Substellar science with the Euclid space telescope







Maruša Žerjal
and the Substellar team











SUBSTELLAR

Substellar Science with EUCLID Space Mission

PRESENTATION

CHALLENGES

GROUP MEMBERS



GROUP MEMBERS

Independent Legacy Scientist team in Euclid

https://research.iac.es/proyecto/substellar/

SUBSTELLAR Research Team at IAC

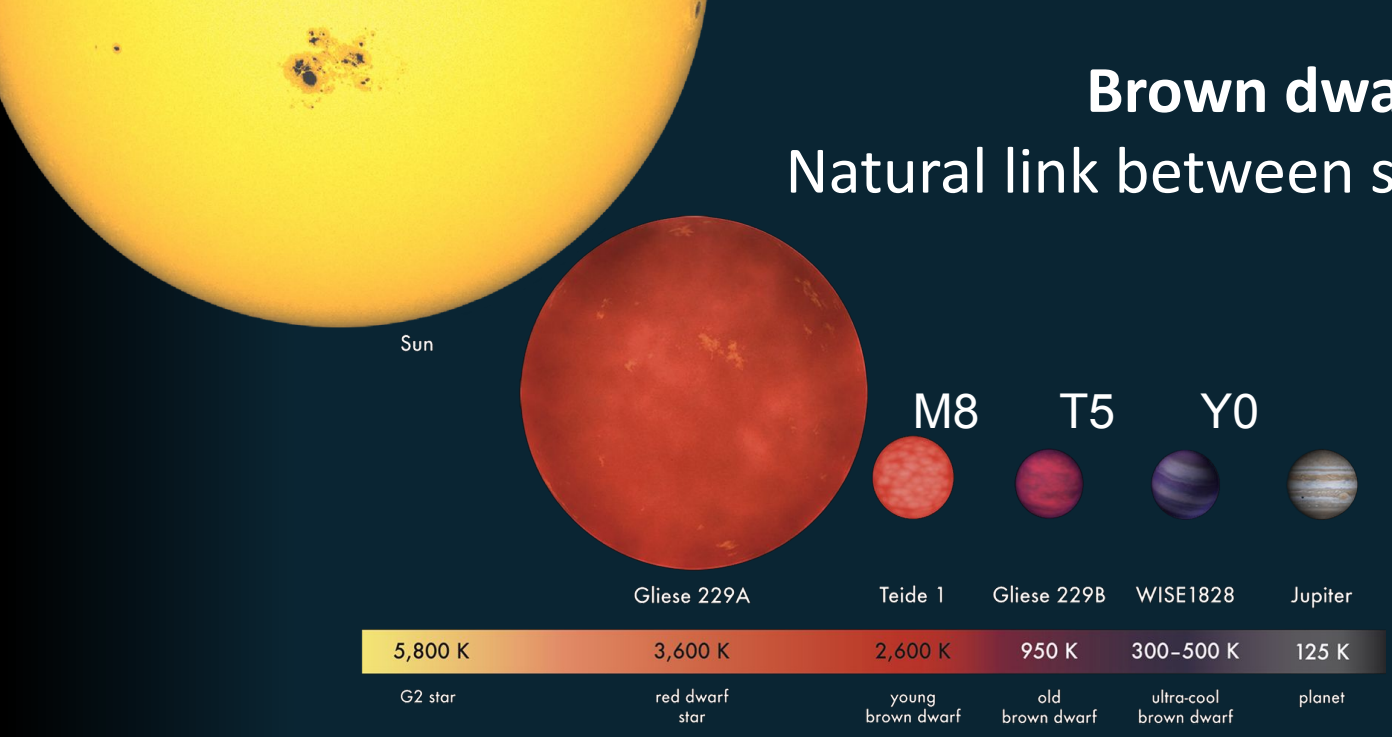
- Prof Eduardo L. Martín , Principal Investigator
- Dr Nicolas Lodieu
- Dr Víctor Sánchez Béjar
- Dr Marusa Zerjal , Postdoctoral Researcher
- Dr Khalid Barkaoui, Postdoctoral Researcher
- Dr Carlos Domínguez Tagle, Postdoctoral Researcher
- Dr Nikola Vitas, Postdoctoral Researcher
- MSc Stella Tsilia, Predoctoral Researcher
- MSc Sara Muñoz Torres, Predoctoral Researcher
- MSc Nafise Sedighi, Predoctoral Researcher
- MSc Jun-Yan Zhang (Jerry), Predoctoral Researcher → Now a postdoc in Canada
- Dr Alberto M. Escobar , Project Manager

Outline of the talk

- Brown dwarfs
- Euclid space telescope
- First ultracool dwarfs with Euclid in Q1
- Early Release Observations
- Ultracool science with Euclid

Brown dwarfs

Natural link between stars & planets



STELLAR DOMAIN

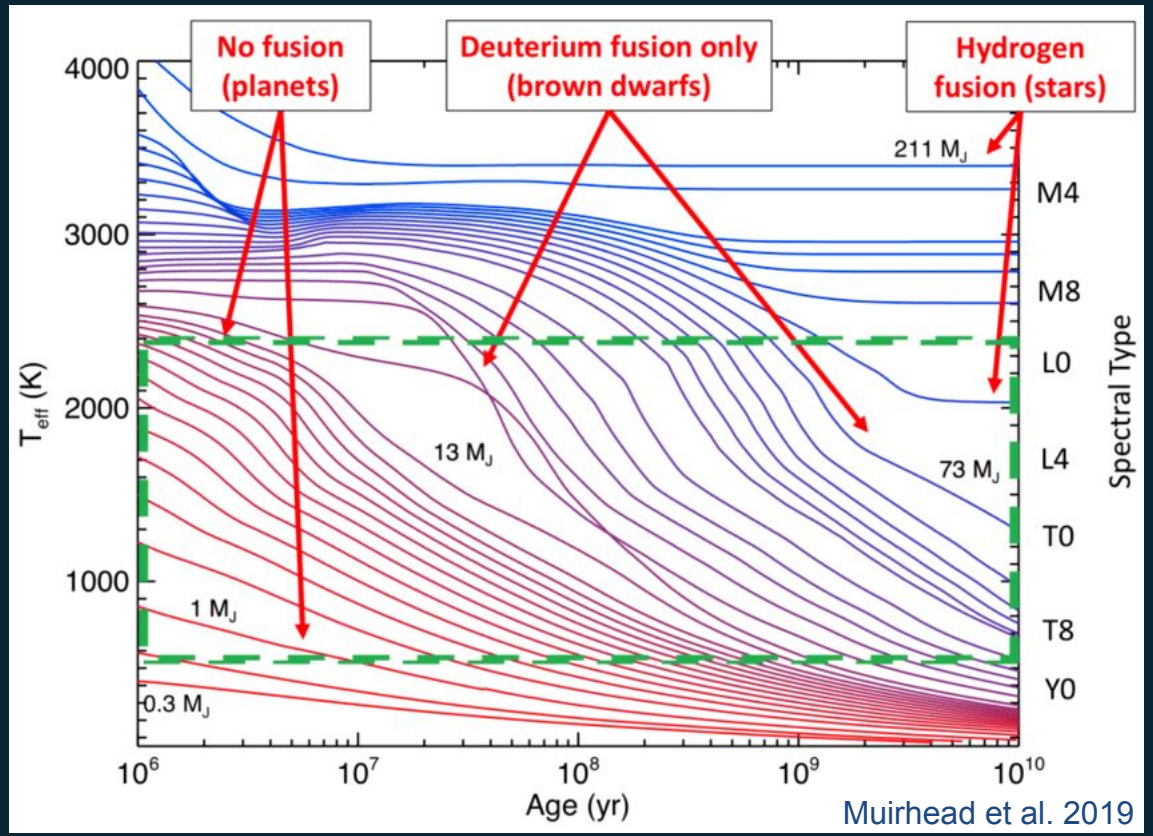
SUBSTELLAR DOMAIN

Ultracool > *Infrared*

Small > *Faint*

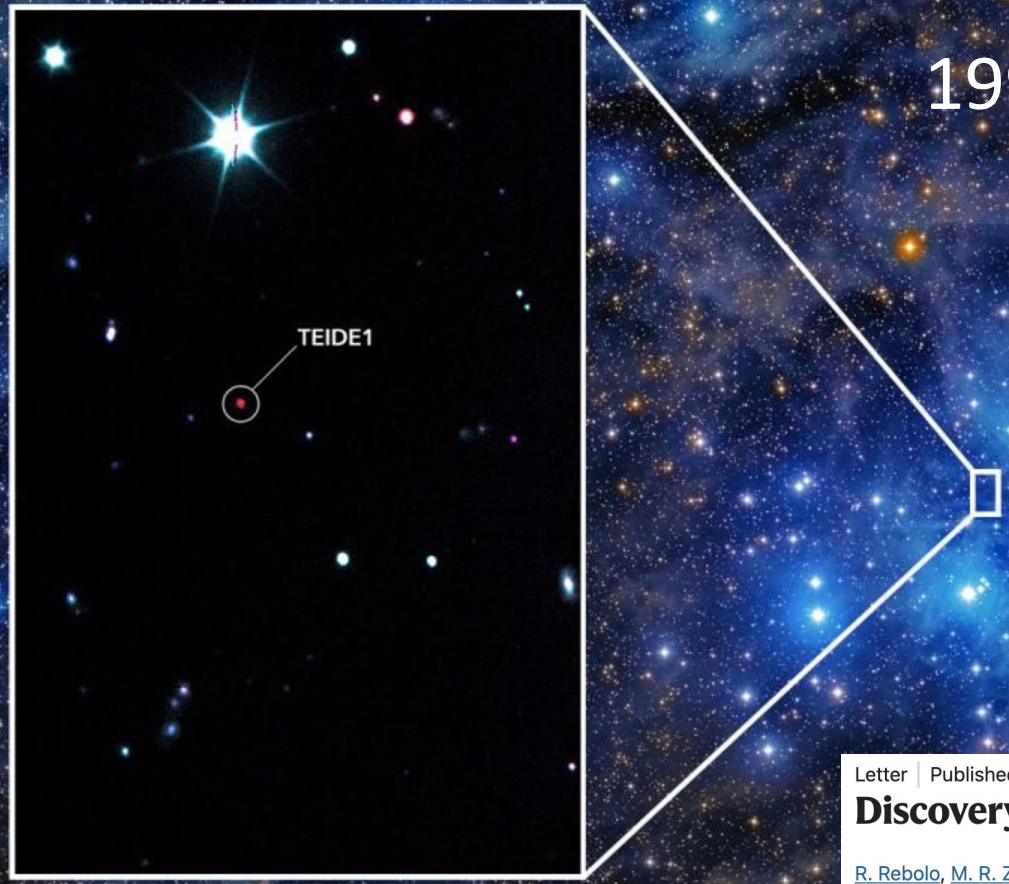
Slide credit: Eduardo Martín

Prediction: Shiv Kumar in the 1960s



Muirhead et al. 2019

1995: First brown dwarf discovered

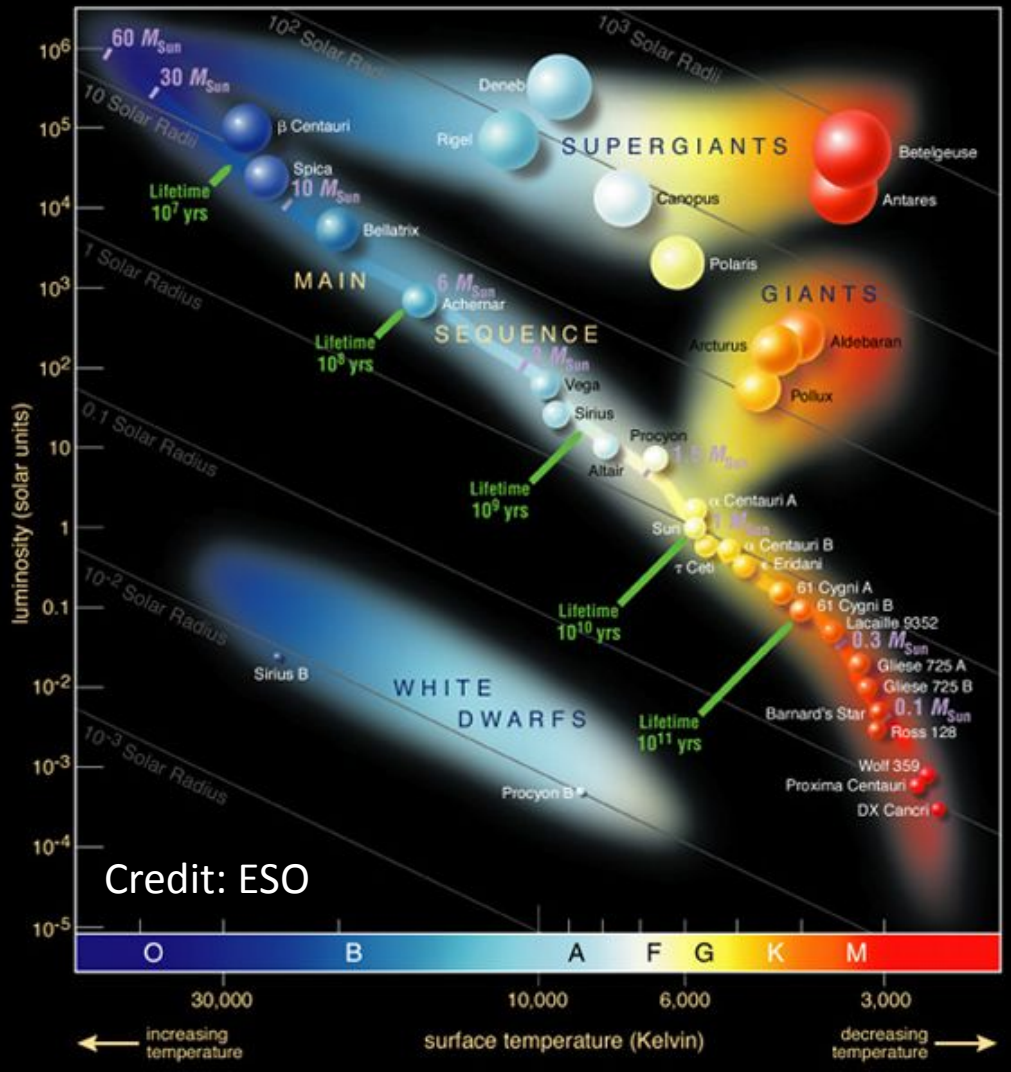


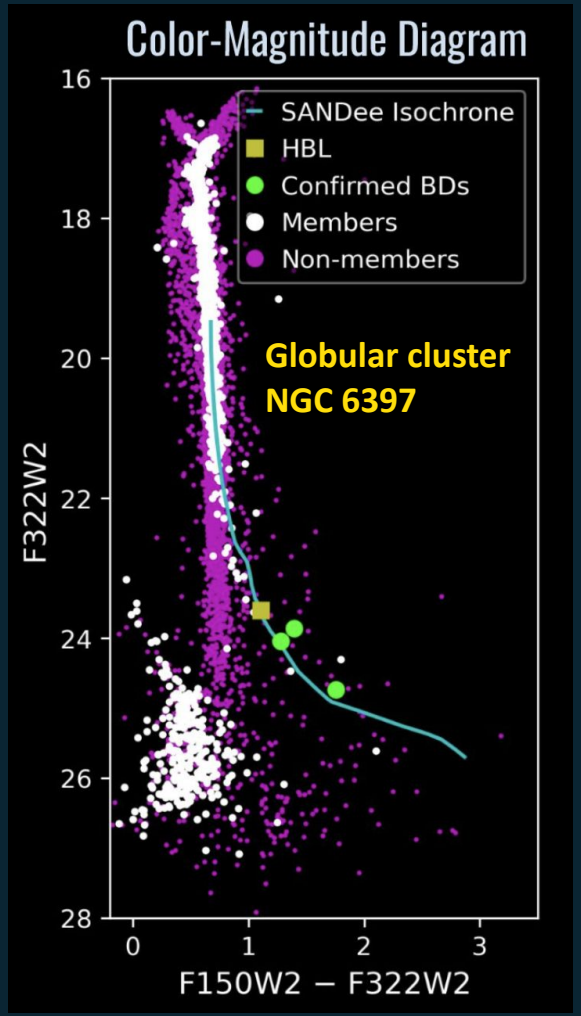
Letter | Published: 14 September 1995

Discovery of a brown dwarf in the Pleiades star cluster

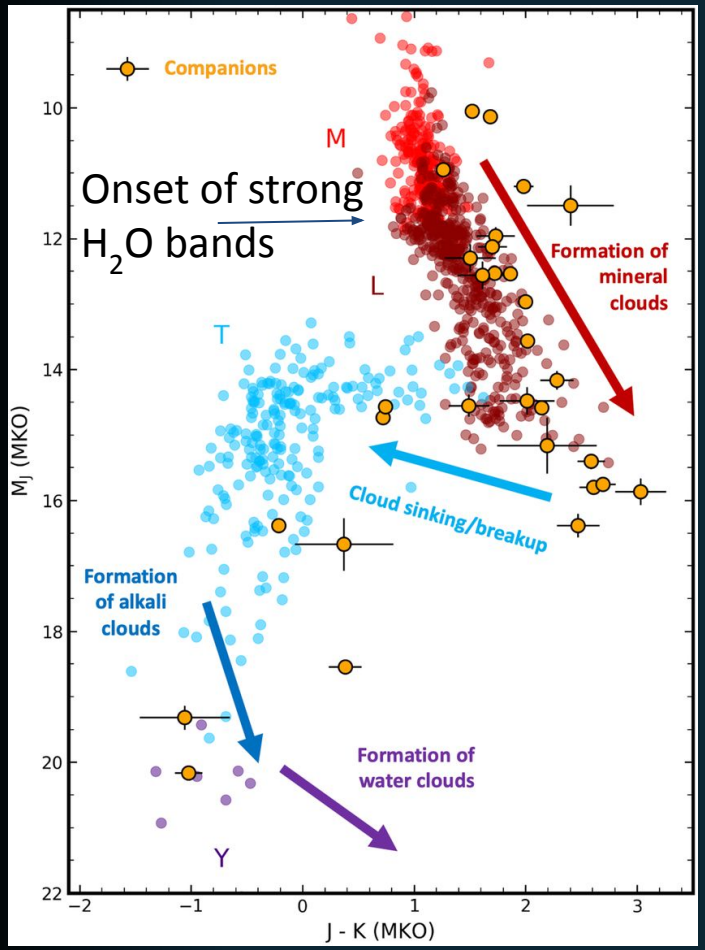
R. Rebolo, M. R. Zapatero Osorio & E. L. Martín

Nature **377**, 129–131 (1995) | Cite this article





R. Gerasimov at al.
poster at Cool Stars 22



Clouds



Gao et al. 2021
2021JGRE..12606655G

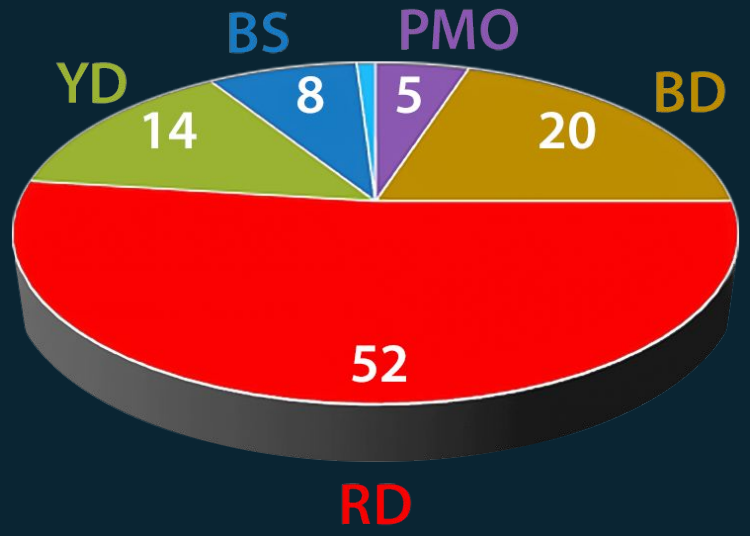
SOLAR VICINITY CENSUS

substellar objects

1994: **0** %

⋮

2022: **25** %



Within 100 pc: Red Dwarfs 52%, Substellar objects 25%, Yellow dwarfs 14%, Blue Stars 8% Evolved Stars 1%

