# Cosmology 2013

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# What's cooking

- Observations of condensed structures on a supra-stellar scale
- Kinematics of homogeneous isotropic flow
- (Non)relativistic behaviour
- Global equations of motion: GRT
- Towards the early Universe
- Observed constraints: composition, CMBR
- Paradoxes: quanta and dark stuff
- Structures big and small

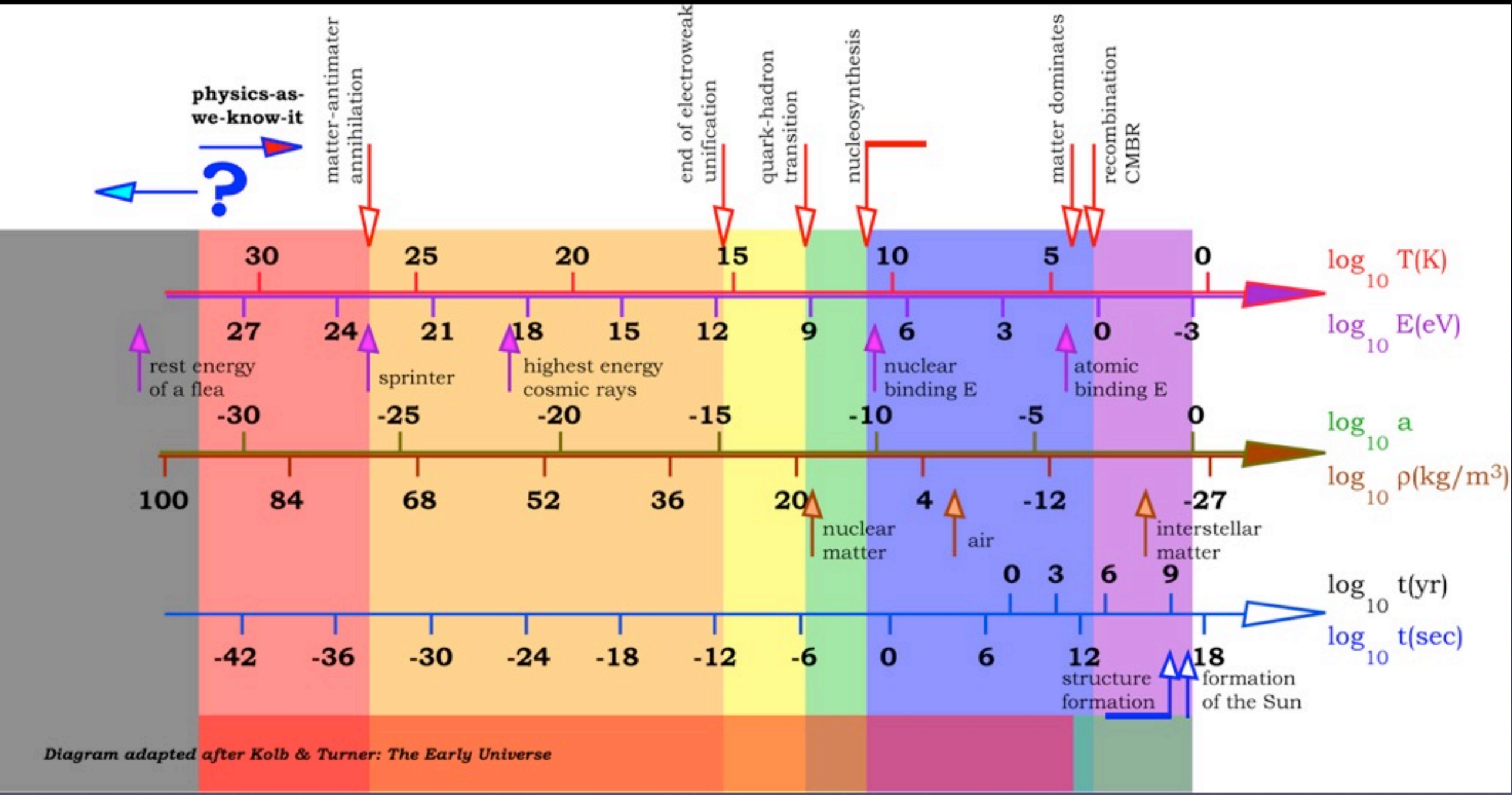
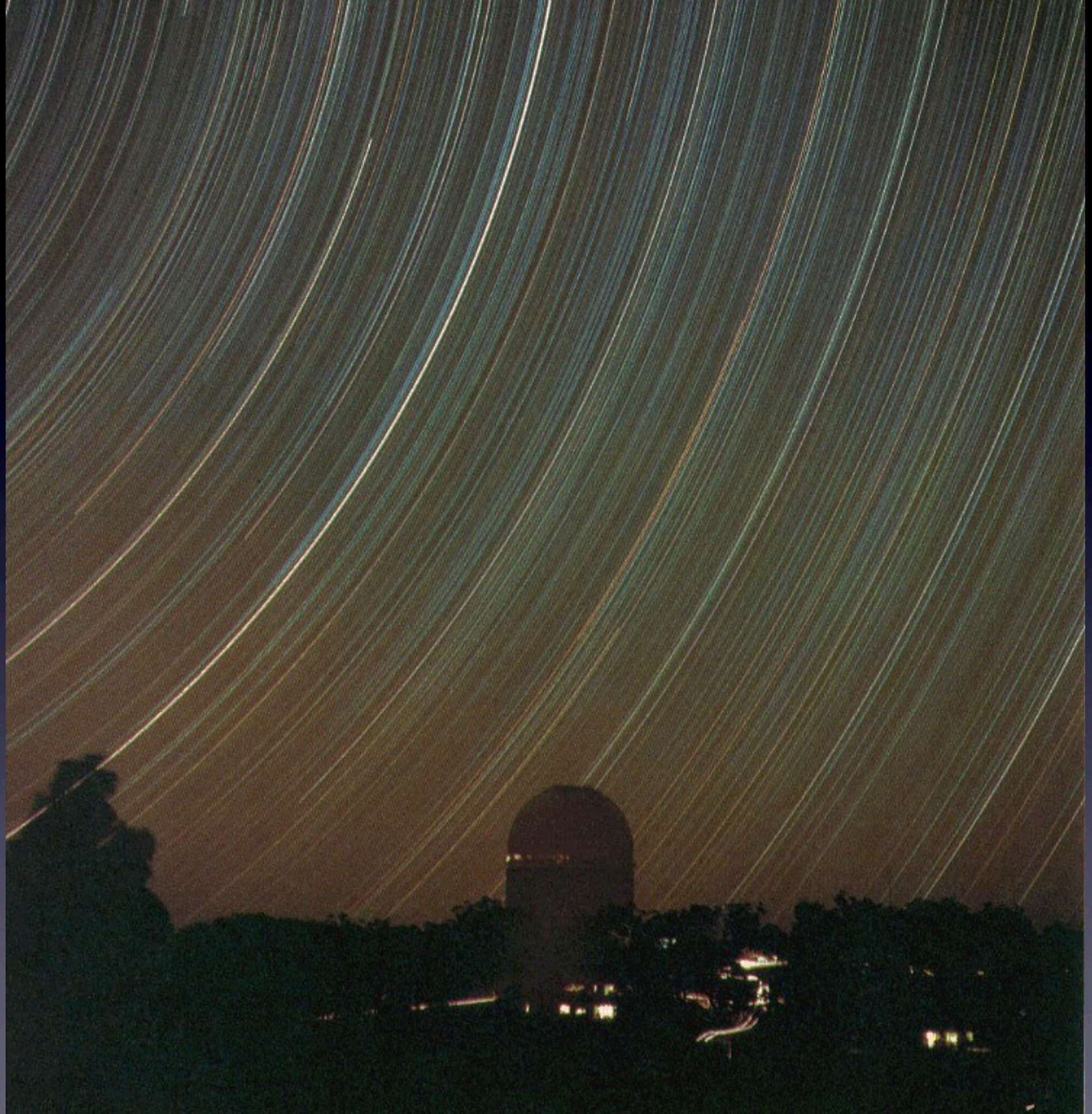


