LAMOST DR7 中发现的极冷矮星

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OUTLINE

- Introduction – ultracool dwarfs

- Sample selection

- Gaia EDR3 Photometry

- Spectroscopic analysis

- Kinematic diagnosis

- Common proper motion binary

- Summary

INTRODUCTION-ULTRACOOL DWARFS

- Definition of ultracool dwarfs
  - Brown dwarfs：0.075 and $0.013M_{\odot}$
  - Late M and early L dwarfs：low mass star & brown dwarfs
  - Mid-L to T dwarfs：all brown dwarfs
 - this sample：Late M ultracool dwarfs – low mass star and brown dwarfs

SAMPLE SELECTION

- Data set used
  - LAMOST DR7 with R~ 1800
  - 11412 M6 or latter:3764 dwarfs (33 %) , 7648 giants(67%)
  - Cross-match with the Gaia EDR3 within 5 arcsec
  - 469 BP-RP <1.0 removed
  - Visually inspection
    - Excluded:giants, early type or bad quality SPECTRA
    - 734 late M dwarfs derived
  - Visually checked the 734 cross-match

SAMPLE SELECTION

- Spectral features of giants versus dwarfs
  - Stronger in dwarfs : K I doublets 7688 Å,
    Na I 8189 Å, CaH between 6800 and 7000 Å ,
    CrH and FeH around 8700 Å

  - Stronger in giants: Ca II triplets at 8498 Å,
    8542 Å, and 8662 Å
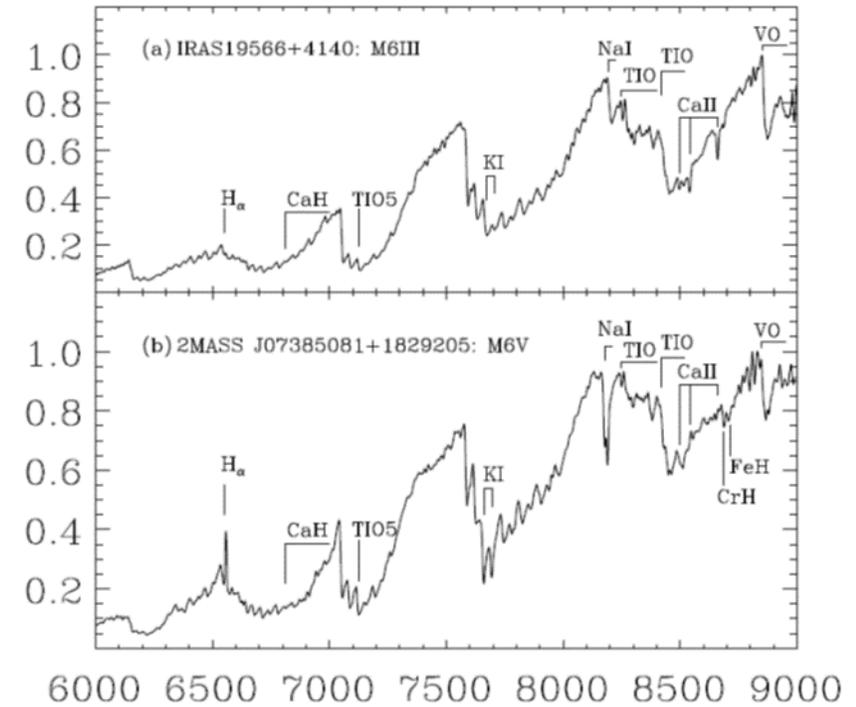
Strong in Dwarf	wavelength	7688A	8189	6800-7000	8700
	Line/band	KI	NaI	CaH	CrH\FeH
Strong in Giant	8498	8542	8662		
	CaII				

SAMPLE SELECTION

- excluded versus reserved
  - Snr_z < 2 excluded(~4% of 11412)
  - Compare spectra
  - Spectra with weaker KI, Na, and CaH
  - Early type M
  - a mixture of two sources, or bad spectra ETC
 - 734 sources are derived(9 are originally classified as giants in the official catalog)

