Dark Matter Deficient Galaxies in the Illustris TNG Simulation

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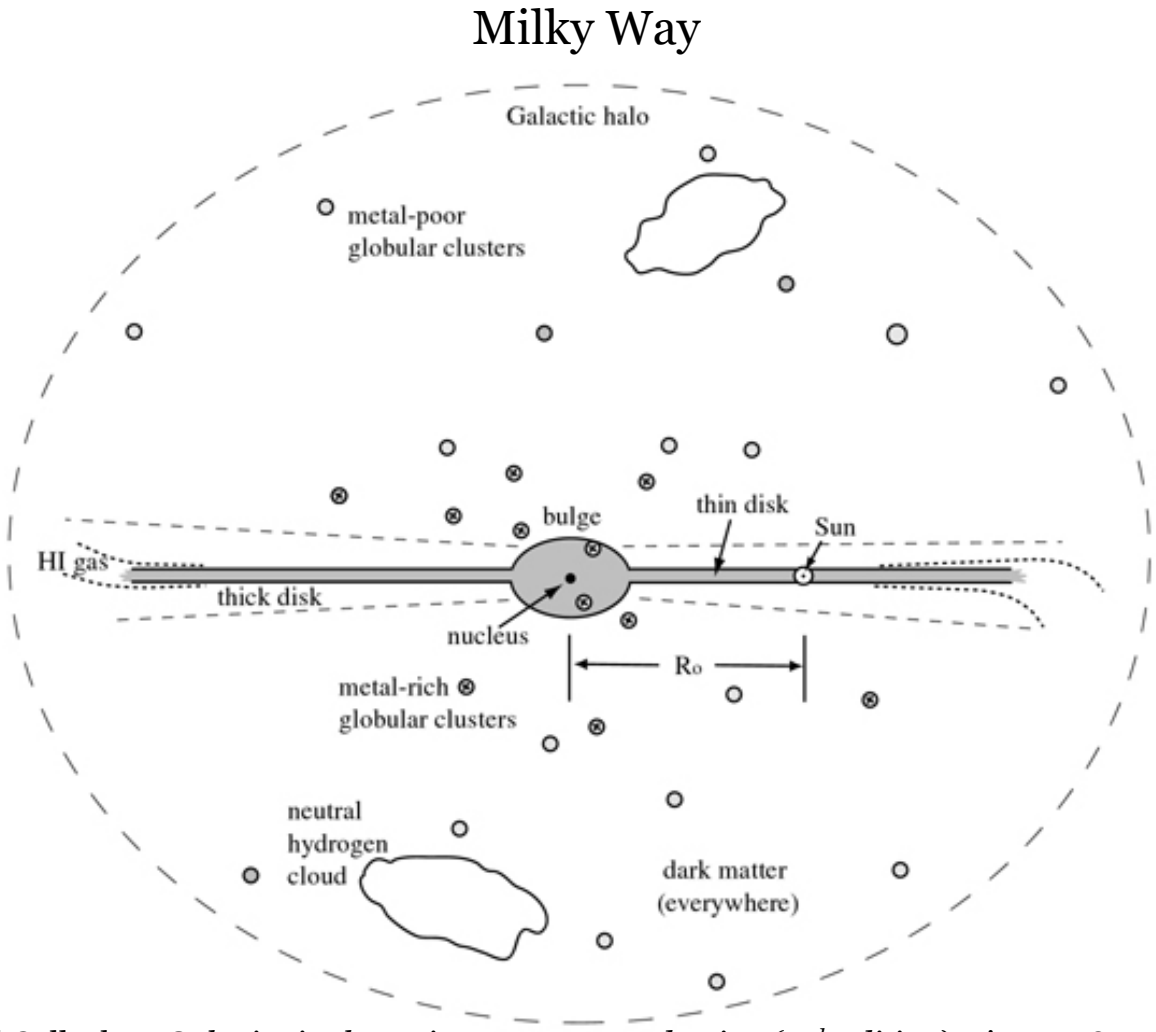
Recall:

- What is a galaxy?
  - Large collection of gravitationally bound stars, gas, dust, and dark matter
- Milky Way:
  - $M_{total} = 15 \times 10^{11}\ M_{\odot}$
  - $M_{baryonic} = 1.2 \times 10^{11}\ M_{\odot}$
  - Therefore ~ **90% dark matter**
    - ***This is a typical value!***



Sparke and Gallagher, *Galaxies in the Universe: An Introduction (2nd Edition)*, Figure 1.8 pg. 26

