The M101 Satellite Luminosity Function And The Halo To Halo Scatter Among Milky Way Analogues

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INTRODUCTION

Understanding the behavior of the faint end of the galaxy satellite luminosity function (LF) is crucial in constraining the formation and evolution of galaxies. ΛCDM models show that the LF of MW-mass galaxies should be steeper than those seen in observations, particularly at faint magnitudes. This steeper LF would result in far more dwarf galaxies than are observed (the 'missing satellite' problem).

Several possible explanations, including observational incompleteness and/or theoretical modeling have been proposed over the past decade. The general consensus is that incorporating feedback, star formation efficiency and re-ionization into cosmological simulations can help reconcile the differences between the observed slope of the LF and the theoretical predictions.

However, these improved models often aim to reproduce the singular case of the MW LF, which may not be representative. Thus, in order to test the robustness of these models against a larger sample, **it is necessary to observe the faint end of the satellite LF of systems beyond the Local Group.** Such observations will allow us to probe the typical value of the LF slope at lower luminosities, as well as constrain the system--to--system scatter.

DETECTION ALGORITHM

In order to detect small and diffuse targets, such as **LSB dwarf galaxies**, that are often hard to find in traditional searches, we have developed a **semi-automated algorithm**. This algorithm works by:

1. Masking all objects that appear in the guide star catalogue.

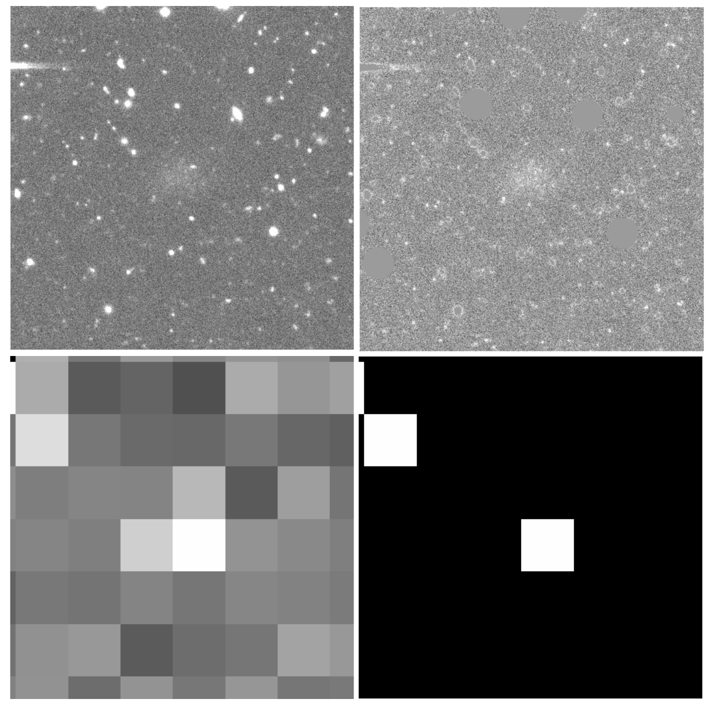

Fig. 1: A demonstration of the detection algorithm being applied to M101 Dw9 in the g band of the CFHTLS. From Fig. 1 of Bennet+ 2017

