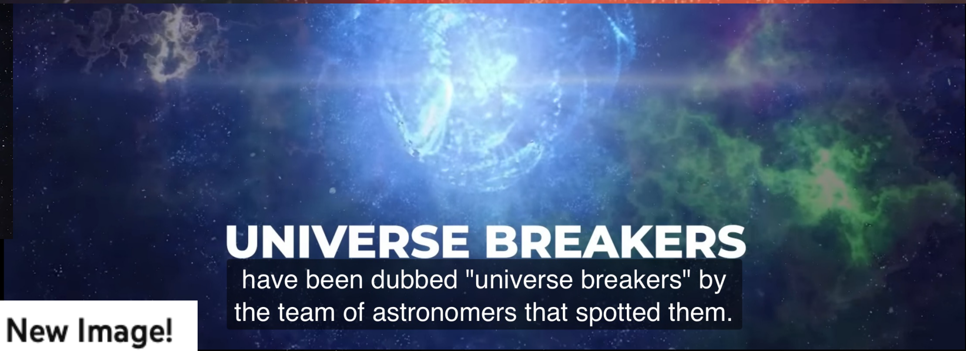
JWST, the promise of the Dawn of the universe

David Elbaz
CEA Saclay

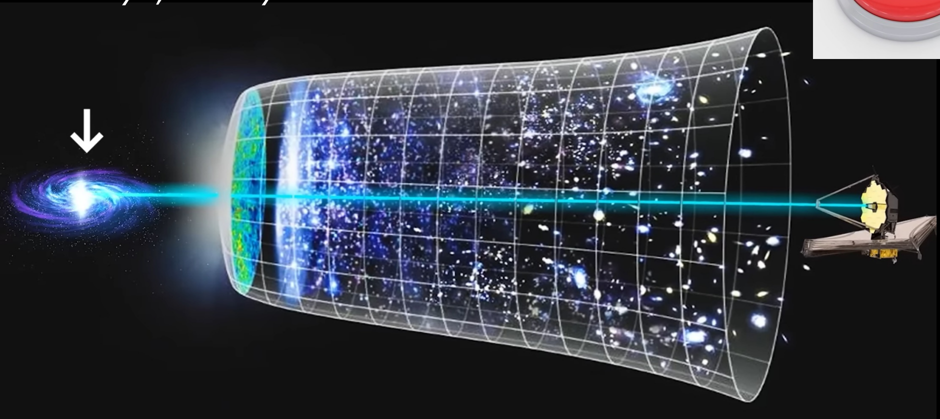
"Our whole universe was in a hot dense state, when nearly 14 billion years ago, expansion started"

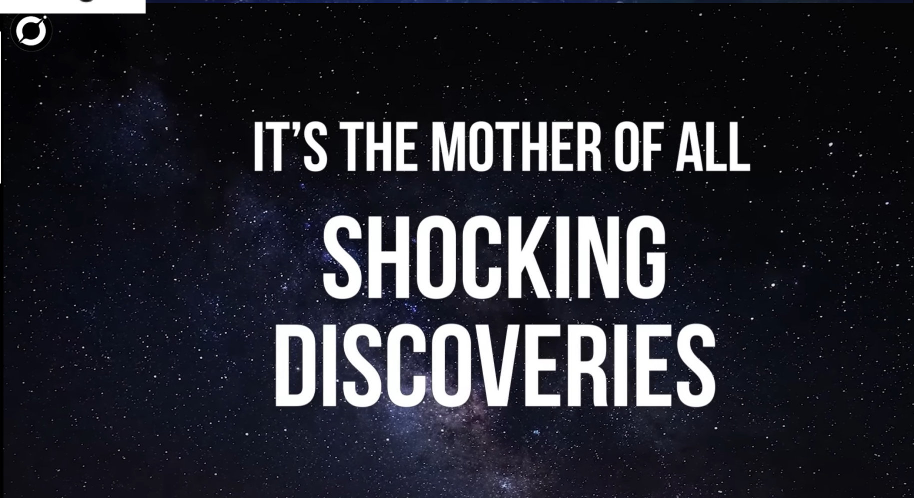


Michio Kaku Breaks Silence On James Webb Telescope's Shocking New Image!

875 591 vues 15 avr. 2023

In 3 days, nearly 1M views





https://www.youtube.com/watch?v=iBMRGYKvuHk

Science News

from research organizations

James Webb spots super old, massive galaxies that shouldn't exist

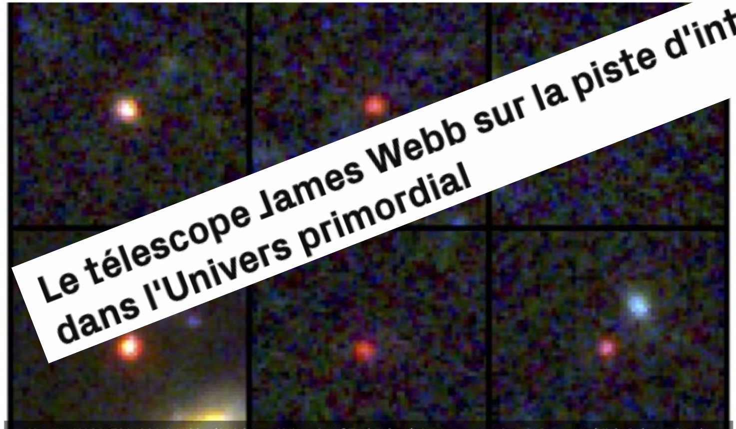
Date: February 22, 2023

NewScientist

Huge young galaxies seen by JWST may upend our models of the universe

„Джеймс Уеб“ откри галактики, които не би трябвало да съществуват

Ваня Милева Последна промяна на 24 февруари 2023 в 00:01 10757 0



Кредит NASA, ESA, CSA, I. Labbe (Swinburne University of Technology). Image processing: G. Brammer (Niels Bohr Institute's Cosmic Dawn Center at the University of Copenhagen

Шест масивни галактики, които вече са съществували 500-800 милиона години след Големия взрив. В една от тях, долната вляво, вероятно има толкова звезди, колкото в Млечния път днес, само че е 30 пъти по-плътна

Le télescope James Webb sur la piste d'intrigantes galaxies dans l'Univers primordial

SCIENCES ET AVENIR

The Brussels Times

'Real shocker': Six massive galaxies could upend 'settled science'

Thursday, 23 February 2023

코로나19 전현직과학기술인 The Science Times

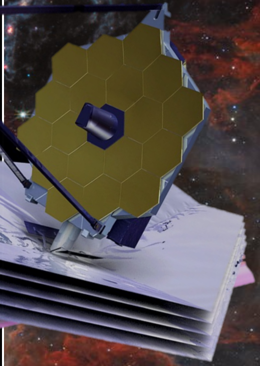
제임스 웹, “존재해서는 안 되는” 거대 은하들을 발견하다

[JWST 발사부터 현재까지] 5억~7억 년 정도의 무거운 은하 후보를 6개나 찾아내다

관련 논문 바로 가기 - “빅뱅 후 약 6억년 이후의 적색 편이 거대 은하 집단 후보의 관측 (A population of red candidate massive galaxies ~600 Myr after the Big Bang)“

JWST, the promise of the Dawn of the universe

David Elbaz
CEA Saclay



OK let’s calm down…

…and who is James Webb by the way?

