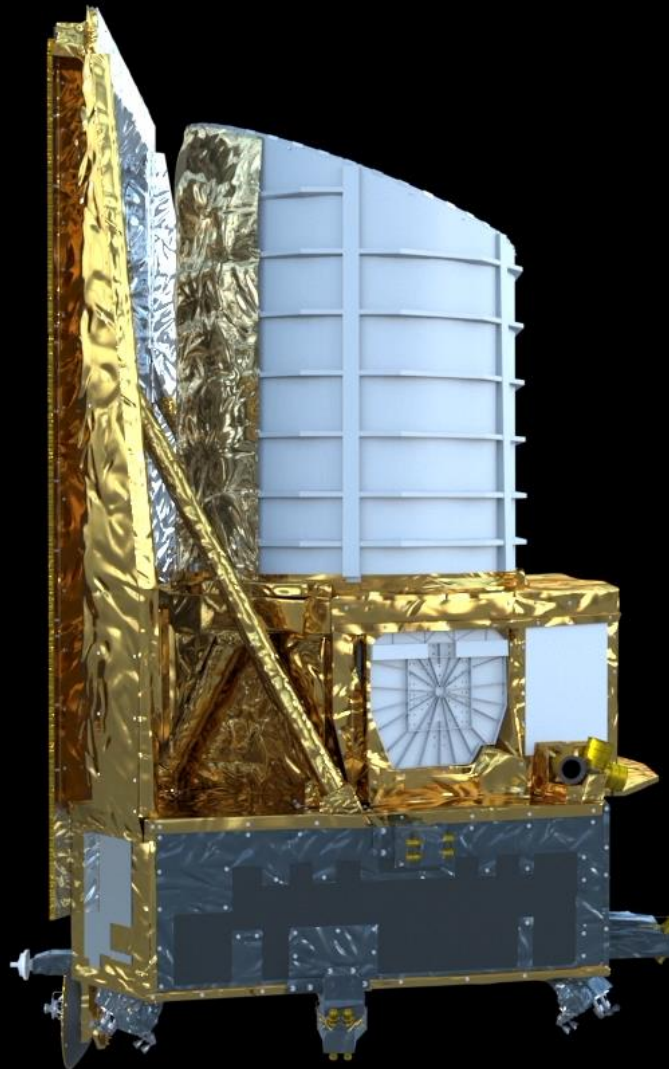


Euclid Update



Jason Rhodes (Jet Propulsion Laboratory, California Institute of Technology)

October 15, 2021

APAC update

Euclid: a survey space telescope led
by European Space Agency (ESA) and
the Euclid Consortium

Prime Science Objectives: quantify Dark
Energy [$w(a)$], Modified Gravity [γ], Dark
Matter [m_ν], and the Universe's Initial
Conditions [f_{NL}]

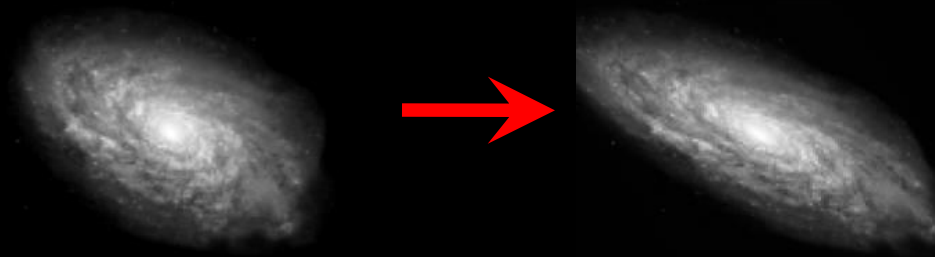
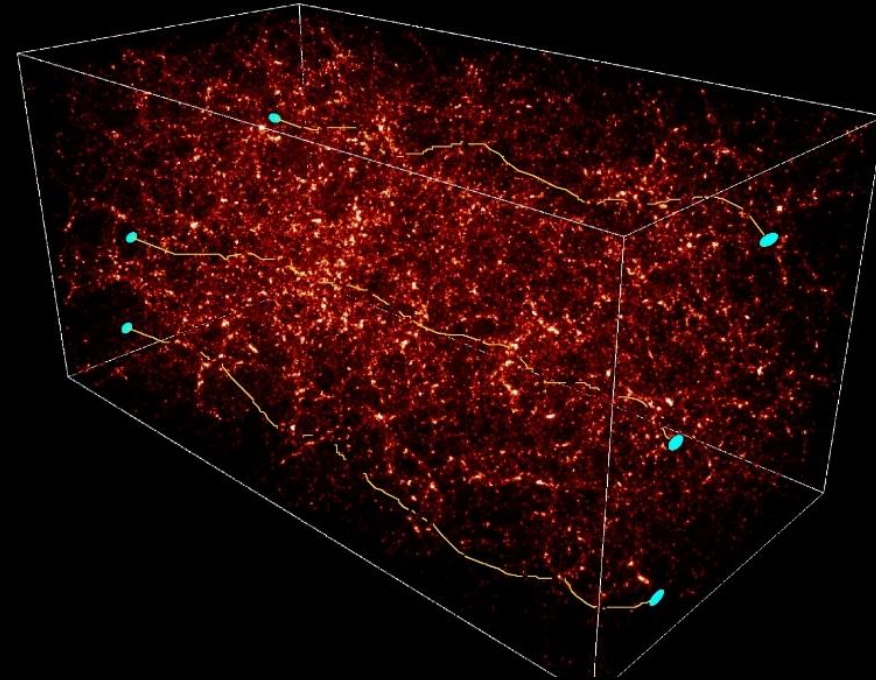
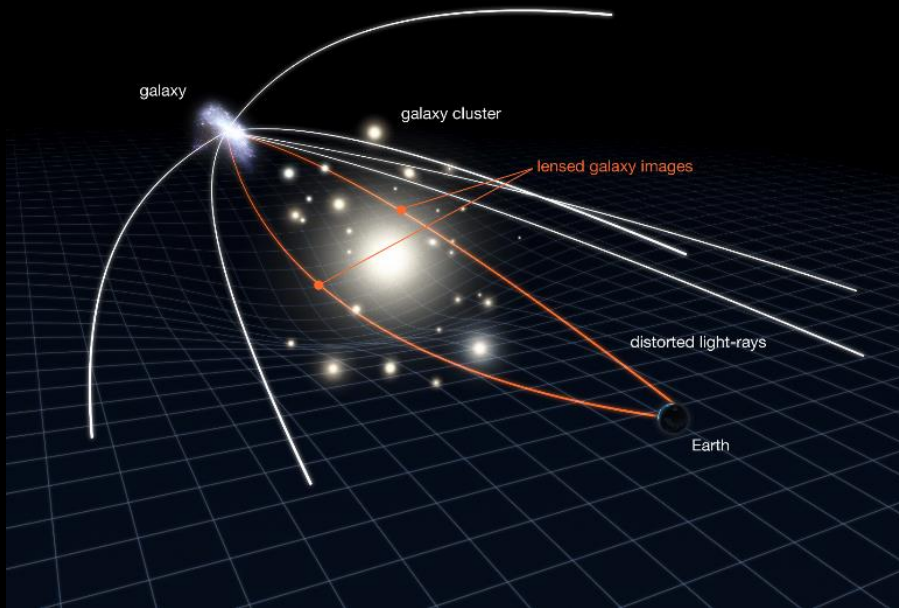
*make a decisive measurement of the accelerated expansion of
the Universe*

Euclid Leadership:
Rene Laureijs- ESA PS
Giuseppe Racca- ESA PM
Yannick Mellier- Euclid Consortium Lead



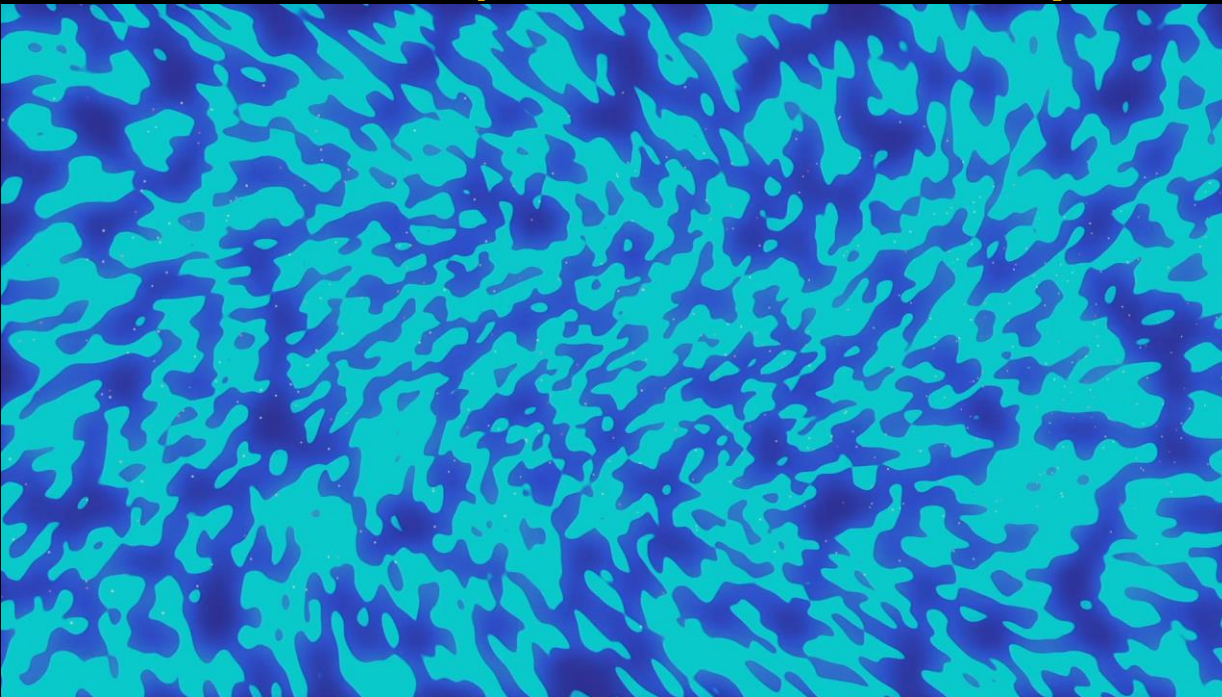
Euclid is designed to measure two cosmological probes:

□ Weak Lensing (WL)

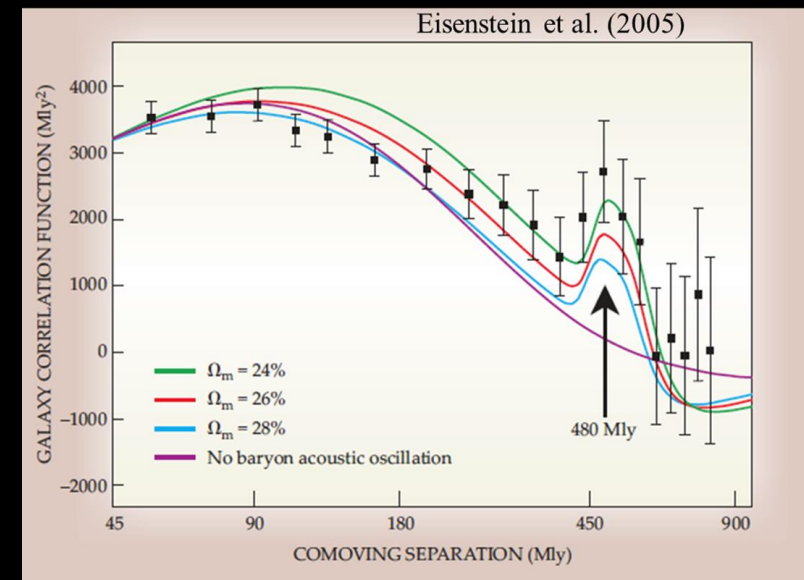


Euclid is designed to measure two cosmological probes:

□ Galaxy Clustering (GC, including Baryon Acoustic Oscillations and Redshift Space Distortions)



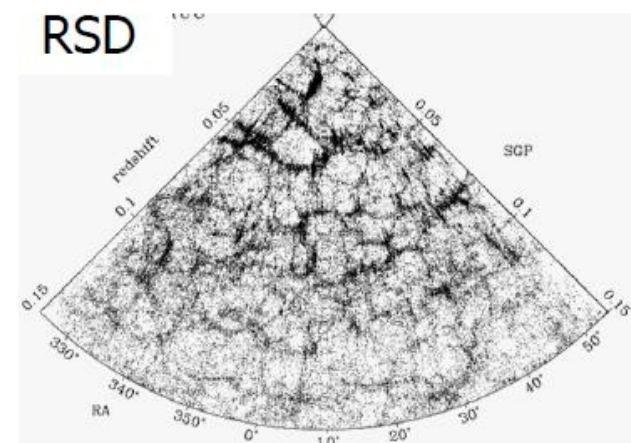
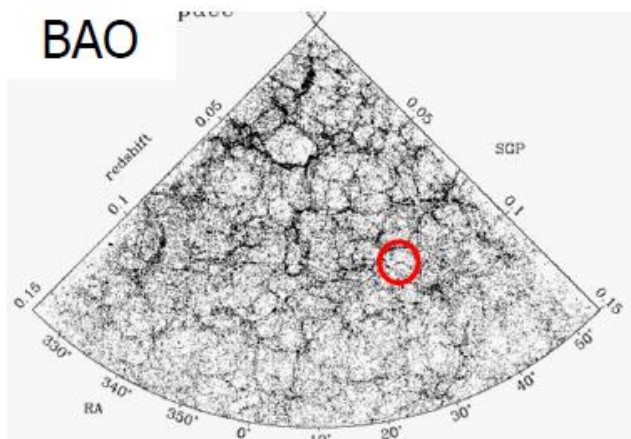
Credit: NASA GSFC



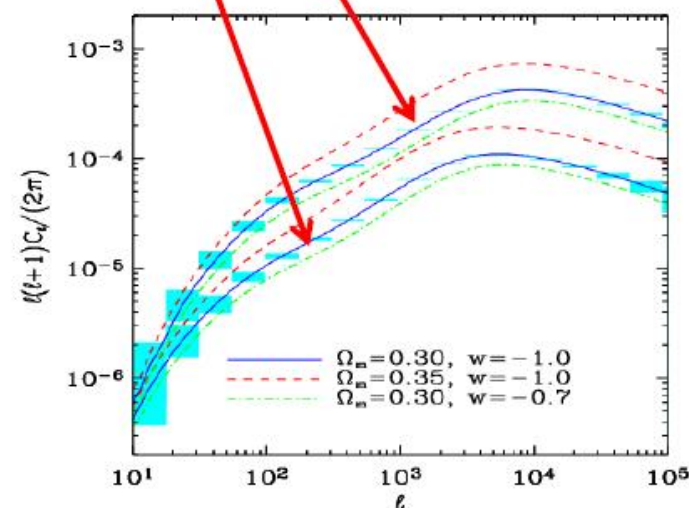
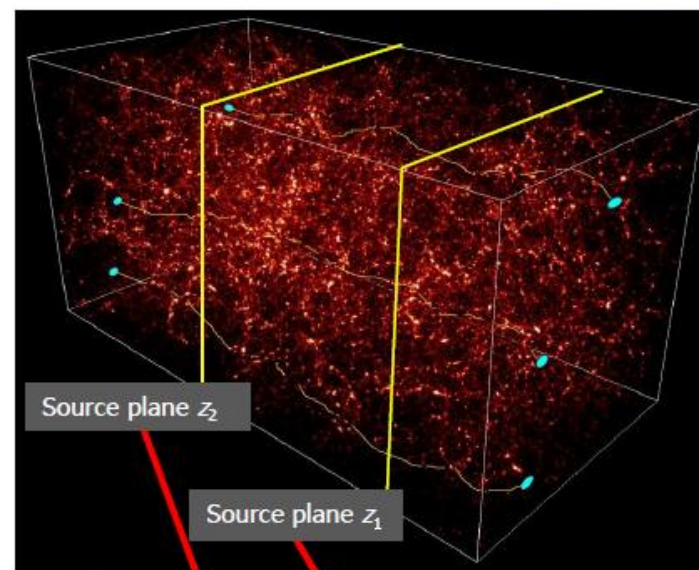
Euclid Primary Probes