SAMPLE SELECTION

- Sample of ultracool dwarfs
 - LAMOST official Spectral type of the sample

SpT	dM6	dM7	dM8	dM9	L0	gM6	gM7	gM8	gM9
number	577	128	16	3	1	3	2	1	3

- Two thirds are spectroscopically studied for the first time(SIMBAD)
- The L0 was once observed by other telescopes and classified as L0e and M9.5
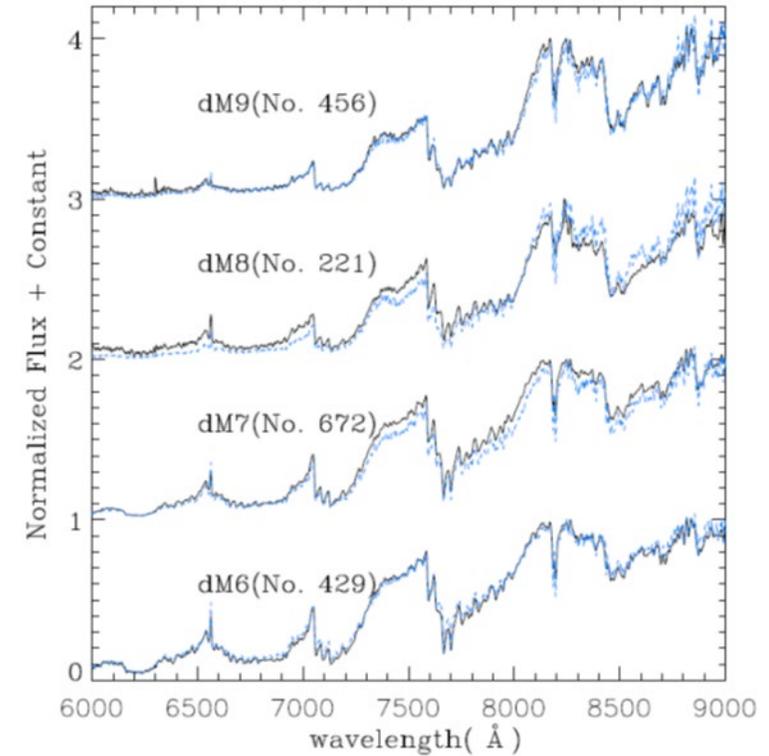
SAMPLE SELECTION

- Diagram of sky distribution
  - Grey big circles the footprints
  - green cross the 11412 late M
  - 4900 plates each 5 Square Degree
  - Footprint 20000 square degree

- Cool dwarf ratio study with Gaia
  - 130,000,000 sources within LAMOST 20000 square degree，143 thousand late M dwarfs(BP-RP >3, G < 19 and G_{abs} >9), cool dwarf ratio 0.11%
  - LAMOST observed10 million Gaia sources, pipeline 3764 late M dwarfs, cool dwarf ratio 0.03%
 - very low portion of ultracool dwarfs

