# Metallicity Gradients of Simulated Dwarf Galaxies

Anahí Favela
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**My advisor**: Dr. Ferah Munshi
**In collaboration with**: Jordan Sligh & Jordan Van Nest

**Telescopes aren't my thing, but computers are!**

**We use computer simulations to study galaxy formation and evolution.**

# What is a N-body Simulation?

- Modeling a dynamical system of particles, usually under the influence of physical forces, in this case: **gravity**

- For us: stars & dark matter, acting under the influence of **gravity**, within a galaxy.

# What is an N-body + SPH Simulation?

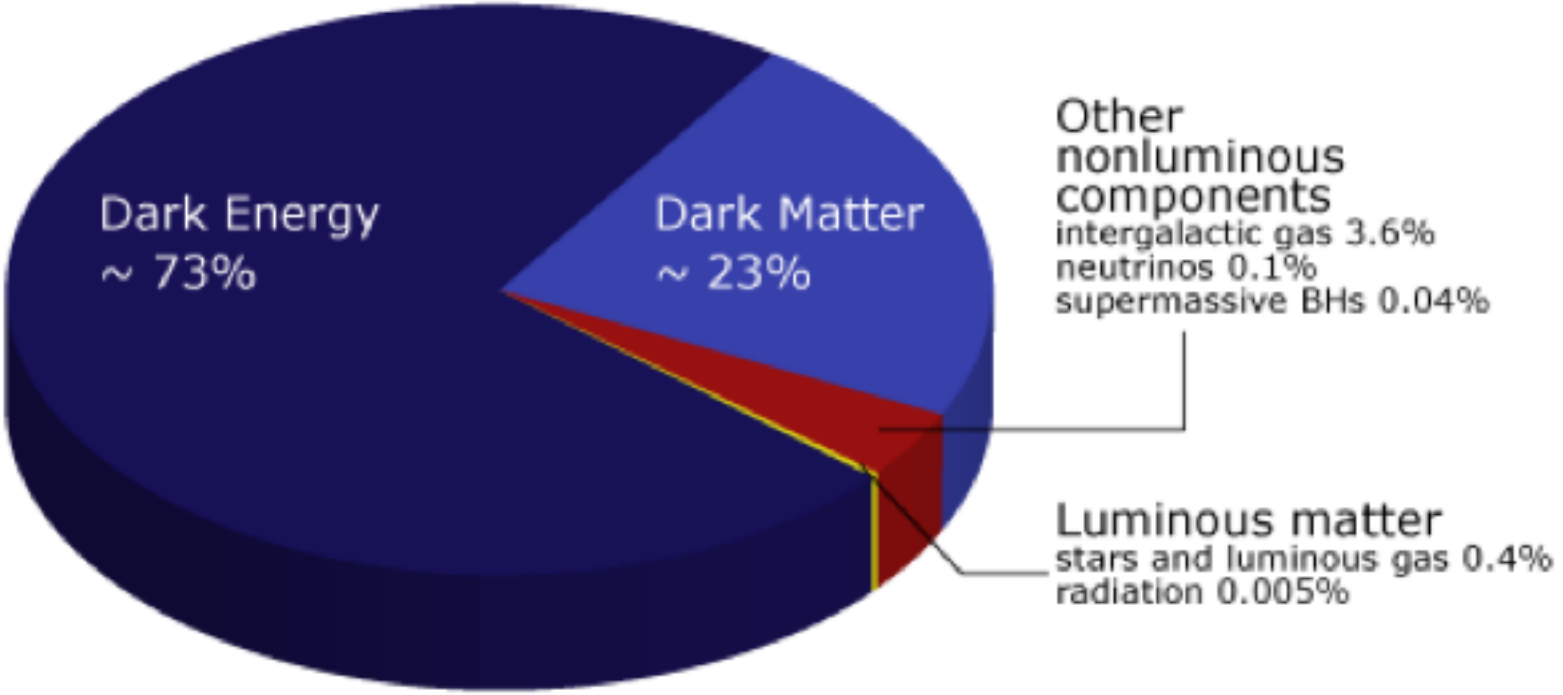
**SPH= "smoothed particle hydrodynamics"**

**Computational method used for simulating fluid flows—like gas**

**Gas is divided into a set of discrete elements, referred to as "particles"**

**"cosmological" = from early times all the way to present day**

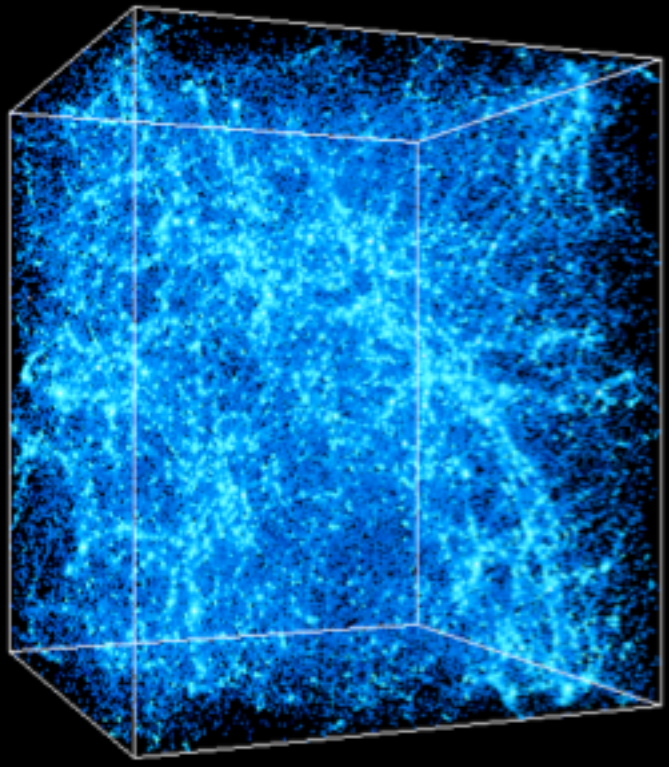
# The Universe




- **Radiation: light (photons)**
- **Baryonic matter (BM): "ordinary matter" like us and stars and galaxies**
- **Dark matter (DM): "exotic" non-baryonic matter (IDK)**
- **Dark energy: unknown form of matter that causes the expansion of the universe to accelerate.**

