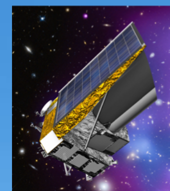
Rubin data products, LSST science requirements and Rubin-Roman-Euclid synergies



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VERA C. RUBIN OBSERVATORY

Joint Survey Processing
Splinter @ AAS 239

Outline

- Rubin Observatory and LSST
  - multi-color time-resolved **faint** sky map
  - 20 billion stars and 20 billion galaxies
- Rubin-Roman-Euclid synergies
  - 2,200 sq.deg. of three-way overlap
  - 7,000+ sq.deg. of LSST-Euclid overlap
- And what to do about it
  - cadence coordination
  - enabling matched-catalog-based analysis
  - joint pixel-level processing

See the talk by Leanne Guy for more details about joint Rubin-Euclid data processing

Science motivation for undertaking the Legacy Survey of Space and Time:

LSST Science Requirements: ls.st/srd

Expansion and history of the Universe and the growth of structure
(dark matter, dark energy, cosmology, spatial distribution of galaxies, gravitational lensing, supernovae): "Was Einstein right?"

Time domain: what changes on the sky?
(cosmic explosions, variable stars, unknown unknowns)

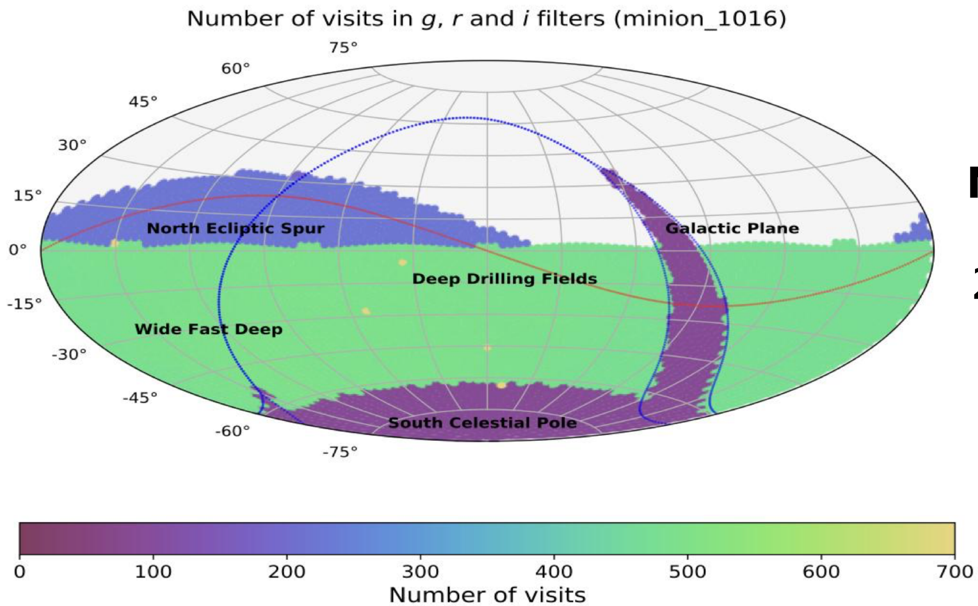
The Solar System structure
(near-Earth hazardous asteroids, main-belt asteroids, trans-Neptunian objects, comets)

The Milky Way structure
(stars as tracers of the structure and evolution of our Galaxy, interstellar matter, the physics of stars)

A key point: most of science programs will utilize the same dataset.

Rubin & LSST overview paper: ls.st/lop

Rubin's Legacy Survey of Space and Time



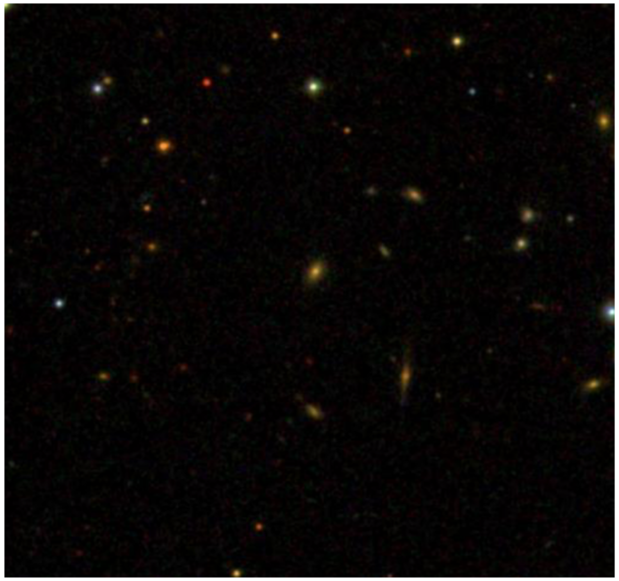
Survey optimization still in progress. Federica Bianco is the new chair of the Survey Cadence Optimization Committee. Final recommendation for baseline cadence by the end of CY 2022.

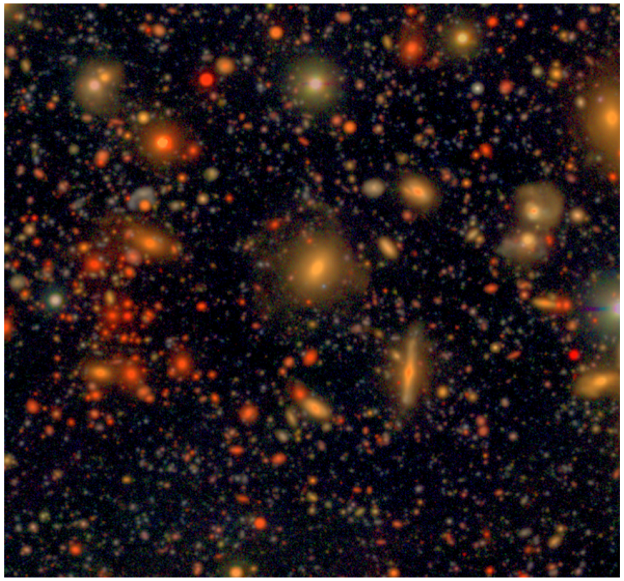
Mission statement: >18,000 sq. deg. observed >825 times in ugrizy: about 2 million "visits" in 10 years, each visit is ~3 Gpix image with 30-second exposure, coadded data: r ~ 27

