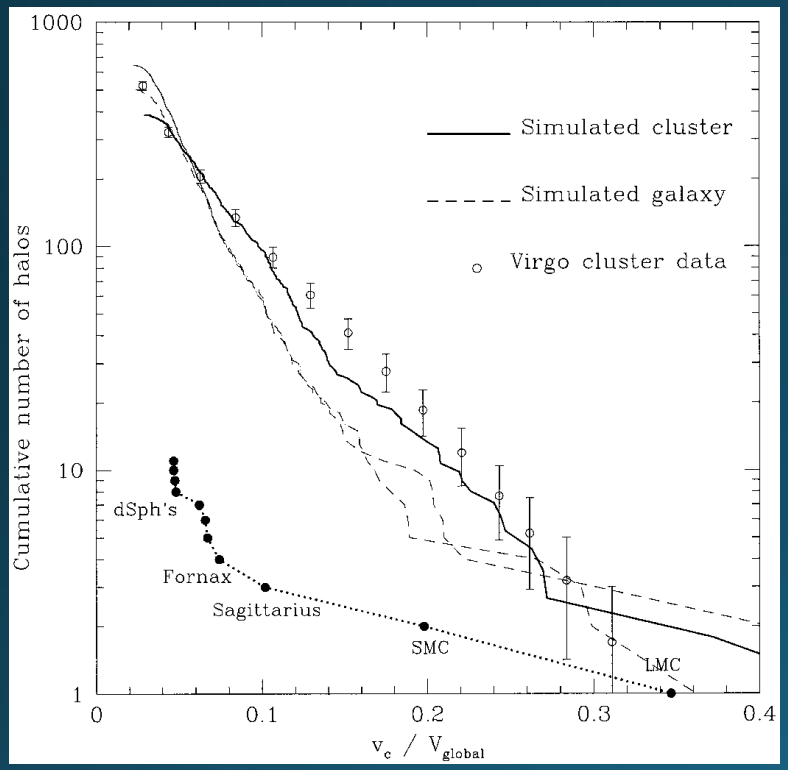
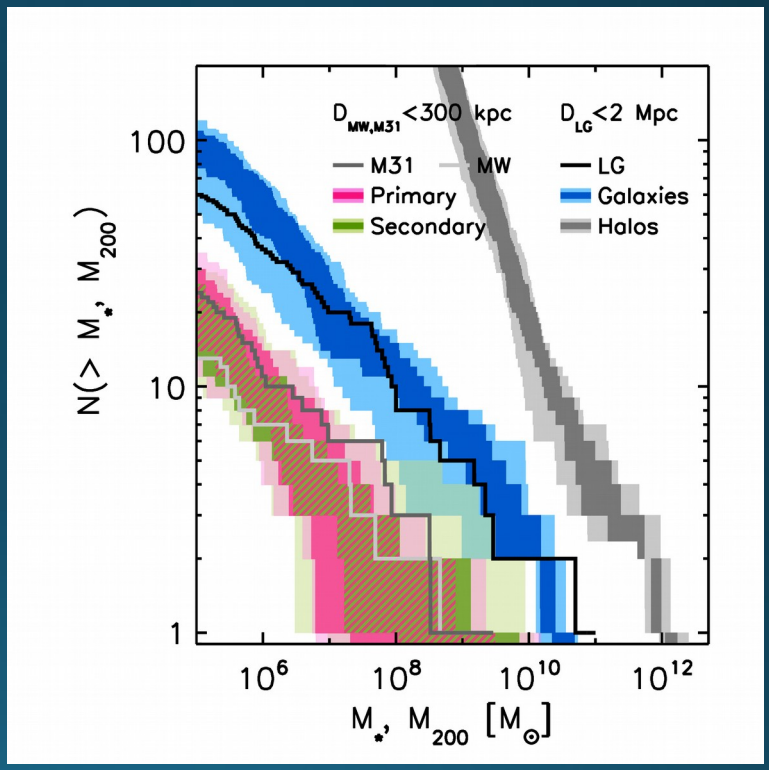
The Missing Satellite Problem Outside of the Local Group

Masayuki Tanaka, Masashi Chiba, Yutaka Komiyama
Mikito Tanaka, Sakurako Okamoto, Takashi Okamoto

