Time Domain and Multi-messenger Astronomy @ INAF

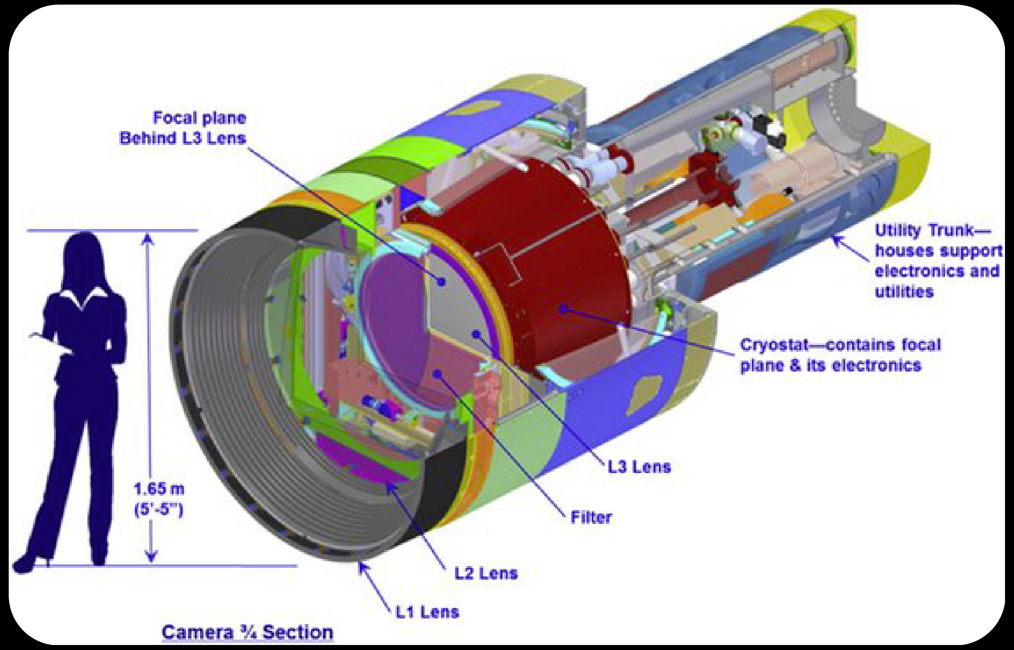
with Rubin Telescope

Silvia Piranomonte
INAF OAR

Rubin Telescope

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, MW, cosmology



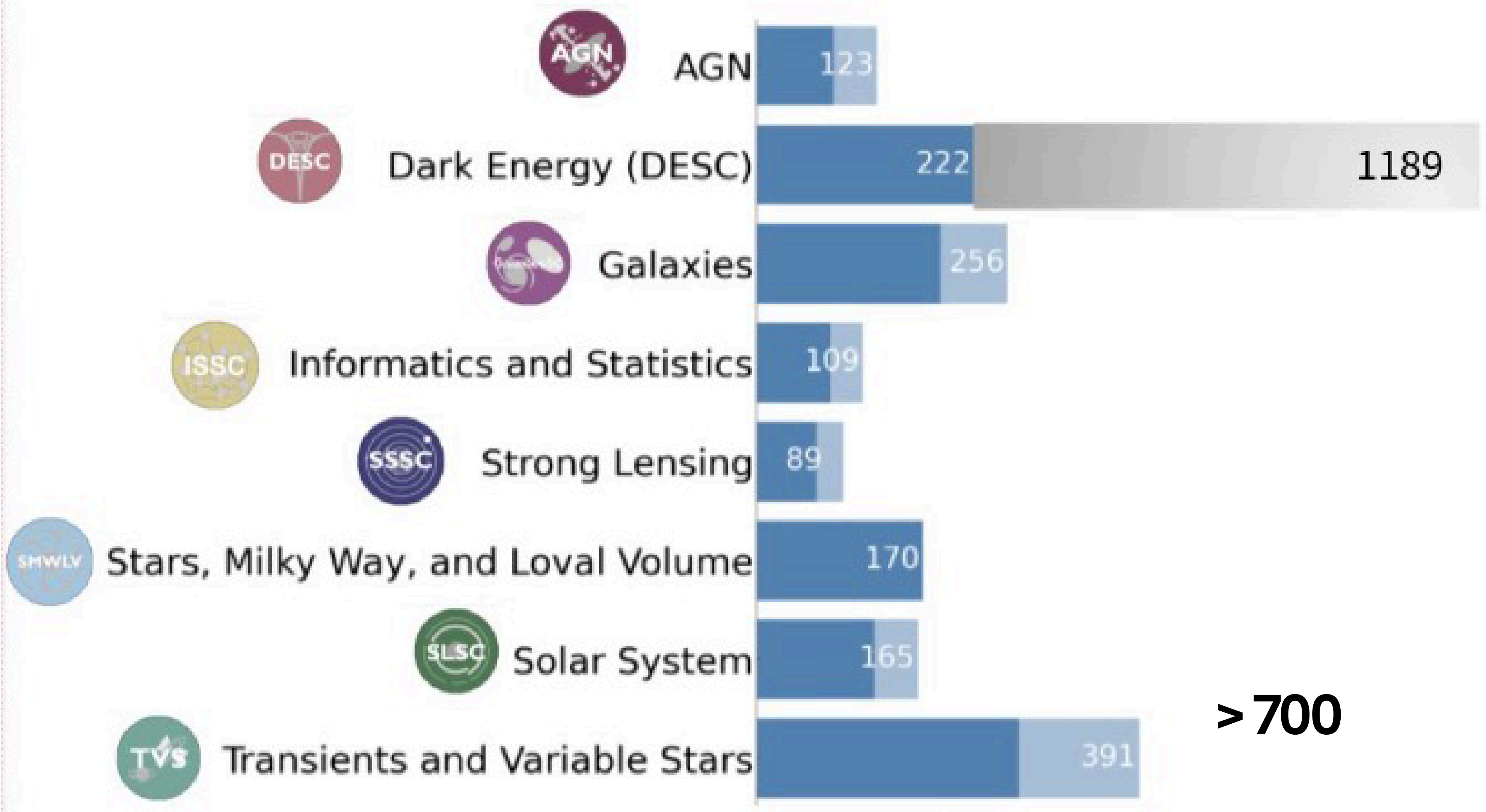
Primary mirror diameter : 8.4 m
Field of View : 9.6 square degrees
Focal plane : 189 4kx4k science CCD chips, 0.2 arcsec/pixel
Survey duration : 10 years
Number of visits: ~2.1 million

KEY NUMBERS

Nightly data size: 20 TB/night
Final database size (DR11) : 15 PB
Number of objects (full survey, DR11): 20B galaxies
17B resolved stars
6M orbits of solar system bodies

Ivezic et al. (2019)

Rubin Science Collaborations (SCs)



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

Credit: FBianco TLoredo

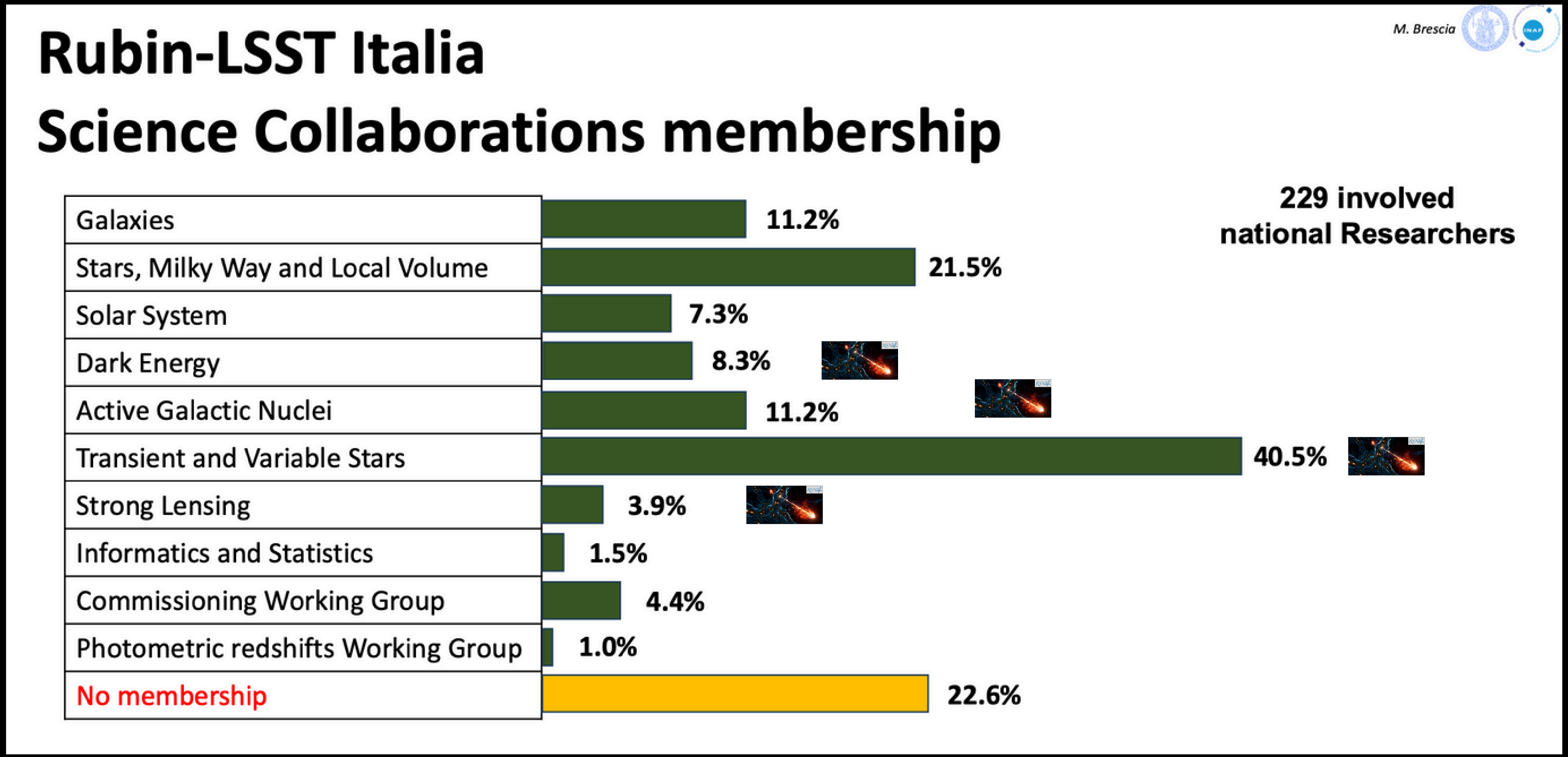
Italian participation to the Project

Almost **200 Italian scientists** interested.

In-kind contribution program led and funded by INAF

Program Lead: Massimo Brescia (Naples University, Italy)

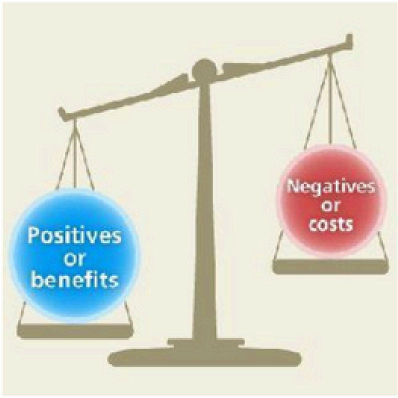
Program Manager: Claudia M. Raiteri (INAF)



Italian participation to the Project

Rubin-LSST Italia in-kind program numbers

M. Brescia



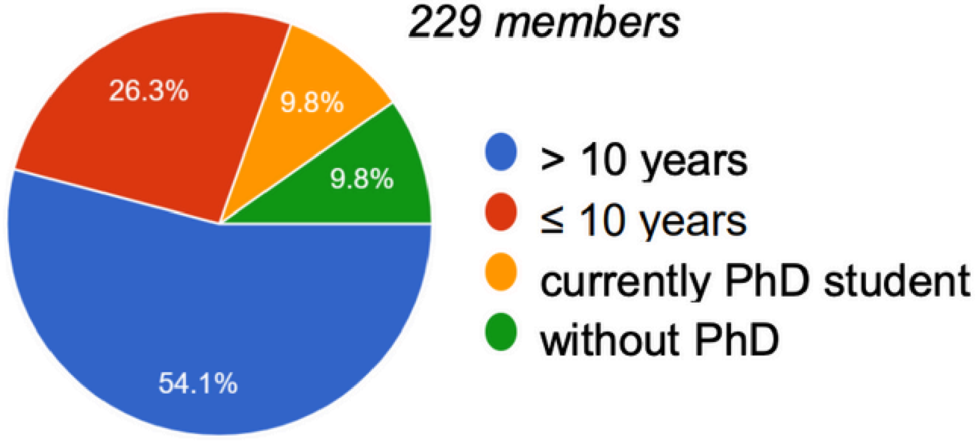
Data Rights provide same real-time data access as US/Chilean community

in-kind program duration: **15** years (*LSST survey duration:* ***10*** *years*)
involved national Researchers: 188 from INAF + 41 from other Institutes/Universities = **229**
in-kind contributions in 15 years: **23**
FTEs from Staff in 15 years: **53.5**
FTEs from contracts in 15 years: **49.8**

Total contributed FTEs in 15 years: **103.3**
Total Data Rights (DR) for 10 years: **96 PIs** + **384 JAs** = **480** DR

PI: senior (postdoc for > 10 years)
JA: junior (postdoc for ≤ 10 years)

Elapsed time from the PhD
229 members



Massimo Brescia Jan 20th, 2026 talk

S16 Contribution Lead: Sergio Campana - **The Son of X-Shooter contribution to Rubin: a set of 2,000 spectra for ML light curve classification**

S26 Contribution Lead: Angelo Antonelli - **A Bridge from Gamma to Optical**

S27 Contribution Lead: Maria Teresa Botticella - **A VST survey to support the Legacy Survey of Space and Time**

S29 Contribution Lead: Maurizio Paolillo - **Toward next-generation time-domain surveys (TIMEDOMES): VST monitoring of the LSST Deep Drilling Fields**

VERA C. RUBIN OBSERVATORY

TVSSC

Transient & Variable Stars SC

INAF

Time-domain goal

discover and characterize a huge range of variable and transient phenomena (SNe, kilonovae, TDEs, AGN variability, flares, microlensing, etc.).

gravitational wave & neutrinos counterparts

Numbers

Up to 10 million alerts, 20 TB of data…every night!

