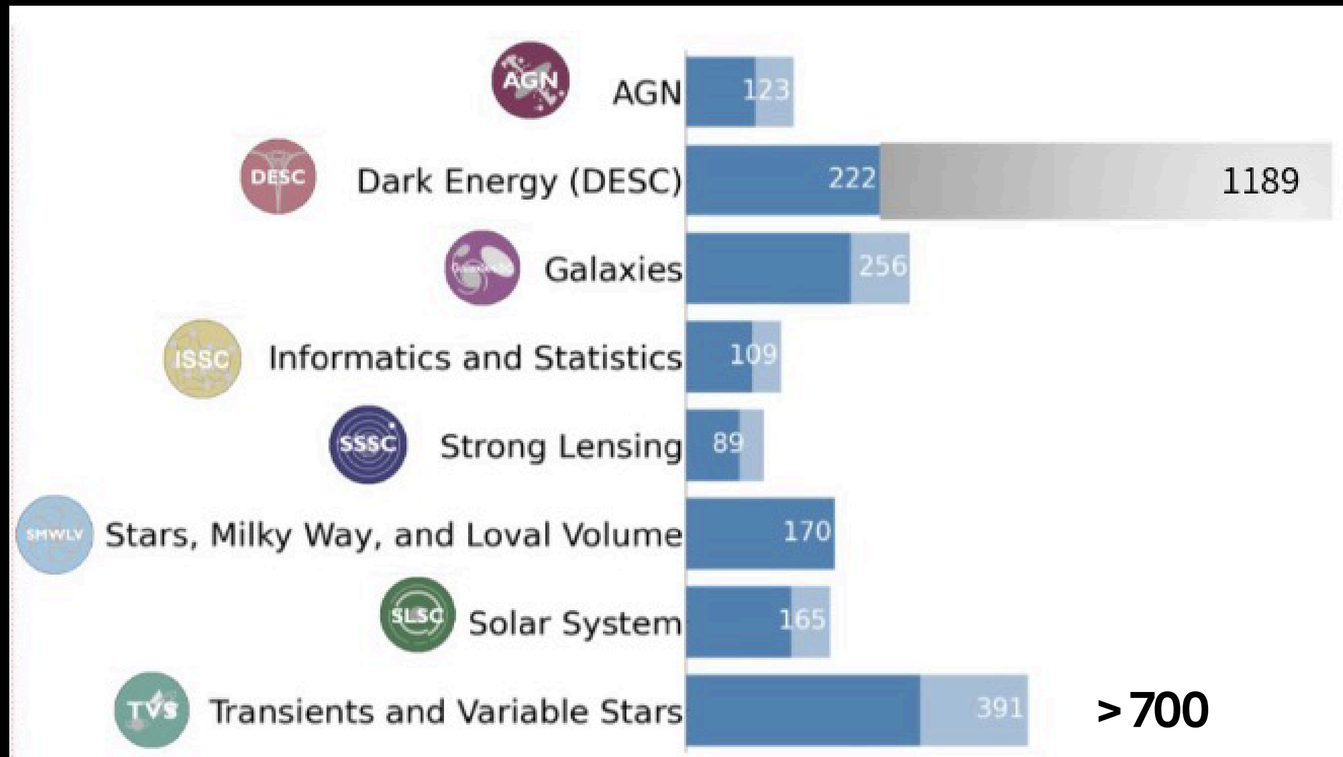
First data preview: Jul 2026

First yearly data release: ~mid-2028

Timescales: 10 seconds to 10 years

Rubin Science Collaborations (SCs)





>700

2000+ members, physicists, astronomers, data scientists, software engineers

Credit: FBianco TLoredo

Transient & Variable Stars SC

Time-domain and multi-messenger astronomy topics

SUBGROUPS



JEDI: JUSTICE, EQUITY, DIVERSITY & INCLUSION

coordinators: Sara Bonito, INAF - Osservatorio Astronomico di Palermo



ANOMALIES AND TRUE NOVELTIES

coordinator: Federica Bianco, University of Delaware



CLASSIFICATION & CHARACTERIZATION

coordinators: Nina Hernitschek, Vanderbilt

DATA VISUALIZATIONS AND CHARACTERIZATIONS

coordinators: Sabina Ustamujic, Sally Macfarlane

DISTANCE SCALES

coordinators: Marcella Marconi, INAF - Osservatorio Astronomico di Capodimonte Lovro Palaversa, Ruđer Bošković Institute



