Rubin-Euclid Derived Data Products

Initial Recommendations

Jean-Charles Cuillandre & Leanne Guy (DDP Working Group chairs)
on behalf of the DDP Working Group (DDP-WG) and Community

Rubin-Euclid Derived Data Products context

- Rubin-LSST (ground) and Euclid (space) : two projects motivated by Dark Energy (core science).
- Complementary imaging datasets : deep optical multi-bands *vs* high resolution + near-infrared.
- The two projects have been talking to each other for nearly a decade.
- The data policies do not allow the Rubin pixels to be shared with the Euclid Consortium & vice-versa.
- A path forward spawned from the promise of maximizing the scientific return of both projects in a way that protects the unique science of each collaboration and is consistent with both data policies.
- All Derived Data Products will be shared openly across the two collaborations.
- Key photometry algorithms from Rubin (LSST) and Euclid (OU-MER) will be adopted.

Charge to the Rubin-Euclid DDP Working Group

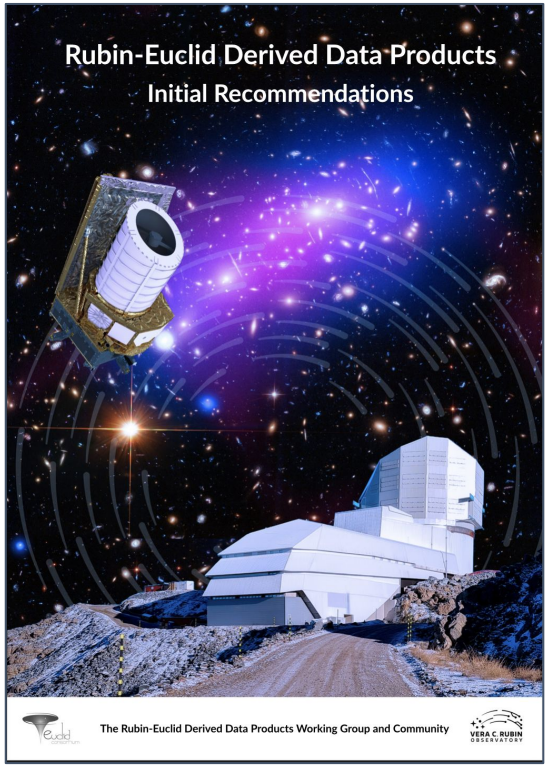
- Derive Data Products charter by Rubin executive and Euclid board, July 2020.
- The DDP-WG Focuses on the design not the creation of the proposed DDPs.
- The DDP-WG charter aimed to ensure both communities were consulted together, and at large, to gather input on the desired DDPs driven by science.
- The ongoing worldwide pandemic did not allow for the execution of the initial plan as laid out in the original charter.

Charge: The DDP-WG should help plan a virtual or in-person workshop that is open to interested Rubin and Euclid data rights holders. This workshop should be focused on gathering community input into the desired initial DDPs. Based on the input from that meeting, the DDP-WG will:

- Design an initial set of DDPs that could be shared promptly and simultaneously with both the Euclid Consortium and the LSST Science Community for scientific use, in a way that protects the unique science of each collaboration and is consistent with both communities' data policies.
- Outline the scientific justification and quantify, approximately, its impact for each proposed DDP.
- **Issue an initial set of recommendations within 9 months** of the creation of the DDP-WG; these recommendations would be made to the ECB and Rubin Observatory Director.
- Set a cadence for virtual and in person meetings and workshops that they feel is consistent with developing recommendations for revised or new DDPs and then make those recommendations to the ECB and Rubin Observatory Director.
- Gather input from their respective communities about desired DDP.
- Focus only on designing DDPs, and not on issues of DDP creation or forming inter-project science collaborations.

DDP creation: The DDP-WG reports to and recommends DDPs to the ECB and Vera Rubin Observatory Director for approval. If approved, the respective consortia will then have to come to an eventual agreement about where, by whom, on what time scale, how, and with what funding the DDPs will be created.

Rubin-Euclid DDPs initial recommendations



- Report released 21 December 2021, 78 pages, 120 authors in total, on the arXiv https://arxiv.org/abs/2201.03862 with a DOI.
- Provides recommendations for an initial set of DDPs covering:
  - Solar System, Milky Way, Transients, Nearby Universe, AGN & Galaxy Evolution, Clusters of Galaxies, Galaxy Clustering, Strong Lensing, Weak Lensing, Primeval Universe.
- Recommendations broadly grouped into two categories:
  - ***Cross-cutting DDPs (5):*** which will enable a wide range of complementary science goals,
  - ***Science-specific DDPs (58):*** which will enhance the science yield for a specific science case.
- Given the diversity in the complexity of the suggestions, a tiered approach is recommended to develop DDPs over the lifetime of both surveys: from simple catalog farming out and cutout exchange, to full blown joint pixel processing.

Management of the Rubin-Euclid DDPs effort

Rubin & Euclid senior management appointed 13 scientists each to a Derived Data Products Working Group (DDP-WG) with a first specific charge for 2021.

DDP-WG oversight committee :

- Rubin : Robert Blum, Phil Marshall, Željko Ivezić
- Euclid : Yannick Mellier, Jason Rhodes, René Laureijs

DDP-WG co-chairs : Leanne Guy for Rubin, Jean-Charles Cuillandre for Euclid

DDP-WG Rubin members : (about ⅓ also in Euclid)
Yusra Alsayyad, Etienne Bachelet, Manda Banerji, Franz Bauer, Jim Bosch, Tom Collett, Siegfried Eggl, Catherine Heymans, François Lanusse, Peter Melchior, Dara Norman, Michael Troxel

DDP-WG Euclid members : (about ⅓ also in Rubin)
Eric Aubourg, Hervé Aussel, Chris Conselice, Adriano Fontana, Henk Hoekstra, Isobel Hook, Konrad Kuijken, Joe Mohr, Michele Moresco, Reiko Nakajima, Stéphane Paltani, Daniel Stern

+2 experts (both Euclid+Rubin) : Benoit Carry (Solar System) & Annette Ferguson (Local Volume)

Thank you for your contribution to the report!