X 11412 LDR7 released late M spectra   • 734 identified late M dwarfs (one L0)
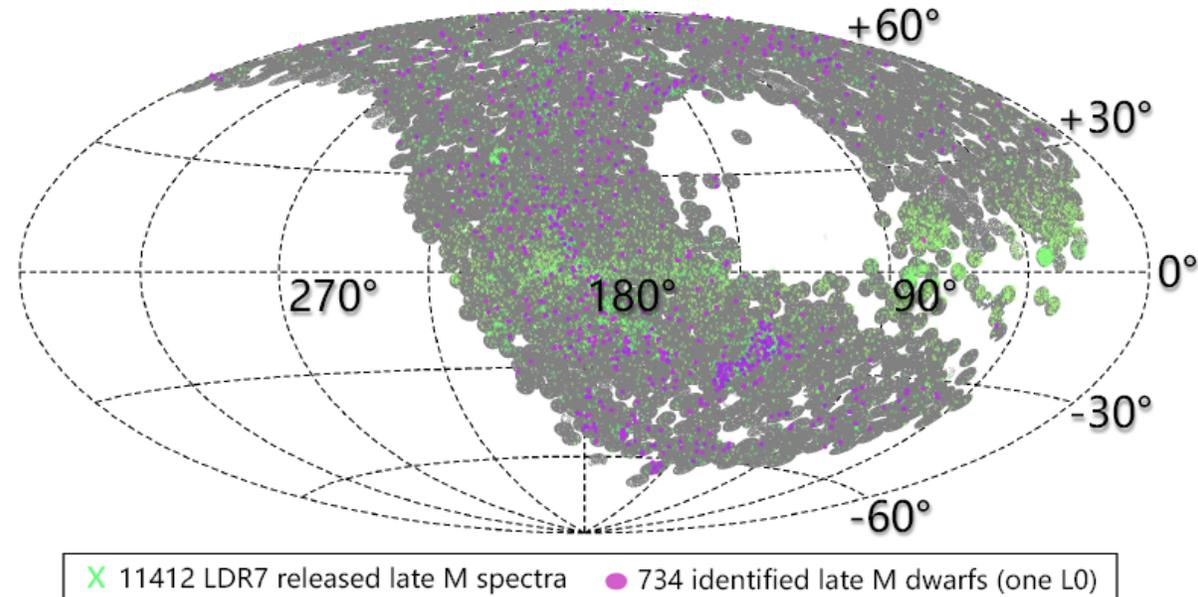
GAIA EDR3 PHOTOM

- Distance and apparent magnitude
  - All within 360pc, 80% within 100pc
  - Magnitude ~12 to ~19.2, mainly ~16.2
  - SNR in z 2 to 432, median 61
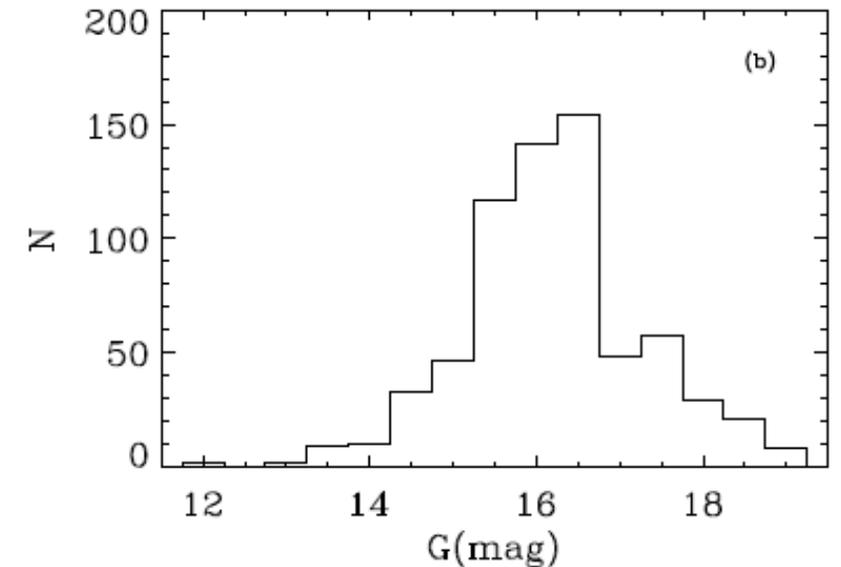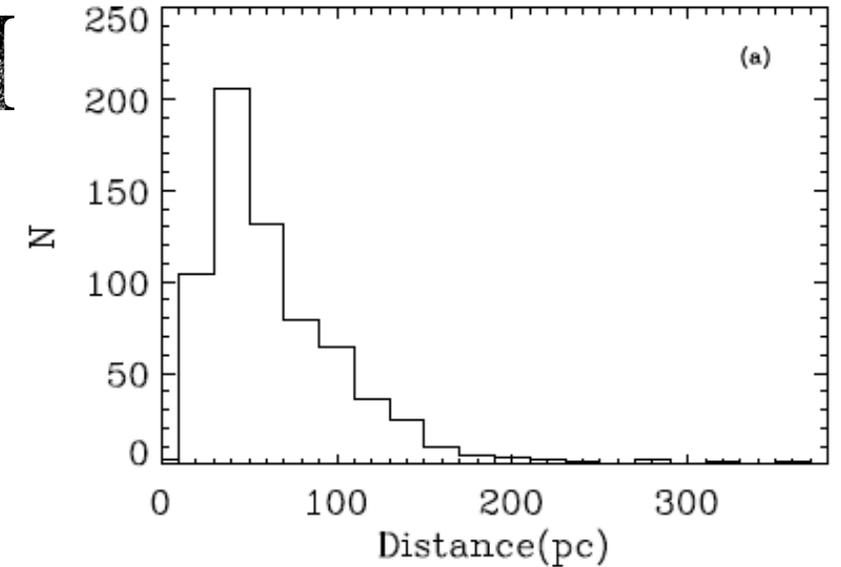
GAIA EDR3 PHOTOMETRY