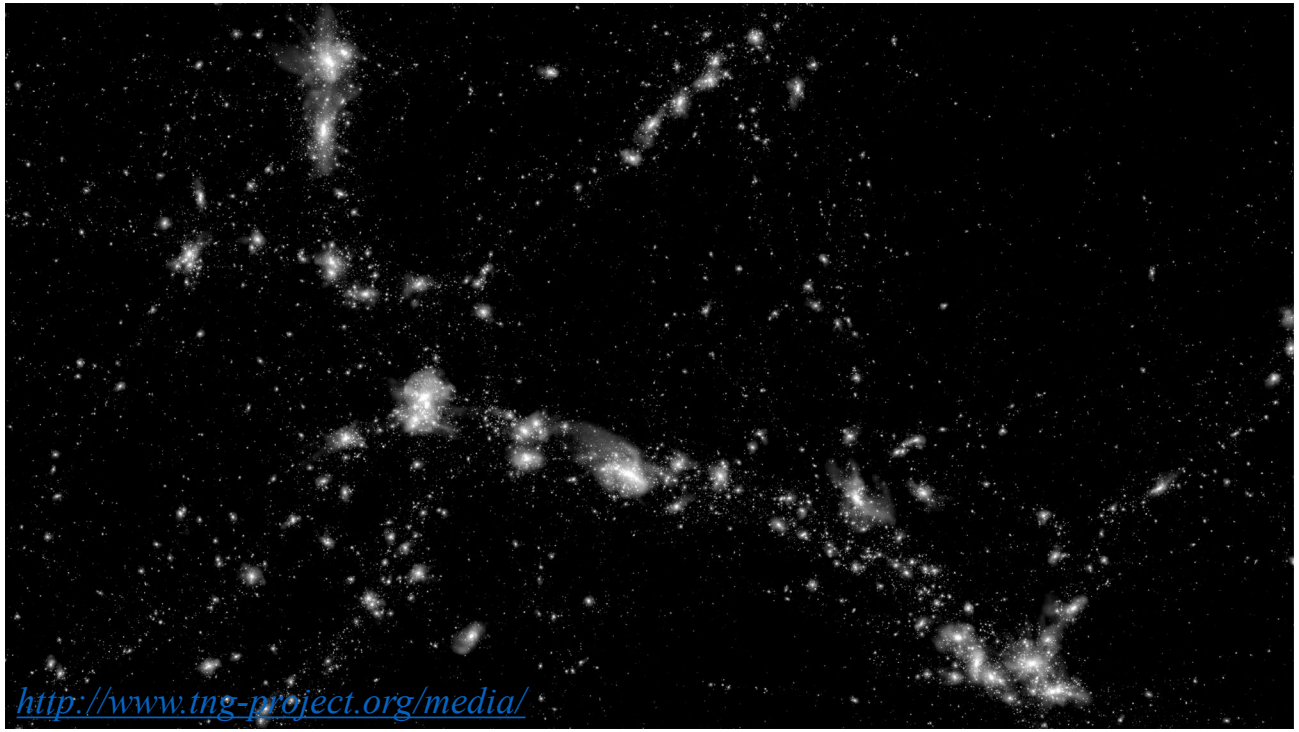
Motivation

- Recently discovered galaxies with no dark matter
  - *Van Dokkum et al. 2018*: NGC1052–DF2
  - *Van Dokkum et al. 2019*: NGC1052—DF4
- Raised some questions:
  - How common are these galaxies?
  - How are these galaxies formed?
  - What are their common properties?