Timescales: 10 seconds to 10 years

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

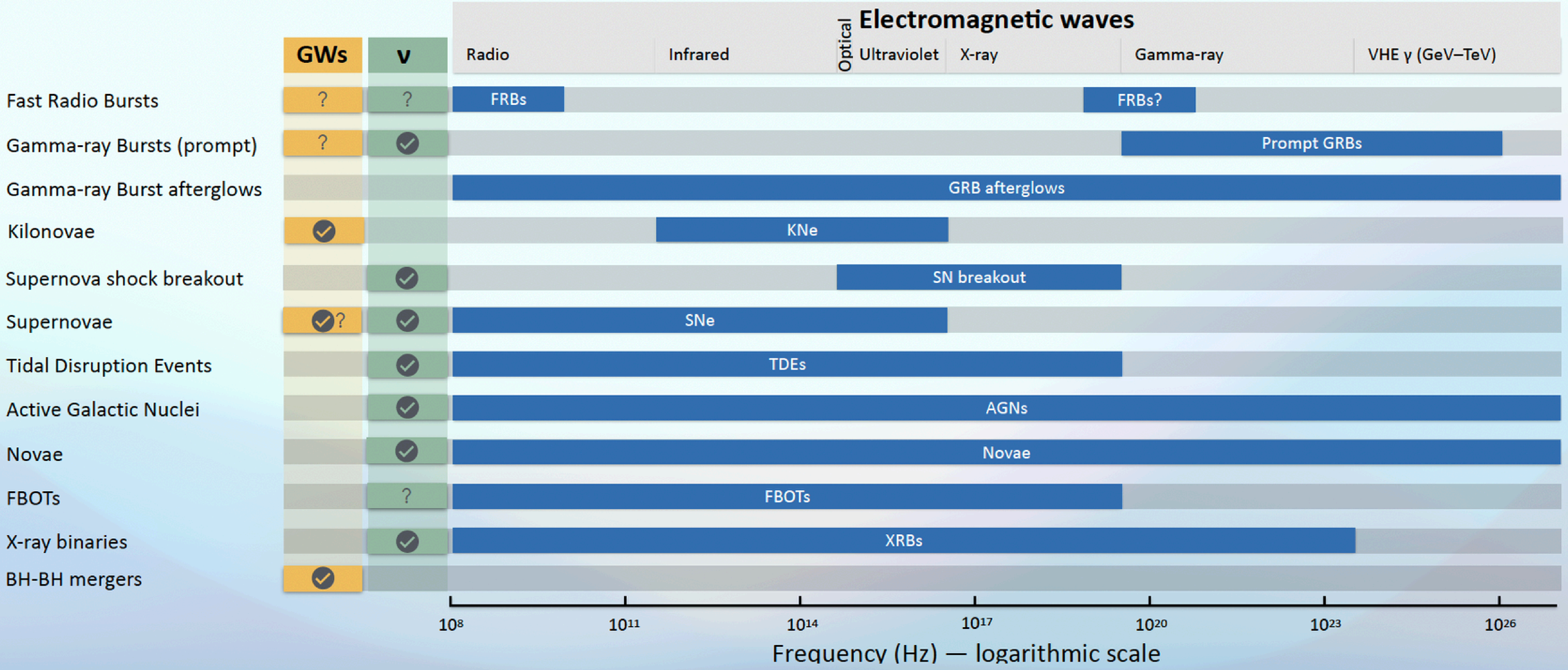
coordinators: Kelly Hambleton, Villanova

VERA C. RUBIN OBSERVATORY

INAF

Multi-messenger detectability of transients

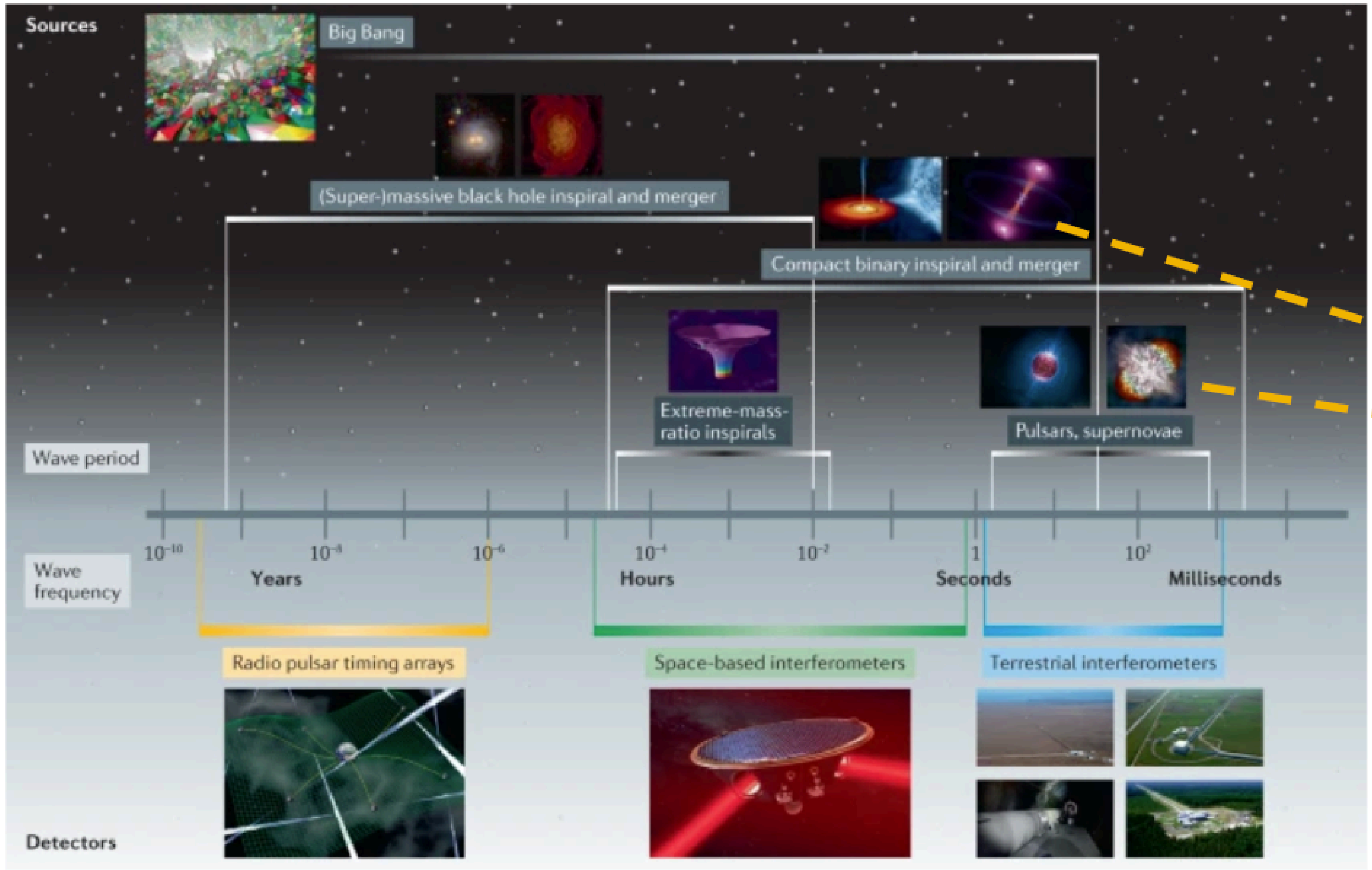
Messenger detection and approximate EM frequencies where emission has been detected



courtesy of Antonio De Ugarte Postigo

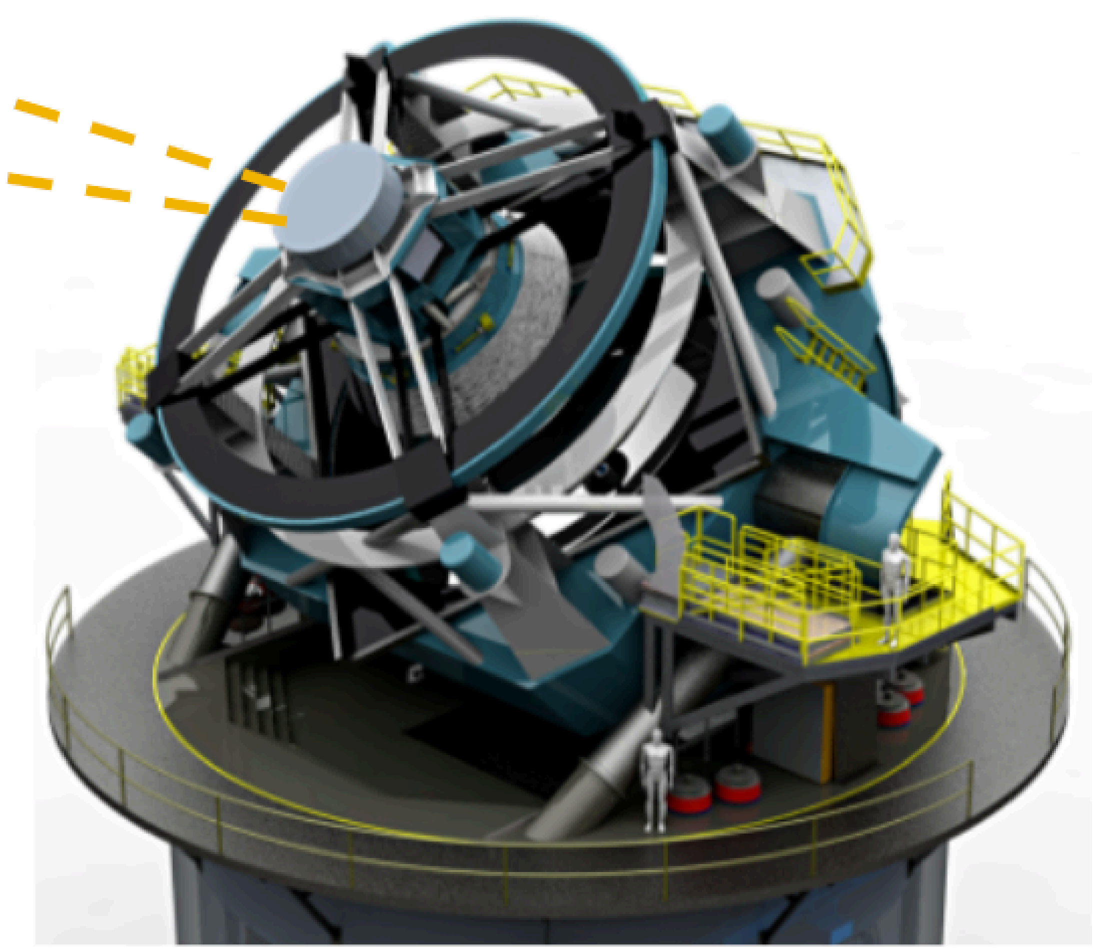
Rubin TVS - Multi-wavelength and GW follow-up sub-group

coordinator: Raffaella Margutti, Berkley, USA



Gravitational-wave physics and astronomy in the 2020s and 2030s, Nature Reviews Physics

- **Rubin as a (ToO) follow-up machine** -> sources from GW - neutrinos detectors
- **Rubin as a discovery machine** -> follow-up from other facilities



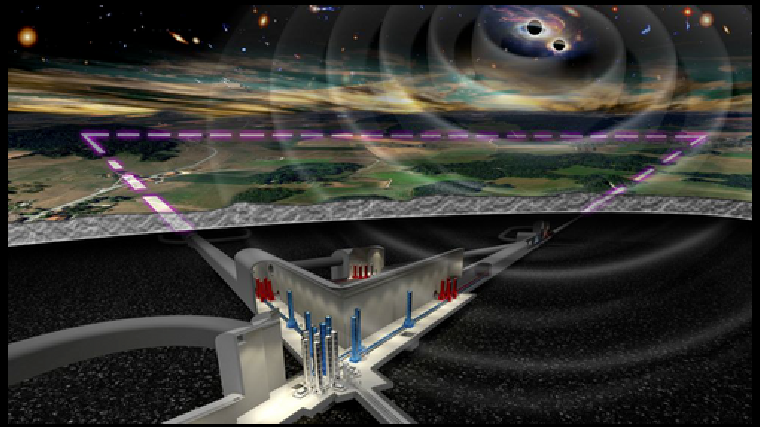
Target of opportunity observations with Rubin

(less than 3% of survey time)

1. Gravitational Waves and Multi-Messenger Astronomy
2. High-Energy Neutrinos
3. Galactic Supernova
4. Small PHA Potential Impactor

