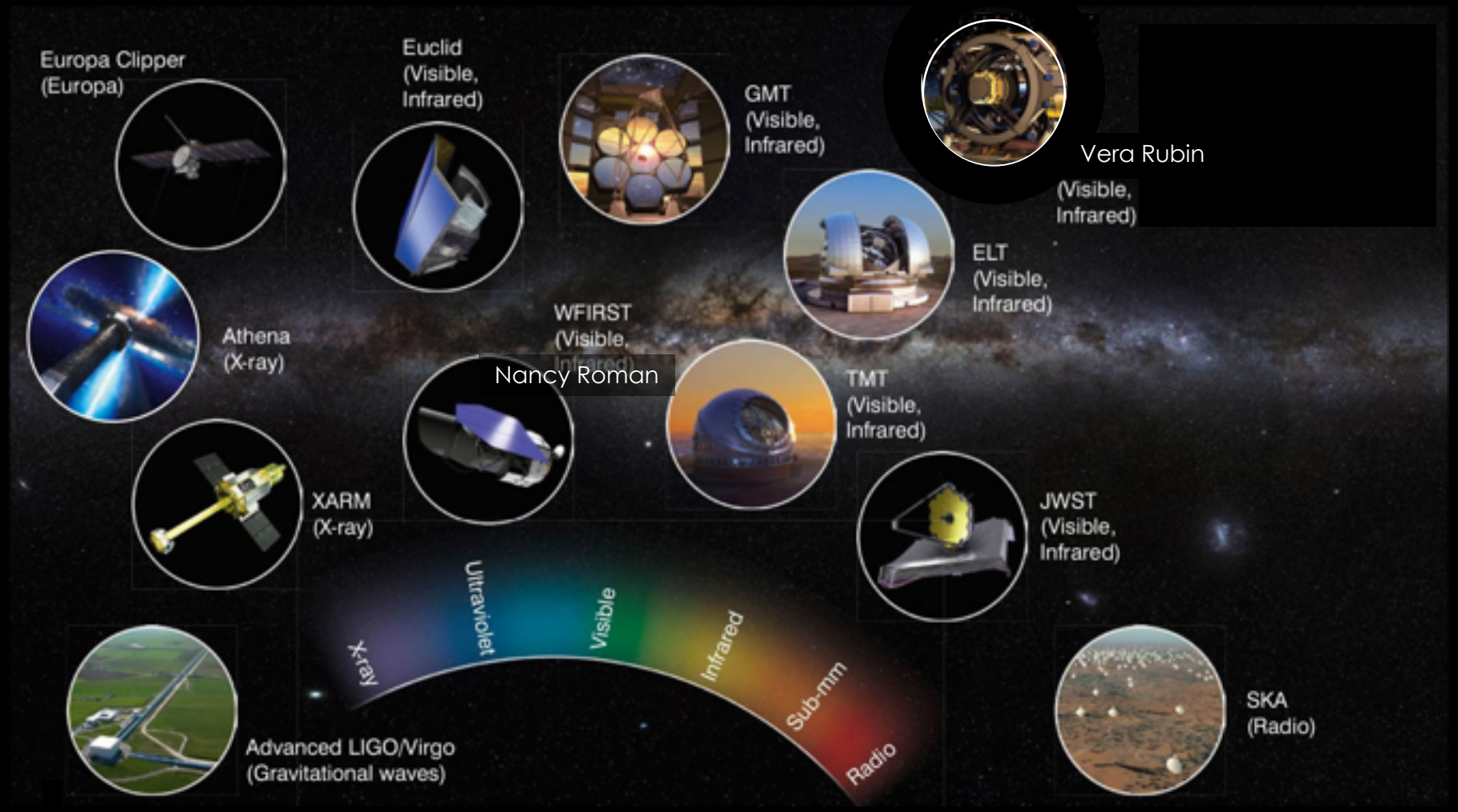
Le survey ottiche nell epoca dell astronomia multimessagera

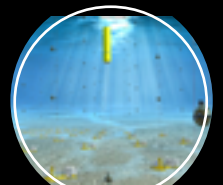
Maria Teresa Botticella

INAF - OSSERVATORIO DI CAPODIMONTE



CTA

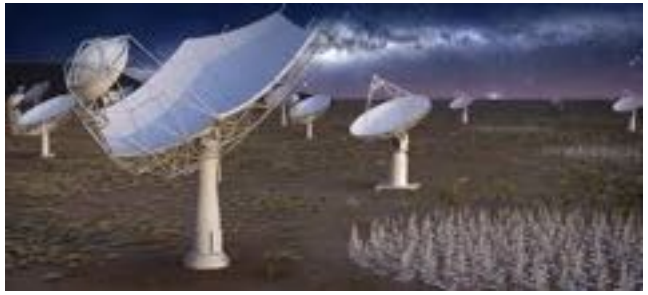
HYPER-KAMIOKANDE

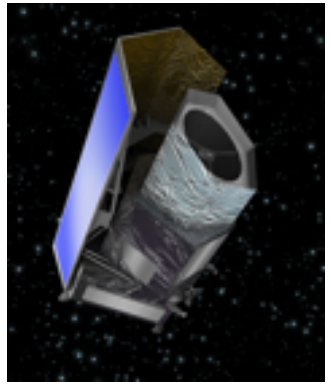


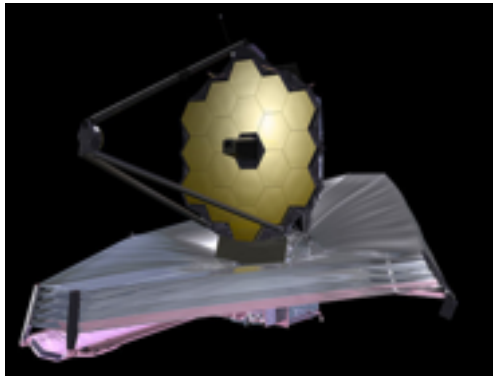
Km3Net

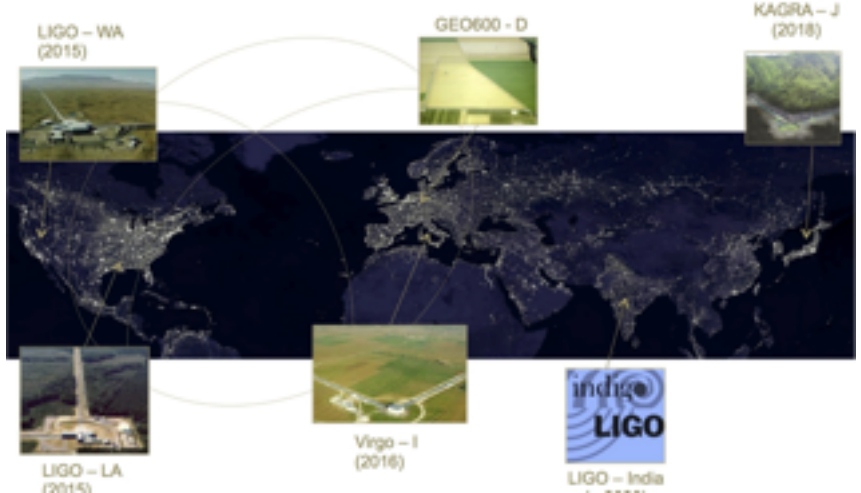
The Astronomy in the next decade

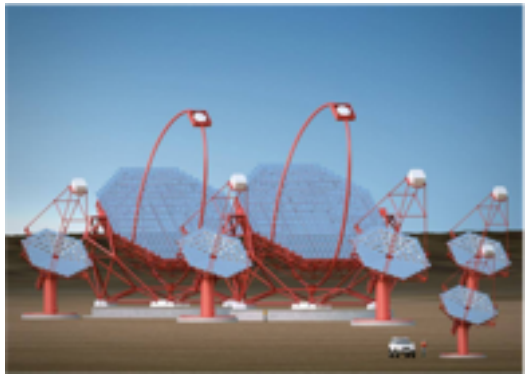
- Time domain
- Multi-wavelength
- Multi-messenger

