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URBANA-CHAMPAIGN

Rubin + Euclid Joint Data Products for SSOs

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June 7, 2022



Rubin Observatory



The Vera C. Rubin Observatory is nearing completion in leaps and bounds.

The Legacy Survey of Space and Time (LSST) set to begin in 2024.

LSST: 10yr ugriz survey of the southern sky.



Euclid

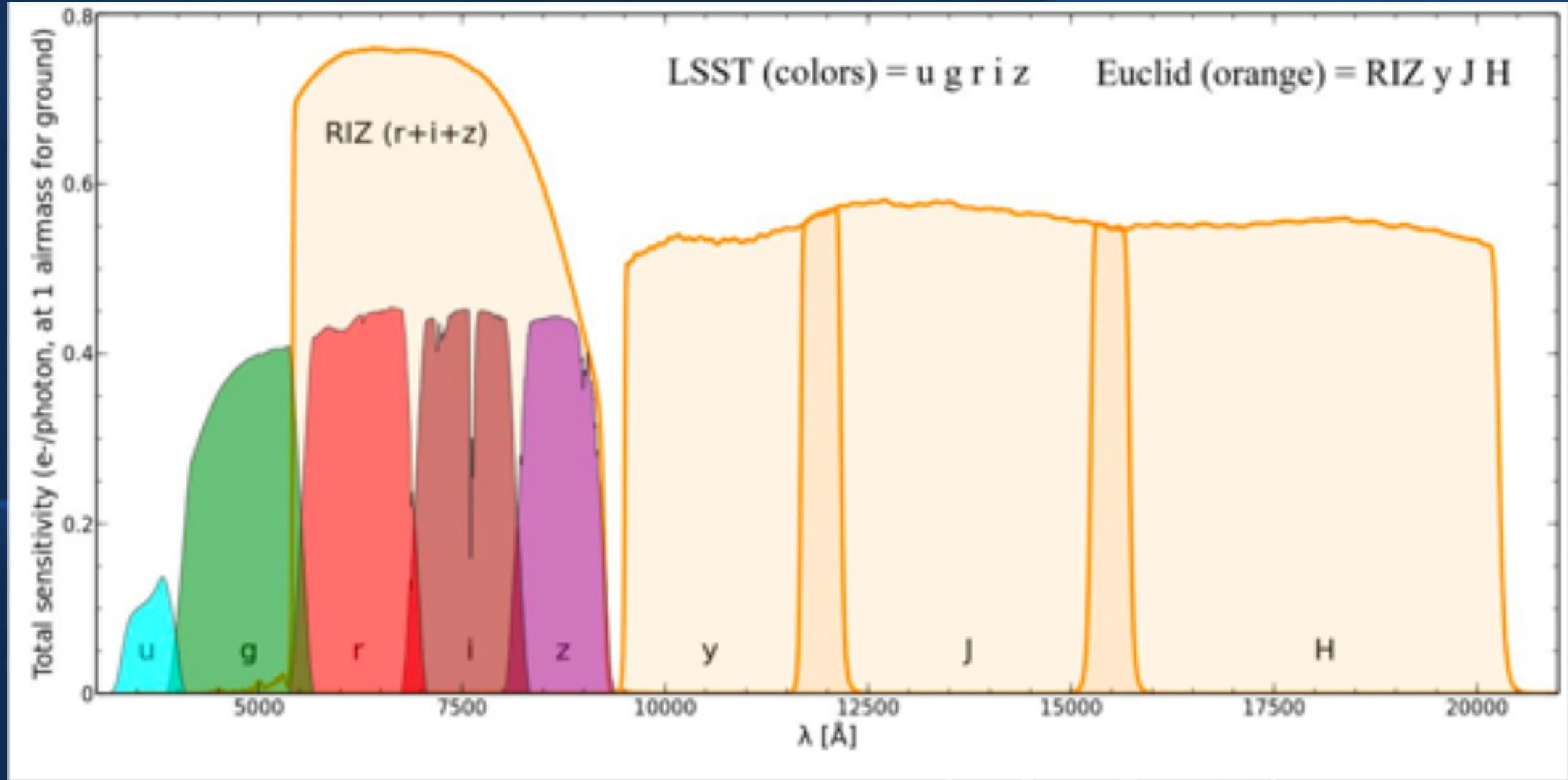


ESA is preparing to launch Euclid in 2023.