More details about Rubin/LSST cadence optimization:
https://iopscience.iop.org/journal/0067-0049/page/rubin_cadence

SDSS
gri
3.5′x3.5′
r~22.5

0.1 full
Moon



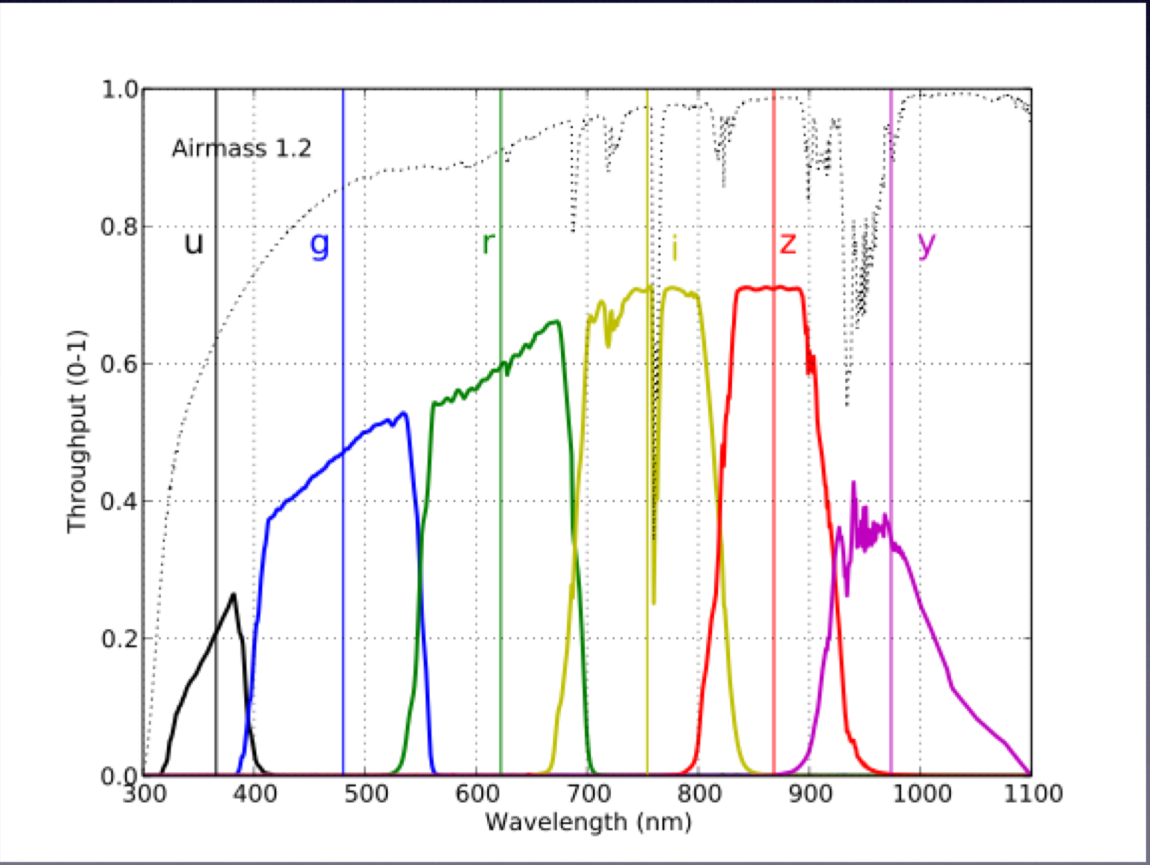


HSC
gri
3.5′x3.5′
r~27

Galaxies:

- **Photometric redshifts:** random errors smaller than 0.02, bias below 0.003, fewer than 10% >3σ outliers

- These photo-z requirements are one of the primary drivers for the photometric depth and accuracy of the main LSST survey (and the definition of filter complement)



Consistent with other science themes (stars, AGNs)