BAO, RSD and WL over 15,000 deg²

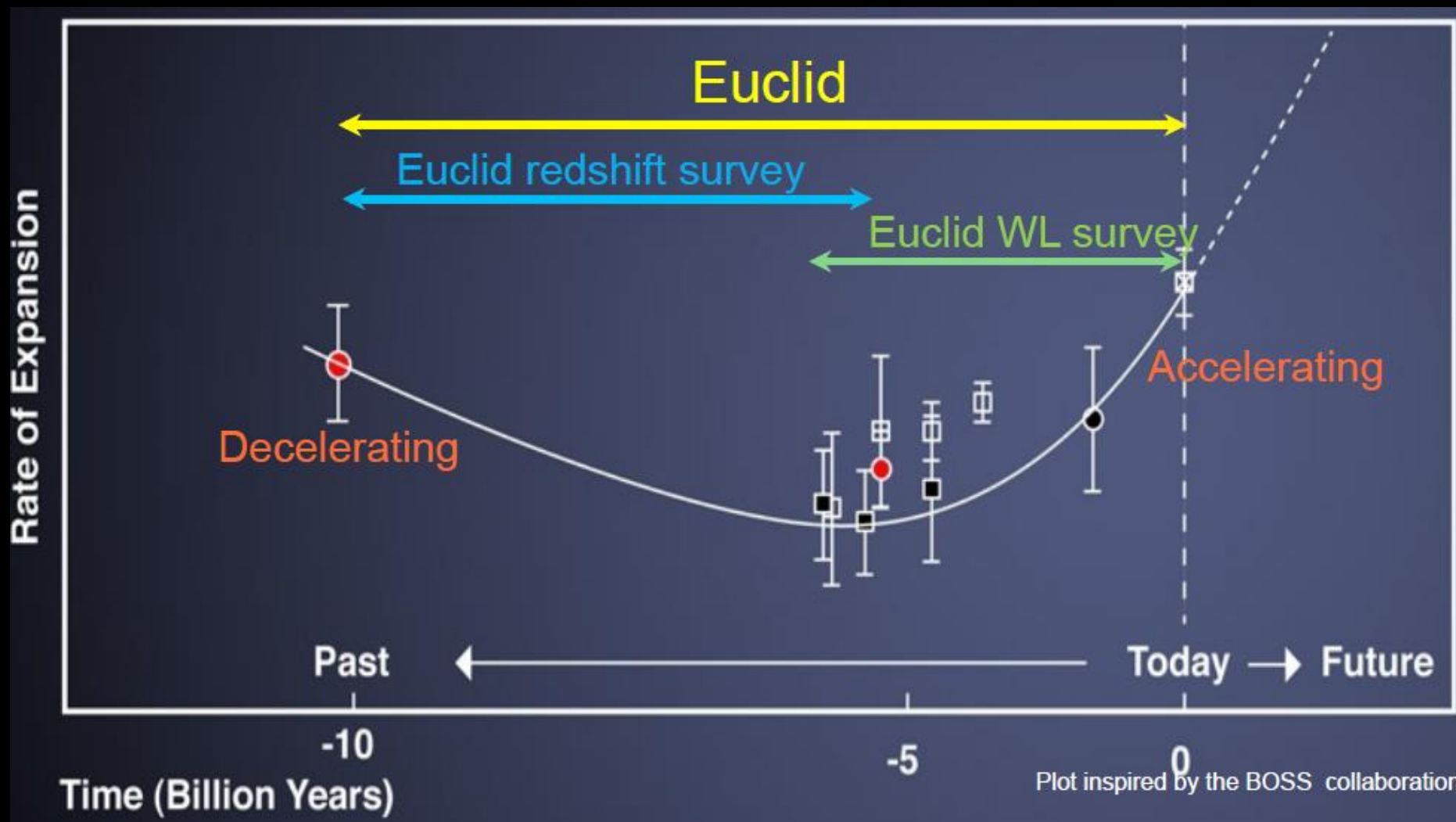
50 million galaxies with redshifts



1.5 billion sources with shapes, 10 slices

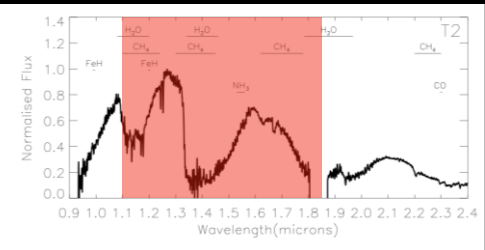


Combining probes



From Y. Mellier

Euclid legacy science - some examples

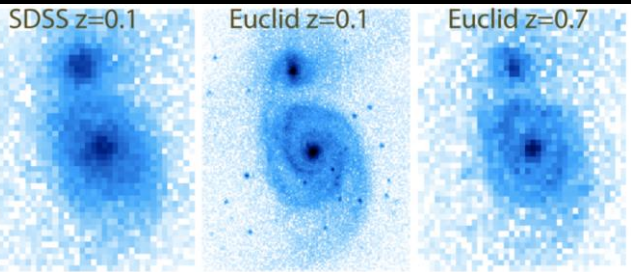


Cool brown dwarfs - both in spectroscopy and imaging

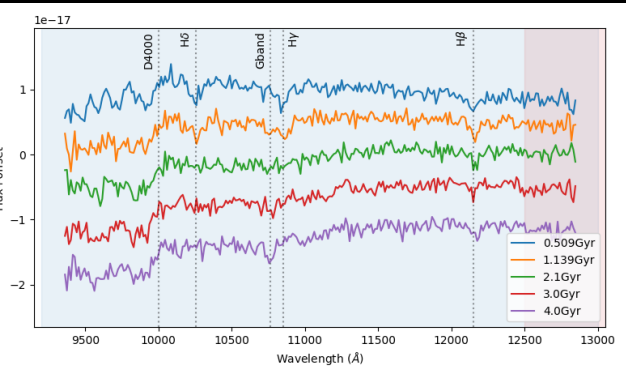
Niall Deacon, Bianca Garilli, Paolo Franzetti

Euclid NIR imaging: detection of giant branch stars out of 5 Mpc - streams, galaxy halos

2-3 orders of magnitude more strong galaxy lenses than before Euclid (1.5 SLACS/week)



Galaxy morphologies across the whole extragalactic sky ($>10^3 \times \text{HST}$)



courtesy Tranin, Cimatti, Moresco, Pozzetti, Ealet, Zoubian et al

Rare objects galore - massive, passive galaxies with spectra to H \sim 23, the brightest $z>7$ Ly- α emitters, ...

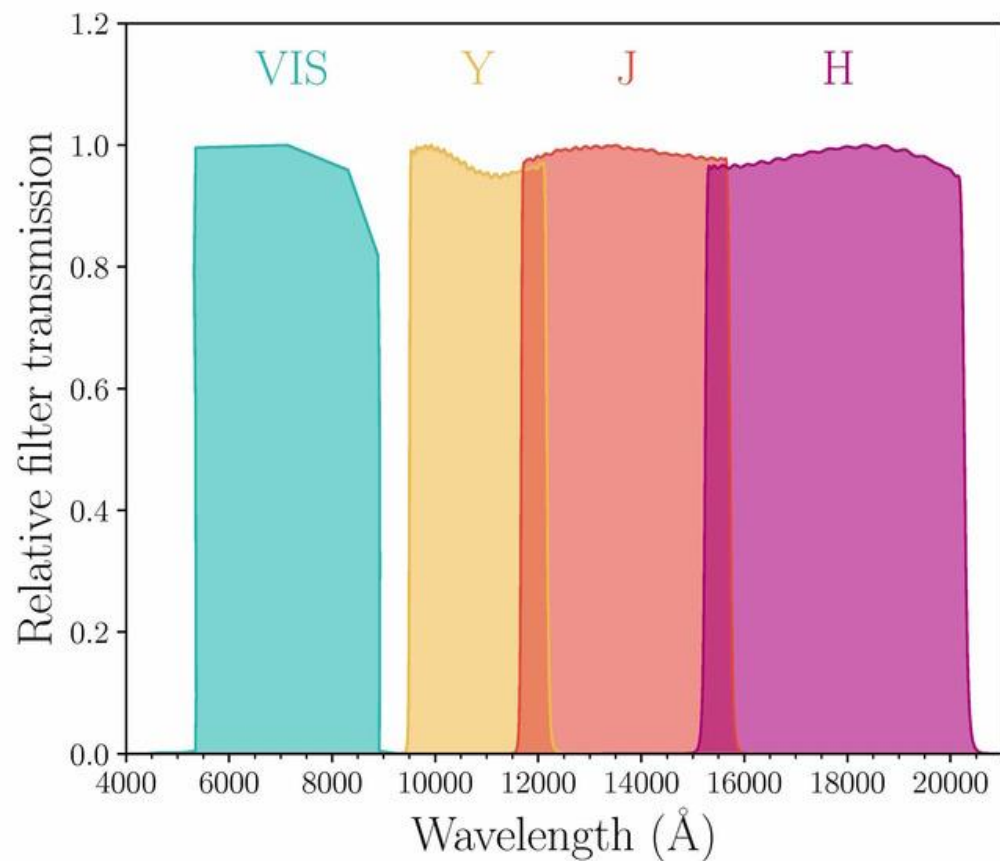
Euclid will find the sources to follow-up for years to come

What	Euclid	Per deg ²
Galaxies at $1 < z < 3$ with good mass estimates and morph.	$\sim 2 \times 10^8$	$\sim 10^4$
Massive galaxies ($1 < z < 3$) w/spectra	$\sim \text{few} \times 10^3$	~ 0.2
H α emitters/metal abundance at $z \sim 2-3$	$\sim 4 \times 10^7 / 10^5$	$\sim 10^3 / \sim 10$
Galaxies in massive clusters at $z > 1$	$\sim (2-4) \times 10^4$	~ 40 (per cluster, $H_{AB} < 22.5$)
Type 2 AGN ($0.7 < z < 2$)	$\sim 10^4$	< 1
Galaxy mergers	$\sim 10^5 - \text{few} \times 10^6$	1-100
Strongly lensed galaxy-scale lenses	$\sim 200,000$	1-10
$z > 7$ Ly- α emitters	$\sim \text{few} \times 10^3$	$\ll 1$
Resolved stellar populations	$\sim 13?$ with $M_{\text{abs}} < -19$	$\ll 1$



Proposed lifetime	2023 - 2033	2022 - 2030	2026 - 2031
Mirror size (m)	6.5 (effective diameter)	1.2	2.4
Survey size (sq deg)	~20,000	15,000	2,227
Median z (WL)	0.9	0.9	1.2
Depth (5 σ AB mag point source)	~27	~24 (NIR) ~26 (Vis)	~27
FoV (sq deg)	9.6	0.5 (Vis) 0.5 (NIR)	0.28
Filters	u-g-r-i-z-y	Y-J-H-Vis	Y-J-H-F184
PSF Size	~0.7"	~0.2" (Vis)	~0.2" (NIR)
Mode	Photometry	Photometry/Grism	Photometry/Grism

M3



1 Blue Grism: 0.92- 1.3 μm
3 Red Grisms: 1.25-1.85 μm

**Near-Infrared
Spectrometer and
Photometer (NISP)**

FOV:
0.78 x 0.73 deg
16 H2RGs
0.3" / pixel

**Visual Imager
(VIS)**

FOV:
0.79 x 0.70 deg
36 4kx4k e2v CCDs
0.1" / pixel



Launch:

on Soyuz
from Kourou,
No earlier
than Oct.
2022



Mission Lifetime:

6+ years
@ L2



Aperture:
1.2m



- “Constraining Dark Energy and Gravity with Euclid”, PI Rhodes (JPL)
 - To measure dark energy and how mass is distributed on the largest cosmic scales, through weak lensing (distortions of galaxy shape), baryon acoustic oscillations (galaxy clustering), and supernova explosions; to study how galaxies form by observing the most youthful (high-redshift) objects
- “Looking at Infrared Background Radiation Anisotropies with Euclid”, PI Kashlinsky (at GSFC)
 - To study unresolved infrared background light from the earliest galaxies, to infer the pace of early star formation.
- “Precision Studies of Galaxy Growth and Cosmology Enabled Through a Physical Model for Nebular Emission”, PI Chary (Caltech)
 - To study the effect of dust and glowing gas on galaxy spectra, to obtain better distance (redshift) estimates from the measured colors.
- Jason Rhodes - member of Euclid Consortium Board and ESA Euclid Science Team
- Michael Seiffert - Project Scientist and participant in Euclid Consortium

NASA flight hardware consists of 16 flight units (+ 4 flight spares) of :

- 2.3 μm cutoff HgCdTe detectors
- SIDECAR ASIC detector readout
- Cold cables

JPL led, with GSFC testing support

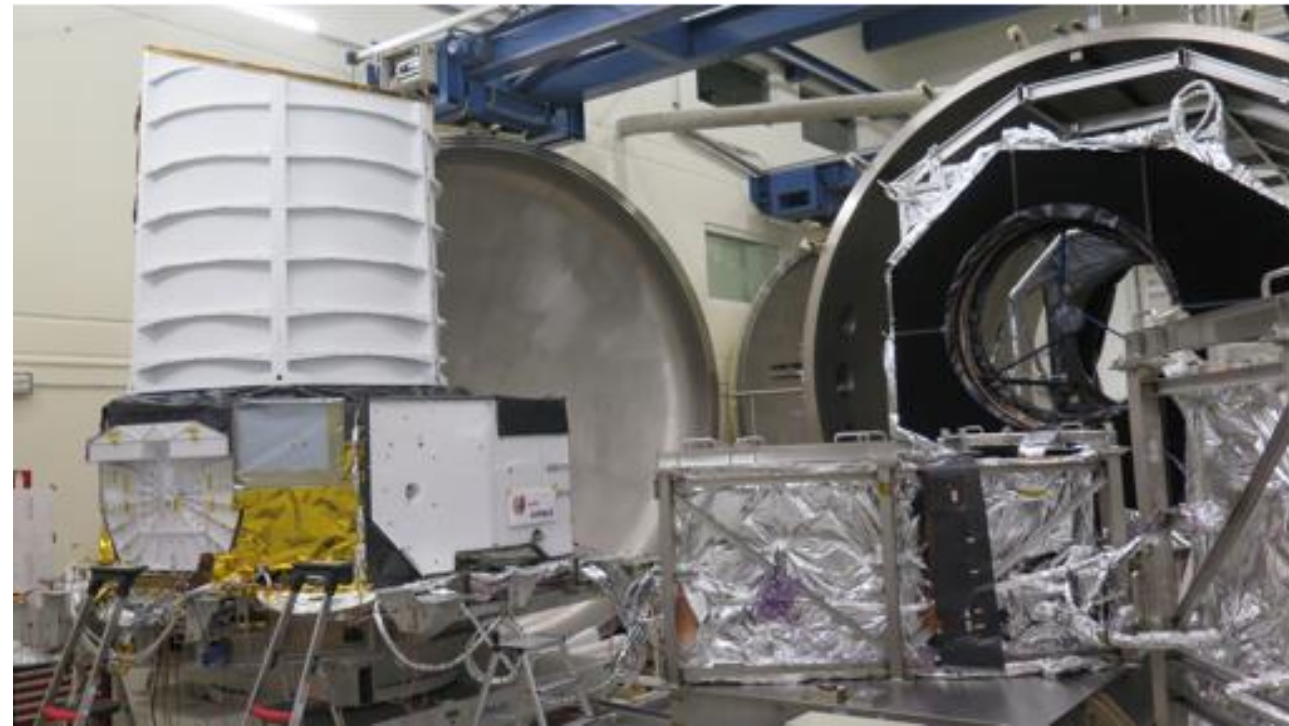
All NASA provided hardware has been successfully integrated with the NISP instrument and shows good performance



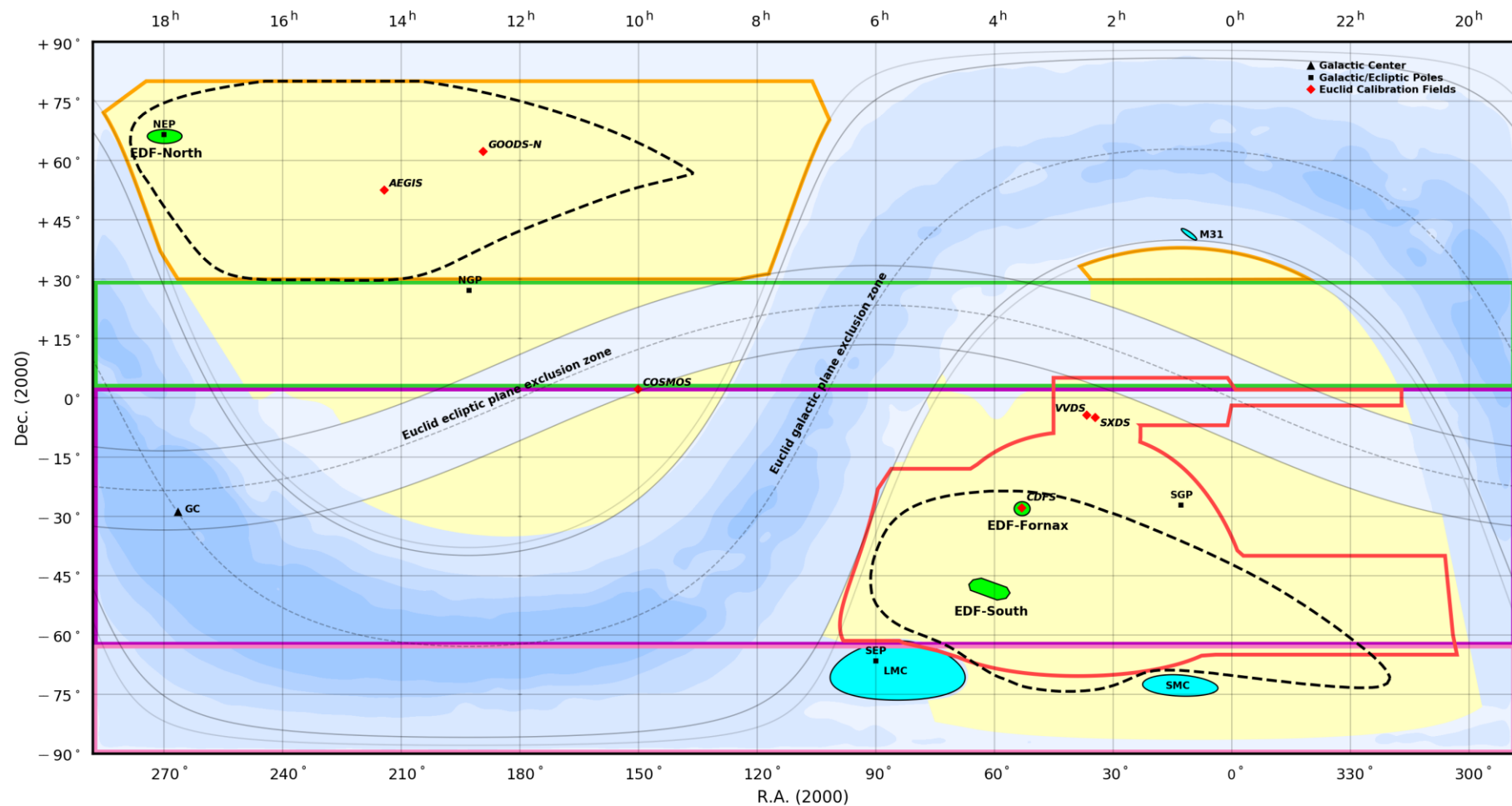
- Payload (telescope + two instruments) has completed thermal vacuum test
- Spacecraft integration and test underway
- Launch no earlier than Oct 2022



Spacecraft I&T at TAS-I




Integrated payload prior to thermal vac test; May '21



Expected ground-based coverage of the Euclid Wide Survey for DR1/2/3 (2.5/7.5/15 Kdeg.²) [origin/bands/calendar/overlap]

