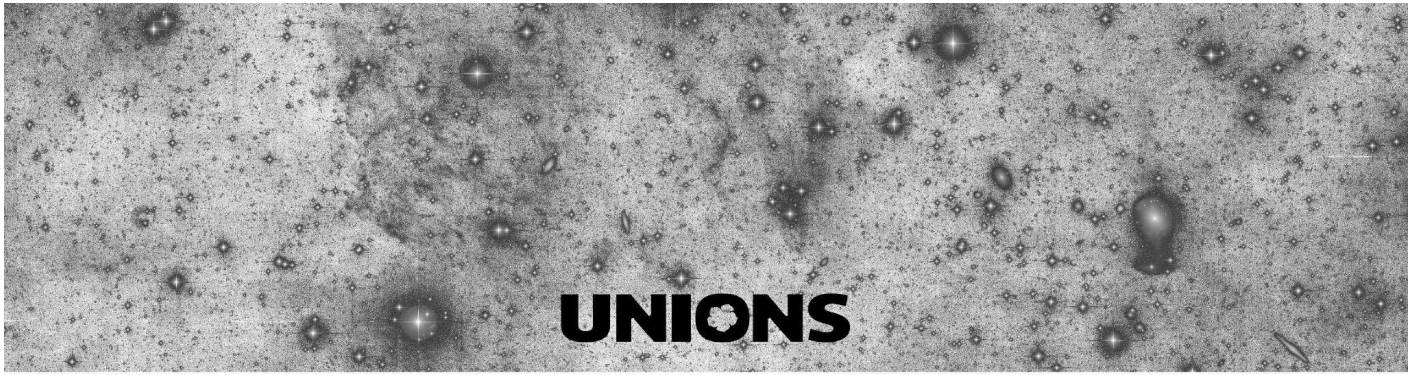
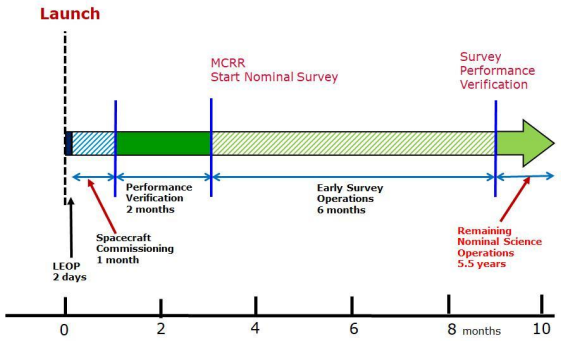
The Ultraviolet Near-Infrared Optical Northern Survey

