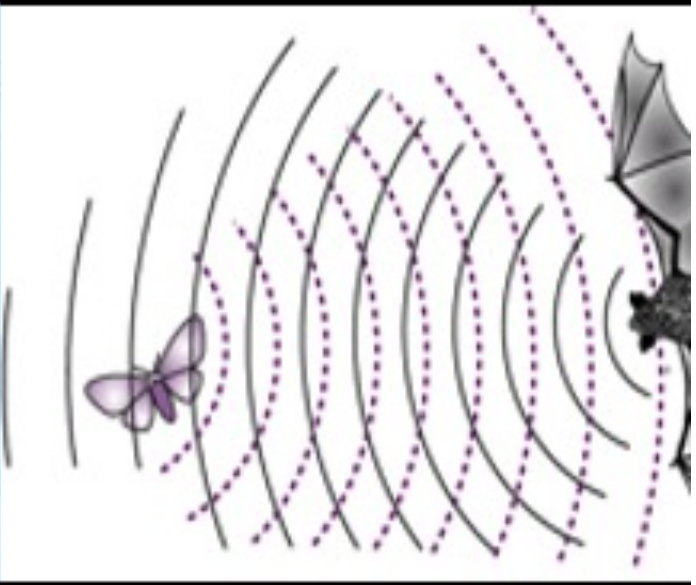
Why did the most massive galaxies stop forming stars?

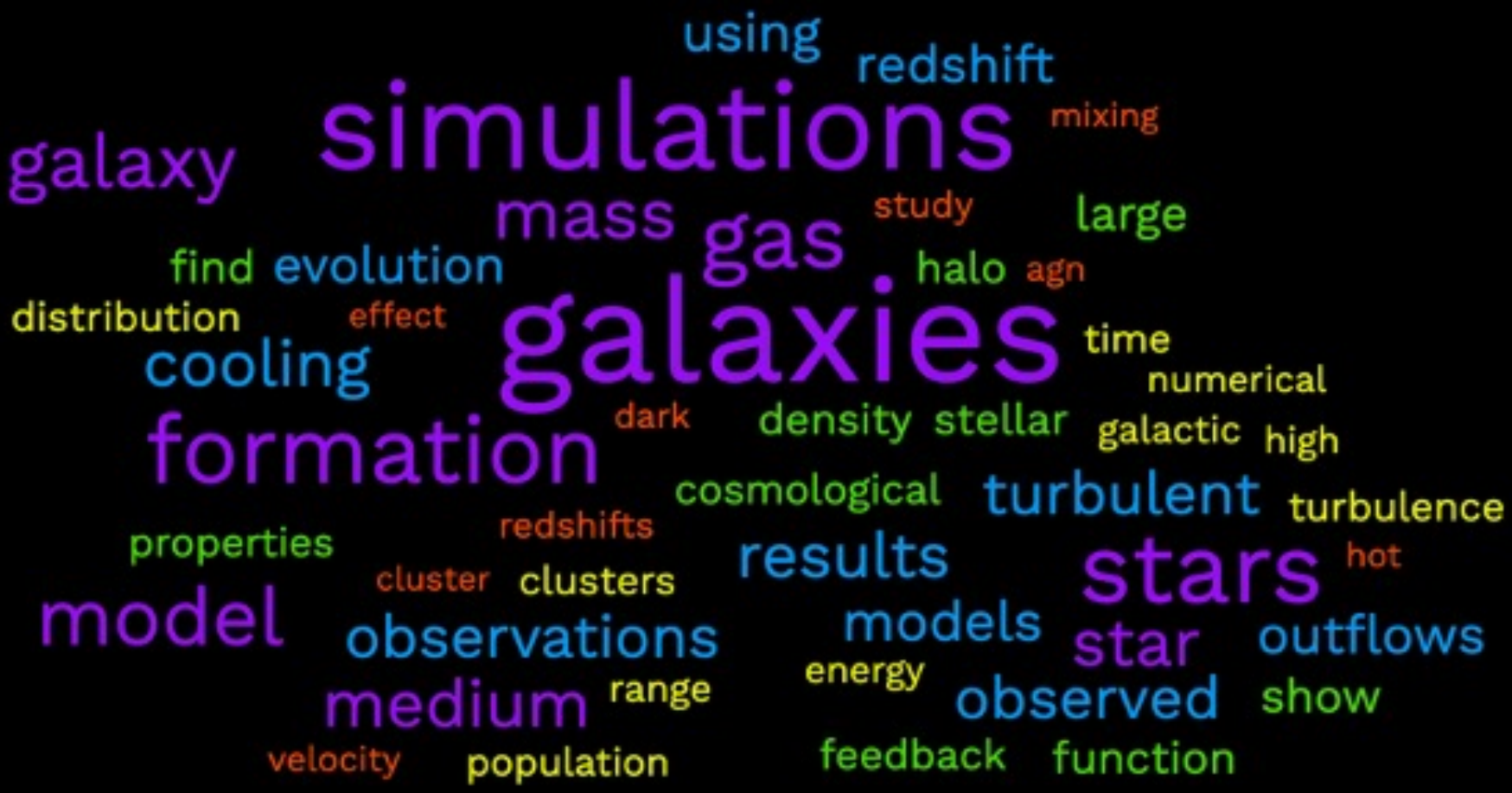
Evan Scannapieco

ASU School of Earth and Space Exploration
Arizona State University

How do you say that?

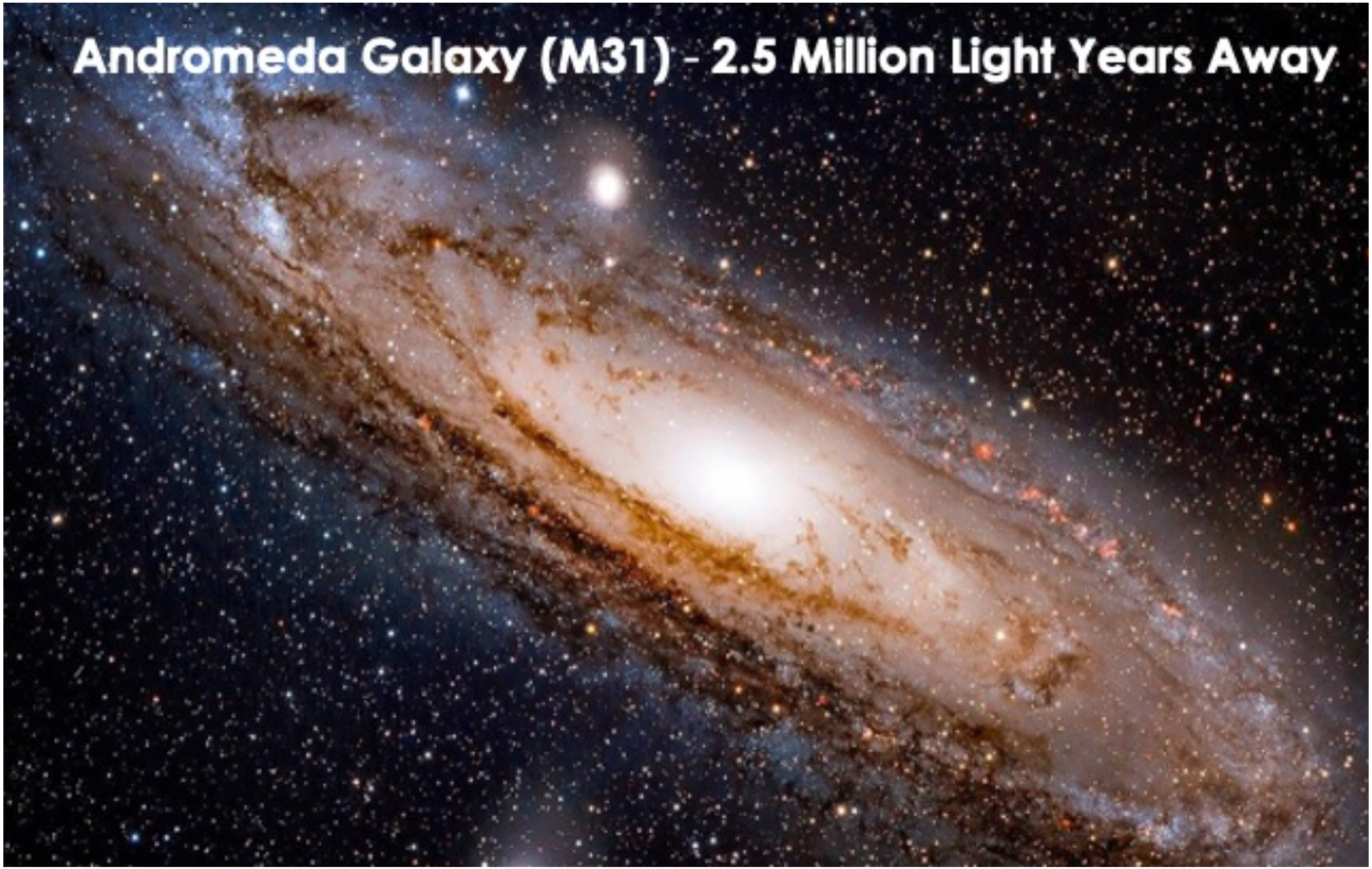


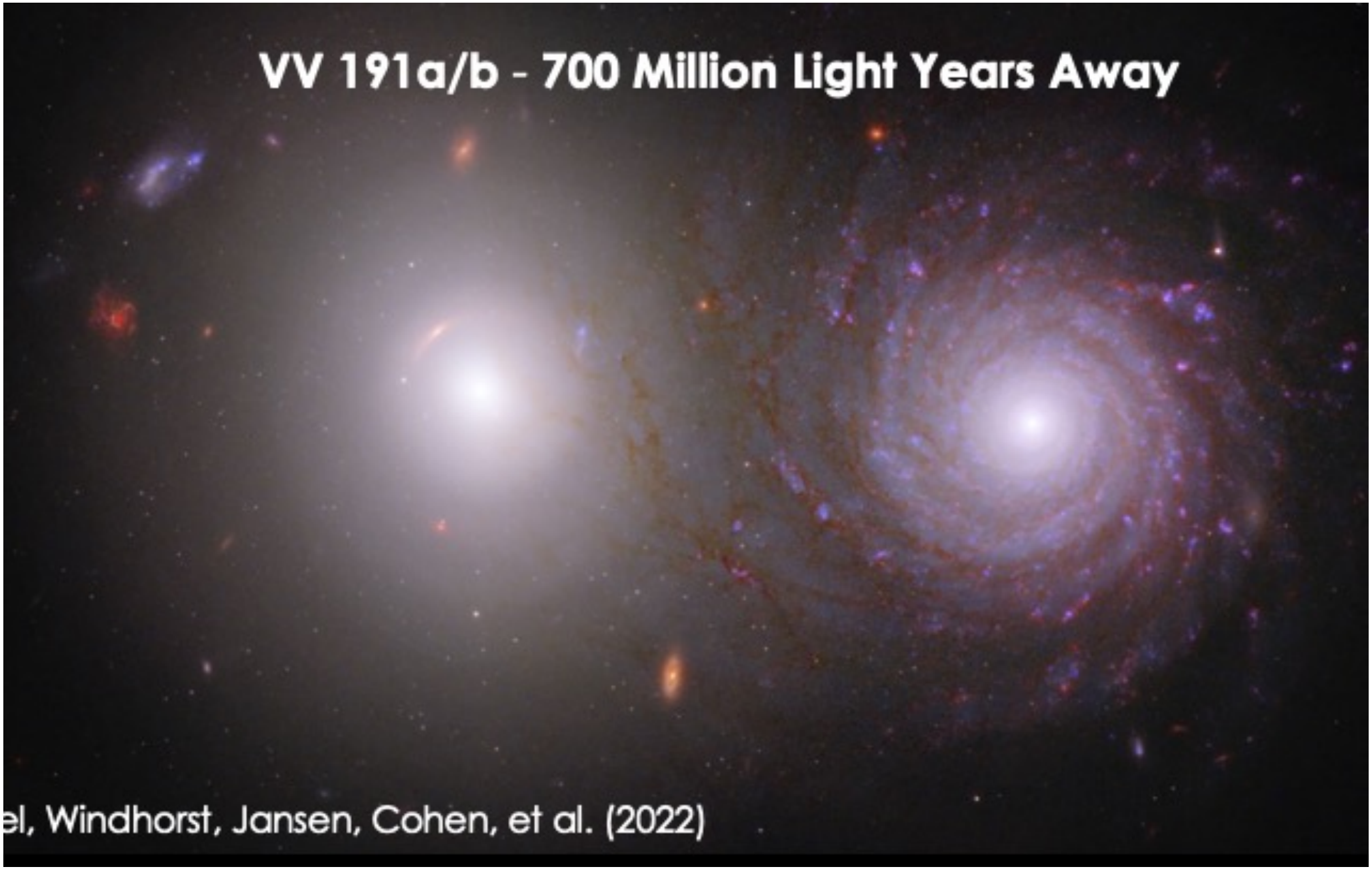
And what do you work on?



ttps://www.freewordcloudgenerator.com/

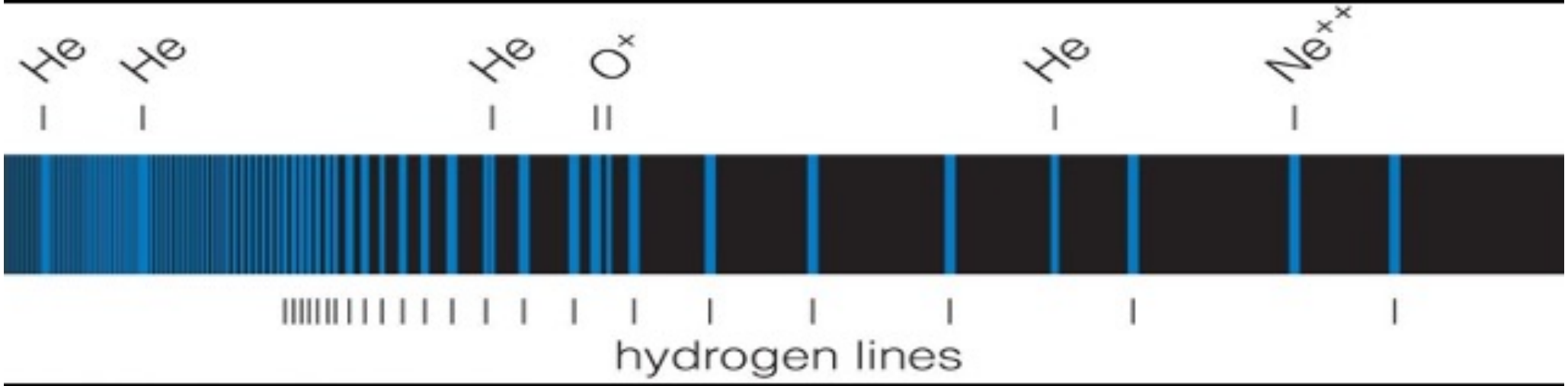

Naked-Eye Stars (10s to 100s of Light Years)


Andromeda Galaxy (M31) - 2.5 Million Light Years Away


VV 191a/b - 700 Million Light Years Away
el, Windhorst, Jansen, Cohen, et al. (2022)


Hubble Ultra Deep Field - Out to 14 Billion Light Years

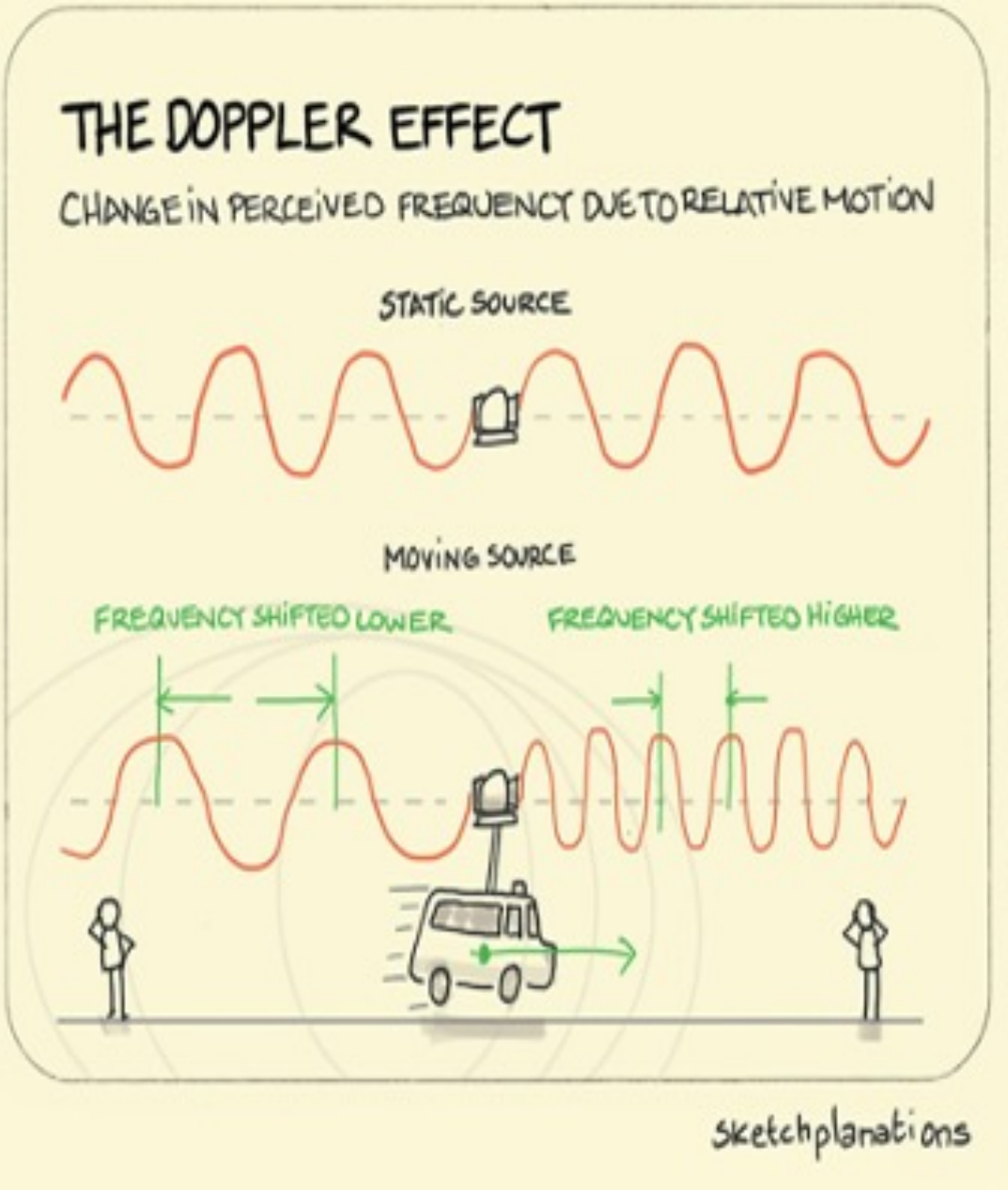
Chemical Fingerprints



Observing the fingerprints in a spectrum tells us which kinds of atoms are present

