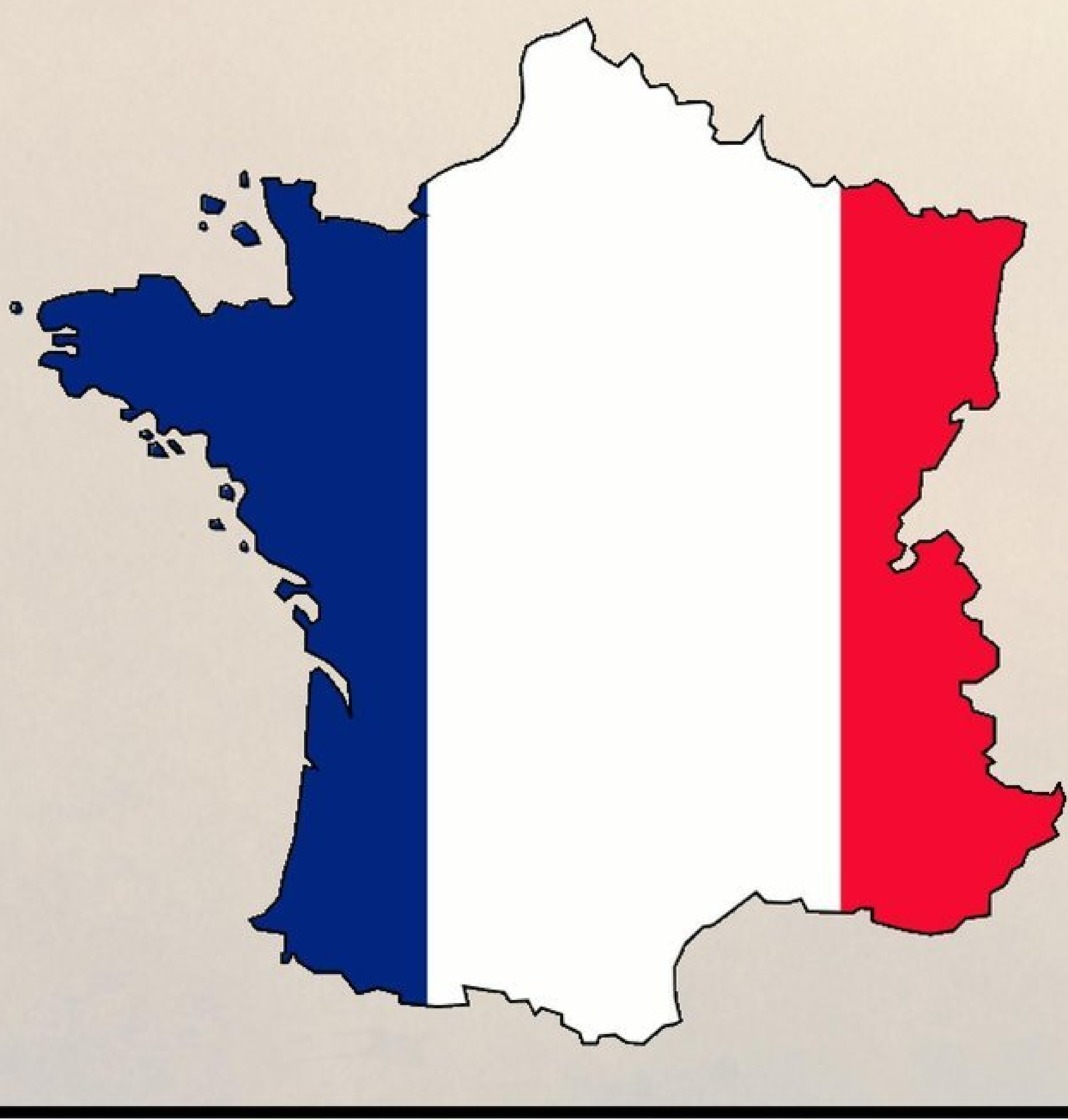
Canada–France Imaging Survey
Observing Status

Jean–Charles Cuillandre *CEA Saclay/Obs. de Paris*
on behalf of the UNIONS CFIS/Pan–STARRS collaboration

CFHT Users' Meeting, May 21–23, Montréal, Canada

The Canada–France Imaging Survey in a nutshell

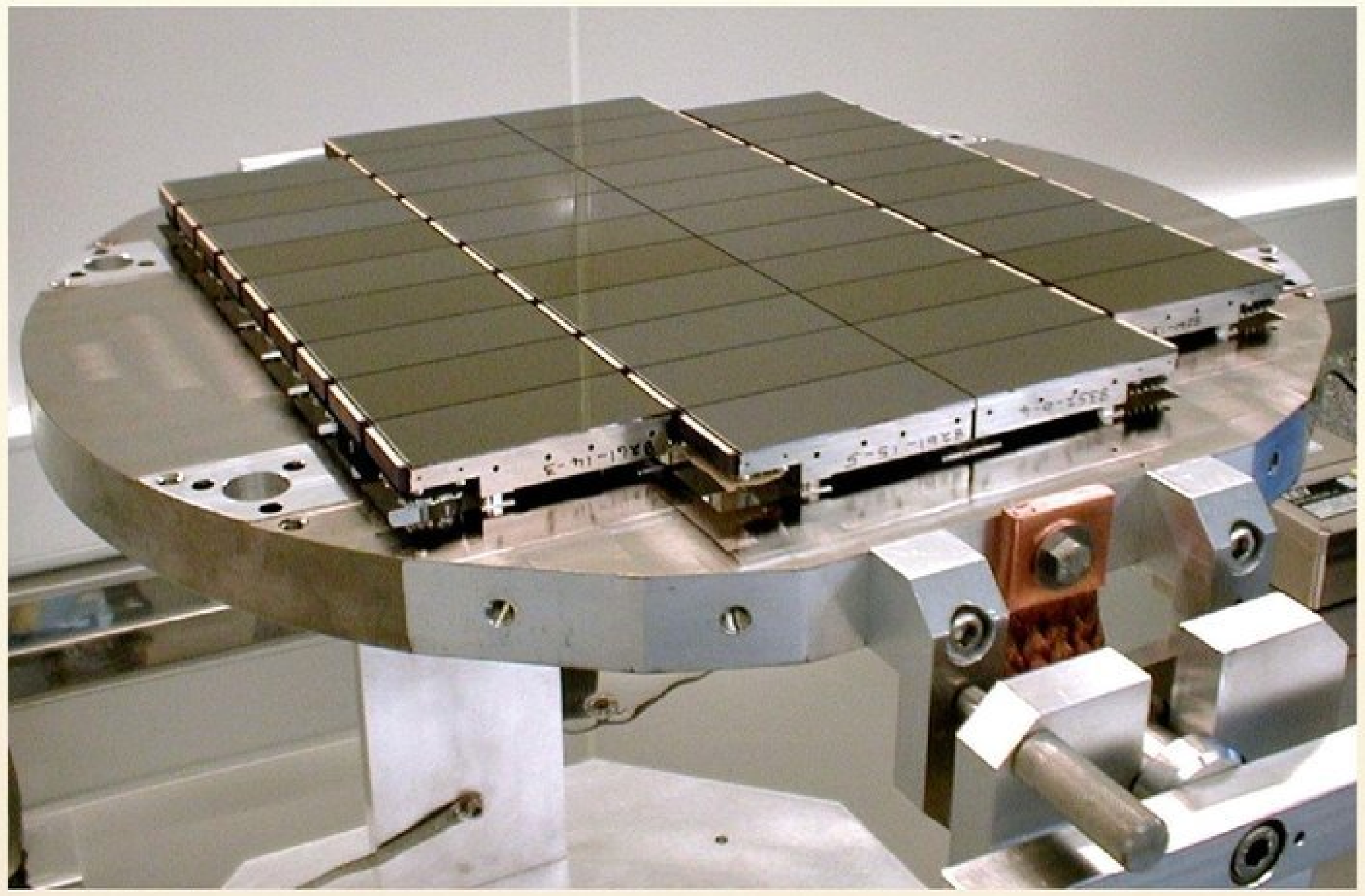
- UNIONS CFIS/Pan–STARRS : 140 scientists ~ 80 France + 40 Canada + 10 Hawaii + 10 International
- CFIS : 271 CFHT–MegaCam nights allocated from Feb. 2017 to Jul. 2021
- A survey serving science from the solar system, the galaxy, nearby universe, and cosmology
- An "all–sky" type survey built on CFHT's greatest strengths (u–band, r–band image quality, FOV)
- A legacy dataset open to all interested scientists in Canada and France
- A collaboration welcoming all interested scientists in France and Canada (pending a few rules)
- A complete logistic support from CADC/CANFAR for data calibration, hosting, and distribution
- The result in France of a large consultation followed by a top ranking at the latest INSU prospective
- A critical component of the Euclid space mission (photometric redshifts)

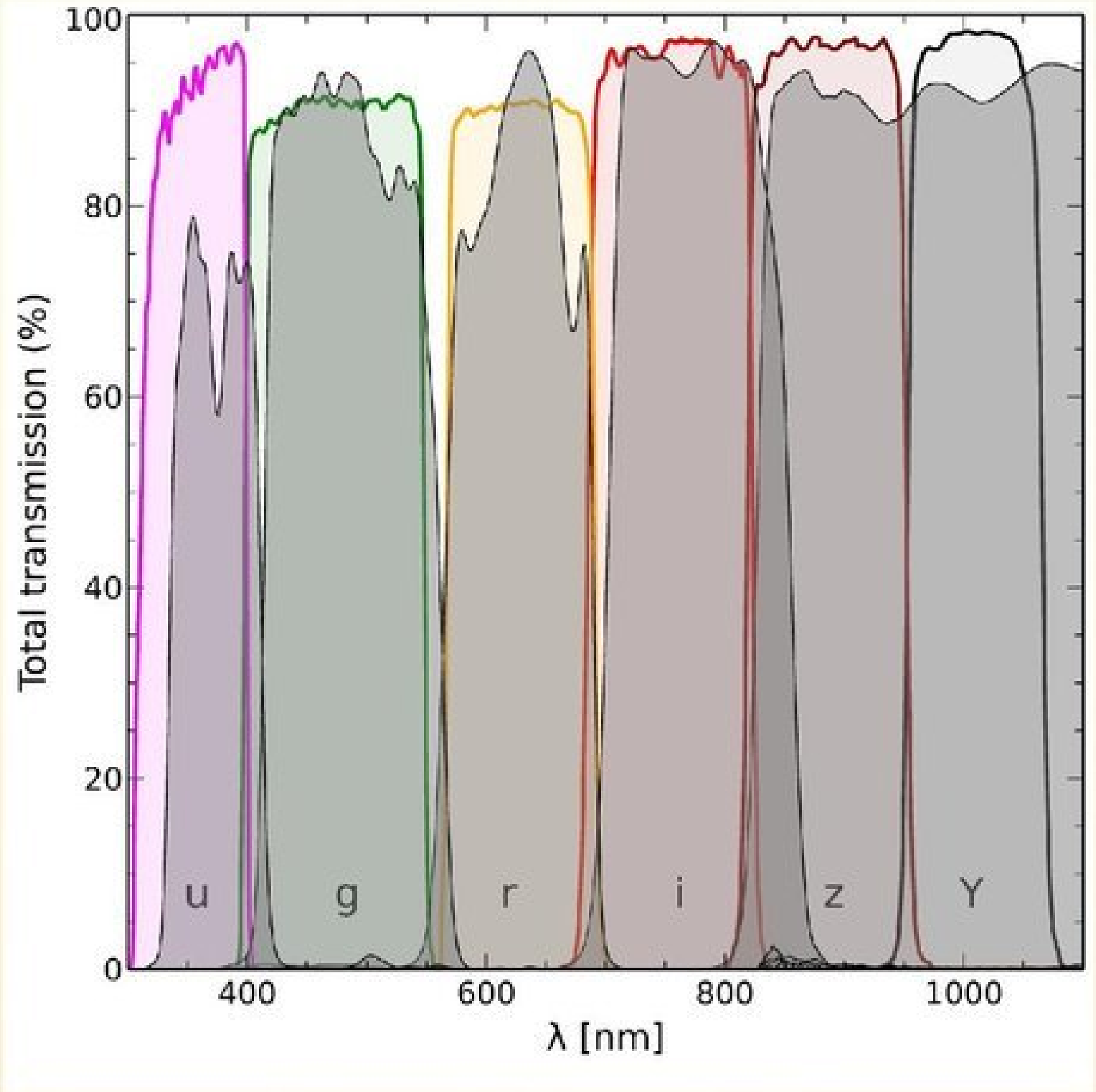


The best wide−field imaging ever on the CFHT

Telescope & instrumental improvements (2011−2014):


Dome venting

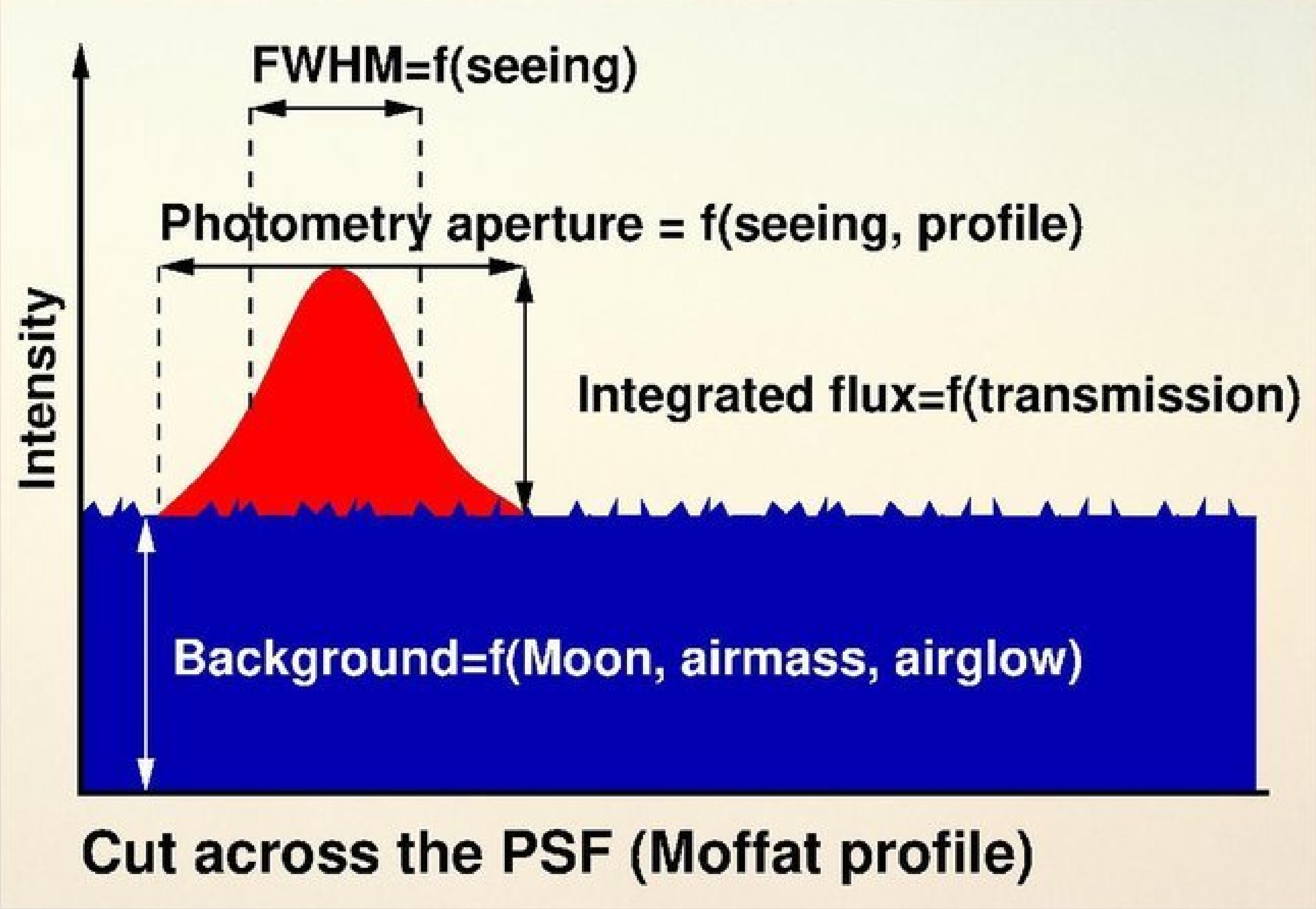

40 CCDs + Fast readout



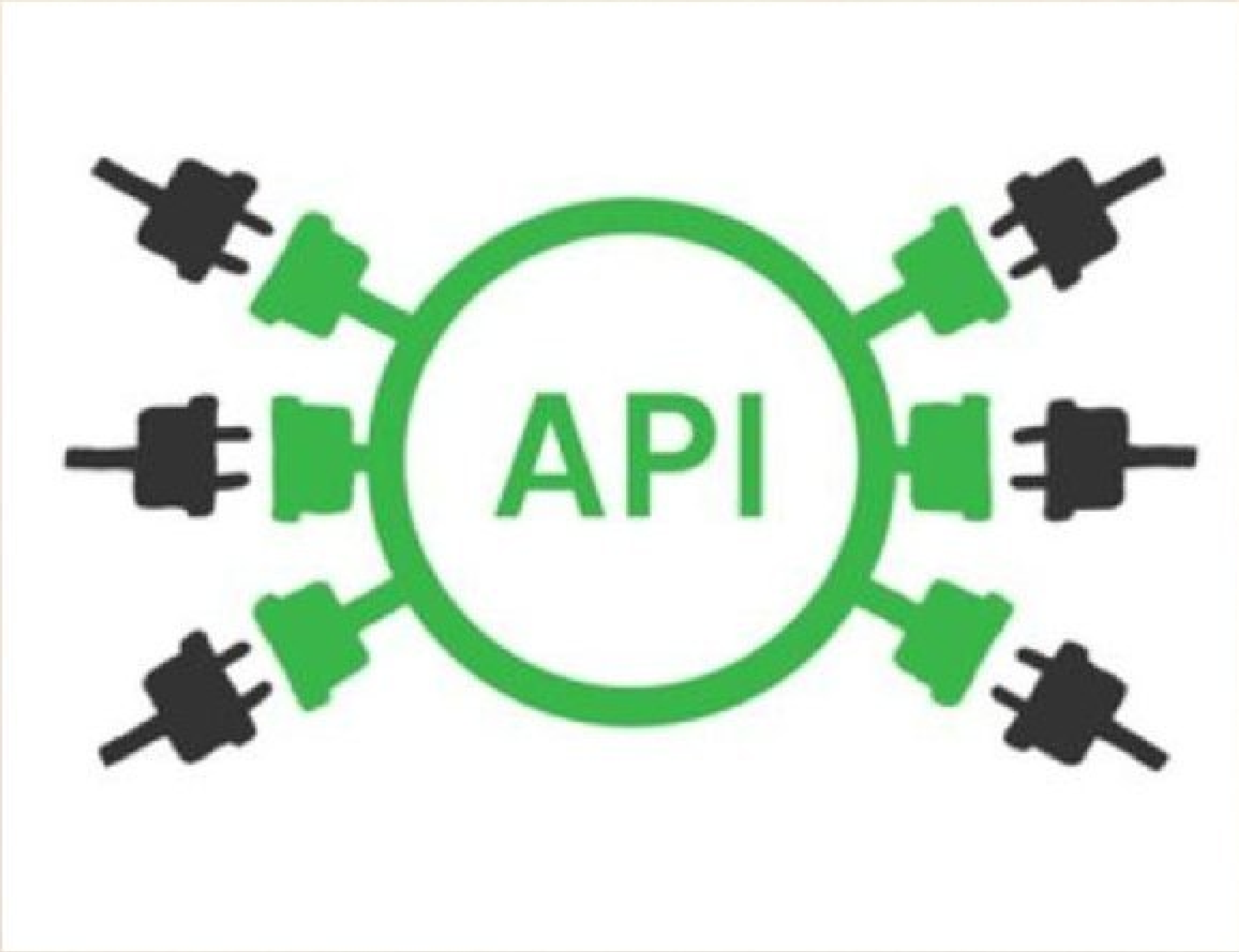
New "square" filters

Data acquisition & processing optimization (2008−2016):


Low Surface Brightness



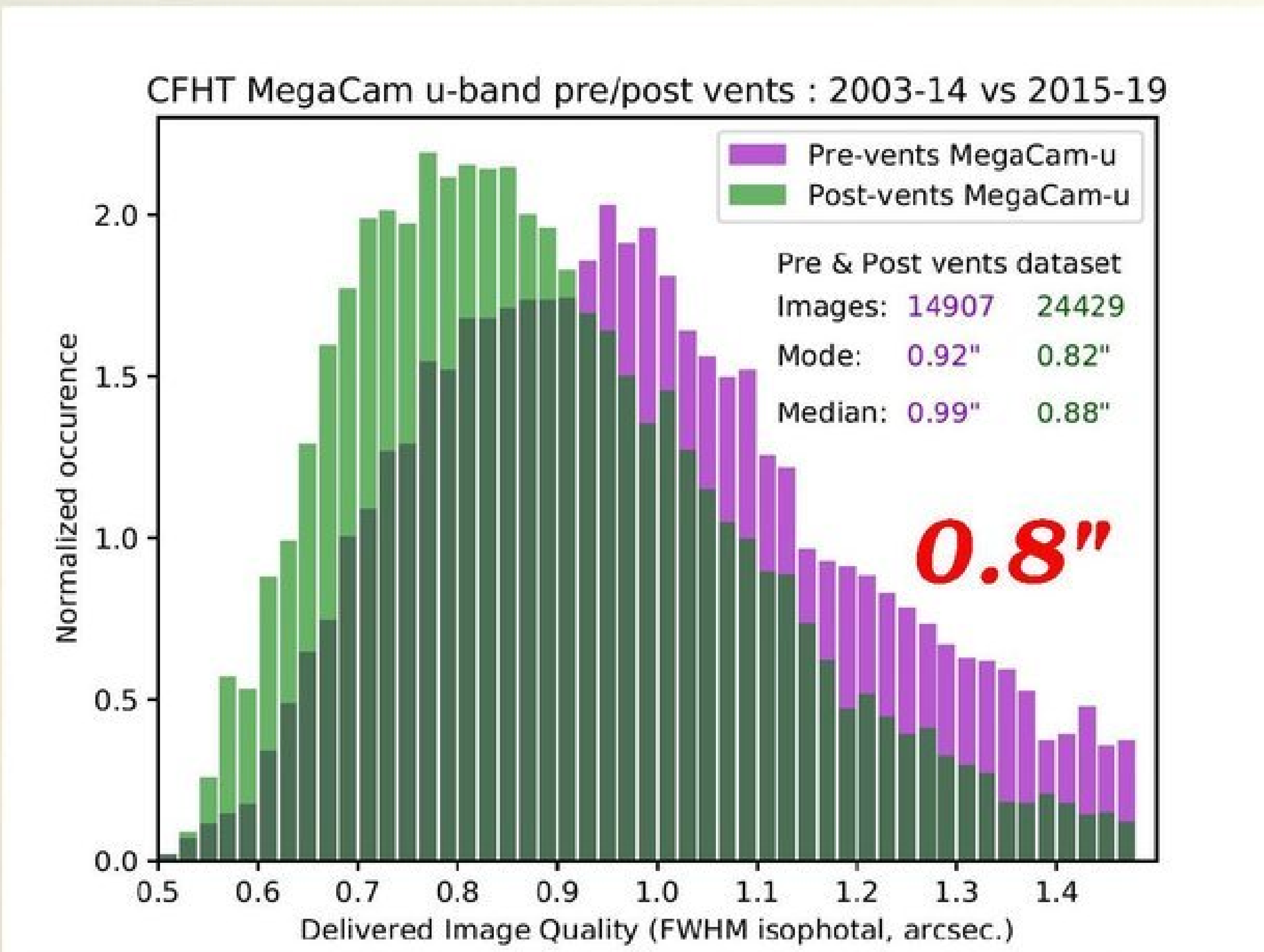
Dynamic integration



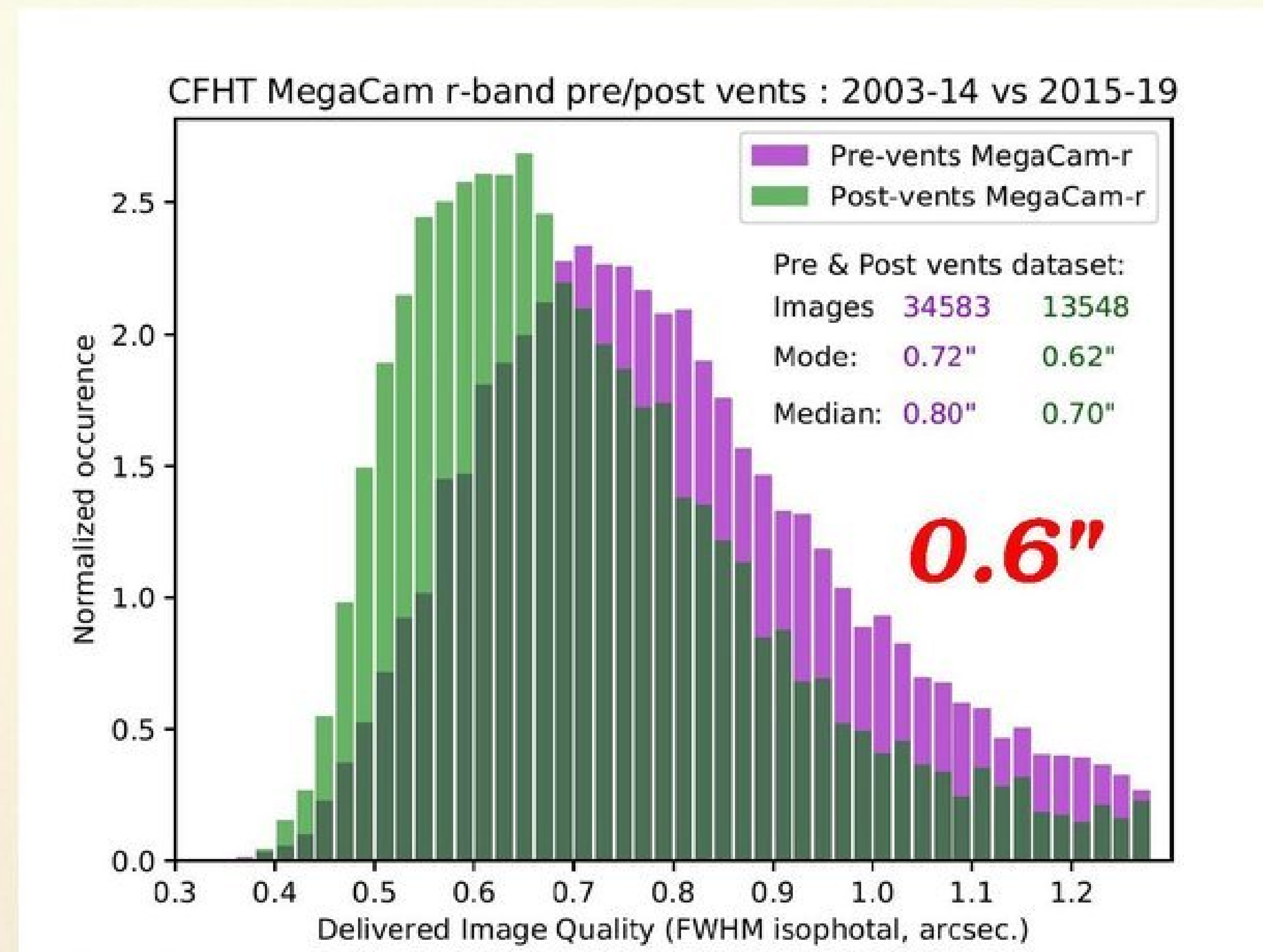
QSO PH2 API

CFIS is focused on CFHT's excellence

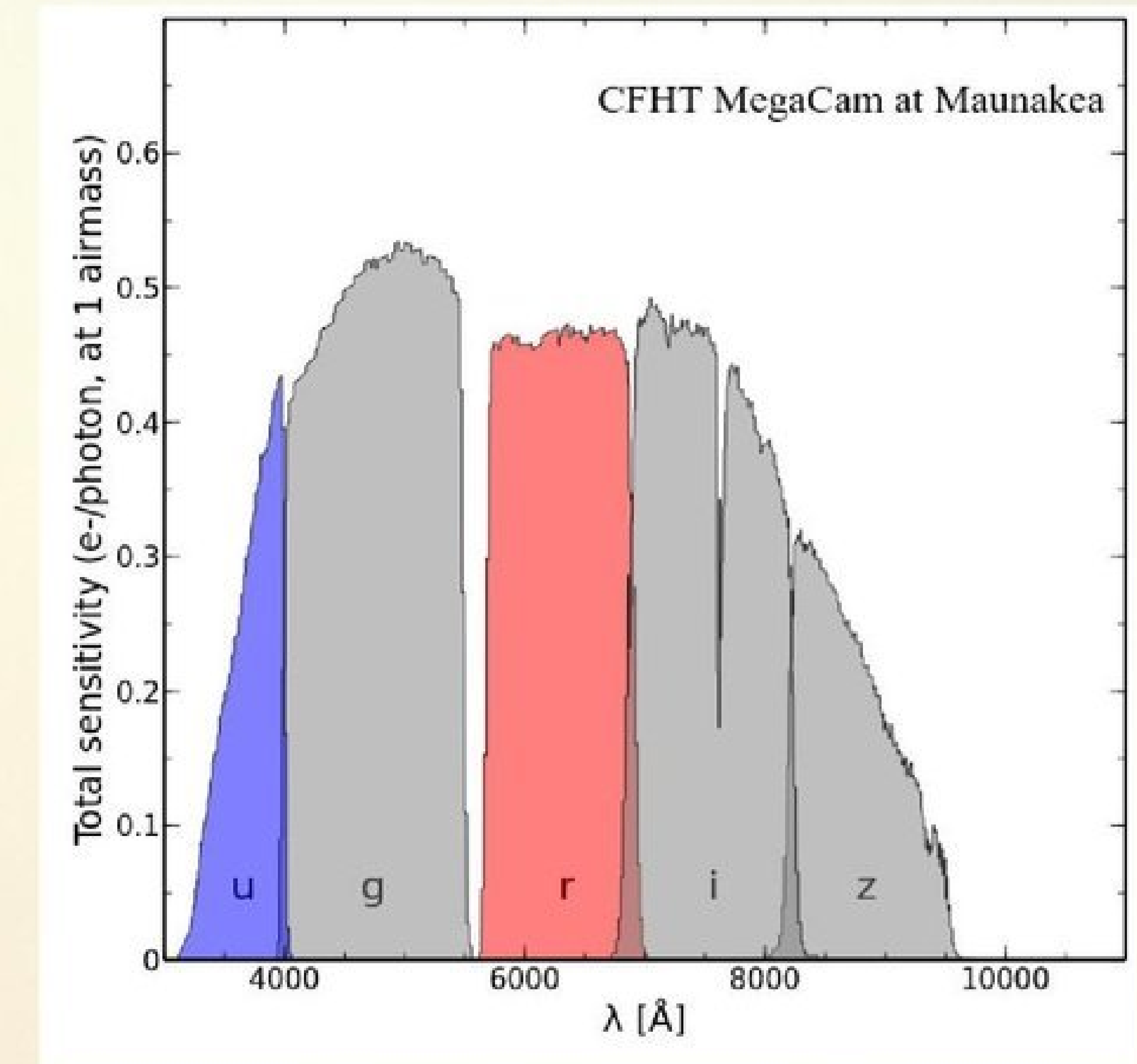
Best u−band sensitivity and image quality in the world over a wide field