INTERACTING BINARIES

coordinator: Andrej Prsa, Villanova Paula Szkody, UW



MICROLENSING SUBGROUP

coordinators: Somayeh Khakpash, UDelaware



MULTIWAVELENGTH CHARACTERIZATION AND COUNTERPARTS

coordinators: Raffaella Margutti, NorthWestern



SUPERNOVAE

coordinators: Fabio Ragosta, UW



TIDAL DISRUPTION EVENTS

coordinators: Sjoert van Velzen, Leiden Observatory



FAST TRANSIENTS

coordinator: Shar Daniels, Unviersity of Delawar



NON-DEGENERATE ERUPTIVE VARIABLES

coordinators: Sara Bonito, INAF

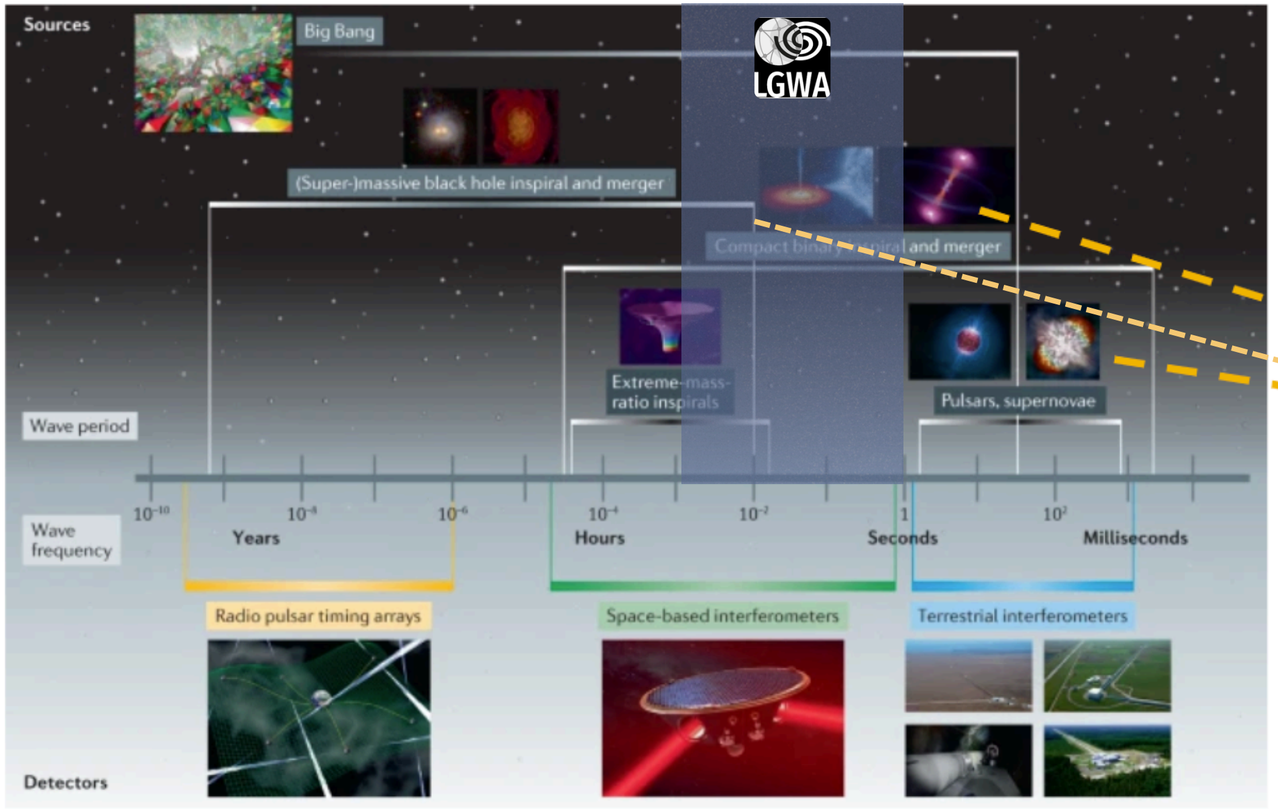


PULSATING VARIABLES

coordinators: Kelly Hambleton, Villanova

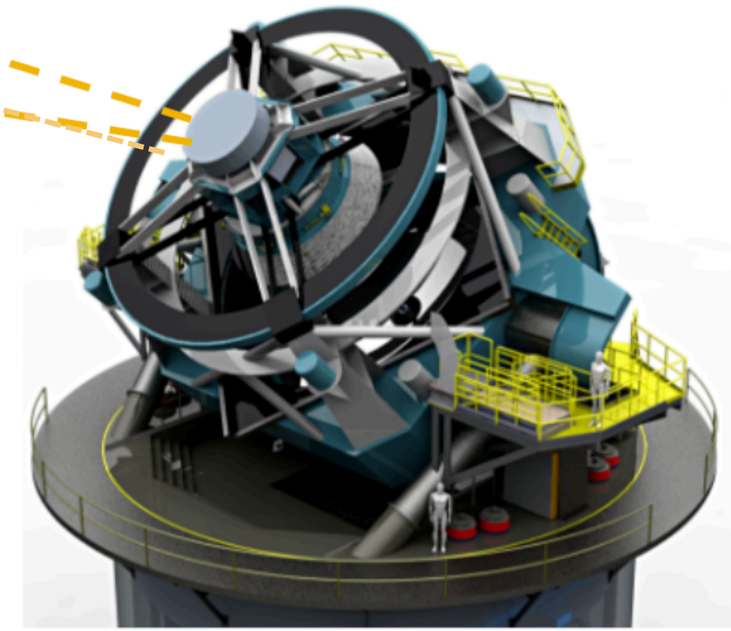
Rubin TVS - Multi-wavelength and Multimessenger sub-group

coordinator: Raffaella Margutti, Berkley, USA



Adapted from Bailes et al. 2021, Nature Reviews Physics

- Rubin as a (ToO) follow-up machine
- Rubin as a discovery machine
- Rubin as a Legacy Survey (10 yr)



VERA C. RUBIN OBSERVATORY

ToO follow-up machine discovery machine legacy machine

INAF ISTITUTO NAZIONALE DI ASTROFISICA

(less than 3% of survey time)*

Envisioning the Vera C. Rubin Observatory LSST Target of Opportunity program - Revised Strategy 2026

LEAD EDITORS

RAFFAELLA MARGUTTI,[1,2] TOMAS AHUMADA,[3] SHREYA ANAND,[4,5,6] IGOR ANDREONI,[7,8,9,10] TIM LISTER,[11] SEAN MACBRIDE,[12,13,14] ANTONELLA PALMESE,[12,13,14] BARBARA PATRICELLI,[12,13,14] SILVIA PIRANOMONTE,[14] GRAHAM P. SMITH,[15] ROBERT STEIN,[8,9,10]

1. Gravitational Waves and Multi-Messenger Astronomy
2. High-Energy Neutrinos
3. GRBS and multi-messenger triggers
4. Multi-messenger gravitational lensing
5. Solar System objects
6. Galactic Supernova
7. Very rare triggers and high-risk high-reward science



KM3NeT



Virgo, Italy



IceCube, South Pole



LIGO, USA

NASA Jet Propulsion Laboratory California Institute of Technology | cneos Center for Near Earth Object Studies



Fermi

CTAO

SNEWS SUPERNOVA EARLY WARNING SYSTEM

*as recommended by the Survey Cadence Optimization Committee (SCOC))

Rubin ToO 2026 in prep

ToO follow-up machine discovery machine legacy machine

From simulations to the sky!