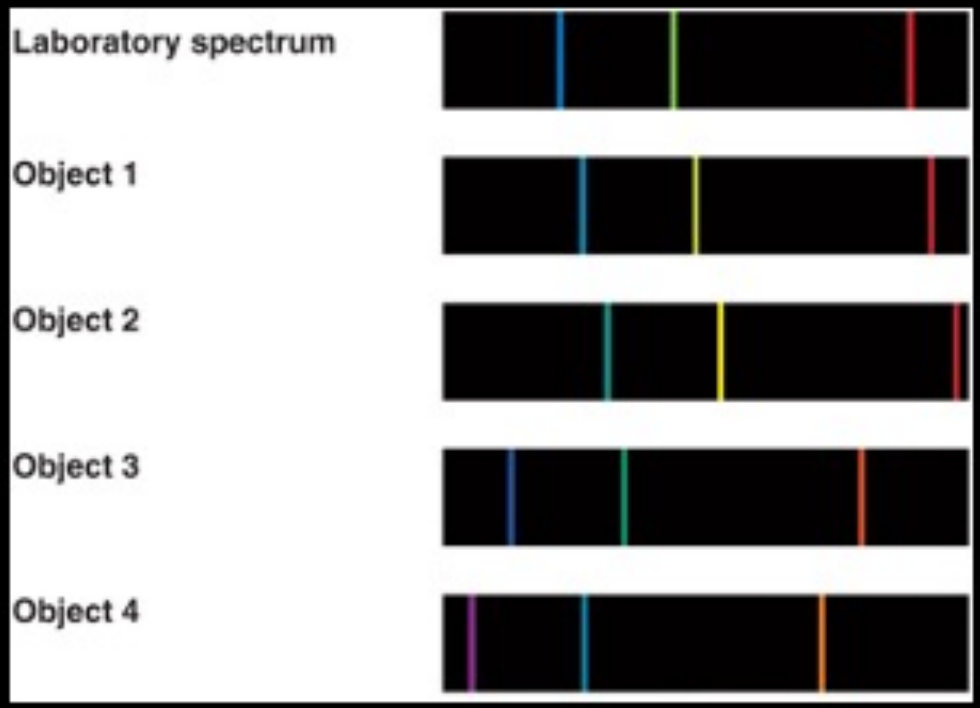
THE DOPPLER EFFECT

CHANGE IN PERCEIVED FREQUENCY DUE TO RELATIVE MOTION

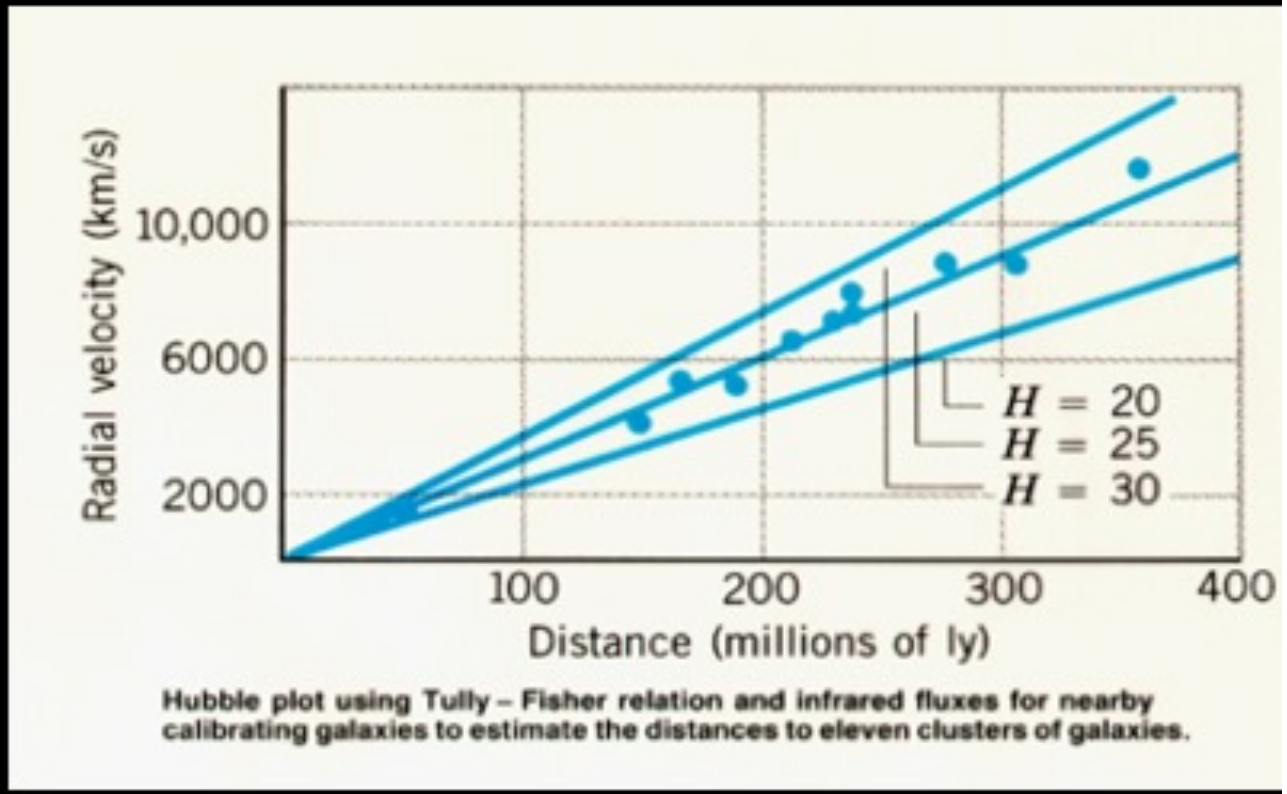


sketchplanations

Measuring the Shift

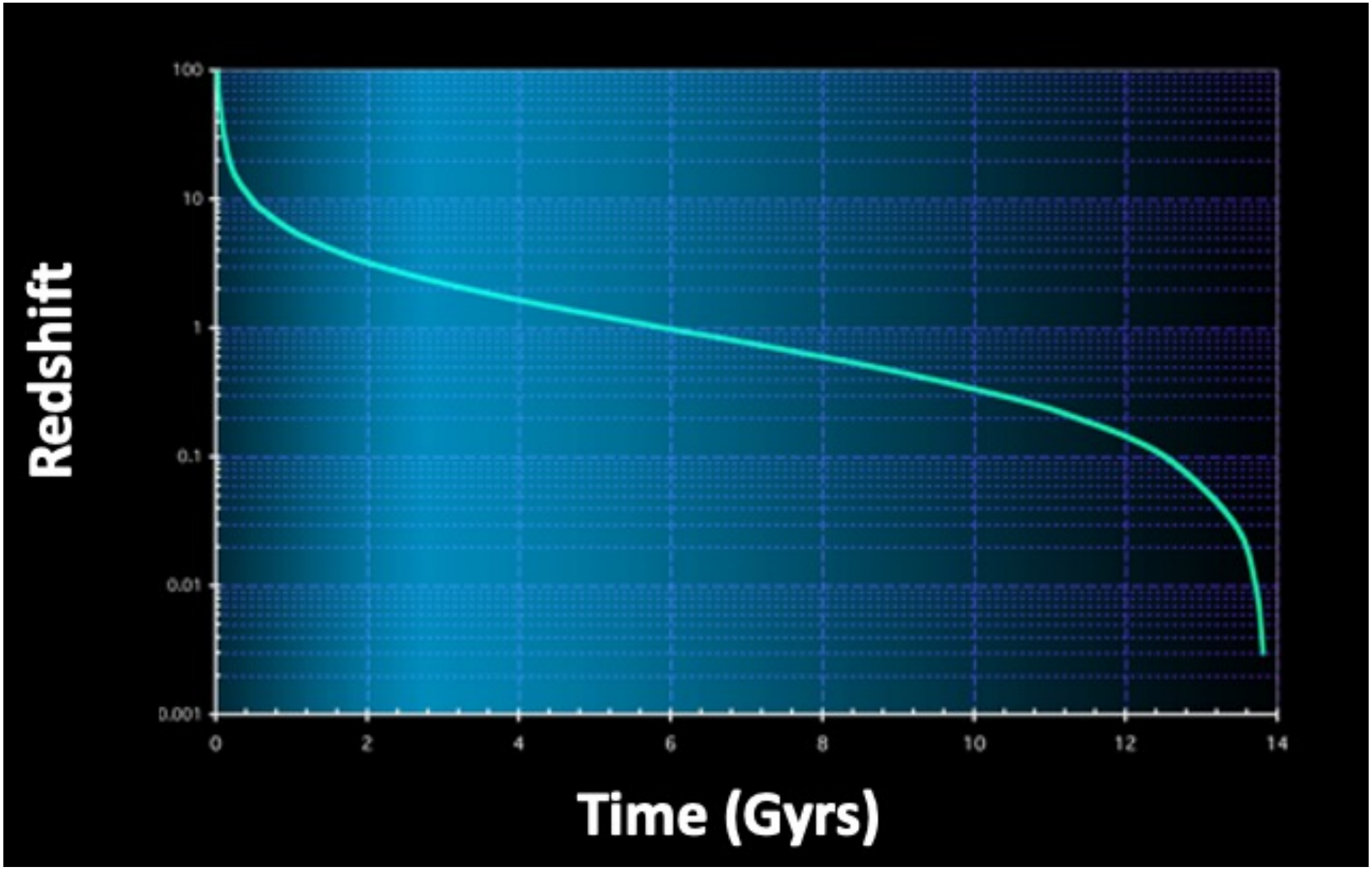


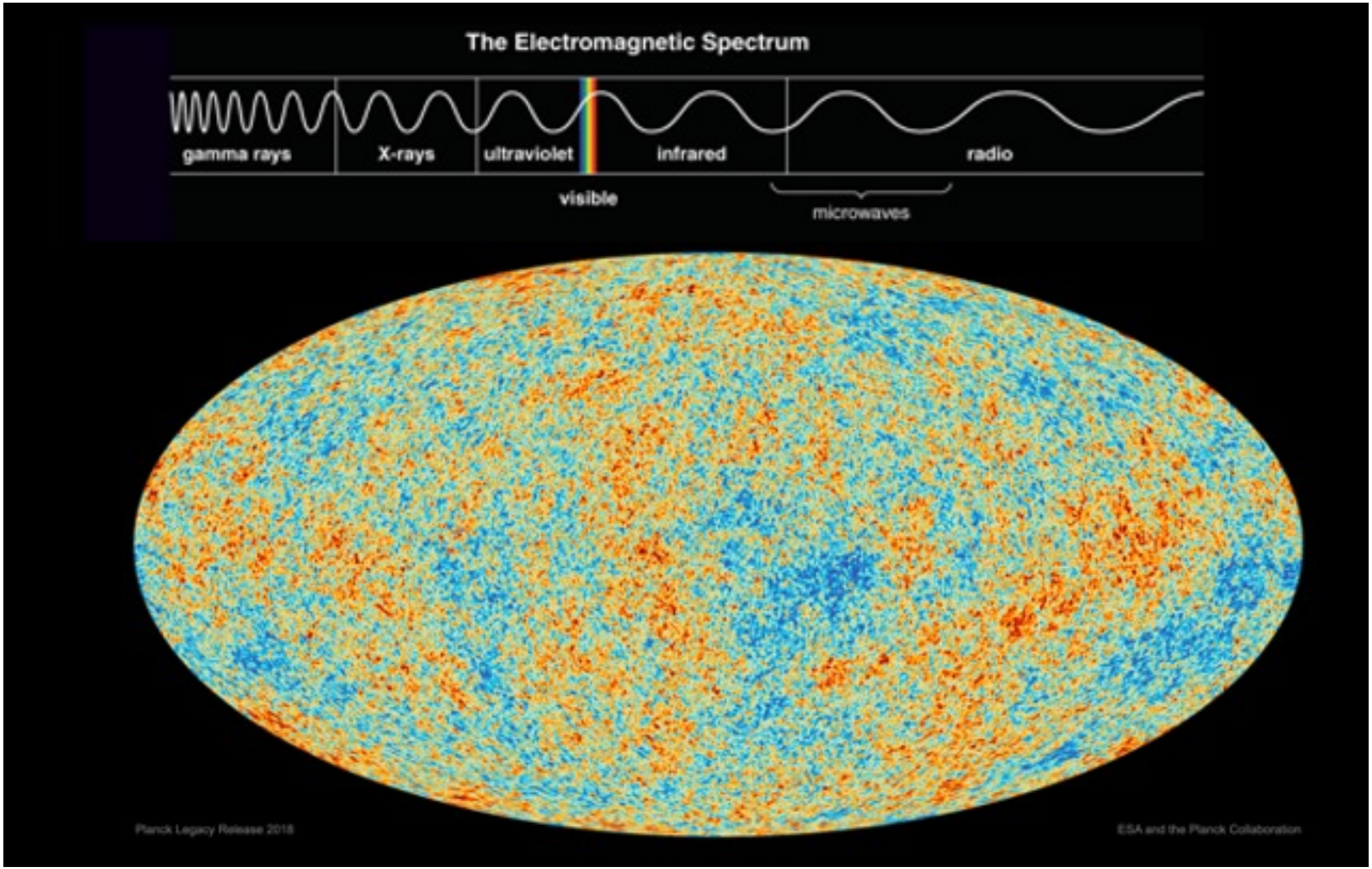
We generally measure the Doppler Effect from shifts in the wavelengths of spectral lines

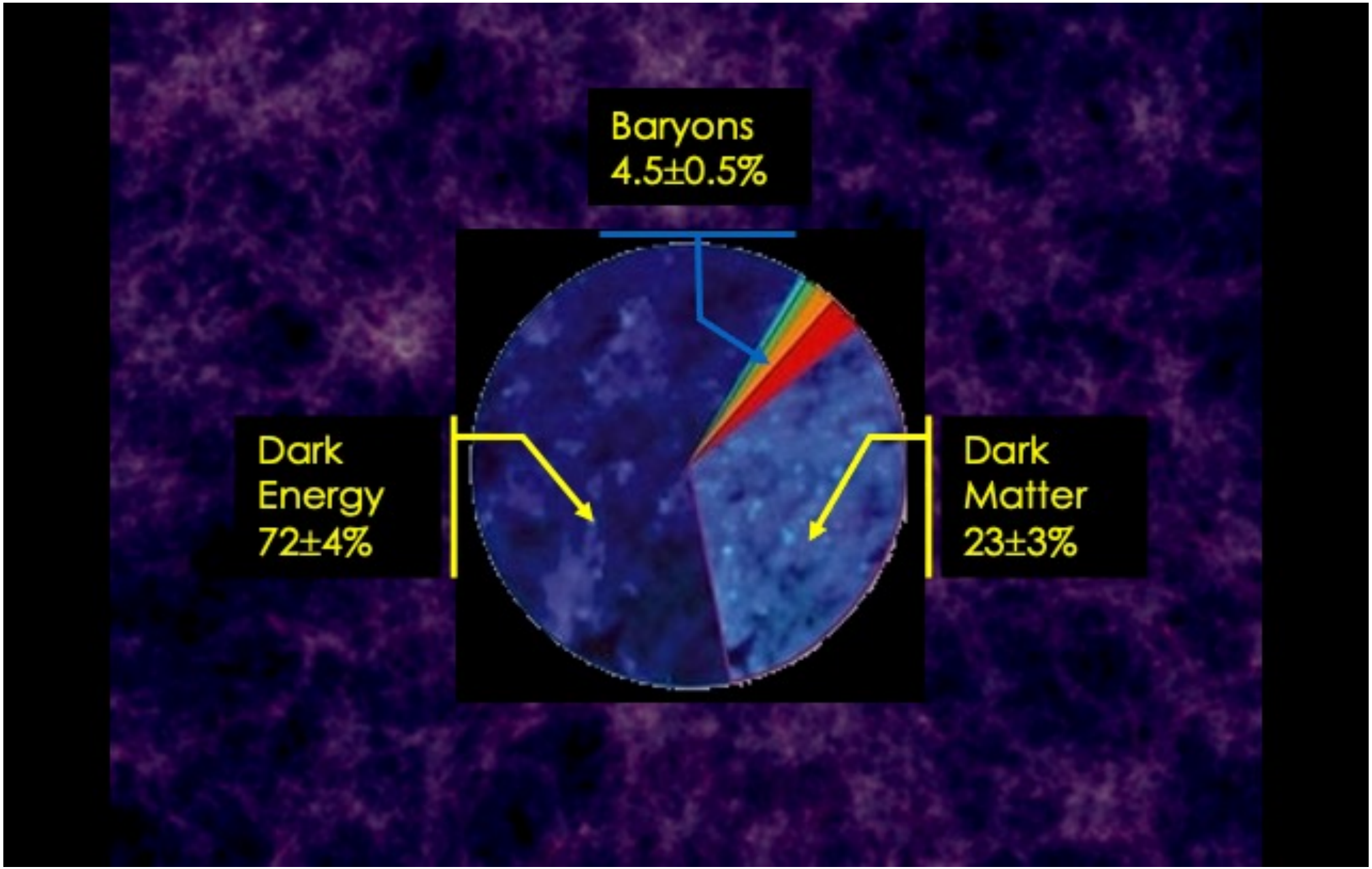


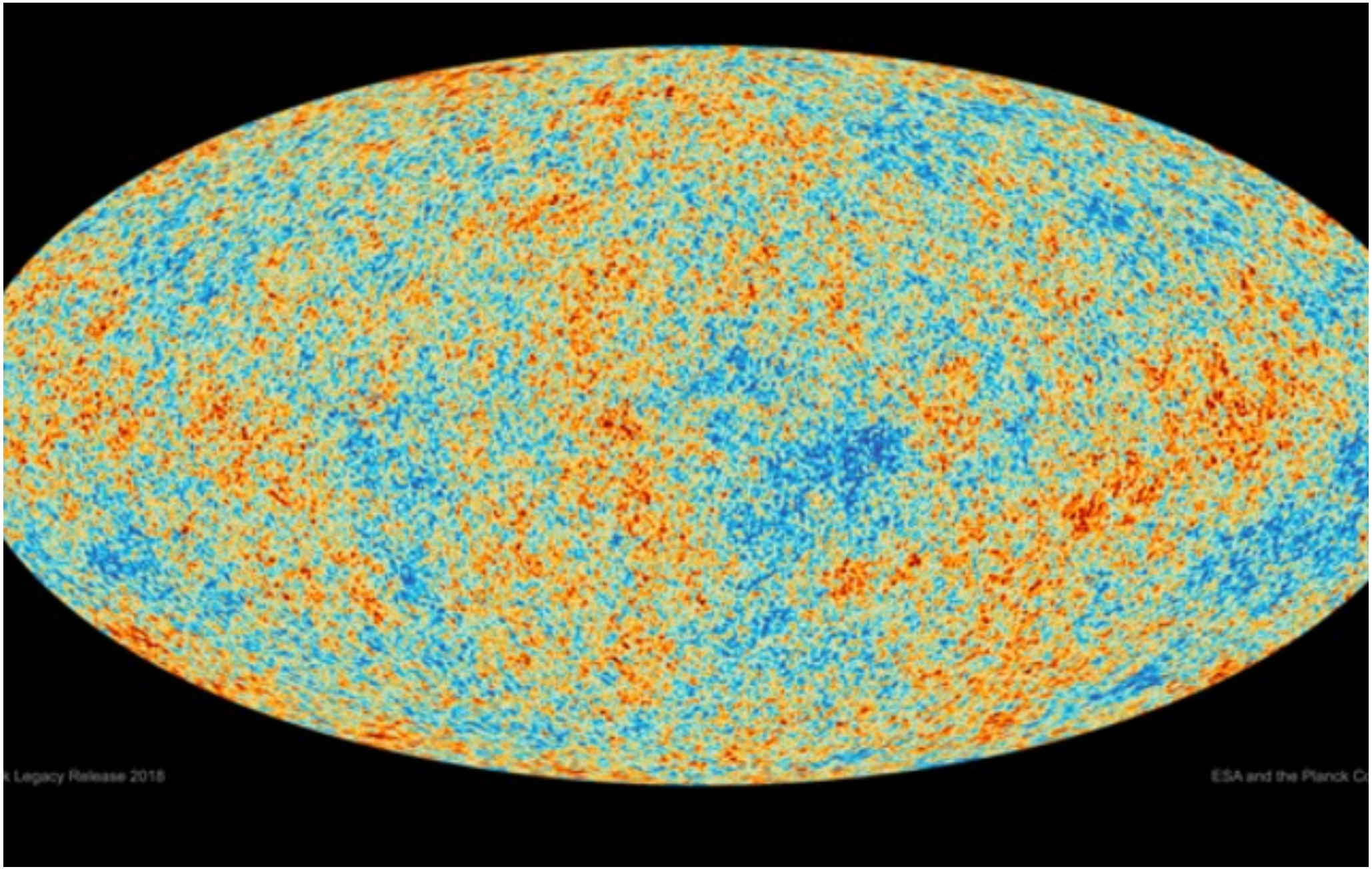
Hubble plot using Tully – Fisher relation and infrared fluxes for nearby calibrating galaxies to estimate the distances to eleven clusters of galaxies.