Slide credit: Eduardo Martín

Catalogue of ultracool dwarfs

Ultracool dwarf (UCD): cooler than 2700K

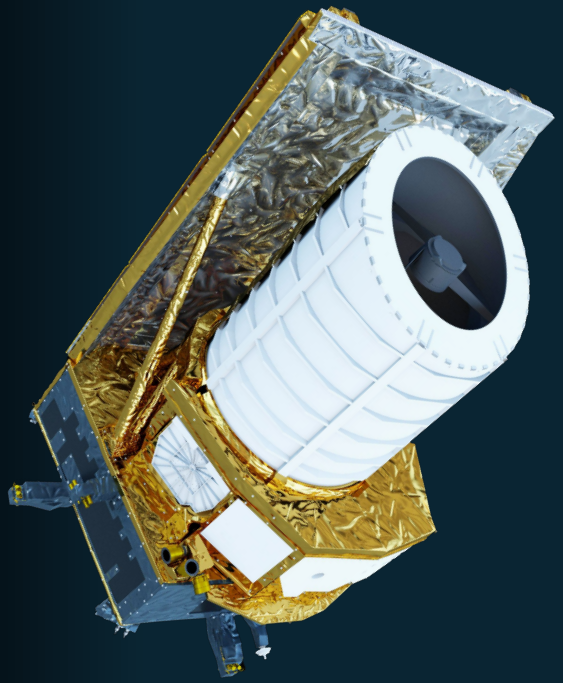
The UltracoolSheet: 3891 confirmed UCDs (8 March 2026)

x 2

exoplanet.eu: 8030 extrasolar objects (8 March 2026)

Dark Energy Survey data: ~19,000 UCD candidates, Dal Ponte+2023

THE APPROACH



EUCLID

Wide-field telescope
1.2 m diameter primary mirror

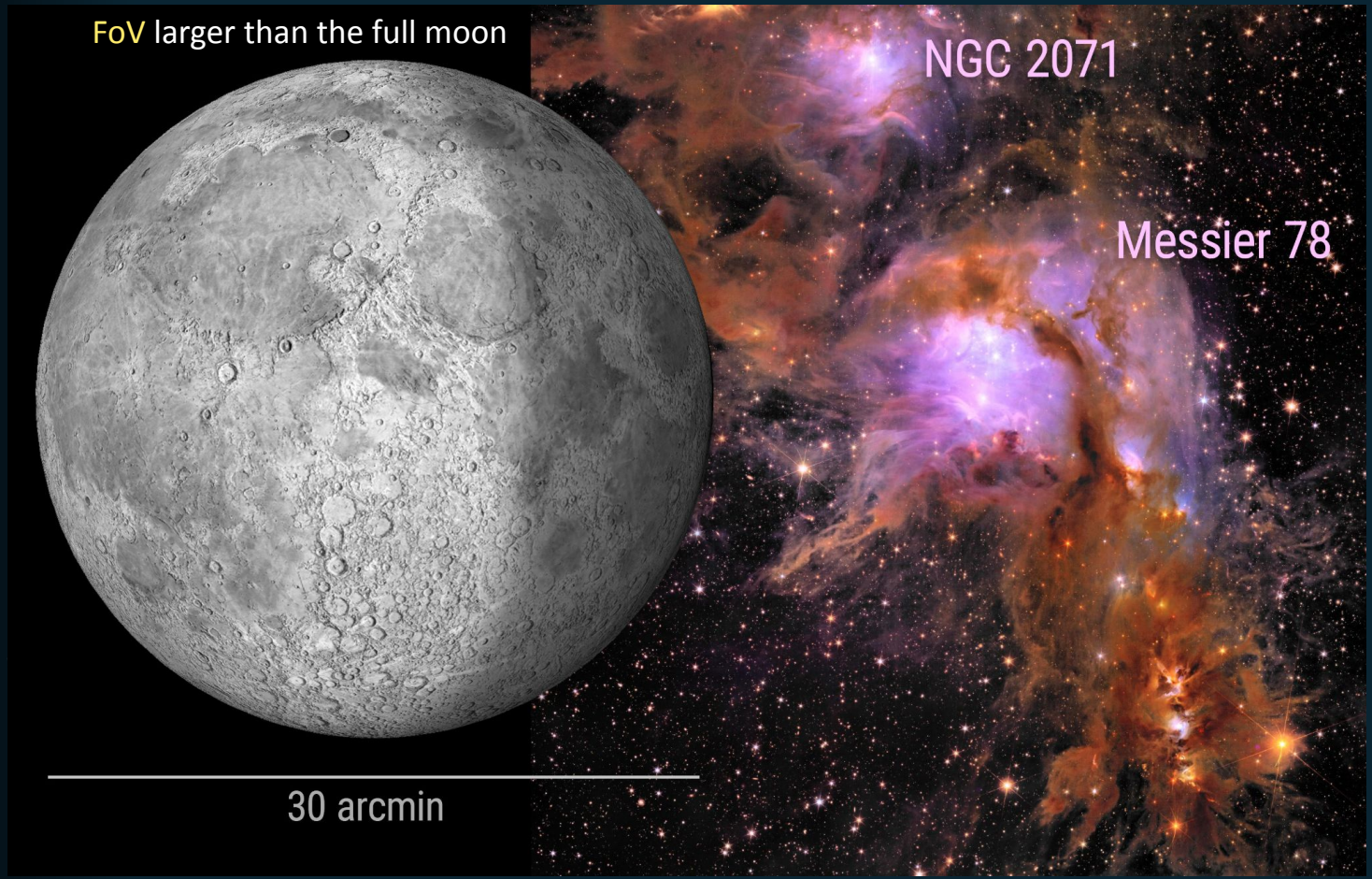
Diffraction limited

Visual Imager
0.55 - 0.9 μm band

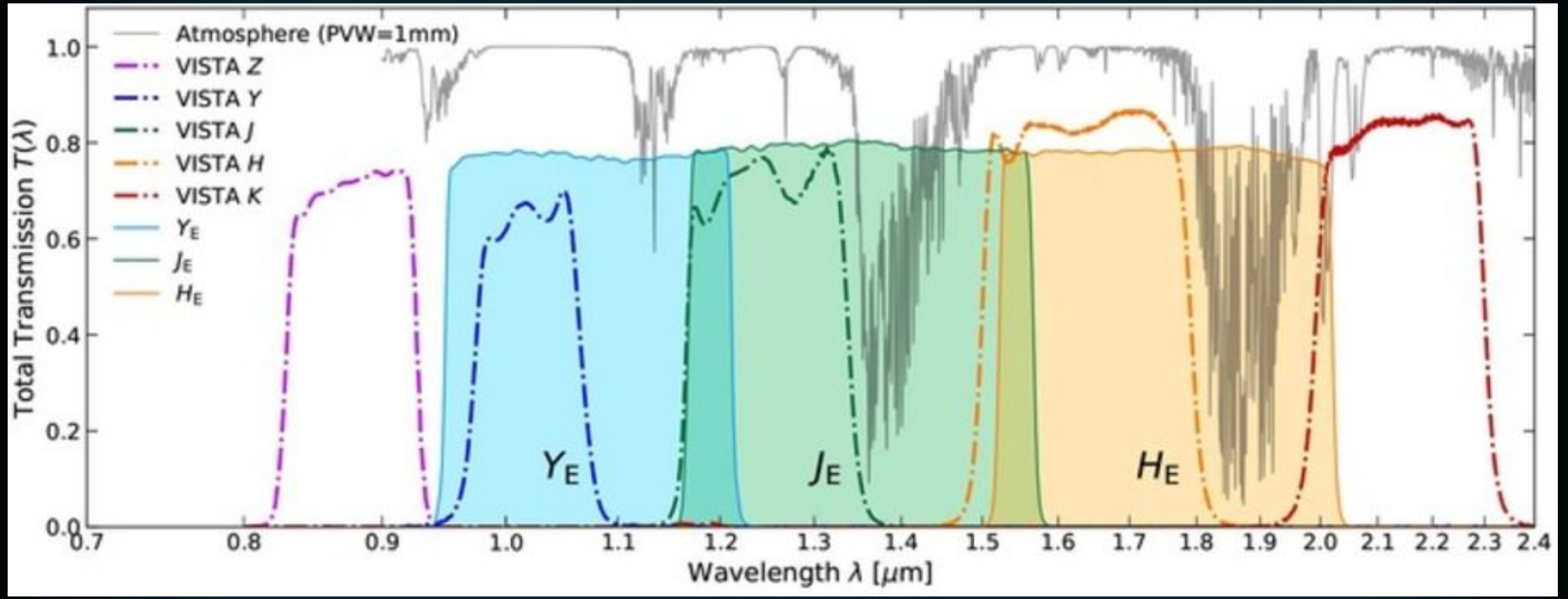
Near-Infrared
Photometric Imager Y, J, H
GRISM Spectrometer 1.25 - 1.85 μm

LAUNCH
July 2023
6 year nominal survey

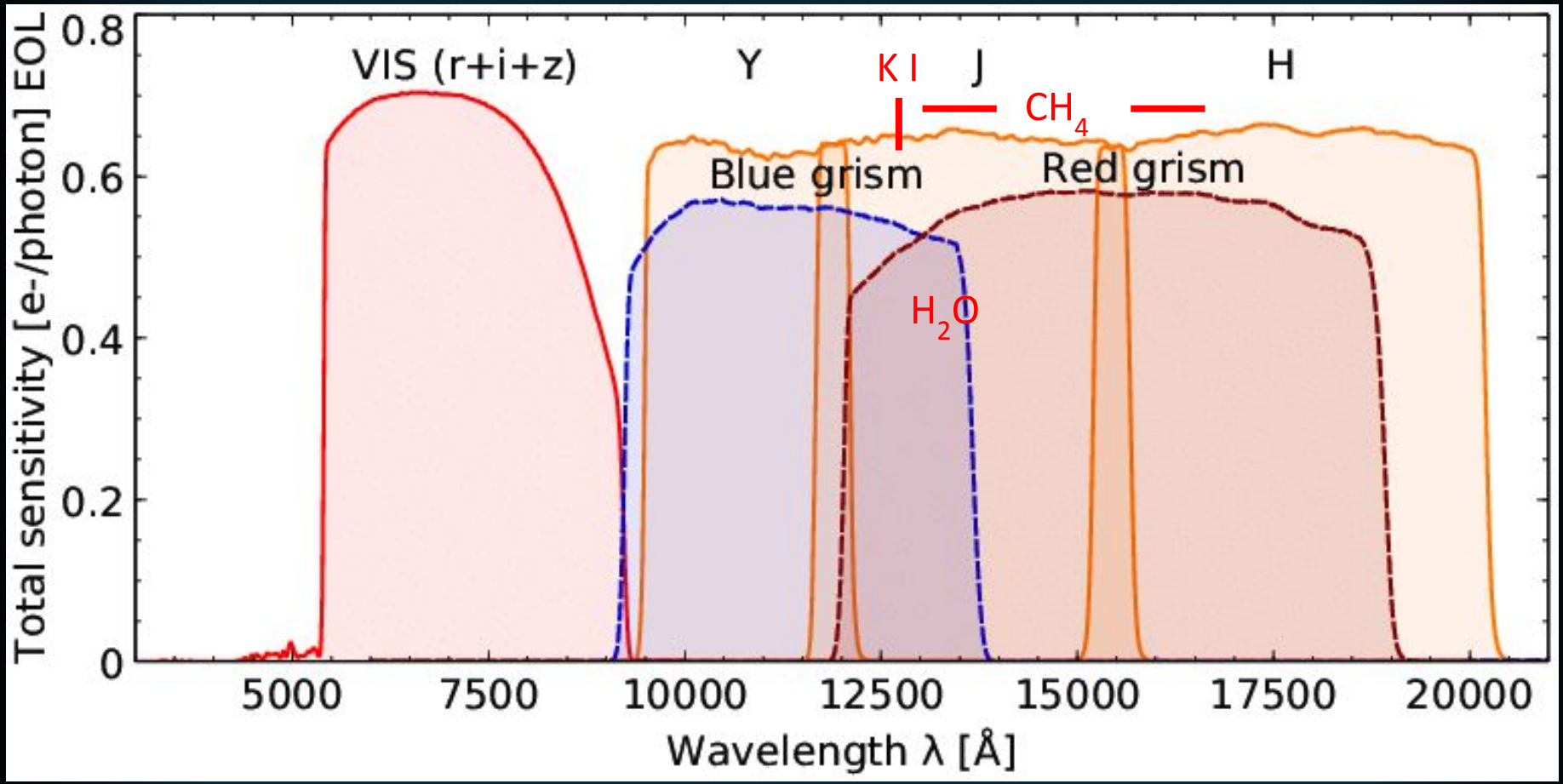
Start of the nominal observations: February 2024


FoV larger than the full moon
NGC 2071
Messier 78
30 arcmin

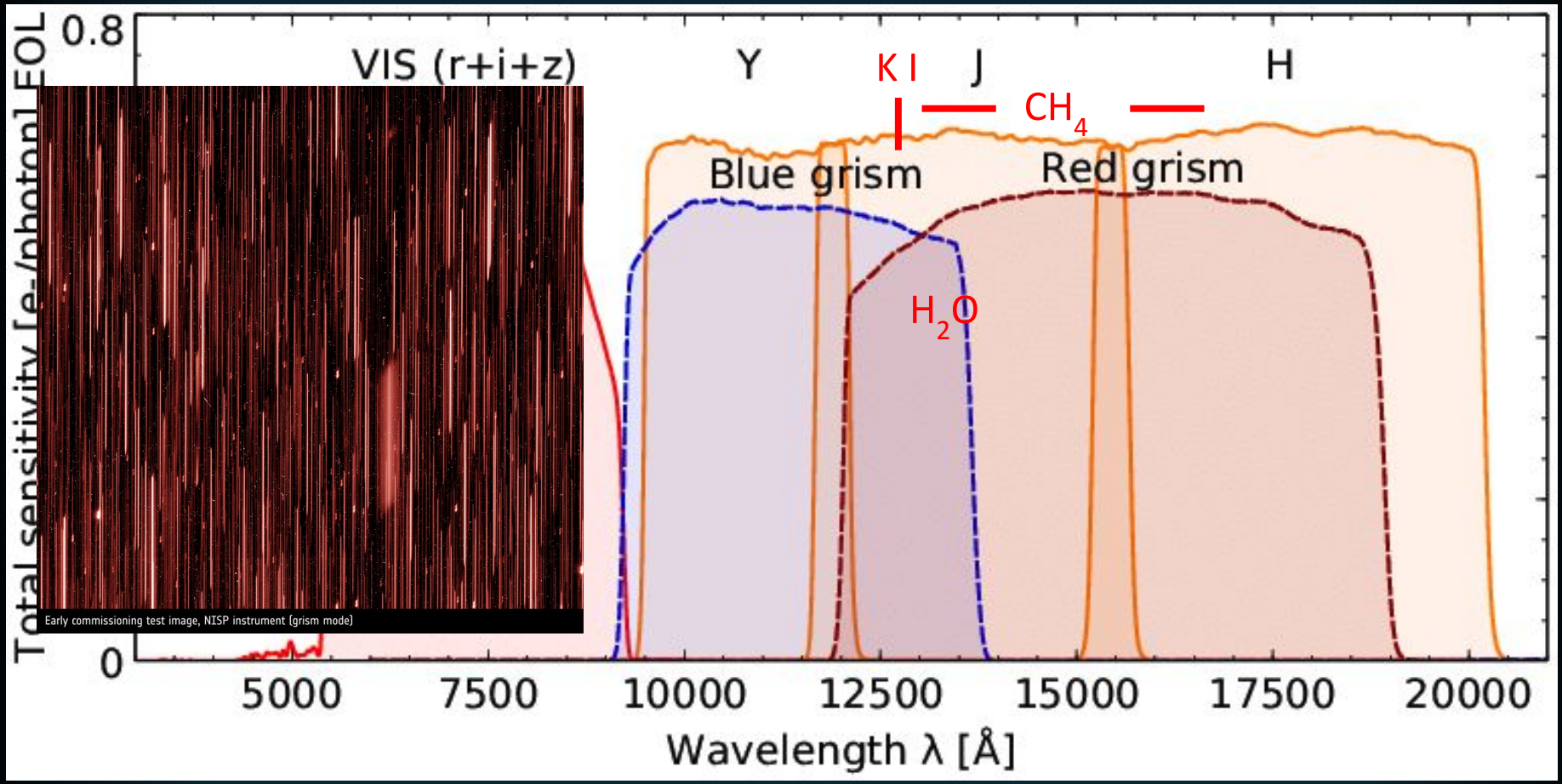
NISP


Atmosphere (PVW=1mm)
VISTA Z
VISTA Y
VISTA J
VISTA H
VISTA K
Y_E
J_E
H_E
Total Transmission $T(\lambda)$
Wavelength λ [μm]
0.0
0.2
0.4
0.6
0.8
1.0
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4

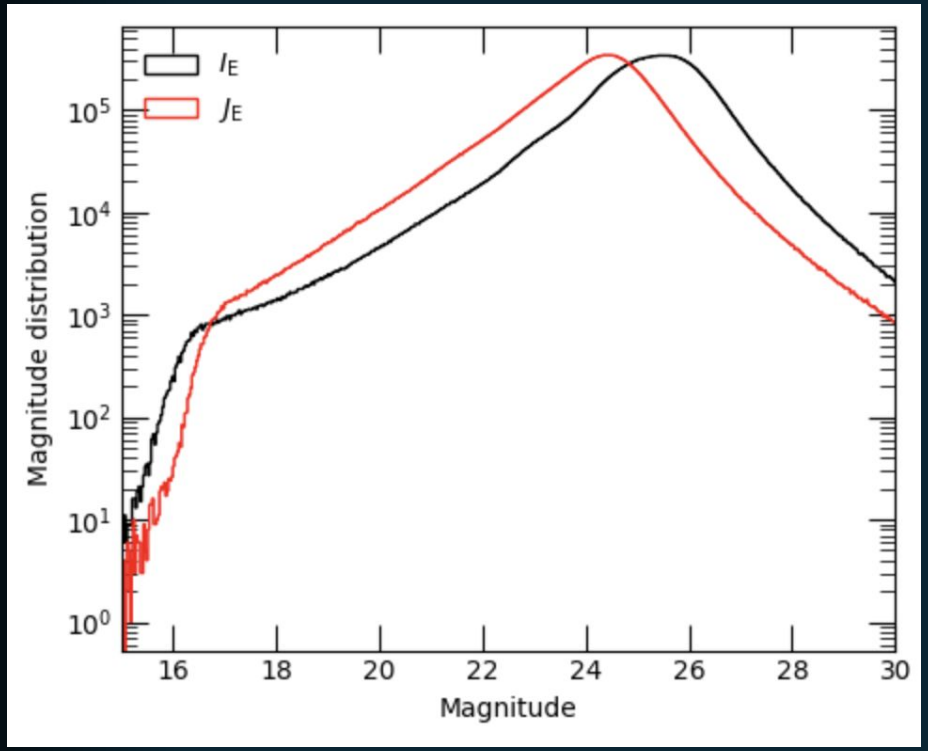
Spectrograph: slitless, R~450



Spectrograph: slitless, R~450

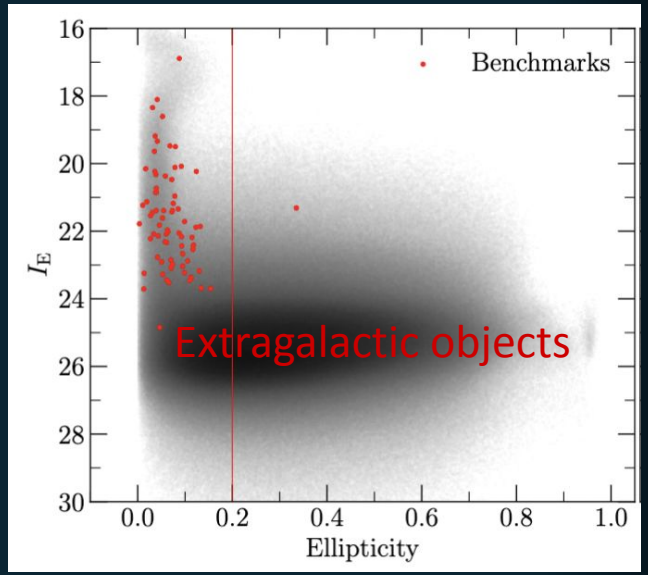


AB magnitude system

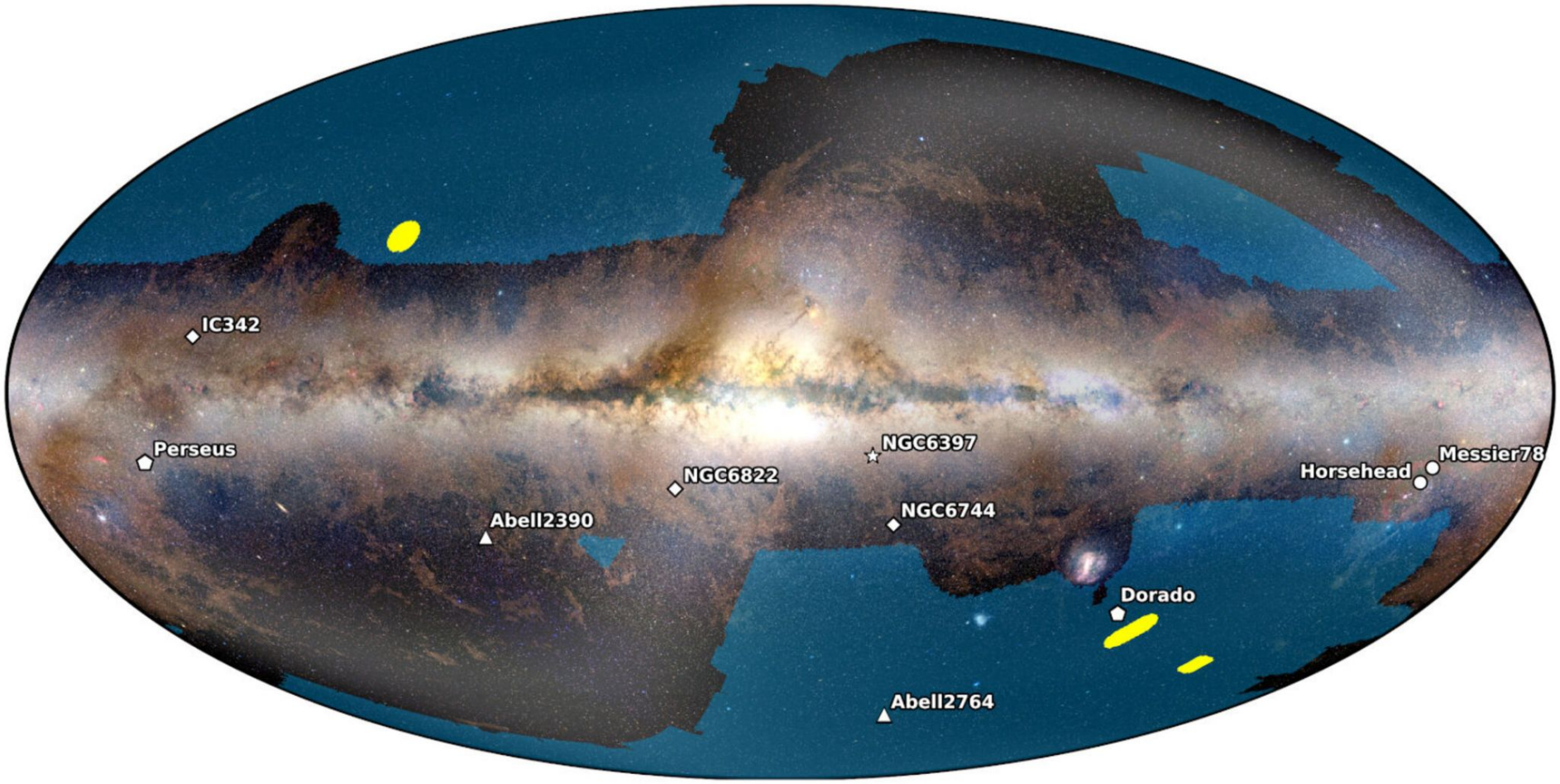


Completeness:

- 24.5 in NISP
- 25.5 in VIS
- Complementary with Gaia



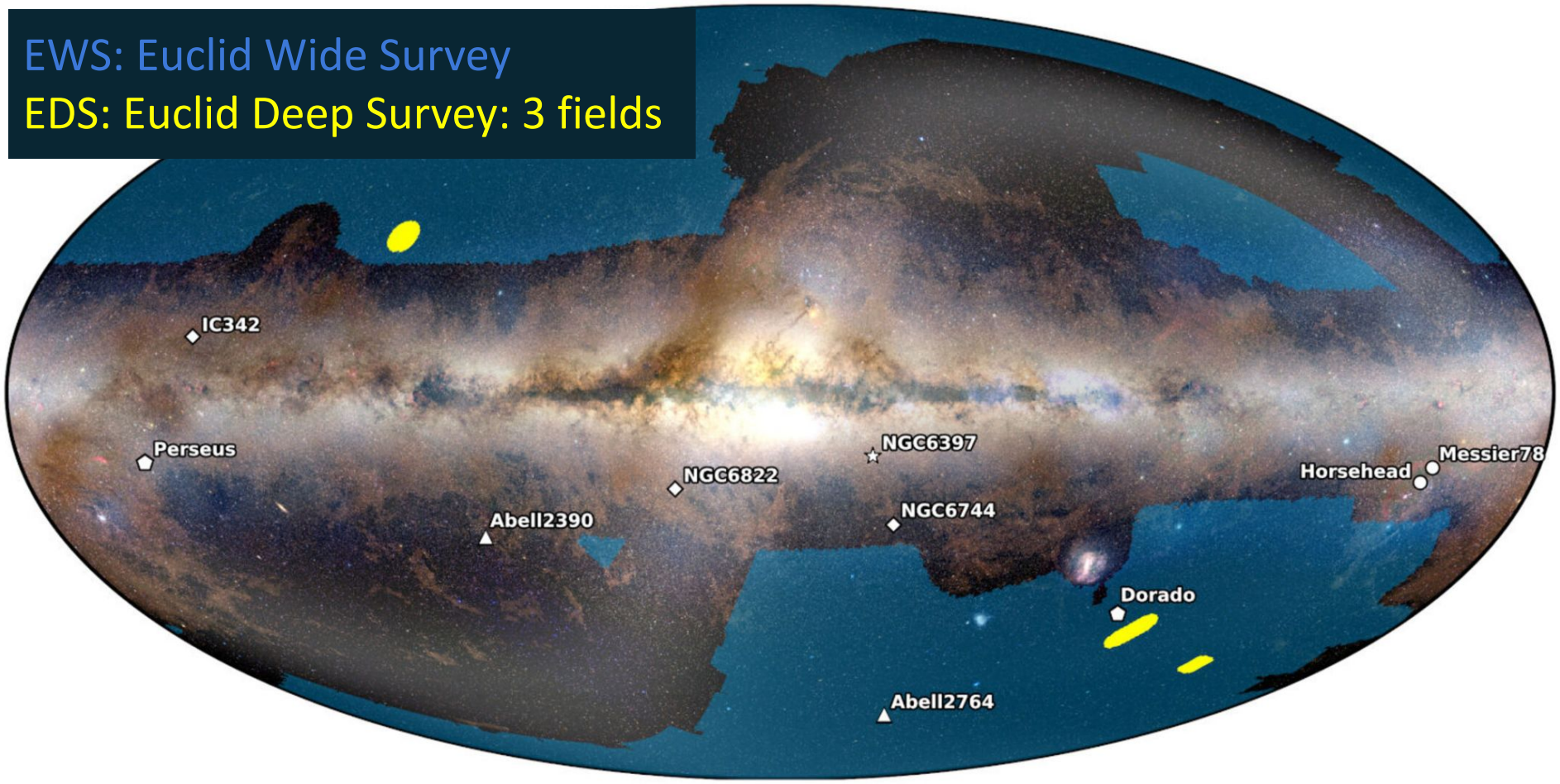
Sky coverage



Sky coverage

EWS: Euclid Wide Survey

EDS: Euclid Deep Survey: 3 fields



Data releases

- 2024: Early Release Observations (ERO)



- 2025: Q1 (62 square degrees)

- DR1 in preparation (~1900 square degrees)

Data releases



- 2024: Early Release Observations (ERO)

- 2025: Q1 (62 square degrees)

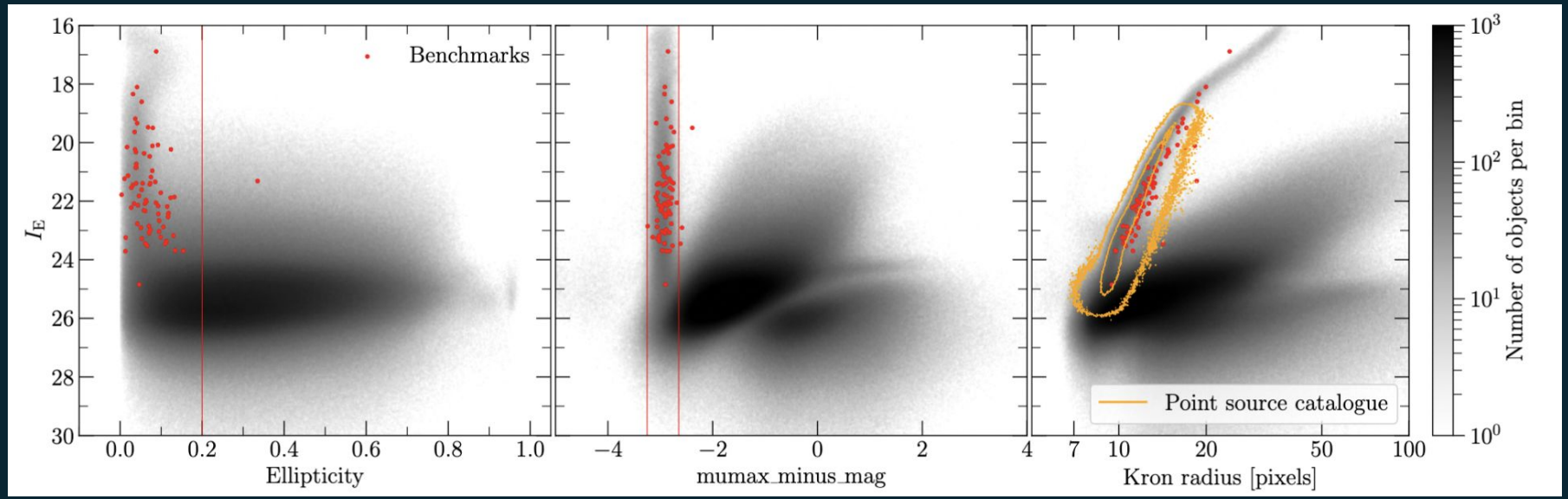
x30

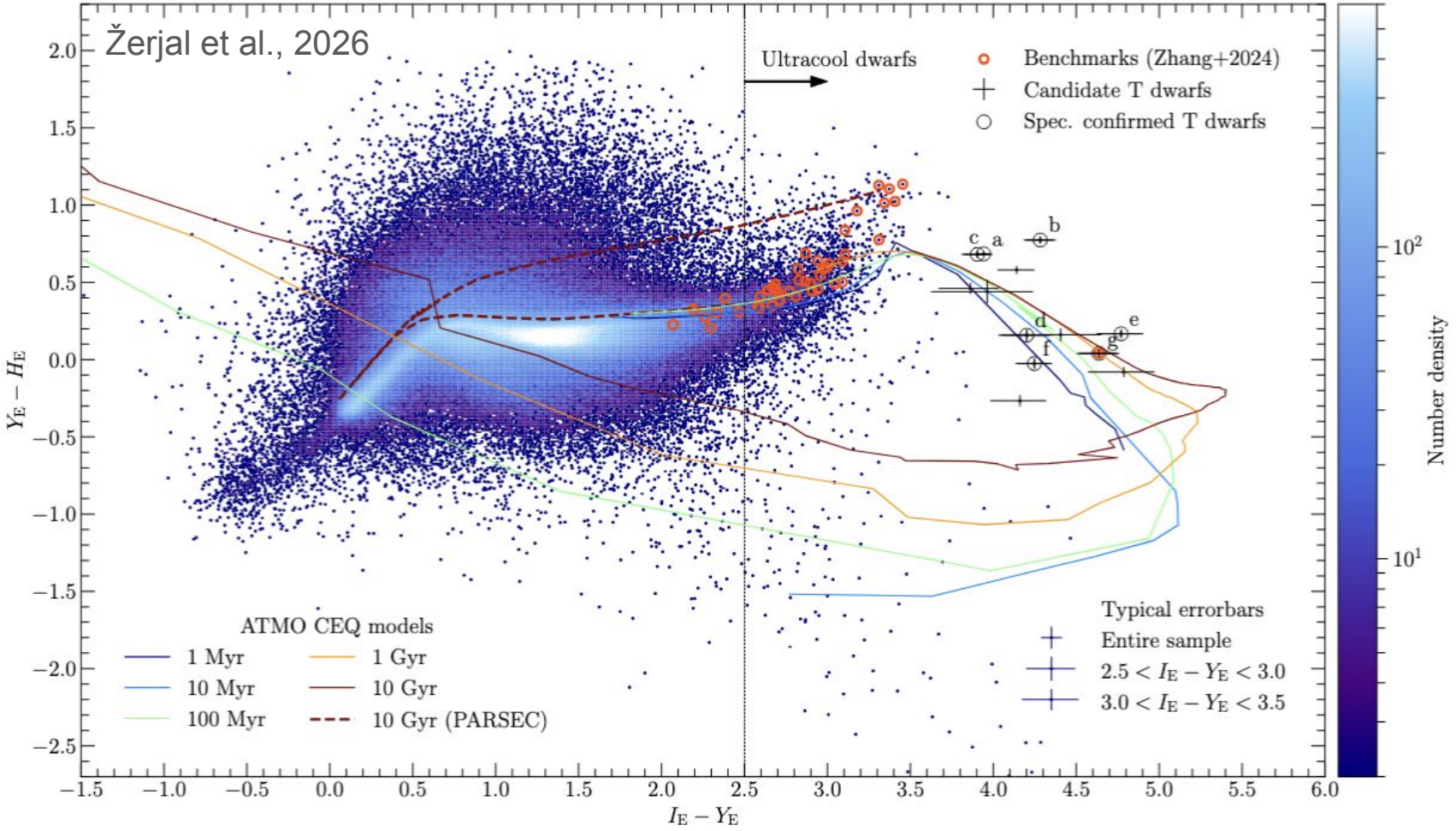
- DR1 in preparation (~1900 square degrees)

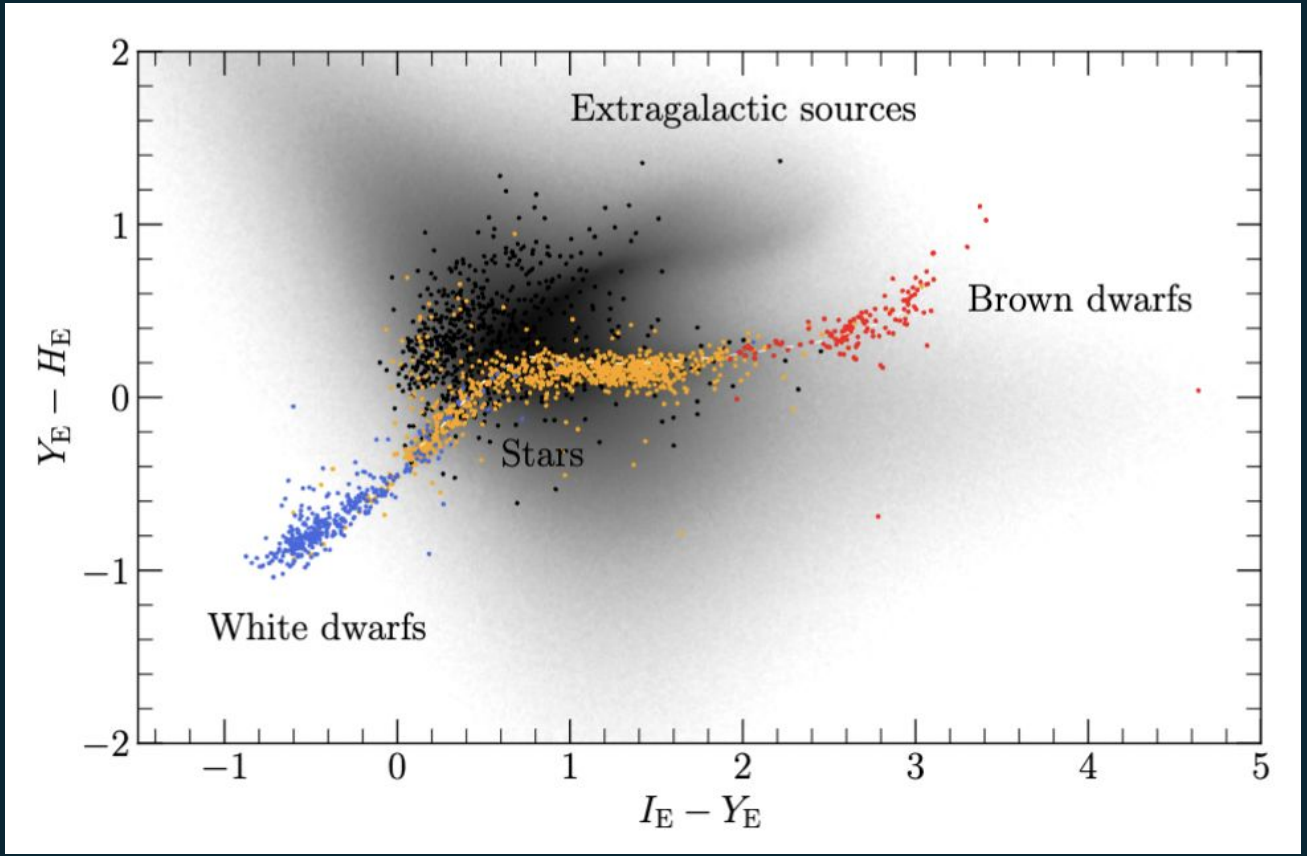
A point-source catalogue

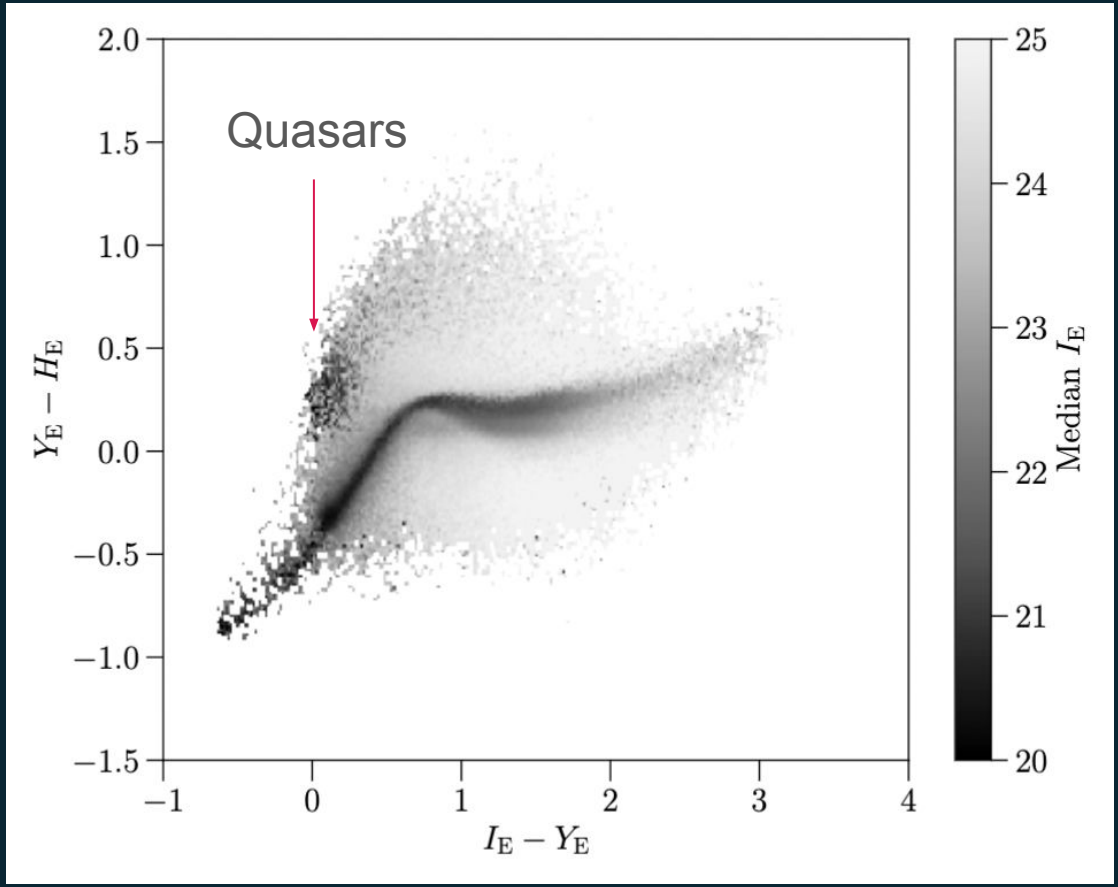
- Ellipticity
- Mumax_minus_mag (extended/point source separation)
- S/N > 4
- Det_quality_flag < 3