Wednesday 21 novembre 1962
White House Office, 10am

(John Kennedy): ...Those that are not essential to the lunar program, but help contribute over a broad spectrum to our preeminence in space, **are secondary**. That's my feeling about this.

(James Webb): All right, sir, but let me say this. If I go out and say that this is the number one priority and everything else must give way to it, **I'm going to lose an important element of support for your program** and for your administration.

(John Kennedy): By whom? Who?

(James Webb): By a large number of people.

(John Kennedy): Who? Who?

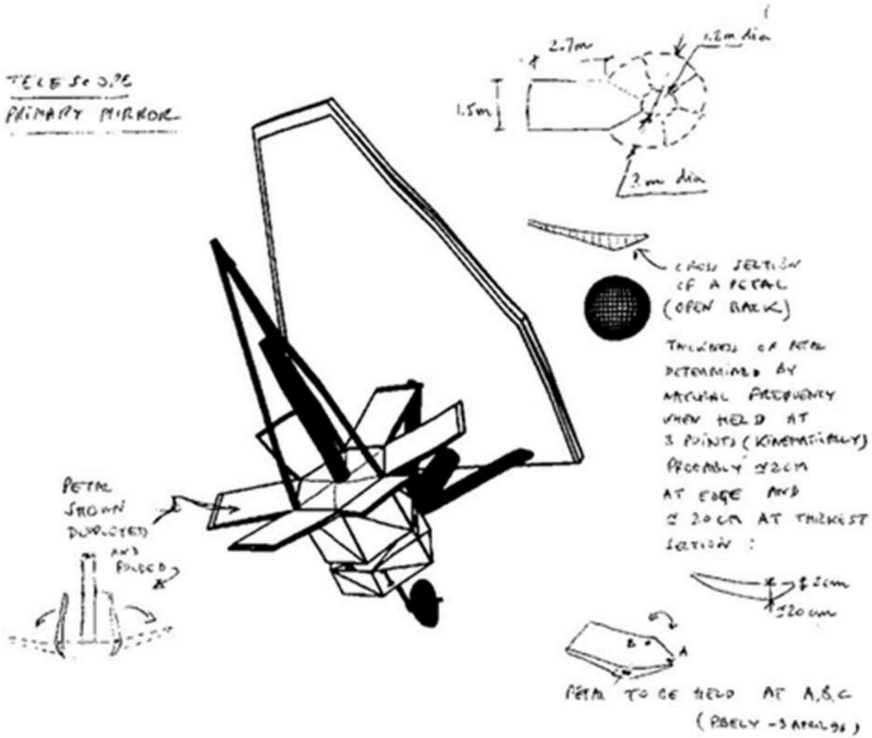
(James Webb): Well, particularly the **brainy people in industry and in the universities** who are looking at a solid base… I have some feeling that you might not have been as successful on Cuba if we hadn’t flown John Glenn and demonstrated we had a real overall technical capability here.

(John Kennedy): We agree. That’s why we wanna put this program

https://millercenter.org/the-presidency/educational-resources/fly-me-to-the-moon

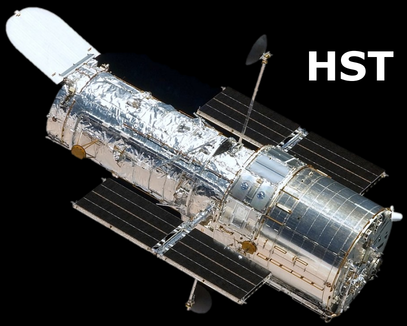
It all started more than 30 years ago…

First concepts **1980's**: **Pierre Bely, chief engineer@CFHT** (then @Hubble)
Giacconi head of NASA asks Pierre Bely, Peter Stockman, Garth Illingworth to **think beyond Hubble**
Conference in 9/**1989** : the **Next Generation Space Telescope**



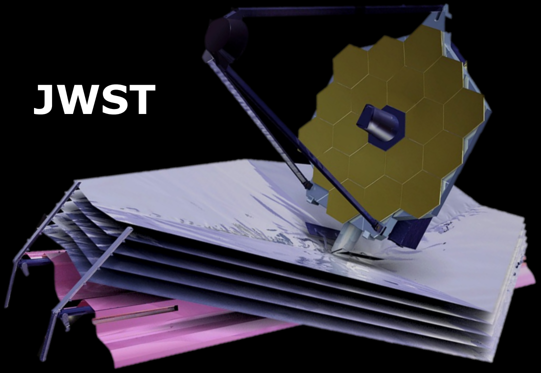
April 1996

25 decembre 2021 : ~30 years after Hubble (24/4/1990)



