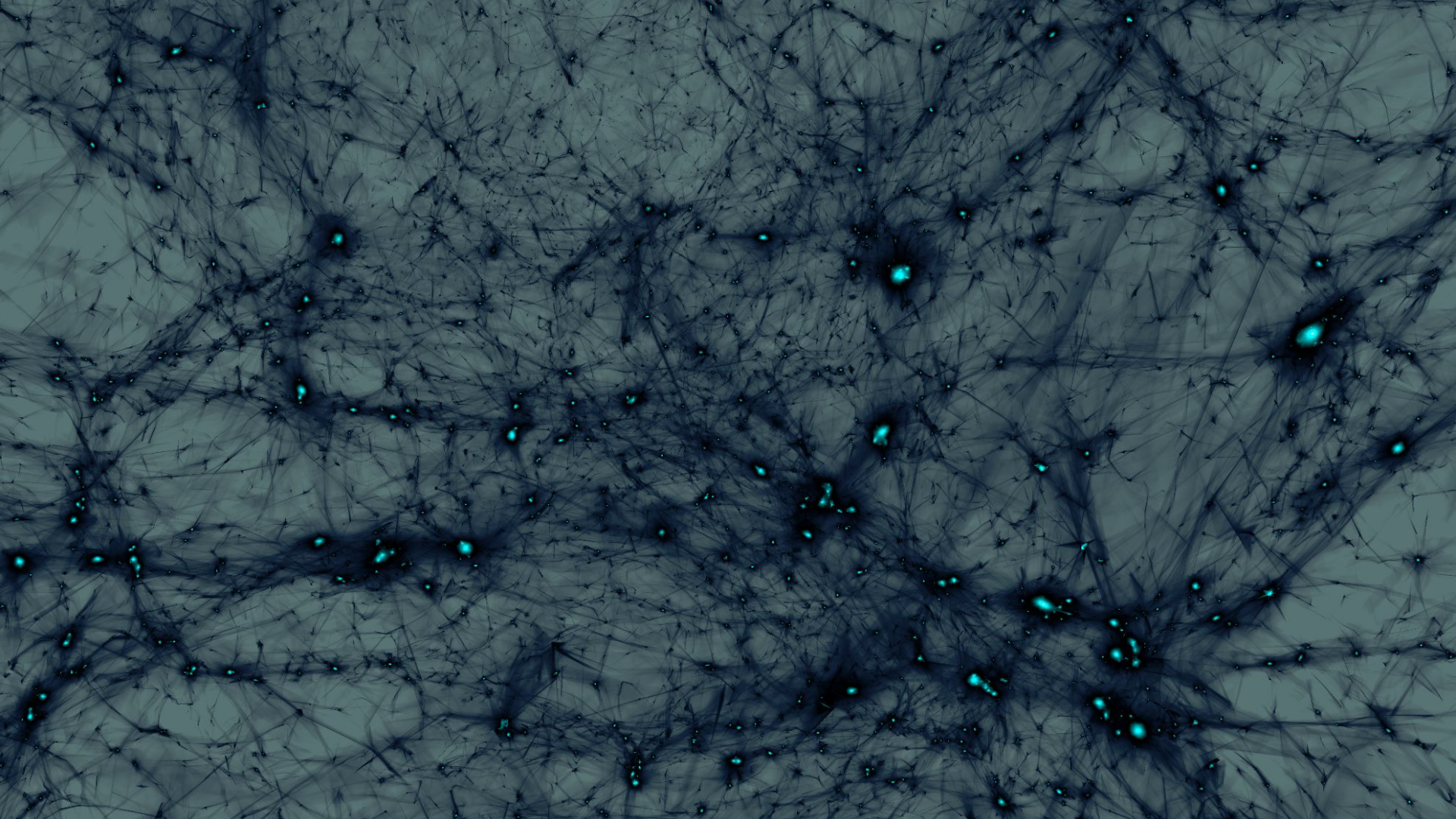
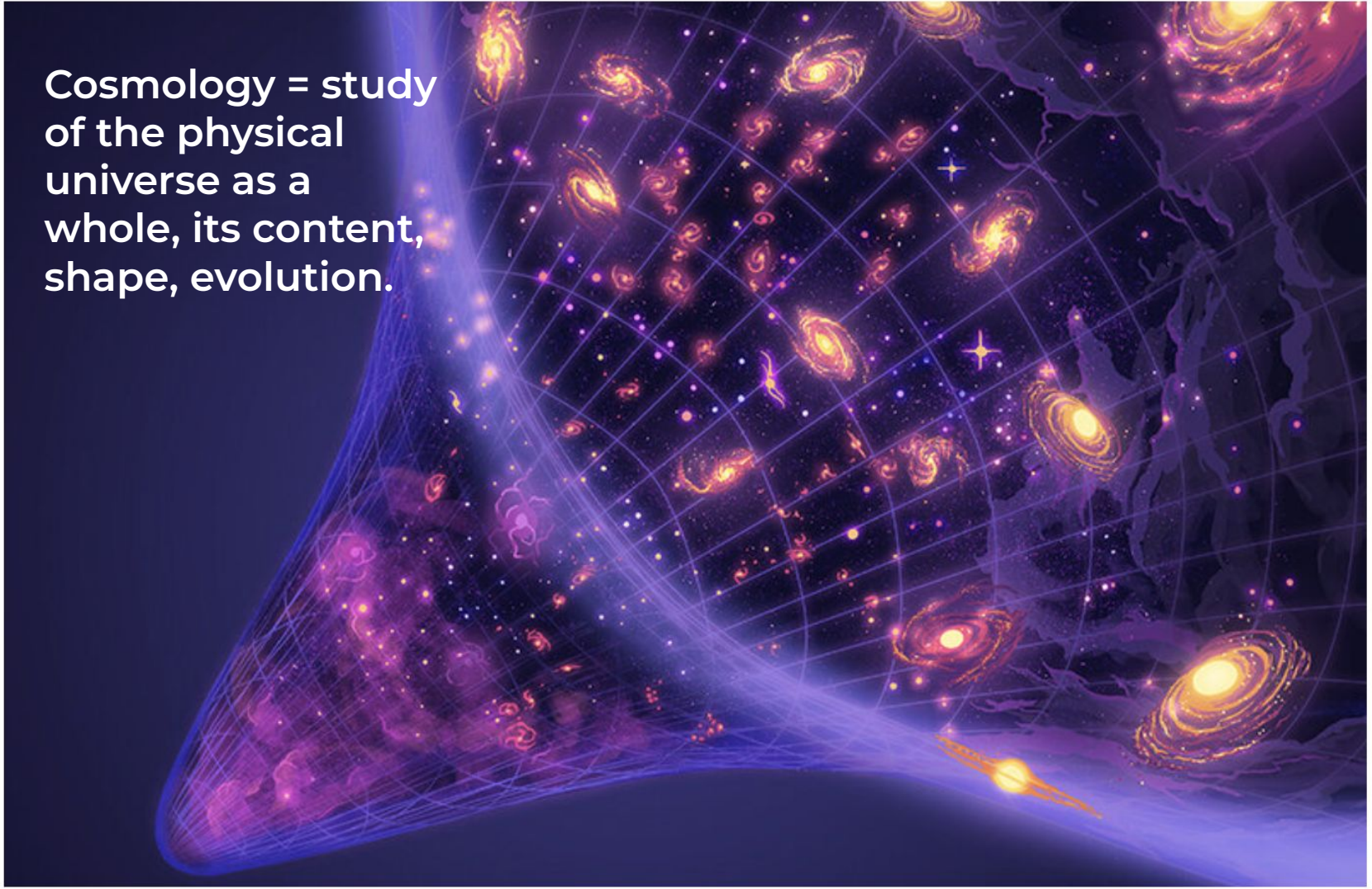
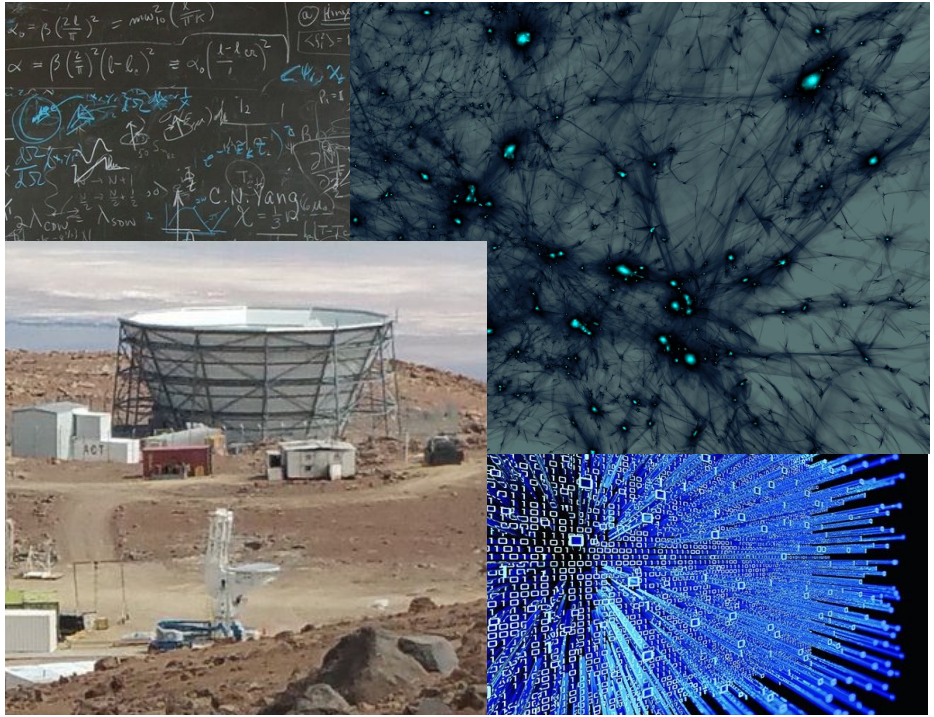
Cosmolab Open House 2022




Cosmology = study of the physical universe as a whole, its content, shape, evolution.

