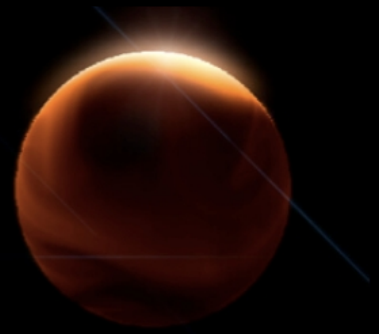
Very low-mass companions to Gaia high proper motion stars



Bartosz Gauza

(Institute of Astronomy Univ. of Zielona Góra, Poland)

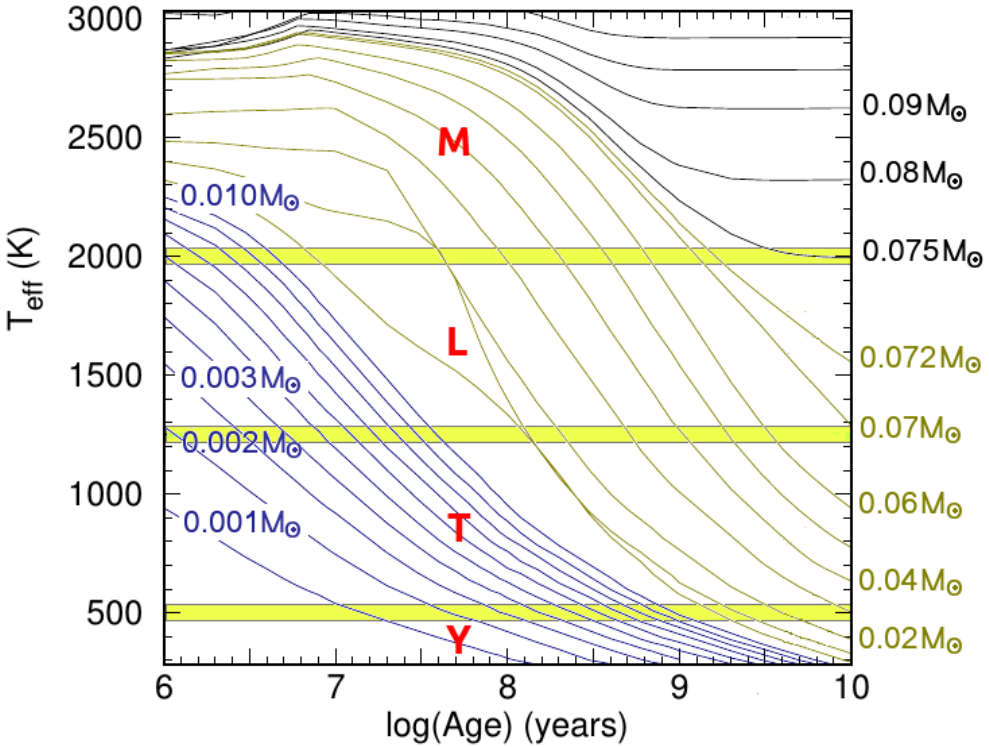
Kamil Rączka (IA UZ)

and the IAC Substellar Team: V. Bejar, J. Zhang, N. Lodieu,
M. R. Zapatero Osorio, R. Rebolo, Z. Zhang, A. Perez-Garrido

National Science Centre Poland

30 Years of Substellar Science

Without the internal source of energy...

