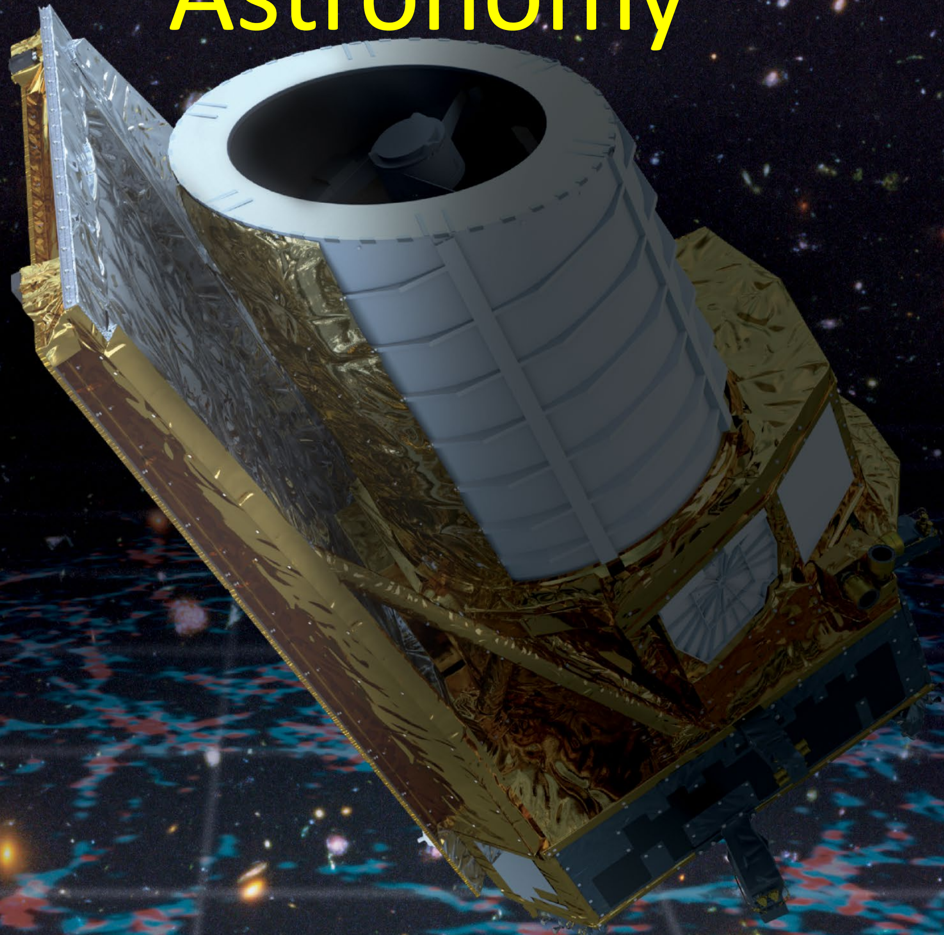
Euclid and the Golden Age of Optical/IR Survey Astronomy



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

March 2023

APAC update

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

Objectives: make a definitive measurement of the expanding universe to quantify Dark Energy [$w(a)$], Modified Gravity [γ], Dark Matter [m_ν], and the Universe's Initial Conditions [f_{NL}]

The Golden Age!!