NGC 1052-DF2

Galaxy Simulations

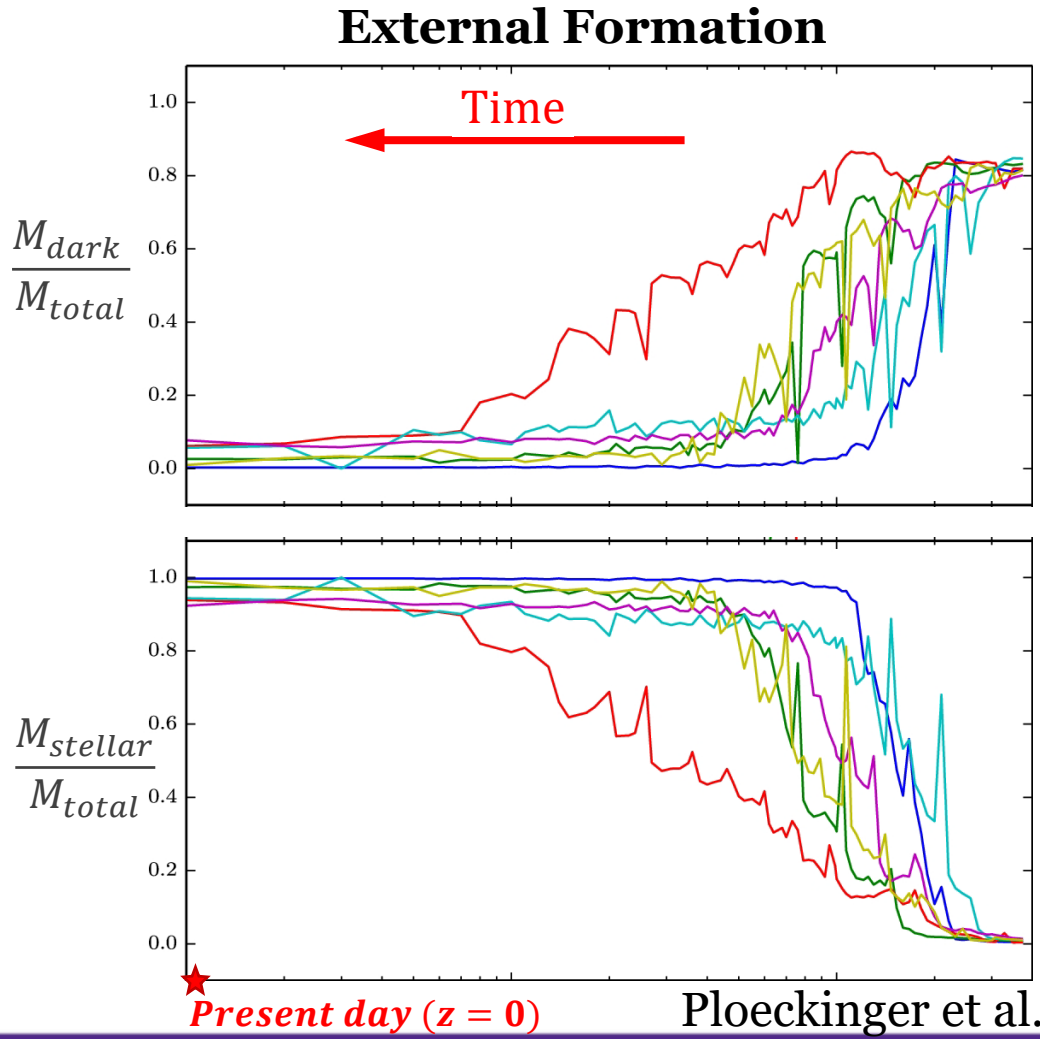
- Observations are difficult, so we use simulations:
  - Look at number density of galaxy populations
  - Look at formation histories



Visualization of the stellar structure in the Illustris TNG100-1 simulation

Formation – what do we know?

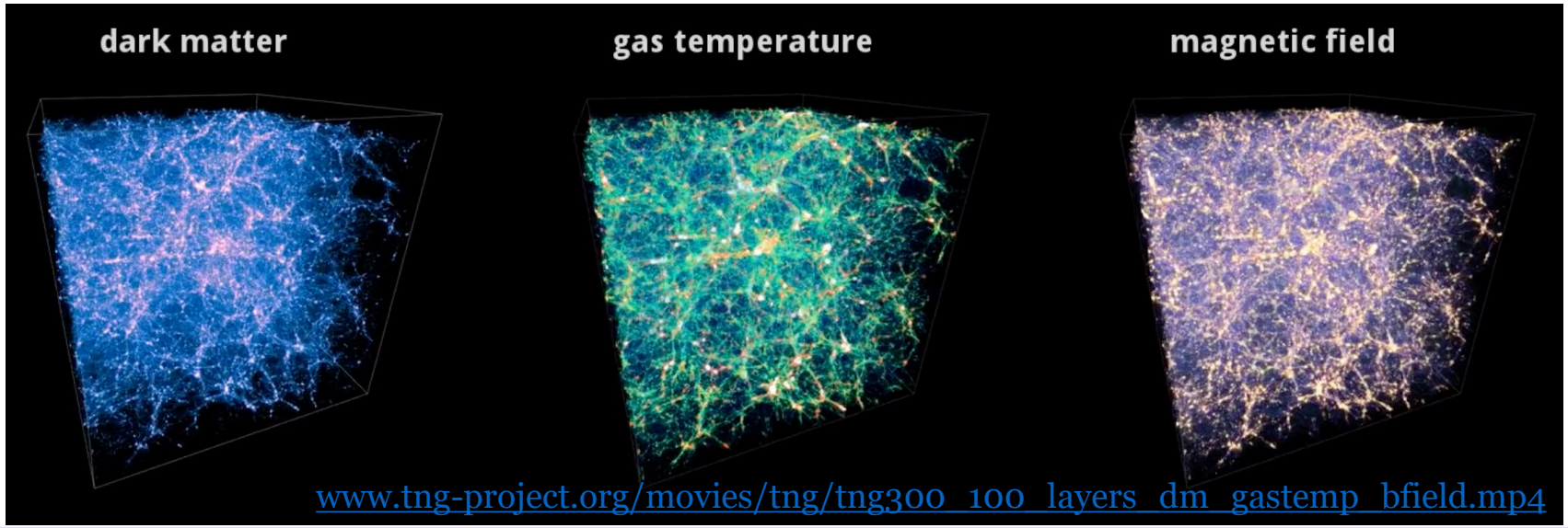
- External Formation (Ploeckinger et al. 2017, Haslbauer et al. 2018)
  - Form from pre-existing galaxies
    - Galaxies merge
    - Tidal forces eject gas and stars
    - Ejected material unable to capture dark matter
  - Result: dark matter deficient galaxy