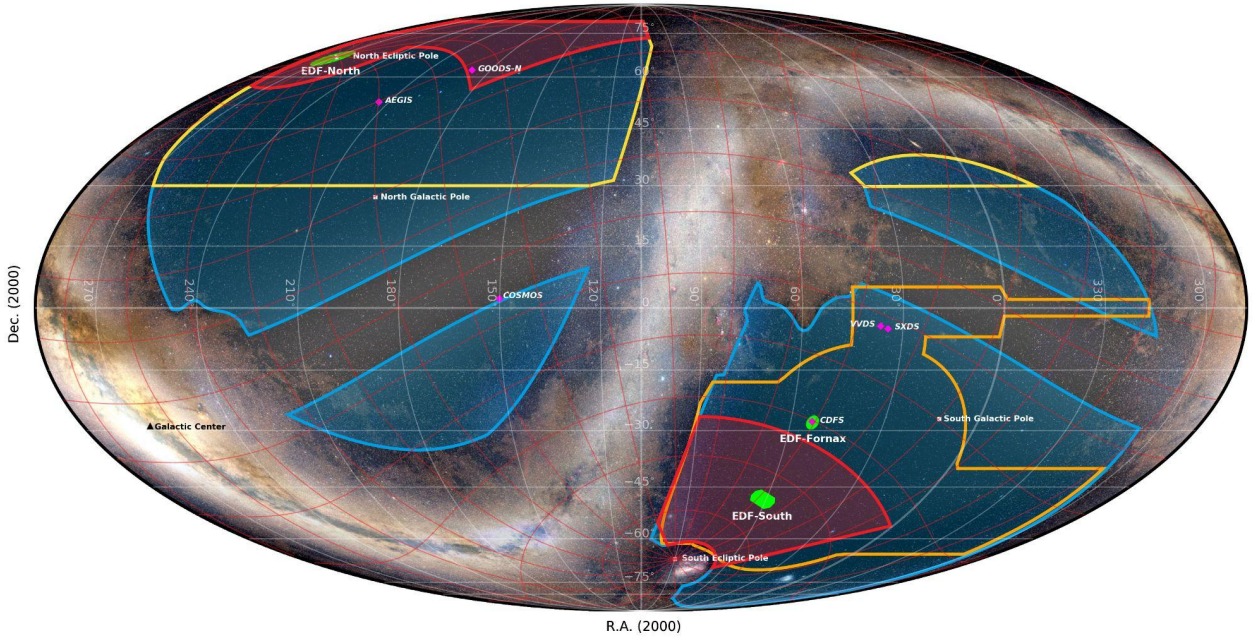


Jean-Charles Cuillandre (CEA Paris-Saclay, Université Paris-Saclay)
on behalf of the UNIONS science collaboration & the Euclid Consortium

Euclid science operations and the Year 1 plan (DR1)



Provided by R. Laureijs, ESA



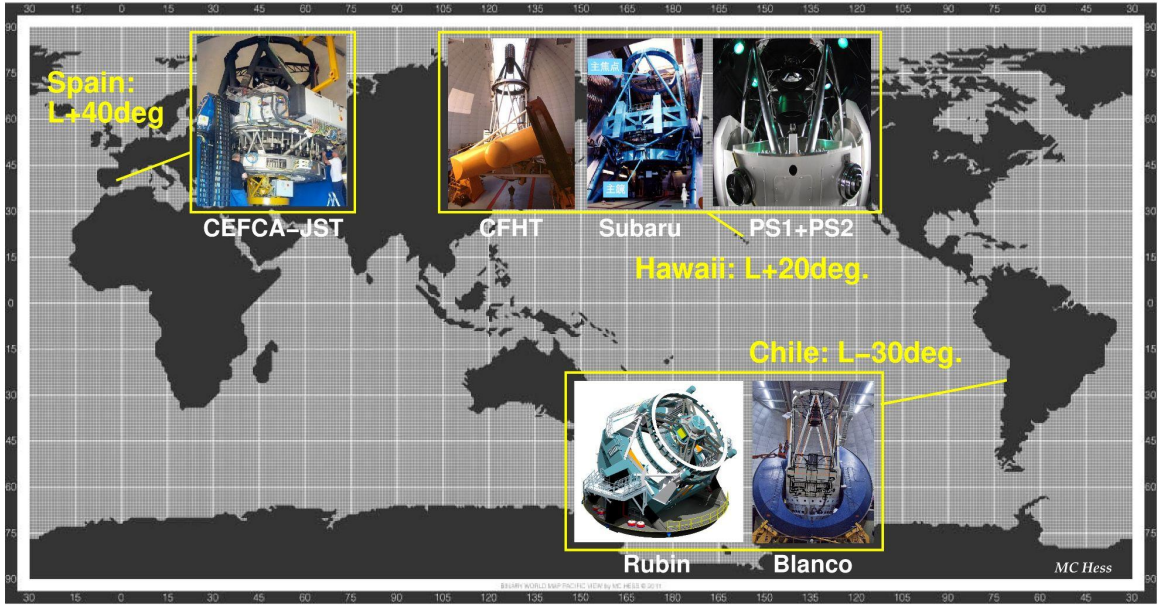
The Euclid Wide Survey DR1 area maximizing the overlap with DES : North = 821 deg^2, South = 1657 deg^2 [Mollweide Celestial]

- Euclid Wide Survey region of interest : 17,354 deg^2
- DES, griz, 2013−19 : 4500 deg^2 overlap with the region of interest
- UNIONS, ugriz, 2017−24 : 4861 deg^2
- Euclid DR1 area, 2023 : 2500 deg^2
- Euclid Deep Fields [total 53 deg^2]