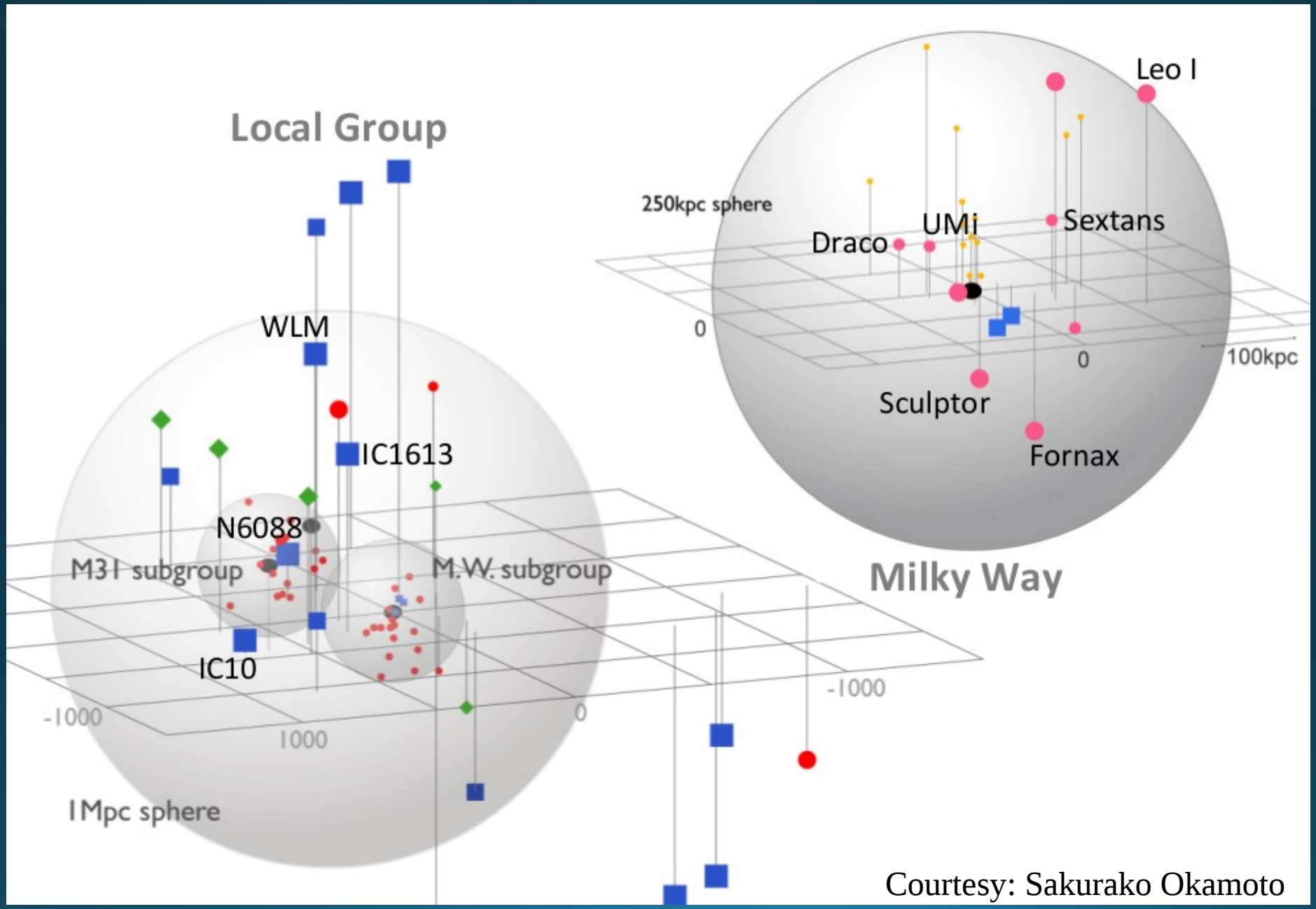
A possible small-scale flaw in LCDM



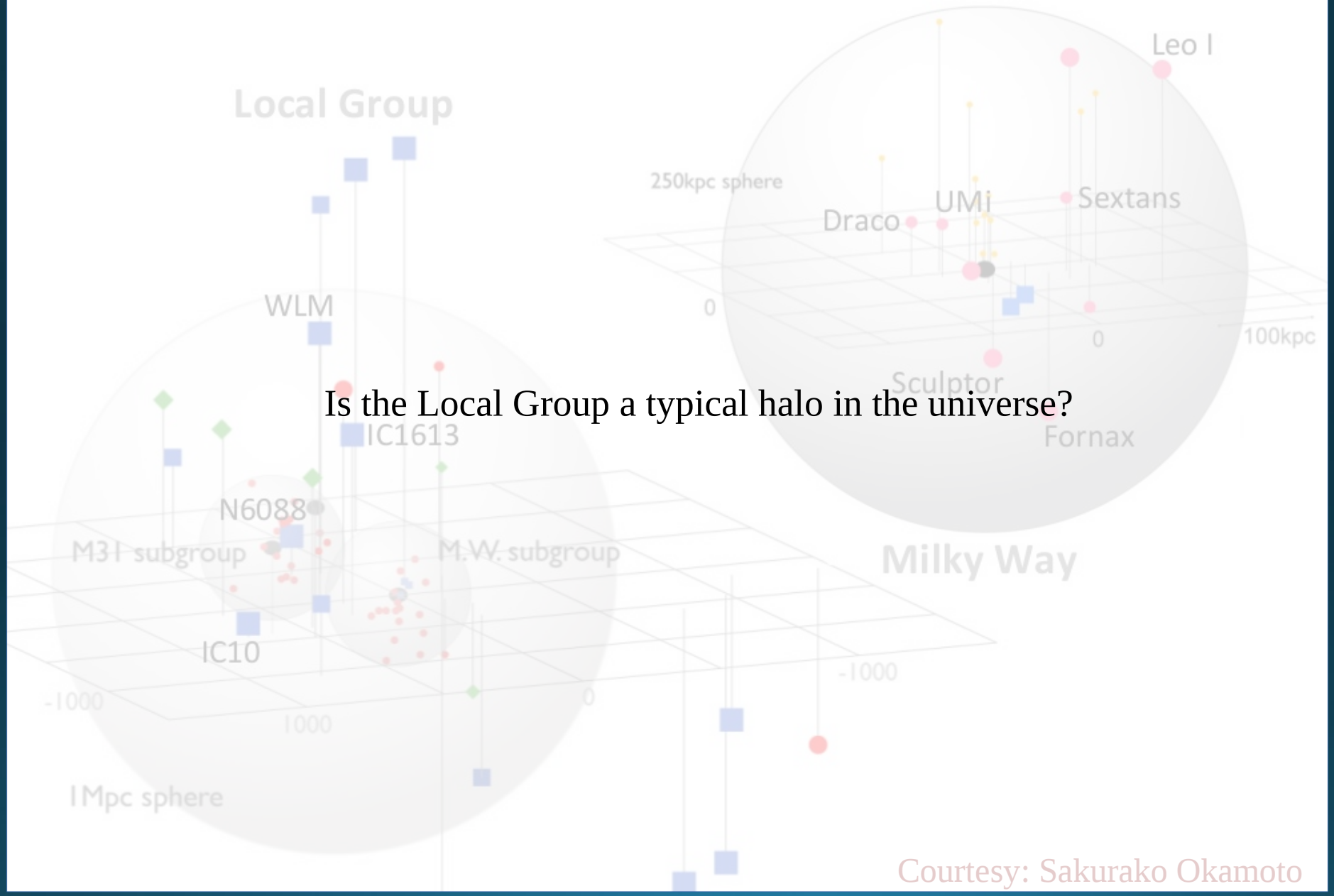
Moore et al. 1999



Sawala et al. 2014



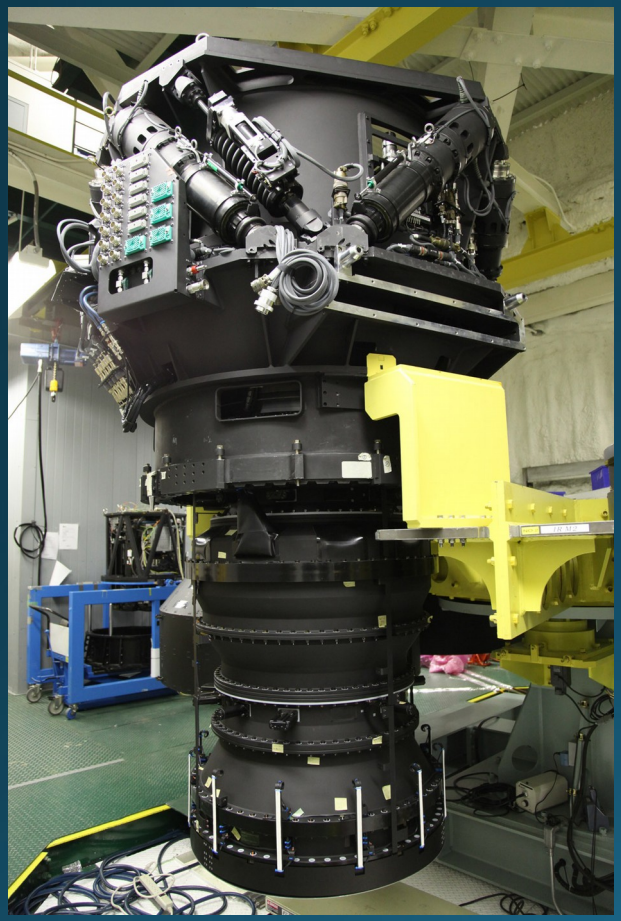
Courtesy: Sakurako Okamoto



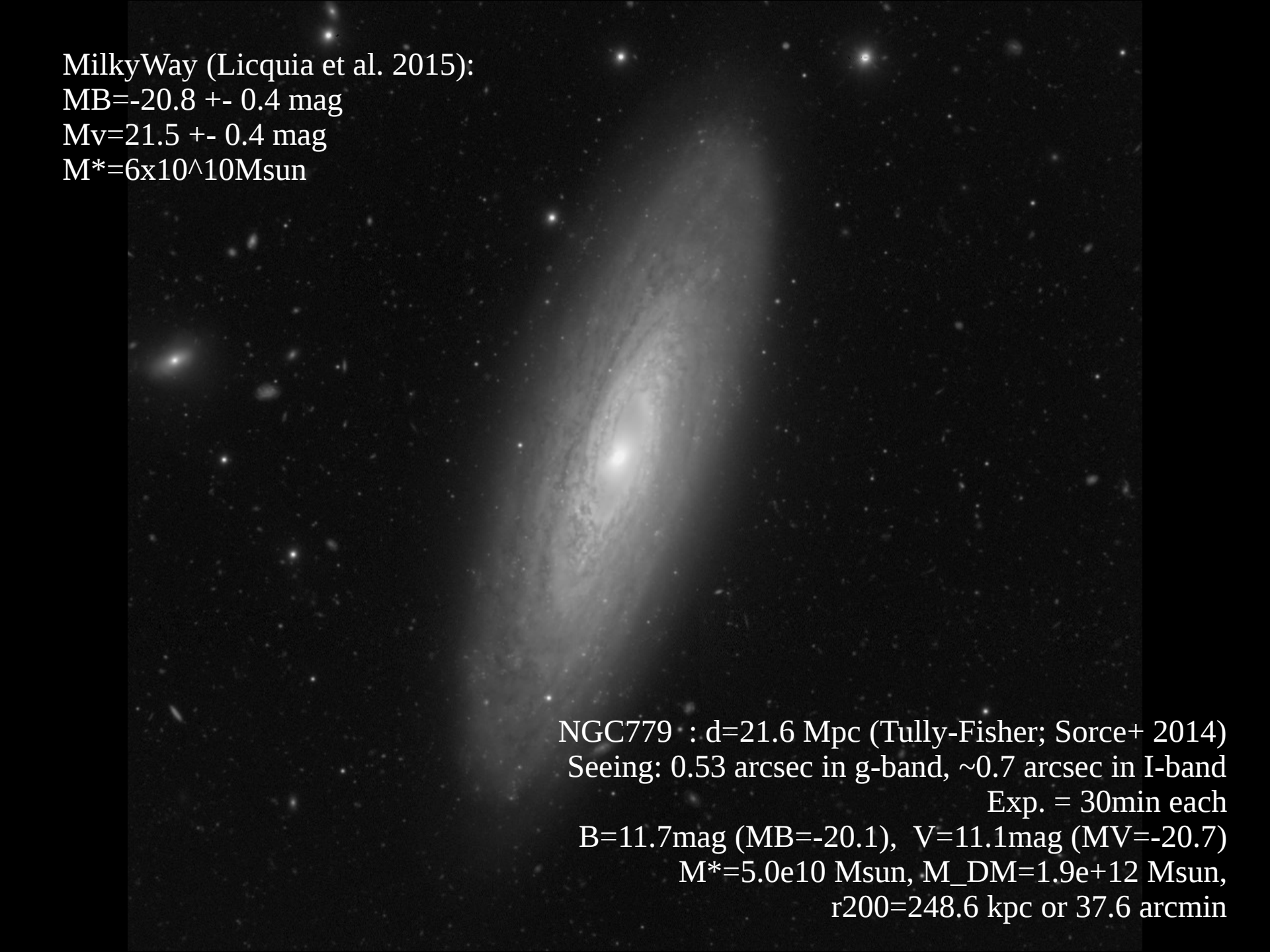
Is the Local Group a typical halo in the universe?