What we really do @ USC

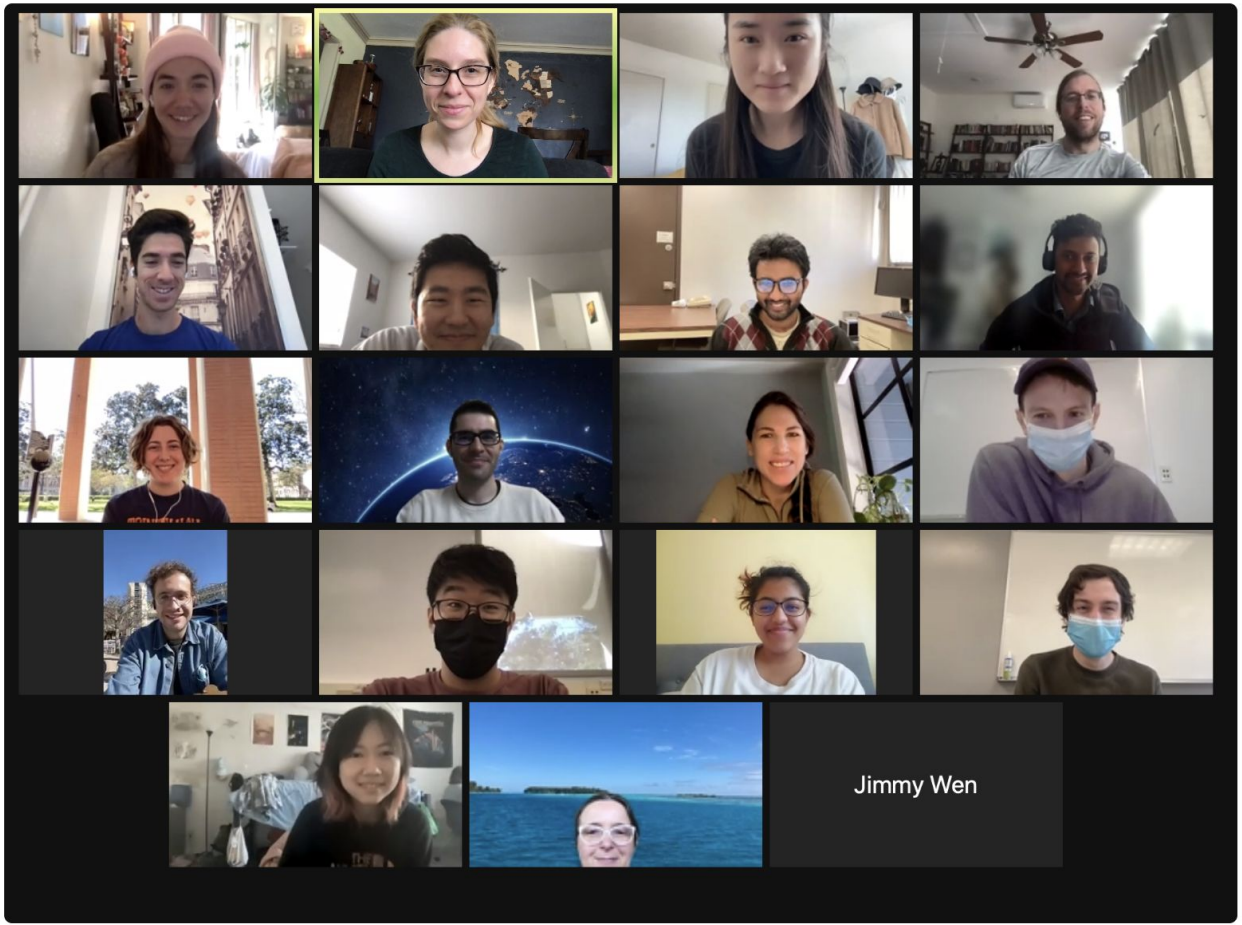


- Paper and pen
- Programming

Computer simulations

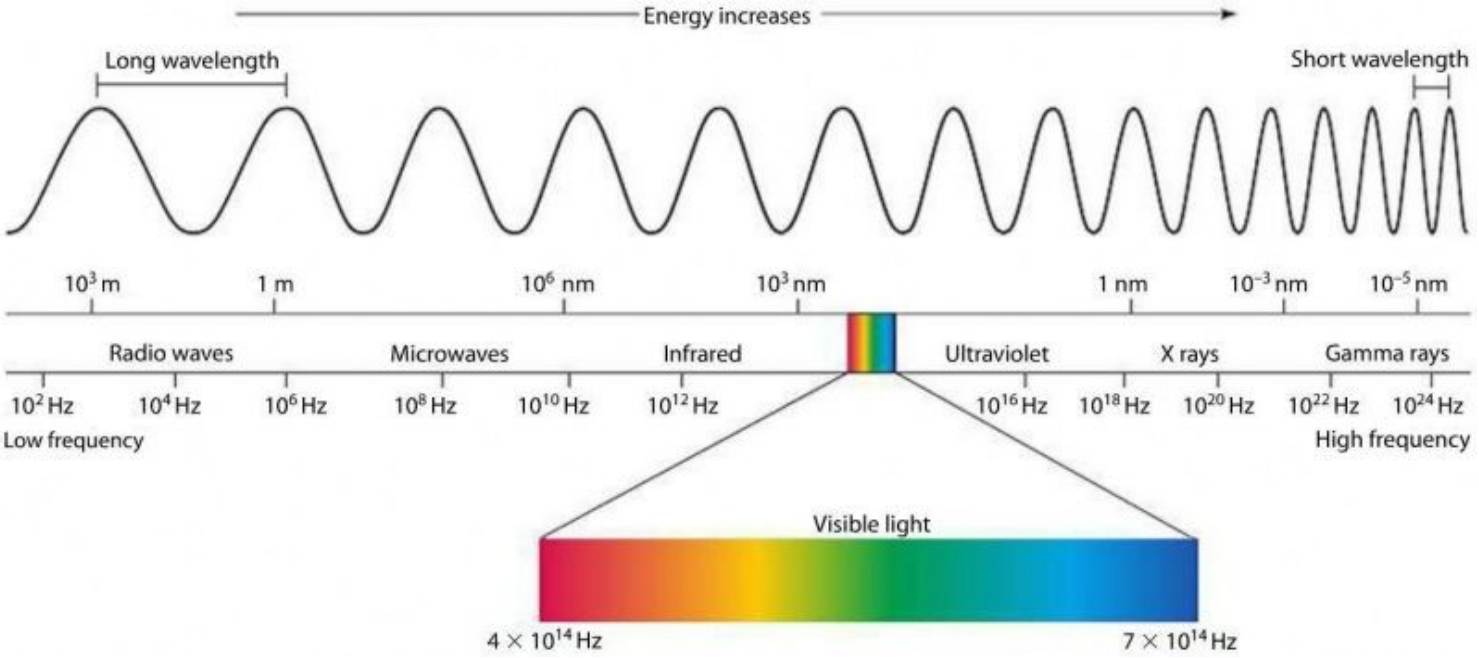
- Statistics and data analysis
- Instrumentation

The team (last year)