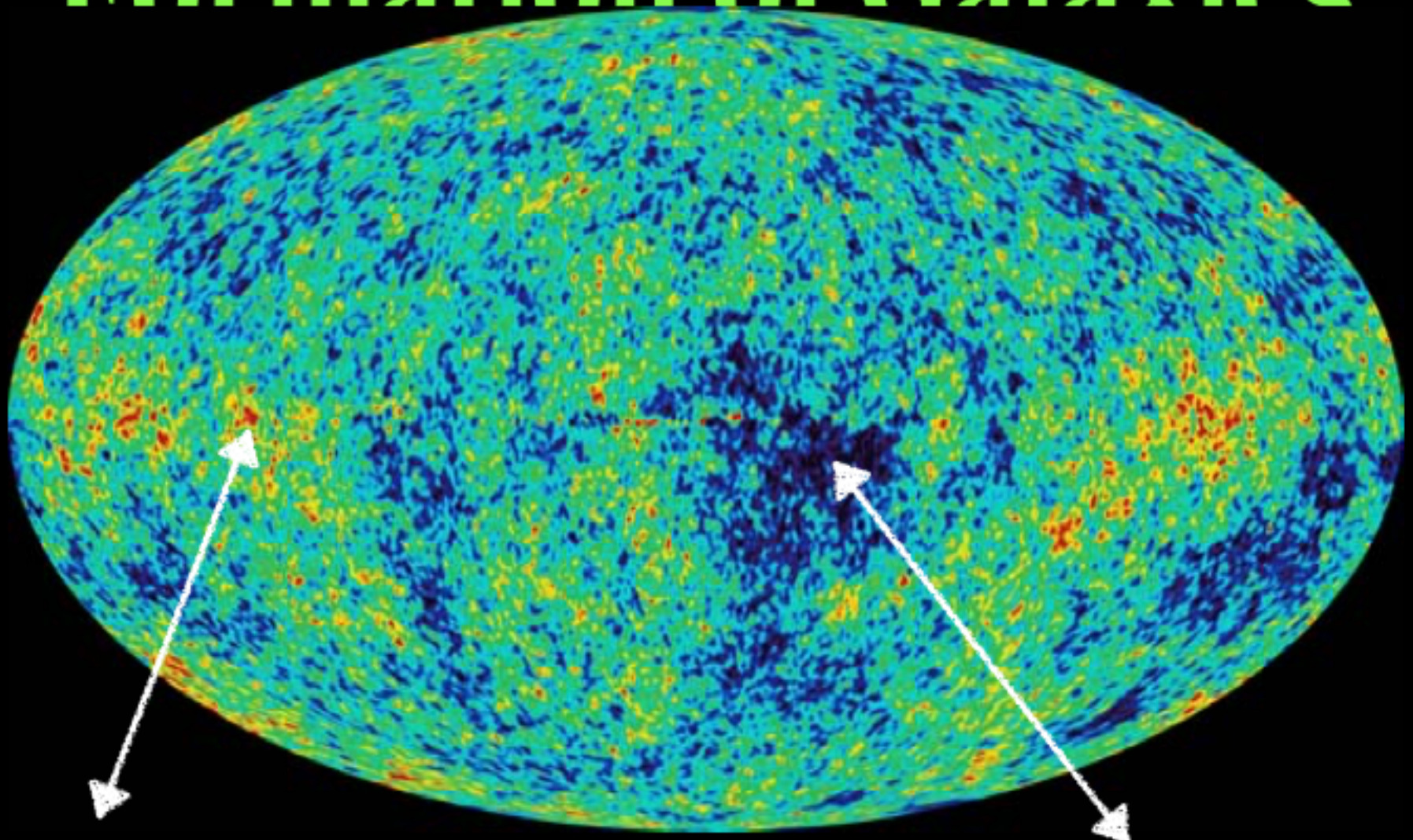
Dr. Ferah Munshi

# Dark Matter sets the structure



Ferah Munshi, UW N-Body Shop

# Formation of Galaxies



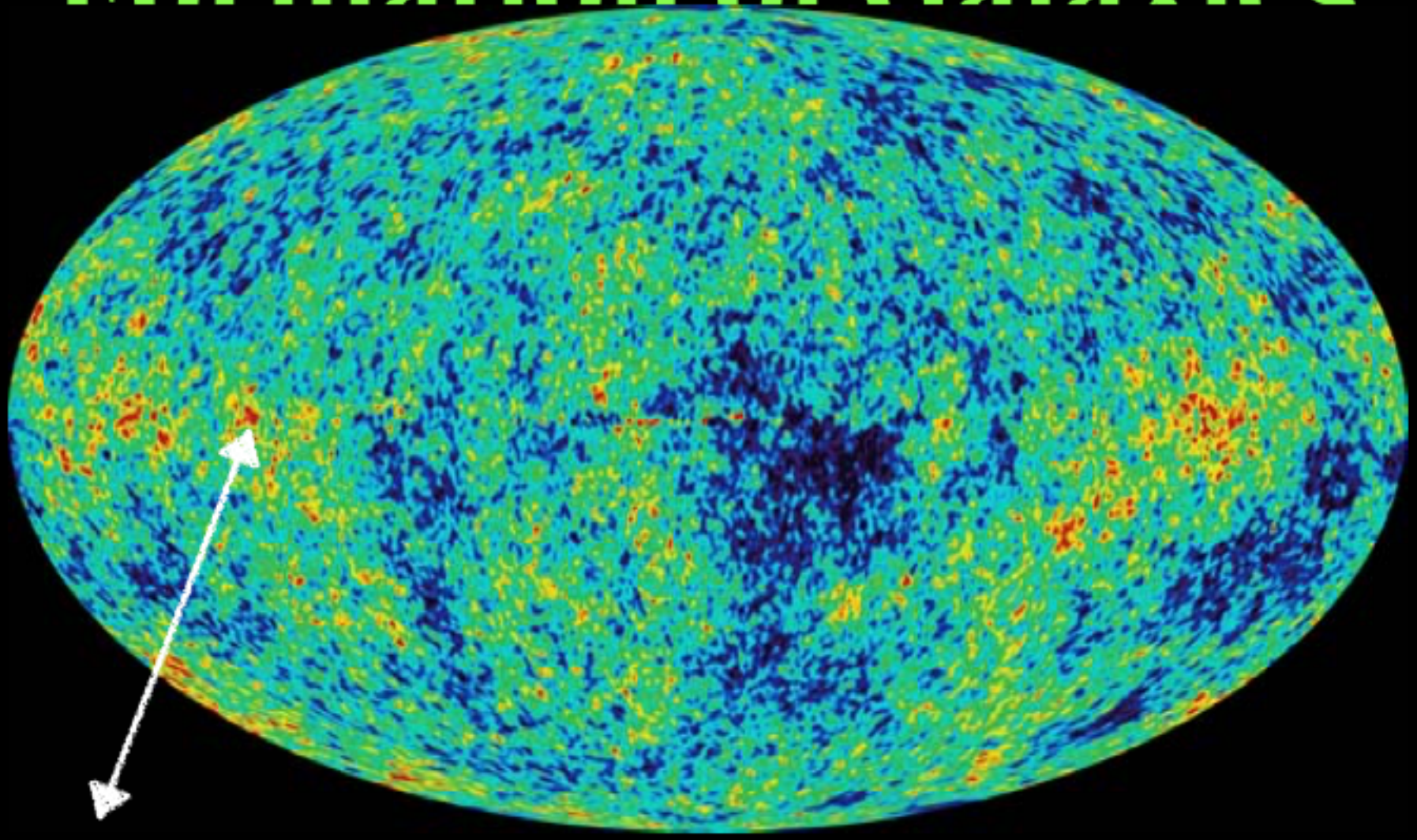
Overdense regions

Underdense regions

http://cosmology.berkeley.edu/Education/CosmologyEssays/The_Cosmic_Microwave_Background.html