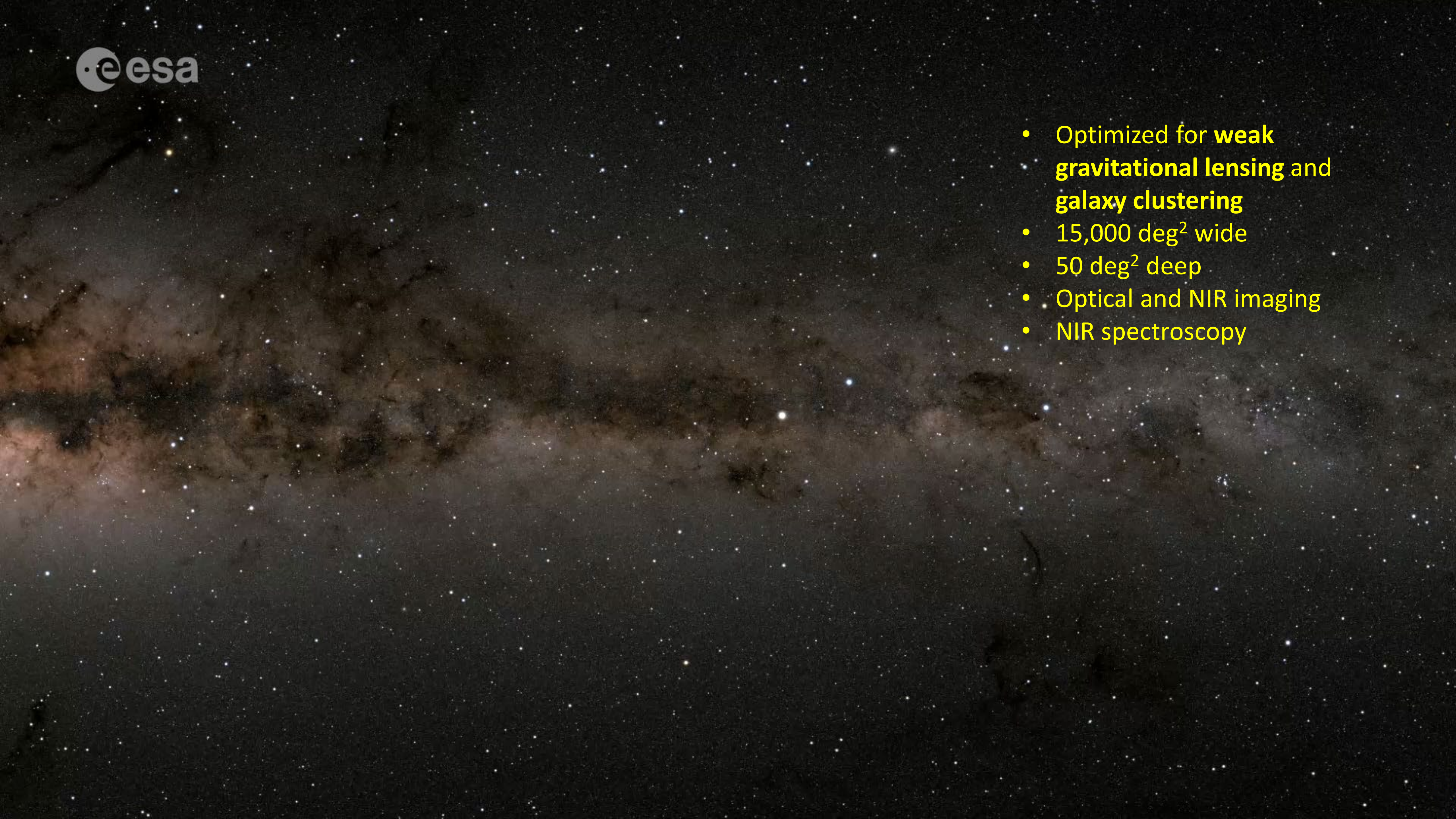
Legacy Survey of Space and Time

Vera C. Rubin Observatory

NANCY GRACE ROMAN SPACE TELESCOPE

Mission Lifetime	2024 - 2033	2023 - 2030	2026 - 2032
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 (5σ 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

Entire observatories designed for precision cosmology



- Optimized for **weak gravitational lensing** and **galaxy clustering**
- 15,000 deg^2 wide
- 50 deg^2 deep
- Optical and NIR imaging
- NIR spectroscopy

