

# Galaxy clusters: the Universe's biggest labs

Matteo Bianconi

Image credit: Illustris-TNG simulation



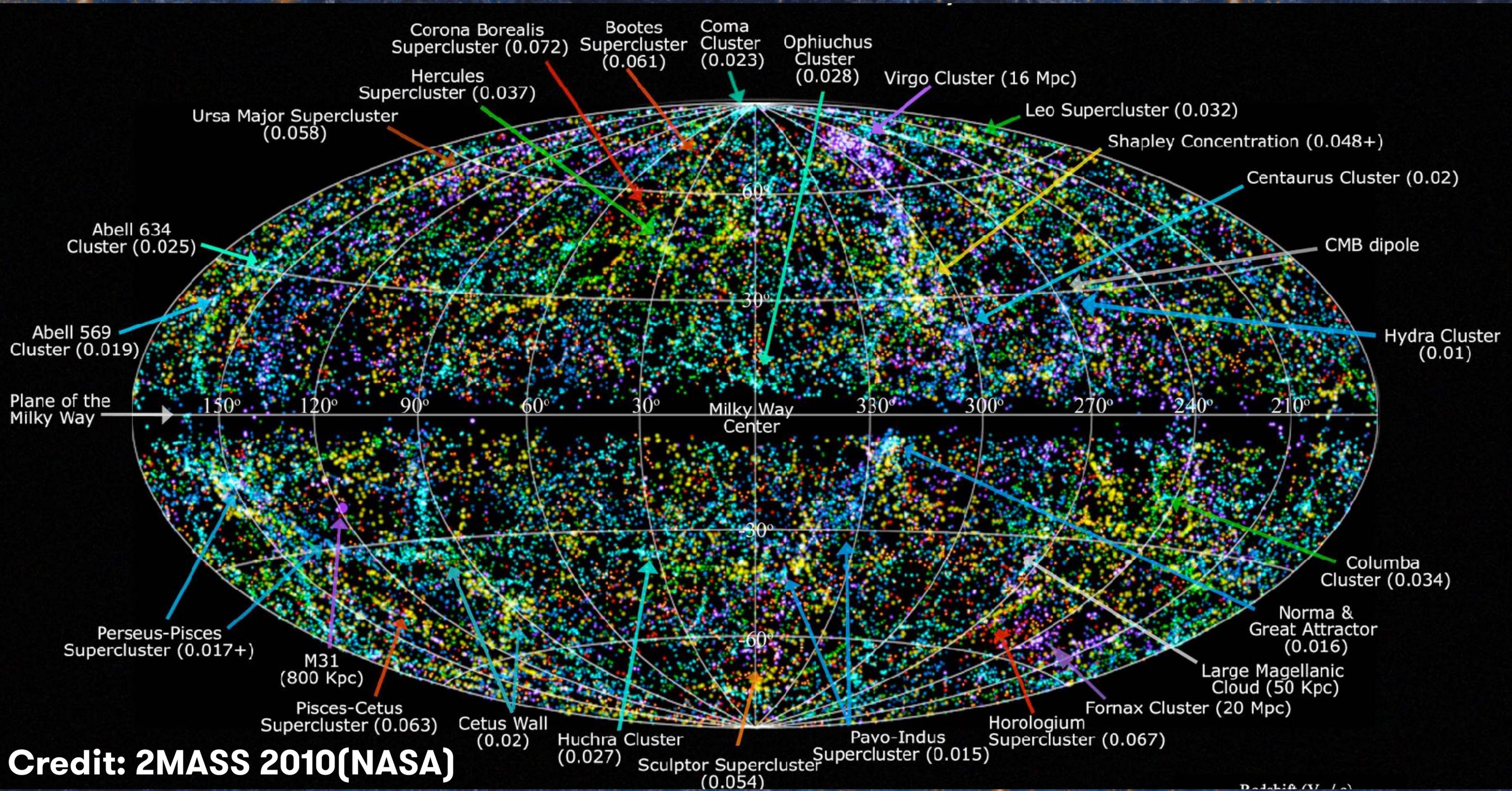
UNIVERSITY OF  
BIRMINGHAM

Astronomy in the City - Oct/23rd, 2019

# An **extragalactic** guide to the talk

**We will:**

- **travel outside our Galaxy**
- **combine observations and numerical simulations**
- **jump back-and-forth in Time and see Space stretching**



**Credit: 2MASS 2010(NASA)**

SDSS

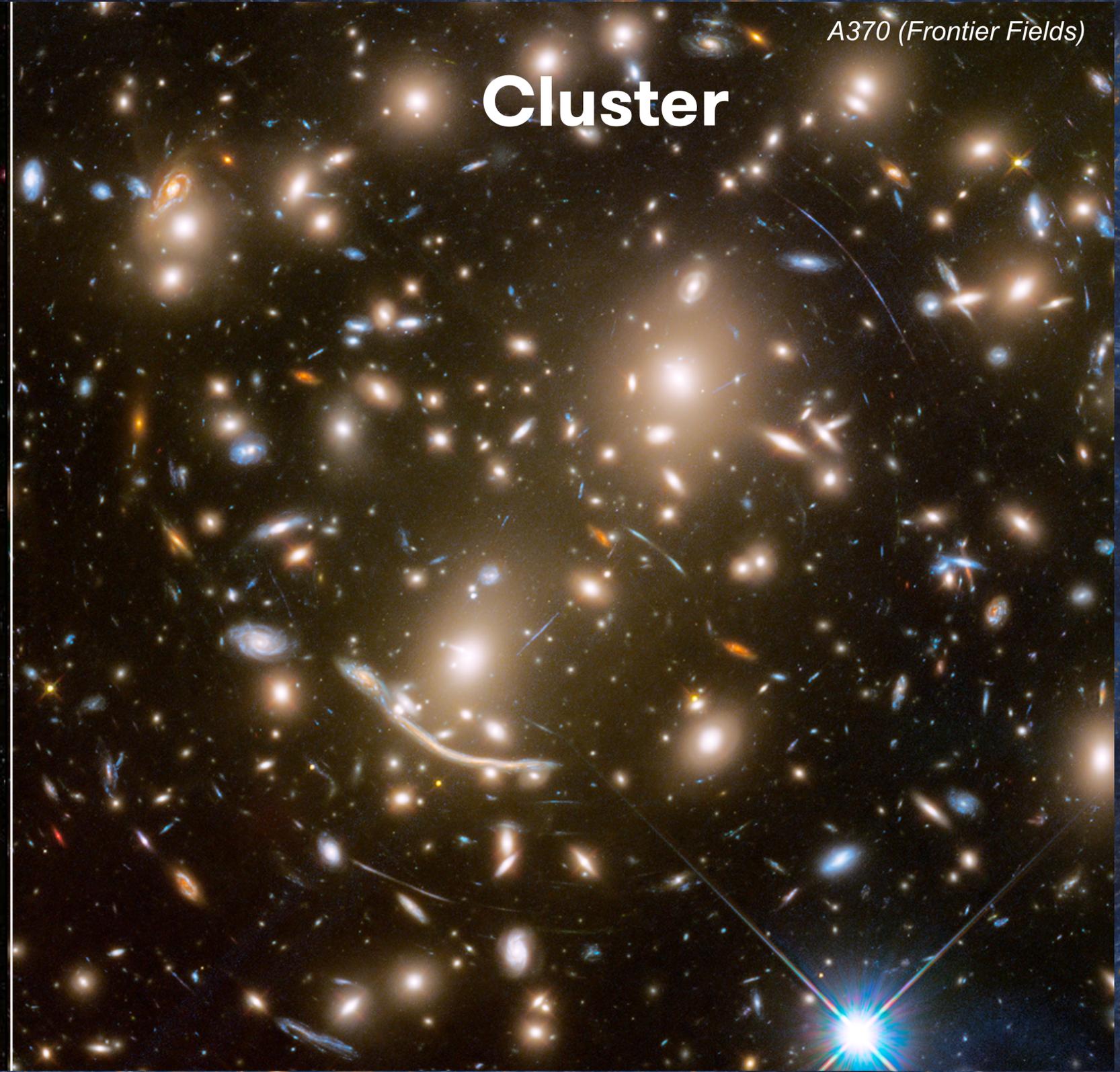
# Isolation



Image credit: SDSS + NASA

A370 (Frontier Fields)

# Cluster



**Satellite view  
of CERN**

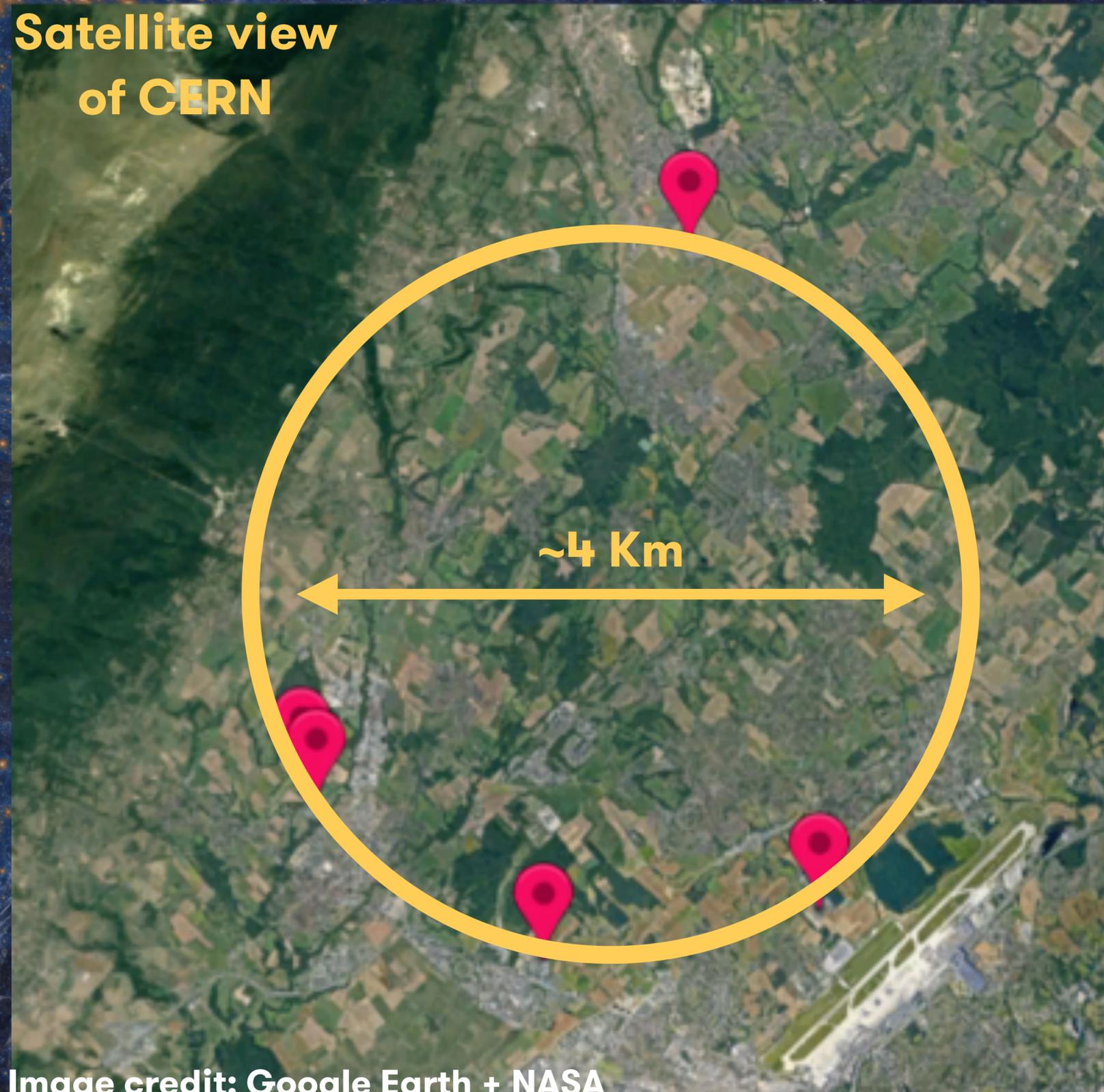
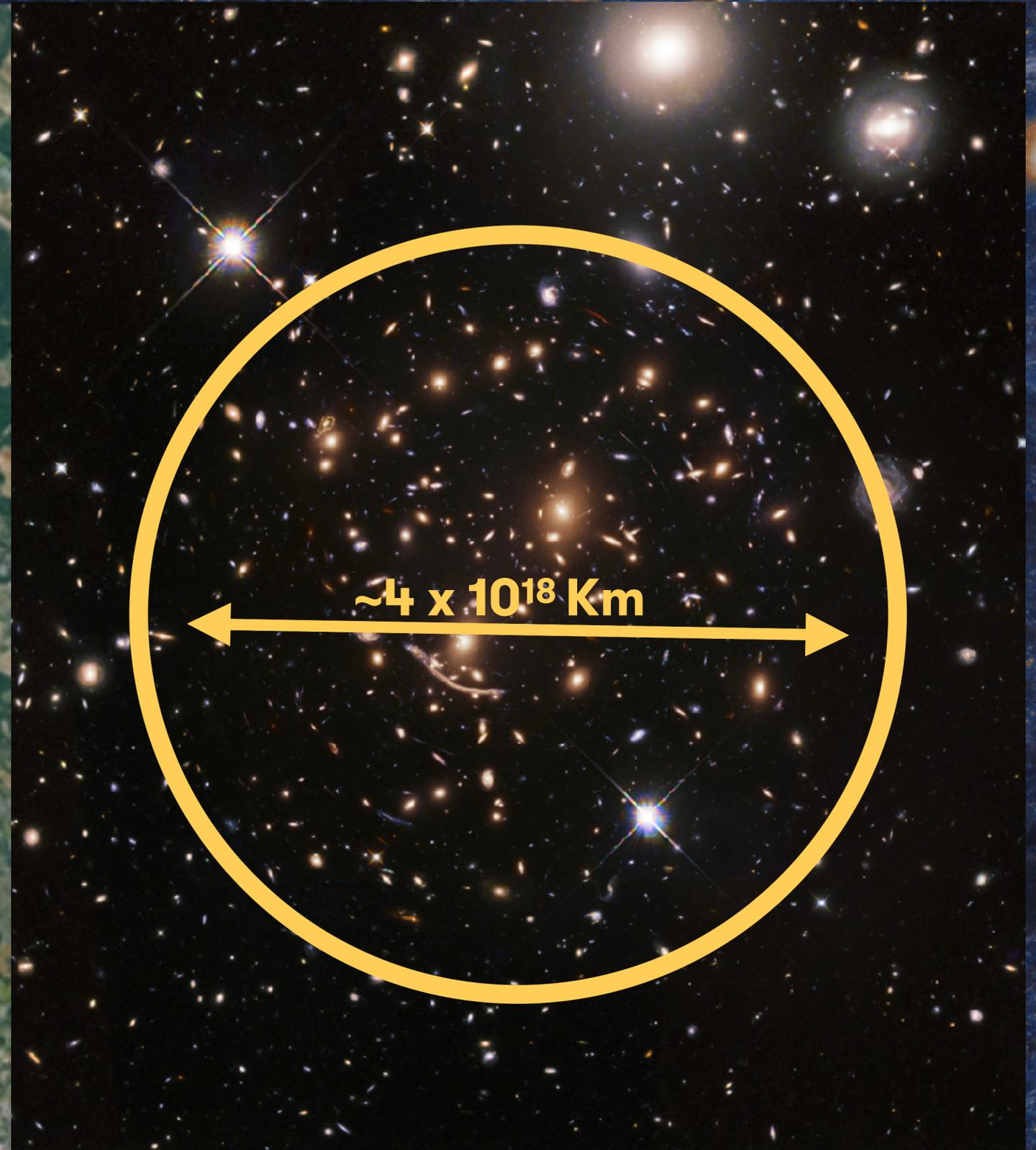
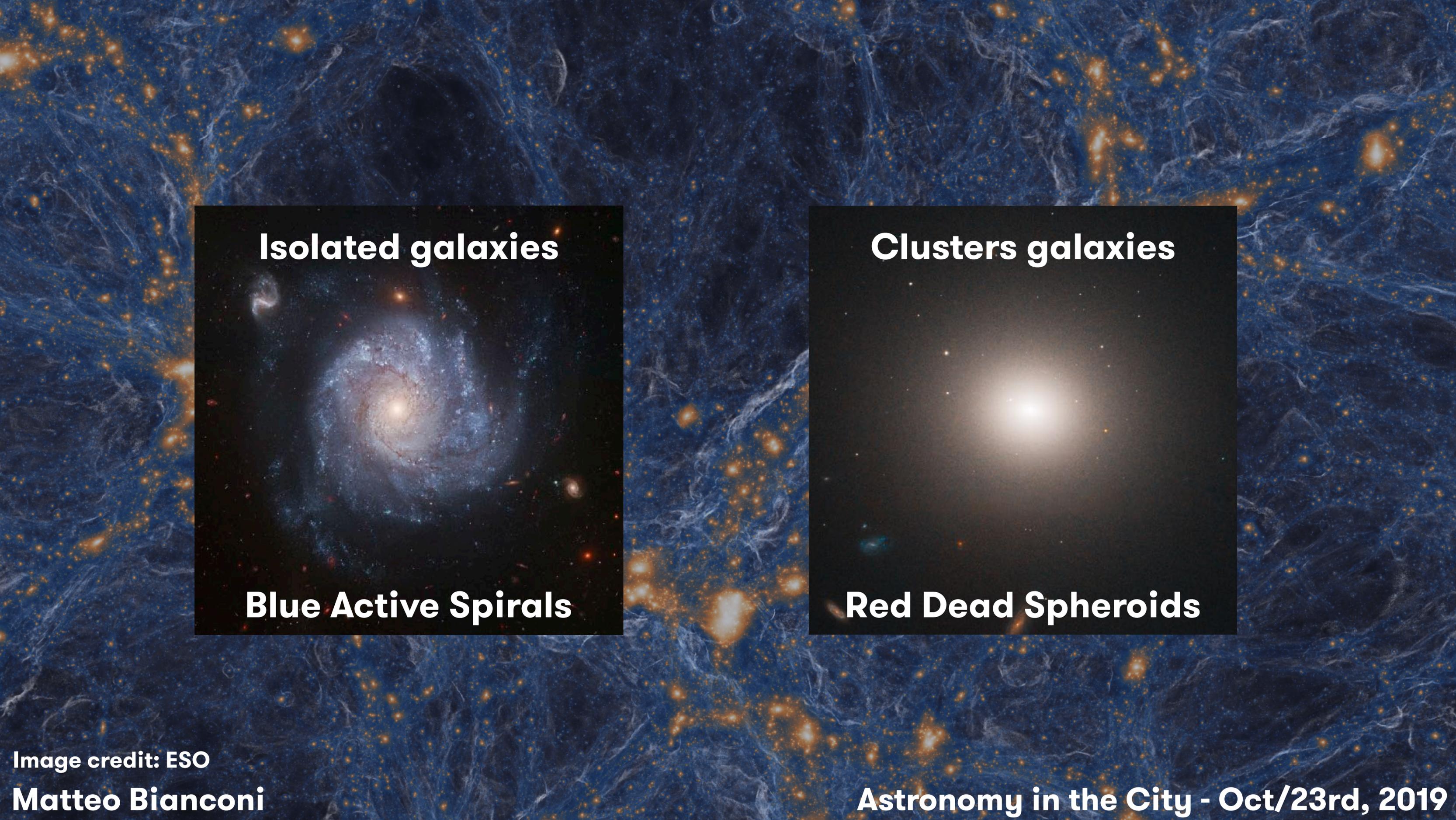