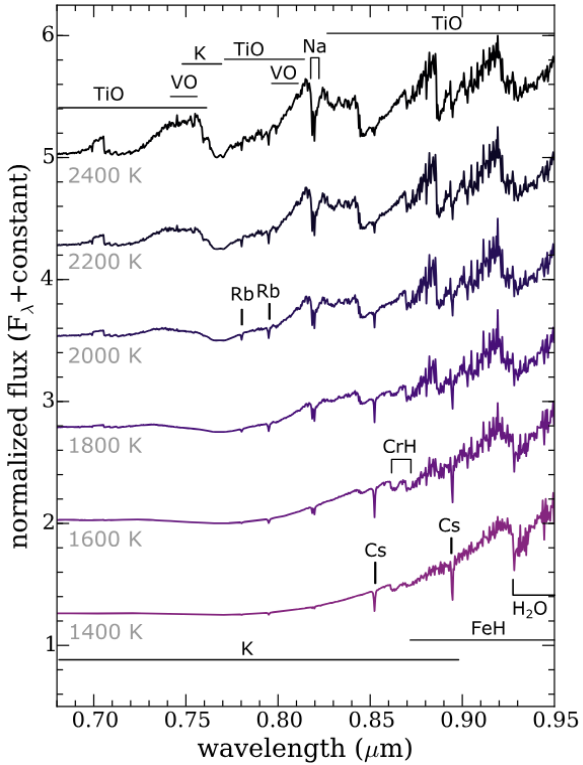


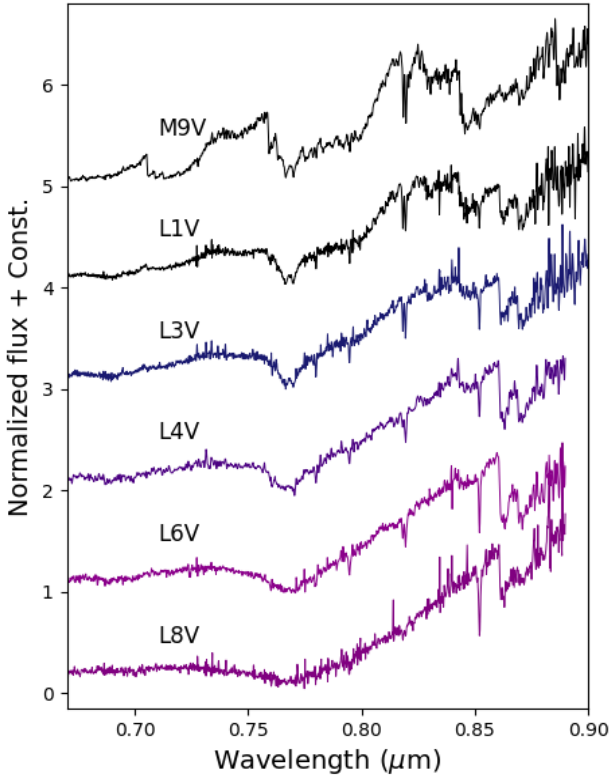
BT-Settl models;
(F. Allard, Homeier, D. Freytag, B.; 2012)

Models are doing very well!

SONORA models

Mark Marley et al. (2021, 2024+)



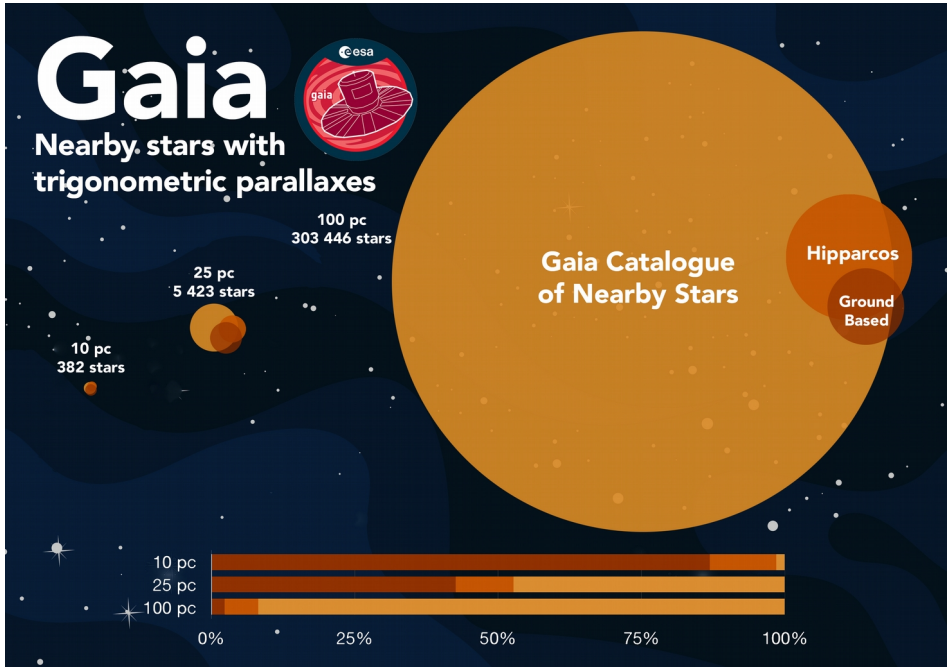


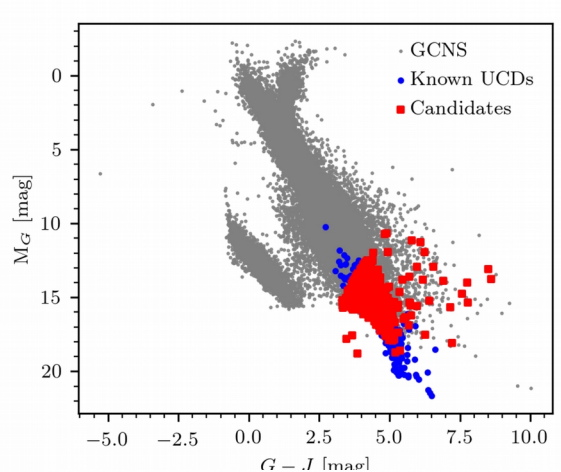
SDSS templates

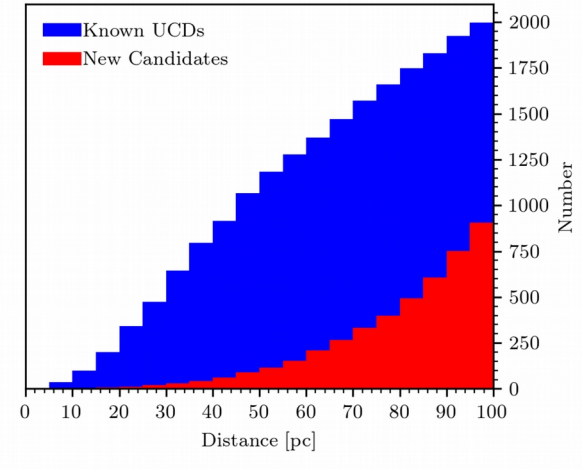
Sarah Schmidt et al. (2014)