Dome venting: 0.1" gain in u

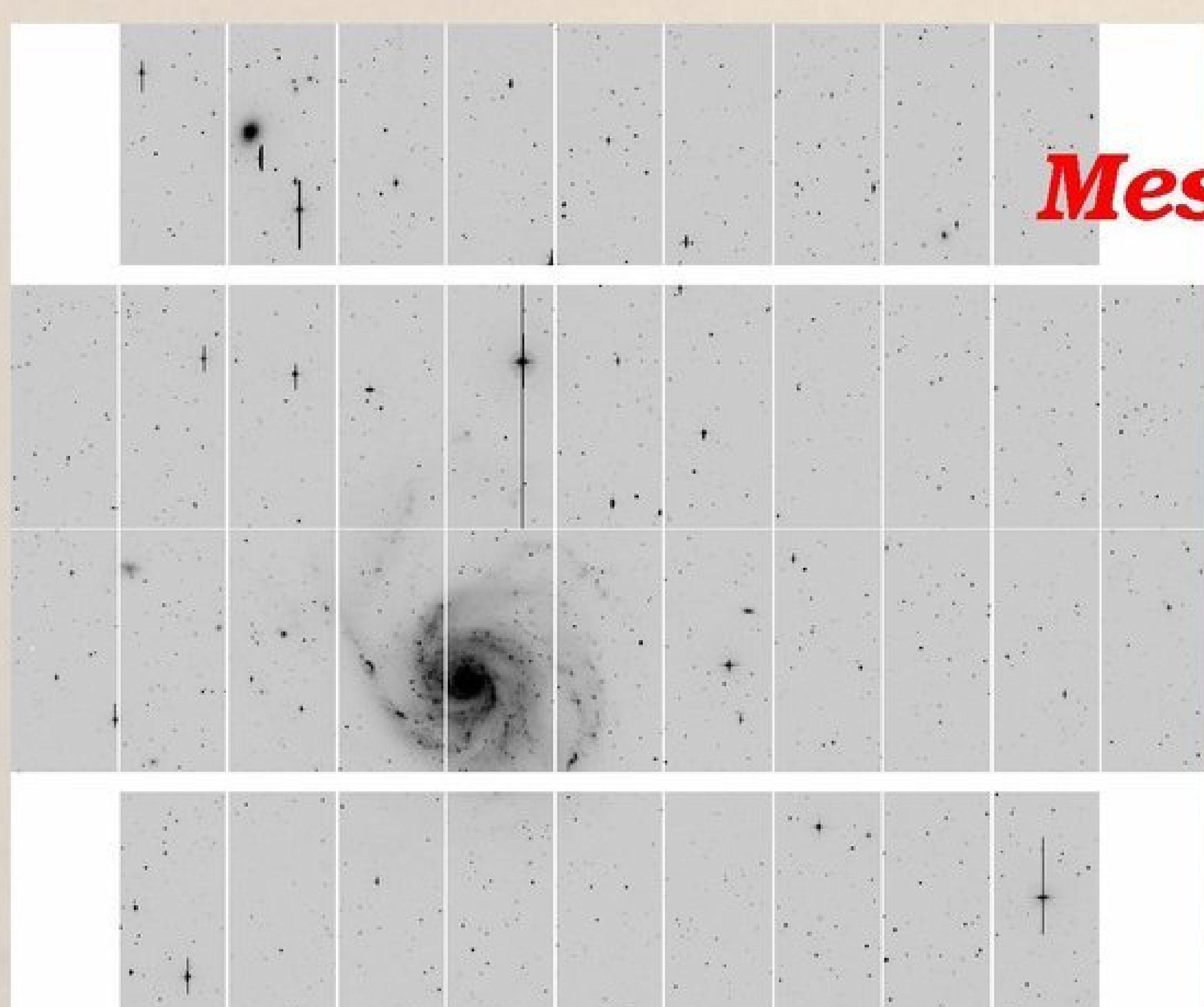


Dome venting: 0.1" gain in r

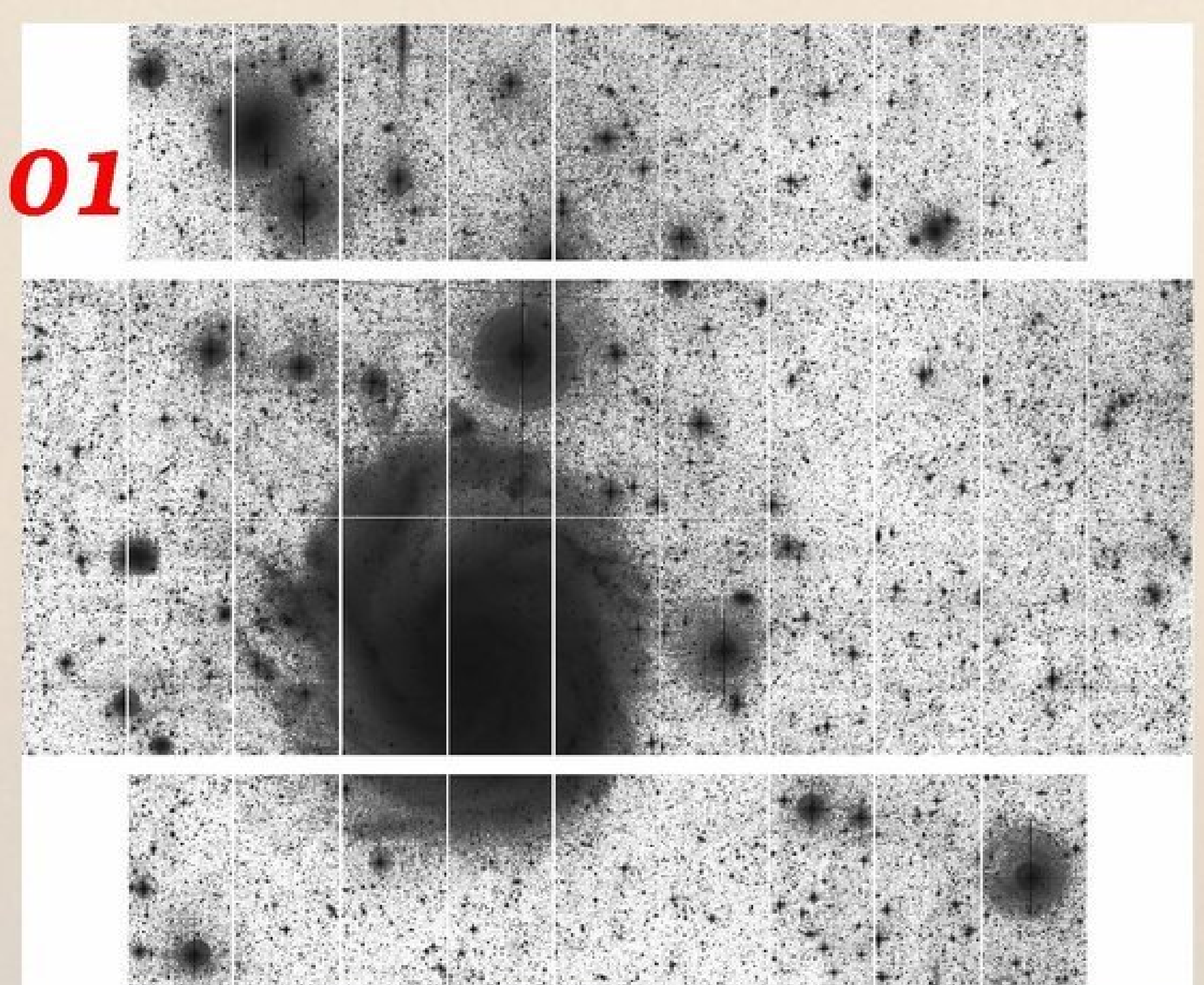


High throughput

CFIS observing strategy optimized for point source and LSB science



Messier 101

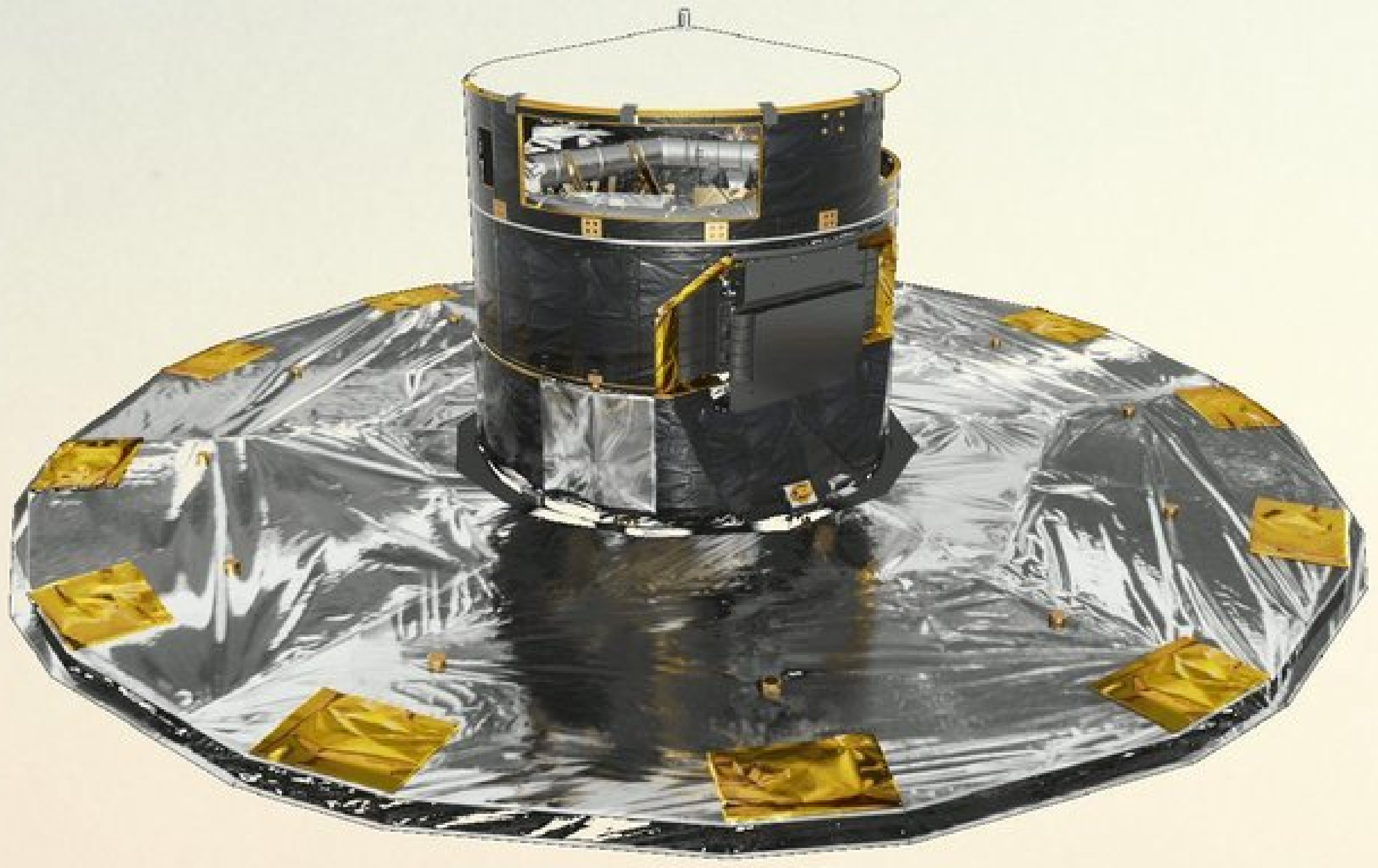


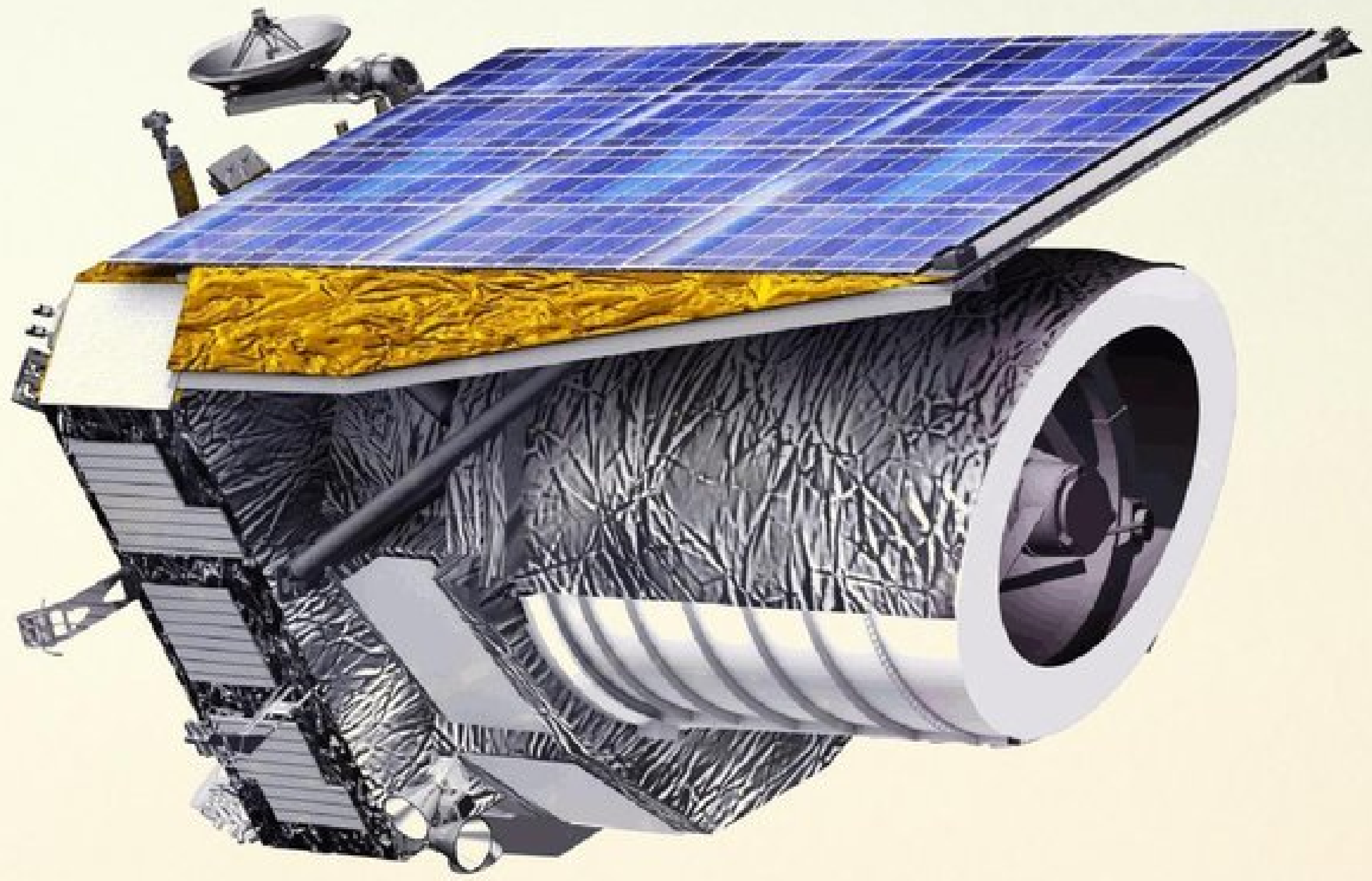
Large FOV: 1.1 deg. square

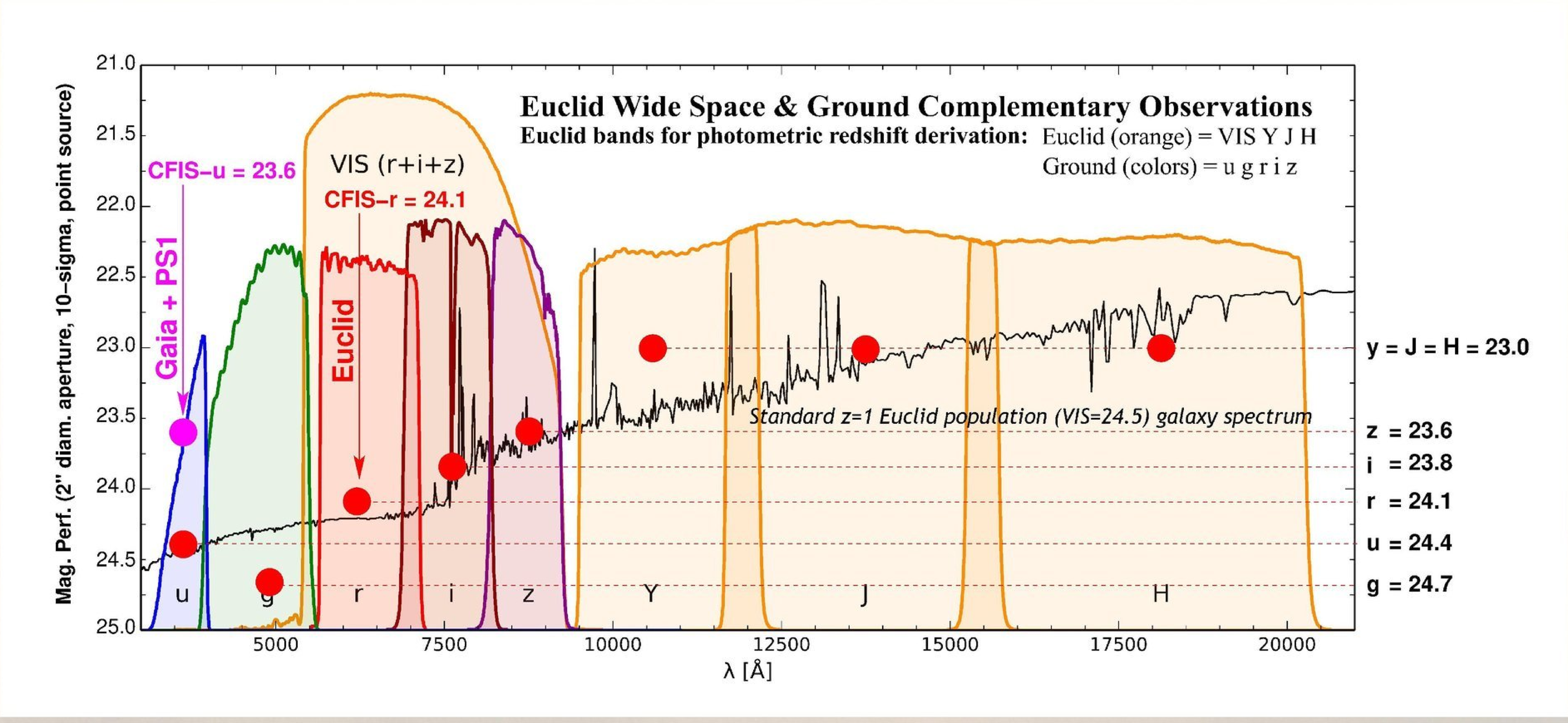
Elixir−LSB

+ Fast readout
+ Dynamic integration
+ QSO PH2 API

CFIS depths are driven by two ESA space missions

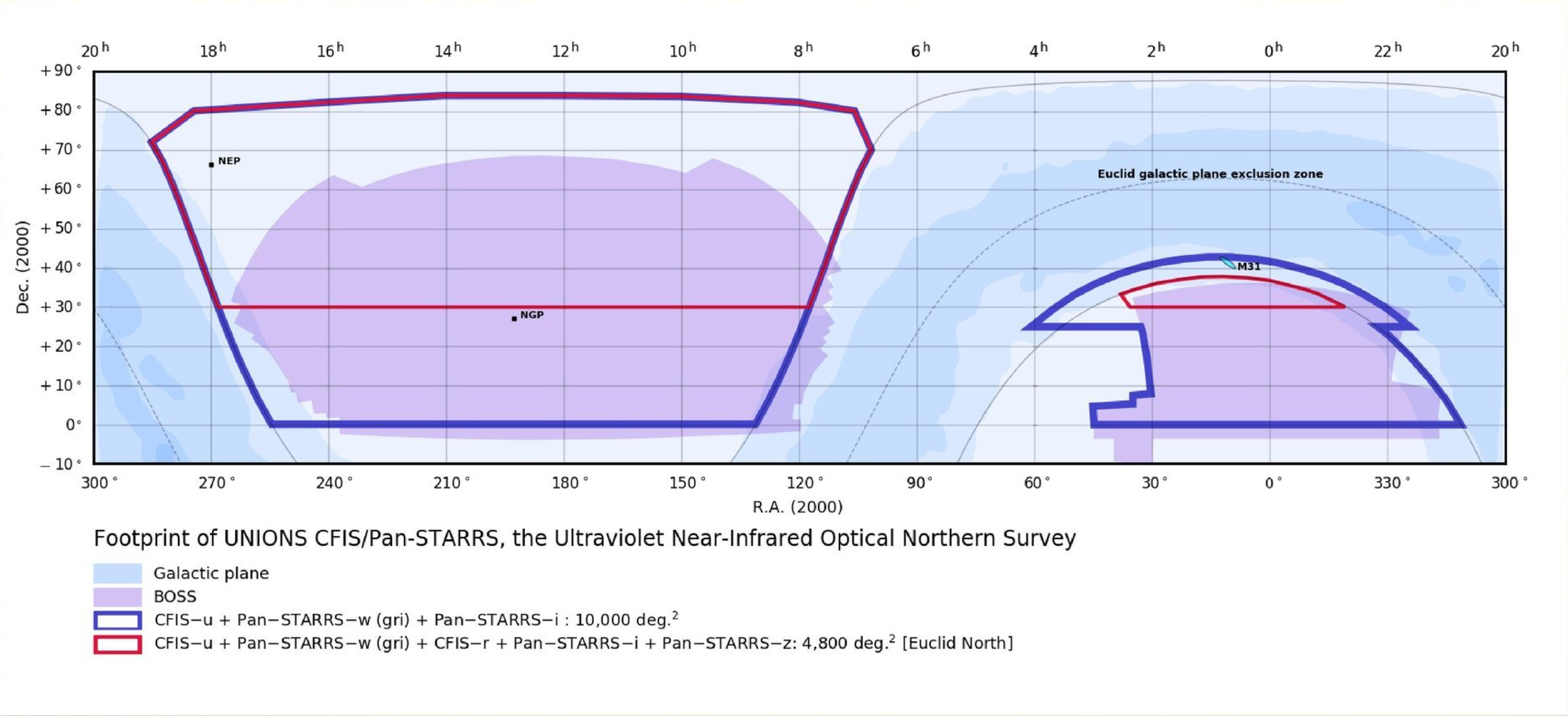






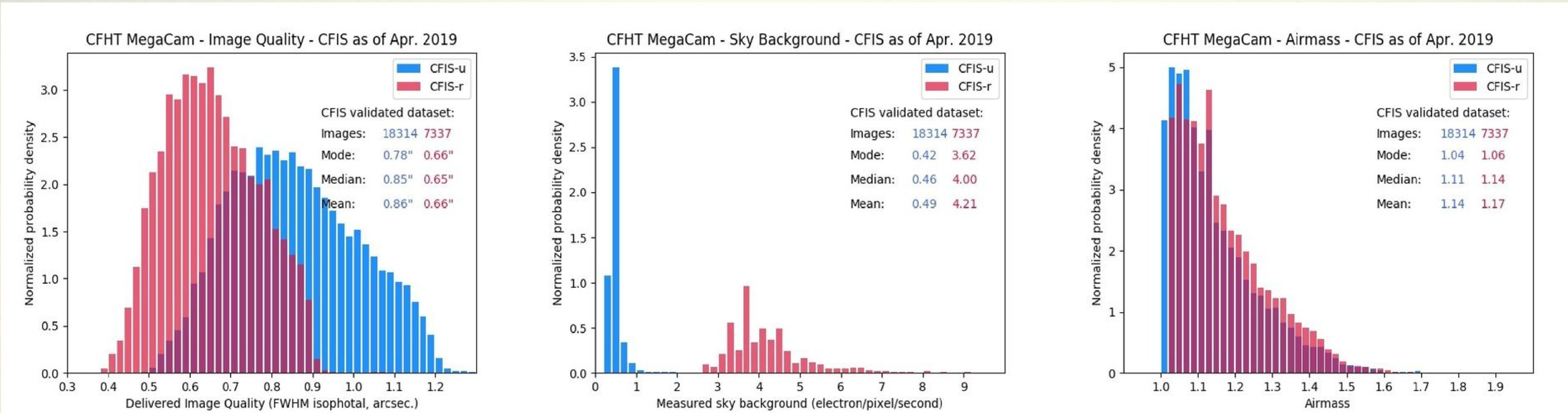
CFIS−u depth is driven by Gaia & Pan−STARRS (PS1), CFIS−r depth set by Euclid photo−z

CFIS sky coverage : the northern sky

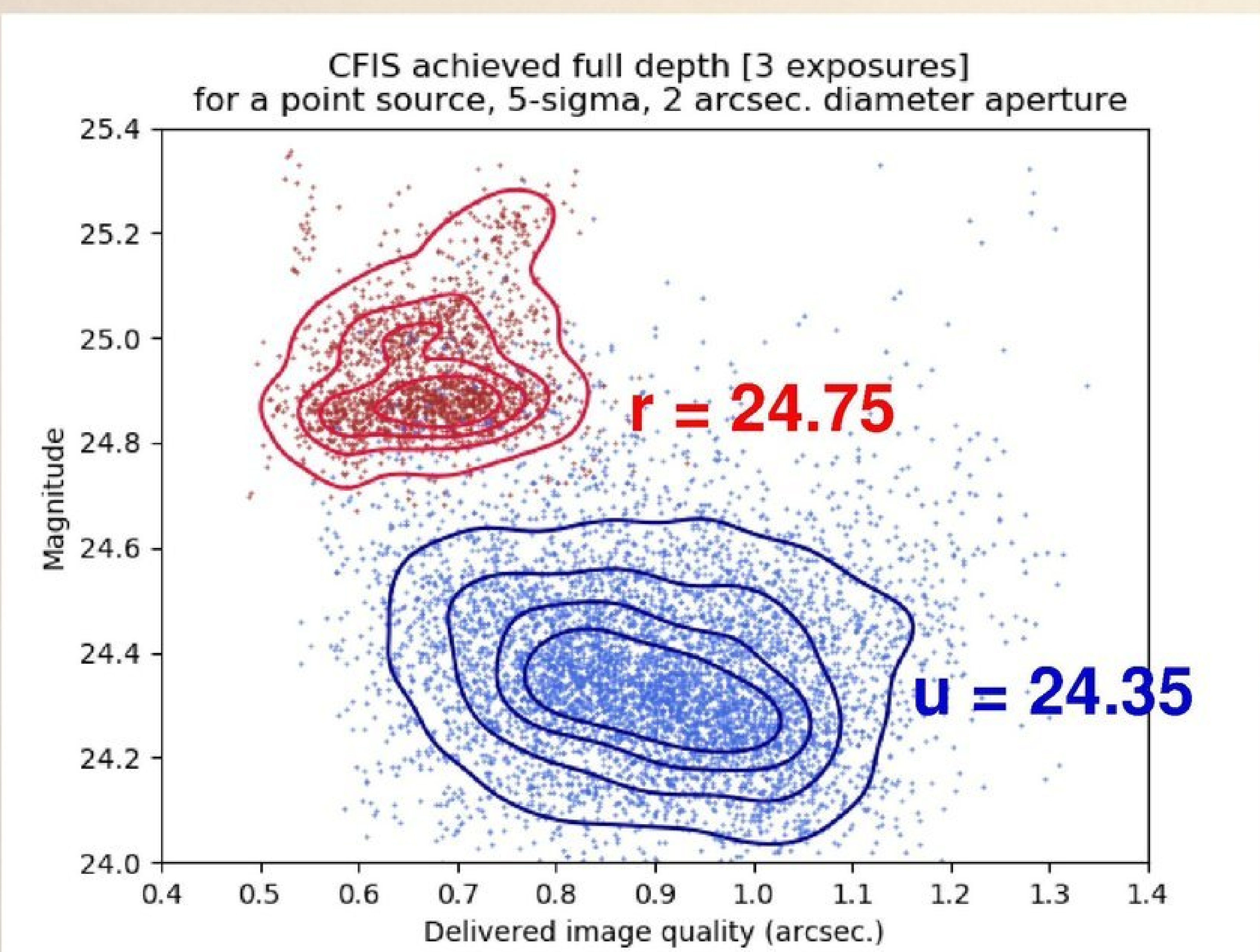


CFIS−r : priority goes to the BOSS area (CFIS core science)

