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60 Million Stars: Inside Euclid's Unprecedented Map of the Milky Way's Core

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Introduction: Repurposing ESA's Dark-Universe Observatory for the Galactic Core

Launched in July 2023, the European Space Agency's (ESA) Euclid space telescope was engineered to map the large-scale geometry of the dark universe by measuring weak gravitational lensing distortions and spectroscopic redshifts across billions of extragalactic sources[1]. Yet the optical characteristics required for precision cosmology -- a wide field of view paired with diffraction-limited angular resolution and high photometric stability -- also make Euclid an exceptional instrument for dense galactic astrometry[1][2].

In March 2025, Euclid paused its extragalactic survey for 26 hours to execute the Euclid Galactic Bulge Survey, targeting the crowded stellar core of the Milky Way[2][3]. Released in June 2026 as part of Euclid Quick Data Release 2 (Q2), the resulting mosaic resolves more than 60 million individual stars across 4.8 square degrees, representing the sharpest wide-field visible-light survey of the galactic bulge ever assembled[2][4]. Beyond cataloging stellar populations, the dataset breaks long-standing mass degeneracies in archival gravitational microlensing detections and establishes a critical astrometric baseline for NASA's Nancy Grace Roman Space Telescope[2][5].

Spacecraft Architecture and the Sixteen-Dither Survey Design

Operating in a large-amplitude Lissajous orbit around the Sun-Earth Lagrange point L2 (~1.5 million kilometers from Earth), Euclid utilizes a 1.2-meter Korsch off-axis three-mirror anastigmat telescope fabricated from silicon carbide to minimize thermo-elastic deformation of its point spread function (PSF)[1][6]. A dichroic beam splitter located at the exit pupil separates collected light into two co-aligned instruments: the Visible Imager (VIS) and the Near-Infrared Spectrometer and Photometer (NISP)[1][6].

VIS employs a mosaic of thirty-six 4k x 4k charge-coupled devices (CCDs) with 12-micrometer pixels (~600 megapixels total), achieving 0.1-arcsecond angular resolution across a broad 550-900 nm optical bandpass that maximizes photon collection from faint, low-mass stars across an area 270 times larger per exposure than the Hubble Space Telescope[3][6]. Complementing VIS, NISP houses sixteen 2k x 2k mercury cadmium telluride (HgCdTe) detectors actively cooled below 100 K, operating between 920 and 2000 nm across three broad photometric bands (Y, J, and H) and four slitless spectroscopy grisms capable of penetrating interstellar dust lanes[6][7].

| Specification | | Visible Imager (VIS) | | Near-Infrared Spectrometer and Photometer (NISP) |

| Primary Capability | | Broadband visual imaging and astrometry | | Near-infrared imaging photometry and slitless spectroscopy |

| Detector Technology | | 36 arrays of 4k x 4k CCDs (~600 MP) | | 16 arrays of 2k x 2k HgCdTe detectors |

| Wavelength Range | | 550 to 900 nanometers | | 920 to 2000 nanometers (Y, J, H photometric bands) |

| Field of View | | 0.56 square degrees | | 0.55 square degrees (Shared 0.53 sq. deg. overlap) |

| Angular Resolution | | 0.1 arcseconds | | 0.3 arcseconds |

| Data Output Volume | | Processed jointly with infrared | | Approximately 240 gigabits per day |

Because strict solar-aspect and thermal-shielding constraints restrict Euclid's viewing angle toward the galactic center to two brief equinox windows per year, the Galactic Bulge Survey was executed over 26 hours on March 23-24, 2025[2][3]. Euclid tiled nine overlapping pointings (E1-E9) covering 4.8 square degrees -- roughly 22 times the angular area of the full Moon[2][4]. Rather than using its standard four-point extragalactic dither sequence, Euclid executed a specialized sixteen-dither strategy, acquiring sixteen 400-second VIS exposures (1.8 hours total integration) per field[2][4]. Sub-pixel pointing offsets enabled oversampled PSF reconstruction in crowded clusters, robust statistical rejection of cosmic-ray hits, and unsaturated photometry of faint microlensing source stars adjacent to bright red giants[2][4].

| Field Designation | | Right Ascension (J2000, degrees) | | Declination (J2000, degrees) | | Galactic Longitude (degrees) | | Galactic Latitude (degrees) |

| E1 | | 267.425 | | -30.019 | | 359.533 | | -1.320 |

| E2 | | 267.441 | | -29.259 | | 0.192 | | -0.942 |

| E3 | | 267.456 | | -28.499 | | 0.851 | | -0.563 |

| E4 | | 268.248 | | -28.610 | | 1.111 | | -1.217 |

| E5 | | 268.237 | | -29.369 | | 0.452 | | -1.595 |

| E6 | | 268.227 | | -30.129 | | 359.792 | | -1.973 |

| E7 | | 269.030 | | -30.236 | | 0.050 | | -2.626 |

| E8 | | 269.036 | | -29.476 | | 0.711 | | -2.249 |

| E9 | | 269.041 | | -28.716 | | 1.371 | | -1.872 |

Crowded-Field Astrometry, Cosmic Ray Rejection, and Dust Extinction

Processing fields containing ~1010 stars per steradian stressed the Euclid Science Ground Segment pipeline, which was originally tuned for sparse extragalactic fields[2]. Standard astrometric calibration against the full Gaia reference catalog failed to converge due to extreme source crowding until engineers restricted the Gaia matching template strictly to reference stars within magnitudes 18.5 to 19.0[2]. Similarly, laplacian edge-detection filters designed to flag sharp

cosmic-ray spikes initially misclassified thousands of genuine unresolved point sources as radiation artifacts, requiring custom threshold recalibration to preserve the photometric integrity of the 60-million-star catalog[2][4].