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

Science without Euclid led to a northern sky alliance

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

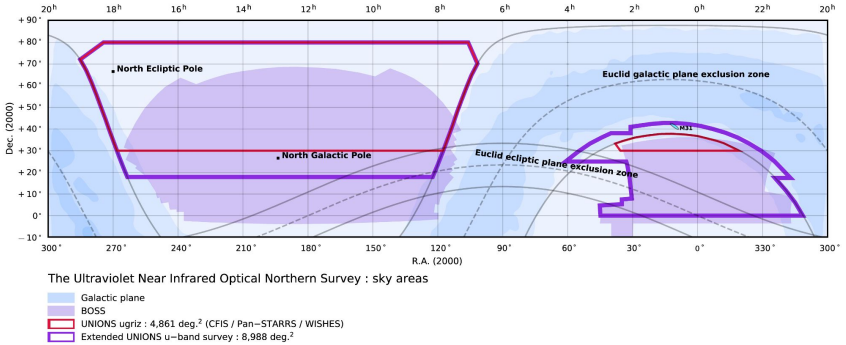


Etendue

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

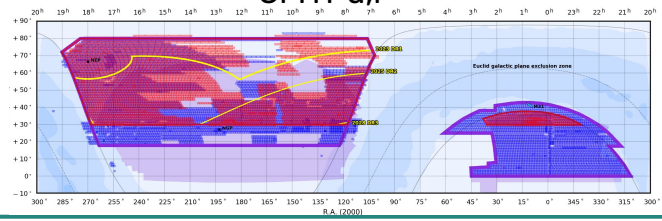


- CFHT-MegaCam: 3 Large Programs (473 nights, 2015-24)
  - u : DEC>+0 on the SGC*, and DEC>+18 on the NGC*
  - r : DEC>+30

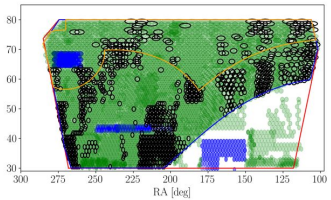
  **SGC = South Galactic Cap, NGC = North Galactic Cap*
- Subaru-HSC: Waterloo-Hawaii-IfA G-band Survey
  - g : DEC>+30 (20 nights)
- Pan-STARRS: (40% of PS1+PS2 observing time since 2017)
  - i : DEC>+30 (integration from NEOs search)
  - z : +30<DEC<+38
- Subaru-HSC: Wide Imaging with Subaru HSC of the Euclid Sky
  - z: DEC>+38 (40 nights)

UNIONS observing status as of November 2022:

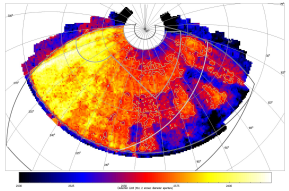
CFHT u,r



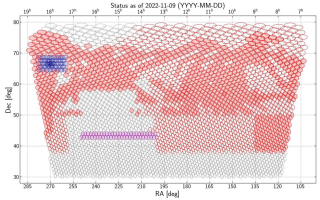
Subaru g



Pan-STARRS i



Subaru z



UNIONS explores today some science of the LSST era

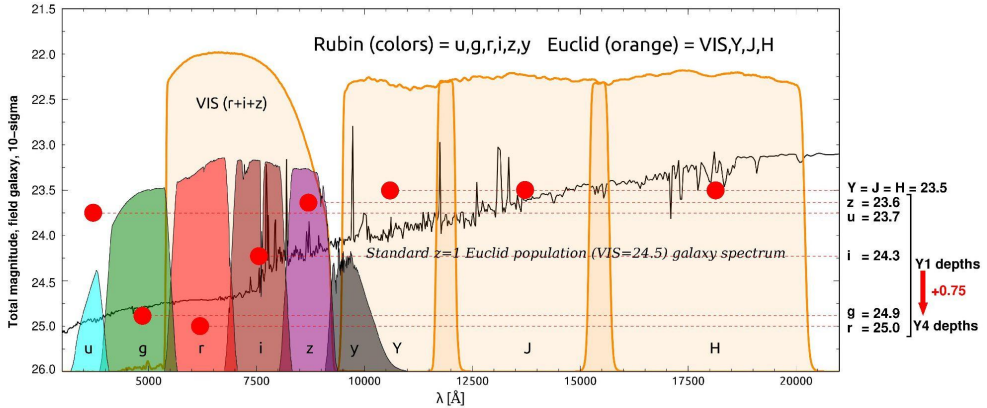


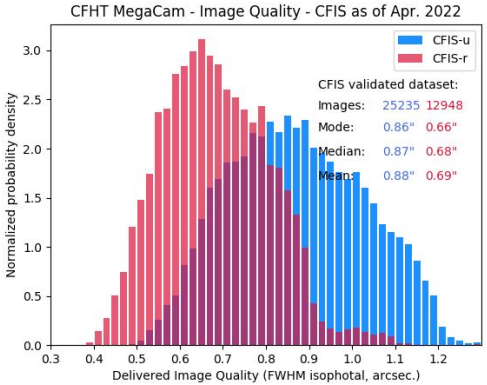
Photo-z depth metric proxy (for all): point source in 2 arcseconds diameter aperture, 10σ