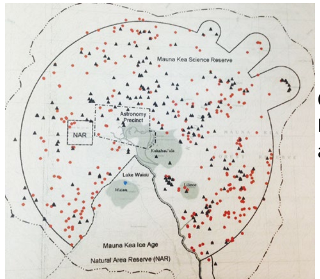
Acknowledgment

- To achieve its scientific goals, Euclid requires data from several ground-based observatories around the world, some of which are located on the lands and territories of indigenous peoples.
- Of these lands, Mount Graham, Haleakala and Maunakea have significant and sacred value to the local indigenous people.
- We want to acknowledge the reverence and importance that these mountains hold within the Apache and Hawaiian communities. There are historic properties, archaeological remains, shrines and burials on their slopes and summits.
- As astronomers alien to these lands, we feel privileged and honoured to have the chance and opportunity to observe the sky and advance our knowledge of the Universe with the facilities hosted on these mountains.

Credit: Vadim Kirland (Wikipedia)

Credit: Kenny Louie (Wikipedia)

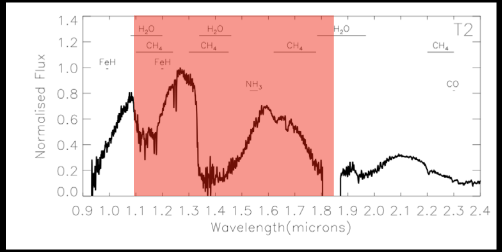
Credit: Paul McClellan



Credit: State of Hawaii, Department of Land and Natural Resources

Slide from Jean-Gabriel Cuby, CFHT director

Euclid legacy science - some examples

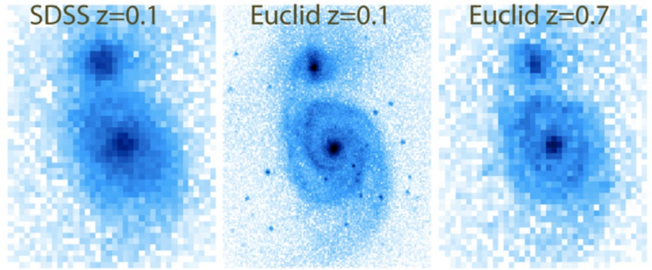


Niall Deacon, Bianca Garilli, Paolo Franzetti

Cool brown dwarfs - both in spectroscopy and imaging

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



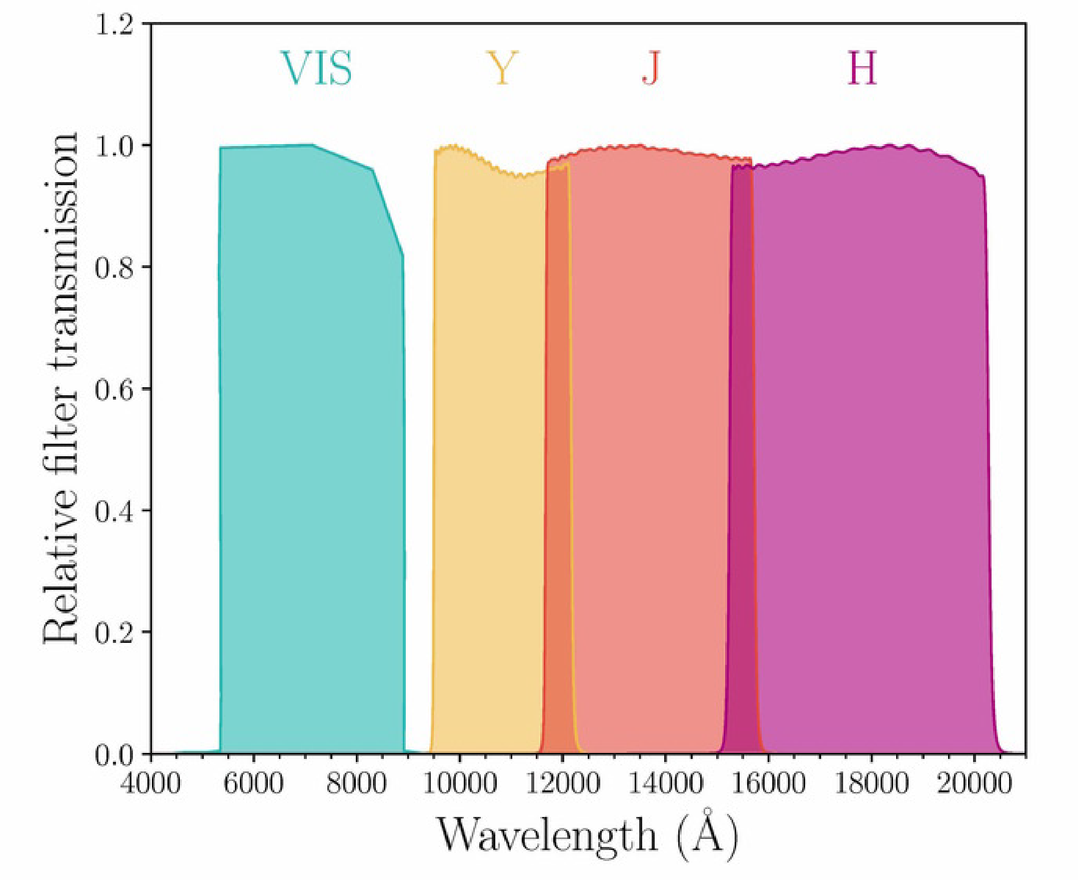
Galaxy morphologies across the whole extragalactic sky (>10^3xHST)