- 6yr long 15,000 deg² survey,
- broadband Visual Imaging Channel (VIS, ~600s exp.),
- Near-Infrared Spectrometer and Photometer (NISP, Y+J+H bands ~100s exp.),
- Earth-Sun L2,
- 1.2m mirror.



Rubin + Euclid Filters



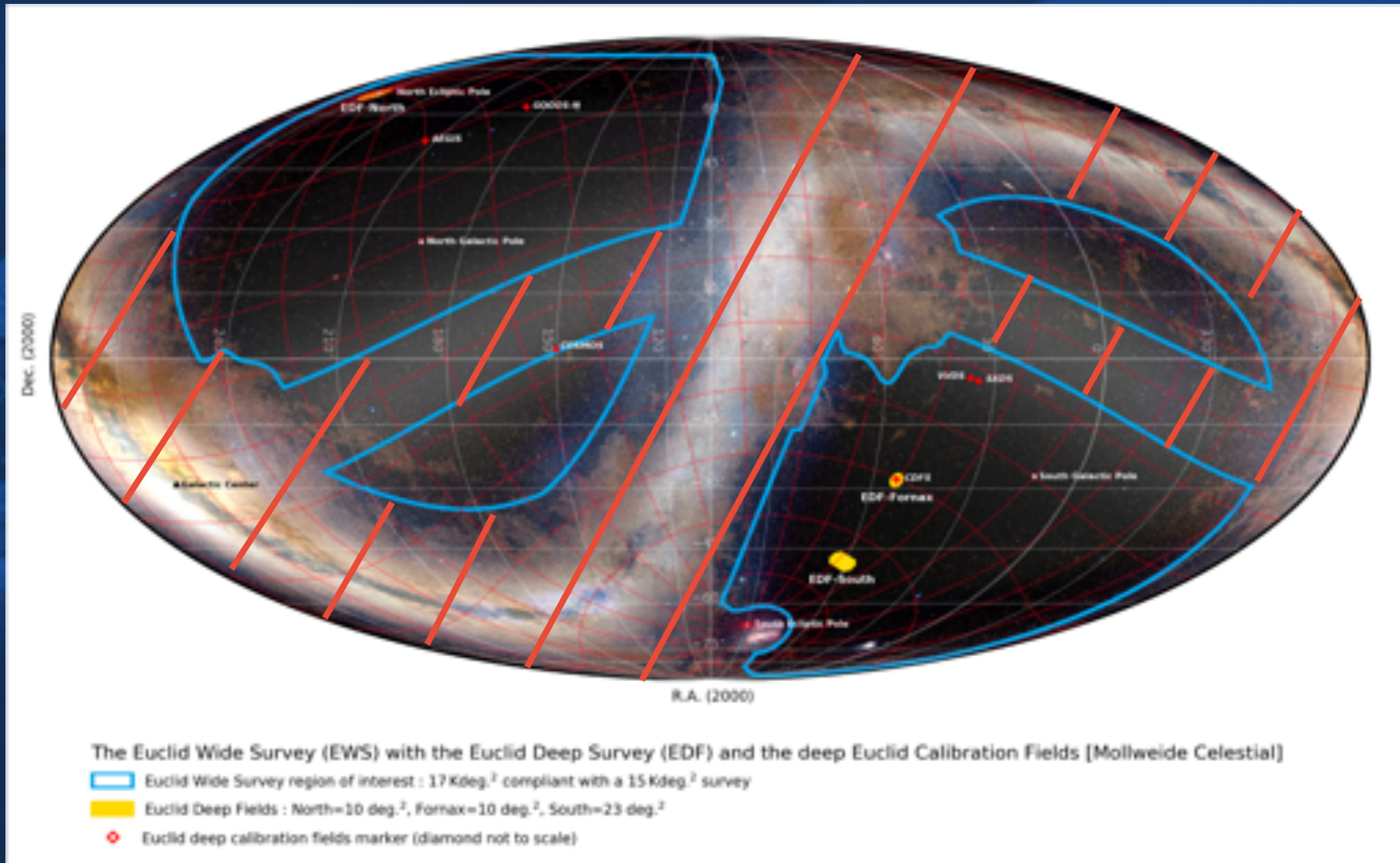
Euclid Science

- What is dark matter?
- What is dark energy?
- What is gravitational lensing?
- What are baryonic acoustic oscillations?