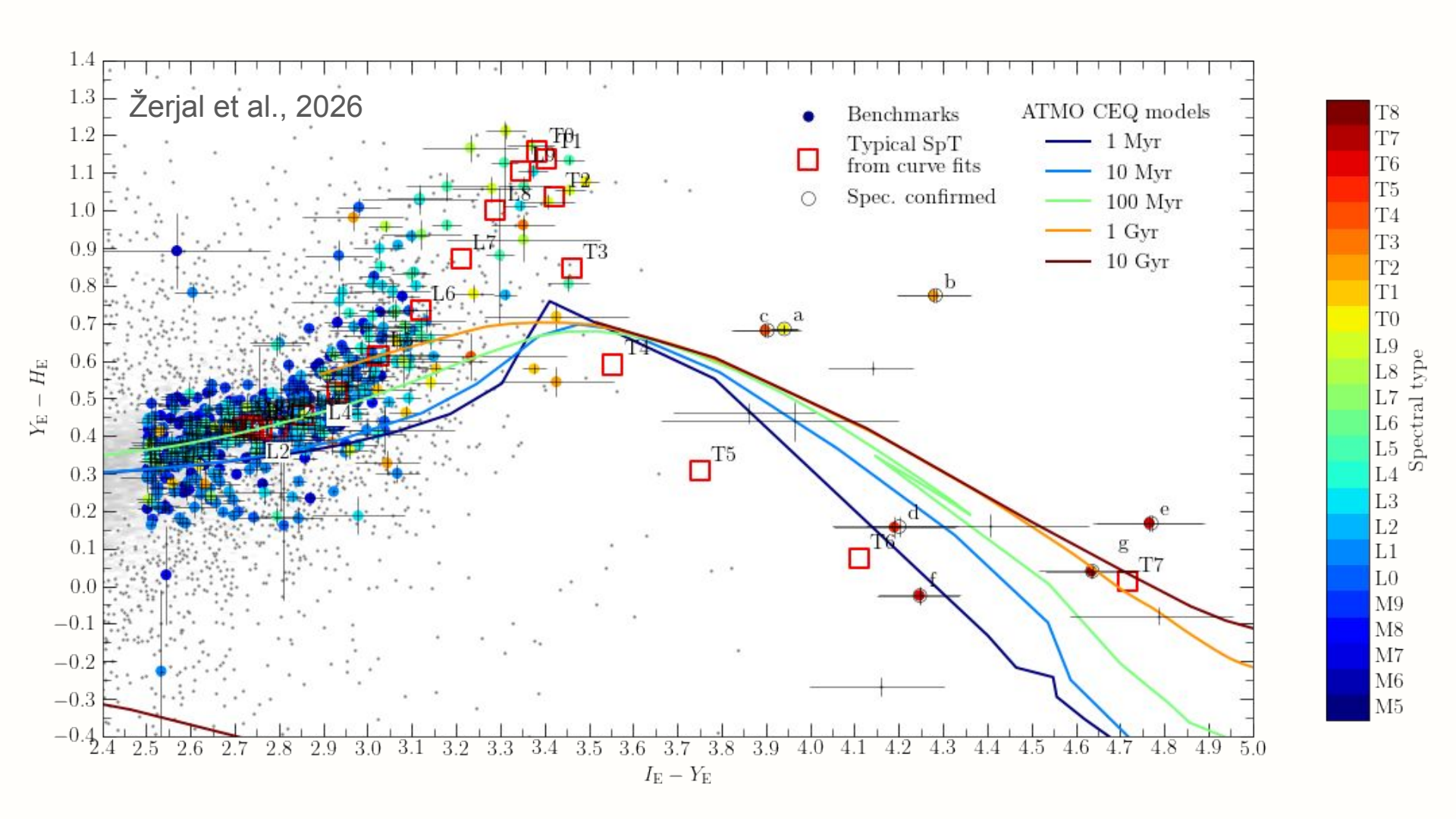
- Almost 700,000 sources
- (2% of the full Q1 dataset)

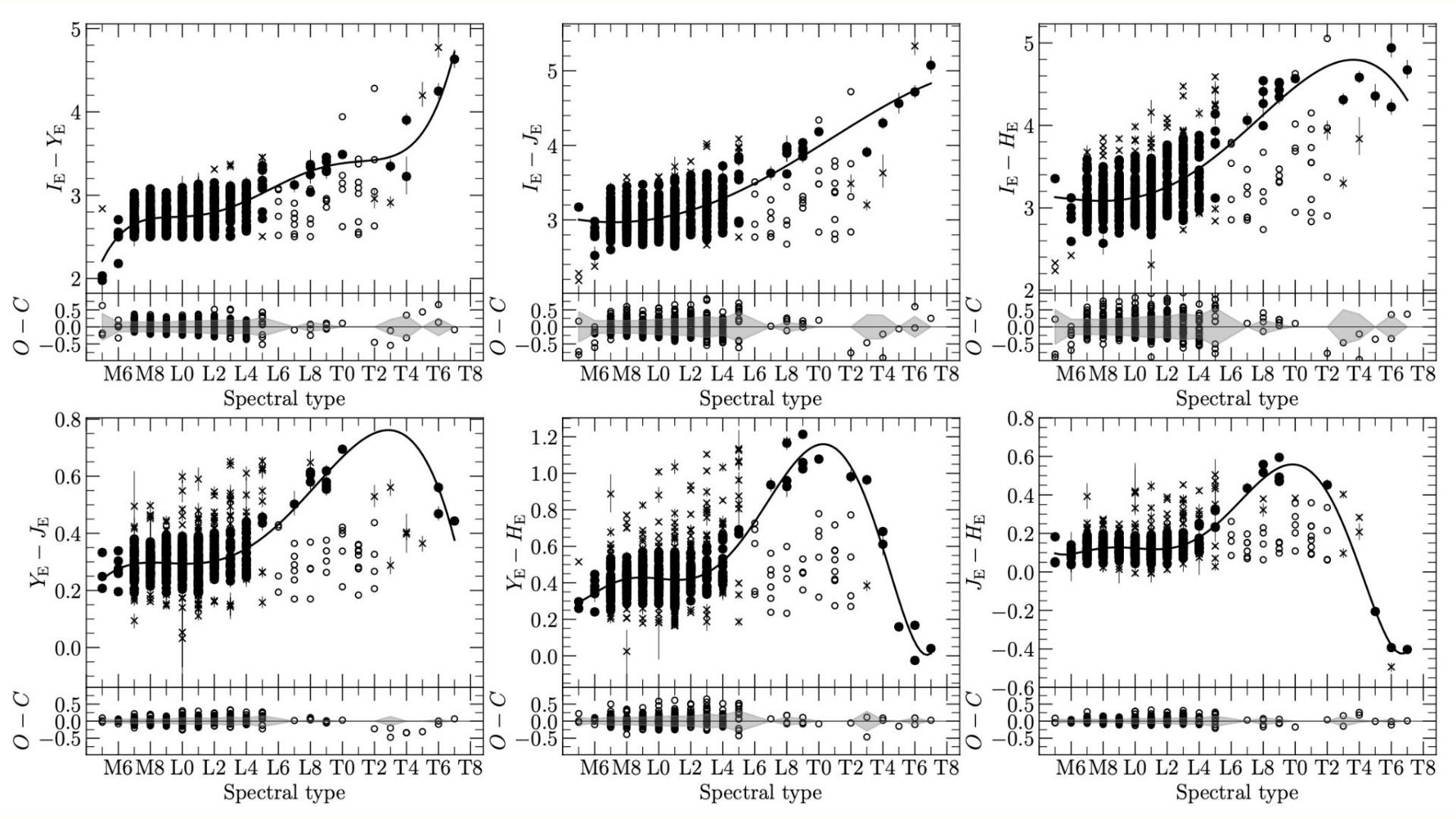



Žerjal et al., 2026
Ultracool dwarfs
Benchmarks (Zhang+2024)
Candidate T dwarfs
Spec. confirmed T dwarfs
a
b
c
d
e
f
g
ATMO CEQ models
1 Myr
10 Myr
100 Myr
1 Gyr
10 Gyr
10 Gyr (PARSEC)
Typical errorbars
Entire sample
2.5 < $I_E - Y_E$ < 3.0
3.0 < $I_E - Y_E$ < 3.5
Number density
10^2
10^1
$Y_E - H_E$
$I_E - Y_E$

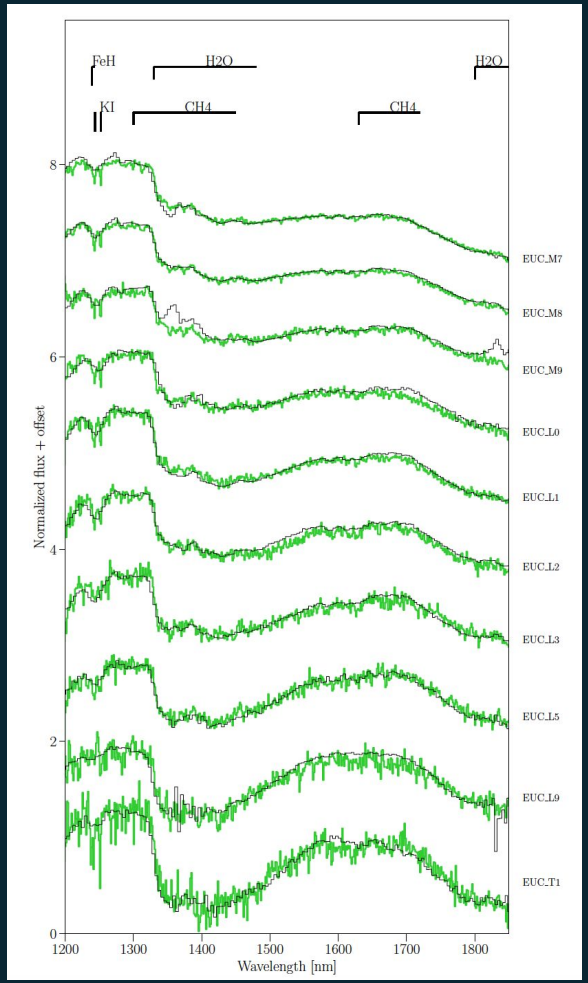

Extragalactic sources
Brown dwarfs
Stars
White dwarfs
$Y_E - H_E$
$I_E - Y_E$
2
1
0
−1
−2
−1
0
1
2
3
4
5

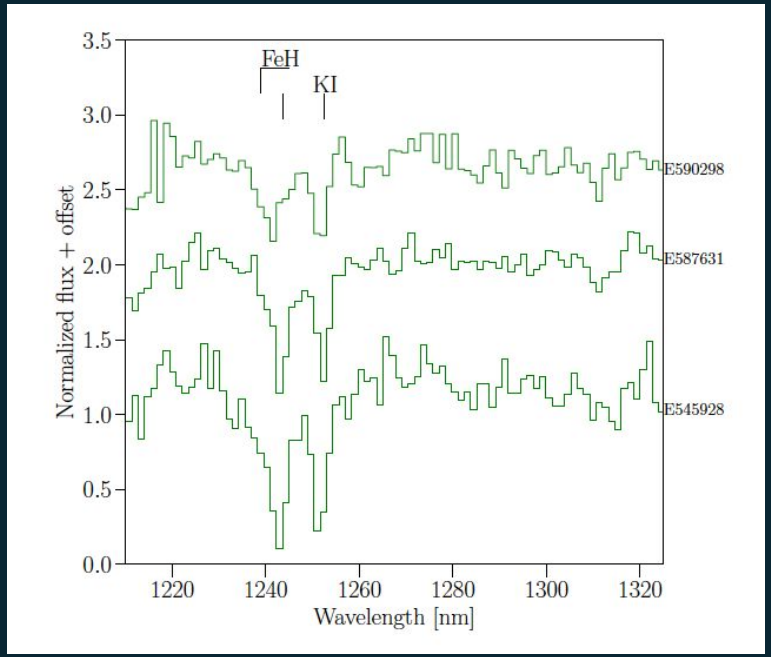

Quasars
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
$Y_E - H_E$
−1
0
1
2
3
4
$I_E - Y_E$
25
24
23
22
21
20
Median I_E


Žerjal et al., 2026
Benchmarks
Typical SpT from curve fits
Spec. confirmed
ATMO CEQ models
1 Myr
10 Myr
100 Myr
1 Gyr
10 Gyr
Spectral type
T8
T7
T6
T5
T4
T3
T2
T1
T0
L9
L8
L7
L6
L5
L4
L3
L2
L1
L0
M9
M8
M7
M6
M5
$Y_E - H_E$
$I_E - Y_E$


$I_E - Y_E$
$I_E - J_E$
$I_E - H_E$
$Y_E - J_E$
$Y_E - H_E$
$J_E - H_E$
$O - C$
M6 M8 L0 L2 L4 L6 L8 T0 T2 T4 T6 T8
Spectral type

Preliminary spectral templates

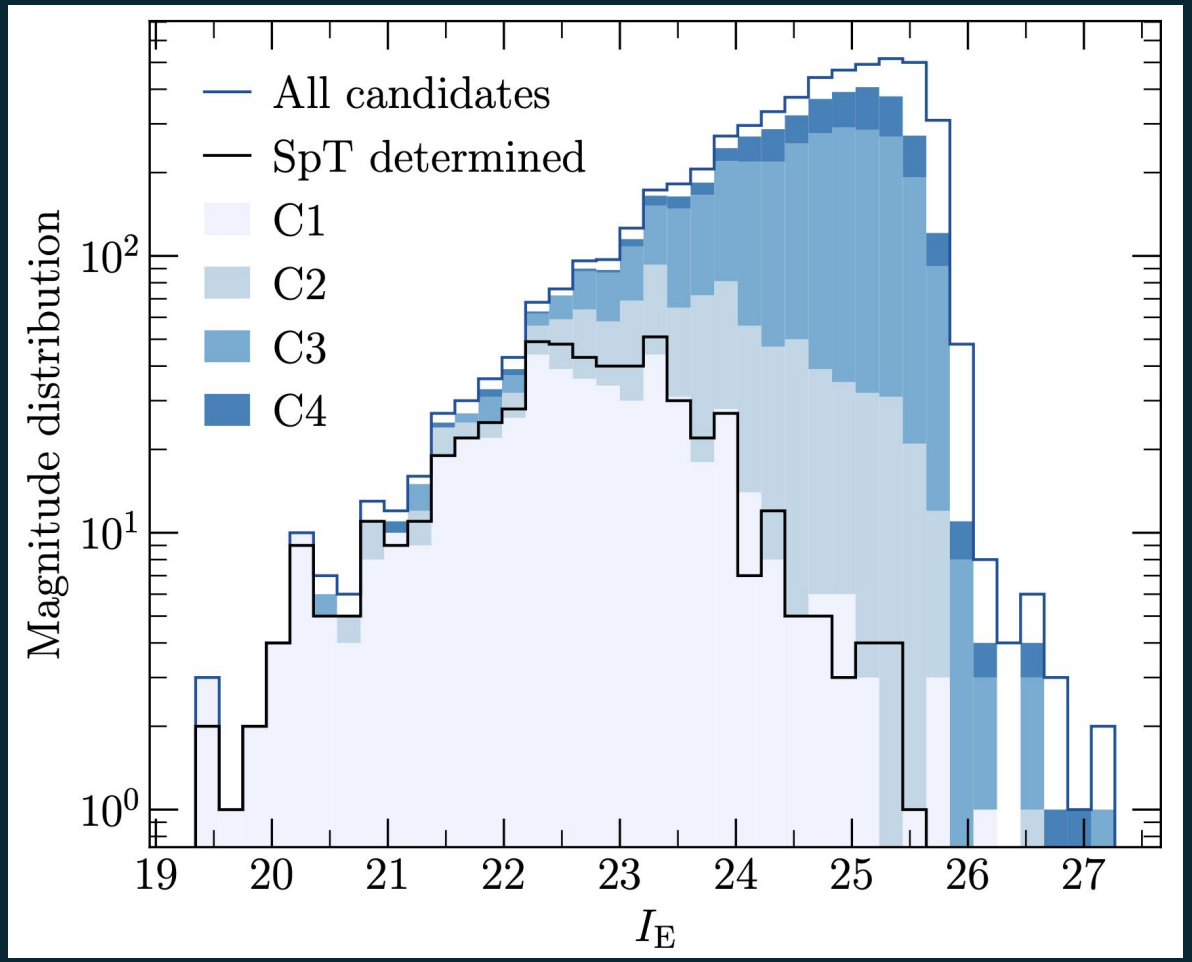




Low gravity

High gravity

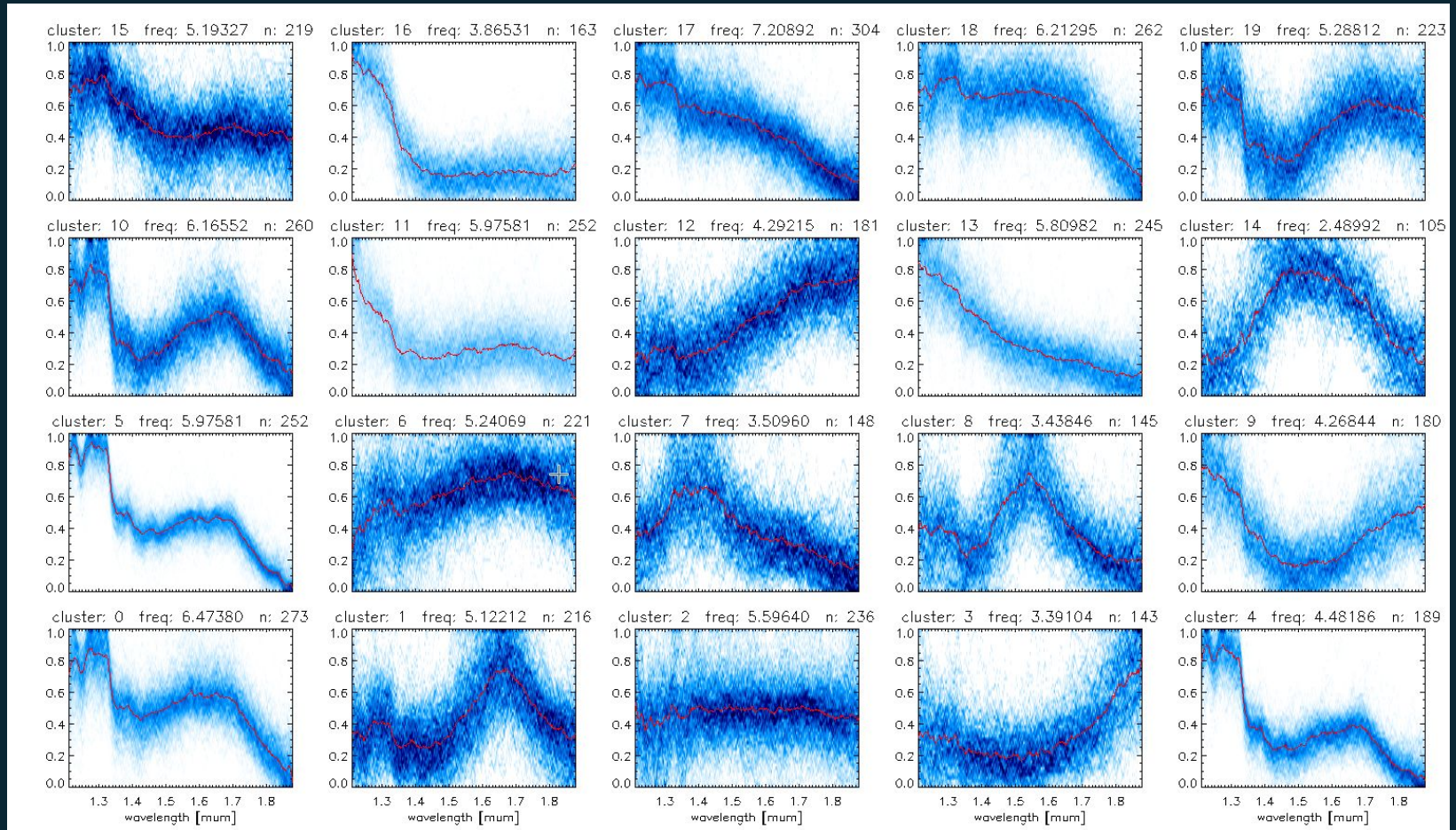
C. Dominguez-Tagle, M. Žerjal et al. 2025