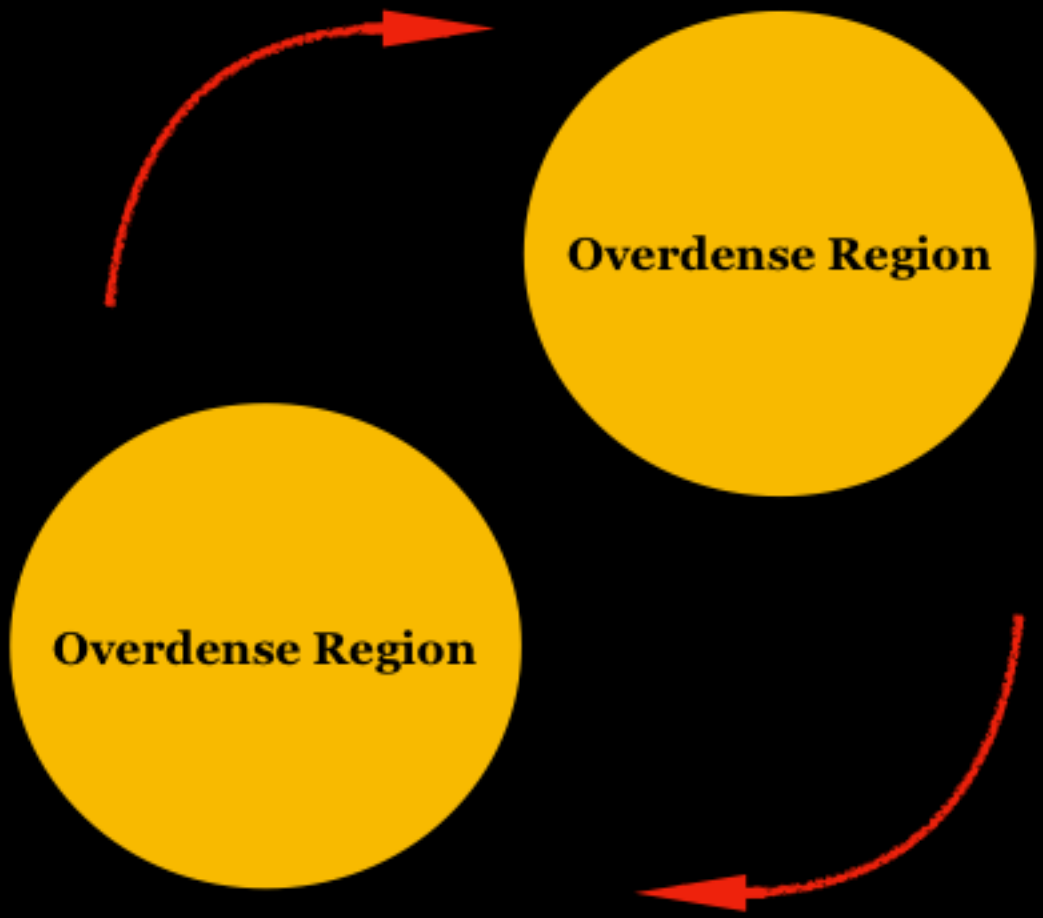
Formation of Galaxies

# Formation of Galaxies

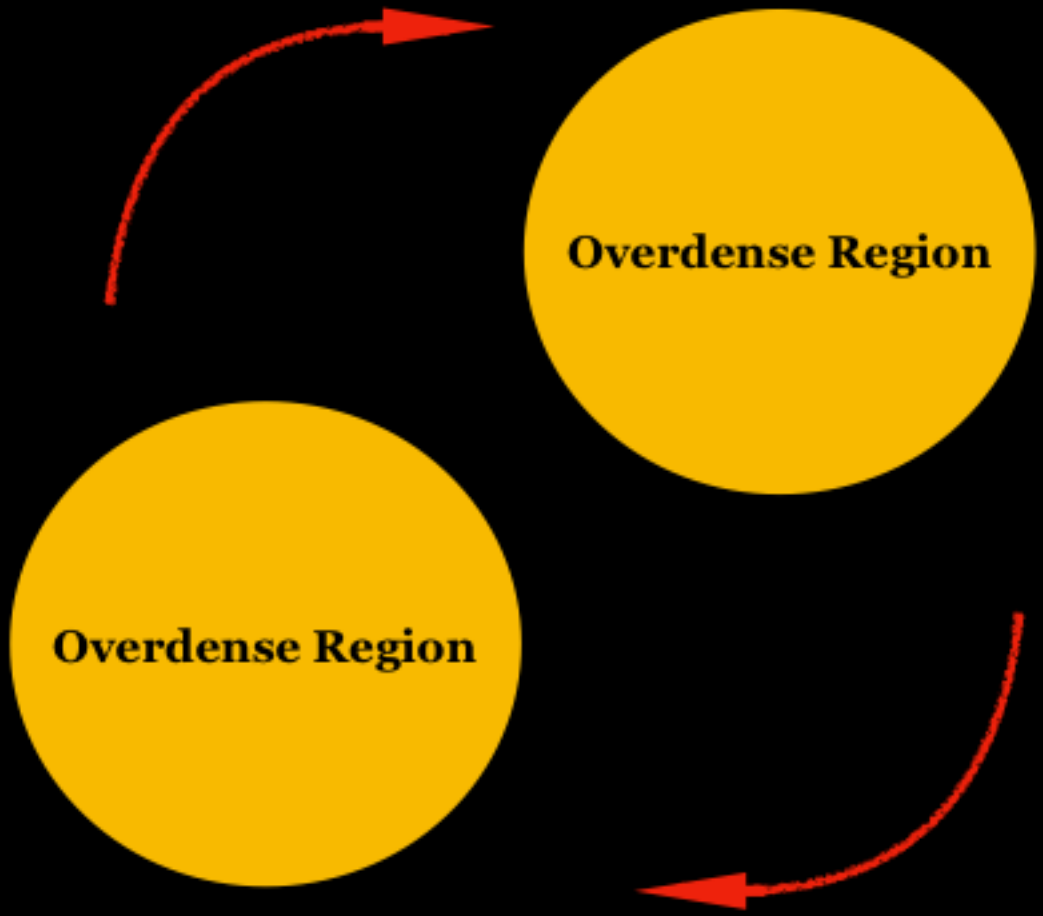


**Overdense regions** → **Gravity starts to do its thing** → **Overdense regions begin to collapse**

http://cosmology.berkeley.edu/Education/CosmologyEssays/The_Cosmic_Microwave_Background.html