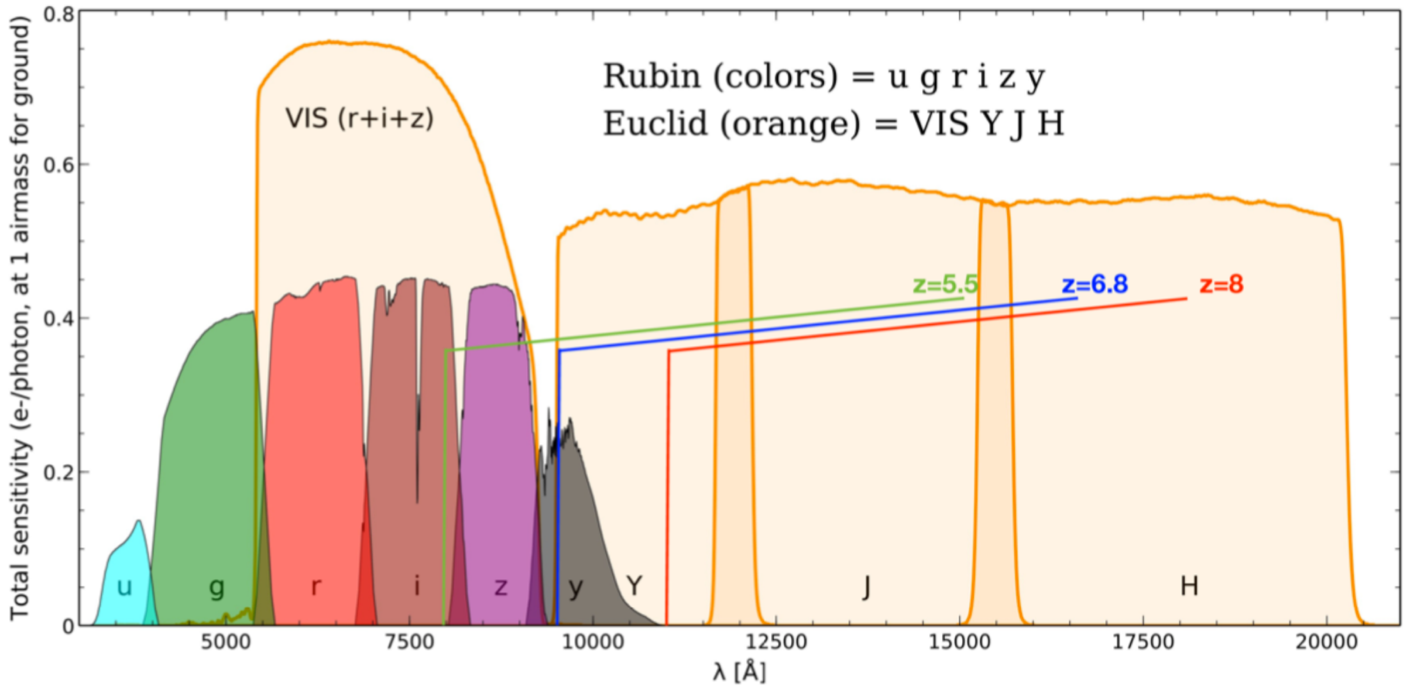


Figure 11: Schematic representation of the spectra of three galaxies at $z = 5.5$, 6.8, 8 (the vertical lines show the position of the Lyα break, the nearly horizontal one the extreme UV spectrum) superimposed to the joint Rubin+Euclid filter set.

The Rubin-Euclid Derived Data Products (DDPs) Working Group (Guy & Cuillandre, 2021)