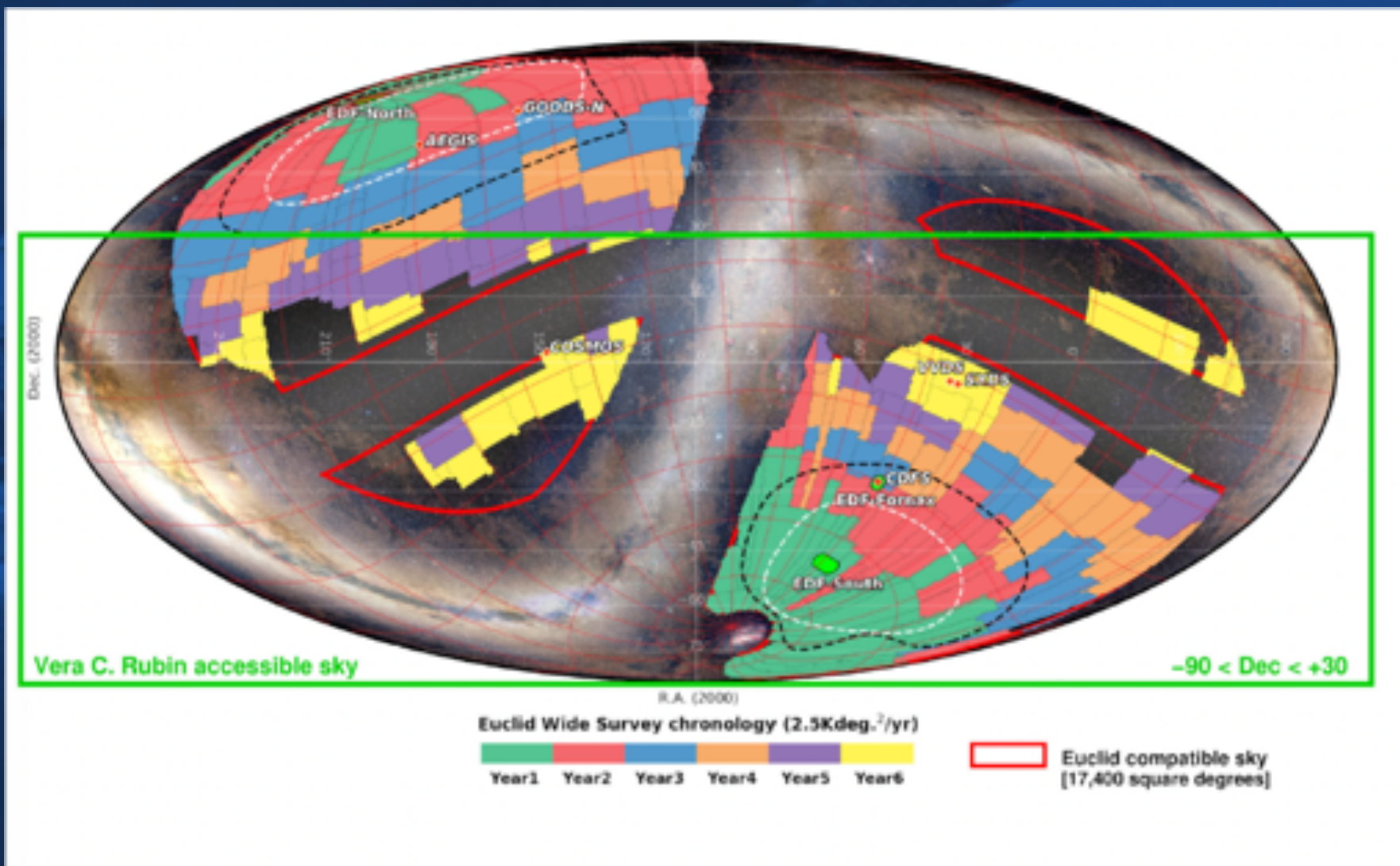
Carry (2018):
Solar System Science with Euclid