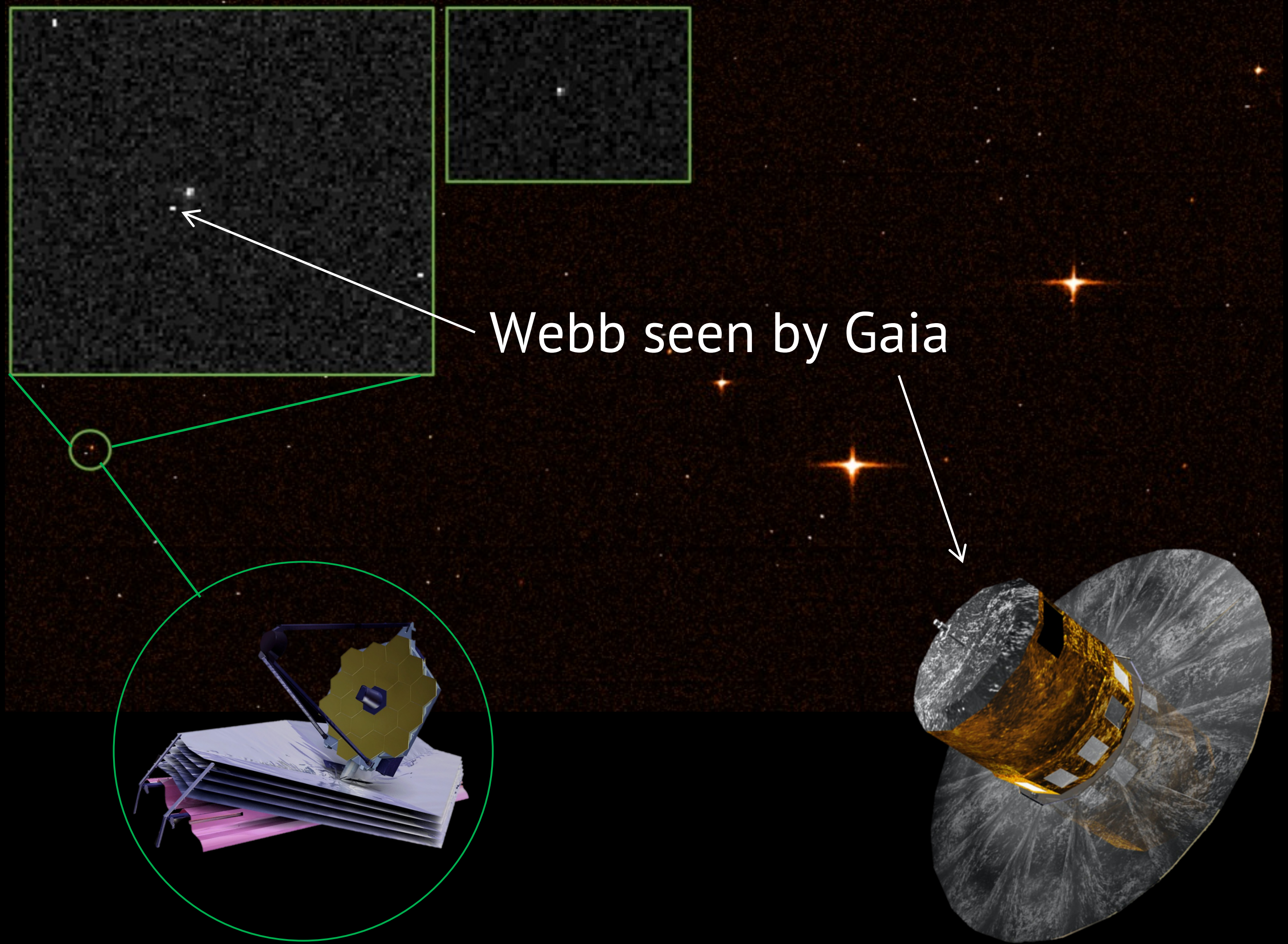
HST

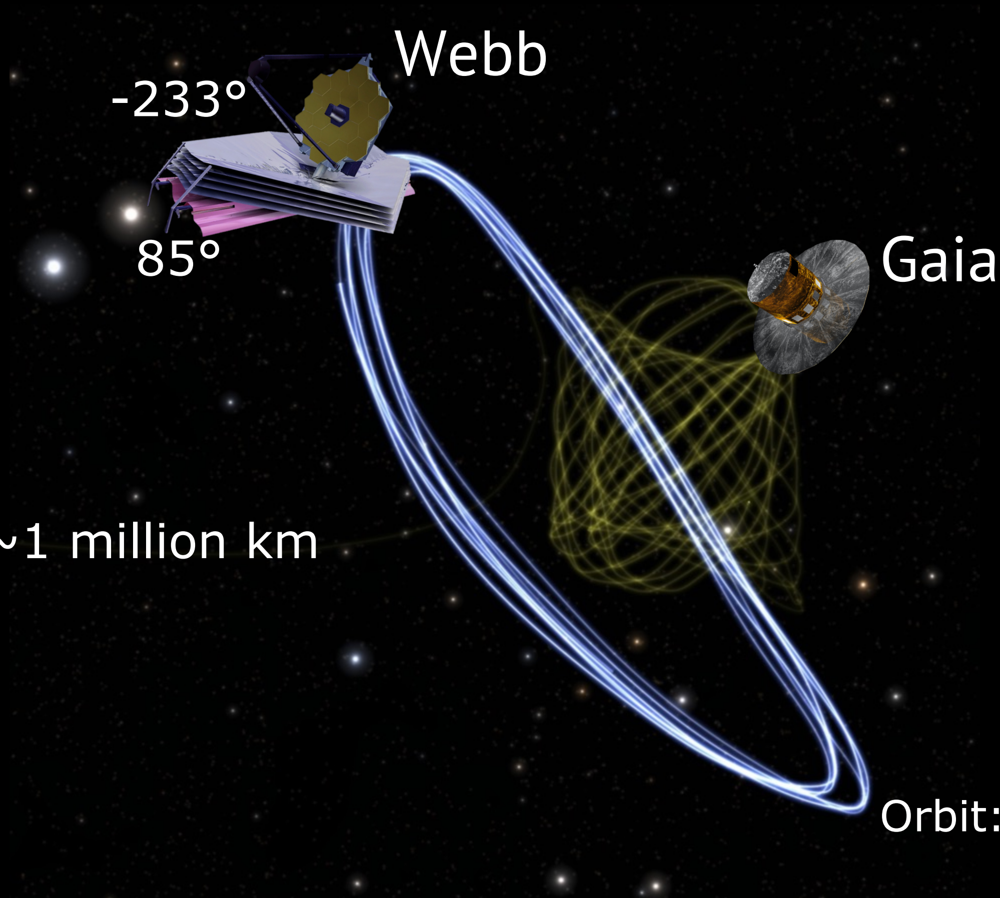
JWST



HST highlights

Hubble discovered	the most distant galaxy, GNz11, at z=11
revealed	the shape of galaxies,
demonstrated	that galactic black holes are ubiquitous,
refined measure of	the age and expansion rate of the universe,
detected	water vapor around giant exoplanets

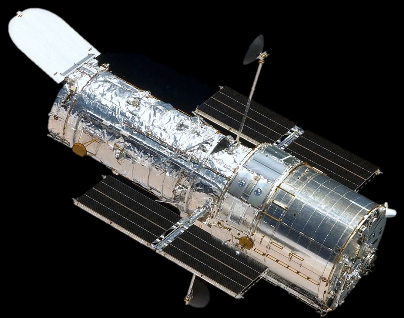

Webb seen by Gaia



Orbit diameter ~1 million km

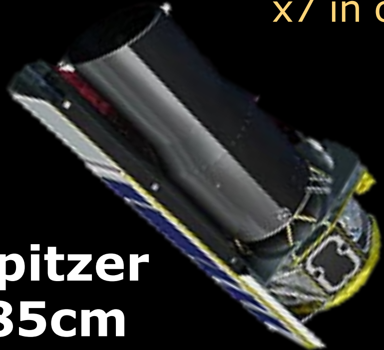
Orbit:168days~6 months

Communication: antennas in Australia, Spain & California, twice/day.
Full week's worth of commands at a time, daily updated.