Chandler+2026

Jul 2025 **3I/ATLAS**

interstellar comet · first Rubin ToO

on sky ~30 min after the alert · detected in g r i z y

ToO follow-up machine discovery machine legacy machine

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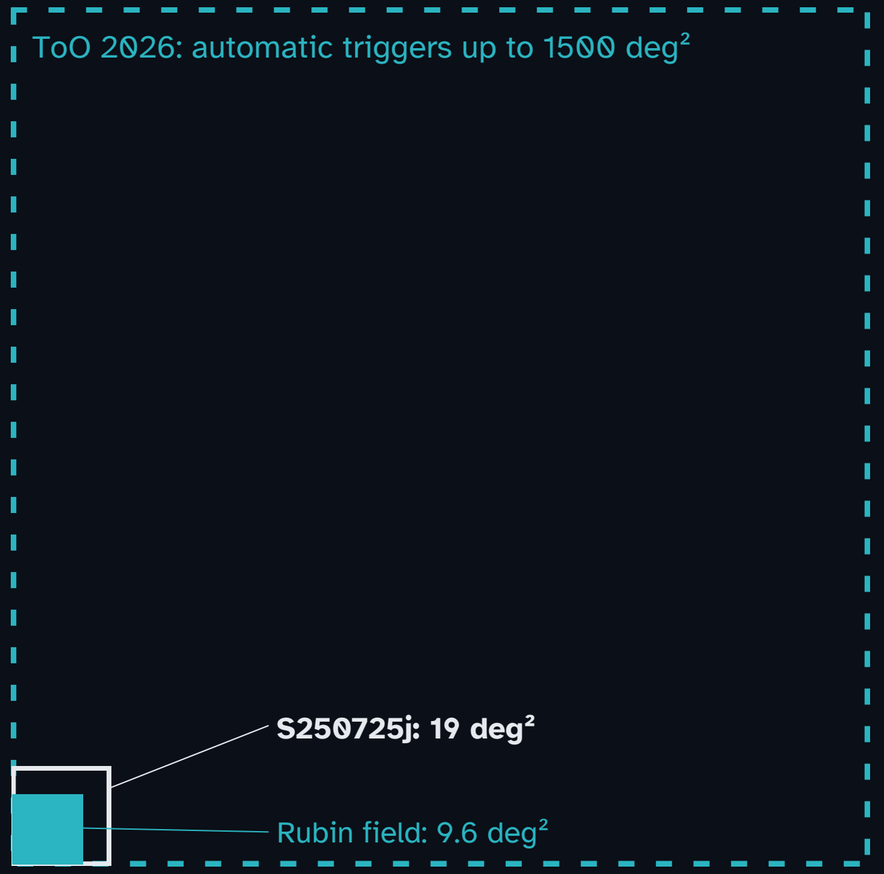
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MacBride et al. 2026

Jul 2025 **S250725j**

binary black hole · 90% area 19 deg² - ~380Mpc

whole 90% region · median r ≈ 24.1, i ≈ 23.8, u ≈ 23.6



ToO follow-up machine discovery machine legacy machine

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MacBride et al. 2026
Report ToO 2026
Hall et al. 2026a
Vieira et al. 2026

Nov 2025 **S251112cm***

> 800 deg² in ~3 h

g + i · 30 s · 4 epochs · median g ≈ 24.5, i ≈ 23.5

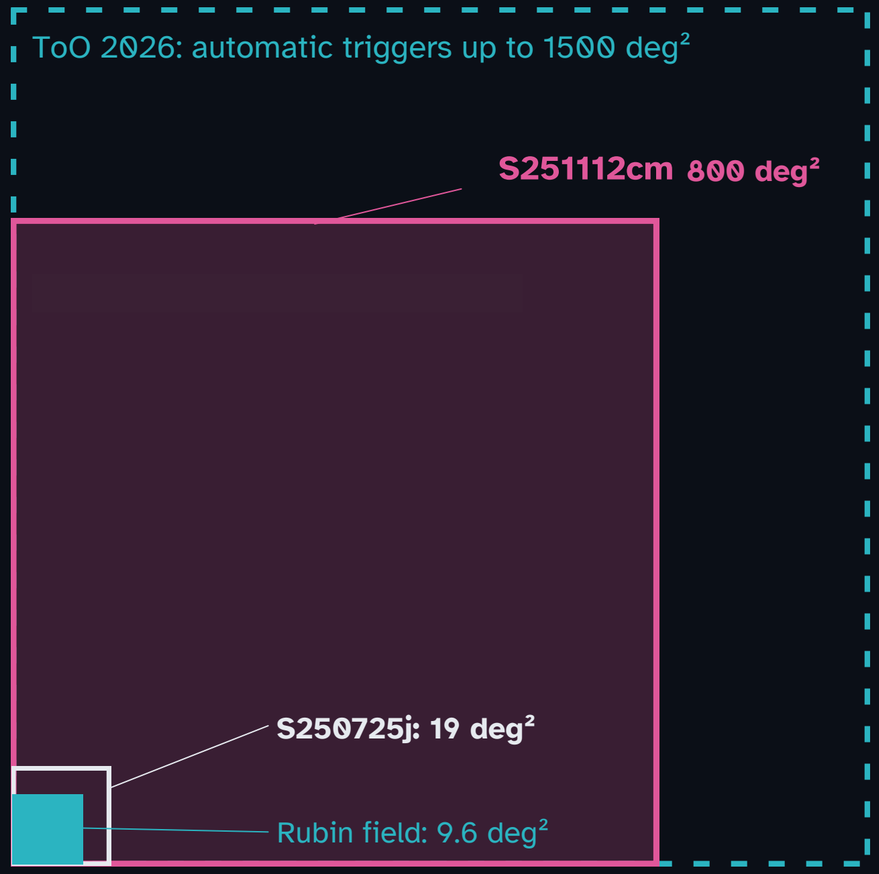
deepest wide-area search for a GW counterpart so far

The bottleneck has moved to vetting

8.7 million alerts, mostly subtraction artifacts

~70 vetted candidates after ~1 month

Areas to scale



*gravitational instability and fragmentation in neutrino-cooled collapsar disks, forming sub-solar-mass neutron stars ·OR Primordial BH

ToO follow-up machine **discovery machine** legacy machine

The transient zoo

WHAT?