Euclid Survey



Overlap Rubin & Euclid

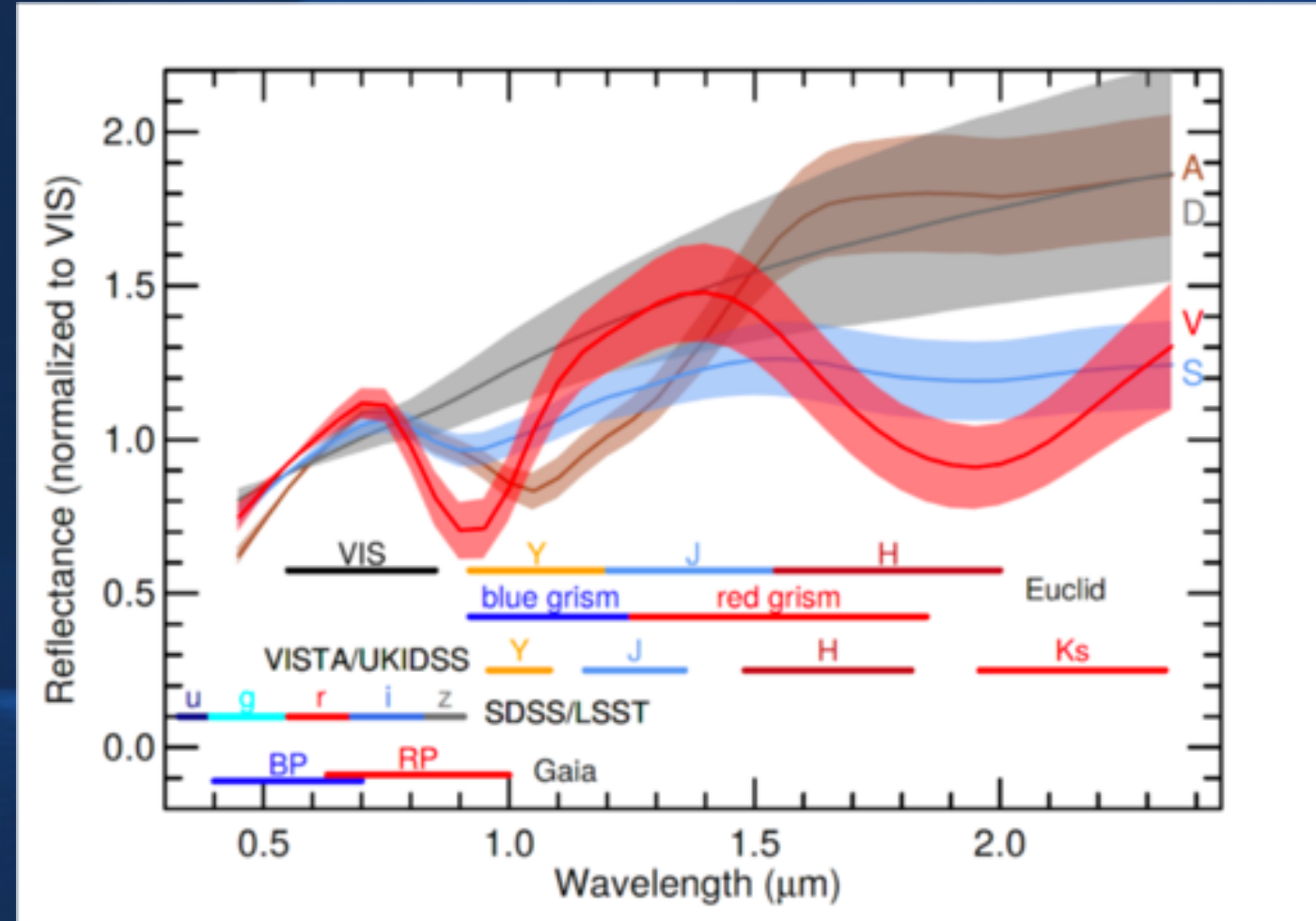


Euclid and SSOs



- detection limit of $m_{AB} = 24.5$ for 10σ on a $1''$ extended source
- wide field of view ($0.8 \times 0.7 \text{ deg}^2$)
- will observe 150,000 SSOs, 99% of which are currently unknown.