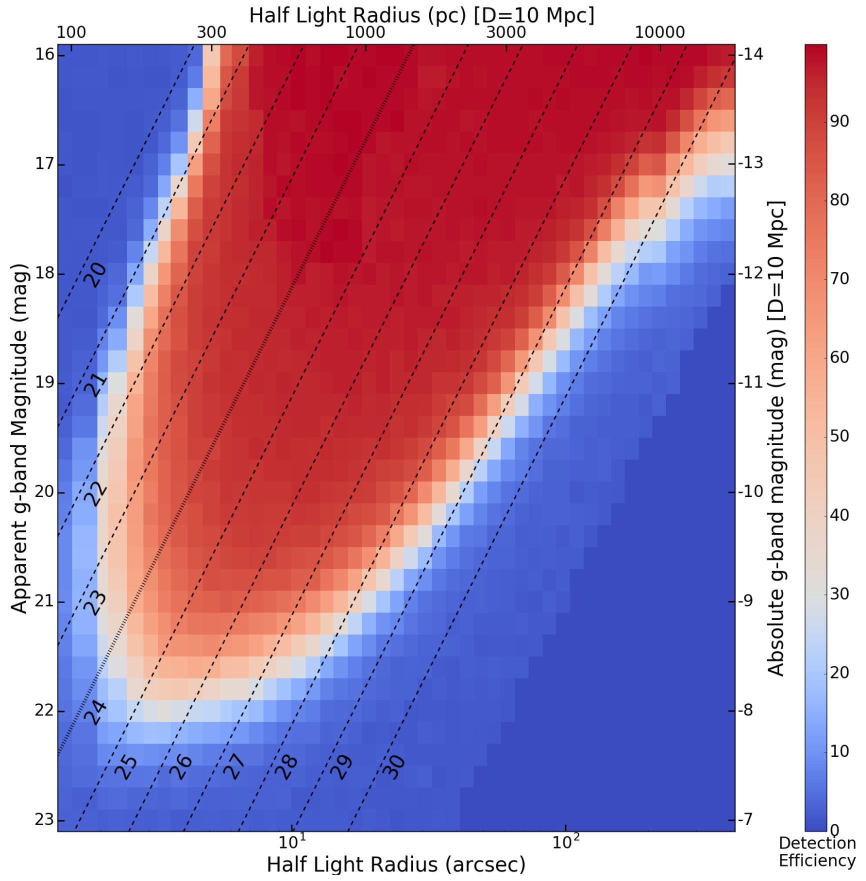

Fig. 2: LSB object detection efficiency as a function of magnitude and half light radius.

2. Masking all remaining groups of bright pixels (>20 pixels at >3σ above sky level).
3. Spatially binning the masked image on several different scales.
4. If an object is detected at all binned scales it is forwarded for final visual inspection.

- In order to test the algorithm we have injected over 1 million simulated dwarfs into CFHTLS images.
- This testing allows us to have a very clear view of the capabilities of the algorithm. See Fig. 2.

M101 SEARCH

- As a **pilot project** for a wider search of the CFHTLS, a 3 square degree region centered on M101 was searched by the detection algorithm.
- M101 is an unusual galaxy, historically showing a small stellar halo (van Dokkum+ 2014) and a poor satellite system.
- This search yielded 38 (Bennet+ 2017) new candidates in addition to 11 previously identified (Merritt+ 2014, Karachentsev+ 2015) LSB objects in this area.
- 19 of these were examined by the Hubble Space Telescope as part of a follow-up campaign (GO-14796).
- 2 of these objects, DwA and Dw9, were shown to be M101 group members. This extends the LF for the M101 group down to M_V= -8.2.

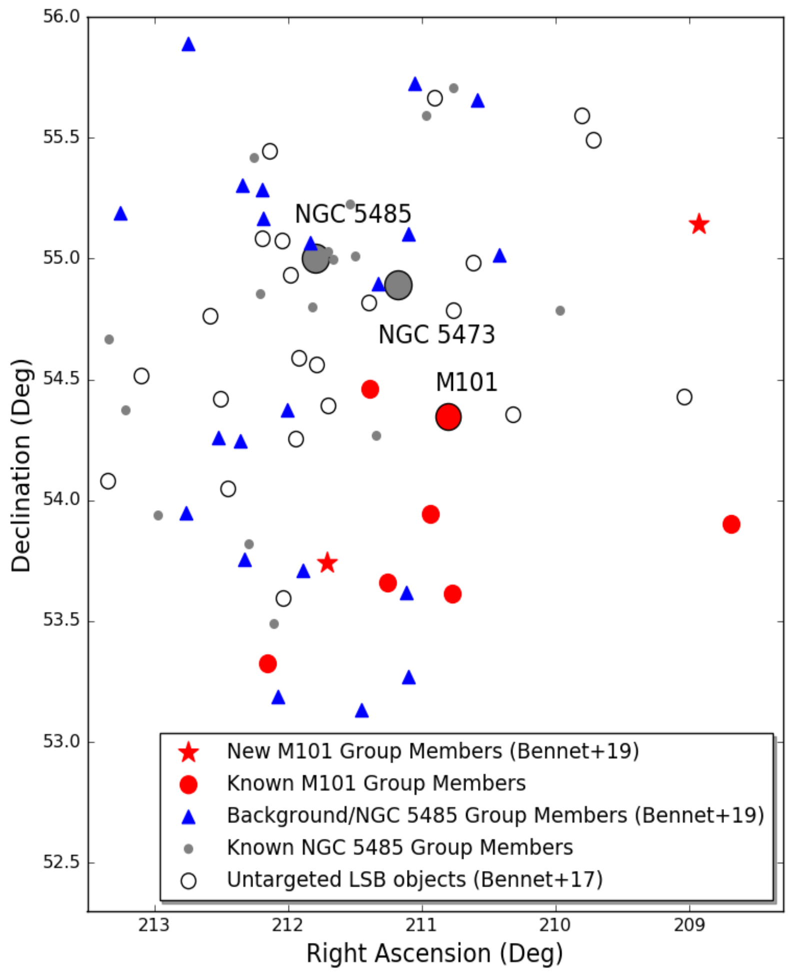

Fig. 3: Spatial map of the M101 group and its surrounding region, as well as the background NGC 5485 group. From Fig. 1 of Bennet+ 2019