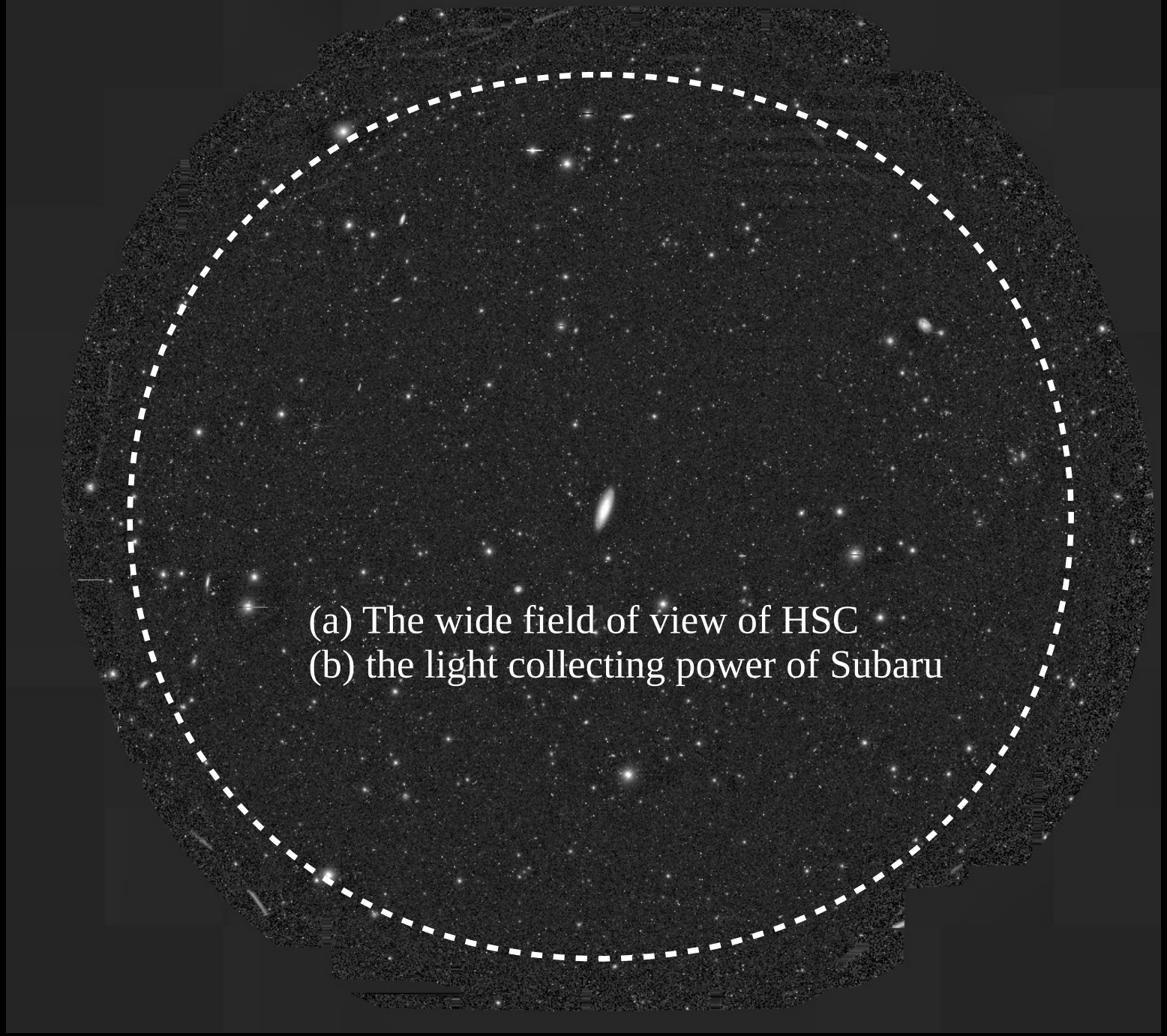
Courtesy: Sakurako Okamoto

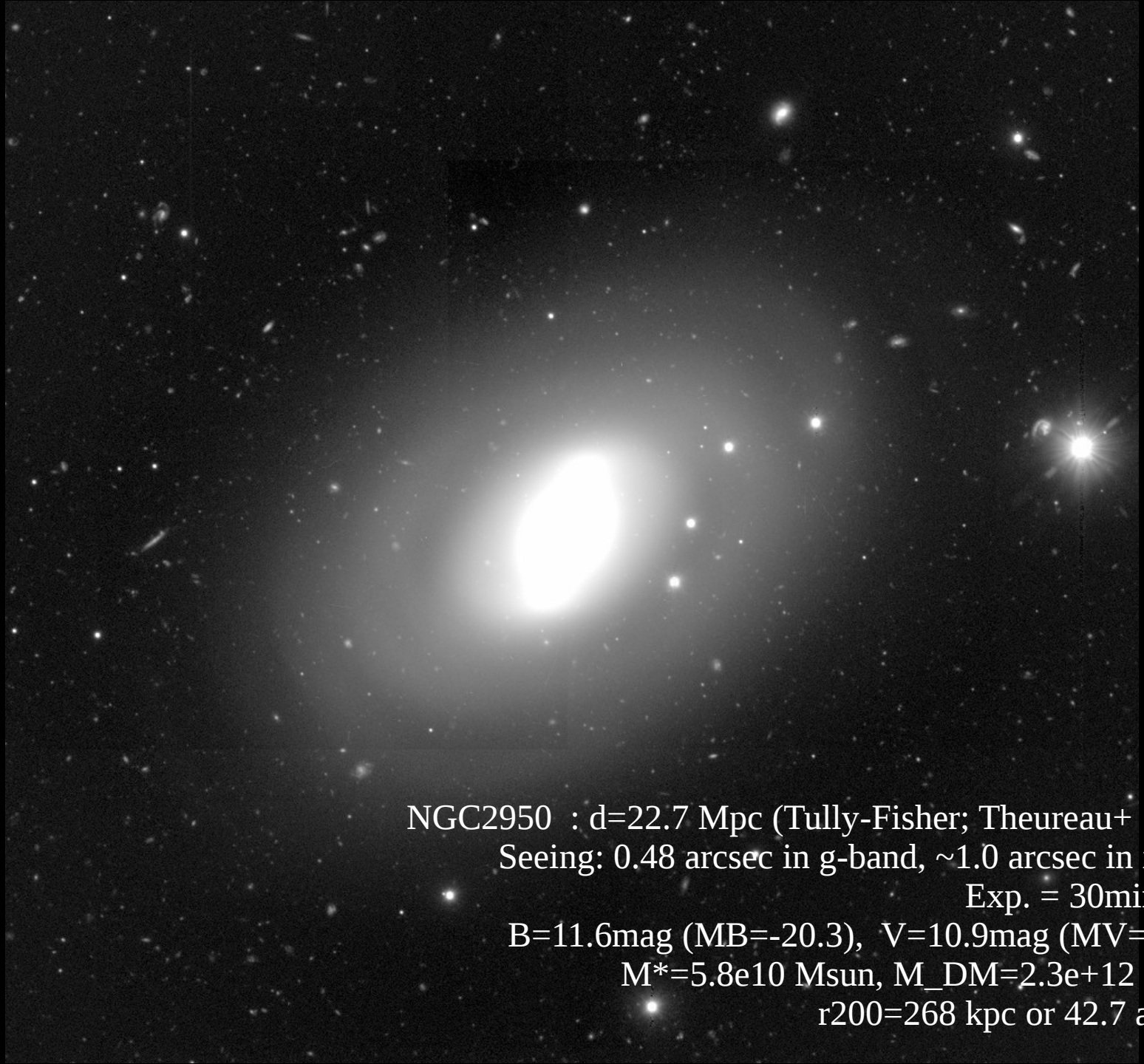
Hyper Suprime-Cam



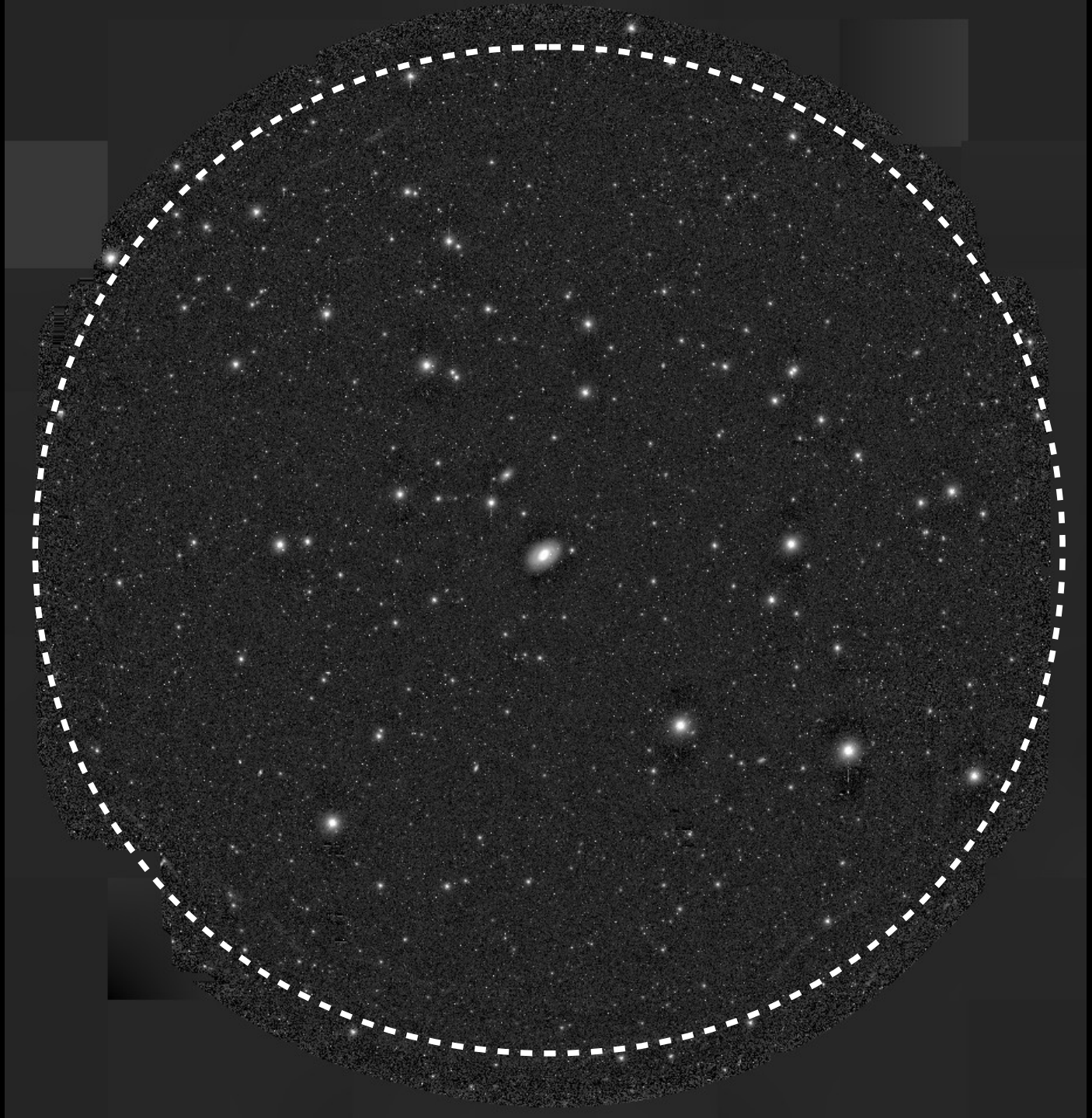
- Fully commissined.
- 5 broad-band filters: grizy
- Lots of narrow-band filters
- 1.5 deg phi field of view
- Very good image quality


