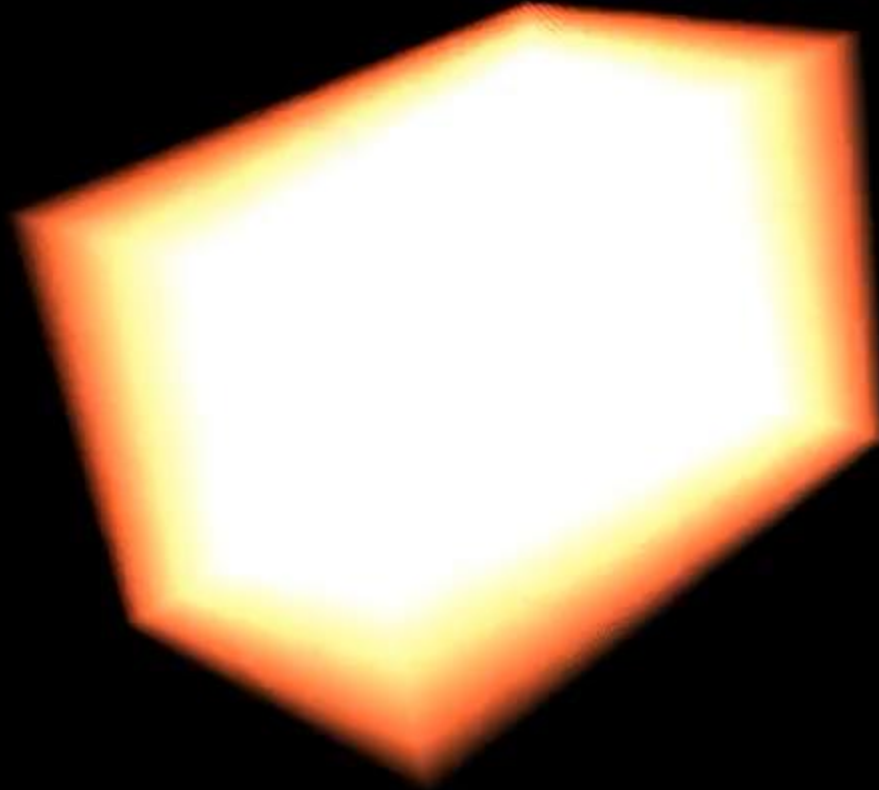


# A New Era of Galaxy Cluster Analysis at Cosmic Noon: JWST's View of a Distant Galaxy Cluster



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$z = 130.09$

# Dark Matter

## Coma Cluster

- 1933 Fritz Zwicky uses data from Mount Wilson
- finds that the galaxies are orbiting too fast for the mass predicted from galaxy light
- he suggested that there must be more mass

→ Dark matter (matter that does not emit light).

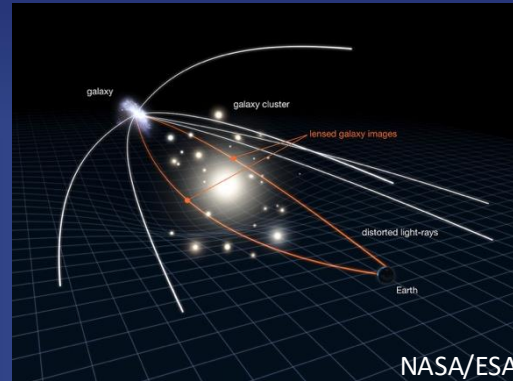
We now measure that approximately 85% of the matter in the universe is dark.

Galaxy clusters are huge dark matter deposits.



# How to detect dark matter.

- The gravitational lensing effect is the deflection of light's path by an intervening massive object.
- It causes the image of the background galaxy to distort.
- Near the densest regions (center) of a galaxy cluster, strong lensing can occur but requires special alignment.
- On the outskirts of a galaxy cluster, weak lensing occurs.