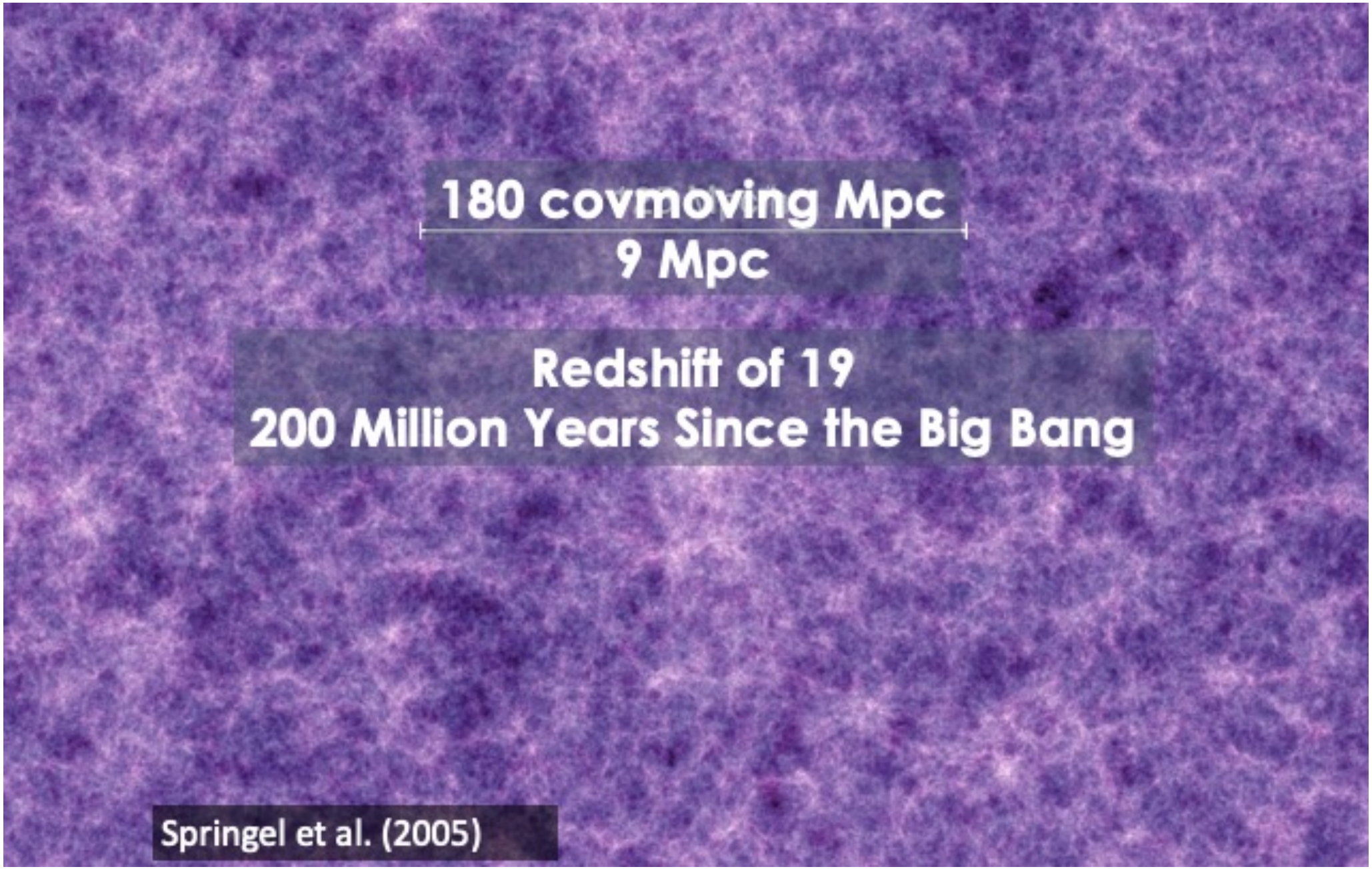

Hubble Ultra Deep Field - Out to 14 Billion Light Years

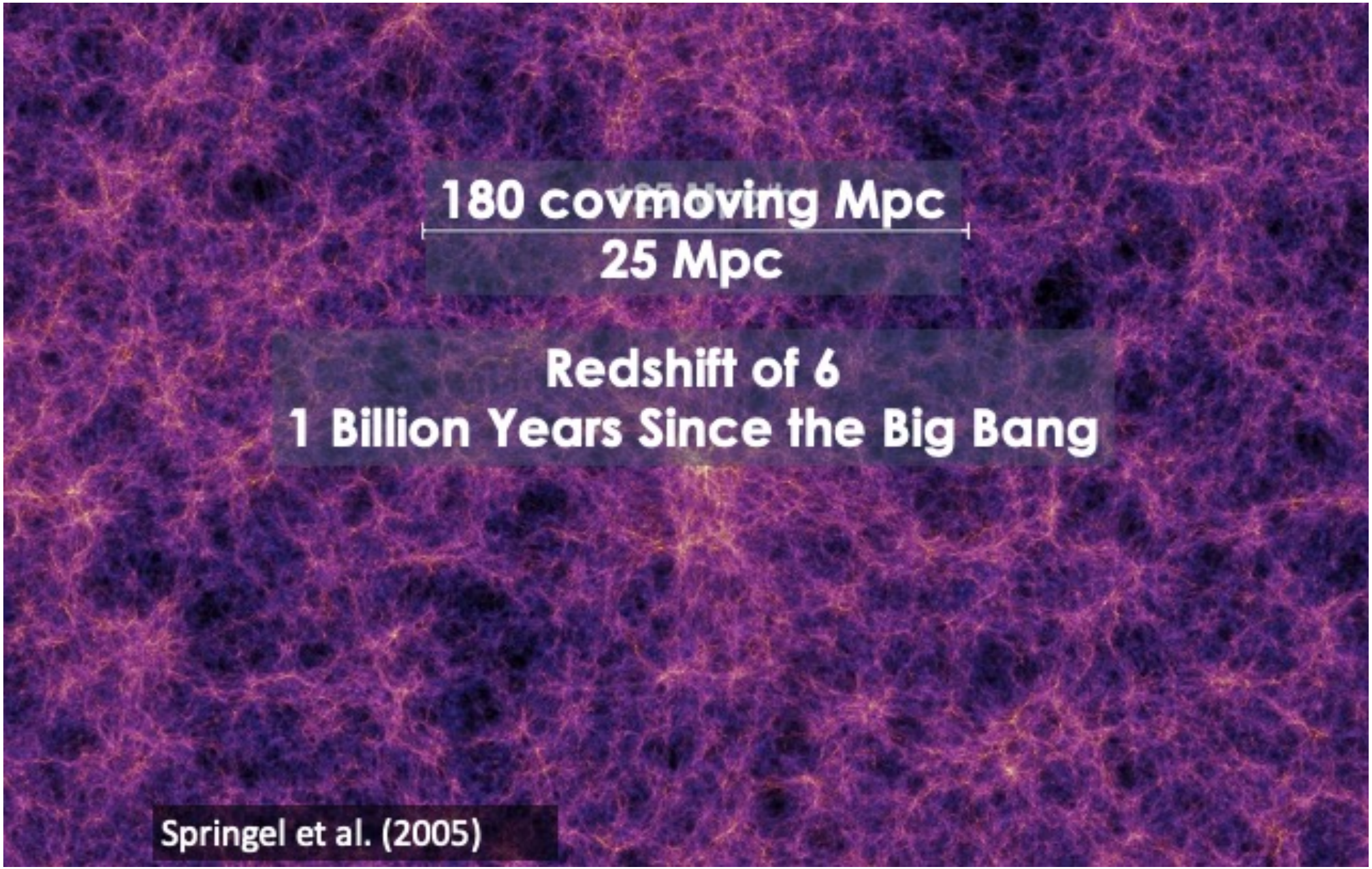

Redshift
100
10
1
0.1
0.01
0.001
0
2
4
6
8
10
12
14
Time (Gyrs)

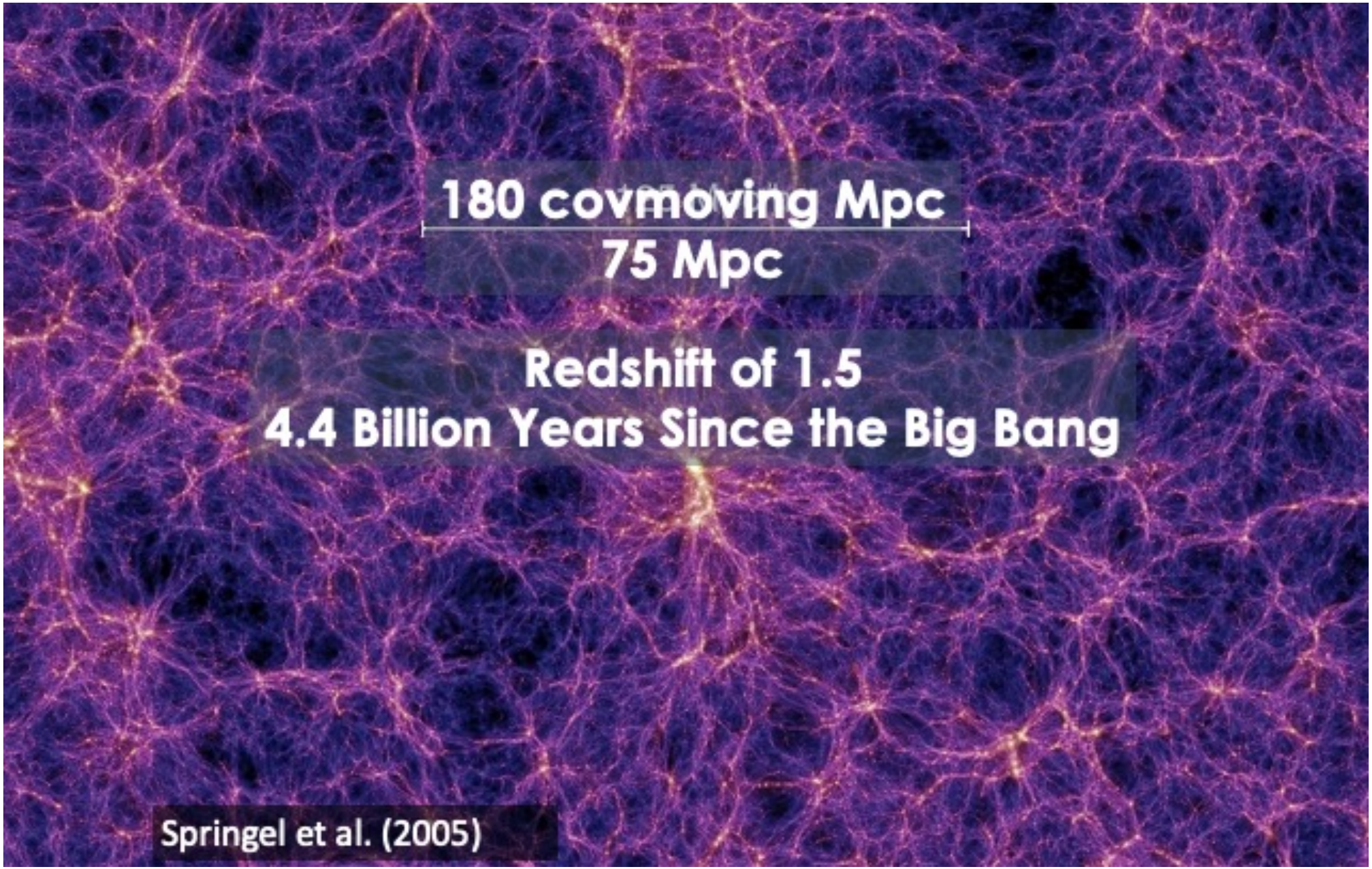

The Electromagnetic Spectrum
gamma rays
X-rays
ultraviolet
visible
infrared
microwaves
radio
Planck Legacy Release 2018
ESA and the Planck Collaboration