7.1 Solar System

Contributors: *Siegfried Eggl (WG), Benoit Carry, Matthew M. Knight, Hayden Smotherman, Colin Snodgrass*

7.2 Milky Way halo & Local Volume

Contributors: *Annette Ferguson, Keith Bechtol, Jeff Carlin, Roelof de Jong, Ariane Lançon, Søren Larsen, Marina Rejkuba*

7.3 The Galactic Plane

Contributors: *Etienne Bachelet (WG), Robert Blum, Hervé Bouy, Leo Girardi, Rodrigo Ibata, Eduardo L. Martin*

7.4 Local Universe

Contributors: *Christopher Conselice (WG), Jean-Charles Cuillandre (WG), Ivan Baldry, Sarah Brough, Michele Cantiello, Jeff Carlin, Chris Collins, Pierre-Alain Duc, Annette Ferguson, Leslie Hunt, Sugata Kaviraj, Johan Knapen, Ariane Lançon, Søren Larsen, Mireia Montes, Polis Papaderos, Reynier Peletier, Javier Roman, Crescenzo Tortora, Chris Usher, Karina Voggel, Aaron Watkins*

7.5 Transients

Contributors: *Isobel Hook (WG), Etienne Bachelet (WG), Pierre Astier, Maria Teresa Botticella, Enrico Cappellaro, Stefano Cavuoti, Jose Diego, Dominique Fouchez, Melissa Graham, Jens Jasche, Rubina Kotak, Guilhem Lavaux, Florent Leclercq, Giuseppe Longo, Seppo Matilla, Gautham Narayan, Stephen Smartt, Charling Tao, Sjoert van Velzen, Benjamin Wandelt*

7.6 Galaxy Evolution

Contributors: *Manda Banerji (WG), Michele Moresco (WG), Viola Allevato, Laura Bisigello, Micol Bolzonella, Jarle Brinchmann, Olga Cucciati, Raphaël Gavazzi, Peter Hatfield, Olivier Ilbert, Clotidle Laigle, Guilhem Lavaux, Claudia Maraston, Manuela Magliocchetti, Henry Joy McCracken, Lucia Pozzetti, E. Sarpa, M. Shuntov, Margherita Talia, Niraj Welikala, Ilsang Yoon, Elena Zucca*

7.7 Active Galactic Nuclei

Contributors: *Franz E. Bauer (WG), Manda Banerji (WG), Viola Allevato, Sotiria Fotopoulou, Hermine Landt, Xin Liu, Maurizio Paolillo, Ilsang Yoon*

7.8 Cosmology from weak gravitational lensing, galaxy clustering and galaxy clusters

Contributors: *Catherine Heymans (WG), Konrad Kuijken (WG), James Bosch (WG), Henk Hoekstra (WG), Francois Lanusse (WG), Peter Melchior (WG), Michele Moresco (WG), Stéphane Paltani (WG), Michael Troxel (WG), Stefano Andreon, Adam Amara, Sandro Bardelli, Micol Bolzonella, Stefano Camera, Francisco Castander, Ranga Ram Chari, N. Elisa Chisari, Olga Cucciati, Melissa Graham, Daniel Gruen, Hendrik Hildebrandt, Olivier Ilbert, Benjamin Joachimi, Rémy Joseph, C. Danielle Leonard, Anja von der Linden, Matteo Maturi, Lauro Moscardini, Emiliano Munari, Roser Pello, Mario Radovich, Barbara*

7.9 Strong Lensing

Contributors: *Tom Collett (WG), Timo Anguita, Simon Birrer, Frédéric Courbin, Tansu Daylan, Jose Diego, Brenda Frye, Raphael Gavazzi, Rémy Joseph, Phil Marshall, Ben Metcalf, Dominique Sluse, Graham Smith, Alessandro Sonnenfeld, Aprajita Verma, Giorgios Vernardos*

7.10 Primaeval Universe

Contributors: *Adriano Fontana (WG), Manda Banerji (WG), Rebecca Bowler, Marco Castellano, Jean-Gabriel Cuby, Daniel Mortlock, Sune Toft*

Thank you for engaging in the discussion!

350 scientists registered on the Rubin-Euclid DDP forum throughout 2021:

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Bob Armstrong
Etienne Bachelet
Manda Banerji
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Jonathan Blazek
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Gianluca Castignani
Nora Elisa Chisari
Johann Cohen-Tanugi
Asantha Cooray
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Hugh Dickinson
Darko Donevski
Jose A. Escartin
Xiaohui Fan
Henry Ferguson
Adriano Fontana
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Troy Joseph Raen
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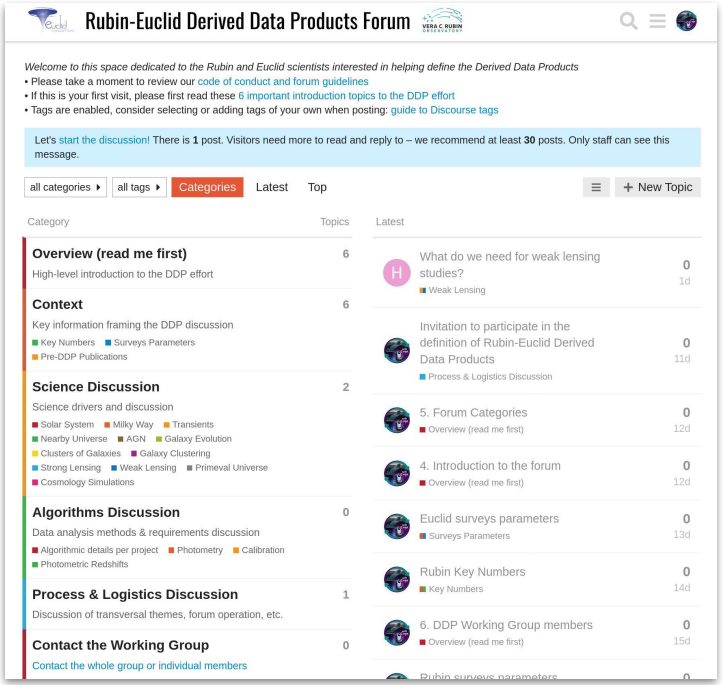
WeiLeong Tee
Francesc Torradeflot
Eleni Tsaprazi
Hector Manuel Velazquez
Benjamin Wandelt
Niraj Welikala
Vivienne Wild
Stijn Wuyts
Mijin Yoon
Yuanyuan Zhang

A virtual discussion open to all in Rubin & Euclid

- The DDP discussion focused on the scientific motivation and nature, not the creation, of the DDPs.
- Standalone, world-public, project-independent forum: https://community.rubin-euclid-ddp.org
- Open to all data rights holders in both the Rubin Euclid communities – this approach ensured that everyone had a chance to contribute to the debate.
- Categories for science topics and algorithms instigated by DDP-WG members.
- The 5-month long discussion (first half of 2021) was the basis for the DDP report.



The "Discourse - Civilized Discussion" platform ensures community exchanges with the power of asynchronicity across continents.

5 high-level questions to guide developing the input

Guidelines along the 5 high-level questions template: 1) Science Case, 2) Nature of the Derived Data Product, 3) Algorithms, 4) Computing, 5)Timescale

Q1: Considering DDPs use cases can be for joint pixel-level processing, or input prior information exchange, or catalog-level processing, what science would be enabled or enhanced with a Rubin-Euclid joint processing?

Q2: Which surveys specific data products are needed to realize your science cases outlined in Question 1?

Q3: Do the algorithms already exist to carry out the necessary processing to deliver the data products described in Question 2?