KM3NeT, Mediterranean Sea

Virgo, Italy



Einstein Telescope

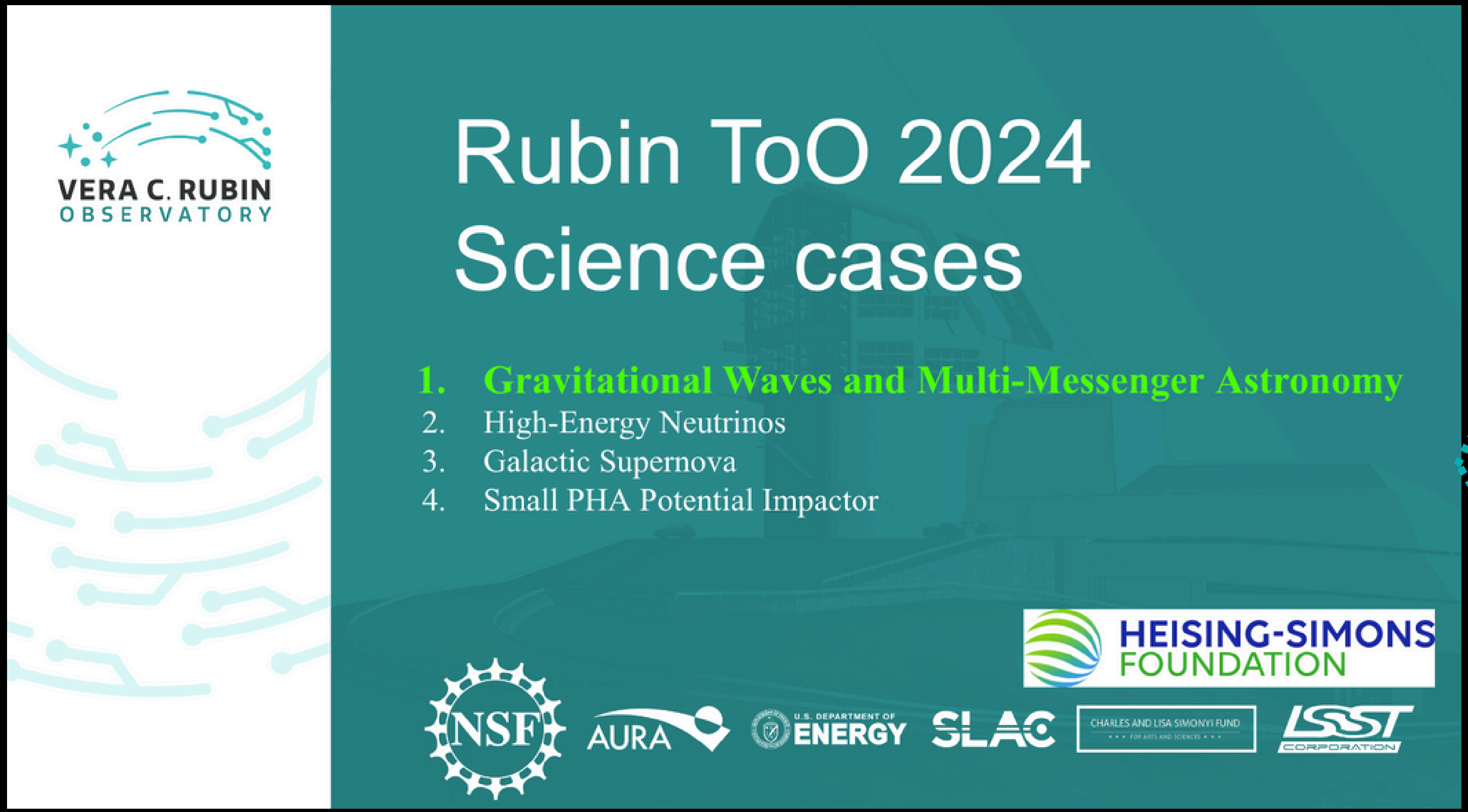
LIGO, USA

IceCube, South Pole

Rubin as a (ToO) follow-up machine

Rubin as a discovery machine

(Key Challenge: Limited resources for multi-wave follow-up vs. number of LSST transients)



1. Gravitational Waves and Multi-Messenger Astronomy

Binary Neutron Star Mergers and Neutron Star - Black Hole Mergers

Science case leads: Silvia Piranomonte, Stephen Smartt

Gravitationally lensed Binary Neutron Star mergers

Science case lead: Graham Smith

Black Hole-Black Hole Mergers

Science case lead: Antonella Palmese

Unidentified GW Sources

Science case lead: Ryan Chornock

Emerging Ideas Science Case: Gravitationally lensed Gamma-Ray Bursts and their afterglows

Science case lead: Graham Smith

Rubin ToO 2024: Envisioning the Vera C. Rubin Observatory LSST Target of Opportunity program – arXiv:2411.04793

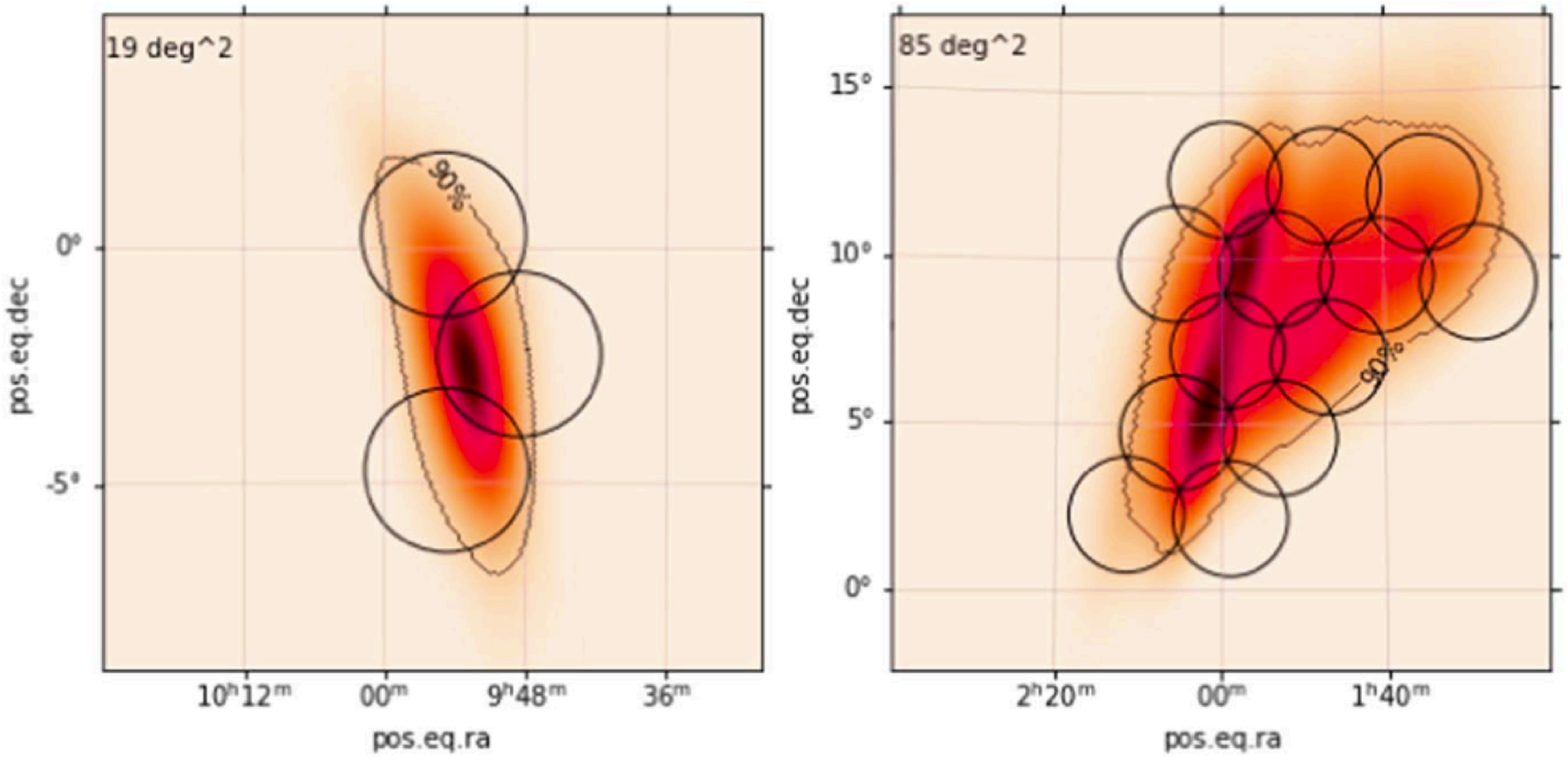
12-Nov-2025: **EM follow-up campaigns of S251112cm+ (SubSolarMassMerger chirp mass ~0.1-0.87$M_\odot$)**

Nov 2025: MoU LVK-Rubin (Patricelli & Piranomonte LVK-Rubin liasions)

WHY RUBIN

large sky maps, faint targets

Rubin tiling of simulated GW skymaps for NS–NS mergers



Sky maps from GW detections can be 100s to 1000s square degrees.

We will limit ourselves to, roughly, **Ω** ≲ 100 square degrees

We will (still) need a large field of view for efficient observations

COVER HUGE REGION

Andreoni et al. 2022

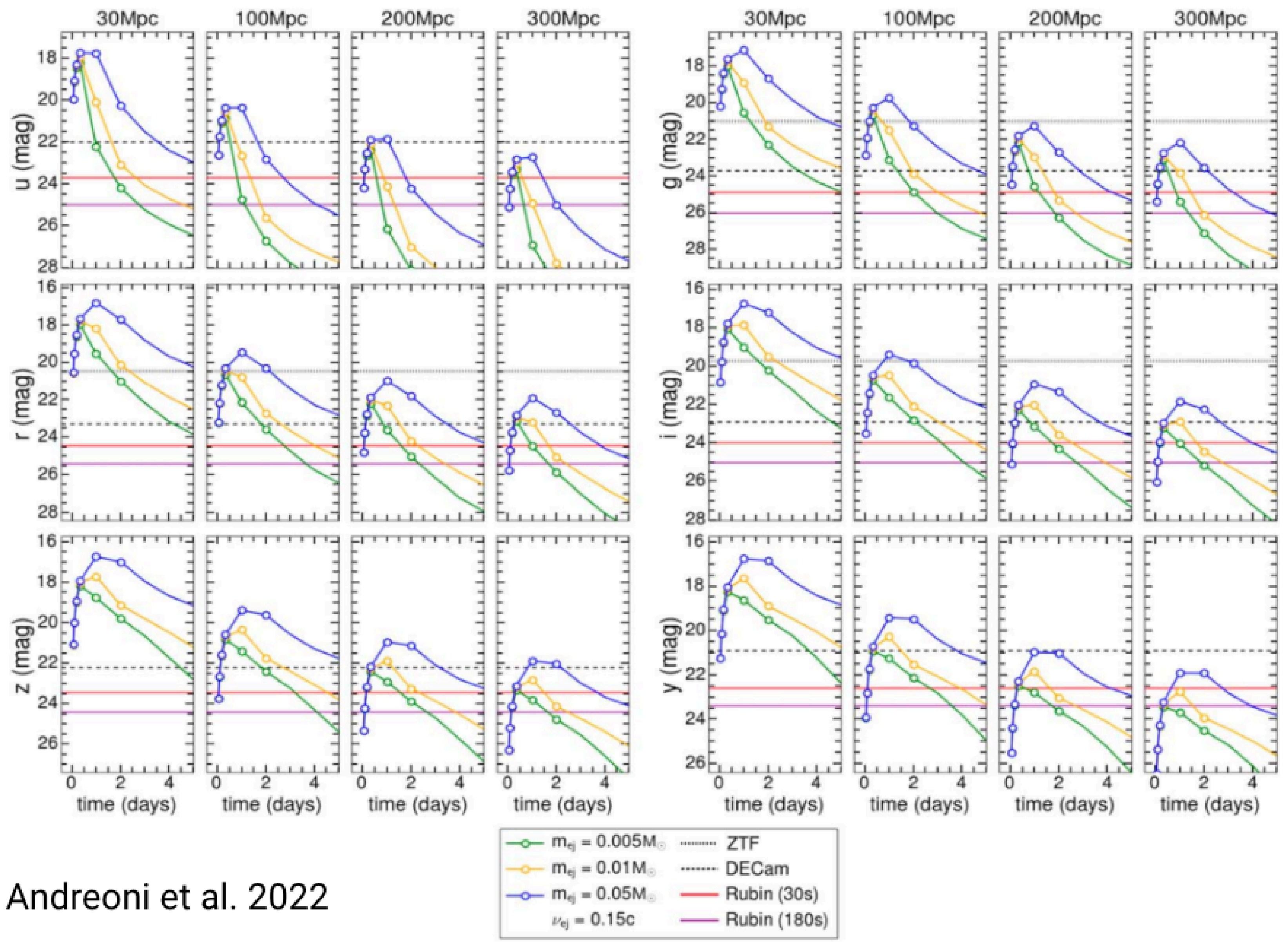
WHY RUBIN

Filter	Depth (AB mag)			*M* (350 Mpc)			*M* (700 Mpc)			Exptime (sec)		
u	24.9	24.7	23.9	-12.8	-13.1	-13.8	-14.4	-14.6	-15.3	180	120	30
g	26.0	25.8	25.0	-11.7	-12.0	-12.7	-13.3	-13.5	-14.2	180	120	30
r	25.7	25.5	24.7	-12.0	-12.3	-13.0	-13.6	-13.8	-14.5	180	120	30
i	25.0	24.8	24.0	-12.7	-13.0	-13.7	-14.3	-14.5	-15.2	180	120	30
z	24.3	24.1	23.3	-13.4	-13.7	-14.6	-15.0	-15.2	-15.9	180	120	30
y	23.1	22.9	22.1	-14.6	-14.9	-15.6	-16.2	-16.4	-17.1	180	120	30

Table 1: The 30-second 5-sigma depths are taken from Bianco et al., 2022 (in orange). The absolute magnitudes in each filter are given at two reference distances (350 Mpc and 700 Mpc). These depths are scaled to 120s and 180s assuming we are background limited. Relevant exposure times are provided for those absolute magnitudes.