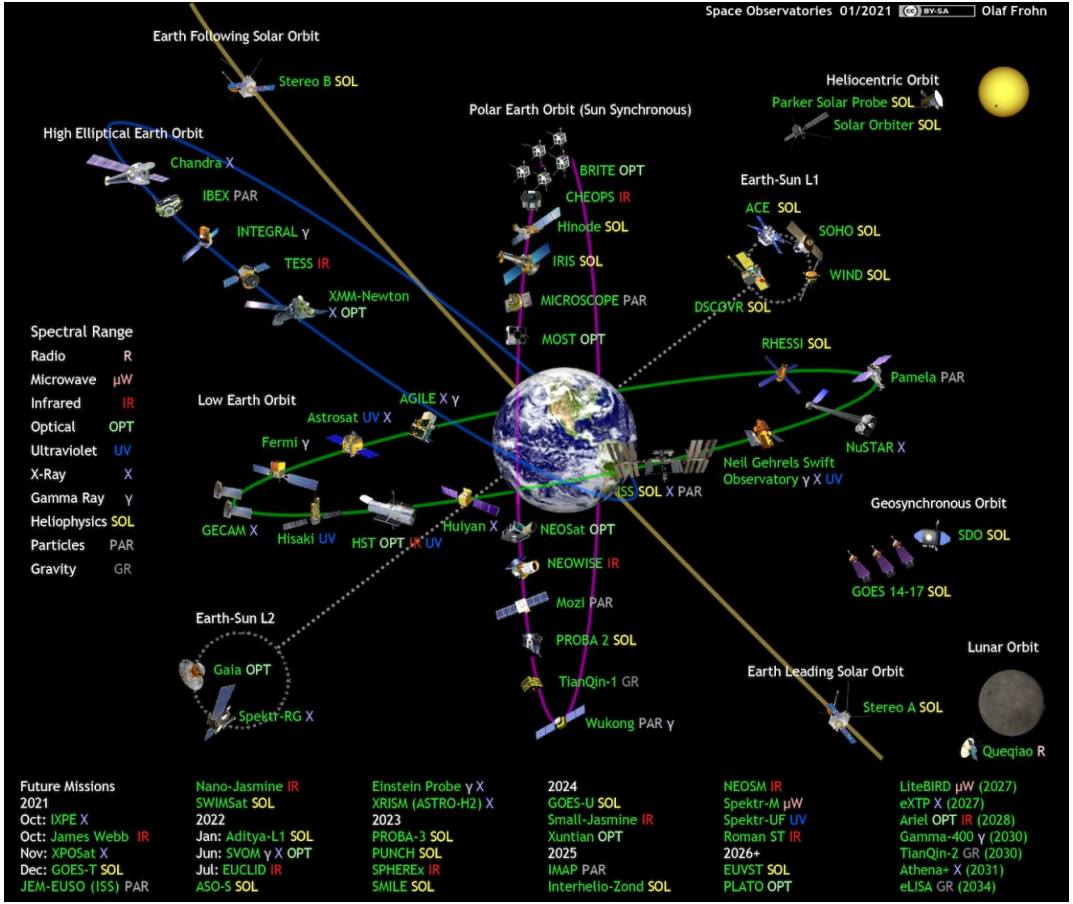


New ways of seeing our Universe

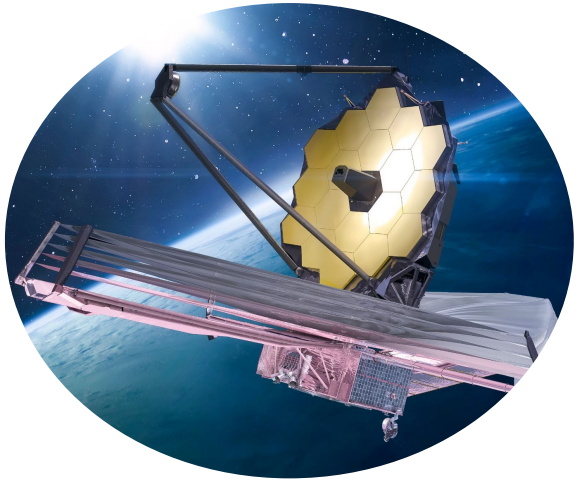
The Electromagnetic Spectrum



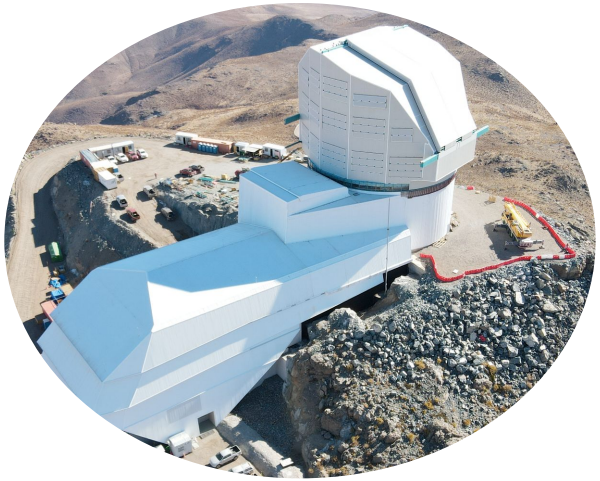
Many current and upcoming telescopes



Three particularly exciting observatories



JWST

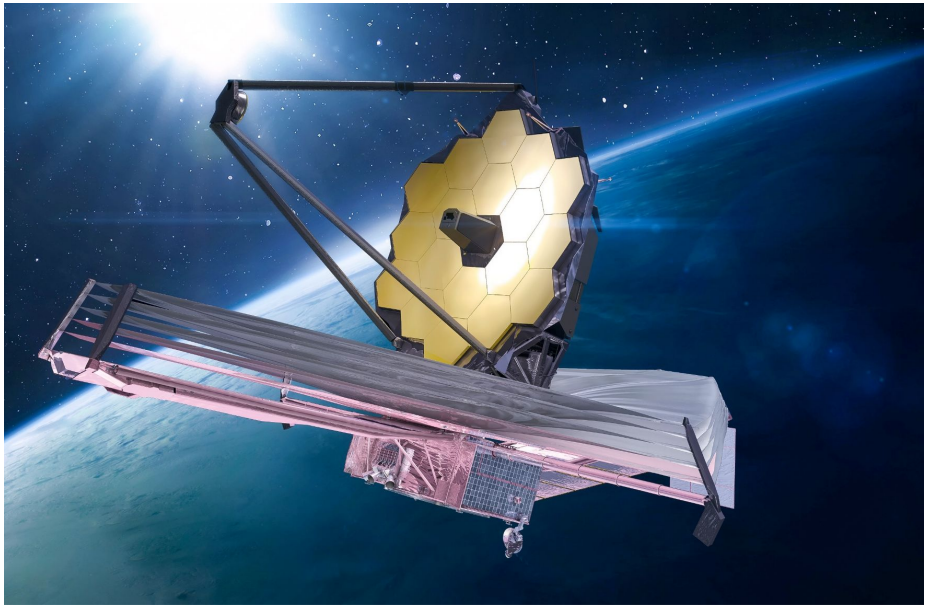


Vera Rubin Observatory

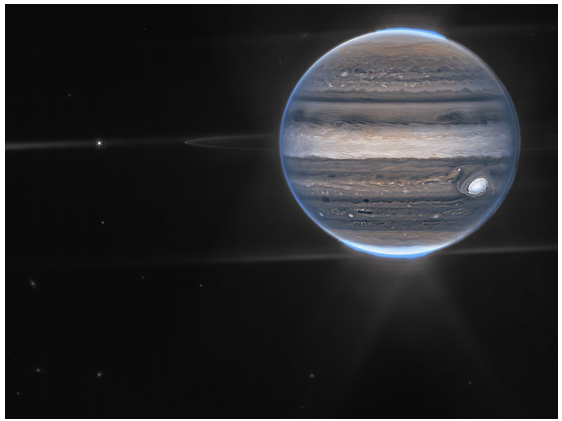
LIGO

JWST

- Launched December 25, 2021
- Observes in the infrared
- 1 million miles away from Earth
- Primary Mirror = 6.5 m (~21 ft) across
- Mass = 6,500 kg (~14,000 pounds)
- Designed to last 5 - 10 years



JWST has taken some pretty awesome pictures



JWST vs. Hubble

Hubble

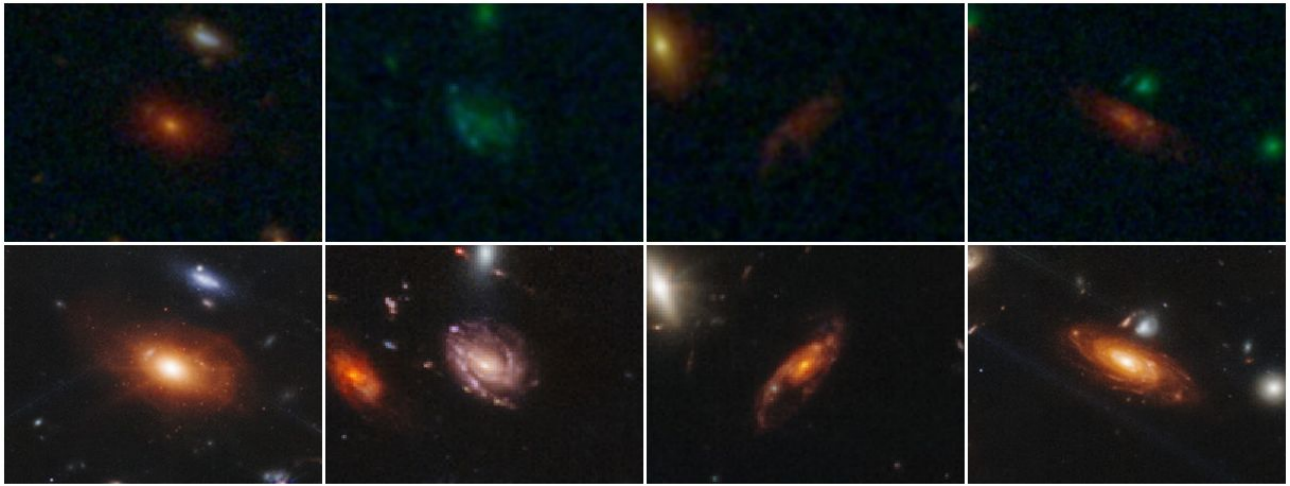
JWST

STScI

What will we learn about cosmology with JWST?

Hubble

JWST



- JWST will observe some of the first galaxies.
- By measuring the number and masses of these galaxies we can learn about dark matter properties.

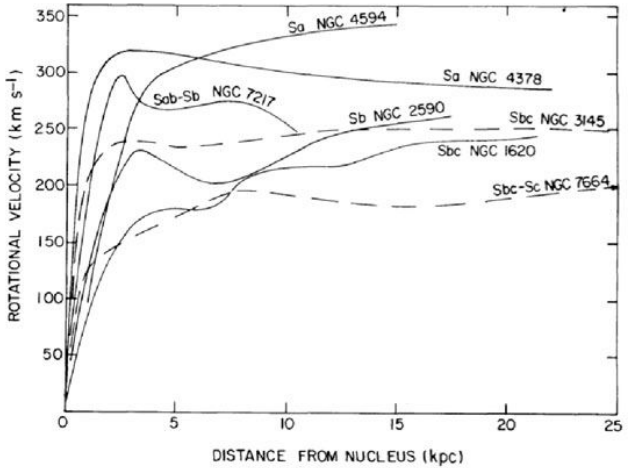
Ferreira et al. (2022); see astrobites article too

Vera Rubin Observatory

- First light expected in 2023
- Based in Chile
- Will observe in optical wavelengths
- Primary Mirror is 8.4 m (~27.5 ft)
- Will scan the entire sky every few nights for over 10 years.

Who was Vera Rubin?

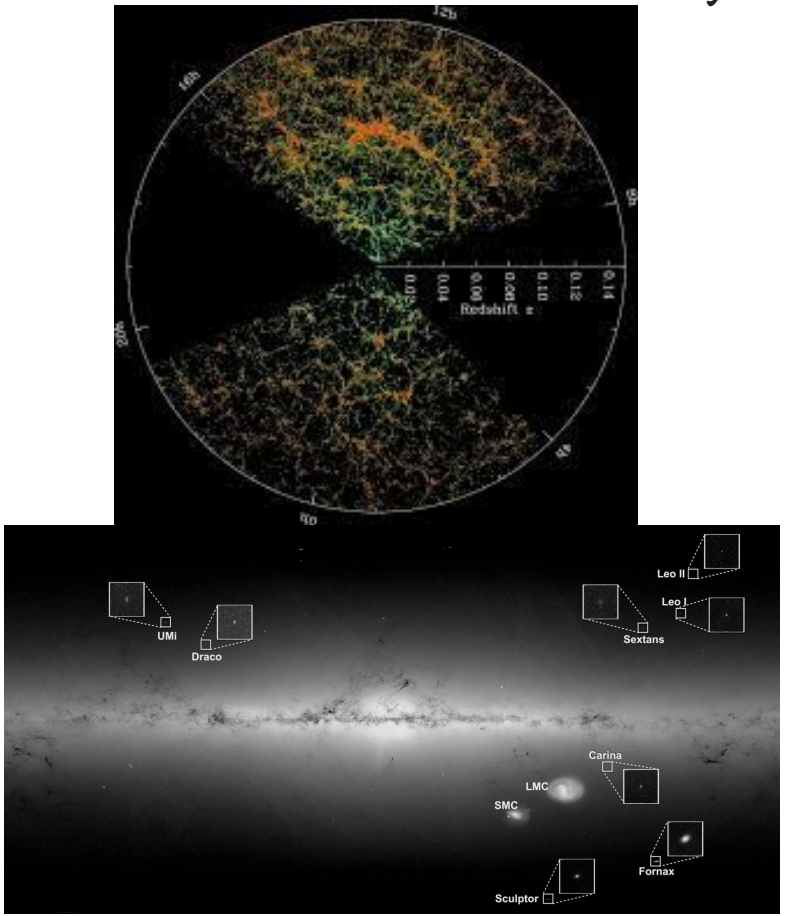
- Astronomer who provided some of the first evidence of dark matter.
- Her measurements of star velocities in nearby galaxies showed that stars move faster than we expect them to given the masses we measure in stars and gas.



Rubin et al. 1978

What will we learn about cosmology with the Rubin Observatory?