Novae

X-ray binaries

Supernovae

GRBs

Luminous Blue Transients

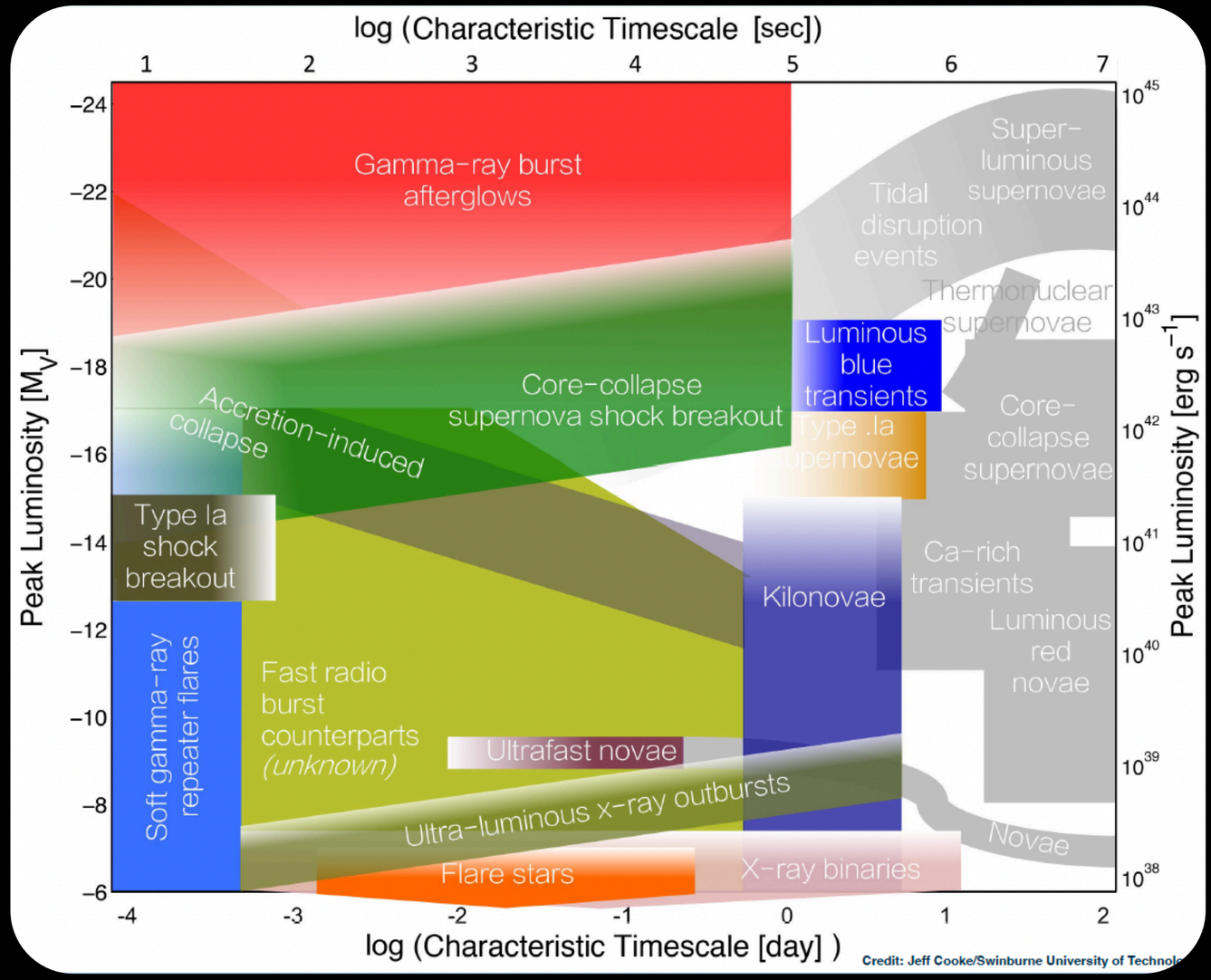
Tidal disruption events

Kilonovae

Soft Gamma-ray Repeaters

Fast radio burst (unkown)

.....

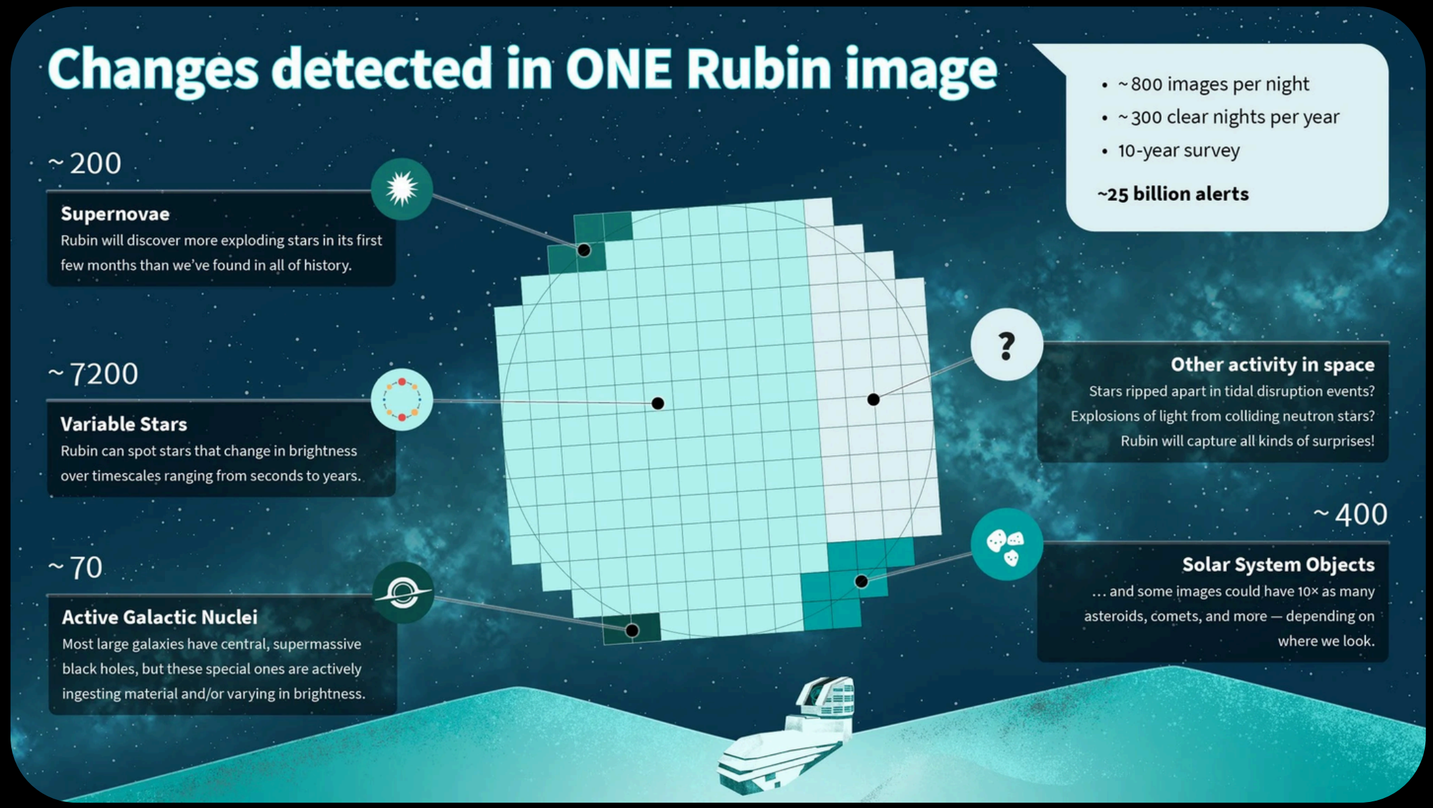


Timescale: from seconds to months

ToO follow-up machine **discovery machine** legacy machine

Alert streams and Brokers

In survey mode, Rubin produces up to several million alerts per night!