Image credit: Google Earth + NASA





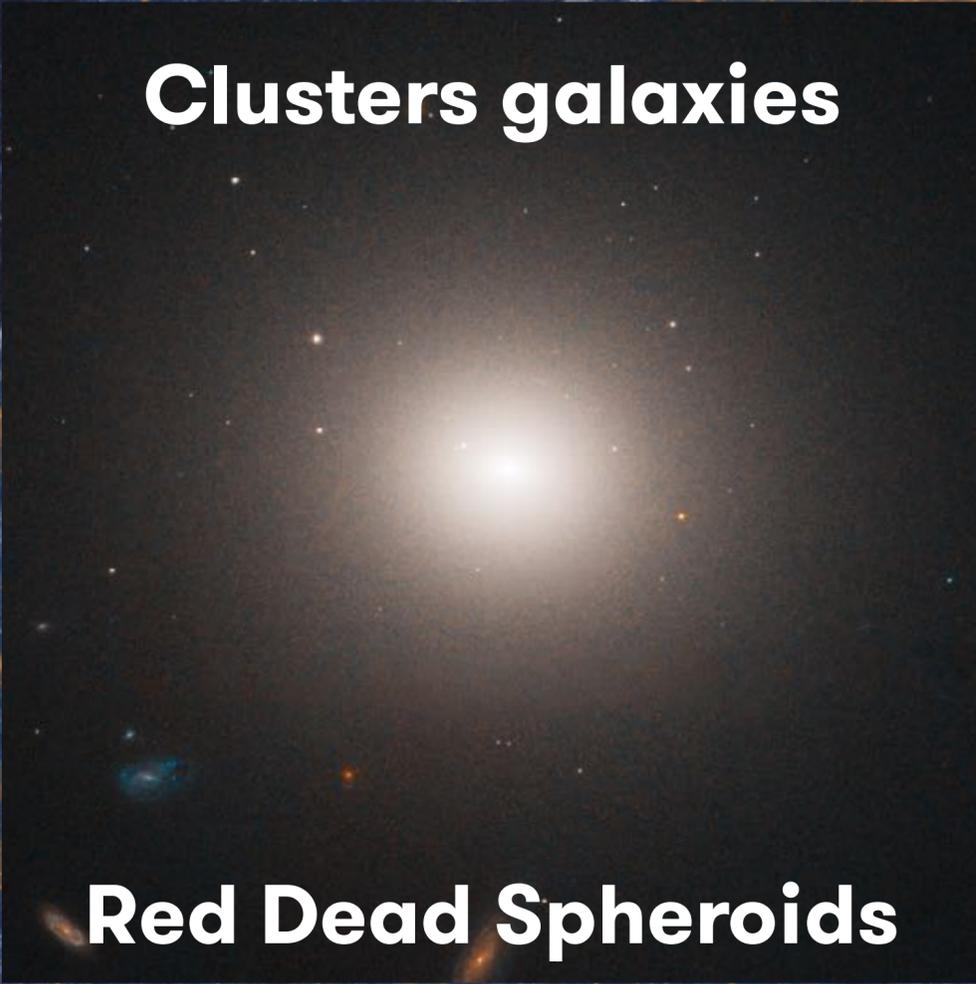
The background of the entire image is a visualization of the cosmic web, showing a complex network of blue filaments and nodes. Numerous bright orange and yellow galaxy clusters are scattered throughout, representing regions of high galaxy density.

**Isolated galaxies**

This inset image shows a single galaxy with a prominent blue color. It has a bright yellowish-white core and several distinct blue spots and streaks scattered across its spiral arms, indicating active star formation or galactic activity.

**Blue Active Spirals**

**Clusters galaxies**

This inset image shows a dense cluster of galaxies. The central region is dominated by a very bright, yellowish-white spheroidal galaxy. The surrounding area is filled with many smaller, dimmer galaxies, mostly appearing in shades of red and orange, suggesting an older population of stars.