Rare objects galore - massive, passive galaxies with spectra to H~23, the brightest z>7 Ly-a 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.	~2x10^8	~10^4
Massive galaxies (1<z<3) w/spectra	~few x 10^3	~0.2
Hα emitters/metal abundance at z~2-3	~4x10^7/10^5	~10^3/~10
Galaxies in massive clusters at z>1	~(2-4)x10^4	~40 (per cluster, H_{AB}<22.5)
Type 2 AGN (0.7<z<2)	~10^4	<1
Galaxy mergers	~10^5-few x 10^6	1-100
Strongly lensed galaxy-scale lenses	~200,000	1-10
z > 7 Ly-a emitters	~few 10^3	<<1
Resolved stellar populations	~13? with M_{abs} < -19	<<1

M3



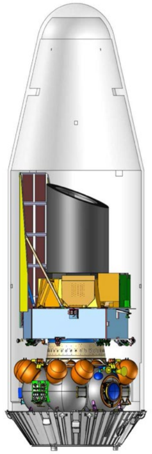
1 Blue Grism: 0.92- 1.3 µm
3 Red Grisms: 1.25-1.85 µm

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:
SpaceX Falcon9 from Florida, July 2023

Mission Lifetime:
6+ years
@ L2

Aperture:
1.2m

SGS Distributed Data Processing

- SDC-US will be a node in the distributed SGS data processing system

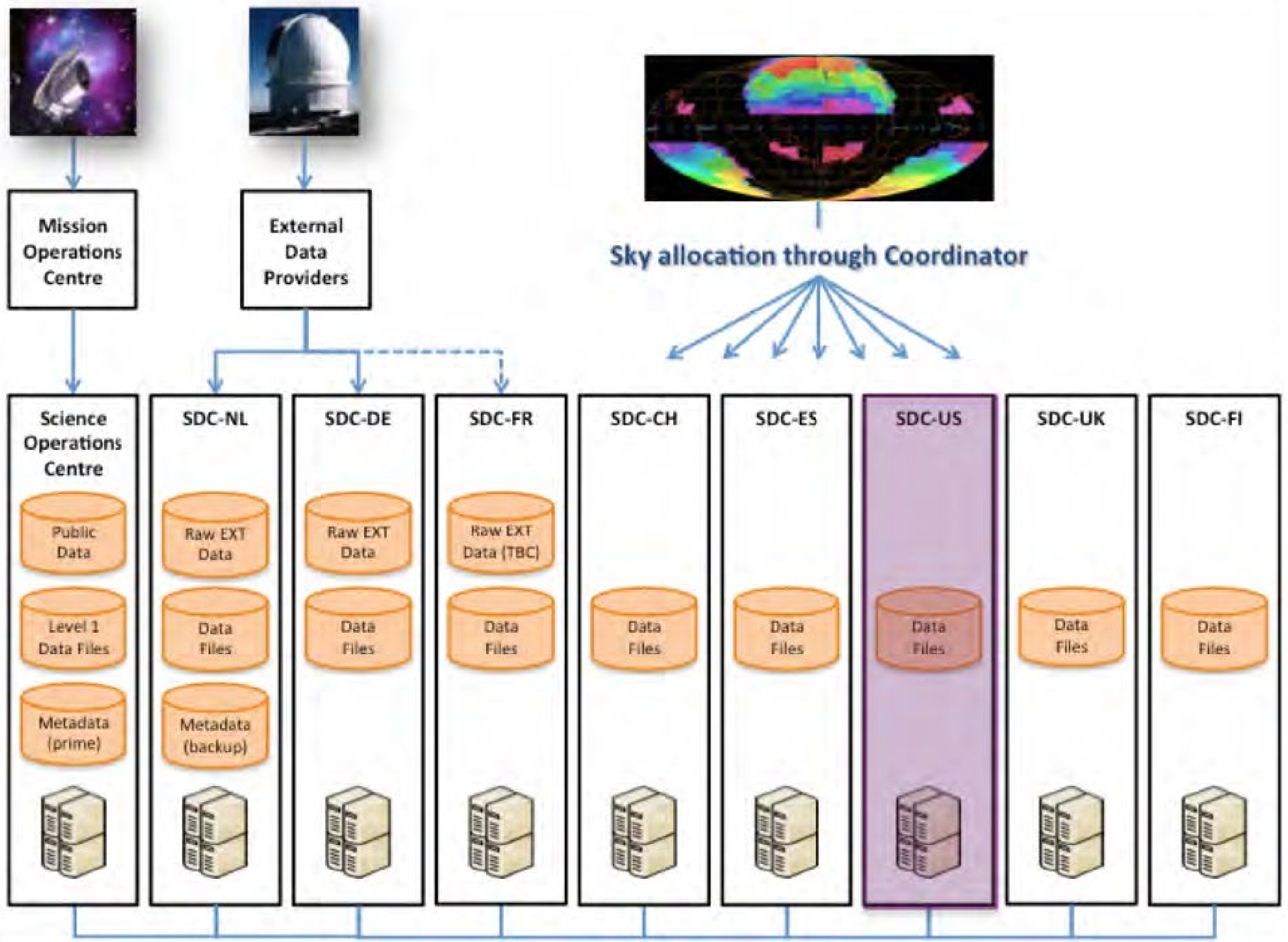


Figure 6-1: Data distribution

Euclid NASA Science Center at IPAC

JPL

Caltech

ENSCI and the US Community

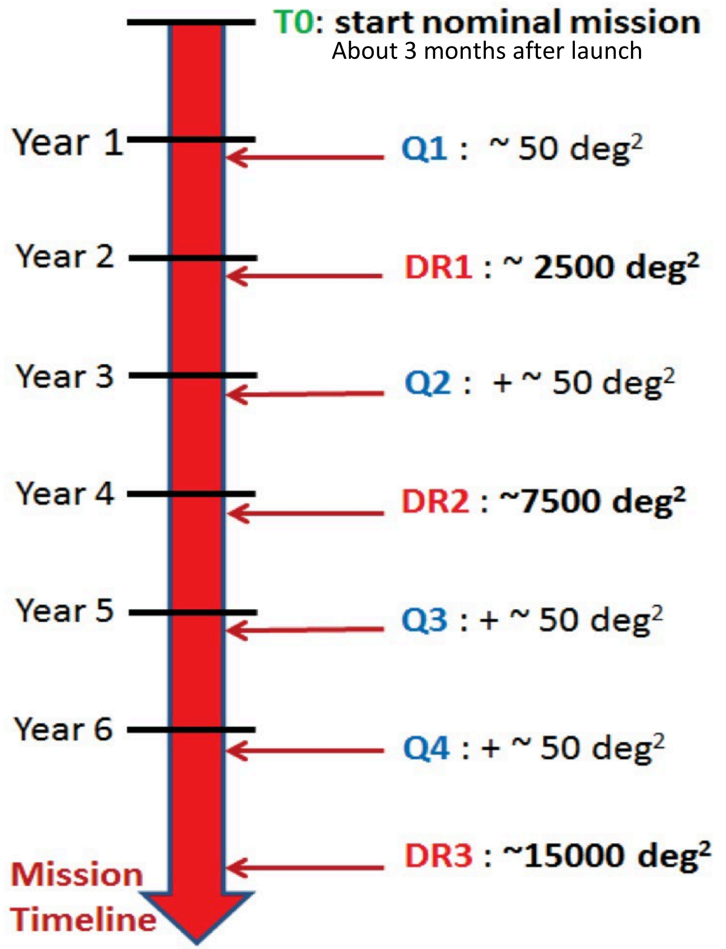
Euclid NASA Science Center at IPAC

- 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 (started 1 year before launch)
- Support US research with Euclid
  - Documents; Data tools
  - Work with IRSA to validate, enhance archive
  - Data Analysis workshops