Distributed immediately to 7 full-stream brokers:

ALeRCE
AMPEL
ANTARES
Babamul
Fink
Lasair
Pitt-Google

Custom alert filters
Automatic classification by wide field spectra surveys

- include photometry, light curves, catalog cross-matches, and image cutouts.
- automatically generated within ~60 s via difference imaging (S/N ≥ 5).
- distributed to community brokers; full data available via Rubin Science Platform (<24h).
- Brokers filter, cross-match and classify alerts wth ML, enabling efficient follow-up selection.

ToO follow-up machine discovery machine **legacy machine**

LSST: the 10-year legacy survey

The survey

- **~18 000 deg² Wide-Fast-Deep** southern sky, ~800 visits per field in ugrizy
- **30 s visits, pairs per night** rolling cadence: sky stripes alternate high/low cadence each year
- **Galactic plane & bulge** coverage extended in recent baselines
- **5 Deep Drilling Fields** COSMOS, CDF-S, ELAIS-S1, XMM-LSS, EDFS: ~5–7% of visit (20,000 visits per field)
- **ToO** < 3% of survey time



Ivezić et al. 2019 · SCOC Phase 3, PSTN-056 (2024) · Hambleton et al. 2023 (TVS Roadmap)

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The products

- **Yearly Data Releases** first ~mid-2028, then every year
- **10-yr light curves** ~800 epochs for every source
- **Deep coadds** r ≈ 27.5 after 10 yr
- **Catalogues** ~20 billion galaxies with photo-z, ~17 billion stars



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What is useful for LGWA

- **Periodic variables** → Galactic DWD targets
- **Decade of AGN light curves** → MBH binary candidates, flare background
- **Deep templates** → pre-explosion view of any host
- **Galaxy catalogue** → hosts for dark sirens
- **Transient rates** → priors for LGWA science



Ivezić et al. 2019 · SCOC Phase 3, PSTN-056 (2024) · Hambleton et al. 2023 (TVS Roadmap)

ToO follow-up machine discovery machine **legacy machine**

What Rubin counts for LGWA

Source	Rubin measures	Use for LGWA
Local SN Ia *links: Benetti*	complete rates and light curves within ~100 Mpc, deeper than ZTF + ATLAS	the ~30 DWD mergers expected in 10 yr (WP Table 5)

Rubin turns LGWA’s predicted rates into measured ones.

LGWA WP §3.2–3.3 (arXiv:2404.09181) · Zenati, Bobrick & Perets 2020 · Benetti et al. 2025

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Luminous red novae *links: Simonato*	rates and luminosity function of stellar mergers	common envelope → how DWDs form; stellar core mergers

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CC SN *Ic-BL, orphan afterglows*	rates of jet-driven explosions	jet memory signals in the deci-Hz

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Galactic double white dwarfs: the targets

What LGWA sees

Galactic DWDs with P $\lesssim$ 30 min $\rightarrow$ f $\gtrsim$ 1 mHz, quasi-monochromatic: the signal does not change over the mission
~30 Galactic sources in 10 yr (Benetti+25); verification binaries = calibration sources with known position (WP)

Rubin gives LGWA a catalogue of targets: position, period and phase

~30 Galactic DWDs for LGWA in 10 yr

Korol et al. 2017 · Benetti et al. 2025 · Burdge et al. 2019 · Roelofs et al. 2010 · LGWA WP

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Rubin before · archive & statistics

Up to ~2×10³ eclipsing DWDs from 10-yr light curves (Korol+17): period, sky position, inclination

Galactic plane & bulge extended coverage where most DWDs live

Targeted search known f, position, inclination → lower detection threshold

Population period & space distribution → rates, Galactic foreground

Examples HM Cnc (5.4 min, interacting, δ=+15°) · ZTF J1539 (6.9 min, eclipsing, northern)

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~10³ eclipsing DWDs from Rubin **~30** Galactic DWDs for LGWA in 10 yr

Korol et al. 2017 · Benetti et al. 2025 · Burdge et al. 2019 · Roelofs et al. 2010 · LGWA WP

links: Benetti · Radice

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Rubin during · if the survey continues

Continued monitoring measure period decay → compare with GW phase (tides, mass transfer)

Follow-up of candidates high-speed photometry + spectroscopy → masses, distances

Caveat Rubin DWDs sit at a few mHz: heart of LISA, lower edge of LGWA → calibrators + demographics