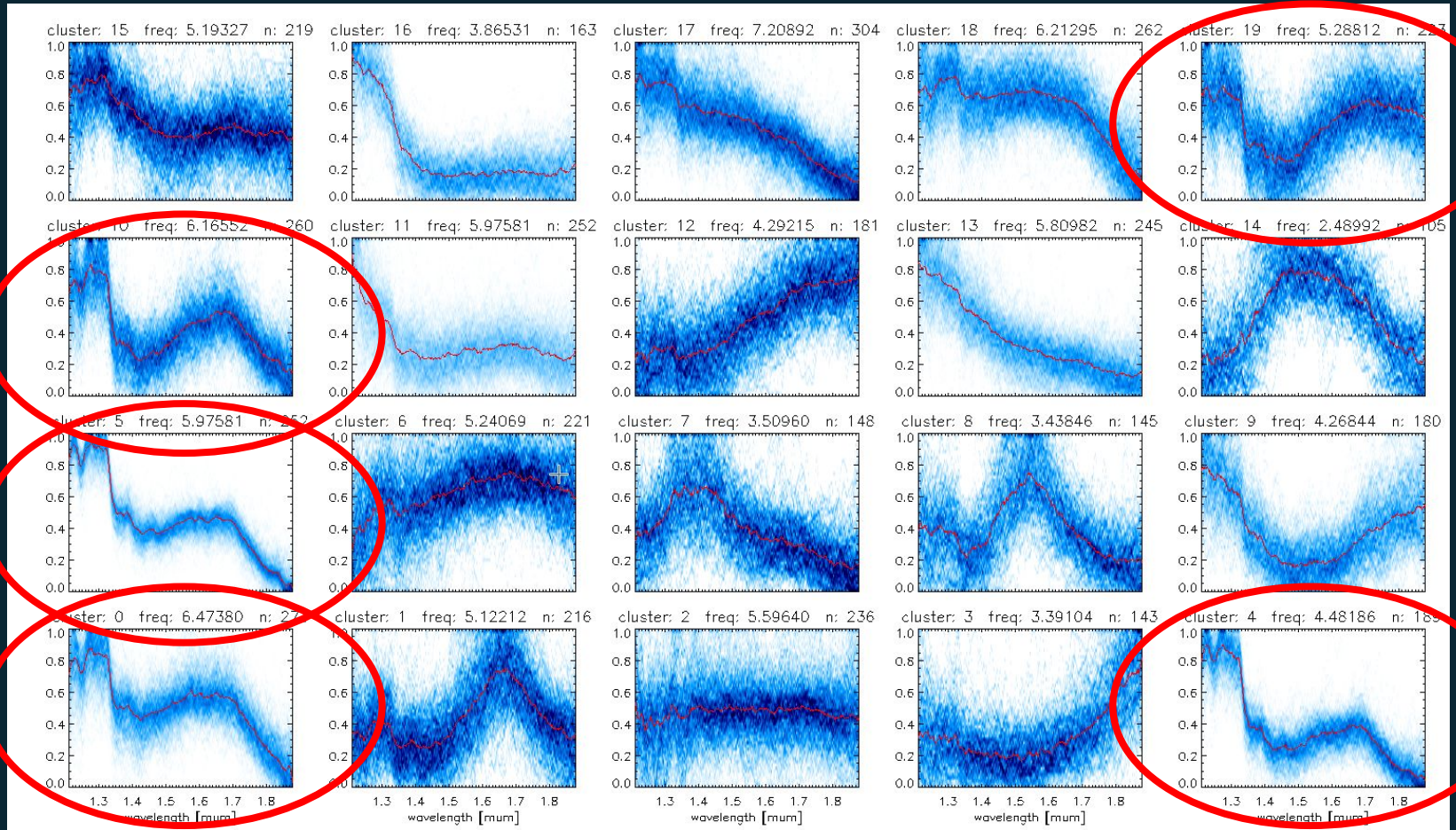
Spectroscopic confirmation

- 546 with SpT (Dominguez)
- >4000 manually classified (Vitas et al., in prep.):
  C1: UCD
  C2: UCD features
  C3: good S/N, but not UCD
  C4: noise, cannot classify
- K-means clustering

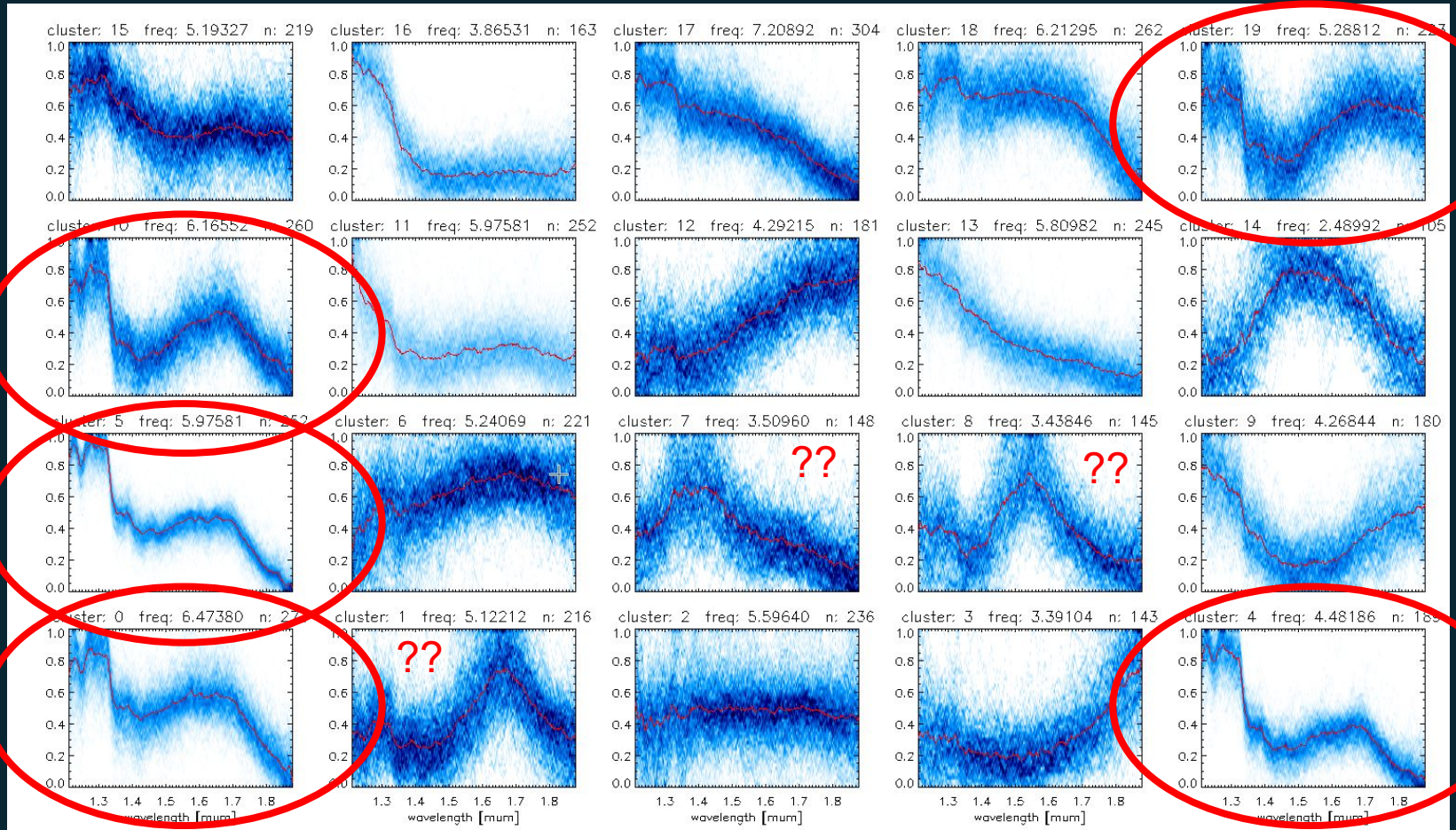
Žerjal et al., 2026



Vitas et al., in prep.

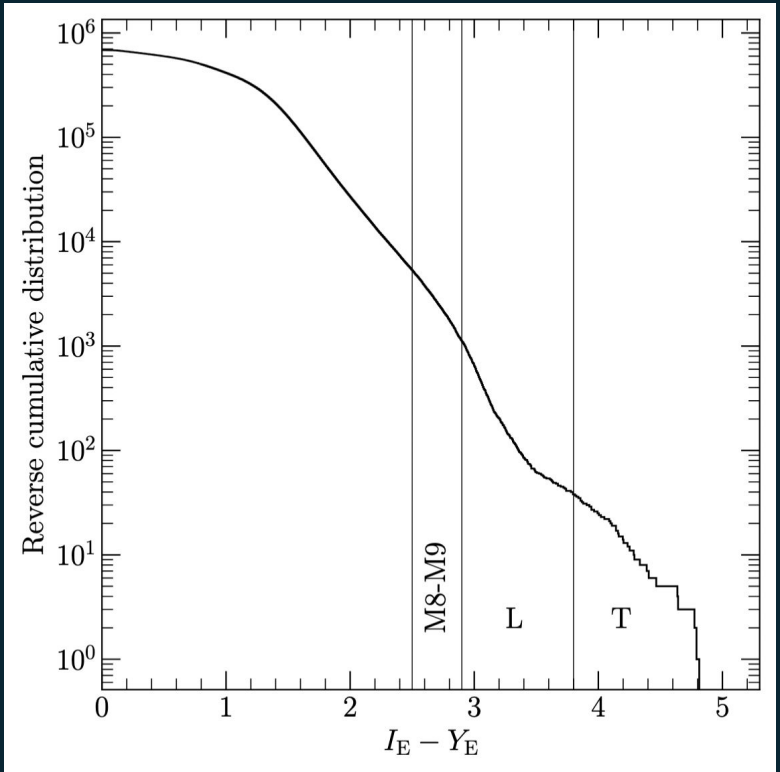


Vitas et al., in prep.



Vitas et al., in prep.

Number of detections



> 5000 UCD candidates in Euclid, 1200 L and T dwarfs
Surface density: 100 UCDs per deg2; this is lower limit

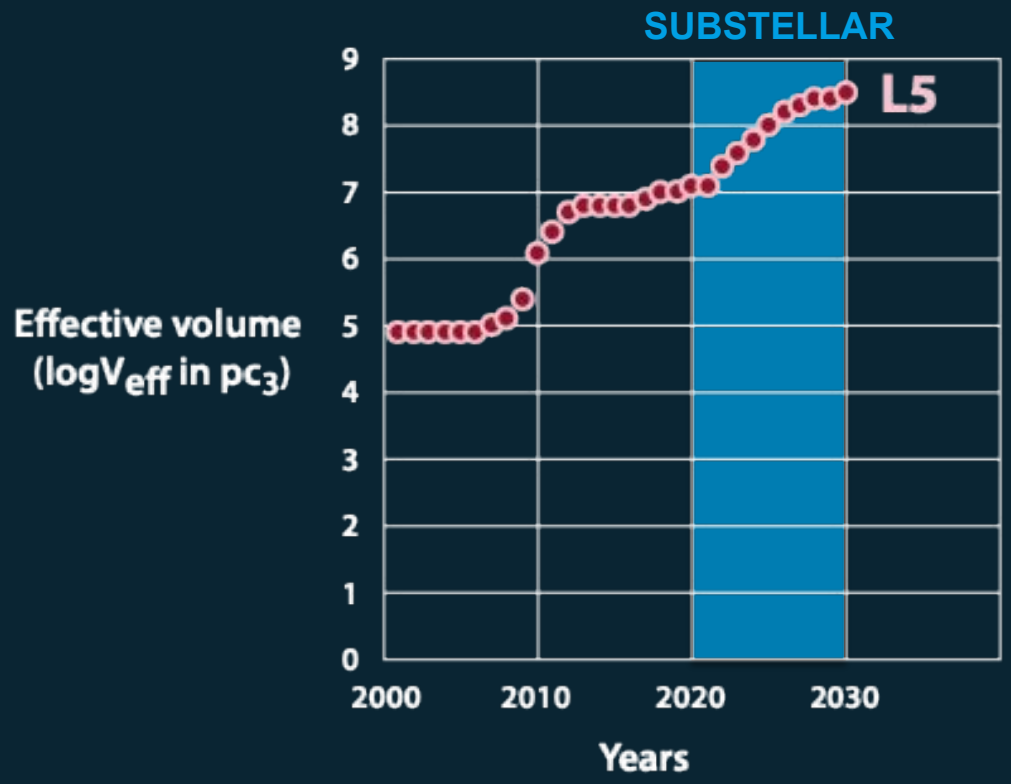
Future: more than 1.5 million UCDs, and more than 300,000 L and T dwarfs in the Wide Field Survey

For comparison:

- Dark Energy Survey: 20 000 candidates (dal Ponte et al. 2023), surface density 4 UCDs per deg2
- Ultracool Sheet: A literature compilation of confirmed UCDs and imaged planets: ~4000 objects (March 2026)

→ Euclid is going to change the UCD field

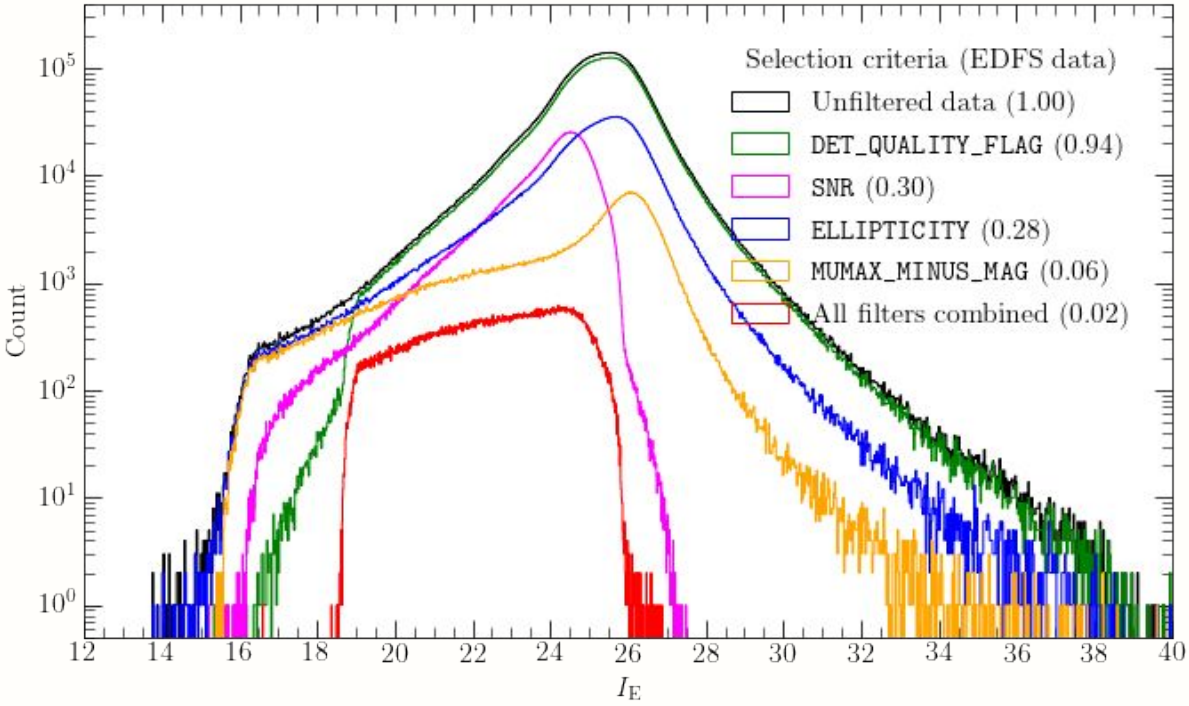
The SUBSTELLAR overarching vision

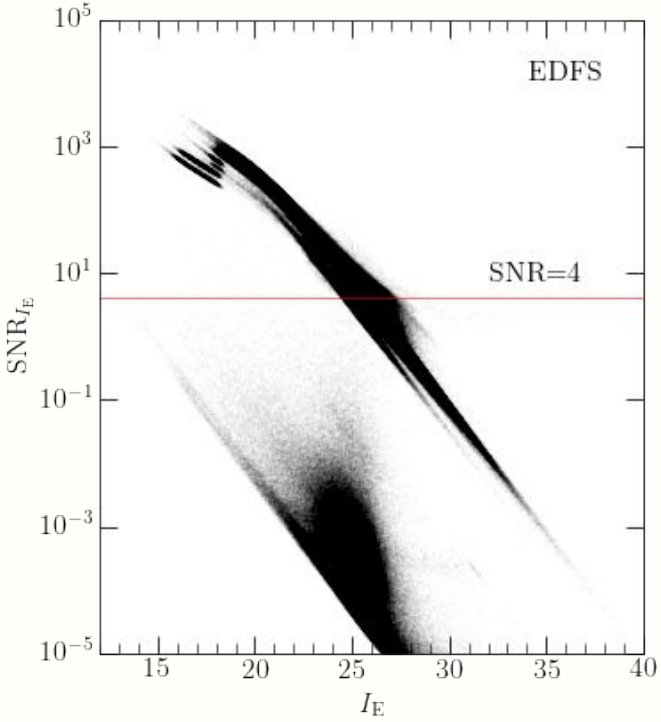


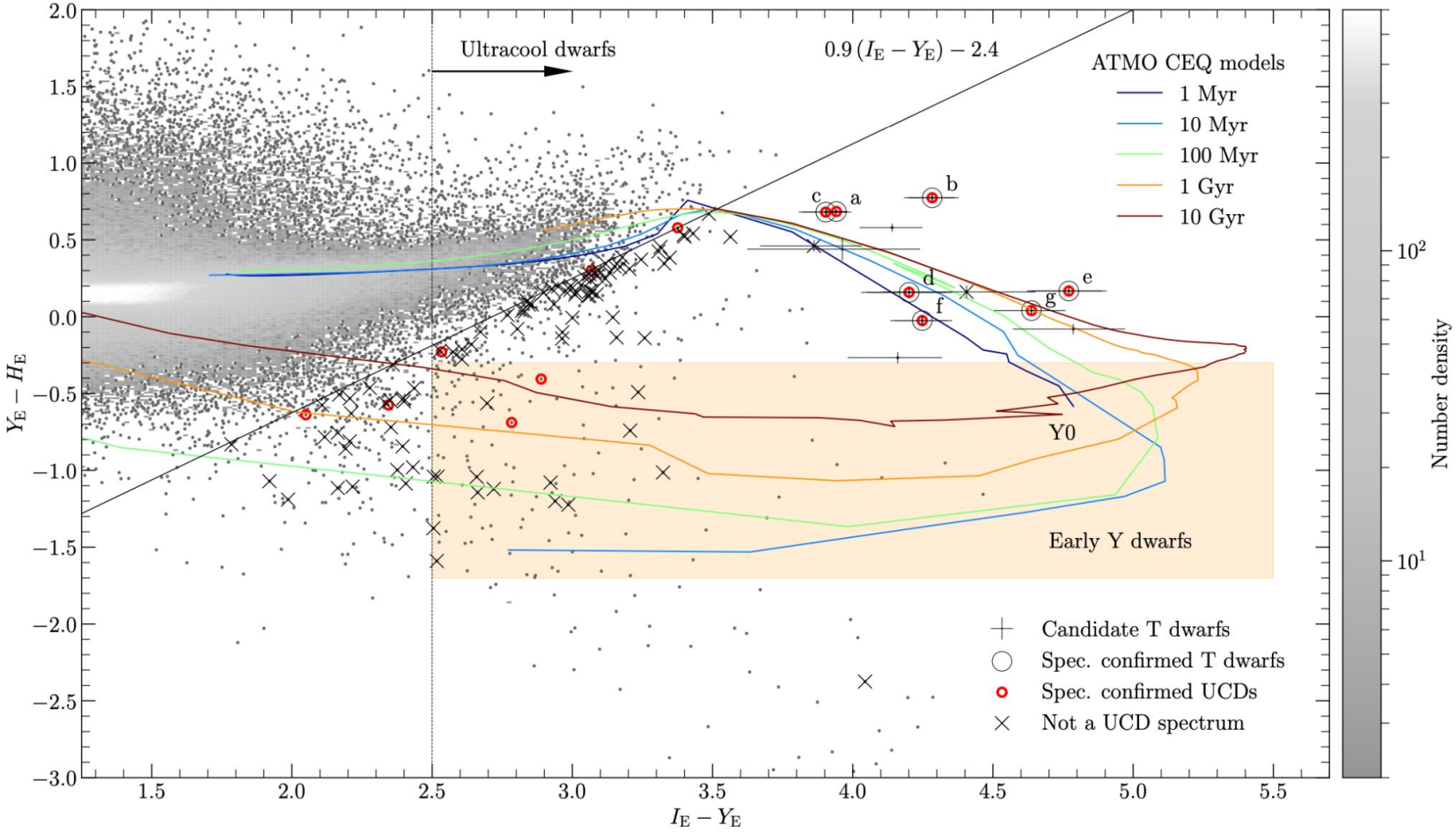
Slide credit: Eduardo Martín

SUBSTELLAR > Euclid + JWST + Vera Rubin + Nancy Roman

Future improvements and challenges






Ultracool dwarfs
$0.9\,(I_E - Y_E) - 2.4$
ATMO CEQ models
1 Myr
10 Myr
100 Myr
1 Gyr
10 Gyr
a
b
c
d
e
f
g
Y0
Early Y dwarfs
Candidate T dwarfs
Spec. confirmed T dwarfs
Spec. confirmed UCDs
Not a UCD spectrum
$Y_E - H_E$
$I_E - Y_E$
Number density
10^2
10^1

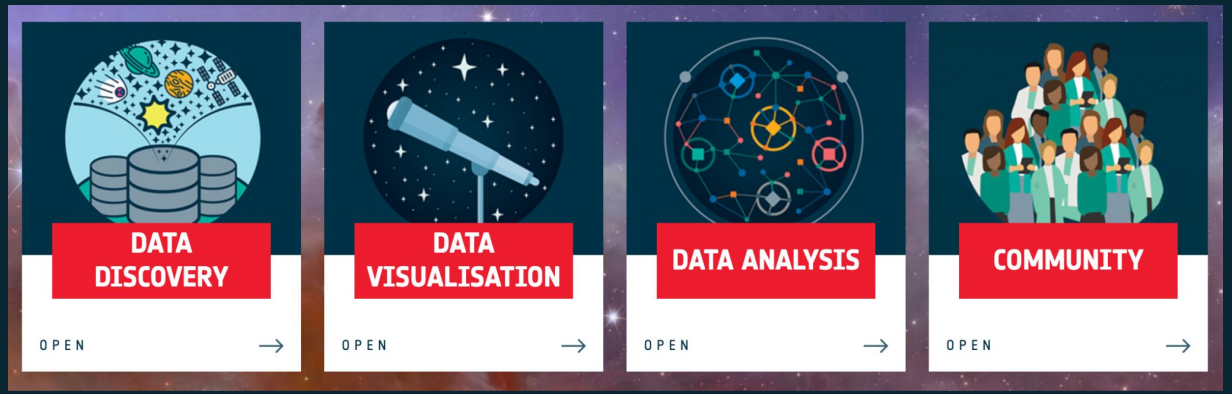
Future: DR1 in October 2026

- 30x larger area than Q1 (~1900 deg^2)
- We expect almost ~200,000 UCD candidates in DR1
- We expect 1.4M UCD candidates at the end of the mission