Euclid Wide Survey : 17 Kdeg.² compliant with a 15 Kdeg.² survey

 DES, griz, 2019 : 4.5 Kdeg.² overlap


UNIONS (CFHT/JST/Pan-STARRS/Subaru), ugriz, 2027, 5 Kdeg.²

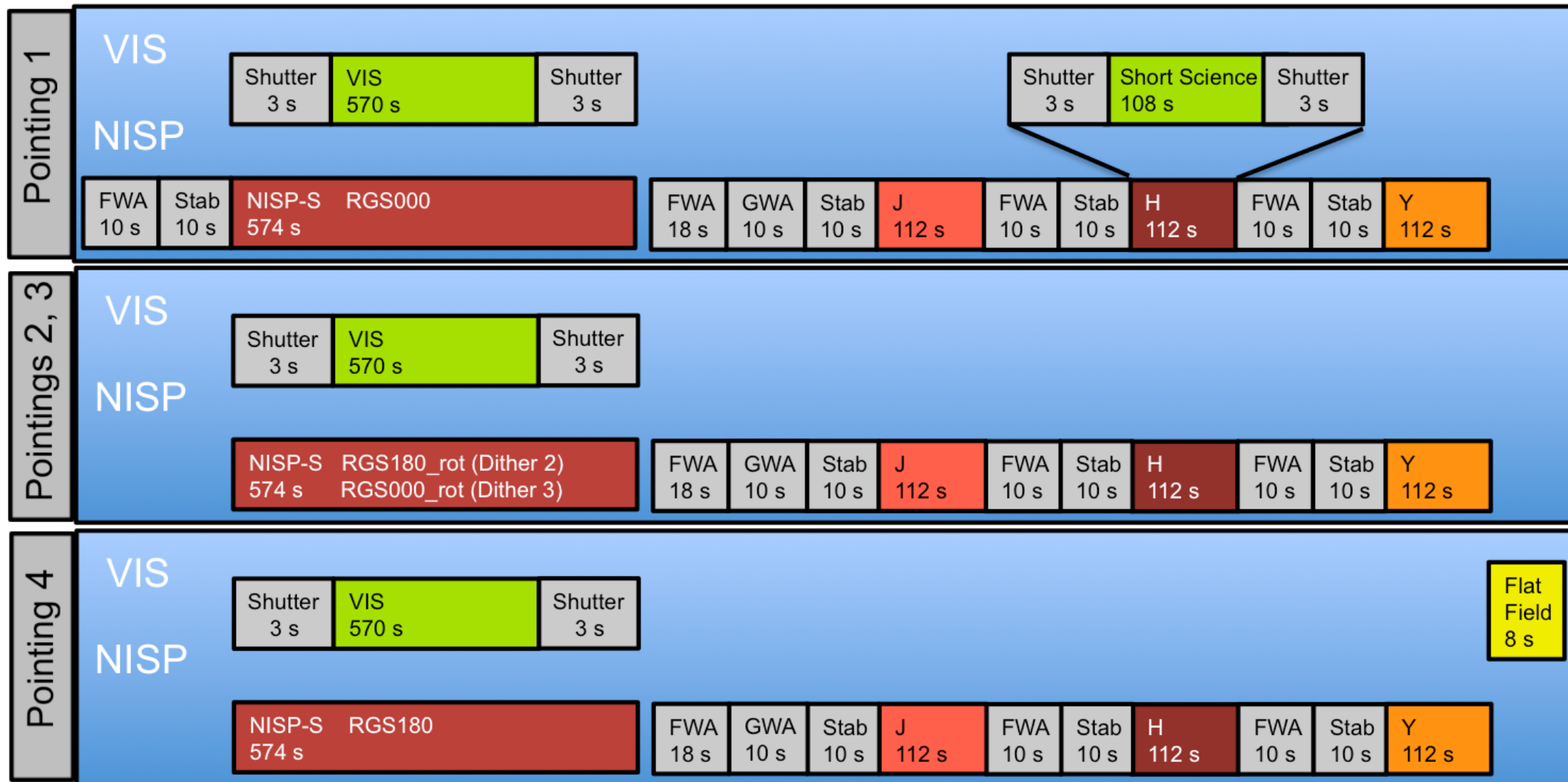
 Rubin LSST WFD, ugriz, 2023 : 8 Kdeg.² overlap

 LSST southern extension, griz, 2027 : 1 Kdeg.² overlap

 LSST northern extension, griz, 2027 : 3 Kdeg.² overlap

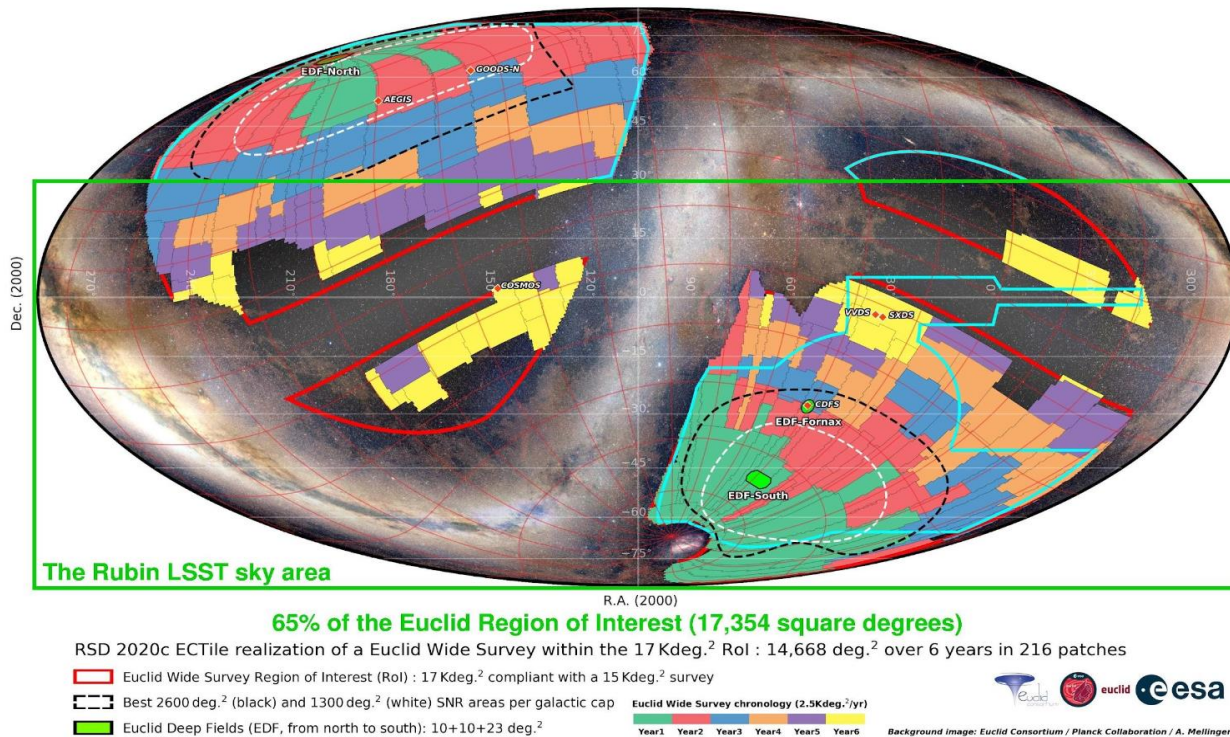


 Best 2600 deg.² SNR areas



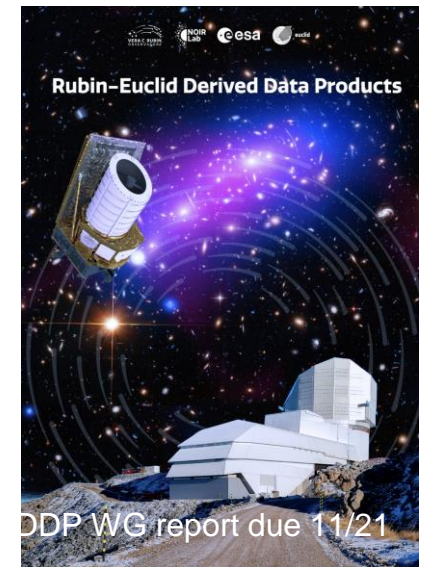
Science Driven Rubin-Euclid Derived Data Products (DDPs)

The DDPs will maximize the science output of both projects independently by generating products shared openly across the two consortia, all the while protecting science that is truly unique to each individual project



Science explored by the 350 Rubin and Euclid scientists during the open community 5-month long discussion on the forum:

- Solar System
- Milky Way
- Transients
- Nearby Universe
- AGN & Galaxy Evolution
- Clusters of Galaxies
- Galaxy Clustering
- Strong Lensing
- Weak Lensing
- Primeval Universe



The great diversity in the complexity of the suggestions point to a tiered approach to developing DDPs : from simple catalog merging and cutouts exchange, enriching each side's catalog with provided algorithms, up to full blown joint pixel processing