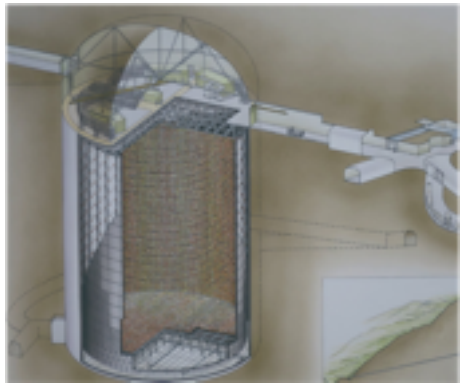






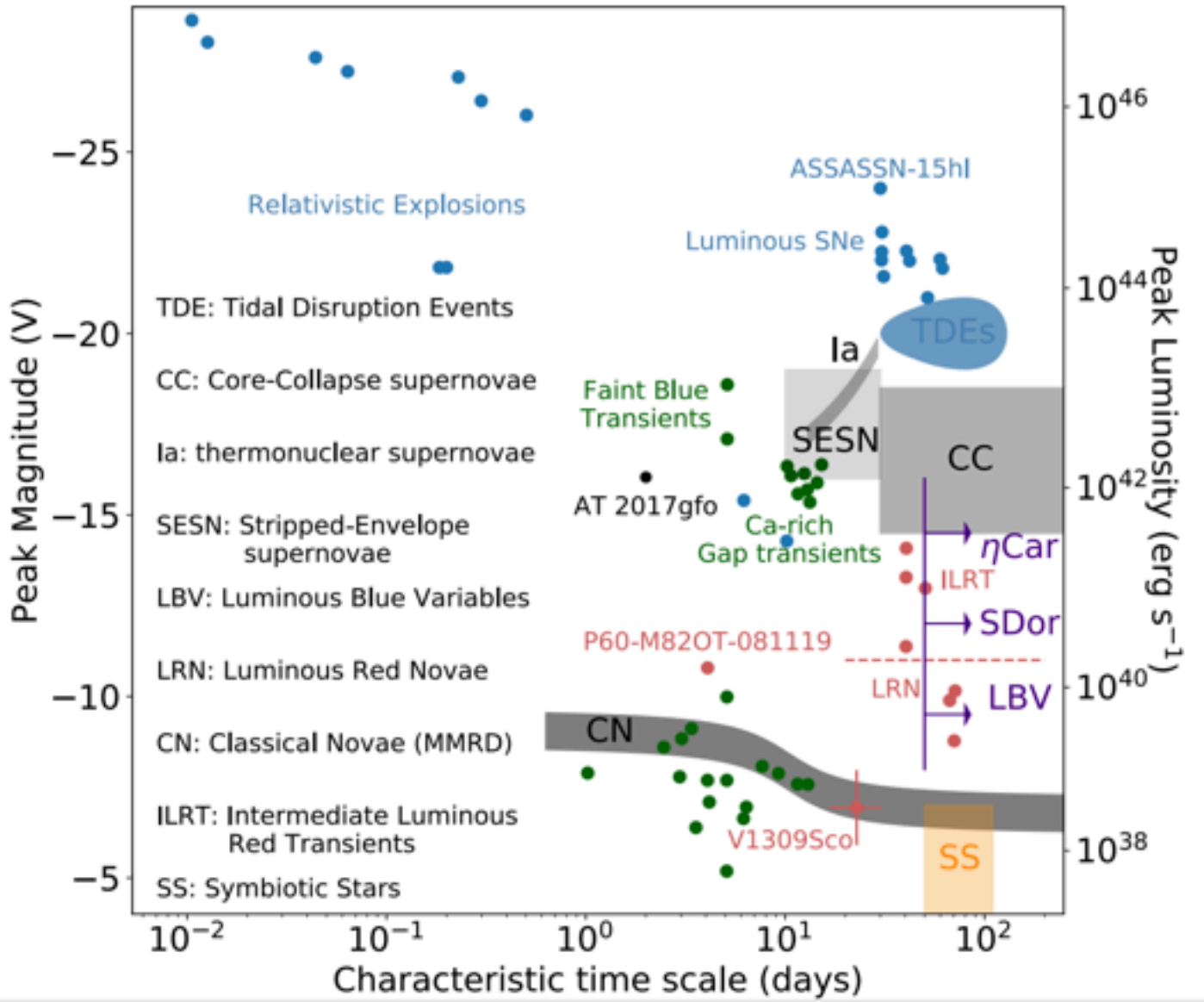




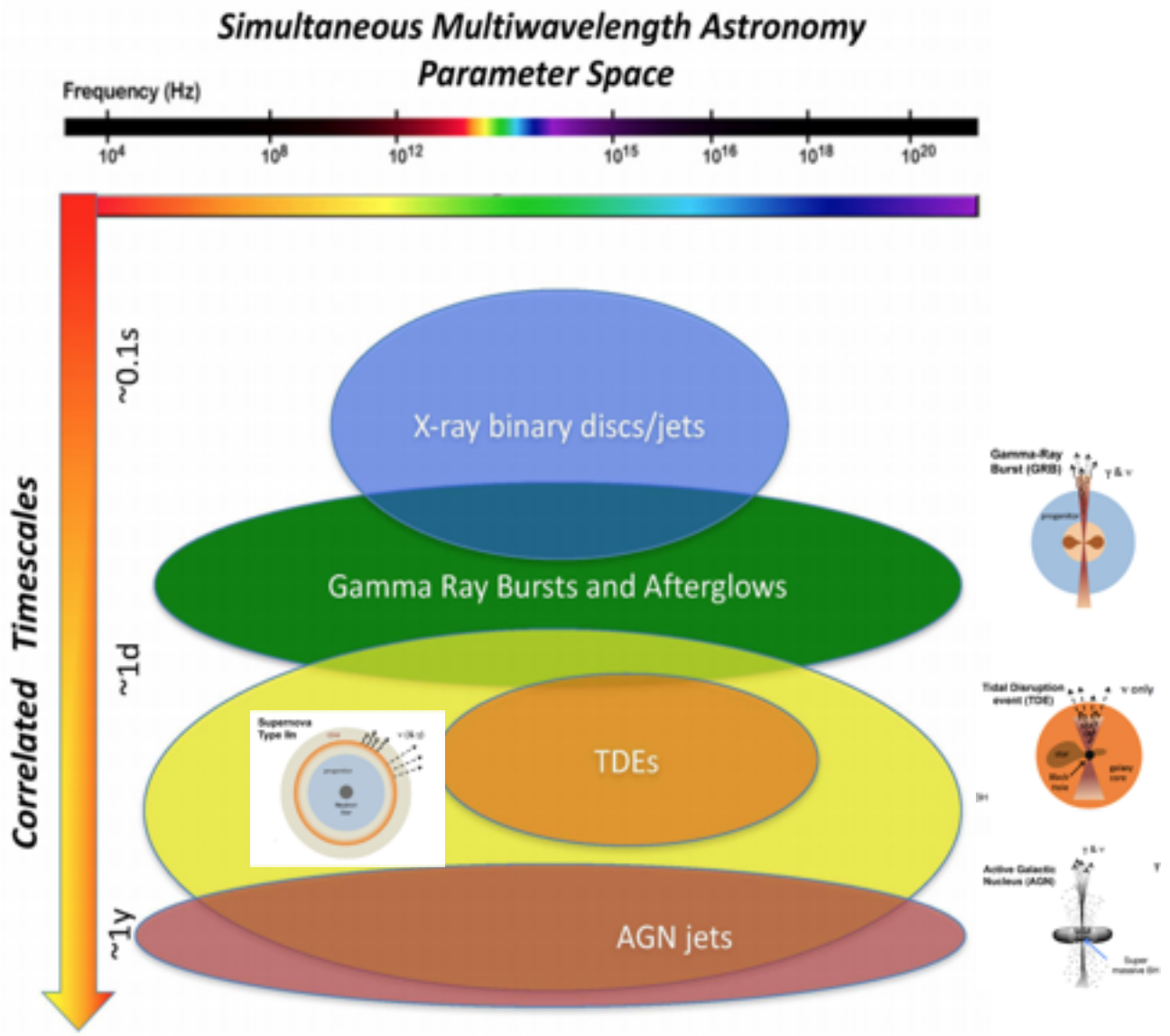


Time domain Astronomy

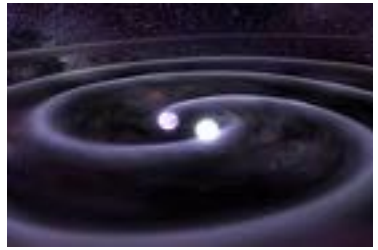
New regimes in observational parameter space