- Datalabs https://datalabs.esa.int/



Image credit: ESA









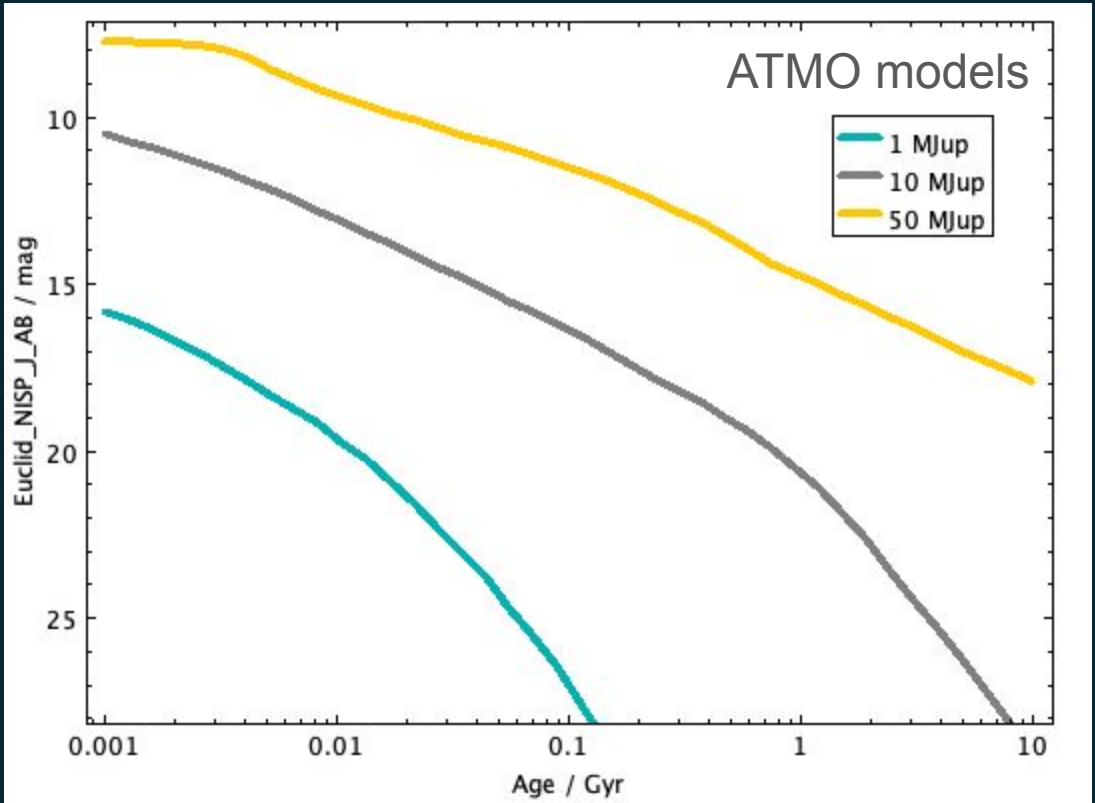

Early Release Observations



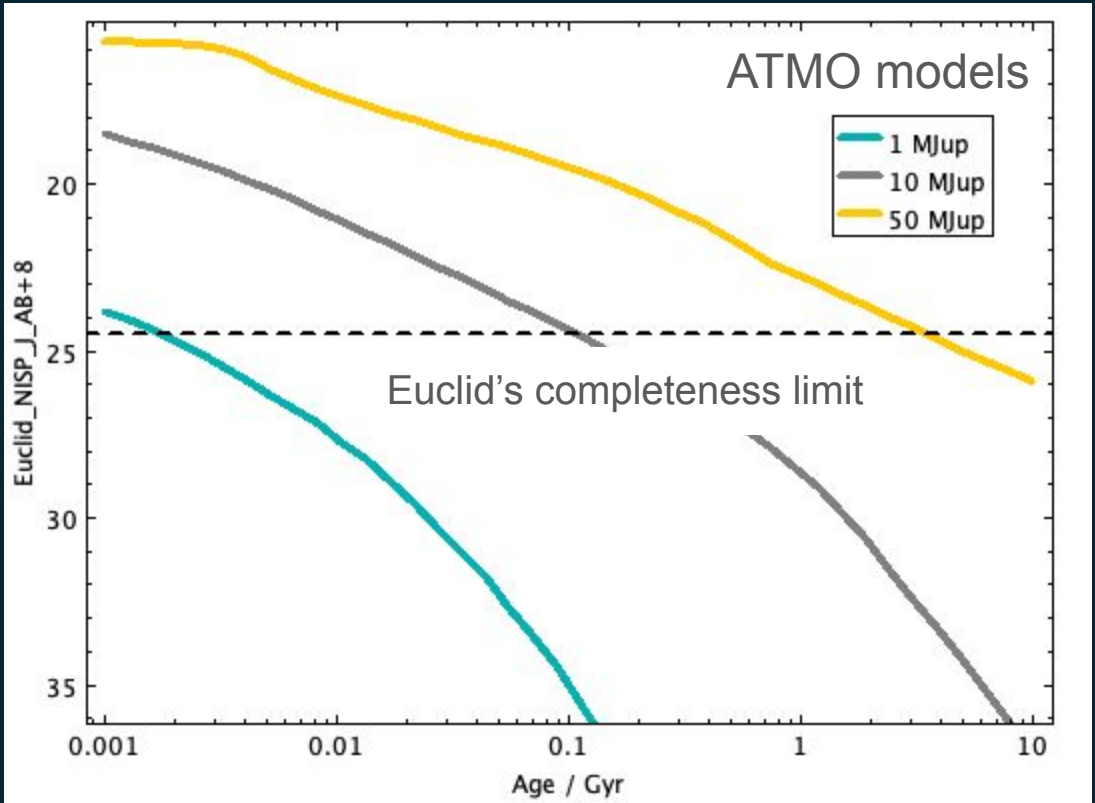


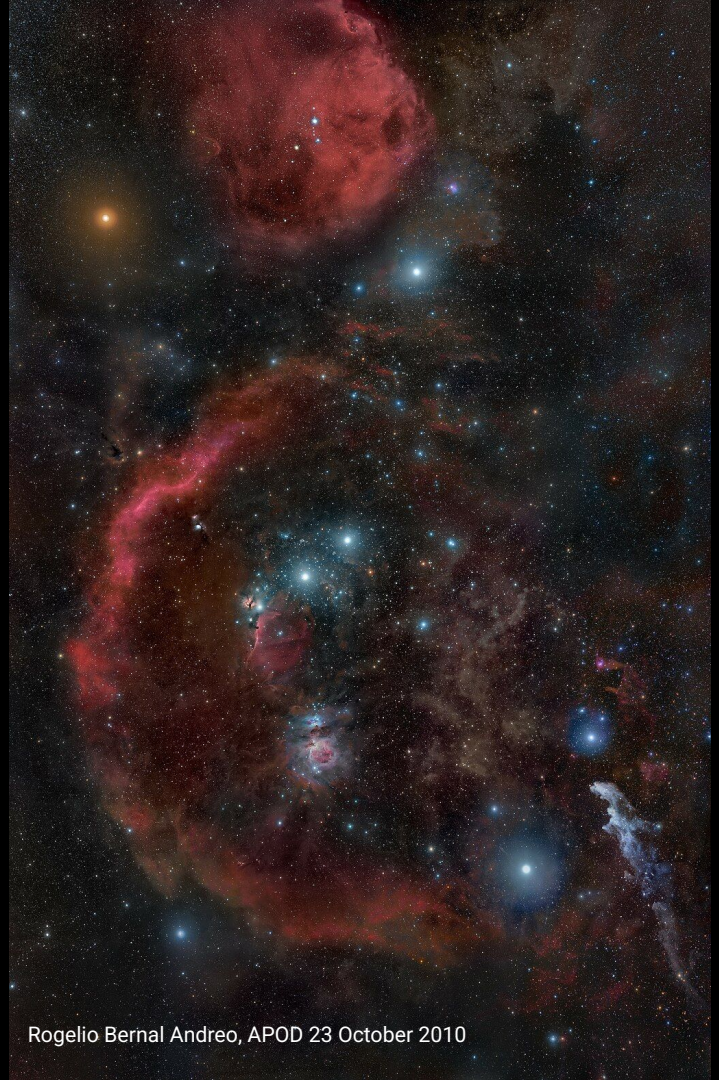


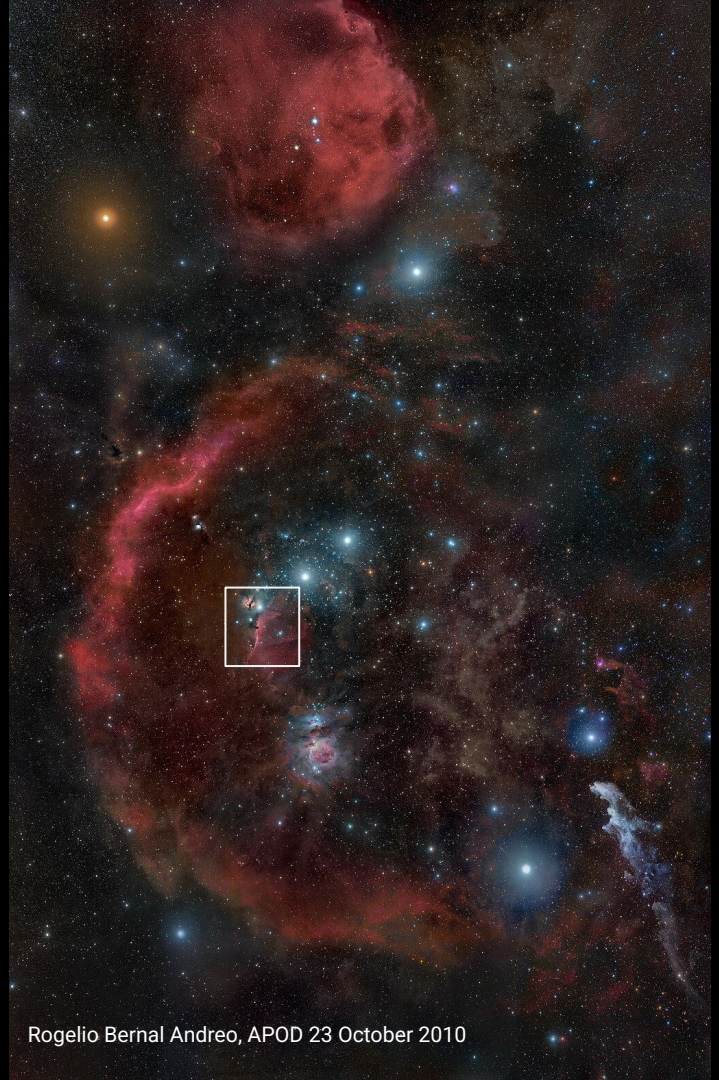

Absolute magnitude



Luminosity at 400 pc



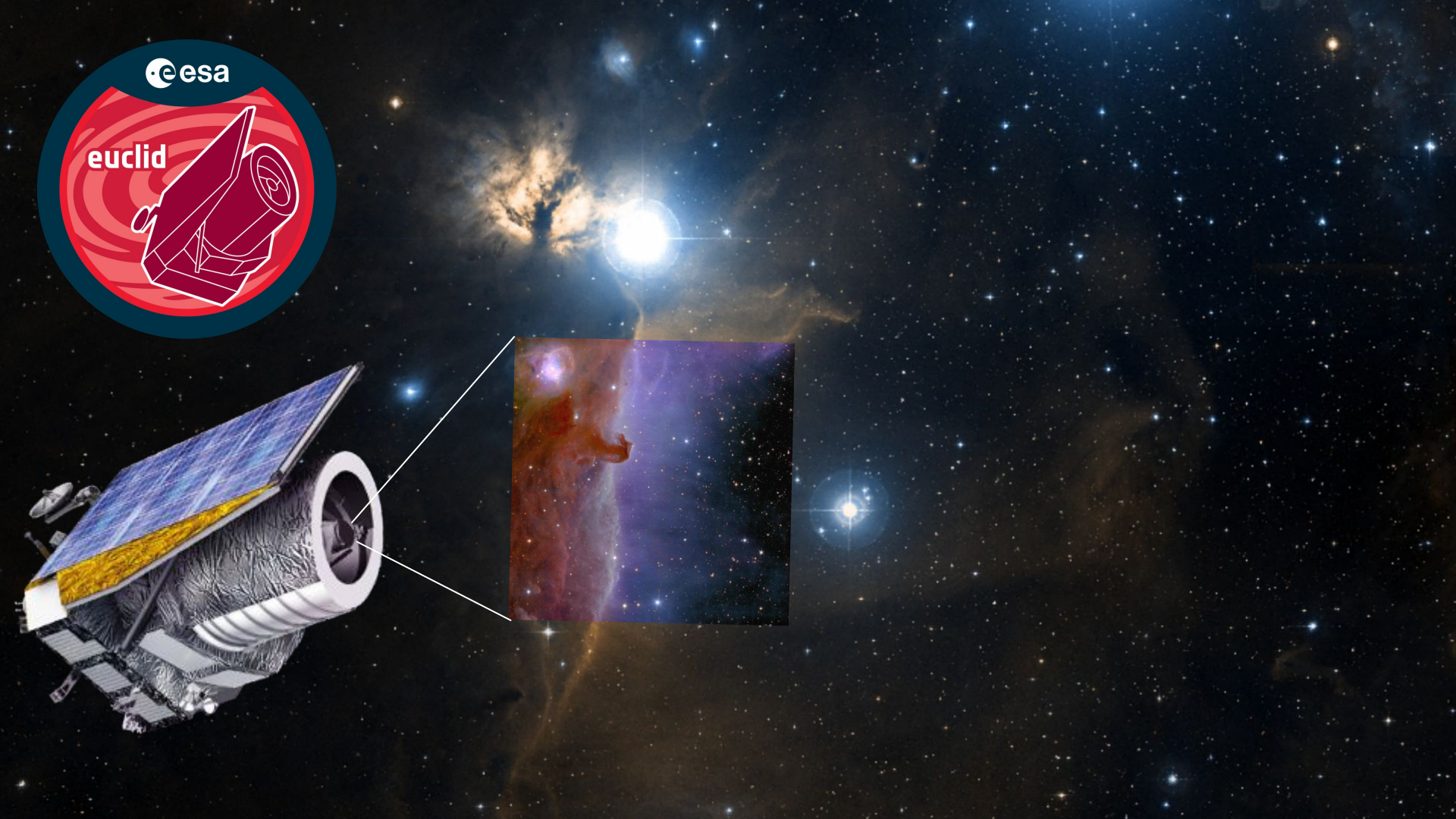

Rogelio Bernal Andreo, APOD 23 October 2010

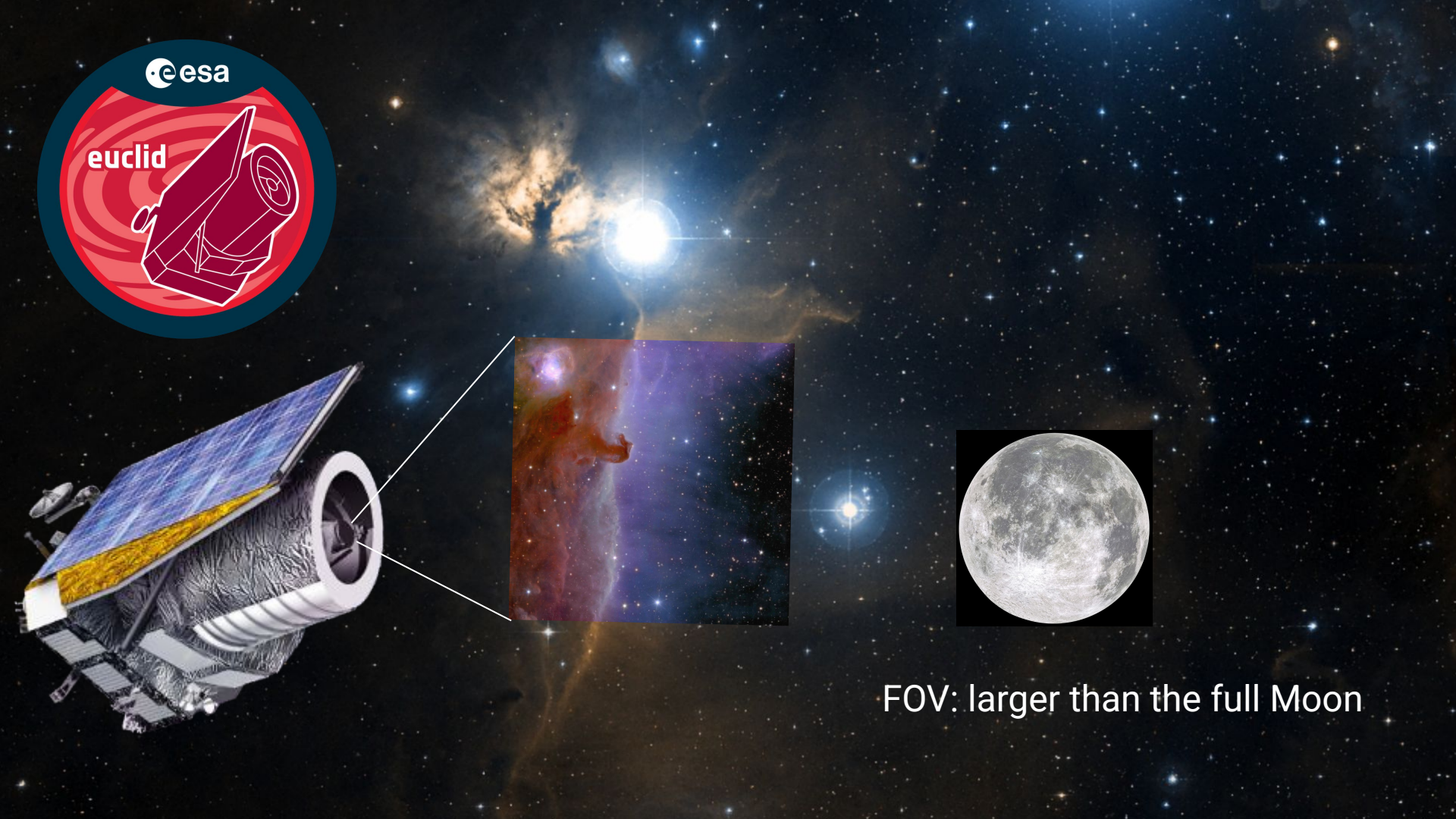

Rogelio Bernal Andreo, APOD 23 October 2010

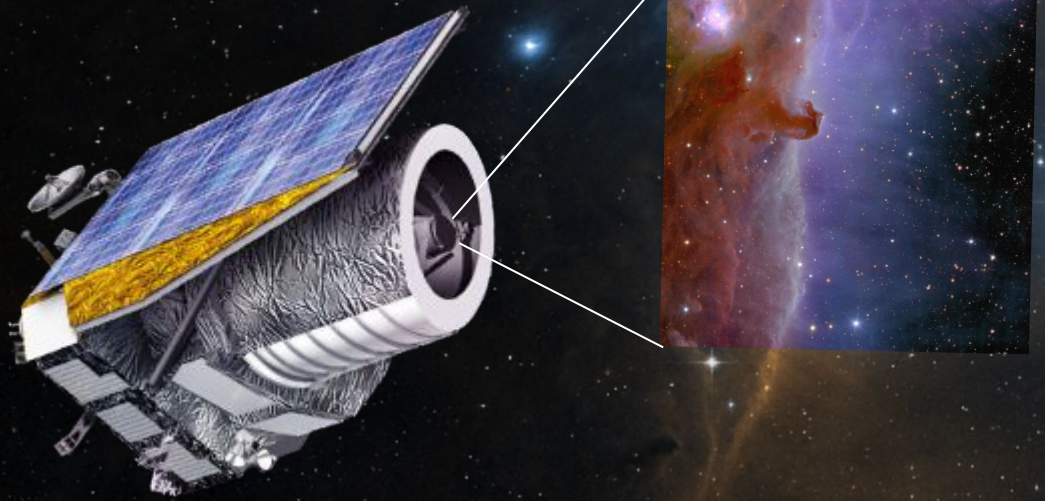



Sigma Orionis


esa
euclid

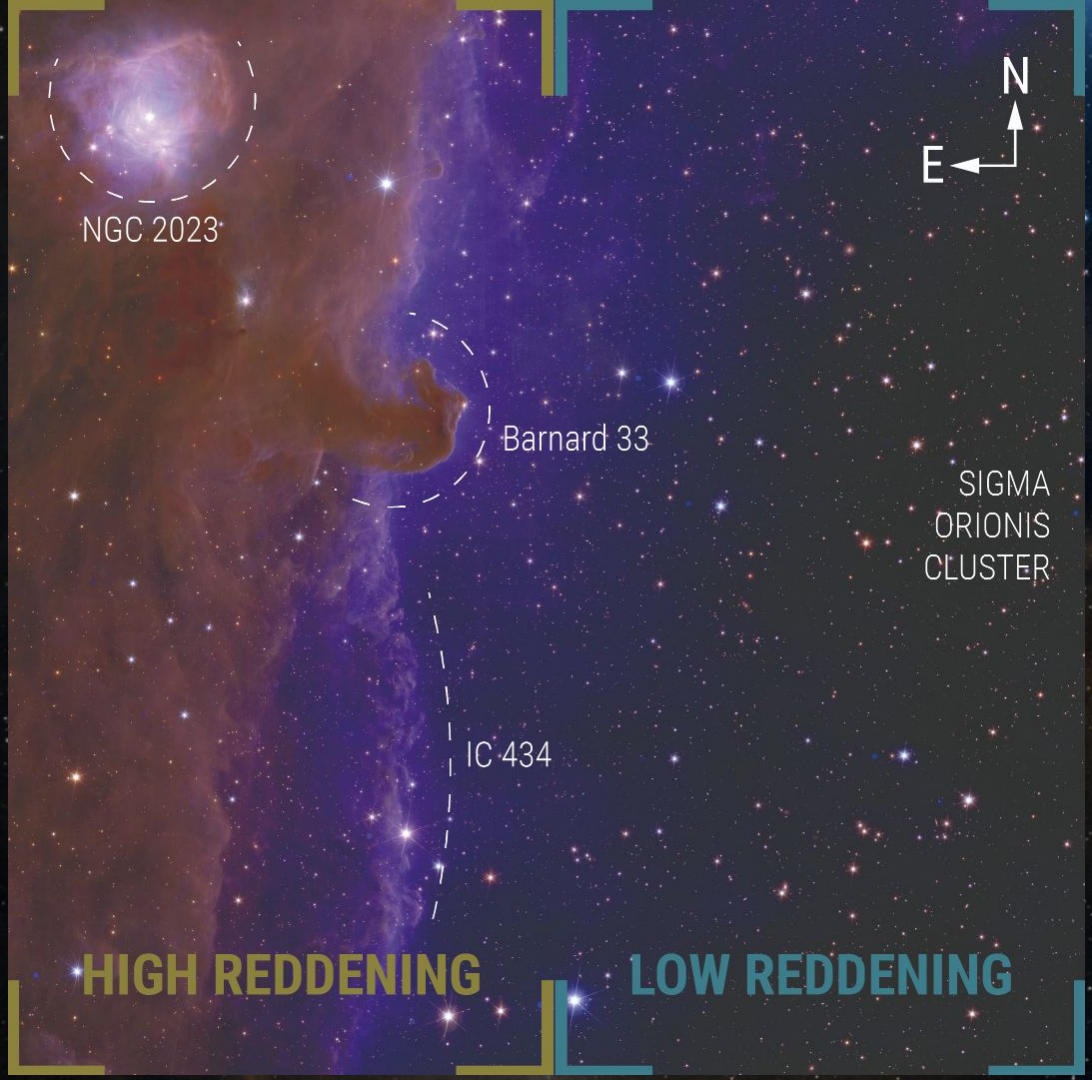

esa
euclid

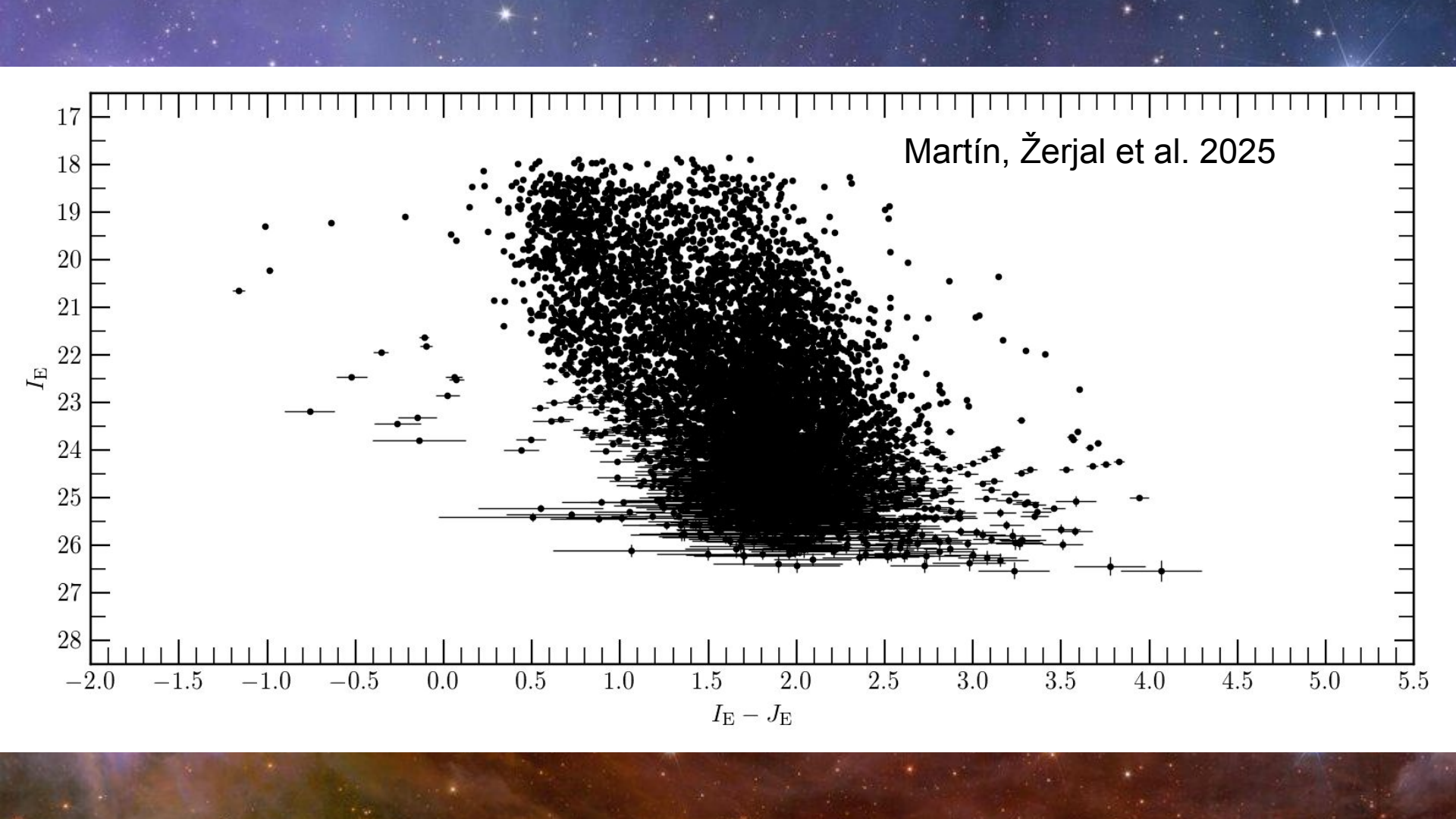

esa
euclid
FOV: larger than the full Moon

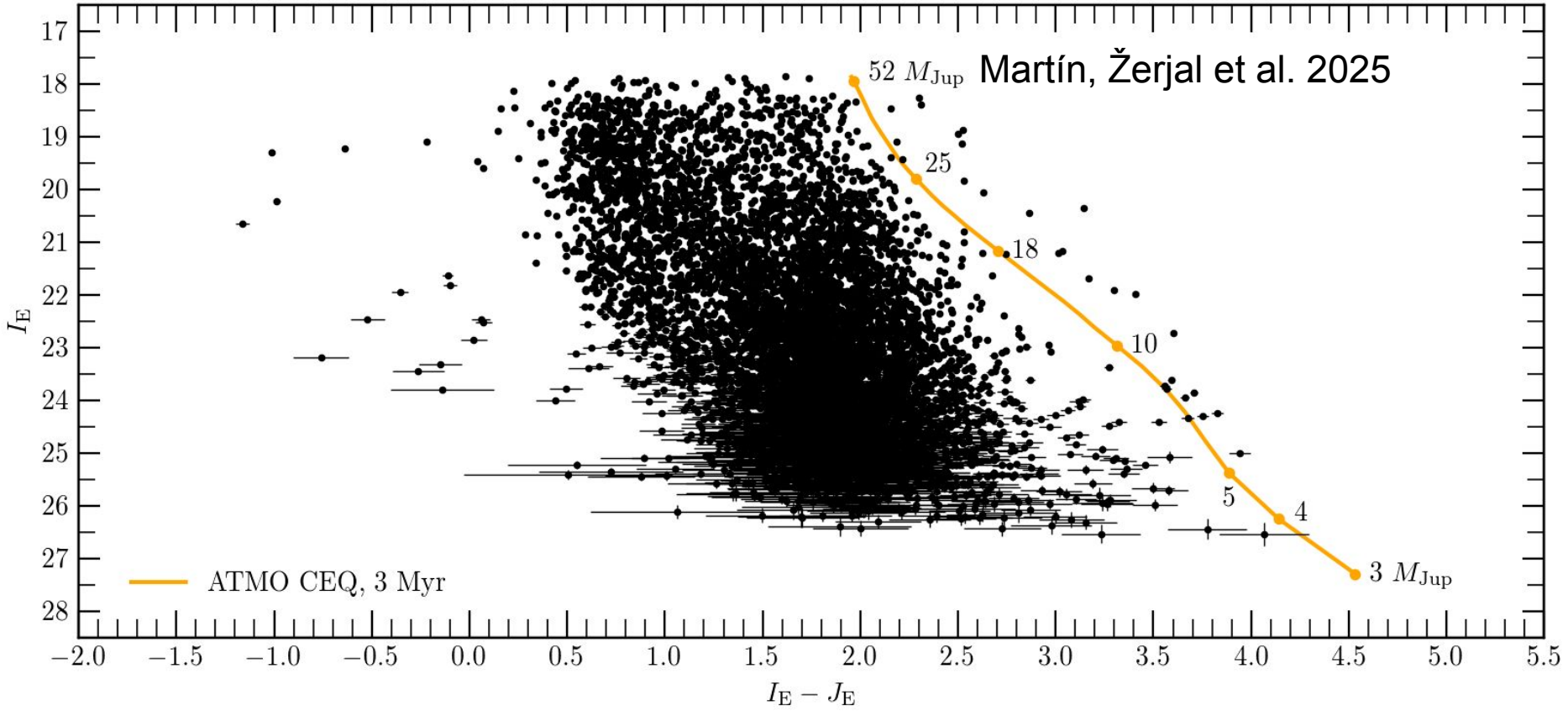


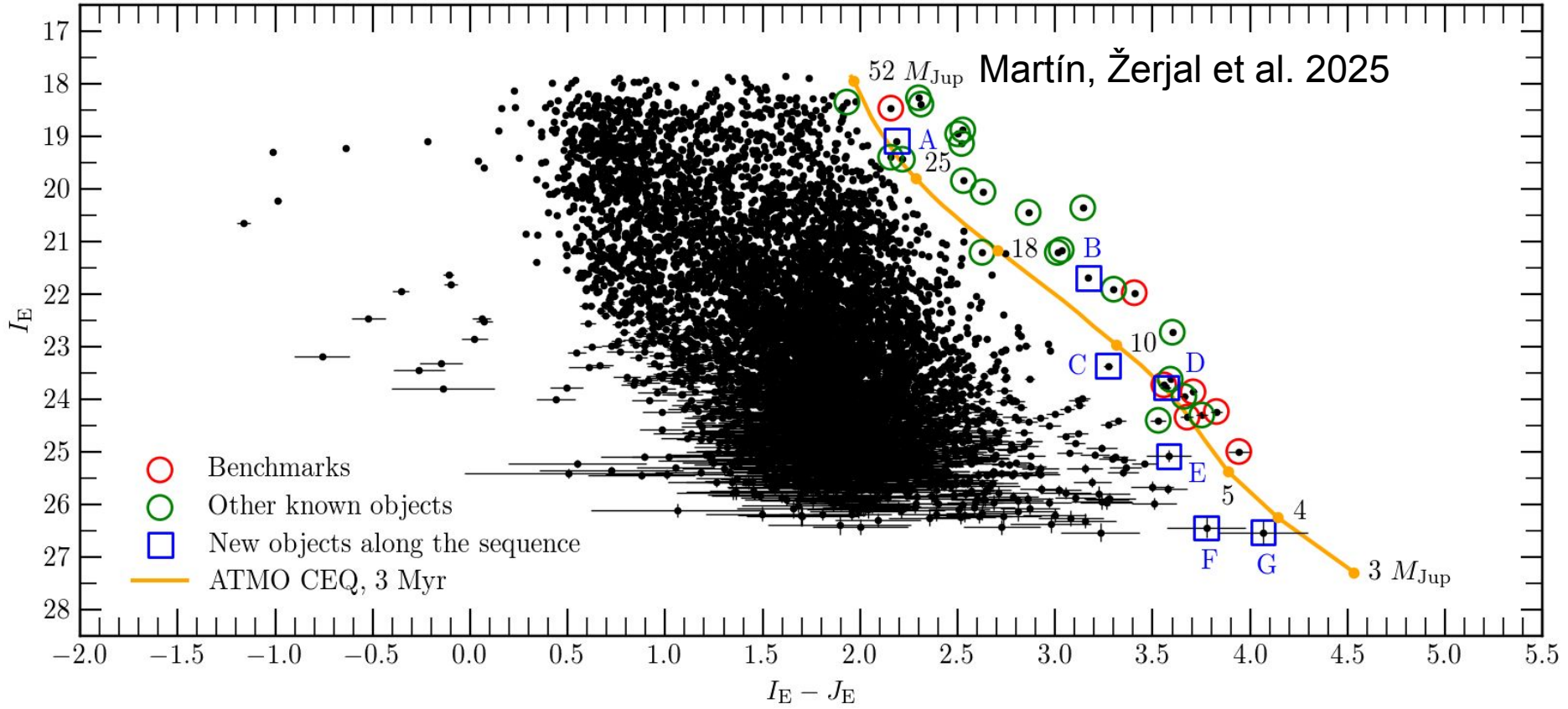
Gaia: 7000 sources
Euclid: > 300,000 sources

Galaxy contamination


N
E
NGC 2023
Barnard 33
SIGMA
ORIONIS
CLUSTER
IC 434
HIGH REDDENING
LOW REDDENING


Martín, Žerjal et al. 2025
I_E
$I_E - J_E$
17
18
19
20
21
22
23
24
25
26
27