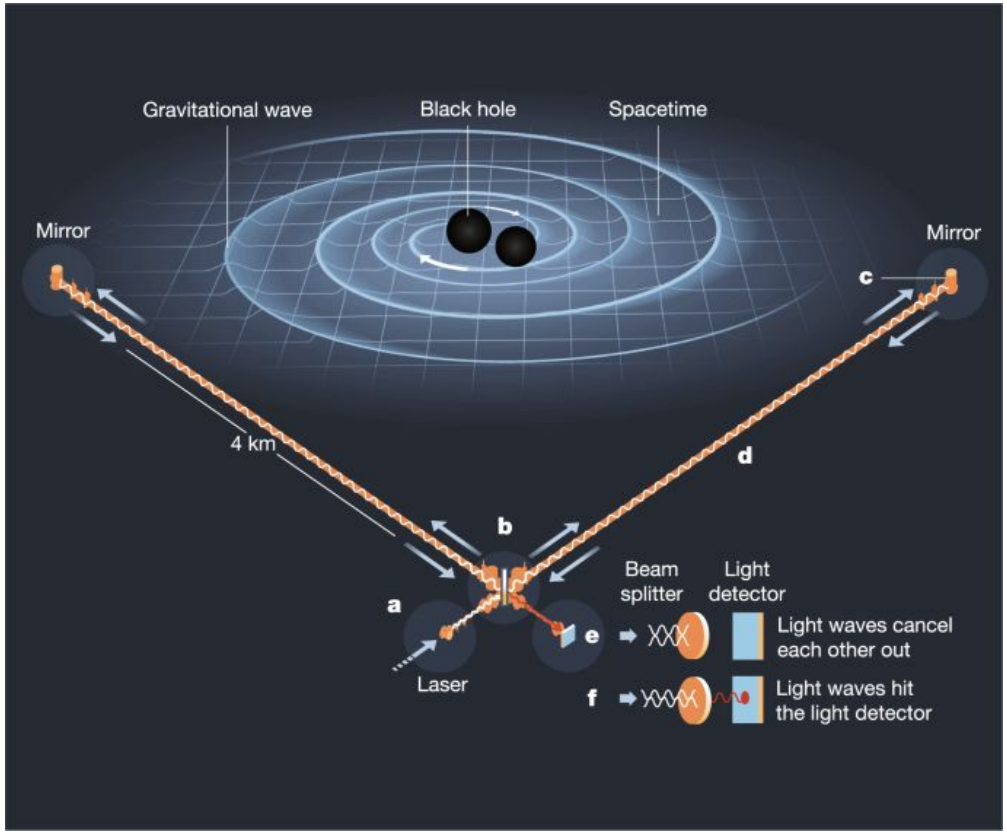
- Will map out galaxy positions and shapes
  - This will tell us about how dark energy has affected the expansion of the universe
  - Will also tell us about how much dark matter there is on large scales
- Will also let us learn more about the Milky Way's satellites. This will tell us about dark matter properties on smaller scales.



SDSS; ESA

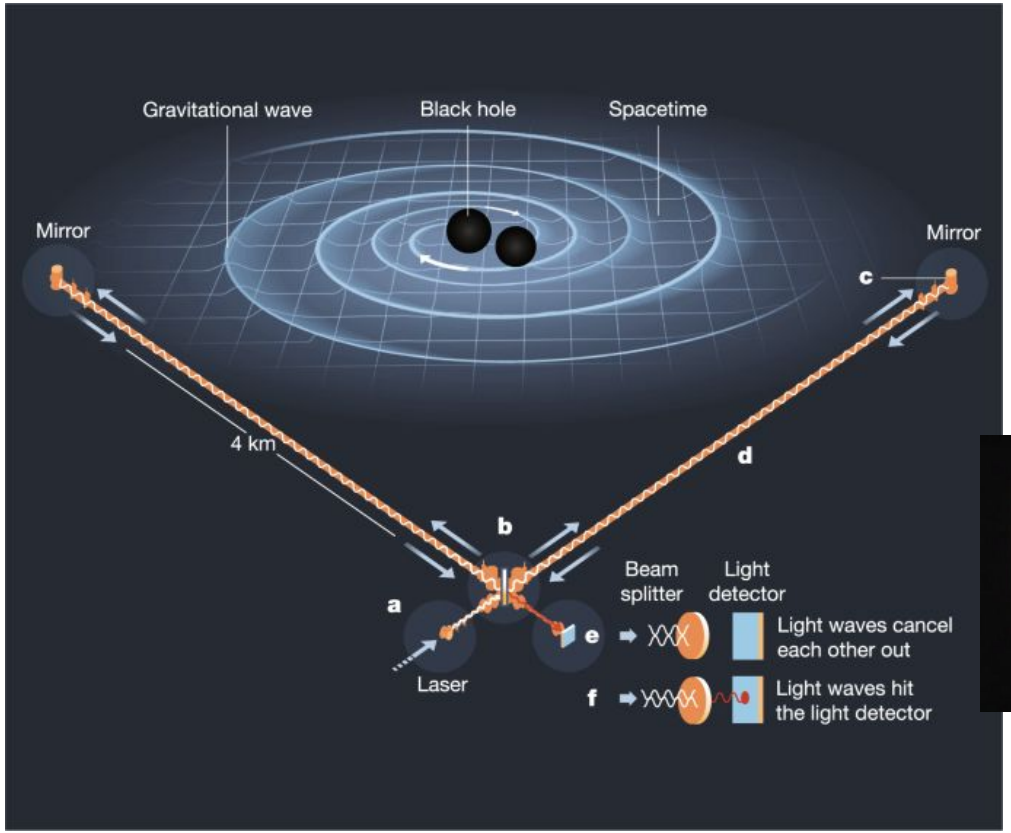
Laser Interferometer Gravitational wave Observatory

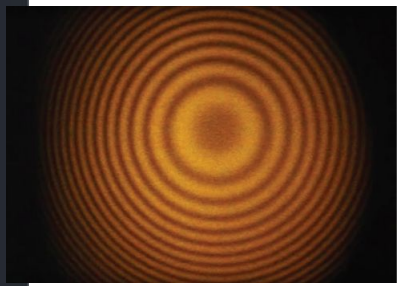
What are gravitational waves?



Miller & Yunes (2019)

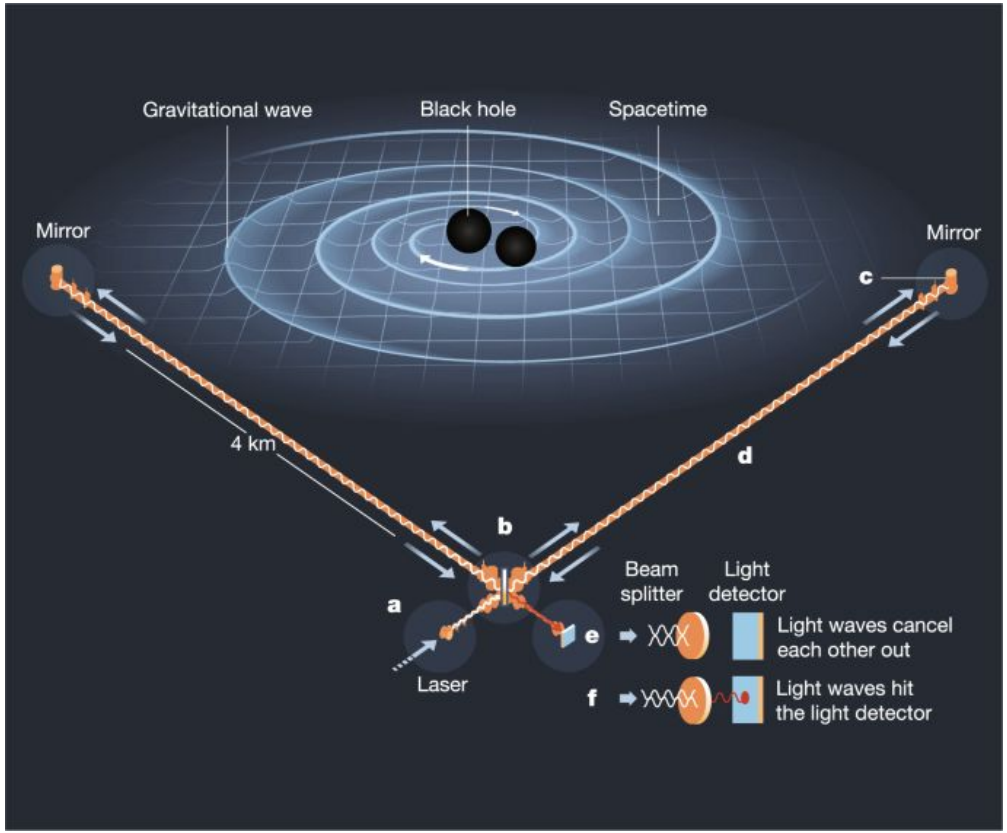
What are gravitational waves?

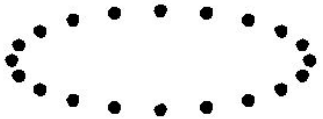


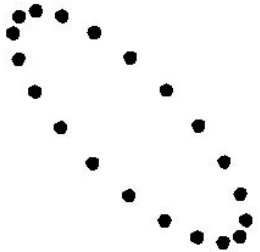


Miller & Yunes (2019)

What are gravitational waves?