Carry (2018)



Rubin + Euclid Benefits for SSOs

- Timely Astrometry and Activity Reporting,
- Parallax,
- Improved taxonomic classification,
- Improved phase curves and absolute magnitudes (H),
- Densification of sparse light curves.
- Better constraints on size, shape and spin, multiplicity/binarity as well as composition of observed SSOs.
- Euclid will reveal “fuzziness” that shows weak activity (hidden within the seeing disc for LSST),
- Early detection of comets, outbursts of cometary activity, and newly arising asteroid activity.



Rubin + Euclid
Joint Derived Data Products

Recommended Rubin-Euclid Derived Data Products summary table [1/2]

Acronyms/Codes per column: 1) DDP code name; 2) Community served: B(oth), E(uclid), R(ubin); 3) Priority (P1 to P2) + Urgency (U1 to U3) + Timescale (Real Time, Yearly, Data Releases); 4) Production tier (T0 to T3)

Cross-Cutting (CC)

DDP-1-CC	B	P1+U1+YR	T1	Multi-band Rubin+Euclid photometry list-driven catalogs
DDP-2-CC	B	P1+U2+DR	T2	Multi-band Rubin+Euclid forced photometry catalog from joint-pixel processing
DDP-3-CC	B	P2+U2+DR	T3	Multi-band Rubin+Euclid deblended photometry catalog from joint-pixel processing
DDP-4-CC	B	P2+U2+DR	T3	Galaxy "pixel" photometric redshifts
DDP-5-CC	B	P1+U1+RT	T0	Image cutouts/stamps delivery service

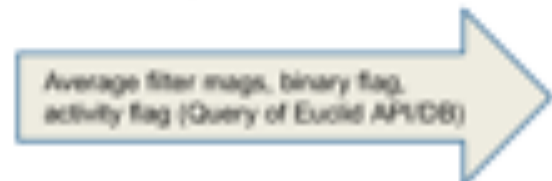
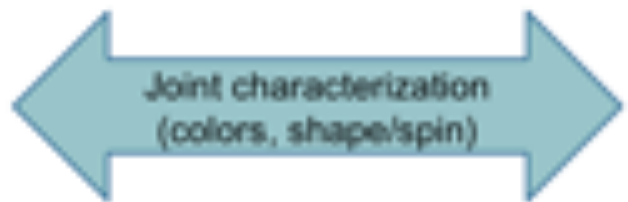
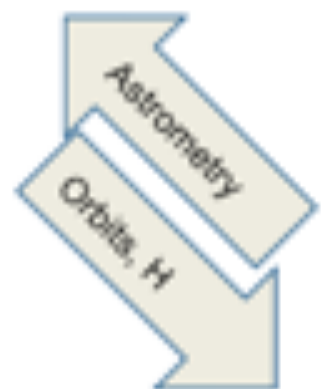
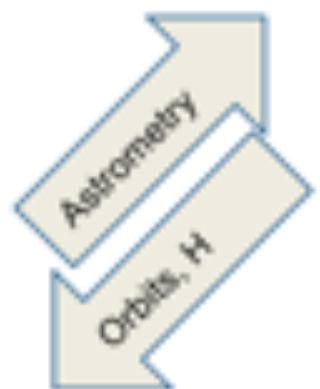
Solar System (SS)

DDP-6-SS	B	P1+U1+RT	T0	Timely Solar System Object astrometry
DDP-7-SS	B	P1+U1+RT	T0	Stamps for Solar System Objects
DDP-8-SS	B	P2+U2+DR	T1	Solar System Object light-curve catalog
DDP-9-SS	B	P2+U3+DR	T2	SSO shape catalog from lightcurves