28
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5


Martín, Žerjal et al. 2025
52 $M_{\rm Jup}$
25
18
10
5
4
3 $M_{\rm Jup}$
ATMO CEQ, 3 Myr
$I_{\rm E}$
$I_{\rm E} - J_{\rm E}$
17
18
19
20
21
22
23
24
25
26
27
28
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5


Martín, Žerjal et al. 2025
52 $M_{\rm Jup}$
25
18
10
5
4
3 $M_{\rm Jup}$
A
B
C
D
E
F
G
Benchmarks
Other known objects
New objects along the sequence
ATMO CEQ, 3 Myr
$I_{\rm E}$
$I_{\rm E} - J_{\rm E}$
17
18
19
20
21
22
23
24
25
26
27
28
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5

Messier 78

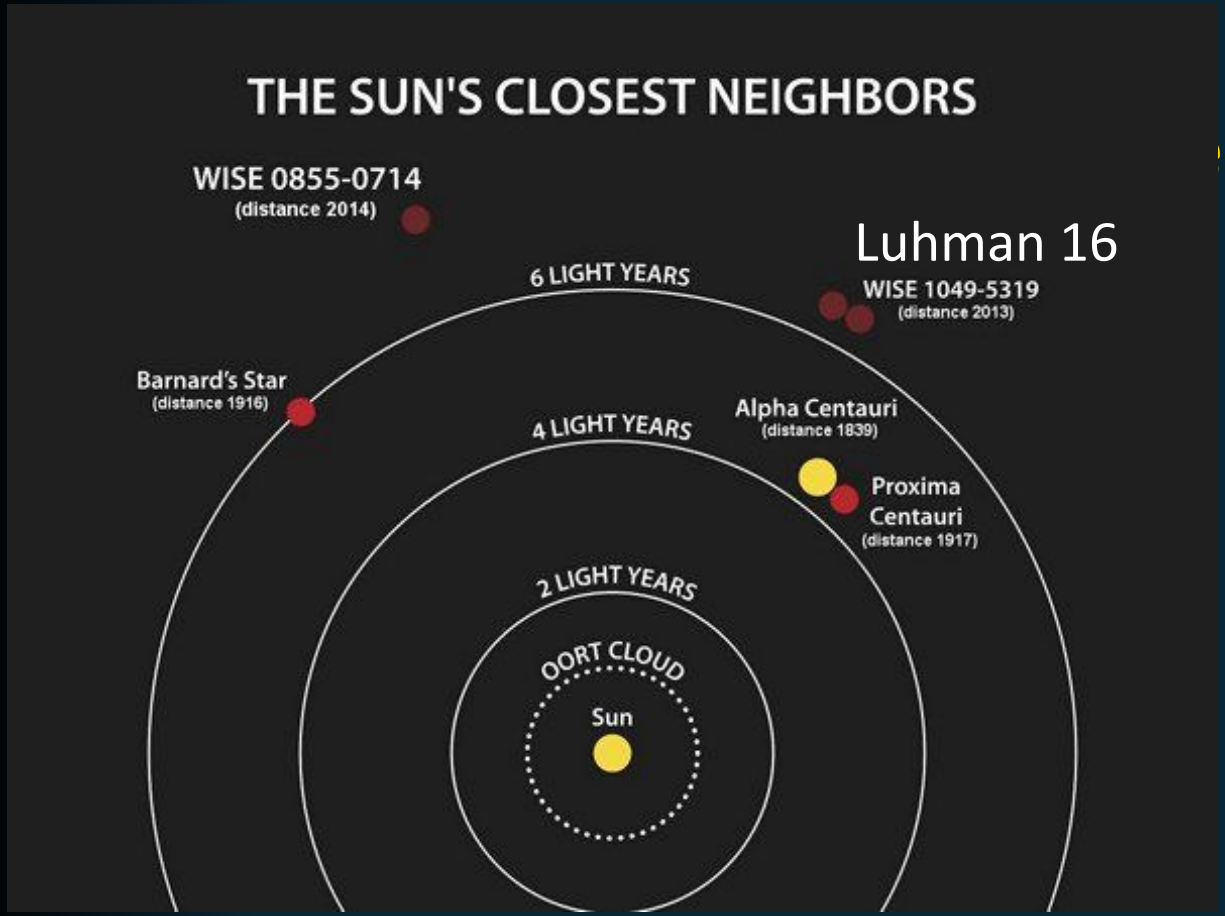


+ Taurus and B30

Open Questions

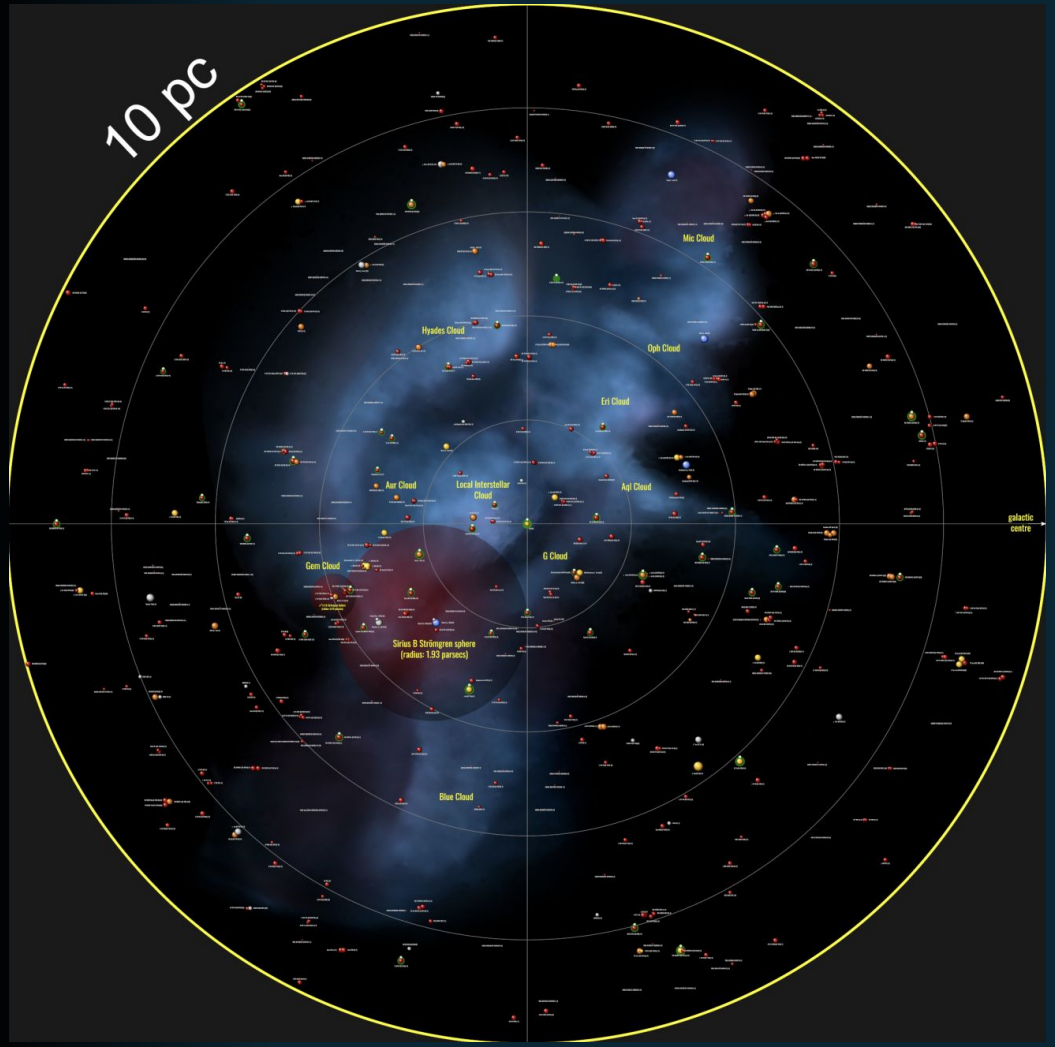
Open Questions

- **Are there unknown substellar objects lurking in our vicinity?**



Luhman 16

cts lurking in our



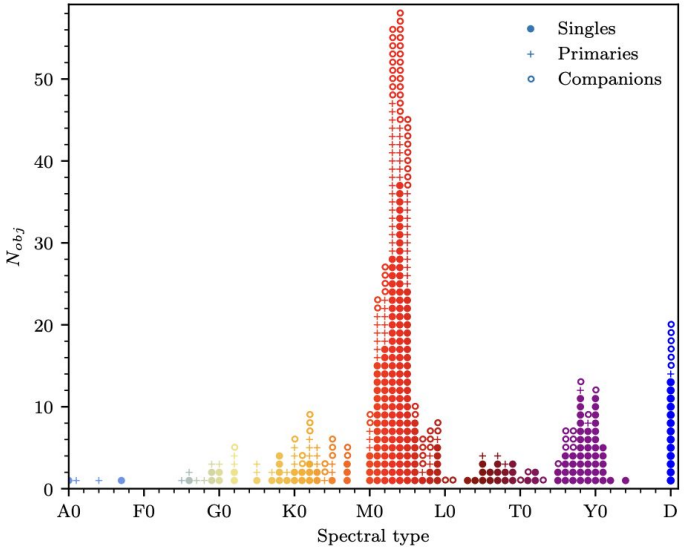


Fig. 2. Spectral type distribution of the 10 pc sample. D are white dwarfs. The different symbols indicate single stars, primaries, and companions.