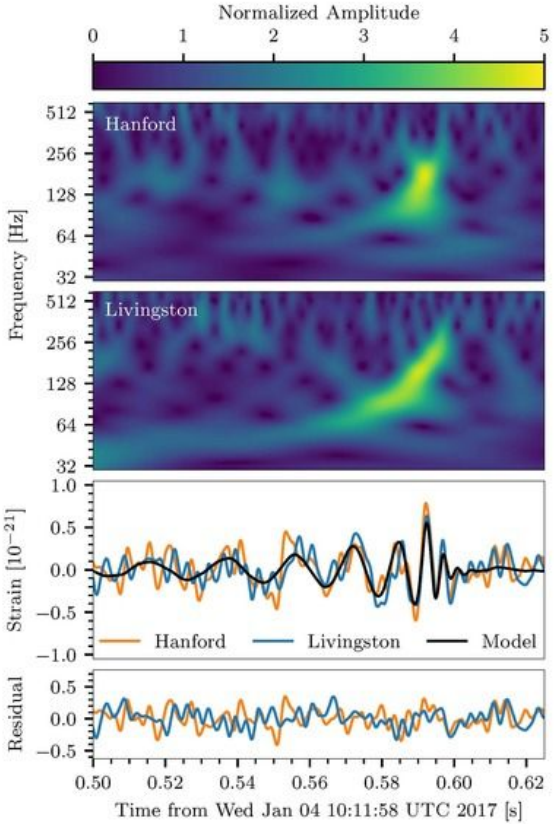




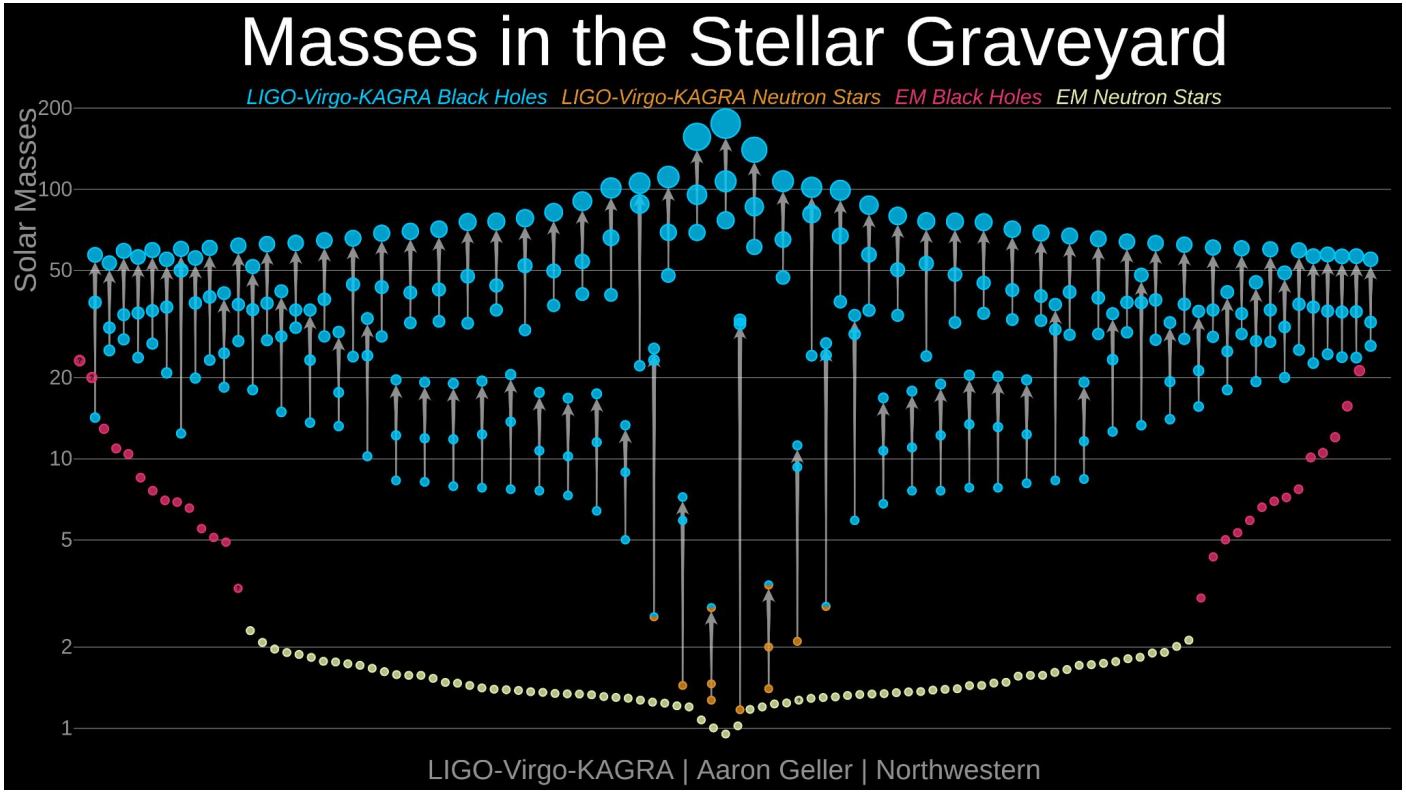


Miller & Yunes (2019)

What does a LIGO detection look like?

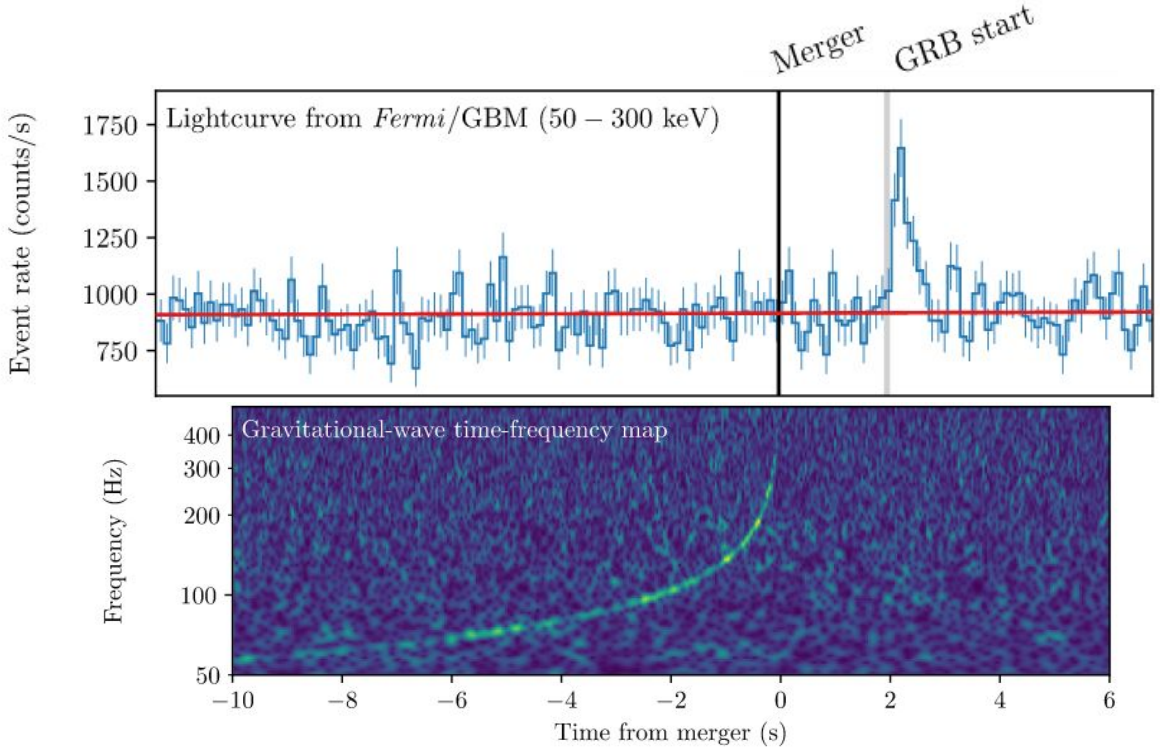


LIGO Detections

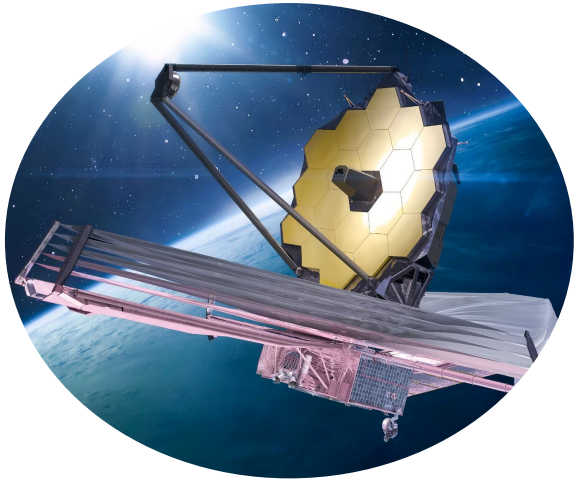


What have we learned about cosmology with LIGO?

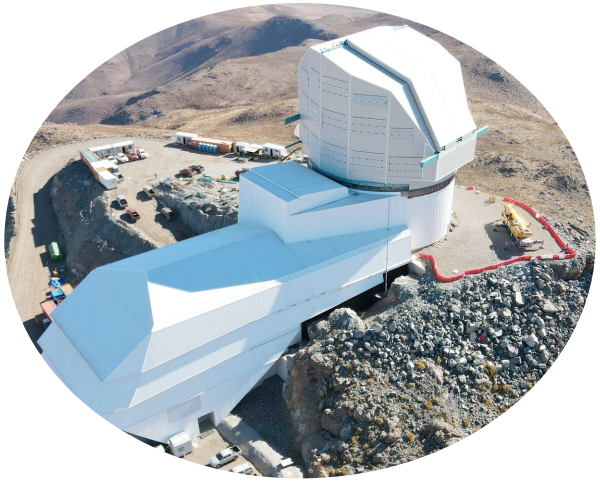
- Gravitational waves travel at the speed of light.
- Can measure the current expansion of the Universe with GWs. It agrees with other measurements.



Abbott et al. (2017)



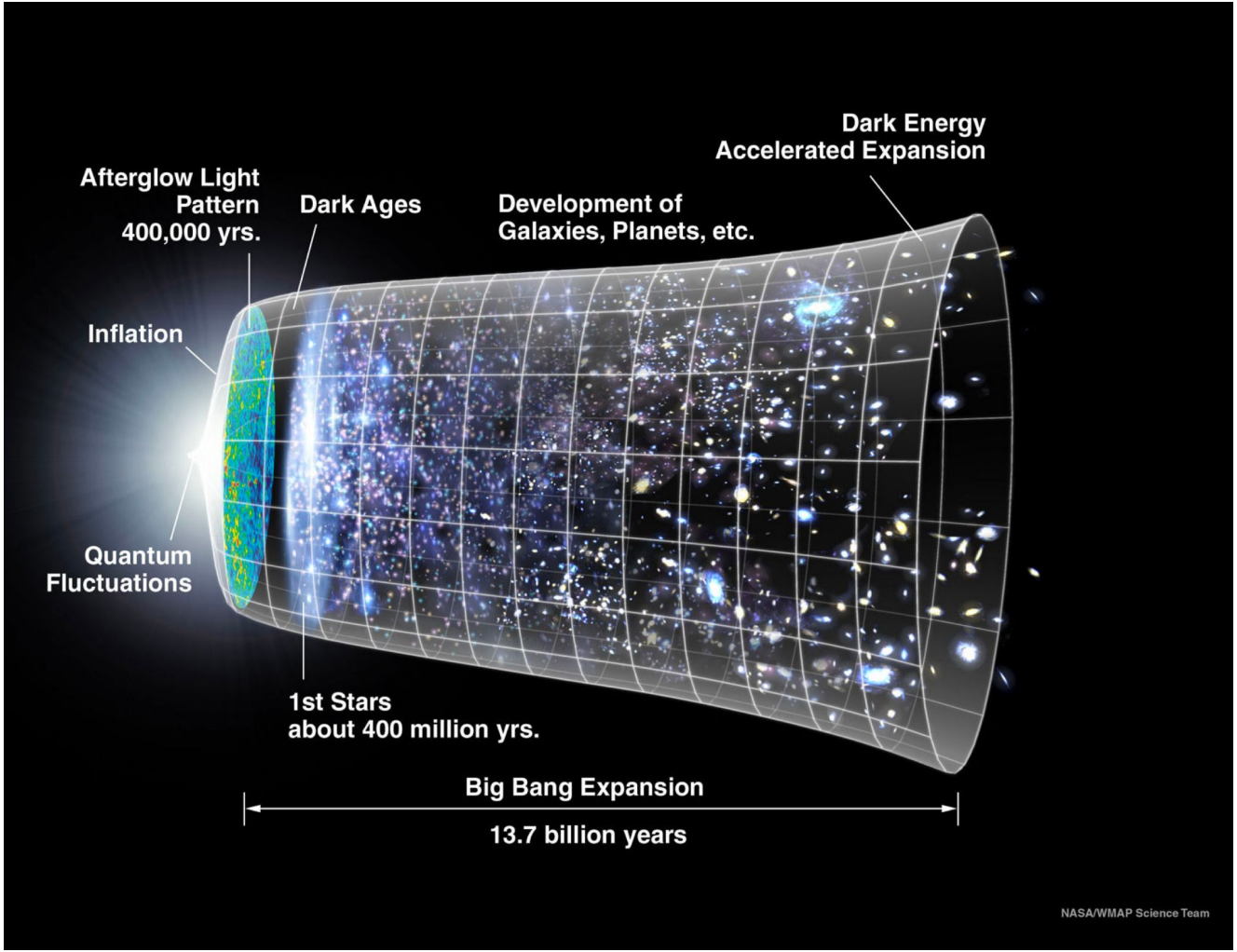
JWST
views of the
earliest galaxies



Rubin Observatory
Map of the entire night
sky every few nights

LIGO
a whole new way to see the
Universe

Image: Science Photo Library, bbc.com/news/science-environment-43543195


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
400,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years
NASA/WMAP Science Team