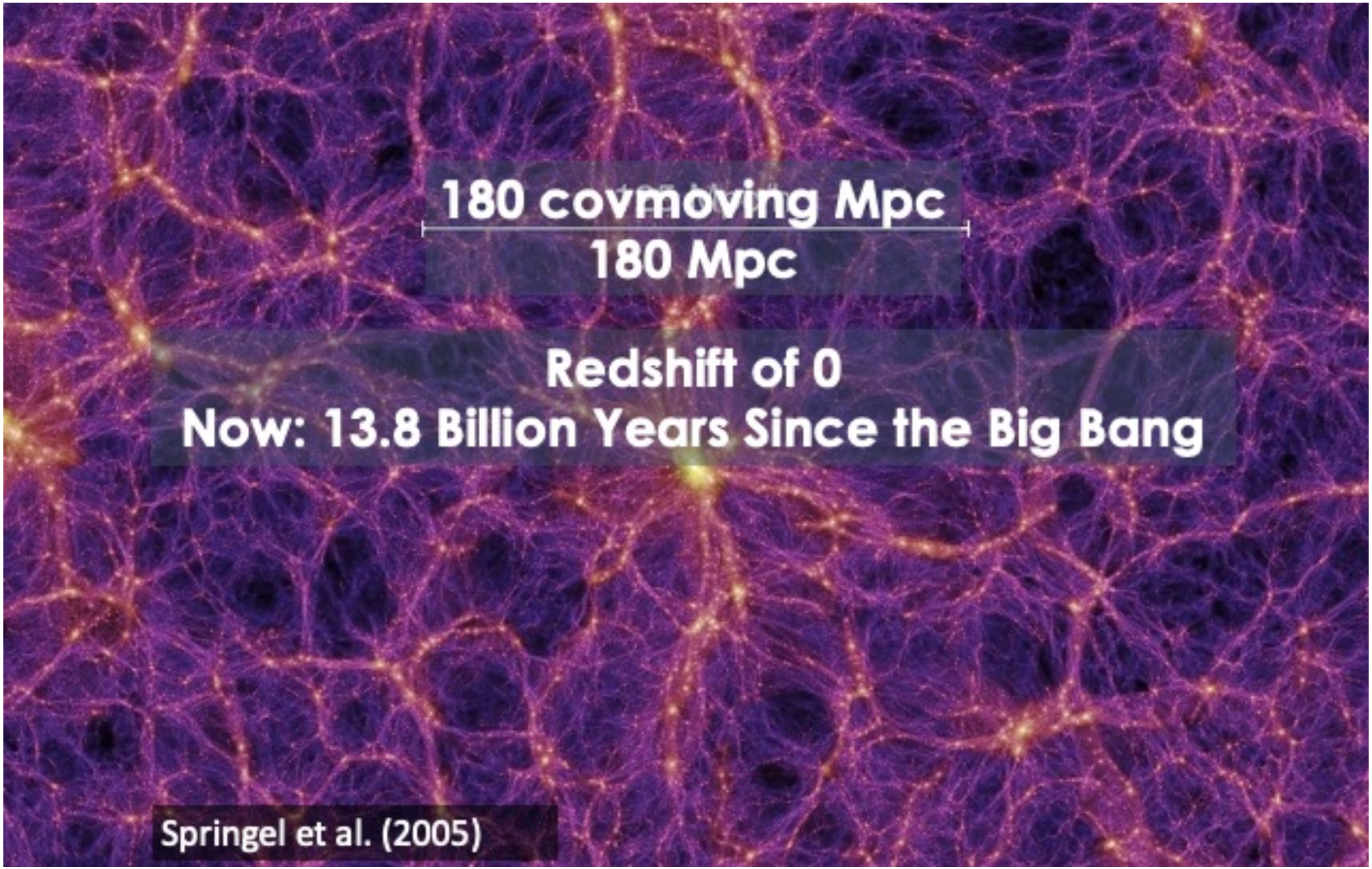

Baryons
4.5±0.5%
Dark
Energy
72±4%
Dark
Matter
23±3%

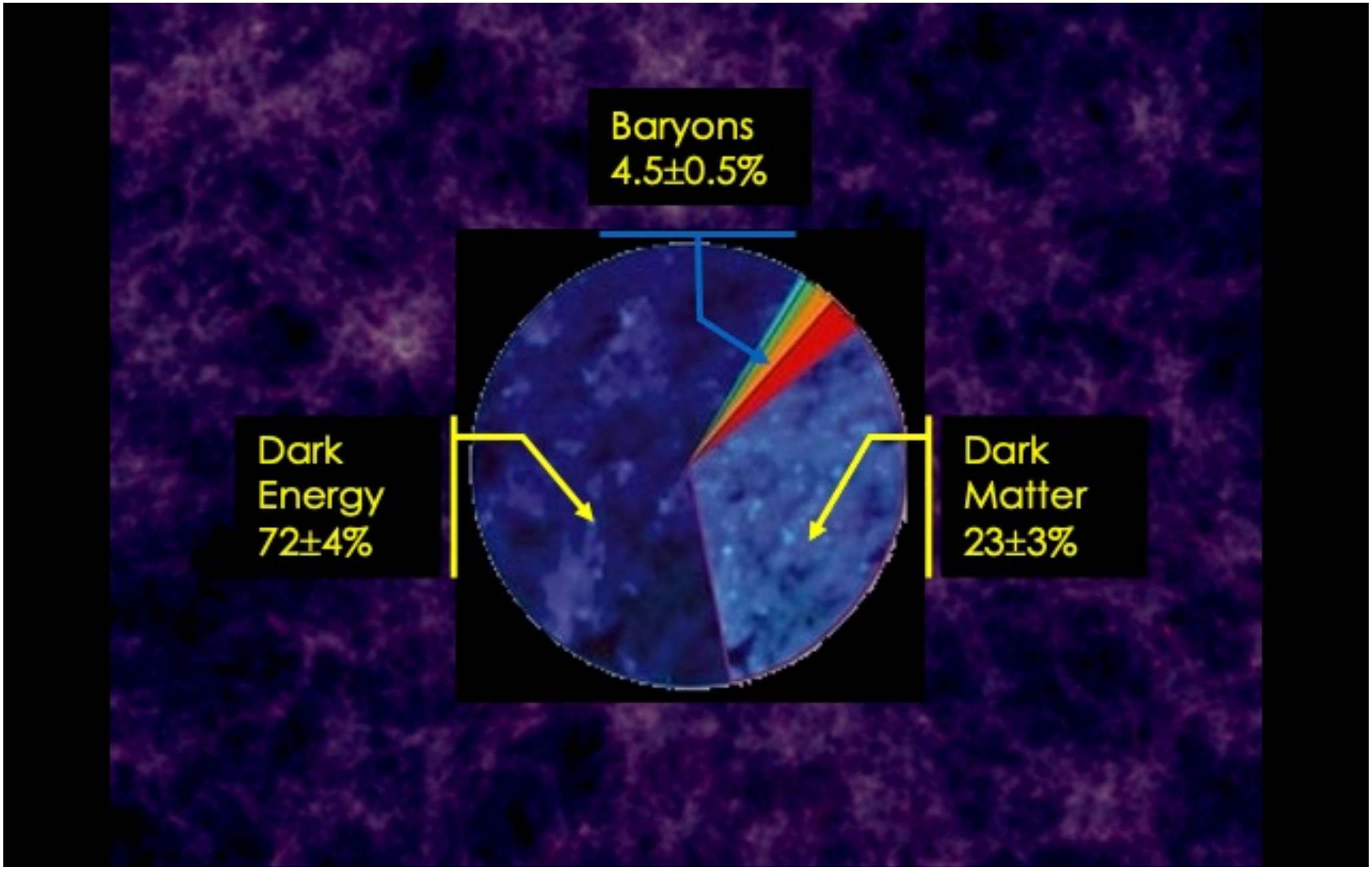

Legacy Release 2018
ESA and the Planck C

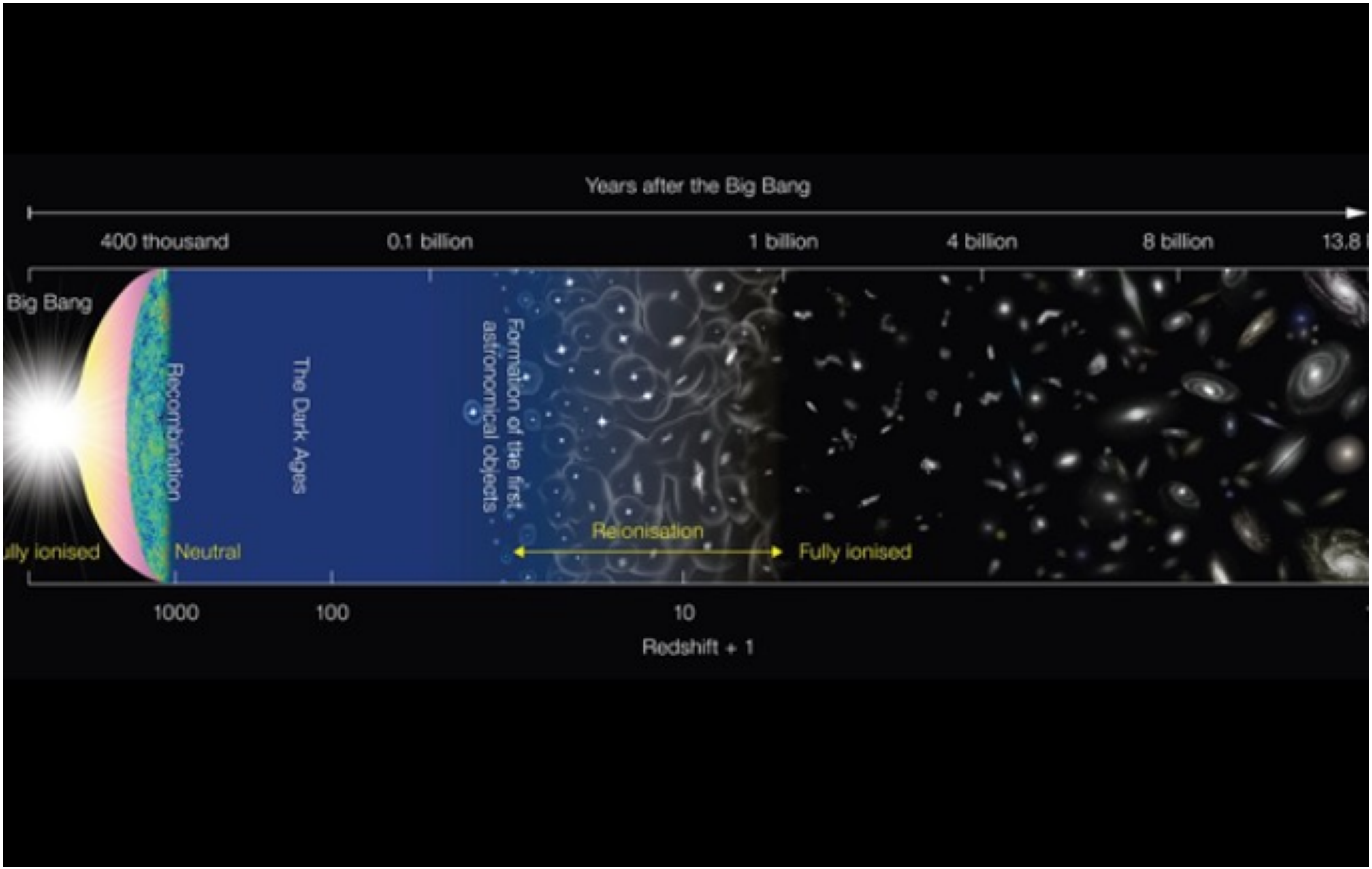

180 covmoving Mpc
9 Mpc
Redshift of 19
200 Million Years Since the Big Bang
Springel et al. (2005)

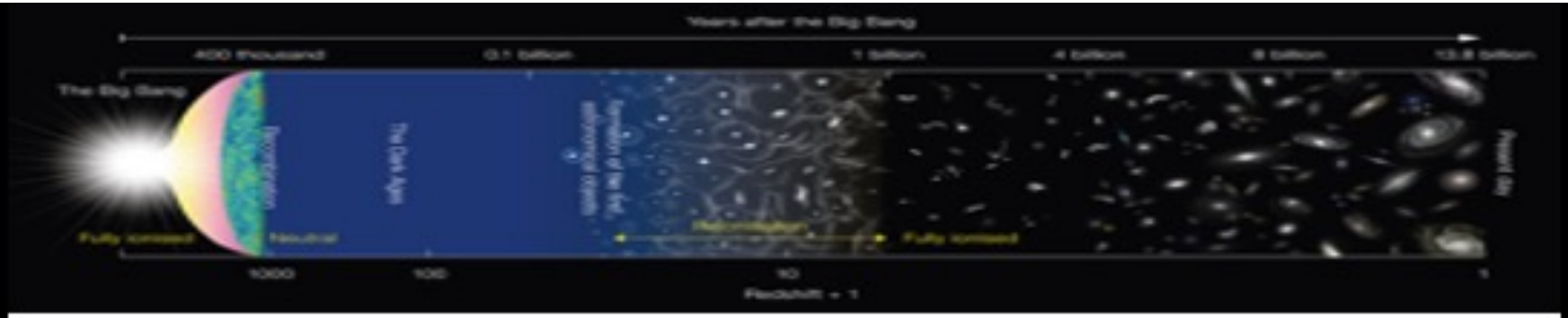

180 comoving Mpc
25 Mpc
Redshift of 6
1 Billion Years Since the Big Bang
Springel et al. (2005)

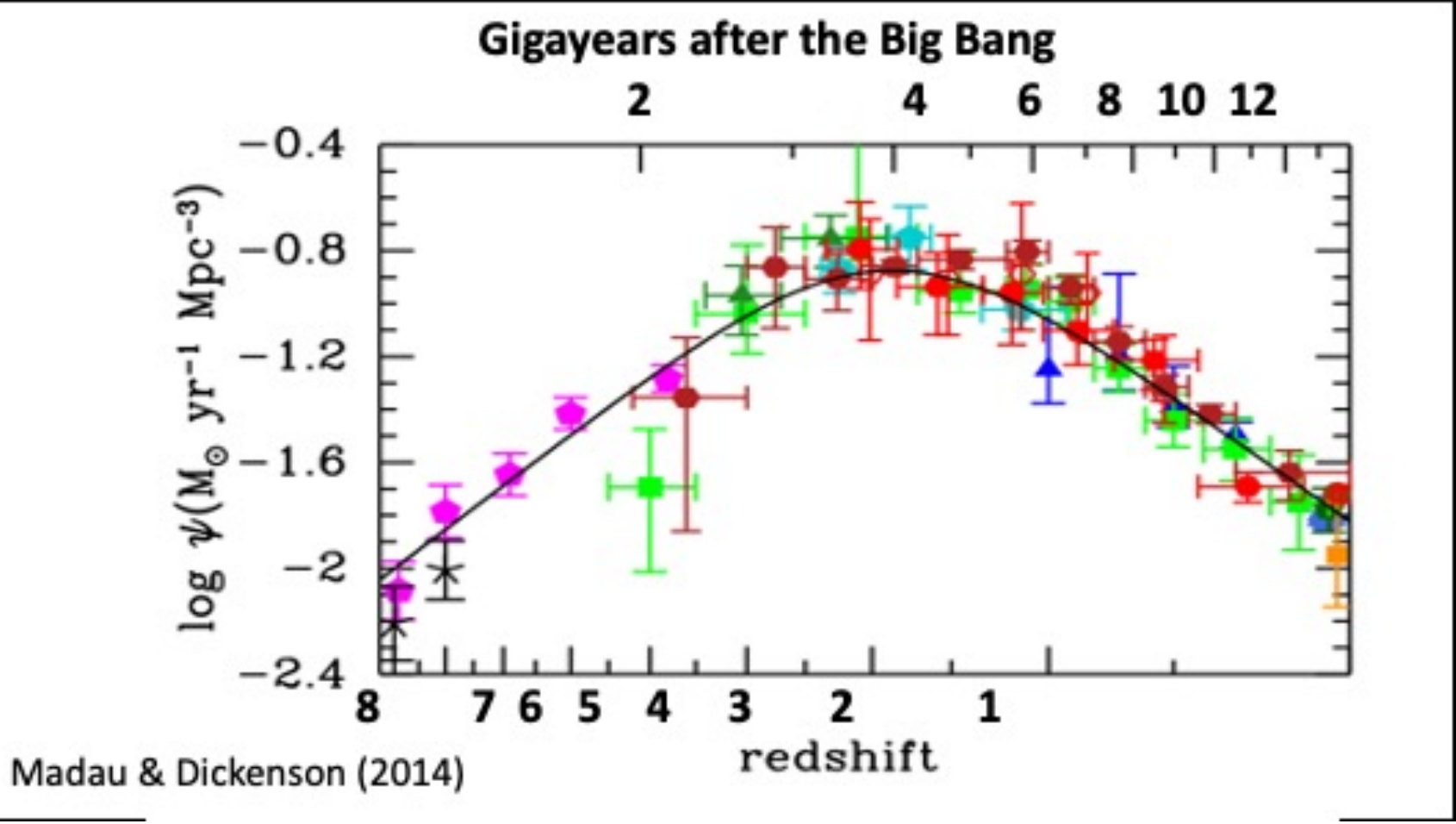

180 covmoving Mpc
75 Mpc
Redshift of 1.5
4.4 Billion Years Since the Big Bang
Springel et al. (2005)


180 covmoving Mpc
180 Mpc
Redshift of 0
Now: 13.8 Billion Years Since the Big Bang
Springel et al. (2005)

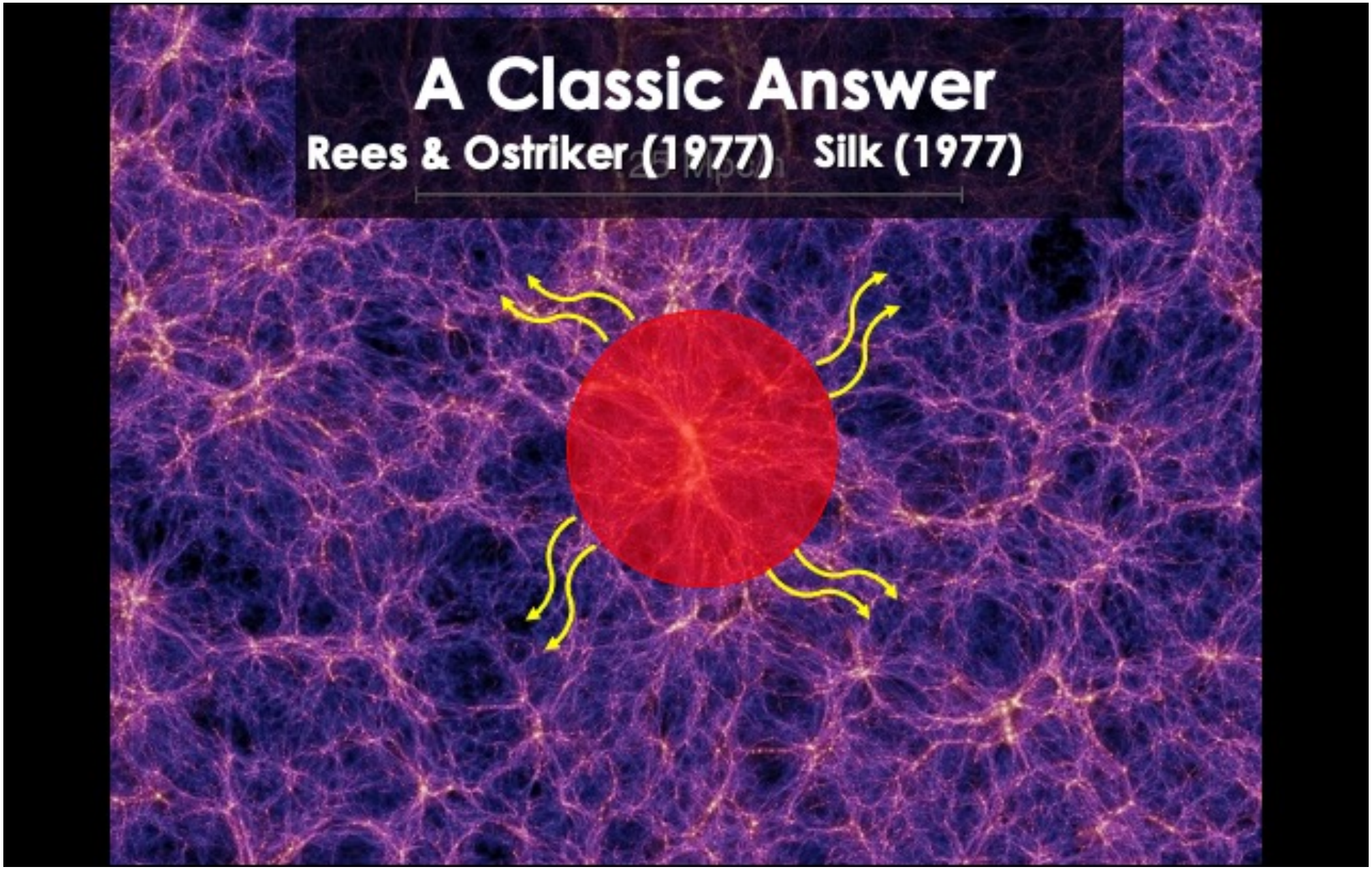

Baryons
4.5±0.5%
Dark
Energy
72±4%
Dark
Matter
23±3%


Years after the Big Bang
400 thousand
0.1 billion
1 billion
4 billion
8 billion
13.8
Big Bang
Recombination
The Dark Ages
Formation of the first astronomical objects
Reionisation
lly ionised
Neutral
Fully ionised
1000
100
10
Redshift + 1





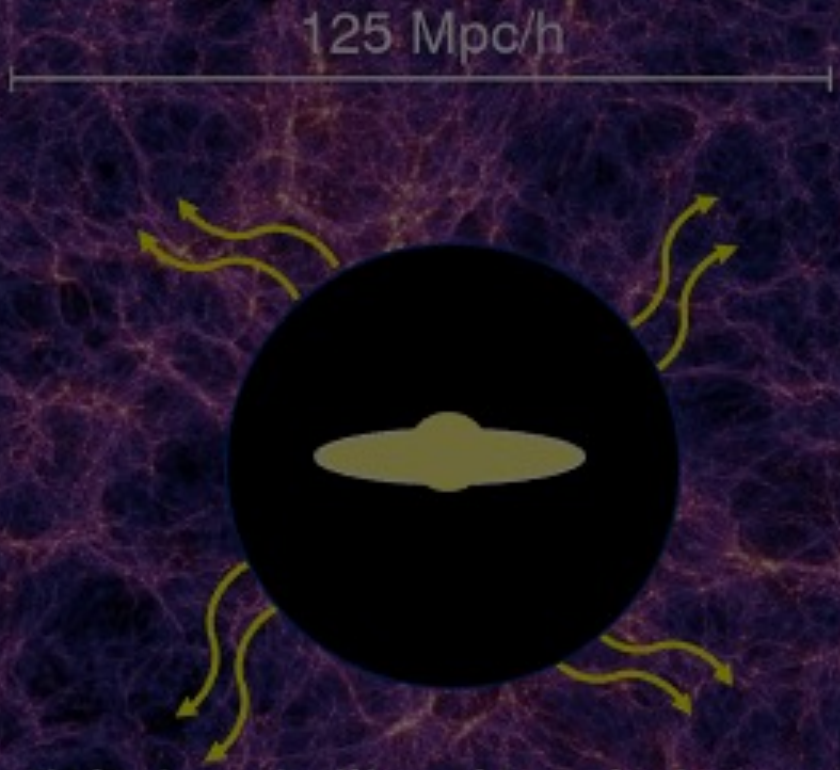
Madau & Dickenson (2014)


A Classic Answer
Rees & Ostriker (1977) Silk (1977)

A Classic Answer

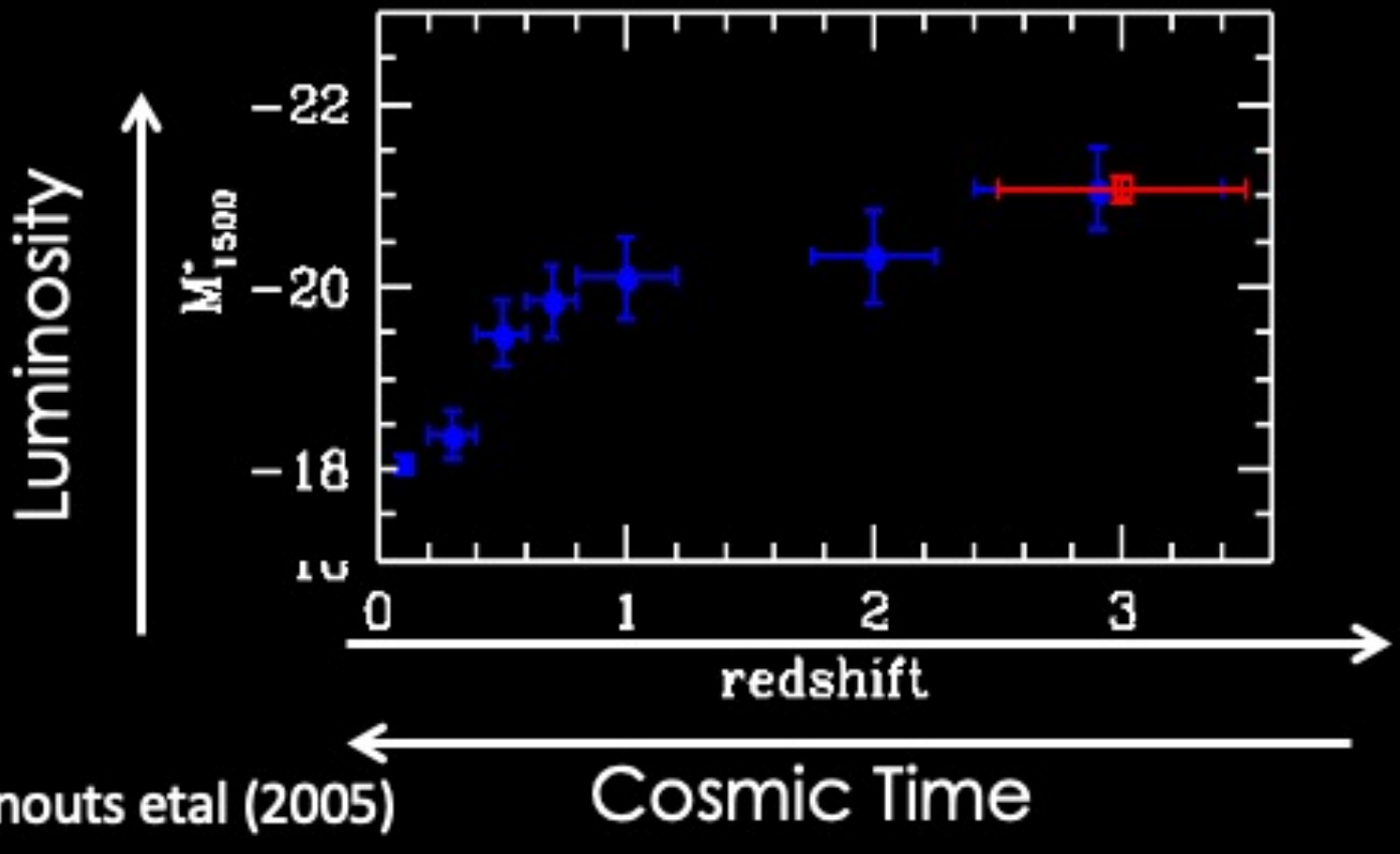
Rees & Ostriker (1977) Silk (1977)

Problem #1 Overcooling



On paper this look like it might work, but with full simulations, it gives supermassive galaxies that don't exist!