Ploeckinger et al. 2017

My Project

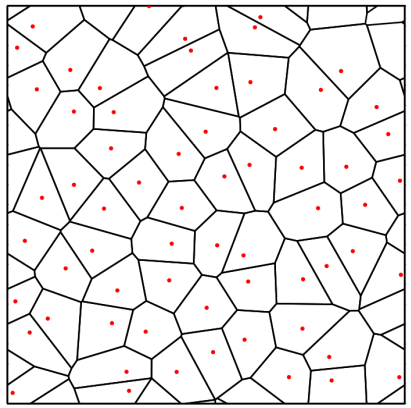
- Build on past research using newer *Illustris TNG* simulations
- Focus: determine some common properties of dm-deficient galaxies to help guide observational expectations



Illustris TNG Simulations

TNG Collaboration – *www.tng-project.org*

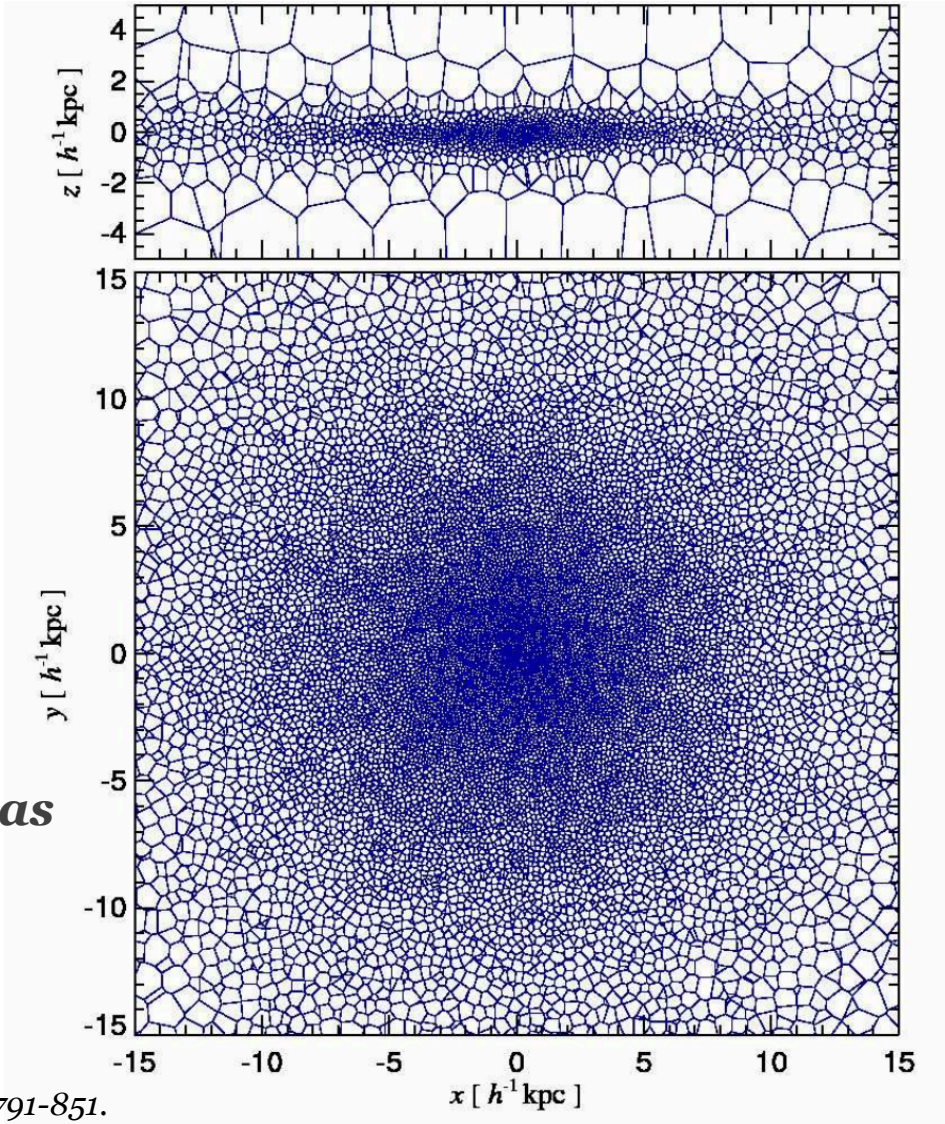
- **Illustris-1 (Old)**:
  - Resolution: 2×1820^3 particles
    - $L_{box} = 75$ cMpc h^{-1}
    - $M_{baryon} = 1.6 \times 10^6\ M_\odot$
    - $M_{dm} = 6.3 \times 10^6\ M_\odot$