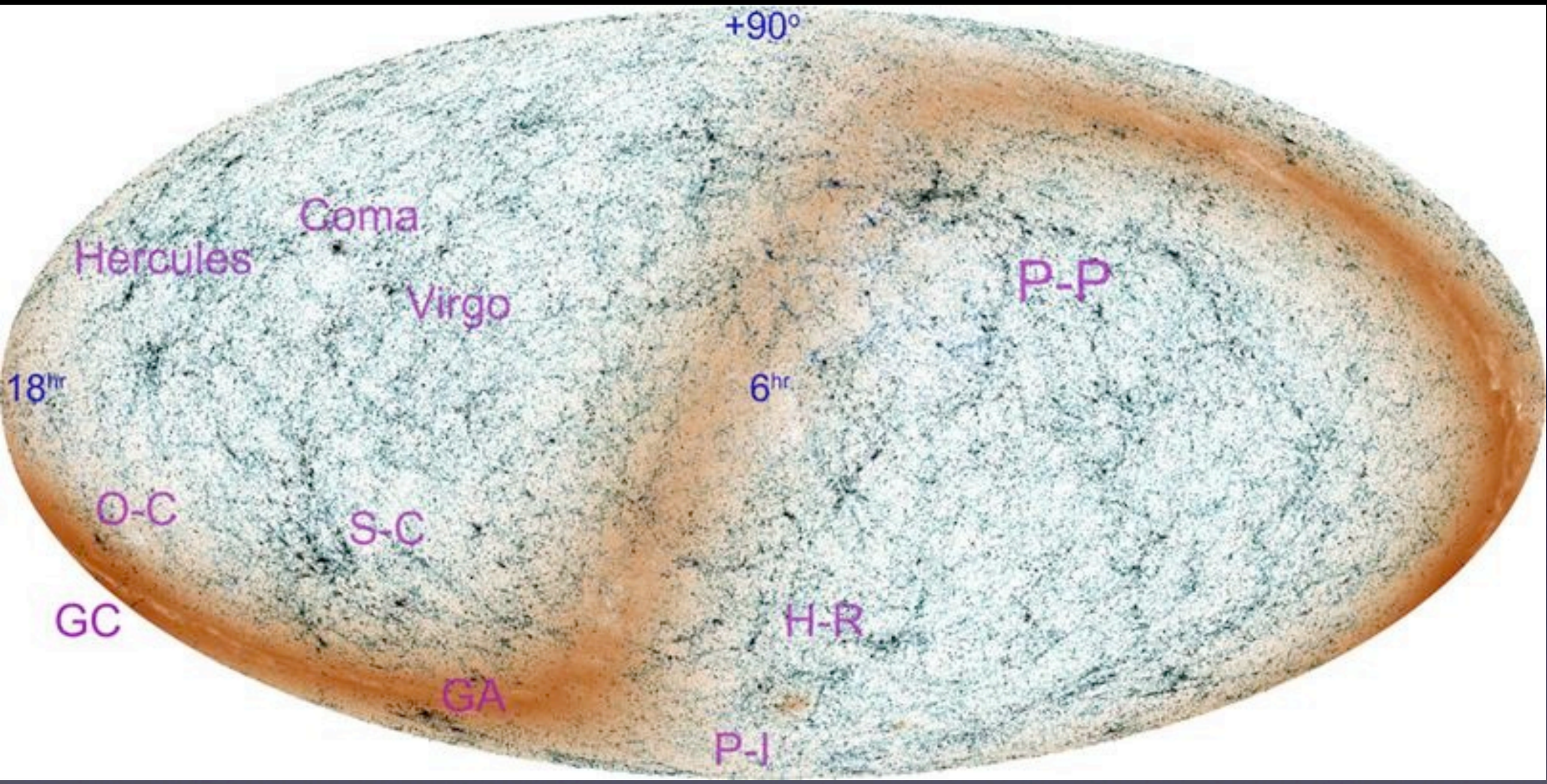

*Diagram adapted after Kolb & Turner: The Early Universe*

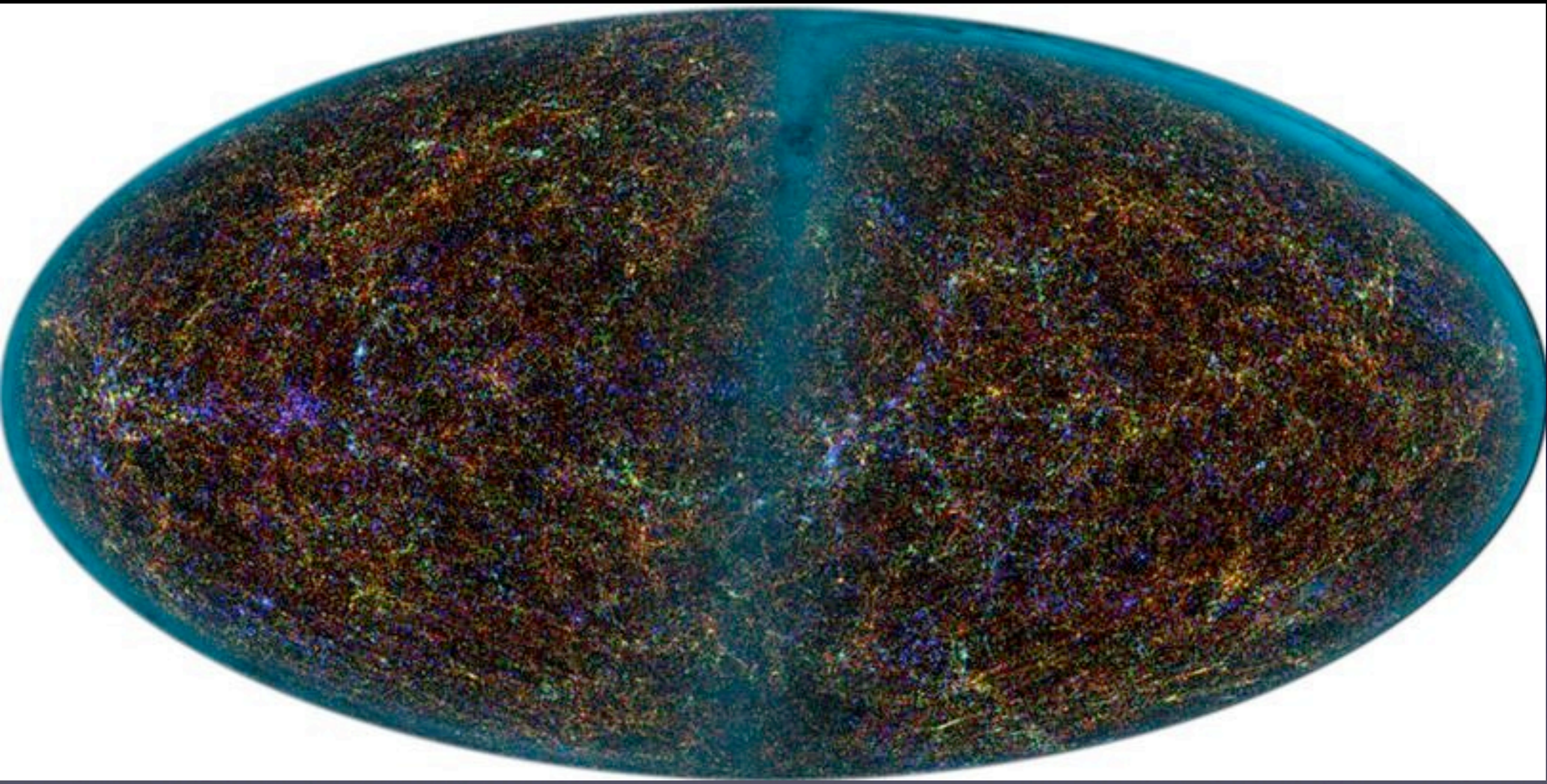
# Quest for the Centre

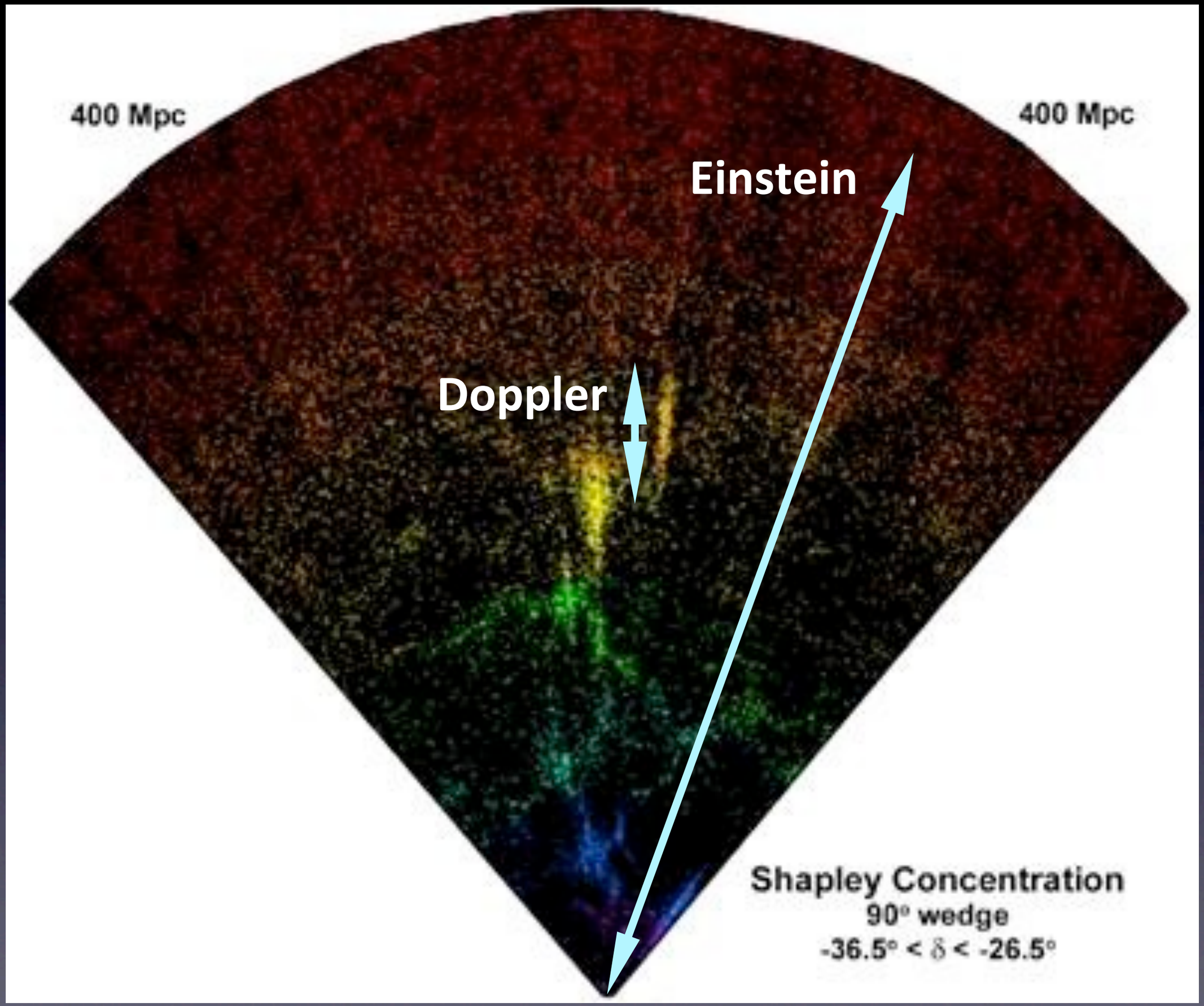
- Our Universe on a large scale tends to be homogeneous and isotropic
- The degree of isotropy and homogeneity increases with increasing length scale
- The kinematics of a homogeneous and isotropic system is severely restricted