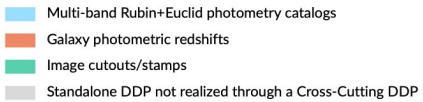
Q4: What level of critical resources would be needed to develop and operate the approaches and data volume described through Questions 2 and 3?

Q5: On what timescales would the DDPs described in Question 2 be useful?

Tiered prioritization of recommended DDPs

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



Column 1: DDP identifier

Column 2: Benefit, **B**=Both communities, **R**=Rubin, **E**=Euclid

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)

P: Relative scientific **P**riority.

U: **U**rgency, timescale on which the DDP is needed, e.g time-sensitive/small area DDPs might be worth producing and sharing before producing DDPs from a fuller analysis of a larger area.

RT/YR/DR: Cadence for producing DDPs. RT= Real-Time (~ day) for transients, YR = "Yearly Release" matching the Rubin-LSST releases, DR = "Data Releases" for products that can wait for longer timescales, such as Euclid DR3.

Recommendations for cross-cutting DDPs

DDP-1-CC: Multi-band Rubin+Euclid list-driven photometry catalogs:
Photometric redshifts are at the heart of the high-profile cosmology science cases of both surveys, with stringent accuracy requirements that cannot be met using a combination of two independent photometry catalogs. ***At a minimum,*** a list-driven photometry source exchange for point sources and galaxies detected in all r,i,z and Y,J,H bands across both catalogs above 5-sigma. **Timescale**: As soon as the two surveys overlap.

DDP-2-CC: Multi-band Rubin+Euclid forced photometry catalog based on joint-pixel processing:
Starting with object detections across both surveys based on the DDP-1-CC selection function, measure PSF, aperture and total fluxes and/or upper limits across all bands using matched images in the other survey. **Timescale**: Post Euclid/Rubin DR1/Y1. Incrementally increasing in area / depth / complexity through the lifetime of both surveys.

DDP-3-CC: Multi-band Rubin+Euclid deblended photometry catalog from joint-pixel processing:
Starting with object detections across both surveys based on the DDP-1-CC selection function, measure deblended component with VIS and total fluxes and/or upper limits across all u,g,r,i,z,y,Y,J,H bands using matched images in both survey datasets, while respecting the data policy driven DDP-1-CC source selection function. This represents the most complex approach. **Timescale**: Post Euclid/Rubin DR1/Y1. Incrementally increasing in area / depth / complexity through the lifetime of both surveys.

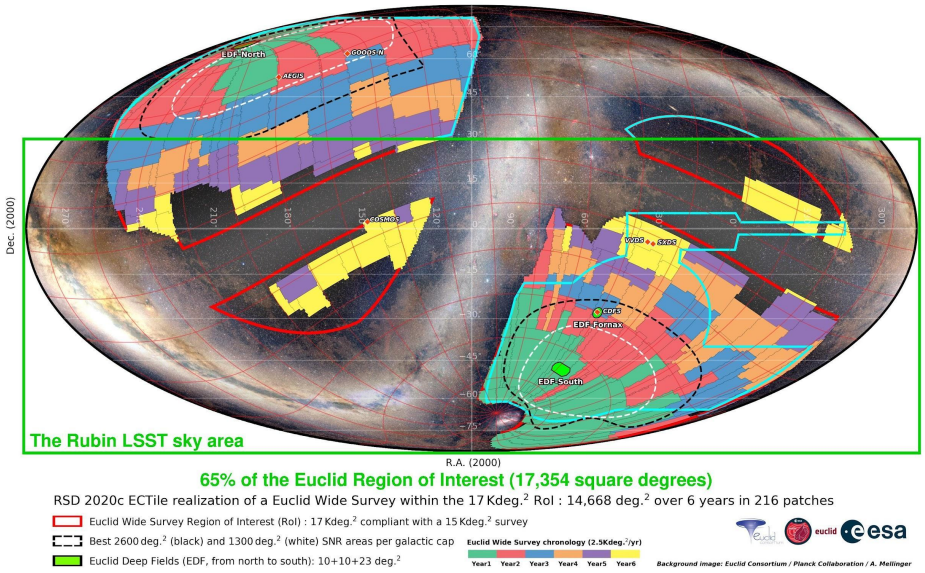
Recommendations for cross-cutting DDPs

DDP-4-CC: Galaxy “pixel” photometric redshifts with machine learning:
Full probability distributions for the photometric redshift estimates are required for all science cases which need to propagate errors into physical parameters using a range of algorithms incorporating both empirical/training-set based methods and template-fitting run on the joint multi-wavelength catalogs. Joint-pixel analysis with machine learning will further benefit photometric redshift estimates at both surveys depth limits in particular when deblending becomes an issue for Rubin. Similar selection function as the above photometric catalogs DDPs.
Timescale: Post Euclid and Rubin DR1. Incrementally increasing in area / depth / complexity through the lifetime of both surveys.

DDP-5-CC: Image cutouts/stamps delivery service:
Exchange of Image cutouts (pixels) on small areas of the sky will enable key scientific investigations, e.g transient science, strong lensing, and drop-out science. Sharing within the two projects a limited number of pixels driven by the angular size of the source of interest is compatible with the DDP definition considering the scientific return of a highly specific usage. **Timescale:** As soon as the two surveys overlap.

Survey Strategy Optimization for DDPs

A key factor in maximizing the impact of Rubin-Euclid DDPs is the coordination of each survey's observing strategy; maximizing the spatial and temporal overlap of the two surveys will enhance almost all science domains.



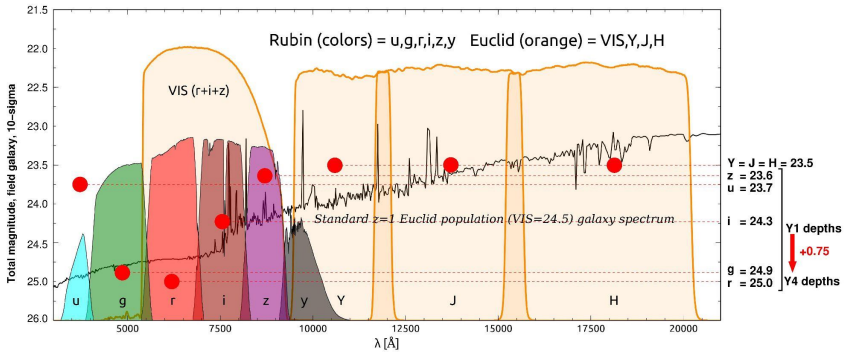
- Wide surveys: Large overlap area of up to approximately 9000 square degrees.
- LSST Cadence Note – *Enhancing LSST Science with Euclid synergy and a mini-survey of the northern sky to Dec < +30*. Modifications to the Rubin Wide-Fast-Deep towards an extended footprint driven by dust extinction already enhances Euclid synergy (9400 deg2 overlap).
- 2 overlapping LSST deep drilling fields (DDF): Rubin and Euclid will both observe EDF-Fornax (10 sq deg) and EDF-South (23 sq deg) which is now confirmed (2022) as a LSST DDF.