UCDs in Gaia

The GCNS (Smart et al. 2021);
UCD Companions (Baig et al. 2024)







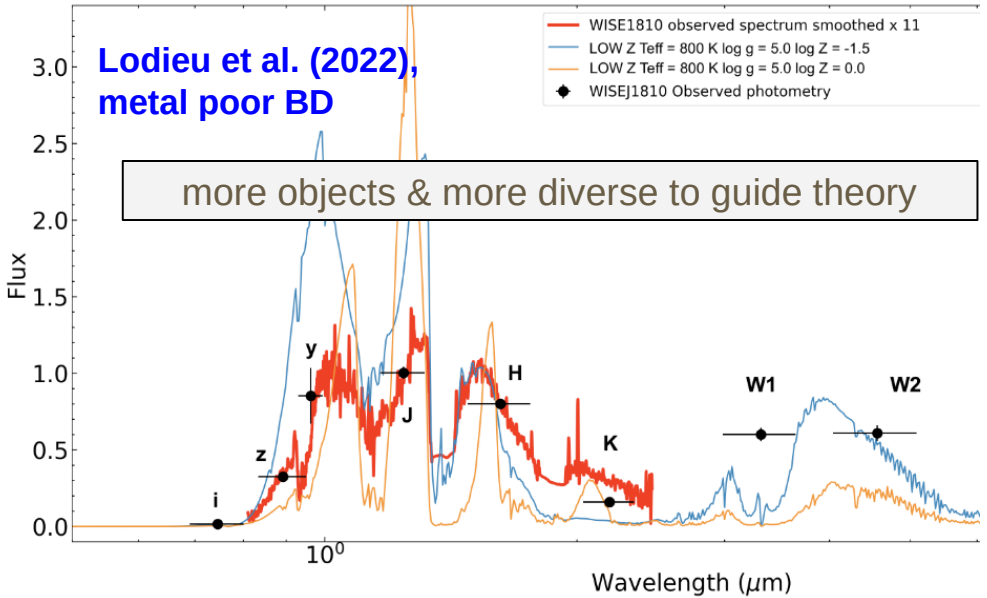
Motivation

Numerous ultracool dwarfs, brown dwarfs, known in the Solar backyard, only a small portion allow a thorough characterization **(e.g. > companions <)**.

A strong need to find and characterize more, to better trace broader range of fundamental parameters:

+ temperatures, masses ages / surface gravities, metallicities

+ study of mass ratios, distribution of orbital separations, frequencies

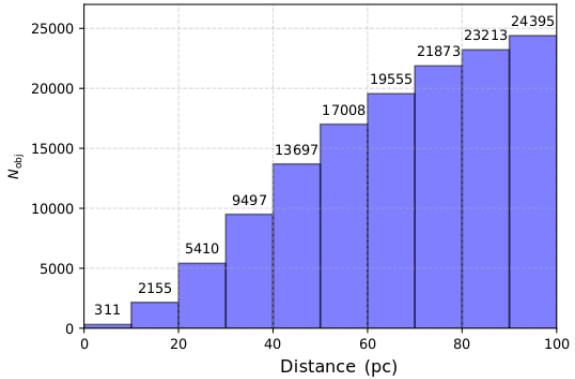


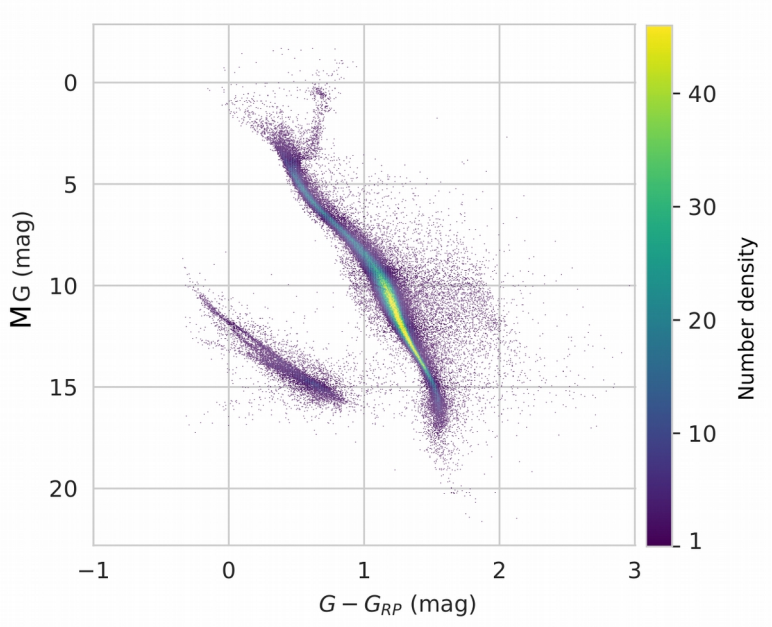
Candidates selection

High proper motion sources within 100 pc in the Gaia DR3:

proper motion: $\mu \geq 100$ mas/yr
parallax: $\pi \geq 10$ mas **and**
$\pi \geq 3 \times \pi\_error$

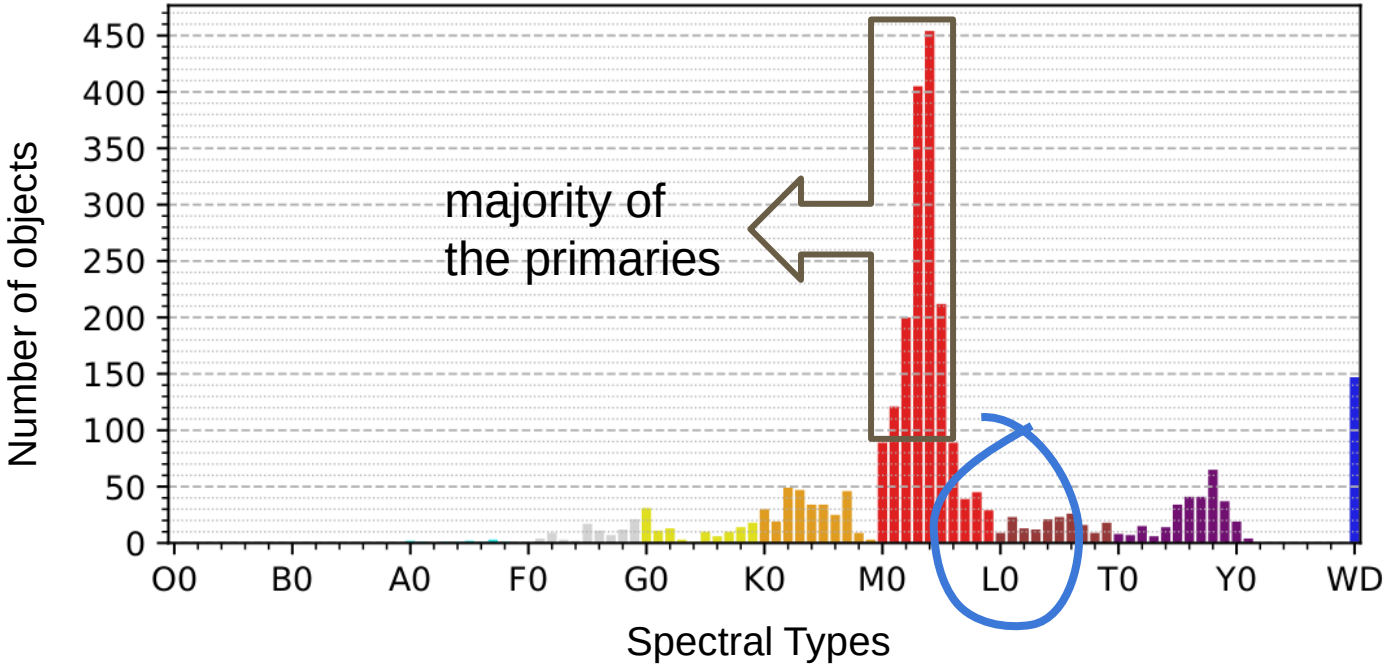
137 114 individual sources





Candidates selection

Stellar, sub-stellar and post-stellar content within 20 pc of the Sun
(data from Kirkpatrick et al. 2024)