To overcome the monochromatic limitation of Euclid's single 550-900 nm VIS filter and account for differential interstellar dust extinction, researchers combined Euclid's space-based astrometry with archival multi-band optical filters from the ground-based Canada-France-Hawaii Telescope (CFHT) MegaCam, alongside Euclid's own Y, J, and H near-infrared bands[2][8].

Gravitational Microlensing and Breaking the Einstein Crossing-Time Degeneracy

The primary scientific driver of the Euclid Galactic Bulge Survey is exoplanetary gravitational microlensing, a relativistic consequence of spacetime curvature governed by gravitational physics and parameterized by the lens mass's Schwarzschild radius[2][5]. When a foreground lens star transits the line of sight to a background bulge source star, gravitational deflection magnifies the source flux over days to weeks[3]. An orbiting planet introduces a secondary caustic perturbation -- a brief, asymmetric spike in the light curve whose amplitude and duration yield the planet-to-star mass ratio (q) and projected separation[3][5]. Unlike radial-velocity or transit surveys that favor close-in planets, microlensing is uniquely sensitive to cold, low-mass planets orbiting beyond the snow line (1-10 AU) as well as unbound free-floating planets ejected from their birth systems, and can even probe compact remnants such as an isolated neutron star[2][9].

However, ground-based microlensing light curves suffer from a fundamental mathematical degeneracy: the sole measurable timescale, the Einstein radius crossing time (tE), blends the lens mass (ML), relative lens-source proper motion (rel), and distance[10]. While a single 26-hour Euclid campaign cannot monitor new multi-week events, it performs forensic high-resolution astrometry on roughly 8,000 historical microlensing events recorded over the past two decades by the OGLE, MOA, and KMTNet ground networks, including 51 confirmed planetary systems[3][10].

Because the foreground lens star and background source star move with different galactic velocities (typically 4-8 milliarcseconds per year), events observed 10 to 20 years ago have now drifted apart by 40 to 160 milliarcseconds[10]. Euclid's 0.1-arcsecond VIS resolution directly resolves the separated lens and source stars -- including landmark systems such as the cold super-Earth OGLE-2005-BLG-390Lb and the binary-star planet OGLE-2013-BLG-341Lb -- measuring both rel and the direct lens flux to pin down absolute planetary masses to better than 10 percent uncertainty[3][10][11].

Synergies with NASA's Nancy Grace Roman Space Telescope and Galactic Demographics

Looking forward, Euclid's 4.8-square-degree mosaic was deliberately positioned to encompass the entire ~2-square-degree footprint of the Galactic Bulge Time-Domain Survey to be conducted by NASA's Nancy Grace Roman Space Telescope following its successful August 30, 2026 launch aboard a SpaceX Falcon Heavy toward Sun-Earth L2; Roman entered science-instrument synchronization in November 2026 ahead of its

scheduled December 7, 2026 first-image release.[5][12][14][15] Over its five-year mission, Roman will image the bulge every 15 minutes in the near-infrared to detect ~1,400 bound cold exoplanets and hundreds of free-floating worlds[5][12]. By capturing high-resolution positions and fluxes of source and lens stars in 2025 -- years before alignment -- Euclid provides a "time-zero" reference epoch that extends Roman's astrometric proper-motion baseline by more than two years, enabling rapid mass determinations without waiting decades for post-event stellar separation[5][9].

| Characteristic | | ESA Euclid (Visible Imager) | | NASA Roman Space Telescope (Wide Field Instrument) |

| Launch Date | | July 1, 2023 (Operational) | | August 30, 2026 (Launched; L2 commissioning) |

| Primary Mirror Diameter | | 1.2 meters | | 2.4 meters |

| Primary Observing Wavelength | | Visible (550 to 900 nanometers) | | Visible to Near-Infrared (480 to 2300 nanometers) |

| Bulge Survey Area | | 4.8 square degrees (Precursor snapshot mosaic) | | 1.7 to 2.0 square degrees (15-minute cadence monitoring) |

| Survey Objective | | Establish temporal baseline, resolve historical lenses | | High-cadence time-domain detection of transient events |

| Dust Penetration | | Low (Visible light scattered by dust; complemented by NISP) | | High (Infrared light penetrates dense molecular clouds) |

Beyond exoplanets, the 60-million-star catalog supports deep studies of galactic structure and stellar evolution across open clusters such as NGC 6451 (8,700 light-years distant in Scorpius), ionized H II star-forming regions like G000.583-00.870, and dark molecular dust clouds including LDN 10, enabling three-dimensional extinction mapping and kinematic separation of the ancient central bar from younger disk populations[3][8][13].

Conclusion: A Dual-Purpose Benchmark for Exoplanetary Astrophysics

The Euclid Galactic Bulge Survey demonstrates how a wide-field cosmological observatory can transform localized galactic and exoplanetary science[2]. By overcoming extreme stellar crowding to catalog over 60 million stars, Euclid simultaneously resolves two decades of archival ground-based microlensing mass degeneracies and establishes the foundational astrometric reference map for NASA's Nancy Grace Roman Space Telescope, anchoring a new statistical census of cold exoplanets across the Milky Way[2][5][10].

Updates... (Nov 22, 2026): Replaced the broken HTTP 404 ESA Euclid overview URL with the live ESA Cosmos Euclid Mission Portal and enriched arXiv, NASA, Caltech IPAC, and Astronomy & Astrophysics citations with verified exact publication dates (building on the Nov 19, 2026 Roman launch and commissioning update).

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