- Restricts on Gaia data
  - Parallax uncertainty smaller than 20%, G、BP and RP greater than 0, 677 sources left
  - reciprocal distance

- Color –magnitude diagram
  - Black solid dots– 677 of the 734 ultracool dwarfs
  - Cyan solid dots– 11412 late m
  - Plot a : 2.5<BP-RP <5mag, 9<G_{abs}<16.7 mag(UCD)
  - Plot b:G-RP color have bigger scatter
    - Fainter or Binary
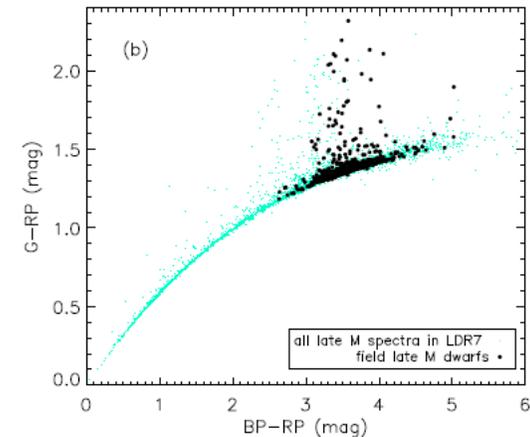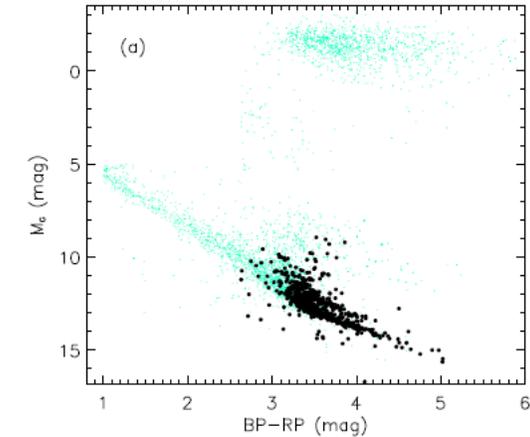
SPECTROSCOPIC ANALYSIS

- Methods to get parameters
  - LAMOST stellar parameter pipeline for M stars (LASPM) , minimize the χ^2 6000 to 8800 , SNr I > 5
  - grids: BT-Settle CIFIST2011(Allard et al 2011,2012)
  - Grids covering