Prob # 2: Antihierarchical Evolution "Downsizing"



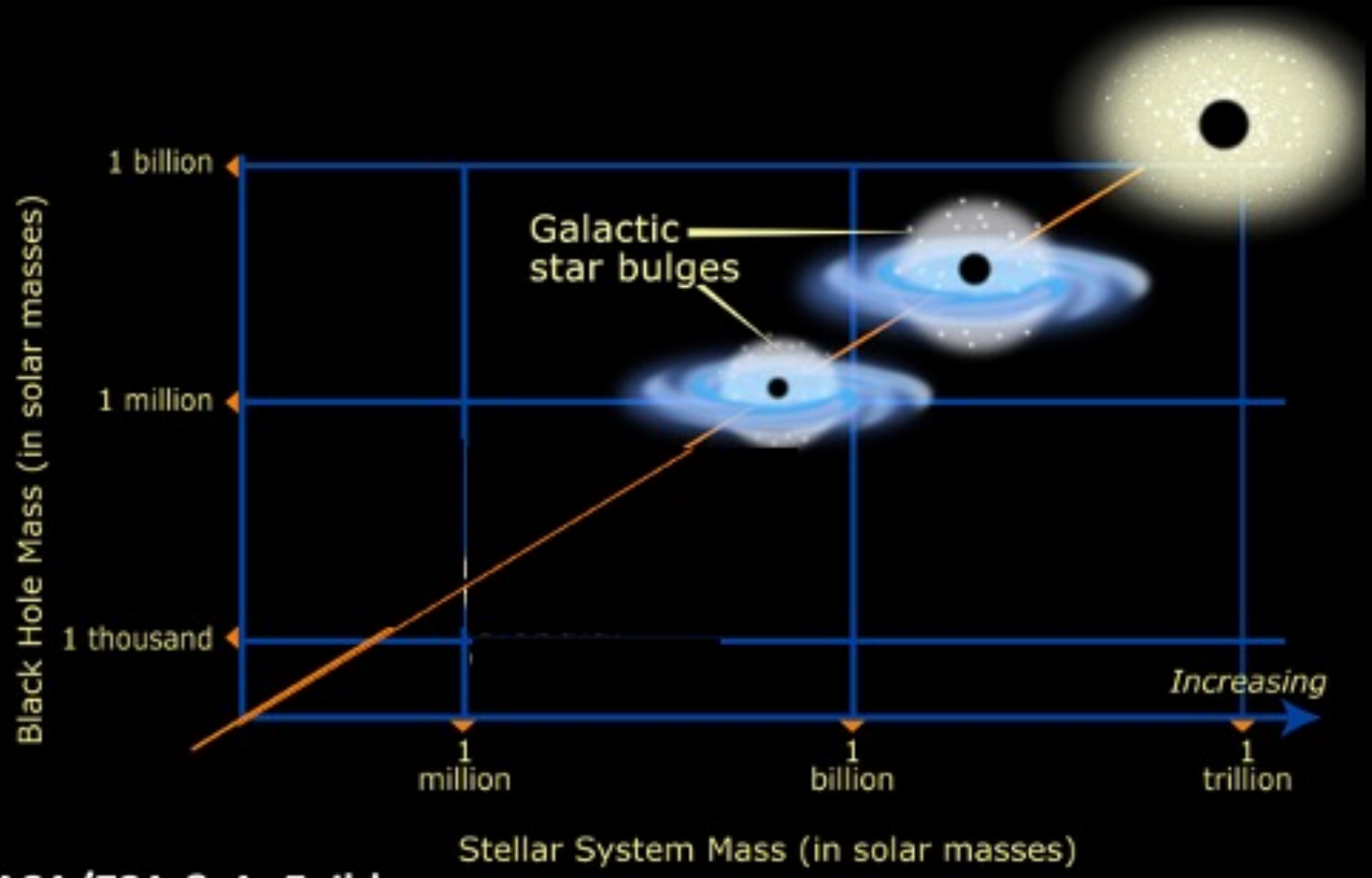
Arnouts etal (2005)


Messier 49- 56 Million Light Years Away

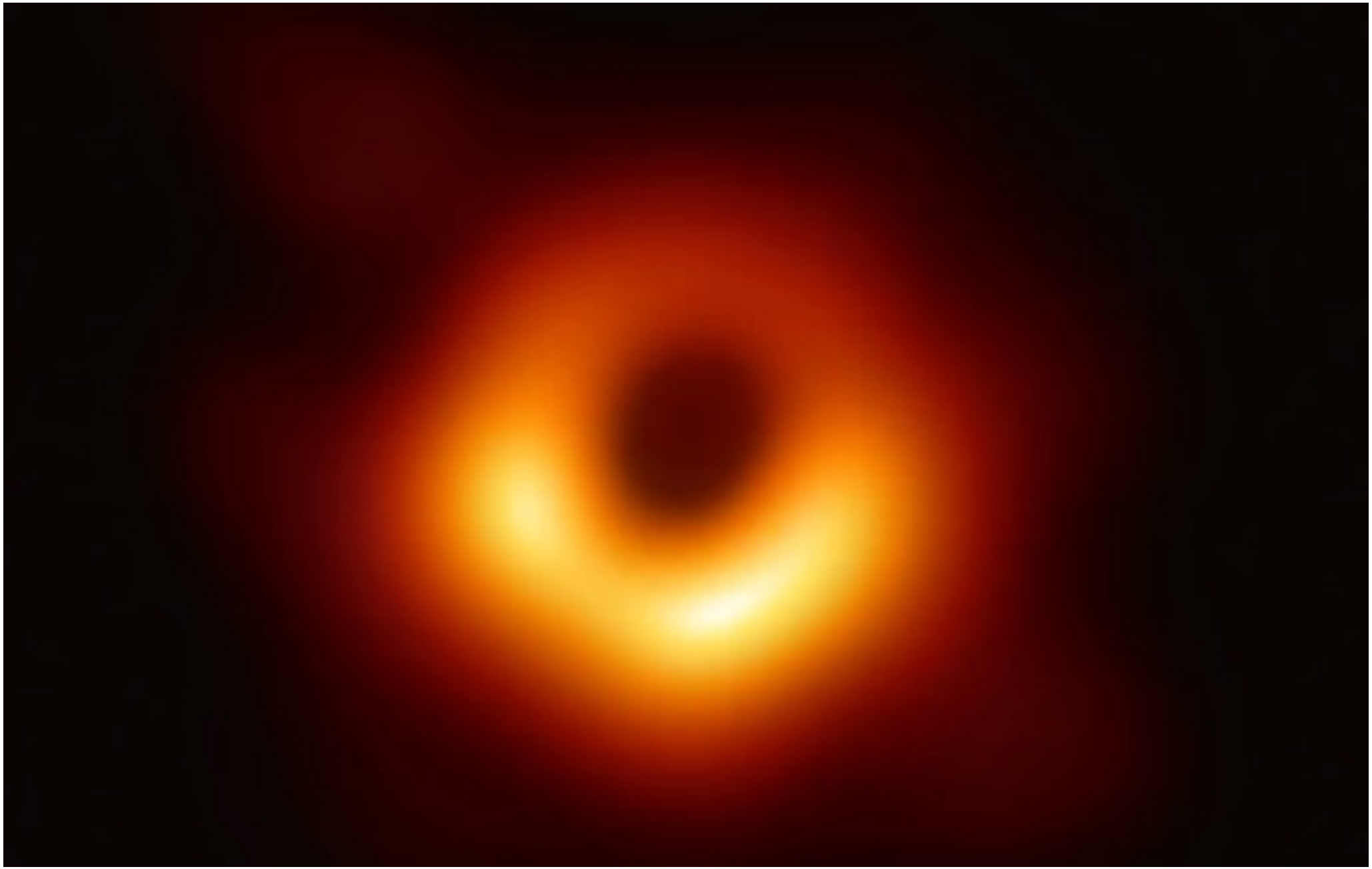

VV 191a/b - 700 Million Light Years Away

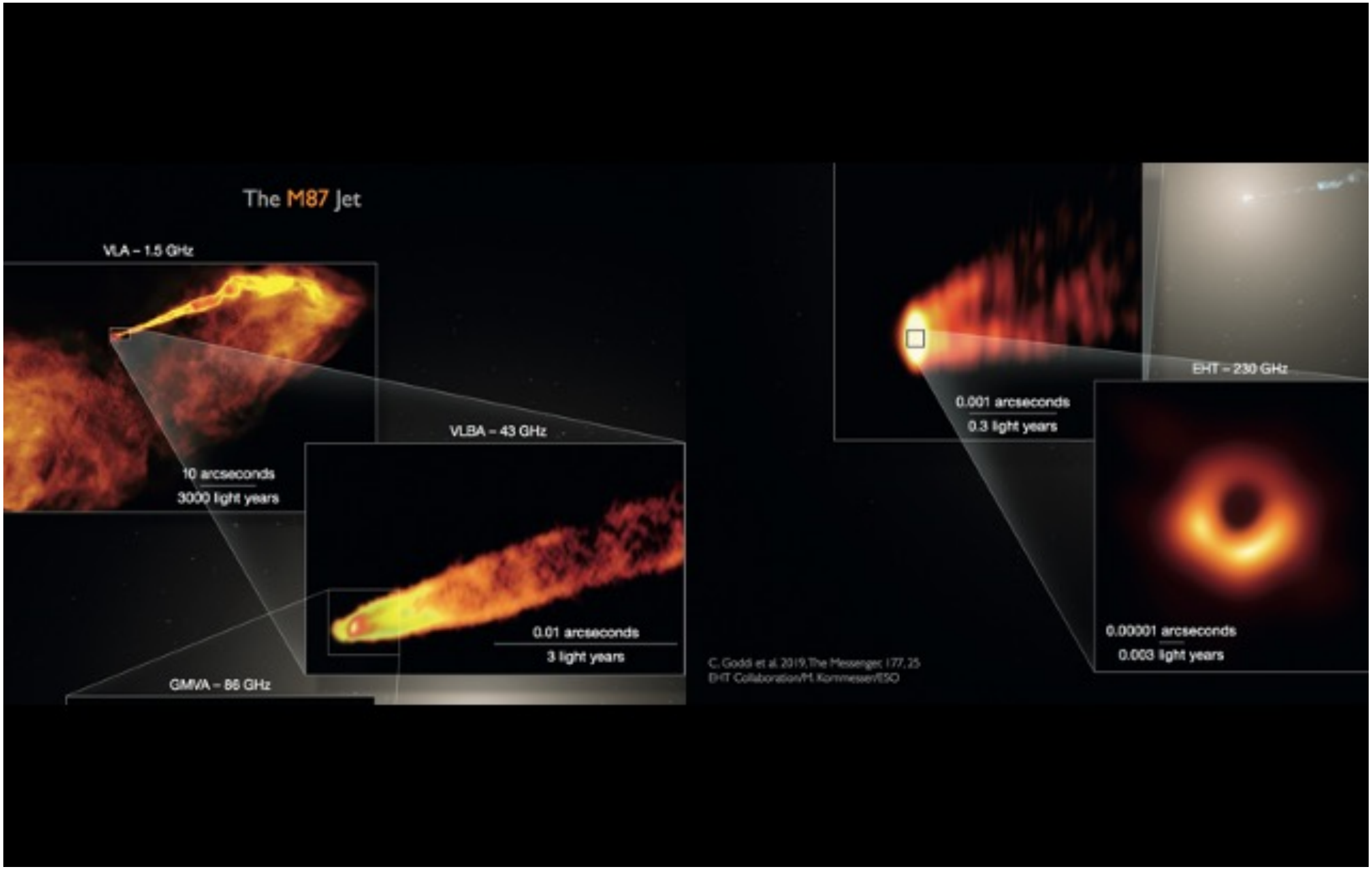

A Mystery
How Can Hierarchical Dark Matter Structure Formation
+
Hierarchical Cooling
=
Antihierarchical History for Galaxies?

The more massive the merger, the more massive the Black Hole



NASA/ESA & A. Feild



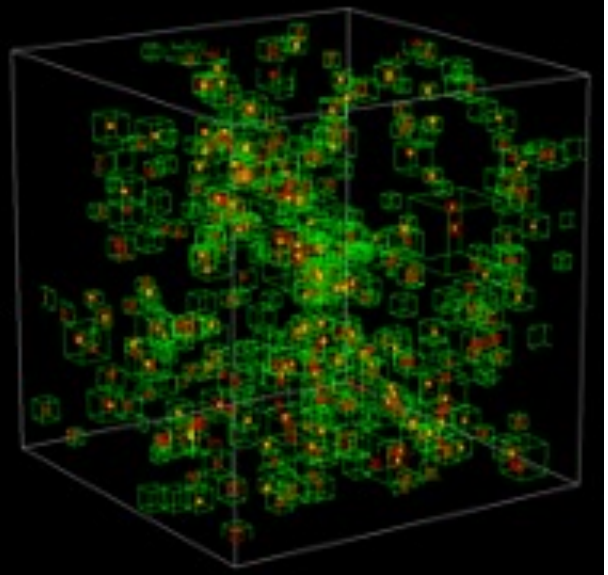

The M87 Jet
VLA – 1.5 GHz
10 arcseconds
3000 light years
VLBA – 43 GHz
0.01 arcseconds
3 light years
GMVA – 86 GHz
EHT – 230 GHz
0.001 arcseconds
0.3 light years
0.00001 arcseconds
0.003 light years
C. Goddi et al. 2019, The Messenger, 177, 25
EHT Collaboration/M. Kommesser/ESO

Active Black Hole Feedback

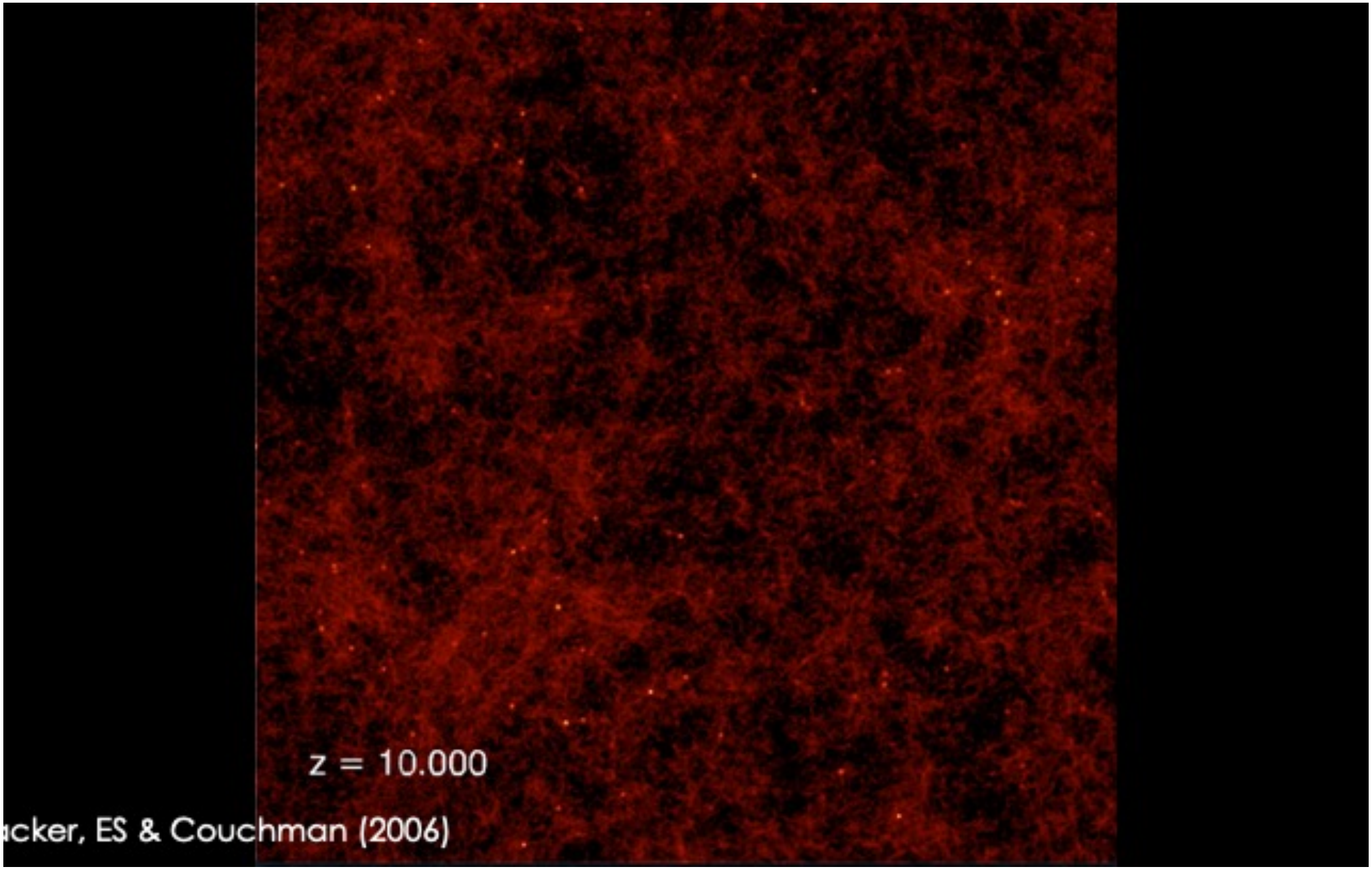
ES & Oh (2004) / Thacker, ES & Couchman (2006)

- Assume some small fraction, ε_k=0.05 of an active black hole's luminosity is converted to mechanical input
- Energy deposited as heat into surrounding medium.