MilkyWay (Licquia et al. 2015):
MB=-20.8 +- 0.4 mag
Mv=21.5 +- 0.4 mag
M*=6x10^10Msun
NGC779 : d=21.6 Mpc (Tully-Fisher; Sorce+ 2014)
Seeing: 0.53 arcsec in g-band, ~0.7 arcsec in I-band
Exp. = 30min each
B=11.7mag (MB=-20.1), V=11.1mag (MV=-20.7)
M*=5.0e10 Msun, M_DM=1.9e+12 Msun,
r200=248.6 kpc or 37.6 arcmin


(a) The wide field of view of HSC
(b) the light collecting power of Subaru



NGC2950 : d=22.7 Mpc (Tully-Fisher; Theureau+ 2007)
Seeing: 0.48 arcsec in g-band, ~1.0 arcsec in i-band
Exp. = 30min each
B=11.6mag (MB=-20.3), V=10.9mag (MV=-20.9)
M*=5.8e10 Msun, M_DM=2.3e+12 Msun,
r200=268 kpc or 42.7 arcmin

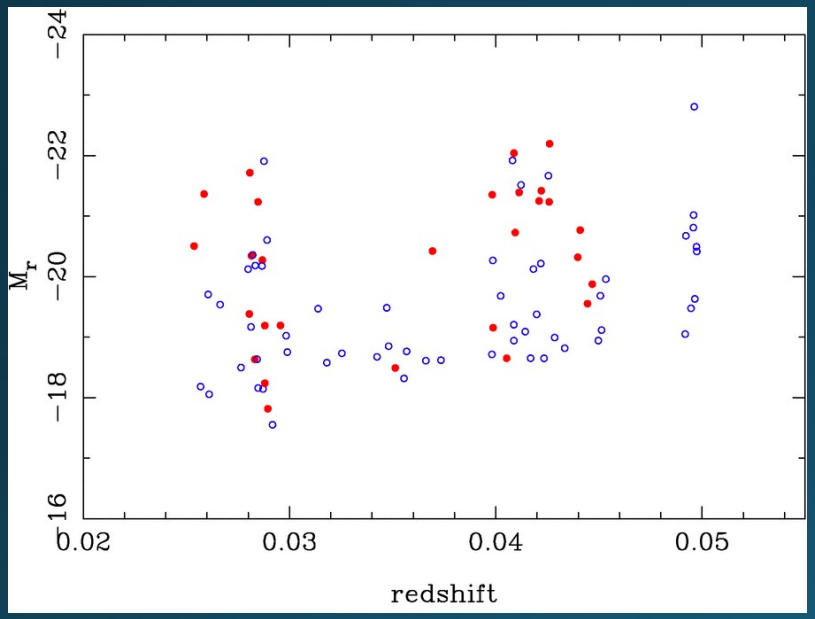


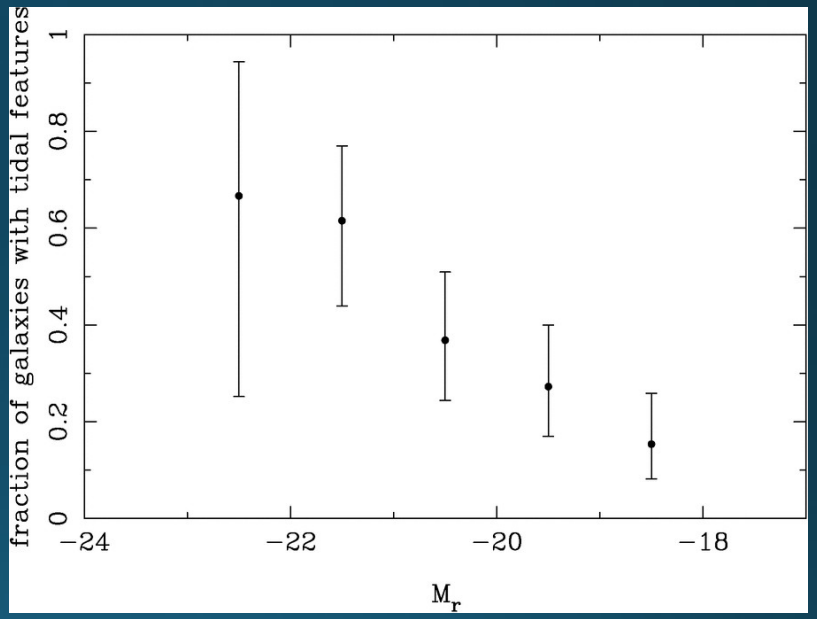
Not just missing satellite problems, but more...

- Stellar tidal streams: a probe of galaxy-scale assembly (Duc et al. 2015, MNRAS)
- Spatial alignment of dwarf galaxies: another potential challenge to LCDM (Ibata et al. 2013, Nature)
- Gaps in stellar streams: potential probe of subhalo mass function (Carlberg 2012, ApJ)

Project #69: tidal streams around nearby galaxies

- Objects with tidal features
- Objects with no obvious tidal features

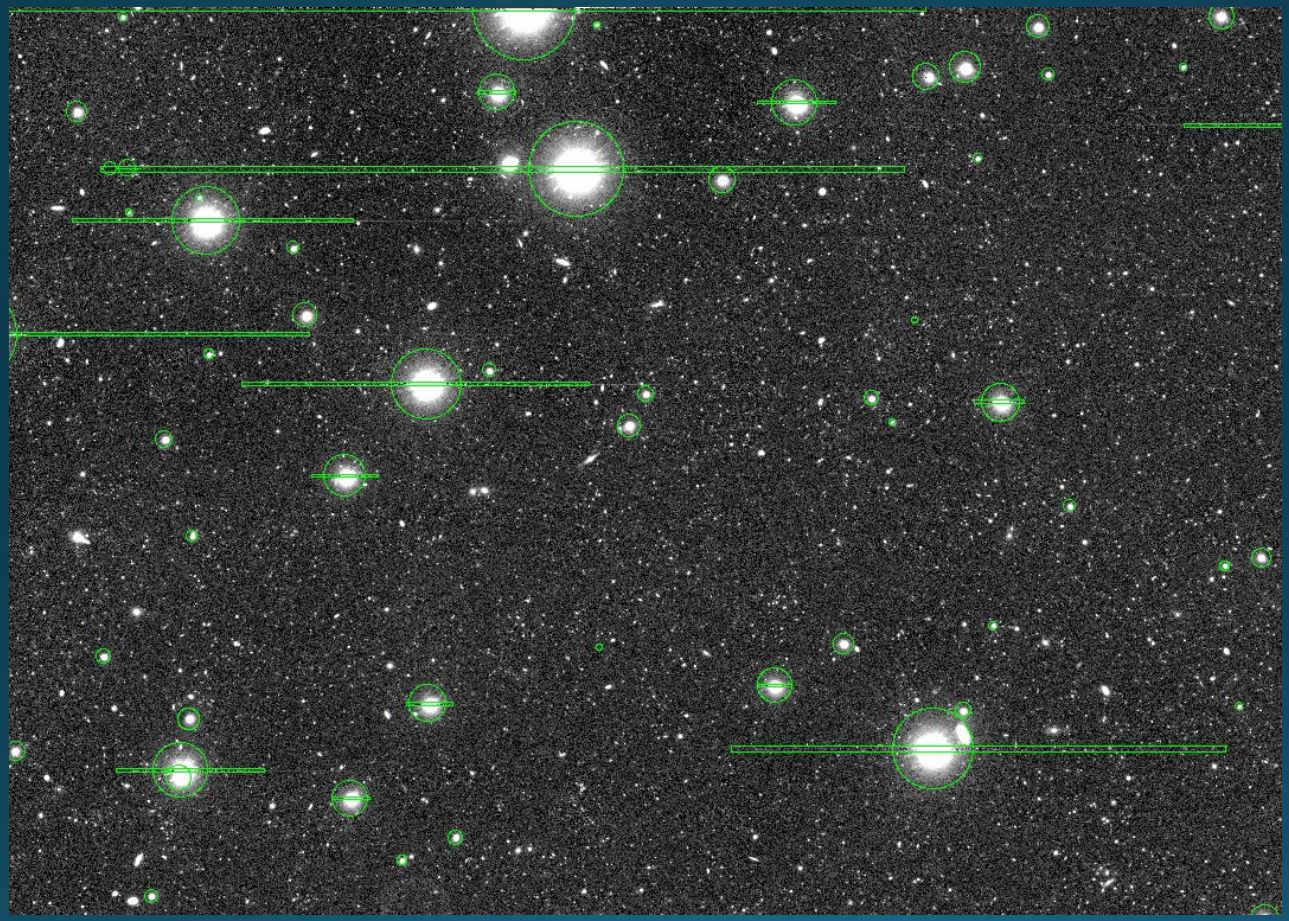




If I interpret the plots very naively, a merger rate is higher for more massive galaxies, which is qualitatively consistent with what we expect in LCDM.