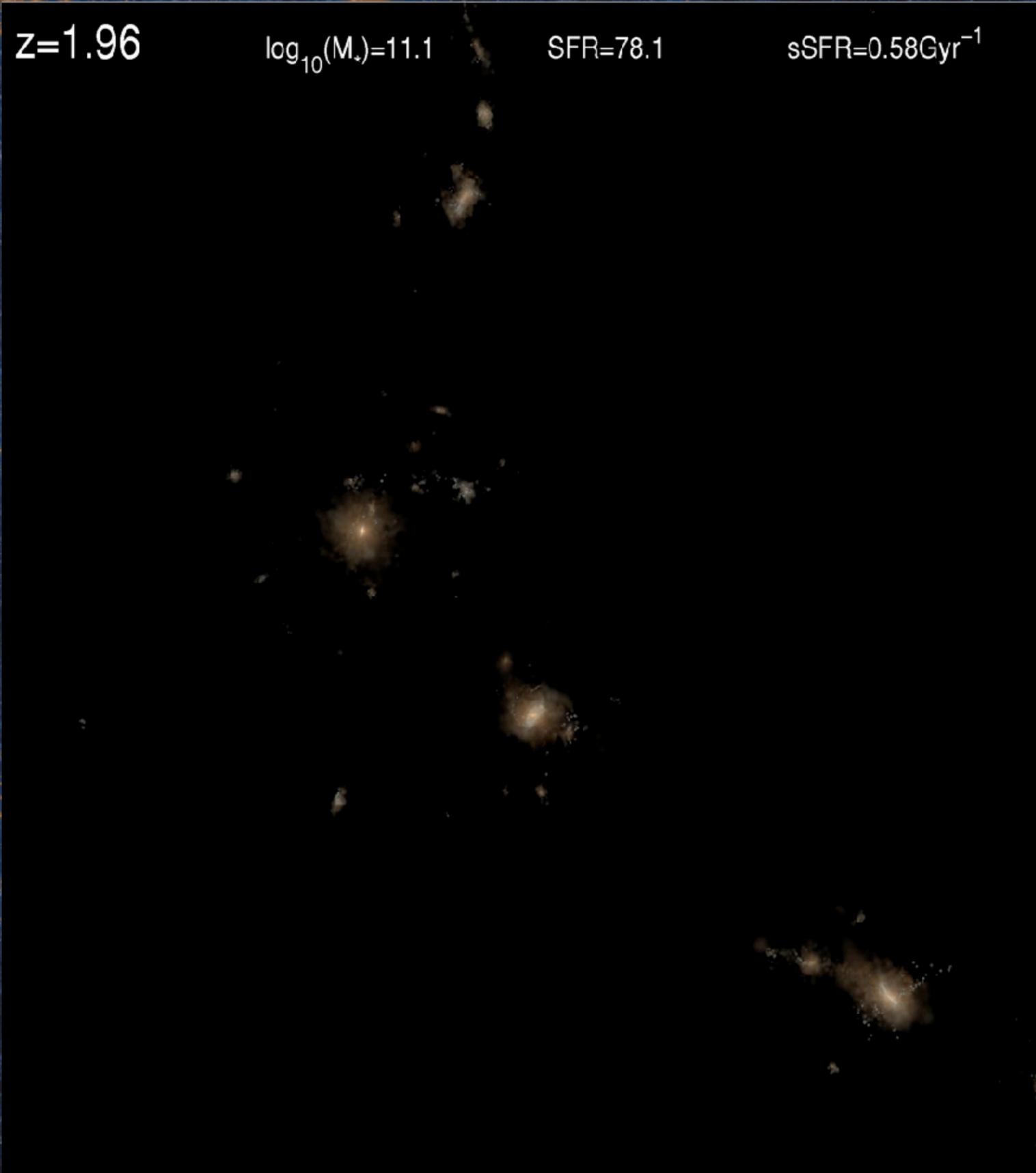
**Red Dead Spheroids**

$z=1.96$

$\log_{10}(M.)=11.1$

SFR=78.1

sSFR=0.58Gyr<sup>-1</sup>



ILLUSTRIS

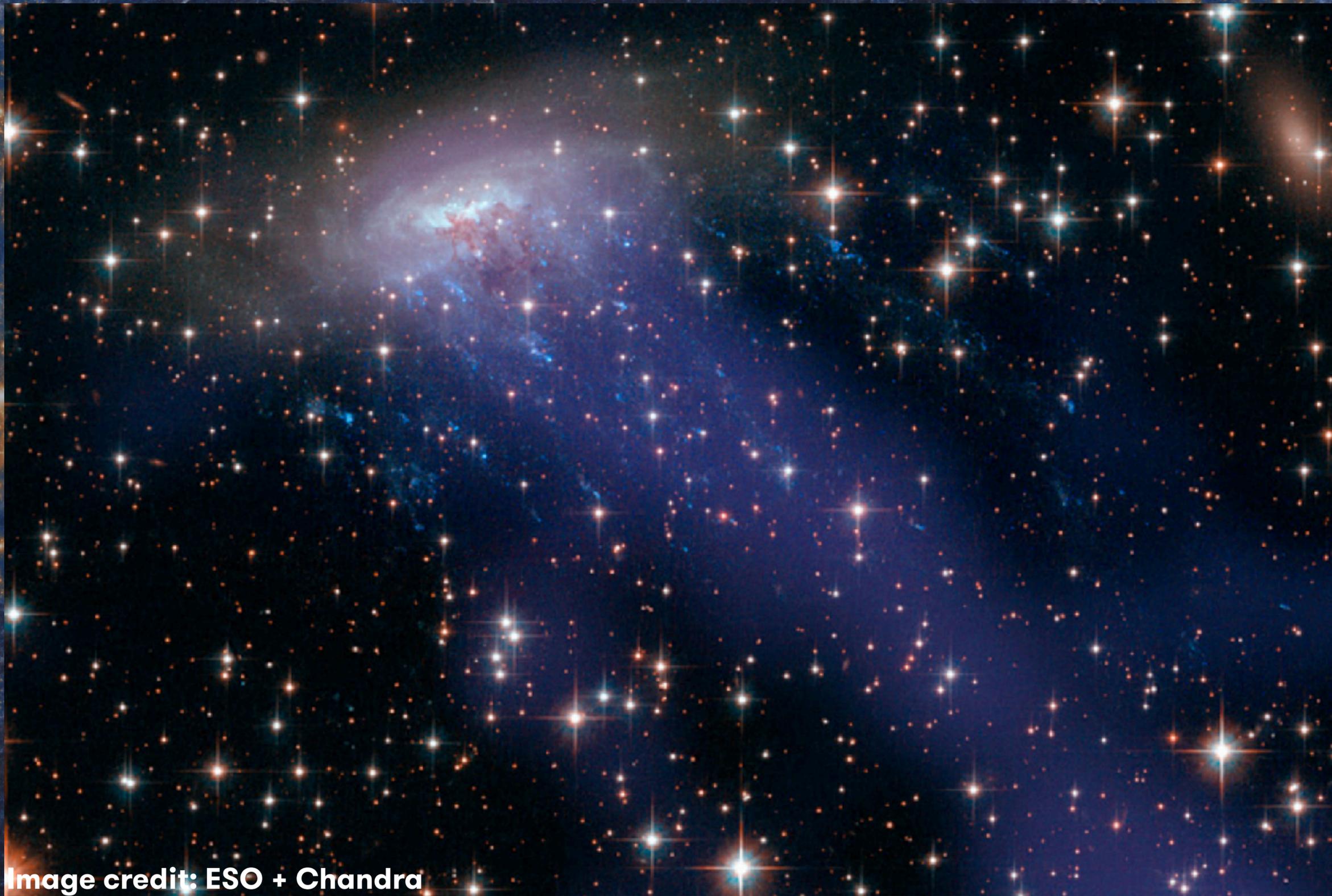


Image credit: ESO + Chandra

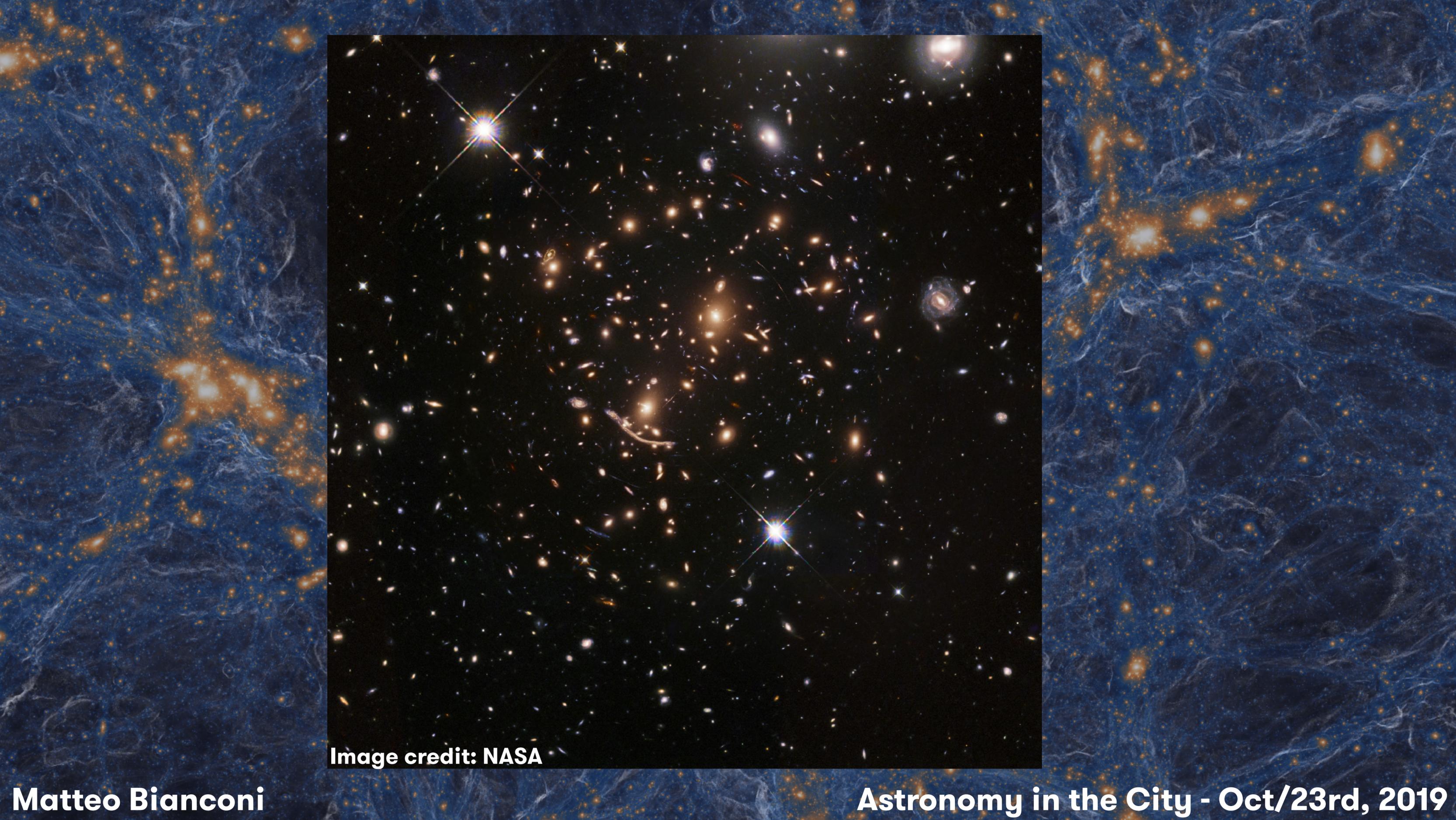


Image credit: NASA

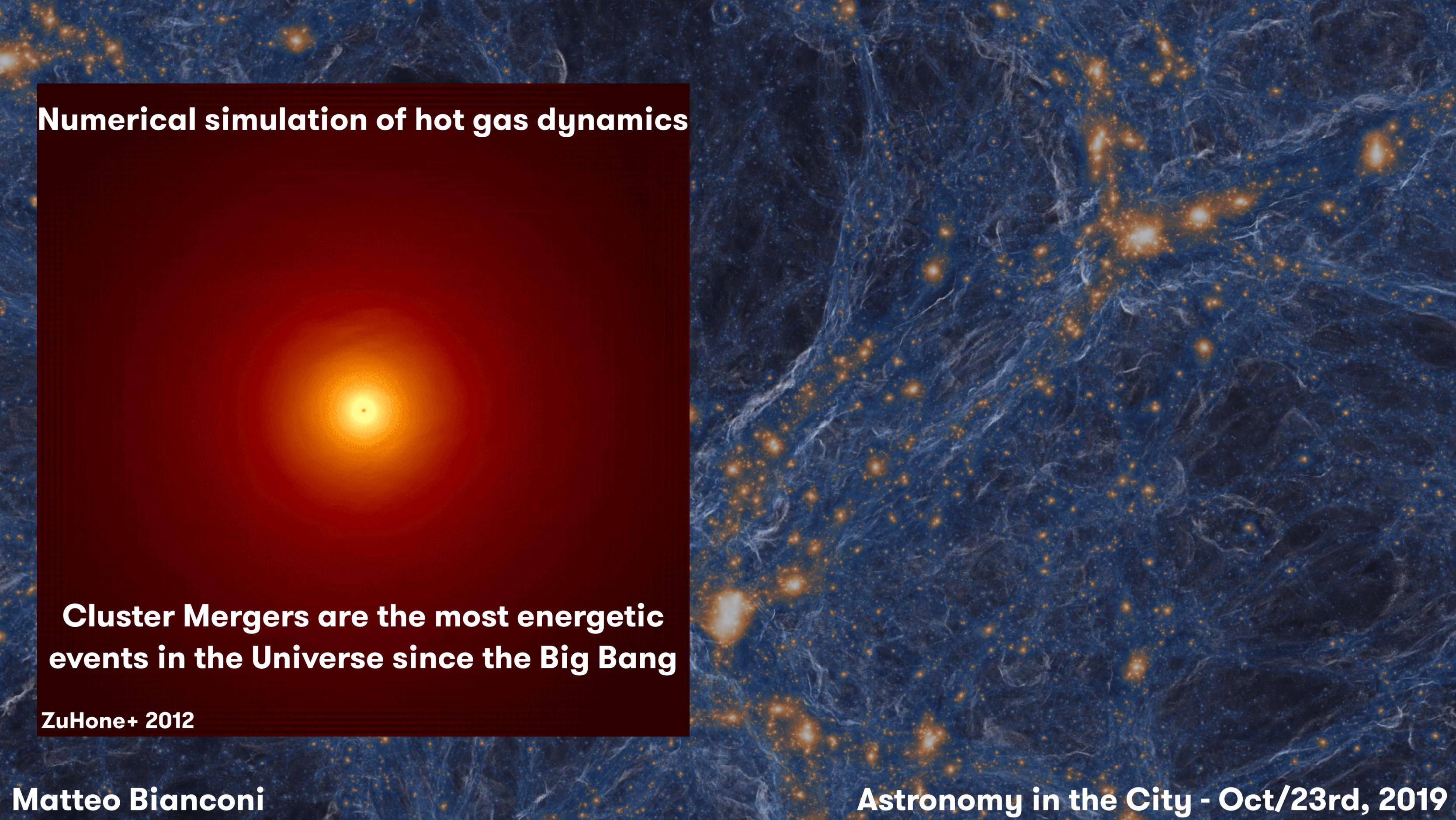
# Hot sparse gas emitting X-rays

→ 10 million Kelvin !

→ 1 particle per cubic centimeter !

**5 times more gas than galaxies**

Image credit: NASA (Chandra)