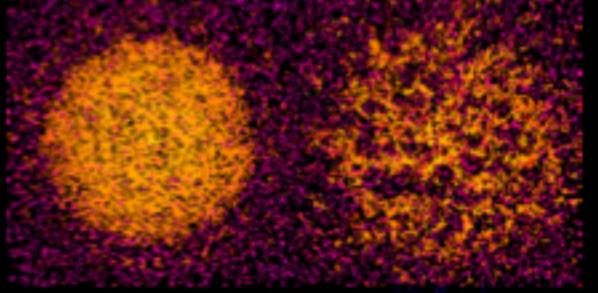


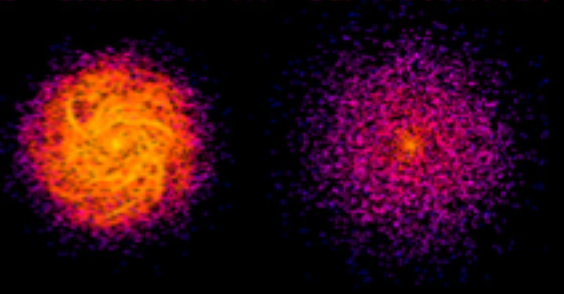

Gravity makes the collapsing overdensities exert a force on each other (torque) and makes them rotate with each other

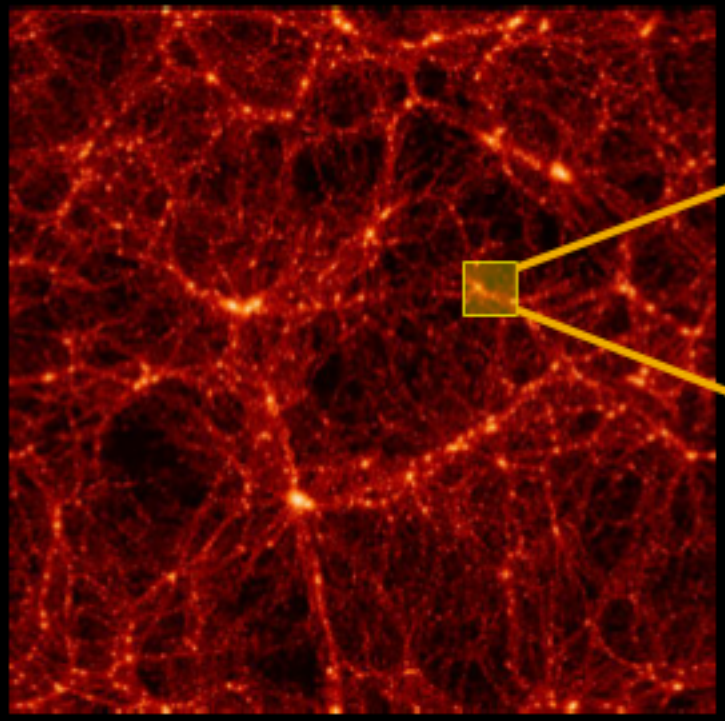



DM and BM continue to collapse until DM reaches virialization (DM no longer loses energy and it stops collapsing)