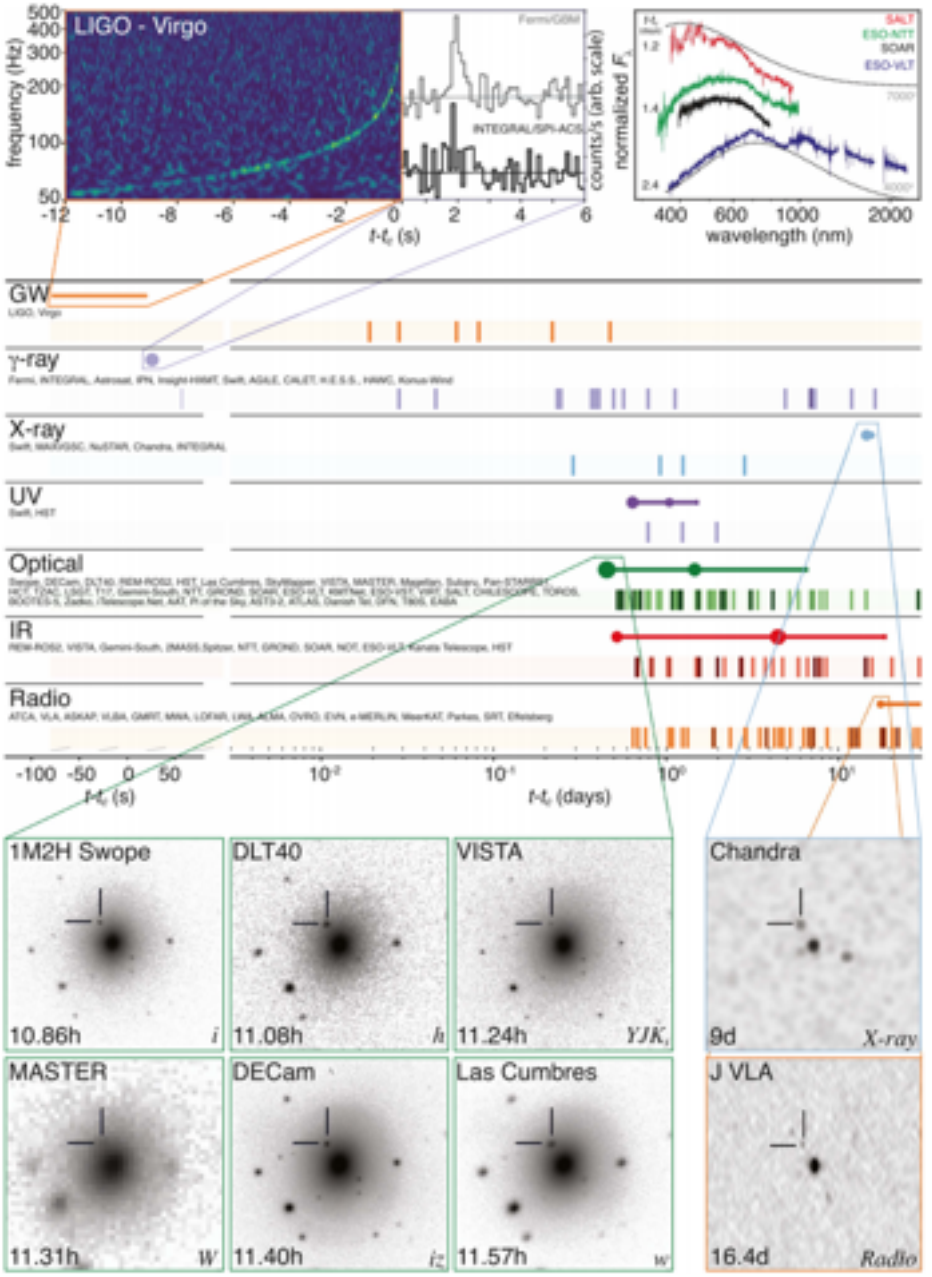
Multi-wavelength Astronomy



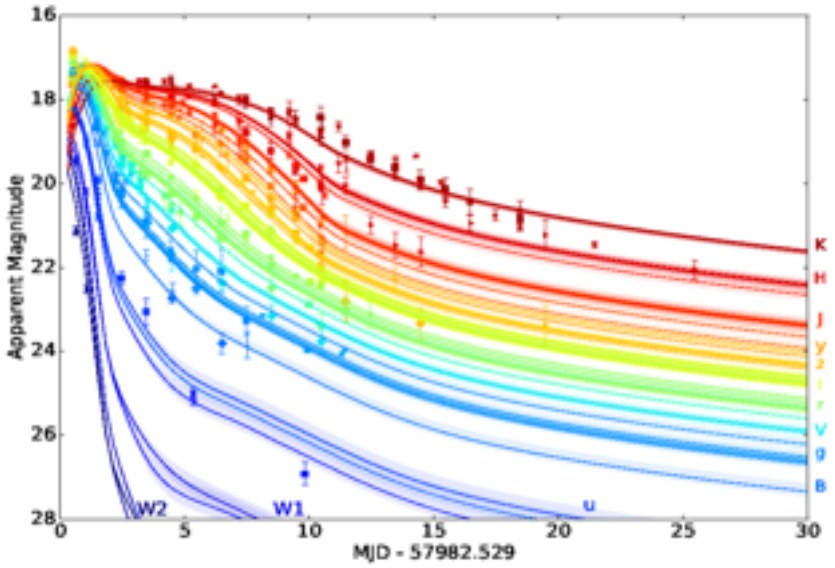
Multi-messenger Astronomy

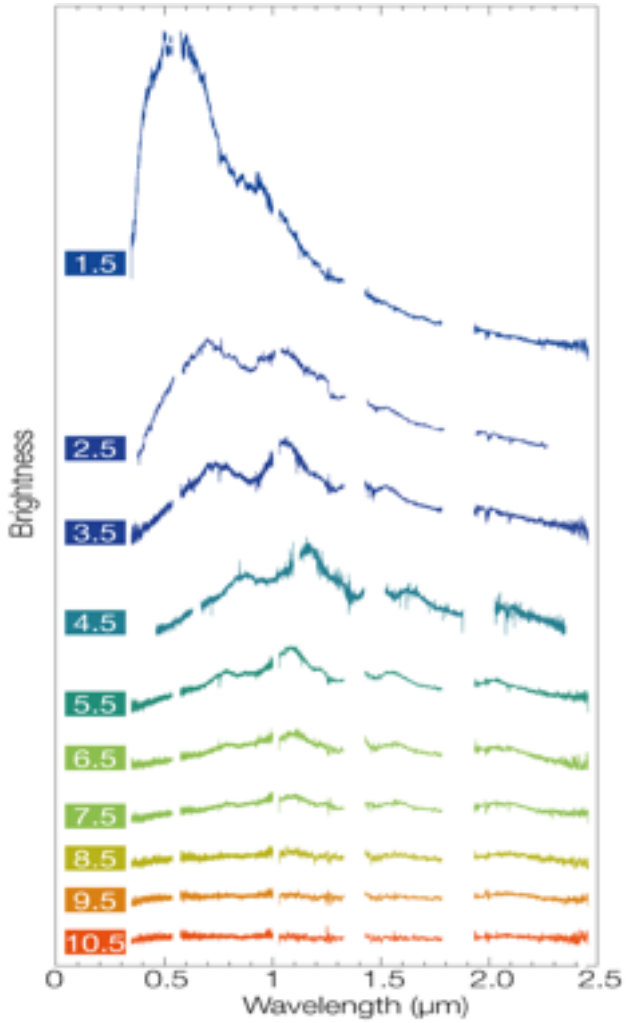


GW170817



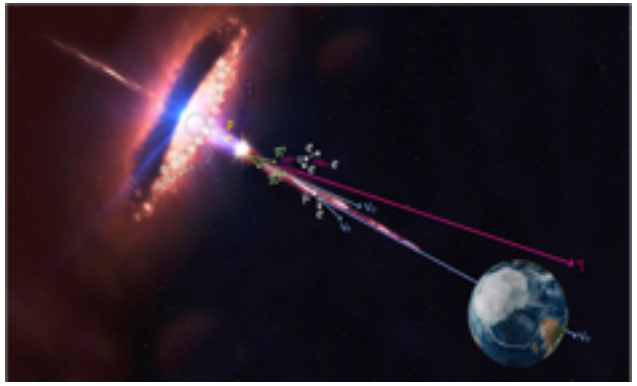
Multi-messenger Astronomy



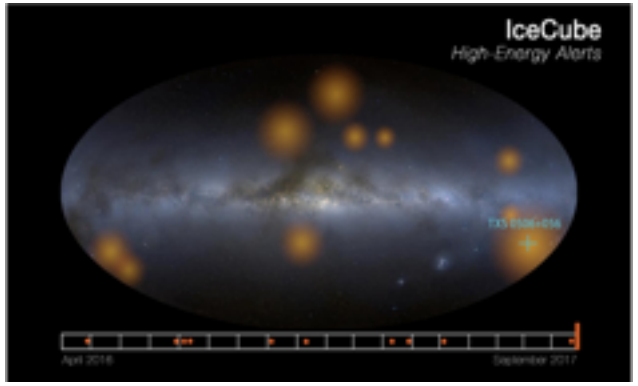


Abott et al 2018

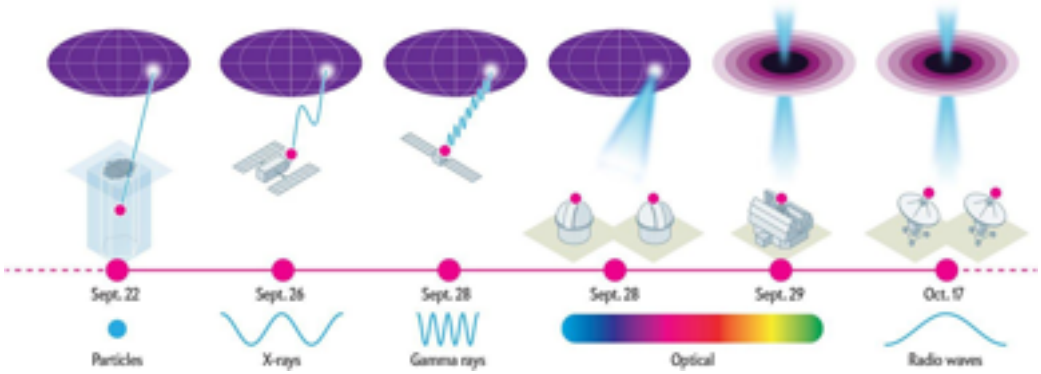
Multi-messenger Astronomy

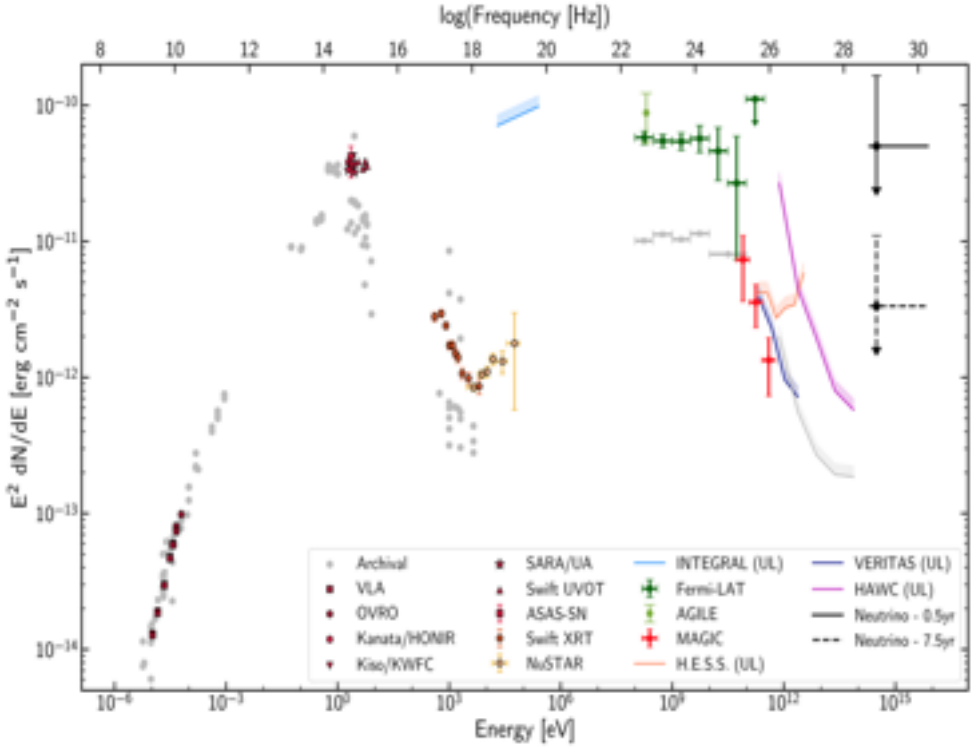


TXS 0506+056



IceCube-170922A

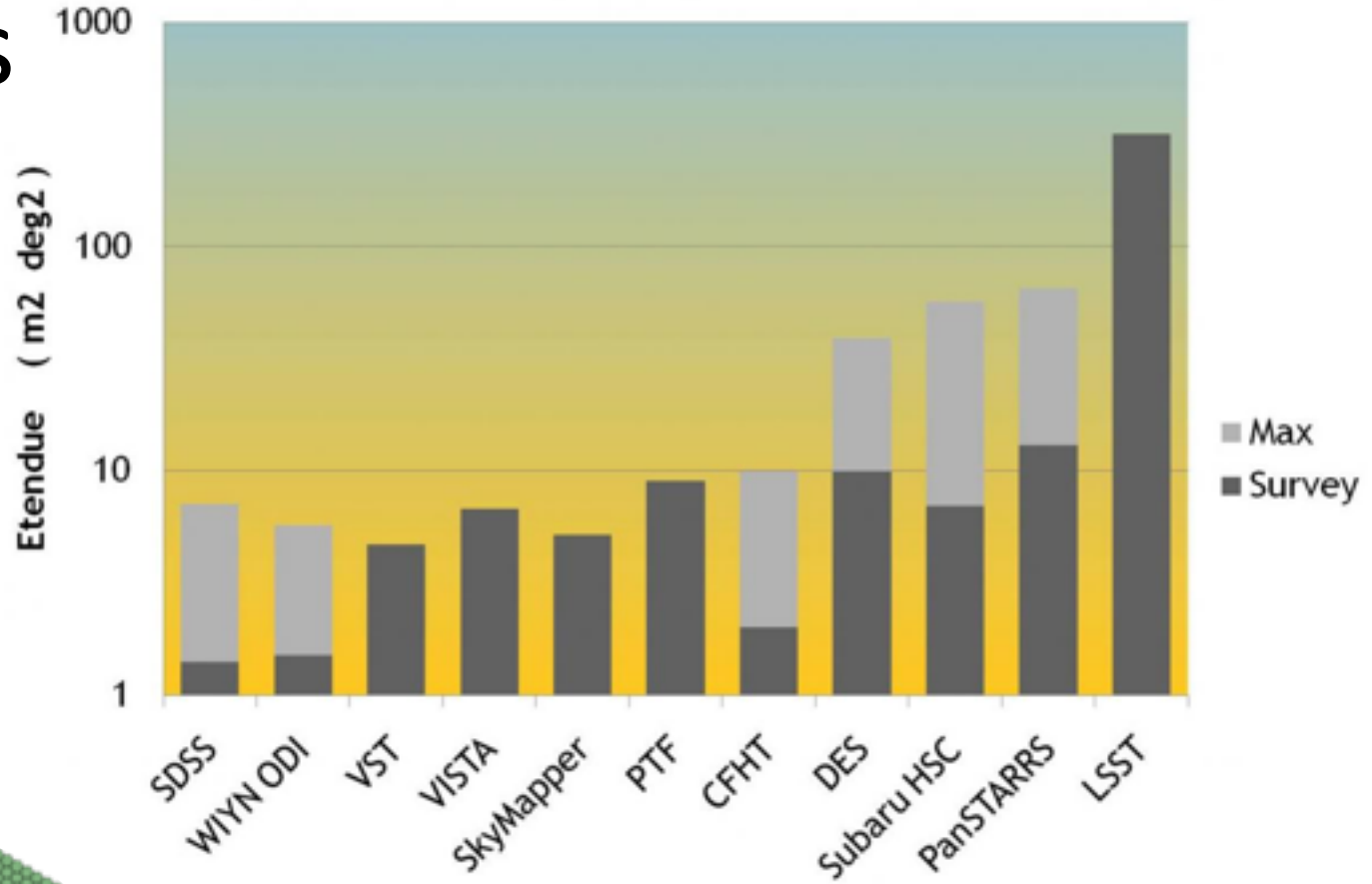


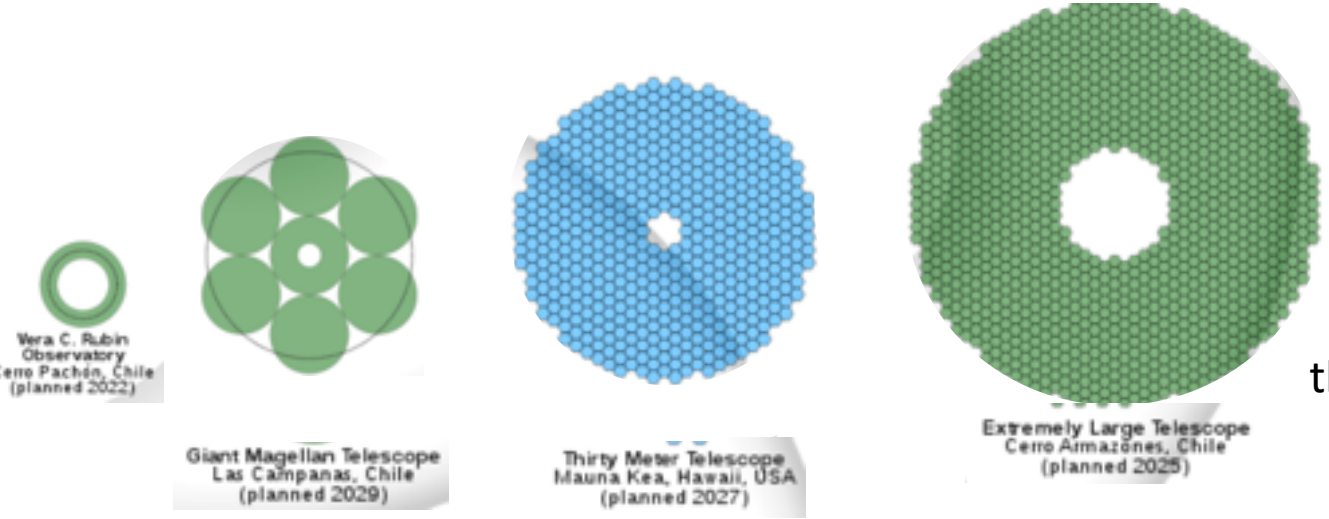


The next decade surveys

new generation of synoptic sky surveys

- wide areas of the sky repeatedly
- well-calibrated surveys
- well-described search method
- large datasets of uniformly selected objects
- discover samples of rare or unusual objects
- legacy archive for future generations





the volume of data will increase by several orders of magnitude

Legacy Survey of Space and Time

- High cadence to discover fast transients
- large volume to discover rare transients
- multi-band to measure transient colours
- longer survey duration (10 years)

huge volume and rate of the data

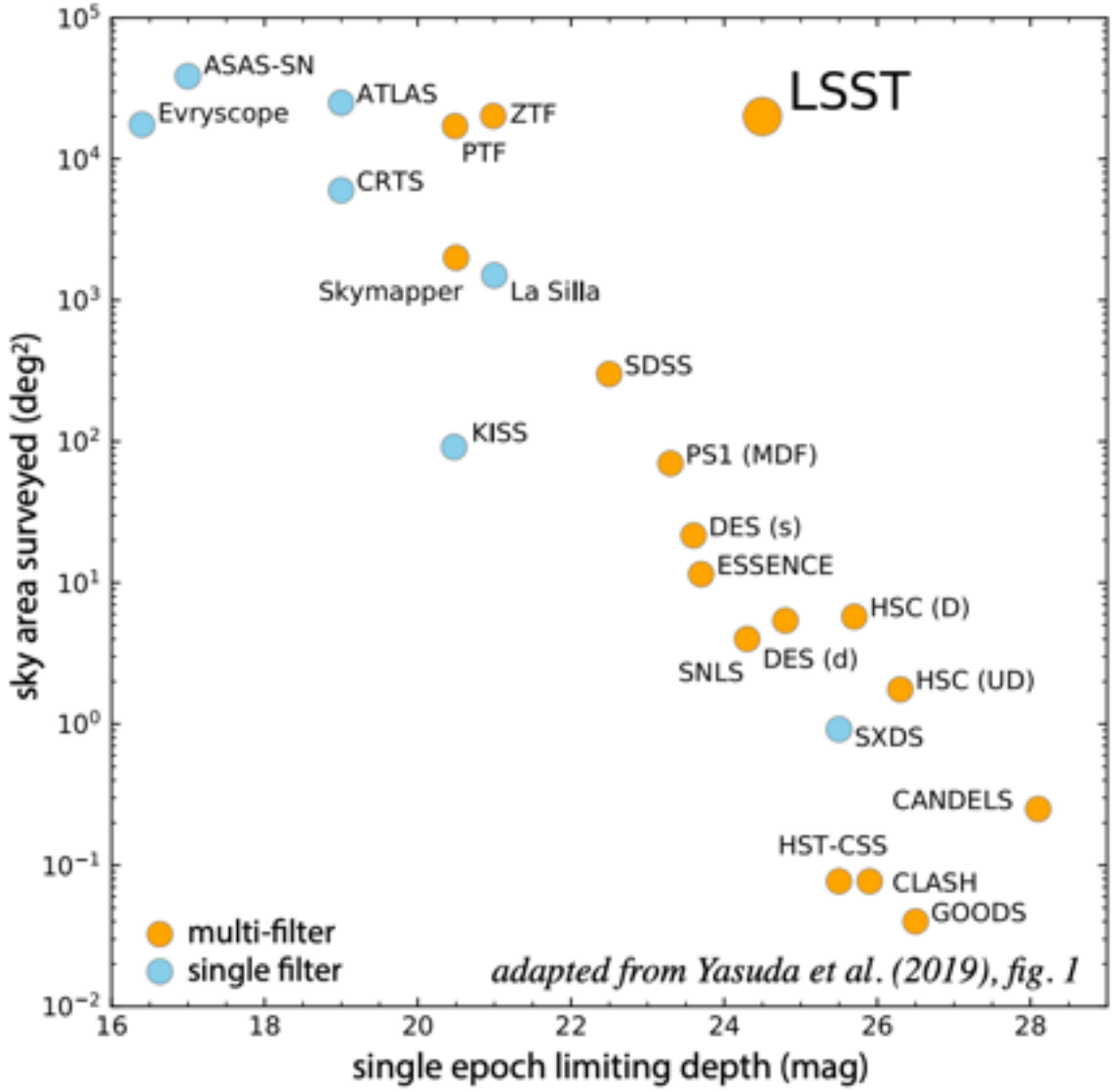
set of challenges :

real-time data processing

(event detection, filtering, characterization)