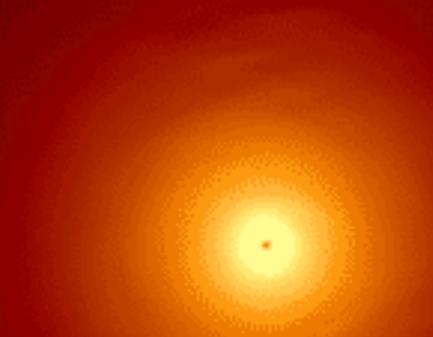


**Numerical simulation of hot gas dynamics**

**Cluster Mergers are the most energetic events in the Universe since the Big Bang**

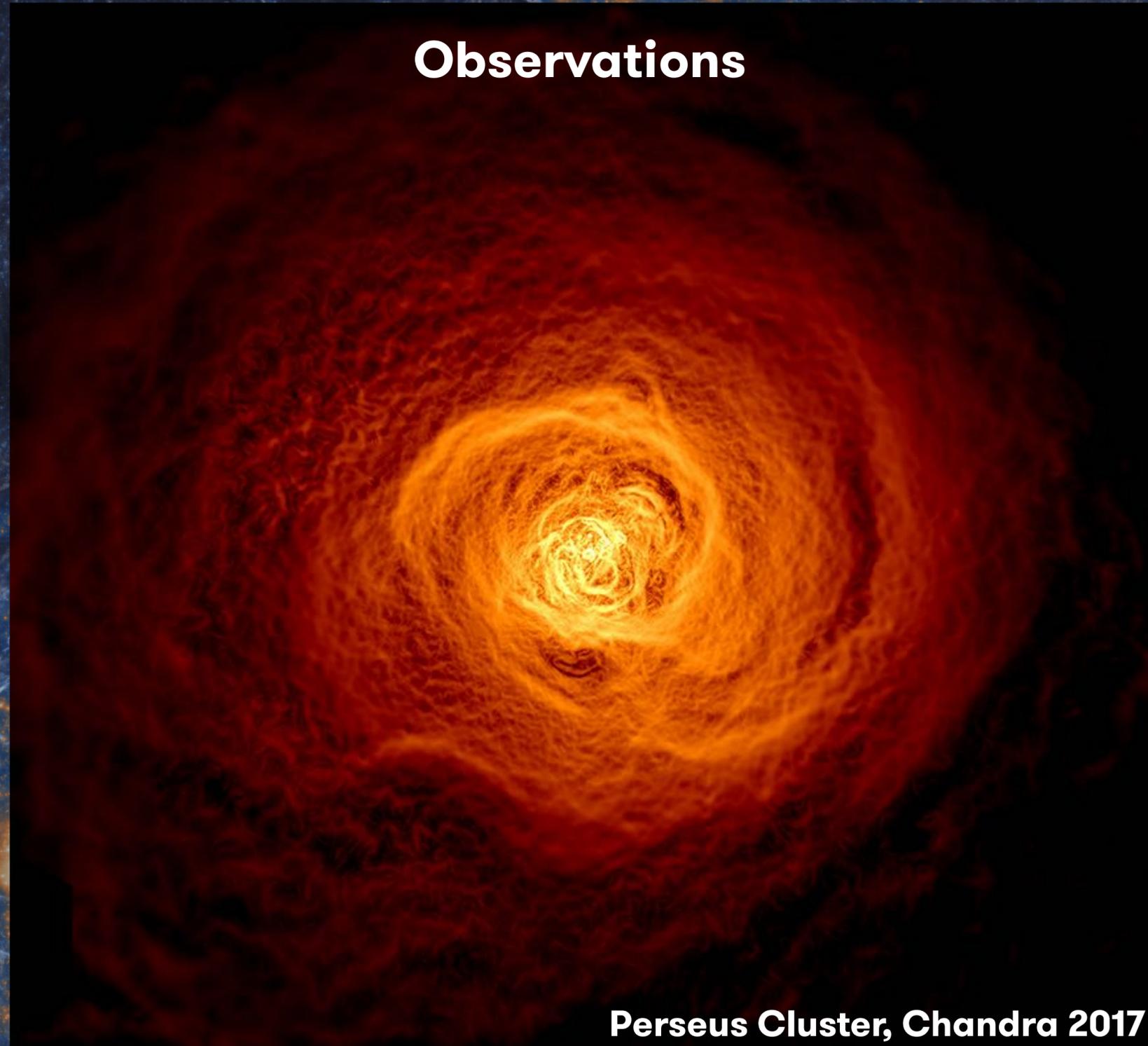
ZuHone+ 2012

## Numerical simulation of hot gas dynamics

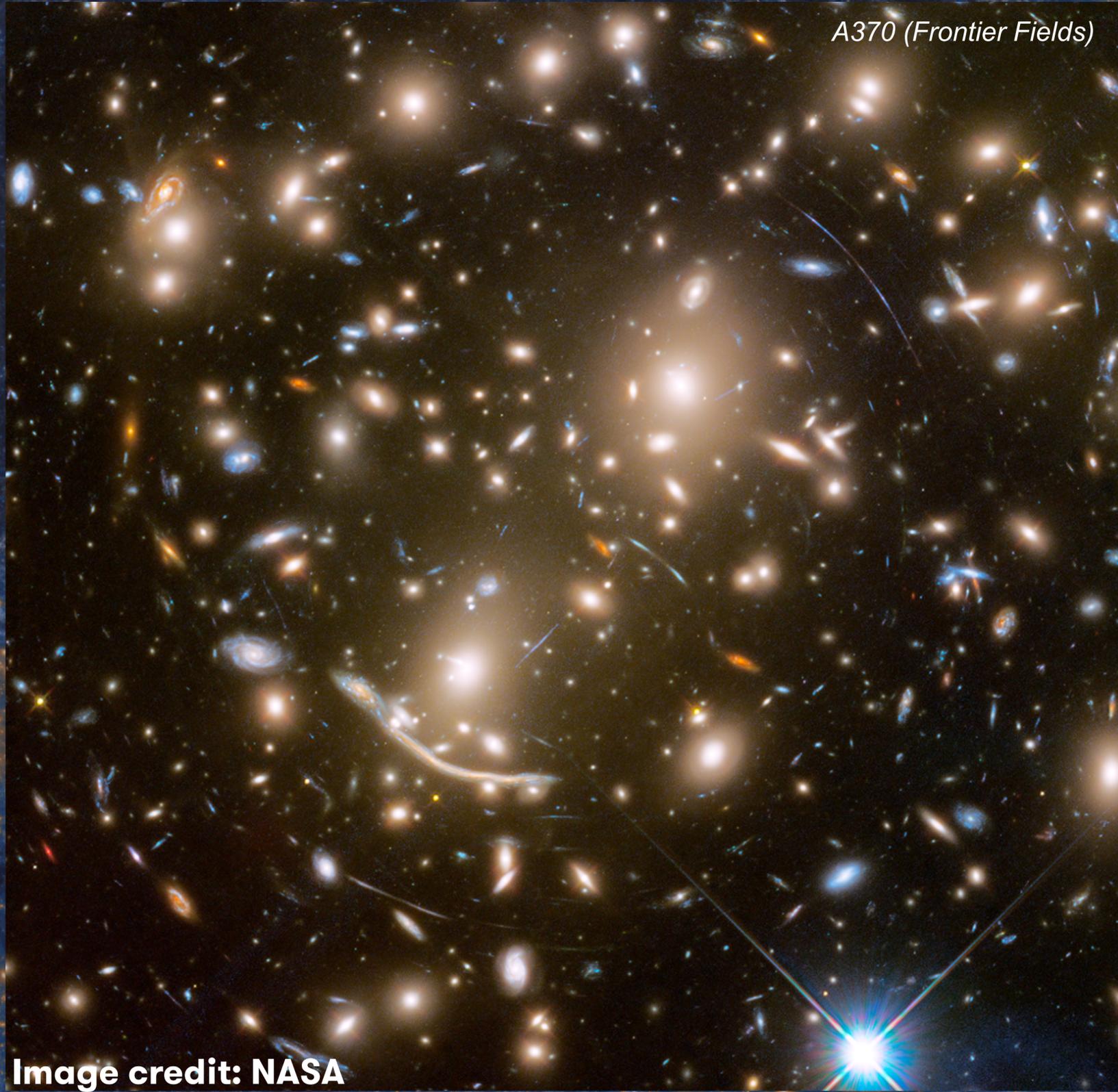
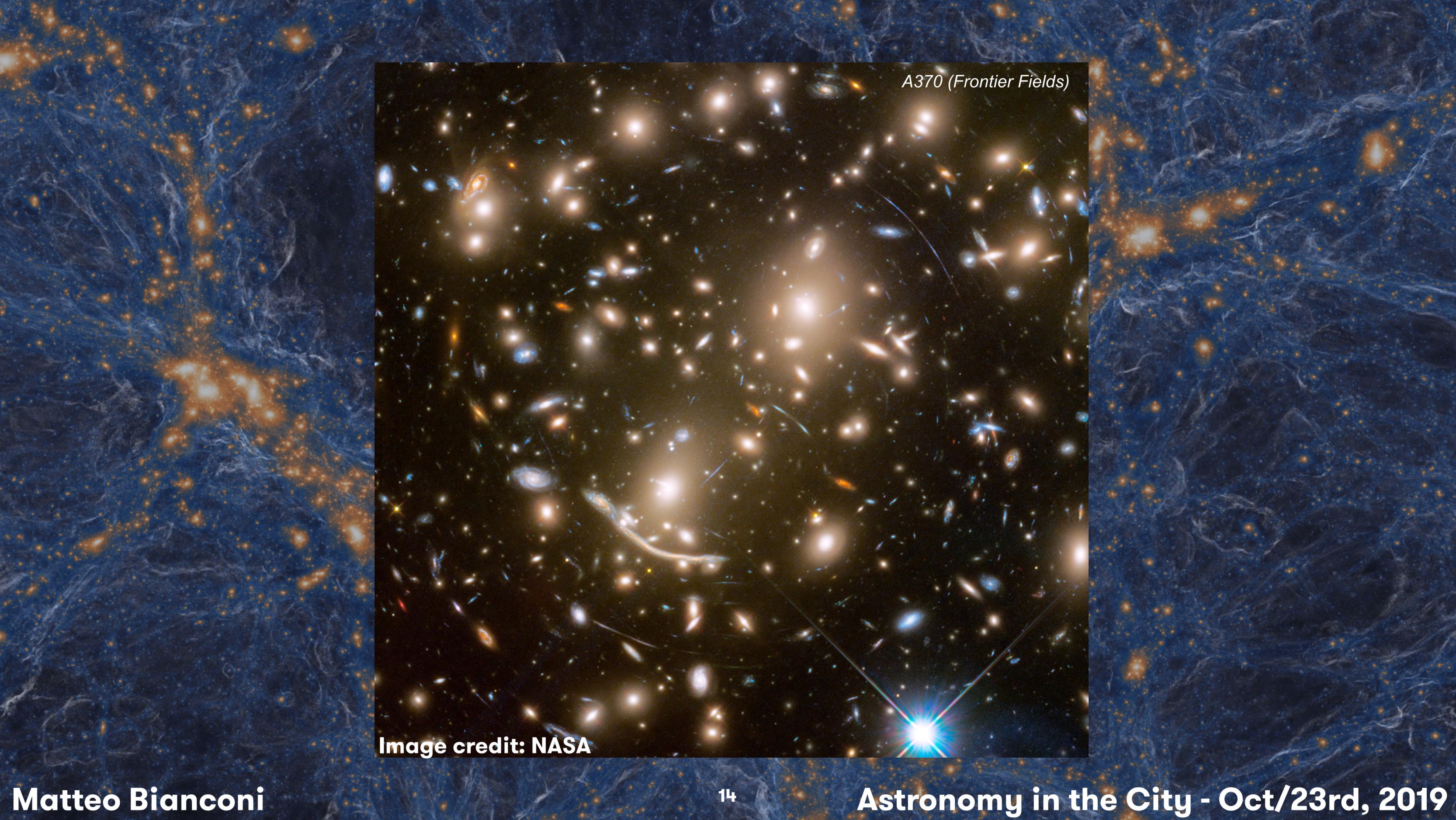