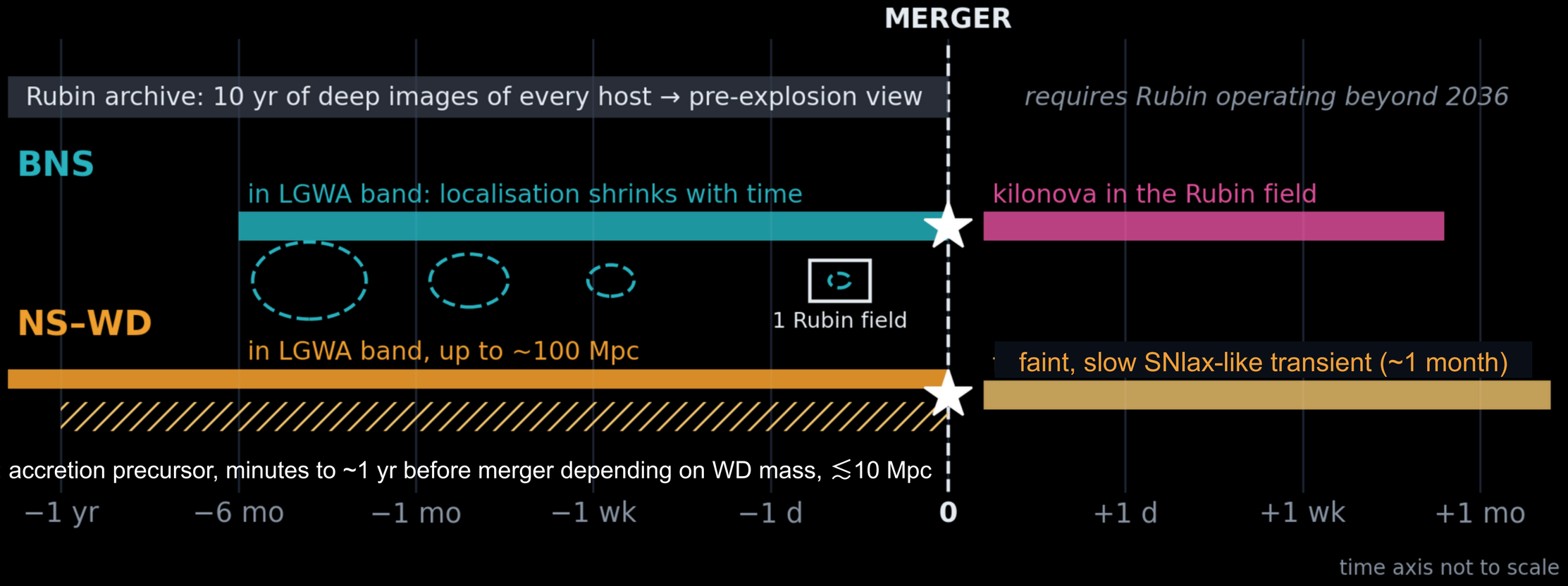
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links: Radice · Benetti

Mergers with white dwarfs and neutron stars



BNS: in band ~6 months before merger, few arcmin² – DWD mergers: ~20 SN Ia-like within 100 Mpc in 10 yr

LGWA tells us where and when – Rubin could catches the explosion

LGWA WP (arXiv:2404.09181) · Yelikar & Jani 2025 (arXiv:2510.05400) · Zenati, Bobrick & Perets 2020 · Bobrick et al. 2022

links: Paiella · Simonato

Tidal disruptions and intermediate-mass black holes

What LGWA sees

WD-TDE 10^{-2}–1 Hz: heart of the LGWA band, only for IMBHs $\lesssim 10^5\ M_\odot$
MS-TDE · IMBH binaries & IMRIs MS-TDE at 10^{-4}–10^{-3} Hz (band edge, closer to LISA) · IMBH inspirals in the deci-Hz

LGWA WP §3.2, §3.3.3 (arXiv:2404.09181) · Toscani et al. 2022

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Rubin before · archive & statistics

Large TDE samples rates vs host mass, in dwarf galaxies and off-nuclear
Occupation fraction the WP asks LSST to pin down TDE rates for MBHs < $10^6\ M_\odot$
WD-TDE candidates faint and fast: M_B −16 to −18, g−r < 0, rise 5–10 d; dwarfs, outskirts, GCs
IMBH demographics variability-selected AGN in dwarf galaxies

Rubin will set the rate

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Rubin during · if the survey continues

MS-TDE optical flare weeks to months after the GW burst → found in the alert stream (post-starburst nuclei)

WD-TDE optical almost simultaneous → reverse trigger: Rubin transient → targeted LGWA search

IMBH binaries mostly dark: Rubin gives the host and its history

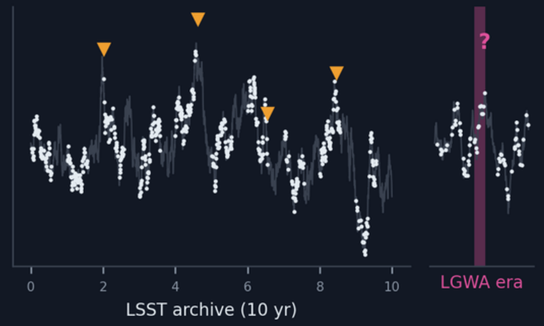
Rubin will set the rate

links: Singh · Ugolini

Massive black holes and AGN: what the archive can test

1 Flare background

archive + monitoring



10 yr of AGN variability → how often flares happen by chance. The flare itself needs someone watching in the LGWA era.

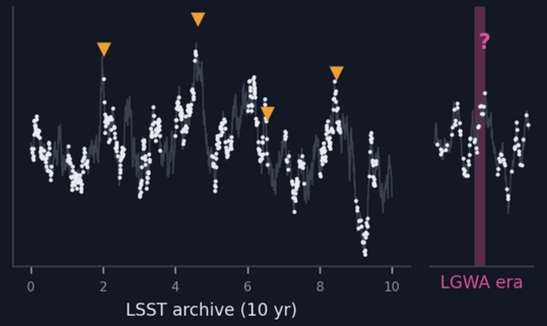
LGWA WP §3.2, §3.3.4 · Graham et al. 2020 · Ashton et al. 2021 · Bartos et al. 2017 · Veronesi et al. 2022 - Tissino et al. 2026 - Xin & Haiman 2021

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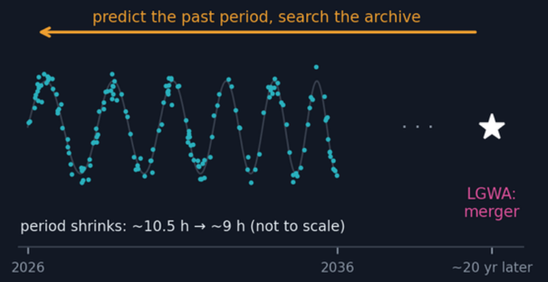
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2 Archival period search

archive only



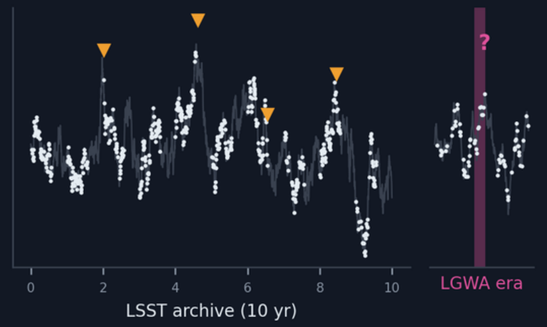
LGWA gives masses and merger time → predict the orbital period during LSST → search the archive.
Needs a bright, varying AGN.

