



A Lonely Giant: The Sparse Satellite Population of M94 Challenges Galaxy Formation

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**Eric Bell, Richard D'Souza, Paul Price, Colin Slater, Jeremy Bailin, Antonela Monachesi,
David Nidever**

Smercina et al. 2018, ApJ, 863, 152

Problems with Galaxy Formation

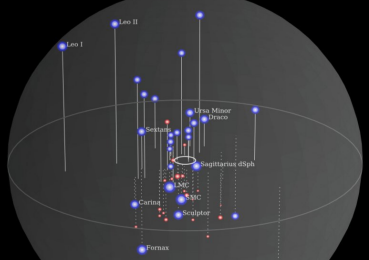
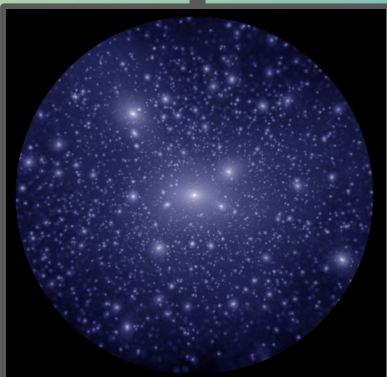
Missing Satellites

Dwarf Galaxy Scales

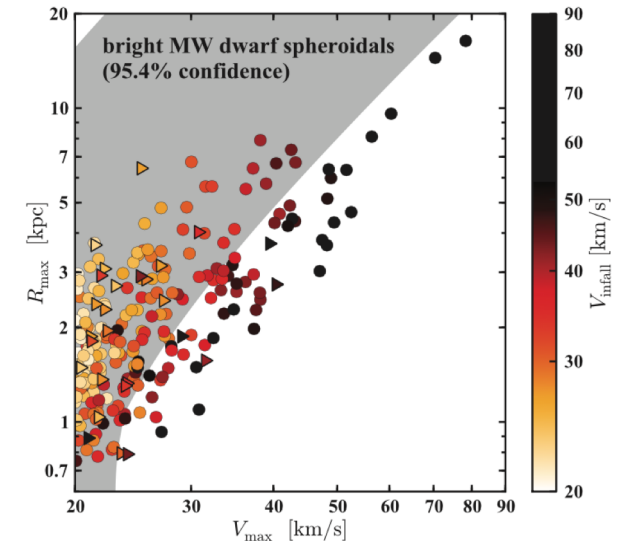
Too Big to Fail

Problem + Solution
Defined in MW/LG

Generalizable?