ZuHone+ 2012

## Observations



Perseus Cluster, Chandra 2017



A370 (Frontier Fields)

Image credit: NASA

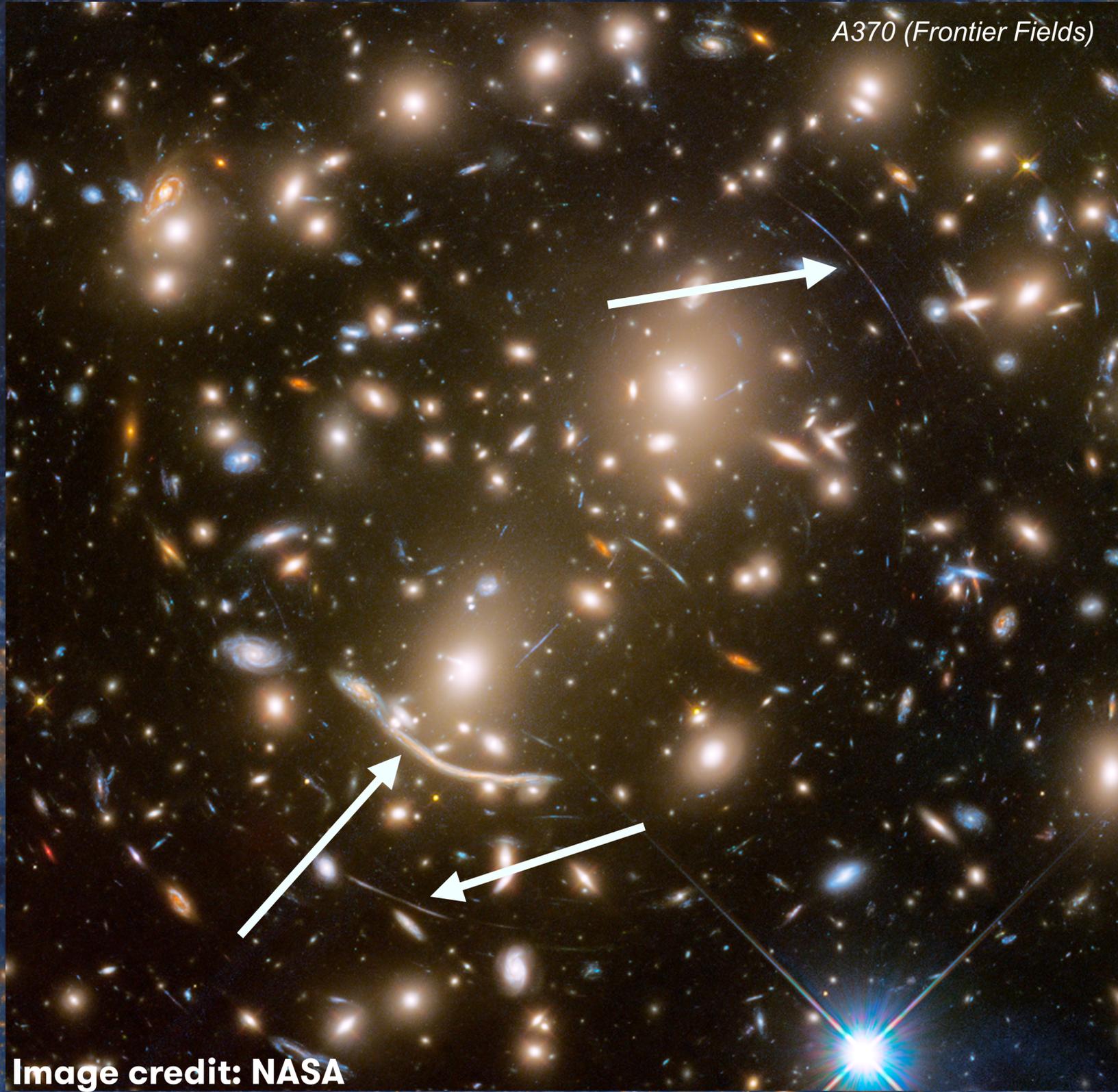
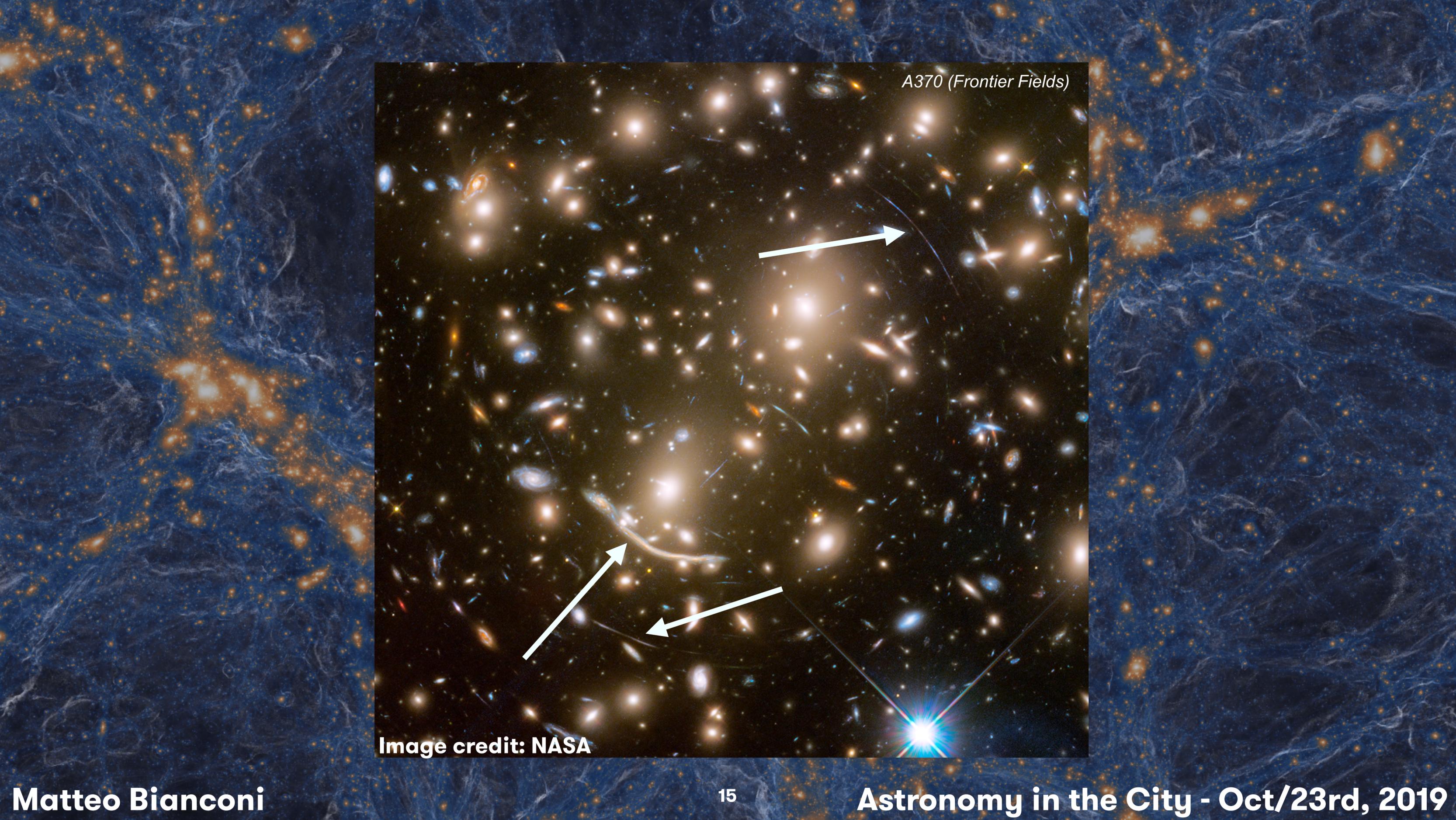
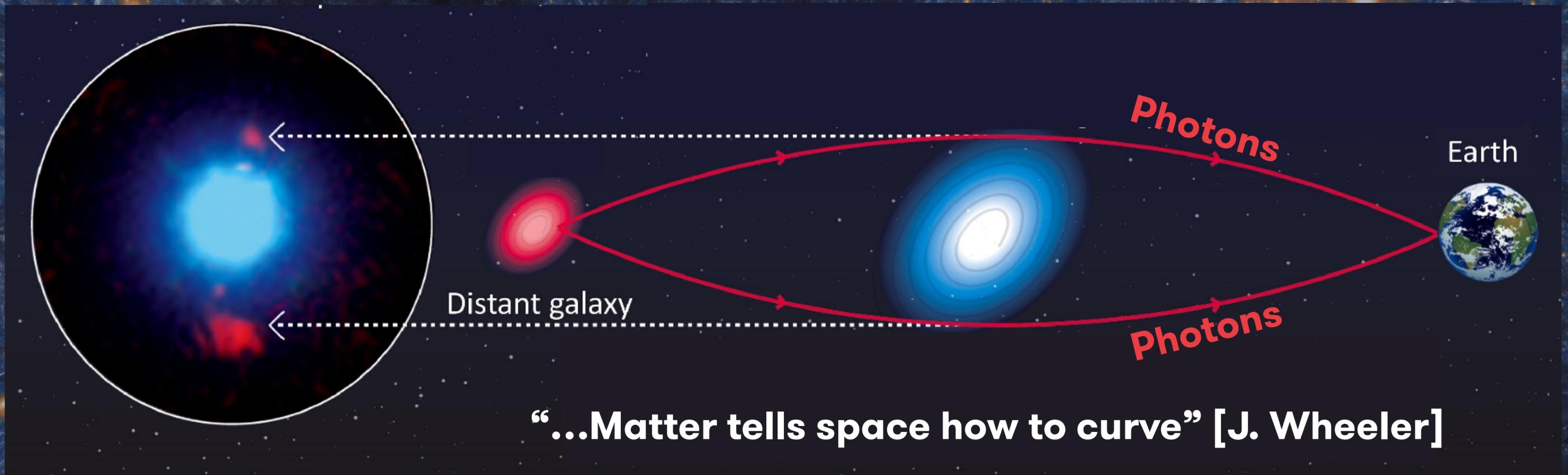
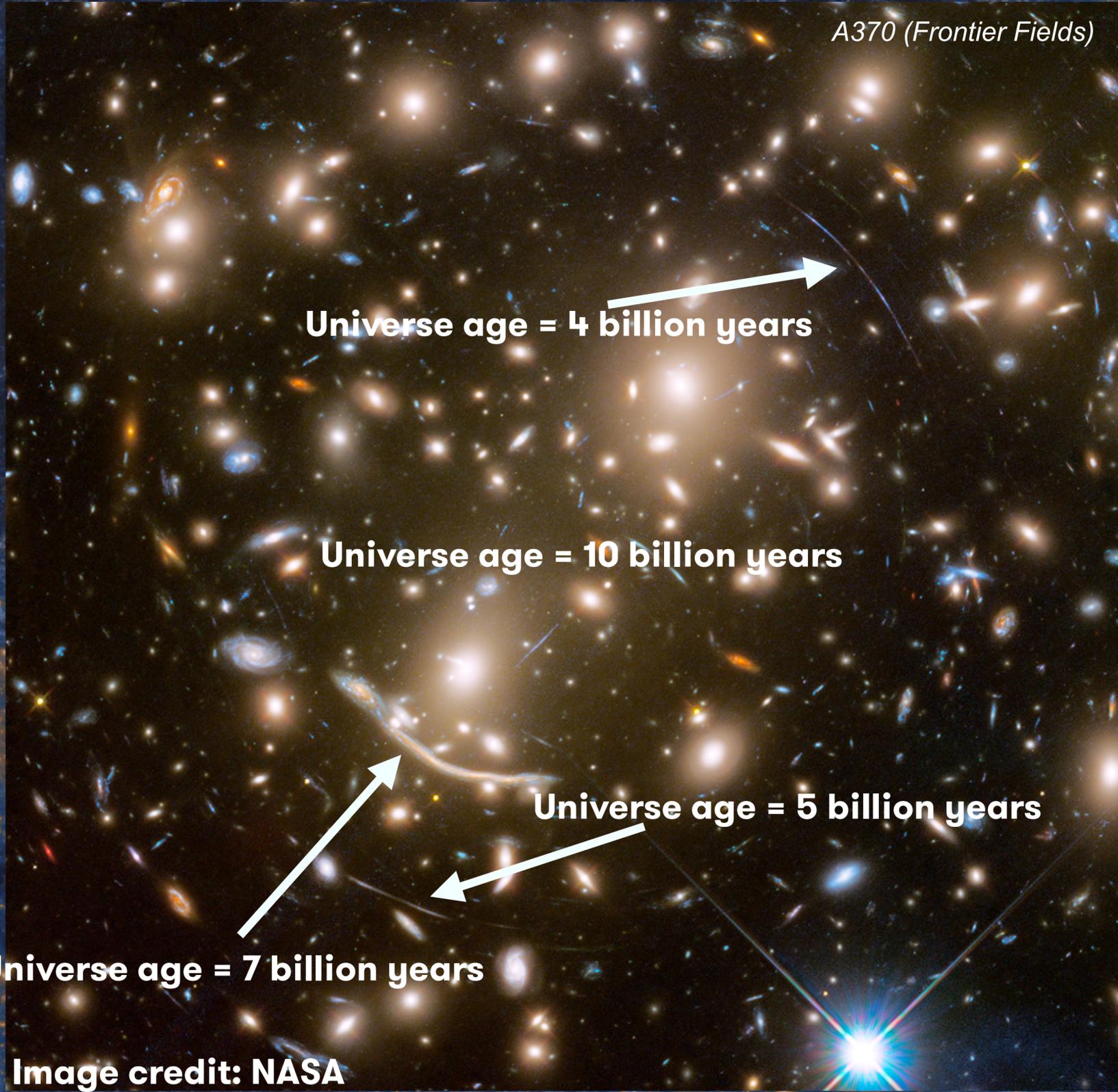
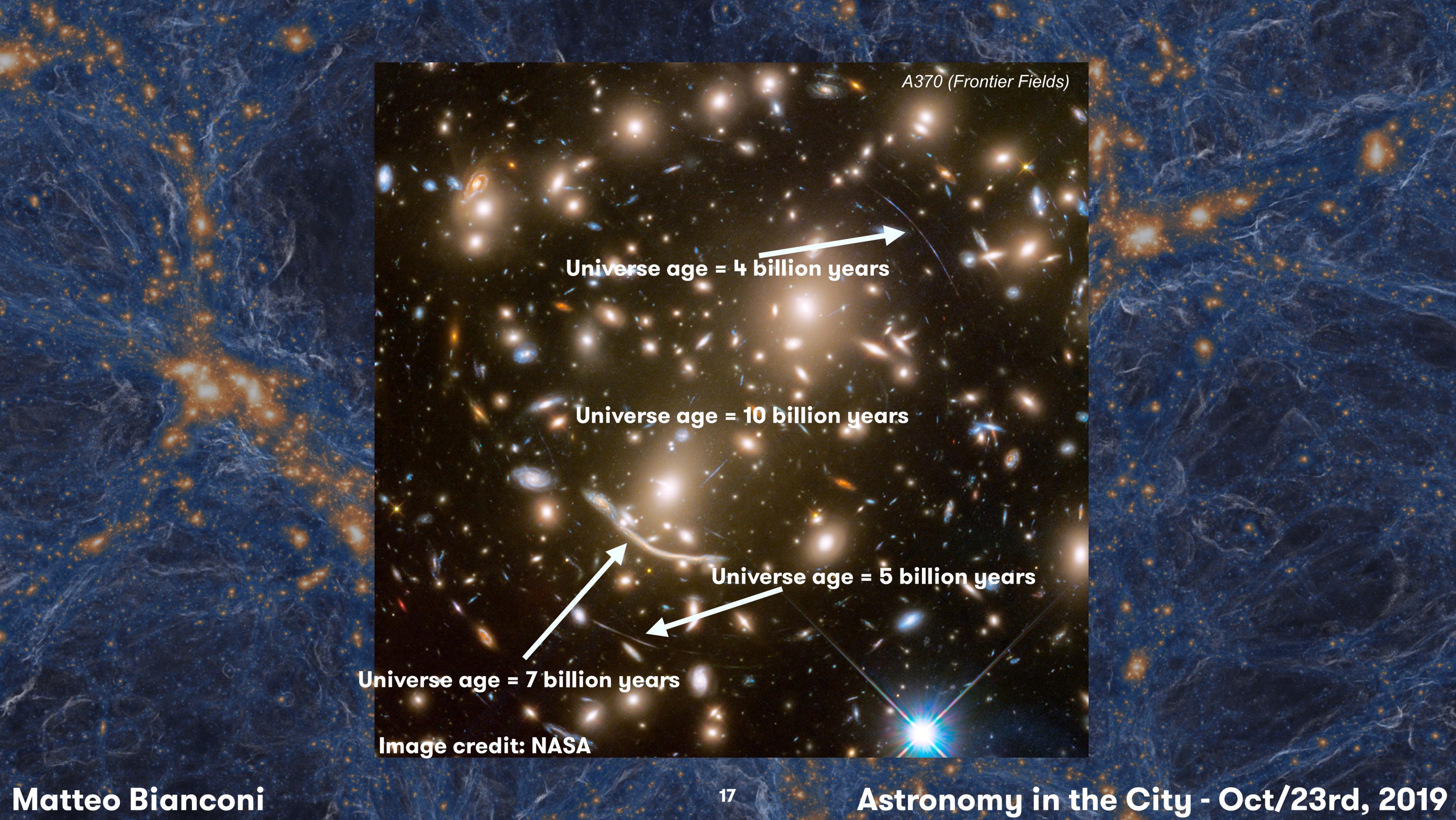