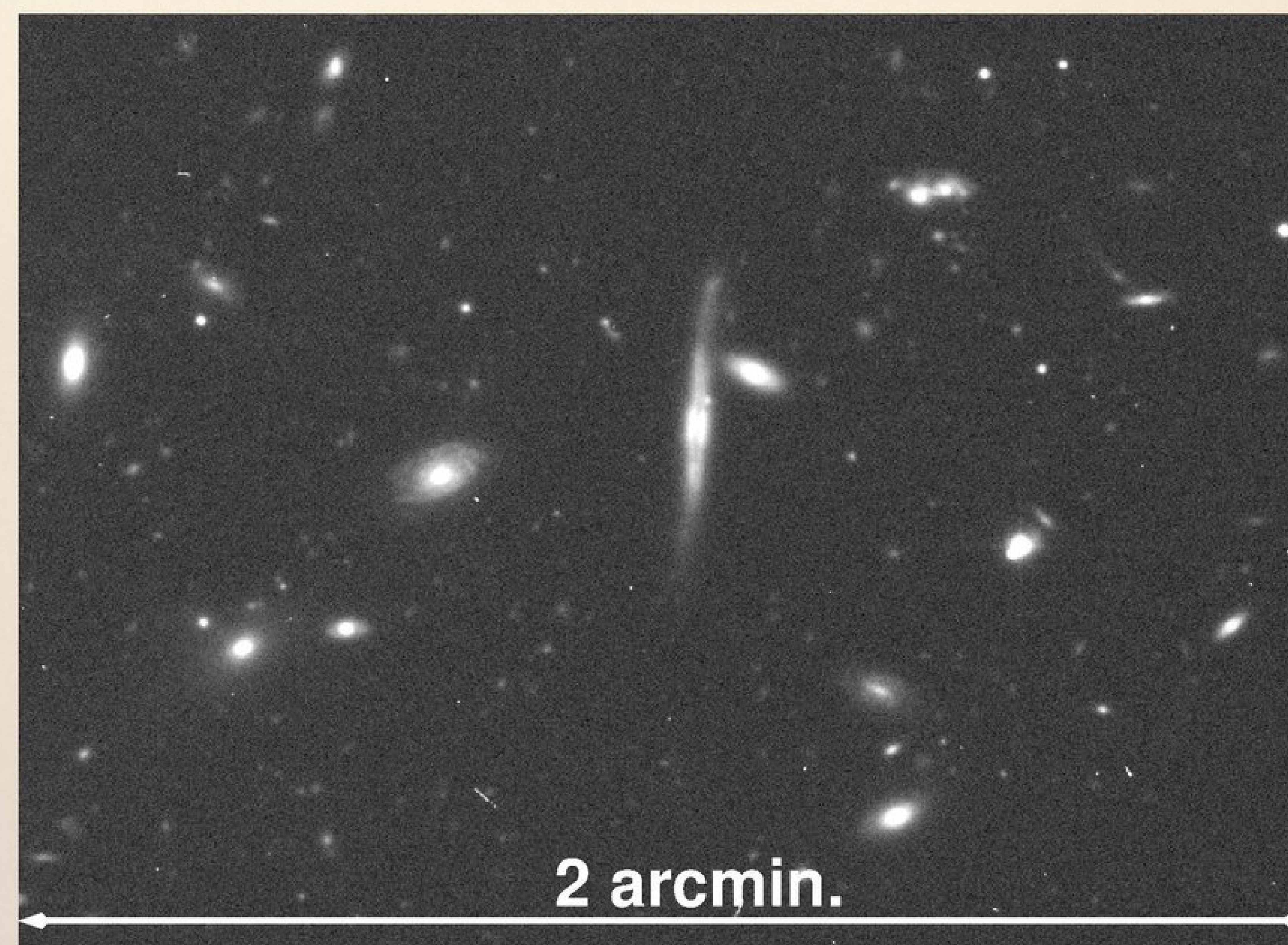
CFIS dataset properties



A high quality dataset

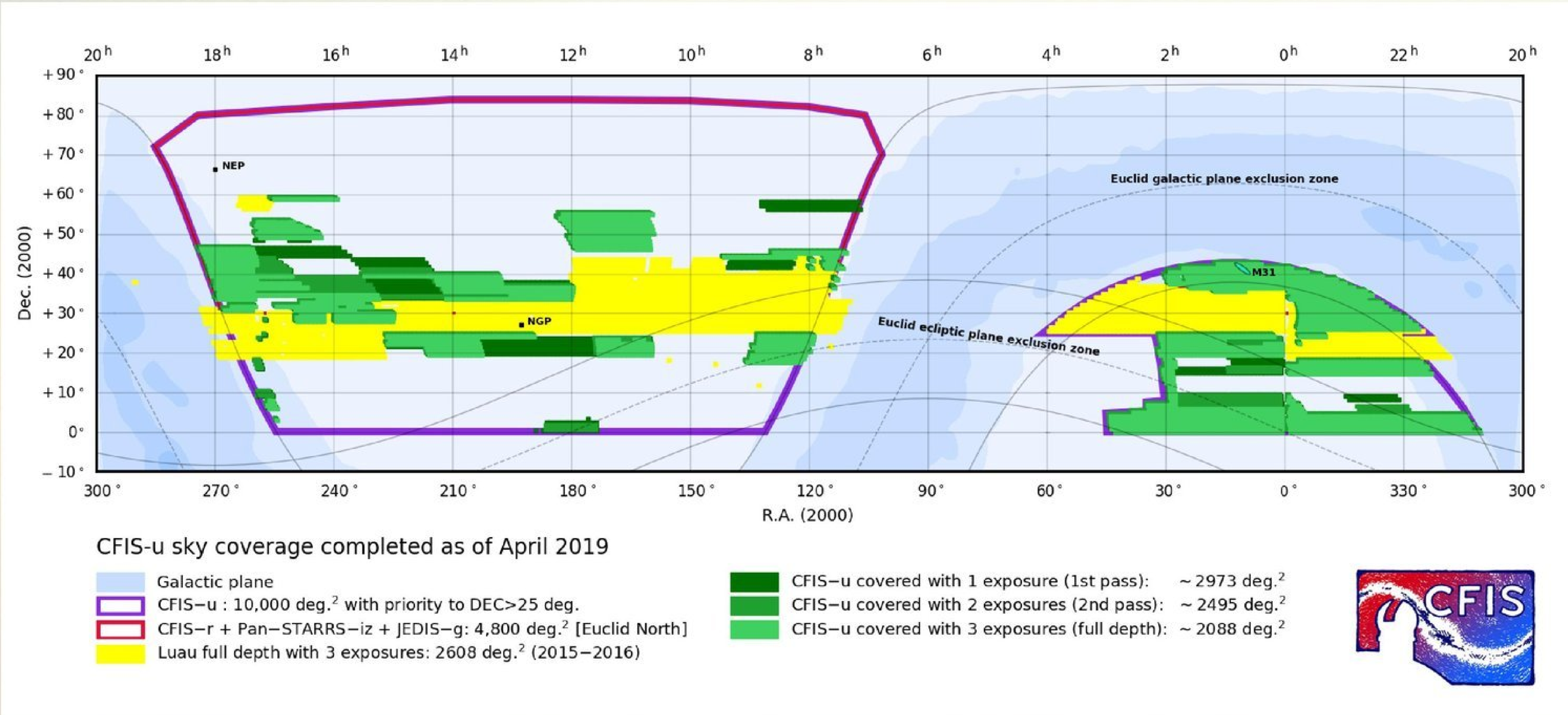


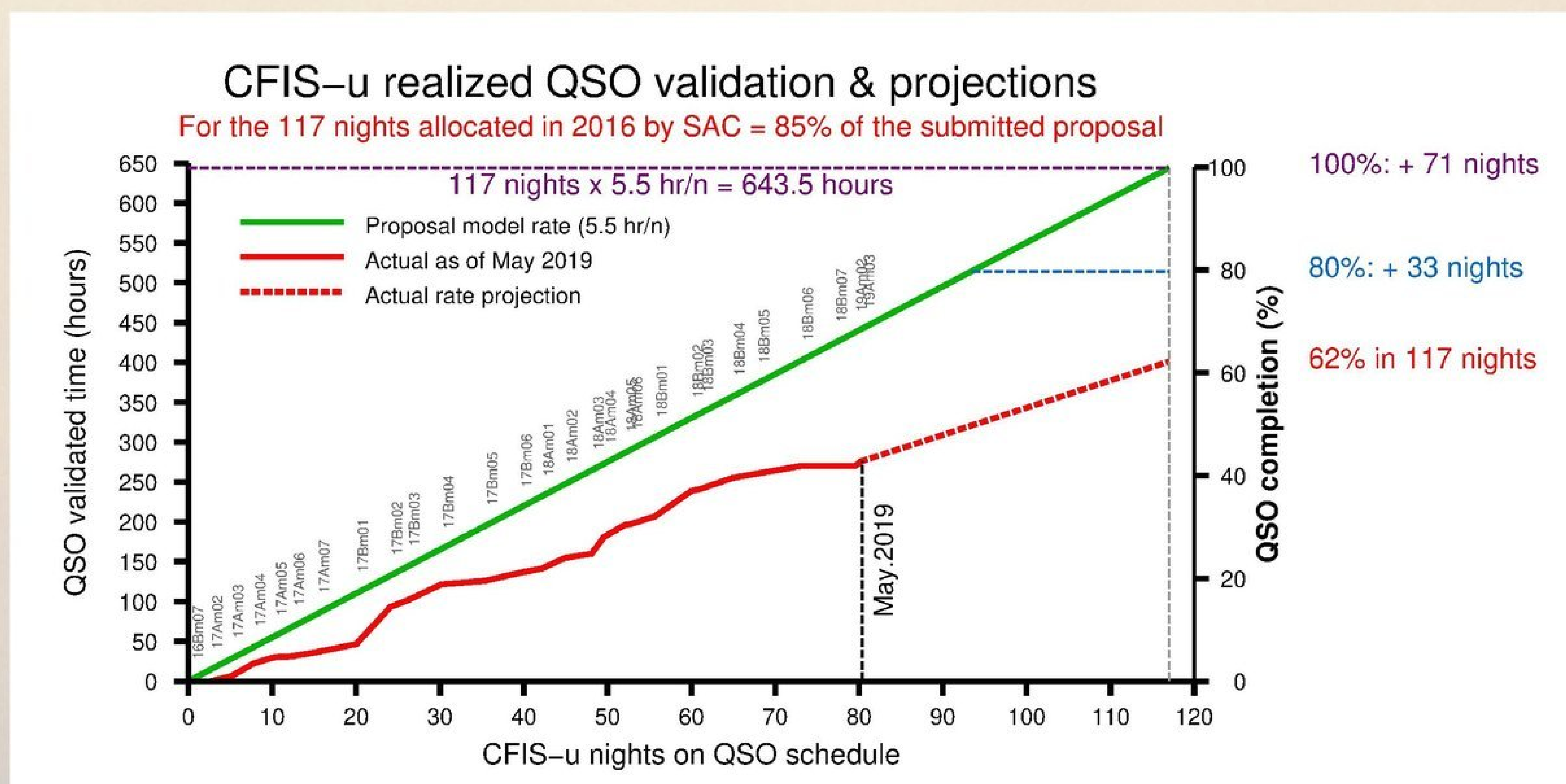
Planned depths achieved (MegaPipe stacks)



Crop of a single frame (r–band, 0.51")

CFIS–u progress and completion forecast





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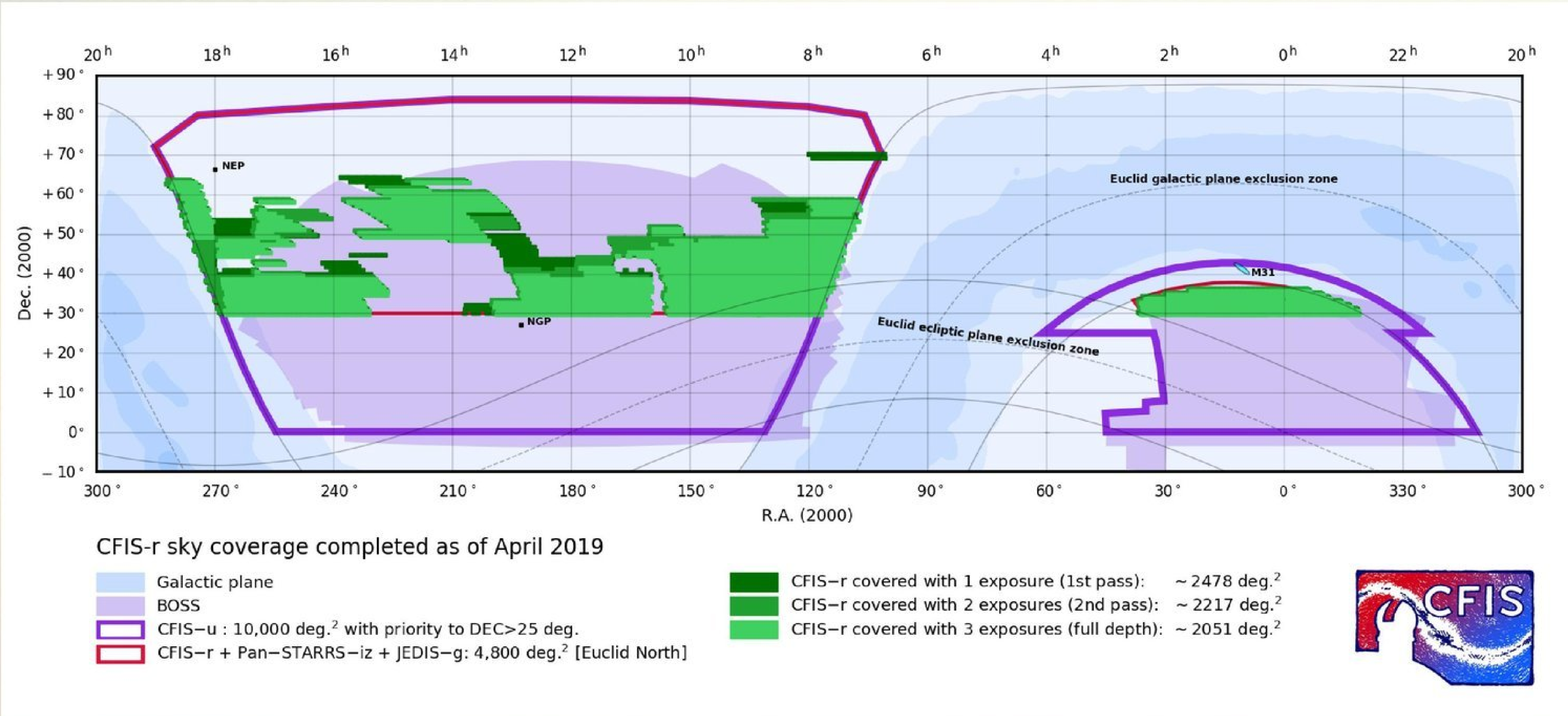
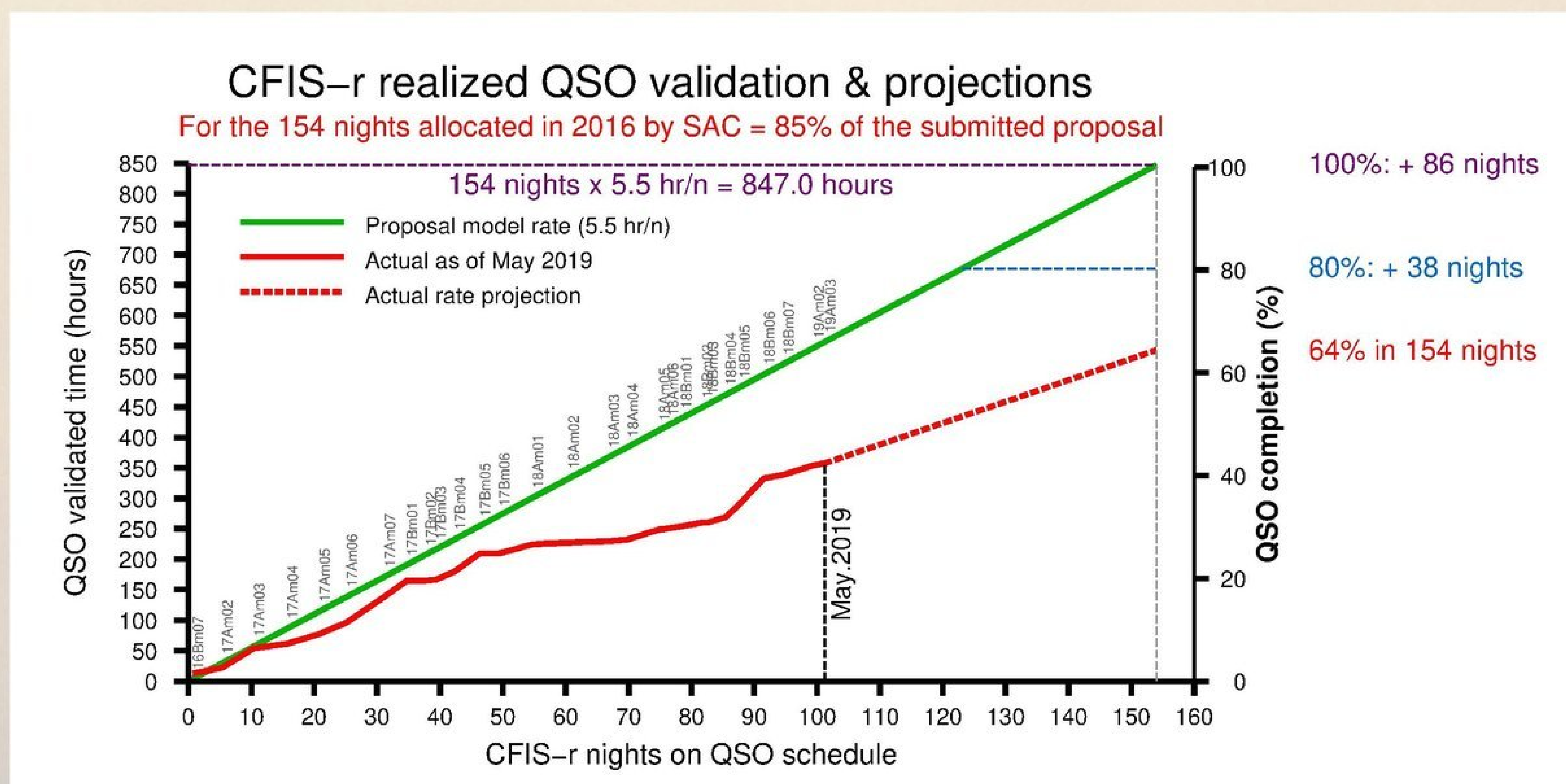
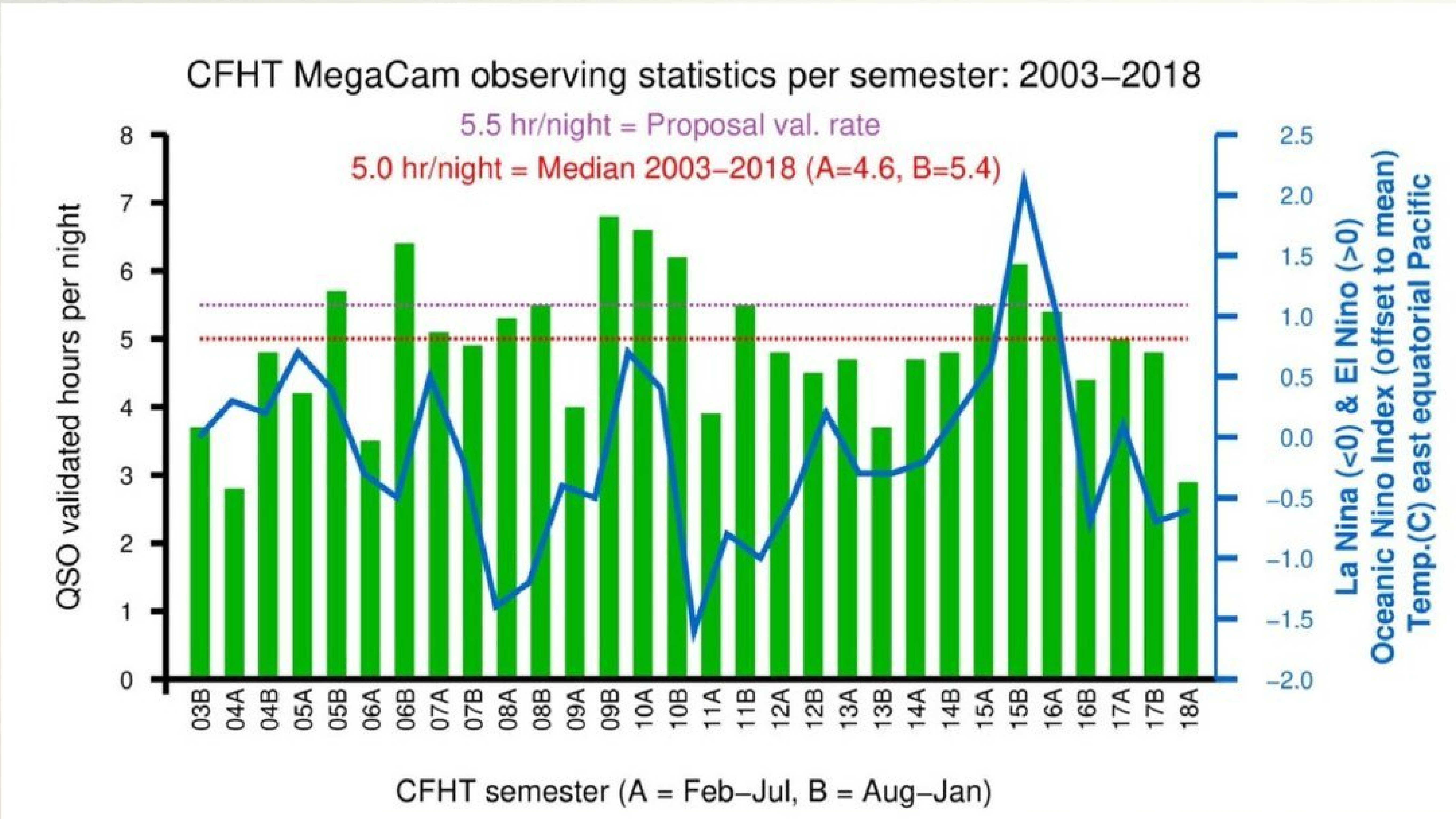
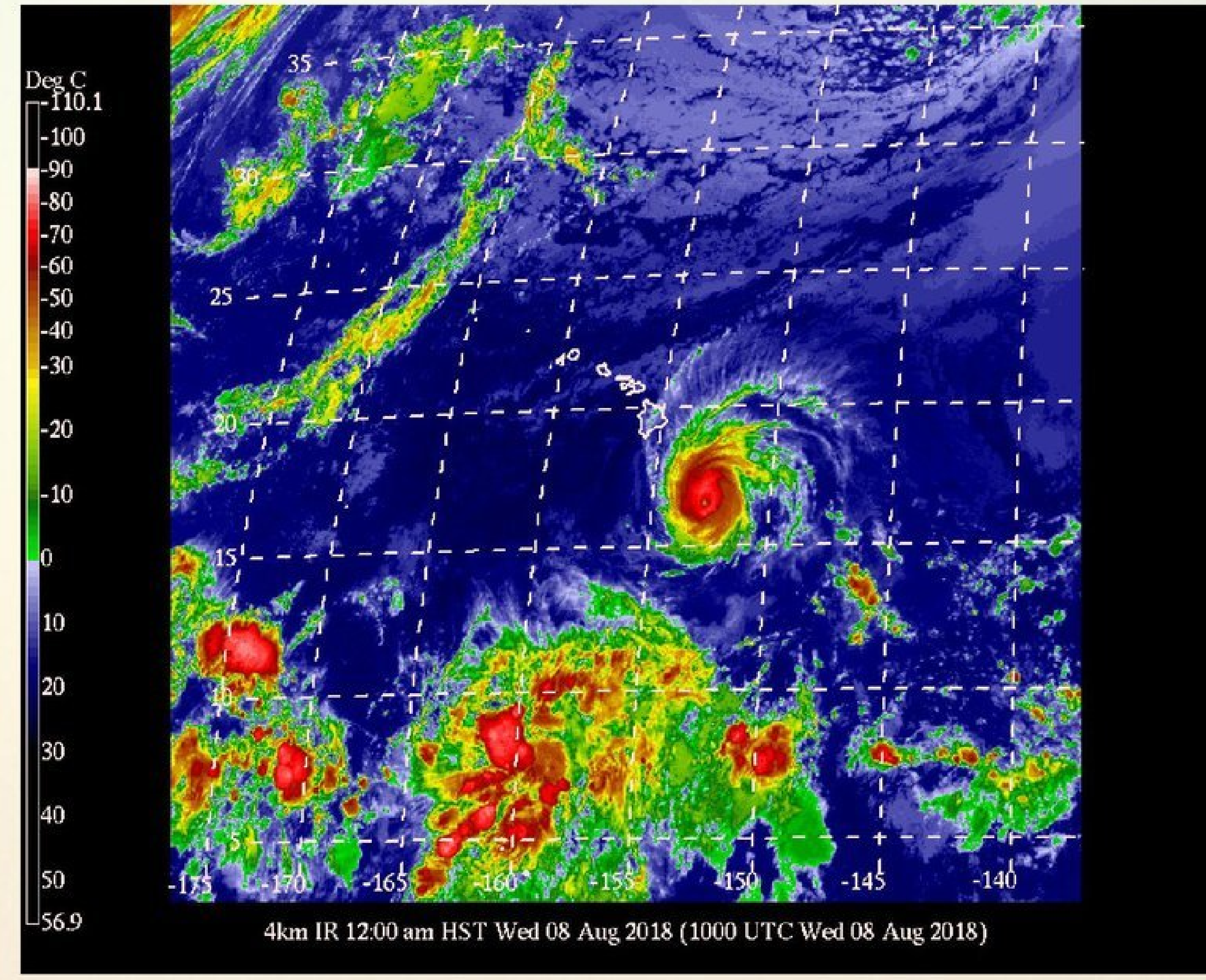




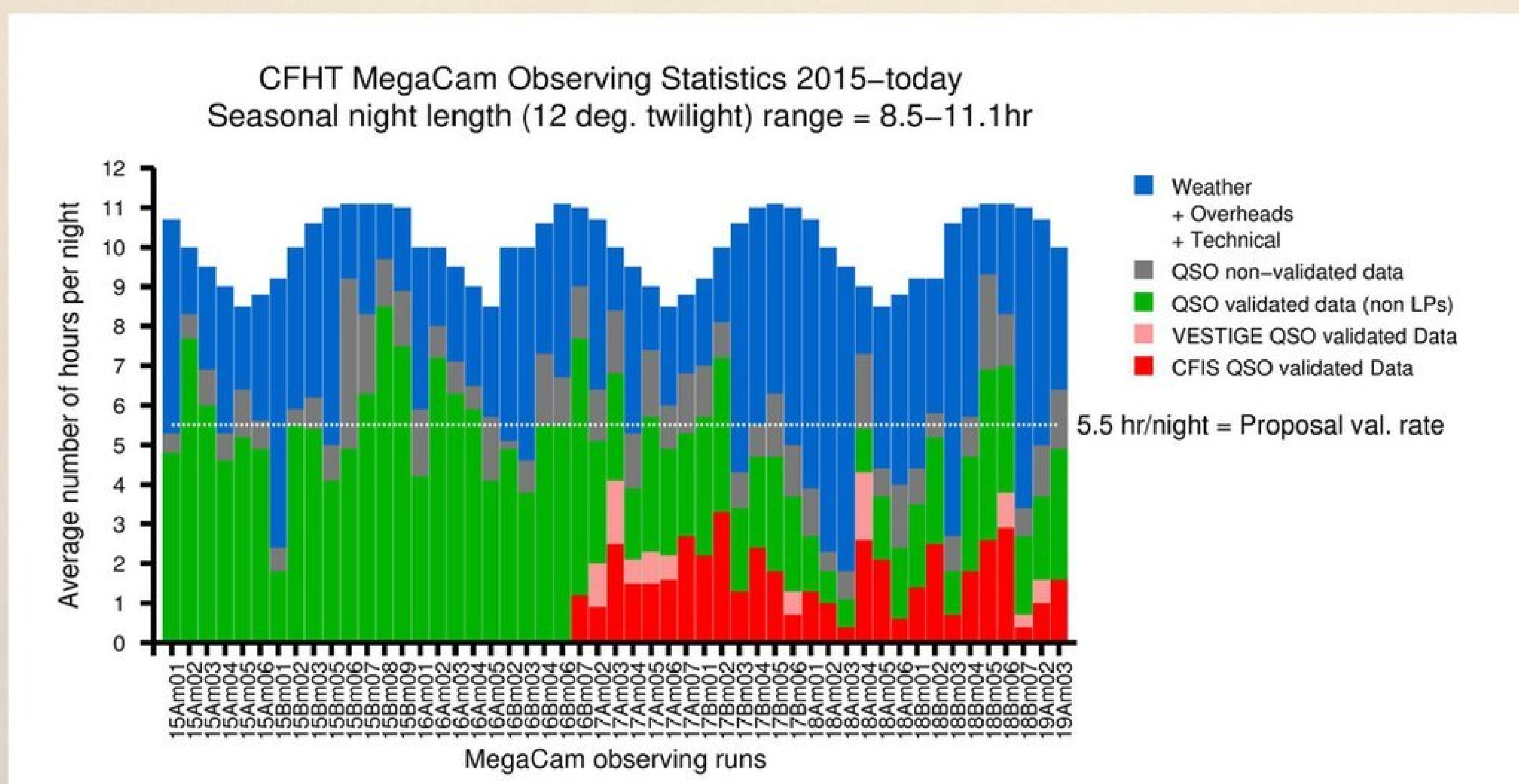
The worst weather in 30 years on Maunakea



15 years of MegaCam operations versus weather

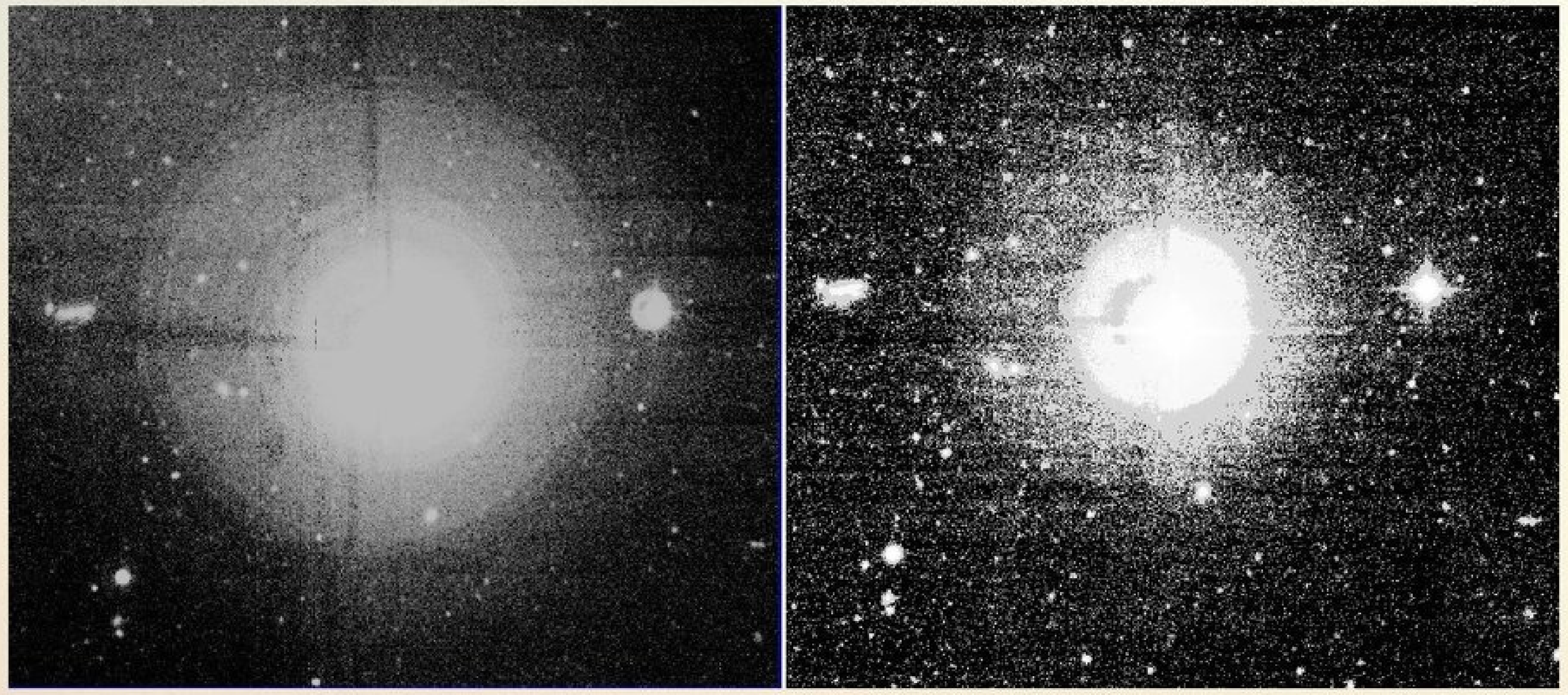


Summer hurricane #3 (Aug. 2018)

