Search for Brown Dwarfs with HSC-SSP survey

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Abstract

We are investigating distribution of brown dwarfs in the Galaxy with the Hyper Suprime-Cam (HSC) Subaru Strategic Program (SSP) data. First, we searched for brown dwarfs using colors in the i, z, and y bands, and up to the limiting distances defined by the HSC-SSP survey depths, in the Deep + UltraDeep catalog. Compact elliptical galaxies at redshift z=1-2, which are very difficult to distinguish with colors from brown dwarfs, were removed based on the effective radius measured by the surface brightness profile fitting tool GALFIT. Second, we estimated the subtypes of brown dwarfs by SED fitting, and the distances to the individual objects from the relationship between the observed magnitudes and the absolute magnitudes of the subtypes. Finally, we compared the number density of brown dwarfs with thin-disk model of the Galaxy, and determined the scale height. The scale height values are smaller in comparison to previous study, as a reason for that, there is possibility of much more contamination by the elliptical galaxies.

1.Introduction

The galactic stellar disk consists of thick-disk and thin-disk, and brown dwarfs are expected tp have similar structure. Estimating the distances to brown dwarfs are easier than for normal stars because they have a relatively simple color-luminosity relationship. We are interested in the actual disk structure of brown dwarfs and how that is related to the normal stellar distribution.

Brown dwarfs are difficult to detect because of their faintness, but the HSC survey can detect them up to unprecedented distances (Fig 1).

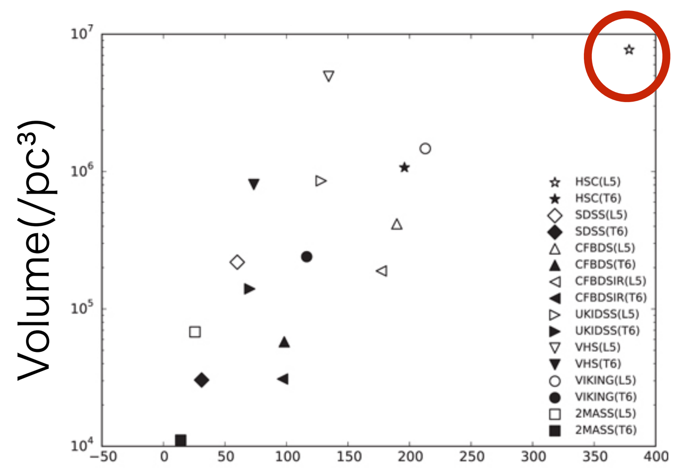

Fig 1. Limiting distances of L5 and T6 dwarfs in the past and the HSC surveys (Sorahana et al.2019)

In the previous HSC-based study (Sorahana et al. 2019, ApJ, 870, 118)……

HSC WIDE + Deep catalog was used

In this study……

We use HSC Deep + UltraDeep catalog to search for brown dwarfs at unprecedented distances, and estimate the scale height of thin-disk

2.Data and Analysis

Data

Subaru HSC-SSP survey S19A Deep + UltraDeep catalog (8753087 objects)

Point source (z - zcmodel < 0.05)
SNR of PSF photometry in the i, z, and y bands >10
0.8 ≦ i- z ≦ 3.7 (Fig 2)
0.61 ≦ z - y ≦ 1.6 (Fig 2)
Limiting distances defined by the HSC-SSP depth

1754 objects

After determining the brown dwarf subtypes by SED fitting, we estimated distances to the individual objects with a relationship between the observed magnitudes and the absolutes magnitudes of the subtypes (R.Barnett et al.2019, A&A, 631, A85) .