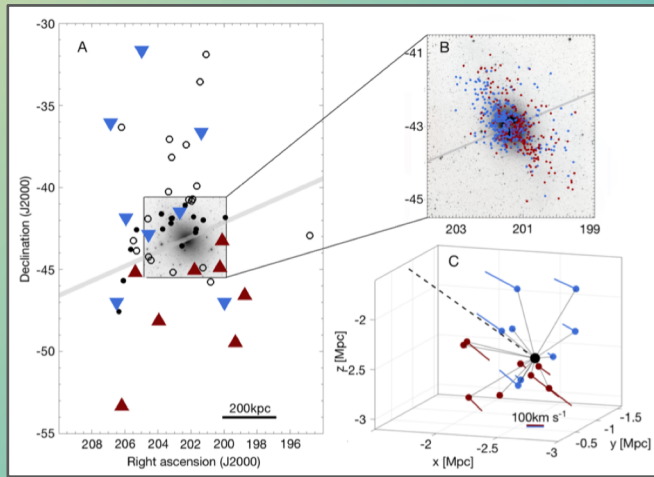


Bullock, Boylan-Kolchin,
Pawlowski 2017

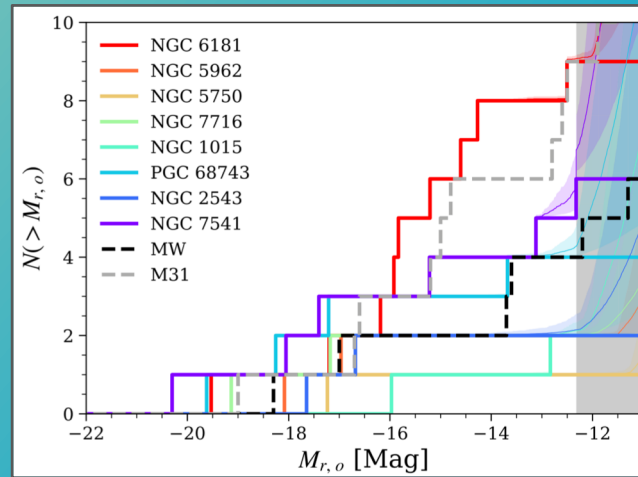


Boylan-Kolchin+2011

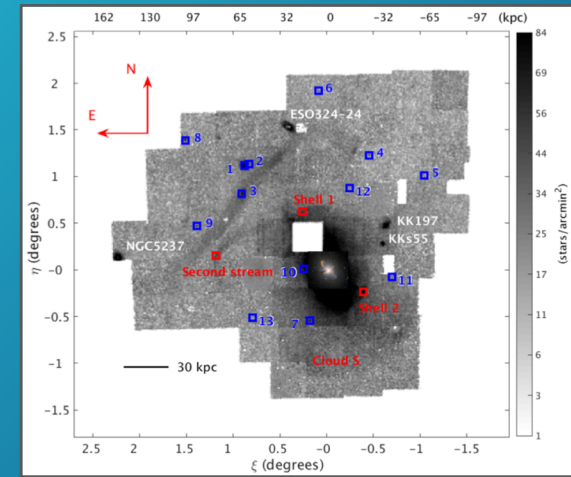
Motivates satellite searches around MW-analogs