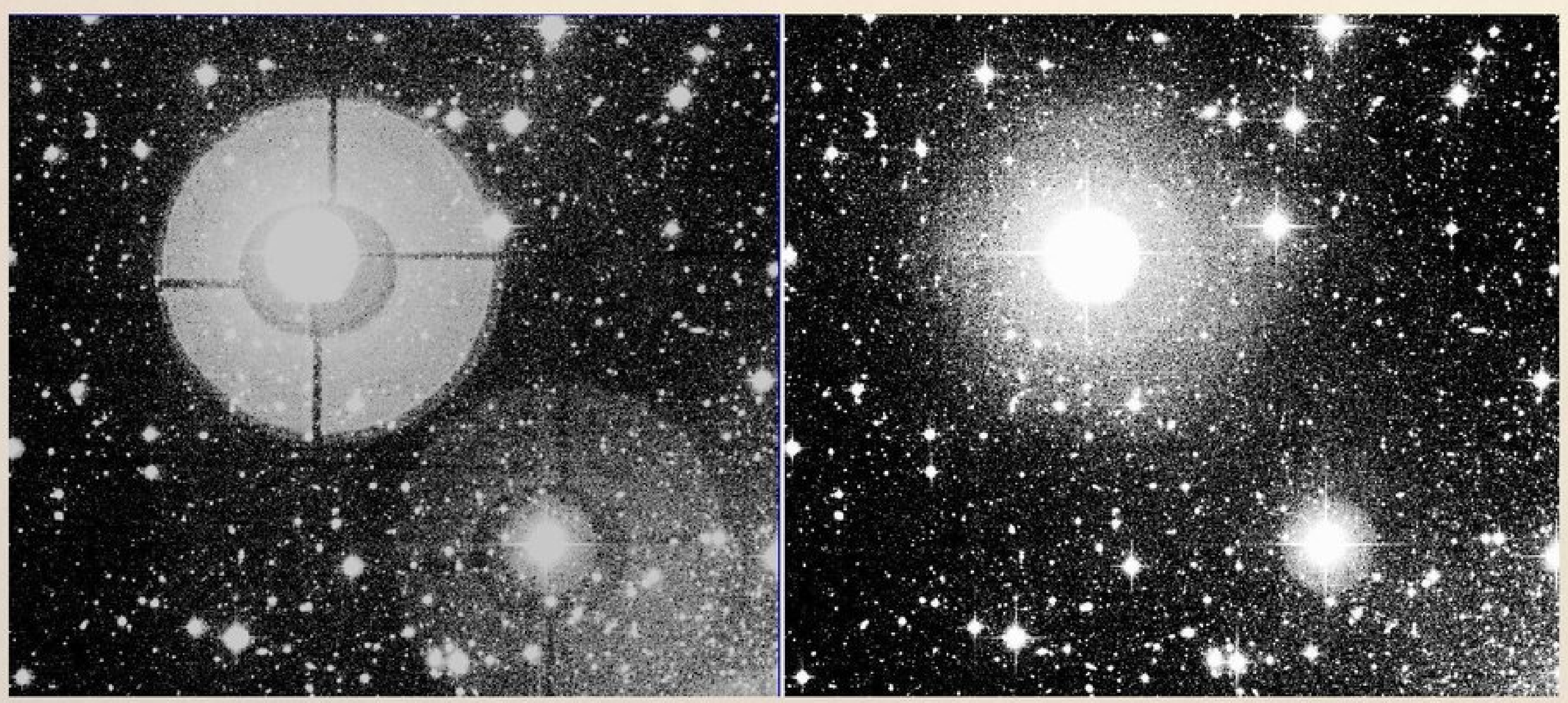


The CFIS seriously lacks sky access

Improved Low Surface Brightness performance



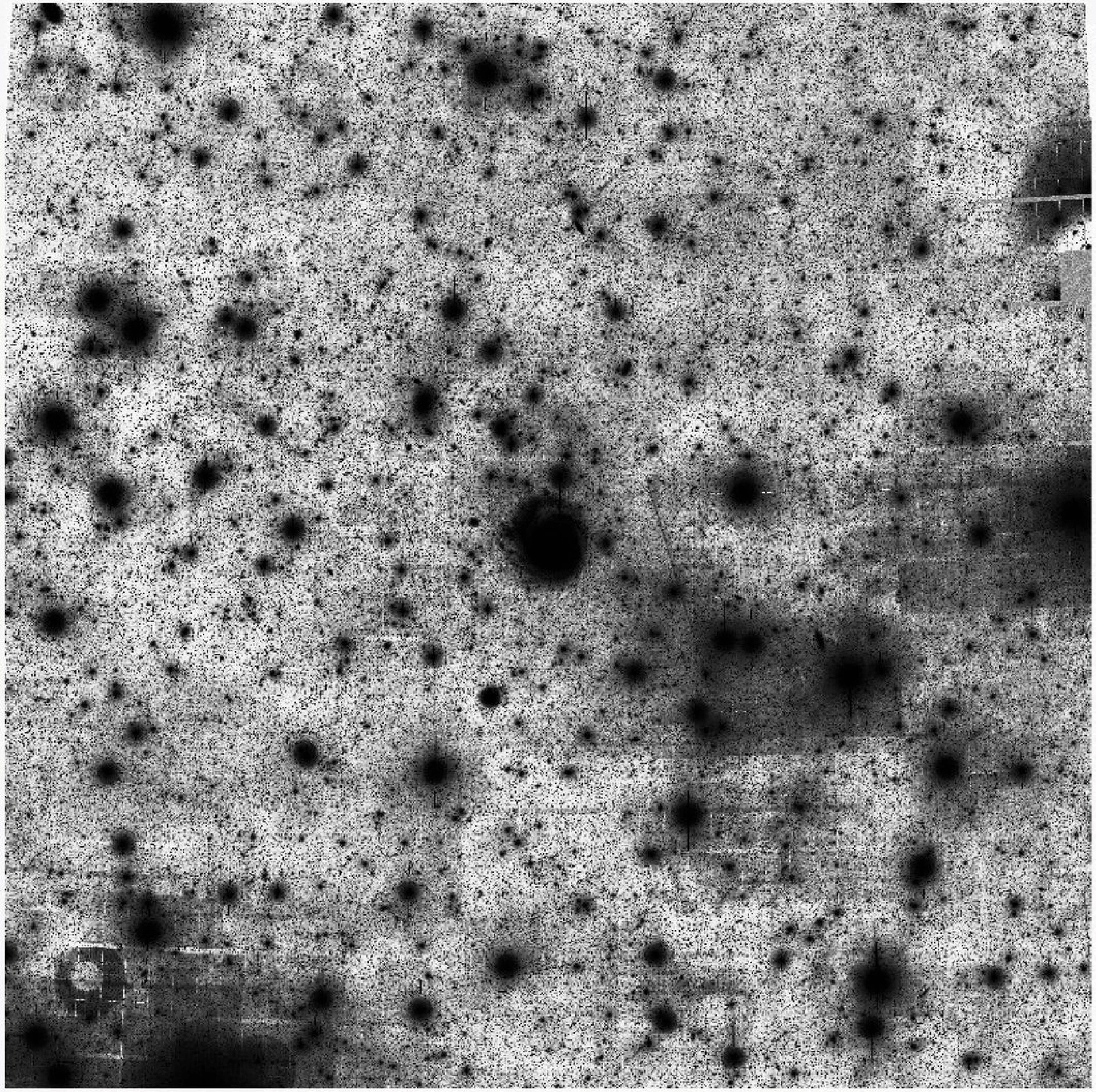
MegaCam u−band halos : old vs new filter



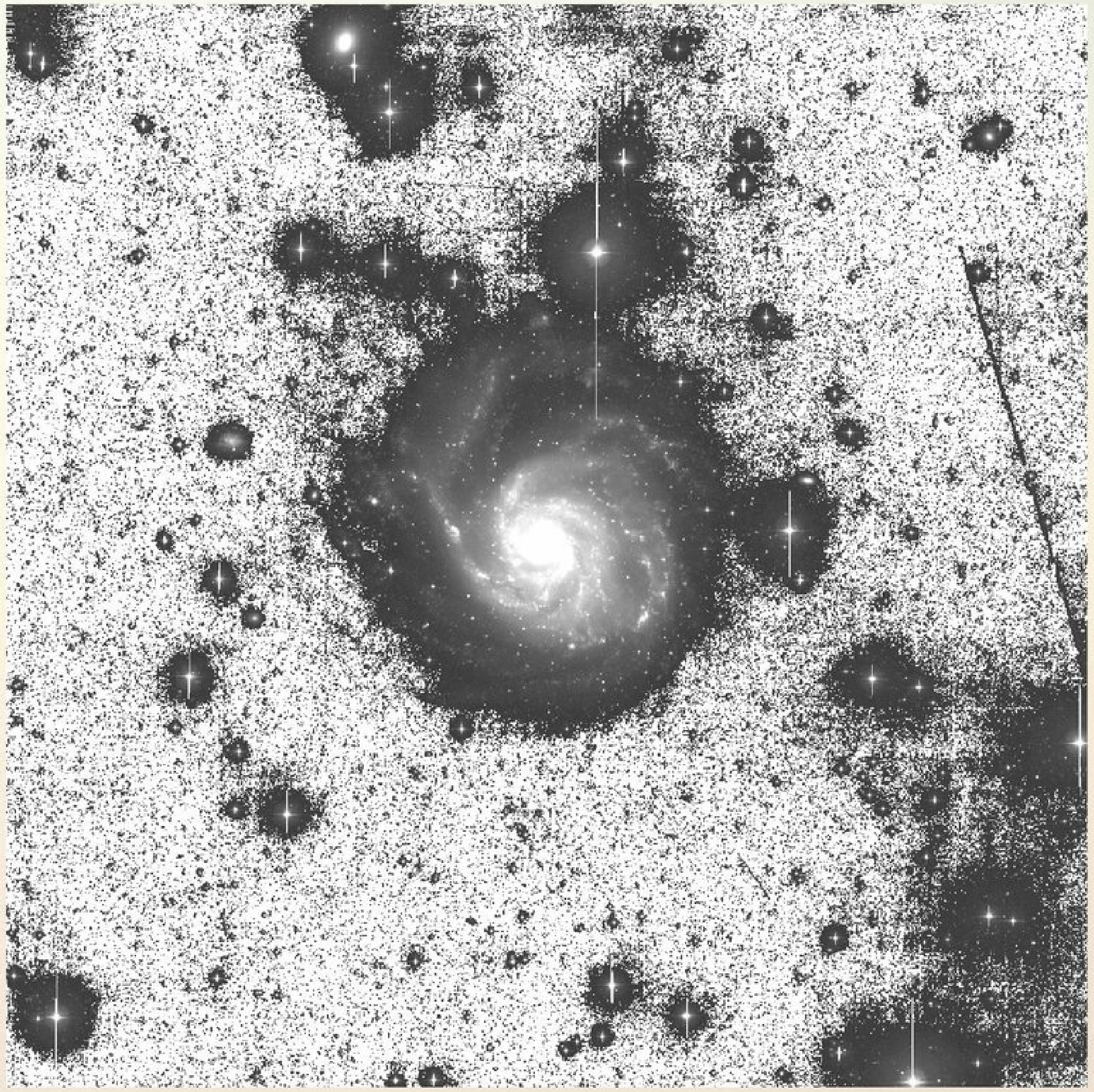
MegaCam r−band halos : old vs new filter

MegaCam LSB performance reached x3 faster

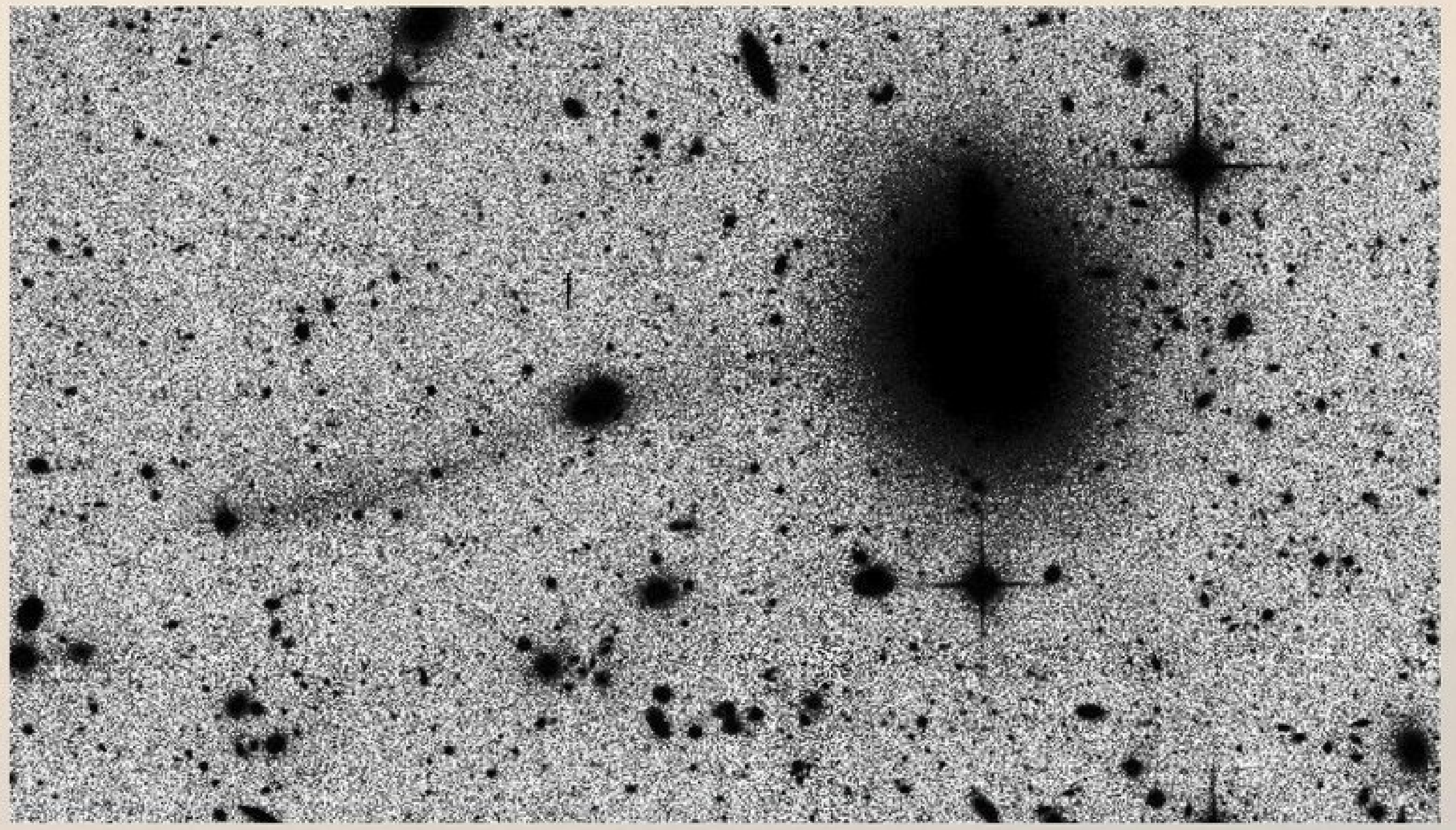
CFIS–r: 1st blind all–sky LSB survey



A 25 square degrees CFIS–r LSB patch (M101 area)



Messier 101 : disk to 28 mag/arcsec2



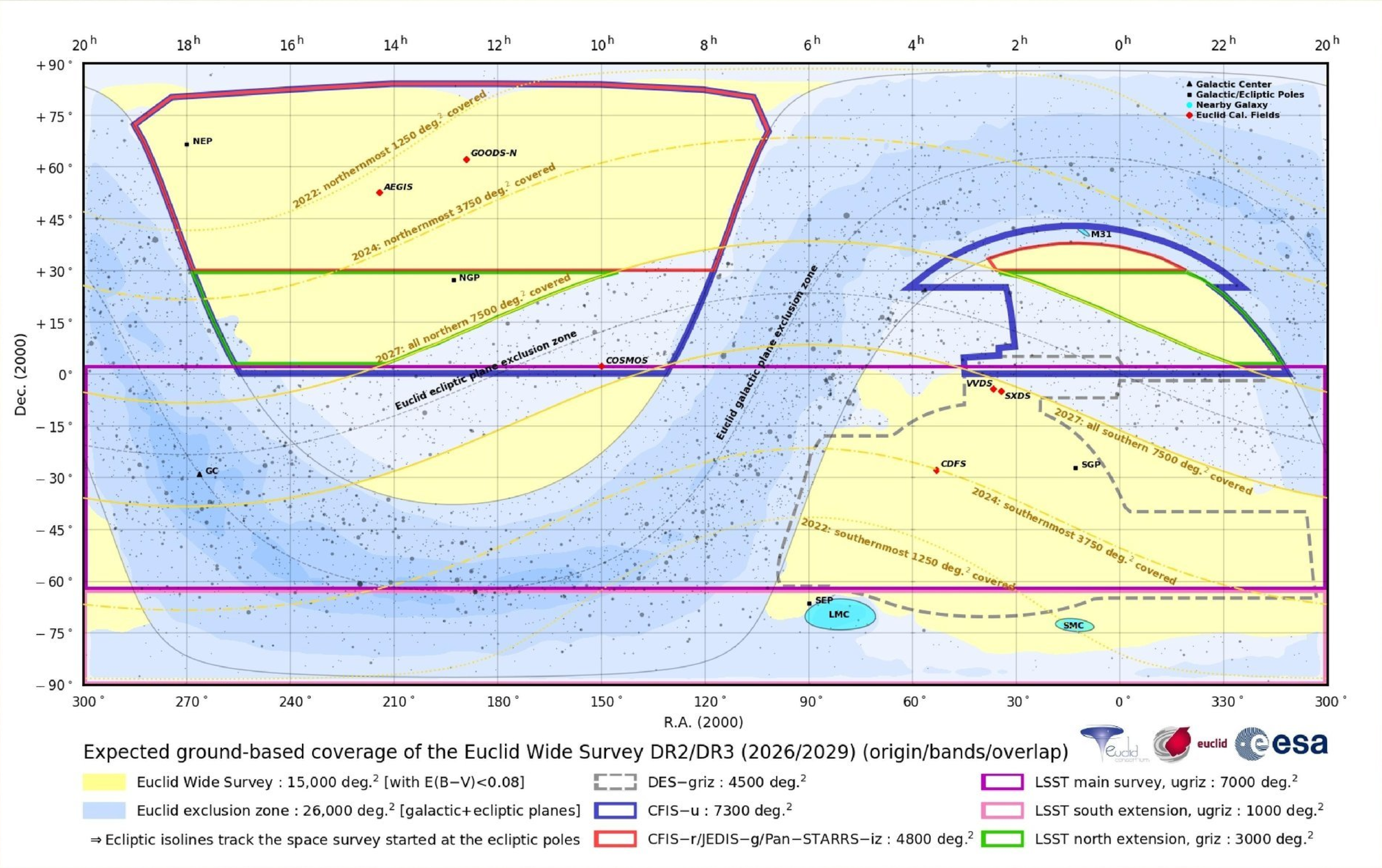
28 mag./arcsec2 = new sky window

Present and upcoming wide–field imagers relevant to Euclid

Facility	Year	Aper.	FOV	IQ	CCD class	Type	Hemisphere
LSST	2022	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	2020	2.5m	4.8 sq.deg.	0.7''	Deep depletion	Surveyor	North
PS1+PS2	2018	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

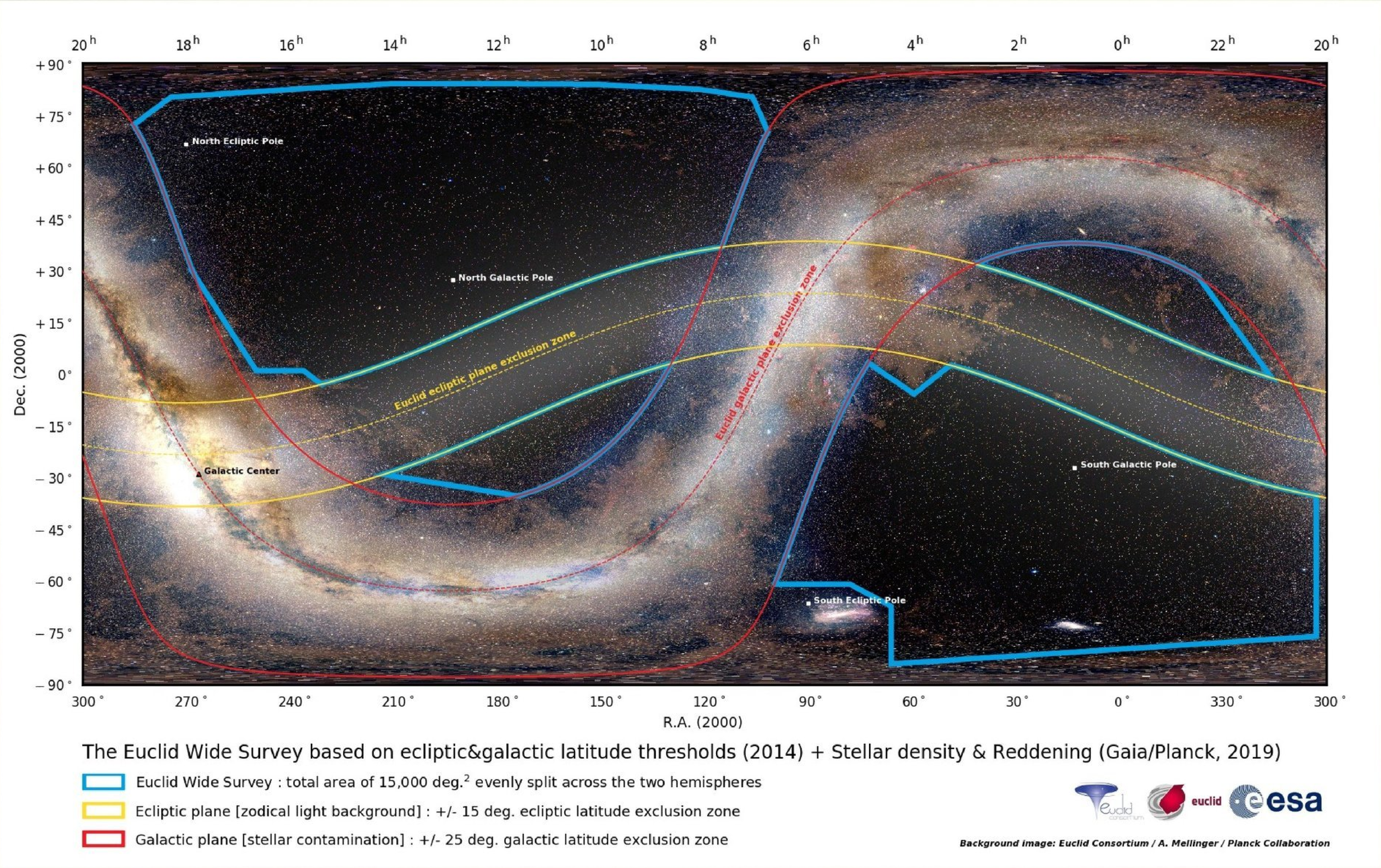
Etendue ↑

UNIONS CFIS/Pan−STARRS and the Euclid sky



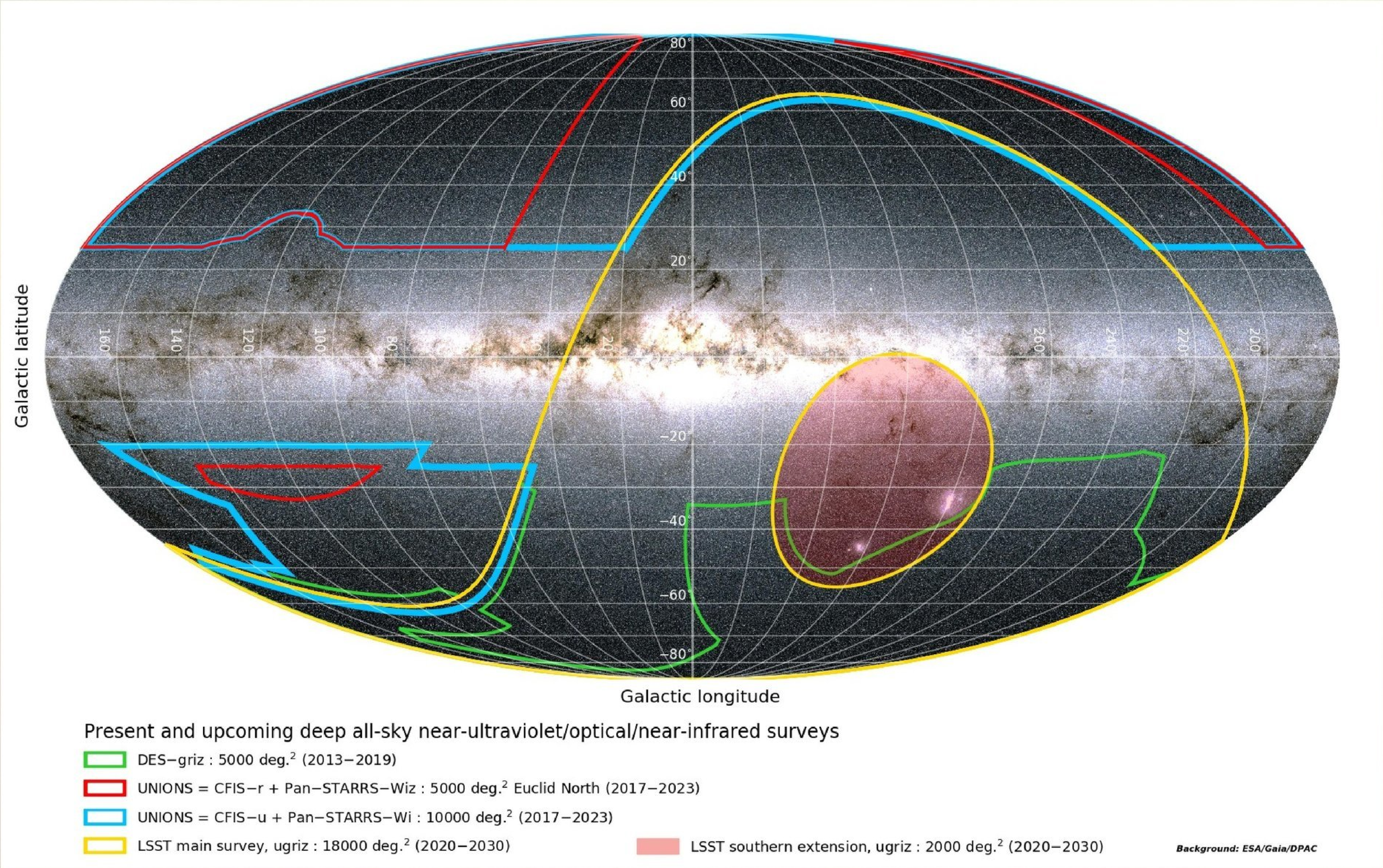
LSST has the potential to cover 66% of the Euclid sky, but UNIONS owns the North

The whole sky as perceived by Euclid at Lagrangian#2



Outline of the Euclid Wide Survey (15,000 square degrees) versus the exclusion zones

Paving the way to MSE targeting



UNIONS CFIS/Pan−STARRS contributes to building a deep static view of the northern sky

Conclusions

CFHT is now the best wide–field imager it has ever been
CFIS exploits CFHT's best strengths
CFIS maximizes sky access for science
Critical mass reached after two years: science percolates
CFIS and Pan–STARRS have joined forces in UNIONS

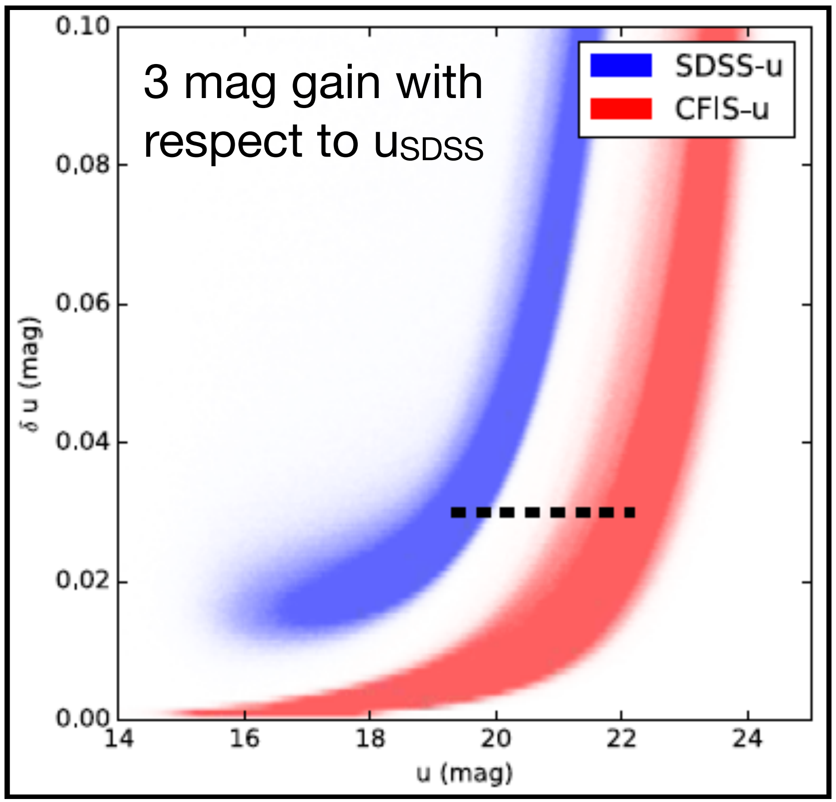
CFIS is progressing very slowly (weather) in the A–semester
At the current rate, CFIS will be completed at 60% by 2021
The CFIS Steering Group welcomes the LP completion policy
Realistic forecast of the 80% goal: CFIS needs 70 extra nights
Euclid will need 100% of the northernmost 5000 square deg.