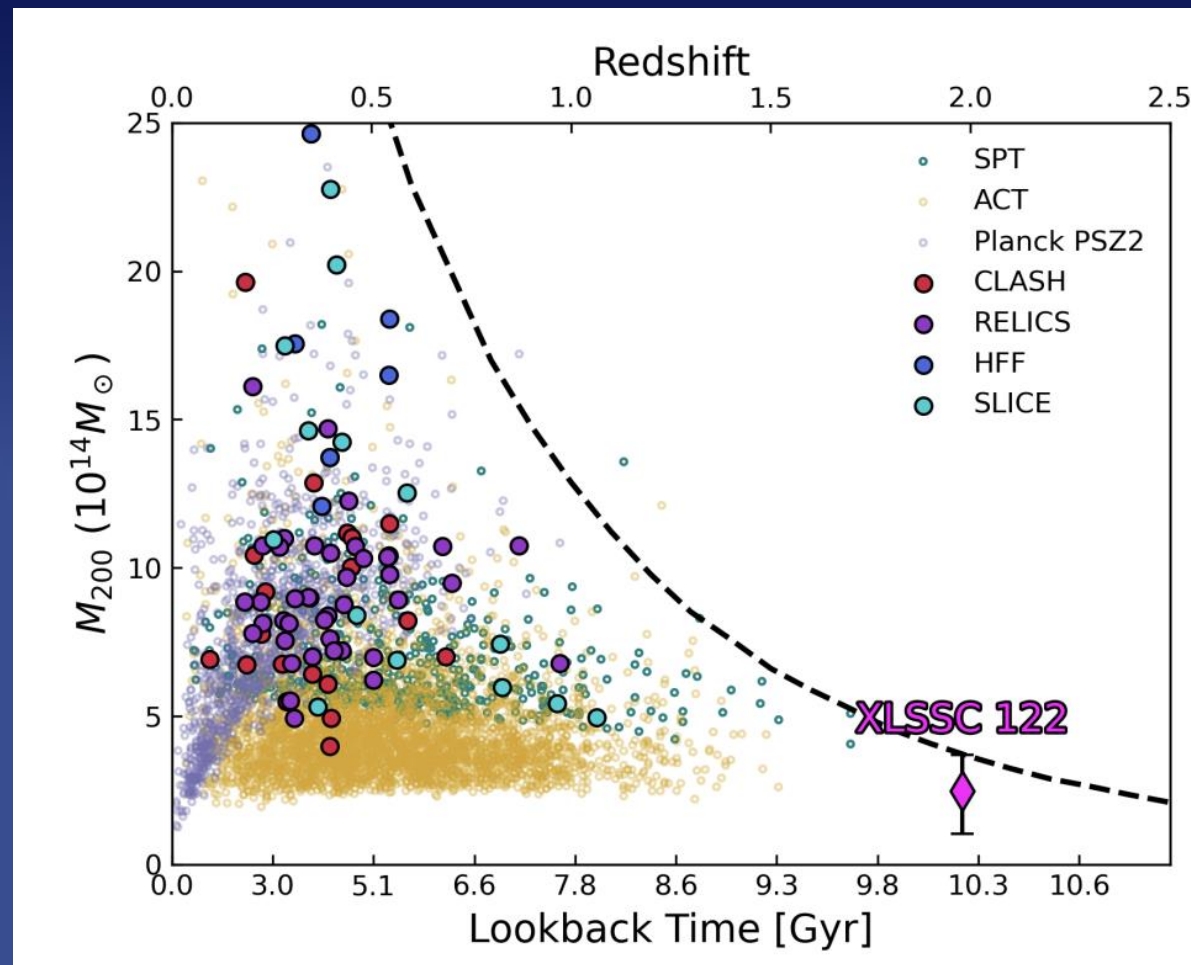
# My Journey with JWST

In the summer of 2022, the first images from JWST were arriving.

Scientifically, what would be the best target for JWST?