WHY RUBIN

Simulated KN light curves in the six Rubin filters for different properties of the ejecta (mass and velocity) at four representative distances (30, 100, 200, and 300 Mpc)

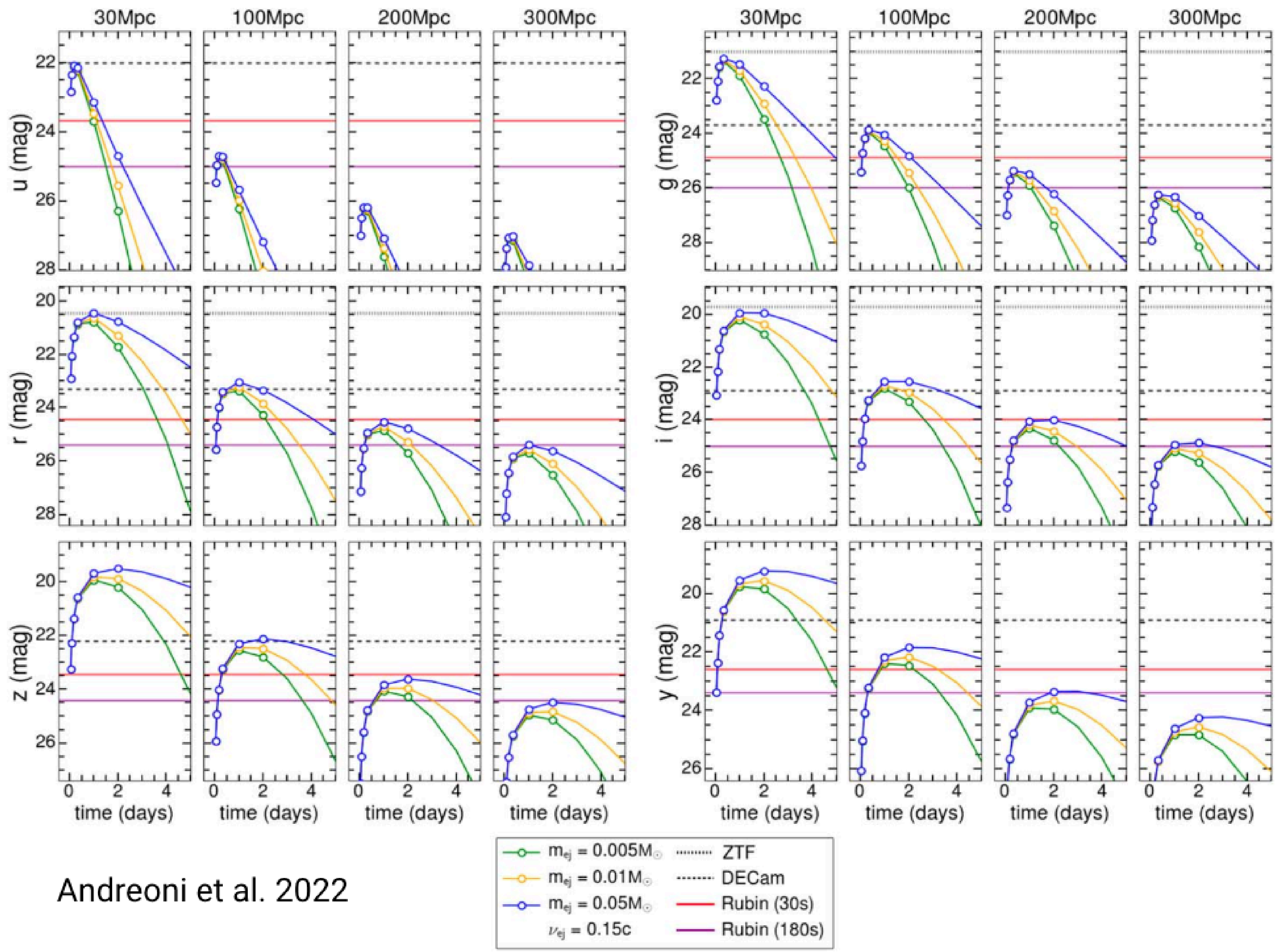


Andreoni et al. 2022

GET ON TARGET PROMPTLY and deep

- “Blue” and luminous kilonovae
- Optimistically, DECam (and potentially Pan-STARRS) could reach the sources
- But this is optimistic ***and*** we will need to go ~1 mag deeper to see a rapid fade and reduce false positives

WHY RUBIN



Andreoni et al. 2022

- “Red” and faint kilonovae
- Impossible with any other facility than Rubin
- In reality - quite possible true candidates will be somewhere in between

Rubin is gold!
Essential, unique and game changing facility in this area

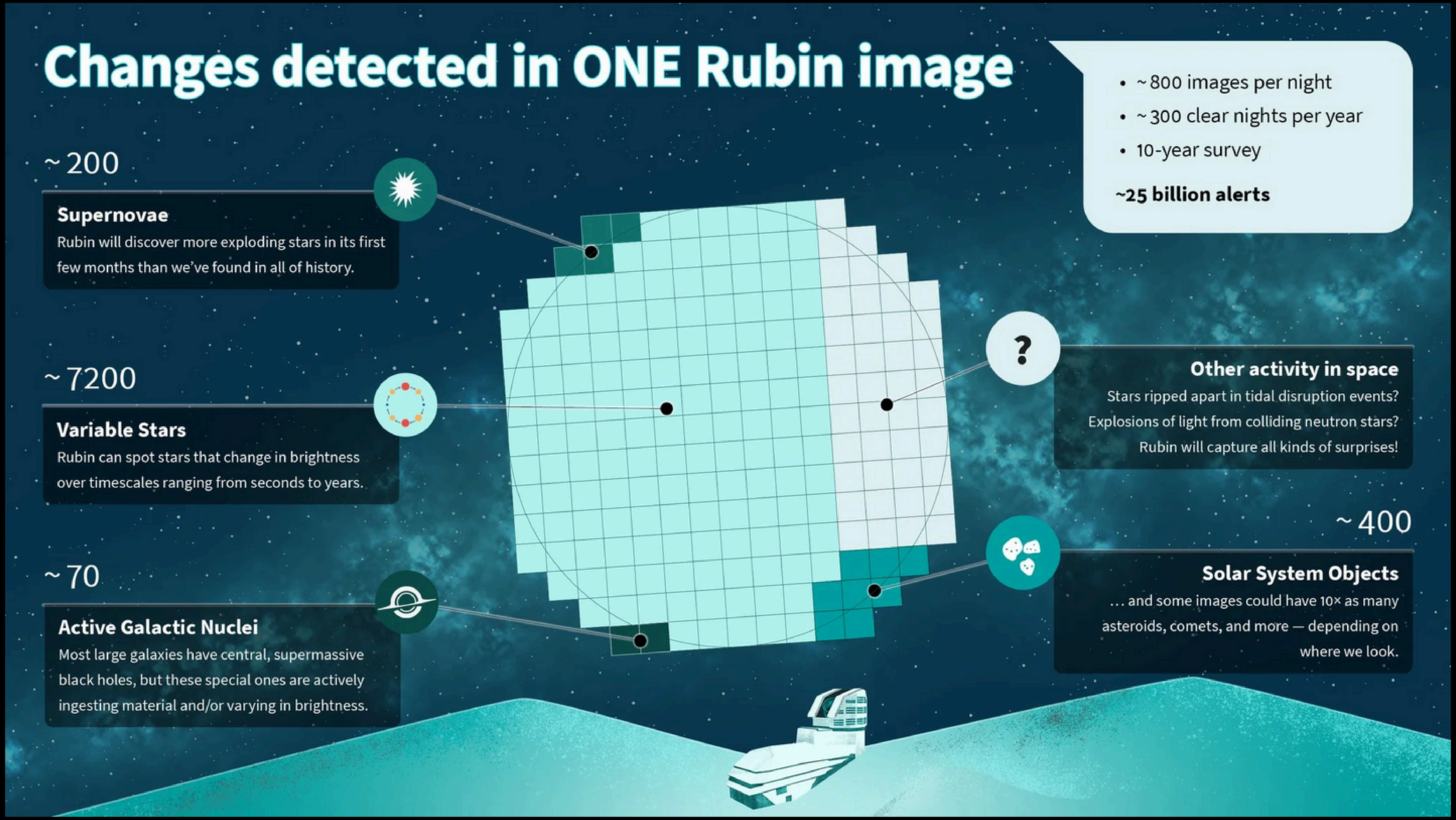
Alert streams and Brokers

Alert stream will have ~10^5 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 metadata, 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, enrich, and classify alerts, enabling efficient follow-up selection.

Fink as an example

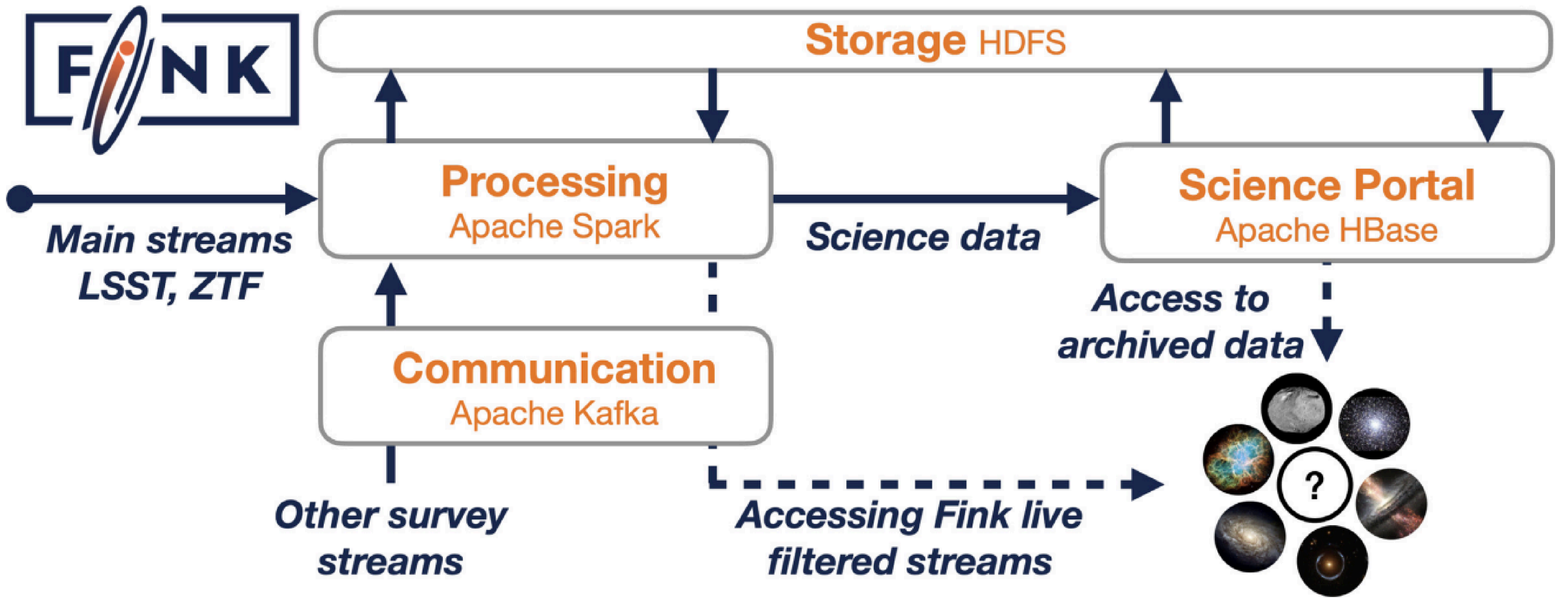


Figure 1. Architecture of FINK. Each box is a cluster of machines deployed on a cloud. The main streams of alerts for FINK (ZTF and LSST) are collected and processed inside the `Processing` cluster running APACHE SPARK (see Sections 4.2 and 4.3). At the end of the processing, a series of filter divides the stream into substreams based on user needs, and data are sent to subscribers via the `Communication` cluster running APACHE KAFKA (see Section 4.6.1). At the end of the night, all processed data are aggregated and pushed into the `Science Portal`, based on APACHE HBASE, where users can connect via a web browser and explore all processed FINK data (see Section 4.6.2). Alert data and added-values are stored at various stages on the HDFS. Other survey data streams (such as alert data from LIGO/Virgo, *Fermi*, or *Swift*) are collected by the `Communication` cluster and sent to the `Processing` cluster to be used to annotate the main stream of alerts. See text for more information on each component.

https://fink-broker.org/

Yesterday NEWS! --> Rubin is getting ready for the first public alerts!
They are being planned for February 4th 2026!