Rubin and Euclid can have a large sky area in common

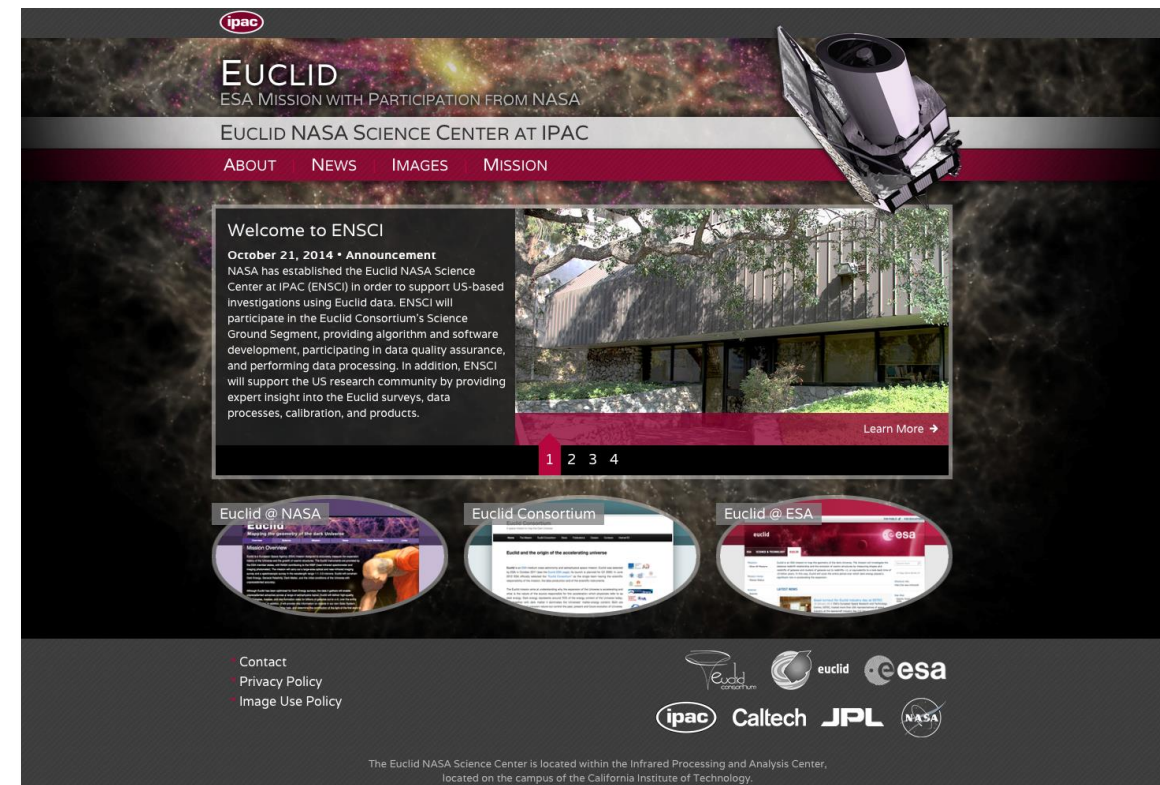
Euclid NASA Science Center at IPAC



- US Node of a distributed (across all Euclid countries) 'Science Ground Segment'
- Each SGS node is developing specific parts of Euclid pipeline
- ENSCI role is centered on US expertise and NIR detectors (will provide lessons learned to Roman)

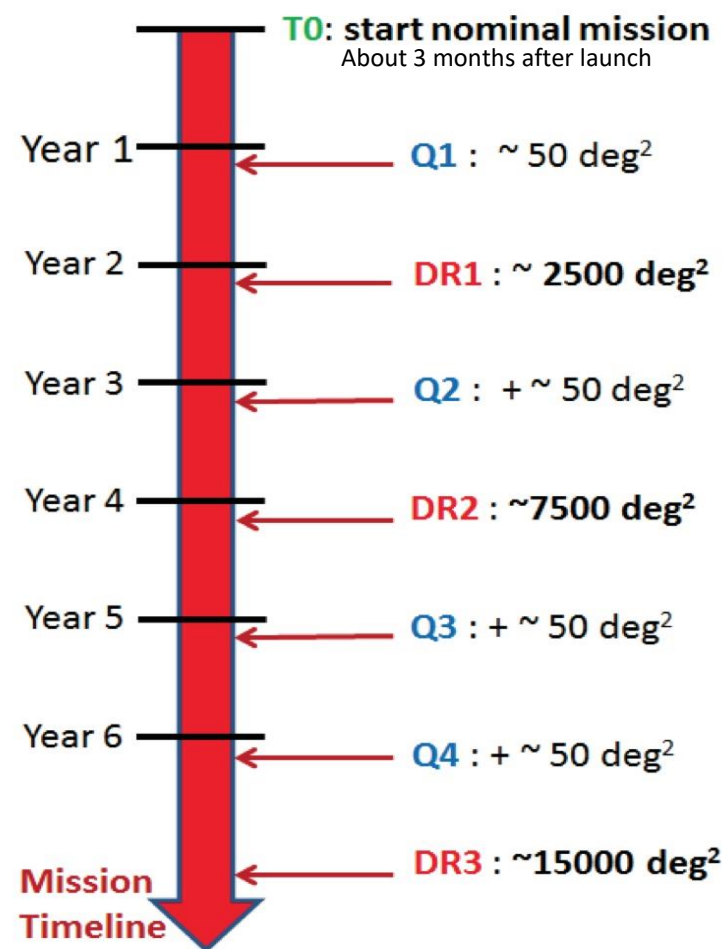
- NASA has established the **Euclid NASA Science Center at IPAC (ENSCI)** in order to support US-based investigations using Euclid data.
- ENSCI primary tasks:
 - T1: US Community Support
 - T2: Detector Characterization Data Archive
 - T3: Contribute/Gain expertise in pipelines
 - Participation in NISP algorithm/software design and high level calibration tasks
 - Develop production software in our role as SDC-US-Dev
 - T4: Establish and operate SDC-US [production side]
 - data processing, storage, and access
 - Node in distributed processing system
 - T5: Work closely with SOC on Data Quick Look Analysis (DQLA)
 - Gain insight into operations, advocate for US community needs
 - T6: Mission Verification working group
 - Insight into the big picture of science mission design
- For more details, see <http://euclid.caltech.edu>

- Web presence
 - Help desk (ensci-support@ipac.caltech.edu)
 - Documents and tutorials
- Support for US Science Teams
 - Meetings, telecons,
 - developer advice; calibration docs/files
- Contact with archival community
 - Conferences/AAS and Workshops
 - Push info to community: newsletters, AAS bulletin, social media, etc.
 - User Panel (starting 1 year before launch)
- Support US research with Euclid
 - Documents
 - Data tools
 - Work with IRSA

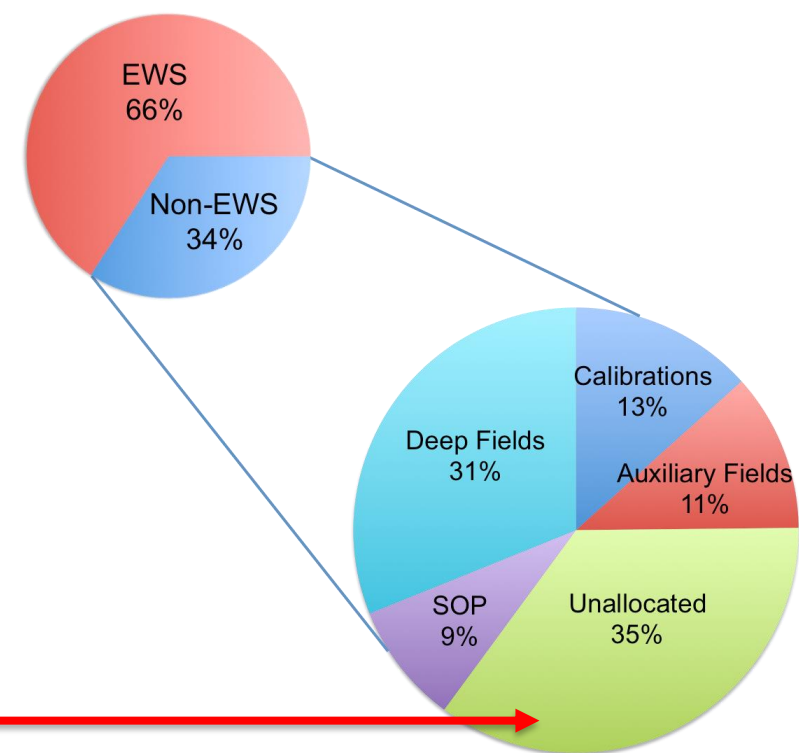


- ENSCI support prioritizes US users but is open to all;
 - European researchers will have access to mission knowledge from national centers

- Data will be public within about 2 years of acquisition
 - ESA will serve public Euclid data through the Euclid Science Archive System
 - The same data (or a subset) will also be available at the NASA/IPAC Infrared Science Archive (IRSA)
 - ENSCI is working with IRSA on archive design
- Euclid will be “big data”
 - Petabyte-scale data products acquired from spacecraft
 - Significant ground-based supporting optical imaging data (release policy is TBD)
- Expect a flood of proposals after first public data release
 - Spitzer and WISE were each ~40% of ADAP in their first year