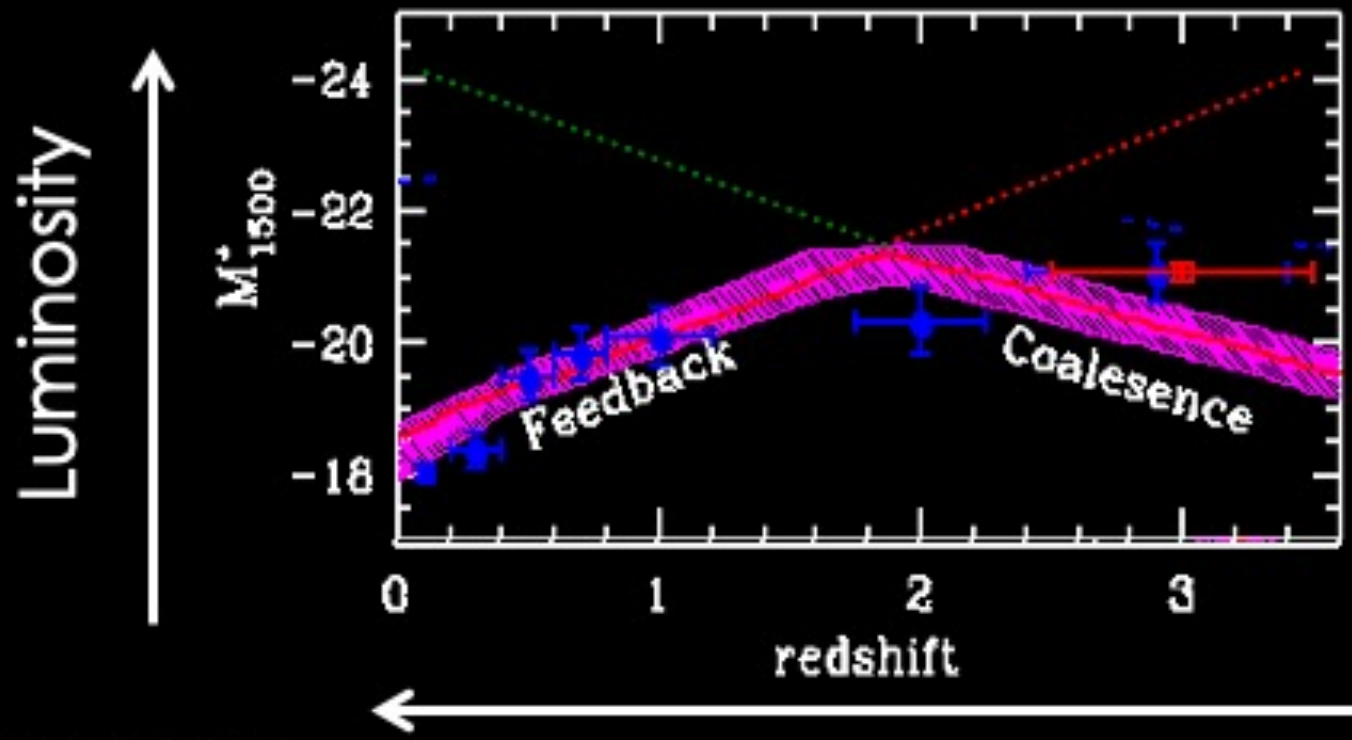
- *OpenMP version of the 'Hydra' SPH code*
- *146 cMpc/h box, 2x640^3 particles, to z=1.2*
- *2x 640^3 particles (half gas, half dark matter)*
- Largest SPH simulation ever carried out at that time




NASA

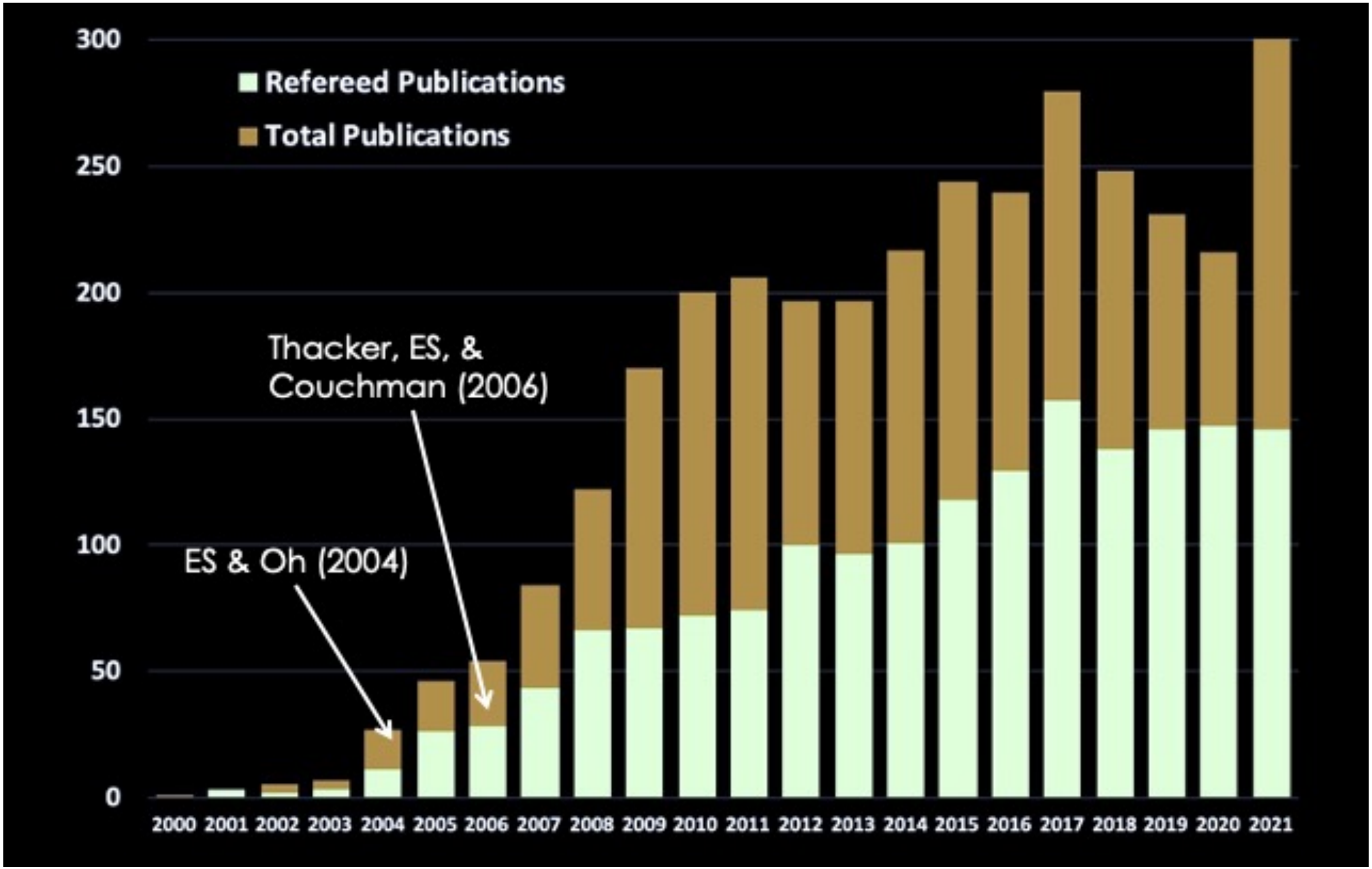

z = 10.000
acker, ES & Couchman (2006)

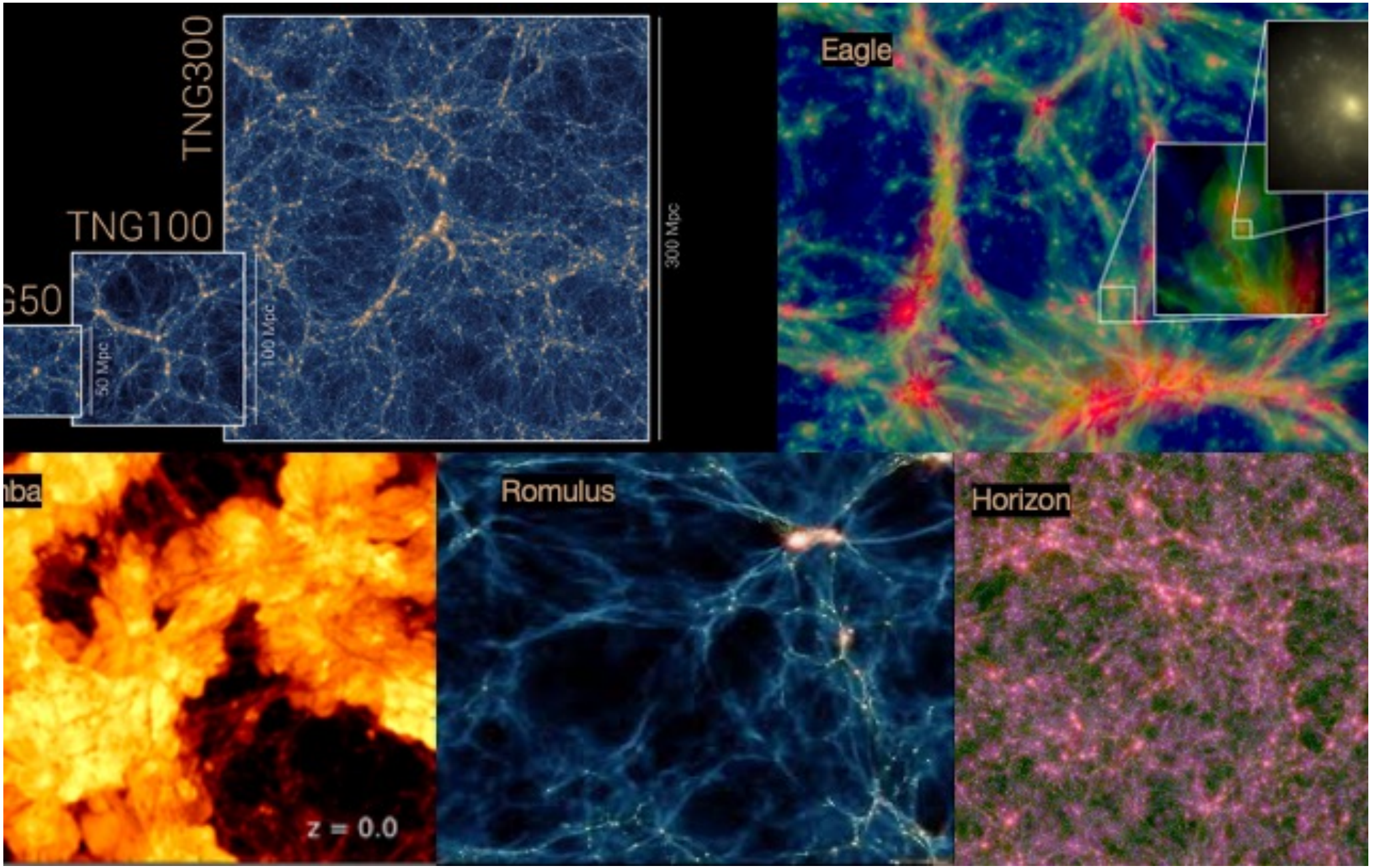
Downsizing



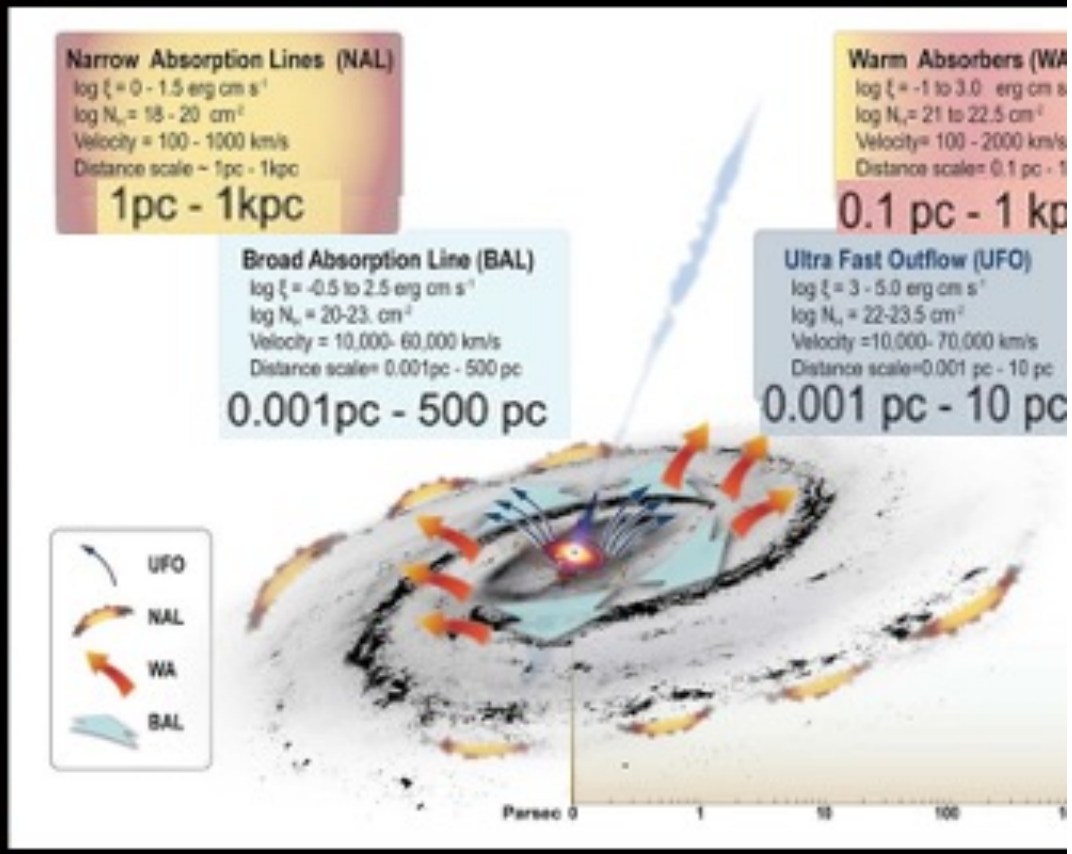
ES & Oh (2004)

ES, Silk, & Bouwens (2005)


300
250
200
150
100
50
0
Refereed Publications
Total Publications
Thacker, ES, &
Couchman (2006)
ES & Oh (2004)
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

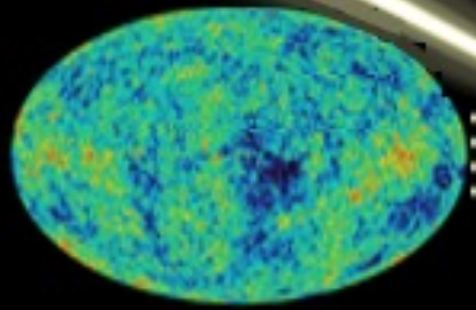

TNG300
TNG100
G50
300 Mpc
100 Mpc
50 Mpc
Eagle
mba
z = 0.0
Romulus
Horizon

Finoguenov et al (2008)

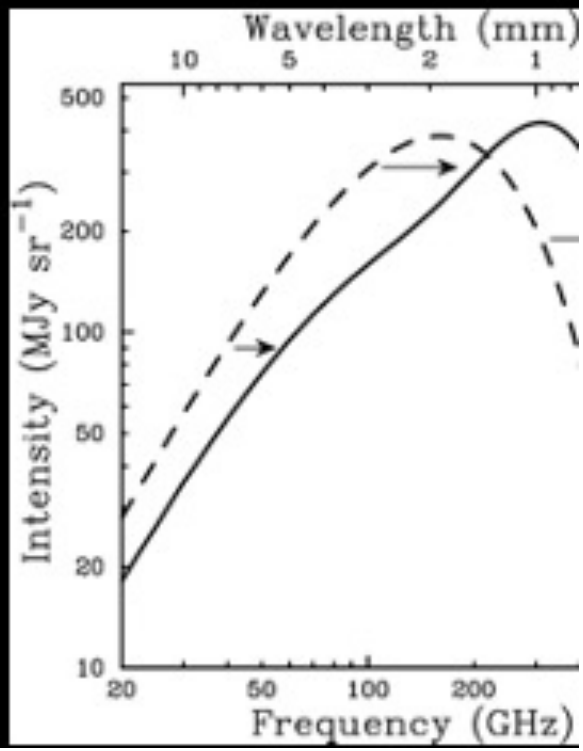


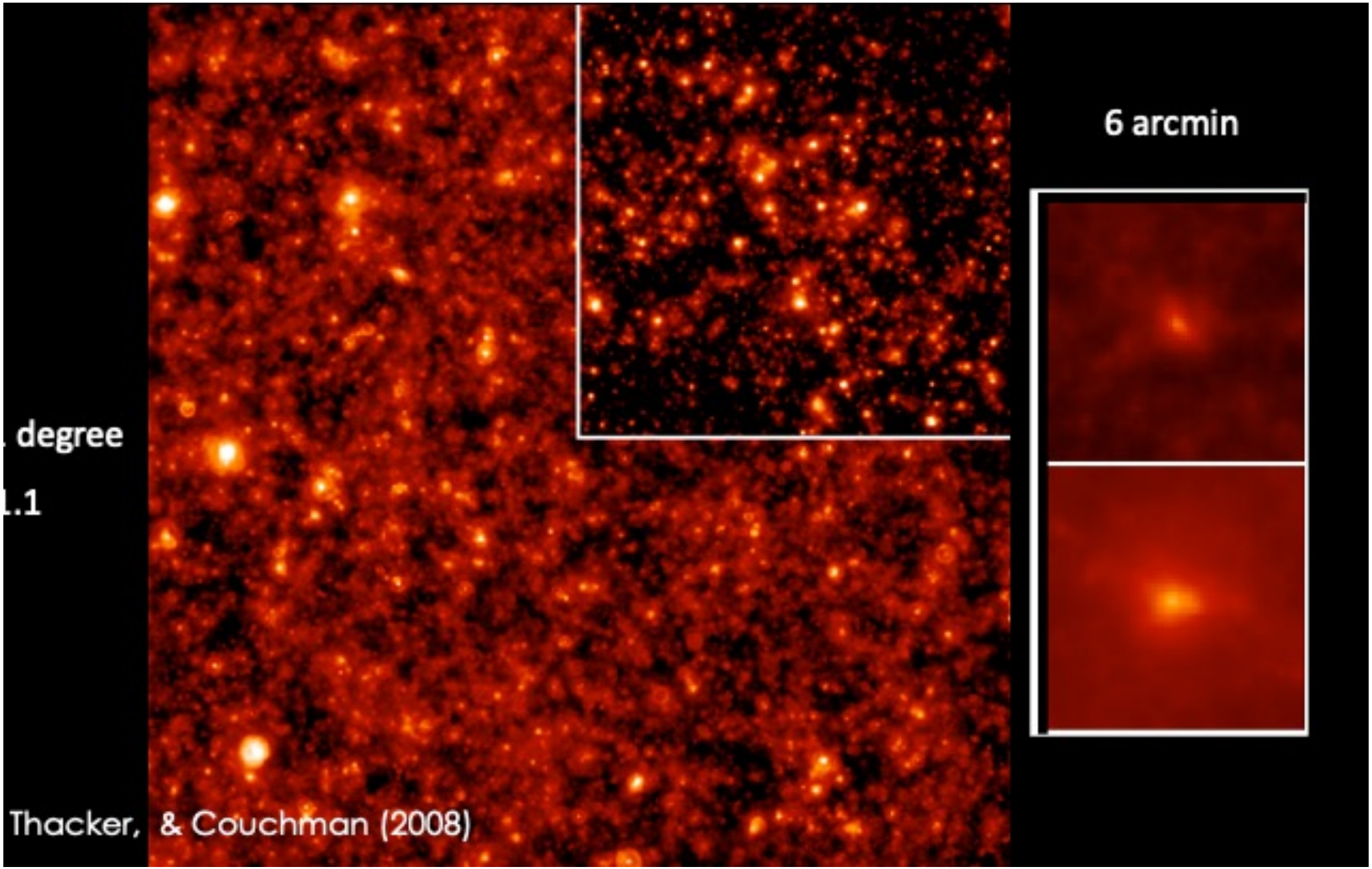
Laha et al (2020)