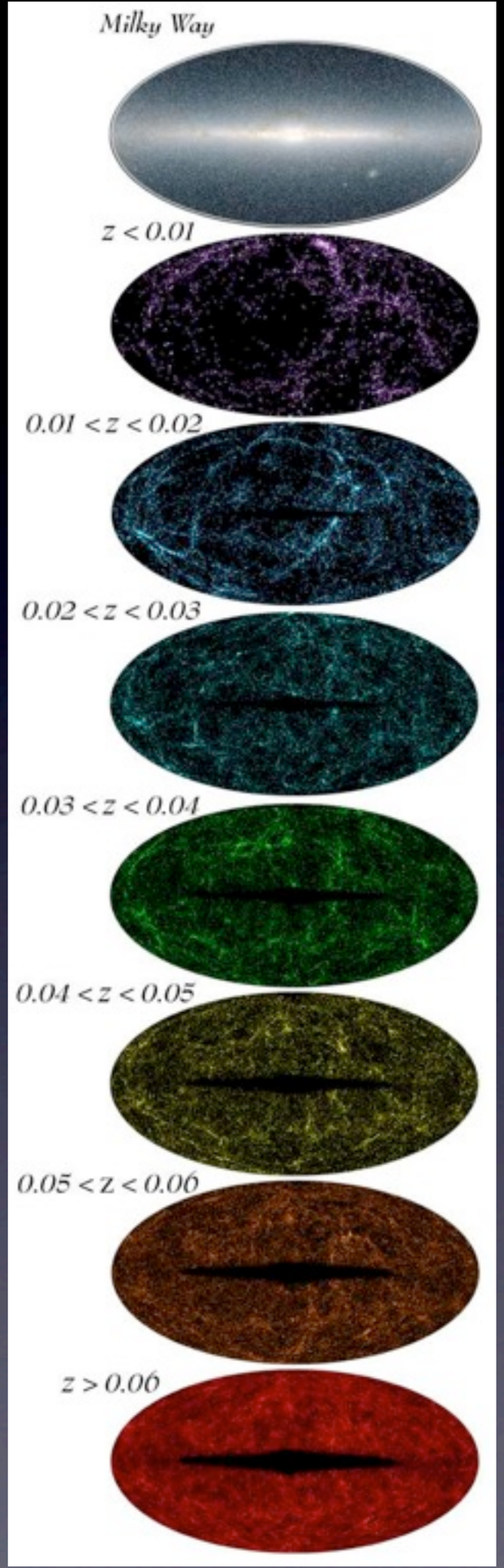


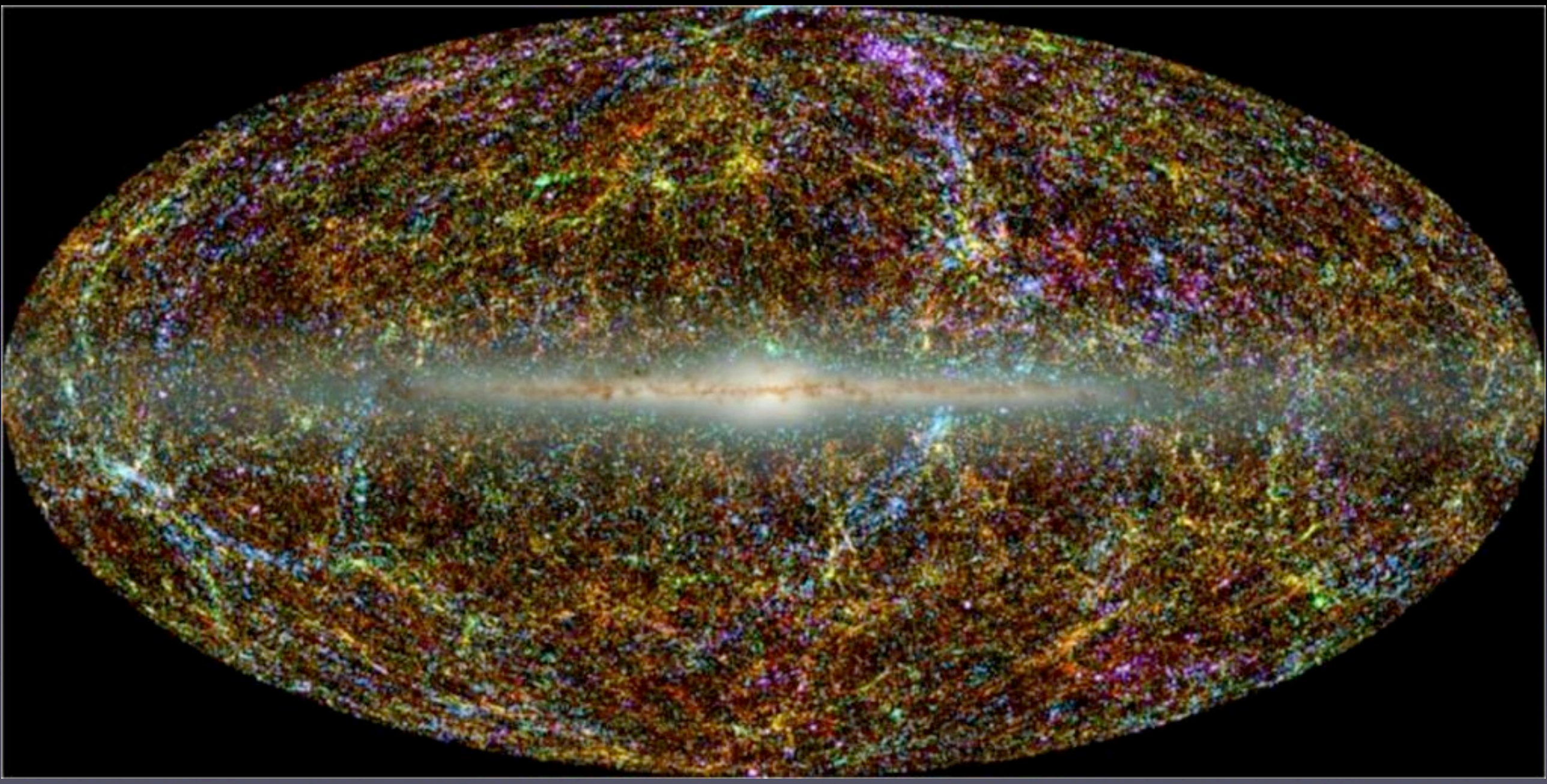
# Far-Infrared Survey

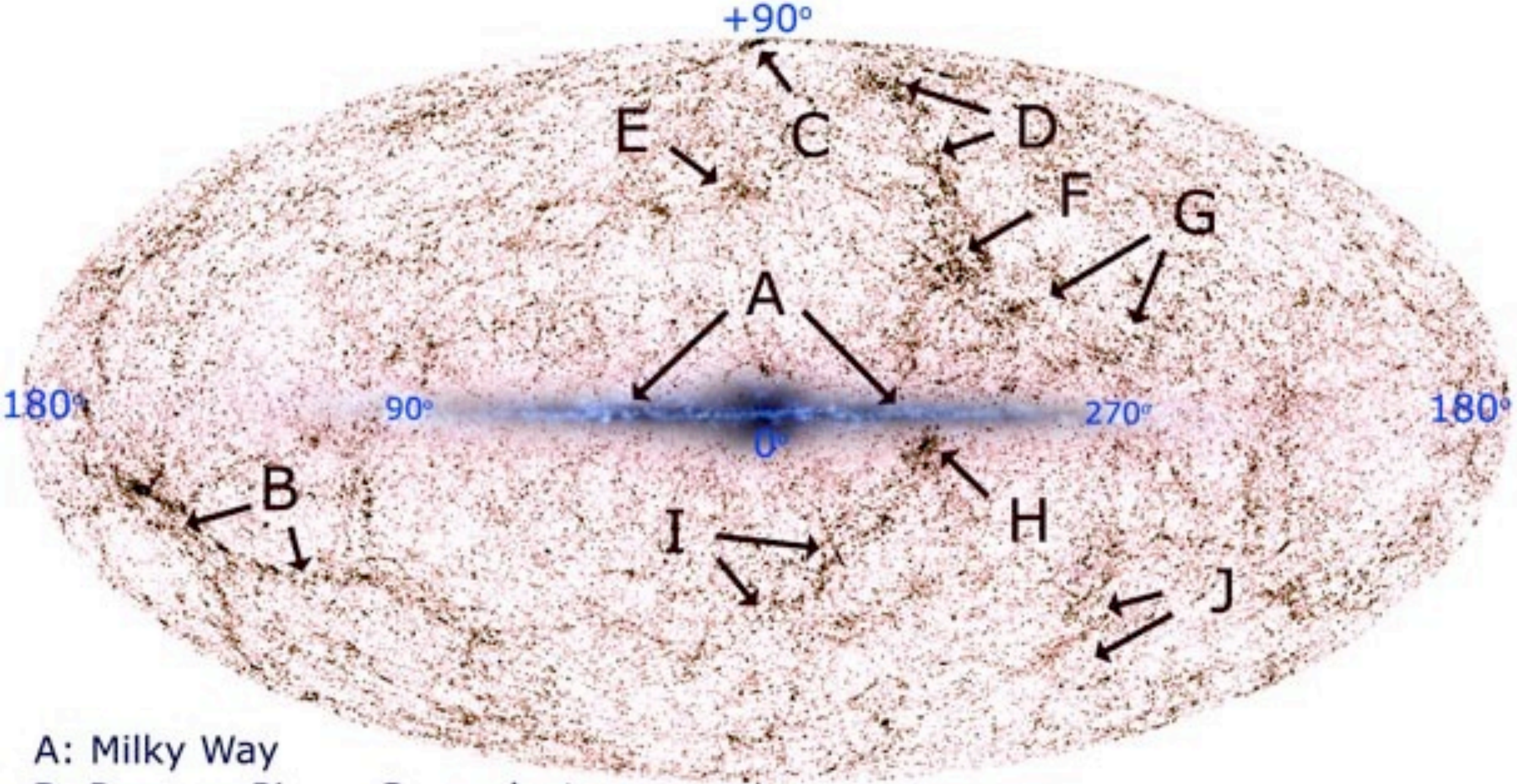

+90°
Coma
Hercules
Virgo
P-P
18hr
6hr
O-C
S-C
GC
H-R
GA
P-I




400 Mpc
400 Mpc
Einstein
Doppler
Shapley Concentration
90° wedge
-36.5° < δ < -26.5°

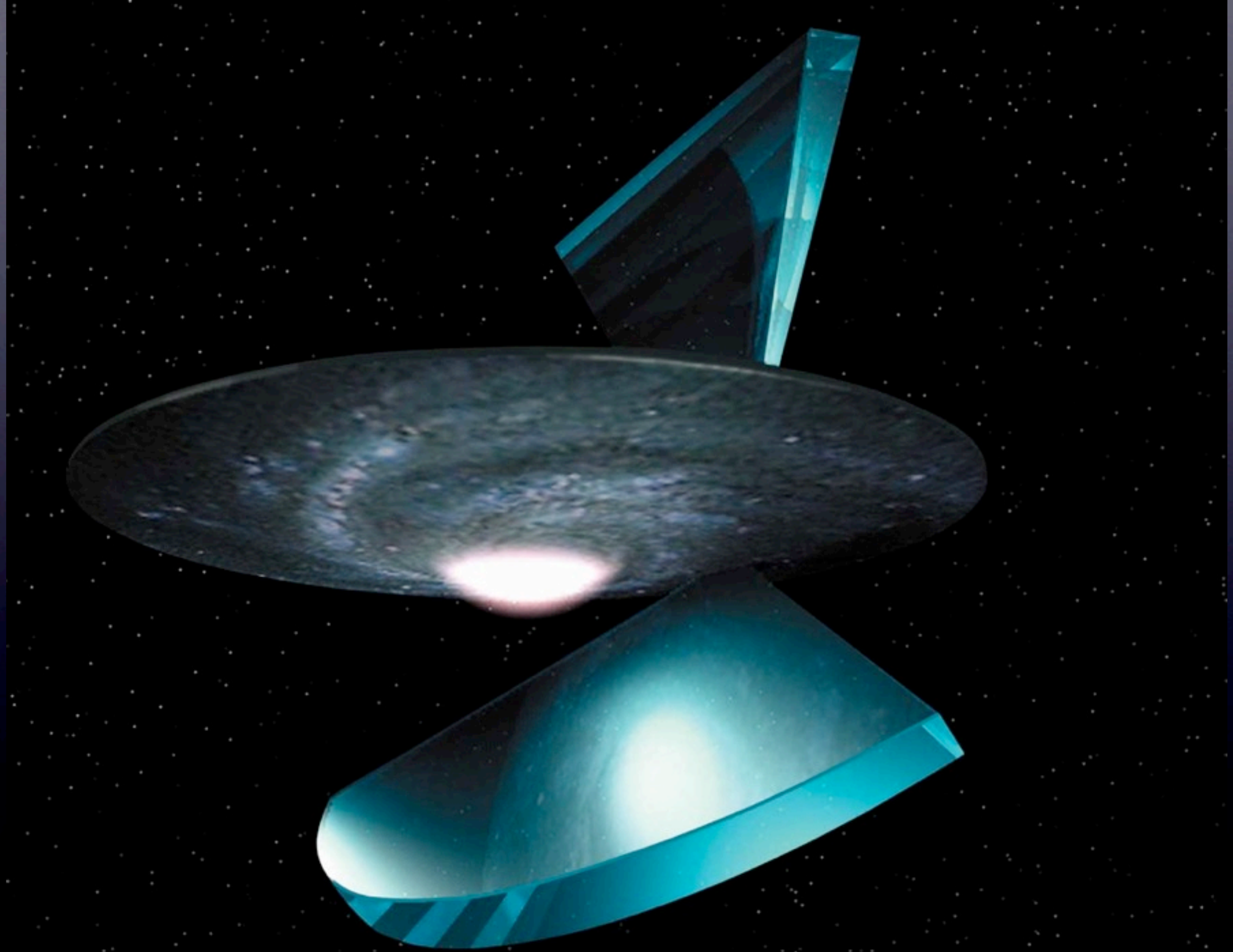

Milky Way
z < 0.01
0.01 < z < 0.02
0.02 < z < 0.03
0.03 < z < 0.04
0.04 < z < 0.05
0.05 < z < 0.06
z > 0.06