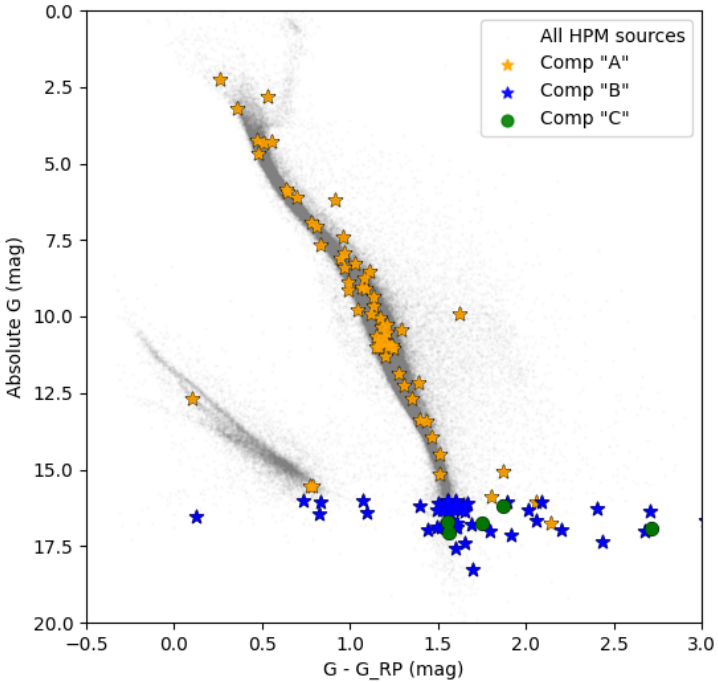
Candidates selection

common proper motions **(μα cos δ, μδ) ⩽ 50 mas/yr difference**
consistent parallaxes **∇π □ 10 x (err_π_A + err_π_B)**
max projected separations equivalent to **r ⩽ 10 000 au**

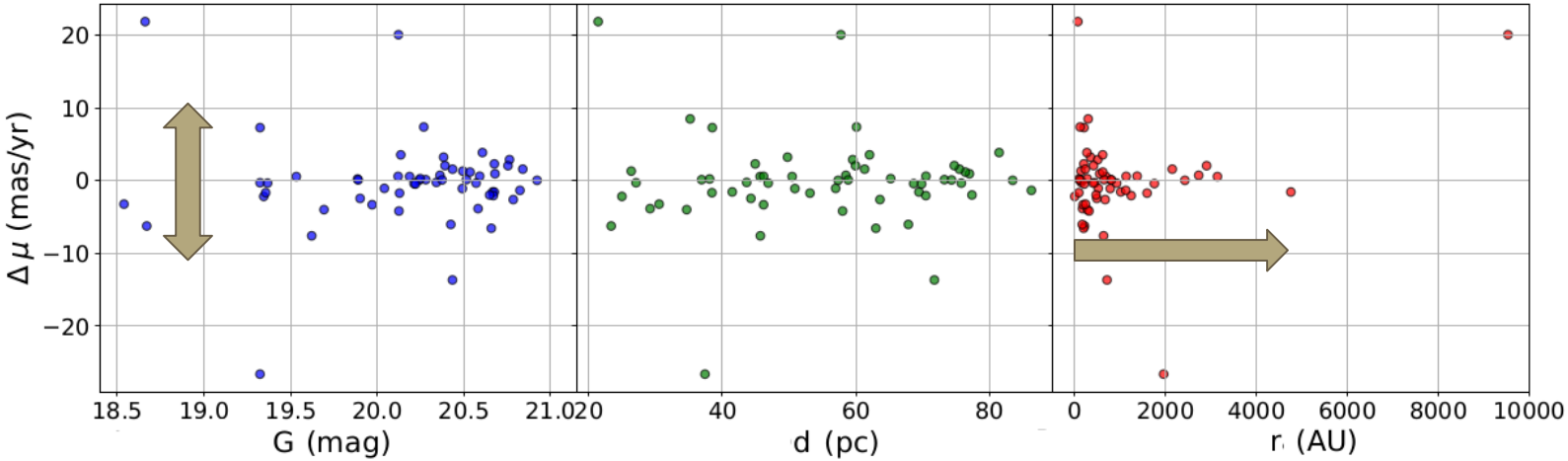
at least one component having **MG ⩾ 16.0 mag –**
corresponding to ultracool dwarfs **SpT ~ M8V and later**
(*and likely some white dwarfs)

	Binaries	Triples	Quad
All identified	**10 026**	**349**	**17**
With UCD candidate	**111**	**7**	**0**
With UCD candidate, yet unknown*	**56**	**5**	**0**

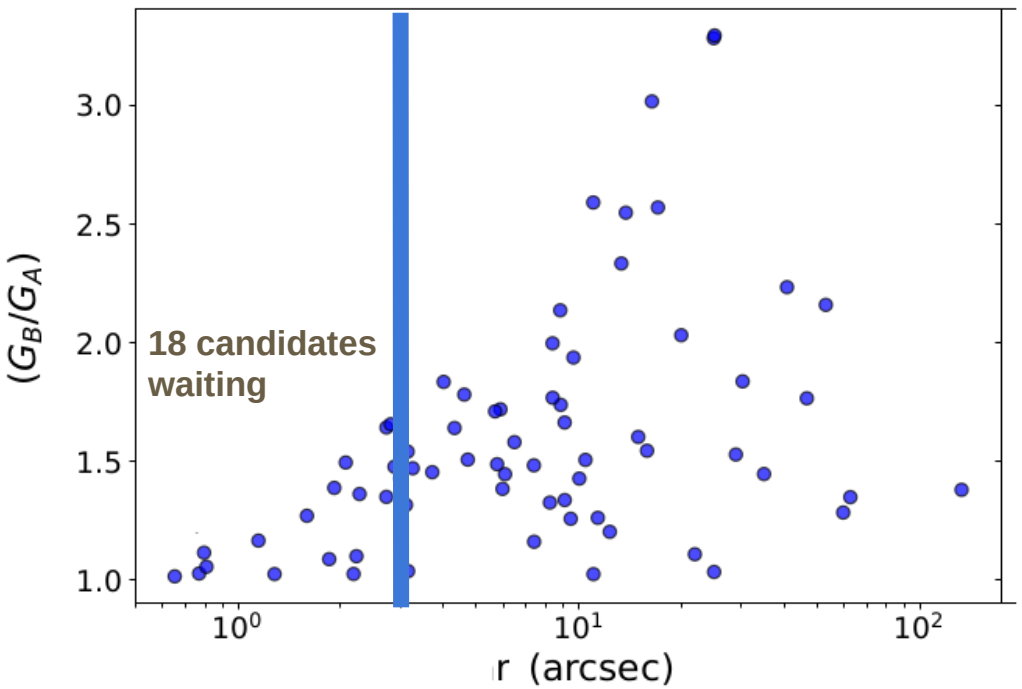
* not recognized as companions, or SpType not known (or both)