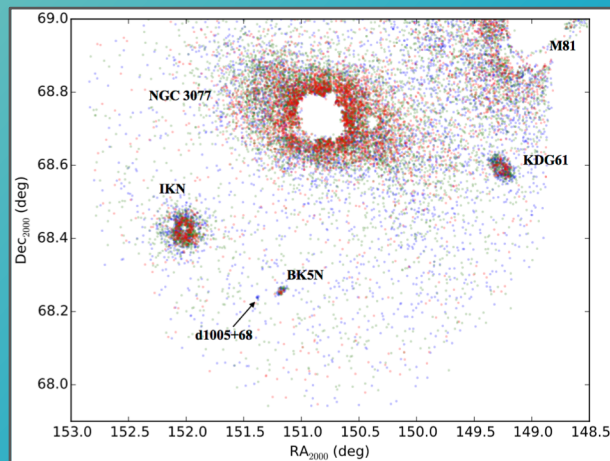
Müller et al. 2018



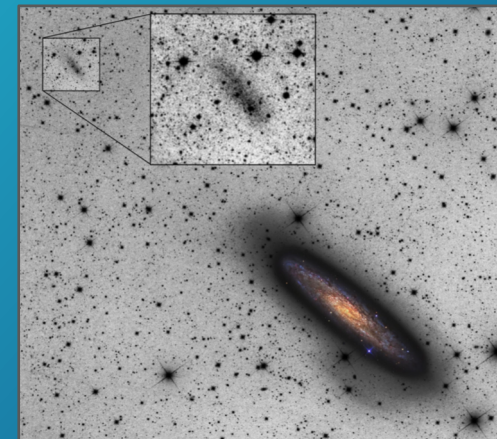
Geha et al. 2017



Crnojevic et al. 2016



Smercina et al. 2017

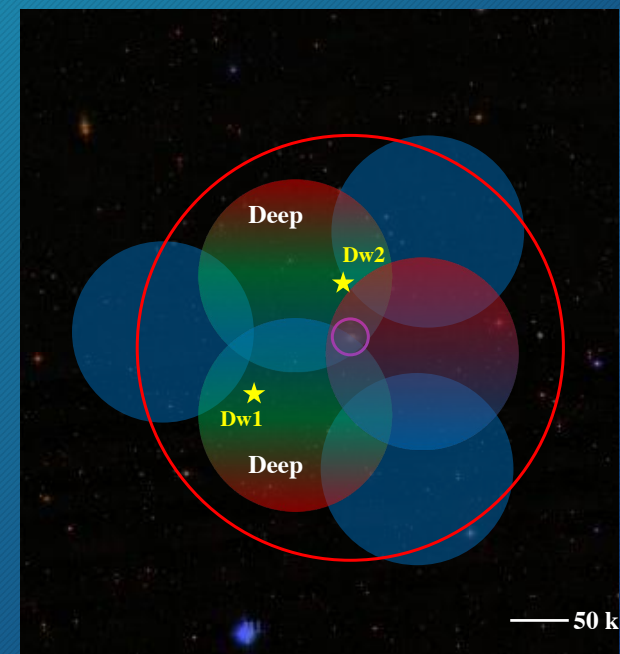
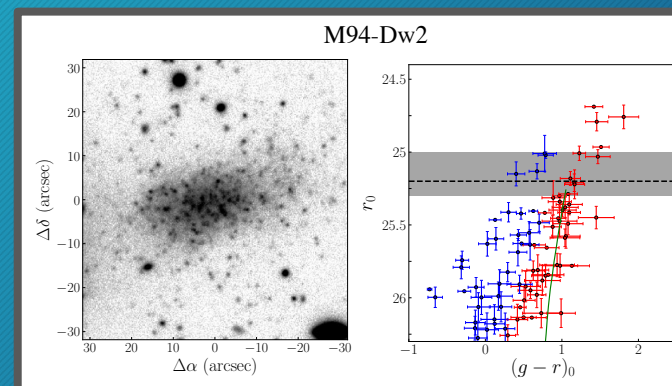
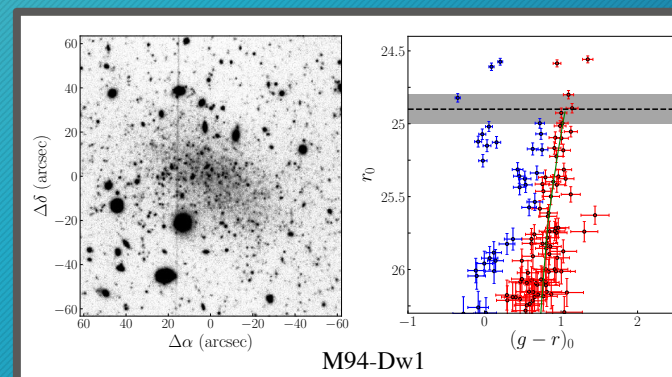
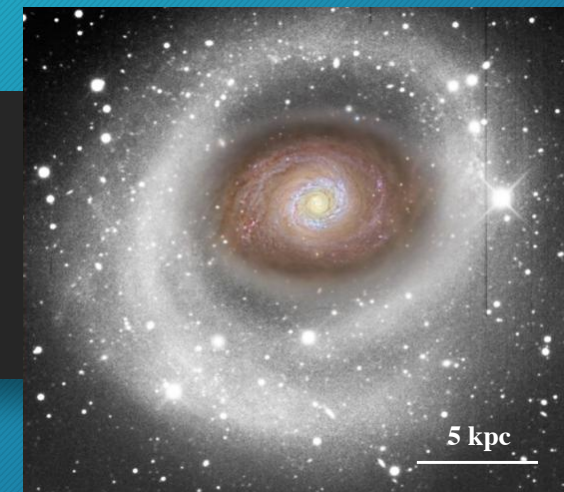


Romanowsky et al. 2017

A Subaru HSC Survey of M94's Satellites

- M94: An isolated MW-mass galaxy
 - Mass: $M_* \sim 4 \times 10^{10} M_\odot$
 - Distance: 4.2 Mpc
- 6 pointings with HSC (g-band)
 - ~ 150 kpc radial coverage in g-band
 - Discovered 2 low-mass satellites

There are only 2 satellites $> 4 \times 10^5 M_\odot$!



How does M94's satellite population compare to other galaxies, and model predictions?

M94's satellite population is **very unlikely** in a 'Standard' Halo Occupation Context