Column 3	Tier	Description
P1 + U1 + RT	T0	Ready when both telescopes observe the same sky in 2023
P1 + U1 + YR	T1	In conjunction with the Rubin-LSST Year 1 release in 2025
P1 + U2 + DR	T2	In conjunction with the Euclid DR2 and LSST Year 3 in 2027
P2 + U2 + DR	T3	In conjunction with the Euclid DR3 and LSST Year 4 in 2029
Non-baseline	T4	Pending definition of Euclid's non-allocated time (illustrative DDPs)

- Multi-band Rubin+Euclid photometry catalogs
- Galaxy photometric redshifts
- Image cutouts/stamps
- Standalone DDP not realized through a Cross-Cutting DDP

Daily Data Exchange
Data Releases



LSST SSO Data Products



A. Real-time Alerts ($\geq 2M$ SSO observations/night)

Astrometry	± 10 mas (bright; ± 140 faint)
PSF flux	± 10 mmag (bright end)
Aperture flux	± 10 mmag (bright end)
Trailed source fit	Flux and on-sky motion for fast-moving (trailed) objects
Appearance characterization	Moments and extendedness of the object's image
Spuriousness score	Probability that the detection is an artifact
Nearby static objects	Information on adjacent objects (up to three)
MPC designation	Given for known objects
Predicted position and magnitude	Given for known objects

More information:

- [1] *LSST Overview Paper*: <http://ls.st/lop>
- [2] *Data Products Definition Document*: <http://ls.st/dpdd>
- [3] *Solar System Data Products Schema*: <http://ls.st/ouq>

B. Daily Solar System Products ($\geq 5.5M$ objects)

Orbits	Computed by the MPC
Light-curve characterization	Period, light curve shape, other features
Absolute magnitude estimates	Estimates of (H, G12) in u,g,r,i,z,y bands
MOID	Minimum Orbit Intersection Distance to Earth
Extendedness indicators	Is/was the object comet-like in its appearance.

C. Solar System Data Release Products (every year)

High-fidelity reprocessing	Catalogs derived from re-reductions of all survey data using improved calibrations and a single, well-characterized, software release.
The LSST Catalog of Solar System Objects	A catalog, suitable for population studies, of objects detected by LSST with orbits estimated using only LSST data.

Euclid SSO Data Products



A. Euclid Alerts

Not foreseen

B. Euclid Daily Data Products (shared with Rubin)

Euclid ID	Euclid internal identification
Number	Official IAU Number
Designation	Official IAU designation
Epoch	Mid-observing time of the sequence (JD)
Binary_flag	Boolean to indicate potential binarity
Activity_flag	Boolean to indicate potential activity
VIS_mag*	Average magnitude in VIS filter
Y_mag*	Average magnitude in Y filter
J_mag*	Average magnitude in J filter
H_mag*	Average magnitude in H filter
RA**	Preliminary EQJ2000 Right Ascension
Dec**	Preliminary EQJ2000 Declination