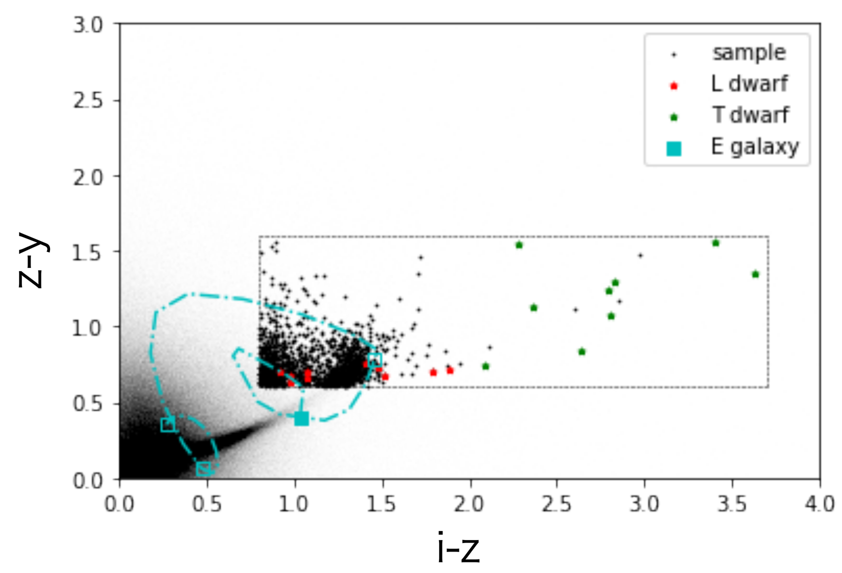

Fig 2. Color - color diagram showing the positions of brown dwarf models (red and green dots represent the L and T dwarfs, respectively), elliptical galaxy model redshifted to z = 1 - 4 (cyan curve), HSC point sources (black dots), and the selection box we used to extract brown dwarfs (dashed rectangle).

To remove elliptical galaxies

Position matching with Ultra VISTA-DR2 to get in the Y, J, H, and Ks bands

76 brown dwarfs and 69 elliptical galaxies (Fig 3)

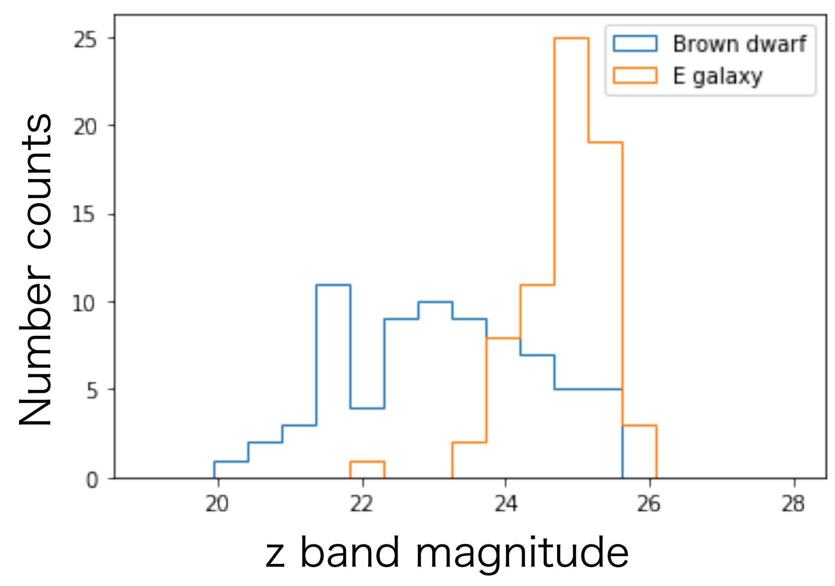

Fig 3. z-magnitudes of the brown dwarfs and the elliptical galaxies (blue:brown dwarfs, orange:elliptical galaxies)

SED fitting with Y, J, H, Ks makes it possible to distinguish brown dwarfs from elliptical galaxies. As a result, we found that the HSC colors and shapes are not enough to remove compact elliptical galaxies at z=1-2 (Fig 2) . So we used GALFIT, which is a surface brightness profile fitting tool, and calculated effective radius (Re) of the brown dwarfs and the elliptical galaxies on z band images with Sersic profile. As a result, we found that brown dwarfs have smaller Re compared to elliptical galaxies (Fig 4) . Thus, for objects without Ultra VISTA-DR2 data, we distinguish brown dwarfs from elliptical galaxies at Re=0.15 pixel, which includes 80% of brown dwarfs and only 10% of elliptical galaxies.