Science highlights

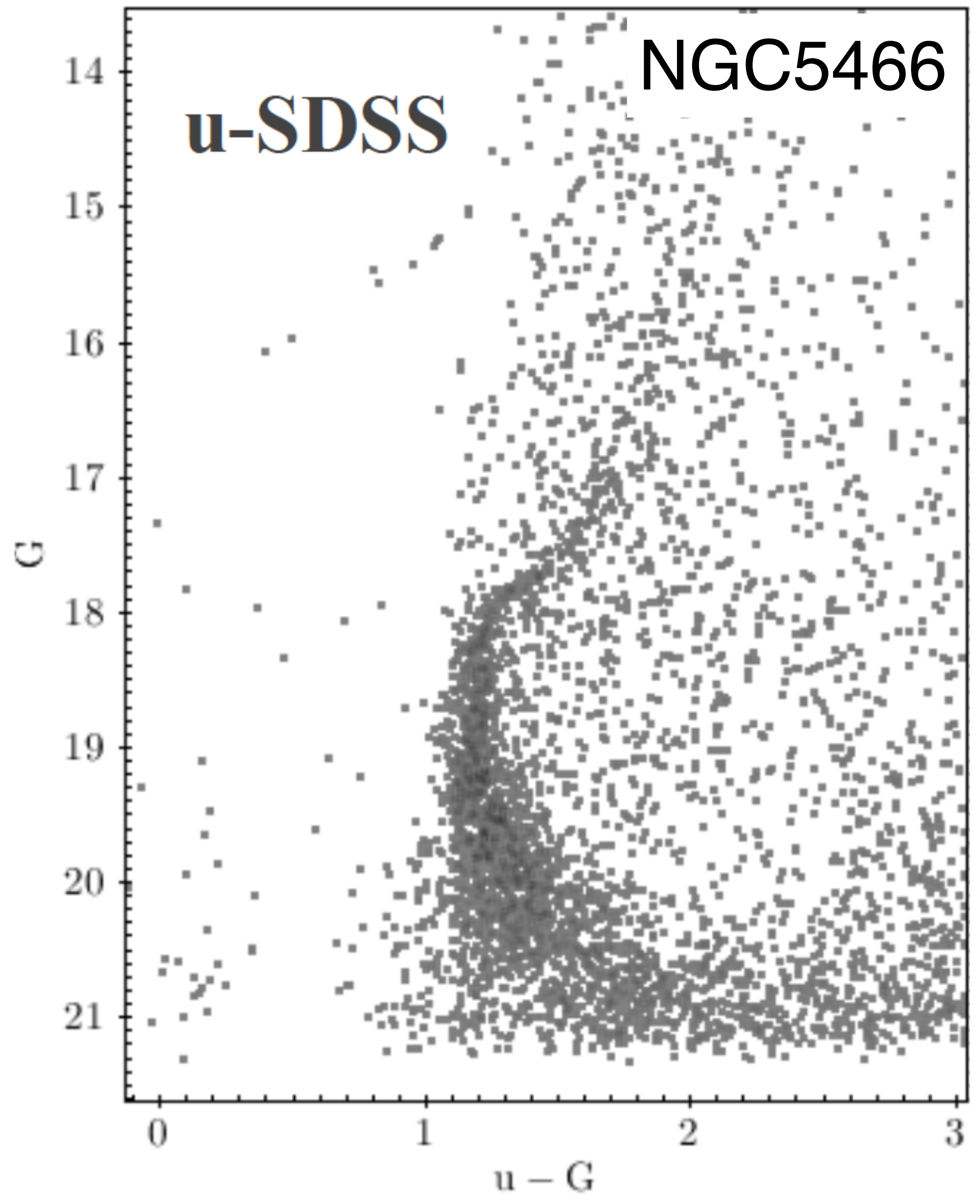
- So far, CFIS has resulted in
  - 4 published peer reviewed publications
  - 1 in press peer reviewed publication (accepted just yesterday)
  - at least 2 peer reviewed publications in the late stages of preparation
- Team - lets get 10 papers submitted/in press/published by the end of the year…!

- In the remainder of this session:
  - ***The three dimensional structure of the outer stellar halo***
  - ***The hierarchical substructure of the Milky Way***
  - ***The tidal tails of the Milky Way***
  - ***The chemodynamics of the Galaxy, at the faint end of the Milky Way***
  - ***Mergers and the triggering of AGN***
  - ***A Universe of ultra-diffuse galaxies***
  - **Weak lensing (Mike Hudson)**
  - **Strong lensing (Raphael Gavazzi)**
  - **The star formation history of the Milky Way from white dwarfs (Nick Fantin)**

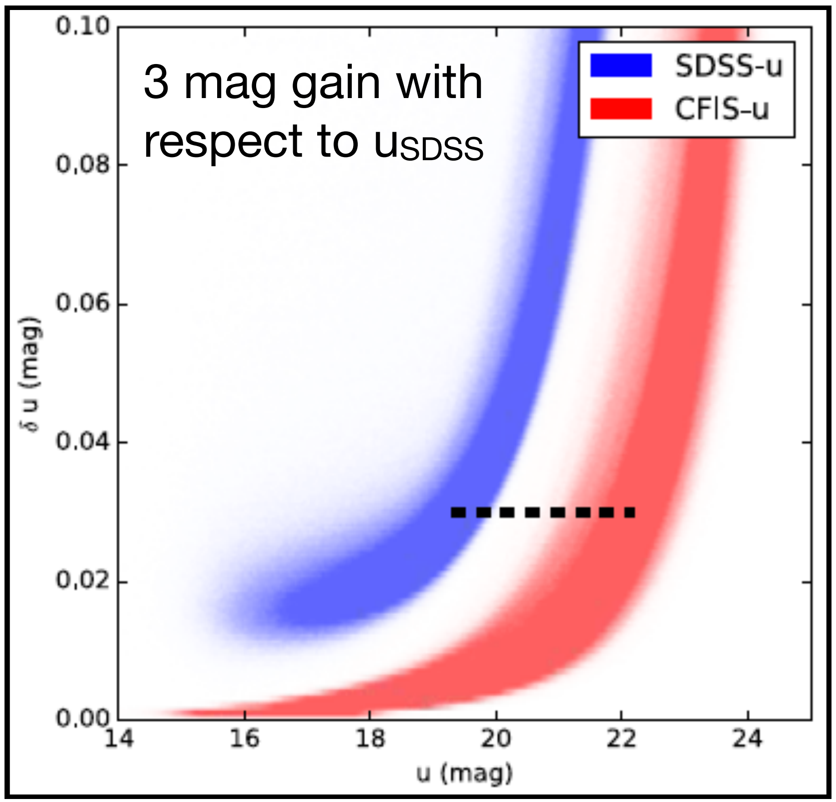
UNIONS

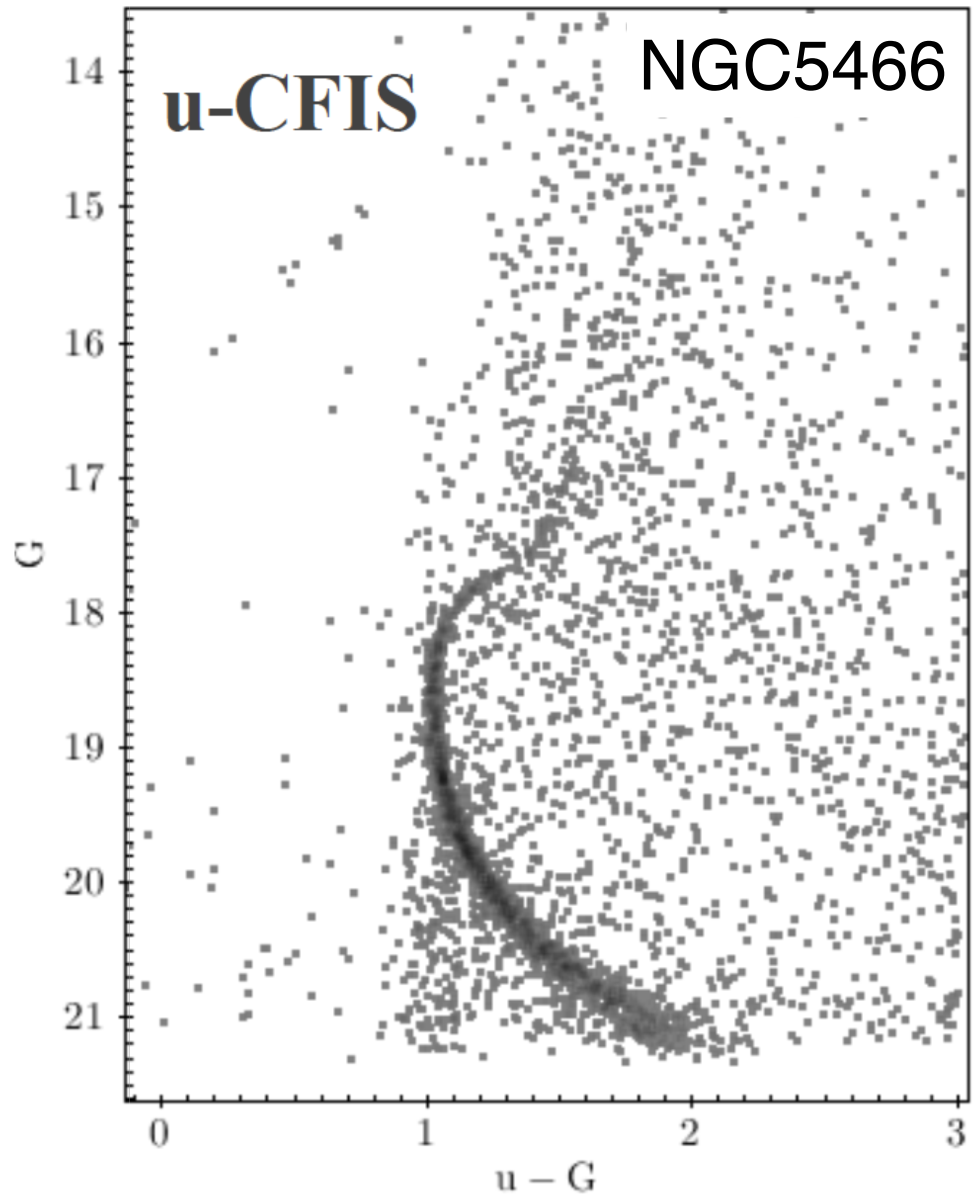


3 mag gain with respect to u_{SDSS}
SDSS-u
CFIS-u
0.10
0.08
0.06
0.04
0.02
0.00
δ u (mag)
14
16
18
20
22
24
u (mag)

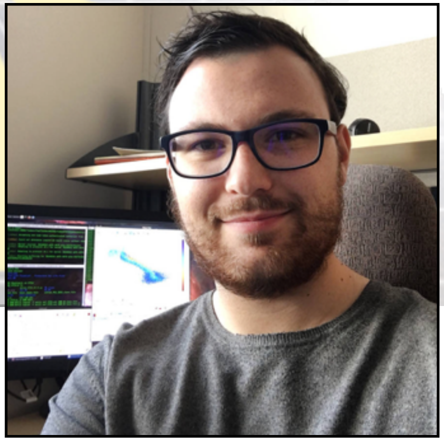


NGC5466
u-SDSS
14
15
16
17
18
19
20
21
G
0
1
2
3
u − G


3 mag gain with respect to uSDSS
SDSS-u
CFIS-u
δ u (mag)
u (mag)


u-CFIS
NGC5466
G
u – G

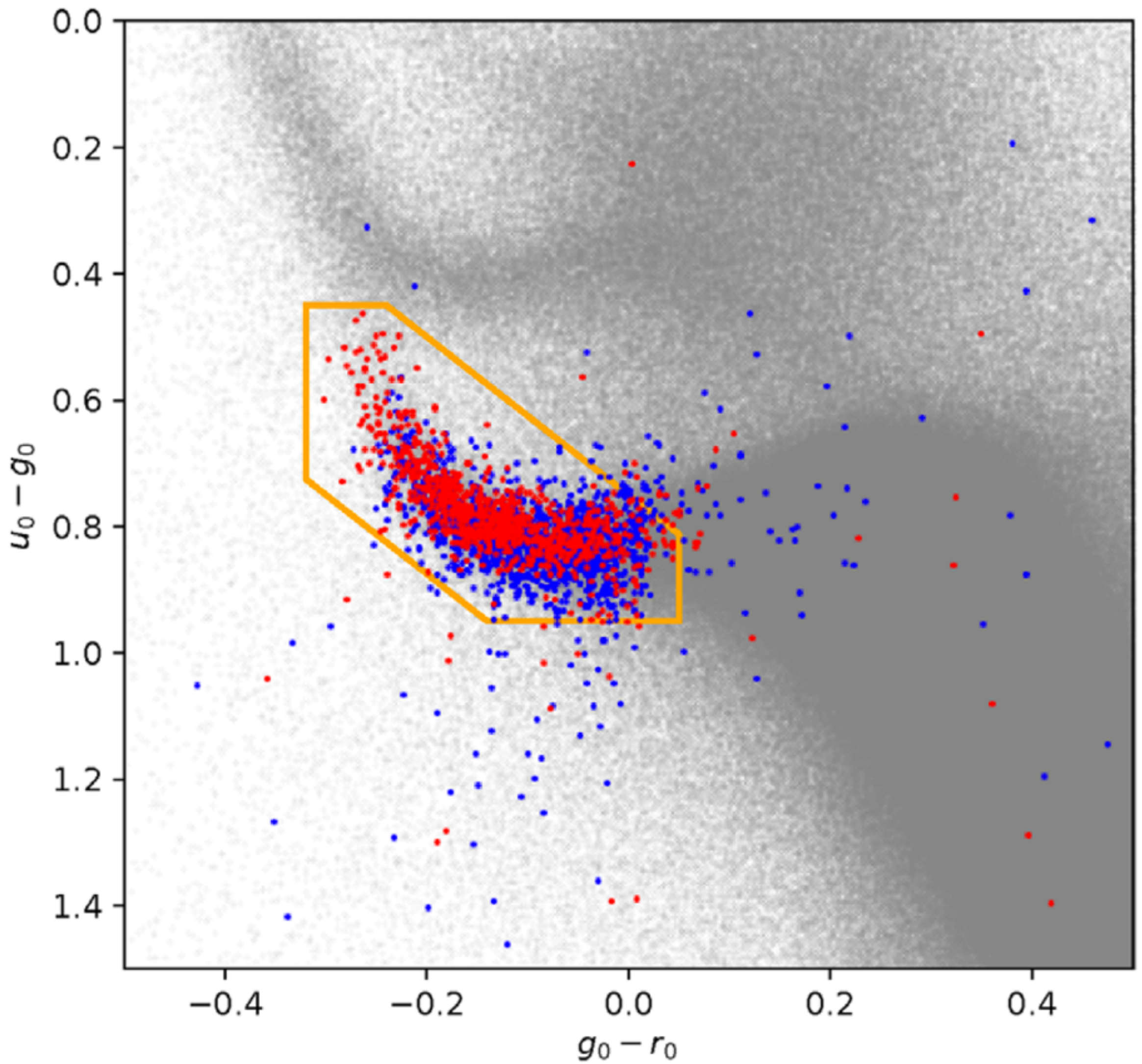
The three dimensional structure of the outer stellar halo



- Use Blue Horizontal Branch stars:
  - Hot stars 7400 < Teff < 9300
  - Relatively accurate standard candle (~10% distance uncertainties)

- Easily traced to large radius (see previous work by (Yanny et al. 2000; Sirko et al. 2004; Deason et al. 2011, and others).

- Major source of contamination is blue stragglers



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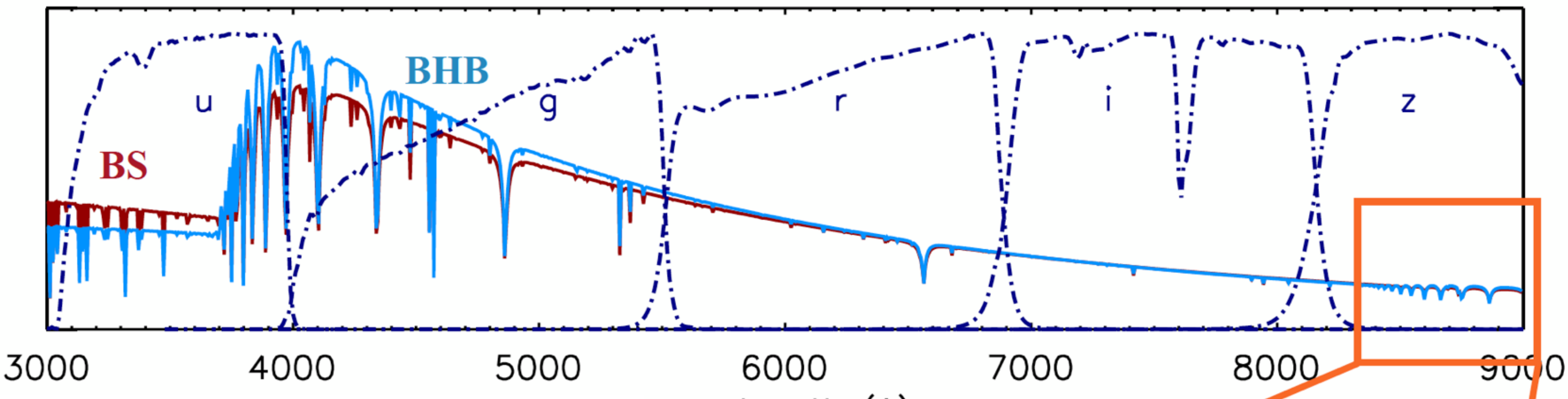
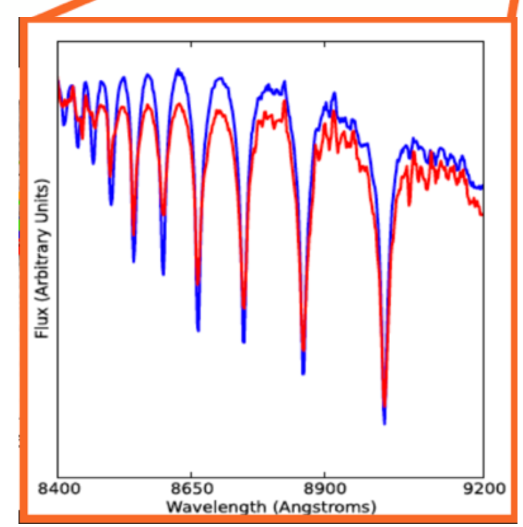
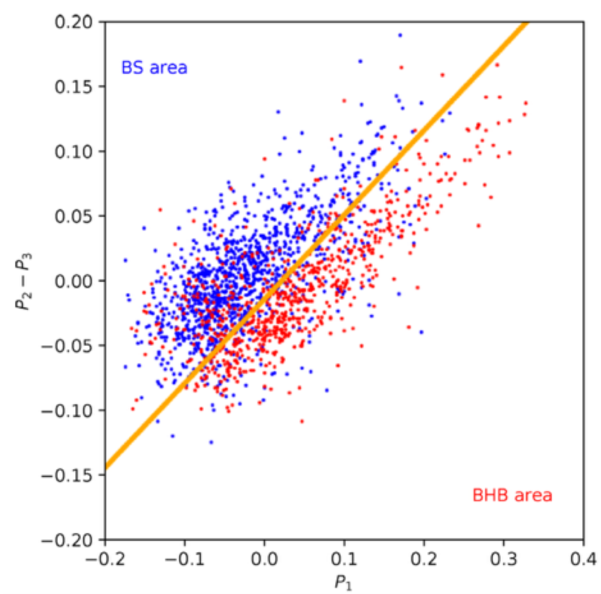


Courtesy of Else Starkenburg (AIP)

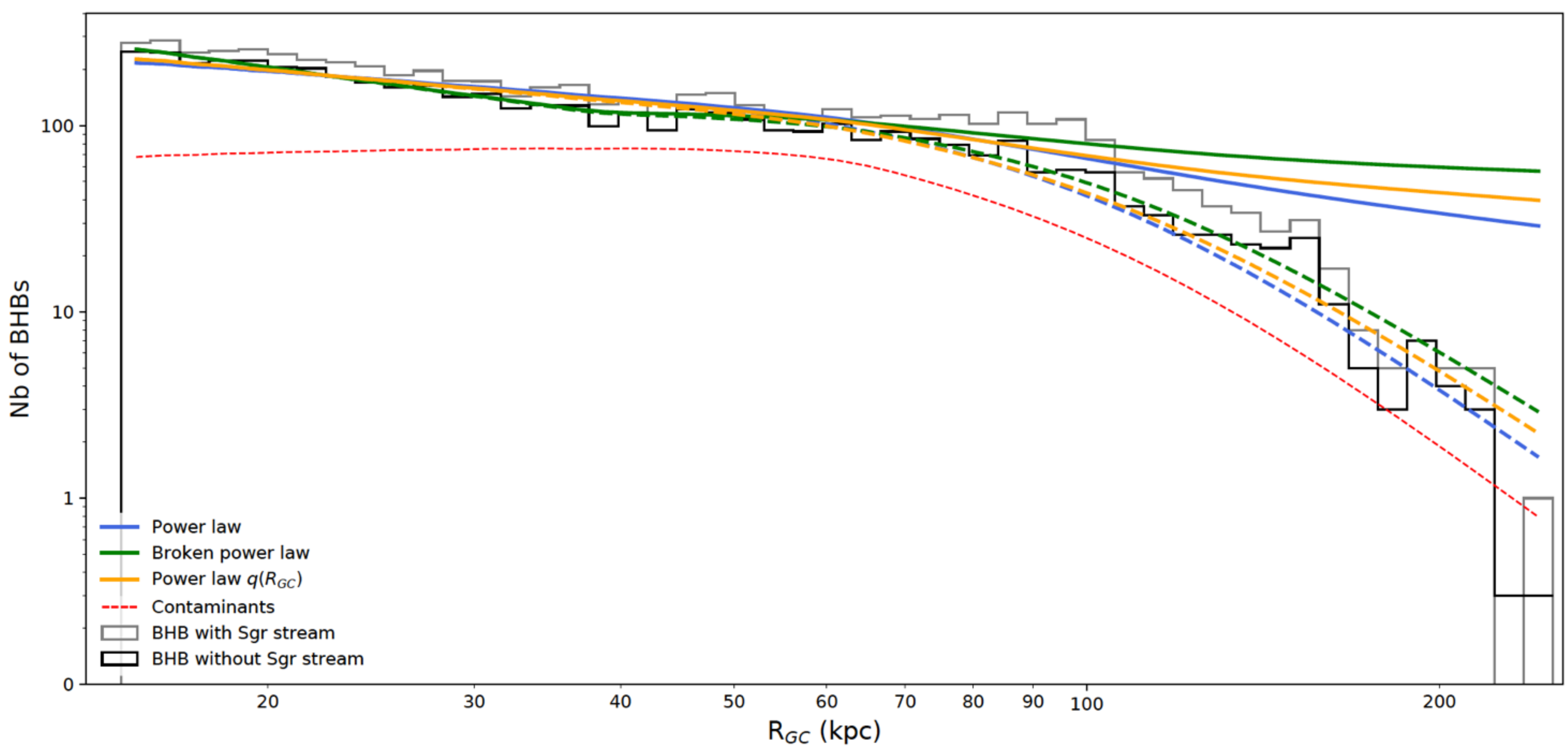


- Comparison of BHB and BS stellar spectra show that the greatest discrimination between the two is in u-band (Balmer jump) and z band (Paschen lines)
- Use PCA technique involving CFIS u and PS1 griz



The three dimensional structure of the outer stellar halo

- Fit to full three dimensional distribution of BHB stars, accounting for CFIS footprint, photometric completeness, residual contaminations.
- Used power law, broken power-law models, with constant and variable flattening
- Formally, a (constant) oblate halo is preferred (q~0.8), with a broken power-law profile (4.24 +/- 0.08 with 40kpc). Profile is shallower (3.21 +/- 0.07) after this radius



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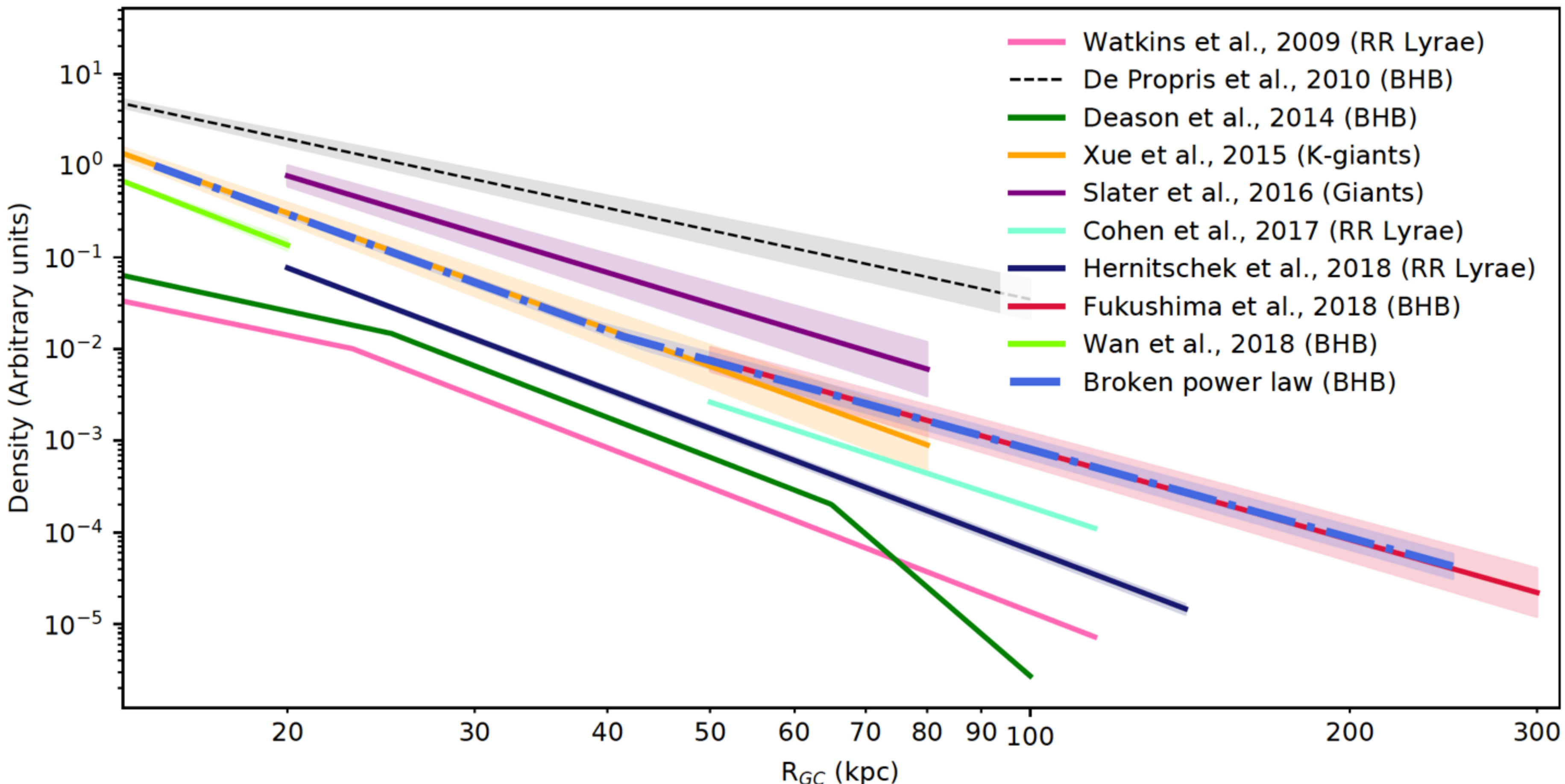
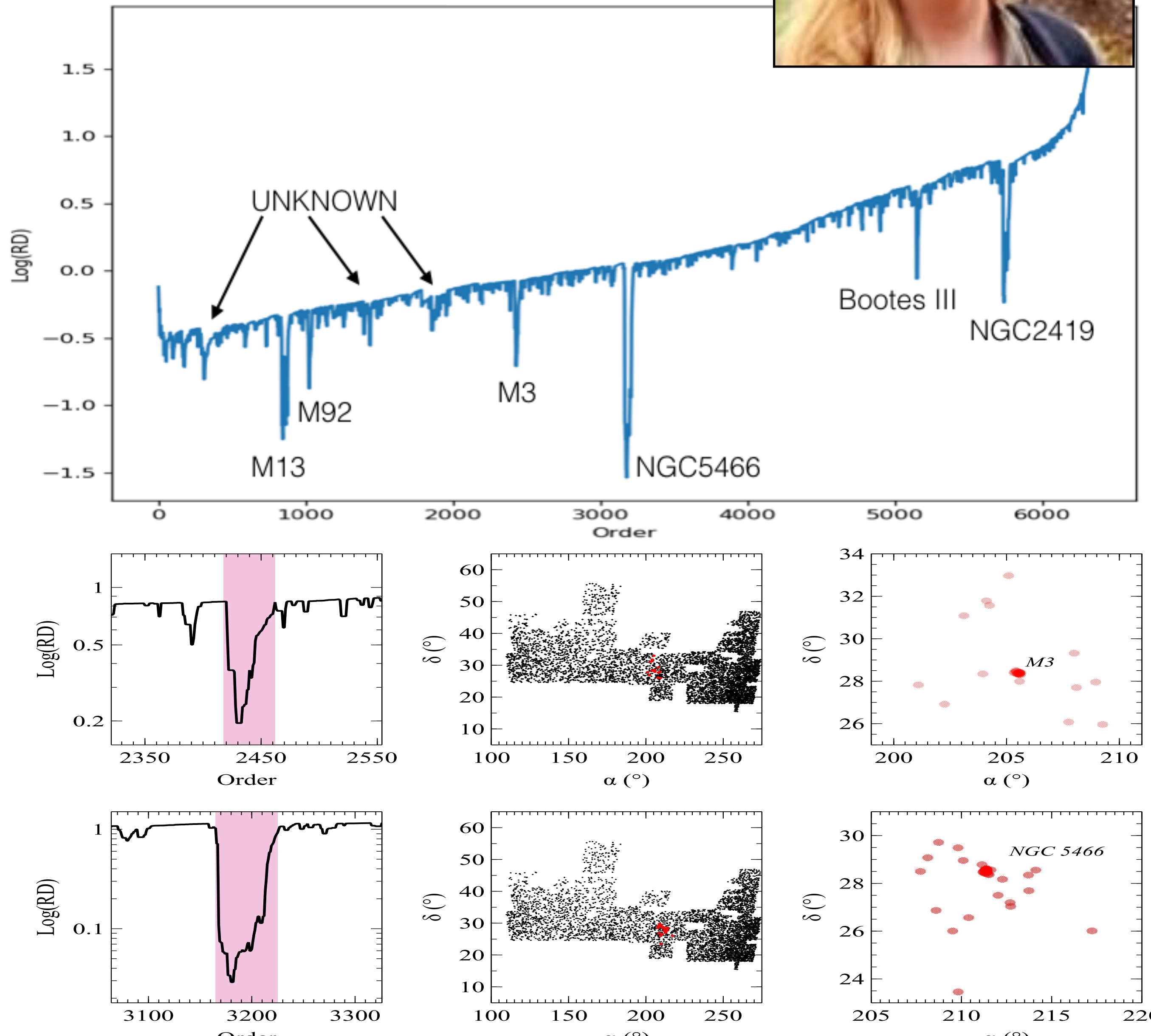


The hierarchical substructure of the Milky Way

- Using the BHB dataset to quantify the hierarchical structure of the Milky Way halo using the OPTICS algorithm (see McConnachie et al. 2018 for application to PAndAS data)
- Recover all known substructures in our footprint, as well as new structures and possible new streams surrounding some globular clusters