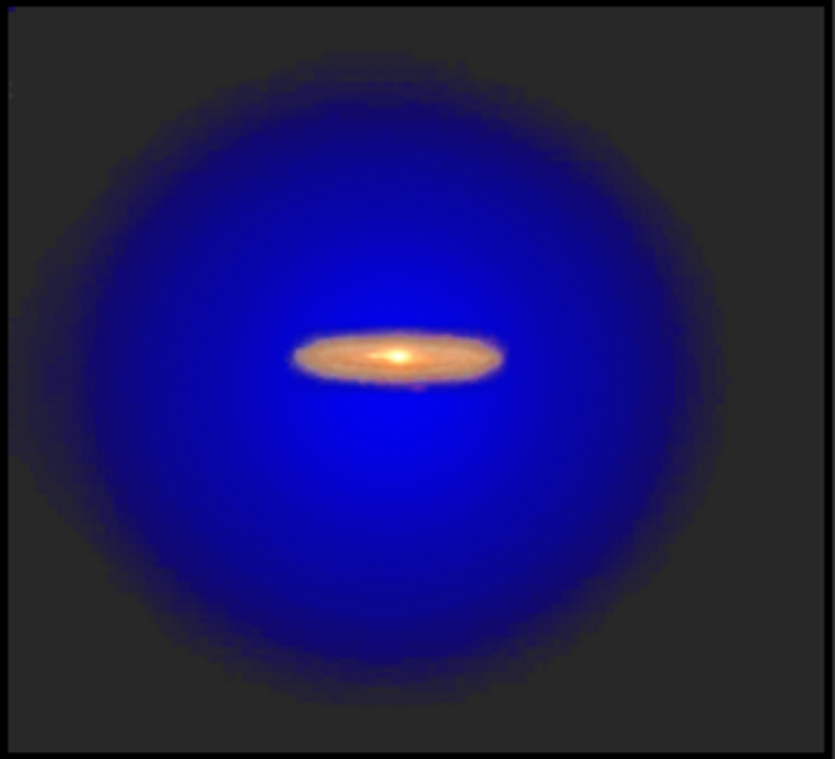
The gaseous disk is shown on top and the stellar disk is shown at the bottom.







http://ned.ipac.caltech.edu/level5/March08/Mayer/Mayer4.html



Dr. Ferah Munshi

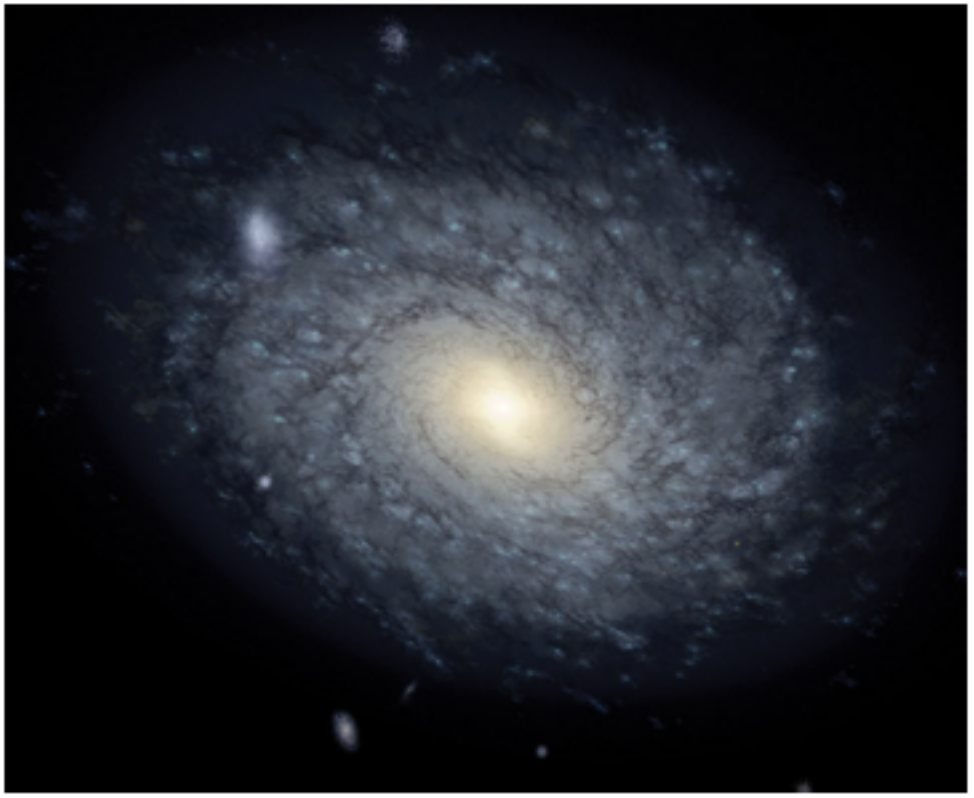
Fundamental question: What does the metallicity gradient look like in dwarf galaxies?

Galaxies are composed of **stars**, **gas** and **dark matter**, all held together by gravity.

https://www.space.com/15680-galaxies.html

# What is a **DWARF** galaxy?

Dwarf galaxies are galaxies ***smaller*** than the Milky Way.



Dwarf Galaxy Size Comparison Chart

4
Dwarf
Volumes

STORM

ROGUE

**64 total resolved dwarfs!**

Dwarf galaxies were expected to show a ***decrease*** in metallicity as radius increased.