Rubin Observatory Construction Schedule

- First light with the main camera: late 2023
- The start of regular survey operations: 2024
- First LSST Data Release: 2025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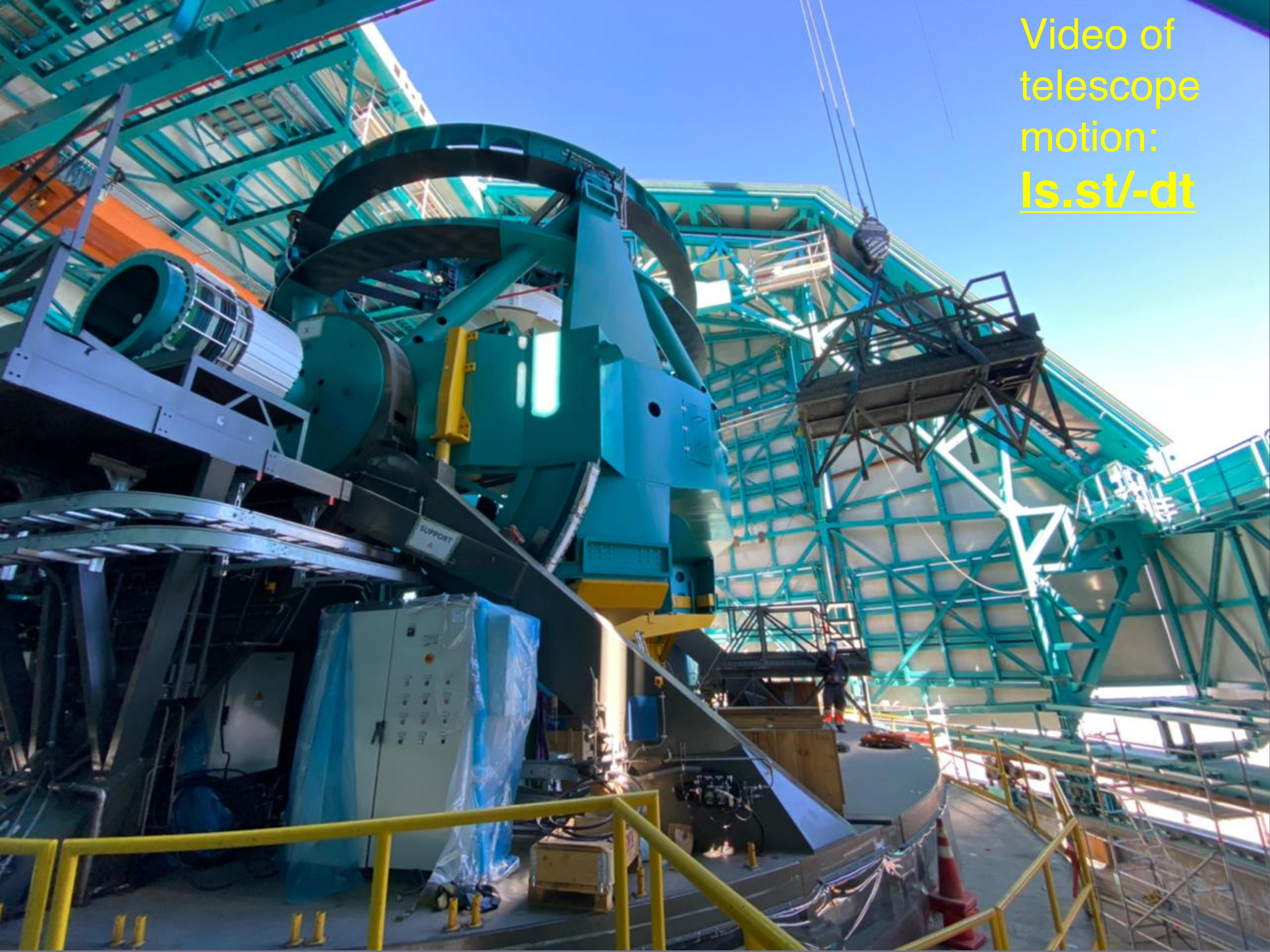
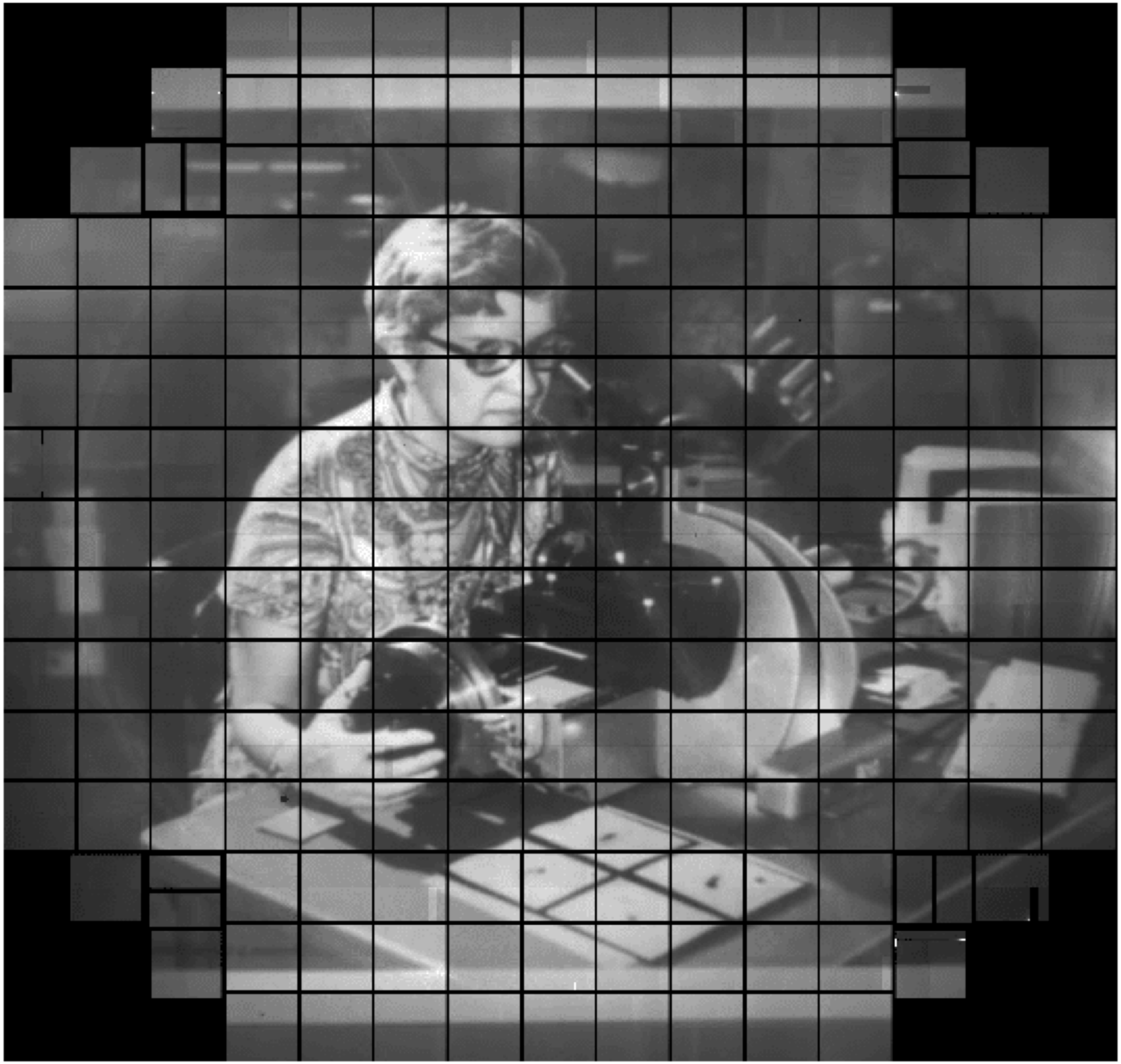