	Teff(K)	Log g(dex)	FeH(dex)
range	300-8000	0-6.0	-2.5-0.5
step	100	0.5	0.5

SPECTROSCOPIC ANALYSIS

- Atmosphere parameters
  - Teff 2600 K to 3300 K, mean temperatures for each SpT :

| SpT	M6	M7	M8	M9
<Teff>	3018	2917	2775	2675

  - usually higher than the literature(200K),
  - reason of bias: saturation of TiO absorption band
- surface gravity: 3.5 to 5.5 dex   mean : 4.43 dex
- metallicity -0.99 to +0.38, <[M/H]> = -0.33, consistent with Galactic disk dwarfs (Wyse & Gilmore 1995, <[M/H]>= -0.4)
- Caution for individual parameter

SPECTROSCOPIC ANALYSIS

- Lithium diagnosis
  - Young late M have higher possibility being brown dwarf
  - Lithium line: indicator of young
  - 0.065 to 0.075 solar mass brown dwarfs burn the lithium up within about 100Myr
  - 77 ultracool dwarfs have lithium
  - labeled H/M/L
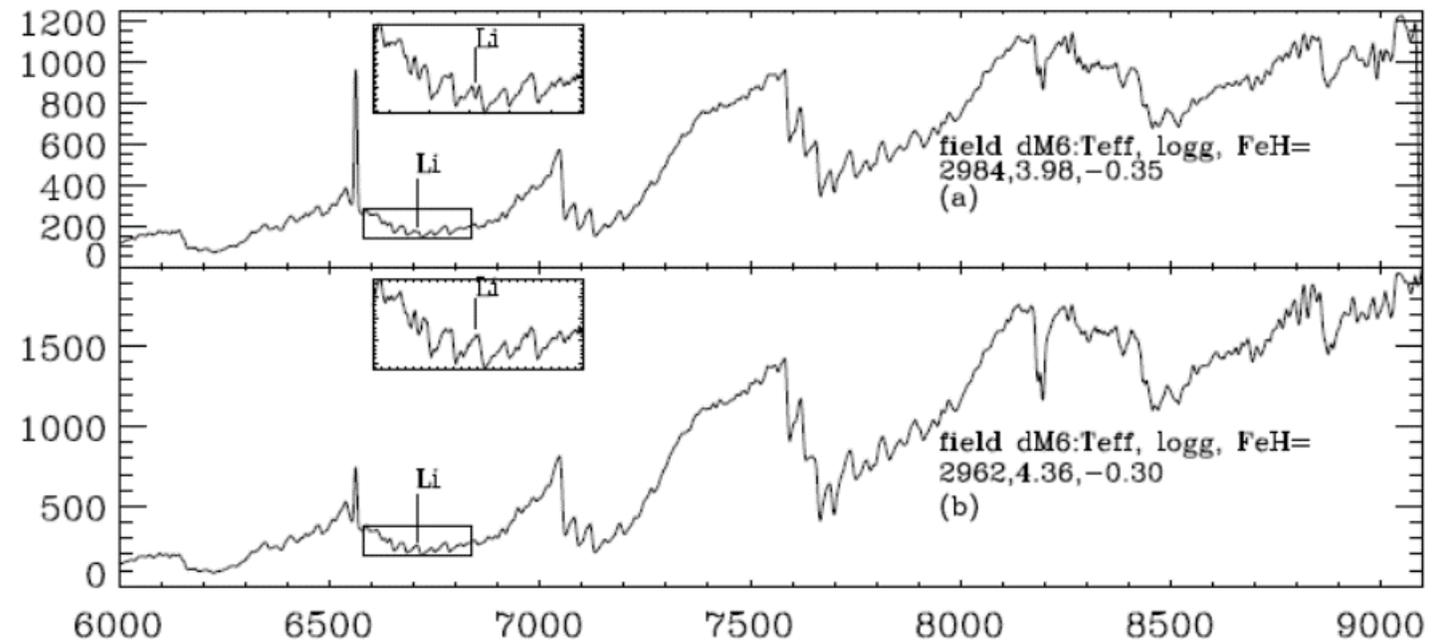
KINEMATIC DIAGNOSIS