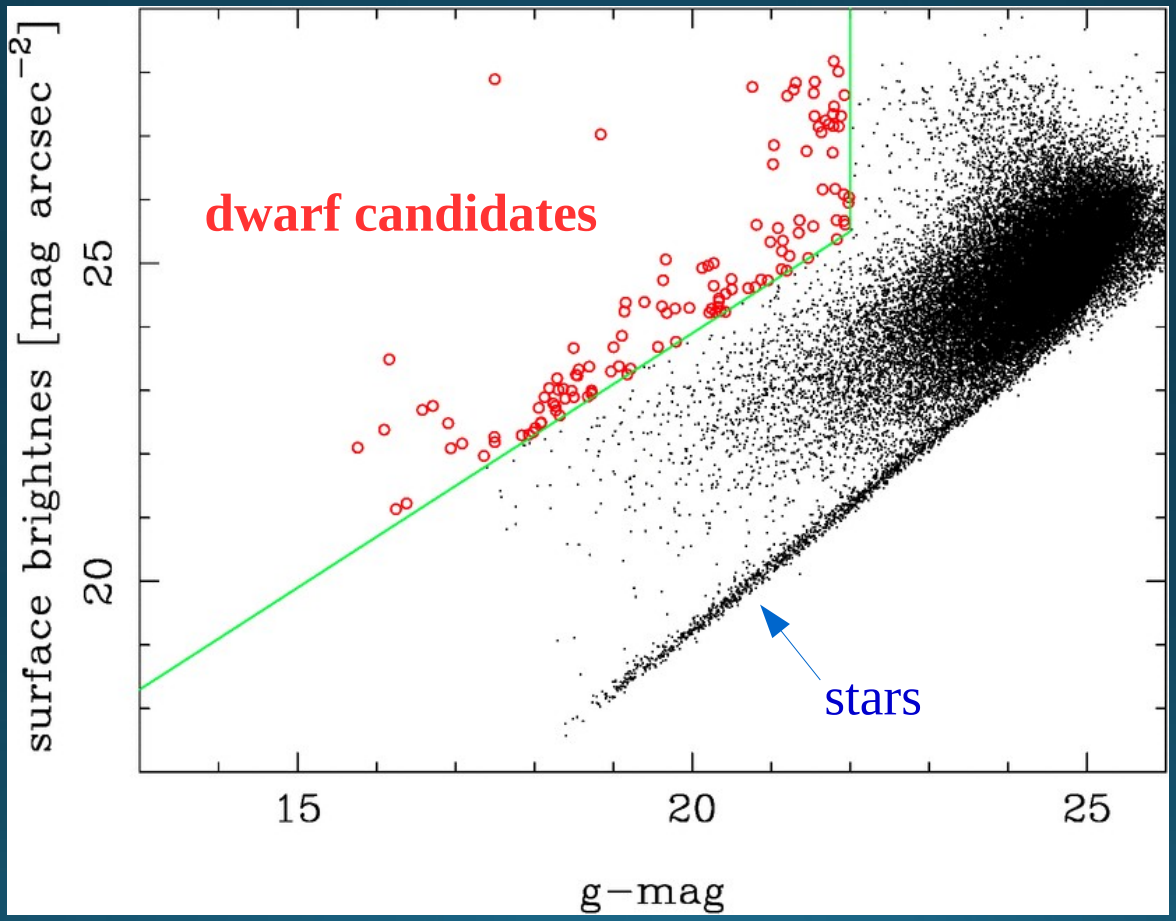
Tanaka et al. in prep...