**Idea:** Let's try to measure the dark matter of one of the most distant clusters that is known.

XLSSC 122 is a massive galaxy cluster at one of the earliest stages of cluster formation (10.3 billion years ago!)



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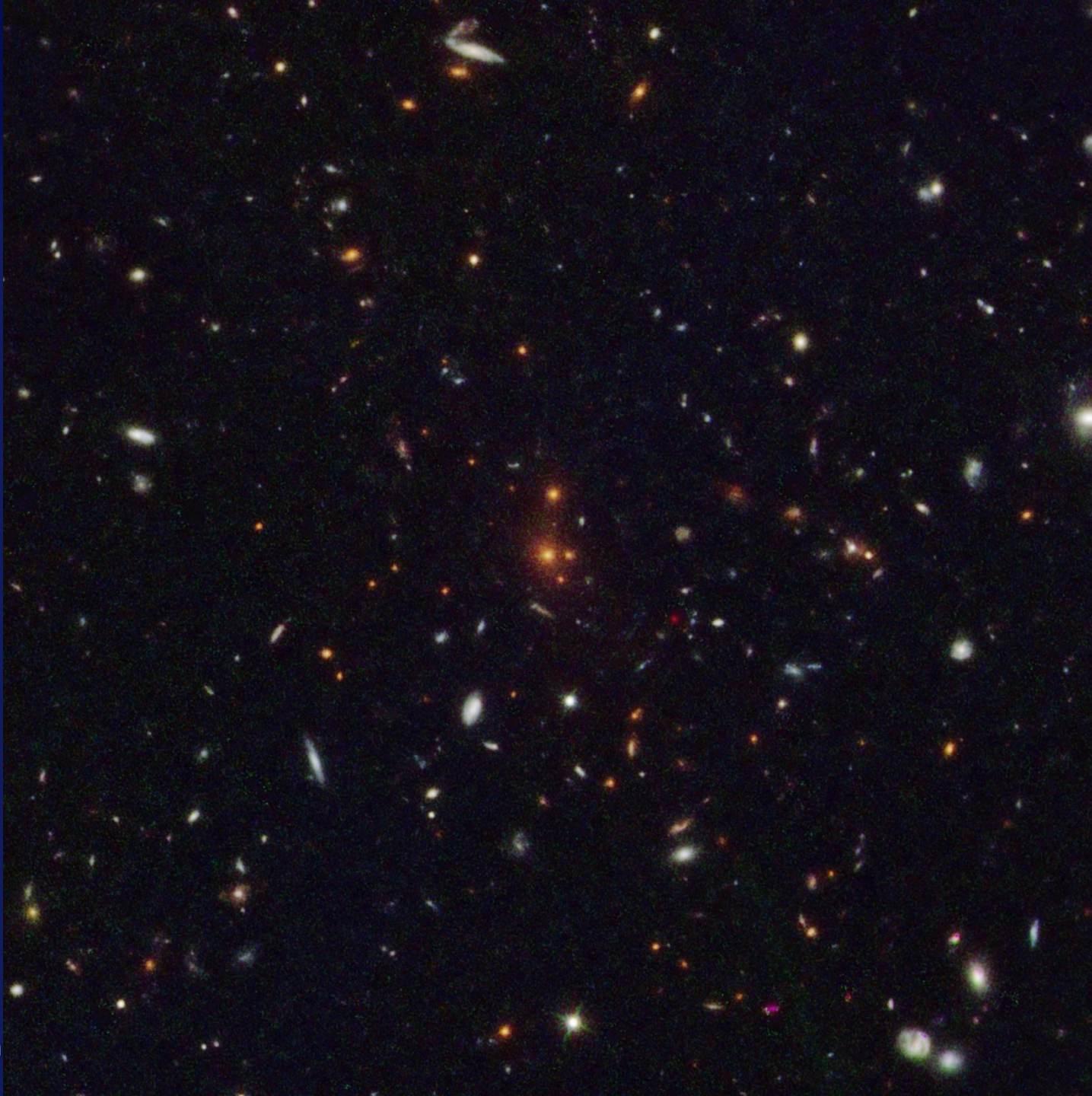
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## Hubble Space Telescope XLSSC 122