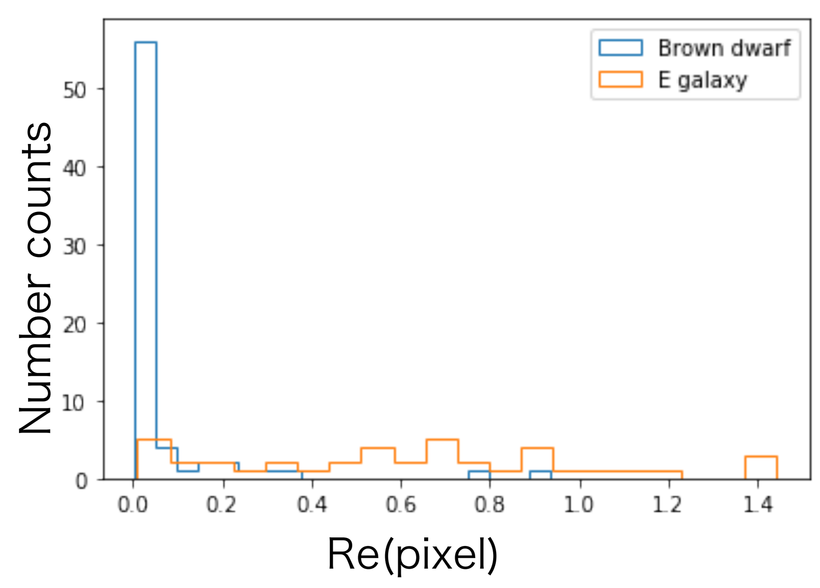

Fig 4. Effective radius (Re) of the brown dwarfs and the elliptical galaxies calculated by GALFIT (blue:brown dwarfs, orange:elliptical galaxies)

To estimate the scale height

We compared the number density of brown dwarfs measured as a function of distance from the Galactic plane with the thin-disk model (J.A.Caballero et al.2008, A&A, 488, 181-190):

$$n_i(d,l,b) \approx n_{0,i} e^{\frac{\mp z_\odot}{h_z}} e^{-d\left(-\frac{\cos b \cos l}{h_R} \pm \frac{\sin b}{h_z}\right)}$$

$n_i(d,l,b)$ (pc^{-3}): Number density at distance d (pc) , galactic latitude b (deg) , galactic longitude l (deg)

$n_{0,i}$ (pc^{-3}): Number density at the Galactic plane

$z_\odot$ (pc): Sun's height above the Galactic mid-plane

h_z (pc): The scale height

h_R (pc): The scale length

and determined the scale height.

3.Result and Discussion

The numbers of brown dwarfs in each subtype, found in the four HSC-SSP Deep/UD fields, are listed in Table 1. The determined mean h_z , n_0 are given in Table 2.

Table 1. Brown dwarf counts in the four HSC-SSP Deep/UD field

Subtype	COSMOS	SXDS	ELAIS_N1	DEEP2_3
L0	33	24	10	24
L1	5	17	2	3
L2	0	4	5	0
L3	12	54	30	12
L4	76	31	71	49
L5	162	91	110	94
L6	0	7	4	5
L7	14	9	2	14
L8	2	1	1	0
L9	2	0	0	0
T0	3	0	0	0
T1	0	0	0	0
T2	0	0	0	0
T3	1	0	0	0
T4	0	0	0	0
T5	0	0	0	0
T6	1	0	0	0
T7	0	0	0	0
T8	1	0	0	0

Table 2. The mean of h_z and n_0 in the four HSC-SSP Deep/UD fields

Subtype	h_z	n_0
L0	127	4.70×10^{-3}
L1	193	5.52×10^{-4}
L2	102	1.92×10^{-2}
L3	134	3.70×10^{-3}
L4	43	2.93×10^{-1}
L5	37	9.15×10^{-1}
L6	40	3.36×10^{-2}
L7	30	2.51×10^{-1}

The scale height values are smaller compared to 380 (pc) , which is estimated in Sorahana et.al 2019. There is possibility of much more contamination because the scale height of which is matched with Ultra VISTA-DR2, especially L4 ～ L7, are also smaller (Table 3) . We plan to take spectra of some of our objects with Seimei/KOOLS-IFU, in order to confirm their brown-dwarf nature.

Table 3. h_z and n_0 determined for the objects classified with Ultra VISTA-DR2

Subtype	h_z	n_0
L0	605	3.55×10^{-6}
L1	239	8.54×10^{-5}
L2	164	1.65×10^{-4}
L3	269	5.86×10^{-5}
L4	51	4.74×10^{-2}
L5	42	6.21×10^{-2}
L6	58	1.35×10^{-2}
L7	34	2.69×10^{-1}

4.Summary

- We searched for brown dwarfs using PSF colors in the i, z, and y bands, and up to the limiting distances defined with the HSC-SSP survey Deep + UltraDeep catalog.
- Compact elliptical galaxies at redshift z=1-2, which are very difficult to distinguish with HSC colors from brown dwarfs, were removed based on the effective radius measured by GALFIT.
- We measured the scale height of the thin-disk as reported in Table 2.
- We are going to observe spectra of some of our objects to test and remove residual contamination.