Euclid Data Releases & expected ground depths

Photo-z depth metric proxy (for all): point source in 2 arcseconds diameter aperture, 10σ

- Euclid (median over the RoI): *VIS=25.0, Y=J=H=23.5*
- DES in Euclid DR1/2/3: *g=24.7, r=24.4, i=23.8, z=23.1*
- UNIONS in Euclid DR1: *u=23.6, g=24.5, r=24.1, i=23.2, z=23.4*
- UNIONS in Euclid DR2: *u=23.6, g=24.5, r=24.1, i=23.4, z=23.4*
- UNIONS in Euclid DR3: *u=23.6, g=24.5, r=24.1, i=23.6, z=23.4*
- Rubin LSST* Y1 in Euclid DR2: *u=23.7, g=24.9, r=25.0, i=24.3, z=23.6*
- Rubin LSST* Y1 to Y4 in Euclid DR3: *u=24.4, g=25.6, r=25.7, i=25.0, z=24.3*

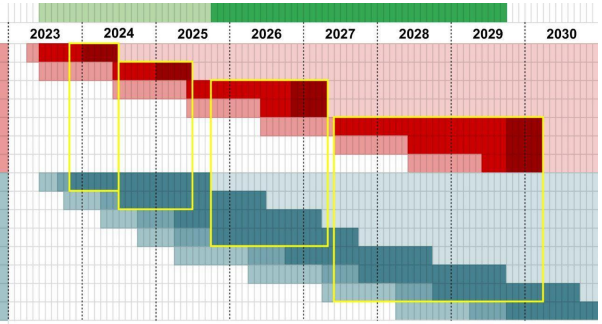
*Rubin-LSST DDP main releases depth with point source PSF performance scaled to the 2” diam. metric



Timescales and data releases

Rubin-Euclid Coordination Timeline

Survey	Data Release	
Euclid	Q1	Misc. sky areas (EDF, etc), total 50 sq deg
Euclid	DR1	Euclid Y1 (2500 sq deg, << 1000 sq deg overlap)
Euclid	Q2	Euclid Y2
Euclid	DR2	Euclid Y3 (7500 sq deg, ~3000 sq deg overlap)
Euclid	Q3	Euclid Y4
Euclid	Q4 (TBC)	Euclid Y5
Euclid	DR3	Euclid Y6 (15000 sq deg, ~7000 sq deg overlap)
LSST	DP1	LSST ComCam
LSST	DP2	LSST SV (~1000 sq deg, 180 visits / Y2 depth)
LSST	DR1	LSST First 6 Months
LSST	DR2	LSST Y1 (90 visits)
LSST	DR3	LSST Y2 (180 visits)
LSST	DR4	LSST Y3 (270 visits)
LSST	DR5	LSST Y4 (360 visits)
LSST	DR6	LSST Y5 (450 visits)



Assumptions:

February 2023	Euclid mission launch date
April 2024	LSST survey start

Surveys color keys:

	Observing
	Processing
	Proprietary Access
	Public Access

Notes:

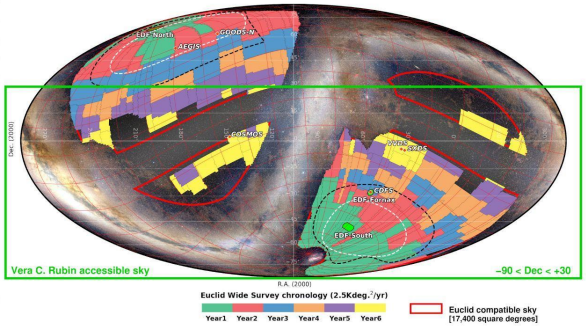
(a) LSST data release dates may move by +/3 months as the operations team adapts to circumstances.

(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 SV 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 SIT-Com team's field selection is not yet determined.

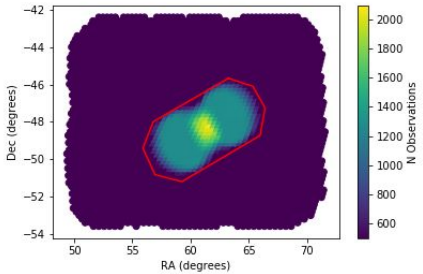
(d) DDP transient science can start in 2023 with limited sky overlap (green bar).

(e) LSST Y1 leads to matched survey depths for photo-z estimation: the production of related DDPs (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.

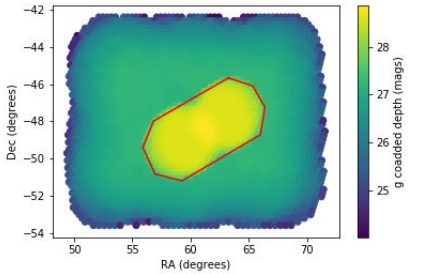


- Recommended DDPs should be produced as soon as Rubin and Euclid observe a common area of the sky, e.g. as early as 2023 in an investigative manner (limited overlap) in order to be mature in time for 2025: Euclid DR2 + LSST Y1.
- DDPs that will enable transient science should materialize on a short timescale, e.g. 24 hr and based on a fast joint processing.
- More complex DDPs would fit better in the context of the annual Rubin data release scenario.

Open sharing of photometric data on a small area



Two Rubin Deep Drilling Fields at half-depth on EDF-South



… or a uniform depth on EDF-South with an optimized Rubin dithering

- Openly sharing all imaging pixel data over a common small area of the sky across both projects will enable the early development of methods, algorithms and software that will be beneficial to all DDPs before embarking on full scale processing,
- … while also allowing both communities to investigate delivered DDPs in depths and propose paths for further improvements in future releases.
- The report recommends for this purpose the confirmed Rubin DDF over the 23 sq degree EDF-South.

Credit: P. Joachim

Differential Chromatic Refraction model improvements

- Rubin's model for correcting differential chromatic refraction can be improved by a factor of ≈ 2 by incorporating pixel-level morphological information from Euclid's high resolution VIS band, which would drive improvements in essentially all downstream DDPs.
- The DCR model can only be improved over the region where the VIS data are available and is fundamentally rooted in joint-pixel level processing.
- Work will be required to understand how to incorporate Euclid morphological and spectral input into the Rubin DCR correction model. We recommend this to be investigated initially over the EDF-South (as a DDF) as a demonstration test case and, if a significant improvement is demonstrated, ultimately applied to the entire overlapping wide area in the long term.