PRESENT & FUTURE

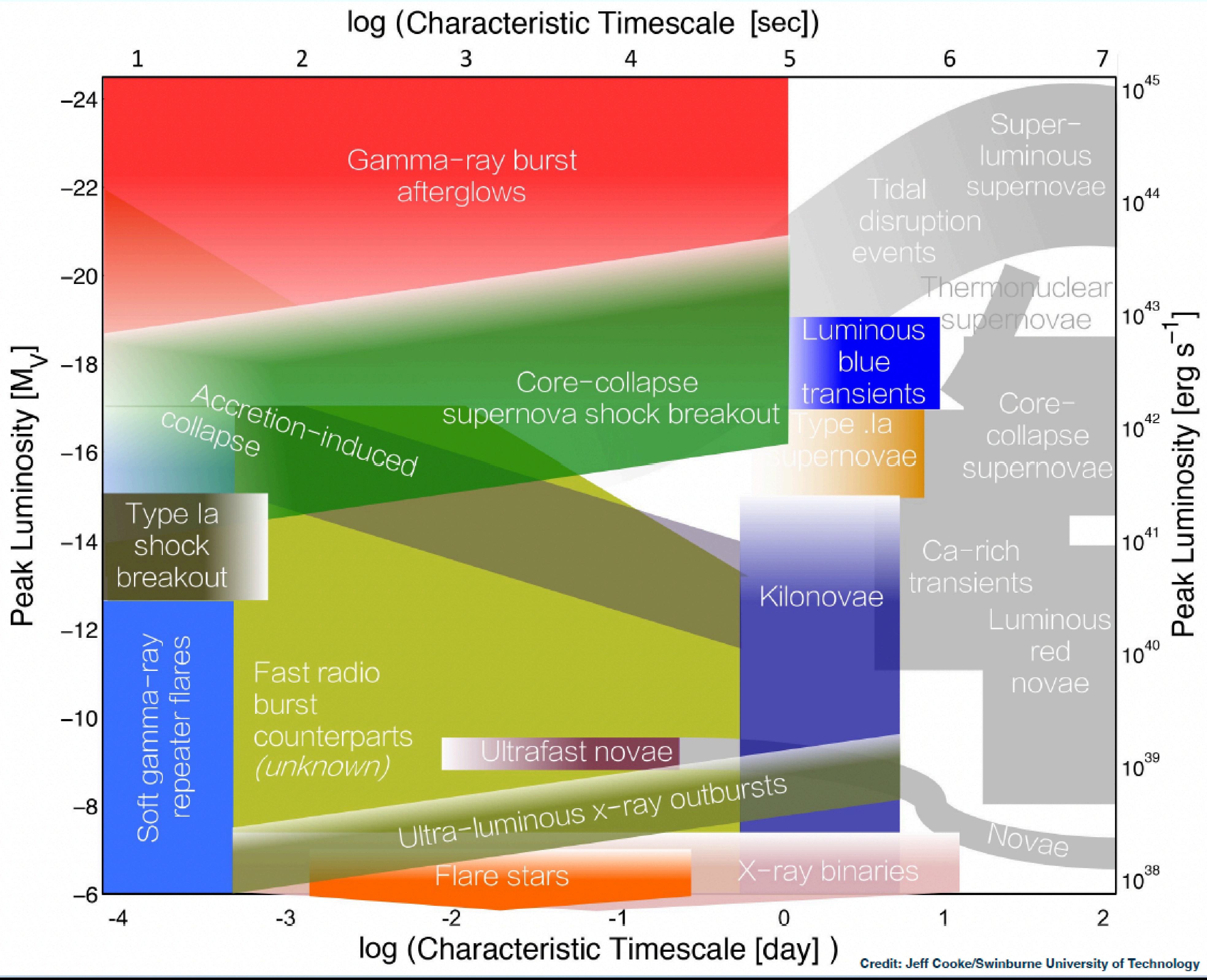
WHAT?

Novae
X-ray binaries
Supernovae
GRBs
Luminous Blue Transients
Tidal disruption events
Kilonovae
Soft Gamma-ray Repeaters
Fast Radio Bursts
unkown?
And their host environments

WHY?

Limits of physics
Life cycle of stars
Galaxy environment and evolution

The transient zoo



Classification is not enough

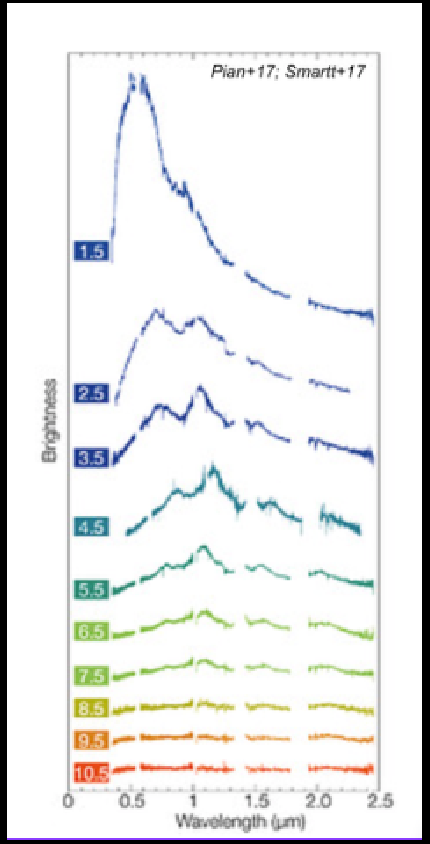
spectroscopic follow-up in the Rubin era

spectroscopy is essential

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

INAF follow-up strategy

- TNG (DOLORES, NICS, ToO)
- VLT (X-shooter - RISOTTO)
- SOXS/MUSE/4MOST/CUBES....
- International Collab. (inside Rubin Community)

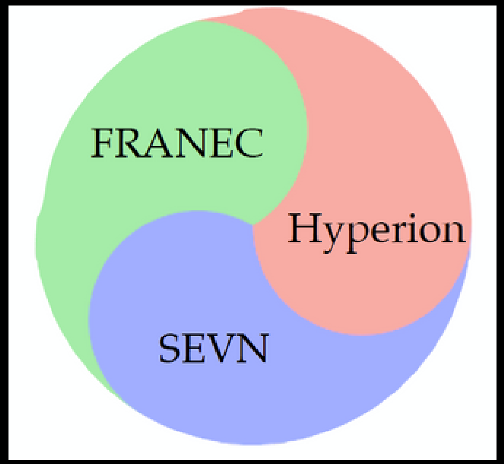


RUBIN-ET: INAF SCIENTIFIC CONTRIBUTIONS

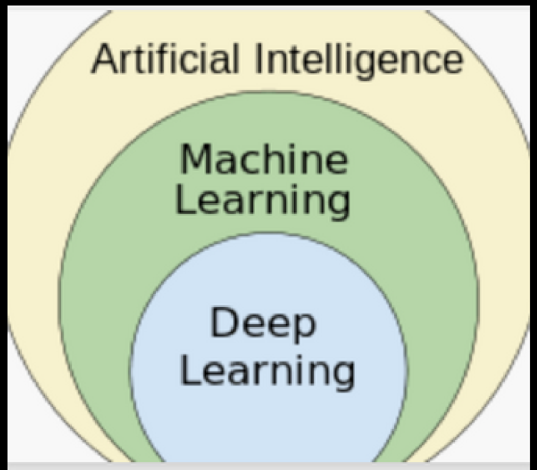
VERA C. RUBIN OBSERVATORY

INAF ISTITUTO NAZIONALE DI ASTROFISICA

Envisioning Tomorrow: prospects and challenges for multi-messenger astronomy in the era of Rubin and Einstein Telescope



+



ET Div: 3, 4, 7

Team building & Training

- ***2 post-docs funded by the grant*** *(E. Loffredo, F. Onori)*
- ***1 PhD student*** *(E. Pappalardo, Univ. Tor Vergata) - Thesis title: "Multimessenger approach to unravel stellar binary physics"*

Ext. collaborators: *Cristiano Ugolini, Manuel Arca Sedda, Irene Di Palma, I. Andreoni, R. Margutti, C. De Bom, A. Moller.*

INAF LARGE GRANT (awarded 2025 – 197 k€) – *PI: Piranomonte*

Co-Is: Melandri, Limongi, Spera, Brocato, Cristallo, Onori, Ragosta

Goal: Prepare the scientific and observational framework to fully exploit the upcoming Rubin Observatory (LSST) and Einstein Telescope era for multi-messenger astrophysics.

Key science themes:

- Formation and evolution of compact binary coalescences - binary population synthesis (with SEVN, POSYDON)
- EM counterparts of GW sources
- Synergies between GW, EM and theory

Approach:

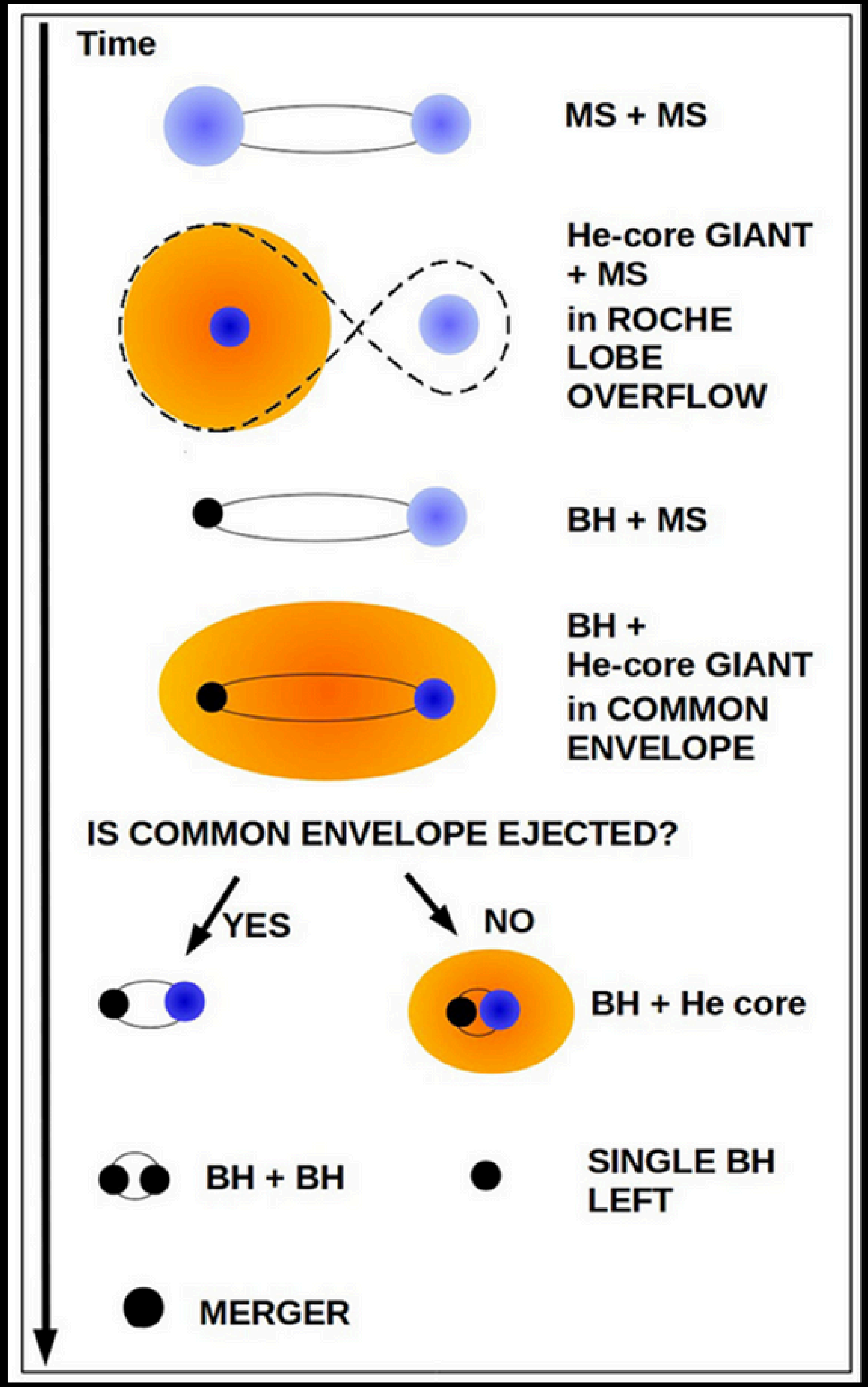
- End-to-end modeling: stellar evolution → explosions → population synthesis
- Machine learning for transient identification and strategy optimization
- Definition of observational strategies for wide-field surveys (e.g. Rubin) + rapid follow-up

Impact:

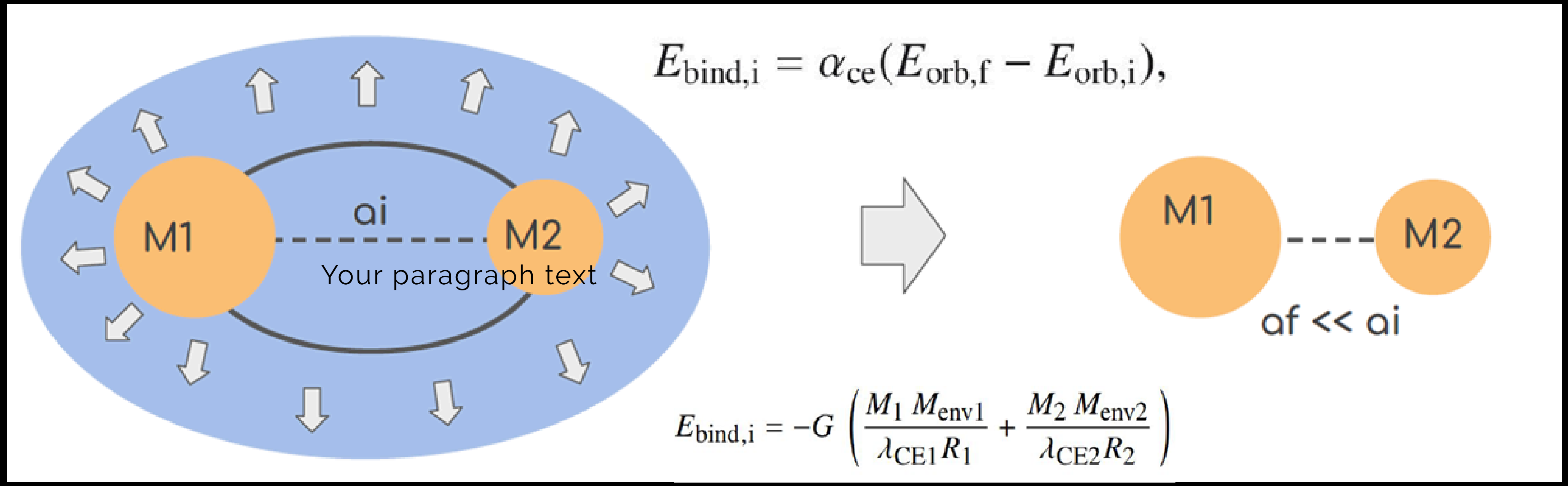
- Maximizing the scientific return of Rubin LSST and ET preparatory science
- Strengthening INAF's leadership in multi-messenger astronomy
- Building a bridge between theory, simulations, and observation

WORKING PROGRESS & SINERGIES

Which object can be informative both for GW and EM?



