

Northwestern



Learning about galaxies and the cosmic web with computer simulations

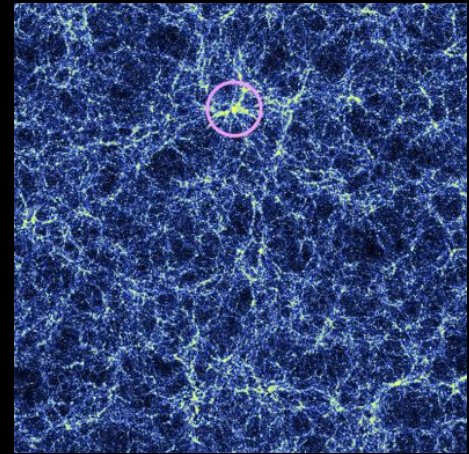
Imran Sultan

Highlights of Astronomy
December 7, 2021

Cosmology: the study of our universe as a whole

How was the Universe formed?

What does the Universe look like?



Earthrise
NASA (Apollo 8)



250,000 miles
1.3 light seconds



Mercury
Venus

Earth

Mars

Jupiter

Saturn

Uranus

Neptune



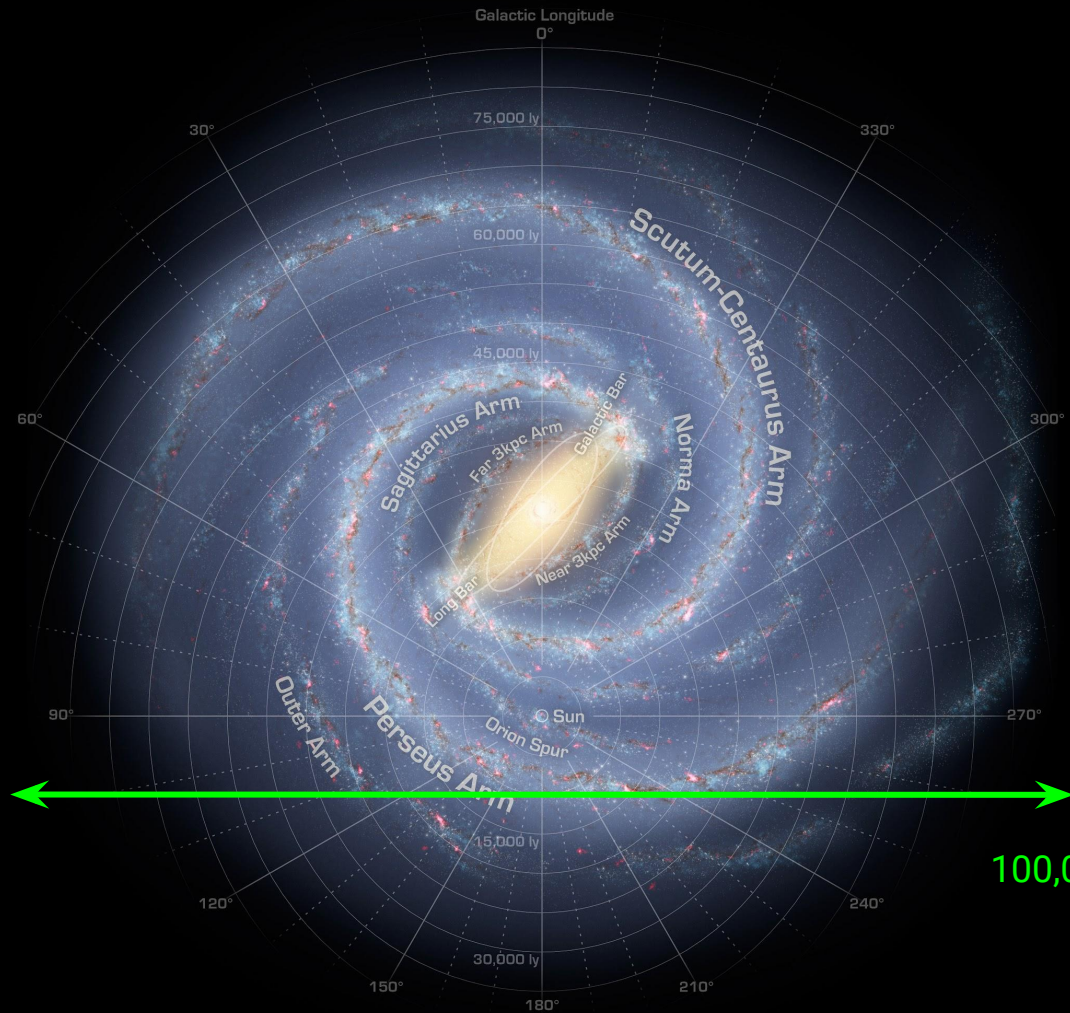
3 billion miles
4 light hours

Solar System
Wikipedia

Pale Blue Dot Revisited
NASA (Voyager 1)