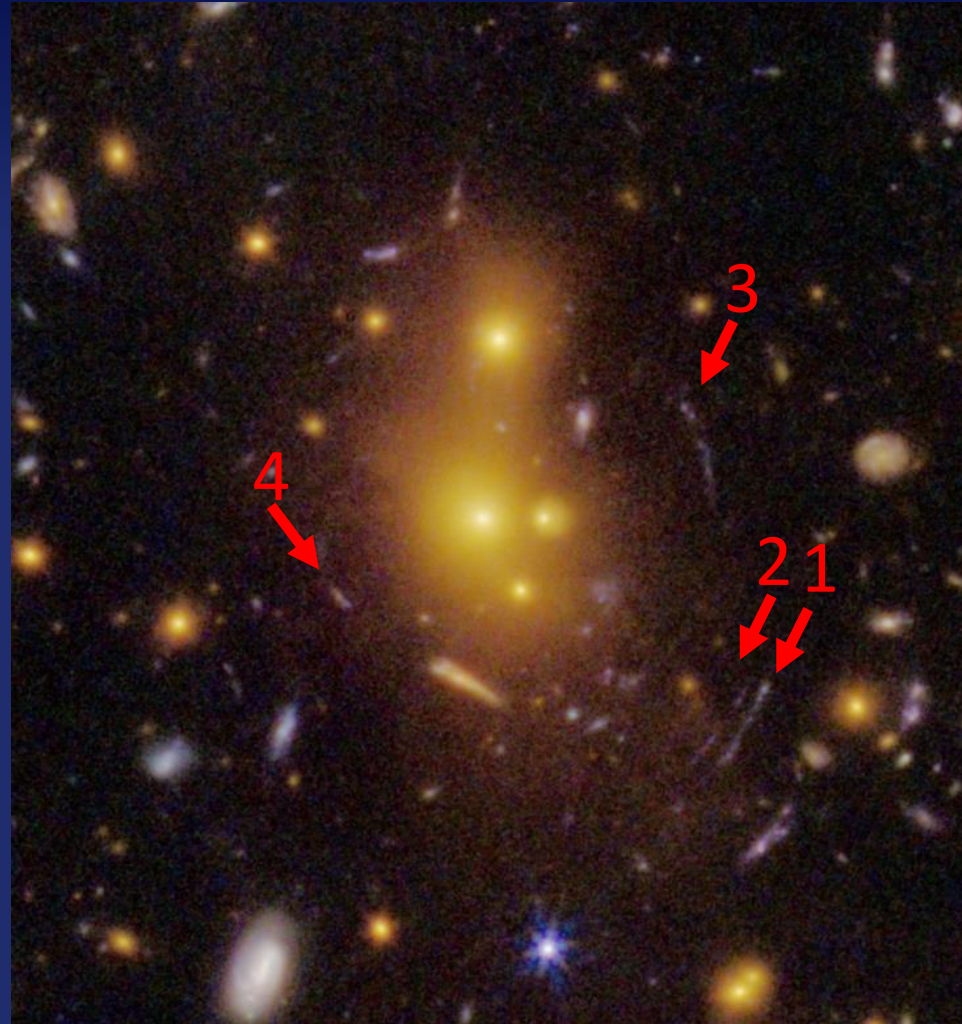








# Wow, Arcs!



# A New Priority

- Most distant galaxy cluster to exhibit strong lensing!
- A lucky alignment of background galaxies with foreground cluster.
- Measured the radial profile of the dark matter and its concentration.