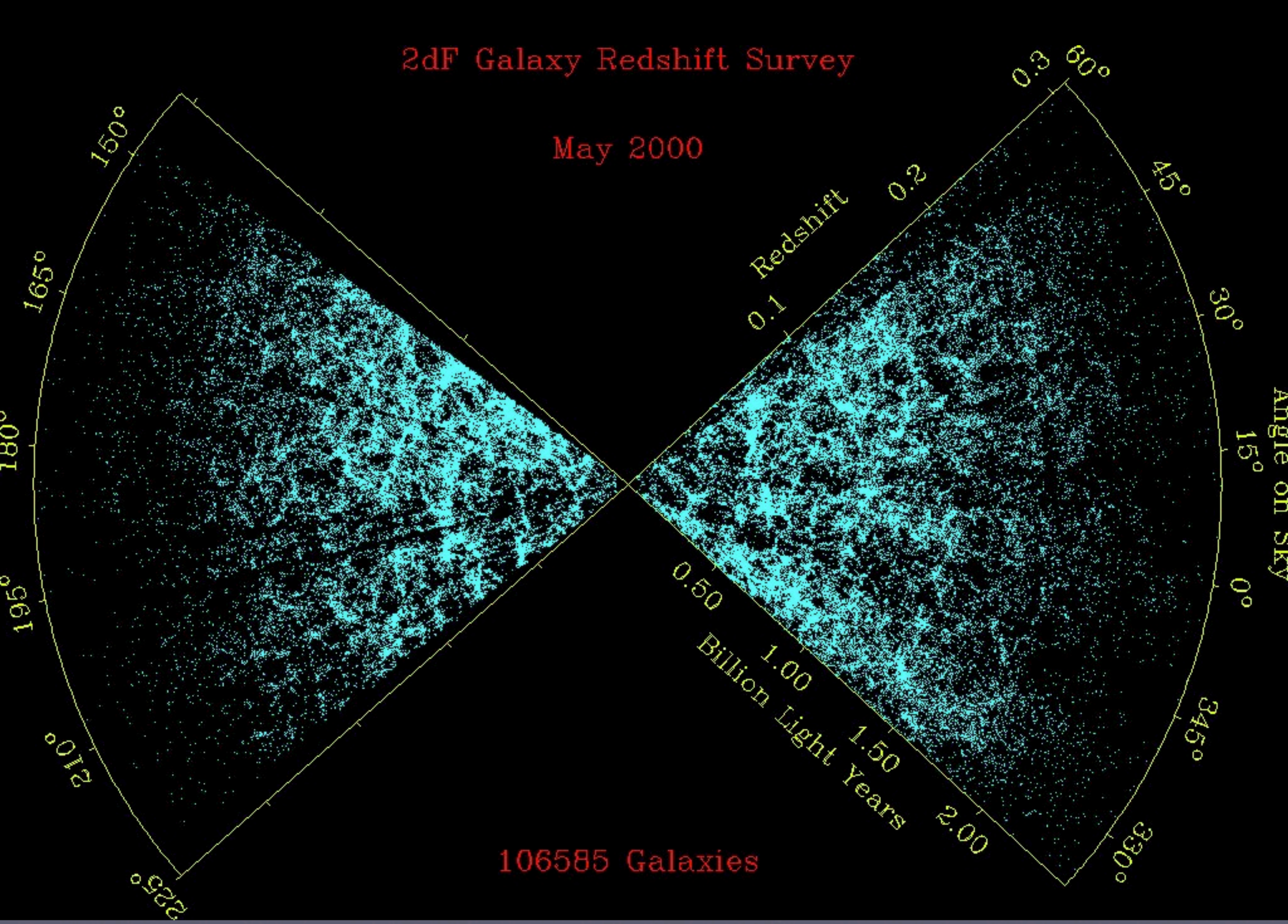


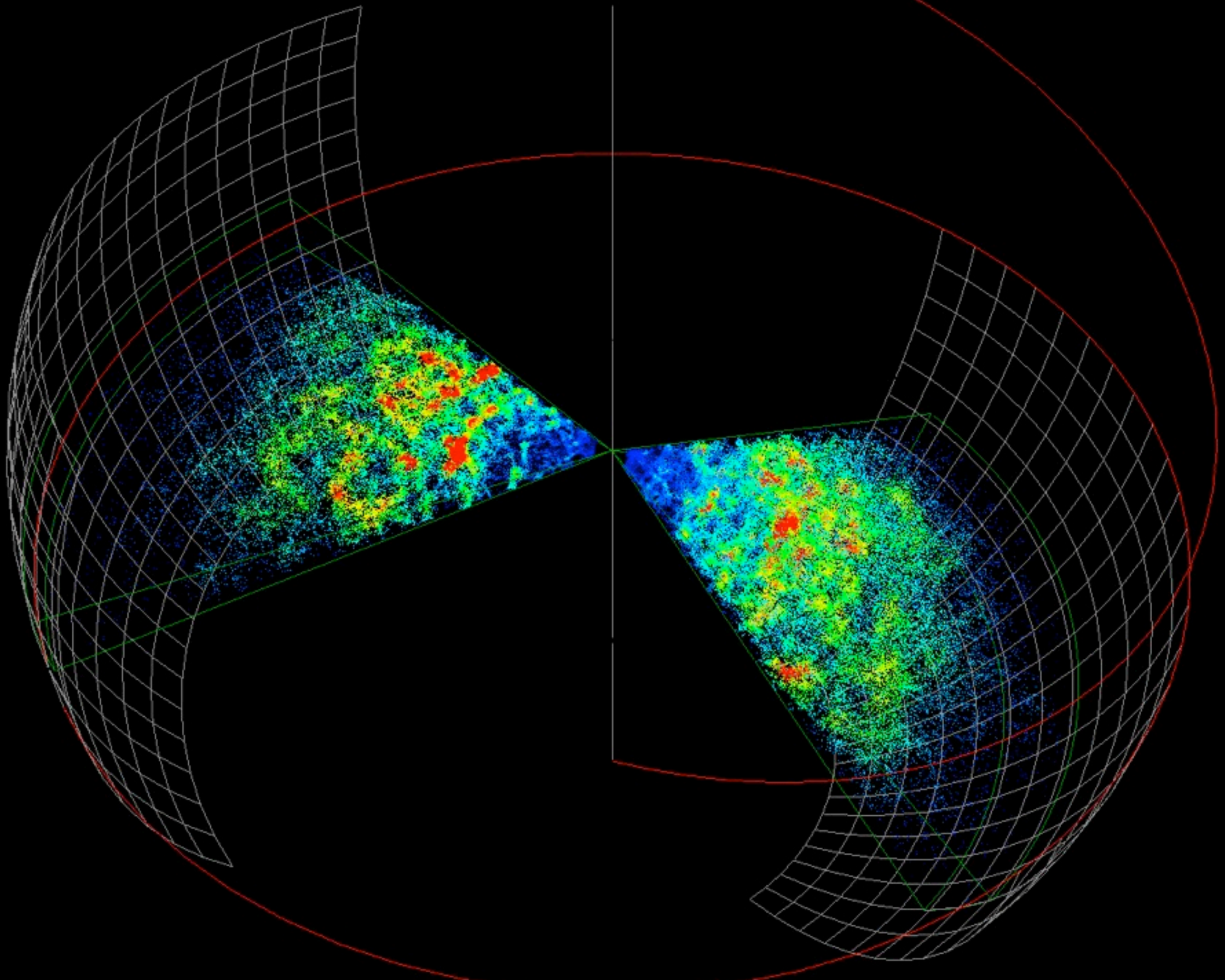


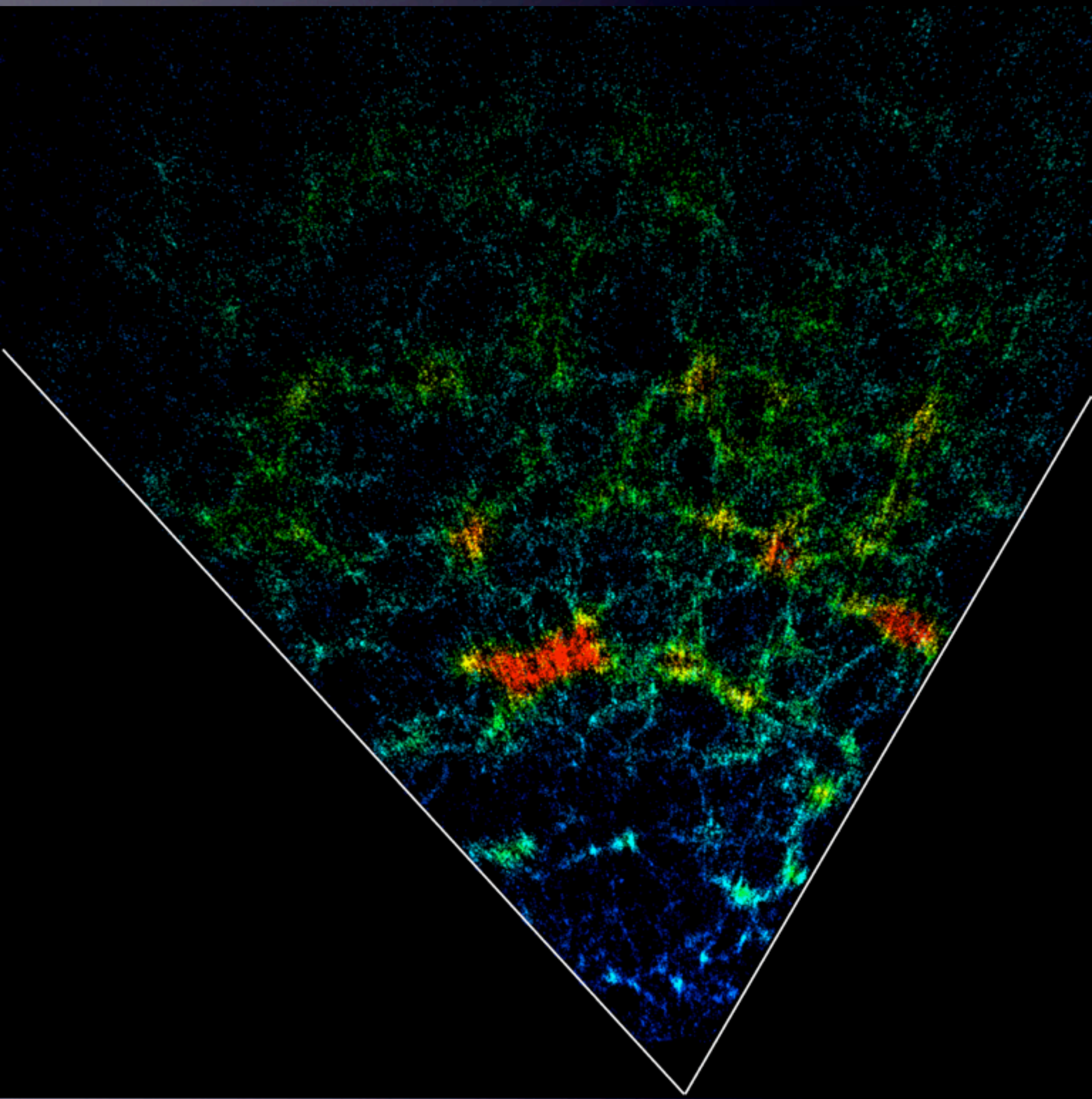

A: Milky Way
B: Perseus-Pisces Supercluster
C: Coma Cluster
D: Virgo Cluster/Local Supercluster
E: Hercules Supercluster
F: Shapley Concentration/Abell 3558
G: Hydra-Centaurus Supercluster
H: "Great Attractor"/Abell 3627
I: Pavo-Indus Supercluster
J: Horologium-Reticulum Supercluster

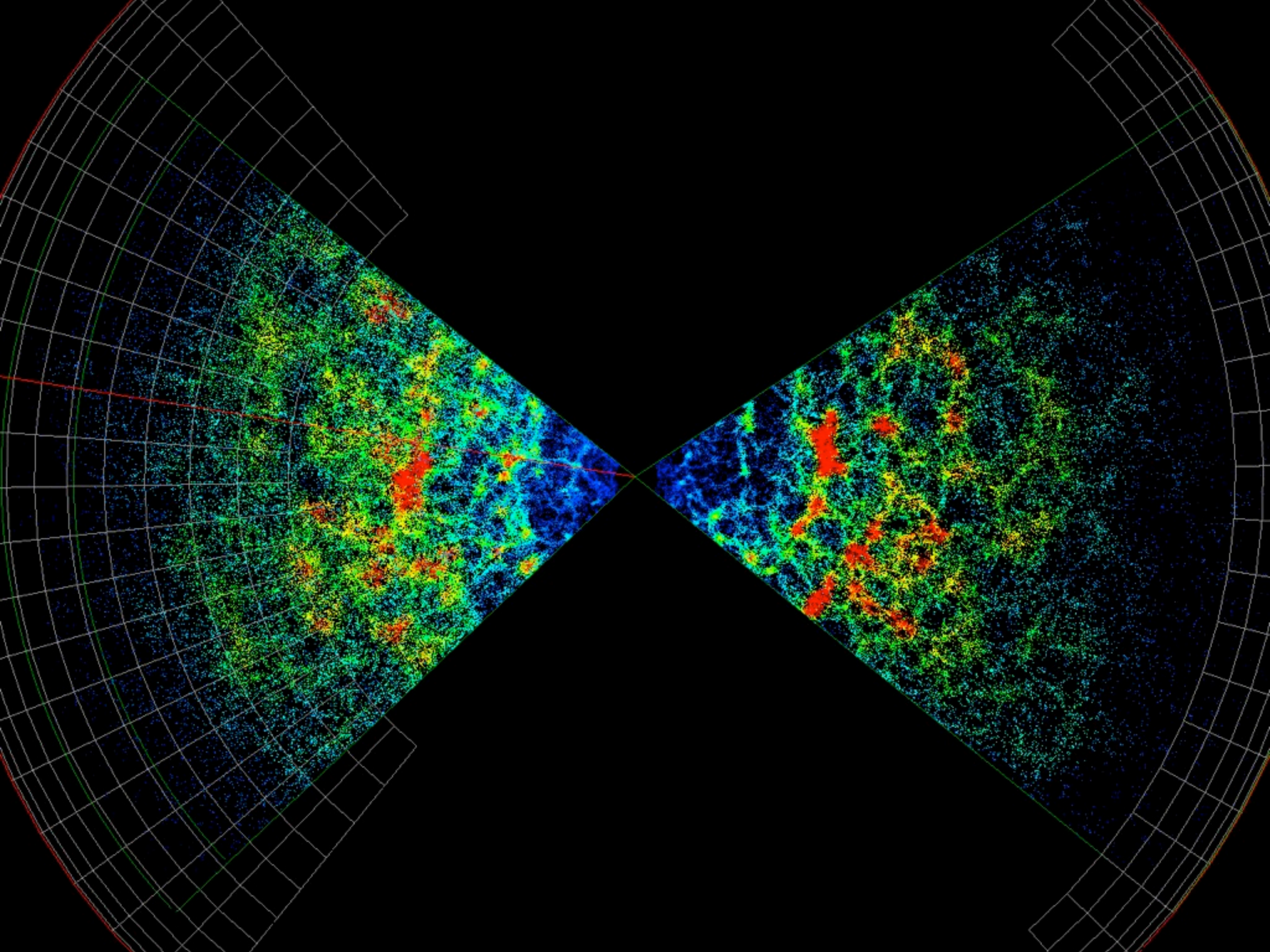
# The Two-Degree Field (2dF)