- Space position and velocity
  - RV(lamost dr7), RV Zhong et al 2015, 3 sigma clip
  - Five astrometric parameter from Gaia EDR3
 - The U V W and R Z derived assume:
    - 1)U V W assume

	Positive direction towards
U	the Galactic center
V	the Galactic rotation
W	the Galactic north pole

  - (2) R = 8.2 kpc (Bland-Hawthorn & Gerhard 2016);
  - (3) LSR 238 km/s, motion of the sun to LSR is [U; V;W] = [14.0; 12.24; 7.25] km/s (Schönrich et al. 2010)
  - 4) the distribution of equatorial coordinates, proper motion, and parallax is a multivariate Gaussian (Marchetti et al. 2019; Li et al. 2021).

KINEMATIC DIAGNOSIS

- Galactic population analysis
    - 1) R vs z diagram : -289 <z<229 pc, 8100<R<8500 pc
    - 2) toomre diagram: 70 thick/ thin disk limit, 180/220 thick disk/ halo limit
    - 3)possibility ratio method(Bensby et al 2003):thick disk to thin disk(TD/D) / thick disk to halo (TD/H)probability, 491 have TD/D greater than 0.1 being thin disk objects.

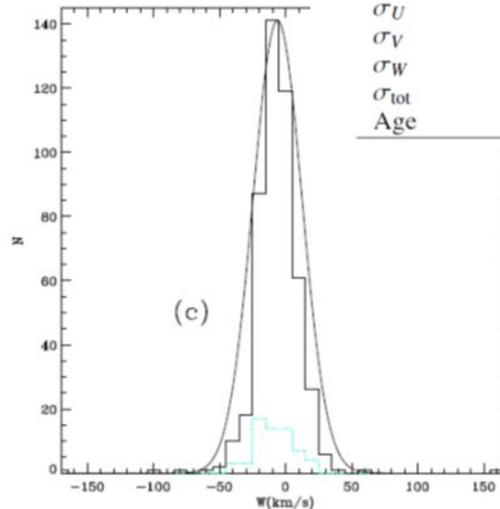- Most of our ultracool dwarfs are thin disk objects, a small part being thick disk
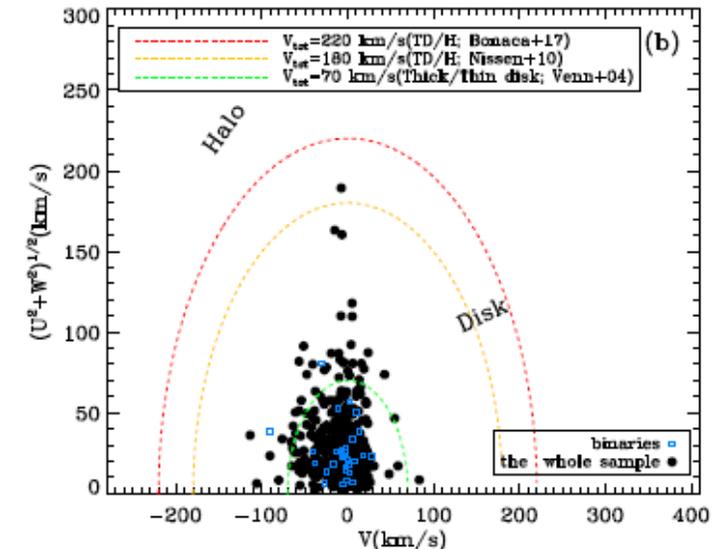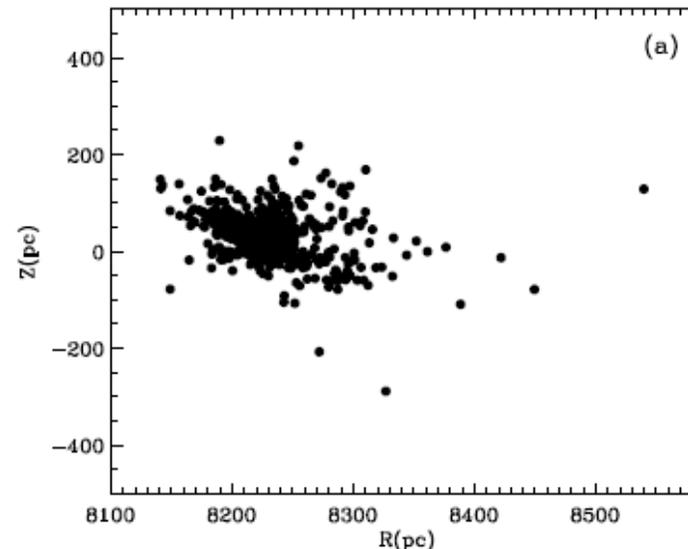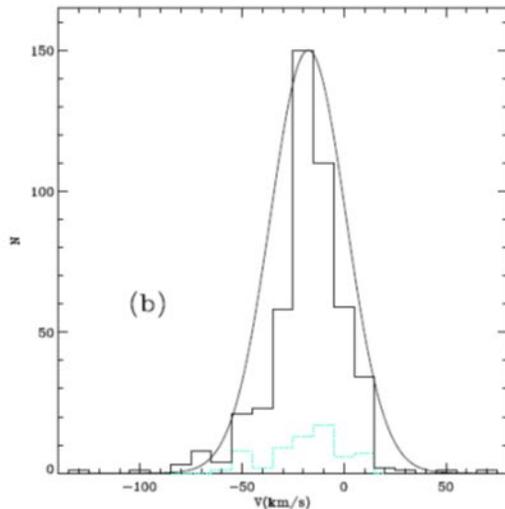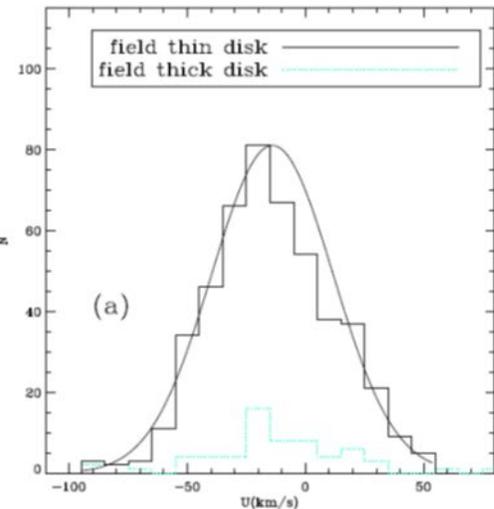
KINEMATIC DIAGNOSIS