HST OBSERVATIONS OF M101 DwA & Dw9

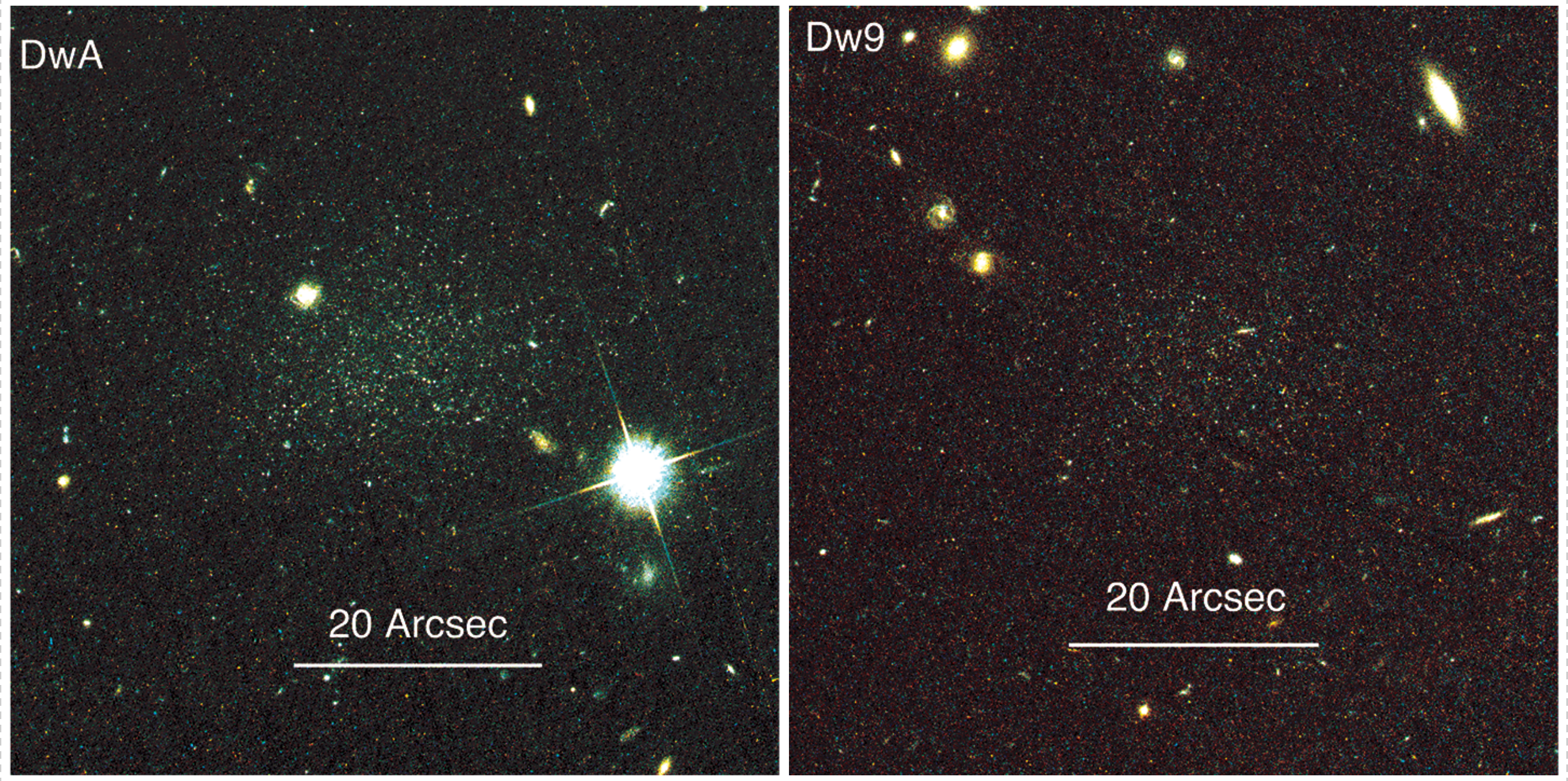

Fig. 4: Colorized image cutouts of DwA and Dw9 from HST/ACS. Images are 1.0'x1.0', north is up, east is left. From Fig. 2 of Bennet+ 2019.