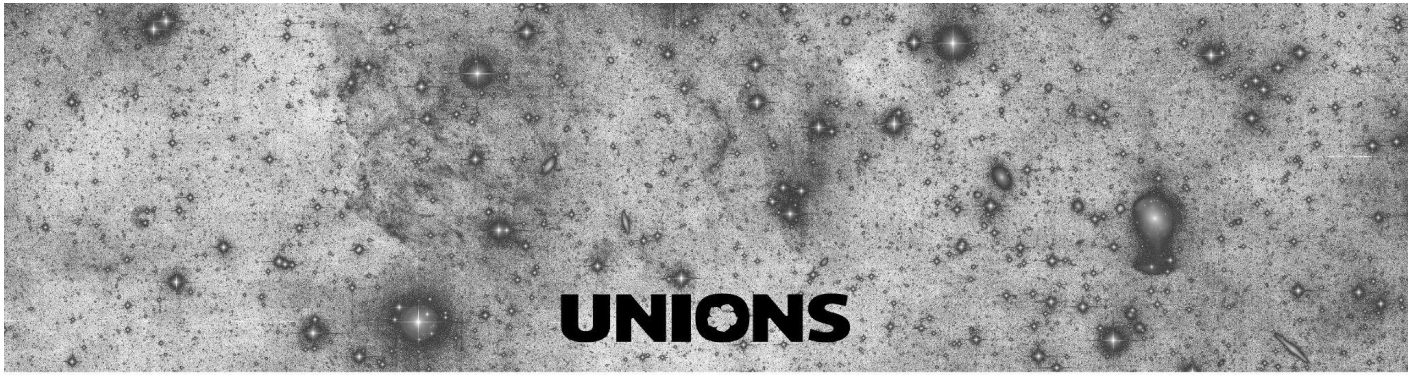
Recent advances and what happens next

- The work of the Rubin-Euclid DDP Working Group is complete, the report is public.
- An ECB sub-committee conducted a final check of the various DDPs with the DDP-WG Euclid co-chair (V1.0->V1.1) : minute clarifications submitted by Euclid to Rubin following a final consultation with SWGs leads and the DDP-WG Euclid members were approved.
- The recommendations are now approved in whole by the ECB, and the respective consortia can proceed to the funding and implementation phase with decisions about where, whom, on what timescale, with what funding, and how the recommended DDPs are produced.
- As both projects approach first light, the ECB will follow up on the recommendation of the prompt creation of a joint implementation group to realize all DDPs listed in this report. This should include people with identified significant availability for these efforts.
- The Community forum will remain open and can be used for ongoing discussions.

Rubin-Euclid Derived Data Products summary

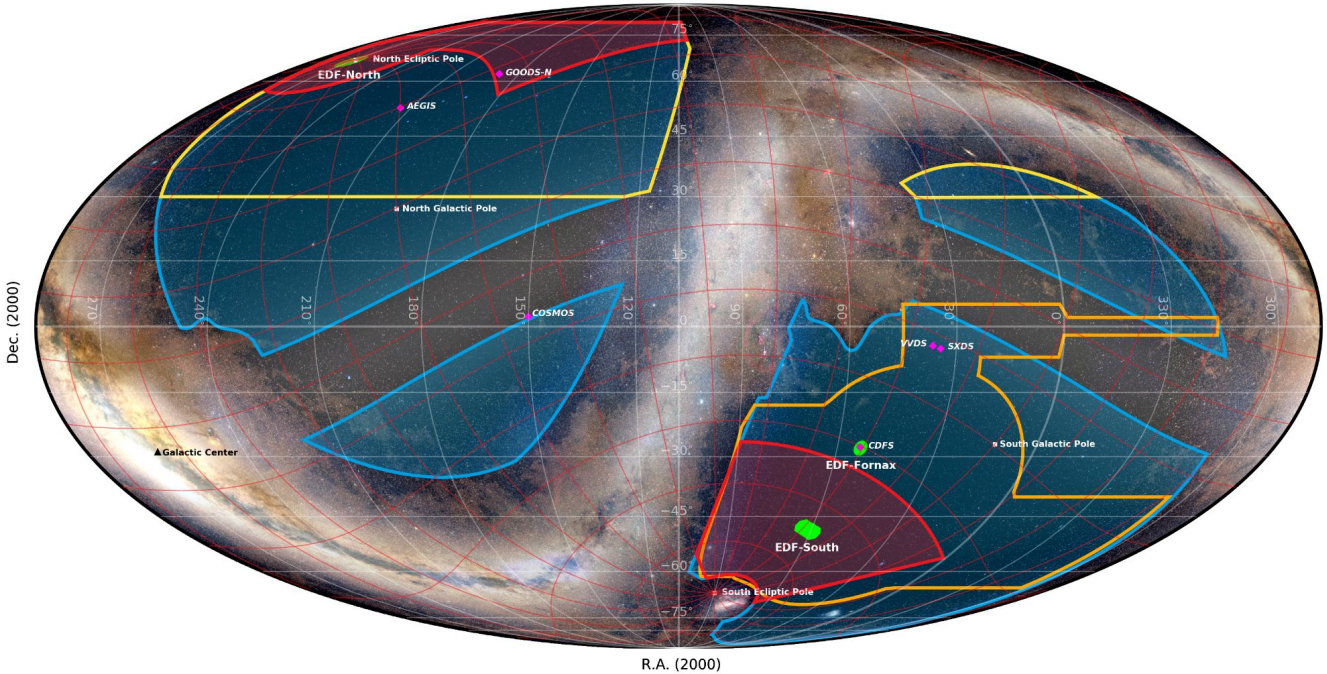
- There is no lesser partner in this effort to maximize the science return of both projects.
- The proposed DDPs are fair to both scientific collaborations and benefit many in each project.
- There is no selection of DDPs based on a scientific comparison between domains.
- Cross-cutting DDPs that serve many scientific domains are however championed (photometric catalogs).
- For Euclid to achieve its core science goals (photo-z), some legacy Euclid science might lose an edge.
- The DDP working group carefully rejected the proposed DDPs that gave too much away.
- The reports recommends that the ECB pushes to implement the report recommendations in whole.
- The DDPs are presented in 4 tiers of importance and timing that address some competitive aspects.

UNIONS and Euclid context



Jean-Charles Cuillandre (CEA Saclay, Université Paris-Saclay)
on behalf of the UNIONS science collaboration & the Euclid Consortium

Euclid science operations and the DR1 plan (year 1)