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

Euclid Data Releases

- Yearly public data releases
- Small (relatively) ‘quick releases’ alternate with huge chunks of the sky
- NASA preparing to support US community via ENSCI and ADAP for Euclid exploitation
- Euclid Consortium will have access to data as soon as it is processed
- Possible ‘additional surveys’ will likely be determined via open call with no proprietary period



Near Infrared Spectrometer – Photometer (NISP) Detector System

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

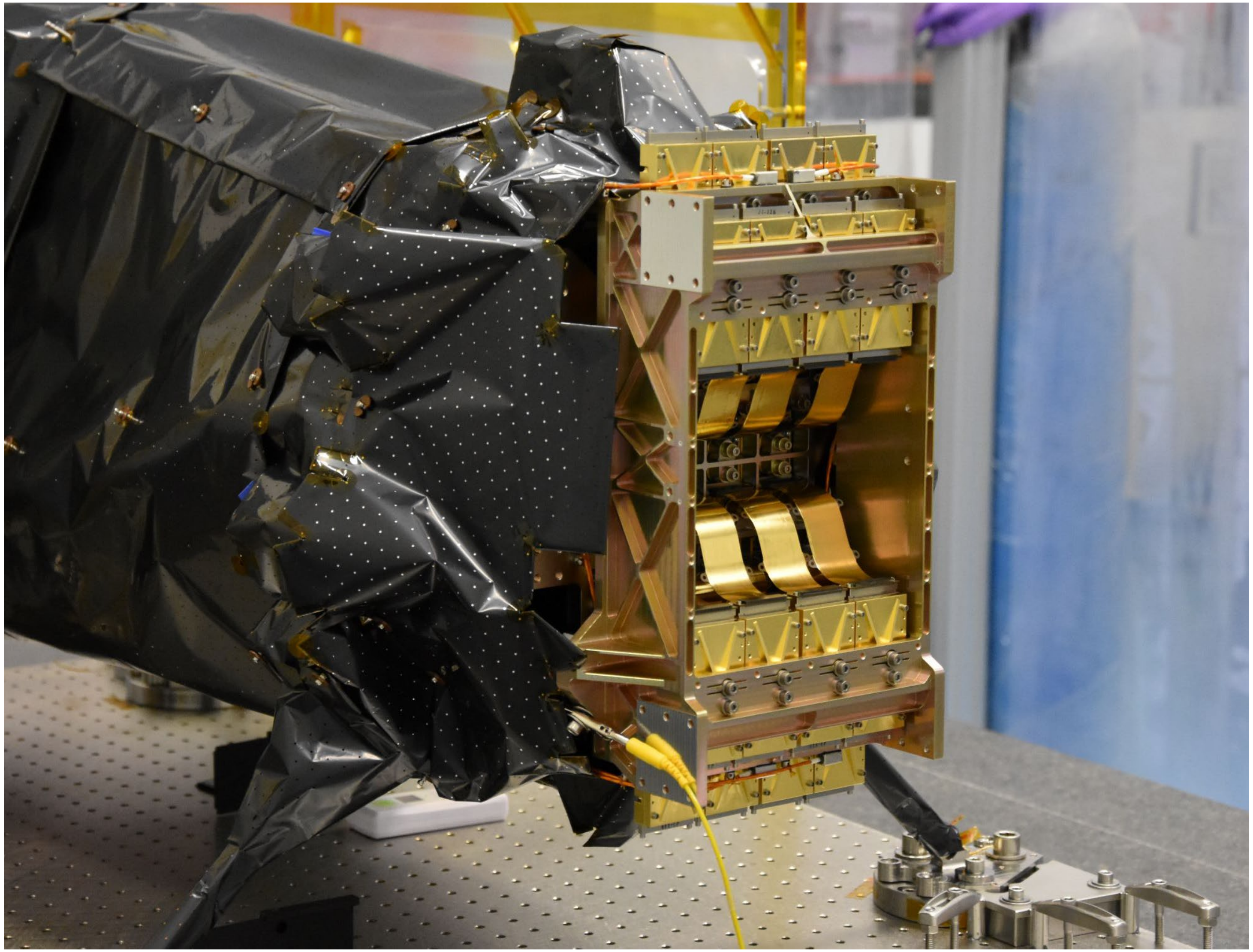
- 2.3 um cutoff HgCdTe detectors
- SIDECAR ASIC detector readout
- Cold cables