Image credit: NASA

# Gravitational Lensing



**Galaxy clusters can be used as space telescopes**



A370 (Frontier Fields)

Universe age = 4 billion years

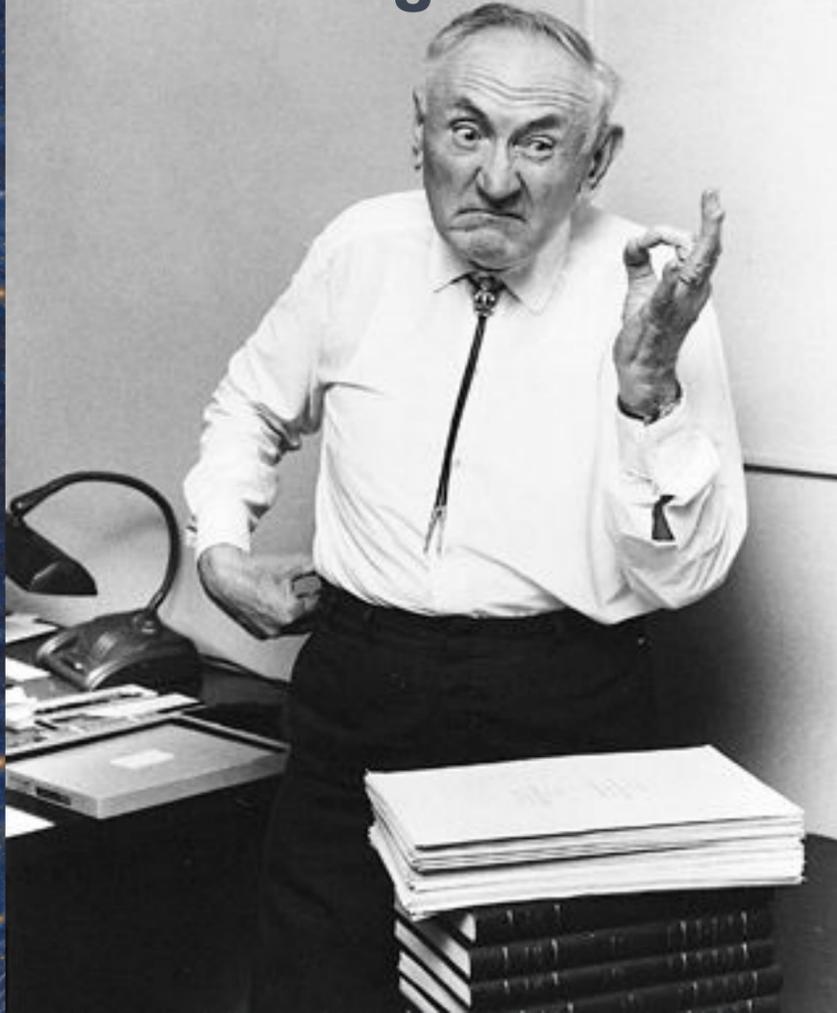
Universe age = 10 billion years

Universe age = 5 billion years

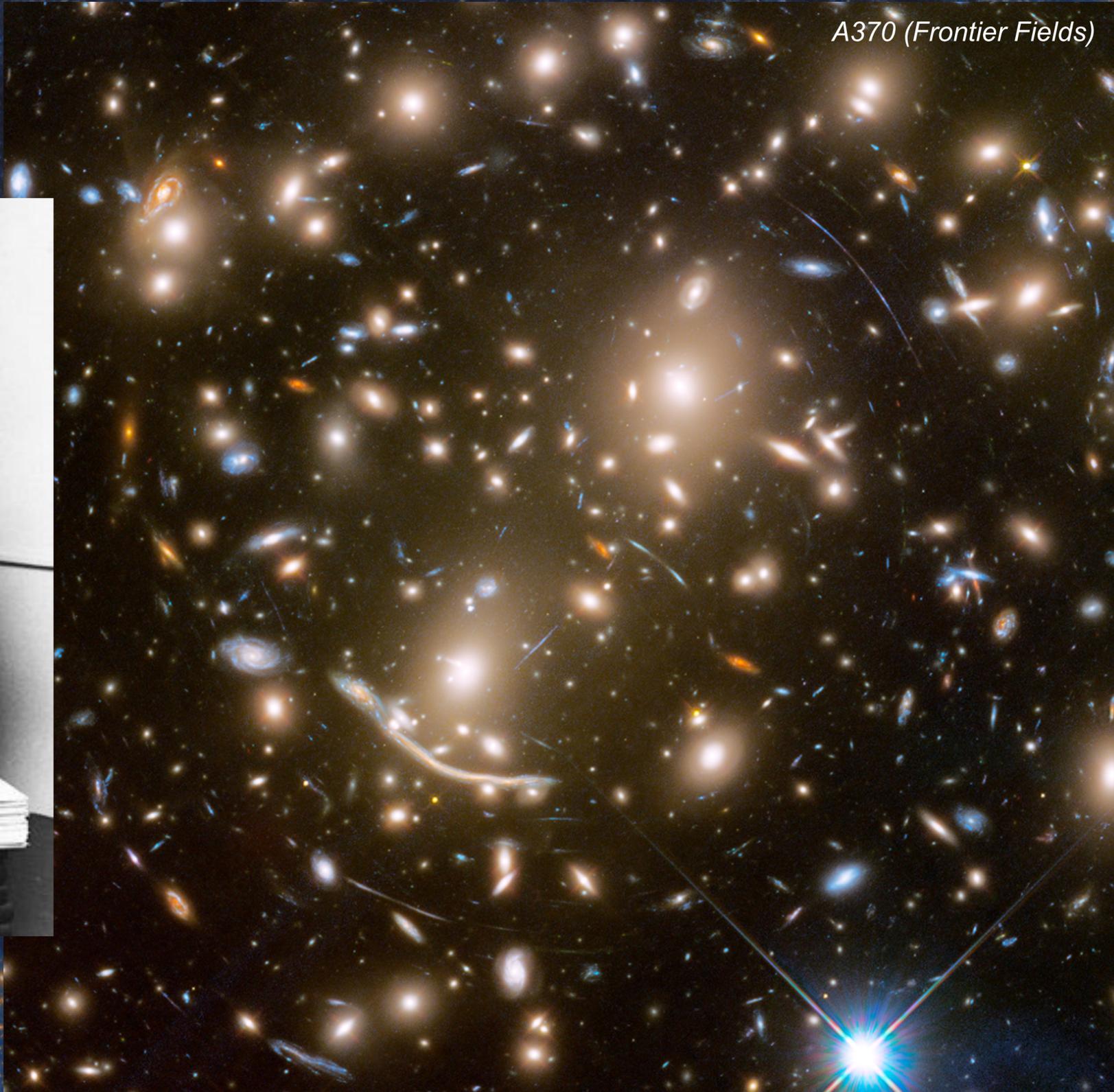
Universe age = 7 billion years

Image credit: NASA

**Fritz Zwicky - 1933**



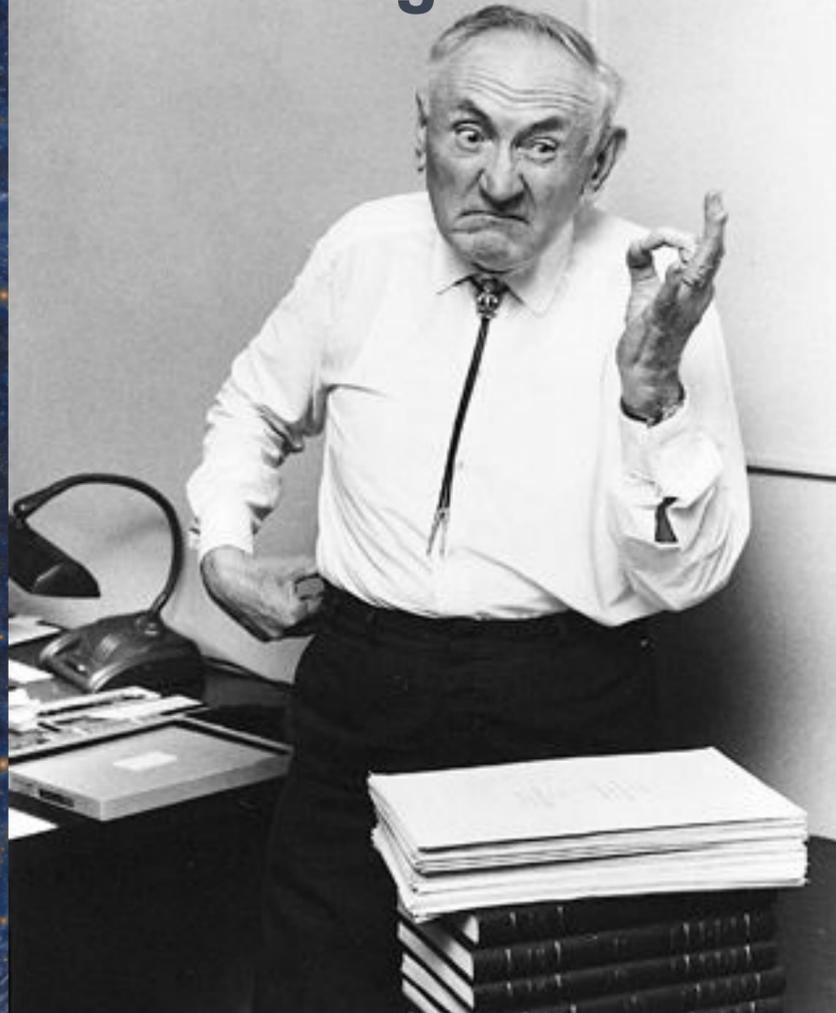
*A370 (Frontier Fields)*



**Materia oscura**

**ΣΚΟΤΕΙΝΗ ύλη**

**Fritz Zwicky - 1933**



**DARK MATTER**

**Matière noire**

**Dunkle Materie**

*A370 (Frontier Fields)*



**Galaxies**

**2%**

**Hot gas**

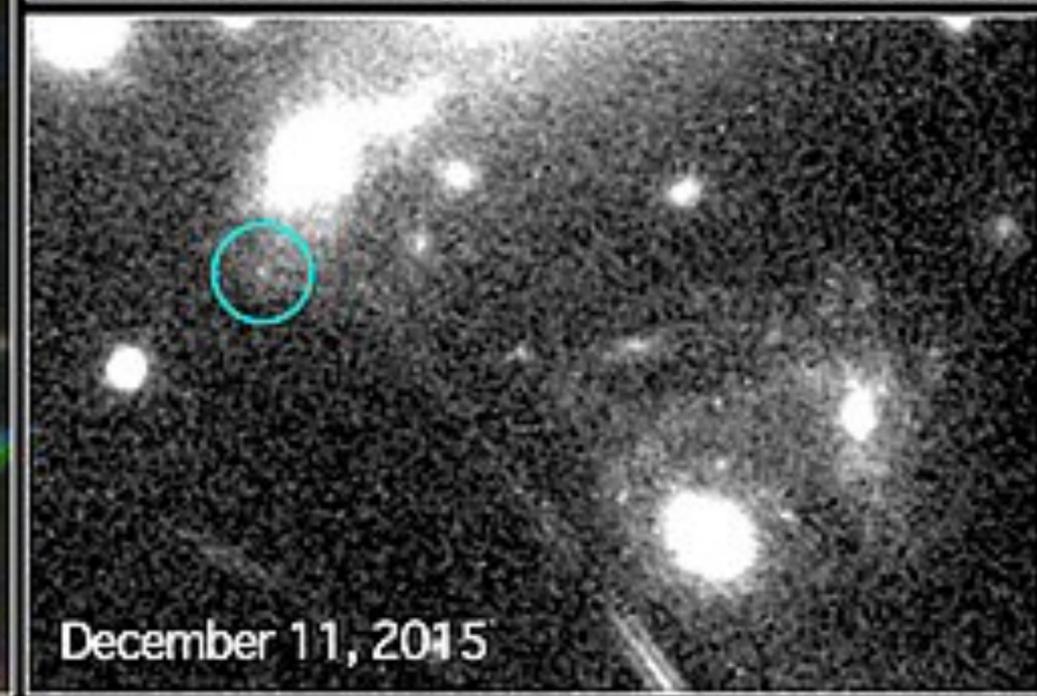
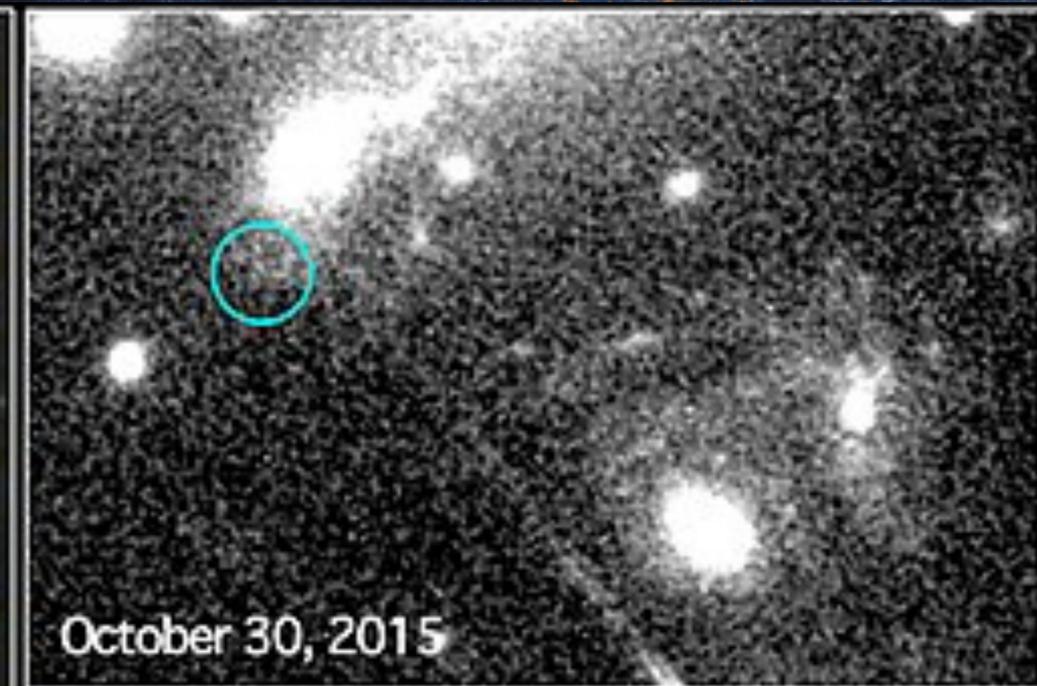
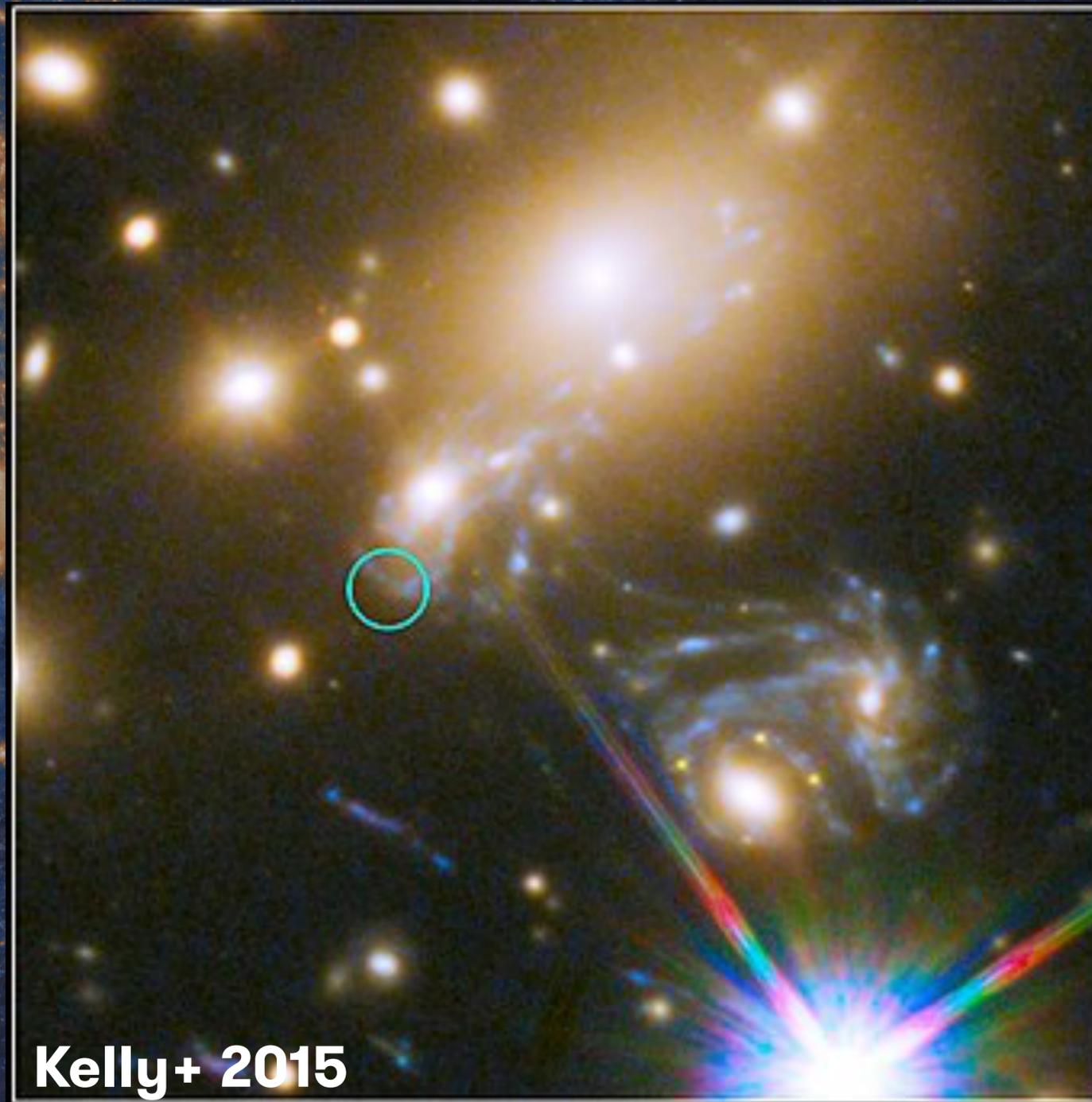
**11%**