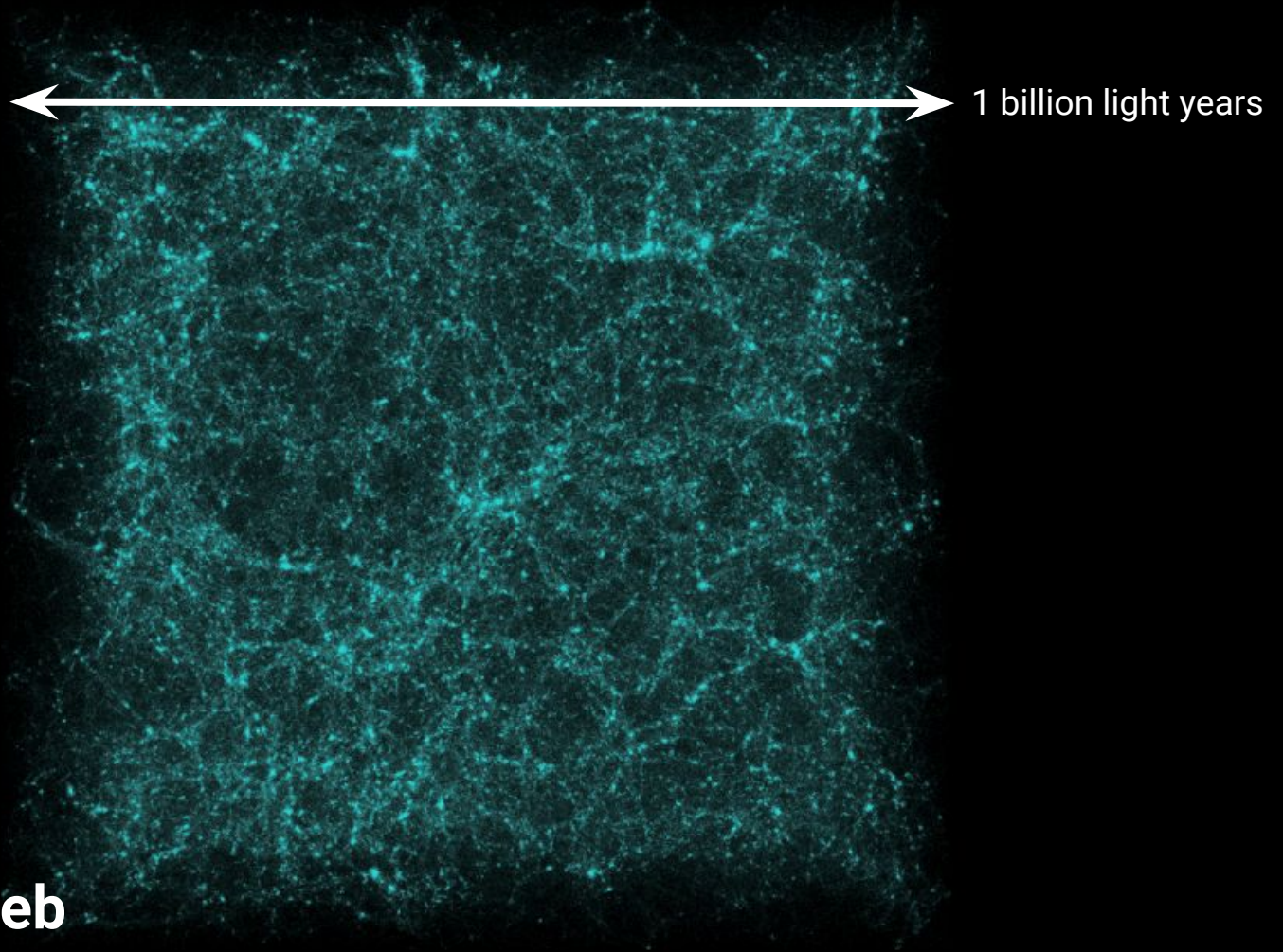
4 billion miles
5.6 light hours



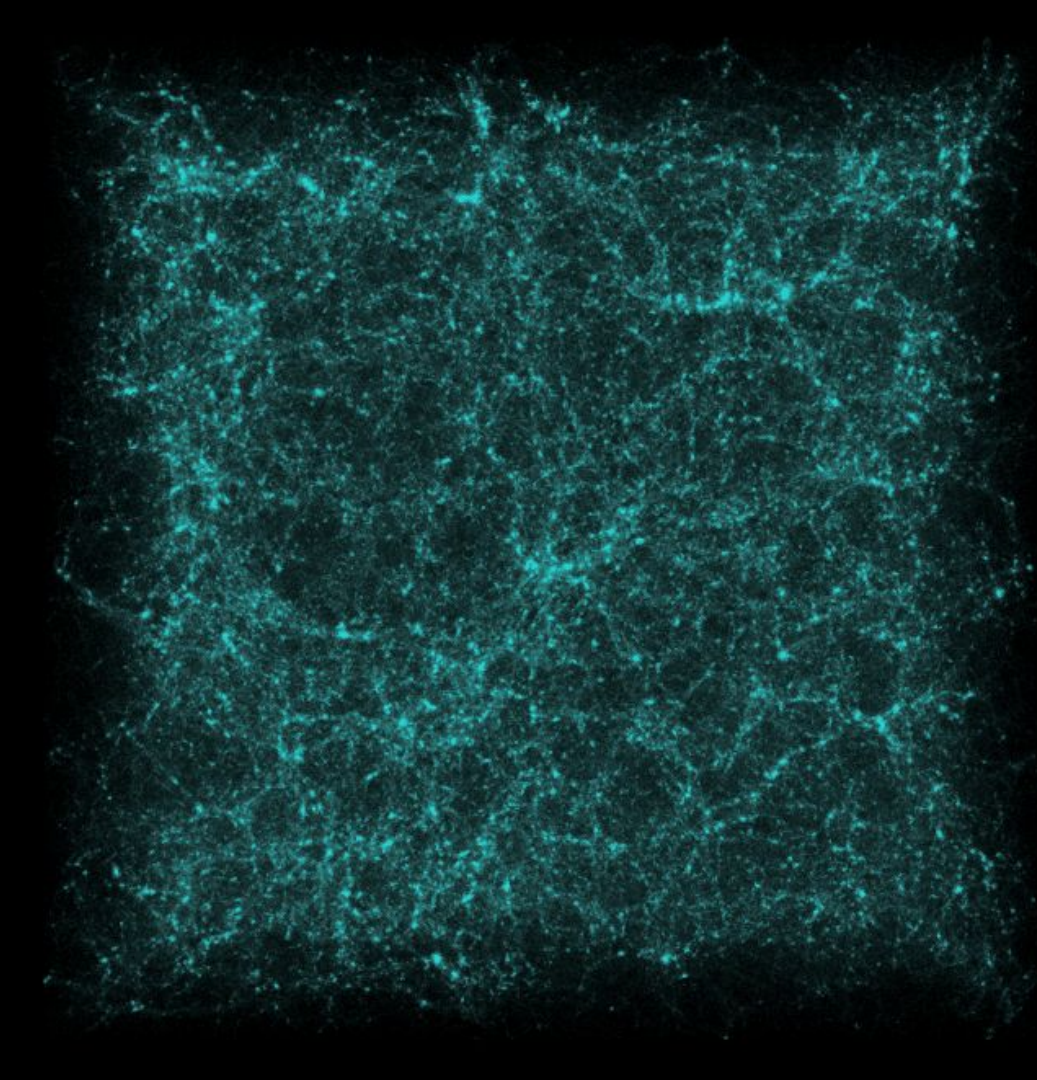
100,000 light years

Milky Way galaxy

NASA/JPL-Caltech/R. Hurt (SSC/Caltech)



The Cosmic Web



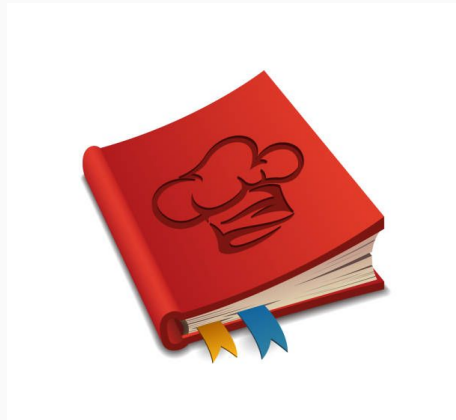
Dark matter: invisible matter that makes up 85% of all the matter in our universe