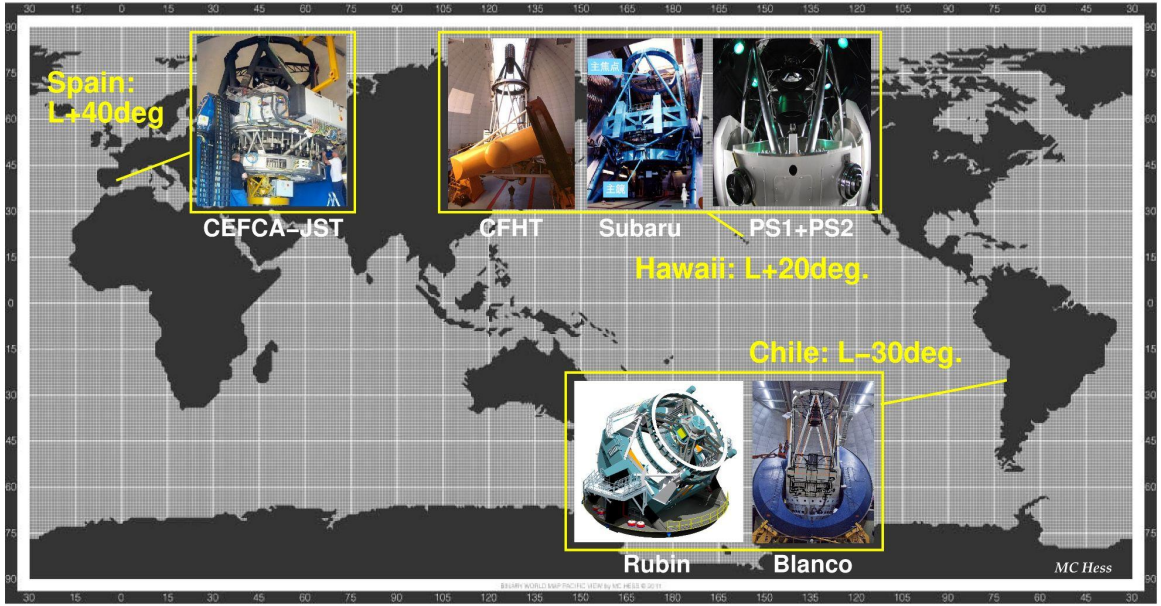
The Euclid Wide Survey DR1 area maximizing the overlap with DES : North = 821 deg^2, South = 1657 deg^2 [Mollweide Celestial]

- Euclid Wide Survey region of interest : 17,354 deg^2
- DES, griz, 2013−19 : 4500 deg^2 overlap with the region of interest
- UNIONS [CFIS/WHIGS/Pan−STARRS/WISHES], ugriz, 2017−24 : 4861 deg^2
- Euclid DR1 area, 2023 : 2500 deg^2
- Euclid Deep Fields [total 43 deg^2]

Background image: Euclid Consortium / Planck Collaboration / A. Mellinger

Euclid rely on wide-field ground-based facilities

All relevant current and future ground-based wide field imaging telescopes are now engaged/associated to the Euclid sky coverage

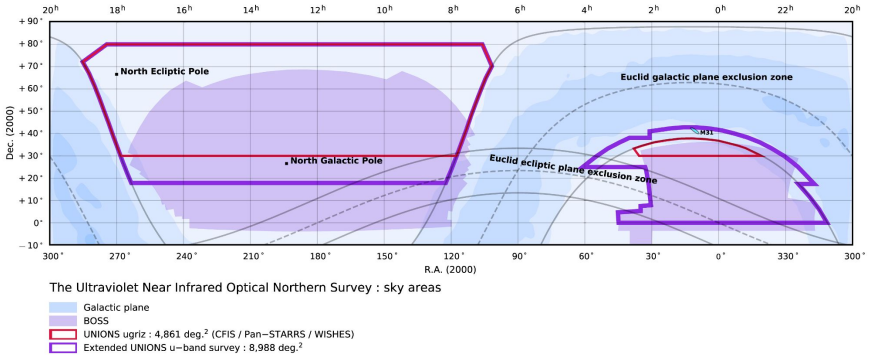


Etendue

Facility	Year	Aper.	FOV	IQ[r]	CCD class	Type	Hemisphere
Rubin	2023	6.6m	9.6 sq.deg.	0.8"	Deep depletion	Surveyor	South
Subaru	2013	8.2m	1.8 sq.deg.	0.6"	Fully depleted	Observatory	North
Blanco	2013	4.0m	3.0 sq.deg.	1.0"	Fully depleted	Observatory	South
JST	2022	2.5m	4.8 sq.deg.	0.8"	Deep depletion	Surveyor	North
PS1+PS2	2019	2x1.5m	7.0 sq.deg.	1.0"	Fully depleted	Surveyor	North
CFHT	2003	3.6m	1.0 sq.deg.	0.6"	EPI	Observatory	North

The Ultraviolet Near Infrared Optical Northern Survey

UNIONS = CFIS (u,r) + WHIGS (g) + Pan-STARRS (i,z) + WISHES (z)



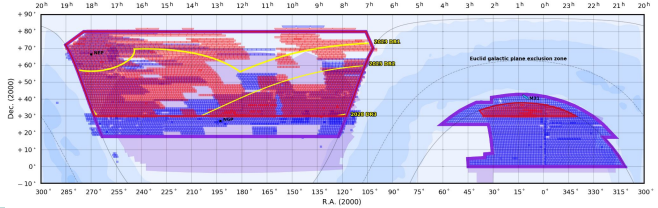
- CFHT: Canada-France Imaging Survey + Luau (2015-16)
  - u : DEC>+0 on the SGC*, and DEC>+18 on the NGC*
  - r : DEC>+30

**SGC = South Galactic Cap, NGC = North Galactic Cap*

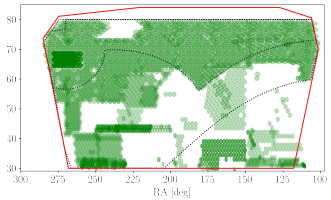
- Subaru: Waterloo-Hawaii-IfA G-band Survey
  - g : DEC>+30
- Pan-STARRS:
  - i : DEC>+30 (integration from NEOs search)
  - z : +30<DEC<+38
- Subaru: Wide Imaging with Subaru HSC of the Euclid Sky
  - z: DEC>+38

UNIONS observing status as of May 2022:

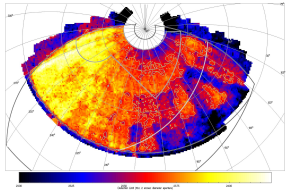
CFHT u,r



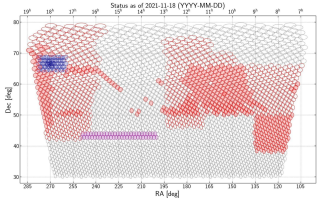
Subaru g



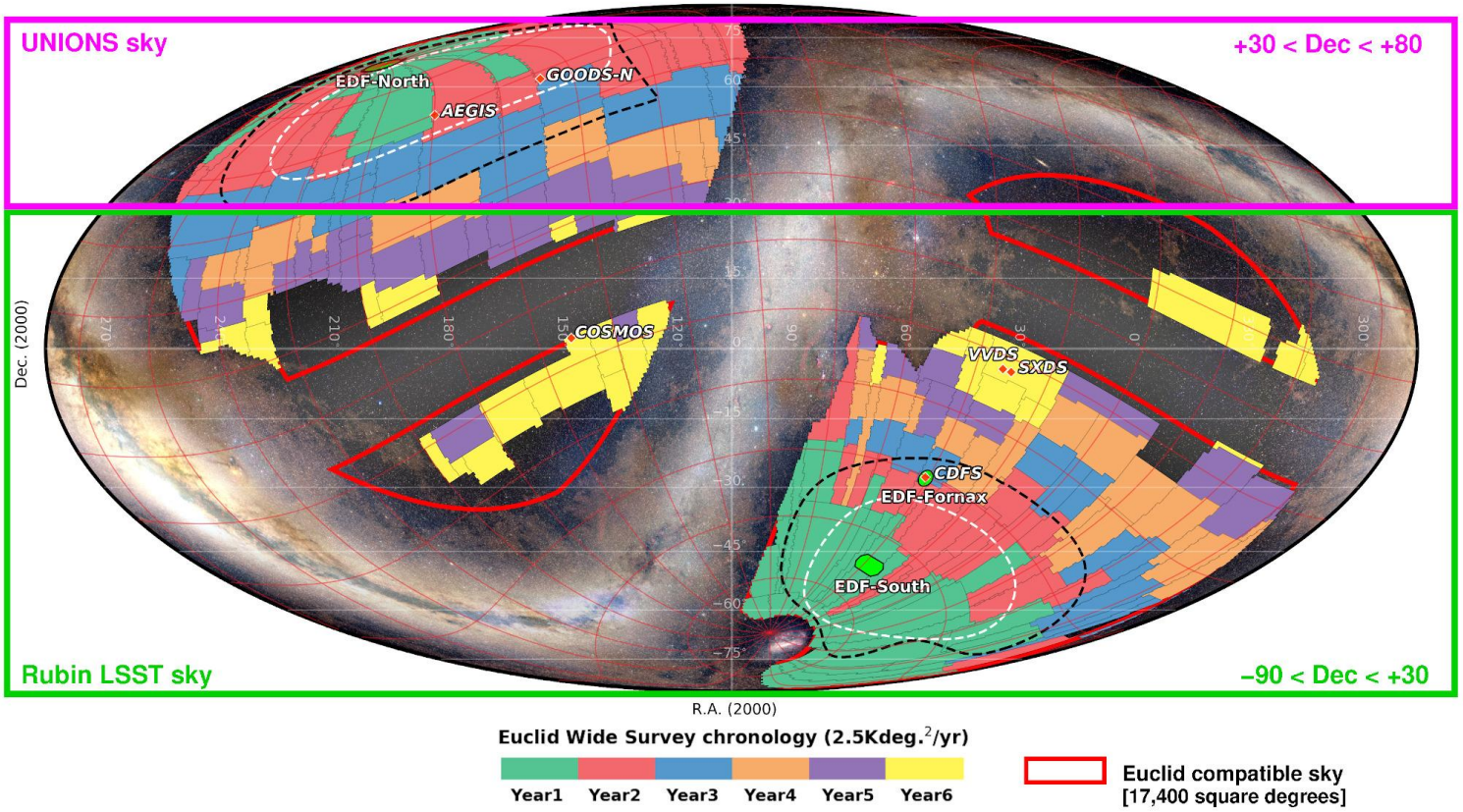
Pan-STARRS i



Subaru z



Euclid DR2/3 ground coverage = UNIONS + LSST

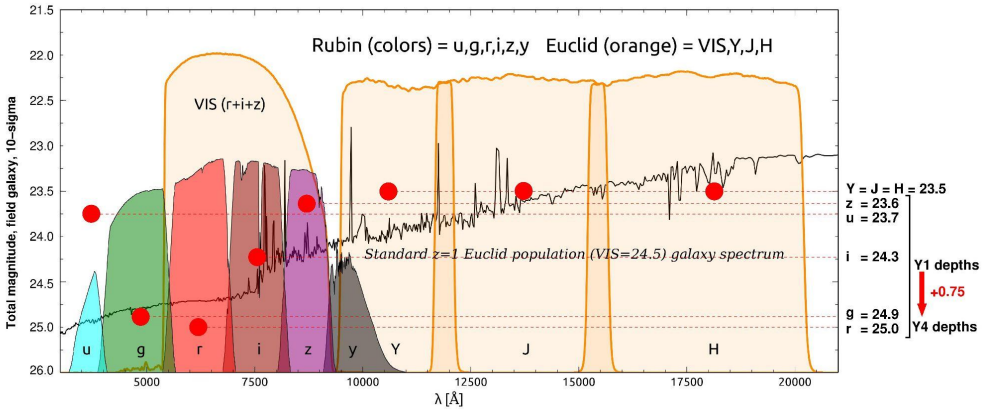


UNIONS explores today some science of the LSST era

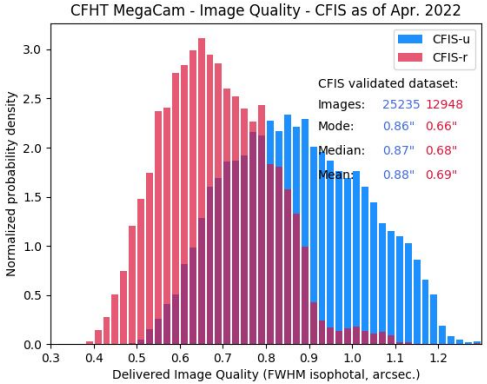
Photo-z depth metric proxy (for all): point source in 2 arcseconds diameter aperture, 10σ

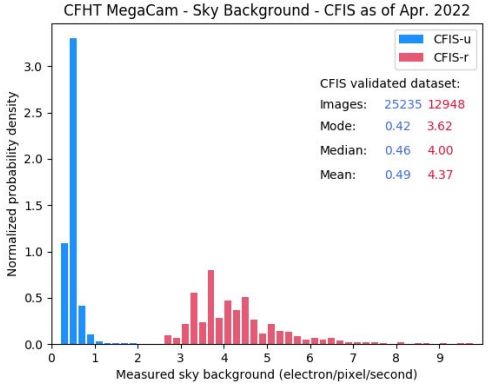
- Euclid (median over the Euclid sky): *VIS=25.0, Y=J=H=23.5*
- DES in Euclid DR1/2/3: *g=24.7, r=24.4, i=23.8, z=23.1*
- UNIONS in Euclid DR1: *u=23.6, g=24.5, r=24.1, i=23.2, z=23.4*
- UNIONS in Euclid DR2: *u=23.6, g=24.5, r=24.1, i=23.4, z=23.4*
- UNIONS in Euclid DR3: *u=23.6, g=24.5, r=24.1, i=23.6, z=23.4*
- Rubin LSST* Y1 in Euclid DR2: *u=23.7, g=24.9, r=25.0, i=24.3, z=23.6*
- Rubin LSST* Y1 to Y4 in Euclid DR3: *u=24.4, g=25.6, r=25.7, i=25.0, z=24.3*