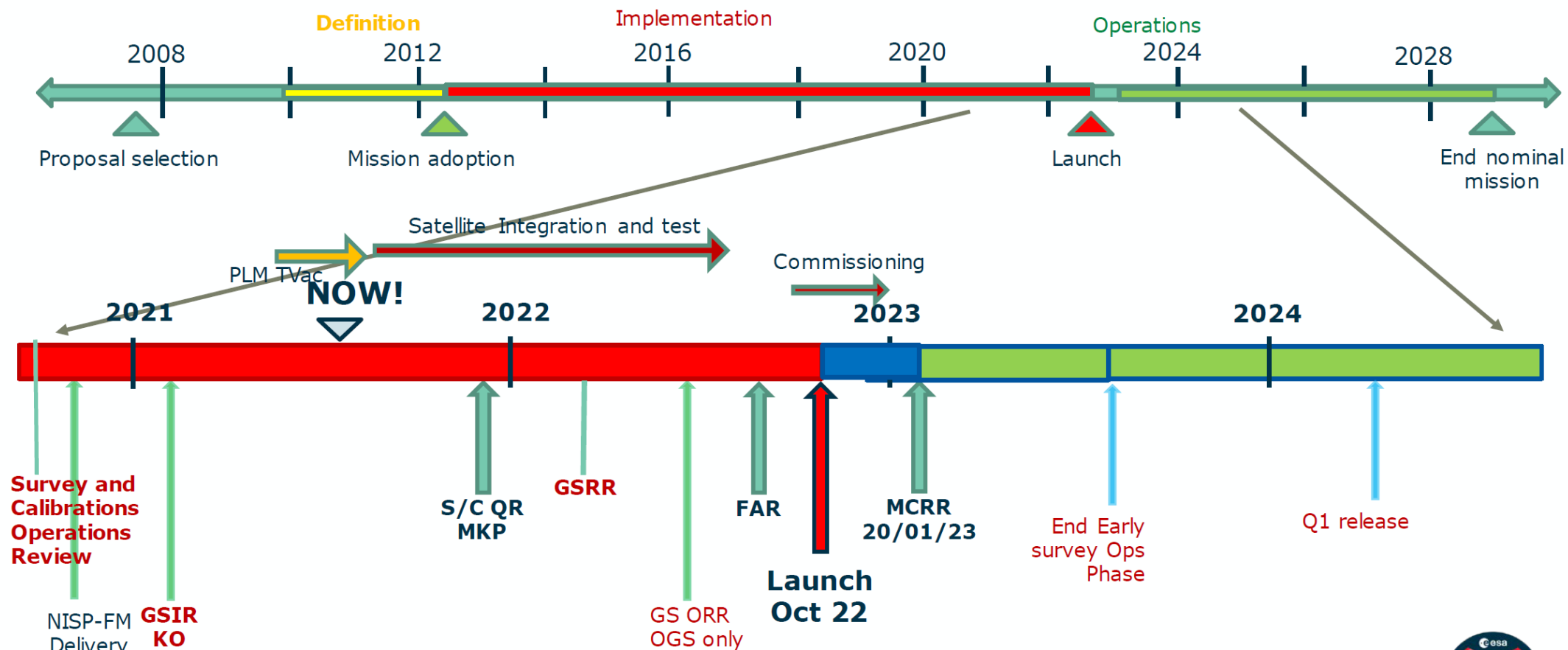


- Euclid Consortium (EC) >2000 members
 - 114 active members from US
 - ~10 science working groups
 - Possible to join: compelling contribution to Euclid, support of science working group lead(s), **sufficient funding to cover engagement**
- Euclid Consortium Board (ECB), ~ 20 member governing body of EC appointed by national agencies (“ultimate authority within Euclid”)
 - Jason.d.rhodes@jpl.nasa.gov is US rep and will be Chair 2022-2023
- ESA Euclid Science Team (EST), 13 member ESA body that ‘safeguards’ science requirements, ensures mission success, **defines additional surveys**
 - Jason.d.rhodes@jpl.nasa.gov is US rep

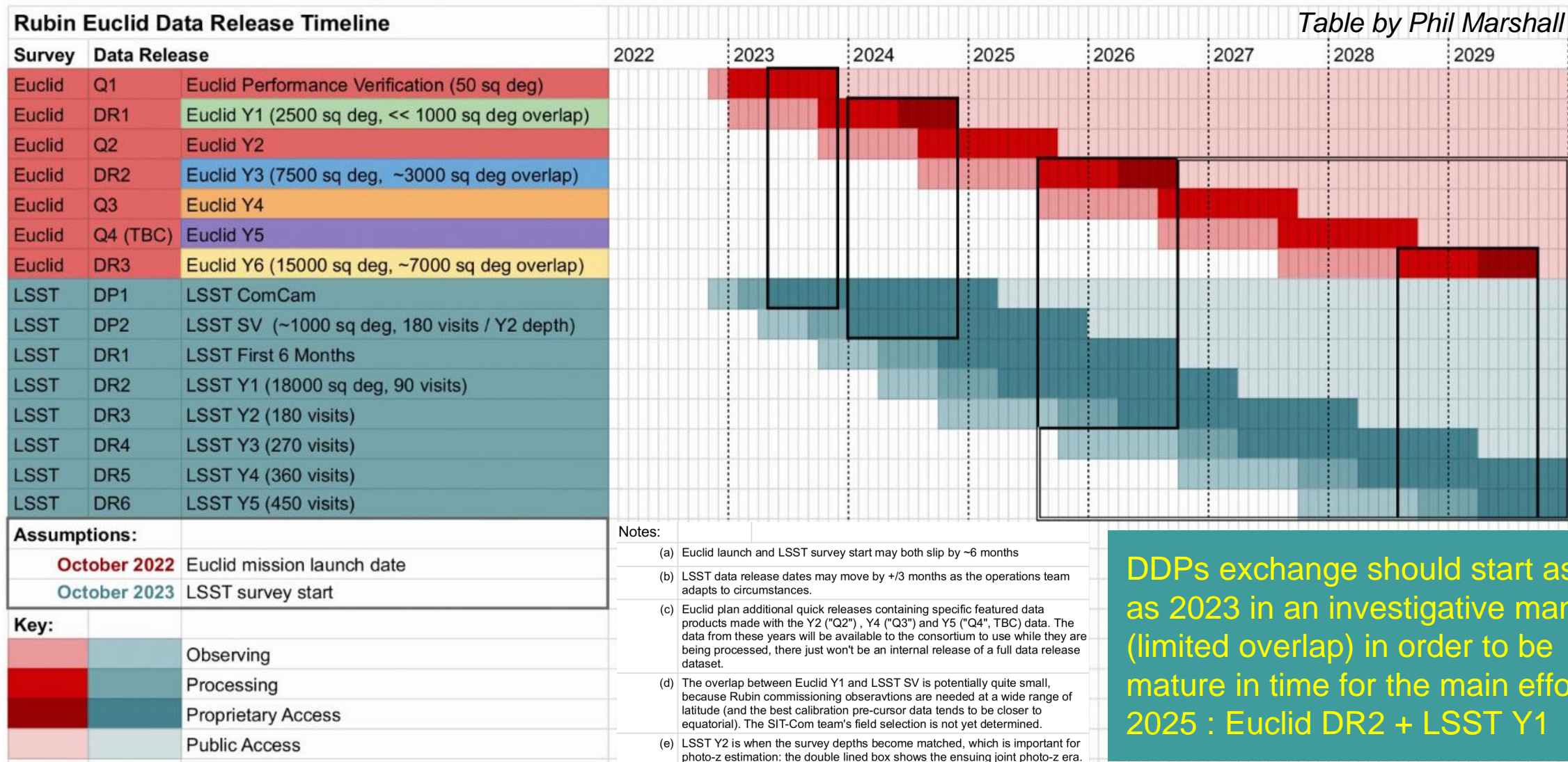


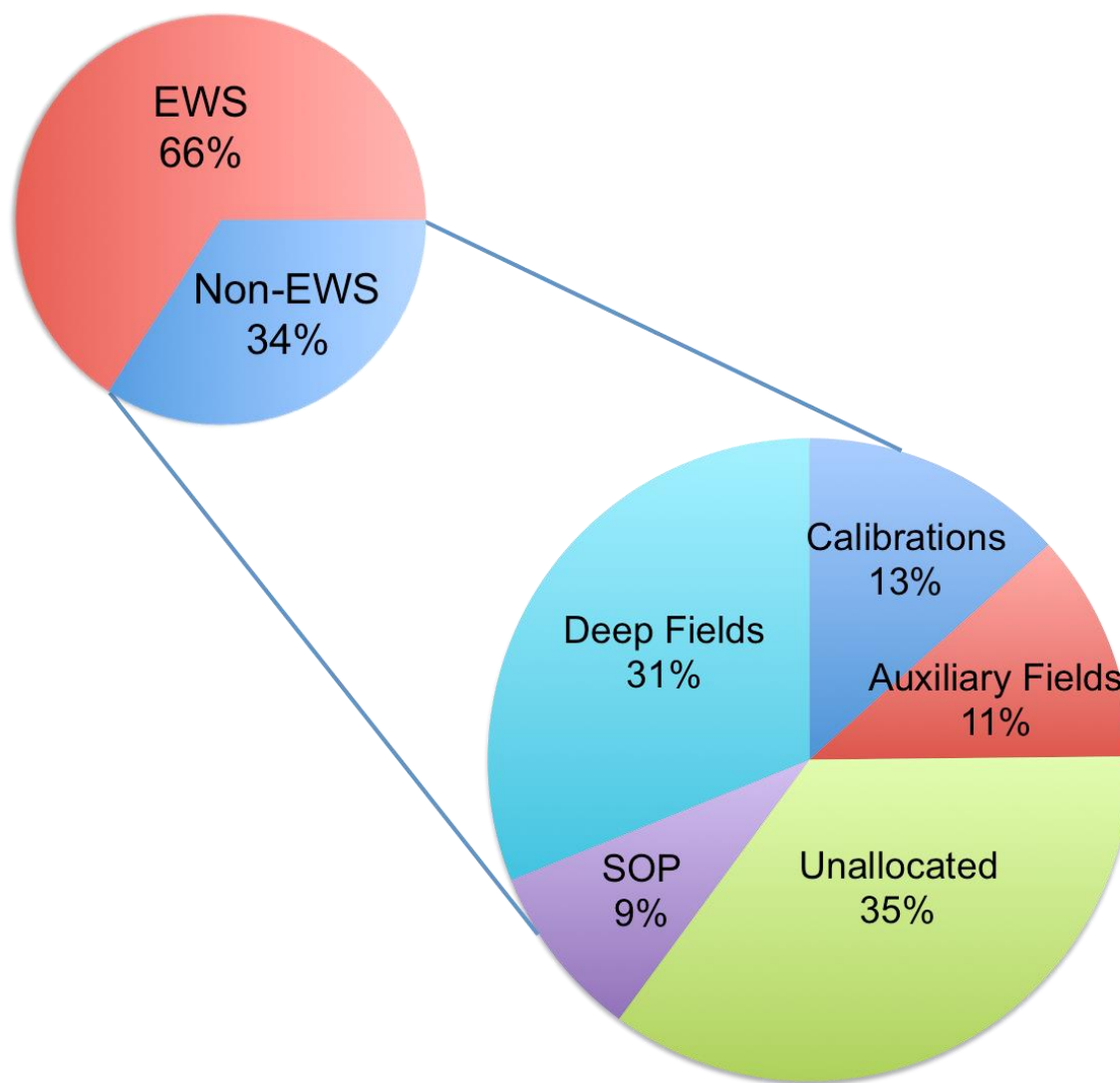
Thanks to ESA and the Euclid Consortium
for many slides in this presentation