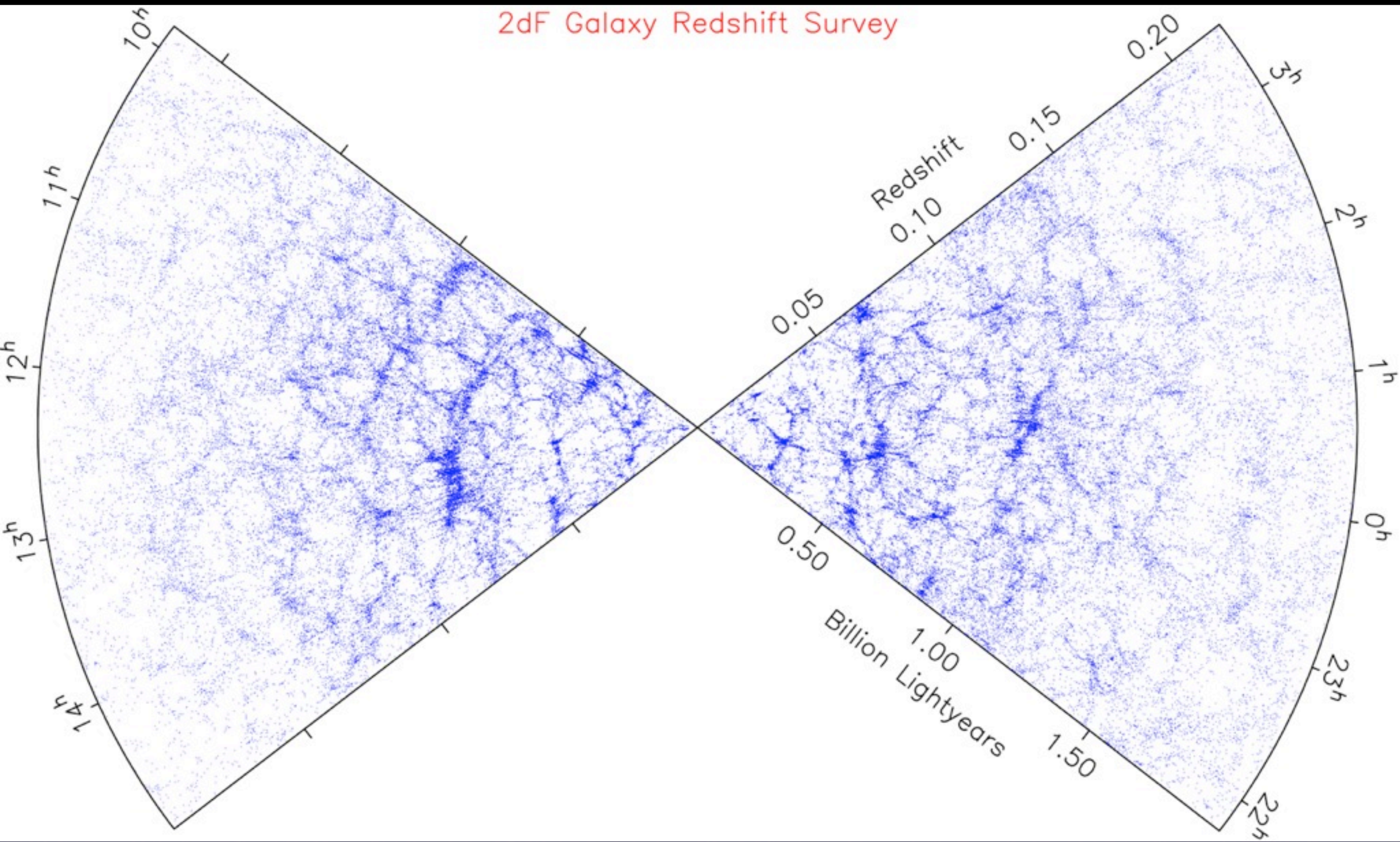



2dF Galaxy Redshift Survey
May 2000
Redshift
0.1
0.2
0.3
Billion Light Years
0.50
1.00
1.50
2.00
Angle on Sky
0°
15°
30°
45°
60°
330°
345°
150°
165°
180°
195°
210°
225°
106585 Galaxies








2dF Galaxy Redshift Survey
10h
11h
12h
13h
14h
Redshift
0.05
0.10
0.15
0.20
0.50
1.00
1.50
Billion Lightyears
3h
2h
1h
0h
23h
22h

# Hubble Ultra-Deep Field (HUDF)

- Single field of observation
- Exposure 11.3 days

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# THE 2012 HUBBLE ULTRA DEEP FIELD (UDF12): OBSERVATIONAL OVERVIEW

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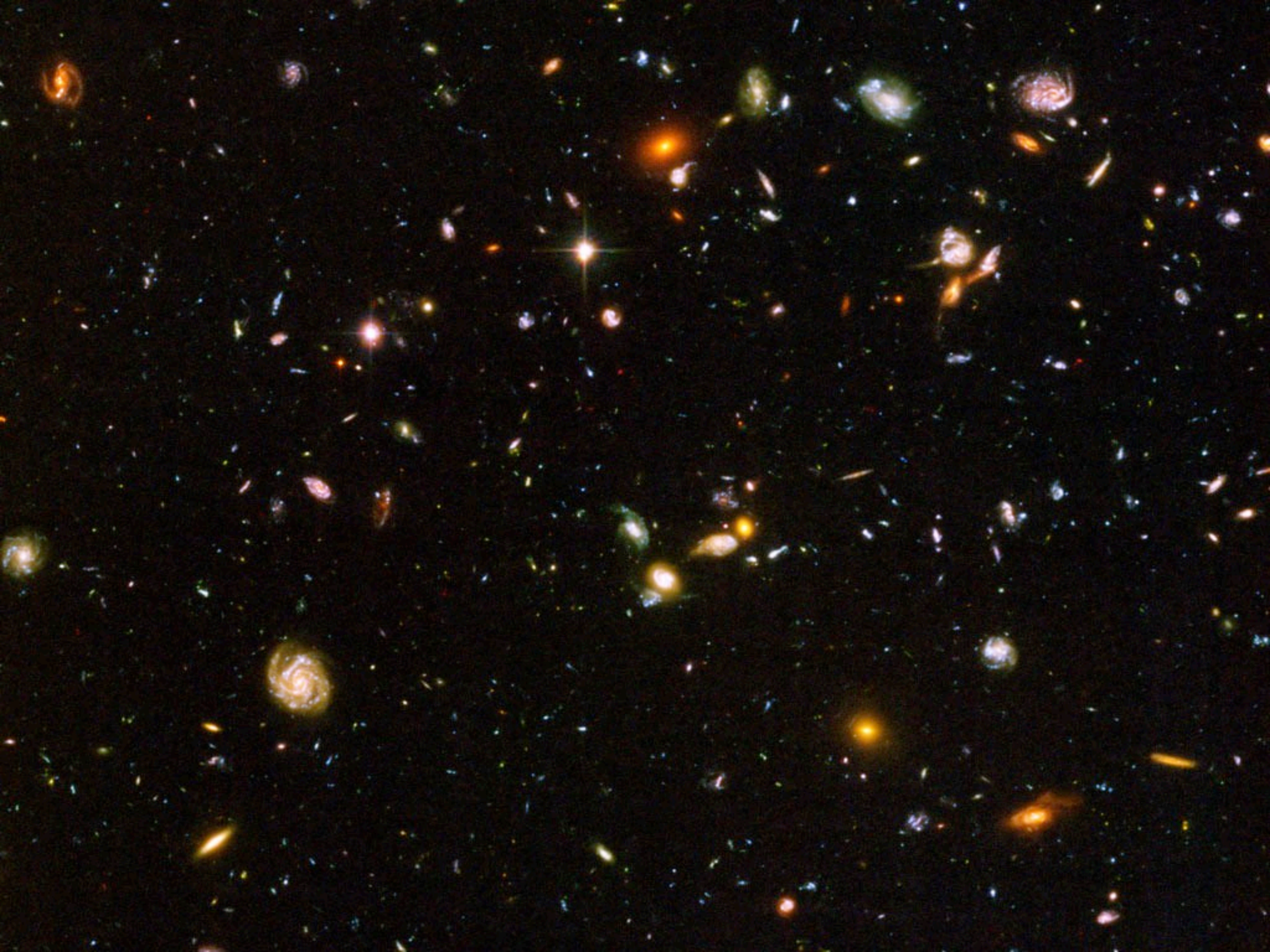
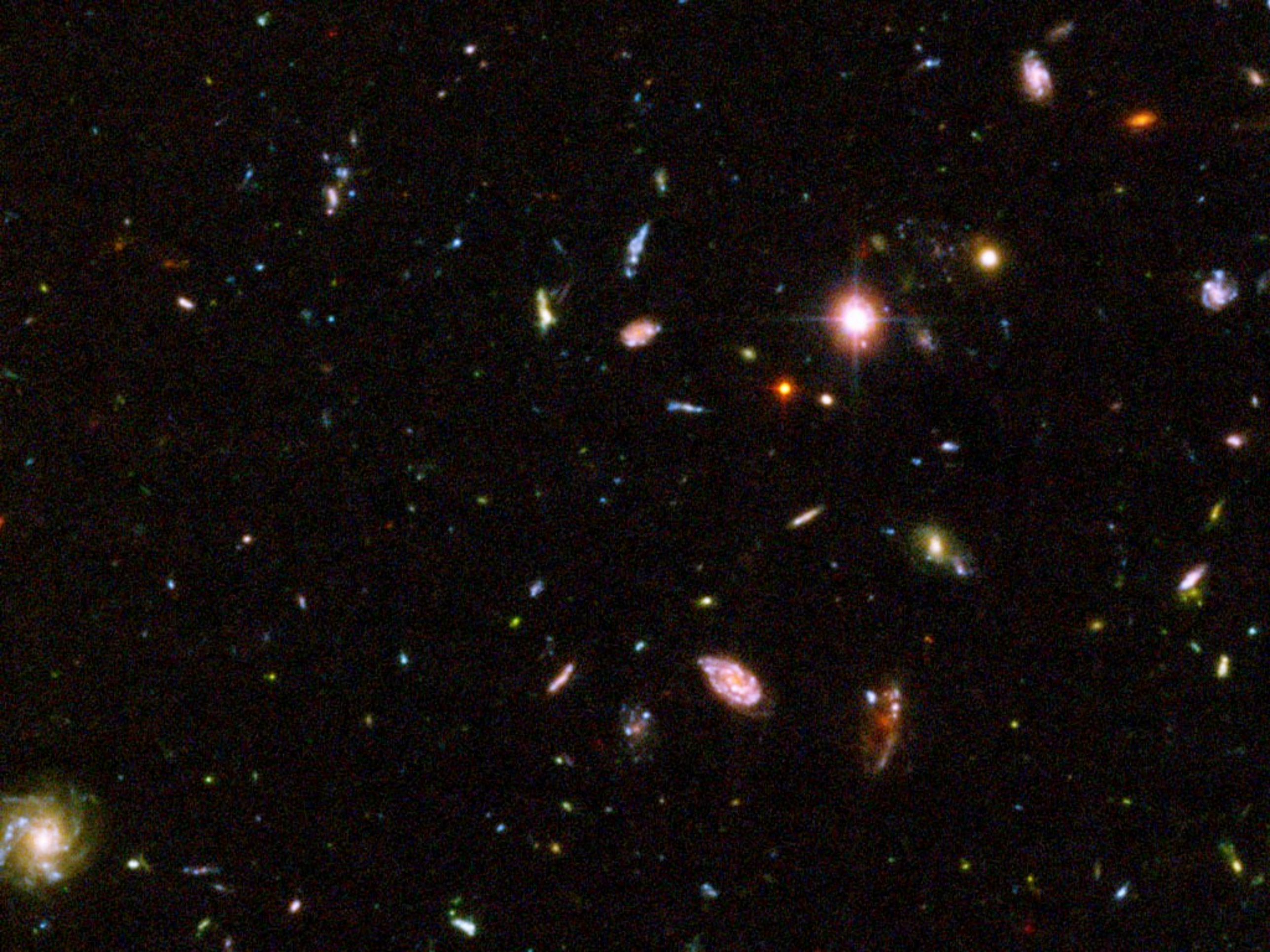
## ABSTRACT

We present the 2012 Hubble Ultra Deep Field campaign (UDF12), a large 128-orbit Cycle 19 *HST* program aimed at extending previous WFC3/IR observations of the UDF by quadrupling the exposure time in the F105W filter, imaging in an additional F140W filter, and extending the F160W exposure time by 50%. The principal scientific goal of this project is to determine whether galaxies reionized the universe; our observations are designed to provide a robust determination of the star formation density at $z \gtrsim 8$, improve measurements of the ultraviolet continuum slope at $z \sim 7-8$, facilitate the construction of new samples of $z \sim 9-10$ candidates, and enable the detection of sources up to $z \sim 12$. For this project we committed to combining these and other WFC3/IR imaging observations of the UDF area into a single homogeneous dataset, to provide the deepest near-infrared observations of the sky currently achievable. In this paper we present the observational overview of the project, motivated by its scientific goals, and describe the procedures used in reducing the data as well as the final products that are produced. We have used the most up up-to-date methods for calibrating and combining the images, in particular paying attention to correcting several instrumental effects. We release the full combined mosaics, comprising a single, unified set of mosaics of the UDF, providing the deepest near-infrared blank-field view of the universe obtained to date, reaching magnitudes as deep as AB $\sim 30$ in the near-infrared, and yielding a legacy dataset on this field of lasting scientific value to the community.

