

# Subaru Hyper Suprime-Cam Survey for the Local Group Dwarf Galaxies: Ursa Minor

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**Abstract.** We have carried out a wide and deep imaging survey for the Local Group dwarf spheroidal galaxy Ursa Minor (UMi) using Hyper Suprime-Cam (HSC). The data cover out beyond the nominal tidal radius down to  $\sim 25$  mag in  $i$  band, which is  $\sim 2$  mag below the main sequence turn-off point. The structural parameters of UMi are derived using red giant branch (RGB) stars and sub-giant branch (SGB) stars, and the tidal radius is suggested to be larger than those estimated by the previous studies. It is also found that the distribution of bluer RGB/SGB stars is more extended than that of redder RGB/SGB stars. The fraction of binary systems is estimated to be  $\sim 0.4$  from the morphology of the main sequences.

**Keywords.** Local Group, dwarf galaxy, star formation, structure

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## 1. Introduction

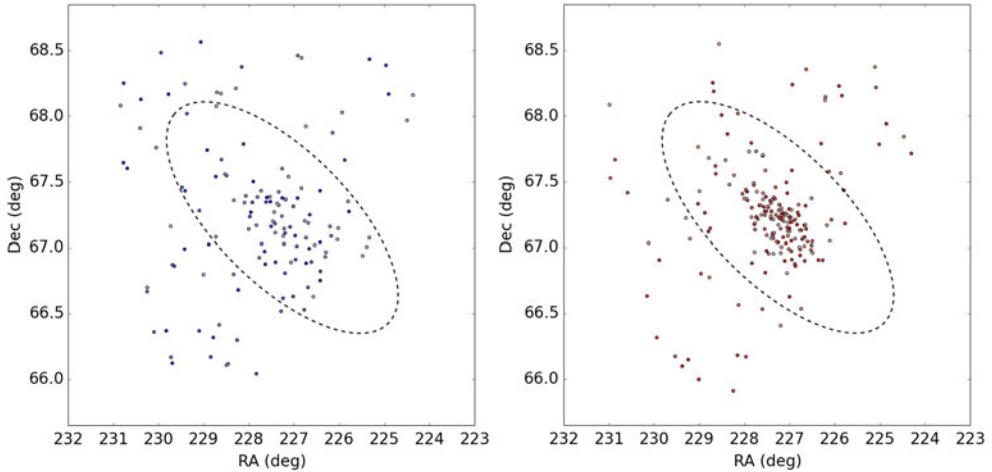
Dwarf galaxies are the important constituent in the universe as they are suggested to be ‘building blocks’ of large galaxies such as our Galaxy. Those dwarf galaxies in the Local Group are valuable targets since they are observed as assemblies of stars and the detailed studies based on the stellar physics can be carried out. However, observations for these galaxies are not easy because of their large apparent sizes on the sky.

The wide-field CCD imager Hyper Suprime-Cam (HSC) on the Subaru Telescope gives a break-through to this difficulty. It has 1.5-degree field of view, and the excellent image quality realized by the Subaru Telescope on Maunakea makes this imager the best instrument to explore the Local Group galaxies. With this camera, we have carried out a wide and deep survey for several Local Group dwarf galaxies.

## 2. Dwarf Spheroidal Galaxy Ursa Minor (UMi)

Ursa Minor (UMi) is one of classical dwarf spheroidal galaxies orbiting around our Galaxy. Due to its proximity ( $\sim 60$  kpc), stars belonging to UMi are distributed over  $\sim 1$  degree on the sky. Wide area surveys have been carried out for this galaxy (e.g., [Kleyna \*et al.\* 1998](#), [Palma \*et al.\* 2003](#)) and intriguing features such as substructures and extra-tidal stars were revealed to exist in this galaxy, but the depth of the surveys were limited.

We have observed UMi using HSC with  $g$ ,  $i$  and  $NB515$  filters. 4 HSC pointings covers UMi beyond the nominal tidal radius. The data reach  $\sim 2$  mag below the turn-off magnitude of the main sequence. The structural parameters are derived using RGB and SGB stars brighter than  $i = 23$  mag, which are completely detected and outnumber foreground stars and unresolved galaxies. The tidal radius is derived to be 72.8 arcmin in this study, which is larger than those estimated by the previous studies (e.g., [Irwin & Hatzidimitriou 1995](#), [Kleyna \*et al.\* 1998](#)).



**Figure 1.** The distribution of bluer (left) and redder (right) RGB stars. The dashed ellipse represent the tidal radius derived in this study. Note that a part of data in the south-west field (i.e., lower right in the figure) is missing.

The spatial distribution of RGB and SGB stars is further investigated by grouping them into bluer/middle/redder groups based on the deviation from the mean RGB/SGB sequence. The bluer/middle/redder group corresponds to  $-0.06 < \Delta(g-i) < -0.01$ ,  $-0.01 < \Delta(g-i) < 0.01$ , and  $0.01 < \Delta(g-i) < 0.06$ , respectively. Figure 1 shows the distribution of bluer and redder RGB stars. It is found that the bluer group is more extended than redder/middle groups. This indicates that multiple stellar populations are likely to exist in UMi. Considering that UMi is dominated by old stars which is suggested from the prominent blue horizontal branch, the difference in stellar population could be due primary to the difference in metallicity.

The fraction of binary stars of UMi is also investigated from the morphology of the main sequence following the method described in Solima *et al.* (2007) and Milone *et al.* (2010). The color-magnitude diagrams (CMDs) of binary systems can be calculated by making use of the isochrone of the representative stellar population (11 Gyr and  $Z = 0.0005$  in the present study), the initial mass function (Salpeter IMF), and the binary mass distribution of the system (flat distribution). By comparing the simulated CMDs of different binary fractions with the observed CMD, the fraction of binary systems in UMi is estimated to be  $\sim 0.4$ . The value is consistent with those estimated for the other Local Group dwarf spheroidal galaxies based on the radial velocity measurements (Minor 2013), but slightly higher than those derived for the most Galactic globular clusters.

## References

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