How do we learn about the cosmic web? Computer Simulations



ingredients

+



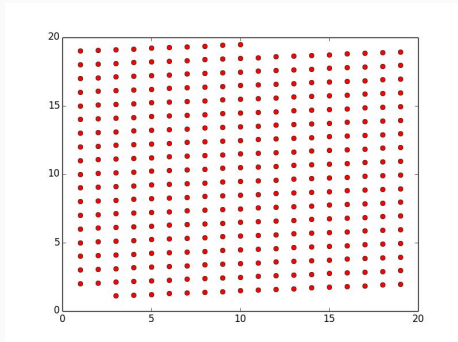
recipe

=



How do we learn about the cosmic web? Computer Simulations

Dark matter particles

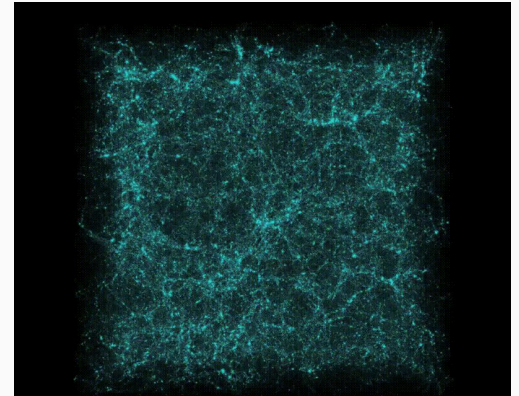


ingredients

Physics

$$+ \quad F_g = \frac{G M_1 M_2}{R^2} \quad =$$

recipe



$z = 142.57$

$z = 3.90$

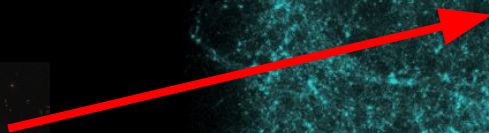
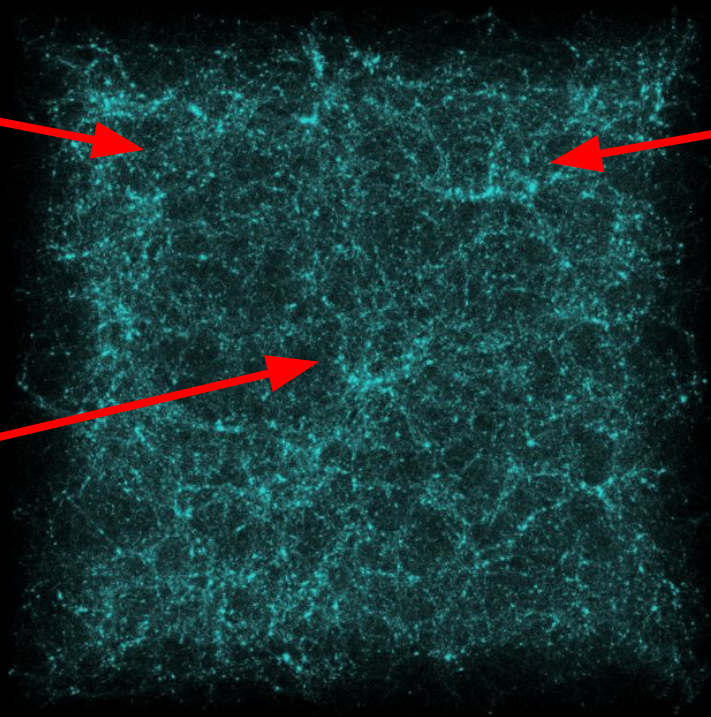
$z = 1.48$