rapid dissemination of alerts to the astronomical community

developing public domain archives



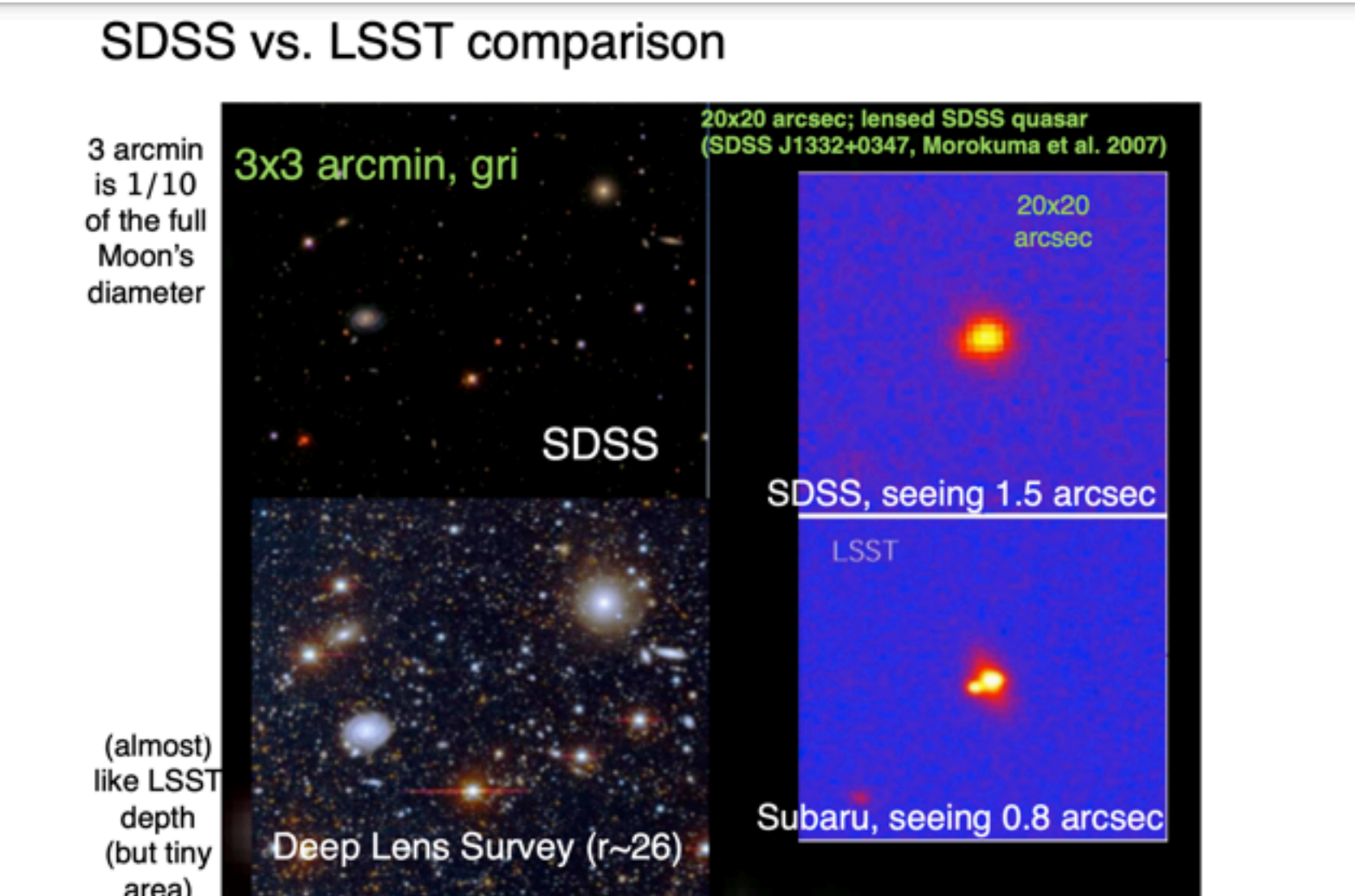
SDSS vs LSST

a digital colour map vs a digital colour movie of the sky

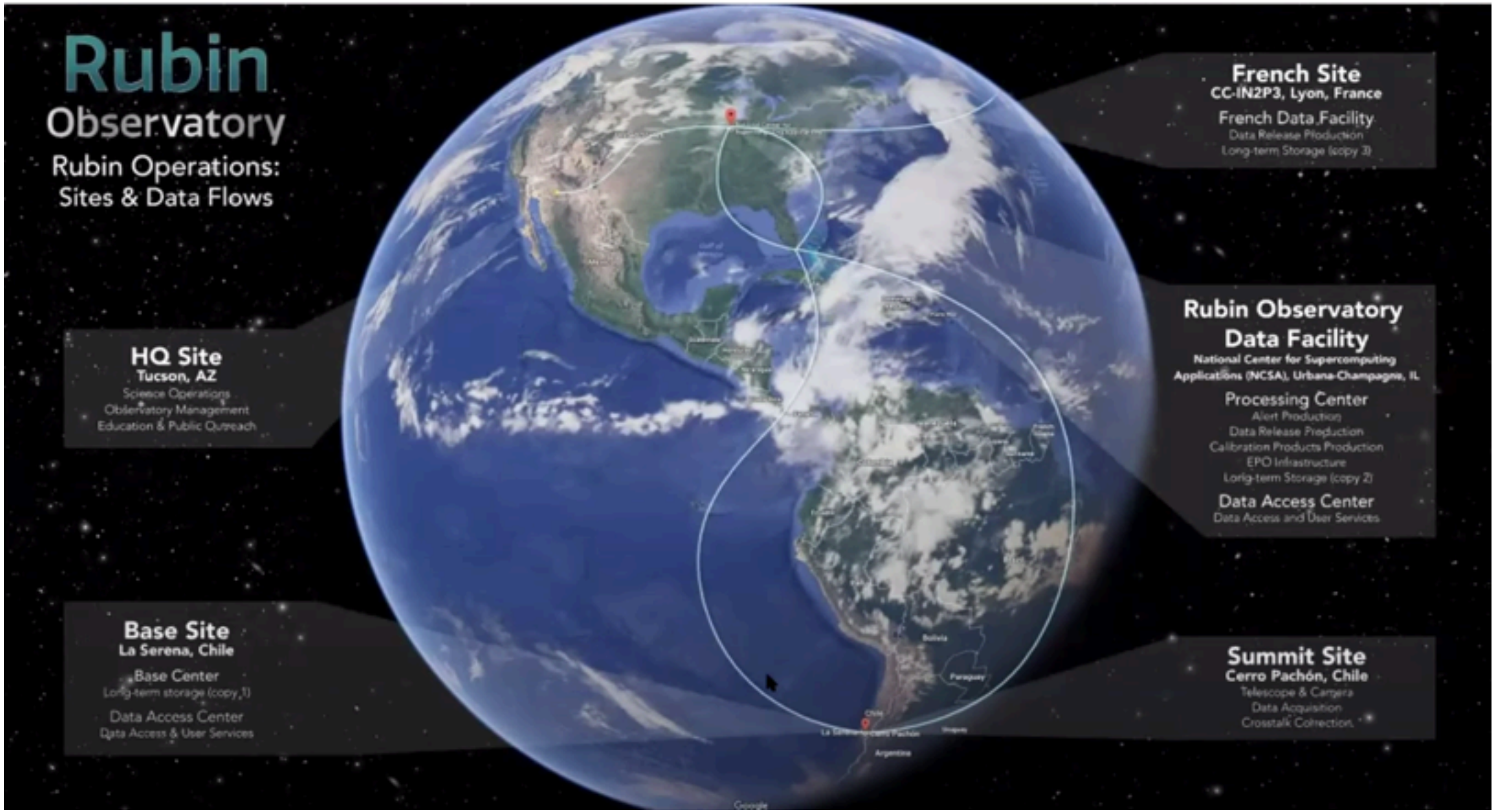
2000-2020 4 surveys I, II,III, IV	2024-2034 1 survey (WDF) + minisurveys over a 10-year period
combination of photometric and spectroscopic surveys	Photometric survey based on ~1000 visits
2.5m Telescope at Apache Point Observatory 2.5 m Irénée du Pont Telescope at Las Campanas Observatory 1-Meter Telescope at Apache Point Observatory	8 m Telescope
one third of the sky	half the sky
u, *g*, *r*, *i* and *z*	ugrizy bands to r~27.5
200 GB of data	20 TB of data
three million astronomical objects. photometric and astrometric catalog of ∼14 million objects.	37 billions stars and galaxies 10 Million of alerts per night
key lesson from SDSS is that such public data releases increase the scientific impact of the data by a factor of five	
Early Data Release in June 2001 SDSS DR 16	
7700 publications	

SDSS vs LSST

a digital colour map vs a digital colour movie of the sky



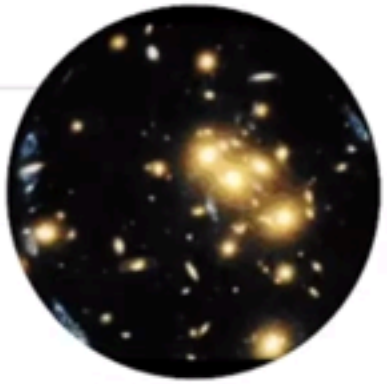
The Vera C. Rubin Observatory



Science Drivers

Dark Matter, Dark Energy

- Weak Lensing
- Baryon acoustic oscillations
- Supernovae, Quasars

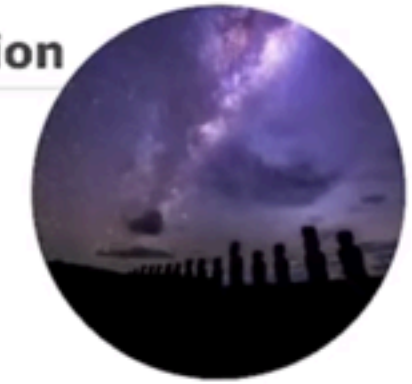


Cataloging the Solar System

- Potentially Hazardous Asteroids
- Near Earth Objects
- Object inventory of the Solar System

Milky Way Structure & Formation

- Structure and evolutionary history
- Spatial maps of stellar characteristics
- Reach well into the halo

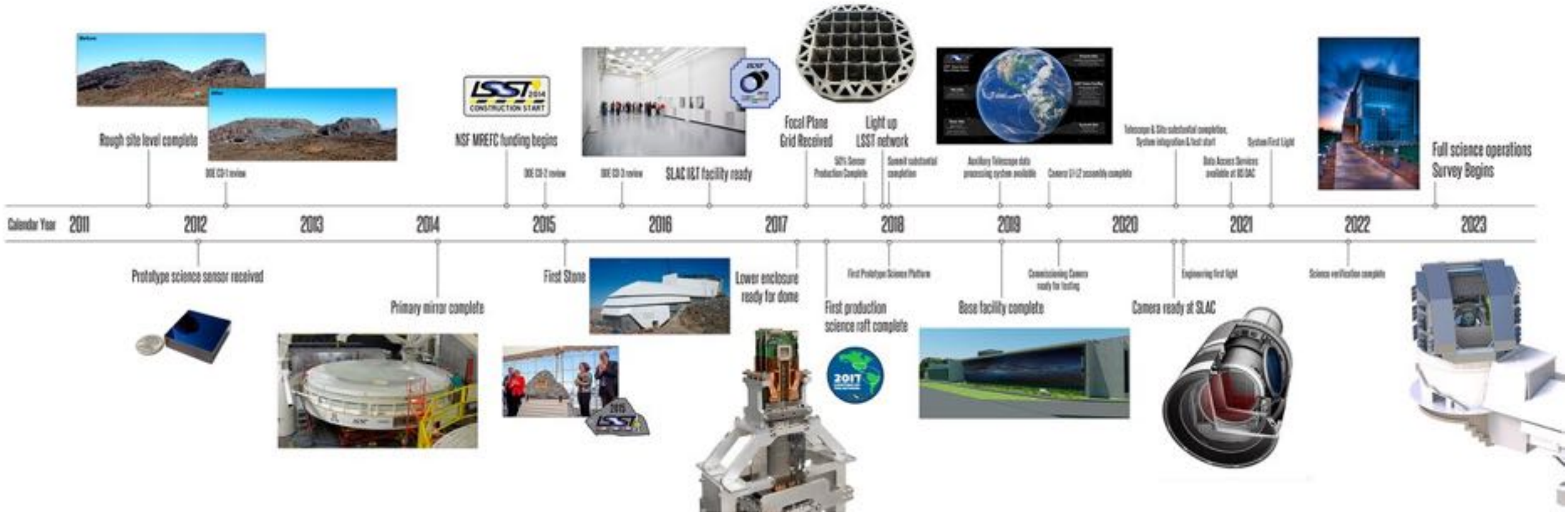


Exploring the Transient sky

- Variable stars, Supernovae
- Fill in the variability phase-space
- Discovery of new classes of transients

"From Science Drivers to Reference Design", Ivezić et al. (2008), arXiv:0805.2366

Timeline

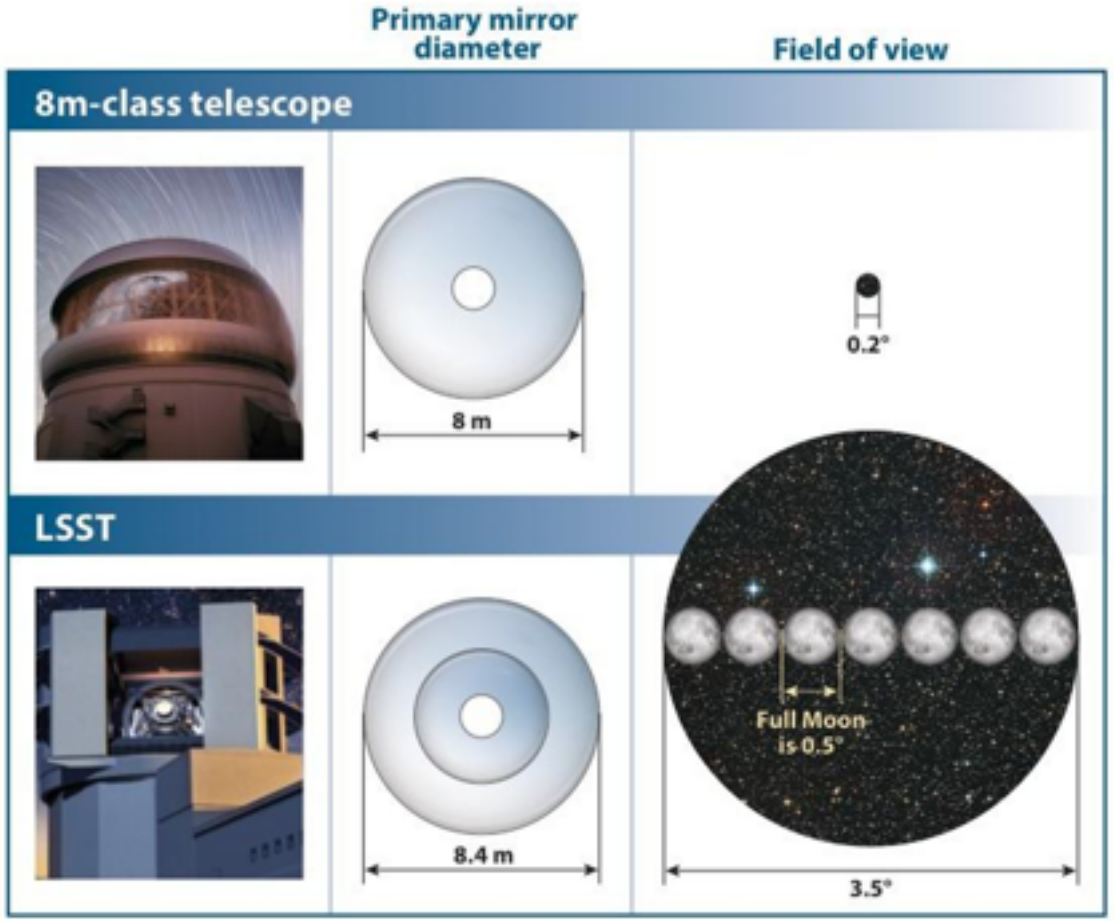

Rough site level complete
DOE CD-1 review
NSF MREFC funding begins
DOE CD-2 review
DOE CD-3 review
SLAC I&T facility ready
Focal Plane Grid Received
Light up LSST network
Auxiliary Telescope data processing system available
Full science operations Survey Begins
Calendar Year
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Prototype science sensor received
Primary mirror complete
First Stone
Lower enclosure ready for dome
First production science raft complete
Base facility complete
Camera ready at SLAC