## Results:

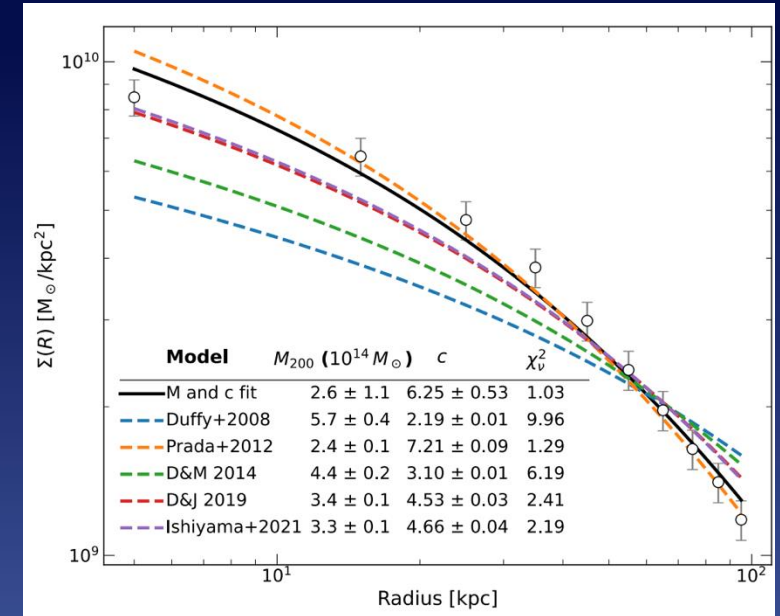
The first constraints on dark matter concentration in galaxy clusters at cosmic noon.

The dark matter in XLSSC 122 is more concentrated than predicted by cosmological simulations.

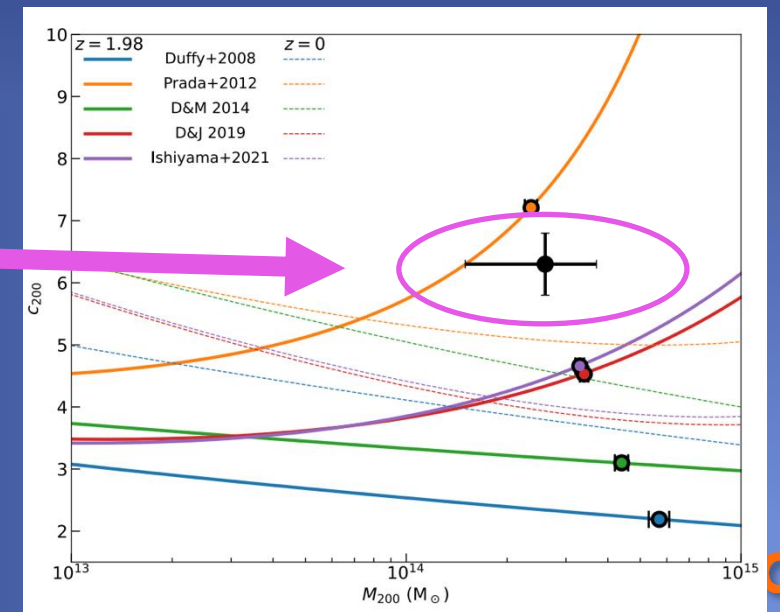
## Why?

- Is the cluster special? Alignment of multiple clusters?
- Could the cosmological simulations be underestimating the concentration of clusters in the early universe?