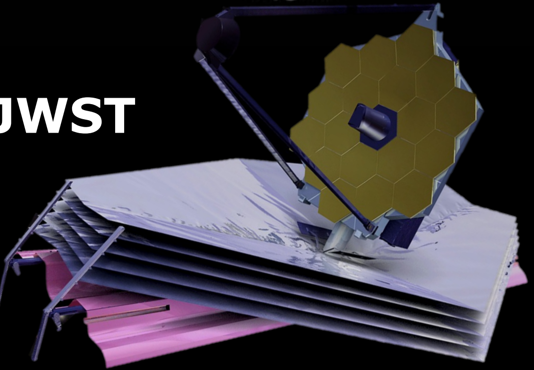
HST

x7 in collecting area & sensitivity !



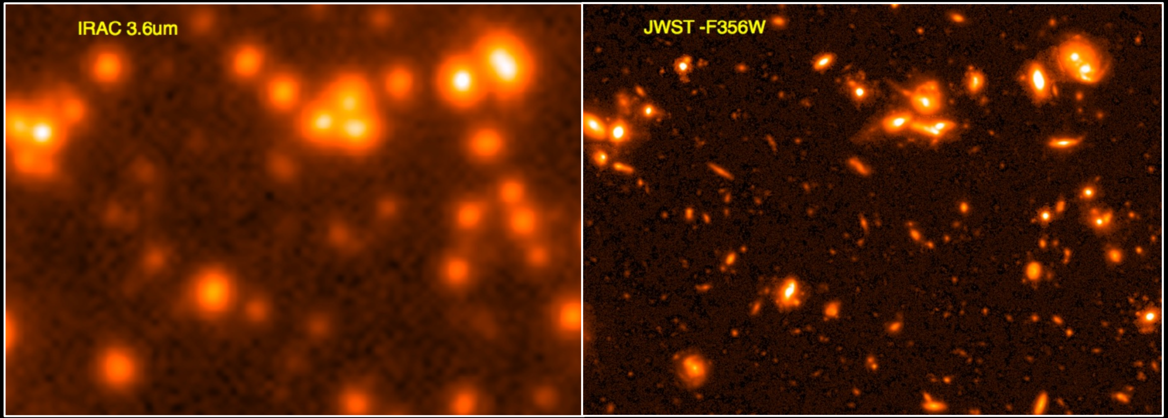
Spitzer
85cm

JWST

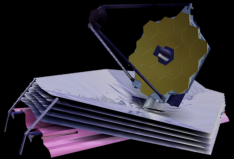


x50 in collecting area & sensitivity !

Jump in angular resolution!

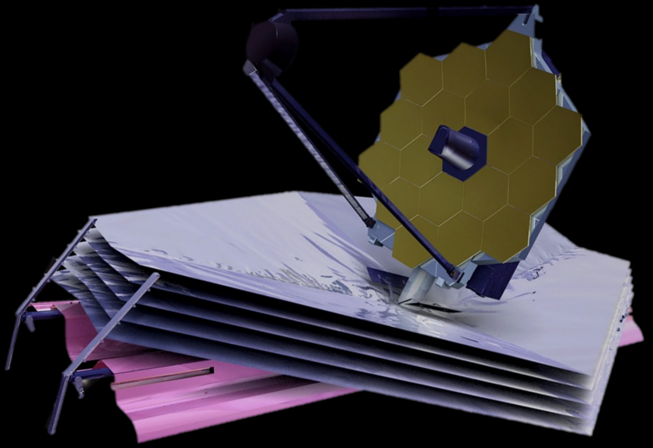


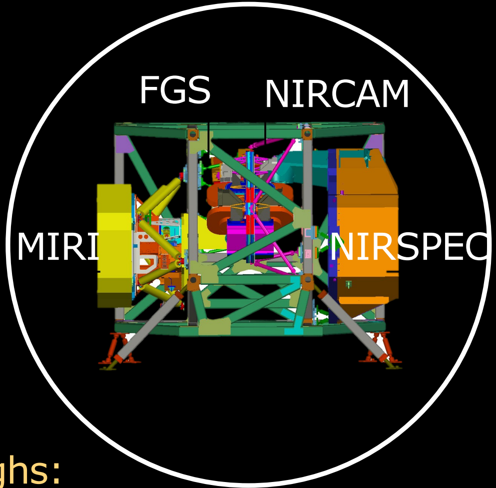
Spitzer
85cm



JWST
6.50m

x50 in collecting area & sensitivity !





Technological breakthroughs:

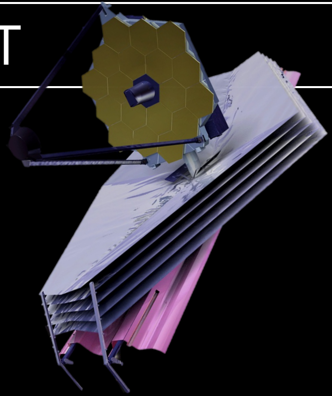
1st deployable mirror in space & largest telescope in space

1st multi-object spectrograph (MOS) in space = NIRSPEC

1st phase mask coronograph in space = MIRI

French contribution : MIRIm, imager of MIRI (5-28µm)
CEA main contractor on MIRIm

Observations with the JWST



- Guaranteed time for instrument builders :

  4020 hours over 30 months

Open to competition :

- Director's time: used for large programs released immediately

  = Early Release Science (ERS) = 500 hours → 1st cycle

- Open time:

  80% of the time with a minimum of 15% (MoU) for Europeans

  → 1st call : 30% of European time obtained !

  & 2 most requested instruments: NIRSPec & MIRI

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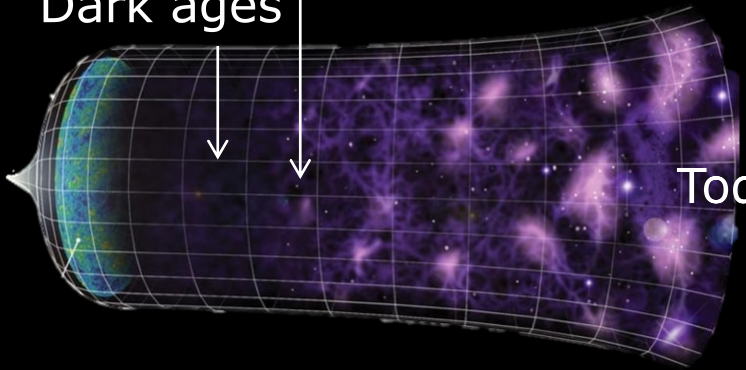
David Elbaz
CEA Saclay

Dark ages: between recombination
& first stars/galaxies.