M101 LF COMPARED TO OTHER MW-MASS SYSTEMS

- This shows that the M101 and M94 groups are very sparse when compared to the other MW-mass galaxies.
- At M_V=-8.0 the M101 group shows 9 confirmed members as opposed to 24.5±7.7 for the median group.
- There is a large scatter between groups with ~3 times more dwarfs in the M81 group compared to the M101 group at M_V=-8.0.
- This scatter is larger than that seen in simulations.

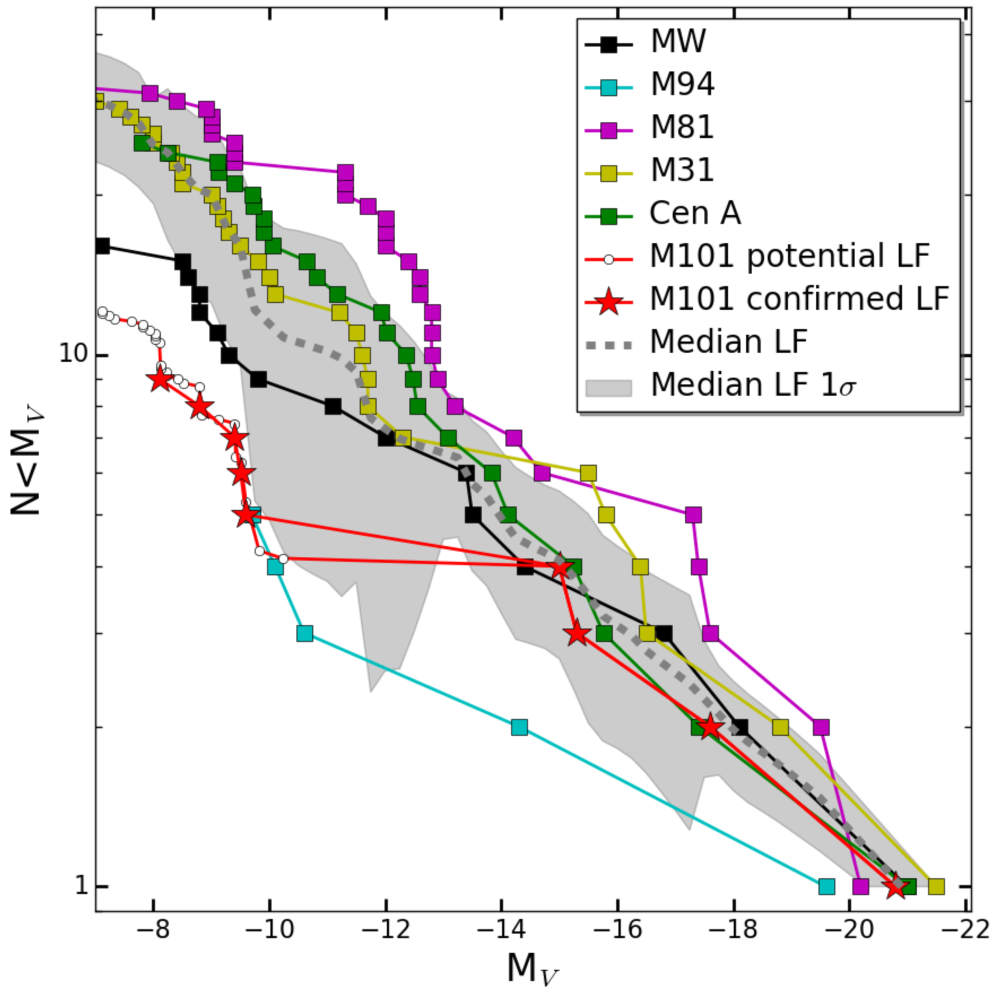

Fig. 5: The cumulative satellite LF for several Milky Way-like systems out to a projected radius of 250 kpc, and the constructed median from the set. From Fig. 7 of Bennet+ 2019.

ENVIRONMENTAL DEPENDENCE

- Host galaxies in more isolated environments (those with smaller tidal index) seem to have fewer satellites (Fig 6, left panel).
- Isolated galaxies also seem to have higher star forming fractions in their satellites (Fig. 6, right panel).
- Our results match those from the SAGA survey (Geha+ 2017) where isolated MW-analogues were found to have generally poor satellite systems and high star forming fractions.