## Dark Matter Profile



## Dark Matter Concentration



# XLSSC 122 in Detail

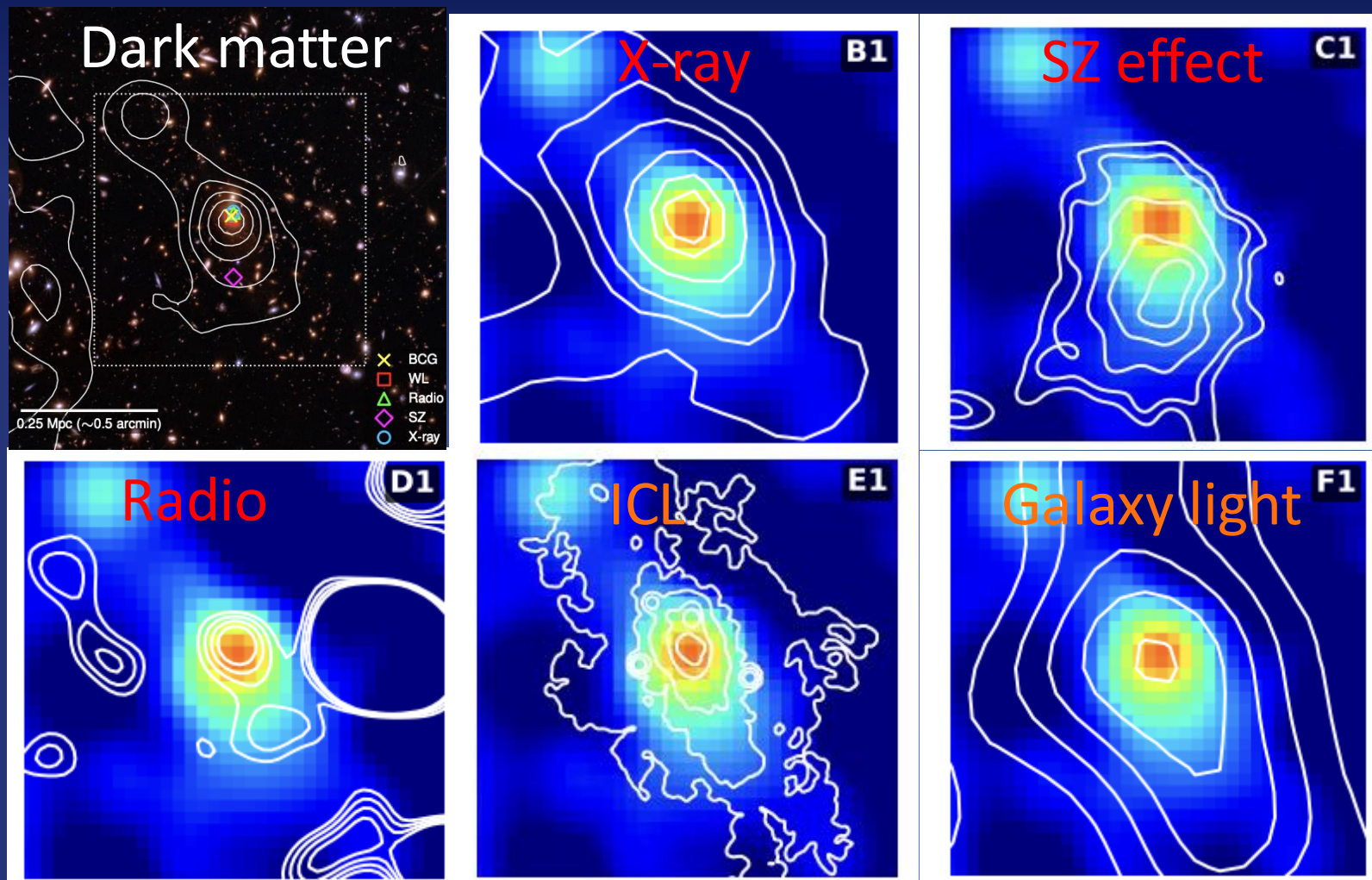
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Most distant detection of the ICL.

XLSSC 122 has many signs of being a merging cluster.

But typically, a merging cluster has a lower concentration.