Results


20
10
0
−10
−20
Δμ (mas/yr)
18.5
19.0
19.5
20.0
20.5
21.0
G (mag)
20
40
60
80
d (pc)
0
2000
4000
6000
8000
10000
r (AU)

Results - follow-up



Spectroscopic follow-up of
40 systems with r > 3.0 arcsec
from the Northern Sky

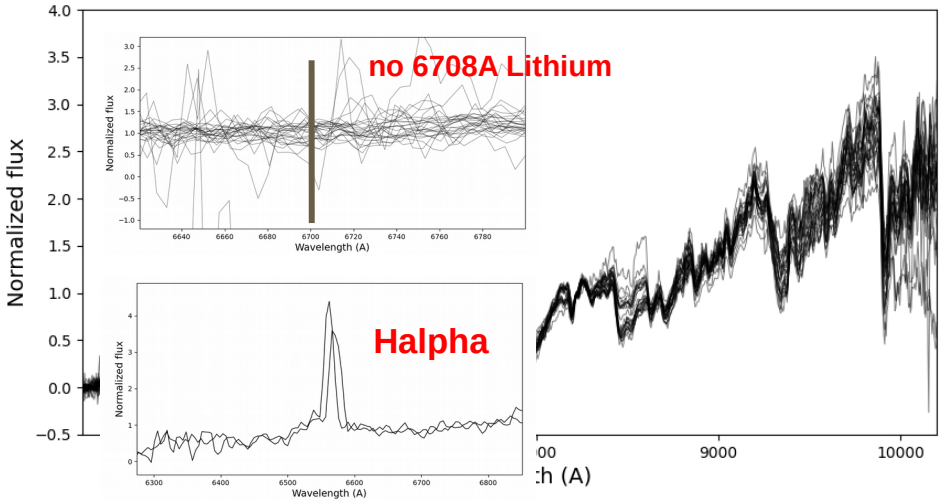
GTC/OSIRIS low-res optical spectra;
Filler program - 25.7 hours in total
September 2024 - March 2025