The majority of GW progenitors evolve through a common envelope phase



How often the CE is ejected rules the number of GW souces

Can we study this problem from a MM perspective? **Yes!**

We expect this events to have an associated transient, the

Luminous Red Novae (LRNe)

WORKING PROGRESS & SINERGIES

Multimessenger approach to unravel stellar binary physics

Team:
• ***1 PhD student*** *(E. Pappalardo, Univ. Tor Vergata)*
Supervisors: *Silvia Piranomonte, Cristiano Ugolini, Manuel Arca Sedda, Irene Di Palma*

LRN - a multimessanger tool for astrophysics

Object: Transients associated with common envelope ejection and/or stellar mergers.

Goal: Produce catalogs of synthetic lightcurves, to cross-validate with Vera Rubin LSST's data.

Key science themes:
• Binary Stellar evolution processes, CE onset and mass transfer stability (with SEVN, POSYDON)
• Synergies between GW, EM and theory

Approach:
• Numerical: Frequency of LRNe in consolidated population syntheis codes → Rates
• Theoretical: Produce catalogs of lightcurves, to compare with observations → Refine astrophysical modelinf of stellar binaries
Theorethical: Improve CE physics in population synthesis codes

Impact:
• Maximizing the scientific return of Rubin LSST and ET preparatory science
• Breaking degeneracies present in stellar physics models → new physics from GW
• Building a bridge between theory, simulations, and observation

TIME DOMAIN & Multi-messenger astronomy

What’s required and what the 2030s will demand

Trigger & alert generation

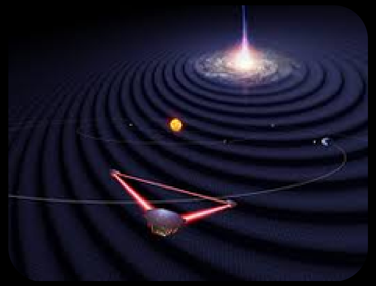
GW, neutrino detectors, high-energy satellites, and wide-field optical and radio surveys (e.g. Rubin, SKA) issue real-time alerts for transient and multi-messenger events.

Rapid localisation and identification

Networks of high energy/UV/optical/IR and radio facilities – from 1–4 m class telescopes to VLT/ELT, SKA, ngVLA, CTAO and future GW/neutrino detectors – rapidly refine positions, associate host galaxies and obtain first-epoch spectra.

Classification and physical characterisation

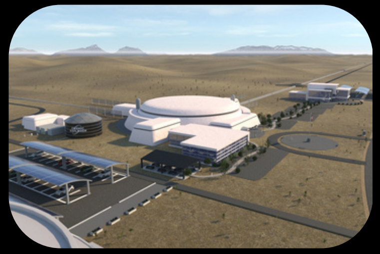
High-throughput spectroscopy and IFUs, combined with high-resolution imaging, deliver ejecta velocities, composition, energetics and environmental diagnostics.

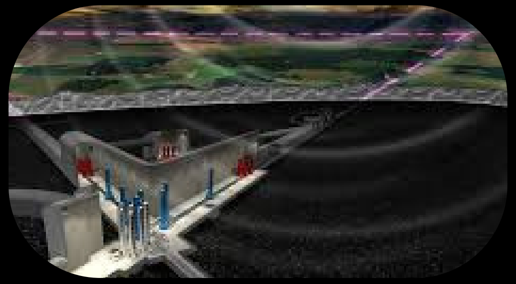

LISA


Virgo, Italy


LIGO, USA

LGWA


Cosmic Explorer

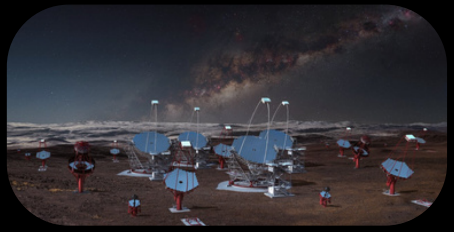

Einstein Telescope


KM3NeT


IceCube, South Pole


ELT


SKA


CTAO

TIME DOMAIN & Multi-messenger astronomy

What's required and what the 2030s will demand

Trigger & alert generation

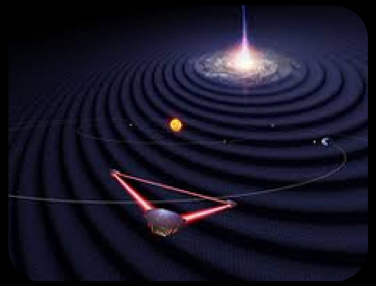
GW, neutrino detectors, high-energy satellites, and wide-field optical and radio surveys (e.g. Rubin, SKA) issue real-time alerts for transient and multi-messenger events.

Rapid localisation and identification

Networks of high energy/UV/optical/IR and radio facilities – from 1–4 m class telescopes to VLT/ELT, SKA, ngVLA, CTAO and future GW/neutrino detectors – rapidly refine positions, associate host galaxies and obtain first-epoch spectra.

Classification and physical characterisation

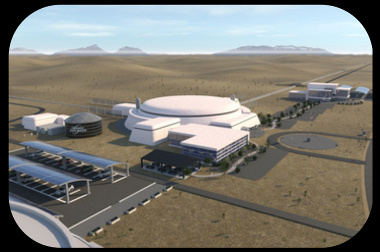
High-throughput spectroscopy and IFUs, combined with high-resolution imaging, deliver ejecta velocities, composition, energetics and environmental diagnostics.


LISA


Virgo, Italy

LIGO, USA

LGWA


Cosmic Explorer


Einstein Telescope


KM3NeT


IceCube, South Pole


ELT


SKA


CTAO

TIME DOMAIN & Multi-messenger astronomy

What's required and what the 2030s will demand

Trigger & alert generation

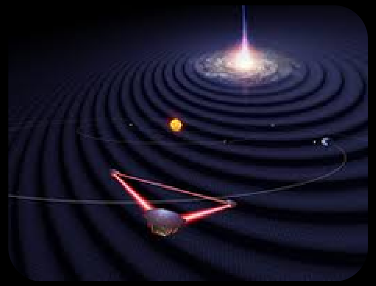
GW, neutrino detectors, high-energy satellites, and wide-field optical and radio surveys (e.g. Rubin, SKA) issue real-time alerts for transient and multi-messenger events.

Rapid localisation and identification

Networks of high energy/UV/optical/IR and radio facilities – from 1–4 m class telescopes to VLT/ELT, SKA, ngVLA, CTAO and future GW/neutrino detectors – rapidly refine positions, associate host galaxies and obtain first-epoch spectra.

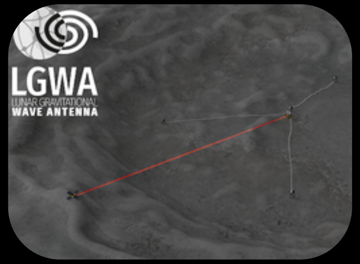
Classification and physical characterisation

High-throughput spectroscopy and IFUs, combined with high-resolution imaging, deliver ejecta velocities, composition, energetics and environmental diagnostics.

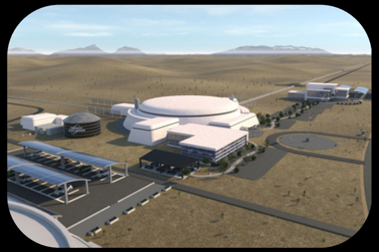

LISA


Virgo, Italy

LIGO, USA



LGWA


Cosmic Explorer

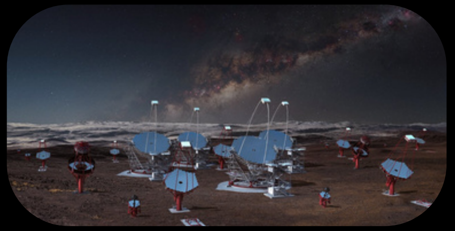

Einstein Telescope


KM3NeT


IceCube, South Pole


ELT


SKA


CTAO

STAY TUNED!

BACKUP SLIDES

VERA C. RUBIN OBSERVATORY

WHY RUBIN

How many BNS and NSBH might we expect to occur in O5?

all sky

Sky area Ω (sq deg)	Median number of BNS	90% confidence range of BNS with maps < Ω/year	90% confidence range of NS-BH with maps < Ω/year
50	14	6-31	0 - 3
100	18	8-41	1 - 4
150	20	9-45	1 - 5
250	25	11-56	1 - 7
500	32	14-70	2 - 9
1000	37	17-83	2 - 11

Table 2: Projected ranges of the number of BNS and NS-BH mergers in O5 (90% confidence) with the expected sky map size. The ranges highlight the current uncertainty in rates and projected detector performance in O5. In the rest of this document, we base our time ToO recommendation on the median number from the calculation described in the text.

with Rubin

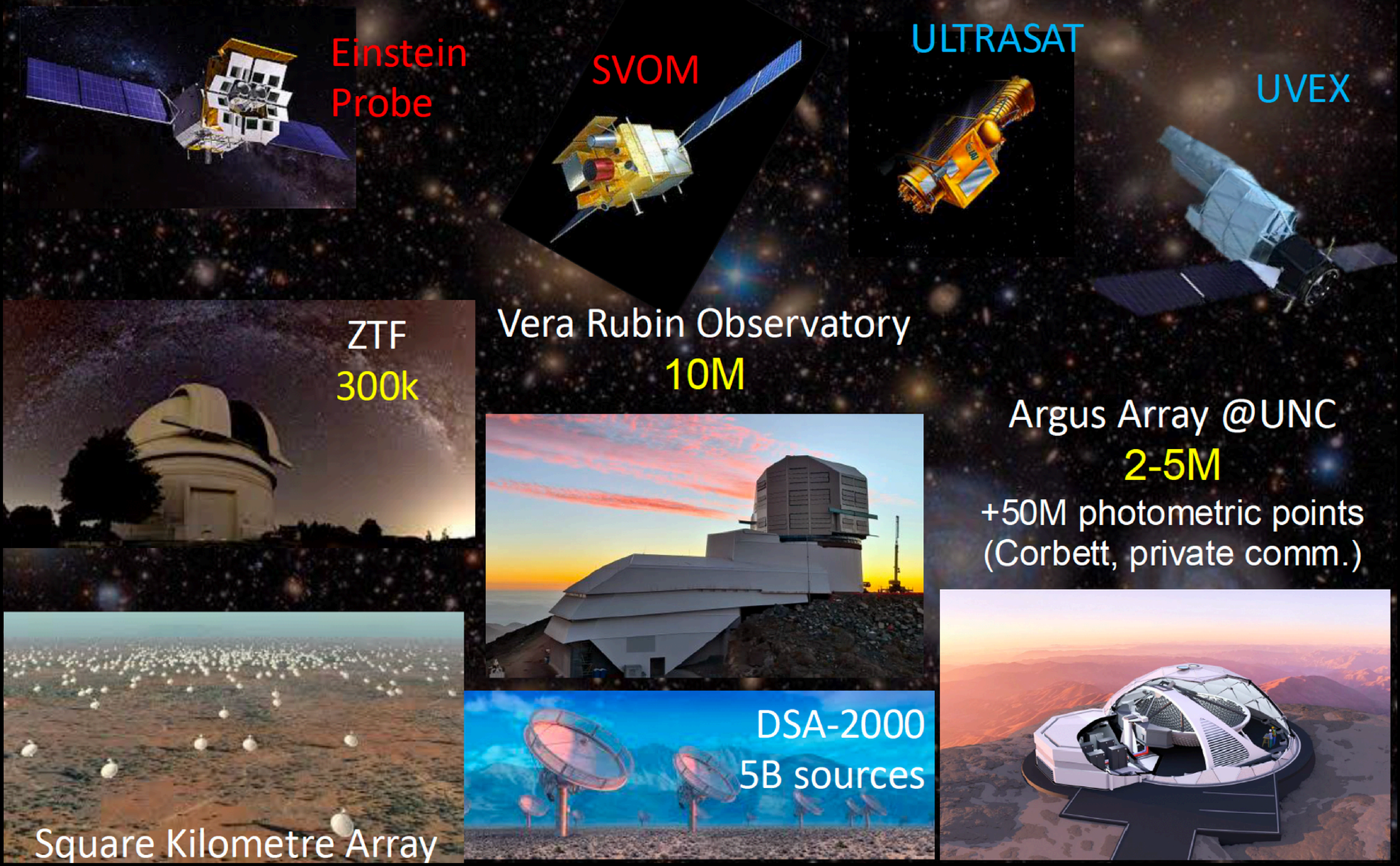
roughly ⅓ of the events in Table 2 are available **for immediate Rubin observing**.