Reylé et al. 2021
540 objects within 10pc
Gaia

Open Questions

- Are there unknown substellar objects lurking in our vicinity?
- Is there a substellar IMF cut off?

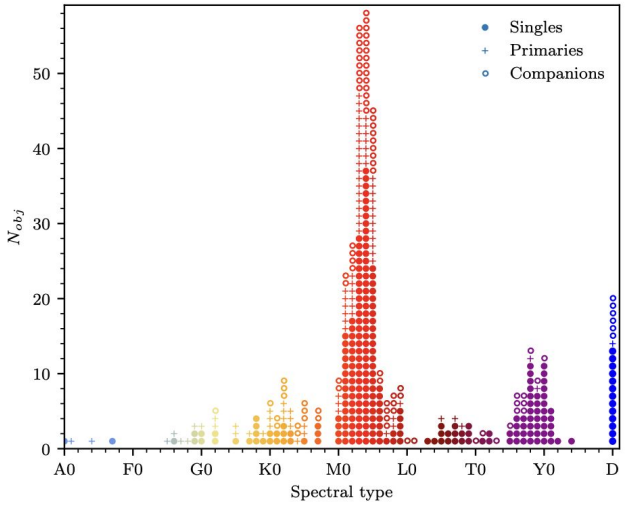
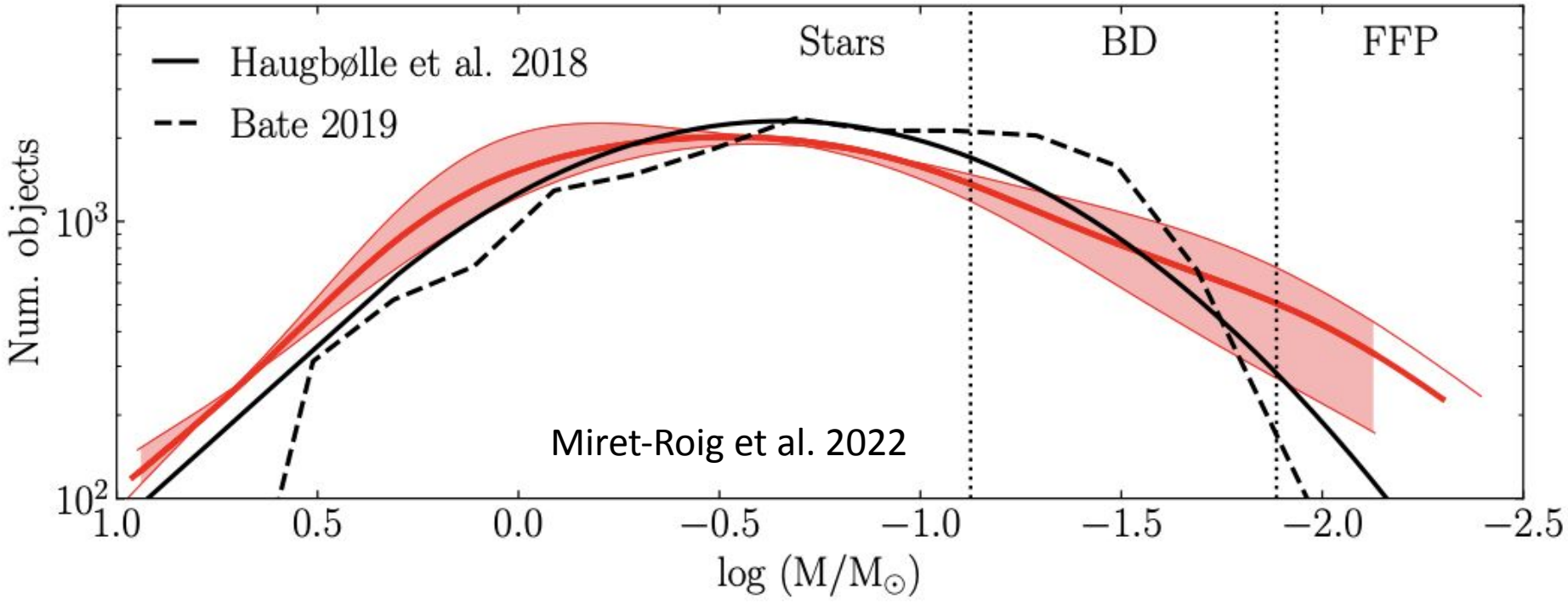


Fig. 2. Spectral type distribution of the 10 pc sample. D are white dwarfs. The different symbols indicate single stars, primaries, and companions.

Reylé et al. 2021
540 objects within 10pc
Gaia

Open Questions



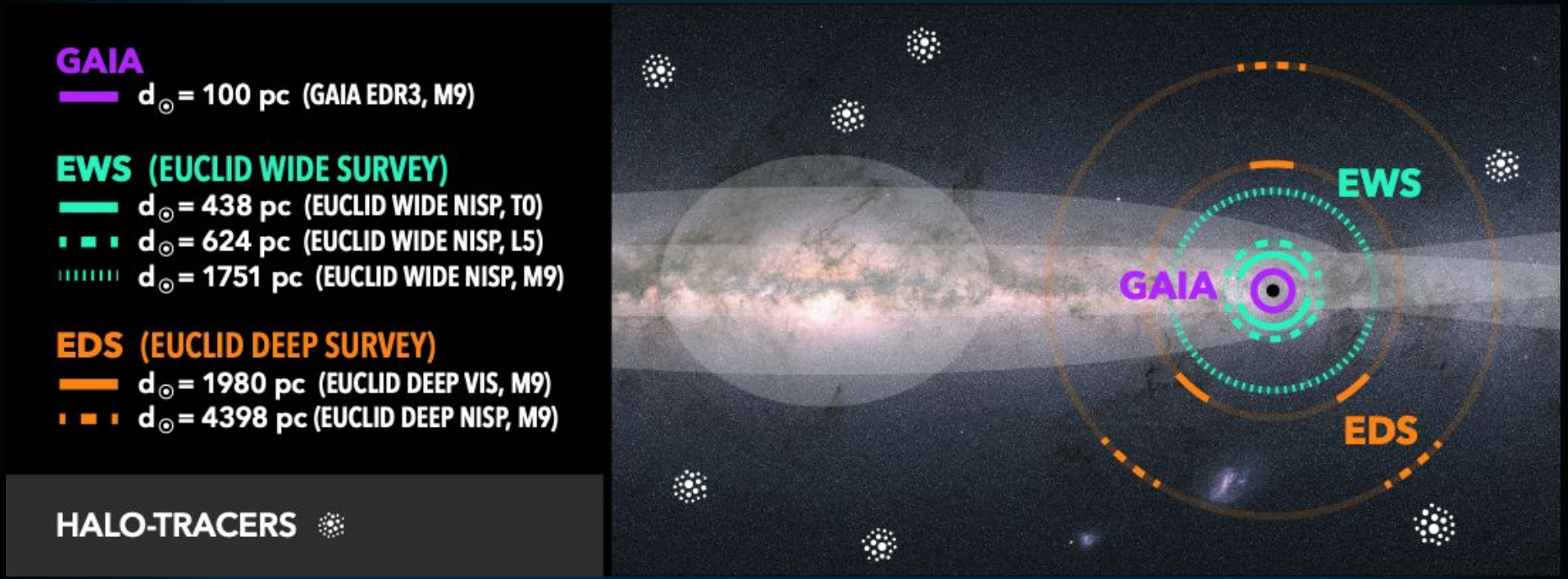
Upper Scorpius in the Scorpius-Centaurus association

Open Questions

- Are there unknown substellar objects lurking in our vicinity?
- Is there a substellar IMF cut off?
- What halo brown dwarfs look like & how numerous?

BREAKTHROUGH

Reach deeper, further & wider than ever before



Slide credit: Eduardo Martín

Open Questions

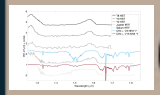
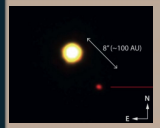
- Are there unknown substellar objects lurking in our vicinity?
- Is there a substellar IMF cut off?
- What halo brown dwarfs look like & how numerous?
- What kind of planets orbit around substellar primaries?

Open Questions

- Are there unknown substellar objects lurking in our vicinity?
- Is there a substellar IMF cut off?
- What halo brown dwarfs look like & how numerous?
- What kind of planets orbit around substellar primaries?
- Does life thrive in habitable atmospheres of substellar objects?



STATE OF THE ART / CHALLENGE

	STATE OF THE ART	CHALLENGE
Substellar objects (with spectra)	 ($2x10^3$)	$2x10^6$ ($2x10^5$)
Substellar binaries (dynamical masses)	150 (40)	$2x10^4$ (400)
Substellar wide companions to stars	 50	1000
Planets around substellar primaries	10	100
Halo substellar objects	0	few $x10^2$

Slide credit: Eduardo Martín

Synergy with other surveys

Rubin Observatory
Nancy Grace Roman Space Telescope
JWST
SPHEREx

IMPACT

Transforming substellar science

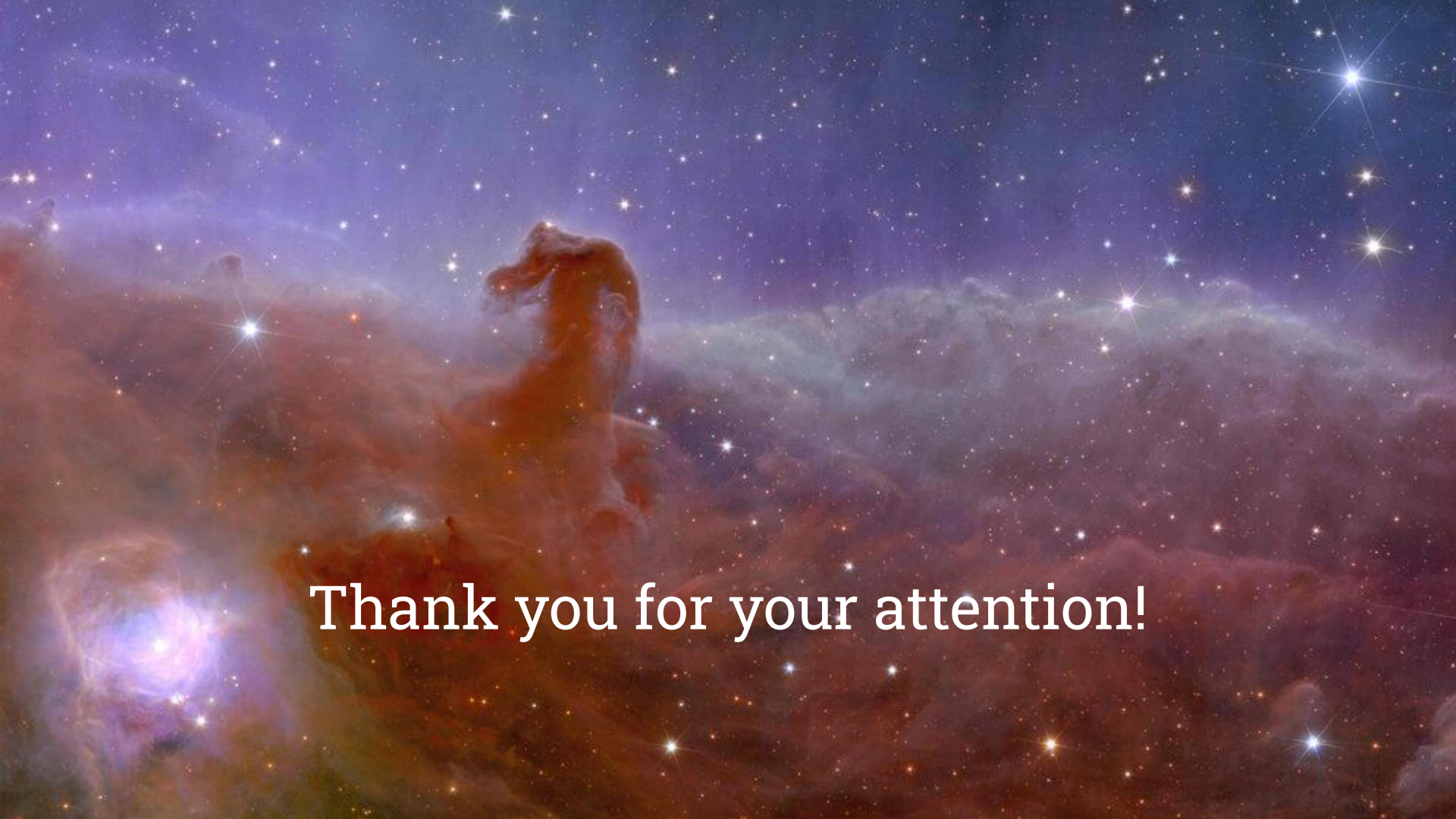
(order of magnitude leap in detections & spectra)

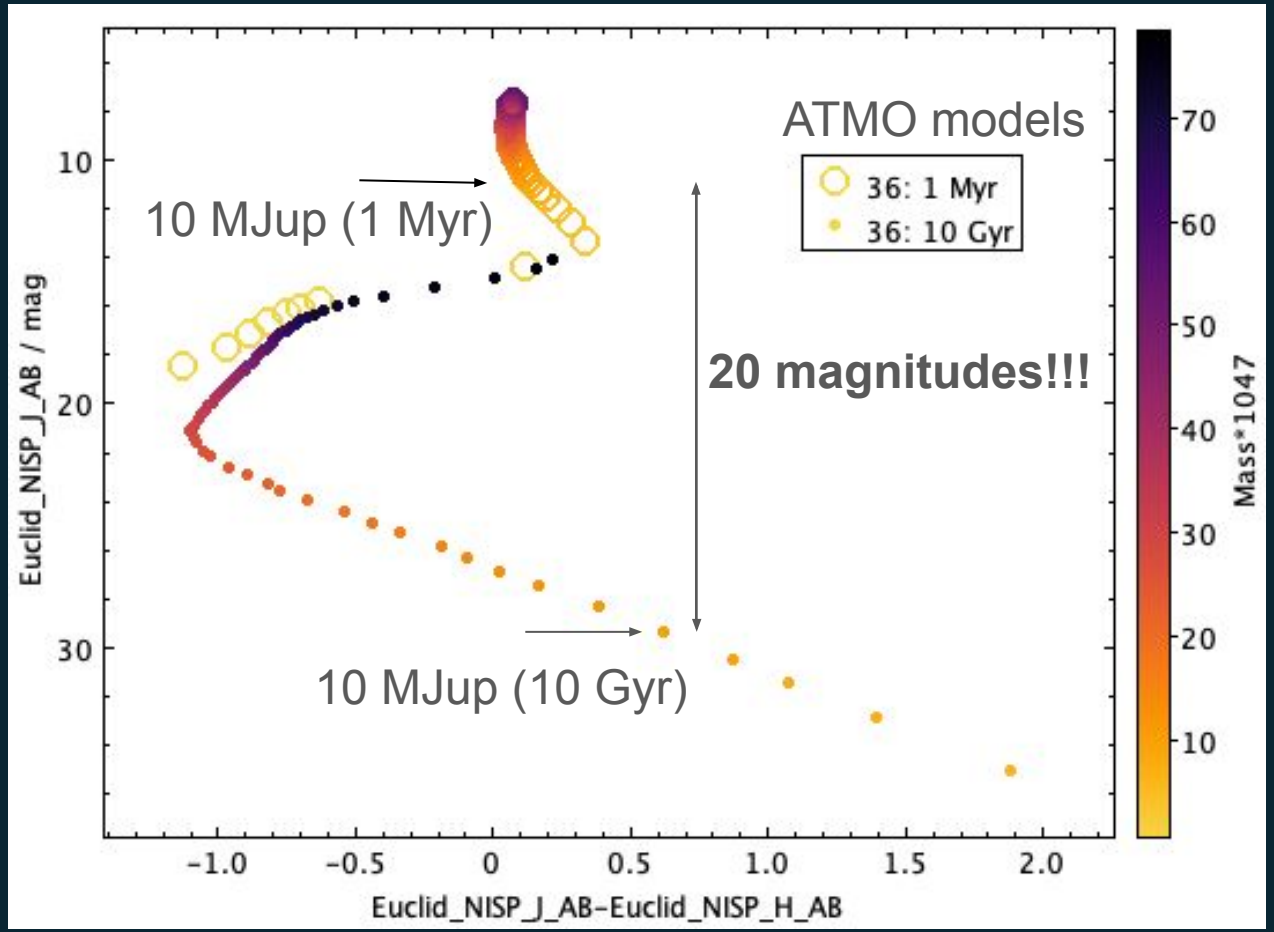
Creating new standards

(order of magnitude leap in substellar binaries & new types of objects)

Connecting substellar with galactic, stellar & exoplanet science

(bridging the IMF across wide range in mass)


Thank you for your attention!


ATMO models
36: 1 Myr
36: 10 Gyr
10 MJup (1 Myr)
10 MJup (10 Gyr)
20 magnitudes!!!
Euclid_NISP_J_AB / mag
Euclid_NISP_J_AB-Euclid_NISP_H_AB
Mass*1047
10
20
30
-1.0
-0.5
0
0.5
1.0
1.5
2.0
10
20
30
40
50
60
70

Open Questions

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2018

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CrossMark

OGLE-2017-BLG-1522: A Giant Planet around a Brown Dwarf Located in the Galactic Bulge

Y. K. Jung[1,10], A. Udalski[2,11], A. Gould[1,3,4,10], Y.-H. Ryu[1,10], J. C. Yee[5,10],
and
C. Han[6], M. D. Albrow[7], C.-U. Lee[1,8], S.-L. Kim[1,8], K.-H. Hwang[1], S.-J. Chung[1,8], I.-G. Shin[5], W. Zhu[3], S.-M. Cha[1,9],
D.-J. Kim[1], Y. Lee[1,9], B.-G. Park[1,8], D.-J. Lee[1], H.-W. Kim[1], R. W. Pogge[4]
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M. K. Szymański[2], P. Mróz[2], R. Poleski[2,3], J. Skowron[2], P. Pietrukowicz[2], I. Soszyński[2], S. Kozłowski[2], K. Ulaczyk[2],
M. Pawlak[2], and K. Rybicki[2]
(The OGLE Collaboration)