$z = 0.66$

$z = 0.25$

$z = 0.00$

Halos: dense areas of dark matter in which galaxies form



How do we learn about how galaxies form? Computer Simulations

- Dark matter
- Stars
- Gas
- Black holes

ingredients

+

Physics

$$F_g = \frac{G M_1 M_2}{R^2}$$

$$R_s = \frac{2GM}{c^2}$$

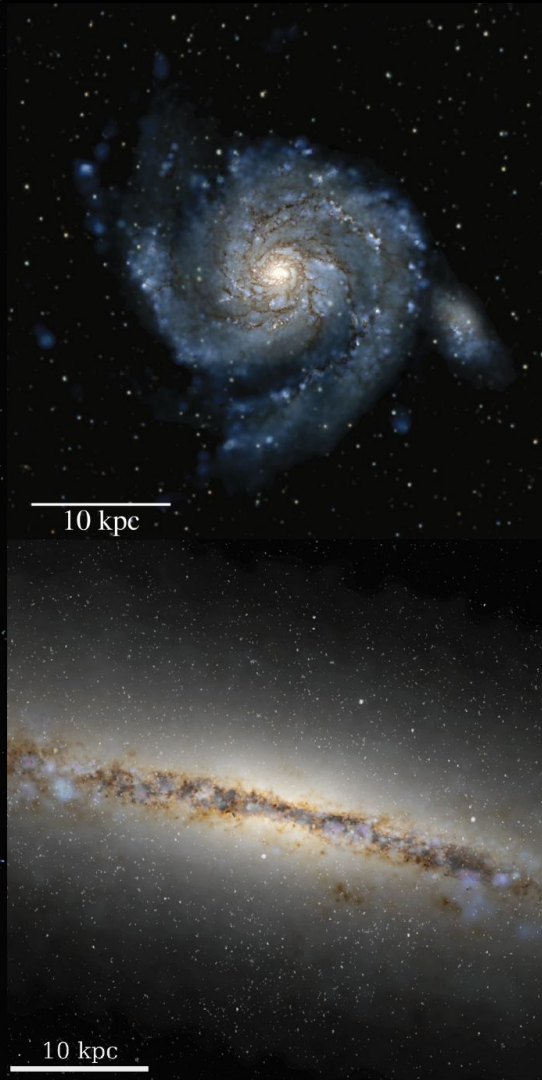
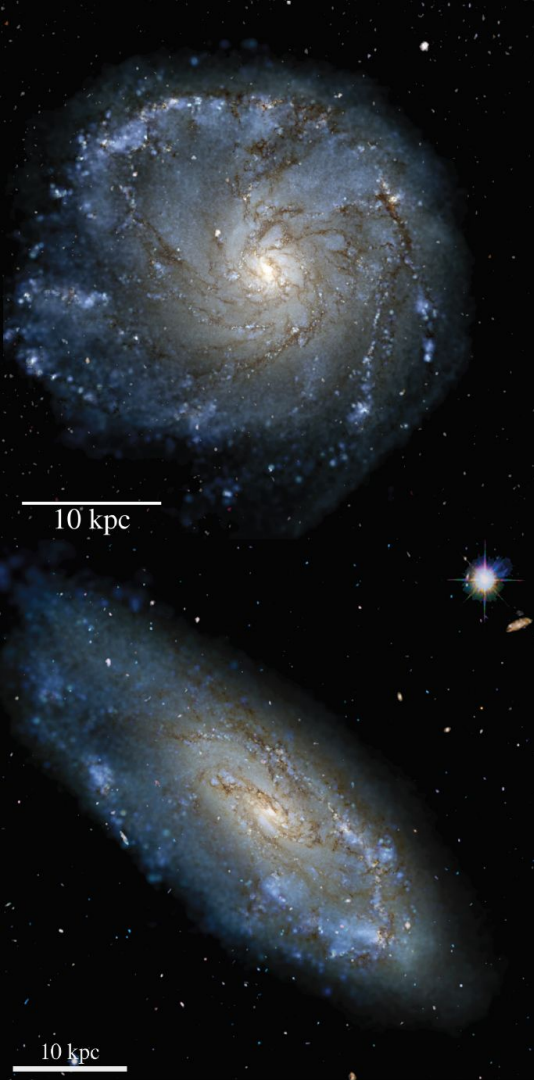
$$\rho = \frac{M}{V}$$

=

recipe



Phil Hopkins



Why do galaxies stop forming new stars once their mass becomes larger than a certain mass?

How do supermassive black holes affect galaxies?



Thanks!

Questions?

[https://en.wikipedia.org/wiki/Lunar_distance_\(astronomy\)](https://en.wikipedia.org/wiki/Lunar_distance_(astronomy))
<https://climate.nasa.gov/news/2206/earth-from-space-15-amazing-things-in-15-years/>
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<https://solarsystem.nasa.gov/resources/285/the-milky-way-galaxy/>
https://en.wikipedia.org/wiki/Milky_Way
https://en.wikipedia.org/wiki/Dark_matter
<https://frugalfamilyhome.com/food/recipes/frugal-homemade-bread-recipe>
<https://media.istockphoto.com>
<https://stackoverflow.com/questions/28144084/many-particles-in-box-physics-simulation>