Video of
telescope
motion:
ls.st/-dt
SUPPORT


OPTO ENGINEERING



LSST From the User's Perspective: A Data Stream, a Database, and a (small) Cloud

Nightly Alert Stream

- A stream of ~10 million time-domain events per night, detected and transmitted to event distribution networks within 60 seconds of observation.
- A catalog of orbits for ~6 million bodies in the Solar System.

Level 1

Yearly Data Releases

- A catalog of ~37 billion objects (20B galaxies, 17B stars), ~7 trillion single-epoch detections ("sources"), and ~30 trillion forced sources, produced annually, accessible through online databases.
- Deep co-added images.

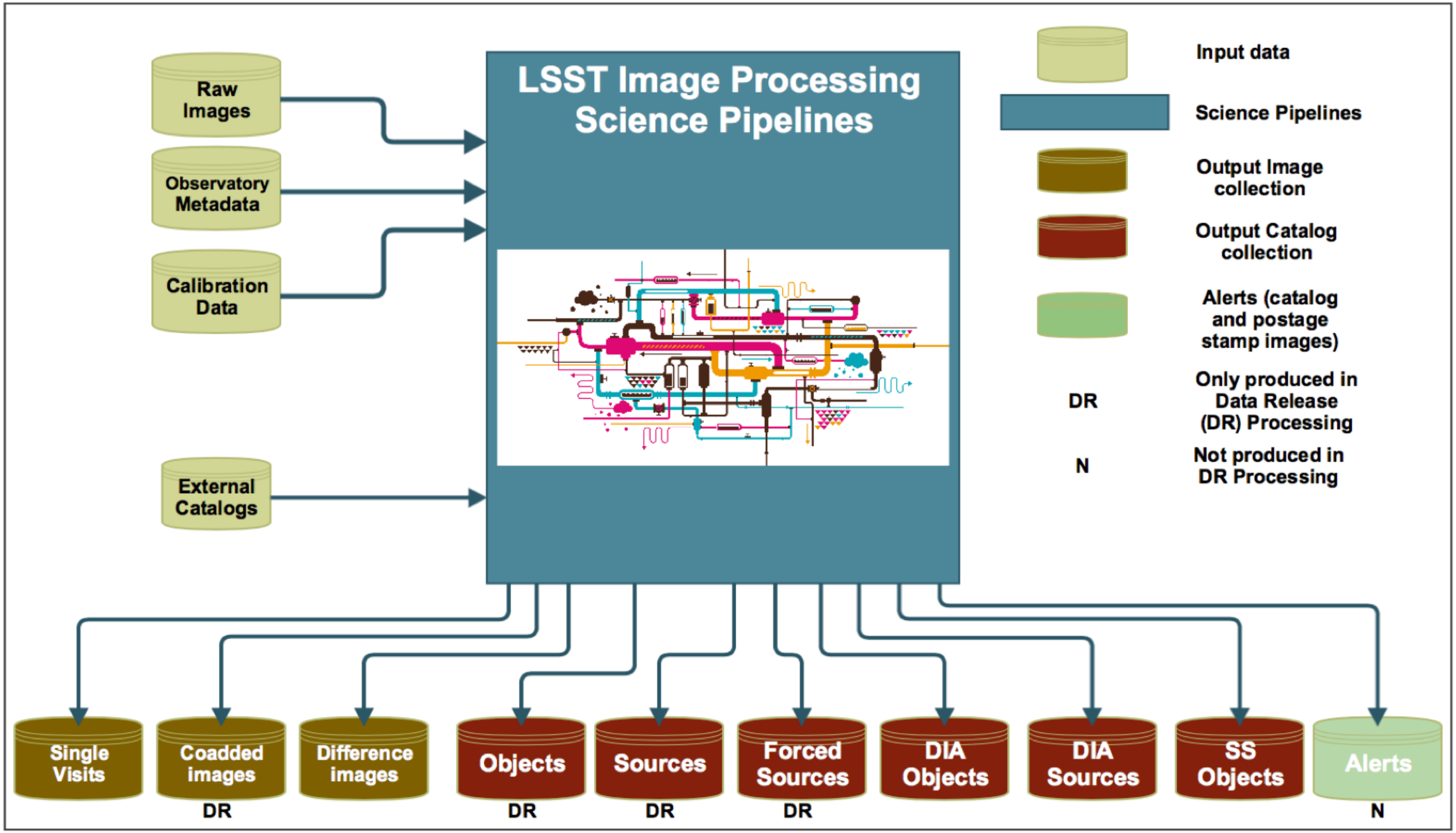
Level 2

Community Services

- Services and computing resources at the Data Access Centers to enable user-specified custom processing and analysis.
- Software and APIs enabling development of analysis codes.

Level 3

LSST Data Products (description and tables): see http://ls.st/dpdd

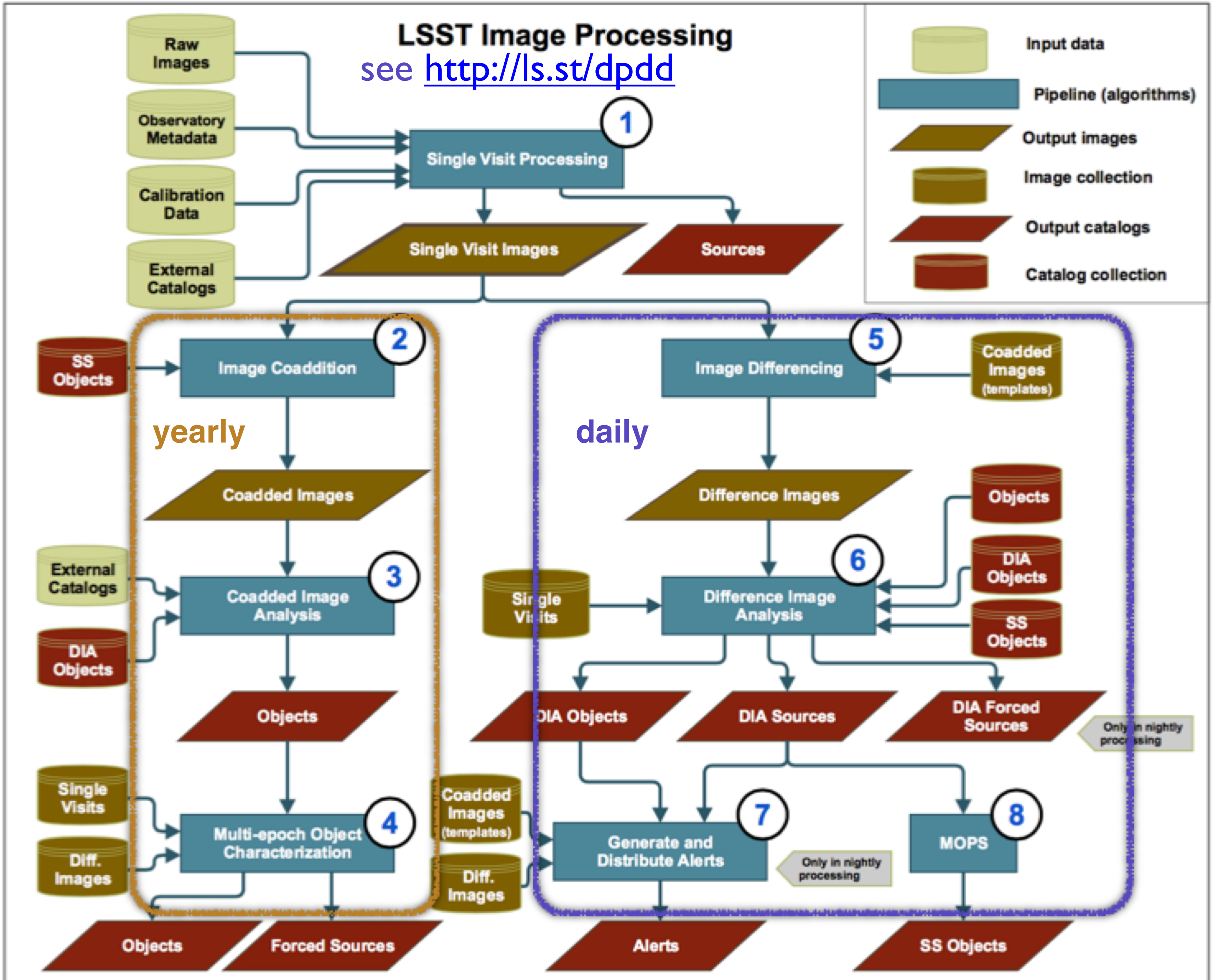


The main classes of LSST data products:

1) **Images**: single visit, coadded images, difference images
2) **Catalogs**:
    Nightly Alert stream: DIA Sources, DIA Objects, SS Objects, Alerts
    Yearly Data Releases: Sources, Forced Sources, Objects

LSST Image Processing

see http://ls.st/dpdd



Rubin, Roman and Euclid are highly complementary missions that offer many synergies.