Visualization of particles in the simulation

- **TNG 100-1 (New):**
  - Resolution: 2×1820^3 particles
  - $L_{box} = 75$ cMpc h^{-1}
  - $M_{baryon} = 1.4 \times 10^6\ M_\odot$
  - $M_{dm} = 7.5 \times 10^6\ M_\odot$

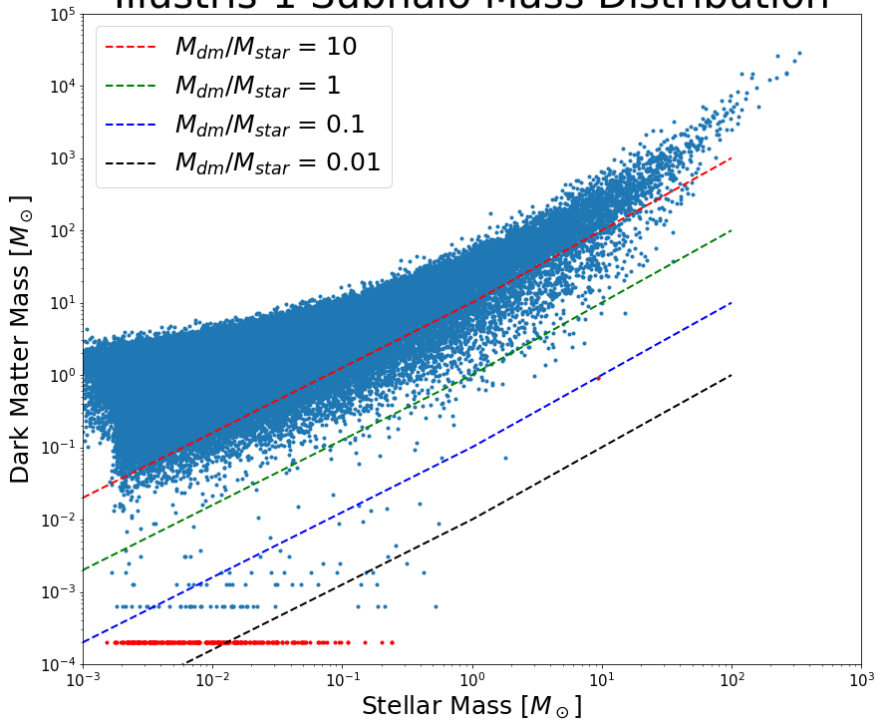
Visualization of gas particles in the simulation



Springel, Volker. MNRAS 401 (2) (2010), pp. 791-851.