Event rate (triggers/year): calculated by Shreya Anand at the meeting, with SNR > 12

Calculated using information from the official LVK observing scenarios study (Kiendrebeogo et al., 2023)

Note this was before the recent update on Virgo, and assumed distance range DBNS for Virgo was ~150 - 240 Mpc

Alerts per Night in 2024-2030

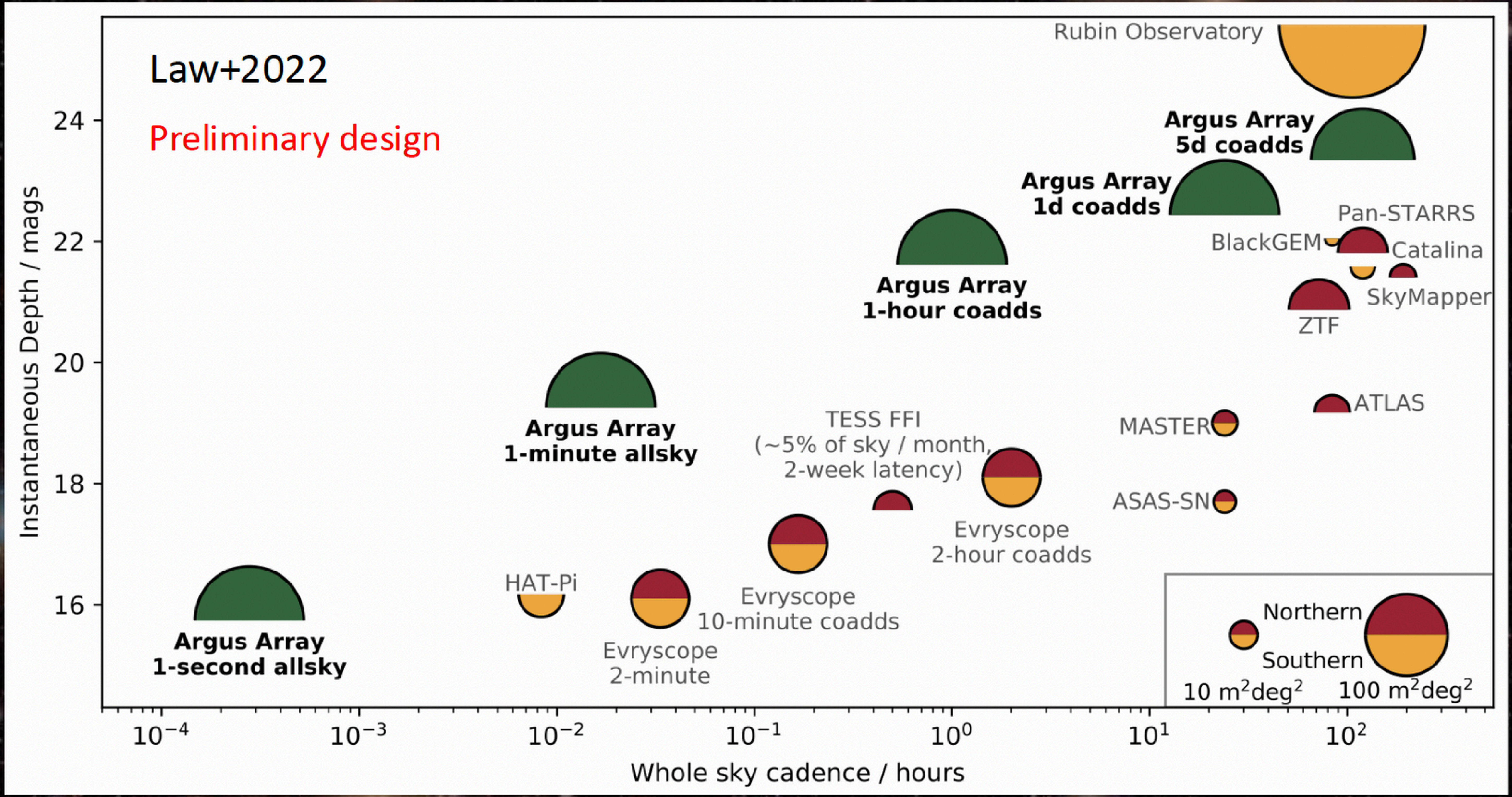


Argus Array

Preliminary

- 900 telescopes, 1.5 arcsec resolution, 55 Gpx
- Continuous 1s-30s observations, field of view of ~8000 deg^2
- Full available sky at ~24 mag in 2 filters every 5 nights via stacking

Argus Array


Law+2022
Preliminary design
Rubin Observatory
Argus Array
5d coadds
Argus Array
1d coadds
Pan-STARRS
BlackGEM
Catalina
Argus Array
1-hour coadds
SkyMapper
ZTF
Argus Array
1-minute allsky
ATLAS
TESS FFI
(~5% of sky / month,
2-week latency)
MASTER
ASAS-SN
Evryscope
2-hour coadds
Evryscope
10-minute coadds
HAT-Pi
Evryscope
2-minute
Argus Array
1-second allsky
Northern
Southern
10 m^{2}deg^2
100 m^{2}deg^2
Instantaneous Depth / mags
24
22
20
18
16
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
Whole sky cadence / hours

https://www.schmidtsciences.org/schmidt-observatory-system/

Argus Array

The Argus Array is a ground-based optical observatory designed for high-cadence, all-visible-sky survey imaging, optimized for the discovery of transient and variable objects as well as deep imaging. Full array operations are planned for 2028.

Argus will consist of 1,200 small-aperture telescopes with a combined collecting area equivalent to an 8-meter-class telescope. It will cover the visible sky from zenith down to an altitude of 38 degrees, yielding an instantaneous field of view of 8,000 square degrees. The combined focal plane will comprise 122 gigapixels of fast-readout, low-read-noise CMOS detectors with a plate scale of approximately 1 arcsecond per pixel. Each sensor will operate in one of two fixed optical filters (blue and red), providing alternating color information as the system tracks the sky.

Operation and data products

Argus' nominal operating mode will be continuous 60-second-cadence imaging of the Northern sky. These observations will be stacked over a wide range of timescales, from 15 minutes to more than six months, enabling time-domain astronomy on previously poorly explored timescales as well as deep survey science. In addition, the sensors can be operated at faster cadence for a bright-time subsurvey, enabling exploration of the transient universe on approximately second-long timescales.

Key data products include:

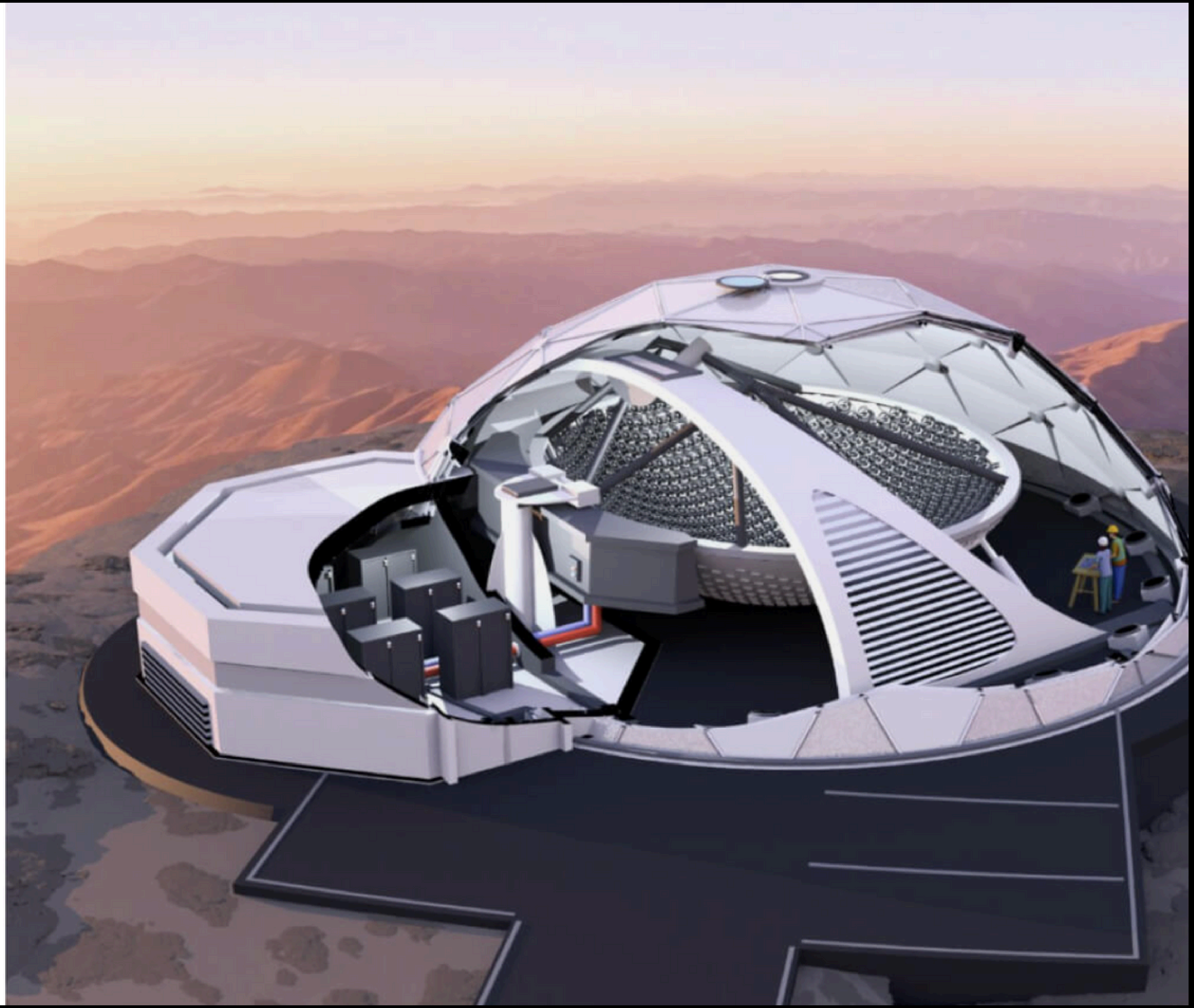
Images:
- 15-minute and longer co-added images transferred to the archive
- 1-minute images stored temporarily

Point-source sensitivity (g band):
- 1 second: m_g = 16.8 mag
- 1 minute: m_g = 20.0 mag
- 15 minute co-add: m_g = 21.5 mag
- 1 hour co-add: m_g = 22.3 mag
- 1 night co-add: m_g = 23.2 mag
- 1 week co-add: m_g = 24.1 mag
- 6 month co-add: m_g = 26.5 mag

Light curves and photometry: available for pre-selected and newly identified transient sources at base (1-second / 1-minute) cadence

Real-time transient alerts: disseminated through alert brokers

Lead Institution: University of North Carolina, Chapel Hill
Co-funder: Alex Gerko



https://www.schmidtsciences.org/schmidt-observatory-system/

Deep Synoptic Array (DSA)

The Deep Synoptic Array is a new radio array under development in Nevada, USA, with full array science operations planned for 2029. Designed for wide-field, multi-epoch survey science, the DSA will deliver time-domain, spectral and polarimetric data products with unprecedented sensitivity and coverage across the radio sky. It will provide near-complete sampling of the *uv*-plane, replacing a traditional correlator digital backend with a "radio camera" that produces images in real time.

Operation and data products

Over an initial five-year survey, the DSA will repeatedly image the entire viewable sky (~31,000 square degrees) over multiple epochs, with a full-width-at-half-maximum (FWHM) beam size of approximately 3 arcseconds. The DSA is expected to detect more than one billion radio sources in a combined full-Stokes sky map, with a typical rms noise of 500 nJy/beam. The array will operate continuously over the 0.7–2 GHz frequency range with full polarization sensitivity.

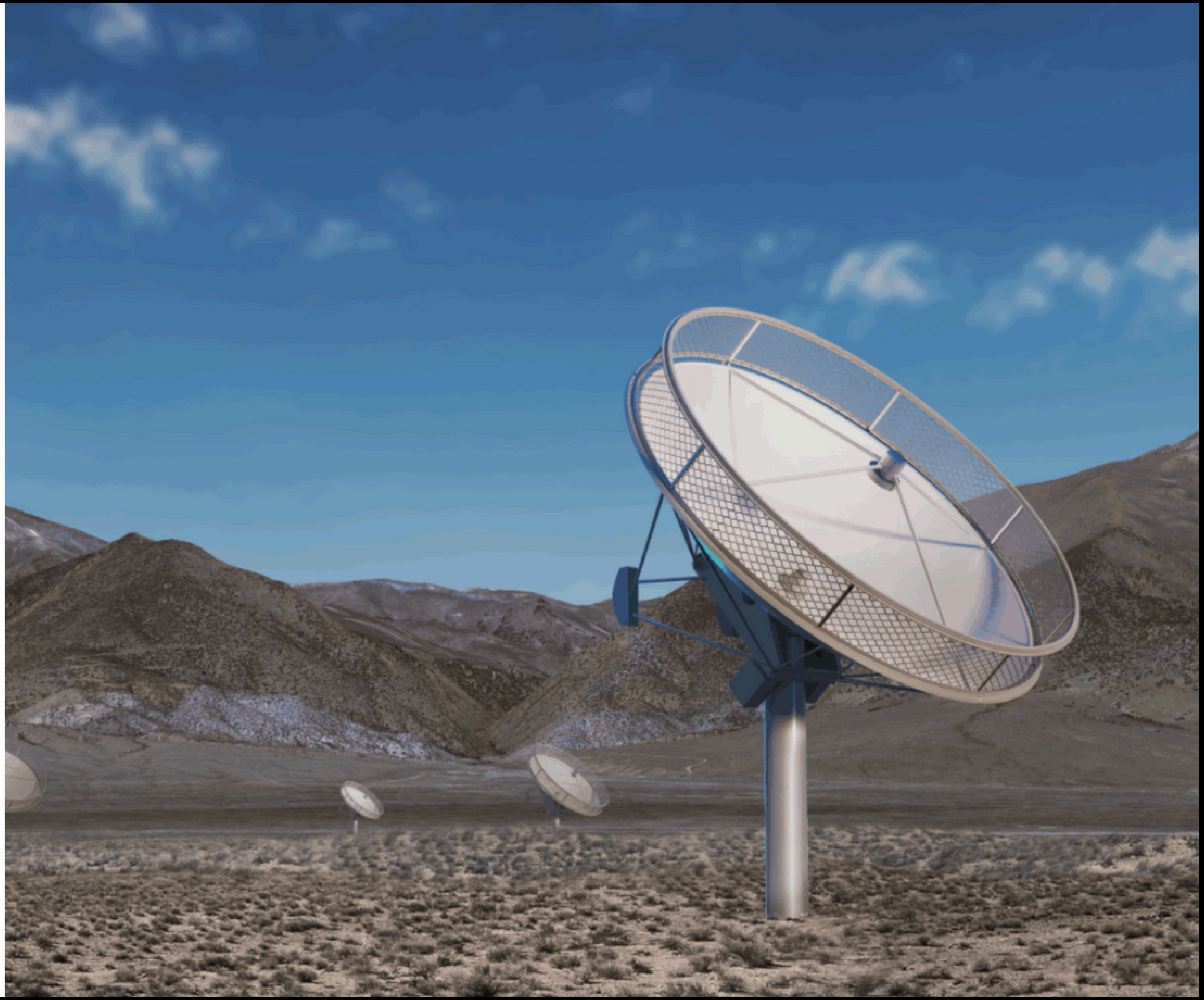
Survey cadence will emphasize maximizing opportunities for time-domain science on timescales ranging from less than one second to years. In addition to survey operations, a significant fraction of observing time will be dedicated to pointed and/or triggered observations, including community-led science programs and follow-up of gravitational-wave events.