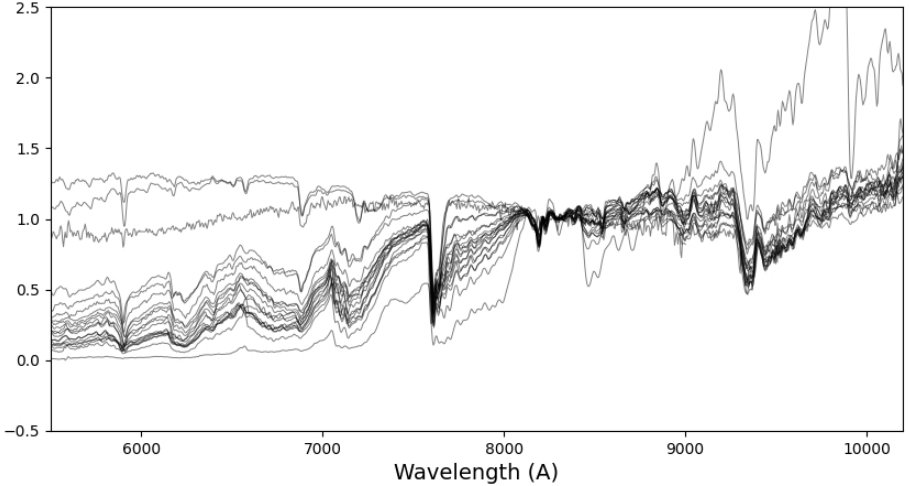
Completed

Results - spectral characterization

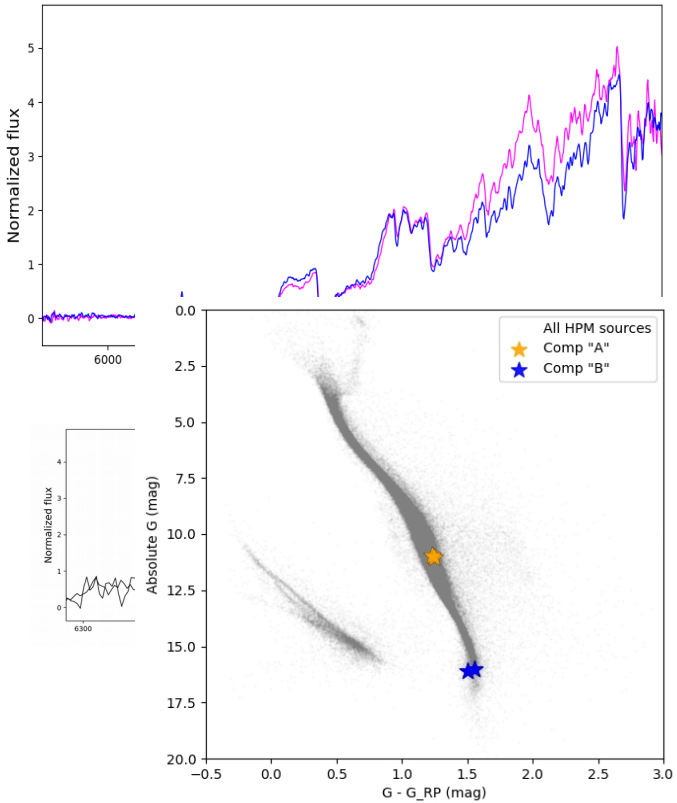
27 confirmed ultracool companions,
M9 - L5 SpType, mostly L0 - L2

+20 primaries,
mostly early-mid M dwarfs





Results - spectral characterization



	A	B	A	B
SpType	**M6.0 +/- 0.5**	**L1.0 +/- 1.0**	**M5.0 +/- 1.0**	**L0.0 +/- 1.0**
parallax	12.83 +/- 0.03	13.09 +/- 0.94	19.87 +/- 0.39	19.82 +/- 0.42
pmra	-167.51	-166.14	117.37	117.15
pmdec	18.04	19.79	-16.93	-14.48
G (mag)	15.47	20.53	14.47	19.53
Vtan (km/s)	62.24	60.58	28.28	28.22
Distance (pc)		77.9 +/- 0.2		50.3 +/- 1.0
Rho (arcsec)		8.22		62.57
Proj. sep (AU)		640.3		3147.7

Mildly large Vtan

High RUWE = 19.6

Comparisons

The Gaia Ultra-Cool Dwarf Sample – III: seven new multiple systems containing at least one Gaia DR2 ultracool dwarf. (Federico Marocco, Richard Smart, Eric Mamajek et al. 2020)

>> 10 new ultracool dwarfs in seven wide binary systems discovered using Gaia DR2

The Gaia ultracool dwarf sample – V: the ultracool dwarf companion catalogue.

(Sayan Baig, Richard Smart, Hugh Jones et al. 2024)

Ultracool Dwarf Companion Catalogue

>> 278 multiple systems, 32 of which were newly discovered, each with at least one spectroscopically confirmed Ultracool Dwarf, within a 100 pc volume-limited sample.

The Gaia ultracool dwarf sample – VI. Spectral types and properties of 51 ultracool dwarfs

(Gemma Cheng, Hugh Jones, Richard Smart et al. 2025)

>> 6 UCDs found to be components in wide systems

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Final remarks

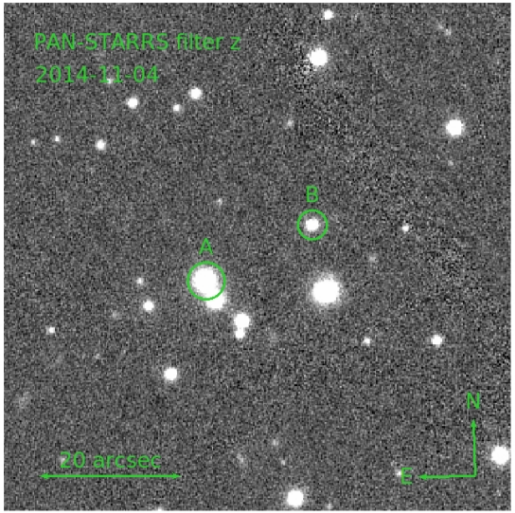
Significant portion of new, confirmed, spectrally characterized ultracool companions within 100 pc