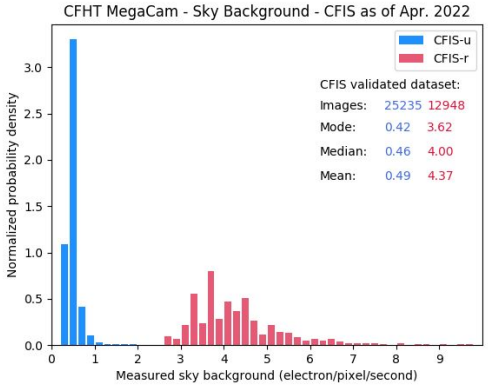
- Euclid (median over the Euclid sky): *VIS=25.0, Y=J=H=23.5*
- DES in Euclid DR1/2/3: *g=24.7, r=24.4, i=23.8, z=23.1*
- UNIONS in Euclid DR1: *u=23.6, g=24.5, r=24.1, i=23.2, z=23.4*
- UNIONS in Euclid DR2: *u=23.6, g=24.5, r=24.1, i=23.4, z=23.4*
- UNIONS in Euclid DR3: *u=23.6, g=24.5, r=24.1, i=23.6,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

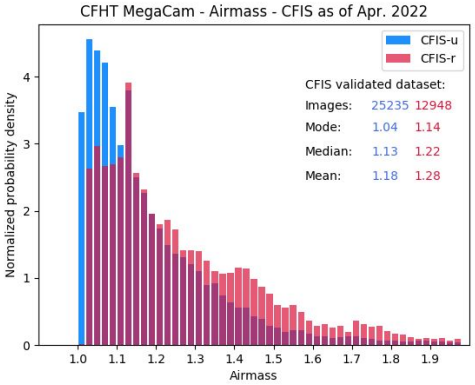
*Rubin-LSST main releases depth with point source PSF performance scaled to the 2" diam. metric

UNIONS ≈ LSST Year 1 depths

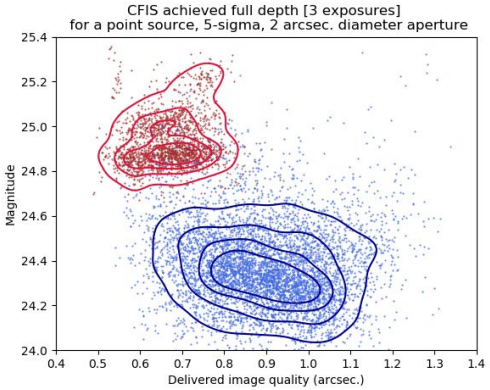
UNIONS u,r dataset built on CFHT's strengths







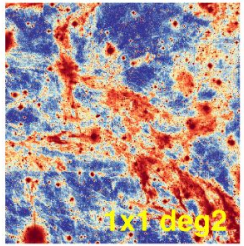
- Field-of-view (1 square degree)
- Image quality (0.6" r-band)
- u-band sensitivity (in 4mn)
- r-band sensitivity (in 6mn)
- MegaCam SNR mode
- MegaCam LSB mode

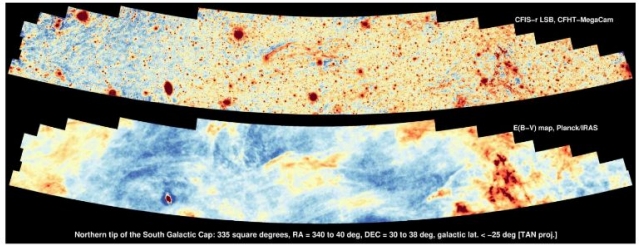


UNIONS r-band low surface brightness performance

magnitude per square arcsecond

>28

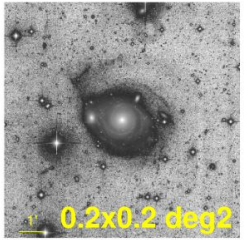


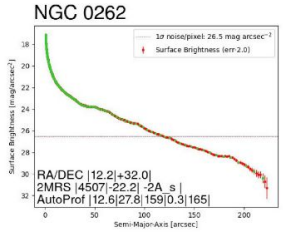


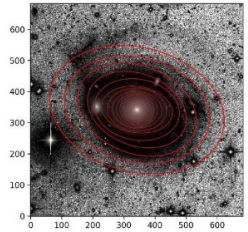
CFIS–r SGC = 335 square degrees

Direct detection regime (cirrus, streams: Sola et al. 2022), also enables large sky mosaics