*El-Badry et al 2016*

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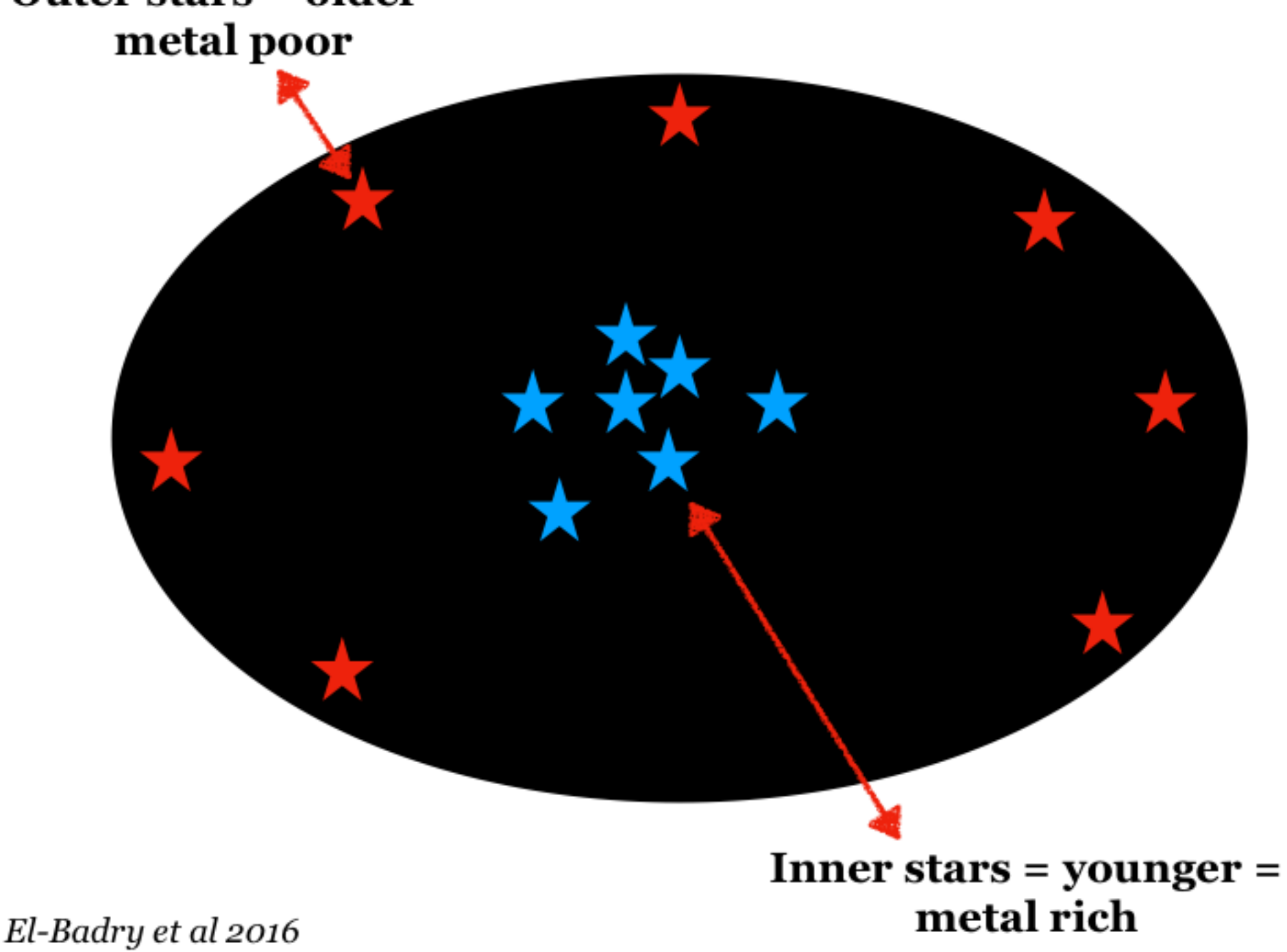
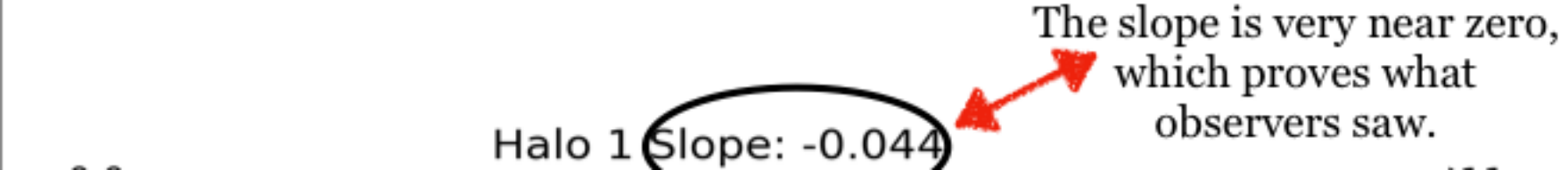
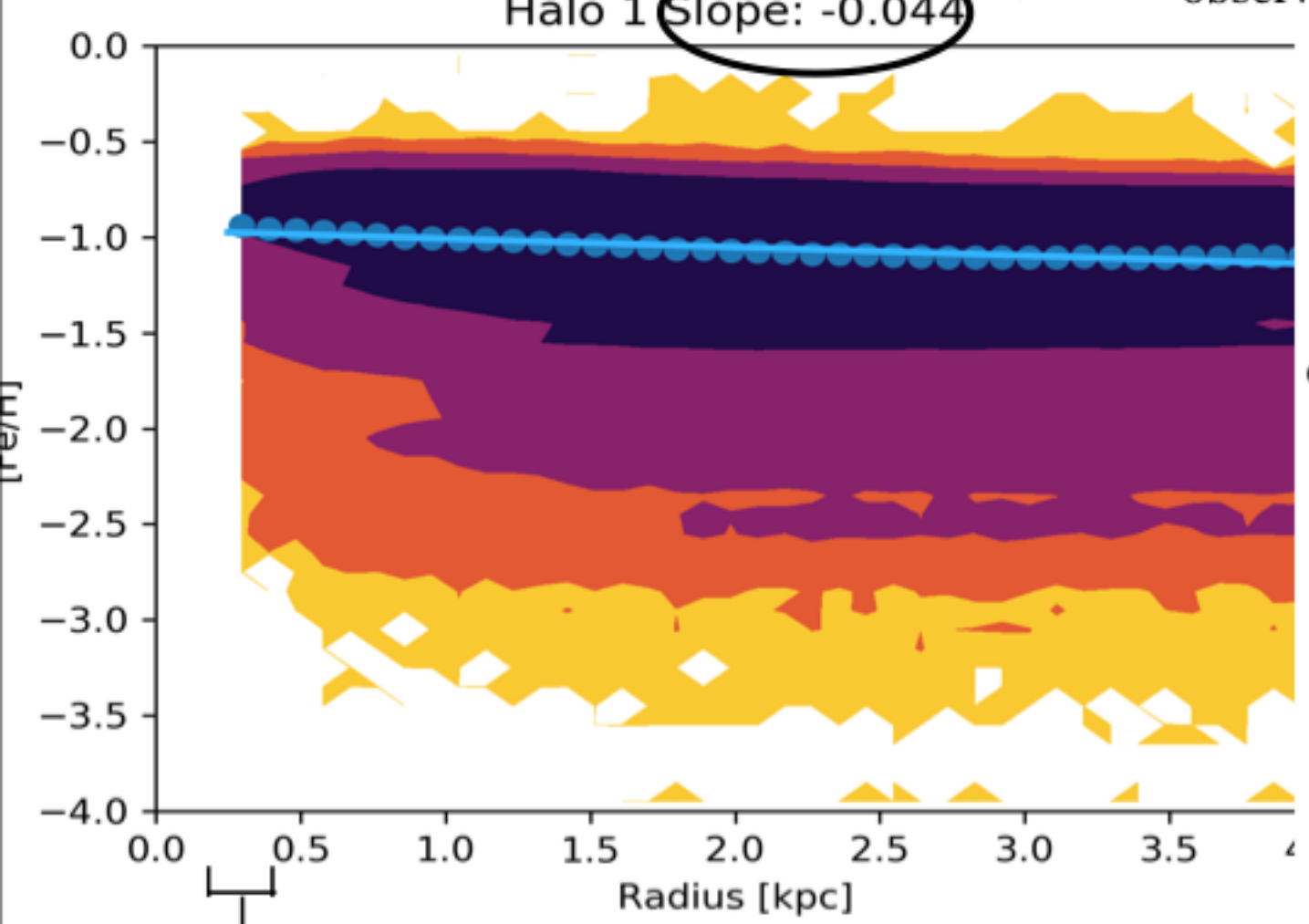
**Outer stars = older =**