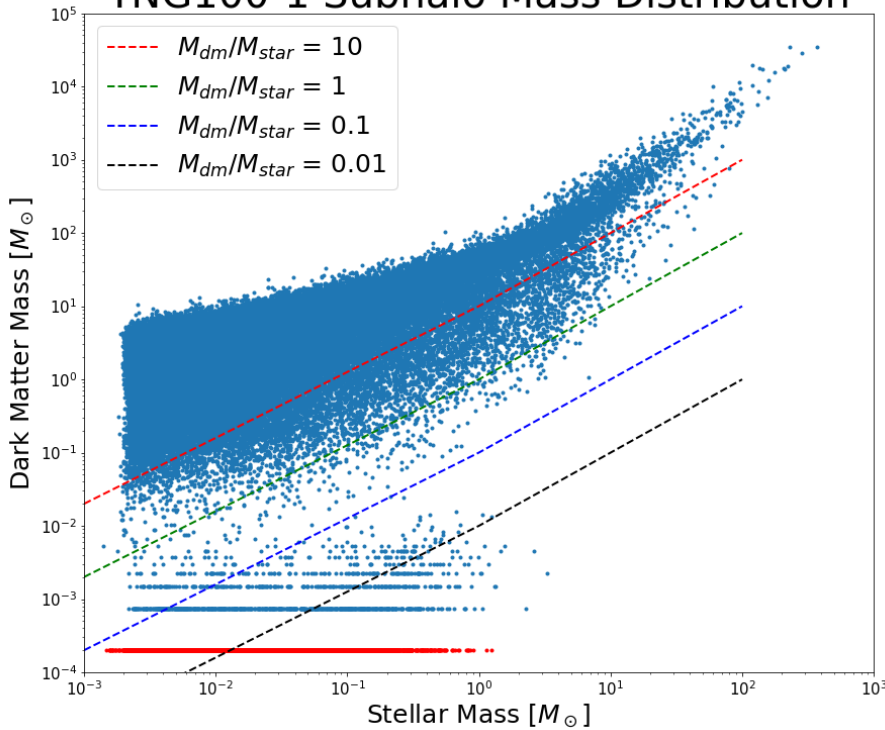
My Results

Illustris-1 Subhalo Mass Distribution



	Illustris	*TNG100*
Total Galaxies	126,254	79,068
DM-Deficient Galaxies	177	3,438
Percent DM-Deficient	0.14%	4.34%

TNG100-1 Subhalo Mass Distribution



Analyzing DM Deficient Galaxies

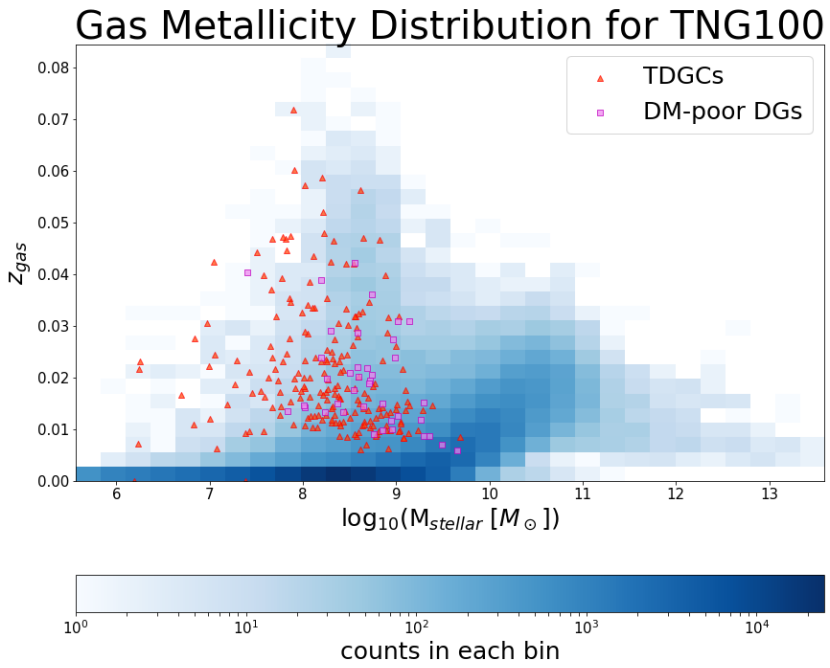
Current progress: analyzing different properties of these DM-deficient galaxies