>30



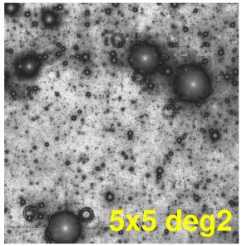


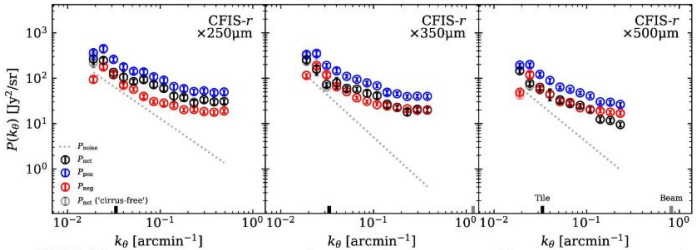


AutoProf : thousands of automated profiles

Radially integrated galactic profiles (Stone et al. 2021)

>32





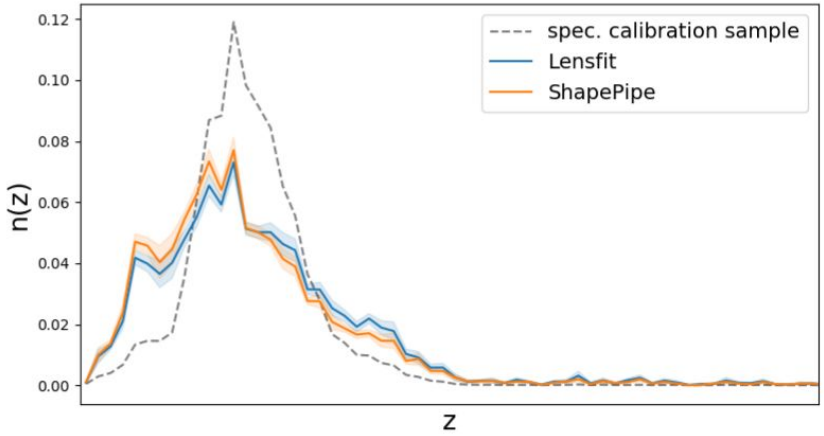
91 square degrees over 5 areas

Cross–correlation, e.g. CIB fluctuations correlated between the optical and submm bands (Lim et al. 2022)

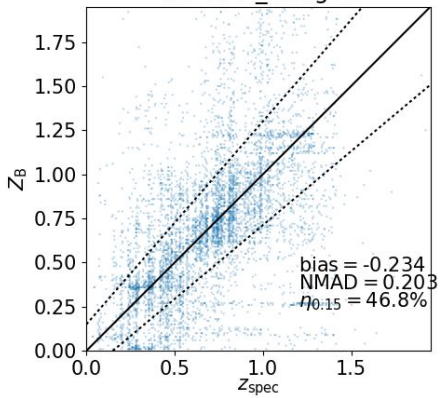
UNIONS redshift calibration

- Accurate redshift distribution is key to cosmological analyses: clustering redshift & photometric redshift
- UNIONS r-band n(z) can be robustly constrained with a SOM method for 2D cosmic shear analyses
- SOM (Self-Organizing Maps) match self-similar galaxies in magnitude/colour space based on a reference
- Turn to tomographic cosmic shear analyses once UNIONS offers large overlap between u,g,r,i,z (soon)