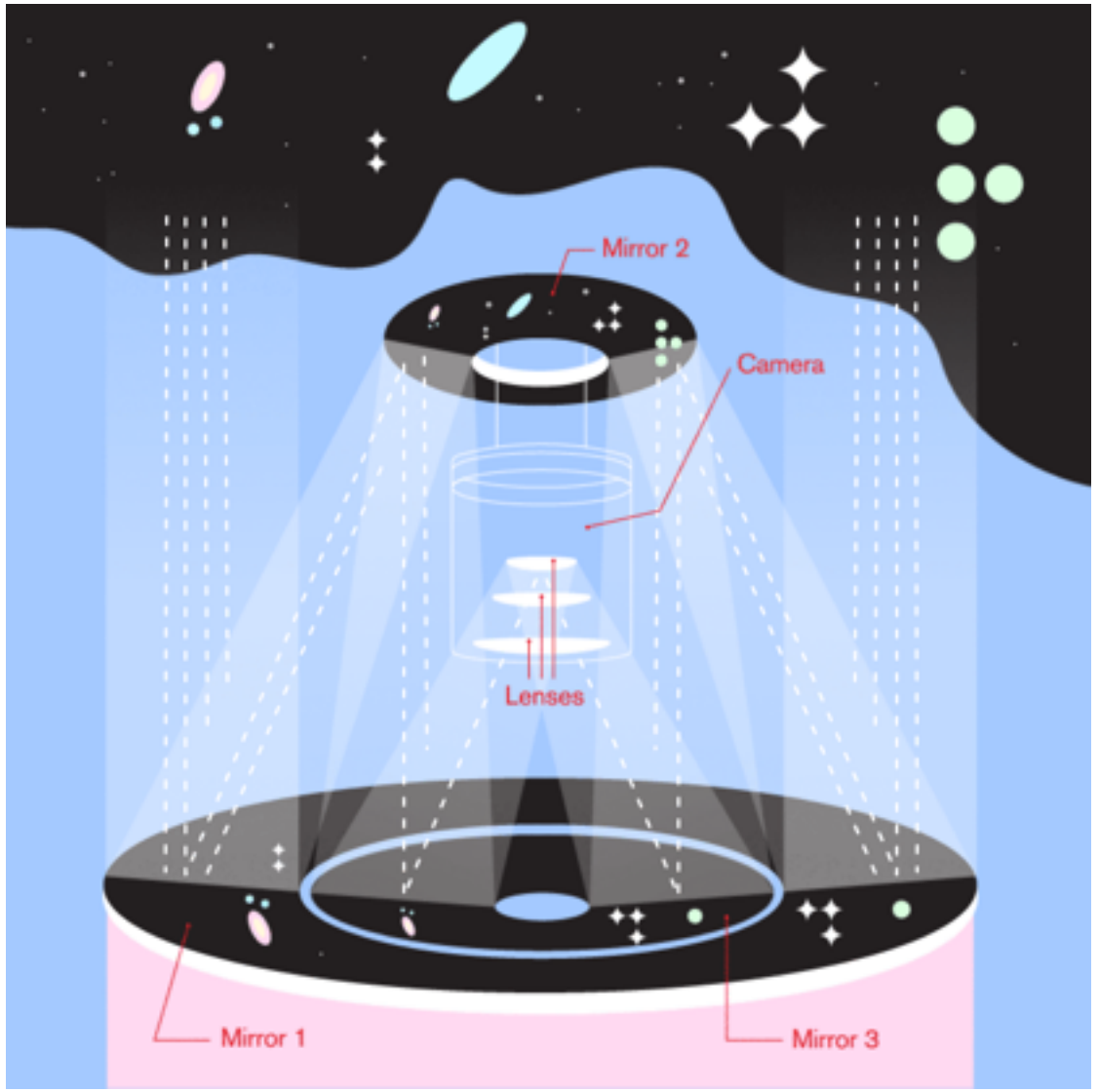
The Simonyi Telescope

- 8.4 m
- effective aperture of 6.5 m

The Simonyi Telescope

Innovative Optical Design

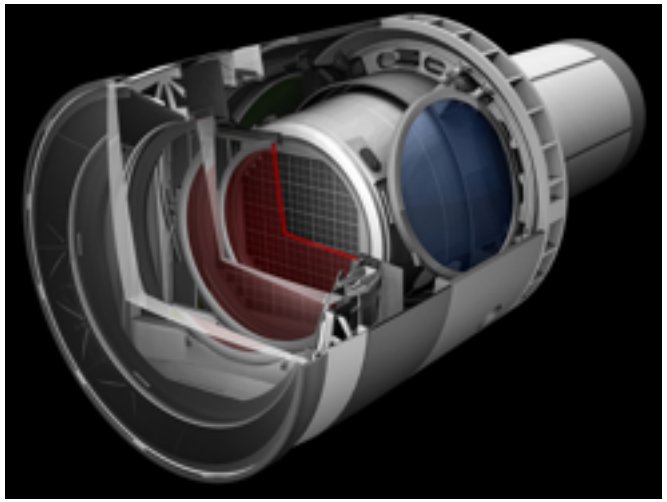


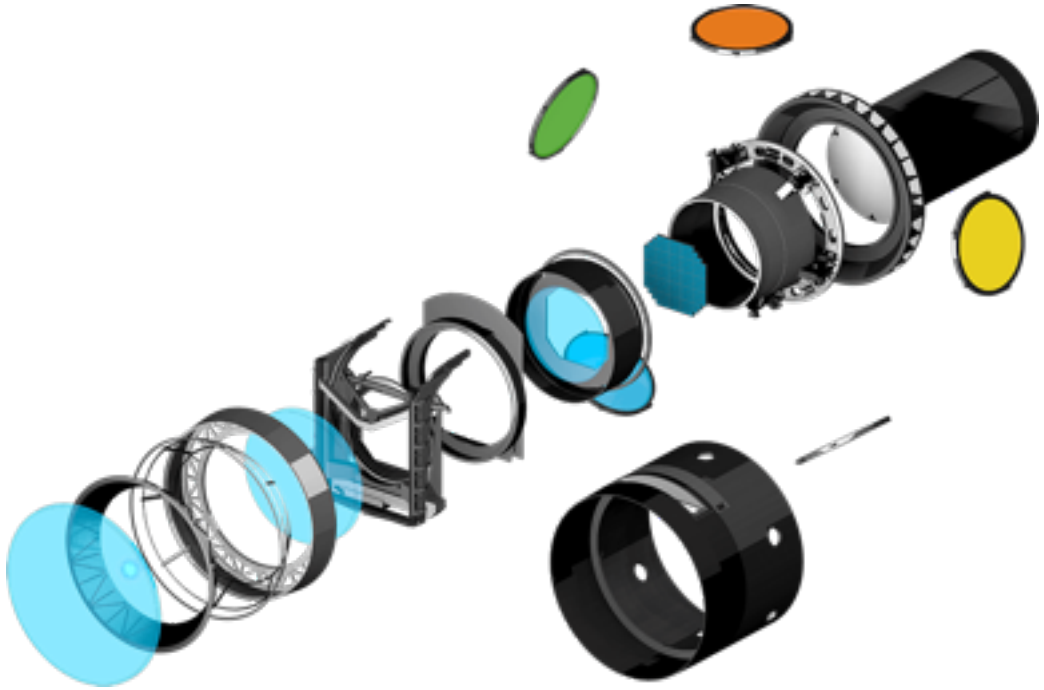


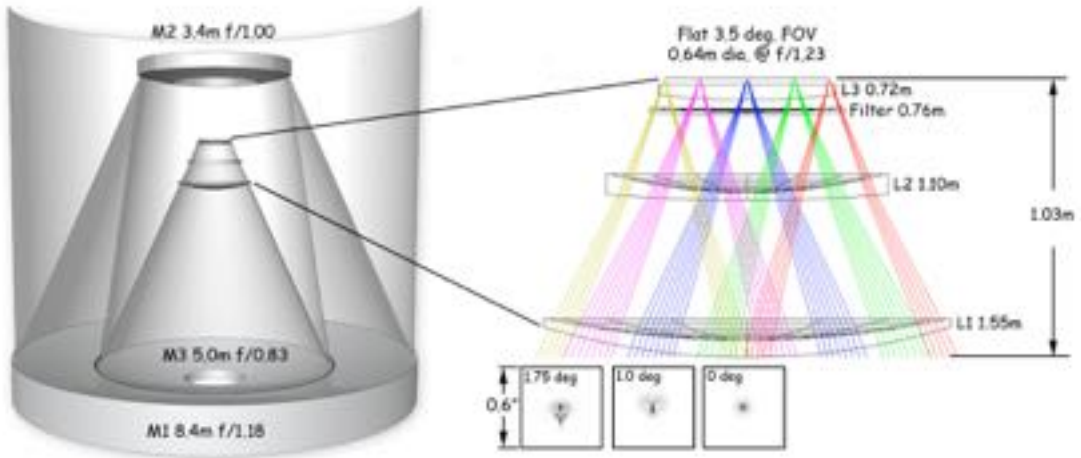
The Simonyi Telescope

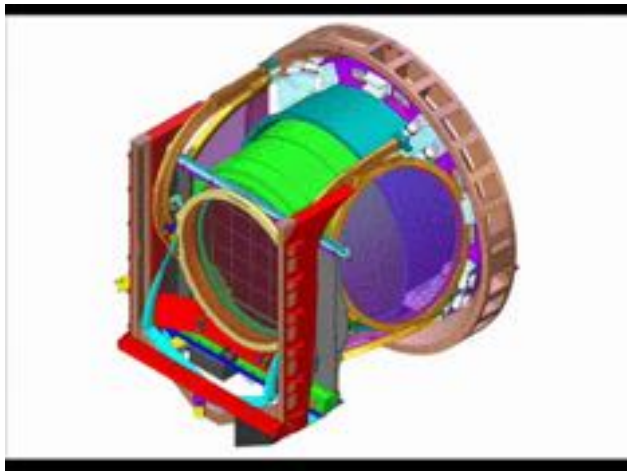
the camera

1.65 m

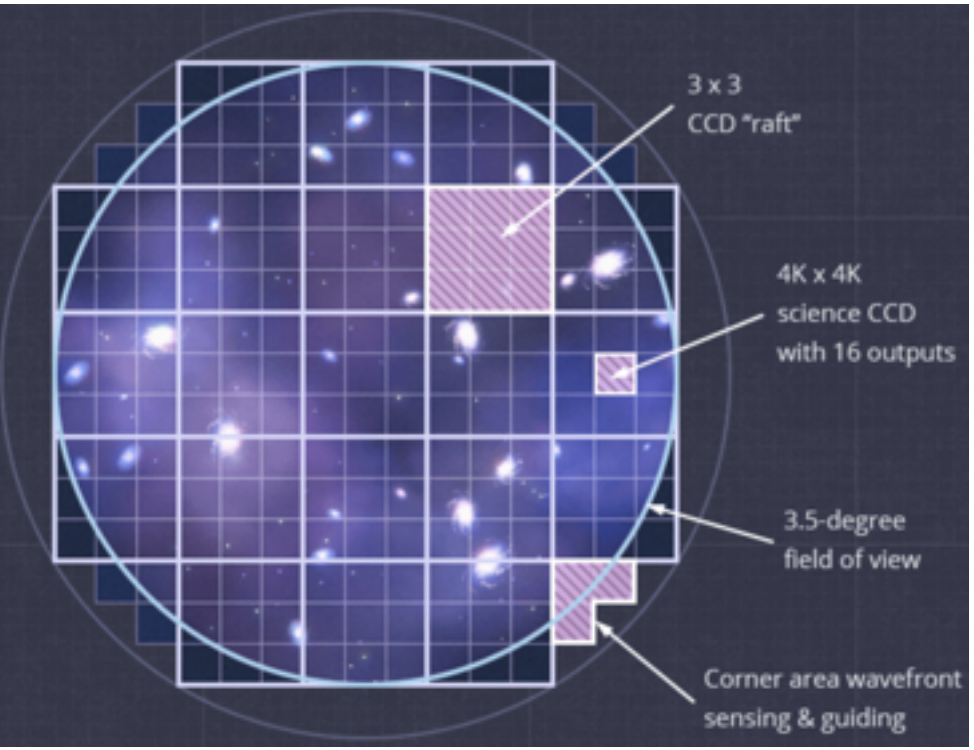


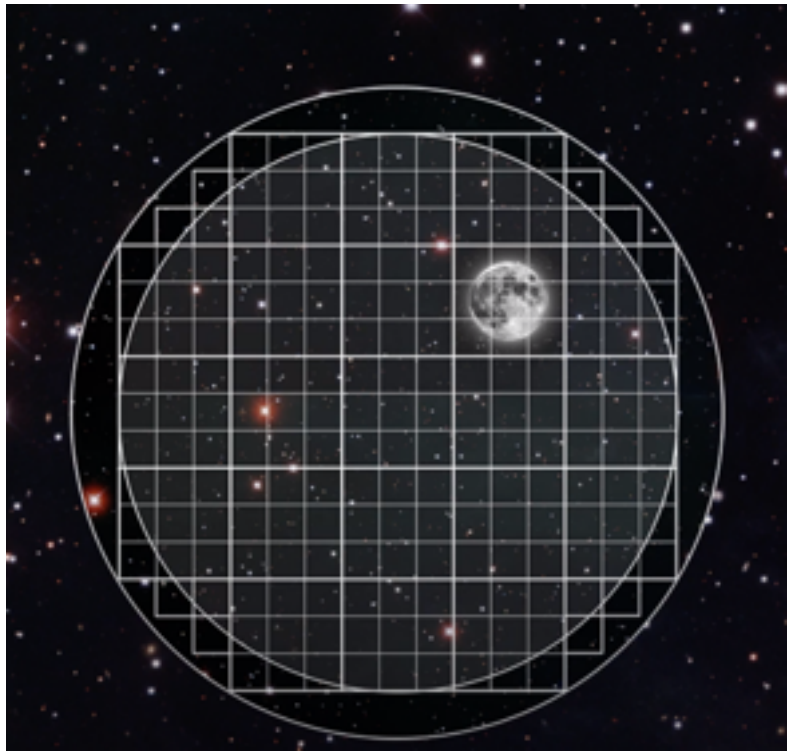


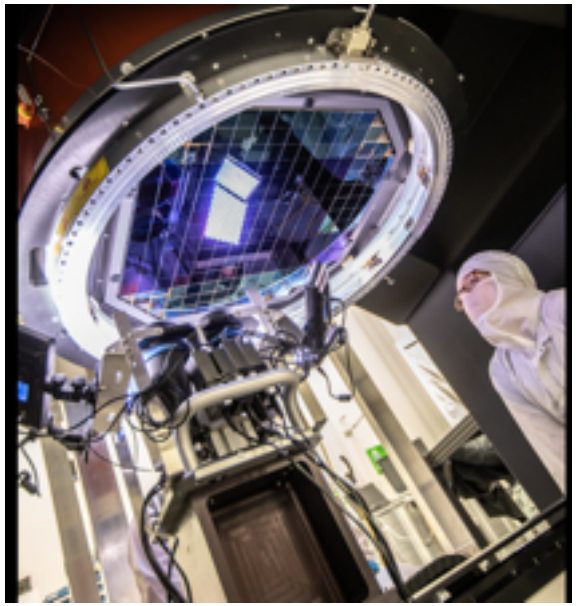


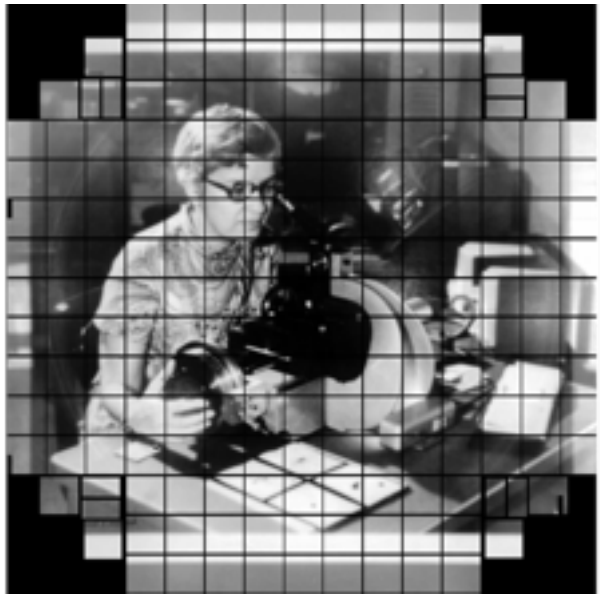


The Simonyi Telescope
the detector









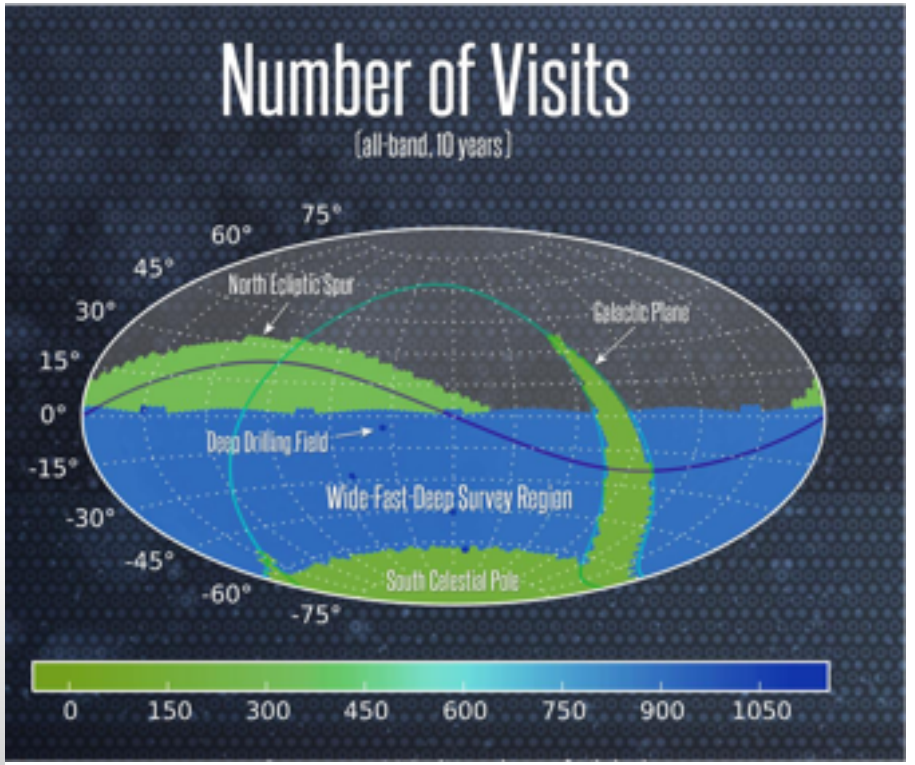
3.2 billion-pixel camera
189 16-megapixel silicon detectors
arranged on 21 "rafts"

9.6 deg^2
more than 40 times the area of the full moon
0.2x0.2 arcsec^2 pix

Wide-Deep-Fast Survey 80-90% total time

cover **large** swaths of sky to **faint magnitudes.** repeatedly at **short intervals**

Survey Property	Performance
Main Survey Area	18000 sq. deg.
Total visits per sky patch	825
Filter set	6 filters (ugrizy) from 320 to 1050nm
Single visit	2 x 15 second exposures
Single Visit Limiting Magnitude	u = 23.5; g = 24.8; r = 24.4; I = 23.9; z = 23.3; y = 22.1
Photometric calibration	2% absolute, 0.5% repeatability & colors
Median delivered image quality	~ 0.7 arcsec. FWHM