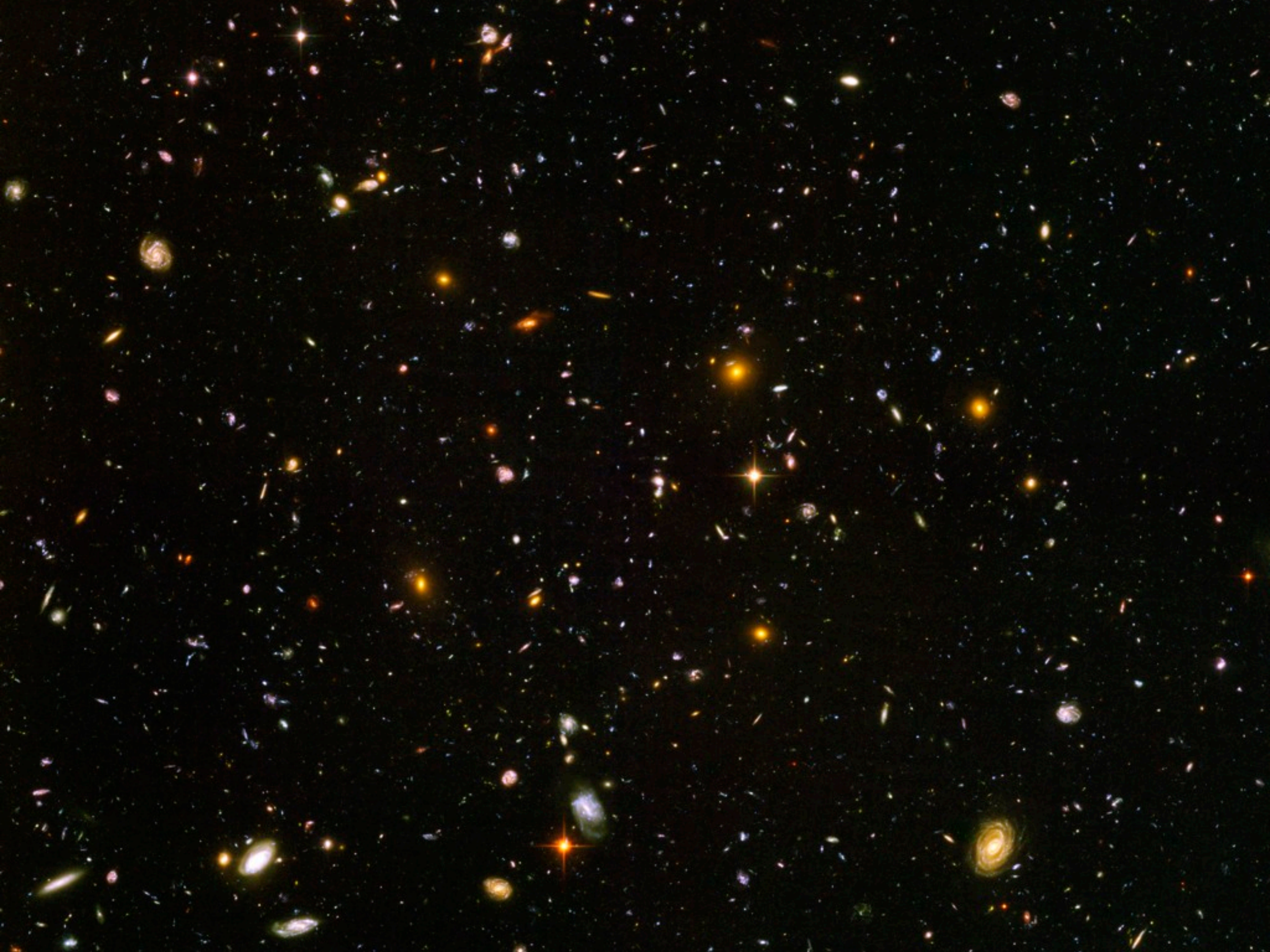
*Subject headings:* Cosmology: observations — Galaxies: high-redshift —

# HUDF





# Kinematics of a Homogeneous and Isotropic Medium



# Motion of the Universe

- The large-scale Universe is homogeneous and isotropic
- Therefore, it must move the same everywhere
- This is only possible by a change of scale (expansion of space)

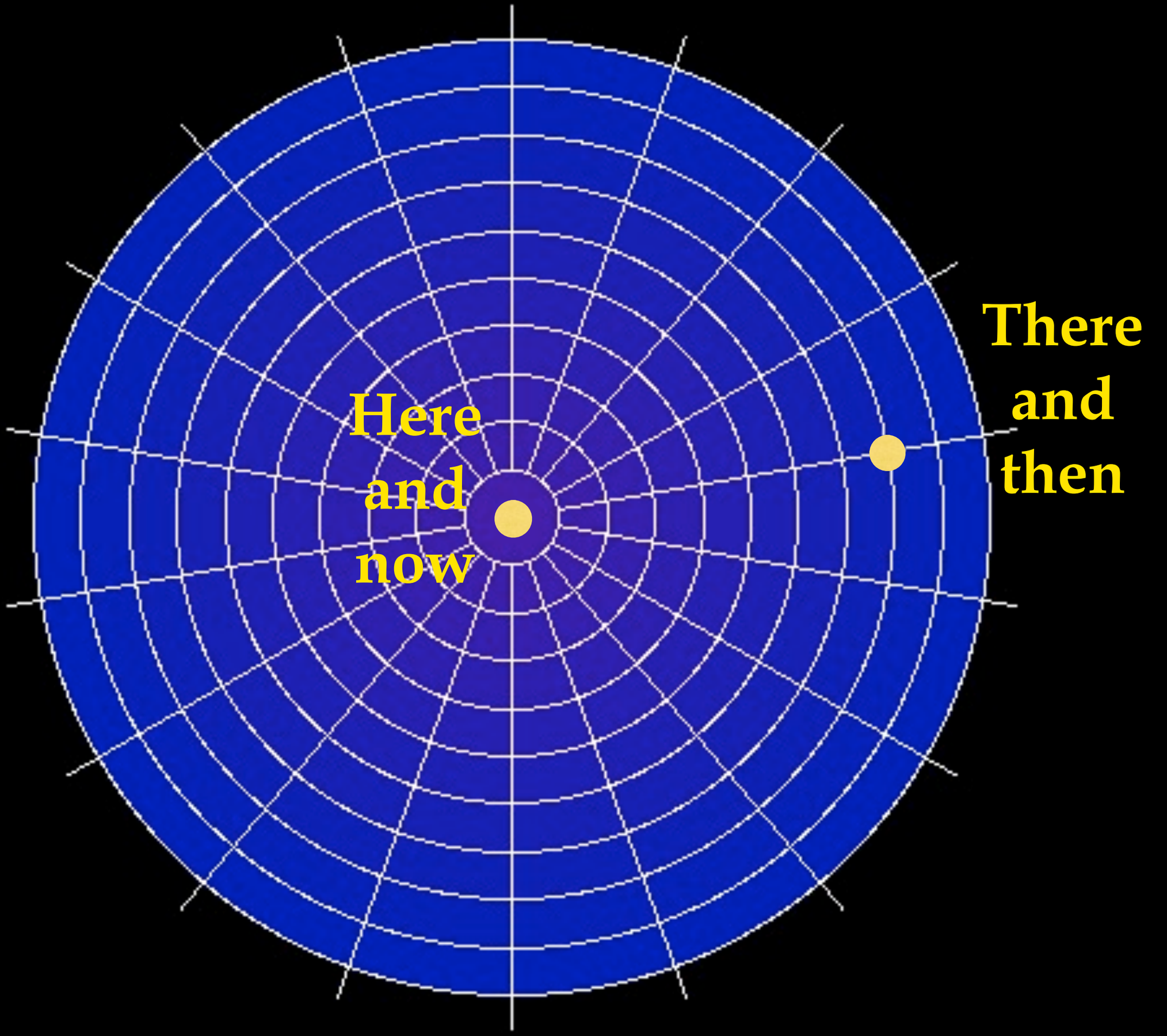
**How may the Universe move in such a way that it remains homogeneous and isotropic?**

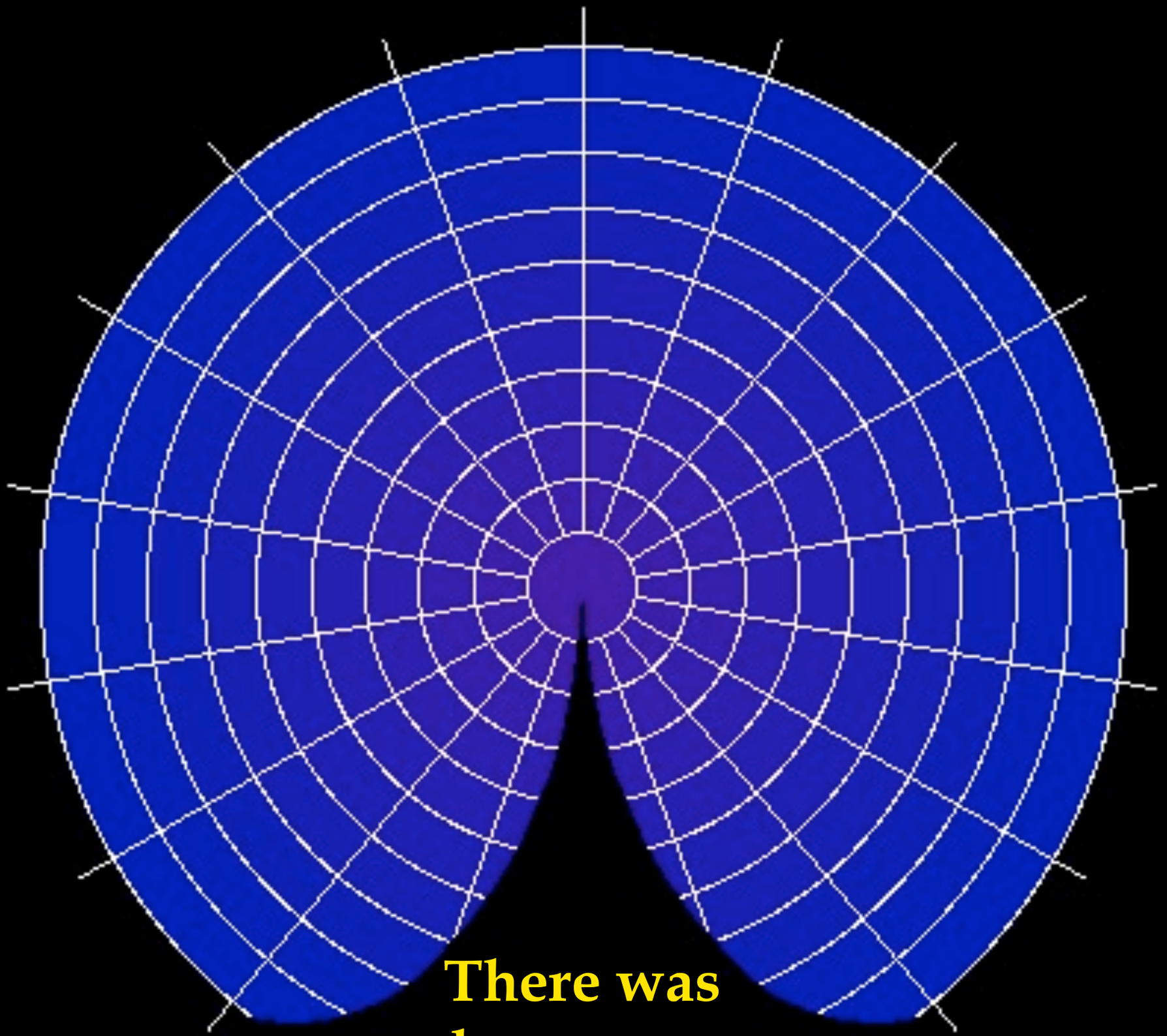
**The Universe must move in the same way everywhere!**