- Velocity distribution and kinematic age
  - Binaries excluded, u v w not LSR corrected, cyan dotted line are thick disk
  - Kinematic age: A monotonic increase of velocity dispersion with age growing for a given stellar population.

$$\sigma_v(\tau) = v_{10} \left(\frac{\tau + \tau_1}{10\,\mathrm{Gyr} + \tau_1} \right)^{\beta}$$

	$\langle v \rangle$	Low err	High err	σ_v	Low err	High err	Age	Low err	High err
		(km s^{-1})			(km s^{-1})			(Gyr)	
U	−14.03	1.20	1.20						
V	−17.60	0.71	0.71						
W	−6.19	1.21	1.20						
σ_U				25.71	1.17	1.18			
σ_V				18.53	0.89	0.89			
σ_W				18.60	1.43	1.37			
σ_{tot}				36.75	4.21	4.07			
Age							2.97	0.90	1.06

COMMON PROPER MOTION BINARY

- Identification

- Data used: Gaia astrometry and PanSTARRS image

- 35 common proper binaries, 6 are newly discovered

- The others are in the literature, e.g. WDS catalog,

- Catalog of ultra-wide binary stars from Gaia DR2
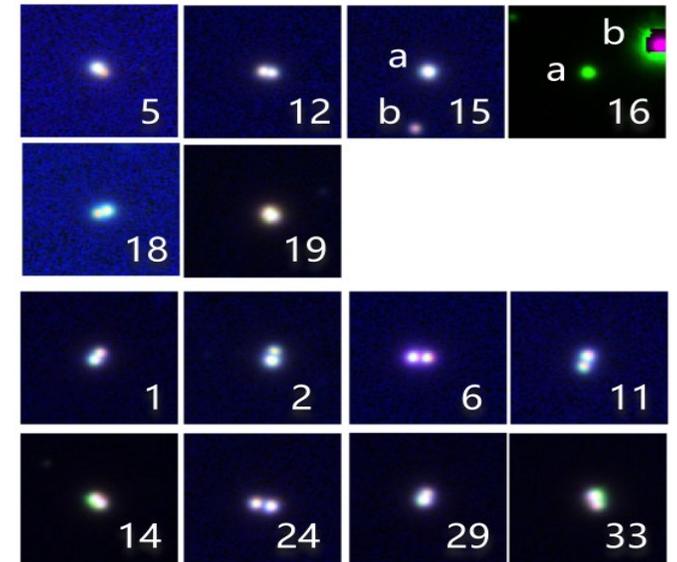
PS1 y/i/g band combined images Top north, bottom south, right west and left east. Scale 20 arcsec

COMMON PROPER MOTION BINARY

- Positions in CAMD(X G-RP, Y absolute G)
  - Black solid circles the 734 UCDs,
  blue open square the A components,
  red open triangles the b components
  - 21 binaries have both component with magnitude
  and parallax data
  - one white-late m binary (26a and 26b) Tian 2020
  - Several line not parallax to the MS
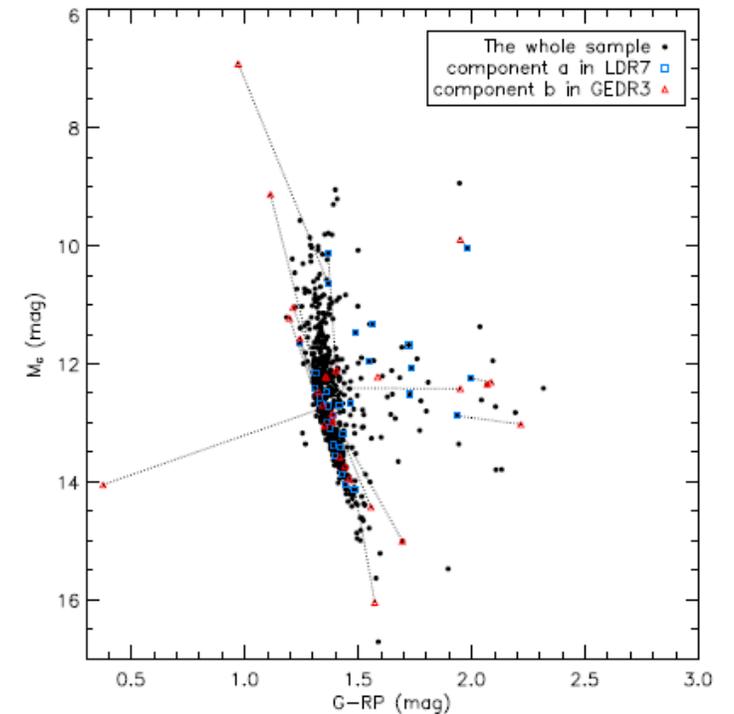
SUMMARY

- 734 ultracool dwarfs (spt M6 or later, one L0), two thirds spectroscopically studied for the first time

- All within 360 pc, Gaia G mainly around 16, 2.63<BP-RP<5, absolute magnitude fainter than 9

- Metallicity consistent with being thin-disk objects, Teff and log statistically reasonable

- 77 with 6708 Å lithium absorption line

- Kinematic suggest the majority thin-disk objects, Kinematic age derived

- 35 common proper motion identified, 6 newly discovered

The end, thanks!

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