Transient processing latency	60 sec after last visit exposure
Data release	Full reprocessing of survey data annually



about 825 visits in 10 years spread over all filters

Other surveys 20-10%

Deep Drilling Field
Galactic plane
North Ecliptic Survey
South celestial Pole

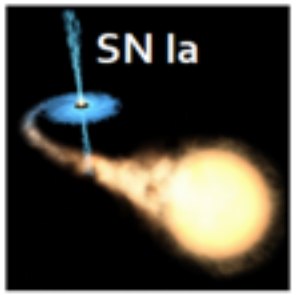
Name	RA (Deg)	Dec (Deg)
ELAISS1	9.450	-44.000
XMM-LSS	35.708	-4.750
ECDFS	53.125	-28.100
COSMOS	150.100	2.182
EDFS	58.970	-49.280
EDFS	63.600	-47.600

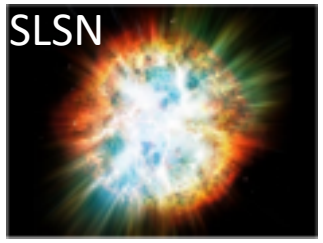
Transient Rates

SNe

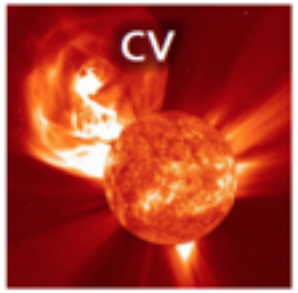
Class	M_v [mag]	τ^b [days]	Universal Rate (UR)	PTF Rate [yr^{-1}]	LSST Rate [yr^{-1}]
Luminous red novae	−9.. − 13	20..60	(1..10) × 10^{-13} yr^{-1} $L_{\odot,K}^{-1}$	0.5..8	80..3400
SNe .Ia	−15.. − 17	2..5	(0.6..2) × 10^{-6} Mpc^{-3} yr^{-1}	4..25	1400..8000
SNe Ia	−17.. − 19.5	30..70	[c] 3 × 10^{-5} Mpc^{-3} yr^{-1}	700	200000[d]
SNe II	−15.. − 20	20..300	(3..8) × 10^{-5} Mpc^{-3} yr^{-1}	300	100000[d]

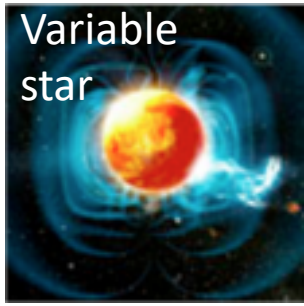
Transients





Variables



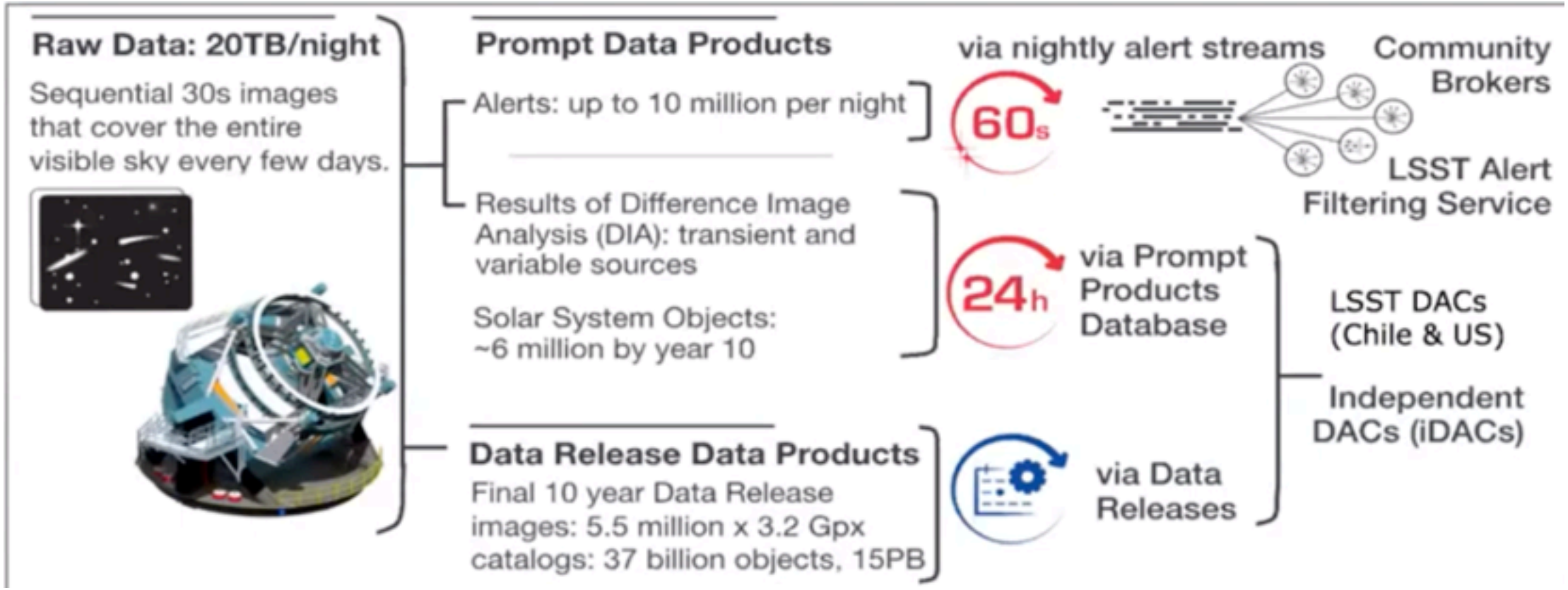


Transient	Before LSST	After LSST
Superluminous SNe	~20	~10^5
Tidal Disruption Events	~20	~10^4
Orphan LGRBs/Dirty Fireball	1	≤10^3
Orphan SGRBs/Kilonovae	1	≤10^2

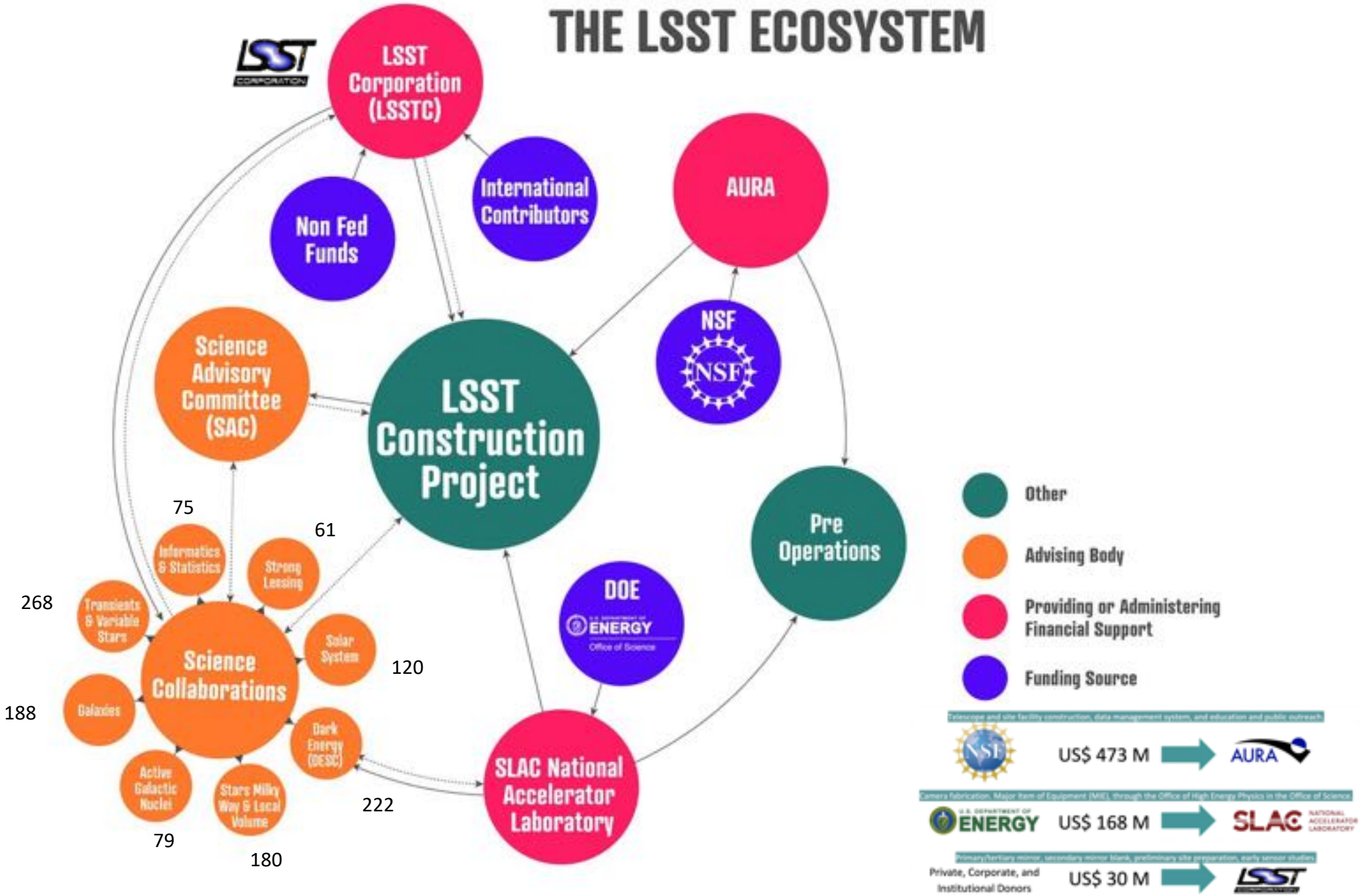
All these transients will be discovered in an unbiased way