Masks and junks

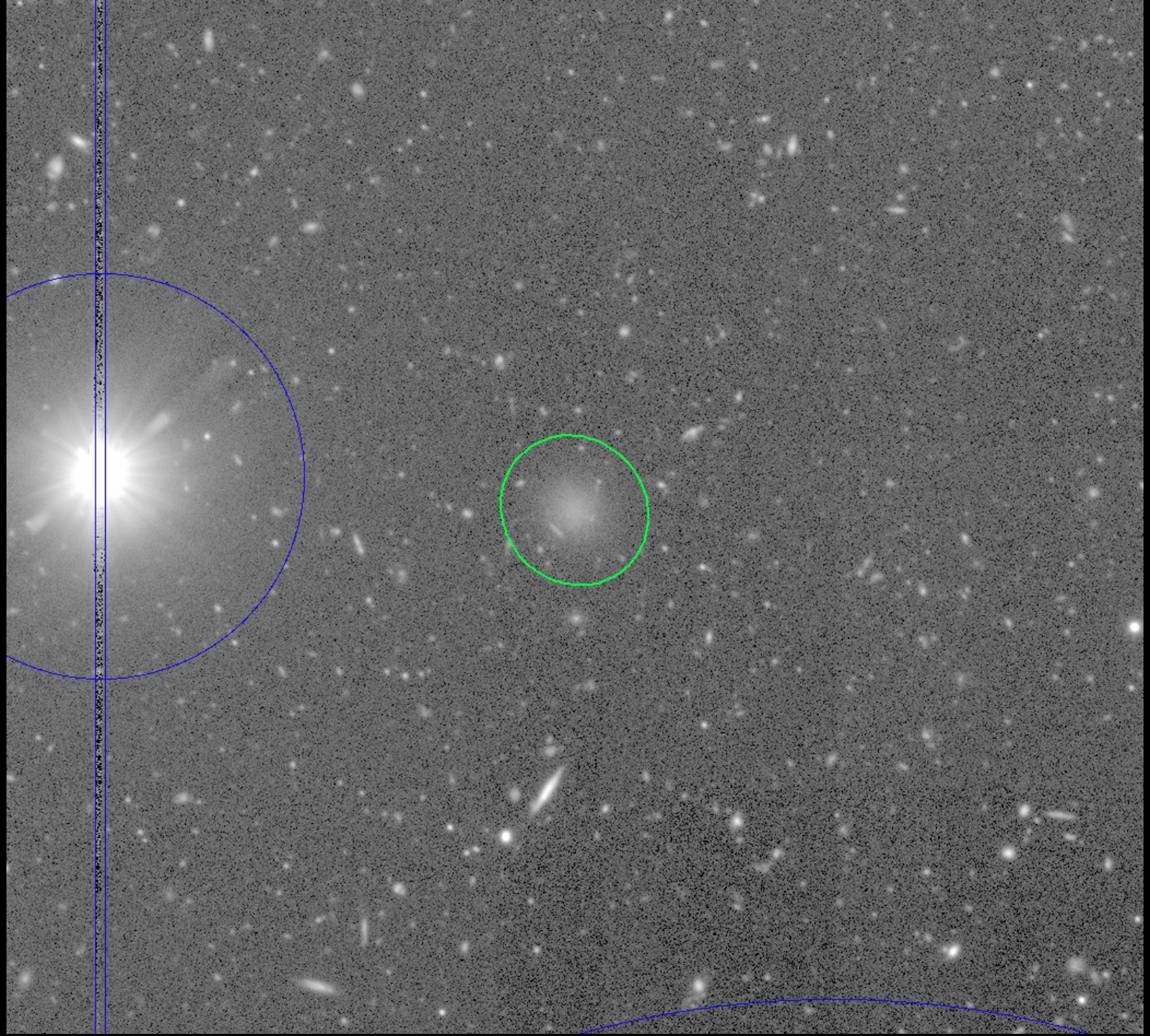


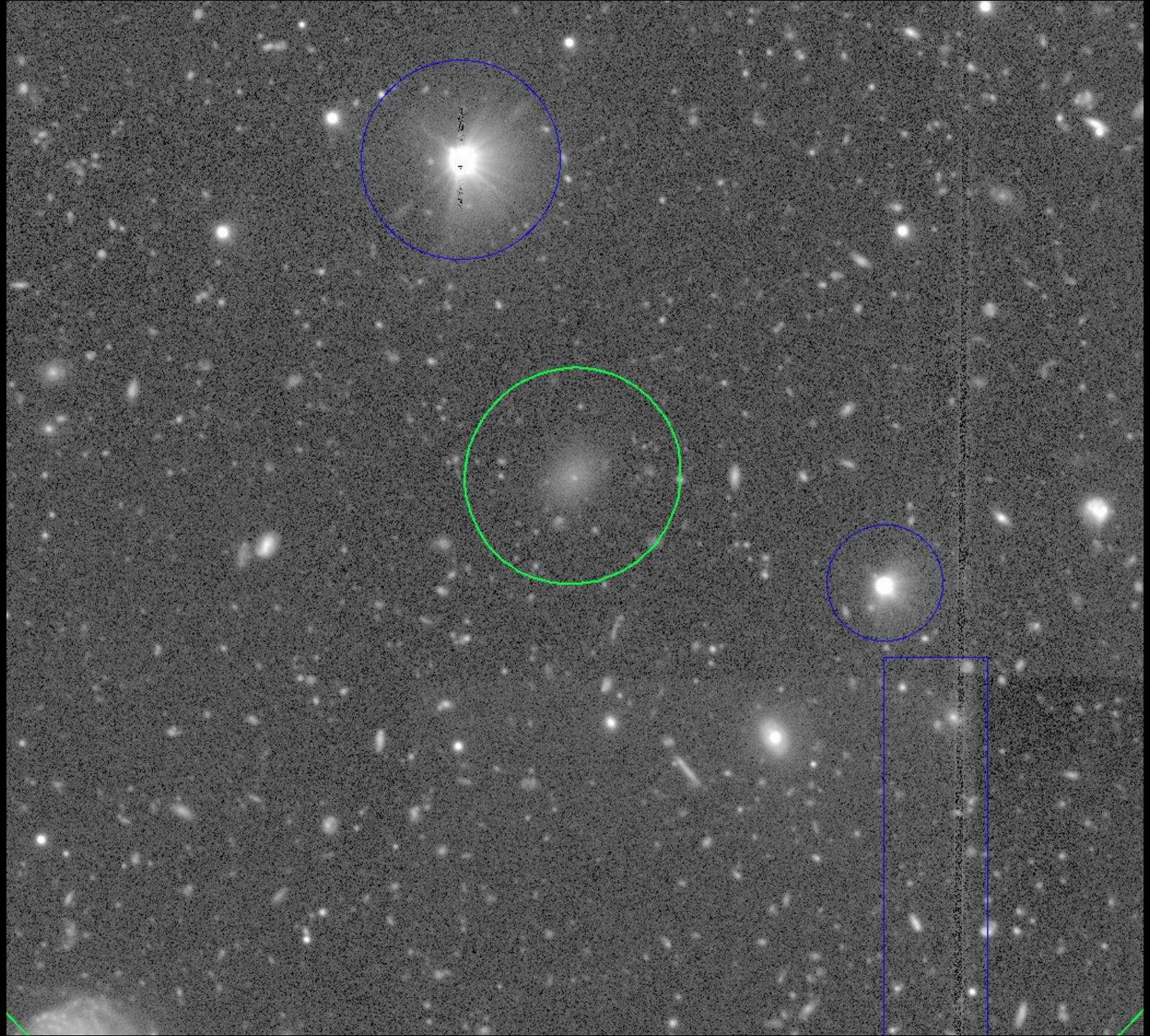
We will mask (approximate) virial radii of near-field background galaxies later.

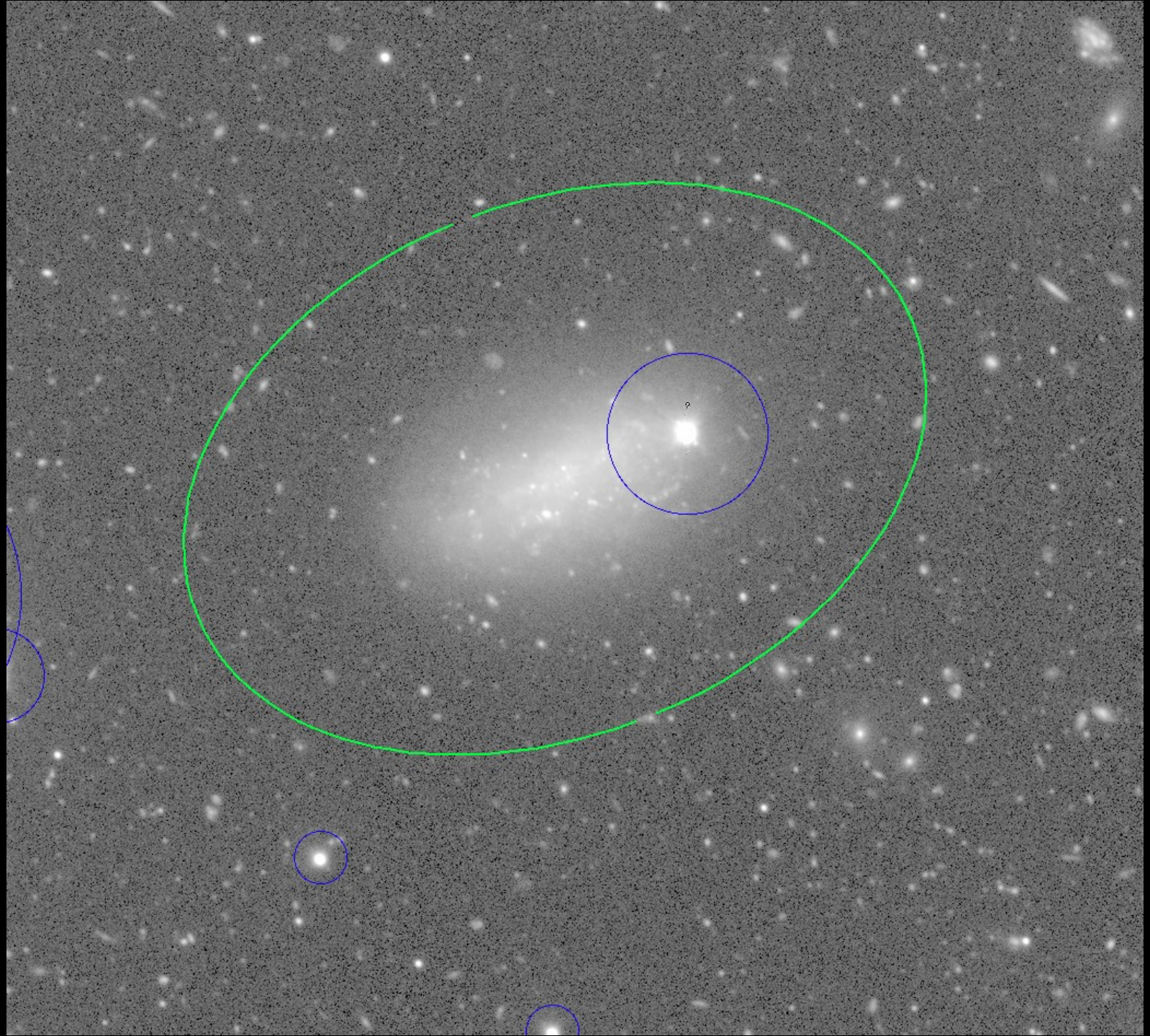
Dwarf galaxy selection



Dwarf candidates (~100 objects per HSC field of view) are visually inspected.