*El-Badry et al 2016*

Observers actually saw that metallicity was ***constant*** throughout the dwarf galaxies.



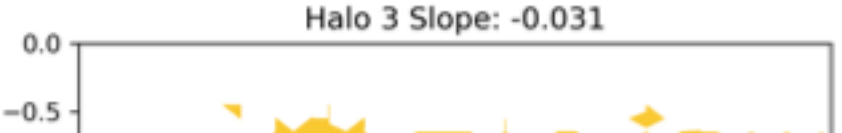


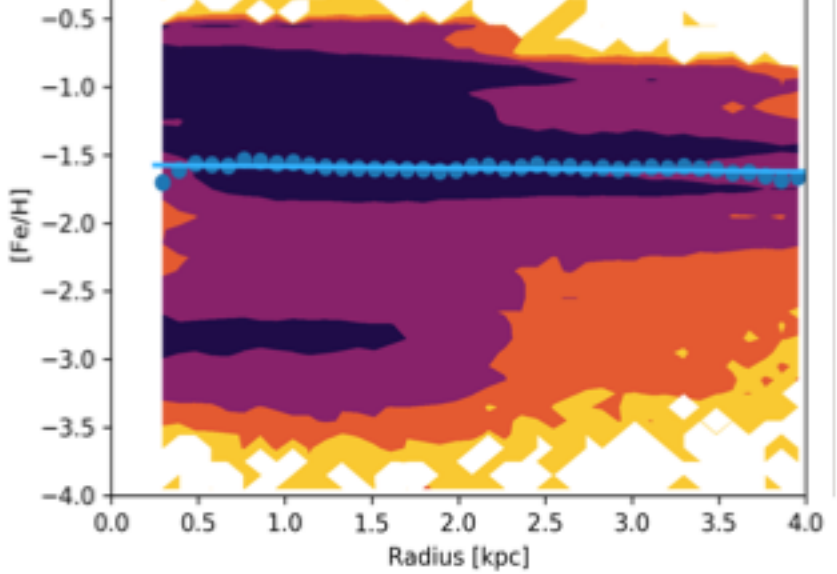

Different colors show a high density of points (darker) to low density of points (lighter)

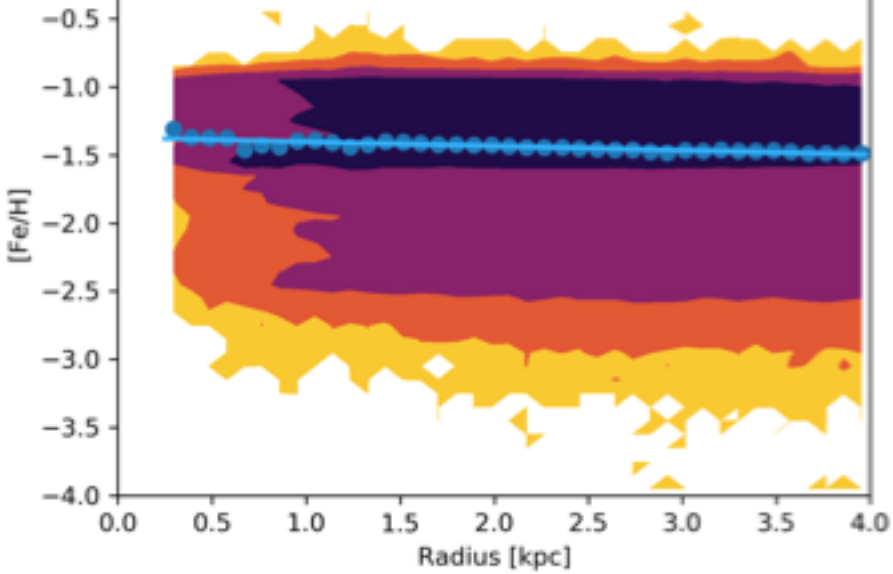
0.0 kpc - 0.25 kpc were neglected
The frame was set from 0.25 kpc to 4.0 kpc

Physics do not act right within that distance, anything within this range is untrustworthy.