LGWA WP §3.2, §3.3.4 · Graham et al. 2020 · Ashton et al. 2021 · Bartos et al. 2017 · Veronesi et al. 2022 - Tissino et al. 2026 - Xin & Haiman 2021

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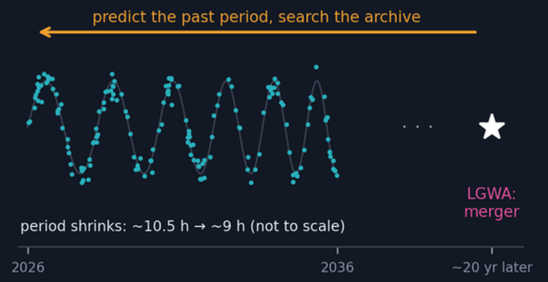
archive + monitoring



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2 Archival period search

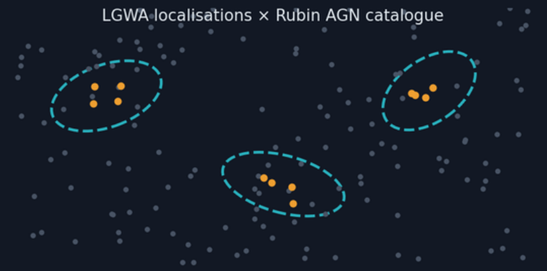
archive only



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3 Statistical association

archive only



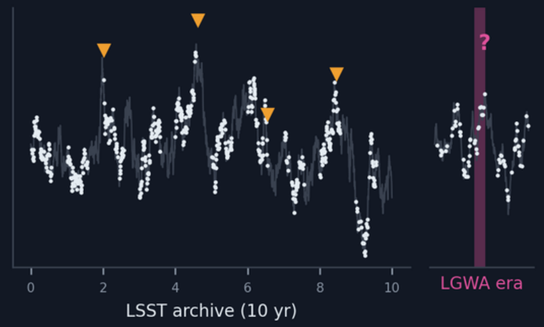
More AGN inside LGWA boxes than by chance? → tests the AGN-disk channel.
No flare needed (Bartos+17).

LGWA WP §3.2, §3.3.4 · Graham et al. 2020 · Ashton et al. 2021 · Bartos et al. 2017 · Veronesi et al. 2022 - Tissino et al. 2026 - Xin & Haiman 2021

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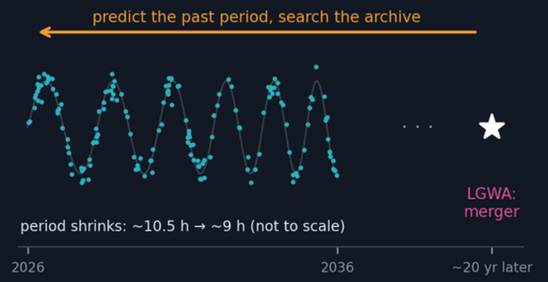
archive + monitoring



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The flare itself needs someone watching in the LGWA era.

2 Archival period search

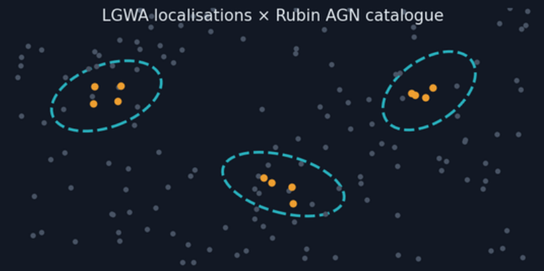
archive only



LGWA gives masses and merger time → predict the orbital period during LSST → search the archive.
Needs a bright, varying AGN.

3 Statistical association

archive only



More AGN inside LGWA boxes than by chance? → tests the AGN-disk channel.
No flare needed (Bartos+17).

4 Demographics

archive only

AGN in dwarf galaxies (variability-selected) → hosts of IMBHs and IMRIs
Periodic AGN → MBH-binary candidates.
If Rubin still runs: flare search in the LGWA box (ToO 2026 Report already covers AGN-disk BBHs).

Even without Rubin on the sky, its archive can test the AGN channel.

LGWA WP §3.2, §3.3.4 · Graham et al. 2020 · Ashton et al. 2021 · Bartos et al. 2017 · Veronesi et al. 2022 - Tissino et al. 2026 - Xin & Haiman 2021

Photometry is only half the story

(Classification is not enough)

spectroscopic follow-up in the Rubin era

spectroscopy is essential

- confirm the physical nature
- identify rare / ambiguous events
- train and validate ML classifiers