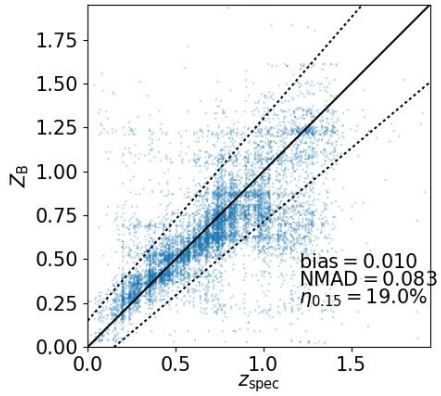
Over 3500 square degrees in r-band



UNIONS standard photometry on u,g,r,i,z stacks



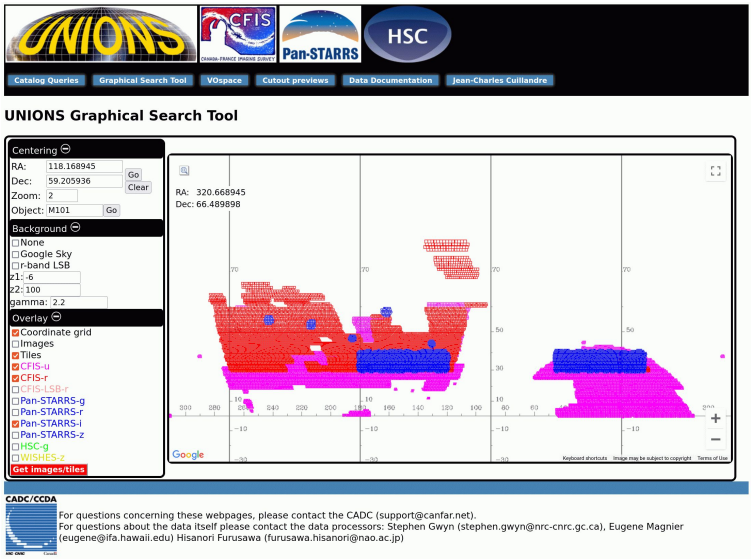
PSF-homogenised photometry on u,g,r,i stacks

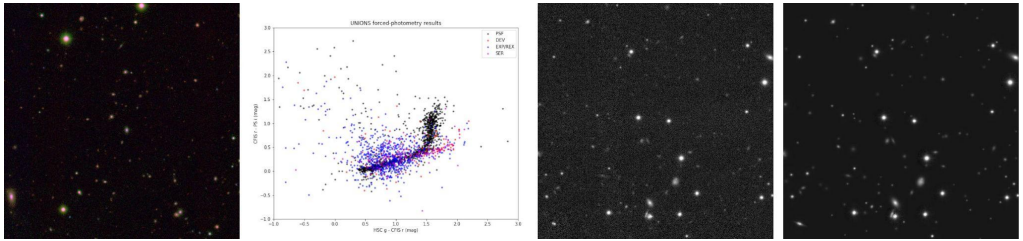


From the UNIONS Photo-z group: H. Hildebrandt, A. Wittje, A. Wright, J.-L. van den Busch et al.

Centralized data access at CADC in Canada (CANFAR)

Once access is granted through the collaboration, images and catalogs can be downloaded at the main data page accessible via the CADC: https://www.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/en/community/unions/csky.html





Left: Seeing and PSF mismatch between Pan-STARRS on Haleakala (in green) and CFHT and Subaru on Maunakea (blue and red) highlight the need for a forced photometry approach like Tractor or HSCpipe. Center left: Tractor color-color diagram of all fitted sources in a small sky area observed by the different telescopes, the stellar locus (black dots) is tight, pointing to a solid match of the various datasets. Right side: a CFIS-r image and the Tractor image of the PSF and galaxies models derived for each CFIS-r source.

- Image stacks and catalogs of point sources and distant (small) galaxies are the basis of our internal DRs

Refereed articles based on UNIONS

26. Bickley, R., et al., 2022, MNRAS, submitted, ”AGN in CNN-identified post mergers in the Ultraviolet Near-Infrared Optical Northern Survey (UNIONS)”
25. Smith, S., et al., 2022, ApJ, submitted, ”Discovery of a new Local Group galaxy candidate in UNIONS: Bootes V” ¨
24. Aycoberry, E., et al., 2022, ApJ, submitted, “UNIONS : impact of systematic errors on weak-lensing peak counts”
23. Robison, B., et al., 2022, ApJ, submitted, “The shape of dark matter haloes: results from weak lensing in the Ultraviolet Near-Infrared Optical Northern Survey (UNIONS)”
22. Lim, S., et al., 2022, MNRAS, submitted, “Constraints on galaxy formation from the cosmic-infrared-background /optical-imaging cross-correlation using Herschel and UNIONS”
21. Savary, E., et al . 2022, A&A, submitted, “A search for galaxy-scale strong gravitational lenses in UNIONS”
20. Chan, J. H. H., et al. 2022, A&A, submitted, “Discovery of Strongly Lensed Quasars in UNIONS”
19. Wilkinson, S., et al., 2022, MNRAS, 516, 4354, ”The merger fraction of post-starburst galaxies in UNIONS”
18. Ellison, S., et al., MNRAS, 517, L92, ”Galaxy mergers can rapidly shut down star formation”
17. Bickley, R., et al., 2022, MNRAS, 514, 3294, “Star formation characteristics of CNN-identified post-mergers in the Ultraviolet Near Infrared Optical Northern Survey (UNIONS)”
16. Farrens, S., et al., 2022, A&A, 664, A141, “A modular weak lensing processing and analysis pipeline”
15. Guinot, A., et al., 2022, A&A, 666, 162, “ShapePipe: a new shape measurement pipeline and weak-lensing application to UNIONS/CFIS data”
14. Sola, E., et al., 2022, A&A, 662, 124, “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 IllustrisTNG”
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., 2021, 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 Formed 17◦Long 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 itswhite dwarf population”
6. Thomas, G., 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., 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., 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 The Canada-France Imaging Survey: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”