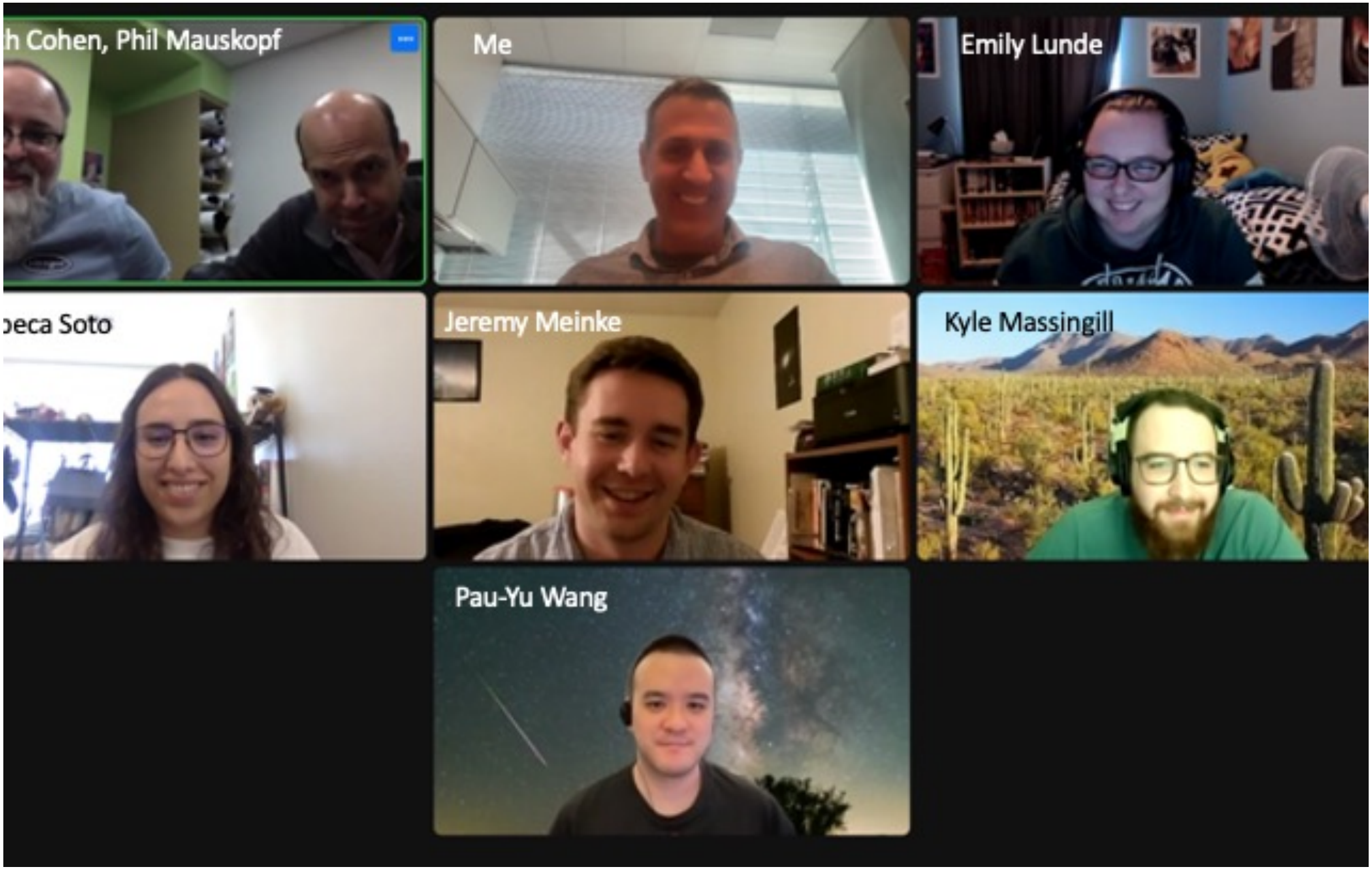
Thermal Sunyaev-Zel'dovich Effect

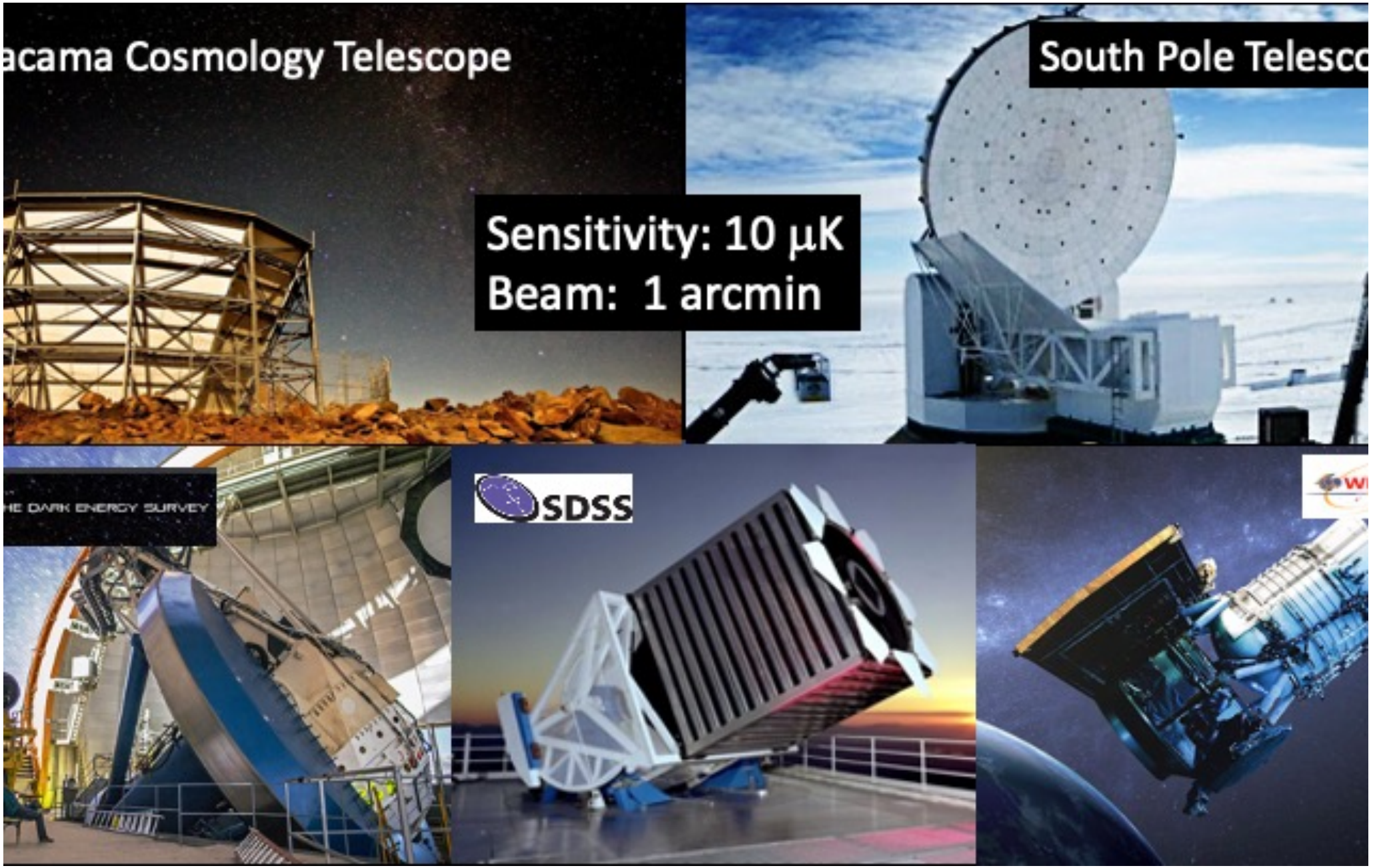


Signal α Gas Density Along Sightline
× Temperature Along Sightline
= Pressure Along Sightline




6 arcmin
degree
1.1
Thacker, & Couchman (2008)

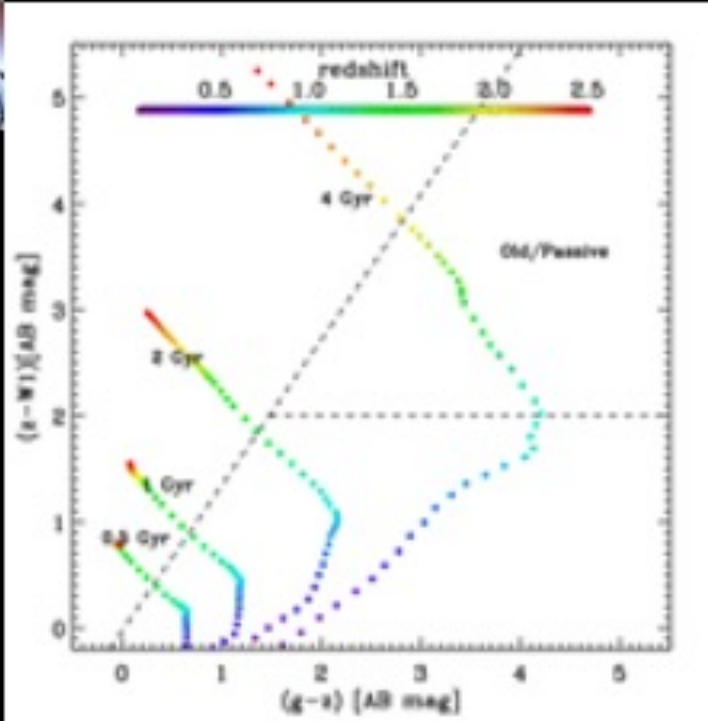

h Cohen, Phil Mauskopf
Me
Emily Lunde
beca Soto
Jeremy Meinke
Kyle Massingill
Pau-Yu Wang


acama Cosmology Telescope
South Pole Telesco
Sensitivity: 10 μK
Beam: 1 arcmin
HE DARK ENERGY SURVEY
SDSS

th Cohen

Selection and Sample

WISE



DES/SDSS

age > 1 Gyr SSFR < 0.01 Gyr^{-1}

Catalog	N	z	$\log_{10}(\overline{M_*}/M_\odot)$
SPT + ACT Overlap	94452	1.06	11.41
ACT Only	387627	1.07	11.44

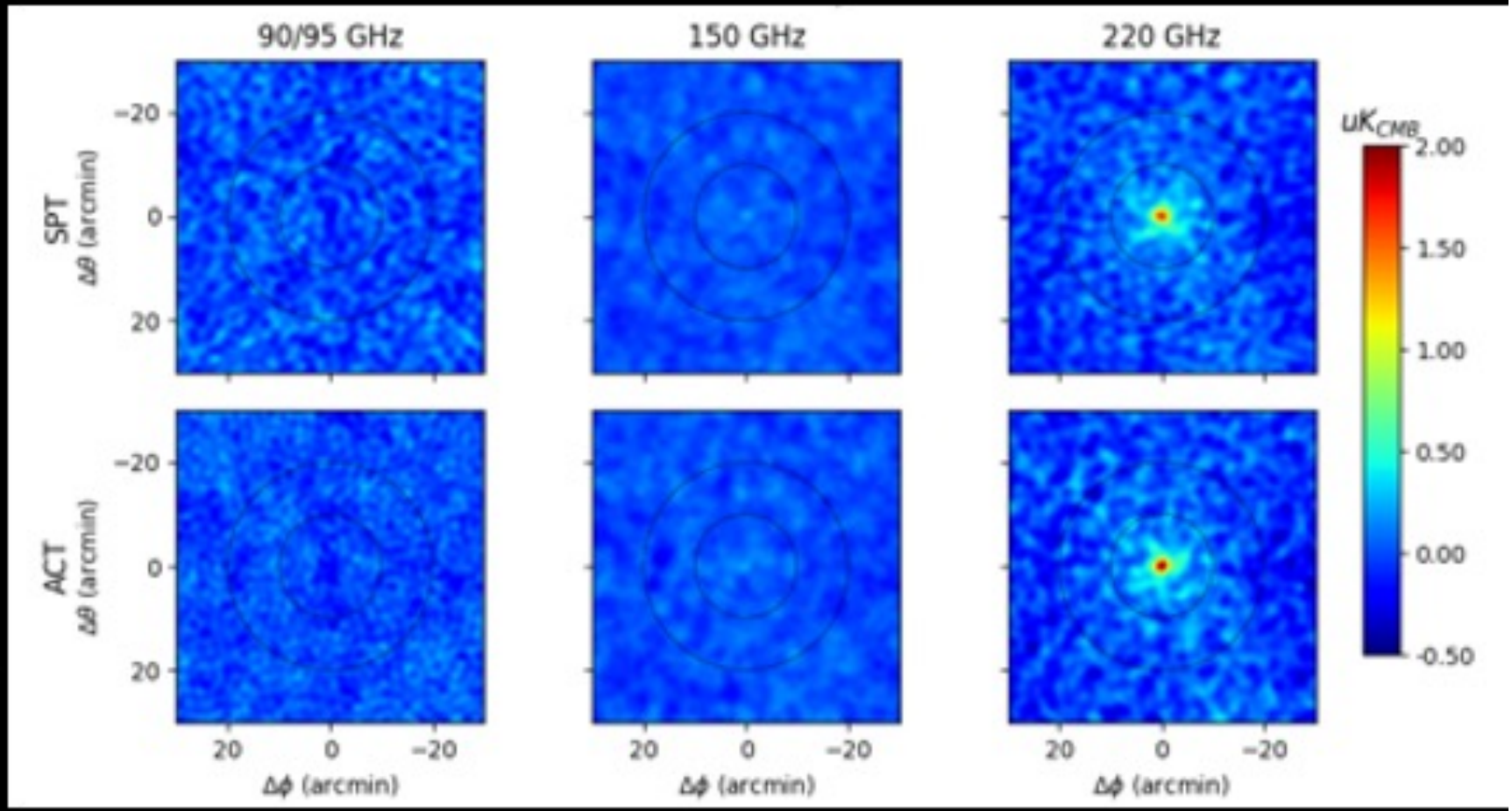
2600 deg^2

18,000 deg^2

Meinke, et al. (2021; 2022)

eremey
leinke

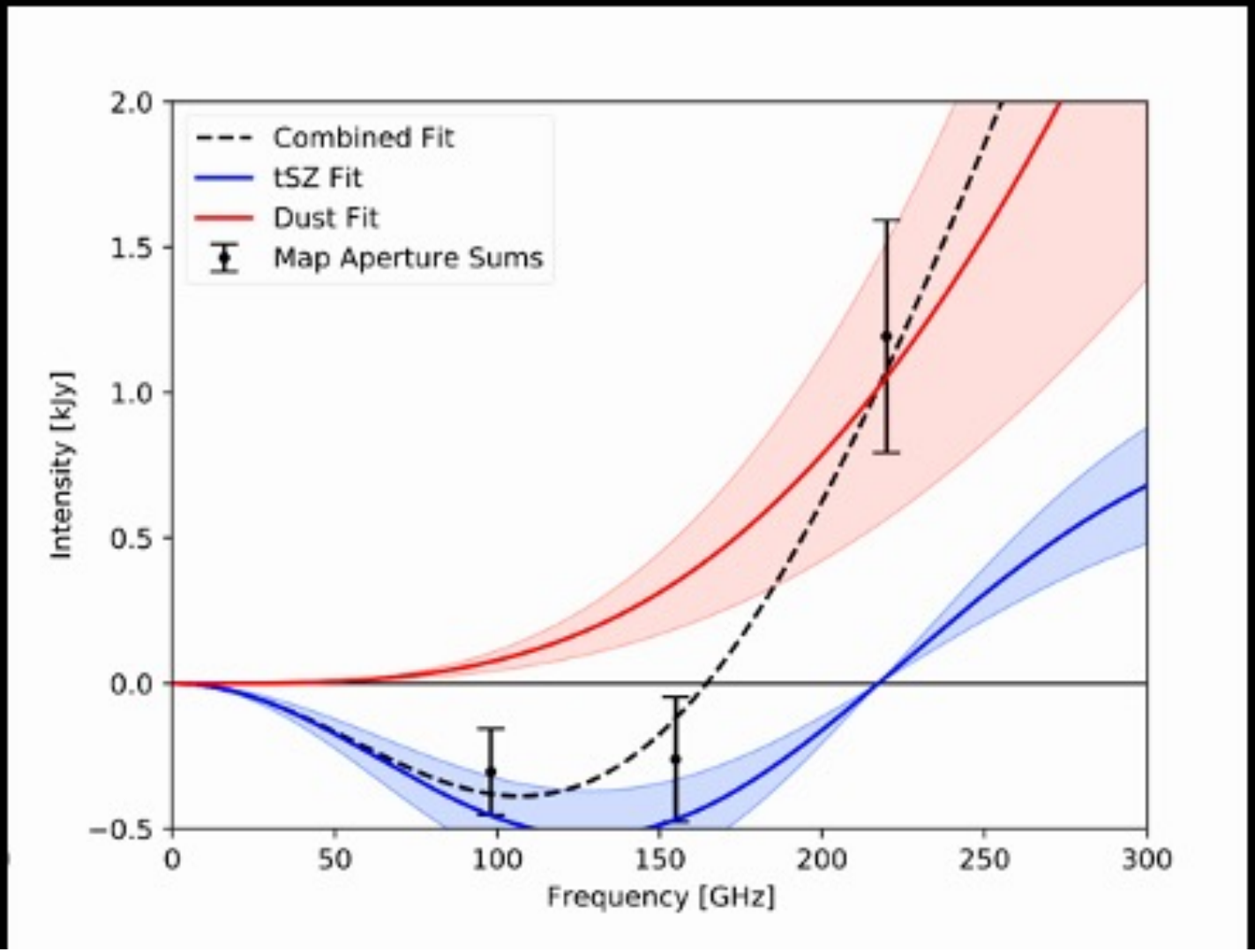
Stacked Signals



Meinke, et al.
021; 2022)

eremey
leinke

Fitting to Dust and SZ



leinke, et al.
021; 2022)

eremey
leinke

Stacked SZ Profiles

Catalog	N	z	$\log_{10}(\overline{M_*}/M_\odot)$
SPT + ACT Overlap	94452	1.06	11.41
ACT Only	387627	1.07	11.44

Compton-y [unitless]