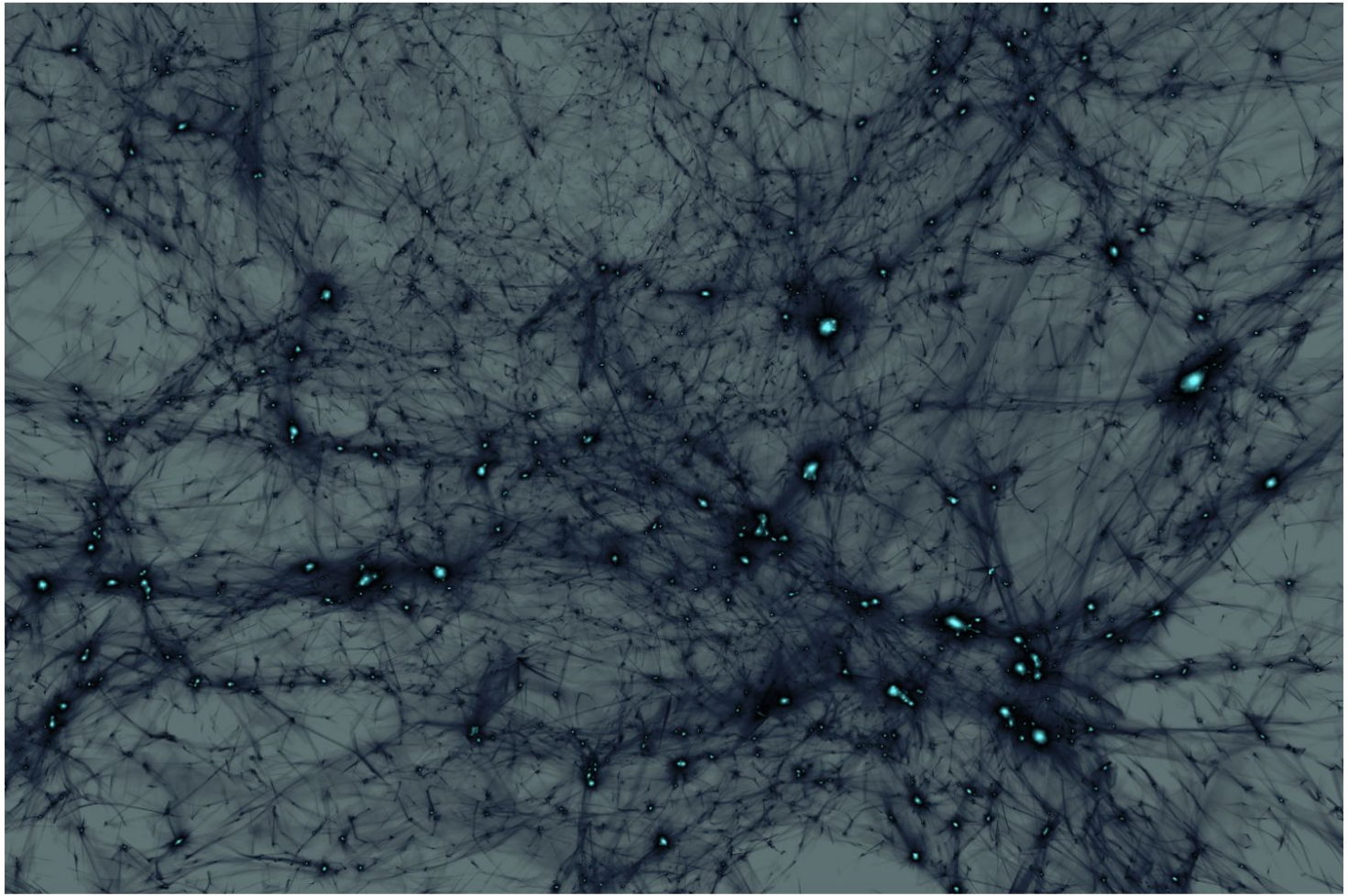


Image: **Ethan Nadler**, Vera Gluscevic, et al.

What is Dark Matter?

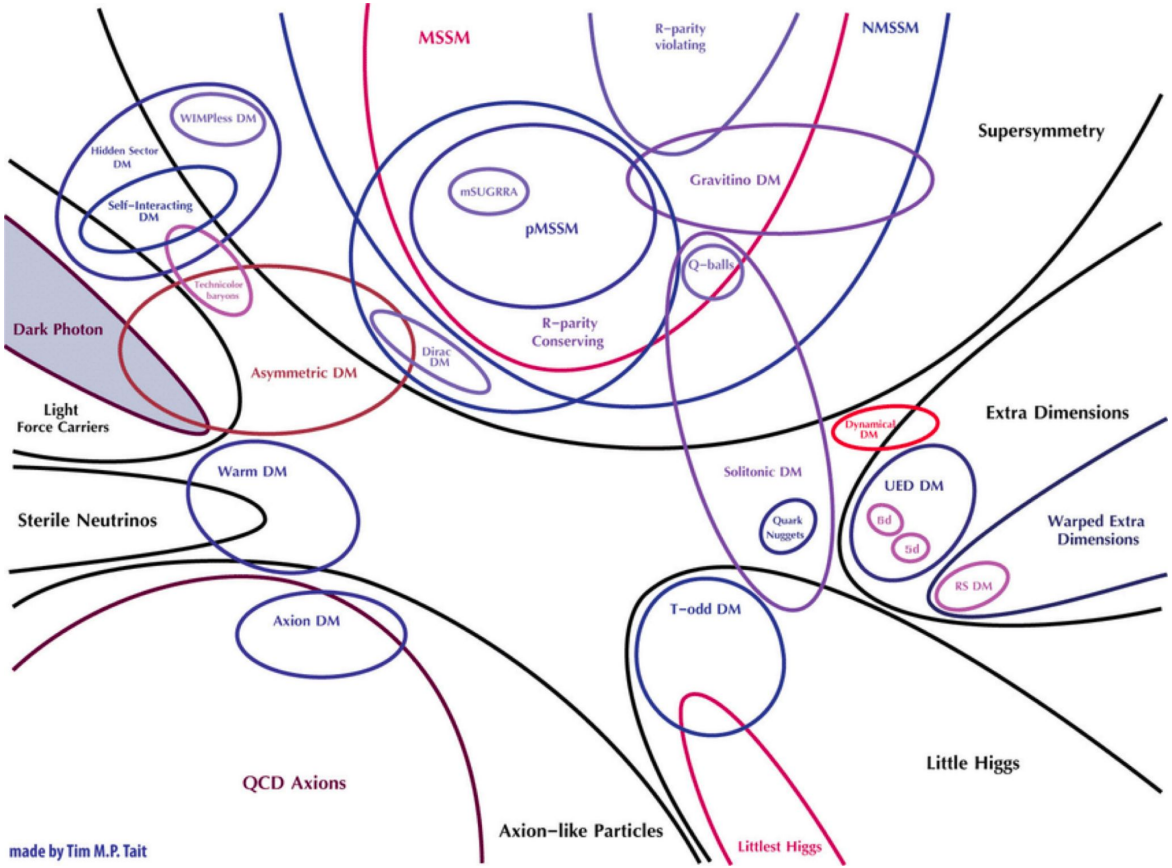
We know that:

- Doesn't (or very weakly) interact with light
- Makes up ~80% of the matter in the Universe
- Feels the force of gravity like "standard" matter
- Clumps and forms clouds of DM called "halos"

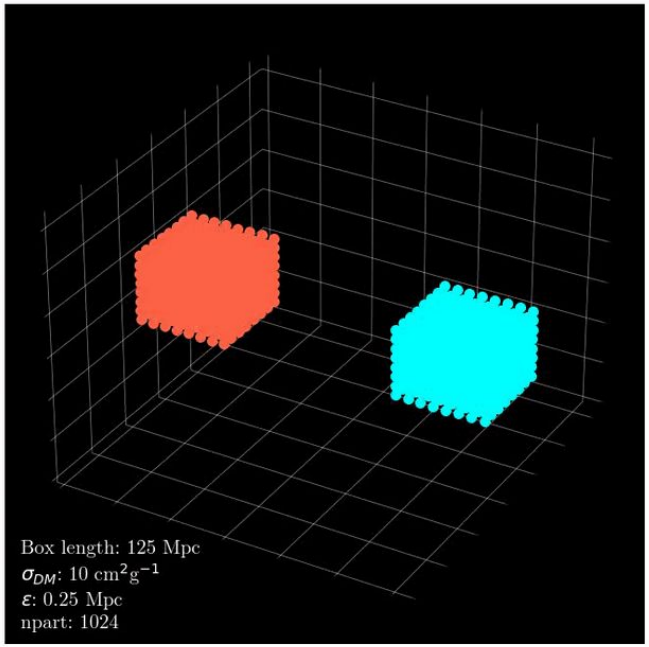
Open Questions:

- Does it interact with itself? ("dark" forces)
- Are the multiple types of DM particles?
- Does it interact with standard matter?
- And so much more!