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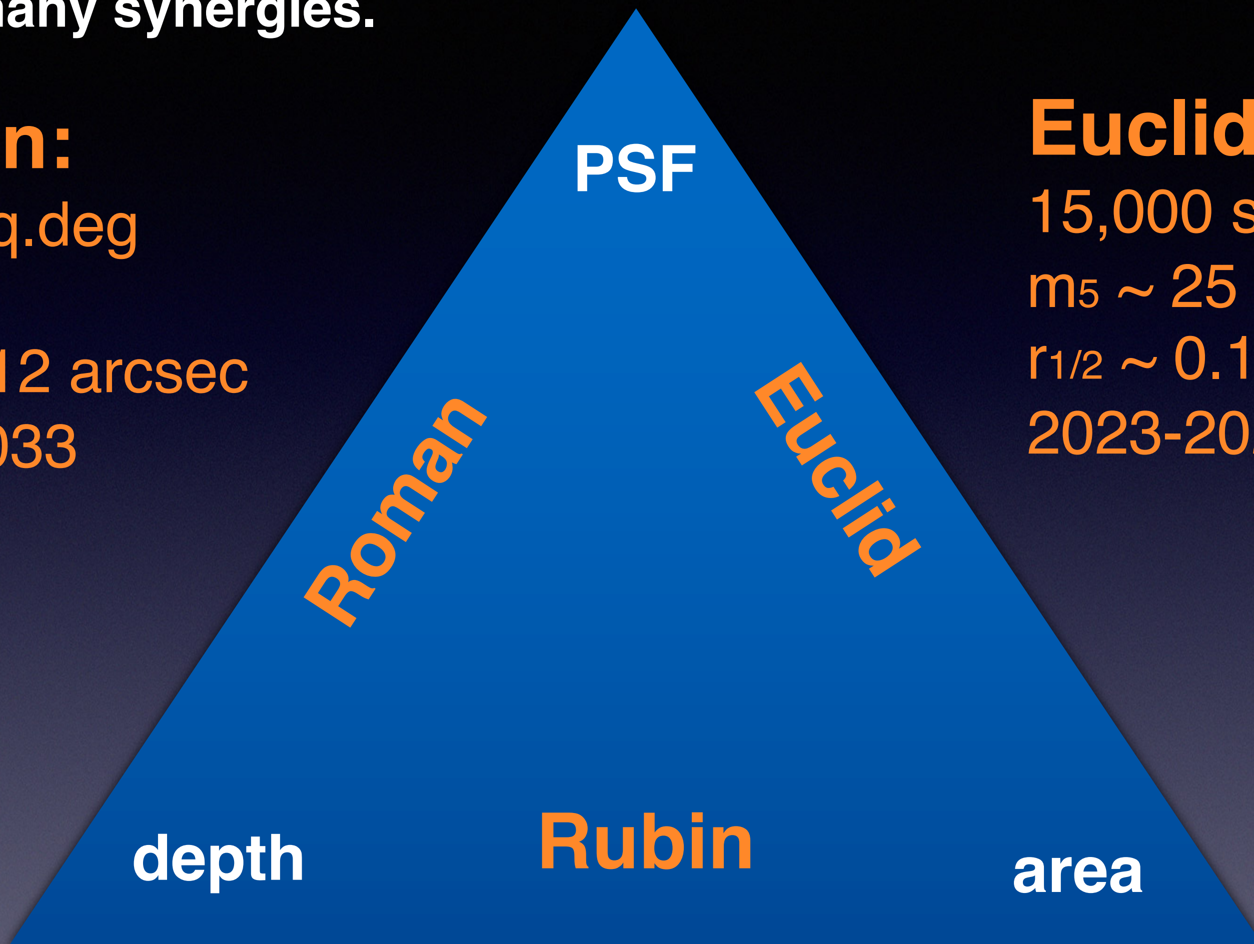
Roman:

2,200 sq.deg

$m_5 \sim 27$

$r_{1/2} \sim 0.12$ arcsec

2027-2033



Euclid:

15,000 sq.deg

$m_5 \sim 25$

$r_{1/2} \sim 0.13$ arcsec

2023-2029

18,000 sq.deg

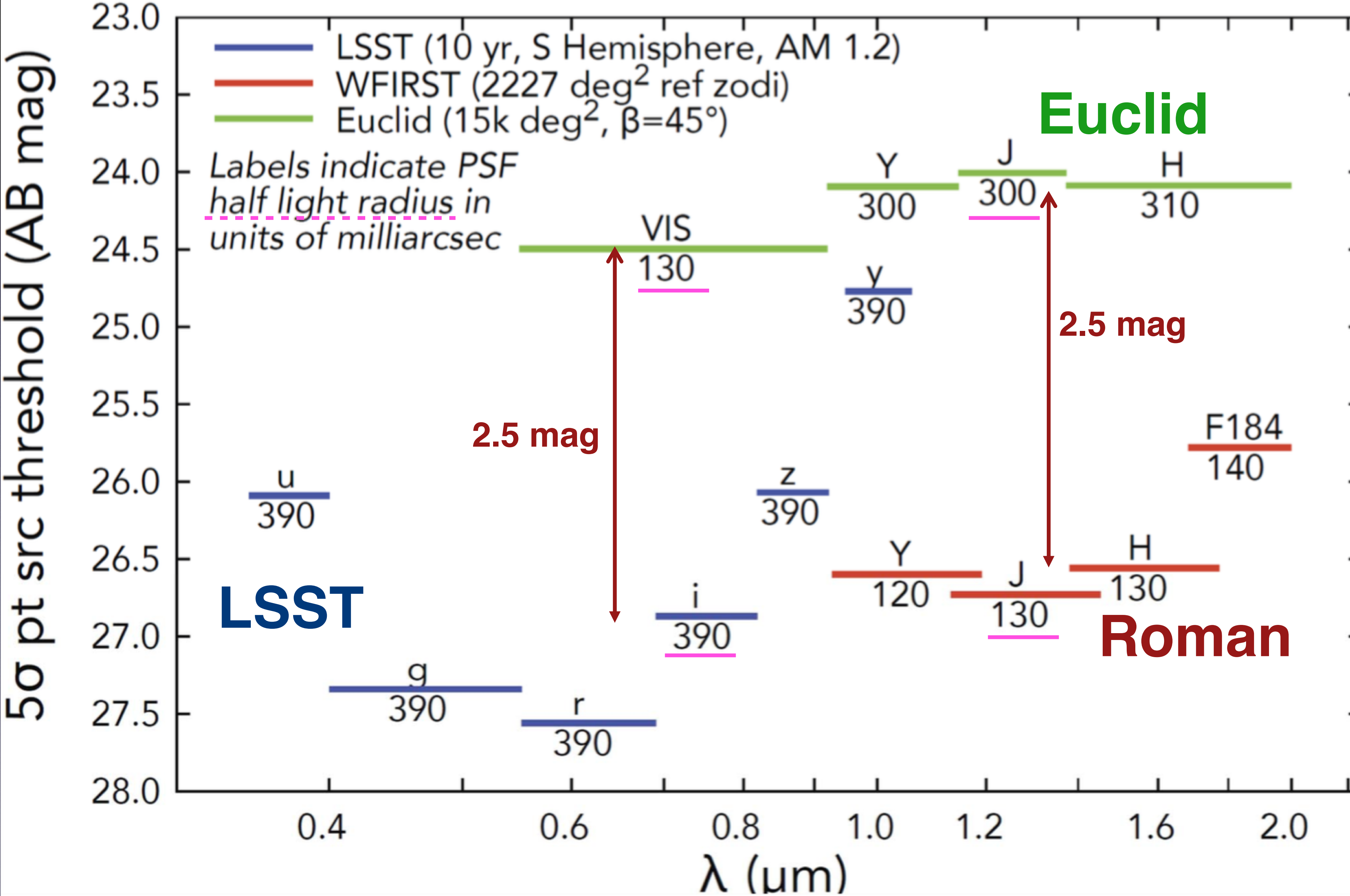
$m_5 \sim 27$

$r_{1/2} \sim 0.4$ arcsec

2024-2034

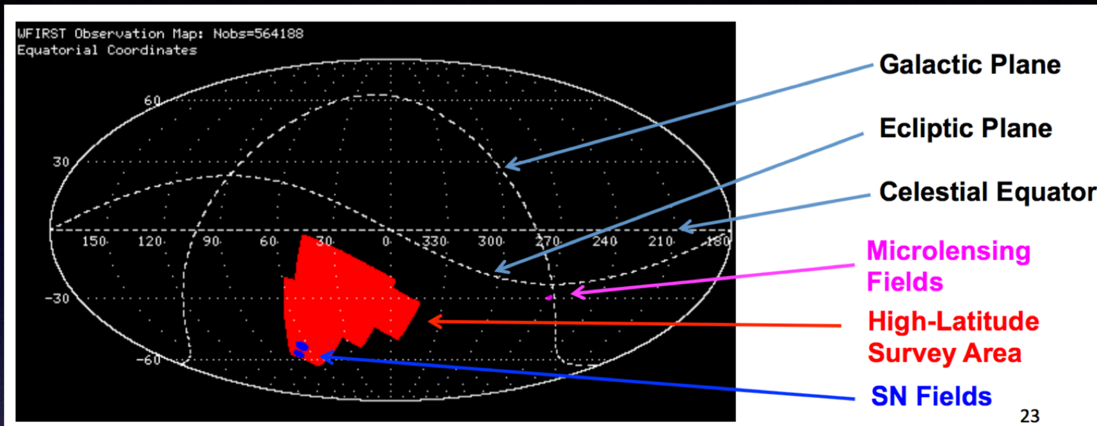
	LSST	WFIRST SPACE!	Euclid SPACE!
Start	2022 (2020)	~2024	2021
Area	18,000	2,300*	15,000
Location	~south	Overlap LSST	Best
Time	10 years	2 of 6 years	6 years
Passes	Many	~5	1
Depth	25-28 optical	27 NIR	24.5 optical and NIR
Bands	ugrizy	4 NIR	1 wide optical, 3 NIR
Spectra	No	Grism & IFC	Grism

Sensitivities of LSST, WFIRST, and Euclid



Rubin, Roman and Euclid are highly complementary missions.

Roman



About **2,200 sq.deg.** will be covered **by all three surveys**: 0.12 arcsec in VIS and YJH and photometry in ugrizyYJH

At least about **7,000 sq.deg.** of **Euclid-LSST overlap**: VIS and photometry in ugrizyYJH

Euclid

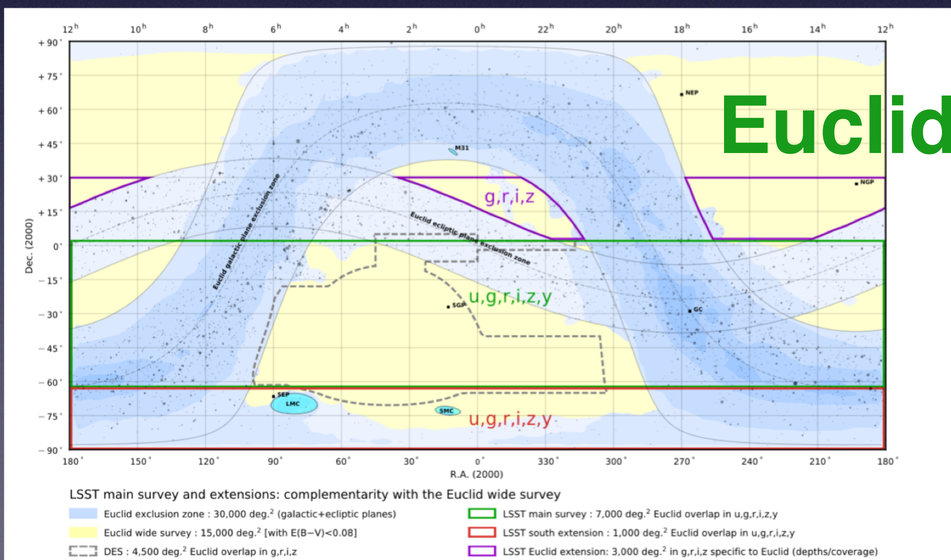
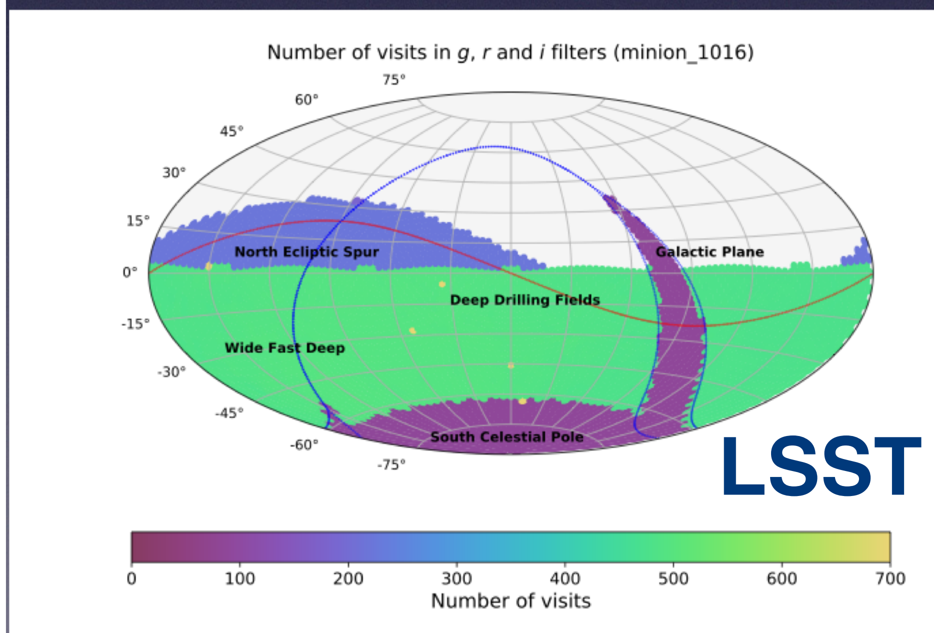