Overview mission timeline



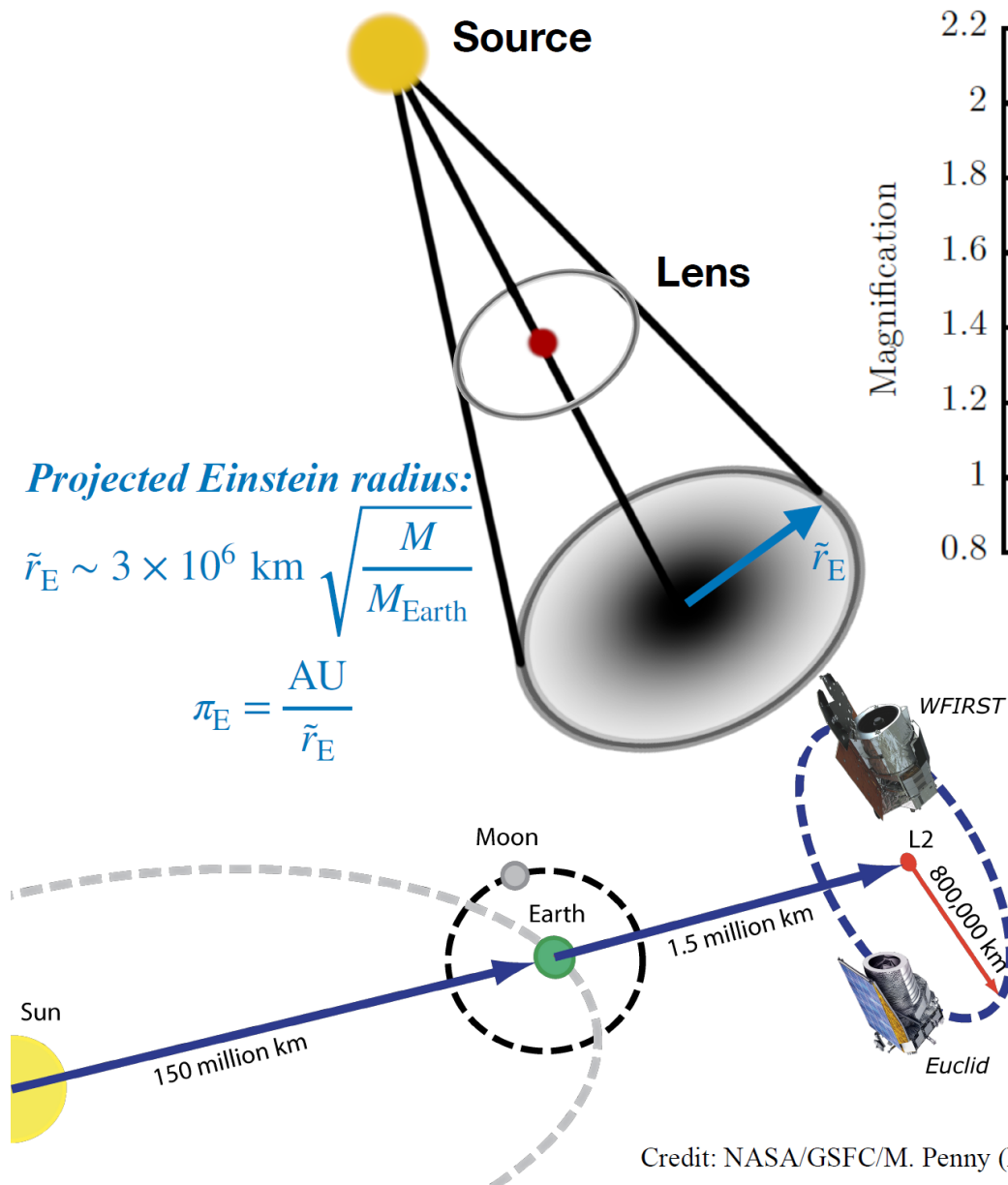
DDP timescale : matching Euclid and LSST data releases



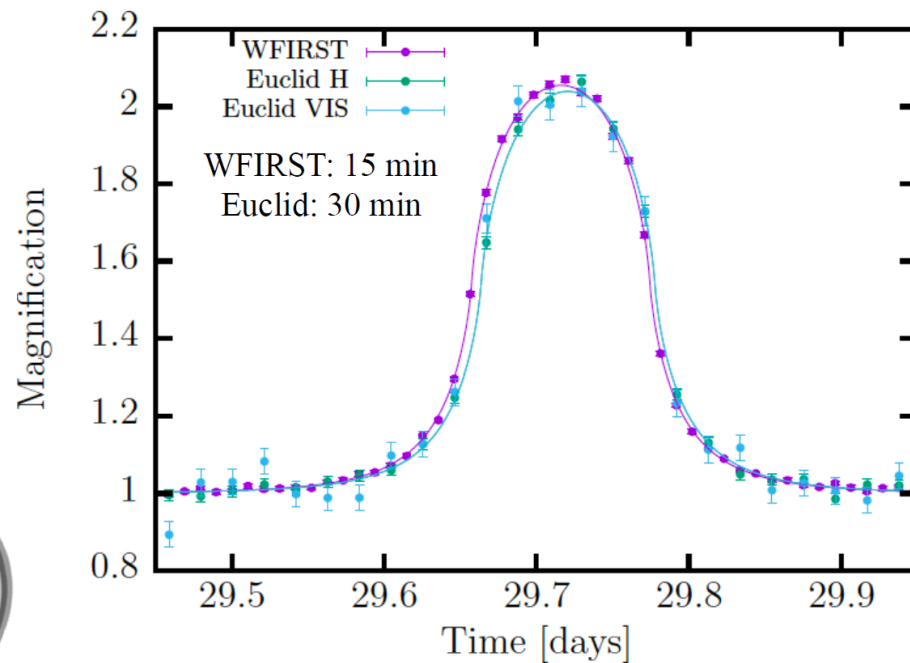


Microlensing with *Euclid* & *WFIRST*: Masses of Free-Floating Planets

Bachelet et al., 2021, submitted



Credit: NASA/GSFC/M. Penny (LSU)



Credit: M. Penny (LSU), S. Johnson (OSU)

$$\pi_E = 61.8 \pm 19.3$$

$$\theta_E = 6.6 \pm 1.3 \mu\text{as}$$

$$M = \frac{\theta_E}{\kappa \pi_E}$$

$$M = 0.44 \pm 0.16 M_{\text{Earth}}$$

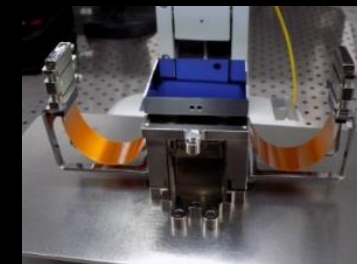
Euclid Collecting Information



- ❑ Euclid carries two types of sensors
 - 36 CCDs (4kx4k pixels) – visible channel
 - 16 HgCdTe CMOS (2kx2k pixels) – infrared channels (NASA contribution)

- ❑ One block observation gives consists of 4 dithers of
 - 1 VIS exposure – 36 x 16 Mpix
 - 1 Spectroscopy field – 16 x 4 Mpix
 - 3 imaging photometry (Y,J,H) – 3 x 16 x 4 Mpix

- ❑ Survey Speed: 20-22 block observations per day



ENSCI in the distributed Euclid data processing system