**Galaxy cluster mass budget**

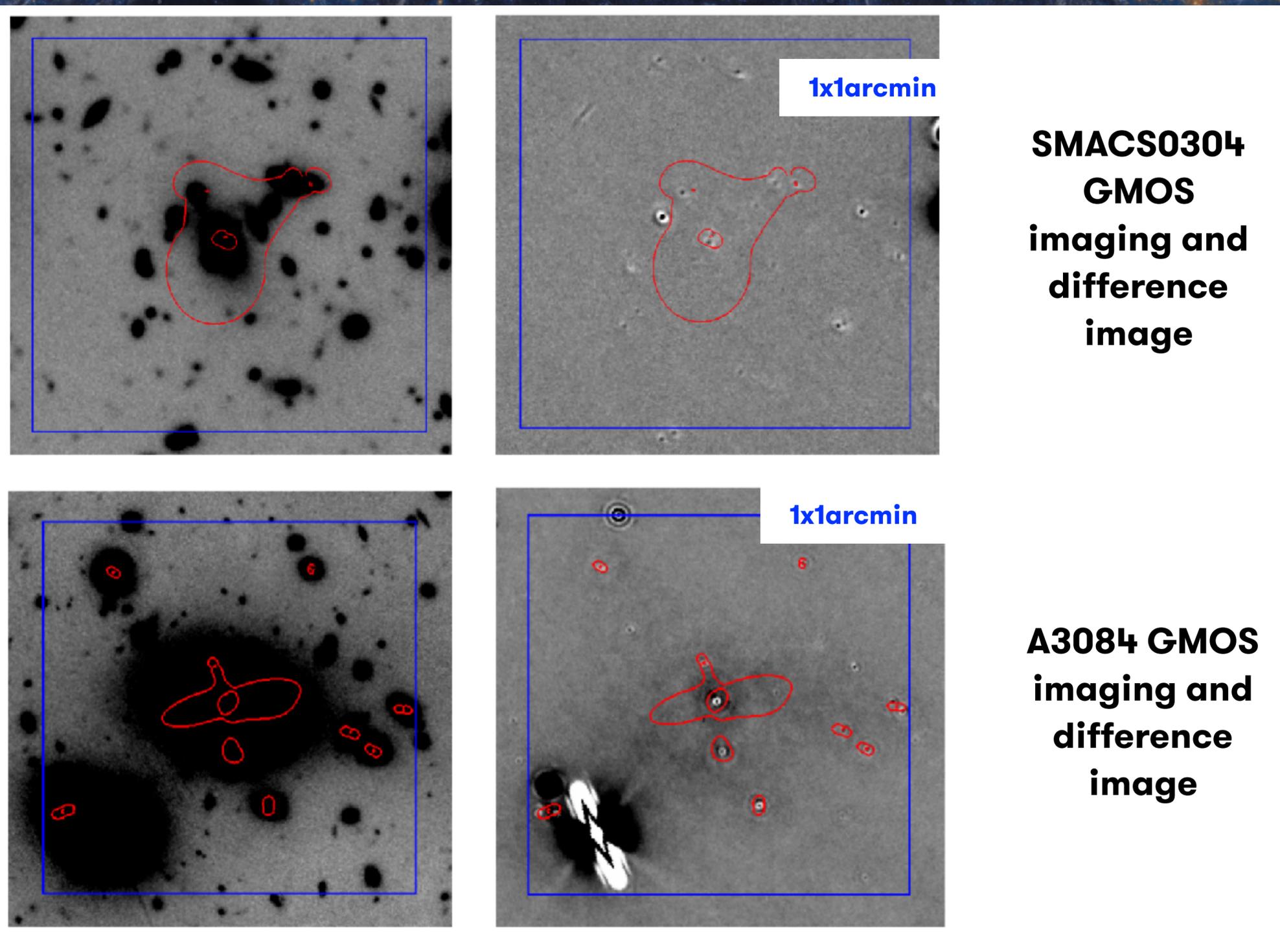
**Dark matter**

**87%**

# Predicting Supernova appearance



# Gravitational lensing of gravitational waves



# Why clusters are **important** labs

- **Large scale evolution:**

**Benchmark for cosmological models**

**Test for nucleosynthesis**

- **Environmental effects on galaxy evolution:**

**How clusters shape galaxy activity**

**Test new probes for galaxy quenching**

- **Gravitational lensing:**

**Towards multi-messenger astronomy**

**New probes for General Relativity**

# Birmingham involvement

- **Large scale evolution:**

**Benchmark for cosmological models**

**Test for nucleosynthesis**

- **Environmental effects on galaxy evolution:**

**How clusters shape galaxy activity**

**Test new probes for galaxy quenching**

- **Gravitational lensing:**

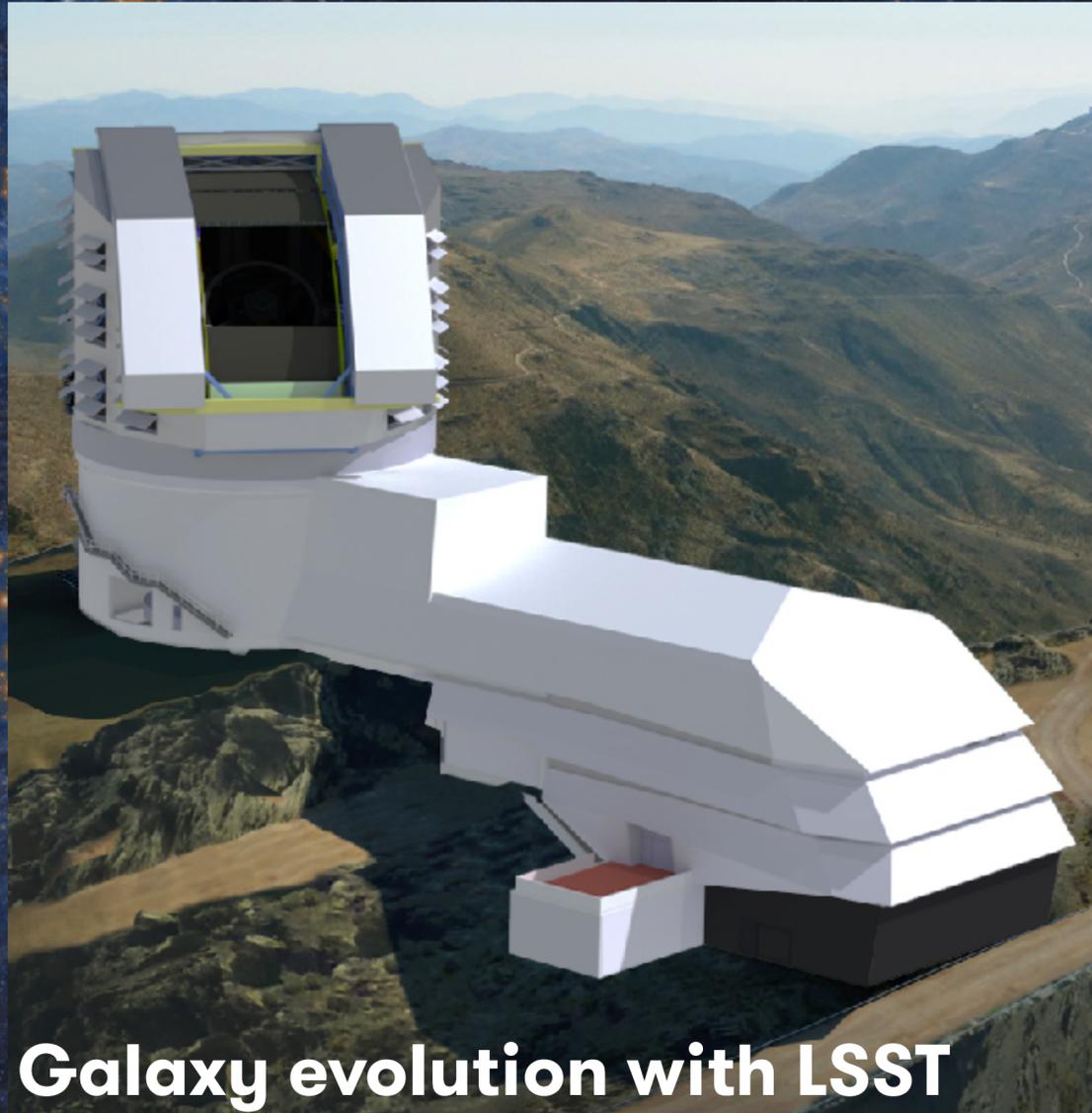
**Towards multi-messenger astronomy**

**New probes for General Relativity**

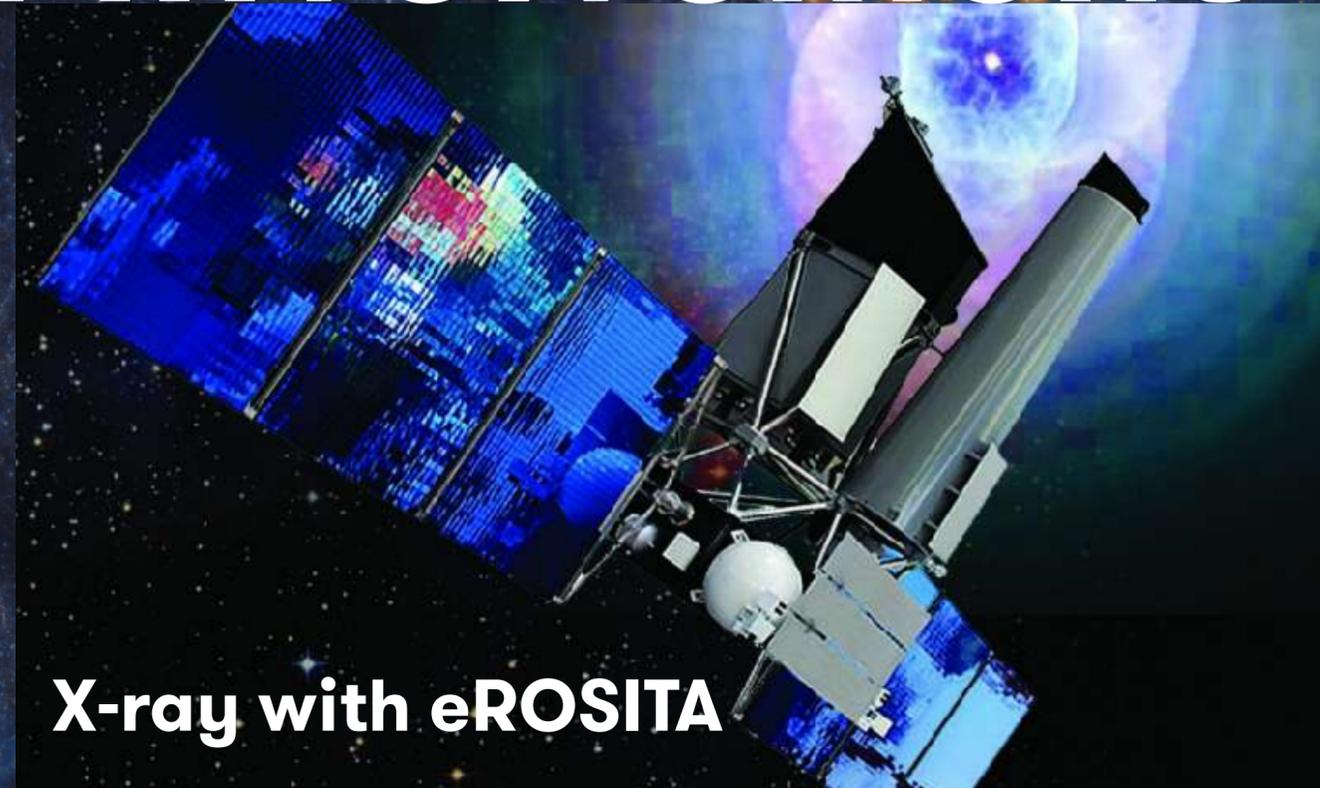
