## Dark matter on small scales

Masashi Chiba (Tohoku University)

A02: F. Takahashi-san's group joining as a renkei 連携 researcher

# Success and problem of ACDM



# Issues in ACDM on small scales

- Missing satellite problem
  - Overabundance of dark subhalos
- Too big to fail problem
  - Too concentrated massive subhalos

+ several other issues (anisotropic distribution of satellites, cusp/core halo center, global halo shape)

Solutions • Baryonic effect, such as feedback?

Yet incomplete observational data?

All of these issues are realized in the Local Group, for which detailed data for DM tracers can be available.

# Galactic dwarf spheroidal galaxies (dSphs) as a probe of DM



4



#### Mass enclosed within stellar extent (~ 4 x $10^7 M_{\odot}$ ) in dSph galaxies





# Merging of Andromeda and MW

Today



# New constraints on structure and evolution of dark halos in dSphs



# M(r<300pc) = const. in dSphs?



But:

UFDs (red marks) are smaller than 300pc
 M<sub>300</sub> is based on an extrapolated mass profile
 Mass models are spherically symmetric

#### NFW halos with M(r < 300pc) = const.



#### More realistic limits on the DM distribution



# New relation for the DM in dSphs

Hayashi & Chiba (2015a, b) based on axisymmetric mass models



# **Evolution of NFW halos**





#### Star formation history under log $\Sigma_{vmax} = 1.3$



#### Comparison with numerical simulation



### Prospects

#### What's to be done? (I) True LF of Galactic dSphs? HSC wide-field survey $1,400 \text{ deg}^2$ Large areas unexplored 1000 800 SDSS RA(deg) (kpc) LG galaxies 600 Searching for new distant dSphs Isochrones 18 ${ m R}_{ m comp}$ 400 at D ~ 200 kpc r 20 Classical Sats unexplored 22 200 UFDs 24 Selection filter for dSph 26 0 -10-15-5 -0,5 0 0.5 M<sub>v</sub> (mag)

# Search for new dSphs in HSC data

with D. Honma +

In XMM field, there are two strong signals at 400kpc.



# What's to be done? (II) On the "too big to fail" problem (Brook+2014)



# What's to be done? (II)

• True MF & DM profiles of Galactic dSphs?



#### HSC imaging campaign of Galactic dSphs international team (Japan + Caltech & JHU)

| Name                  | Short exposure (RGBs)                       |   |                   | Long exposure (~ MSTO)                      |   |                   | Note                                    |   |     |
|-----------------------|---|---|-------------------|---|---|-------------------|---|---|-----|
|                       | g   | i   | NB515             | g   | i   | NB515             |   |   |     |
| Draco (2 fields)      | F1, F2                                      | F1, F2                                      | F1, F2            | F1, F2                                      | F1, F2                                      | F1, F2            |   | Field numbe   | er  |
| Sculptor (4 fields)   | F1, F2,<br>F3, F4                           | F1, F2,<br>F3, F4                           | F1, F2,<br>F3, F4 | F1, F2,<br>F3, F4                           | F1, F2,<br>F3, F4                           | F1, F2,<br>F3, F4 | S15B                                    | Red: done<br>Black: not y   | vet |
| Fornax (4 fields)     | <mark>F1,</mark> F2,<br>F3, <mark>F4</mark> | <mark>F1,</mark> F2,<br>F3, <mark>F4</mark> | F1, F2,<br>F3, F4 | <mark>F1,</mark> F2,<br>F3, <mark>F4</mark> | <mark>F1,</mark> F2,<br>F3, <mark>F4</mark> | F1, F2,<br>F3, F4 | S15B                                    |   |     |
| Ursa Minor (4 fields) | F1, F2,<br>F3, F4                           | F1, F2,<br>F3, F4                           | F1, F2,<br>F3, F4 | F1, F2,<br>F3, F4                           | F1, F2,<br>F3, F4                           | F1, F2,<br>F3, F4 | \$15A                                   |   |     |
| Leo I                 |   |   |                   |   |   |                   |   |   |     |
| Sextans (19 fields)   | F1 –<br>F19                                 | F4, 5,<br>6,<br>12,13,<br>14,18             | F1 –<br>F19       | Not required                                |   |                   | Short expos<br>were made<br>halo run in | ort exposures for (g, i)<br>re made during M31<br>o run in 2014 Nov |     |
| Draco                 | Sculptor                                    |   | Fornax            |   | Ursa Mi                                     |                   | nor                                     | Sextans   |     |
| Draco dSph            | (   | Sculptor dSph                               |                   |   | 24  |                   | Urse Miner (169x180)                    | 6     5     3       18     4     2     8                            |     |

# And more from TMT

- Proper motions of stars in dSphs
  - ~ 0.03 mas/yr for stars of 10km/s at D=70kpc Measureable with TMT/IRIS
  - ⇒ velocity anisotropy of stars
  - ⇒ ultimately very precise DM profile





#### Supplementary files

#### Milky Way sized dark halo Anderhalden+12



### Too big to fail problem





#### NB515 filter for HSC

NB515 (CW: 515 nm, FWHM: 8nm) (from S15A) Separation of <u>RGB</u> stars in M31 + <u>MW satellites</u> from the foreground MW dwarfs