Key data products include:

- **All-sky continuum images:** mosaics, multi-epoch data and wide-band products with 10 spectral windows
- **H I data cubes:** Galactic and extragalactic spectral line data
- **Polarization data cubes:** spectrally resolved full Stokes for millions of sources
- **Pulsar timing datasets:** folded pulsar profiles
- **Transient alerts:** rapidly issued for transients identified in continuum and high-time resolution data
- **Source catalogs** released with every major data release

Lead Institution: California Institute of Technology

Learn More



https://www.schmidtsciences.org/schmidt-observatory-system/

Large Fiber Array Spectroscopic Telescope (LFAST)

The Large Fiber Array Spectroscopic Telescope (LFAST) is a modular spectroscopic facility in which light from many small telescopes can be incoherently combined and delivered via optical fibers to medium- and high-resolution optical and near-infrared (NIR) spectrographs. Designed for flexible, fiber-fed spectroscopy, LFAST supports spectral resolutions spanning R ≈ 1,000 to 100,000.

The prototype system, LFAST-20x, consists of 20 modules with a combined collecting area equivalent to a 3.5 m^2 mirror and is planned to be installed in the Northern Hemisphere for on-sky testing. The optical arm of the prototype is expected to feed a reconfigurable optical spectrograph providing spectral resolutions ($R = \lambda/\Delta\lambda$) from approximately 1,000 to 10,000, with wavelength coverage spanning roughly 350–1,000 nm. The near-infrared arm is expected to feed a high-resolution NIR spectrograph with sensitivity spanning approximately 1–2 microns at spectral resolutions of order R ≈ 40,000.

Following an extended testing and commissioning phase, the LFAST-20x prototype will be evaluated for value as a scientific resource to the community, and may then be made available for queue-scheduled science operations. Successful deployment of the prototype will inform concept studies for a larger-scale LFAST array with custom spectrographs optimized for high-impact science, from time-domain and multi-messenger astrophysics to exoplanet studies.

Operations and data products

LFAST is designed to deliver science-ready data products with low latency and relatively modest data volumes.

Key data products include:

- **Raw data**
- **Extracted and calibrated spectra:** order-by-order spectra
- **Stitched one-dimensional spectra**
- **Quick-look one-dimensional spectra** for rapid transient follow-up

–Minute-scale latency for quick-look products
-Approximately 24-hour latency for fully science-ready products
-Planned integration with LSST/Rubin alert brokers

- **Derived data products**, including products for precision radial velocity measurements and other community-driven applications

Lead Institution: University of Arizona

Learn More →

https://www.schmidtsciences.org/schmidt-observatory-system/

Lazuli Space Observatory

The Lazuli Space Observatory is a 3-meter-class space-based astronomical facility designed for rapid-response observations and precision astrophysics across optical and near-infrared wavelengths. An unobscured, off-axis three-mirror anastigmat telescope delivers diffraction-limited image quality (Strehl ratio > 0.8 at 500 nm) over a broad 400–1700 nm bandpass, enabling high-performance imaging, spectroscopy, and high-contrast observations from a single platform.

Lazuli carries a focused suite of three complementary instruments. A wide-field optical imager provides imaging over a 30′ × 15′ field of view with high-cadence photometric capability across broad- and narrow-band filters spanning roughly 300–1000 nm. An integral field spectrograph delivers contiguous optical–near-infrared spectroscopy from 400–1700 nm at moderate spectral resolution ($R \approx 100–500$), optimized for stable spectrophotometry and rapid transient classification. A high-contrast coronagraph enables direct imaging of exoplanets and circumstellar environments, achieving raw contrasts of order 10^{-8} and post-processed contrasts approaching 10^{-9}.

Lazuli is designed around rapid responsiveness as a core capability. Operating from a lunar-resonant orbit, the observatory will be able to respond to external targets of opportunity within four hours of trigger receipt, with a goal of 90 minutes, and will support continuous observations of individual targets for up to ~12 hours. Its mission concept emphasizes flexible scheduling, automation-first operations, and coordination with contemporaneous time-domain surveys and multi-messenger facilities.

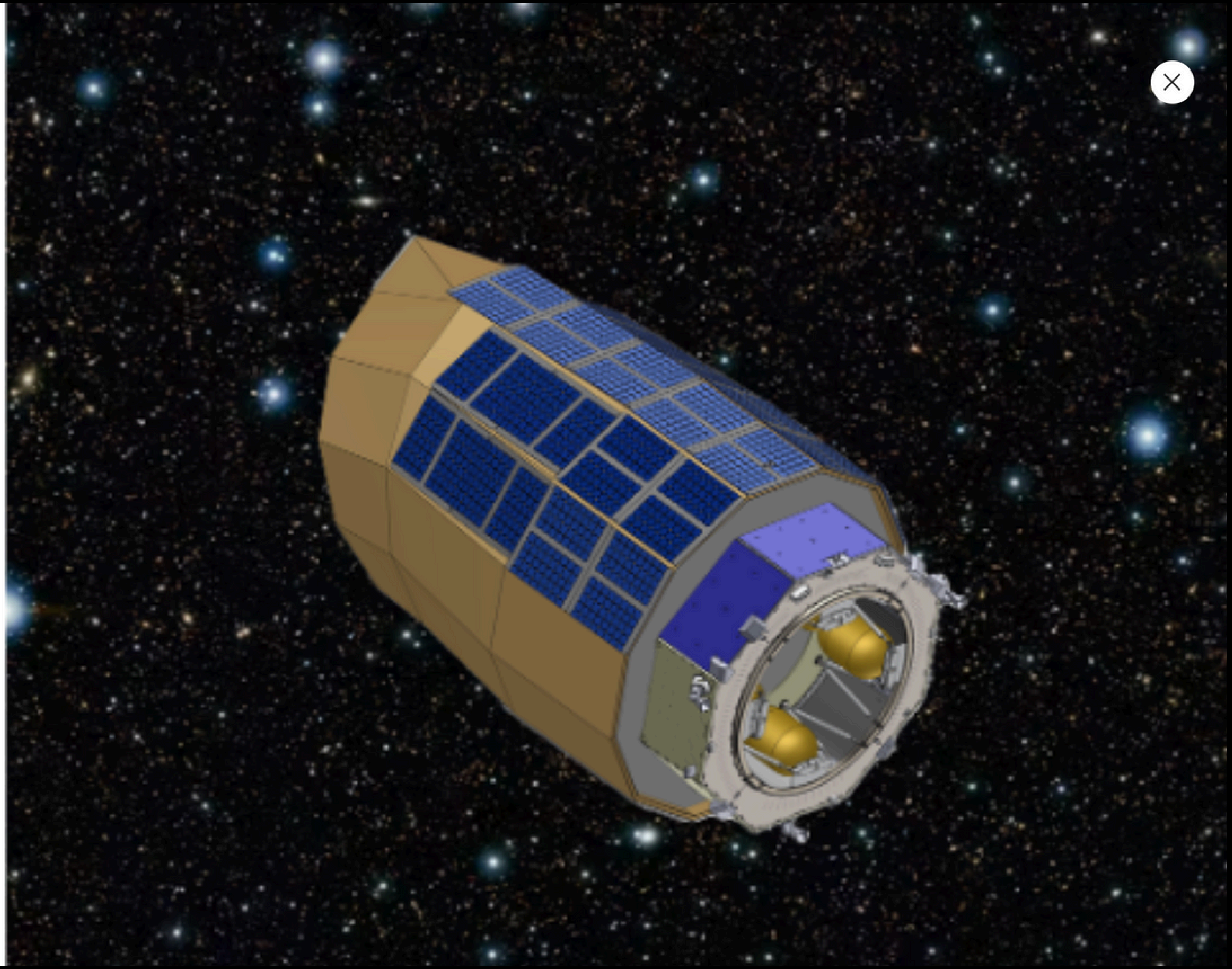
Operations and data products

Lazuli is designed for near-continuous ground contact and rapid data delivery, enabling responsive processing and dissemination of observations. The mission adopts an open data philosophy, with science-ready data products released to the global community following quality assurance and calibration, typically within days.

Key data products include:

- **Wide-field imaging data:** calibrated optical images and high-cadence photometric time series
- **Integral field spectroscopy:** raw frames, calibrated spectra, and reduced three-dimensional data cubes spanning 400–1700 nm
- **Coronagraphic imaging products:** science images, wavefront sensing data, and point-spread-function stability diagnostics
- **Rapid-response products:** quick-look data products supporting time-critical transient classification and follow-up
- **Spacecraft and instrument telemetry** supporting calibration, performance assessment, and archival analysis

Lead Institution: Schmidt Sciences



Understanding the nature of dark matter and dark energy

Goal
percent-level measurements of expansion history and growth of structure

Use multiple probes
weak lensing, galaxy clustering/Baryon Acoustic Oscillations (BAO), clusters, lensed time delays, Type Ia SNe, all as functions of redshift and combined with CMB.

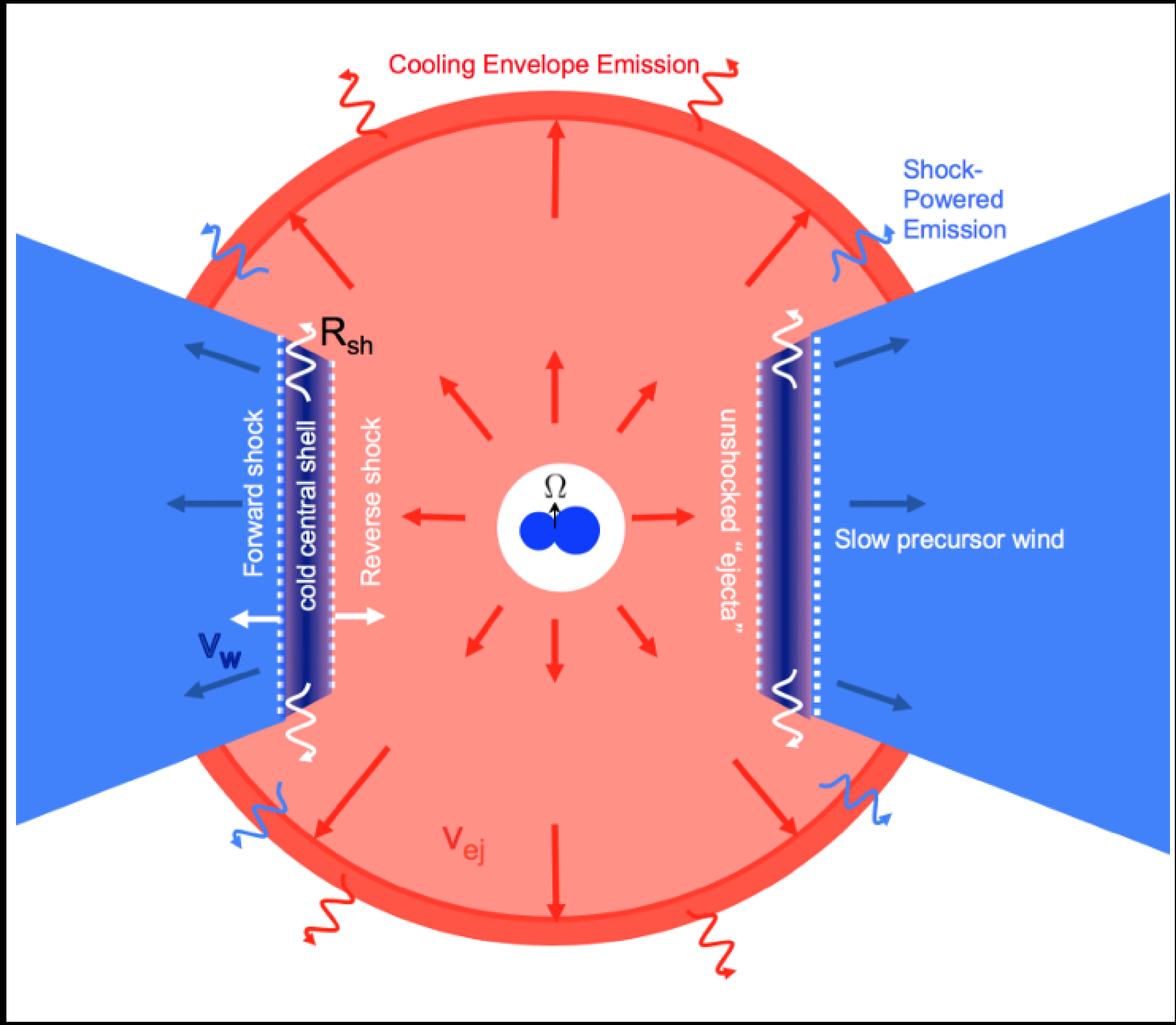
Numbers
~ 2 billion galaxies with measured shapes
~ 400,000 Type Ia supernovae


Credits: VRO


Credits: VRO

Ivezic et al. (2019)

LRNe emission mechanism



Metzger et al. 2017