JPL led, with GSFC testing support

Heritage from HST, JWST

Same detector systems as CASE on ARIEL (another NASA contribution to an ESA mission)

Roman detectors are next generation and have built on Euclid experience



US Euclid Science Engagement

- Detector system contributions enabled 40 US-based astronomers to join the Euclid Consortium (EC) in 2013
- Number of US scientists, developers, and engineers in EC is now 130
- Three NASA-funded Euclid science investigations are part of the EC
  - "Constraining Dark Energy and Gravity with Euclid", PI Rhodes (JPL)
  - "Looking at Infrared Background Radiation Anisotropies with Euclid", PI Kashlinsky (GSFC)
  - "Precision Studies of Galaxy Growth and Cosmology Enabled Through a Physical Model for Nebular Emission", PI Chary (Caltech)

Euclid will inform Roman on detector systematics, wide field space-based weak lensing and galaxy clustering, and combination with ground-based data (especially Rubin)

Euclid Status

- Final tests passed
- Ready to go in Cannes, France
- Leaves Cannes April 6
- Launch week in July will be selected mid April
- Launch date will be chosen ~10 days ahead of launch

Me (middle) and Euclid in Cannes, February 2023

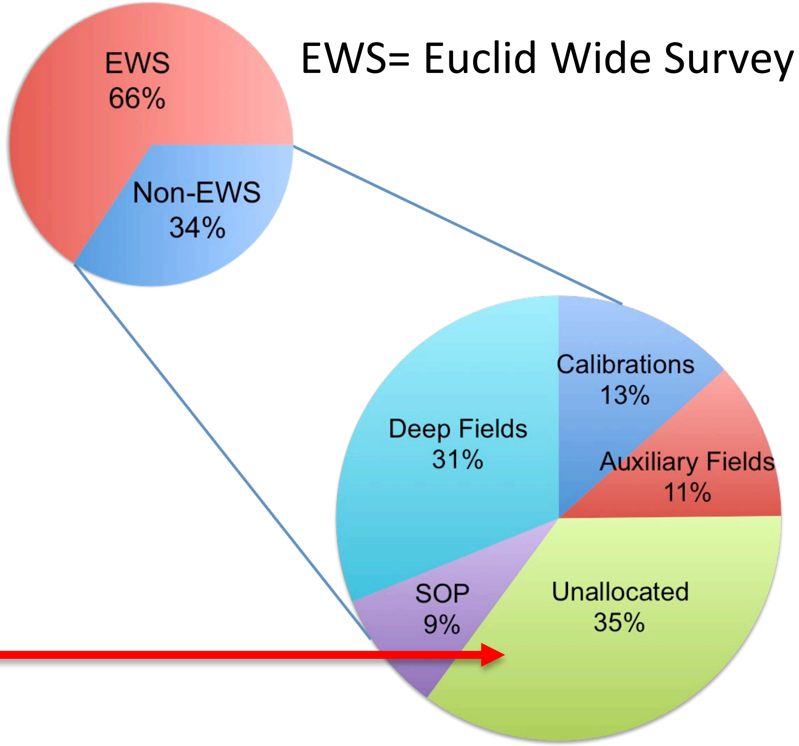
Euclid Structures- how to join/engage