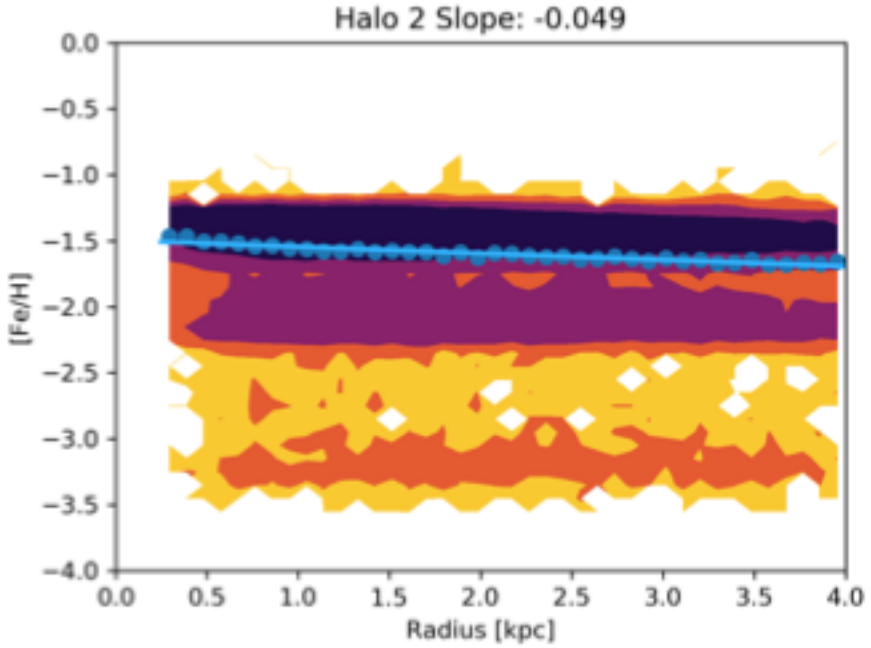
*Leaman et al 2013*




**Rogue**




**Captain Marvel**

# Stellar Age & Its Relation

# Stellar Age & Its Relation to Metallicity

- Mean age of stellar population is younger toward the center of the galaxy.
- Older stellar populations are more spatially extended than younger ones.

*Hidalgo et al 2013*

# Conclusions

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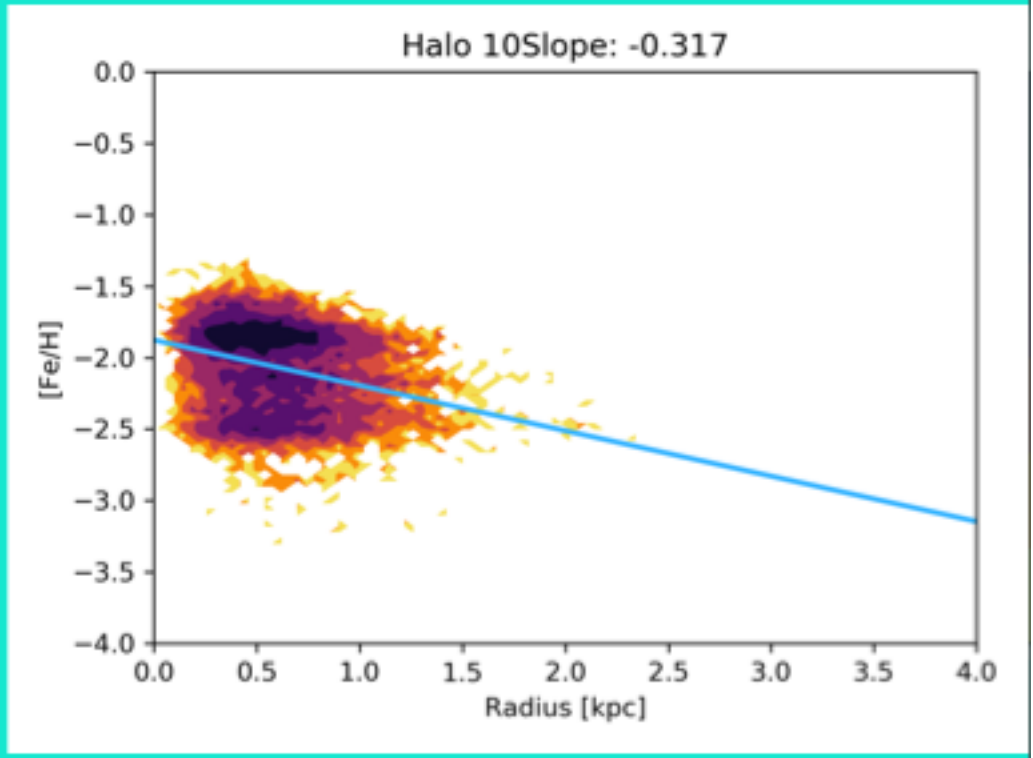
- Our simulations show that the ***observed*** metallicity gradients are flat in galaxies that are the mass of the Large Megallanic Cloud (LMC) and SMC

- The smaller mass halos have steeper slopes.

- Prediction: Something is going on at bigger masses that make the metallicity gradient become constant rather than decreasing.




**Captain Marvel**

# Special Thanks

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REU Program

# ¡Gracias!

**¿Alguna pregunta?**