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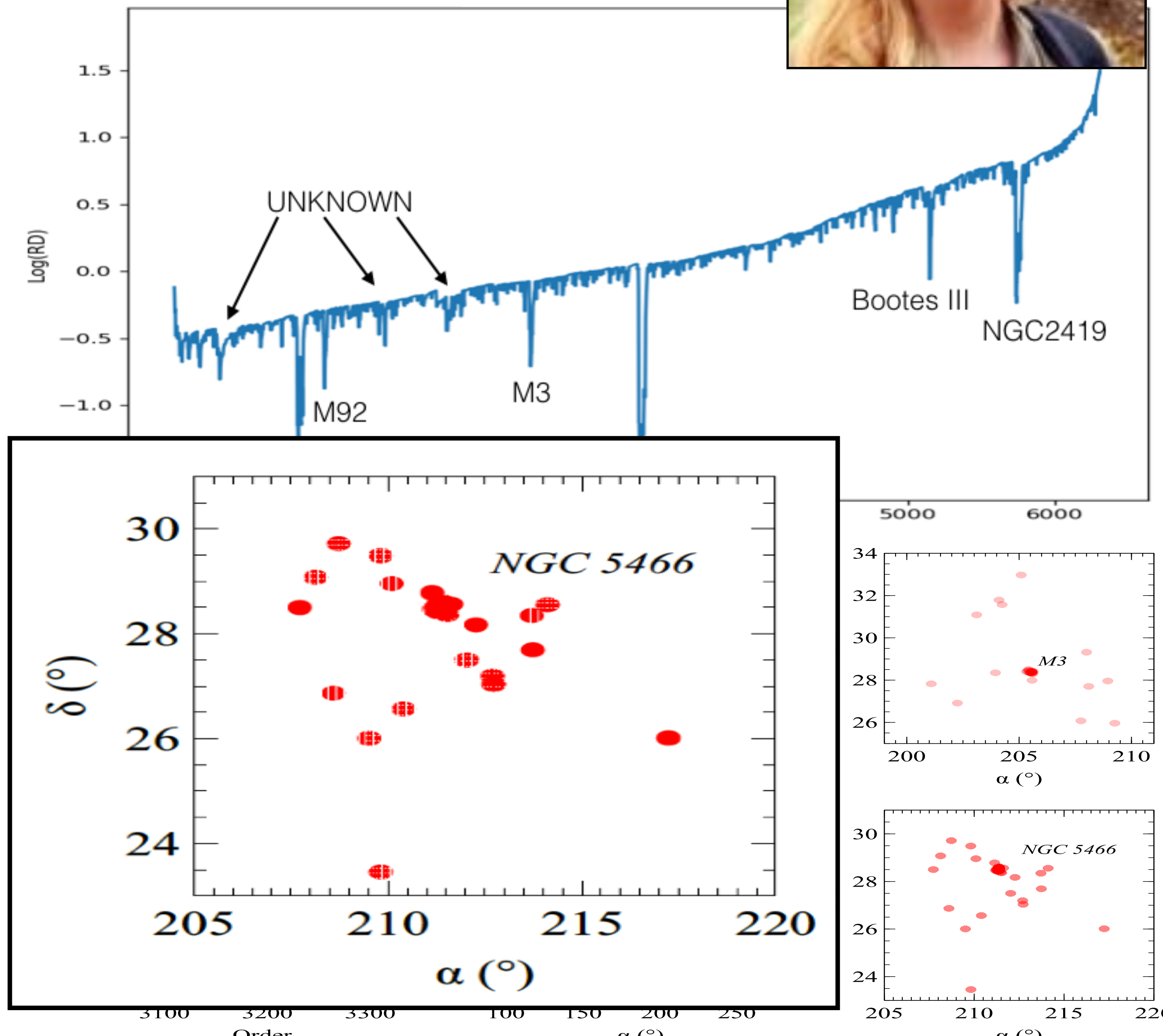
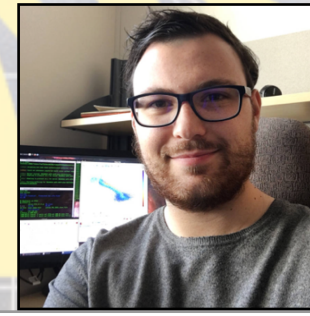
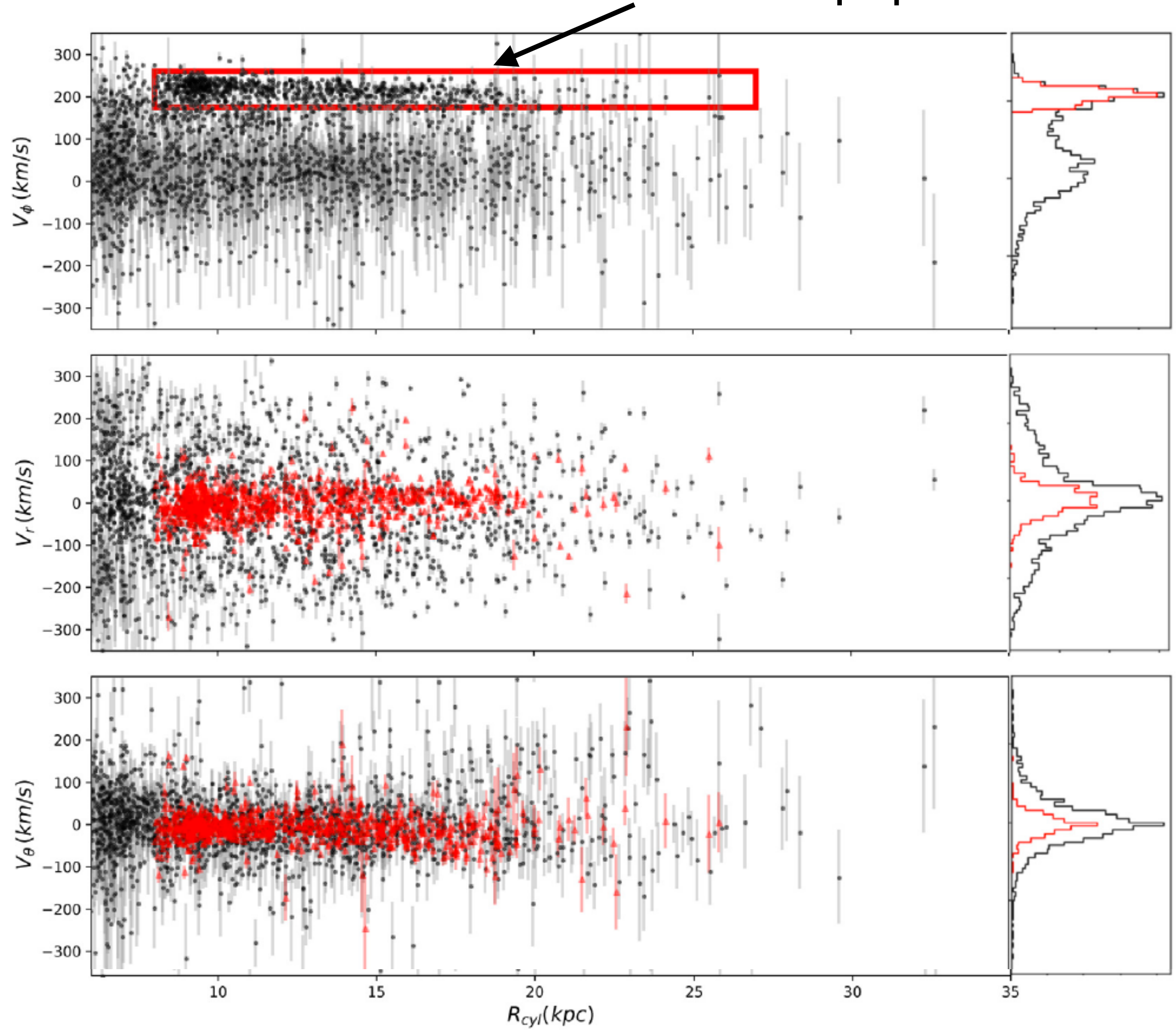


The tidal tails of the Milky Way

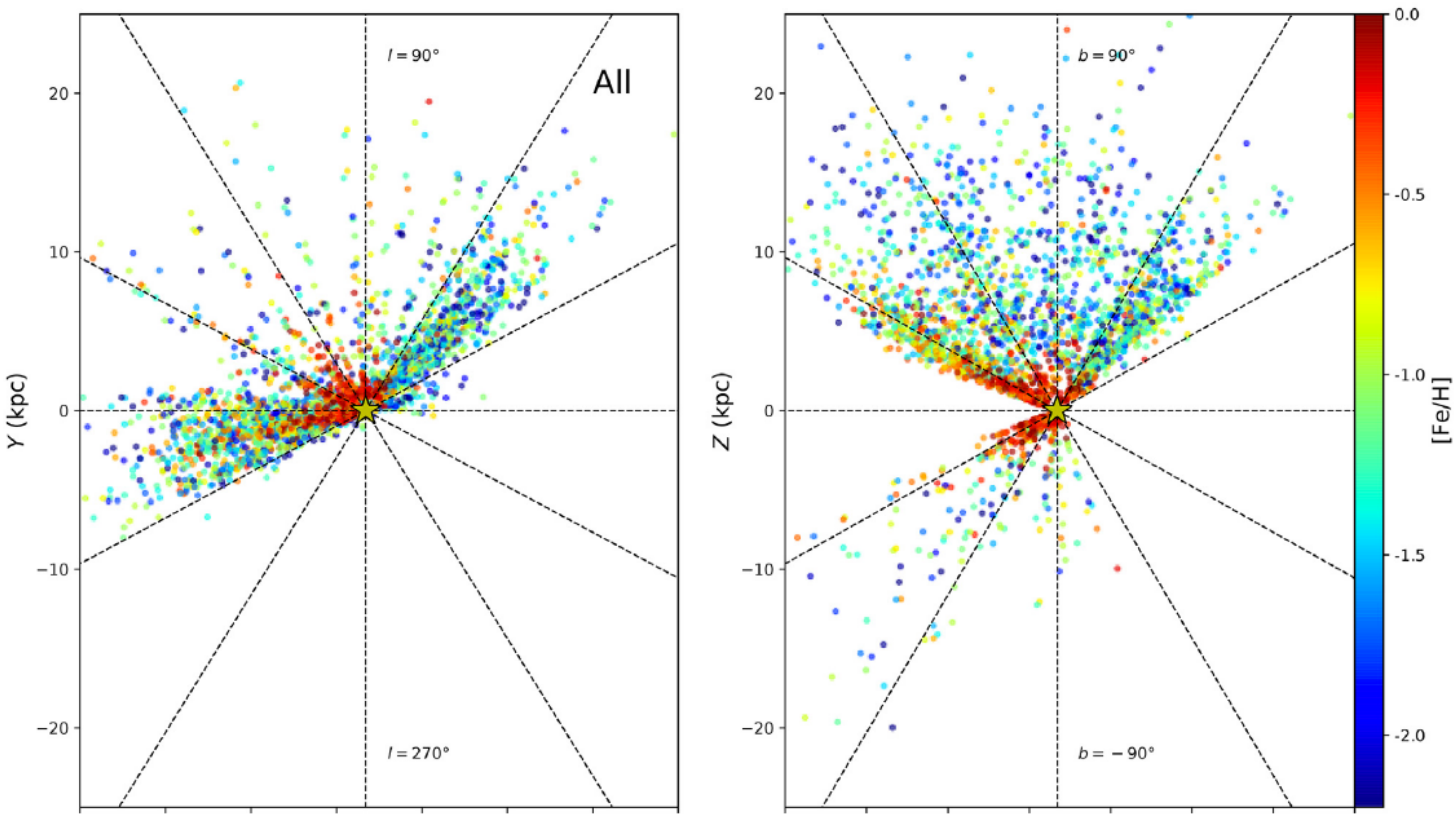


Disc BS population?



- Blue stragglers are much brighter than main sequence stars and reasonably numerous in denser stellar populations
- Ideal tracers of the outer disk!
- Cross-match the CFIS blue straggler population with Segue radial velocities and Gaia proper motions
- Note: Gaia parallaxes to these objects are less accurate than our photometric estimates
- (Based on empirical calibration by Deason et al. 2011 and confirmed on CFIS GCs)

The tidal tails of the Milky Way



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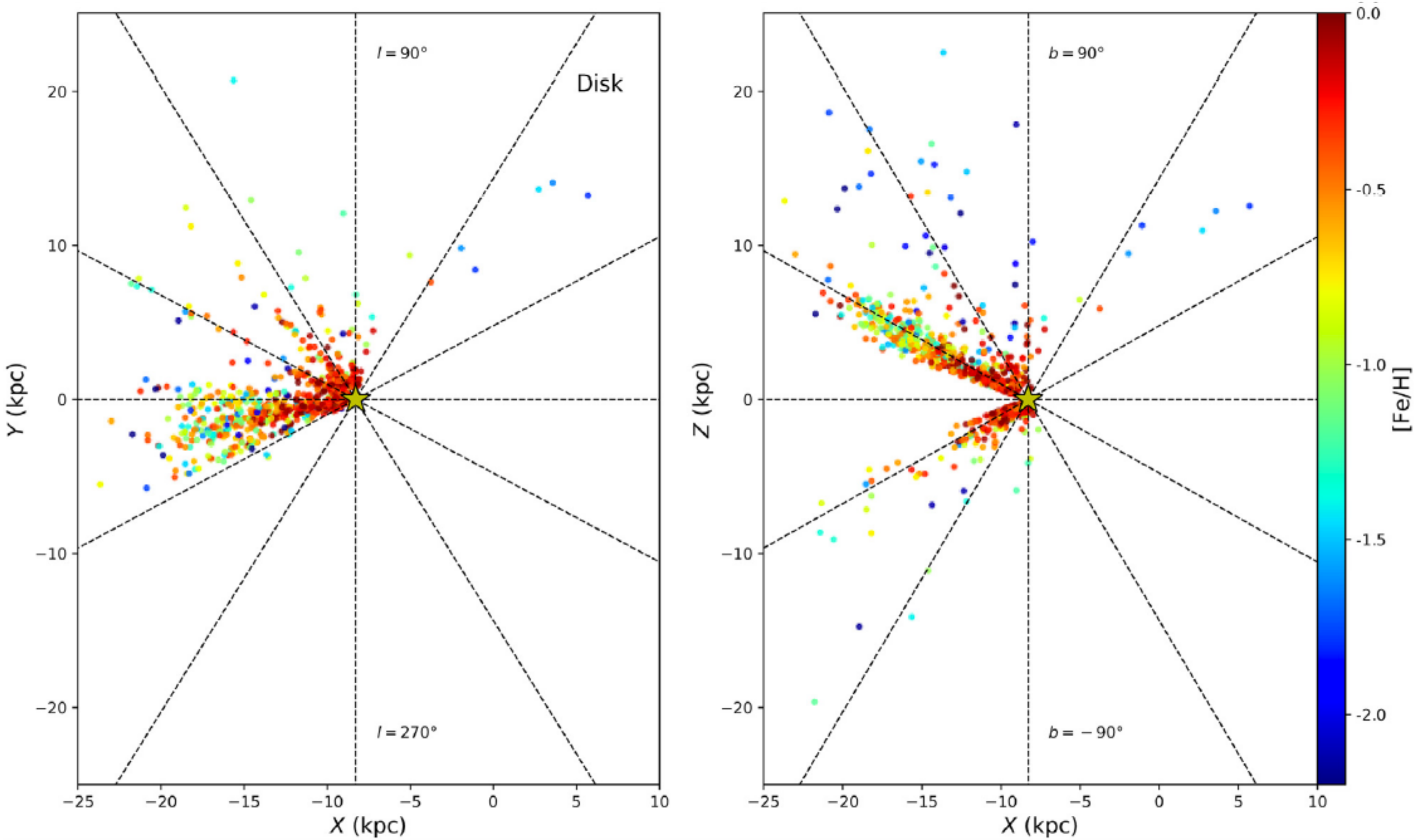

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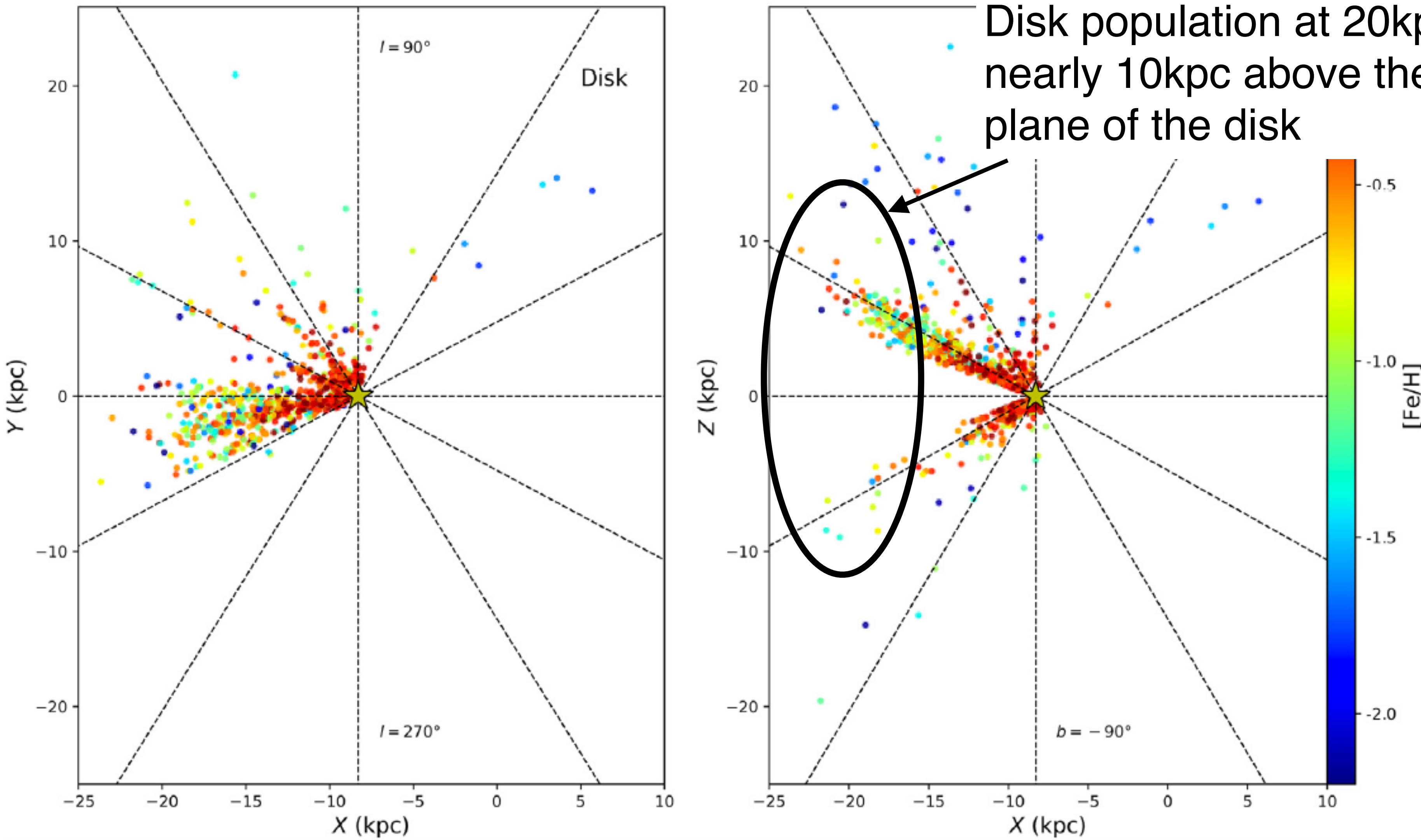
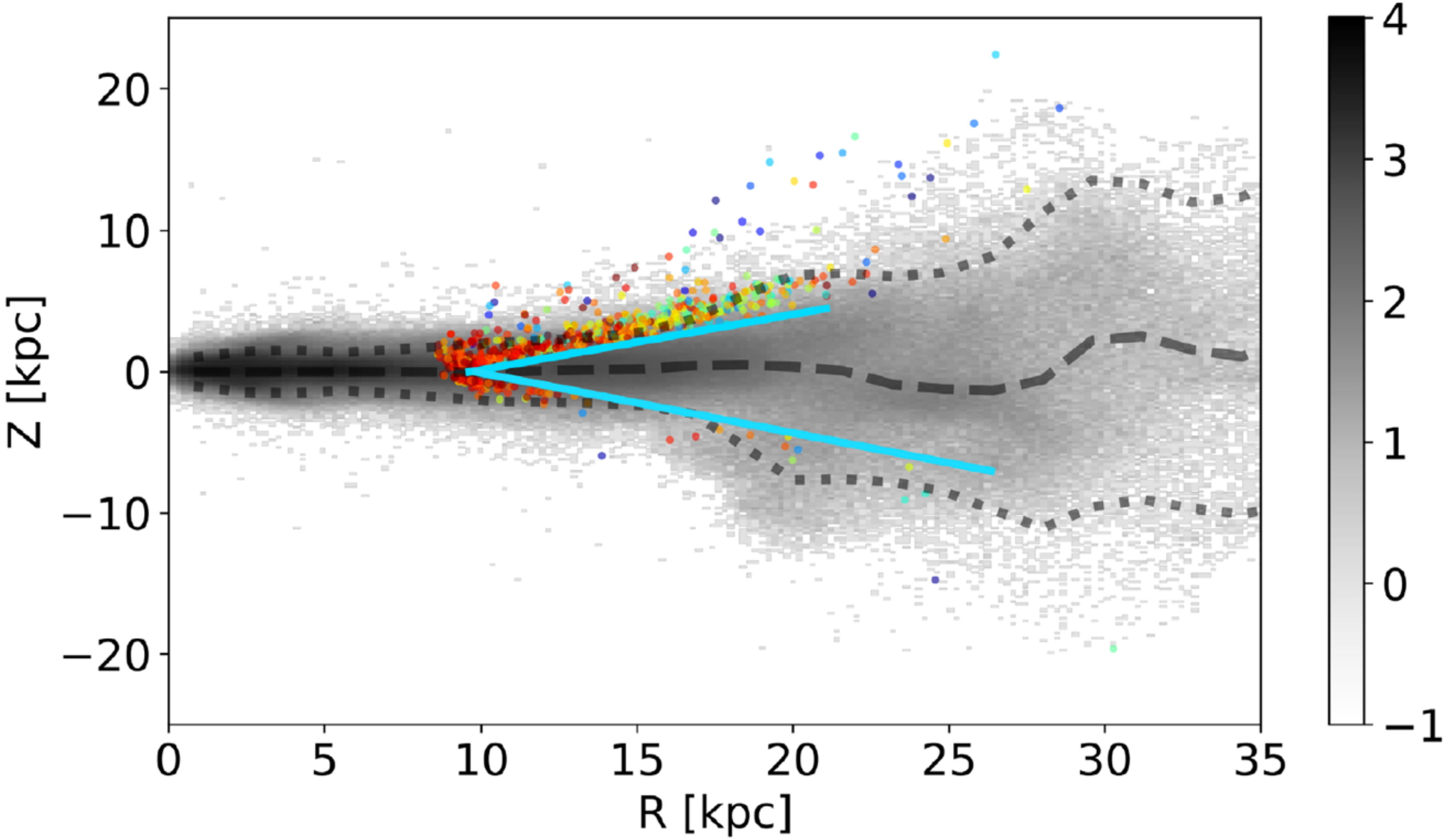


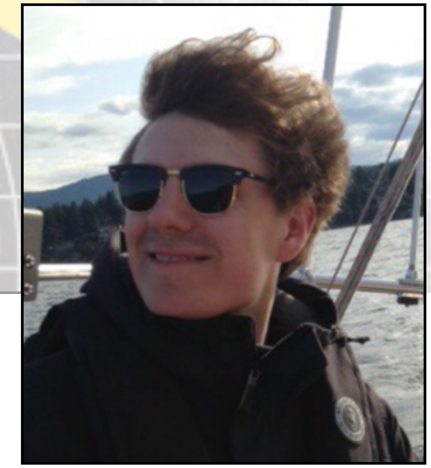
Disk population at 20kpc, nearly 10kpc above the plane of the disk

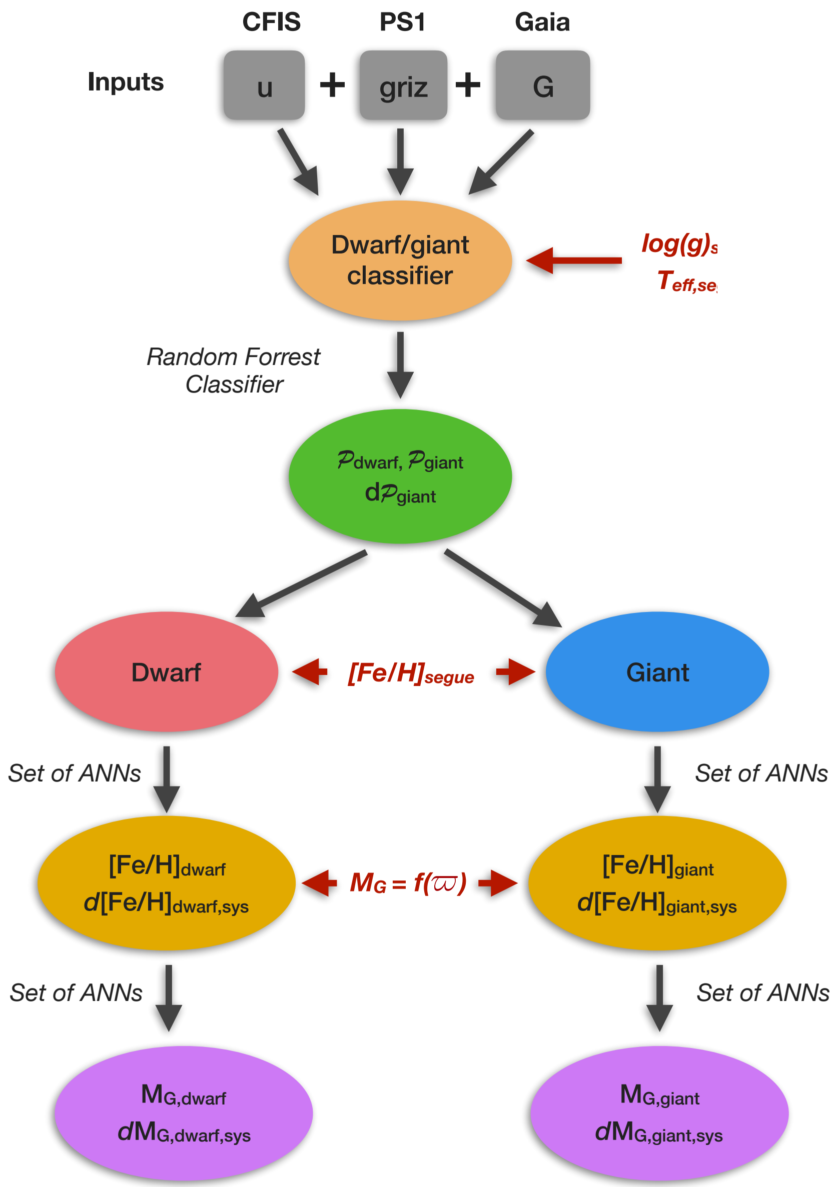
The tidal tails of the Milky Way

- Comparison with Laporte et al. 2018, simulating the interaction of Sgr with the disk of the MW
- Sgr dSph can create the flare, with stars at a vertical elevation of z~8.5 kpc at R=25 kpc