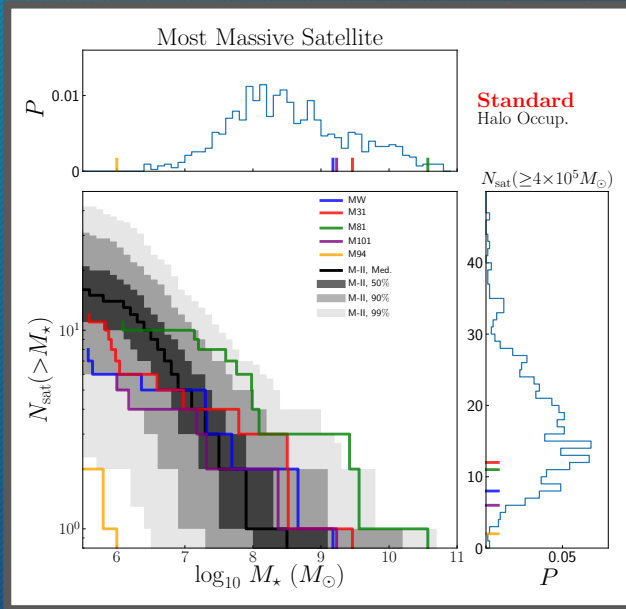
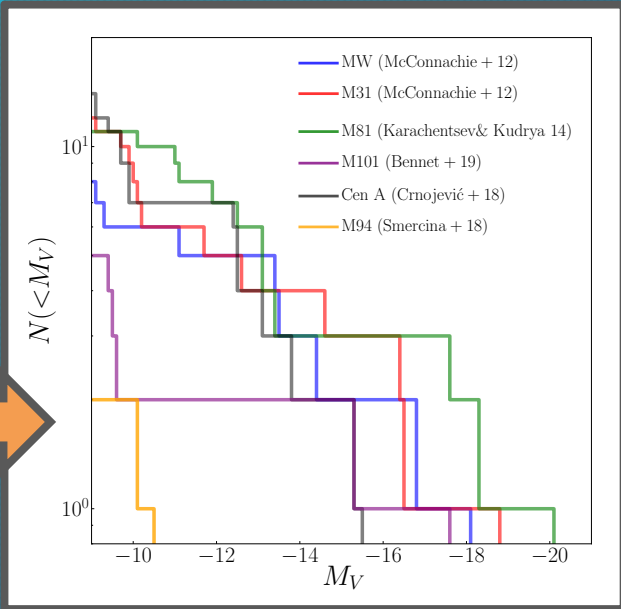
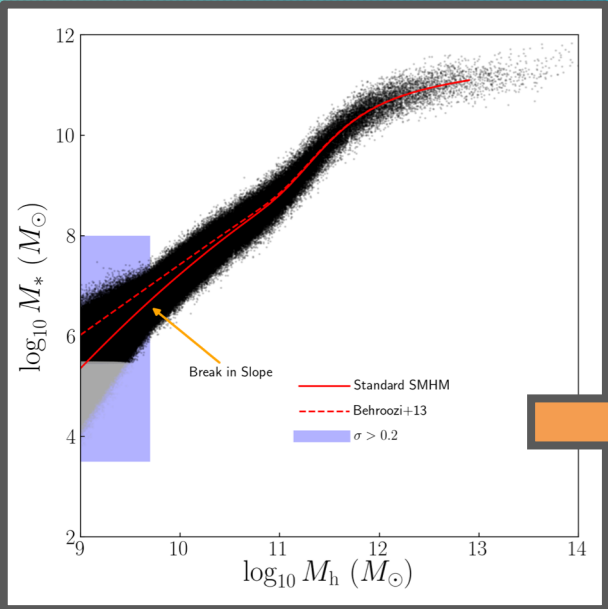
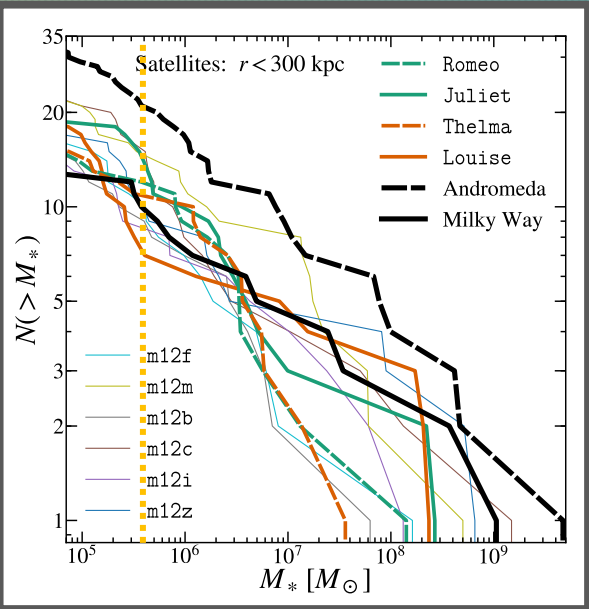
<0.2% in 1500 galaxies!