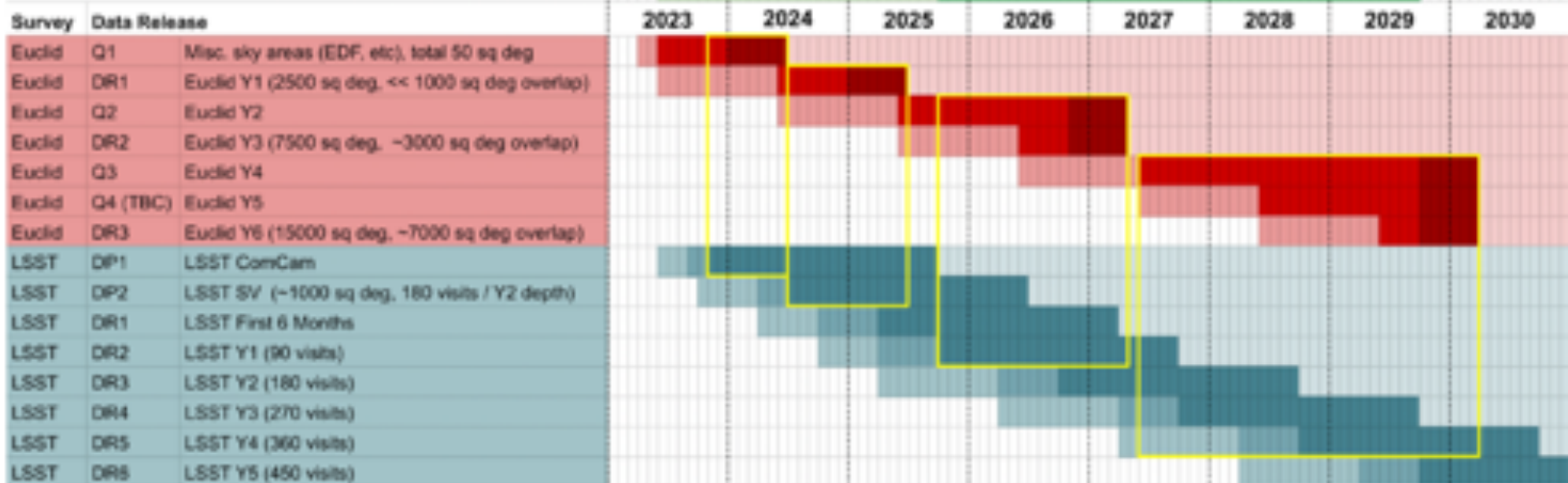
* Average filter magnitudes are not corrected for rotational variation during exposure.

** Preliminary astrometry does not account for potential field distortions.

C. Euclid Data Releases (once for each Euclid image)

Number	Official IAU Number
Designation	Official IAU designation
Instrument	VIS NISP
Filter	VIS Y J H
Epoch	Mid-observing time (JD)
RA	EQJ2000 Right Ascension
Dec	EQJ2000 Declination
Mag	Apparent magnitude in VIS
err_RA	Uncertainty on EQJ2000 Right Ascension
err_Dec	Uncertainty on EQJ2000 Declination
err_Mag	Uncertainty on apparent magnitude in VIS
Stamp	Stamp centered on source
(once for each Euclid tile)	
VIS-Y	VIS-Y color, corrected for rotational variation
VIS-J	VIS-J color, corrected for rotational variation
VIS-H	VIS-H color, corrected for rotational variation

Rubin-Euclid Coordination Timeline



Assumptions:

February 2023 Euclid mission launch date

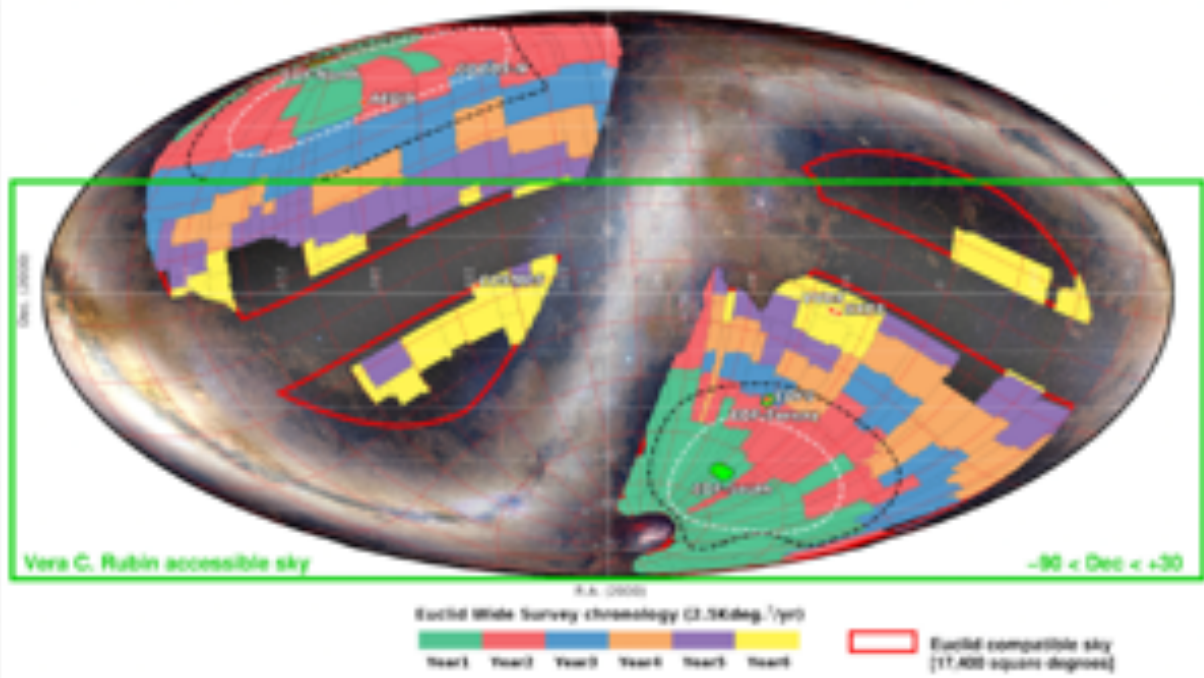
April 2024 LSST survey start

Surveys color keys:

Light Red	Observing
Dark Red	Processing
Light Blue	Proprietary Access
Light Green	Public Access

Notes:

- (a) LSST data release dates may move by +3 months as the operations team adapts to circumstances.
- (b) Euclid plan additional quick releases containing specific featured data products made with the Y2 ("Q2"), Y4 ("Q3") and Y5 ("Q4", TBC) data. The data from these years will be available to the Euclid Consortium to use while they are being processed, there just won't be an internal release of a full data release dataset.
- (c) The overlap between Euclid Y1 and LSST SIV is potentially quite small, because Rubin commissioning observations are needed at a wide range of latitude (and the best calibration pre-cursor data tends to be closer to equatorial). The ST-Com team's field selection is not yet determined.
- (d) DOP transient science can start in 2023 with limited sky overlap (green bar).
- (e) LSST Y1 leads to matched survey depths for photo-z estimation: the production of related DOPs (photometric catalogs) spans 4 years (top darker green bar, 2025 to 2029) based on LSST Y1 to Y4 yearly data releases progressively matched to the Euclid survey increasing overlap.

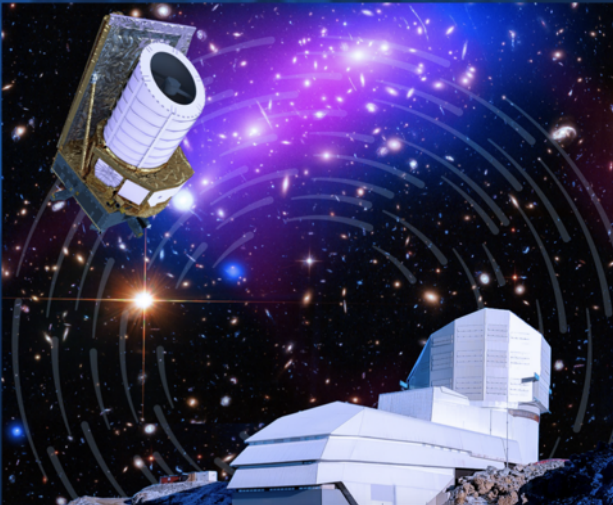


Suggested Data Products

Name	Approx. Size	Details	Description
shapes	2GB	150k * 1k light curve points * vertex xyz * 32bit float	Shapes can be stored in text files containing vertex coordinate information.
light curves	1GB	150k * (1k light curve points + 10 derived parameters) * 32bit float	Joint Euclid - Rubin light curve data files with filters, measured filter magnitudes, time stamps and derived color information such as spectral slopes and absolute filter magnitudes.
stamps	13GB	150k * 10 filters * 30x30pixel * (32 + 32 + 16)bit float (flux + variance + mask)	Stamps of objects jointly observed by Euclid and Rubin and derived pixel values in all filters.

Table 1: A preliminary list of proposed data products (DP) for Solar System science. DP size estimates are approximate, uncompressed file sizes for a population of 150k jointly observed Solar System Objects.

Rubin + Euclid Derived Data Products Report



<https://arxiv.org/abs/2201.03862>