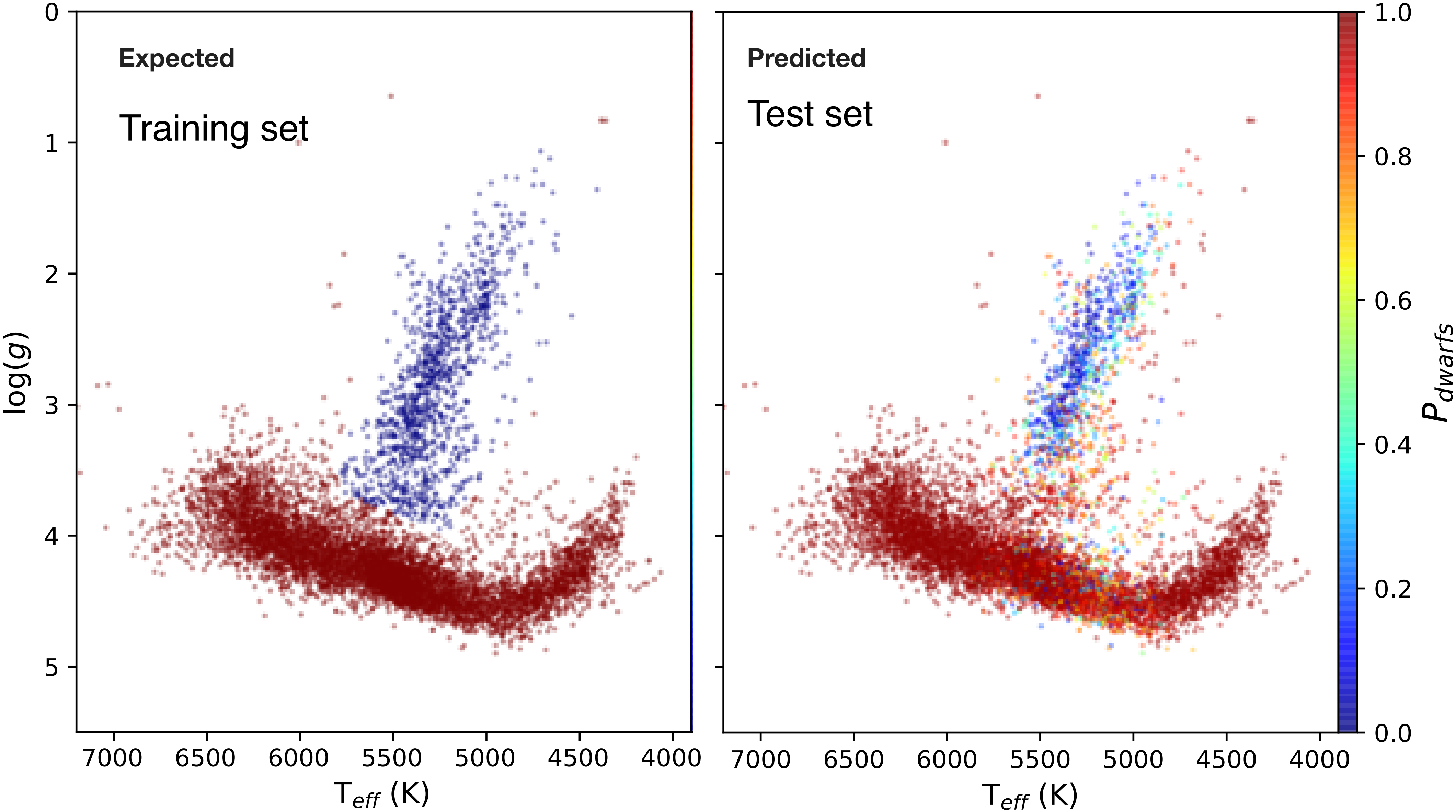


The chemodynamics of the Galaxy, at the faint end of the Milky Way

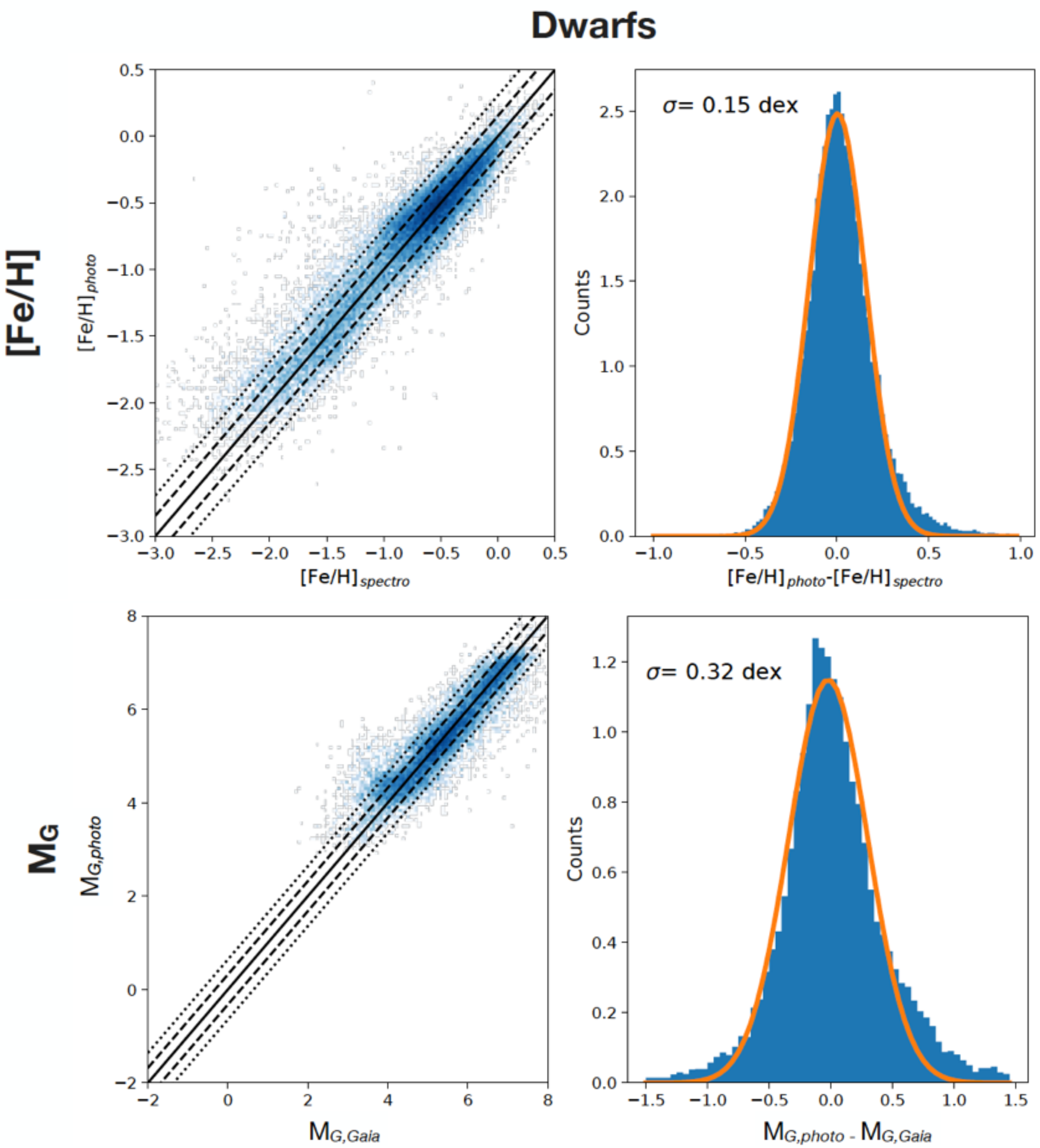




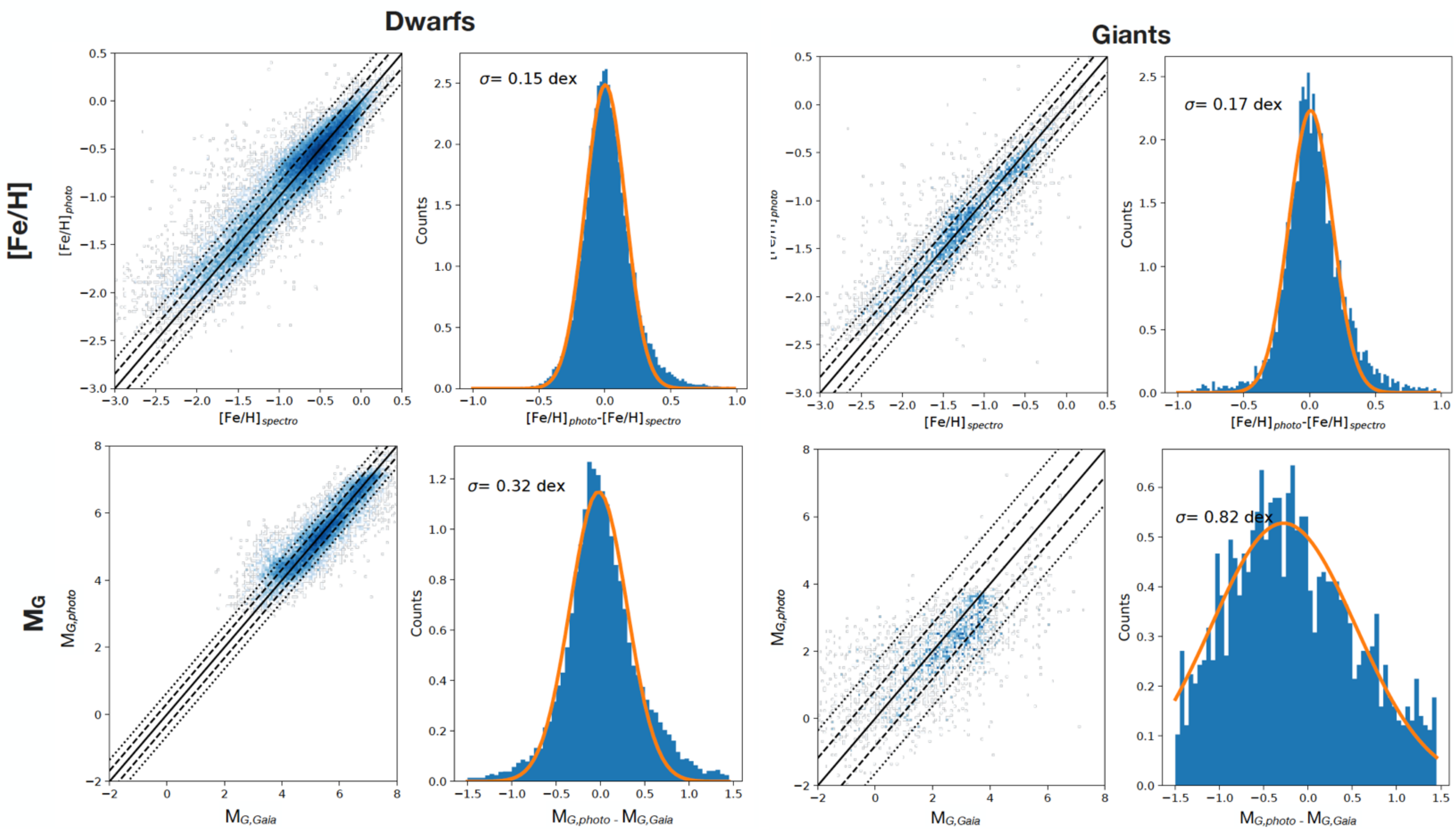
- Extending the ideas of Juric et al. and the principles of separating BHB from BS to the next level…
- Idea is to get the distance (via absolute magnitude) and metallicity for all dwarfs and giants in a photometric dataset, without knowing whether they are dwarfs or giants to begin with…
  - Use PS1 and CFIS photometry
  - Train to SDSS segue spectra for dwarfs/giants + [Fe/H]
  - Use Gaia parallaxes for absolute magnitude


Expected
Training set
Predicted
Test set
log(g)
0
1
2
3
4
5
7000
6500
6000
5500
5000
4500
4000
T$_{eff}$ (K)
P_{dwarfs}
0.0
0.2
0.4
0.6
0.8
1.0

The chemodynamics of the Galaxy, at the faint end of the Milky Way

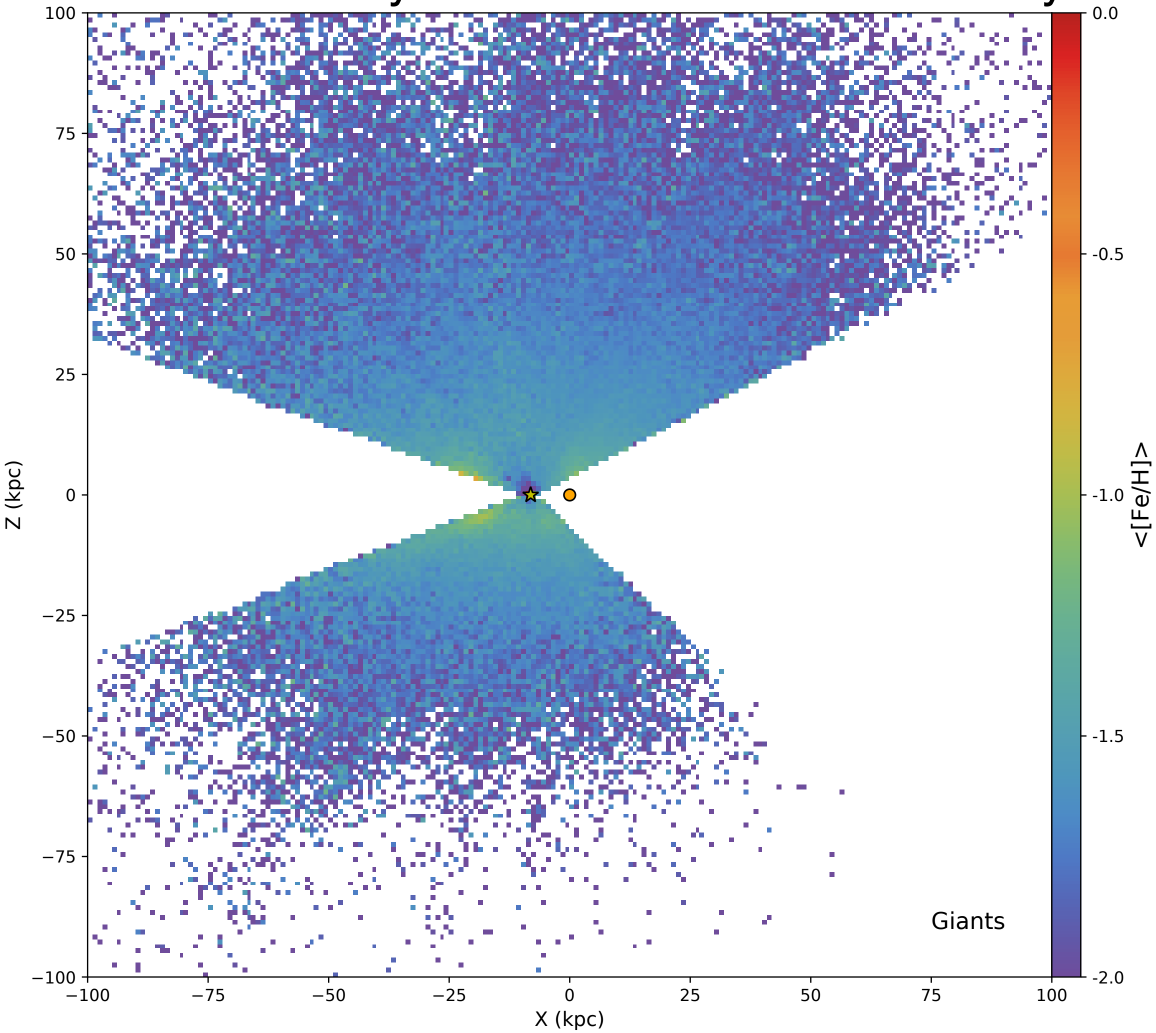


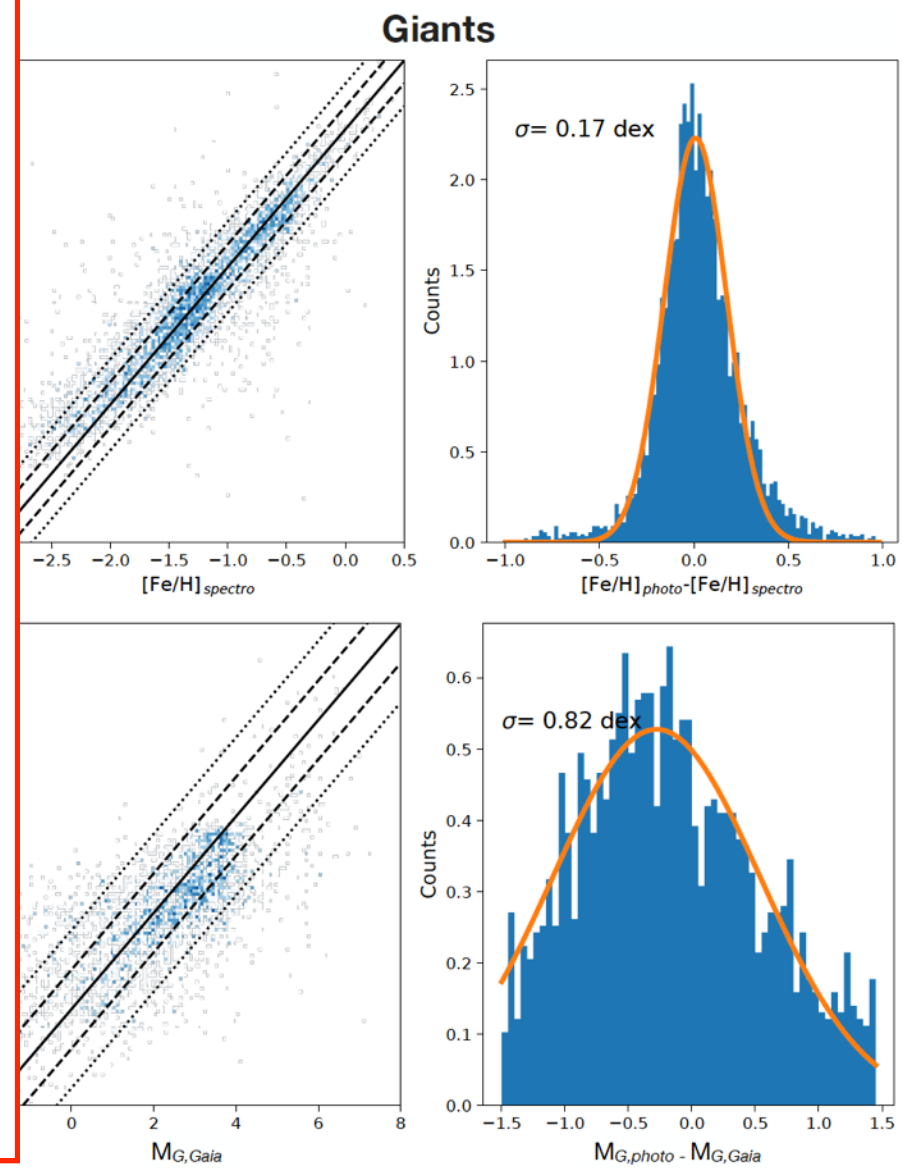
The chemodynamics of the Galaxy, at the faint end of the Milky Way



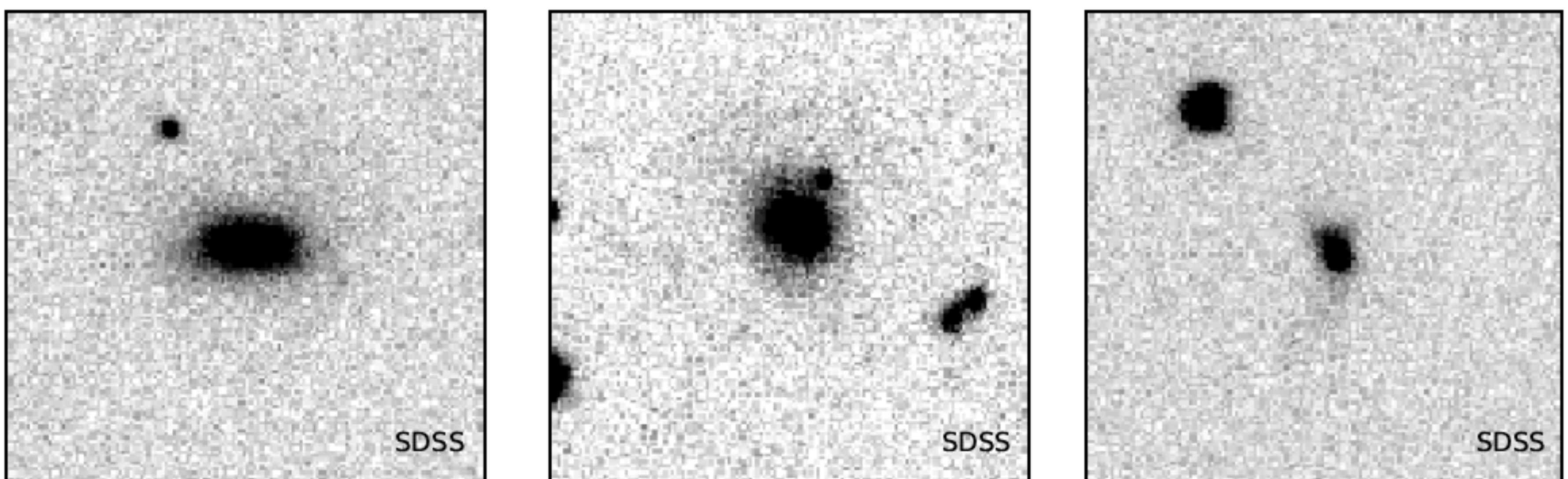
The chemodynamics of the Galaxy, at the faint end of the Milky Way