- Euclid Consortium (EC) >2000 members
  - > 100 active members from US
  - 14 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 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

EWS= Euclid Wide Survey



> ∑ (parts)

- The best dark energy constraints will come from a joint analysis of data from all three telescopes
- Deblending and photometric redshifts are prime examples
- Early (shallower) Euclid/Rubin will teach us to how to jointly process and analyze later (deeper) Roman and Rubin
- Benefits go beyond cosmology

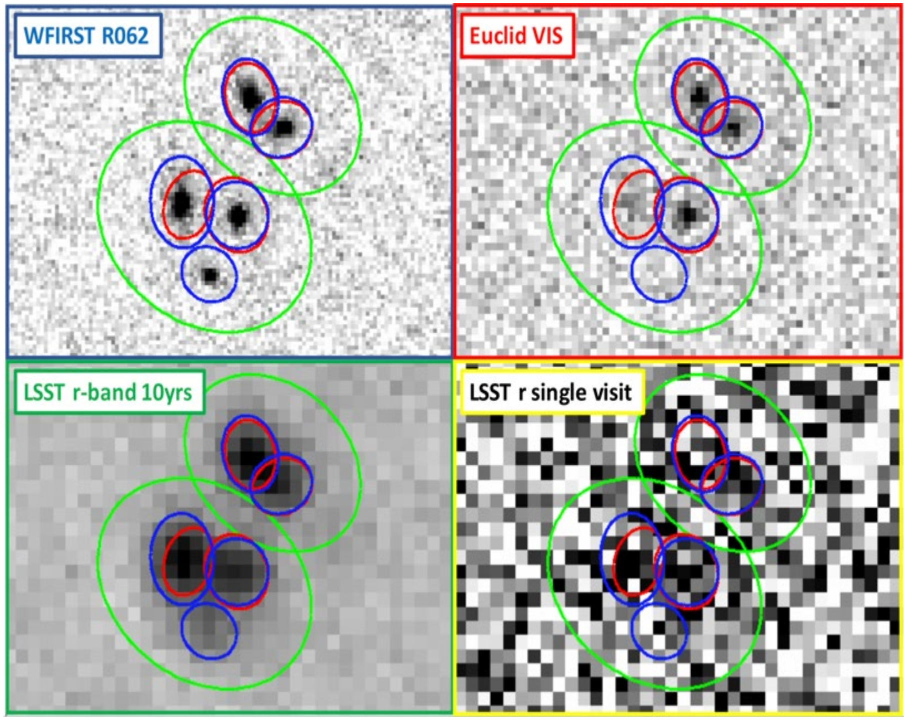


Figure from Ranga Chary (Caltech/IPAC)

4.5.1 Data Archiving, Curation, and Pipelines

The importance of joint analysis of observations from different facilities and wavelengths, and of sophisticated archiving with associated science platform tools, will grow dramatically over the next decade. A prime example is the measurement of cosmological constraints on dark energy and other parameters in the coming decade, which will rely heavily on the joint processing and analysis of data from the Euclid (ESA), Roman, and Rubin observatories.

Need to ensure funding for joint processing and analysis of the Golden Age data is available.

Additional Slides

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