**This implies a unique velocity field**

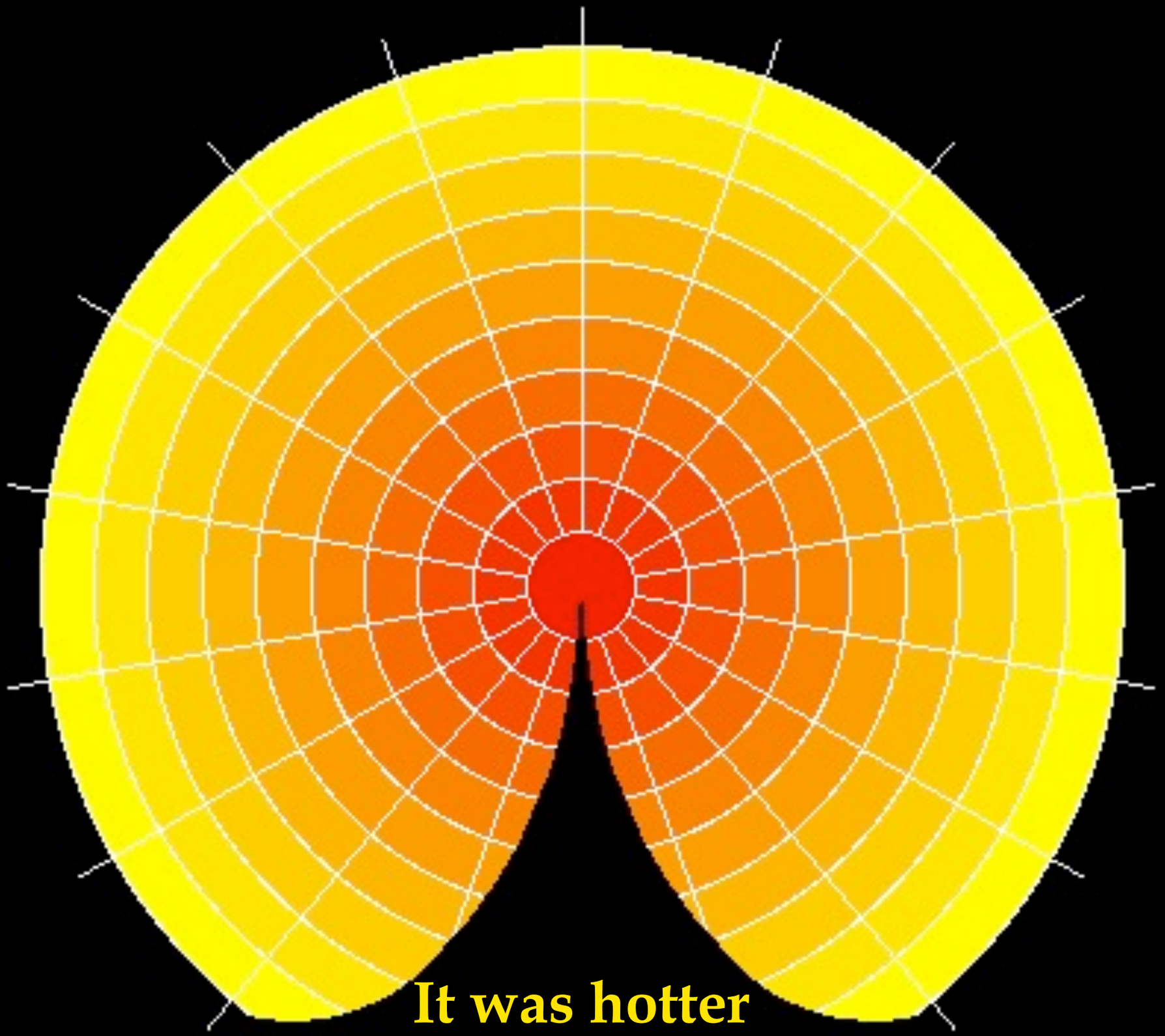
$$v_i = H(t)x_i$$

**"Hubble Velocity" is a change of scale**

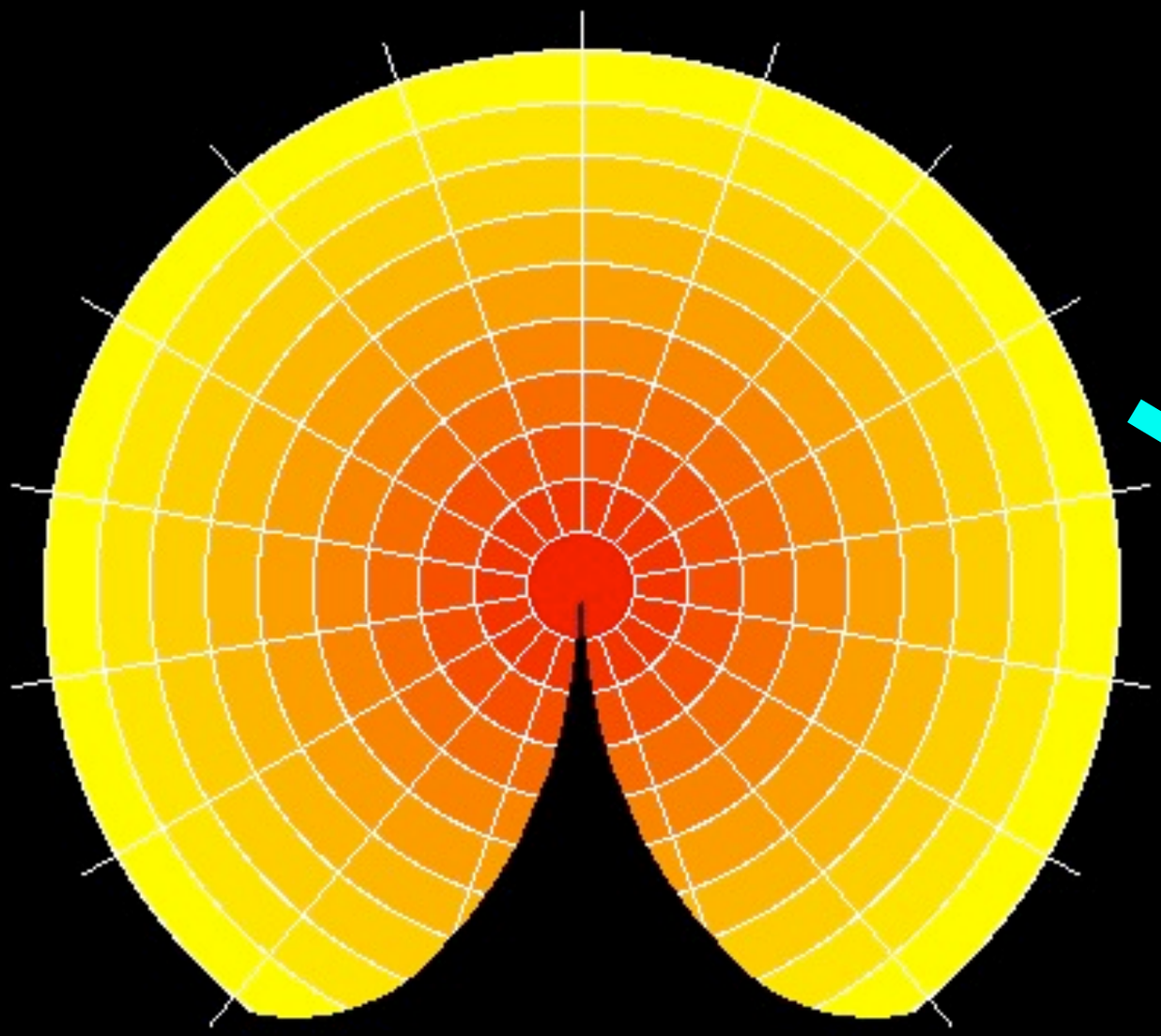

Here and now
There and then



There was
less space
in the past

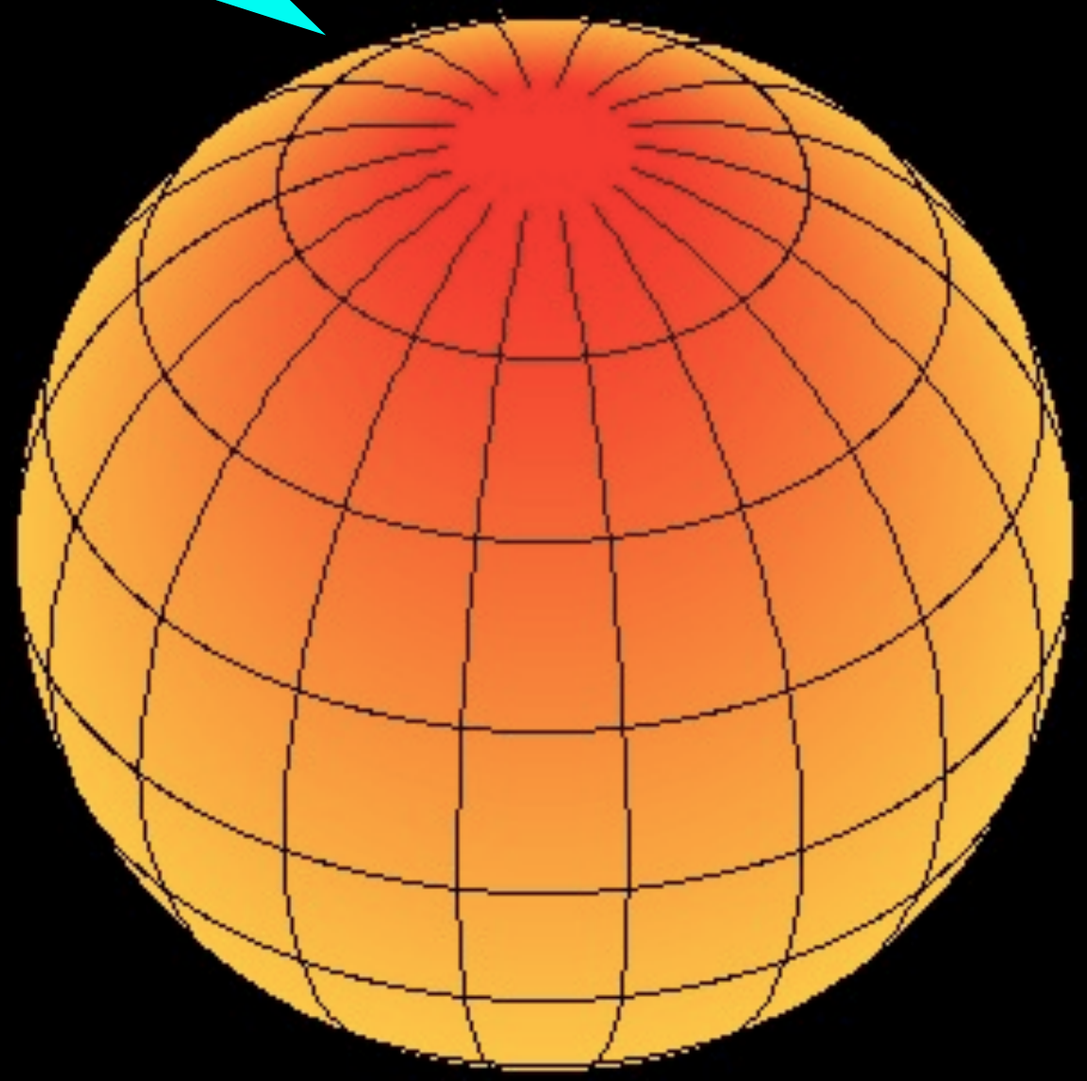


It was hotter
and denser
in the past

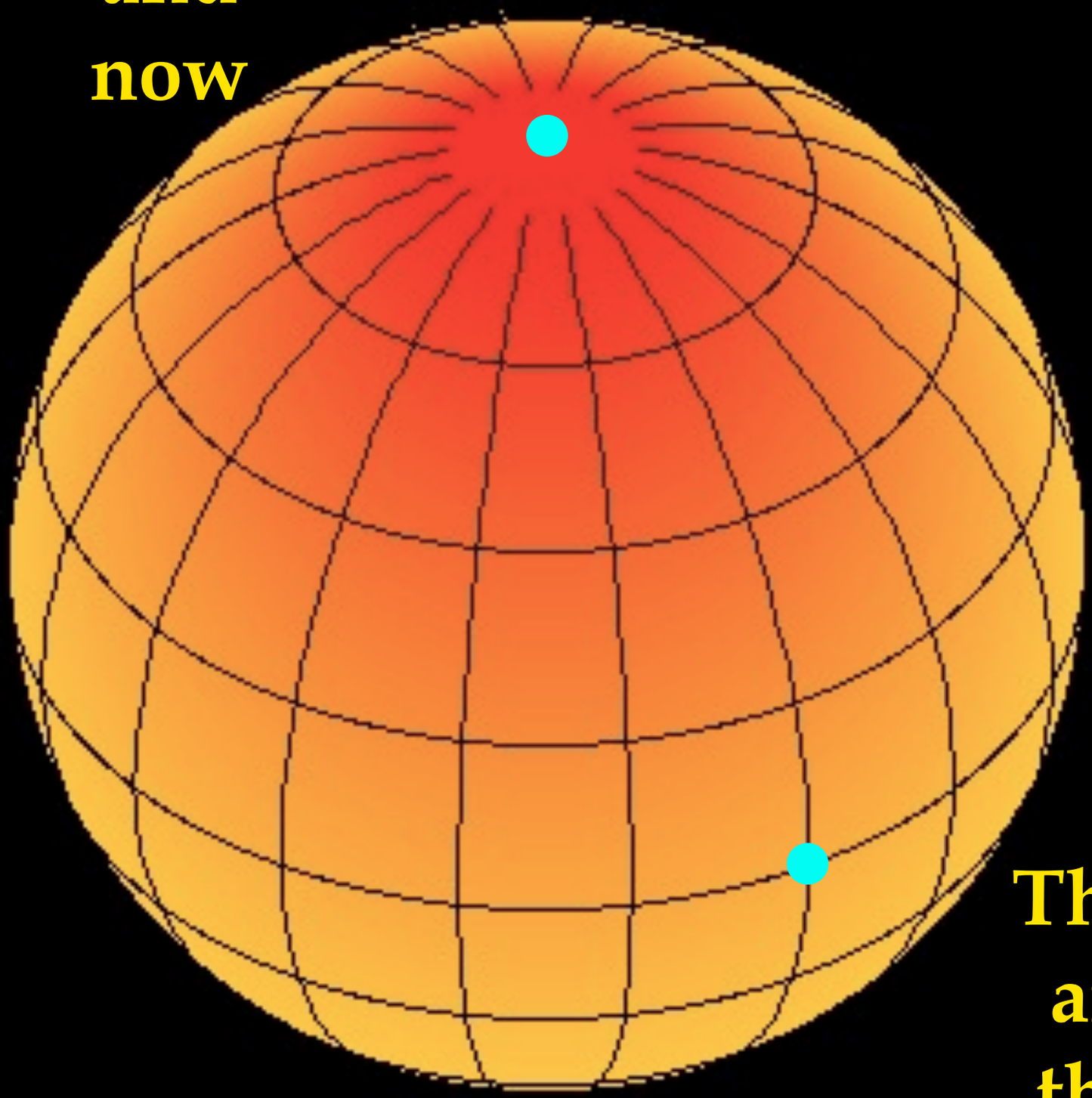


Cut-and-paste
space-time