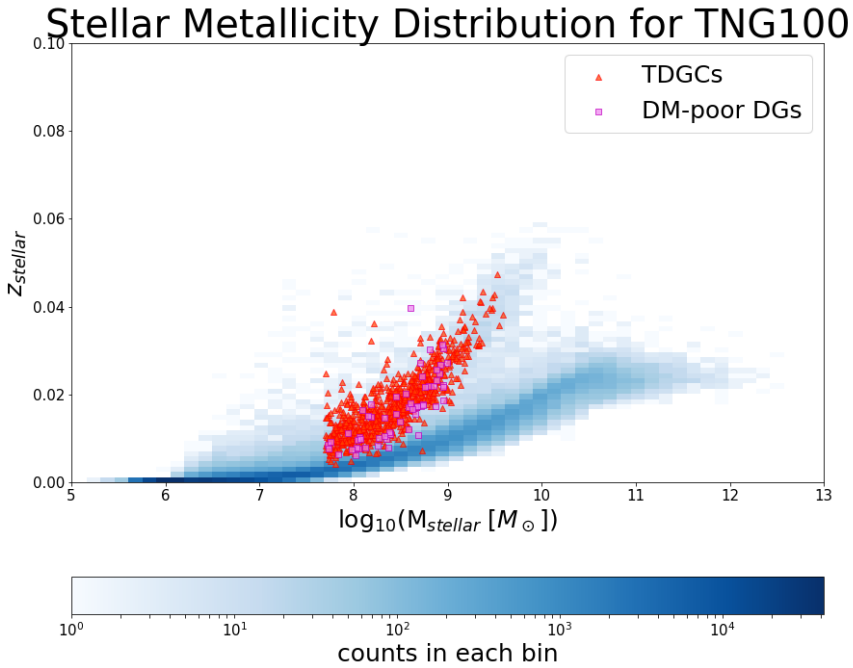
***Metallicity**: fraction of all elements heavier than He*

$$Z = \frac{M_{>He}}{M_{tot}}$$

DM Deficient Galaxies:

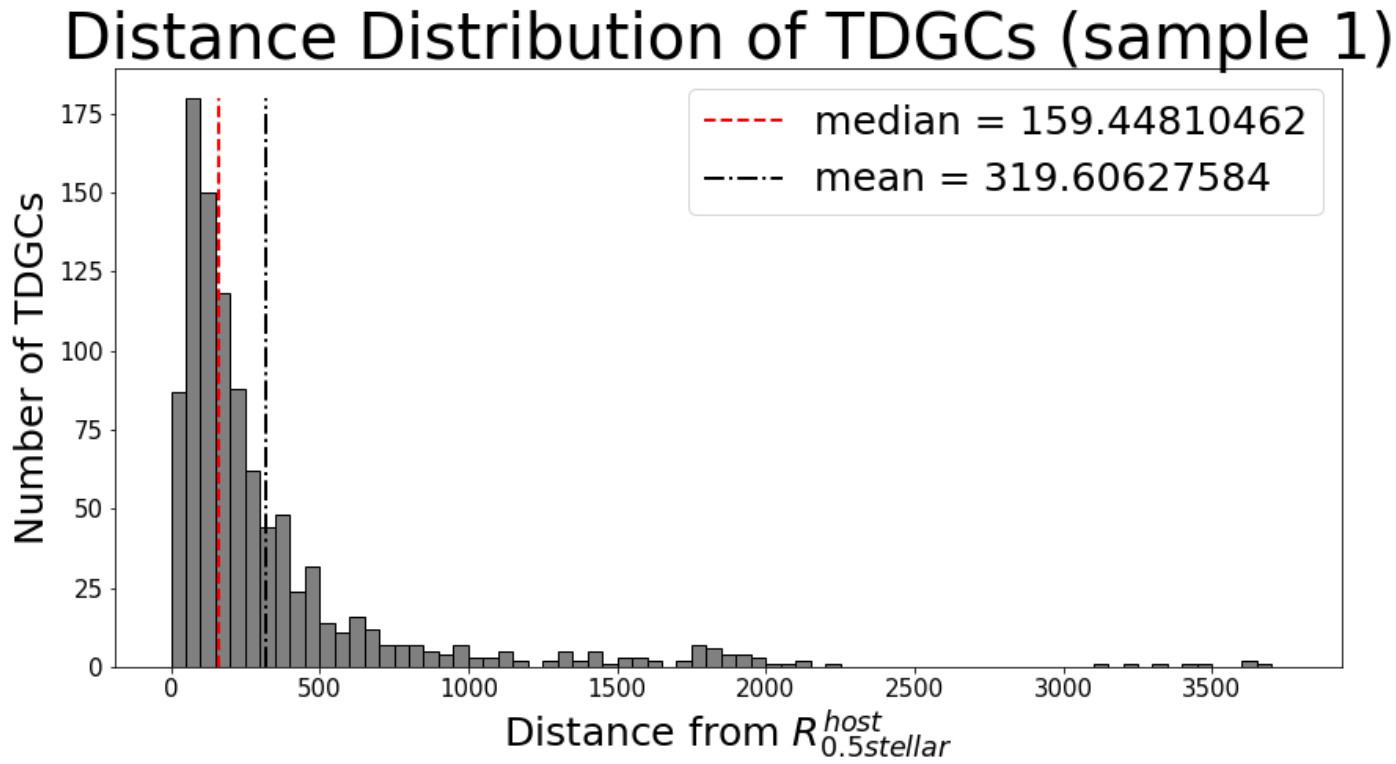
- Form from pre-existing galaxies, therefore already metal enriched
- Result: higher metallicity than normal