Collaboration and Early Career Members

UNIONS has 202 collaborators from Canada, France, Hawaii, Japan and other nations.

- To date, 26 papers have been submitted, accepted or published using UNIONS data
- The majority of these have used only 1 band of UNIONS data
- The first multi-band papers are being written now - expect a big increase in publication rate now that the overlap areas are larger
- 22 of these papers are led by students or postdocs

There have been 25 students and 7 postdocs working on UNIONS science, including 8 undergraduates.

- 6 students have already completed their graduate theses based on UNIONS data
- Another 11 theses are ongoing
- Again, most of these theses were enabled using data from only one band

The promise of a multi-band, completed, UNIONS as a training platform in wide field optical astronomy for the upcoming generation of Canadian, French, Hawaiian and Japanese astronomers is tremendously exciting.

Reasons to join UNIONS today

What is unique to UNIONS:

- DES offers 5000 square degrees in g,r,i,z at similar depths but until LSST-Y2, UNIONS z will be the deepest wide survey: +0.4 mag vs DES, and UNIONS has u-band
- Median image quality of UNIONS is u=0.9”, g=0.8”, r=0.7”, i=1.0”, z=0.8” (DES is 0.9” at best)
- UNIONS overlaps, unlike DES, thousands of square degrees of SDSS/BOSS spectroscopy, and now DESI
- A weak lensing catalog over 2000 deg^2 of the CFHT r (median IQ=0.65”) is now available in the UNIONS
- CFIS delivers data to explore the low surface brightness Universe (~28th mag/sq. arcsec in the r-band)
- Dataset is fully proprietary until August 2023 for CFHT u&r, but just the basic CFHT frames, a far cry from the rich collection of UNIONS advanced products (that will be offered later on through public releases)

Why joining UNIONS:

- UNIONS will be the deep optical survey of the northern sky throughout the 2020s and beyond (synergies)
- UNIONS allows you to gear up to the Rubin LSST & Euclid datasets by testing your ideas and algorithms

How to join UNIONS

Who can join and how:

- For France: any scientist (grad students to permanent staff) based in a French research lab
- Contact the UNIONS Steering Group (unions-sg@cfht.hawaii.edu) to describe your science program and state that you read and endorse the UNIONS internal rules (https://www.skysurvey.cc/collaboration/)
- Once integrated in the collaboration (mailing list, etc.) you can consult all on-going science activities on the UNIONS “Who Does What” internal wiki page and add your own science project or seek collaborations
- 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

The UNIONS Steering Group is committed to help you realize your science:

- Canada & France : Jean-Charles Cuillandre (co-PI France), Alan McConnachie (co-PI Canada), Mike Hudson (science lead Lensing), Rodrigo Ibata (science lead Galaxy), Stephen Gwyn (data management lead), and Michael Balogh, Ray Carlberg, Raphael Gavazzi, Vanessa Hill, Yannick Mellier
- Pan-STARRS (IfA-UH) : Ken Chambers (Director), Eugene Magnier, Richard Wainscoat
- Japan : Masamune Oguri (PI), Hisanori Furusawa, Satoshi Miyazaki

The Ultraviolet Near-Infrared Optical Northern Survey

UNIONS

- 202 scientific collaborators (mostly Canada, France, Hawaii, Japan), and growing
- The UNIONS ambitious science is now shifting into high gear
- Full completion of UNIONS is a top priority in Canada (LRP 2020) and France (Prospective 2019)
- Follow the UNIONS scientific activities at www.skysurvey.cc