Data Stream

10 million time-domain events per night
a catalogue of 37 billion source (20 billion galaxies 7 billion stars)



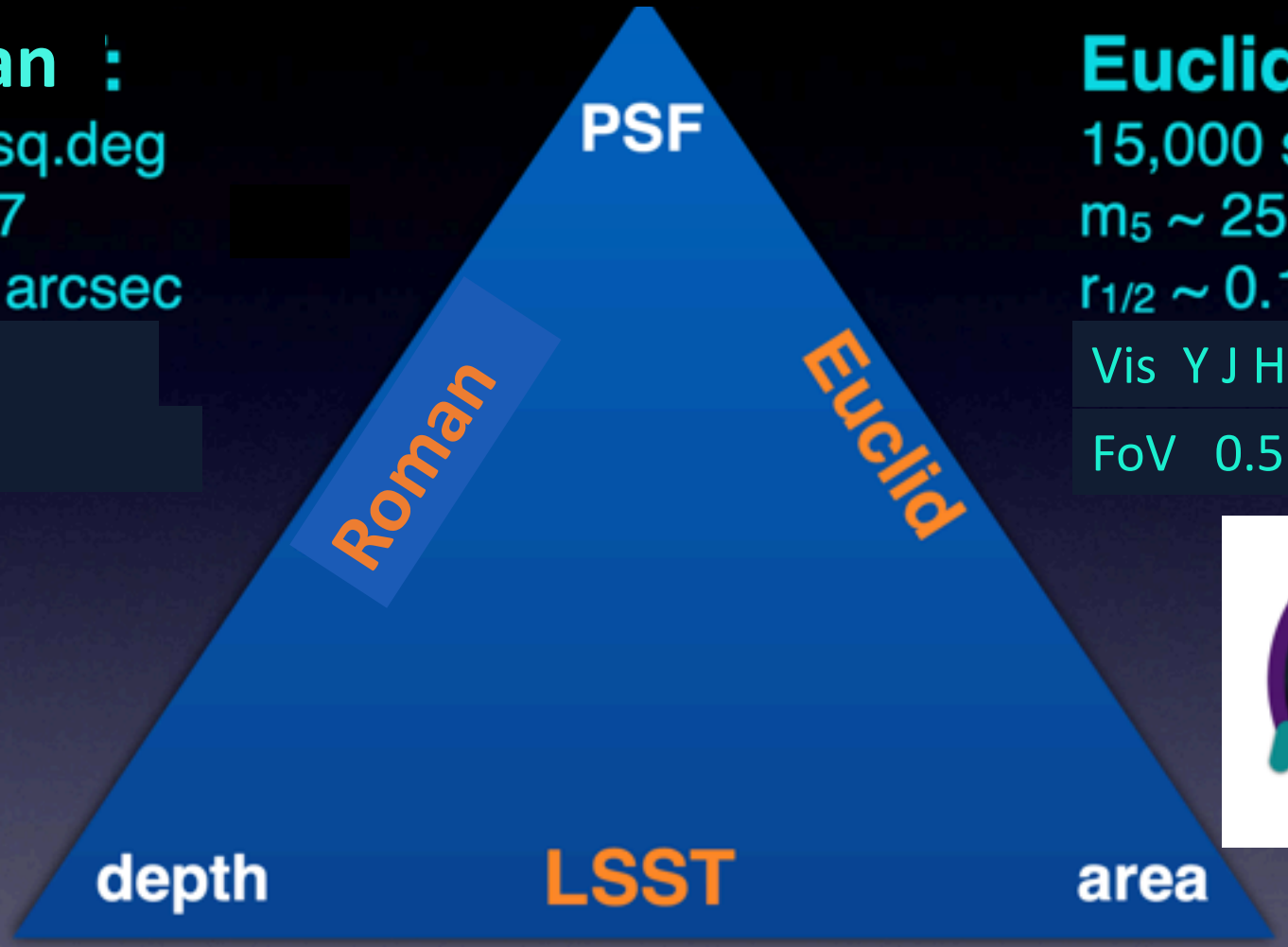
THE LSST ECOSYSTEM



LSST and multi-wavelength Astronomy

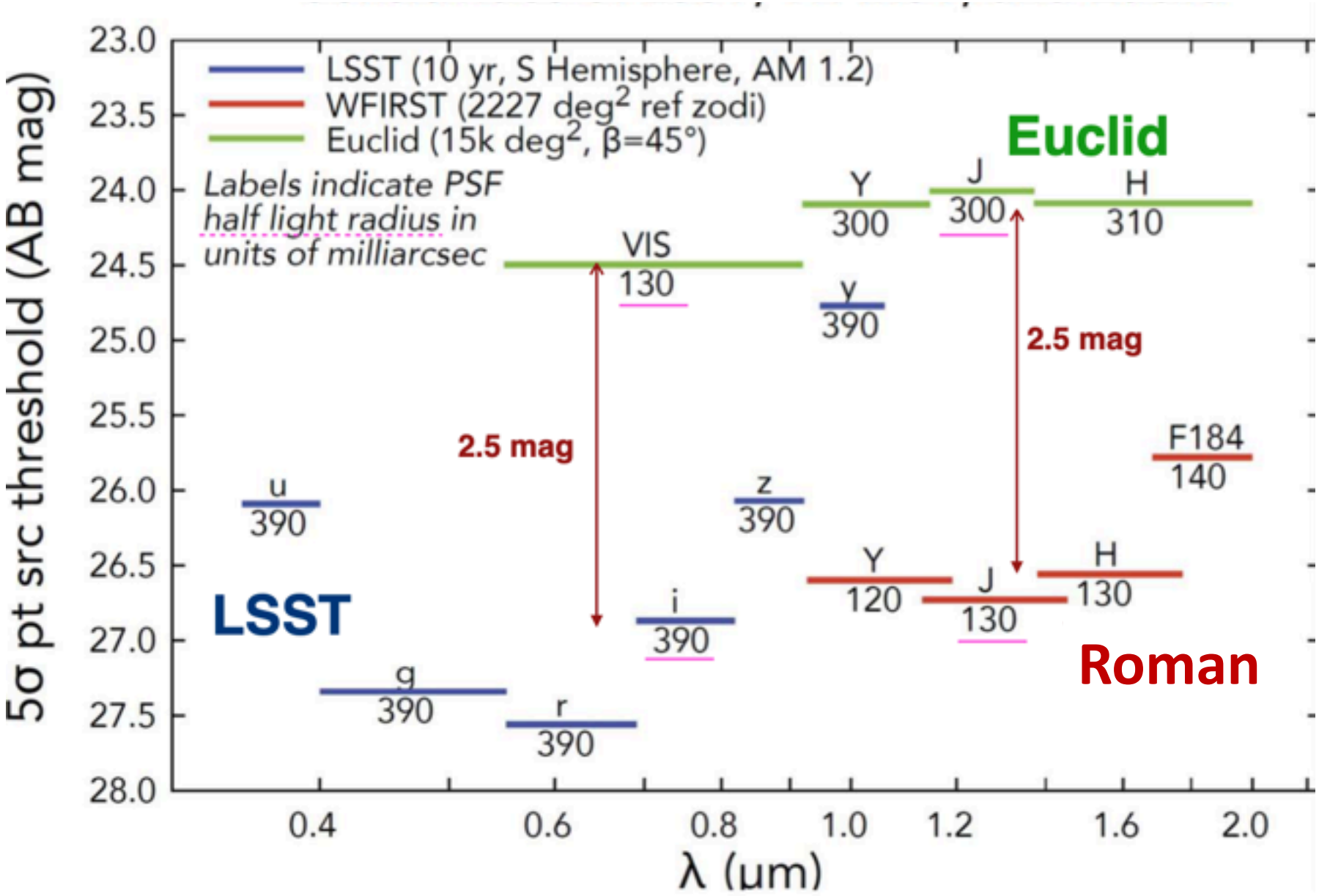
Roman :
2,200 sq.deg
$m_5 \sim 27$
$r_{1/2} \sim 0.12$ arcsec
Y J H
FoV 0.28