Distance Distribution

- Host galaxy:
  - Closest galaxy with the most mass
- Where do we expect DM-deficient galaxies in relation to the host?
  - Closer…



Summary

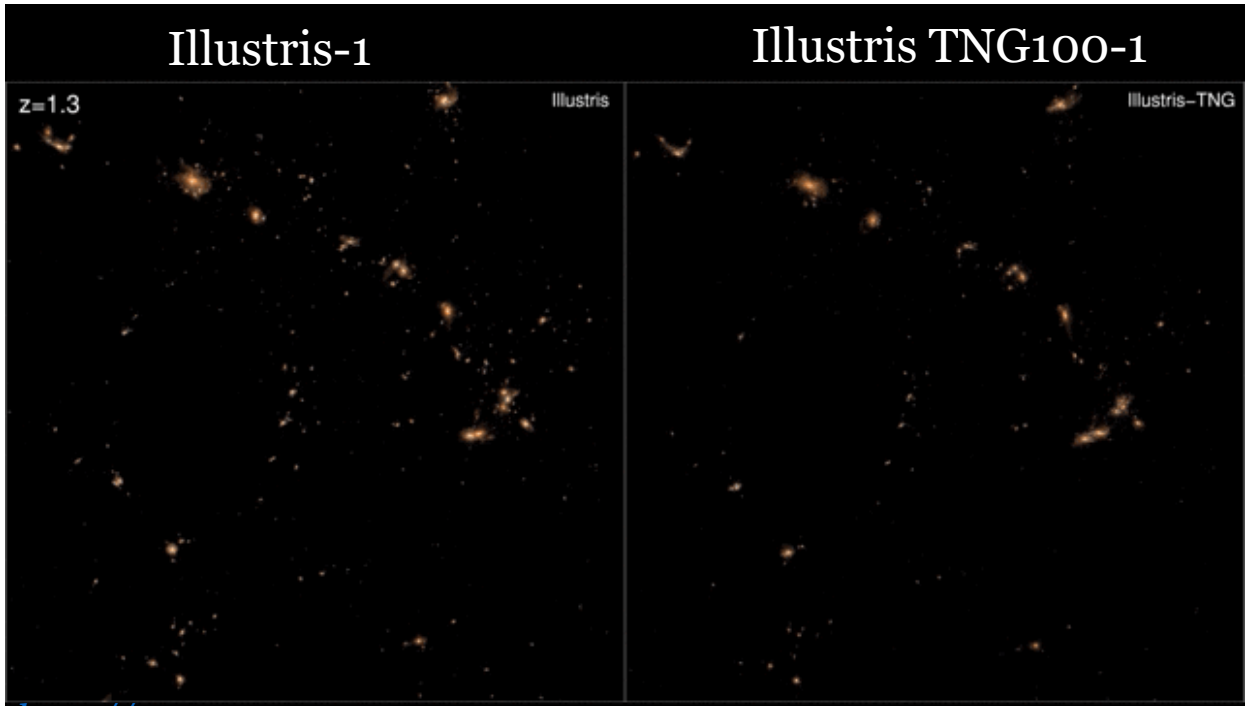
Goal: Identify galaxies in simulations with no dark matter

- Motivation: NGC1052-DF2
  - *How common are they?*
  - *How do they form?*
  - *Common properties?*

Moving Forward:

- Continue working on project
- Focus on histories of subhalos

Illustris vs. Illustris-TNG



http://www.tng-project.org/movies/tng/tng100_vs_illustris_sbo_stars_1080p.mp4

Stellar content from redshift z=1.3 to z=0 (z=0 corresponds to present day)

Acknowledgements

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The TNG Collaboration

And of course…

NSF Research Experiences For Undergraduates