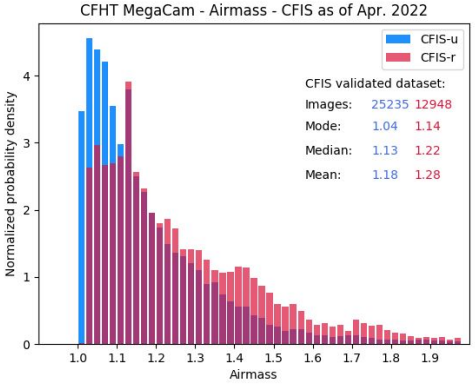
*Rubin-LSST DDP main releases depth with point source PSF performance scaled to the 2" diam. metric



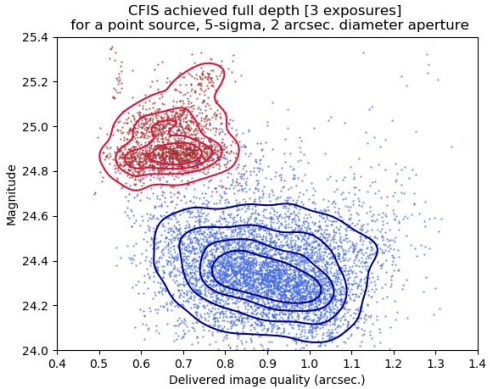
CFIS UNIONS u,r dataset built on CFHT's strengths







- Field-of-view
- Image quality
- u-band sensitivity
- MegaCam SNR mode
- MegaCam LSB mode



UNIONS publications

24. Wilkinson, S., et al., to be submitted, “The merger fraction of post-starburst galaxies in UNIONS”
23. Farrens, S., et al., 2022, submitted, “A modular weak lensing processing and analysis pipeline”
22.Aycoberry, E., et al., 2022, submitted, “UNIONS : impact of systematic errors on weak-lensing peak counts”
21.Robison, B., et al., 2022, submitted, “The shape of dark matter haloes: results from weak lensing in the Ultraviolet Near Infrared Optical Northern Survey (UNIONS)”
20.Bickley, R., et al., 2022, submitted, “Star formation characteristics of CNN-identified post-mergers in the UNIONS”
19.Lim, S., 2022, MNRAS, submitted, “Constraints on galaxy formation from the CIB - optical imaging cross-correlation using Herschel and UNIONS”
18.Savary, E et al . 2022, A&A, submitted “A search for galaxy-scale strong gravitational lenses in UNIONS”
17.Chan, J. H. H. et al. 2022, A&A, submitted “Discovery of Strongly Lensed Quasars in UNIONS”
16.Spitzer, I. et al. 2022, MNRAS, submitted, “Galaxy group & cluster masses from weak lensing in UNIONS”
15.Guinot, A. et al. 2022, A&A, in press, “ShapePipe : a new shape measurement pipeline and weak-lensing application to UNIONS/CFIS data”
14.Sola, E., et al. 2022, A&A, in press, “Characterization of LSB structures in annotated deep images”
13.Roberts, I., et al., 2022, MNRAS,509, 1342, “Ram Pressure Candidates in UNIONS”
12.Jensen, J., et al. 2021, MNRAS, 507, 1923, “Uncovering fossils of the distant Galaxy with UNIONS: NGC 5466 and its stellar stream”
11.Bickley, R., et al. 2021, MNRAS, 504, 372, “Convolutional neural network identification of galaxy post-mergers in UNIONS using Illustris TNG”
10.Fantin, N., et al. 2021, ApJ, 913, 30, “The Mass And Age Distribution Of Halo White Dwarf Candidates In The Canada-France Imaging Survey”
9.Liaudat, T., et al., A&A, A27, “Multi-CCD modelling of the point spread function”
8.Thomas, G., et al. 2020, ApJ, 902, 89, “The Hidden Past of M92: Detection and Characterization of a Newly FormedLong Stellar Stream Using the Canada-France Imaging Survey”
7.Fantin N. et al. 2019, ApJ, 877, 148, “The Canada France Imaging Survey: Reconstructing the Milky Way from its whitedwarf population”
6.Thomas, G. F., Annau, N., et al., 2019, ApJ, 866, 10, “Dwarfs or giants? Stellar metallicities and distances from ugrizG multi-band photometry”
5.Ellison, S., et al. 2019, MNRAS, 487, 2491, “A definitive merger-AGN connection at z~0 with CFIS: mergers have an excess of AGN and AGN hosts are more frequently disturbed”
4.Thomas, G. F., Laporte, C. F. P. et al. 2019, MNRAS, 483, 3, “A-type stars in the Canada-France Imaging Survey - II.Tracing the height of the disc at large distances with Blue Stragglers”
3.Thomas, G. F. et al., 2018, MNRAS, 481, 4, “A-type stars in the Canada-France Imaging Survey I. The stellar halo of the Milky Way traced to large radius by blue horizontal branch stars”
2.Ibata, R. et al., 2017, ApJ, 848, 2, 129, “Chemical Mapping of the Milky Way with CFIS: A Non-parametric Metallicity-Distance Decomposition of the Galaxy”
1.Ibata, R. et al. 2017, ApJ, 848, 2, 128, “The Canada-France Imaging Survey: First Results from the u-Band Component”

Good reasons for IN2P3 scientists to join UNIONS

What is unique to UNIONS today:

- DES now offers 5000 square degrees in g,r,i,z at similar depths but until LSST-Y2, UNIONS z from will be a bit deeper (+0.4 mag), and UNIONS also has a shallow u-band
- Median image quality of UNIONS is u=0.9”, g=0.8”, r=0.7”, i=1.0”, z=0.8”
- Image stacks and catalogs of point sources and distant galaxies are the basis of our internal DRs
- UNIONS overlaps thousands of square degrees of SDSS/BOSS spectroscopy, and now DESI
- A weak lensing catalog over 3000 deg^2 of the CFIS-r (median IQ=0.7”) is now available in UNIONS
- CFIS delivers data to explore the low surface brightness Universe (~28th mag/sq. arcsec in the r-band)
- Dataset is fully proprietary for another year (August 2023 for CFIS, but just the basic frames)

Why joining UNIONS today:

- UNIONS will be the deep, wide optical survey of the northern sky throughout the 2020s and beyond
- There is no guarded science in UNIONS, but openness is enforced and collaboration is encouraged as members must endorse a set of simple rules, our goal being to enable great science
- UNIONS allows you to gear up to the Rubin-LSST and Euclid dataset by testing your ideas and algorithms
- UNIONS is open to all interested IN2P3 scientists through the CNRS INSU contribution with CFIS

The Ultraviolet Near Infrared Optical Northern Survey

UNIONS

- 202 scientific collaborators (mostly Canada, France, Hawaii, Japan), and growing
- UNIONS ambitious science is now shifting into high gear (following talks & posters)
- A complete coverage in u&r by CFHT is critical to the UNIONS and Euclid science
- Full completion of CFIS is a top priority in Canada (LRP 2020) and France (Prospective 2019)
- Follow the UNIONS scientific activities at www.skysurvey.cc