JWST *expected* highlights

First galaxies, made of population III stars **Primordial galaxies**

First stars **Population III stars**

When the metallicity is 10^{-5}–$10^{-4} Z_\odot$ clouds do not fragment (less opacity, less cooling)

→ *100-1000 $M_\odot$ stars → the most massive PopIII* spontaneously collapse into a black hole*

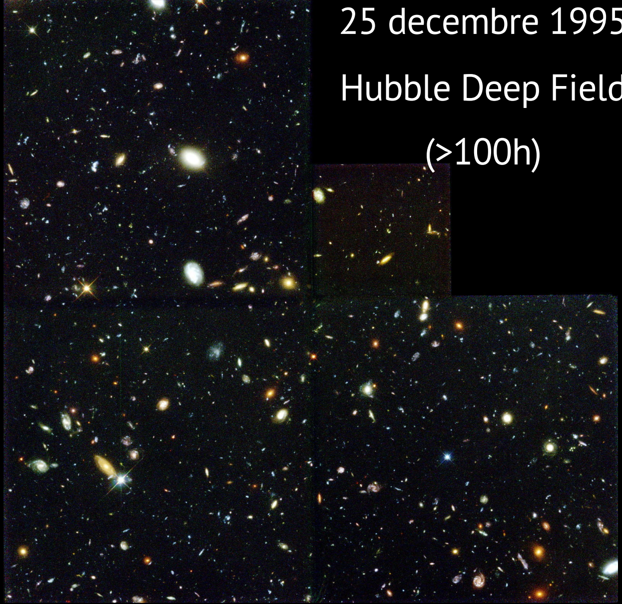
→ *Signature = hard radiation field → HeII 1640Å line about 1/3 of $H\alpha$ line (6563Å)*

First black holes **Supermassive black hole seeds**

25 decembre 1995

Hubble Deep Field

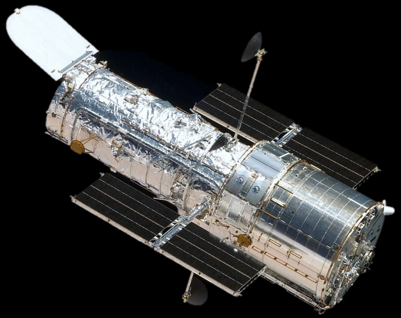
(>100h)

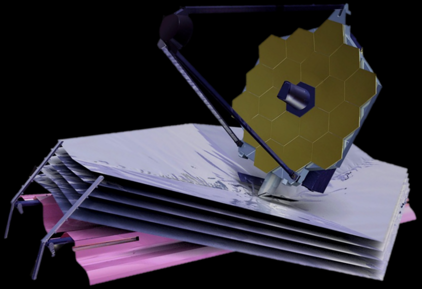


25 decembre 2021 = launch JWST

SMACS0723

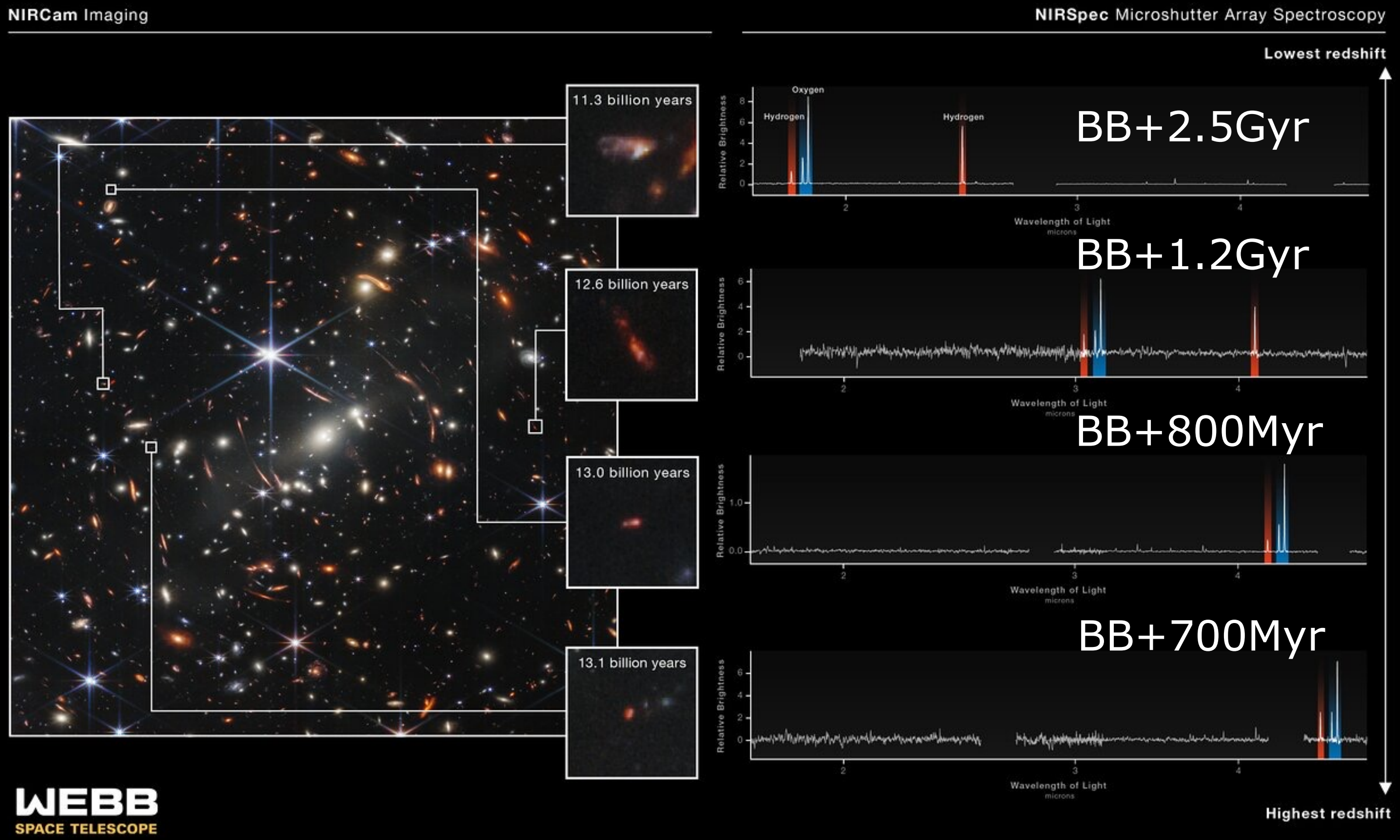
(12.5 heures)