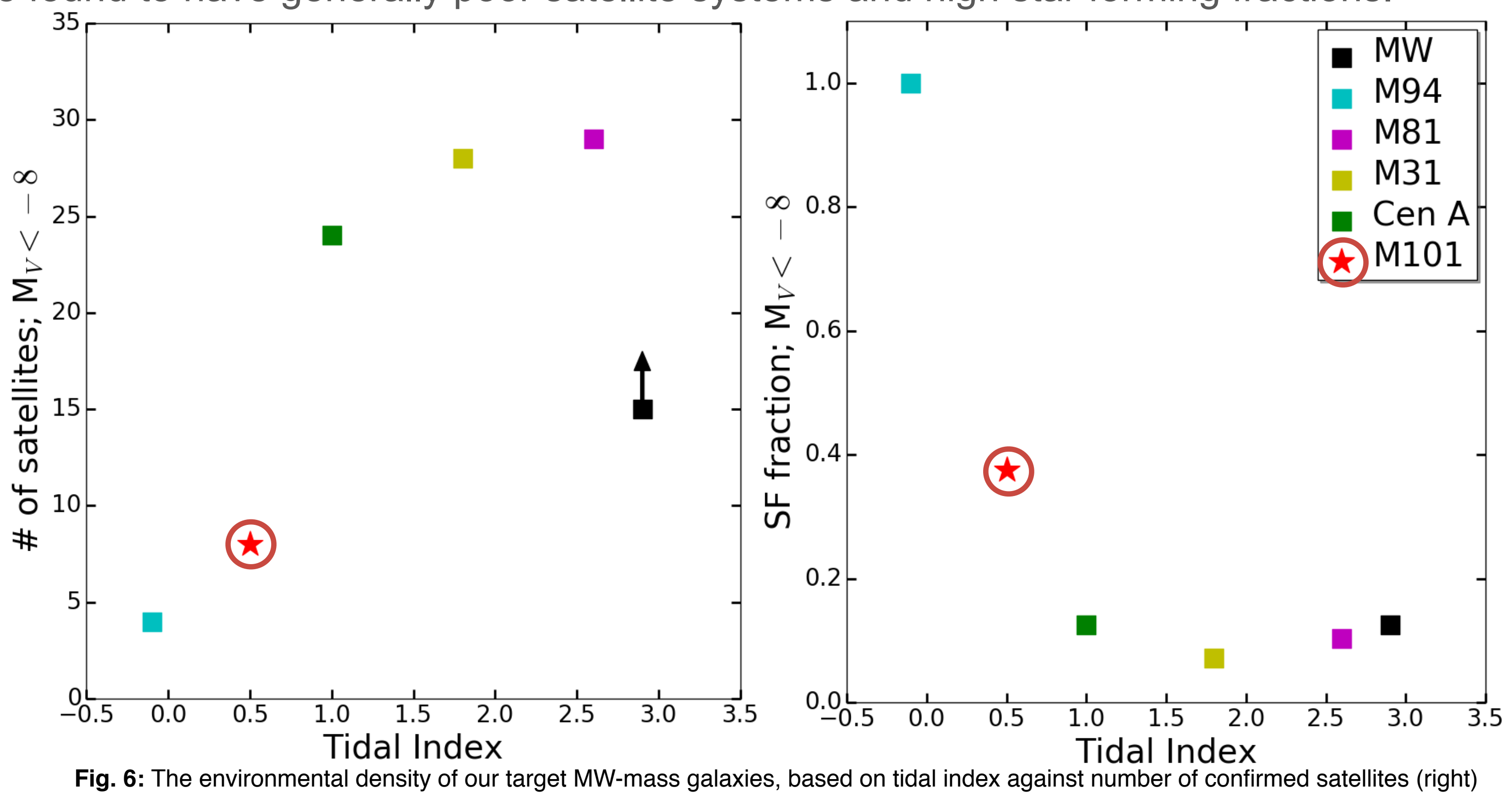

Fig. 6: The environmental density of our target MW-mass galaxies, based on tidal index against number of confirmed satellites (right) and star forming fraction (left) for satellites with $M_V \leq -8$. From Figs. 8 & 9 of Bennet+ 2019.

For more details see Bennet et al. (2019)
https://arxiv.org/pdf/1906.03230.pdf