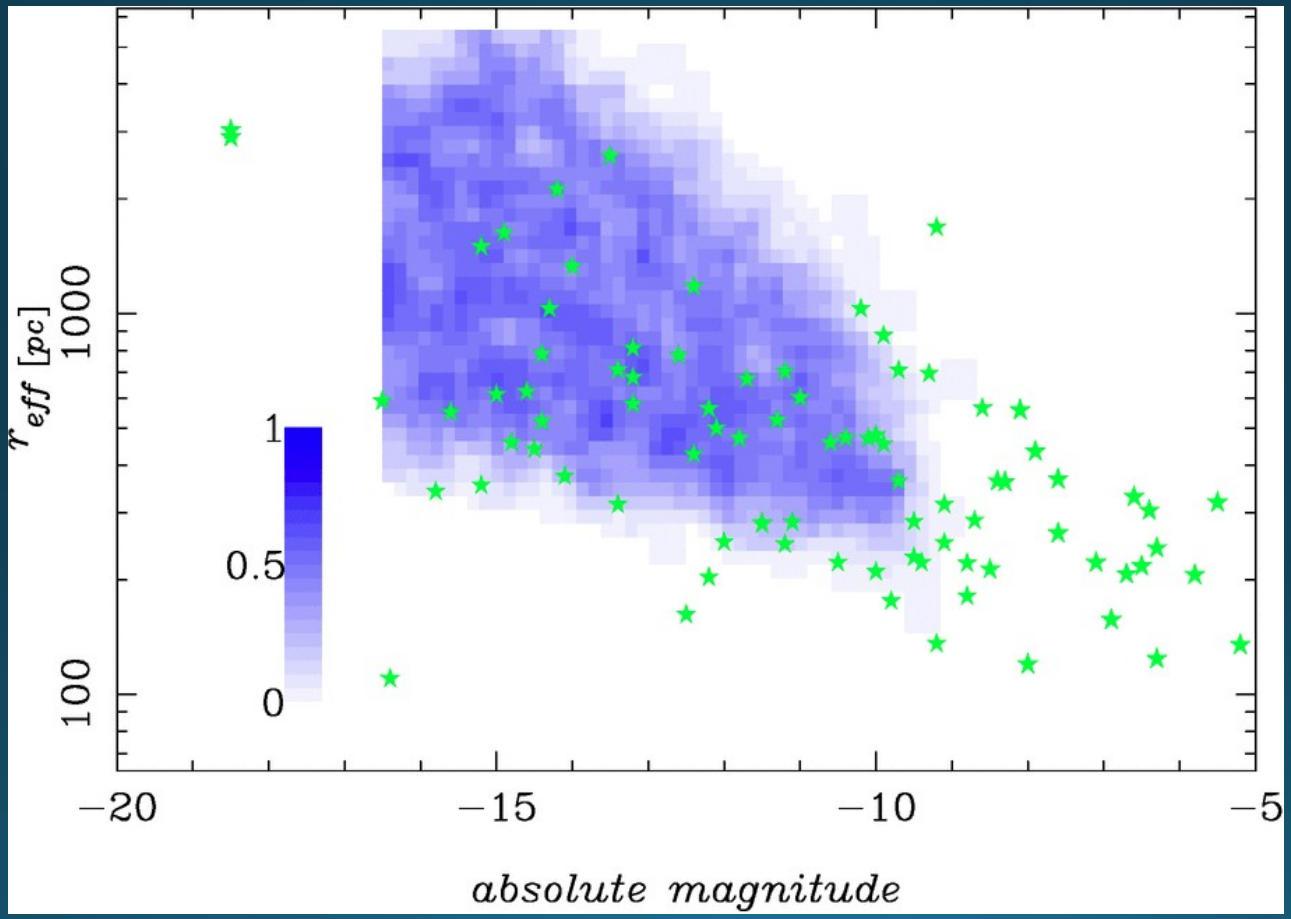


Simulations: detection completeness and flux biases

1. Assume dwarf galaxies have an exponential profile
2. Add artificial sources with a range of sizes and magnitudes to the real image
3. Detect objects
4. Apply masks
5. Match the input and output catalogs
6. Repeat the above procedure
7. Measure the detection completeness and biases in measured fluxes
8. Statistically correct for the incompleteness and flux bias

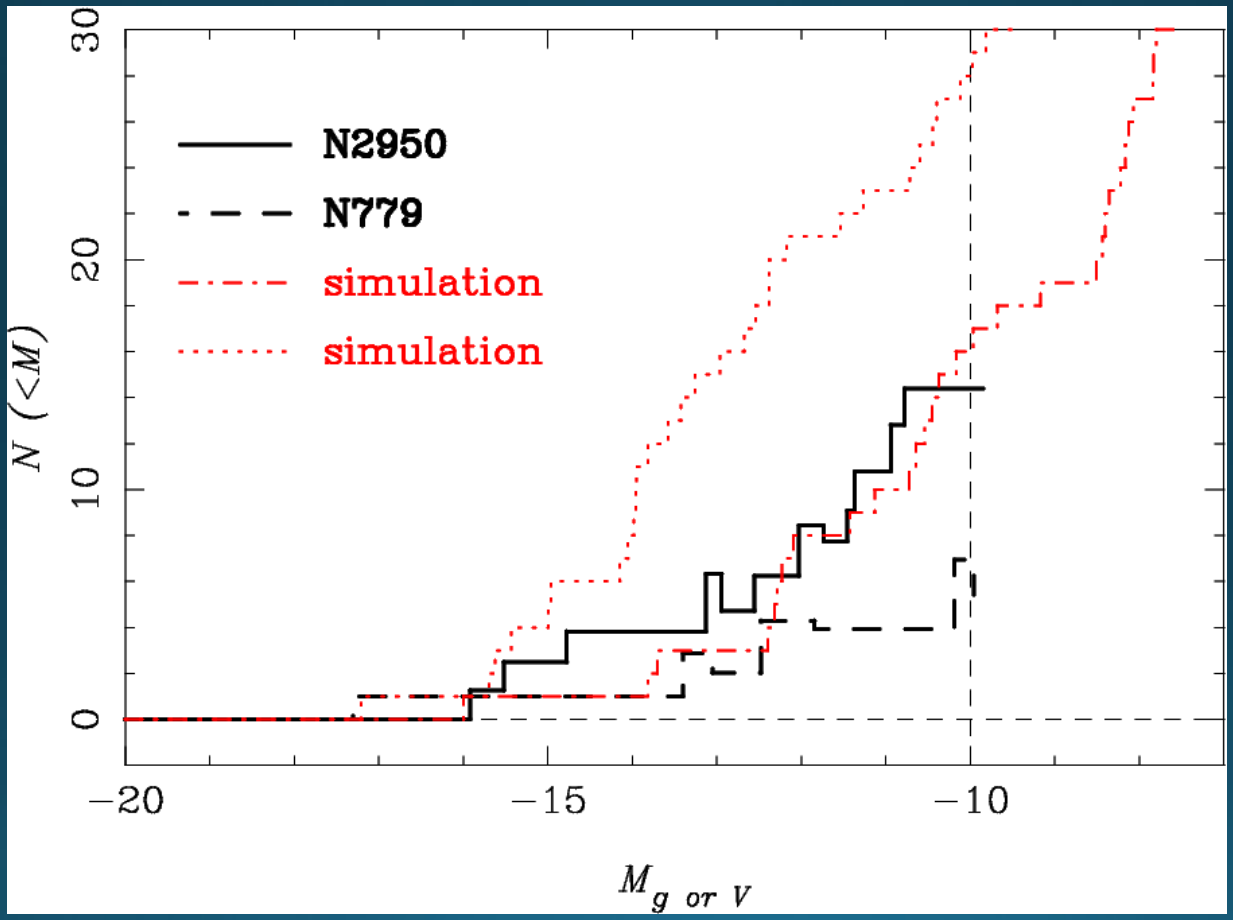
Simulations: detection completeness and flux biases

