Subaru Hyper Suprime-Cam Wide-Field Imaging Survey of the Local Group Galaxies: Andromeda and the Seven Dwarfs

Yutaka Komiyama (NAOJ)
Power of Subaru Telescope: Prime Focus

**Suprime-Cam (1999 ~ 2017)**
- 80M-pixel CCD Camera with 30arcmin FoV (largest FoV among 8m telescopes in 2000s)
- First open-use instrument of Subaru
- Used for ~1/2 observing time of Subaru
  
  (Miyazaki et al. 2002)

**Hyper Suprime-Cam (HSC: 2012 ~ )**
- 1G-pixel CCD Camera (116 2k4k FDCCDs, 0”.16/pix) with 1.5 degree FoV
- Used for ~1/2 observing time of Subaru
- The world’s most powerful survey camera
  
  (Miyazaki et al. 2018; Komiyama et al. 2018)

**Prime Focus Spectrograph (PFS: 2021 ~ )**
- Multi-object fiber spectrograph with 2400 fibers on 1.3 degree FoV covering 380nm to 1300nm
- To be an enormous spectrograph in 2020’s
  
  (Tamura et al. 2018)
M31 Observed by HSC/PFS

Subaru HSC+PFS is powerful tool to investigate galaxies in Local Group and nearby universe.

HSC imaging $\rightarrow$ PFS spectroscopy
HSC/PFS Target Galaxies

• M31 and 7 dwarf galaxies were chosen for the PFS target and pre-imaging with HSC have been carried out
  – The HSC imaging data cover each dwarf galaxy out beyond the tidal radius
  – 5 deep exposures for the NW stream in the outer halo of M31
HSC/PFS Target Galaxies

- M31 and 7 dwarf galaxies were chosen for the PFS target and pre-imaging with HSC have been carried out
  - The HSC imaging data cover each dwarf galaxy out beyond the tidal radius
  - 5 deep exposures for the NW stream in the outer halo of M31
  - Subaru openuse time + Keck time exchange program

Taken from Chiba-san
Color-Magnitude Diagrams
HSC Deep Survey of Andromeda Halo


Aims of HSC Survey:
- Detailed Structure of Stellar Stream
- Search for Lower-SB Substructures

HSC Deep Survey
Intensive Proposal
(S14B-060, S15B-061: PI M.Chiba)
5 pointing on NW Stream field
- g-band: 80min, seeing<0”.8
- i-band: 120min, seeing<0”.8
- NB515: 16min, seeing<1”

PAAndAS survey
[Fe/H] ~ -2.3
[Fe/H] ~ -1.4
[Fe/H] ~ -0.7

Martin et al. 2013

North West Stream

~15 degrees
Color-Magnitude Diagram of Andromeda Halo

- Deep CMD: ~2mag deeper than PAndAS
  - Probe Red Clump (RC) stars, Blue Horizontal Branch (BHB) stars $\rightarrow$ stellar population can be investigated. RC stars are abundant and good tracers of the stellar substructures.
NW Stream: Distribution of Stars

- Distribution of Stars: Left: Narrow-band Selected RBGs  Right: Red Clump
- Both density maps show the detailed structure of NW Stream
  → CMDs are investigated for 4 sub-regions (Stream/Off-Stream, North/South)

Clean sample of M31 halo = RGBs
RC stars are abundant in the Off-Stream South region compared to the Off-Stream North. The stellar population is different between the Stream and Off-Stream South regions. → Distinct diffuse substructure is suggested to exist in the Off-Stream South region.
Numerical Simulation

- To reproduce the NW stream (shape, number density gradient, gap...)
  - Led by Univ. of Tsukuba group (Y. Miki, T. Kirihara, M. Mori)
HSC Deep Survey of NGC6822
NGC6822: Past Observation

- **NGC6822**
  - Local Group dIrr
  - $M_V = -16$
  - 500 kpc from MW
  - Ongoing SF activity

- **Viewed in HI**
  - Embedded in a huge HI envelope (deBlok & Walter 2000)
  - Stellar population / SF activity in the HI envelope was unknown

- **Observation by Suprime-Cam**
  - Revealed star formation occurred in the HI gas envelope (Komiyama et al. 2003)
NGC6822: Past Observation

- Intermediate-age to old population (>1Gyr) traced by red-tangle stars
- Spherical Distribution → main component of the galaxy
- Young population (<1Gyr) traced by main-sequence stars
  - Elongated distribution
  - More extended than old population

Trace the HI envelope

Current Star Forming Activities in the HI envelope? → Hα observation
HSC Survey of Local Group dIrr NGC6822

Wide and deep imaging survey with HSC in g, r, Hα, i bands
The data cover not only the main body but out beyond the tidal radius

Objectives:
Stellar population (old and young), star forming regions, globular clusters, ...
Future multi-object spectroscopy (~2400 objs) with Subaru PFS

Komiyama et al., in prep
NGC6822: Continuum-Subtracted Hα Image

Overlaid: Efremova+ 2011
Blue: FUV selected SF region
Red: Hα bright region

Komiyama et al., in prep
NGC 6822: Diffuse HII Regions

Overlaid: Efremova + 2011

Blue: FUV selected SF region

Red: Hα bright region

GALEX FUV image
NGC 6822: Diffuse HII Regions

Overlaid:

Efremova + 2011

Blue: FUV selected SF region

Red: Halpha bright region

GALEX FUV image

HI map (deBlokt & Walter 2000).
We found 25 diffuse HII regions with UV counterparts for the outer regions of NGC6822 (+14 possible ones).

H$\alpha$ fluxes are measured assuming E(B-V)=0.22 for the extinction by Galactic ISM.

Example: Northwest part of NGC6822

SB(H$\alpha$)=26.2 mag/arcsec$^2$
Outer HII Regions: Size vs Hα Flux

- Outer HII regions follow the size-Hα flux relation found for the bright HII regions at the center of galaxy (Efremova+2011).
- They seem to be more extended than those HII regions with same Hα flux located at galaxy center.
• **Total Hα flux** of outer HII regions is \(~1\%\) of that of bright HII regions at the center of the galaxy.

• They are not significant population but could be important for the build-up of the extended population of the galaxy.
Outer HII Regions: Hα Flux vs UV Flux

- Hα flux of outer HII regions shows loose correlation with UV flux. (Note that the extinction of UV flux in each region is not corrected)
Summary

- Wide-field (FoV 1.5deg) imager Hyper Suprime-Cam (HSC) on the Subaru Telescope provides us deep photometric data for the Local Group galaxies and enables us to investigate the unexplored new diffuse features.

M31 NW Stream:
- We obtained deep CMD for the NW part of M31 halo which covers RC stars.
- RC stars are abundant in the Off-Stream South region compared to the Off-Stream North. The stellar population is different between the Stream and Off-Stream South regions. **Distinct diffuse substructure** is suggested to exist in the Off-Stream South region.

NGC6822:
- **25 diffuse HII regions** with UV counterparts are found for the outer regions of NGC6822.
- They are coincident with GALEX FUV sources and show good correlation with HI.
- They seem to be more extended than those HII regions with same Hα flux located at galaxy center.
- Total Hα flux of outer HII regions is ~1% of that of bright HII regions at the center of the galaxy.