The possibilities are **endless**... for now

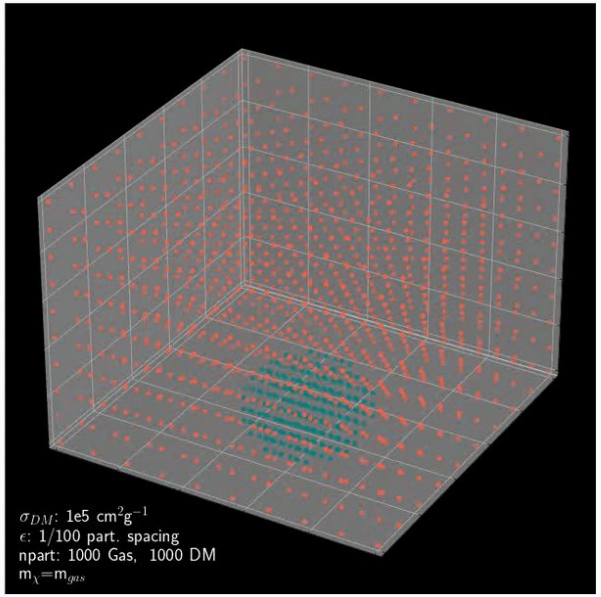


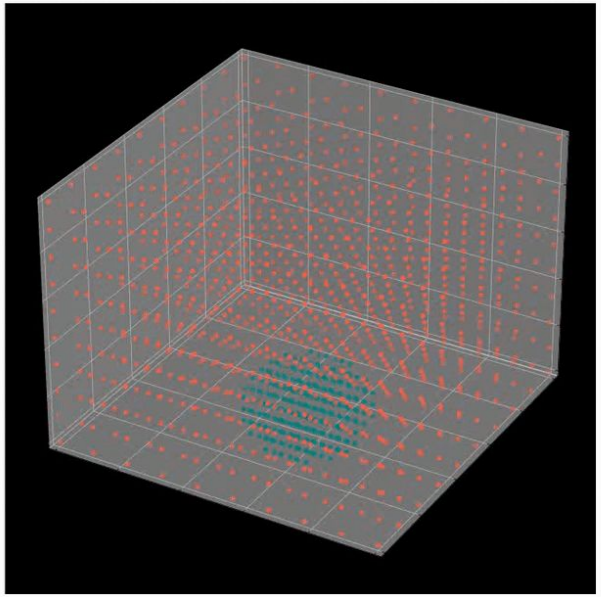
Interactions between DM and SM

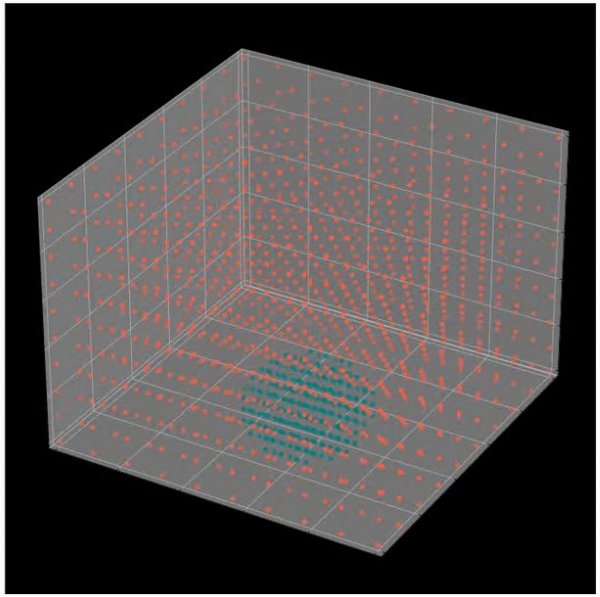


Video: **Karime Maamari**

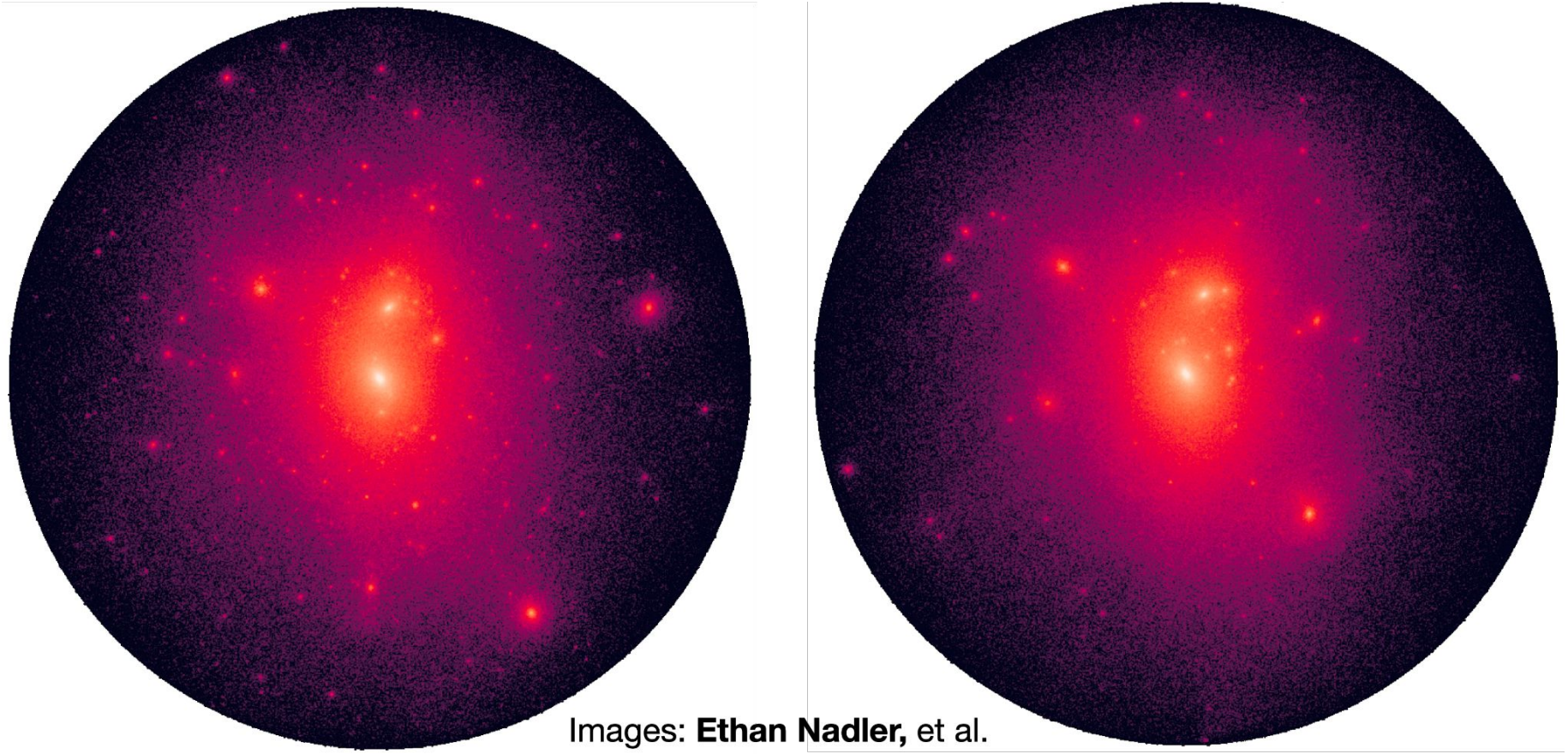
Varying the Interaction Strength





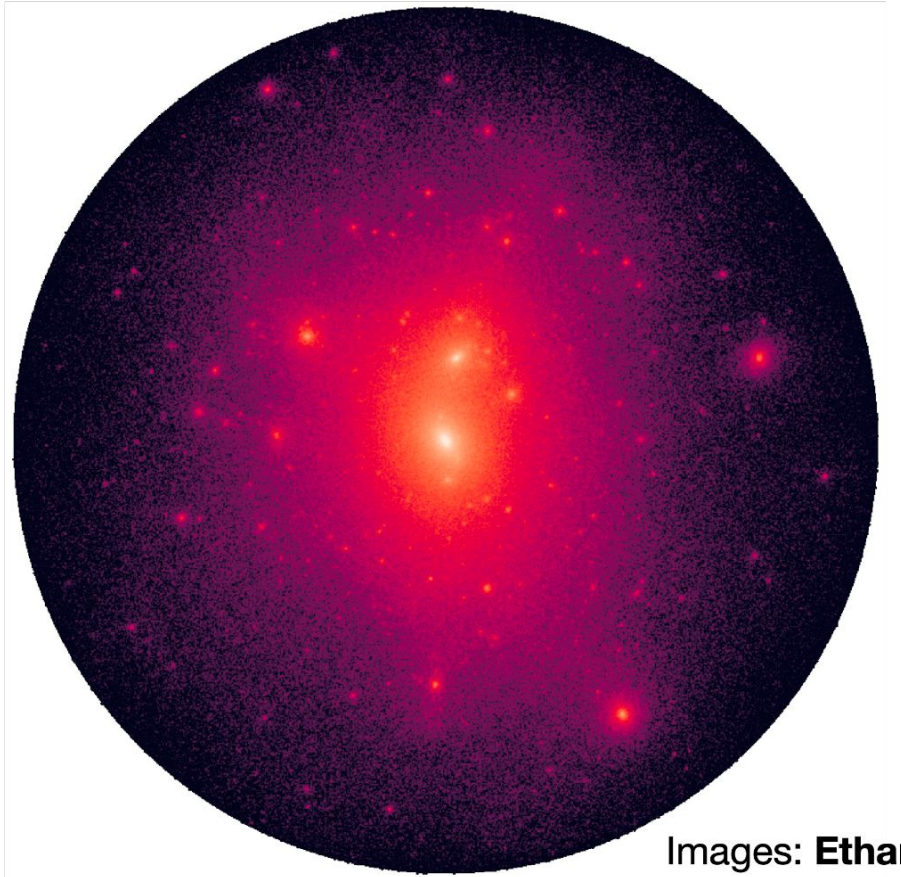


Videos: **Karime Maamari**

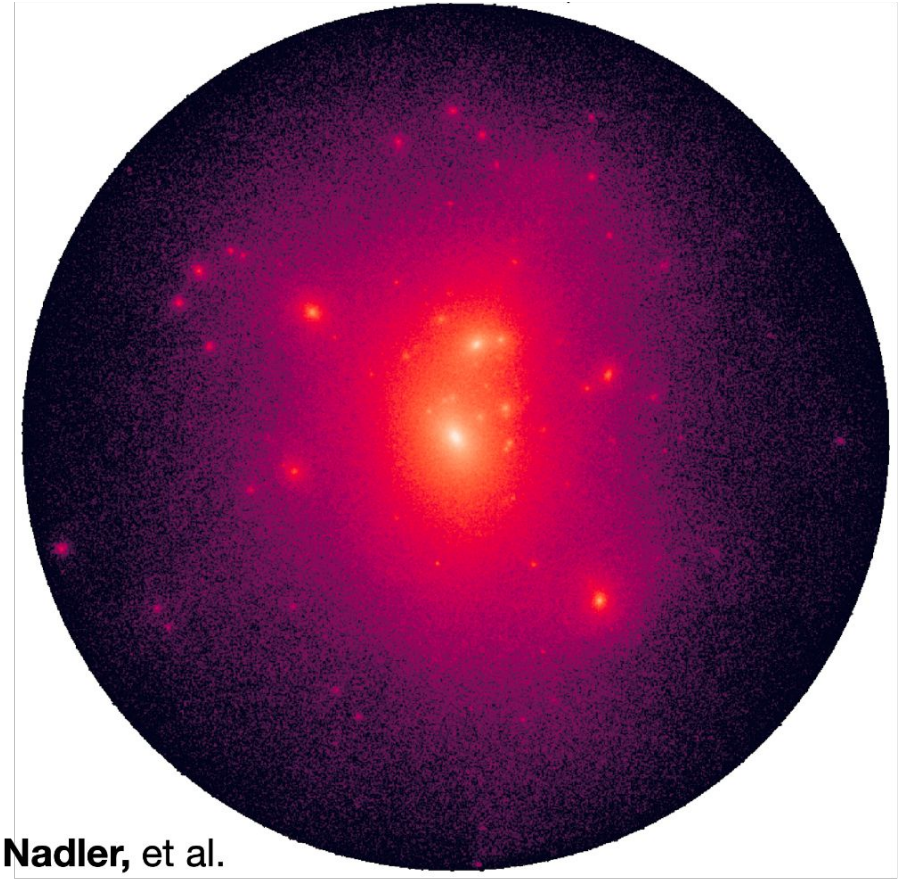


Images: **Ethan Nadler,** et al.

Gravity only

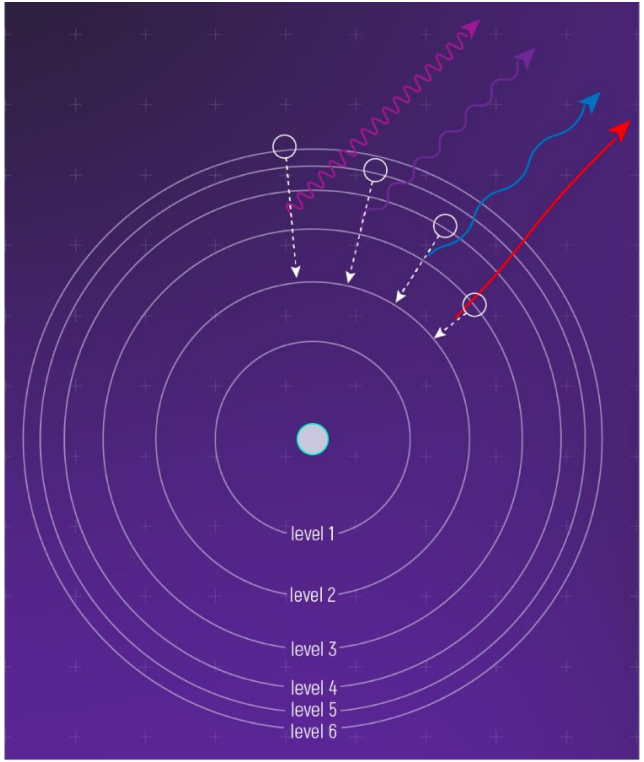


Gravity + Interactions

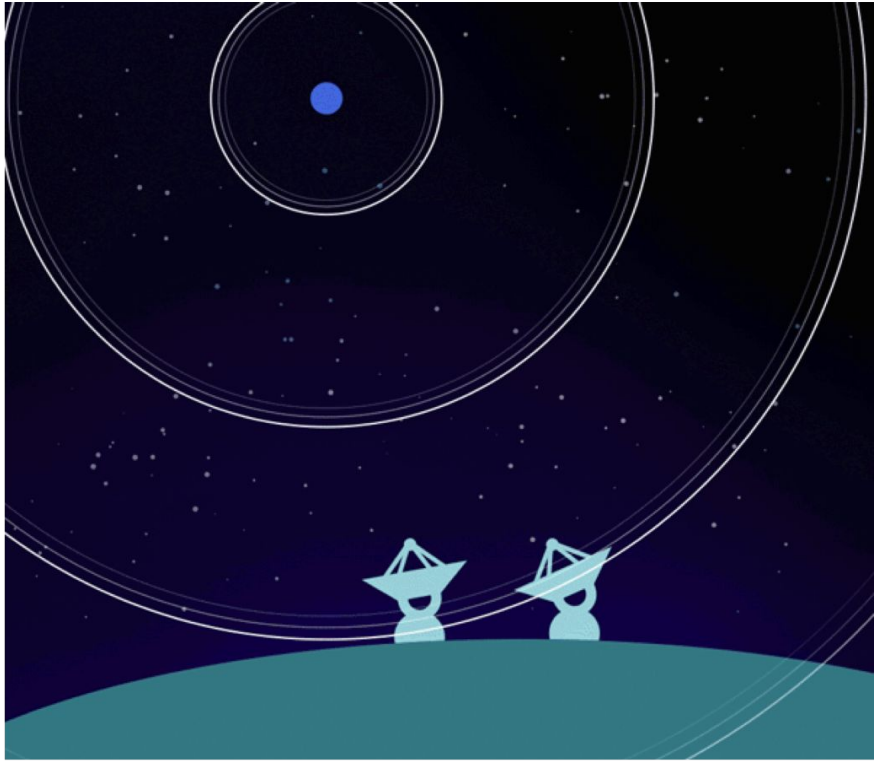


Images: **Ethan Nadler,** et al.

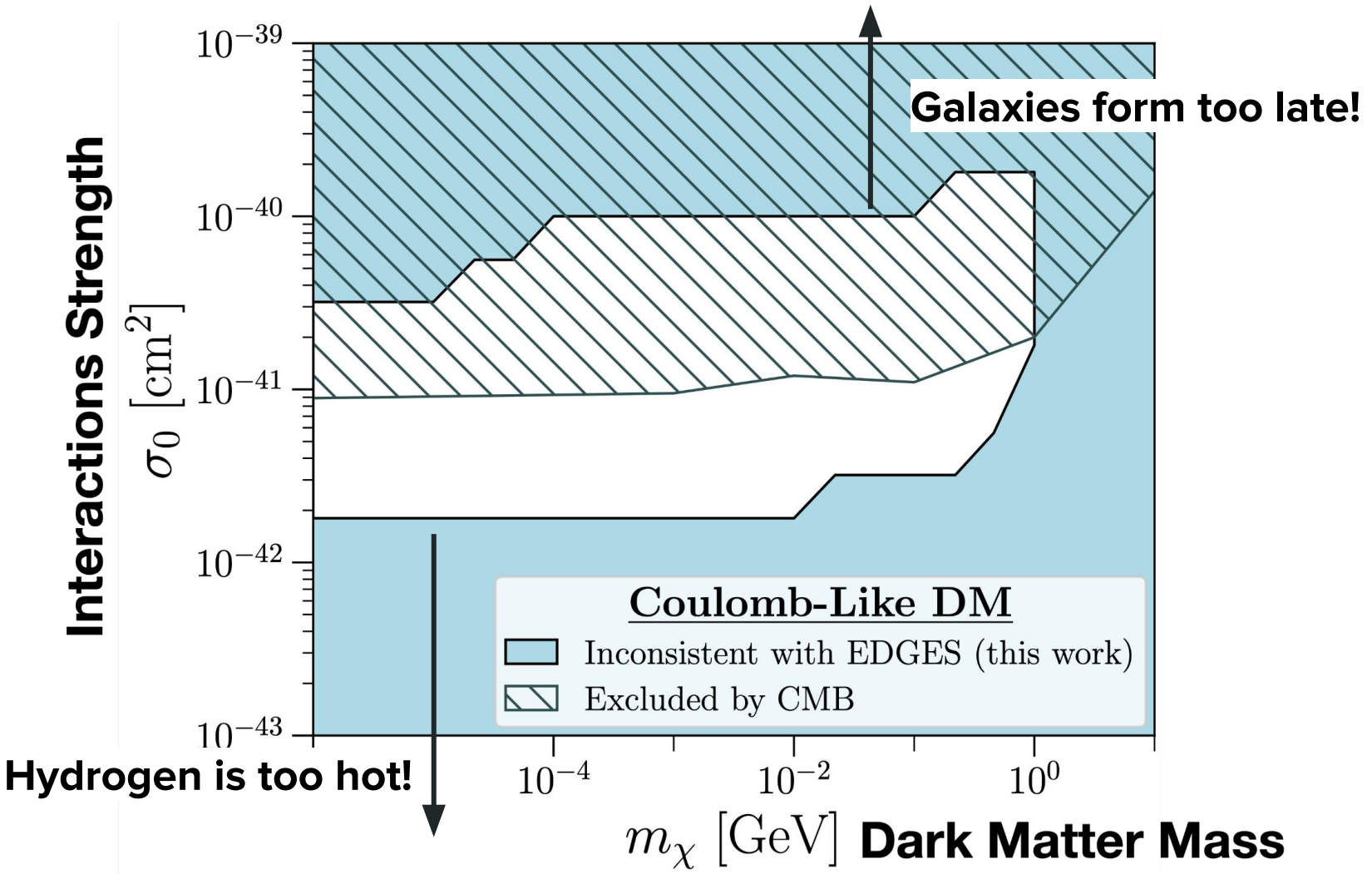
Case Study: Hydrogen Emissions



https://webbtelescope.org/contents/media/images/01F8GFBF8YZEY6KY9WNRWEV1N2?Tag=Astronomy%20Basics



Irwin I. Shapiro, "Measuring light deflection with radio telescopes" in: Einstein Online Band 12 (2020), 12-1001


Galaxies form too late!
Interactions Strength
σ_0 [cm^2]
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
Coulomb-Like DM
Inconsistent with EDGES (this work)
Excluded by CMB
Hydrogen is too hot!
10^{-4}
10^{-2}
10^{0}
m_χ [GeV] Dark Matter Mass

Tips for starting on research

- Take your core physics courses
- Come to cosmolab weekly
- Learn to code in python
- Read some astrophysics and cosmology!
- **Get in touch (best in 3rd of 4th year).**

How to get involved

Email: kmpardo@usc.edu, vera.gluscevic@usc.edu

Slack: **cosmolabusc.slack.com**
usc-physics.slack.com

Coming: https://usc-cosmolab.github.io/cosmolab-site-v2

Meetings: Fridays, ACB 5th floor conference room.