# LoCuSS

# Survey

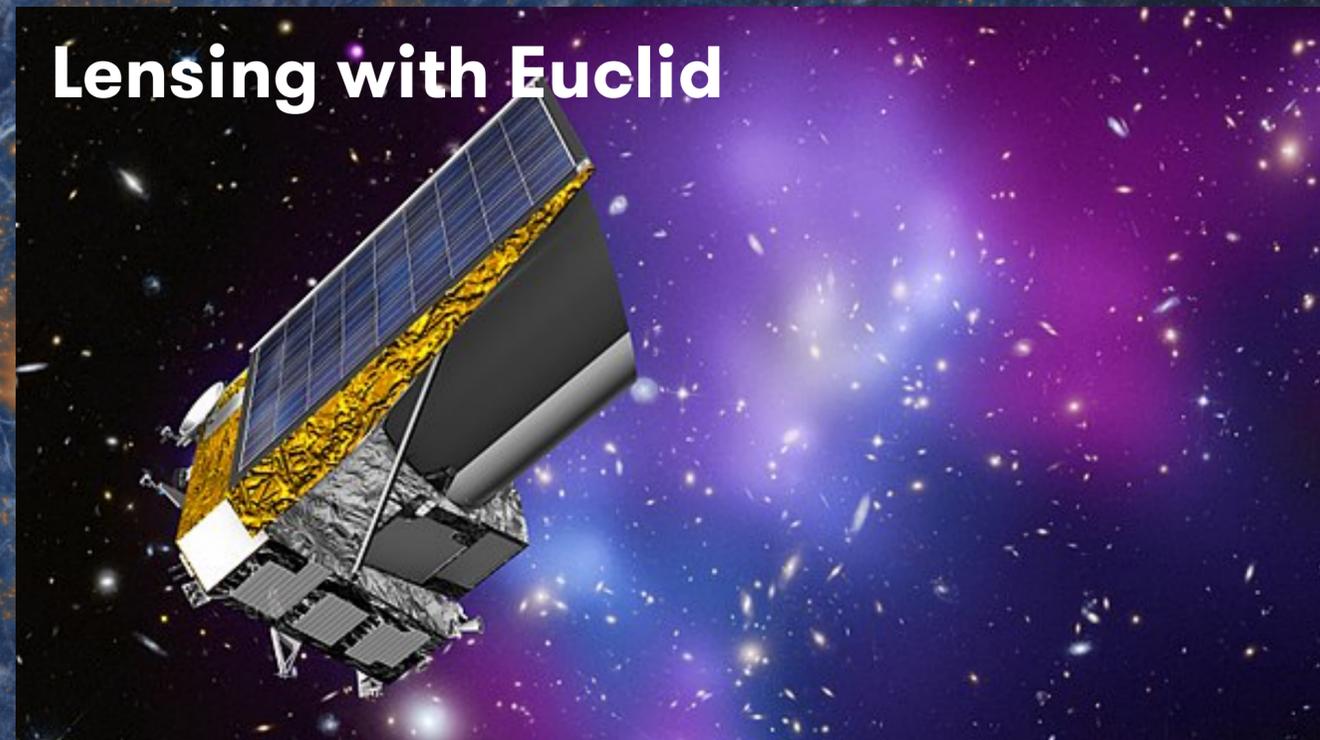
# Birmingham involvement



Galaxy evolution with LSST

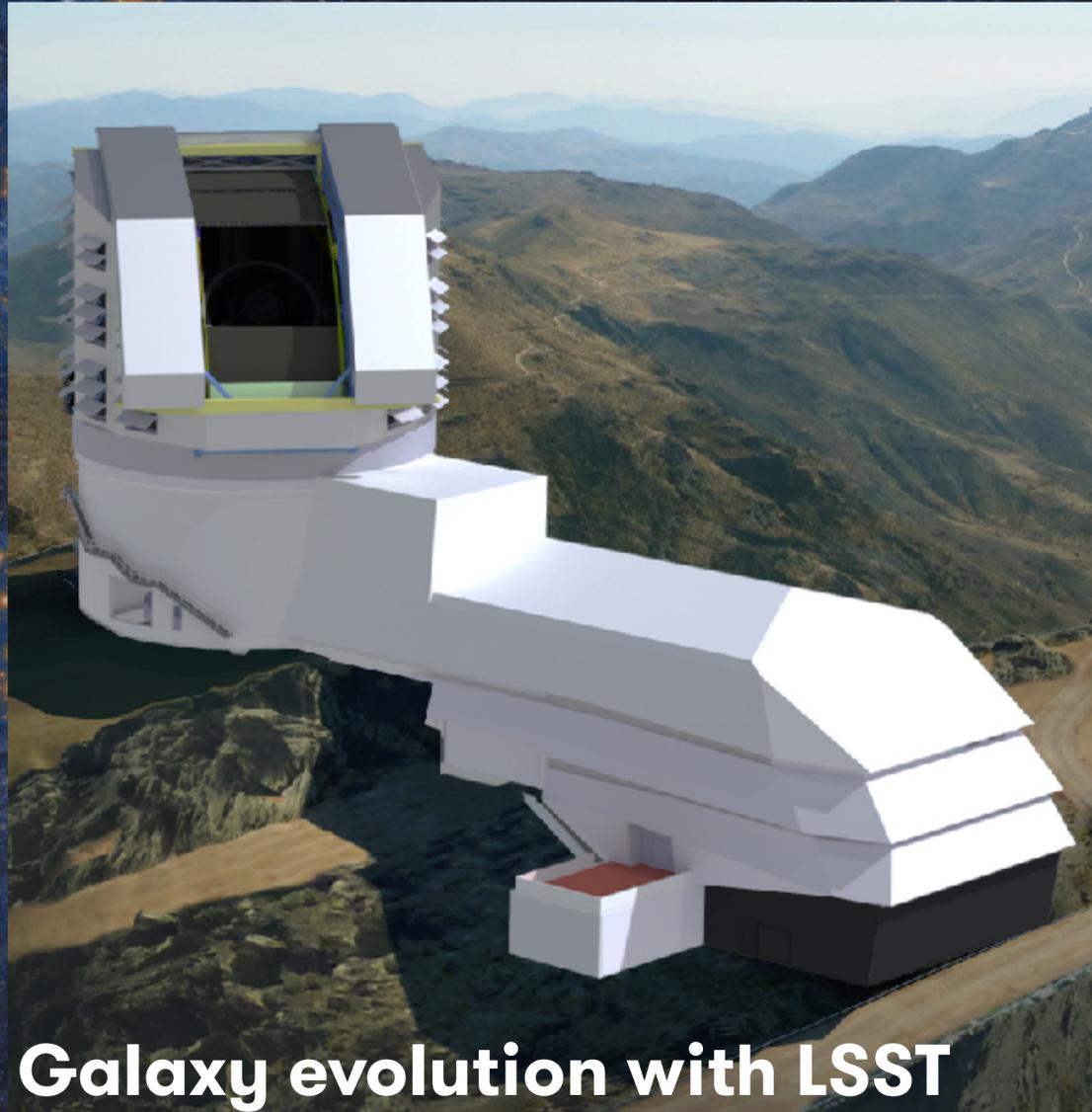


X-ray with eROSITA

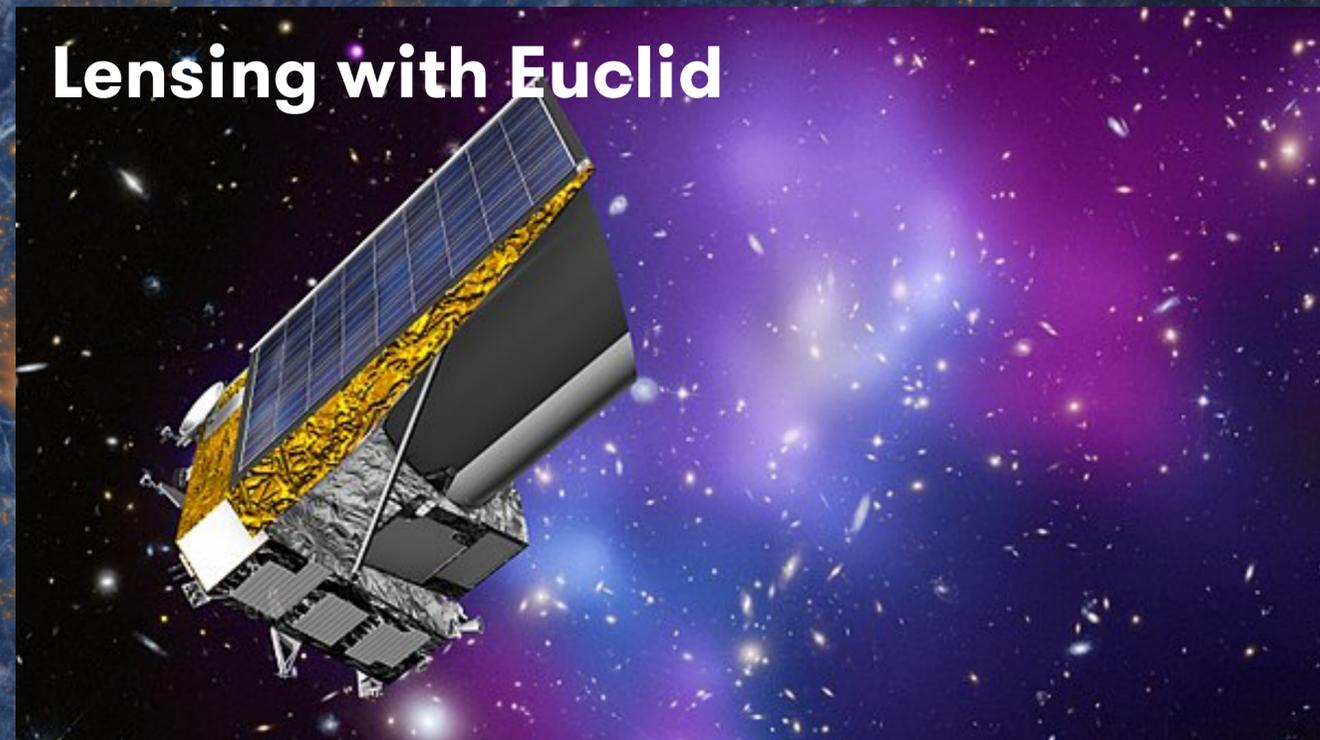
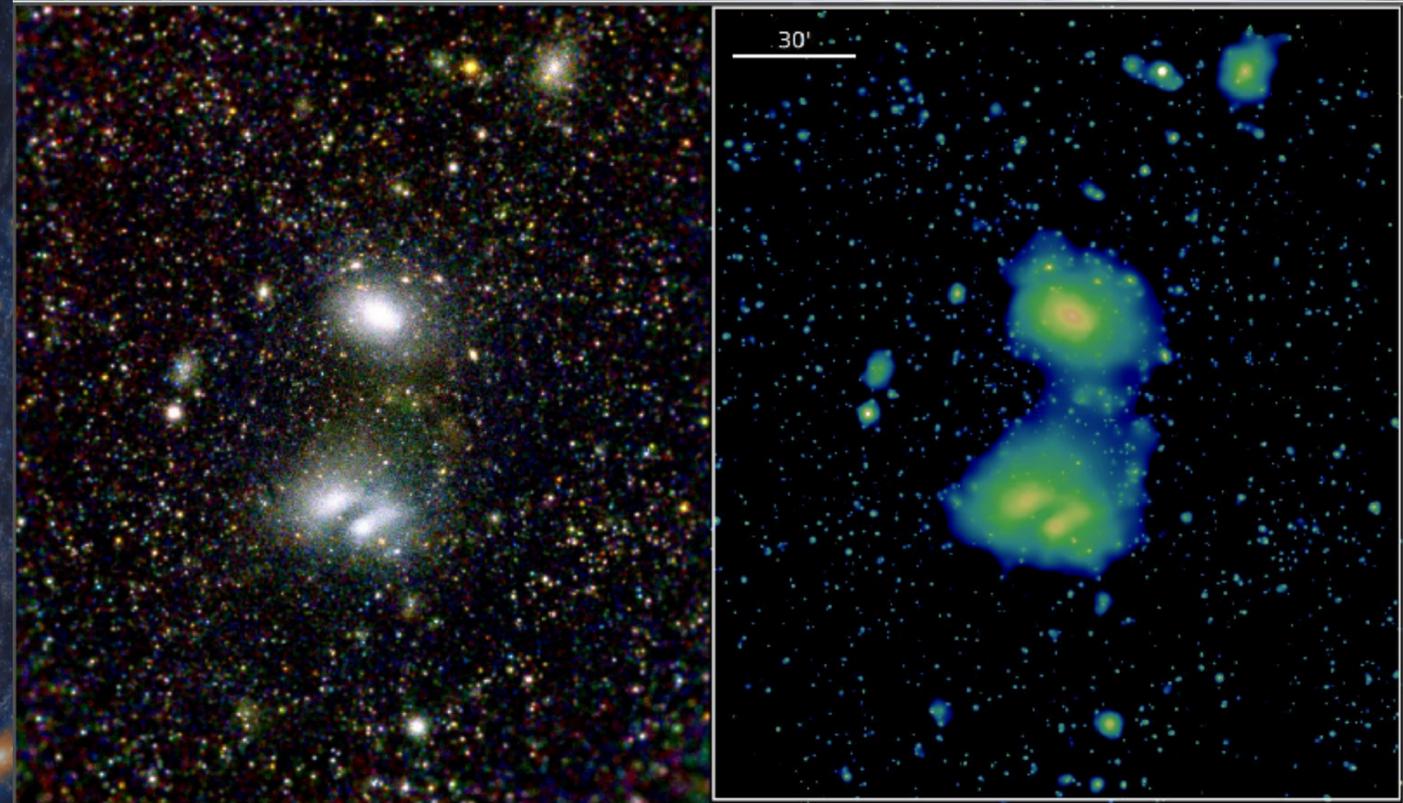


Lensing with Euclid

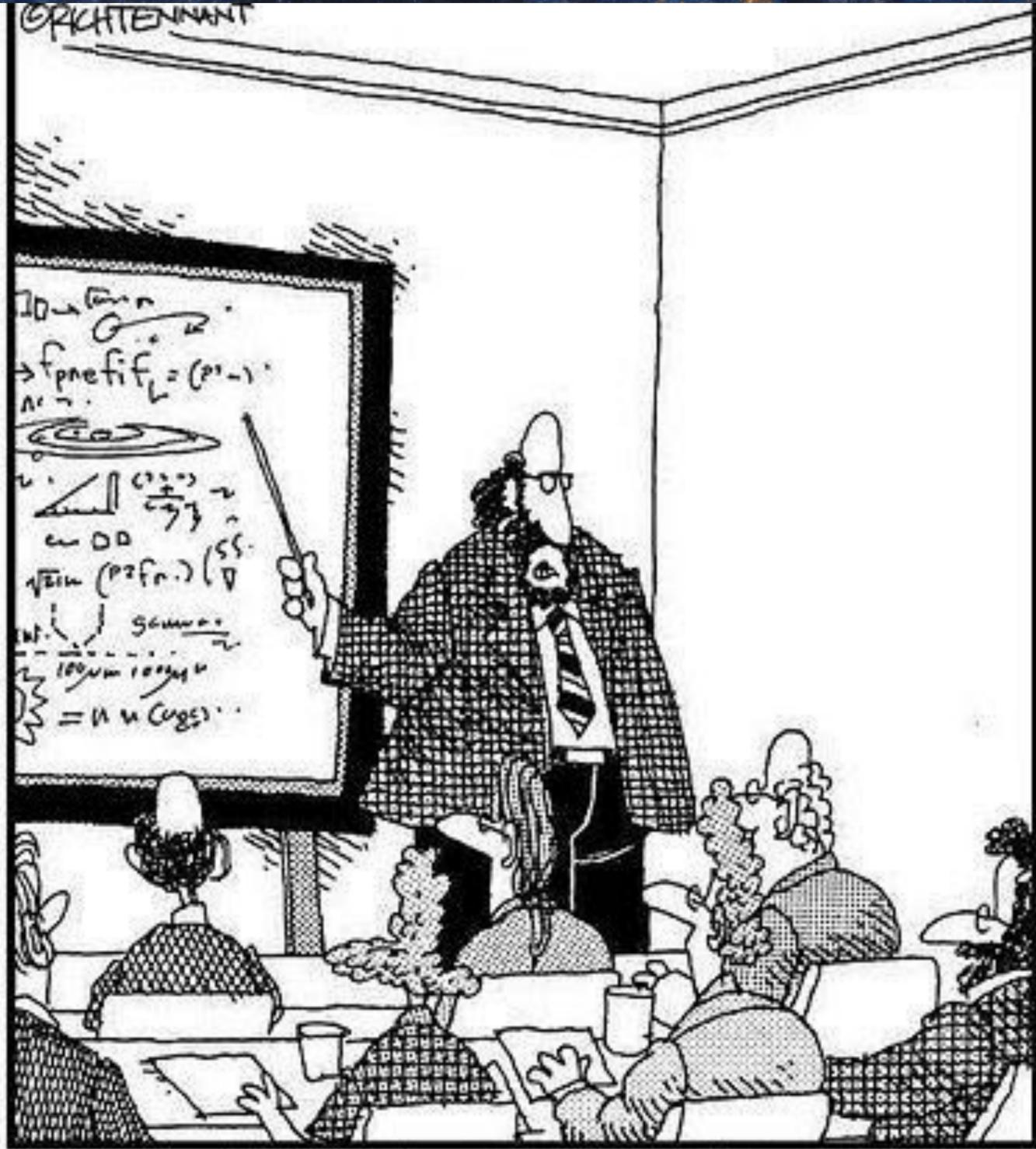
# Birmingham involvement



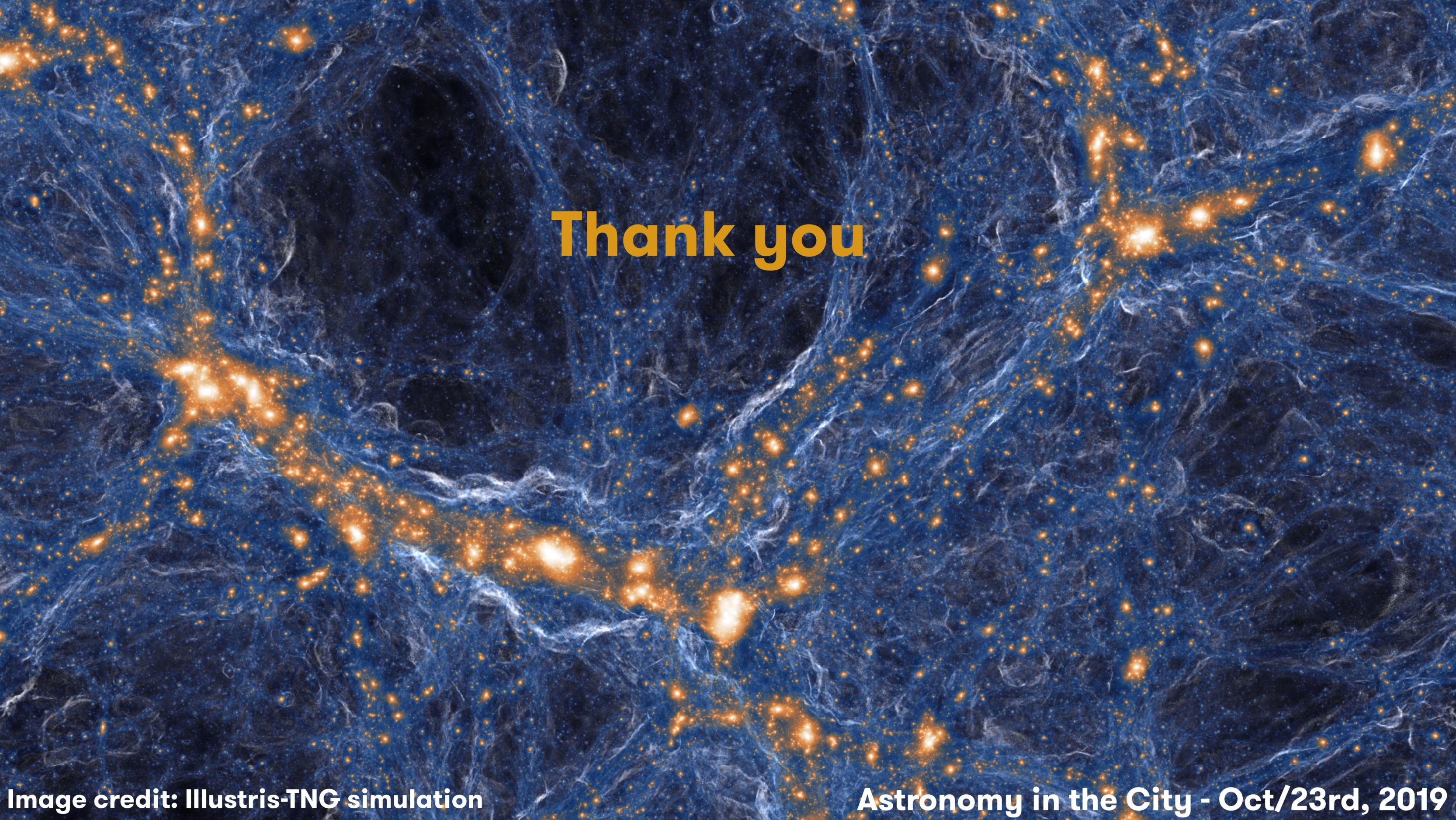
Galaxy evolution with LSST



Lensing with Euclid



“Along with ‘Antimatter,’ and ‘Dark Matter,’ we’ve recently discovered the existence of ‘Doesn’t Matter,’ which appears to have no effect on the universe whatsoever.”

A detailed simulation of the cosmic web, showing a complex network of blue filaments and nodes. Numerous bright orange and yellow galaxies are scattered throughout, with a prominent horizontal band of galaxies crossing the center. The background is a deep, dark blue, suggesting the vastness of space.

**Thank you**