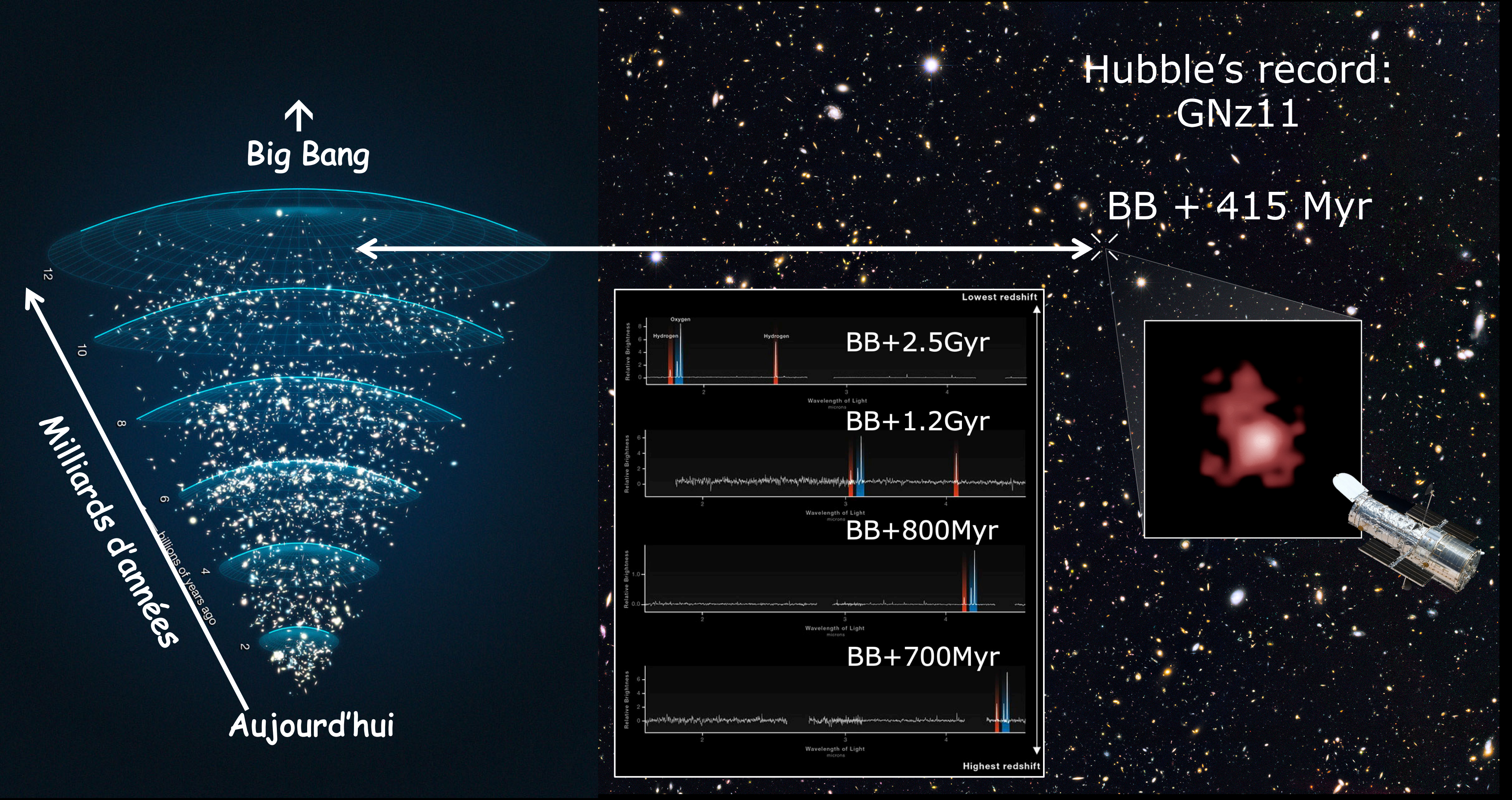




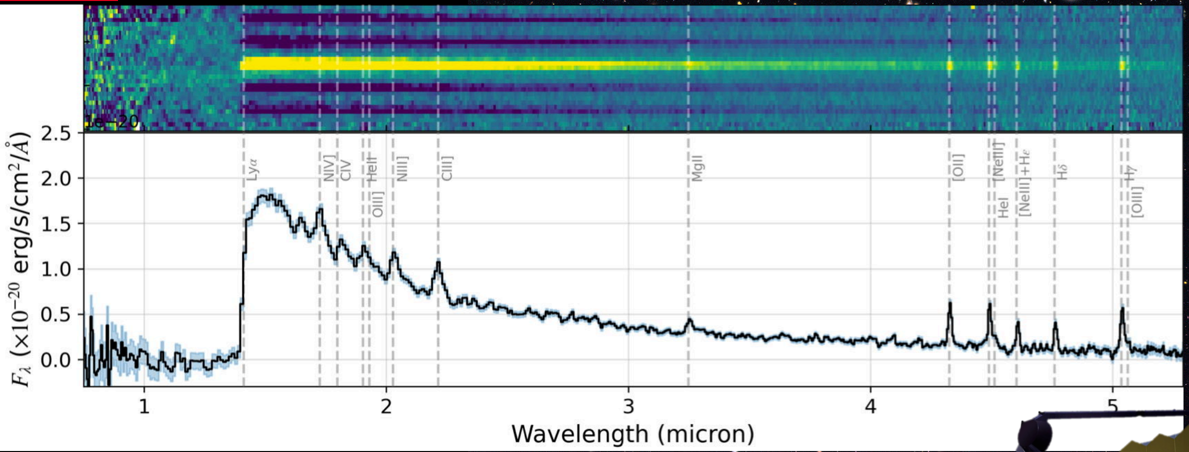
GALAXY CLUSTER SMACS 0723

WEBB SPECTRA IDENTIFY GALAXIES IN THE VERY EARLY UNIVERSE

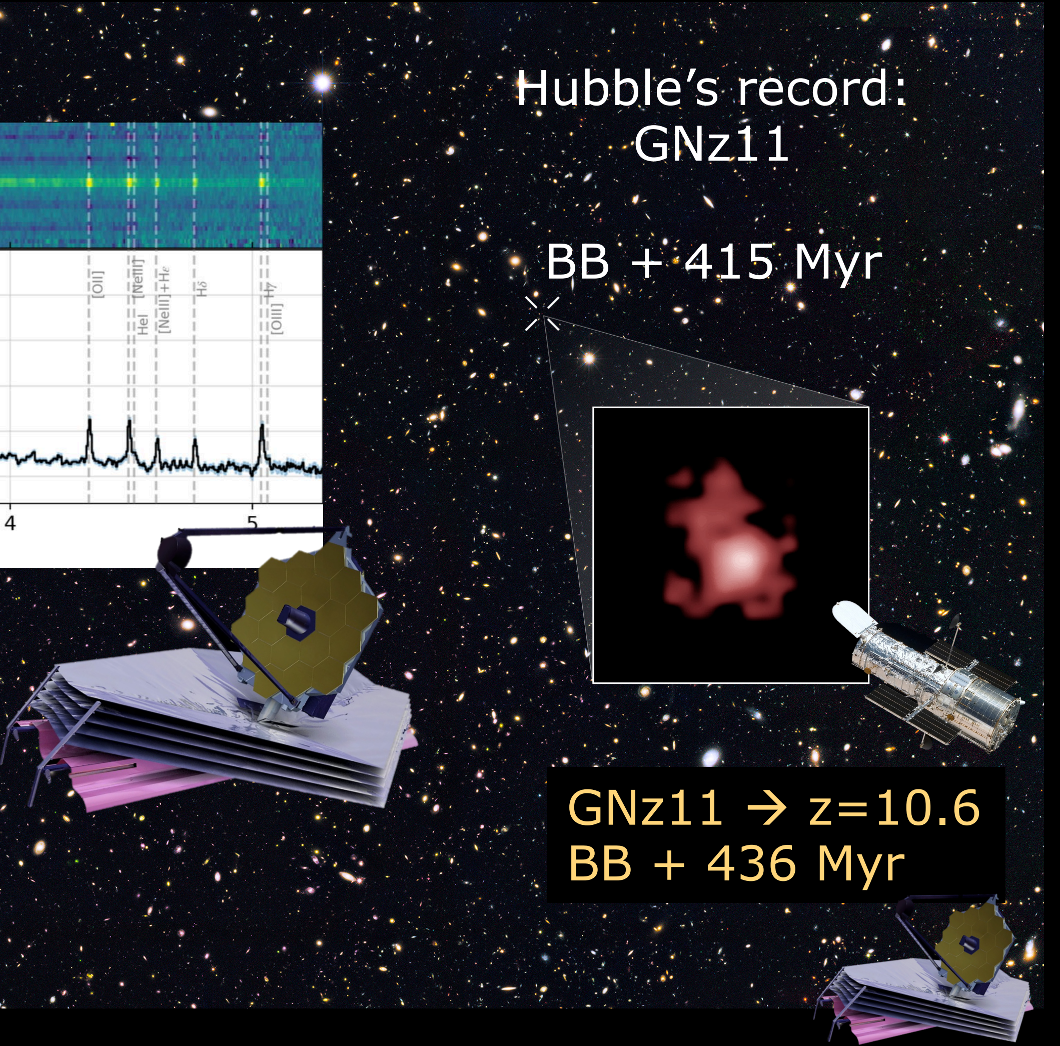




Oesch et al. 2016



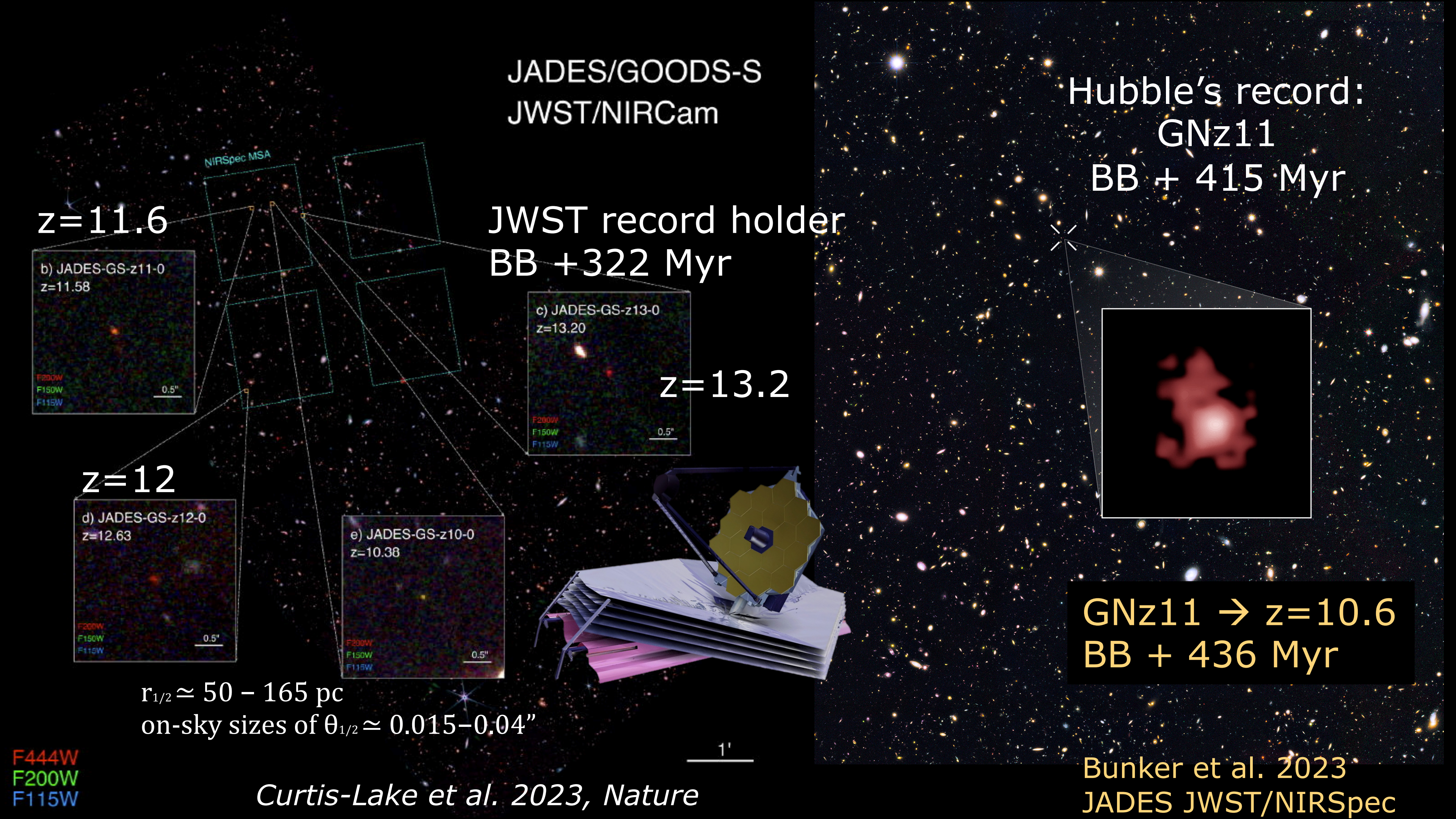
Bunker et al. 2023
JADES JWST/NIRSpec



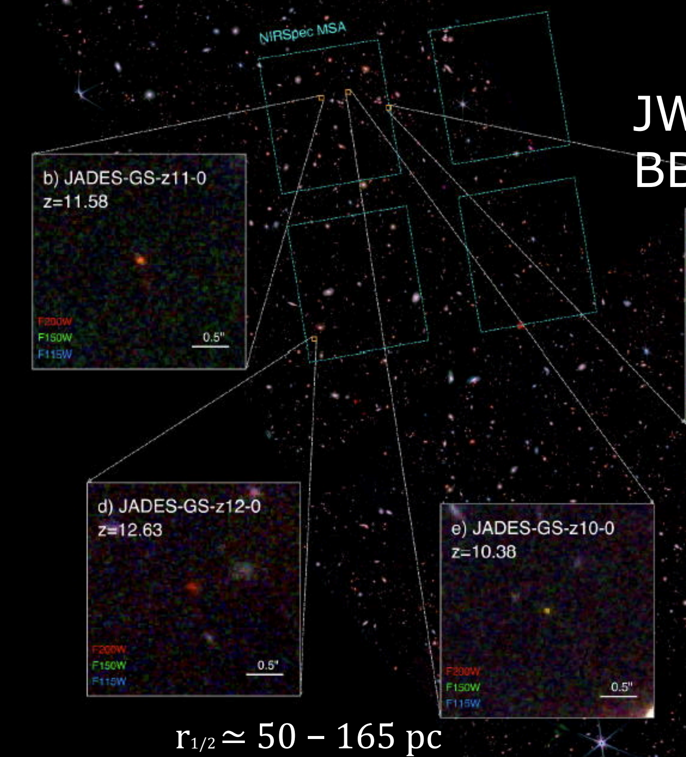
Hubble's record:
GNz11

BB + 415 Myr

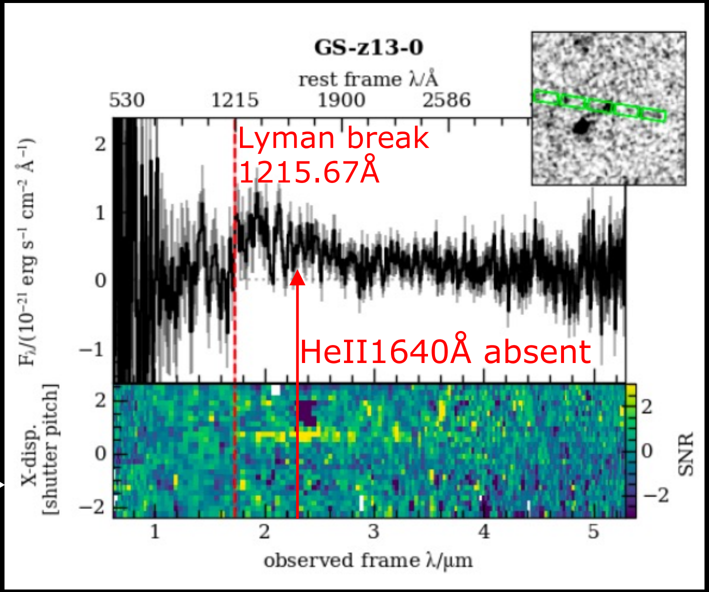
GNz11 → z=10.6
BB + 436 Myr

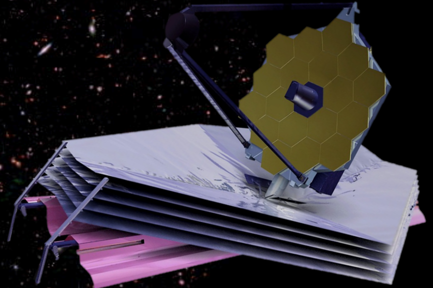

JADES/GOODS-S
JWST/NIRCam