Figure 4.3.1: LSST survey areas (boxes) and the Euclid wide survey (yellow) with its exclusion zones (blue: galactic plane + ecliptic plane + reddening). We indicate the number of square degrees from the LSST surveys that overlap the Euclid wide survey along the relevant photometric bands. The points of interest indicated on this equatorial coordinate projection centered on the south galactic cap are: North&South Ecliptic&Galactic Poles (NEP/SEP/NGP/SGP), the Galactic Center (GC), the Magellanic Clouds (LMC/SMC), and the Andromeda galaxy (M31).

LSST



Rubin, Roman and Euclid are highly complementary missions.

1) Rubin-Roman-Euclid: about 2,200 sq.deg. will be covered by all three surveys: 0.12 arcsec in VIS and YJH and photometry in ugrizYJH
- with 68 gals/arcmin2: 0.5B galaxies

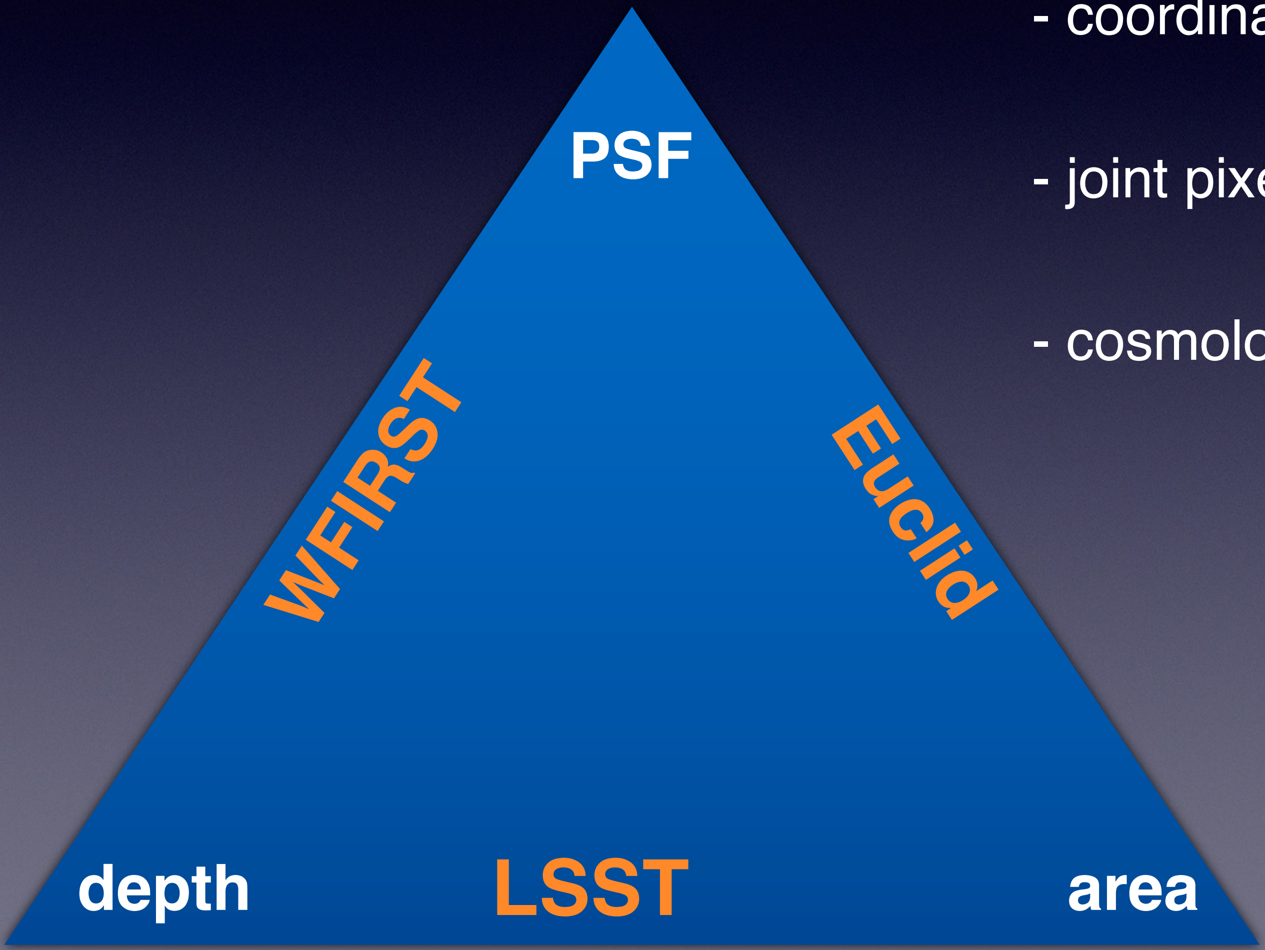
2) At least about 7,000 sq.deg. of Euclid-LSST overlap: VIS (0.13 arcsec) and photometry in ugrizyYJH
- with 40 gals/arcmin2: 1.0B galaxies

3) LSST alone, compared to 1):
~8 times larger area
~5 times more well-resolved galaxies (~2.6B at 40 gals/arcmin2)
but no JH photometry and
~3 times larger PSF

4) Additional synergies from deep fields and coeval observations...

Summary

Rubin, Roman and Euclid are highly complementary missions.



Coordination needs:

- cadence coordination
- coordinated data releases
- joint pixel-level processing
- cosmological simulations