No most massive satellites $\leq 10^6 M_\odot$

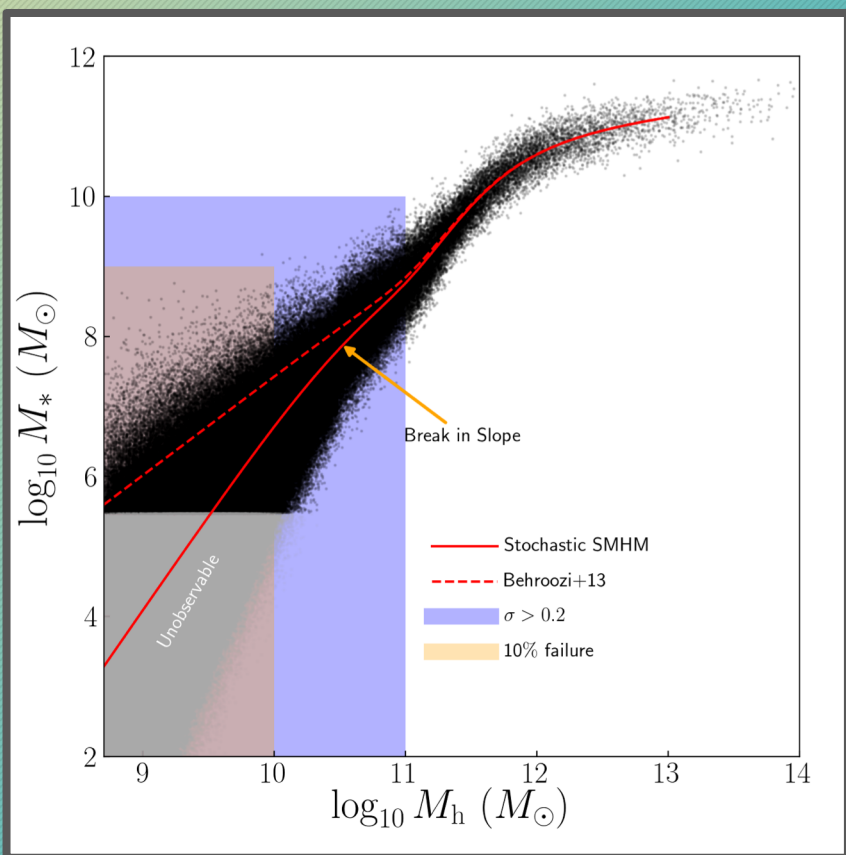
FIRE
(Garrison-Kimmel+19)

EAGLE
(Halo Occupation)

Known galaxies



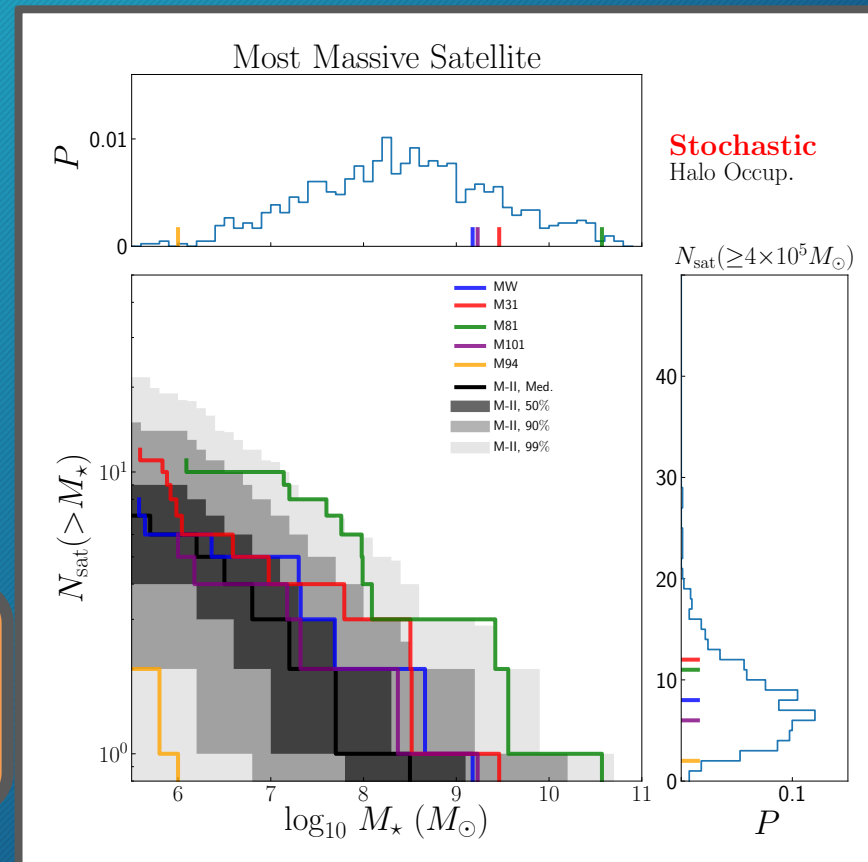
A 'Stochastic' Halo Occupation model produces M94-like systems much more frequently



~4-5% in 1500 galaxies



Some systems have a most massive satellites $\leq 10^6 M_\odot$



Stochastic Halo Occup.

M94's Sparse Satellite System suggests that galaxy formation is surprisingly stochastic for $<10^{11} M_{\odot}$ halos

Missing Satellites

MW-mass galaxies have large scatter in their # of satellites

Scatter from best current simulations is much lower!

M94's Satellites

Galaxy formation at **ALL** dwarf-galaxy scales may be **much more stochastic**

Too Big to Fail

M94 lacks any satellite $>10^6 M_{\odot}$

Large scatter may persist for halos $>10^{10} \rightarrow$ the **TBTF** mass