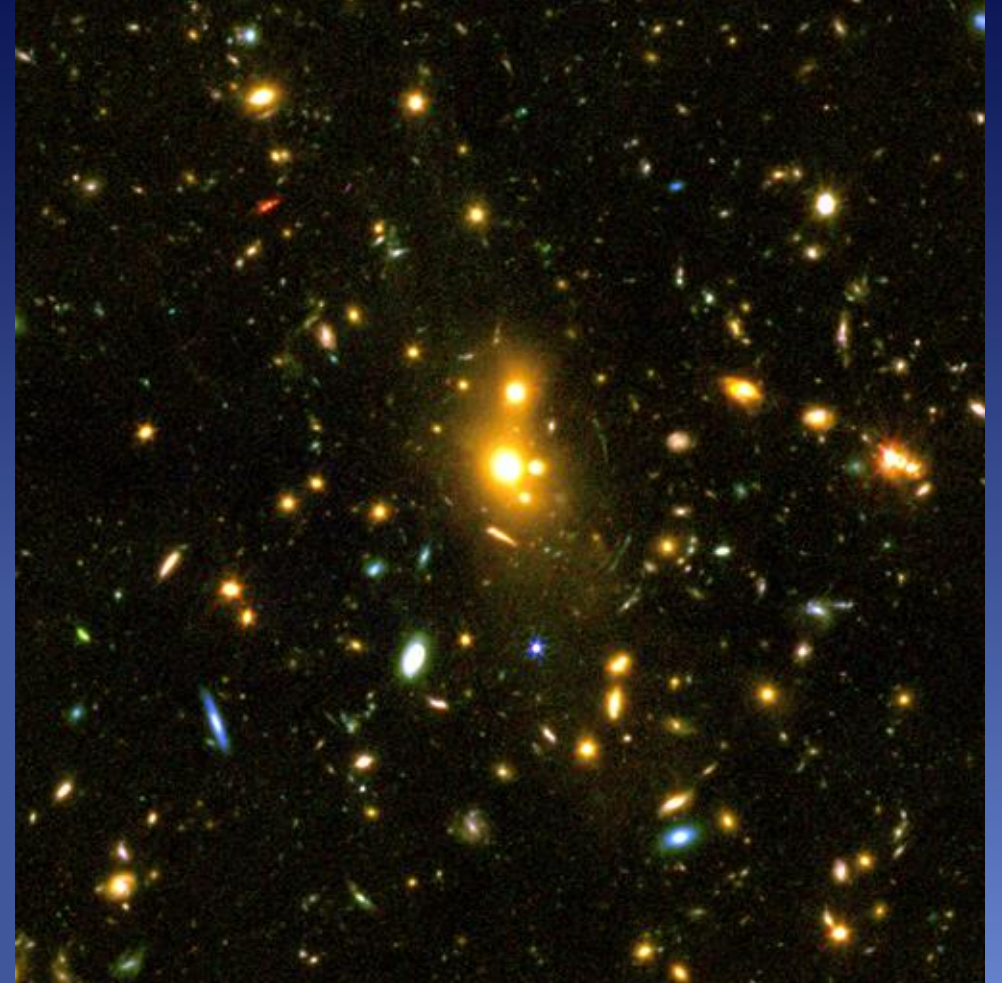
# What's Next?

XLSSC 122 is a single example of highly concentrated dark matter in one of the first galaxy clusters to have formed in the universe.

More galaxy clusters are being discovered at these early stages through telescope surveys.

JWST is the best telescope for follow-up observations to detect strong and weak lensing signals.

We are actively applying for time on JWST to perform a statistical analysis of the dark matter in the first galaxy clusters.



# Summary

Discovered strong lensing arcs in one of the earliest galaxy clusters to have formed in the universe (3 billion years after the big bang).

Measured the concentration of dark matter and found it to be more concentrated than cosmological simulations predict.

Most distant cluster strong lensing, weak lensing, and intracluster light detection.

Used multiwavelength data to determine that the cluster is merging.

JWST is unlocking studies of dark matter in the first clusters to have formed in the universe.

[Paper 1](#), [Paper 2](#), [Paper 3](#) Press release.