The metallicity structure of the outer Galaxy

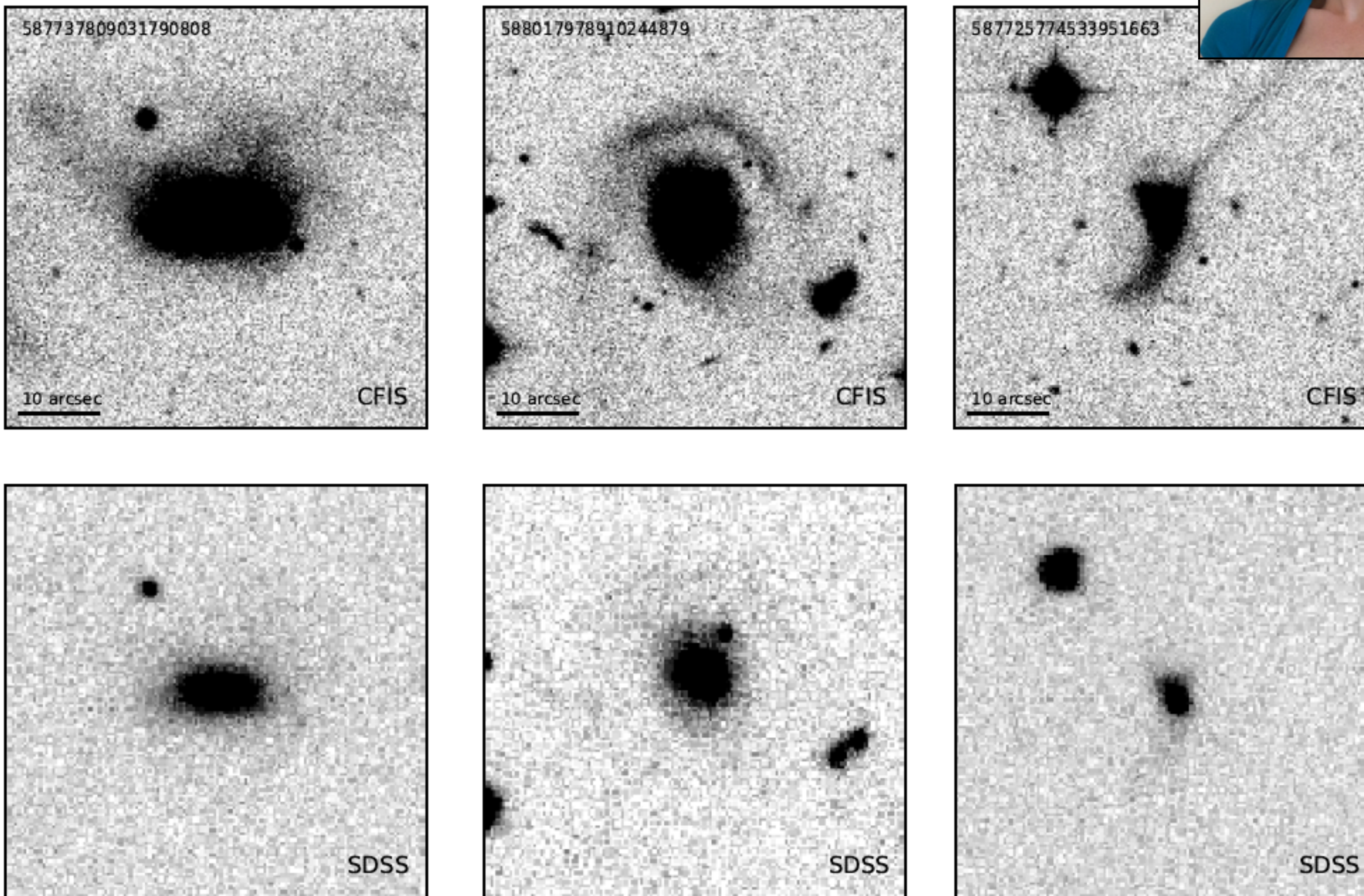




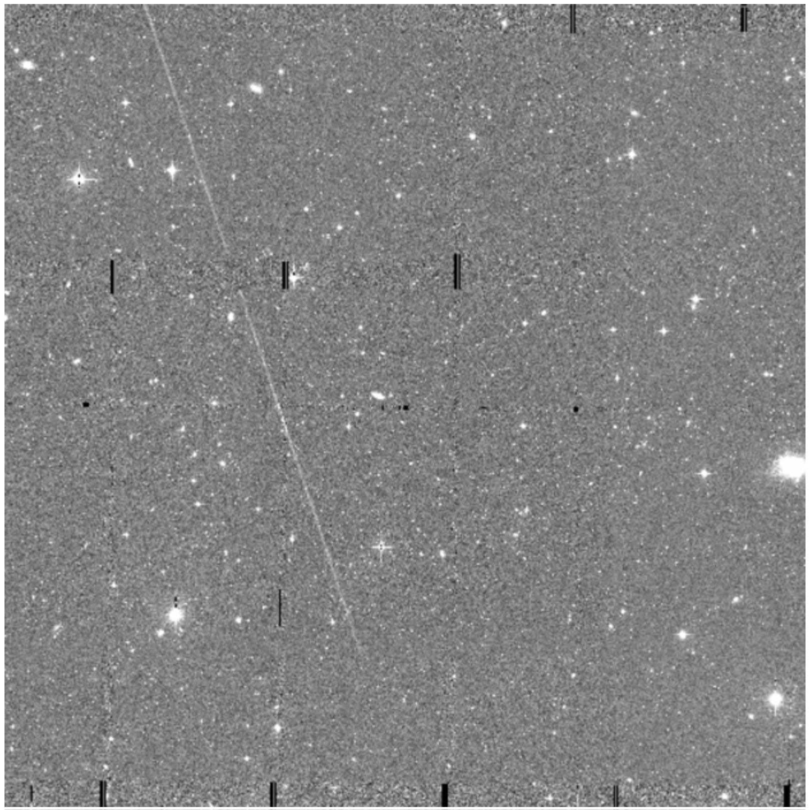
Mergers and the triggering of AGN



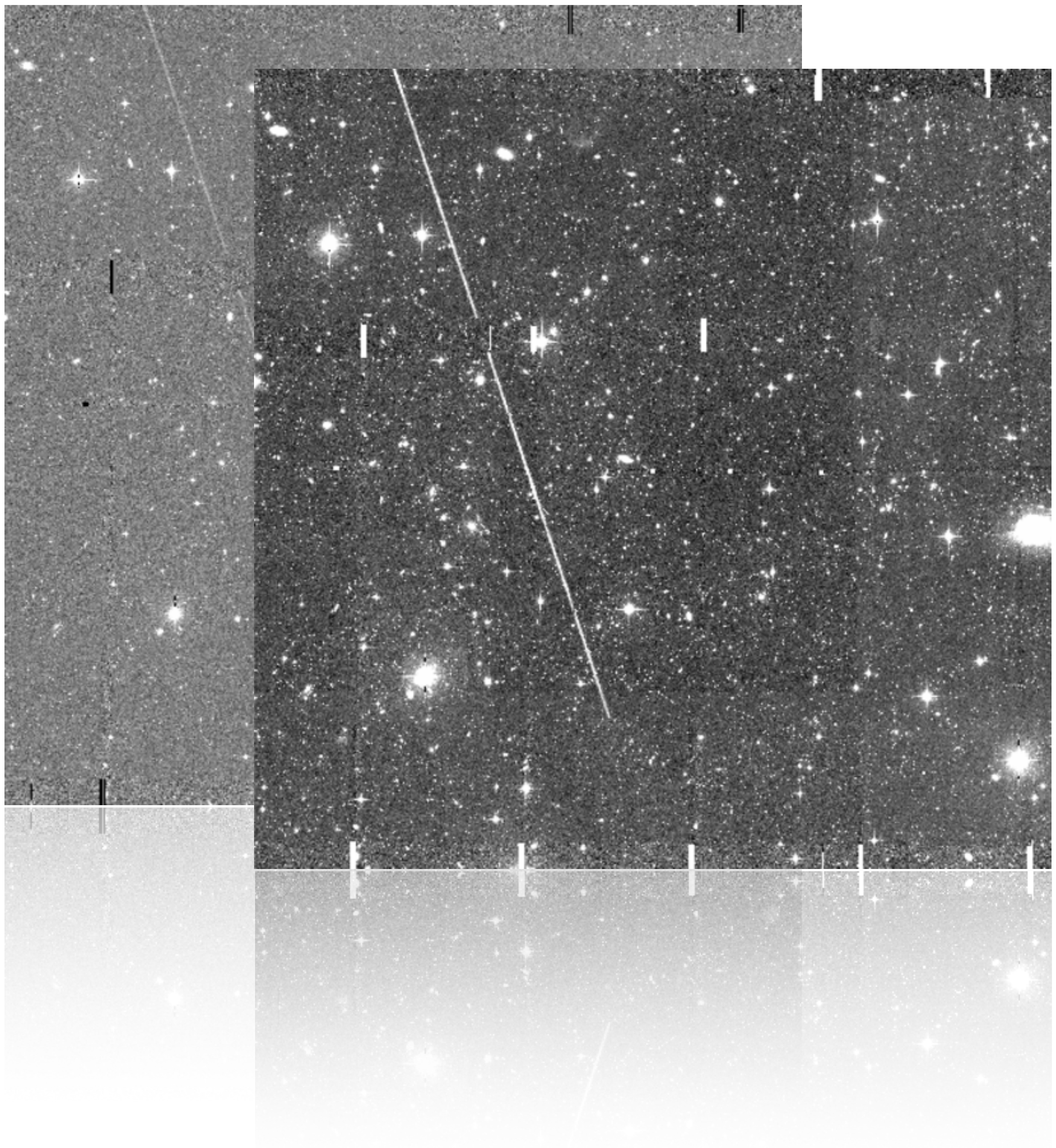
Mergers and the triggering of AGN



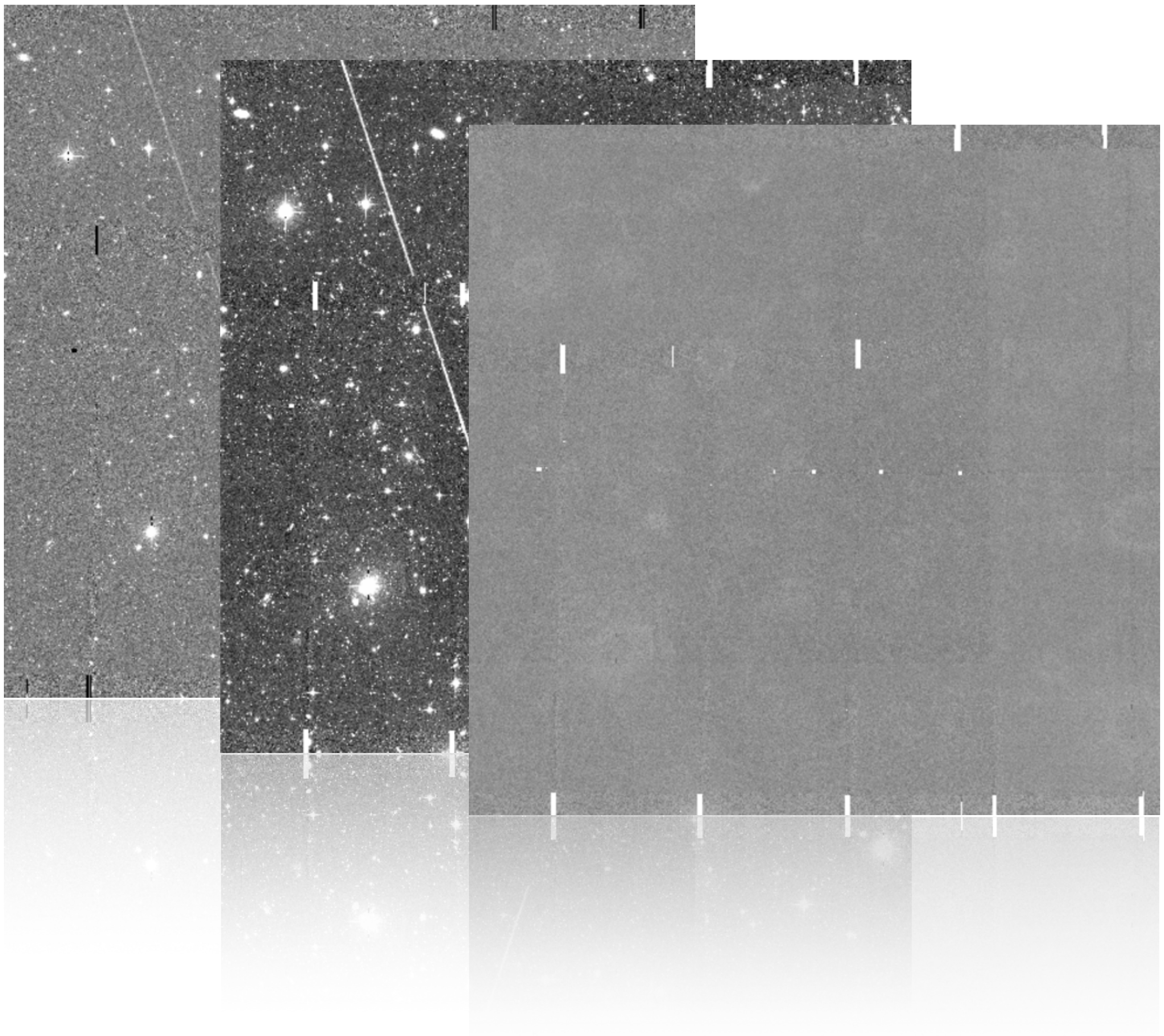
A Universe of ultra-diffuse galaxies



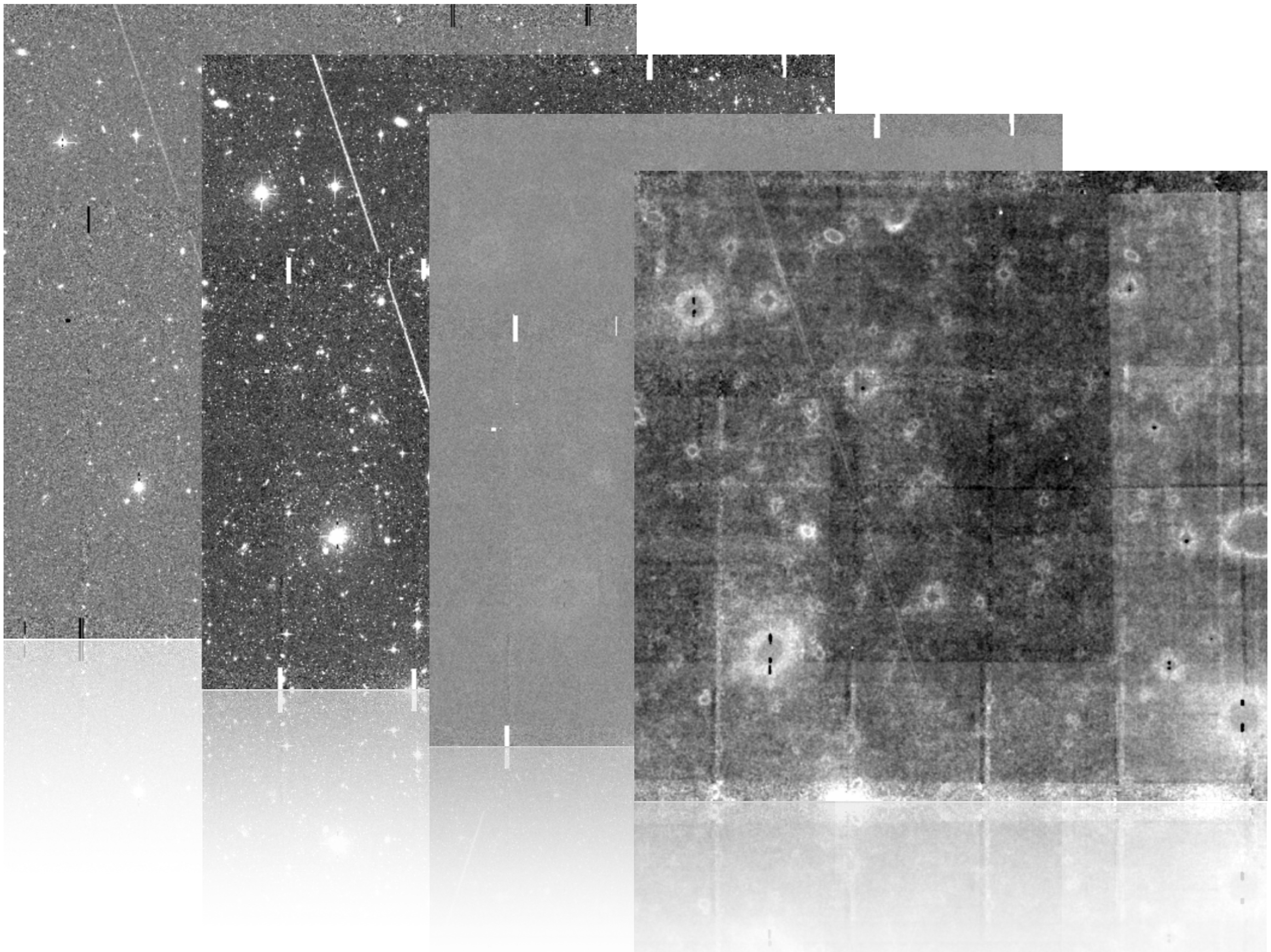
A Universe of ultra-diffuse galaxies



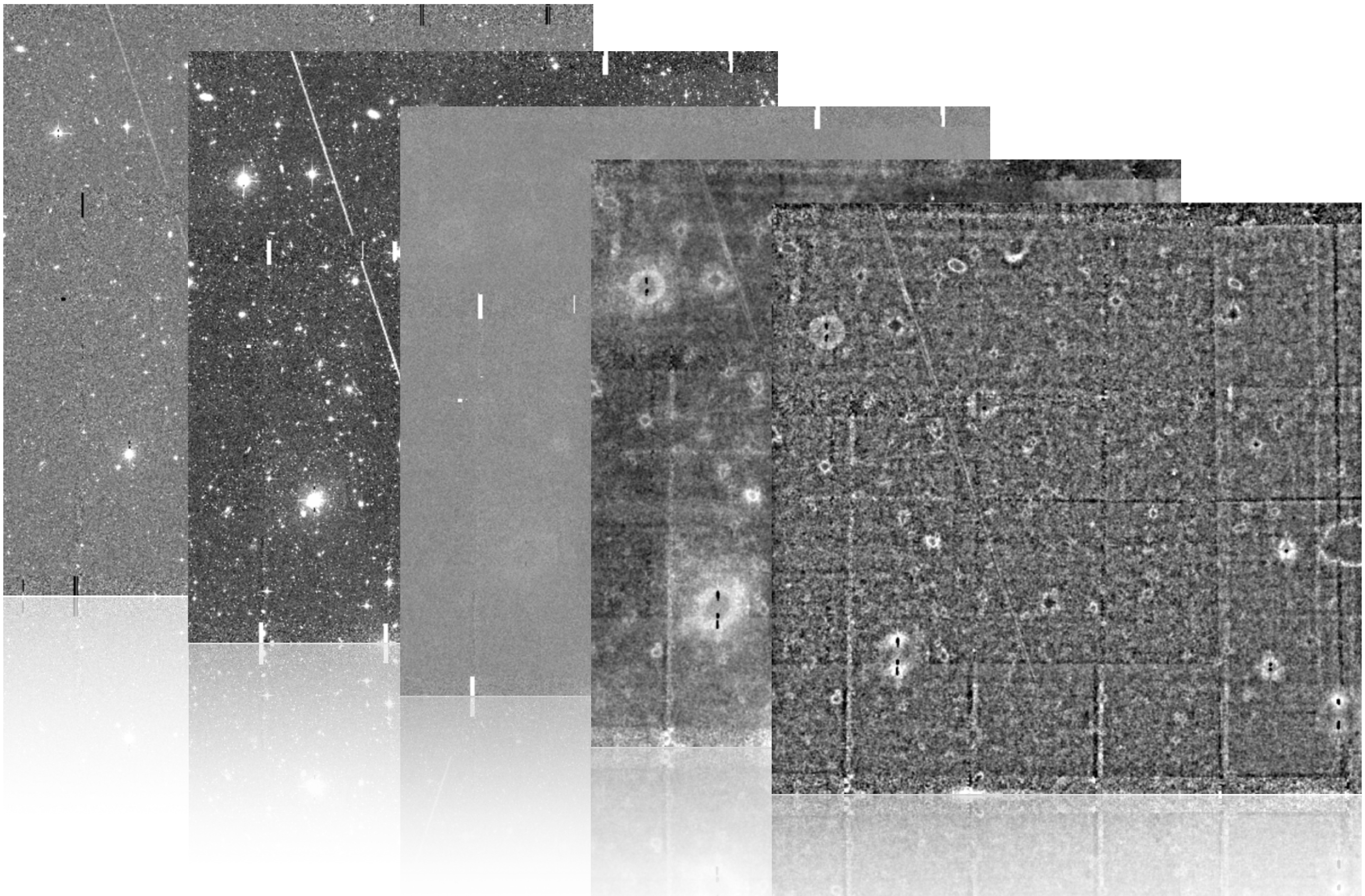
A Universe of ultra-diffuse galaxies



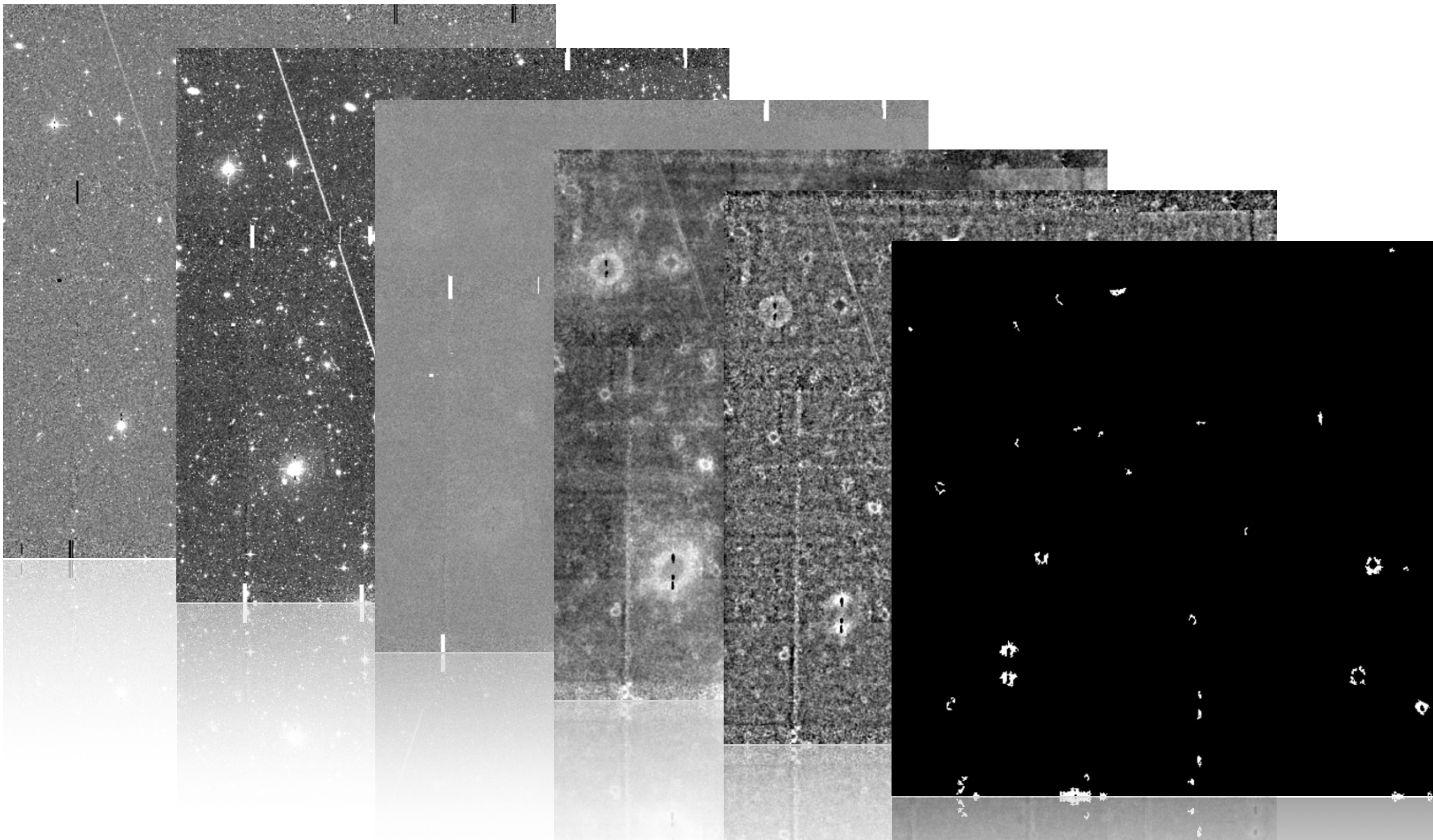
A Universe of ultra-diffuse galaxies

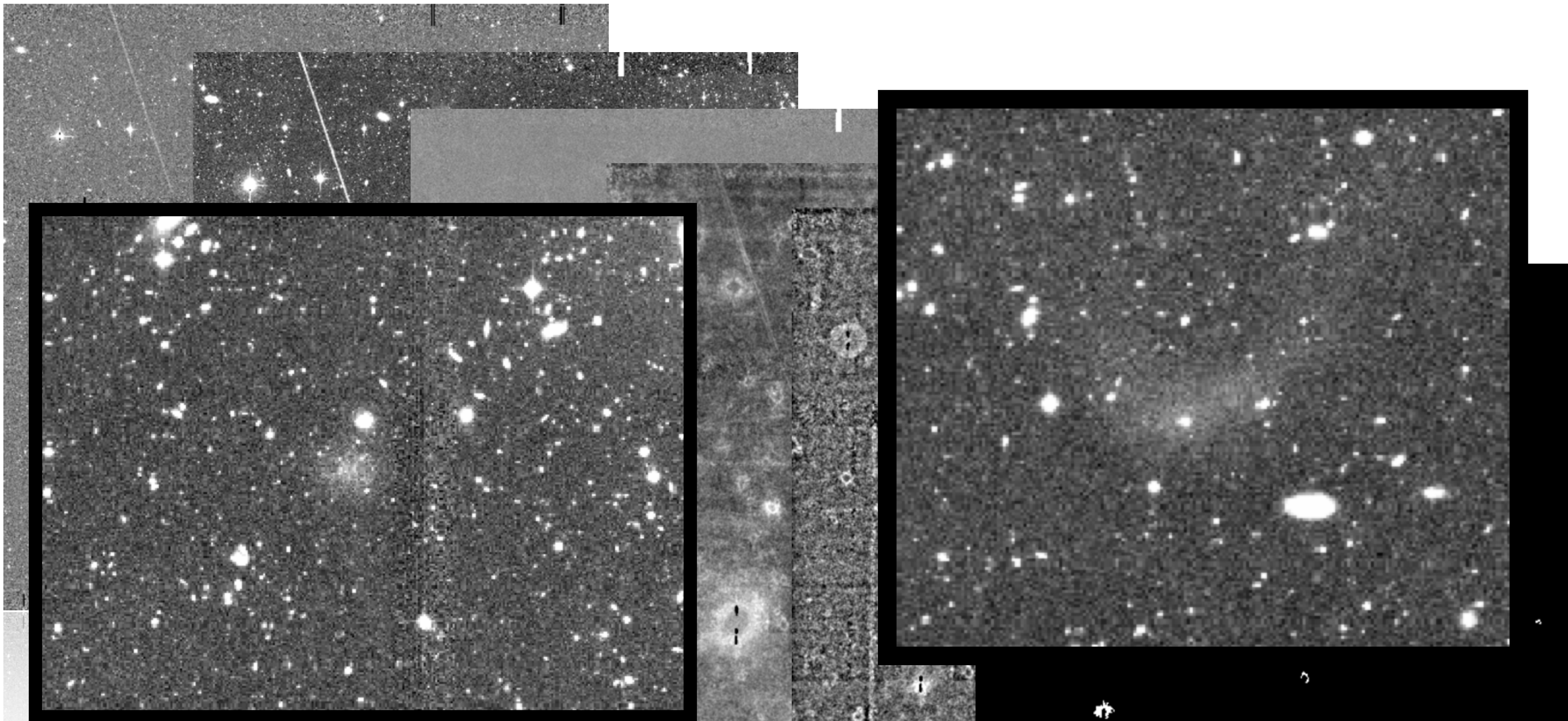


A Universe of ultra-diffuse galaxies



A Universe of ultra-diffuse galaxies





This is one tile out of a current total of 11,620 in an unbiased survey of the sky…

CFIS publications

Jensen, J., et al., 2019/2020, MNRAS, in preparation
A-type stars in the Canada-France Imaging Survey III. The hierarchical structure of the Milky Way's stellar halo

Thomas, G. F., Annau, N., et al., 2019, MNRAS, to be submitted
The estimation of stellar parameters with the Canada-France Imaging Survey

Fantin N. et al. 2019, MNRAS, to be submitted
The Canada France Imaging Survey VI: Reconstructing the Milky Way using its stellar graveyard

Ellison, S., et al. 2019, MNRAS, in press
A definitive merger-AGN connection at z ~ 0 with CFIS: mergers have an excess of AGN and AGN hosts are more frequently disturbed

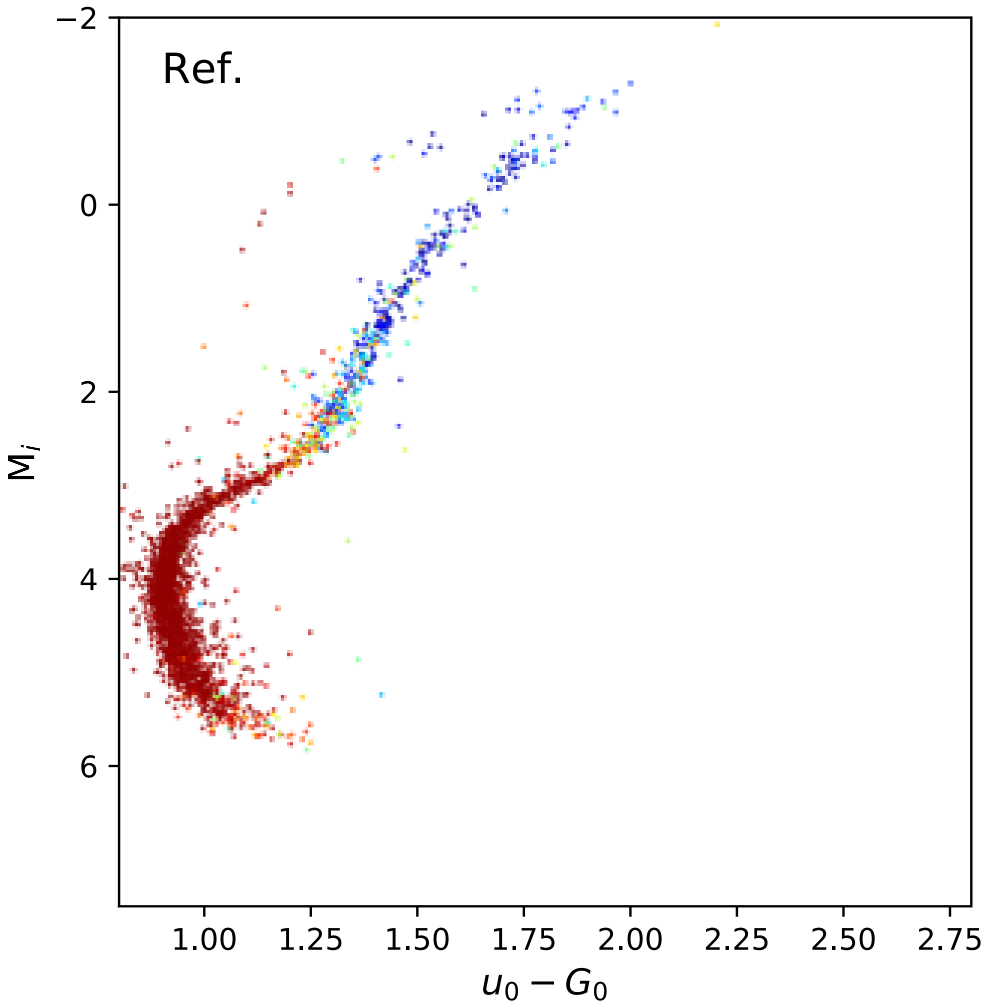
Thomas, G. F., Laporte, C. F. P. et al. 2019, MNRAS, 483, 3
A-type stars in the Canada-France Imaging Survey - II. Tracing the height of the disc at large distances with Blue Stragglers

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

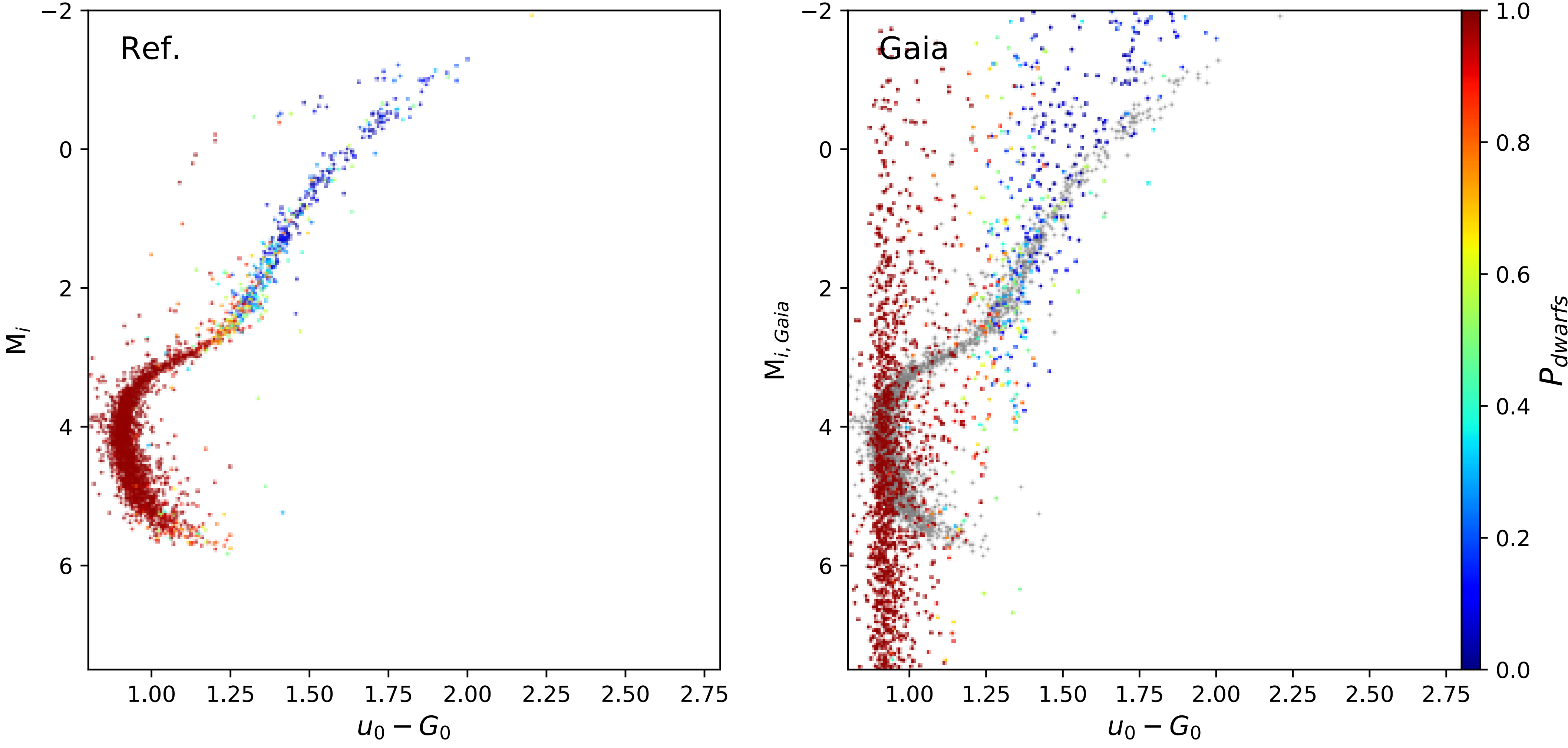
Ibata, R. et al., 2017, ApJ, 848, 2, 129
Chemical Mapping of the Milky Way with The Canada-France Imaging Survey: A Non-parametric Metallicity-Distance Decomposition of the Galaxy

Ibata, R. et al. 2017, ApJ, 848, 2, 128
The Canada-France Imaging Survey: First Results from the u-Band Component

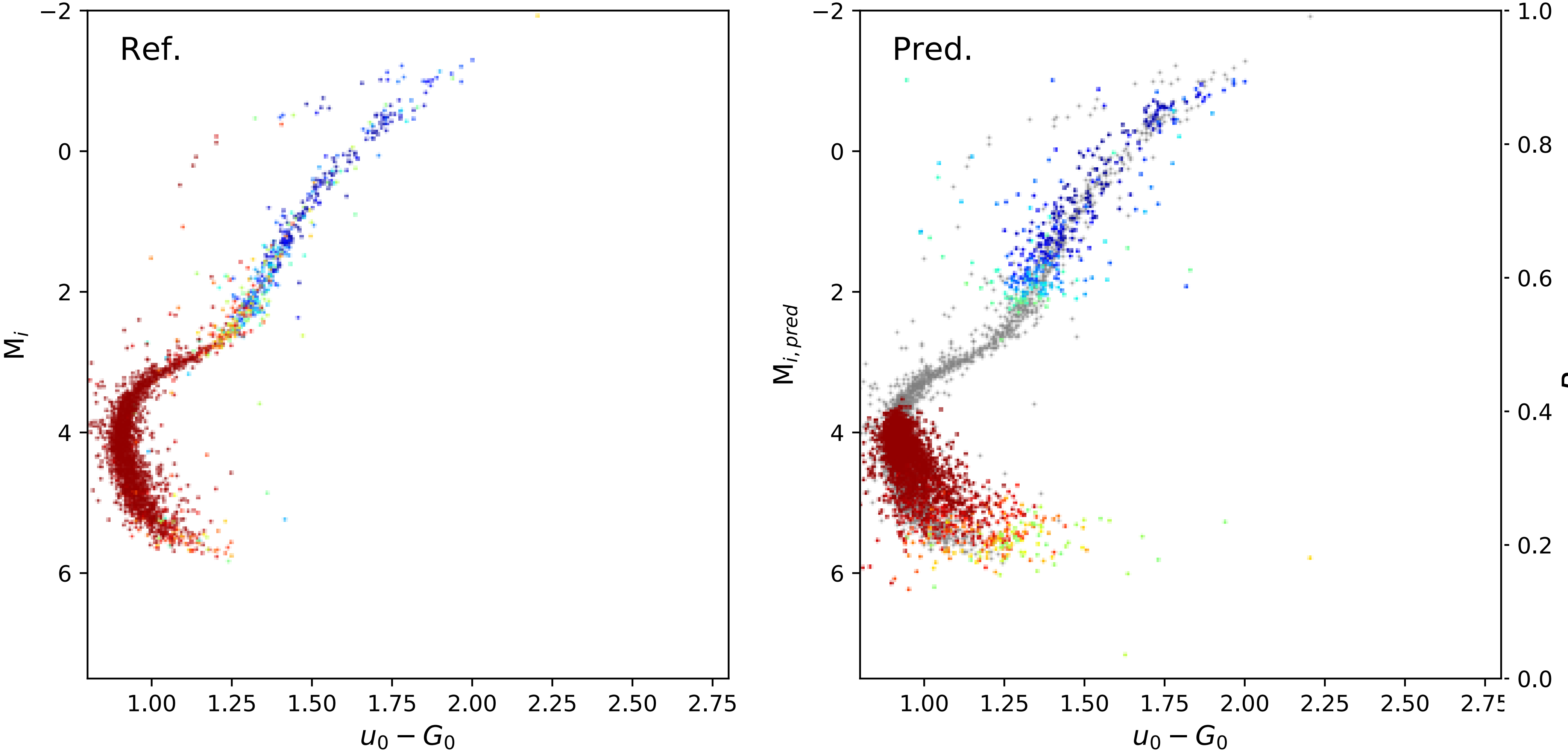
NGC6341 (M92): 8.3kpc

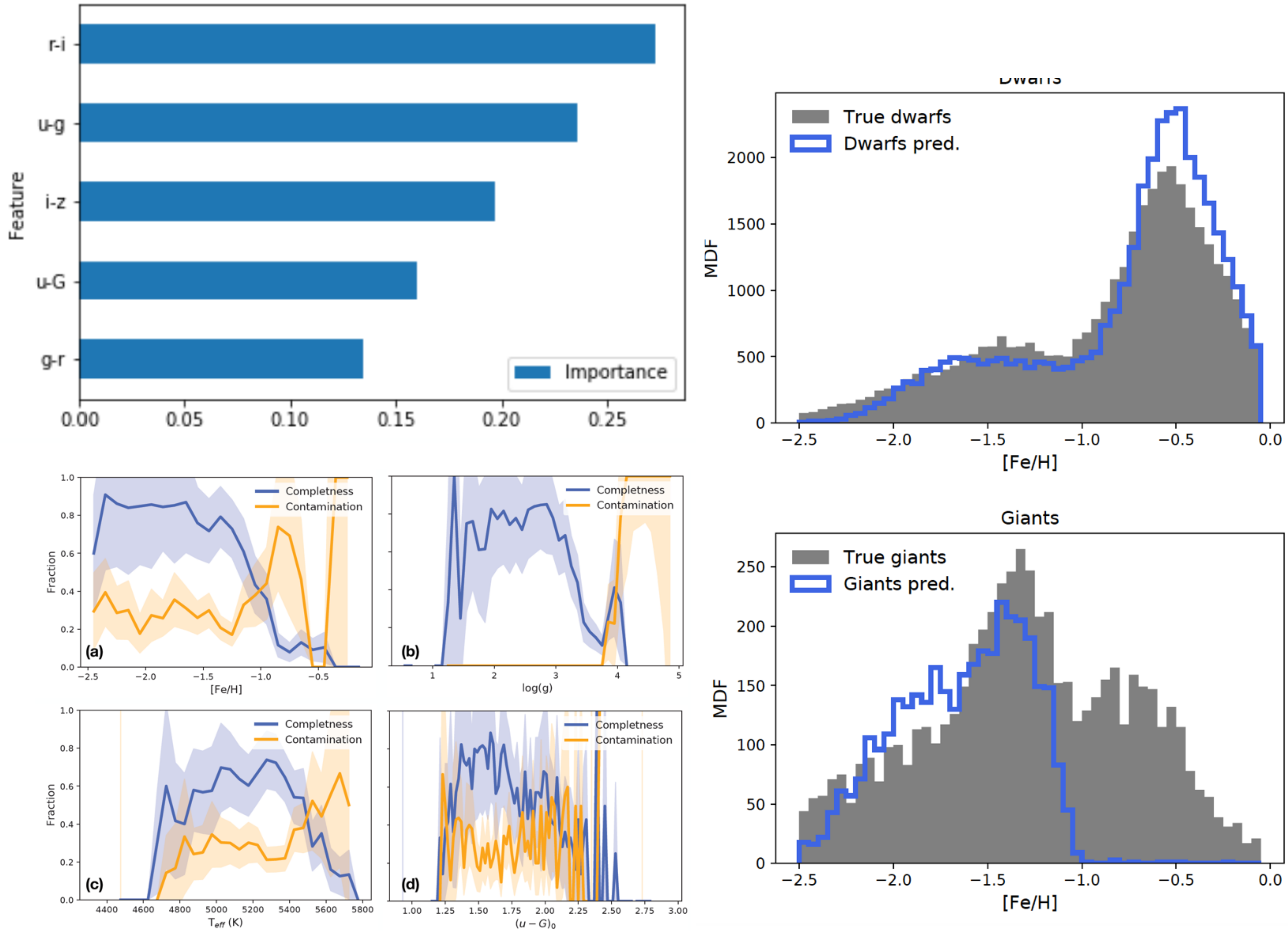


NGC6341 (M92): 8.3kpc



NGC6341 (M92): 8.3kpc




Feature
r-i
u-g
i-z
u-G
g-r
Importance
0.00
0.05
0.10
0.15
0.20
0.25
Dwarfs
True dwarfs
Dwarfs pred.
MDF
[Fe/H]
Giants
True giants
Giants pred.
MDF
[Fe/H]
Completness
Contamination
Fraction
(a)
[Fe/H]
(b)
log(g)
(c)
T_{eff} (K)
(d)
$(u-G)_0$