General
Relativity

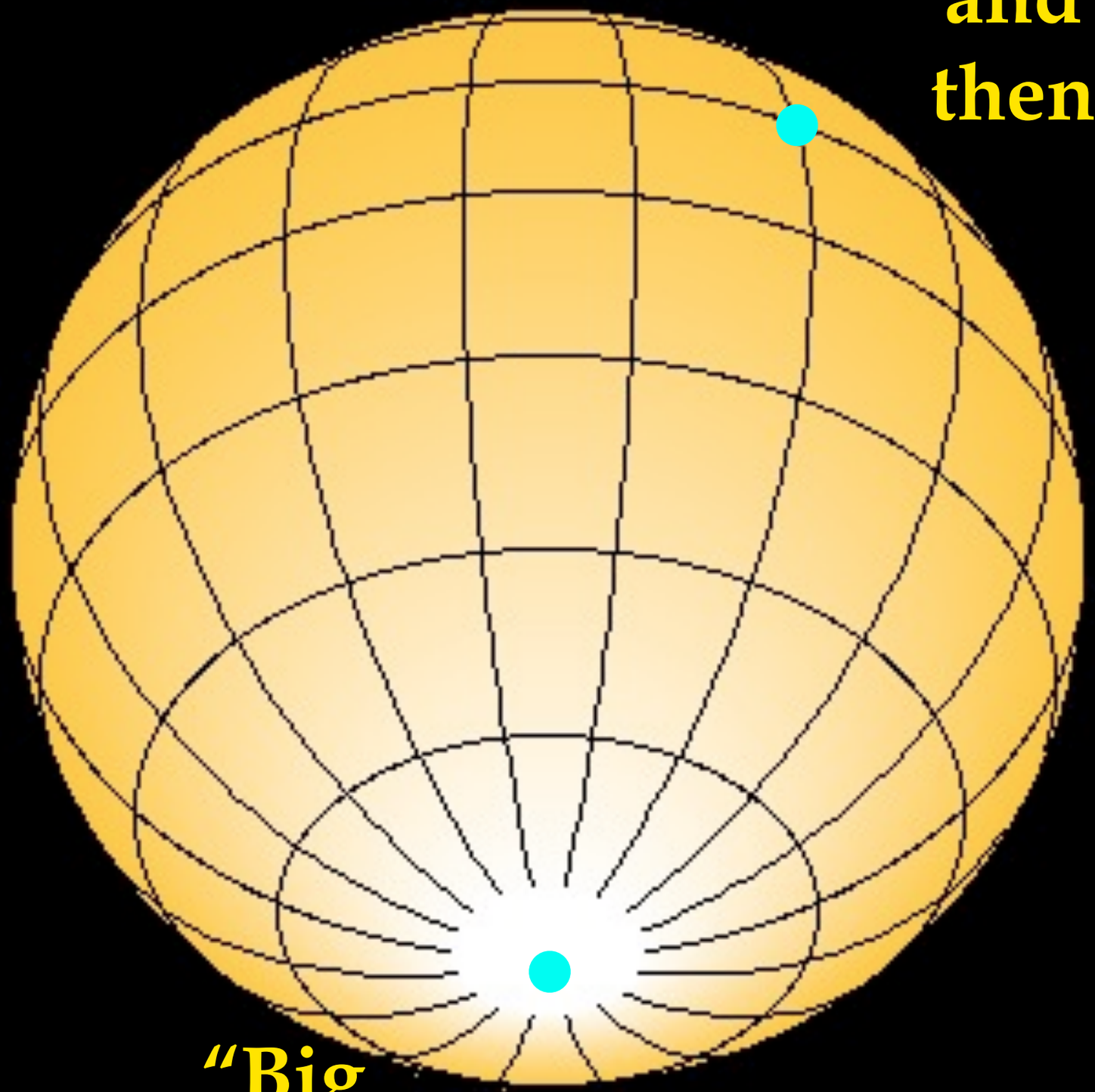


Here and now



There and then

There and then



"Big Bang"

# Friedmann Equations

$$\left(\frac{da}{dt}\right)^2 = \frac{8\pi}{3}G\rho a^2 - kc^2 + \frac{\Lambda}{3}a^2$$

$$\frac{d}{dt}\left(\rho a^3\right) + \frac{P\,da^3}{c^2\,dt} = 0$$

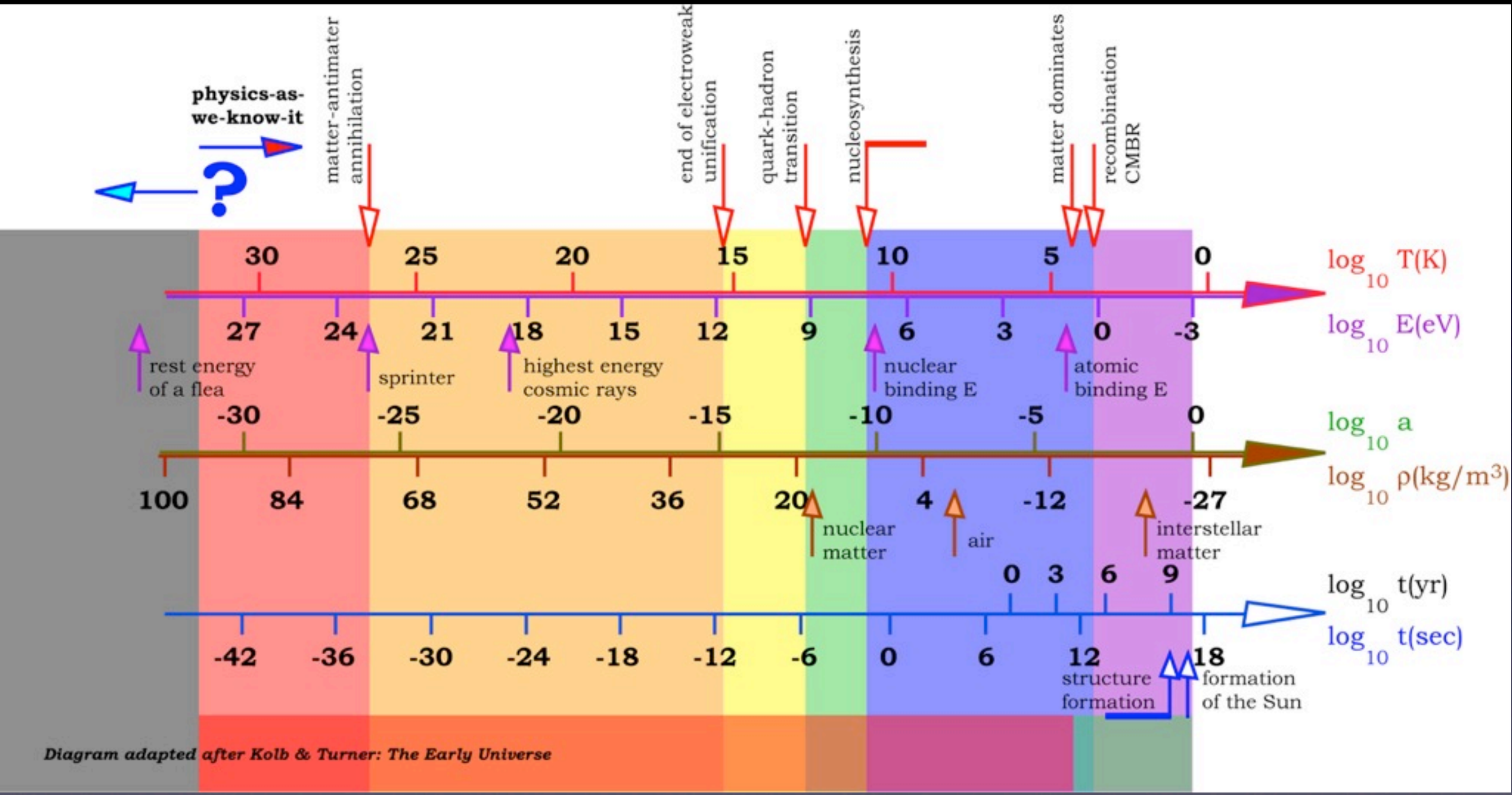



*Diagram adapted after Kolb & Turner: The Early Universe*