10^{-7}

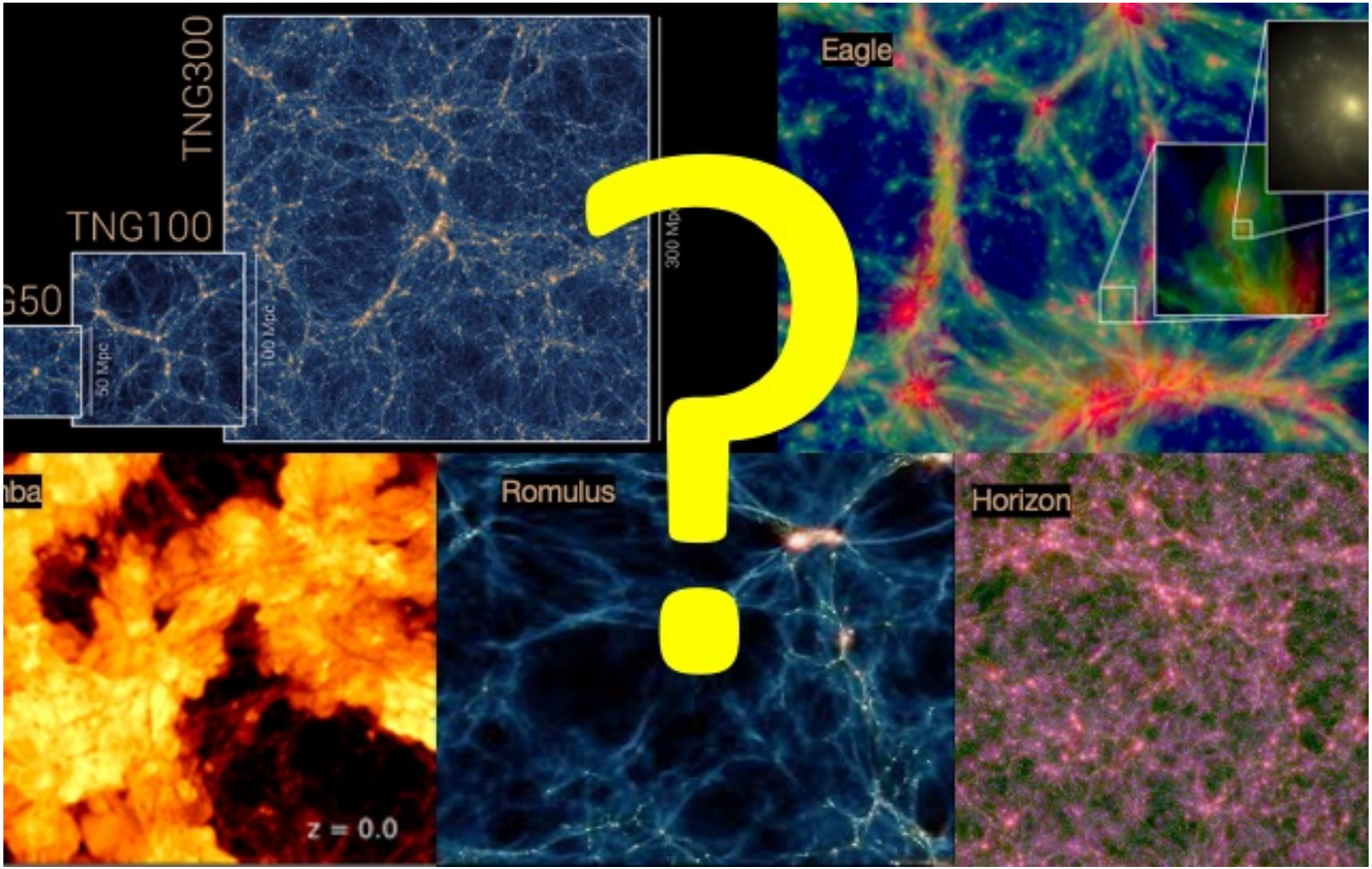
10^{-8}

10^{-9}

0.0 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0

R [Mpc]

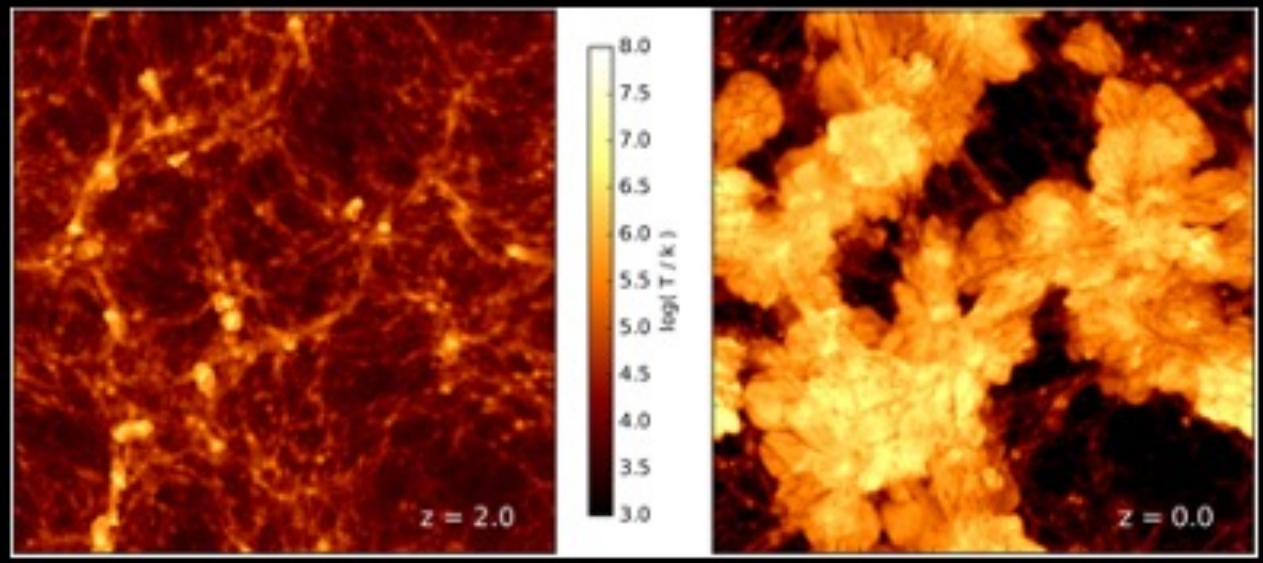
Meinke, et al.
021; 2022)


TNG300
TNG100
G50
50 Mpc
100 Mpc
300 Mpc
Eagle
?
nba
z = 0.0
Romulus
Horizon

SIMBA

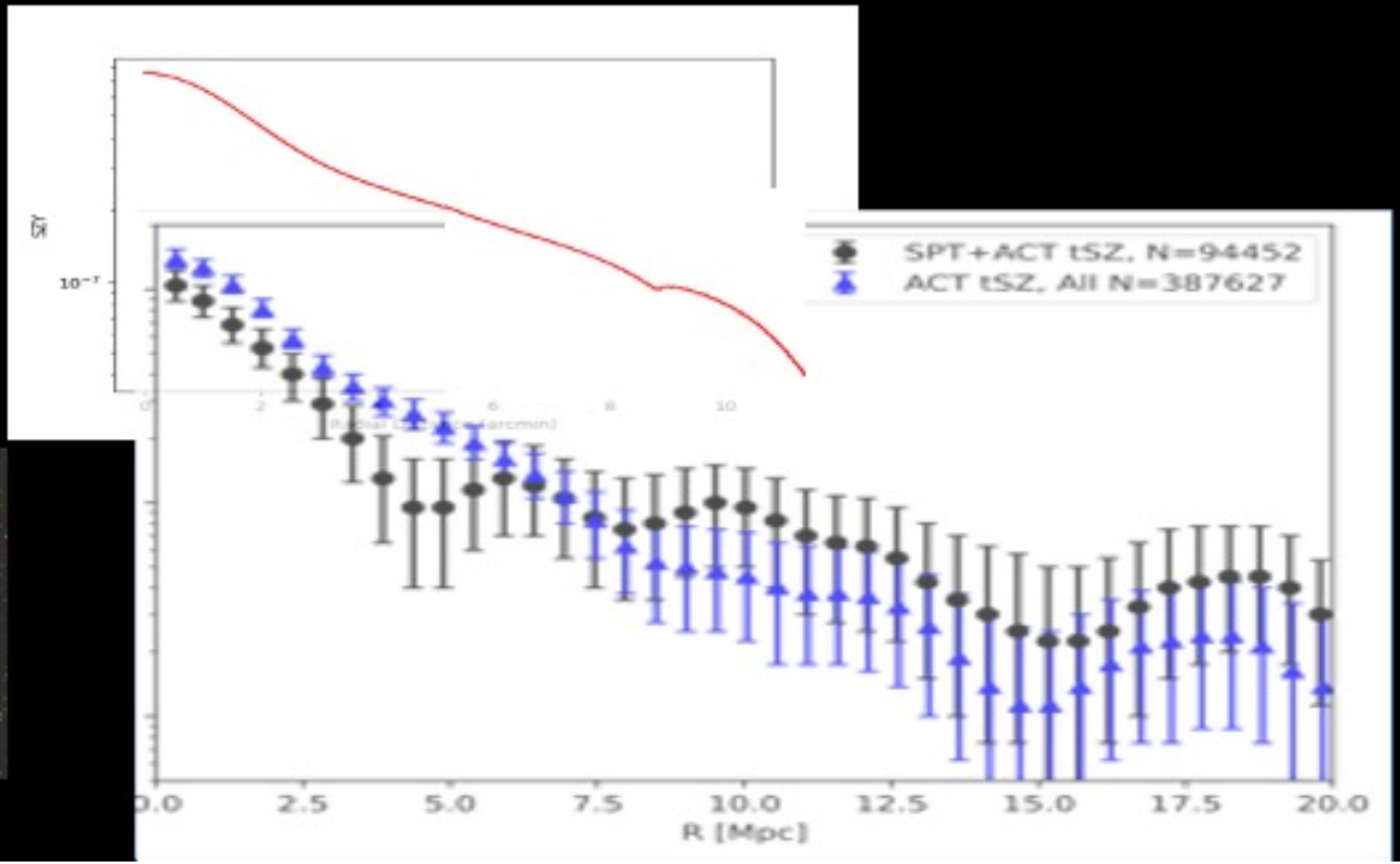
- MPI version of the GIZMO meshless code
- 100 cMpc/h box, 2 x1024^3 particles, to z=0
- Includes updates to Mufasa's sub-resolution star formation and feedback prescriptions.
- AGN are associated torque limited accretion (cold) / Bondi accretion (hot).
- 3-25% of energy in light goes into outflows depending L_{edd}

ylar Grayson

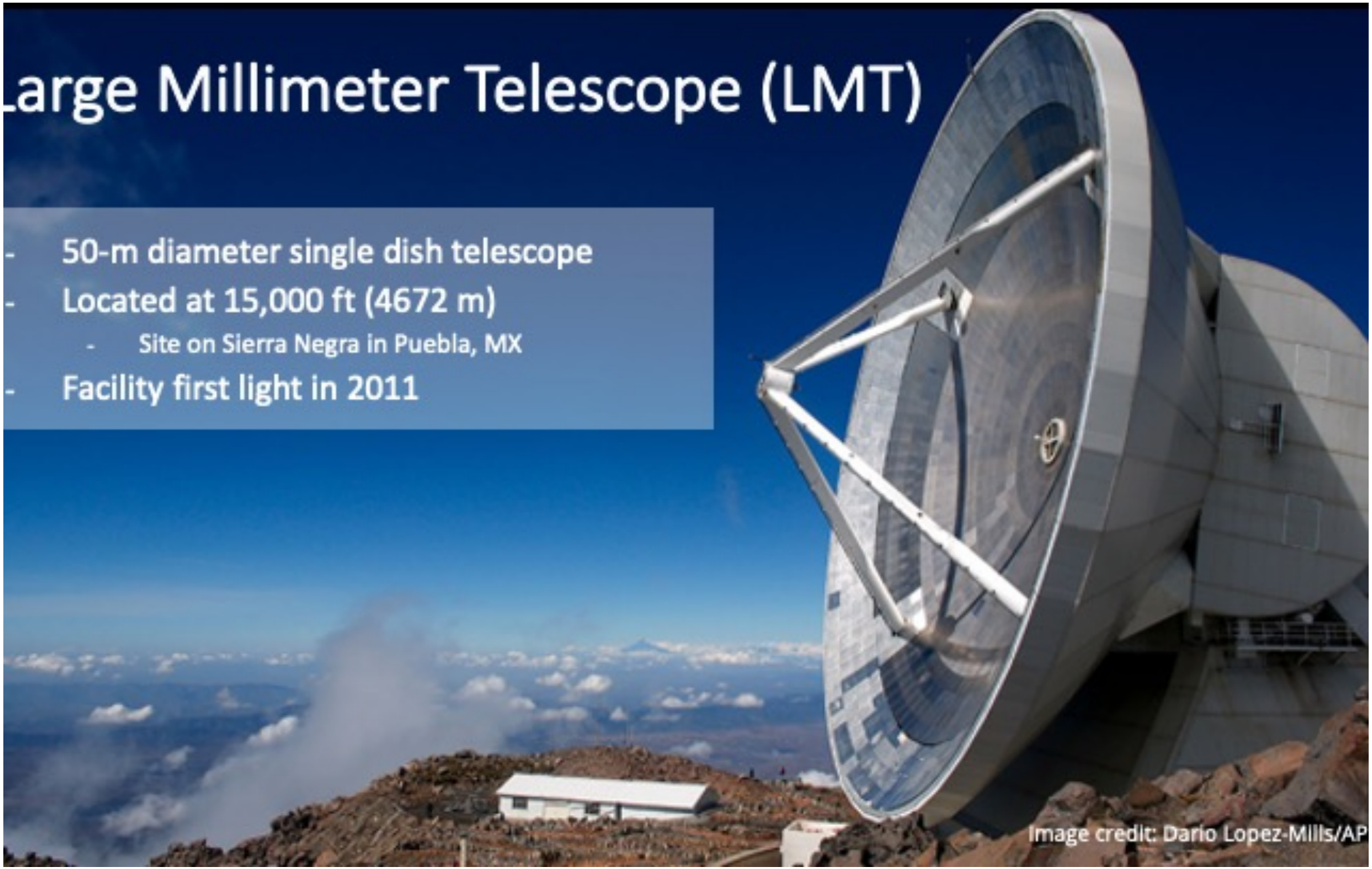


Davé et al (2019)

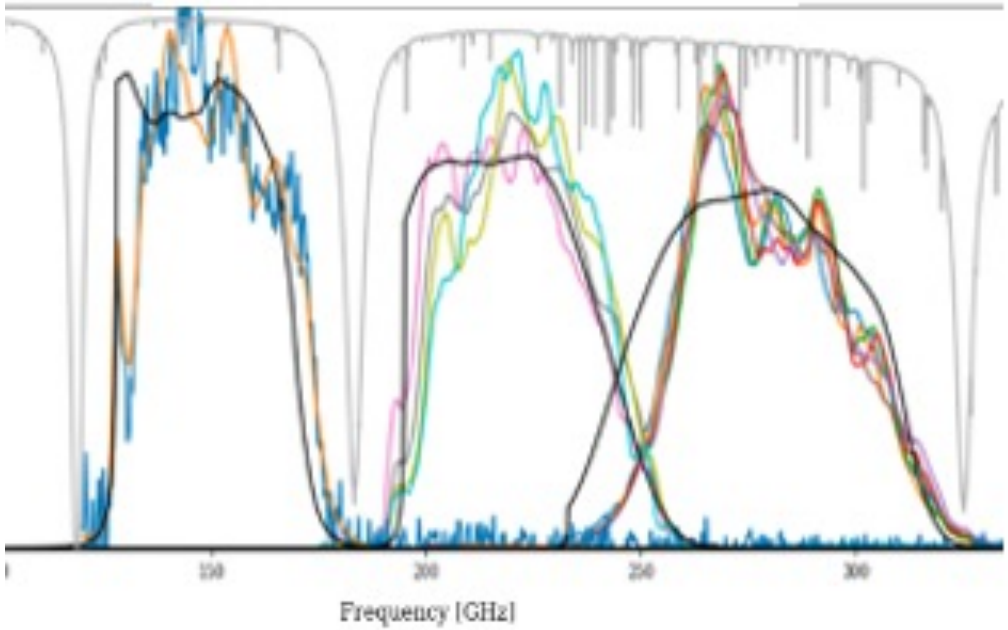
Preliminary Stacking SZ Data from SIMBA / 300 Project

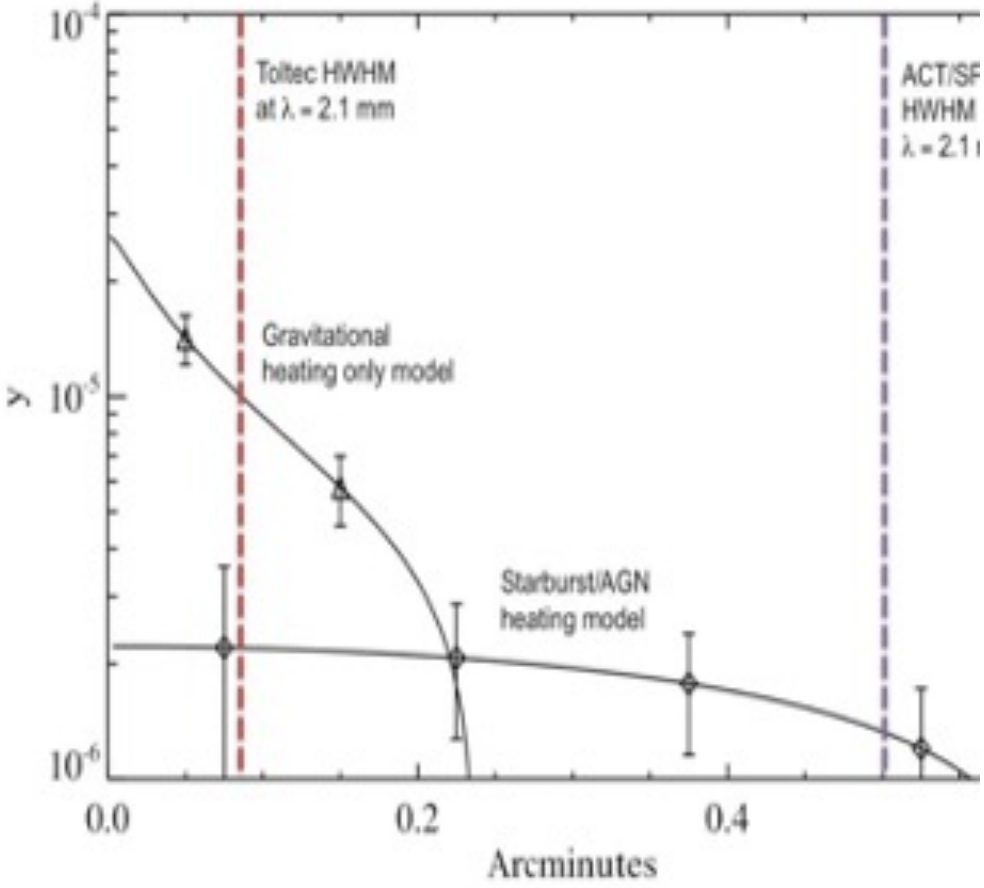


Kylar Grayson


Large Millimeter Telescope (LMT)
- 50-m diameter single dish telescope
- Located at 15,000 ft (4672 m)
  - Site on Sierra Negra in Puebla, MX
- Facility first light in 2011
Image credit: Dario Lopez-Mills/AP

PI: Grant Wilson (UMass)
ASU-PI: Phil Masukopf





Installing TolTEC

From: N. Denigris

Installing TolTEC

Observations start this fall

From: N. Denigris


Thank you!