Euclid and the Golden Age of Optical/IR Survey Astronomy

Jason Rhodes (Jet Propulsion Laboratory, California Institute of Technology)
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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 \([\gamma]\), Dark Matter \([m_\nu]\), and the Universe’s Initial Conditions \([f_{NL}]\)
<table>
<thead>
<tr>
<th>Mission Lifetime</th>
<th>2024 - 2033</th>
<th>2023 - 2030</th>
<th>2026 - 2032</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mirror size (m)</td>
<td>6.5 (effective diameter)</td>
<td>1.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Survey size (sq deg)</td>
<td>~20,000</td>
<td>15,000</td>
<td>2,227</td>
</tr>
<tr>
<td>Median z (WL)</td>
<td>0.9</td>
<td>0.9</td>
<td>1.2</td>
</tr>
<tr>
<td>Depth (5σ AB mag point source)</td>
<td>~27</td>
<td>~24 (NIR)</td>
<td>~27</td>
</tr>
<tr>
<td>FoV (sq deg)</td>
<td>9.6</td>
<td>0.5 (Vis) 0.5 (NIR)</td>
<td>0.28</td>
</tr>
<tr>
<td>Filters</td>
<td>u-g-r-i-z-y</td>
<td>Y-J-H-Vis</td>
<td>Y-J-H-F184</td>
</tr>
<tr>
<td>PSF Size</td>
<td>~0.7”</td>
<td>~0.2” (Vis)</td>
<td>~0.2” (NIR)</td>
</tr>
<tr>
<td>Mode</td>
<td>Photometry</td>
<td>Photometry/Grism</td>
<td>Photometry/Grism</td>
</tr>
</tbody>
</table>

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.
Euclid legacy science - some examples

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 (>10³xHST)

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

<table>
<thead>
<tr>
<th>What</th>
<th>Euclid</th>
<th>Per deg²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Galaxies at 1&lt;z&lt;3 with good mass estimates and morph.</td>
<td>~2x10⁸</td>
<td>~10⁴</td>
</tr>
<tr>
<td>Massive galaxies (1&lt;z&lt;3) w/spectra</td>
<td>~few x 10³</td>
<td>~0.2</td>
</tr>
<tr>
<td>Hα emitters/metal abundance at z~2-3</td>
<td>~4x10⁷/10⁵</td>
<td>~10⁹/10</td>
</tr>
<tr>
<td>Galaxies in massive clusters at z&gt;1</td>
<td>~(2-4)x10⁴</td>
<td>~40 (per cluster, H_AB&lt;22.5)</td>
</tr>
<tr>
<td>Type 2 AGN (0.7&lt;z&lt;2)</td>
<td>~10⁴</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Galaxy mergers</td>
<td>~10⁵–few x 10⁶</td>
<td>1-100</td>
</tr>
<tr>
<td>Strongly lensed galaxy-scale lenses</td>
<td>~200,000</td>
<td>1-10</td>
</tr>
<tr>
<td>z &gt; 7 Ly-a emitters</td>
<td>~few 10³</td>
<td>&lt;&lt;1</td>
</tr>
<tr>
<td>Resolved stellar populations</td>
<td>~13? with M_abs &lt; -19</td>
<td>&lt;&lt;1</td>
</tr>
</tbody>
</table>
Launch:
SpaceX Falcon9 from Florida, July 2023

Mission Lifetime:
6+ years @ L2

Aperture:
1.2m

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

1 Blue Grism: 0.92-1.3 μm
3 Red Grisms: 1.25-1.85 μm
SGS Distributed Data Processing

- SDC-US will be a node in the distributed SGS data processing system
**ENSCI and the US Community**

- **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
• 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

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