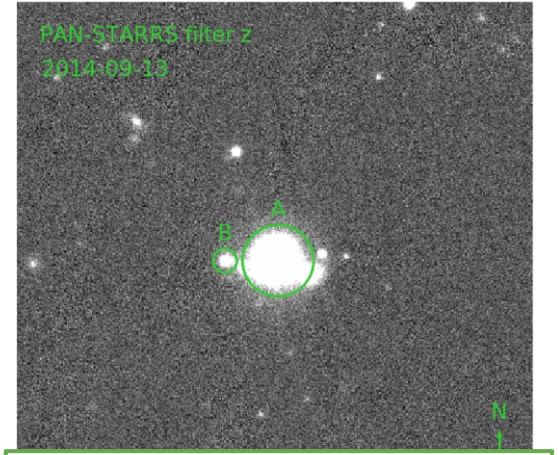
Having Gaia primaries, all of these are useful anchor points to improve theory (atmospheric, evolutionary models, formation scenarios, role of log(g), age, [M/H], atmospheric structure, vertical mixing, role of disequilibrium chemistry)

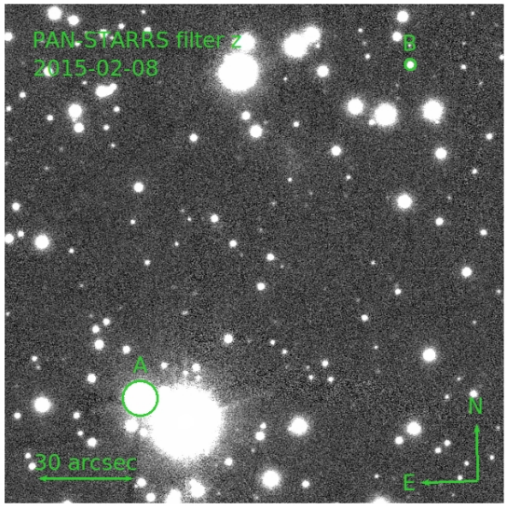
Still lots of valuable ultracool stuff hiding overlooked in the vast Gaia DR3;

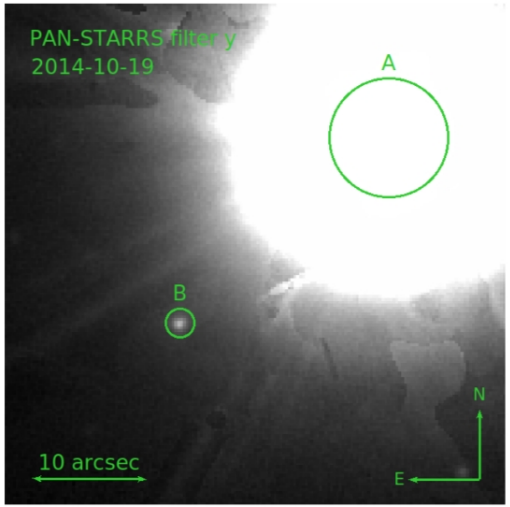
Fine-tune the tools to efficiently mine the DR4, DR5 for more UCD companions (*or other type of objects)

WE NEED IR GAIA

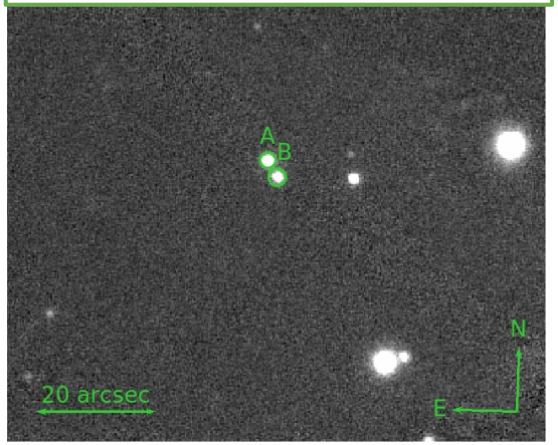

PAN-STARRS filter z
2014-11-04
A
B
N
E
20 arcsec

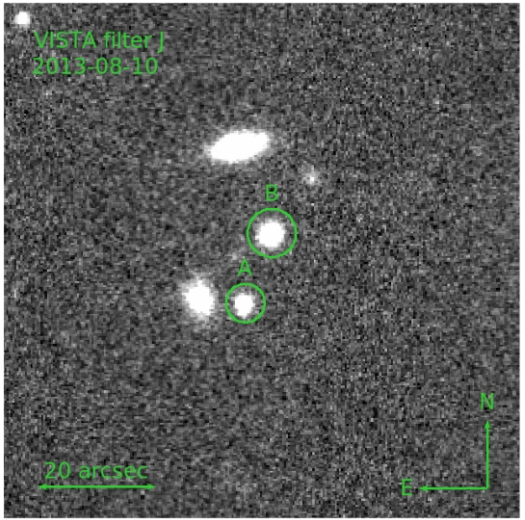

PAN-STARRS filter z
2014-09-13
A
B
N
E


PAN-STARRS filter z
2015-02-08
B
A
N
E
30 arcsec


PAN-STARRS filter y
2014-10-19
A
B
N
E
10 arcsec

Thank you!


A
B
N
E
20 arcsec


VISTA filter J
2013-08-10
B
A
N
E
20 arcsec