Euclid:
15,000 sq.deg
$m_5 \sim 25$
$r_{1/2} \sim 0.13$ arcsec
Vis Y J H
FoV 0.5

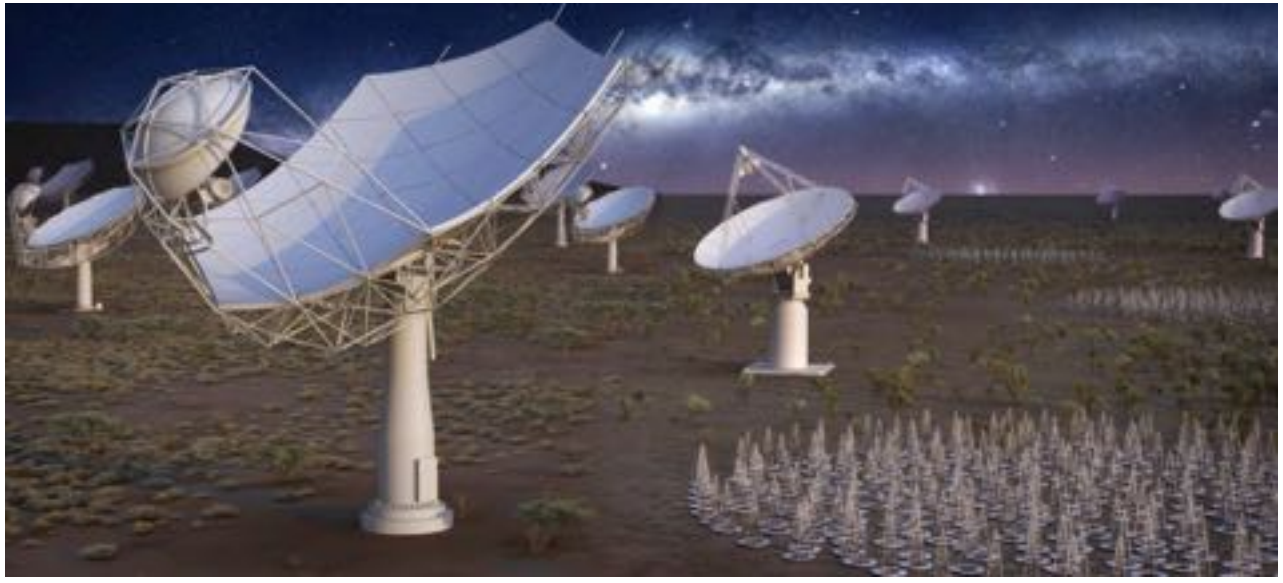


18,000 sq.deg
$m_5 \sim 27$
$r_{1/2} \sim 0.4$ arcsec
u,g,r,i,z,y
FoV 9.6

LSST and multi wavelength Astronomy

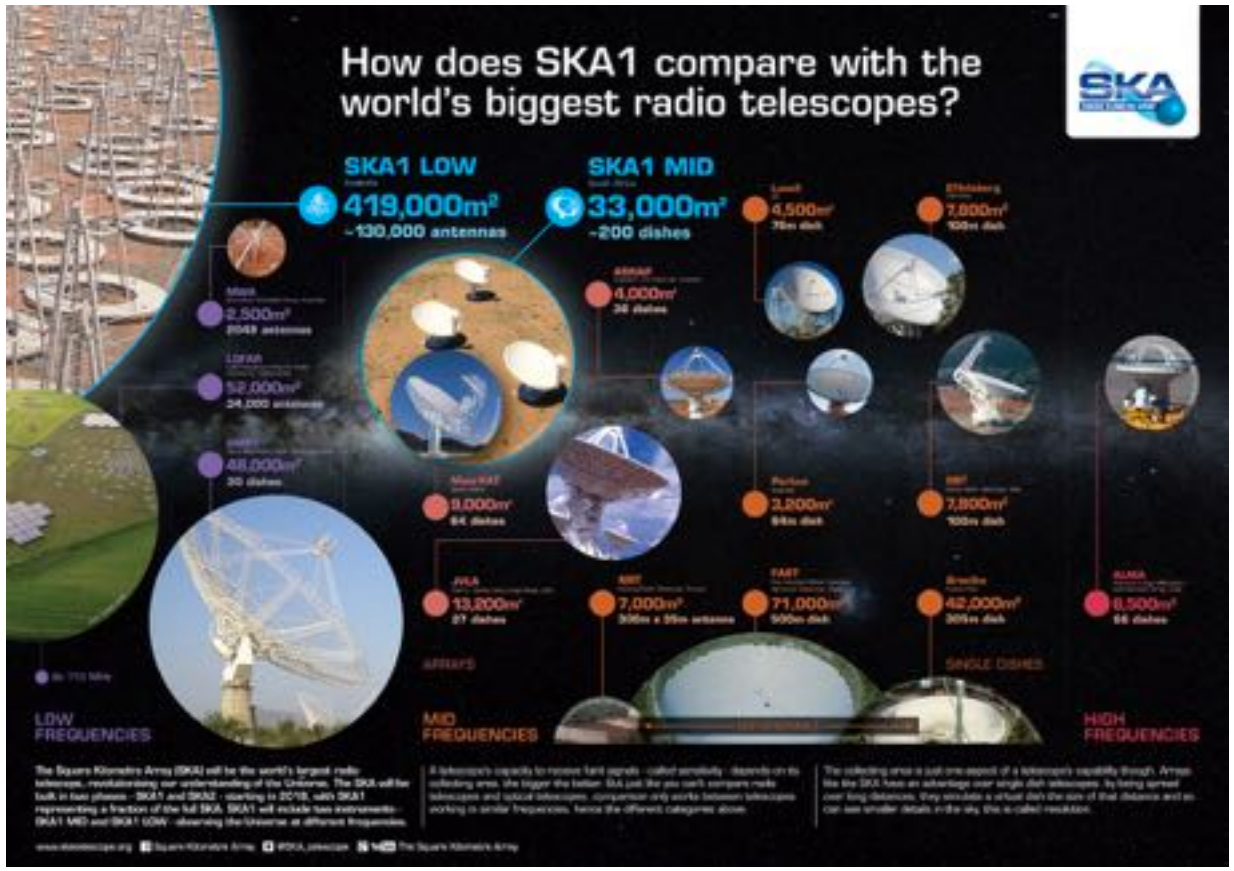


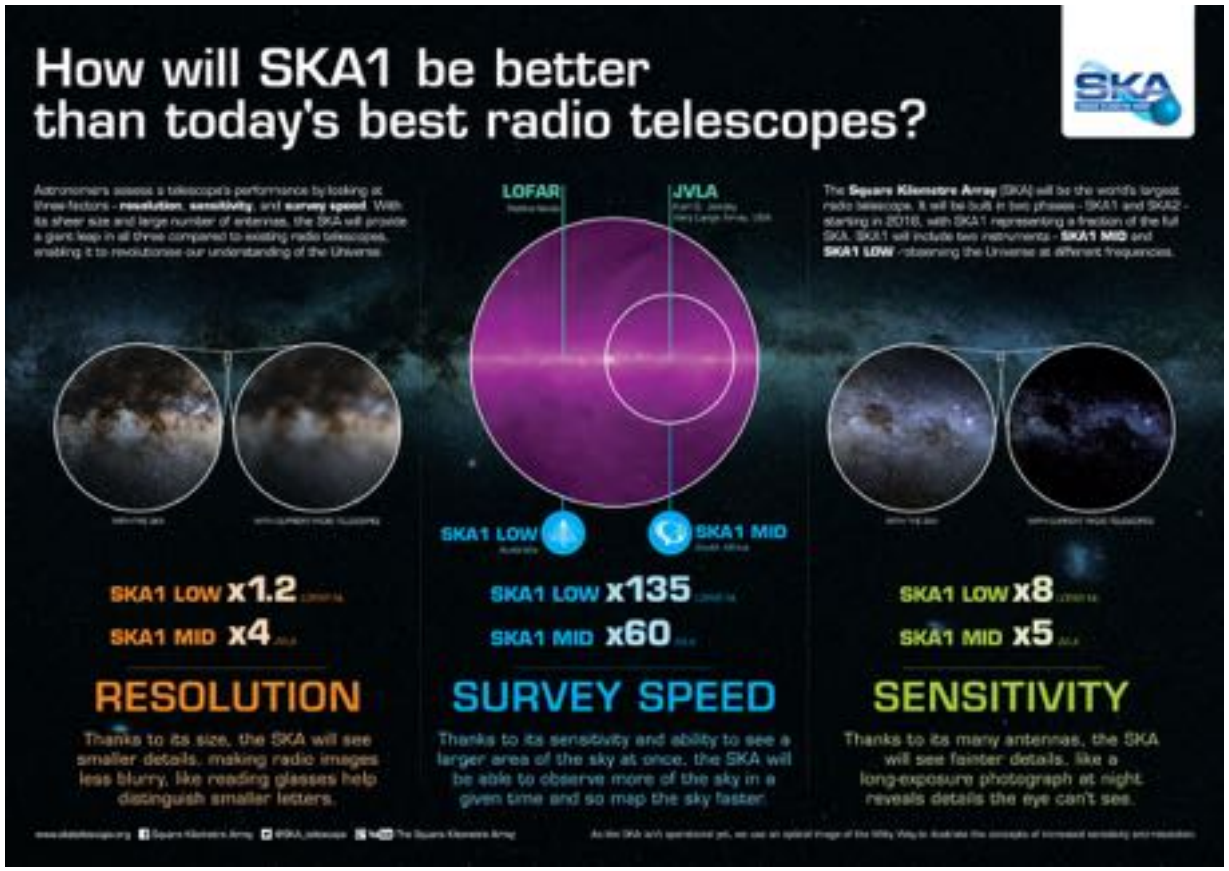
LSST and multi-wavelength Astronomy



LSST and multi-wavelength Astronomy

huge [areas of sky in parallel] a feat which no survey telescope has ever achieved on this scale with this level of sensitivity





LSST and multi-wavelength Astronomy

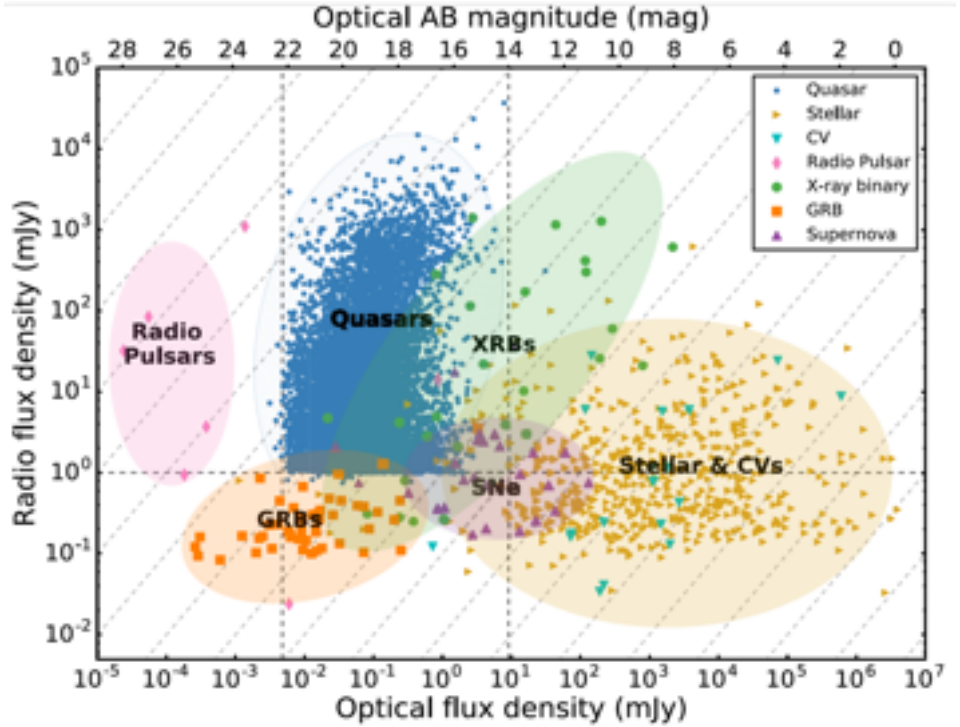
Several science questions and challenges in common between the two projects

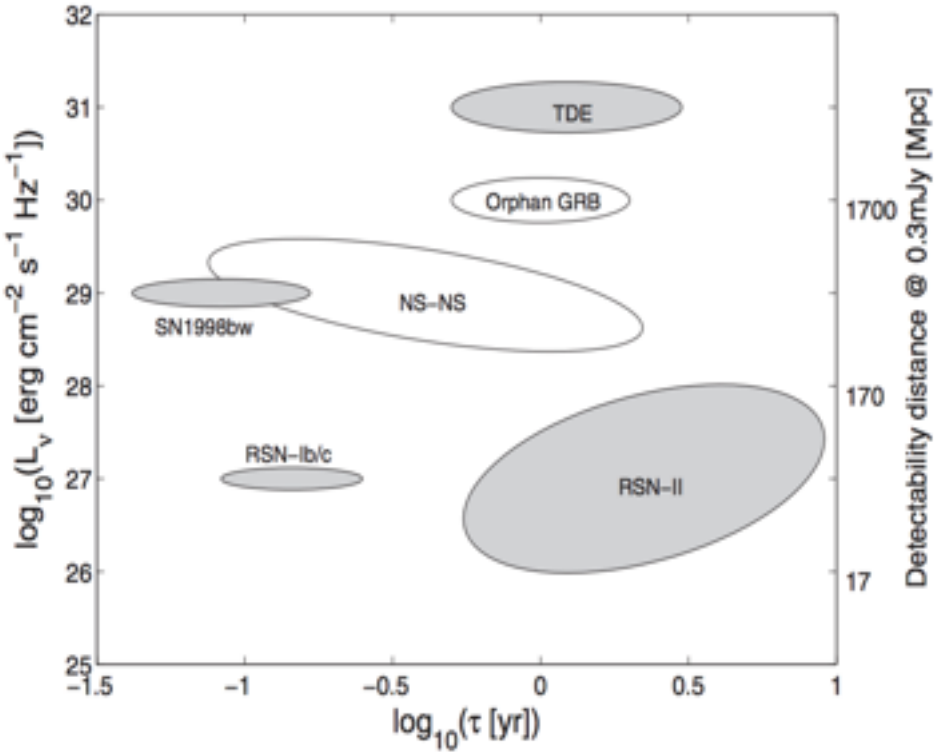
- cosmology
- galaxy evolution
- time-domain astrophysics

- monitoring a large sky area
- on the sky over much of the same time-period
- Match between the temporal cadence in the optical bands and time resolution in the radio bands

LSST and multi-wavelength Astronomy

There is still a large range of transient parameter space that has not yet been sampled. correlating optical and radio properties





the relation between the radio and optical flux densities

can be used to classify radio transients

LSST follow-up ecosystem

LSST will stimulate a large number of follow-up studies, especially of a spectroscopic character

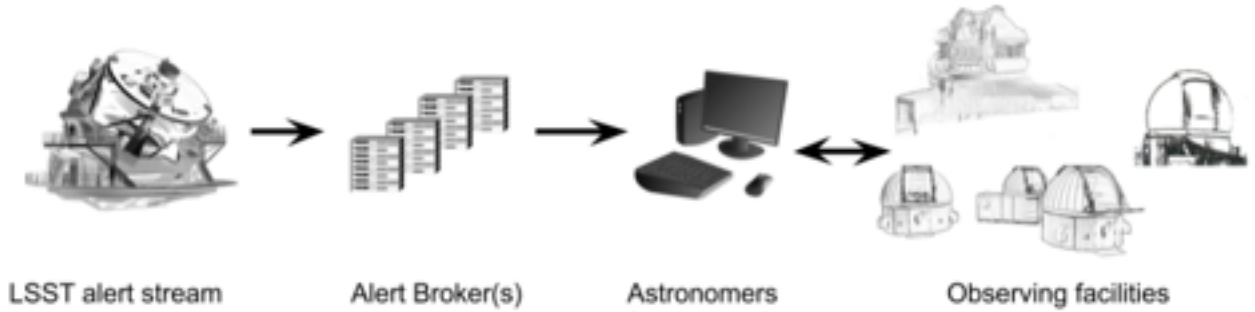
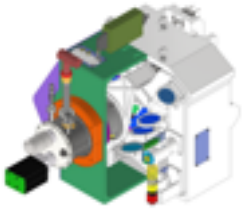


Photo z
Transient classification
Strong lens

Dark Energy Spectroscopic Instrument (DESI)

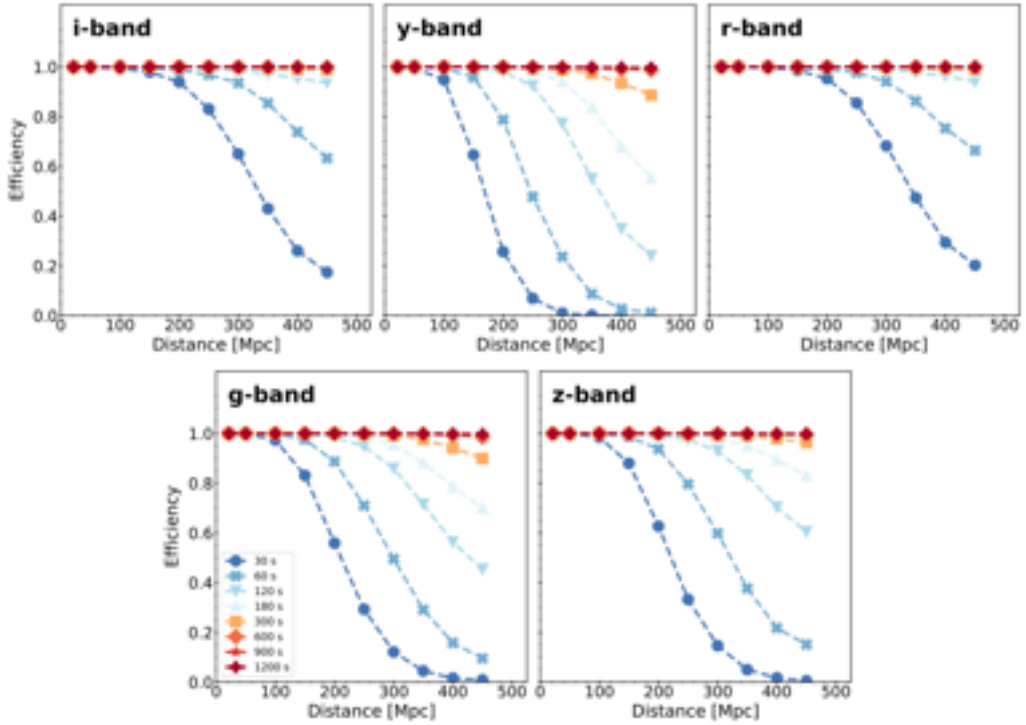
4 m Multi-Object Spectrograph **Telescope (**4 MOST)

Son of X-Shooter (SoXS)



LSST and multi-messenger Astronomy

- target-of-opportunity (ToOs) capabilities (~ 1.5% of the total survey time)
- a large sample of EM counterparts
- very early observations of KNe
- discovery of the EM counterparts of NS-BH mergers



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Rubin
Observatory
LSST
Legacy Survey of Space and Time
Thank you