Detection completeness



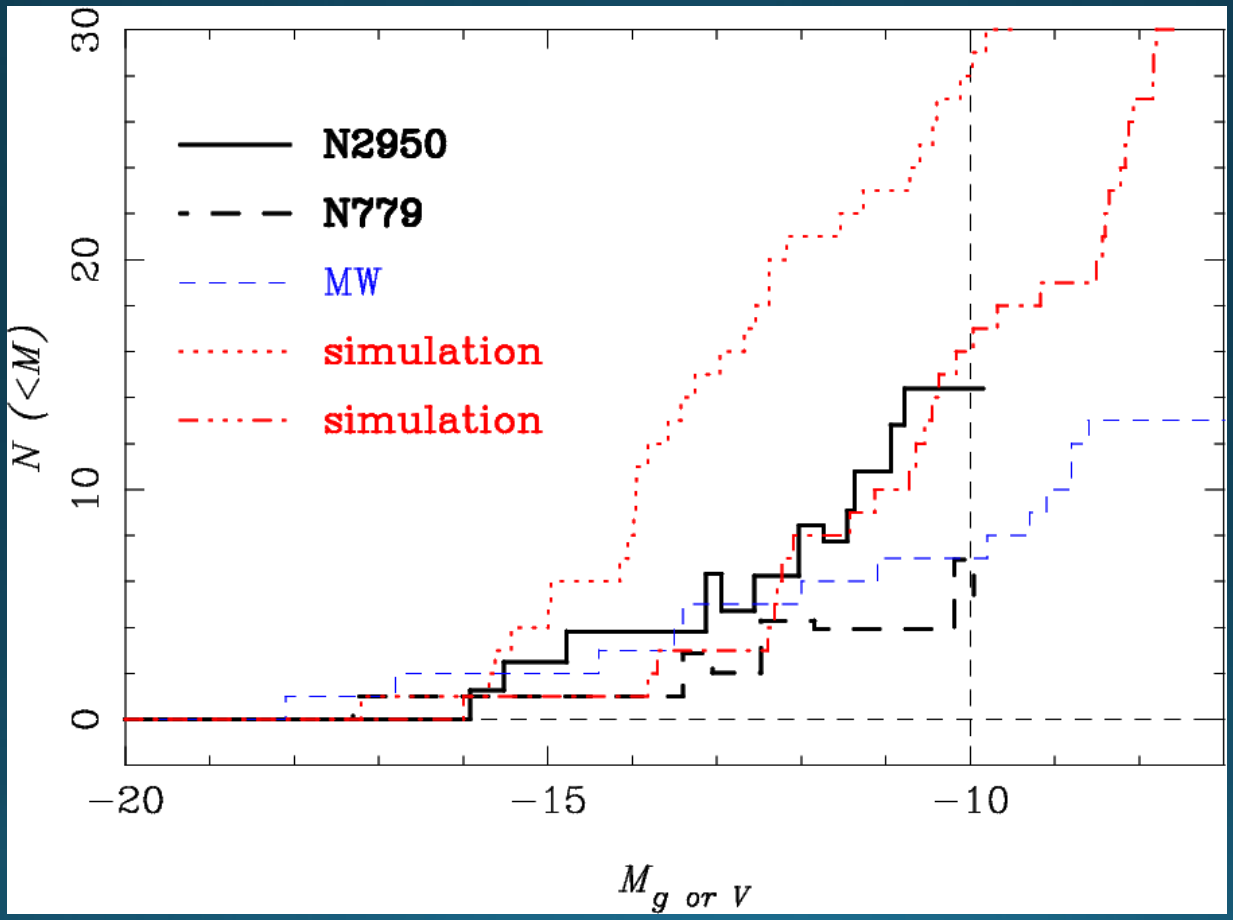
★ Dwarf galaxies in the Local Group

Preliminary results – cumulative luminosity function



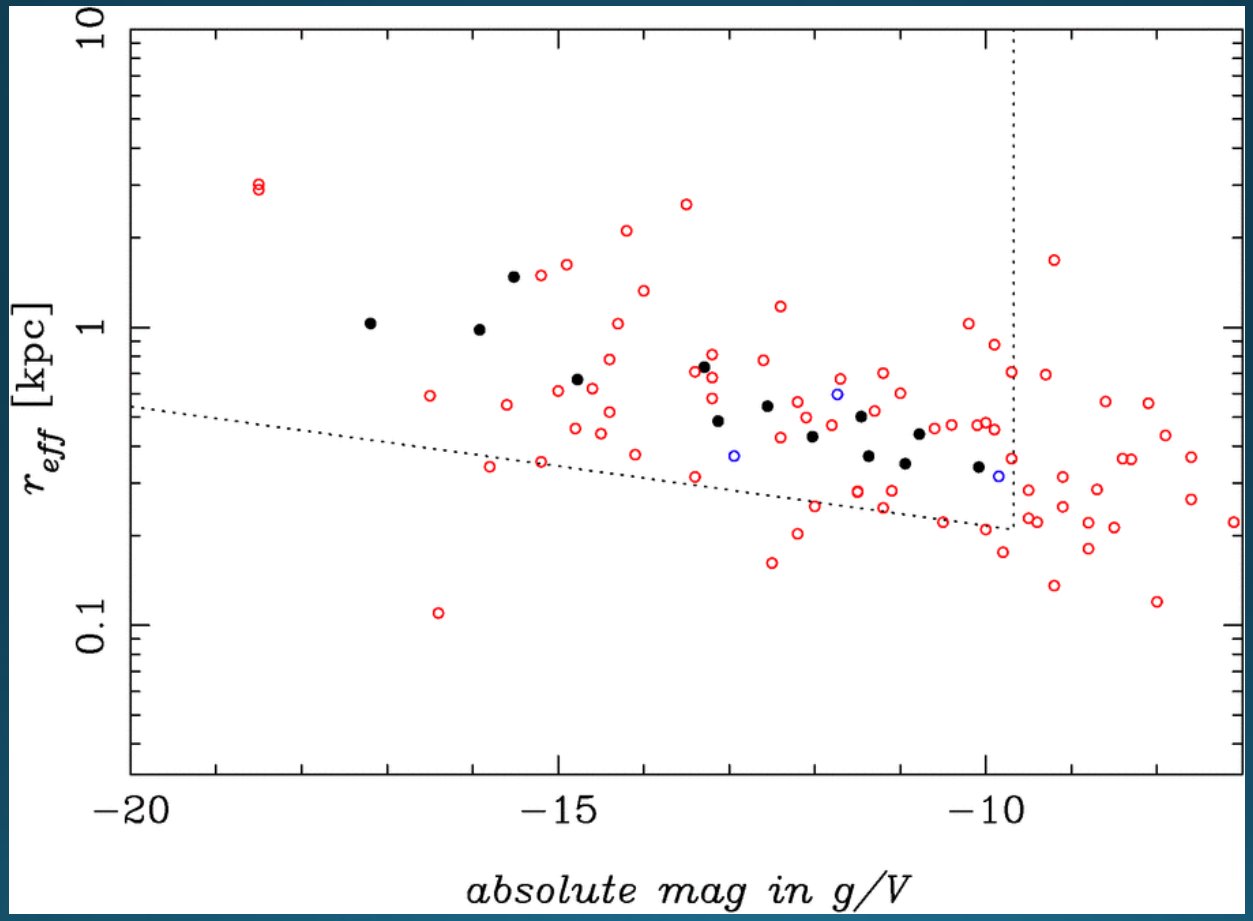
Simulations are from Okamoto (2013, MNRAS, 428, 718).

Preliminary results – cumulative luminosity function



Simulations are from Okamoto (2013, MNRAS, 428, 718).

Preliminary results – size-luminosity relation:

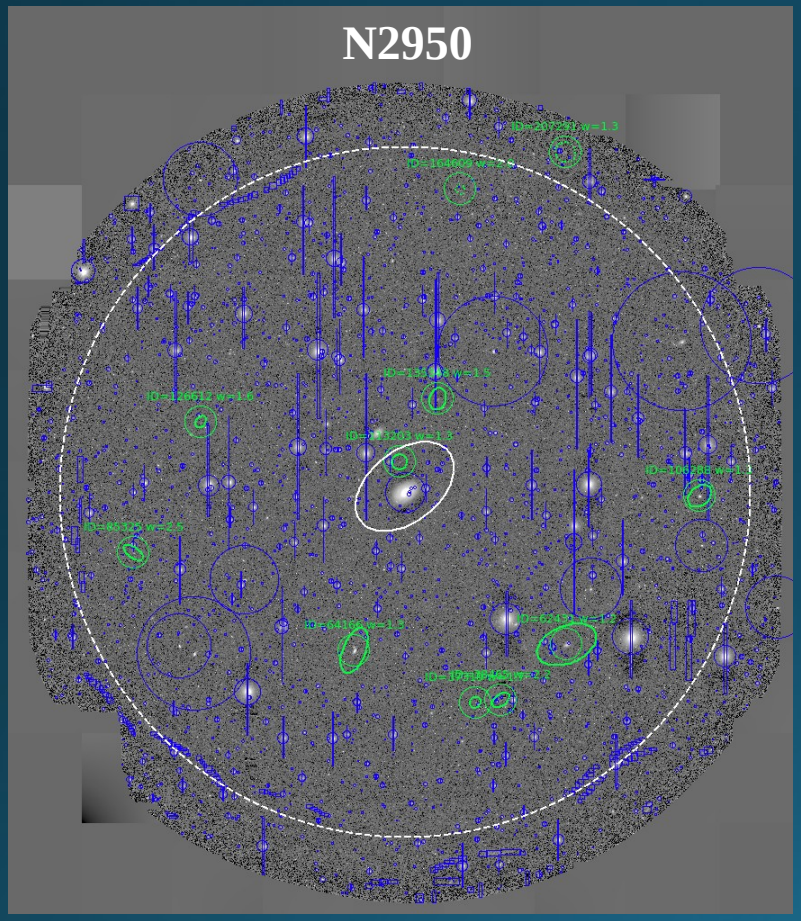


Dwarf galaxies in the Local Group

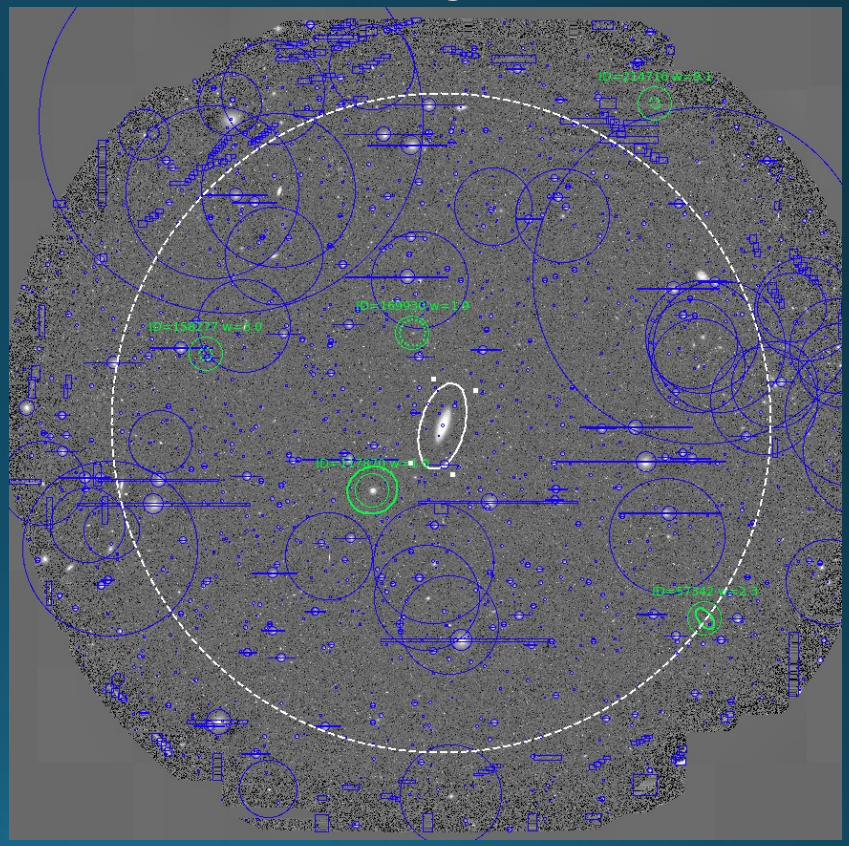
Dwarf galaxies around N779 + N2950

Preliminary results – spatial distribution

N2950



N779



Hm...

Future work

– Look at the g-i color of the dwarfs – quenching at low-mass.

– Our pilot observation was successful. We developed a method to identify dwarf galaxies and we learned a lot of lessons.

– The current statistics is too poor to draw any conclusions (but we are already comparable to MW + M31), and we now need more galaxies!

Summary

We started a survey to statistically address the missing satellite problem with Hyper Suprime-Cam on Subaru.

Our pilot observation shows:

– LFs of dwarf galaxies around N779 and N2950 show a factor of 2 scatter (but still consistent within statistical uncertainties)

– Okamoto et al. models seem to overpredict the abundance of dwarfs.

– MW LF is consistent with those of N779 and N2950.

Our pilot observation was successful and we learned a lot of lessons.
We now move on to construct a statistical sample of nearby galaxies.
Stay tuned...