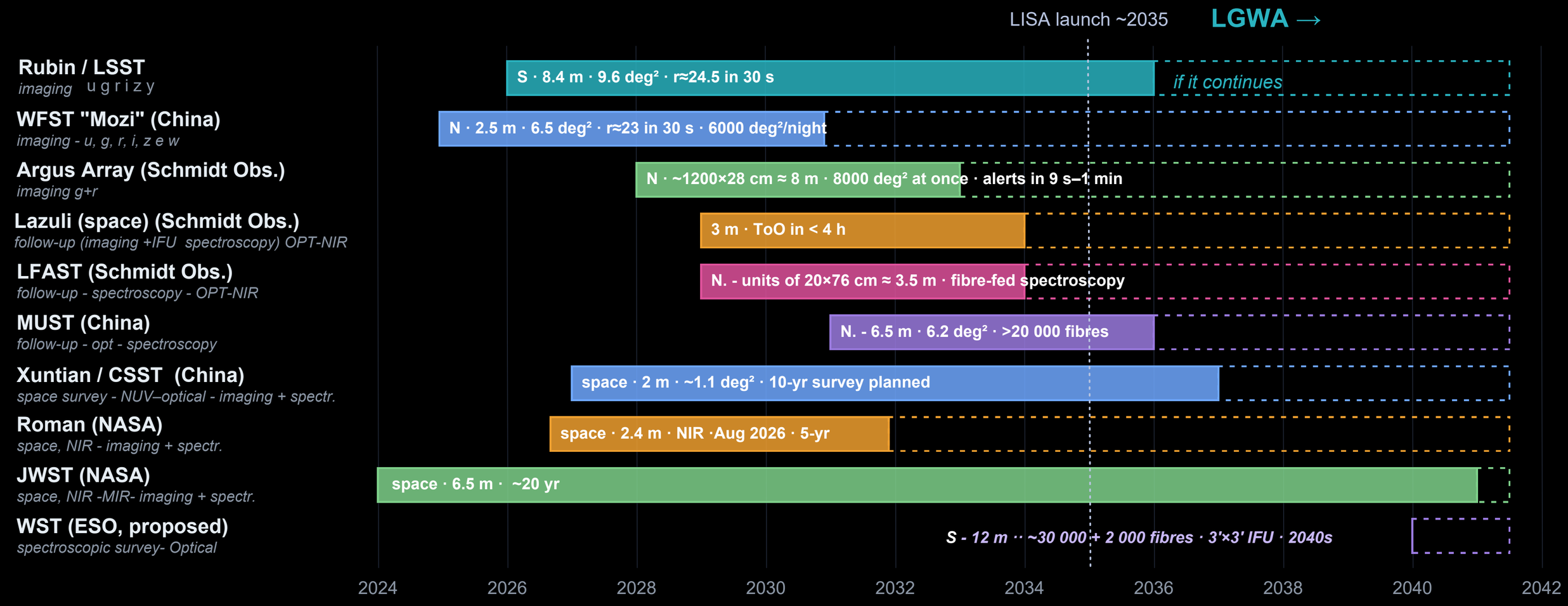
follow-up strategy

- VLT (X-shooter - RISOTTO collaboration - 386 hrs) - NOW
- SOXS - NOW
- 4m telescopes (International Collab. inside Rubin Community) - NOW

WHAT ABOUT THE FUTURE?

Beyond Rubin: who else will be watching the sky with us ?

The future seems to be “bright”!!

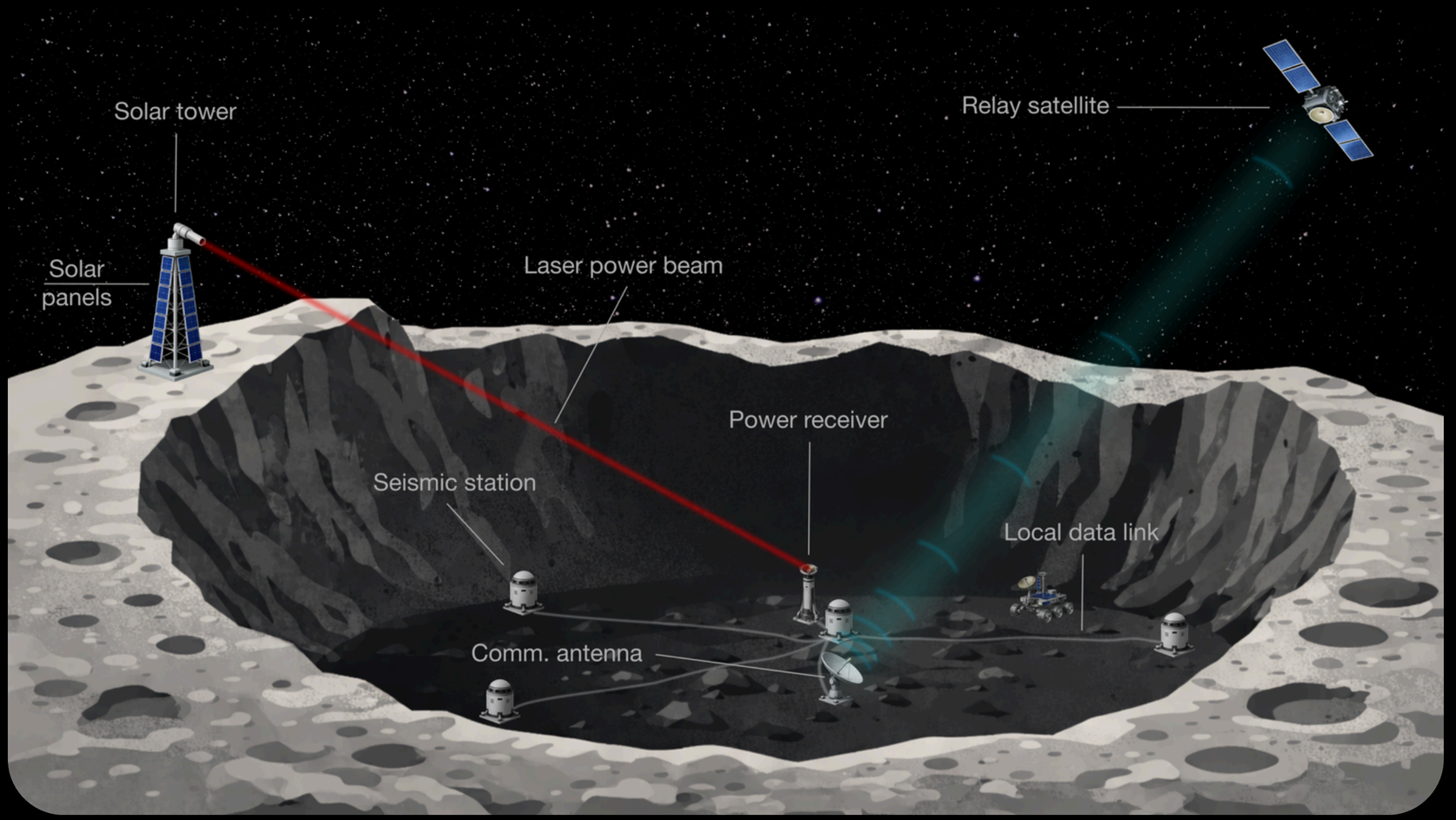


Solid: planned survey/mission years (approx.) · dashed: possible extension · end dates for Lazuli, LFAST, MUST not yet defined; JWST from Dec 2021; WST in Phase A (2025–27)

Most of today’s surveys end before LGWA flies: its optical-nir partners are still being built!

Argus: Law et al. 2022; arXiv:2604.13650 · Schmidt Observatory System (Jan 2026) · WFST: Wang et al. 2023 · MUST: arXiv:2605.10102 · NASA (Roman, JWST) · WST: arXiv:2607.23786





From Rubin to the MOON



Have Fun!

BACKUP SLIDES

LGWA sources: GW frequency vs time to merger