NIRSpec MSA
z=11.6
b) JADES-GS-z11-0
z=11.58
0.5"
JWST record holder
BB +322 Myr
c) JADES-GS-z13-0
z=13.20
z=13.2
0.5"
z=12
d) JADES-GS-z12-0
z=12.63
0.5"
e) JADES-GS-z10-0
z=10.38
0.5"
F200W
F150W
F115W
$r_{1/2} \simeq 50 - 165$ pc
on-sky sizes of $\theta_{1/2} \simeq 0.015 - 0.04''$
1'
F444W
F200W
F115W
Curtis-Lake et al. 2023, Nature
Hubble's record:
GNz11
BB + 415 Myr
GNz11 → z=10.6
BB + 436 Myr
Bunker et al. 2023
JADES JWST/NIRSpec

JADES/GOODS-S
JWST/NIRCam



JWST record holder
BB +322 Myr





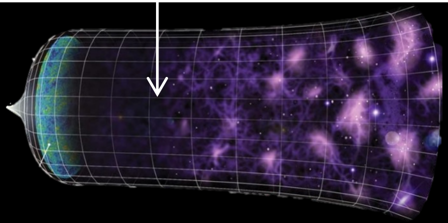
$r_{1/2} \simeq 50 - 165$ pc
on-sky sizes of $\theta_{1/2} \simeq 0.015–0.04$”

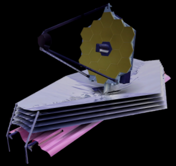
Curtis-Lake et al. 2023, Nature

Webb’s record:
GS-z13-0 at z=13.2
BB + 322 Myr
$M_* = 10^8\ M_\odot$
No sign of HeII

age~70 Myr
→ birth: 250Myr at z~16

Is the promise of the *dawn of the universe* kept?





First galaxies ~250 Myr post-big bang.

No sign yet of Pop.III stars/galaxies.

10 months after the first data release…

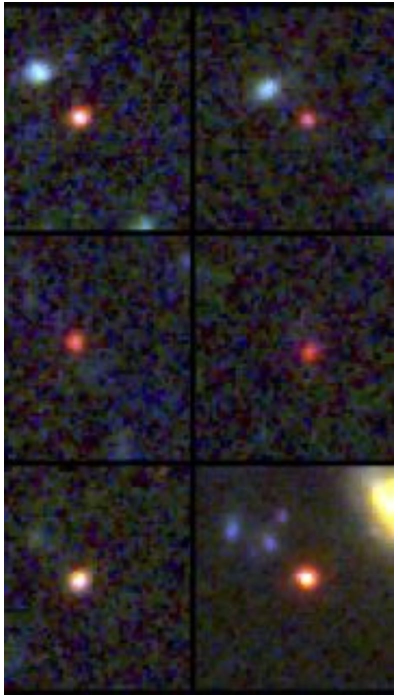
…Seven surprises

Surprise #1 :

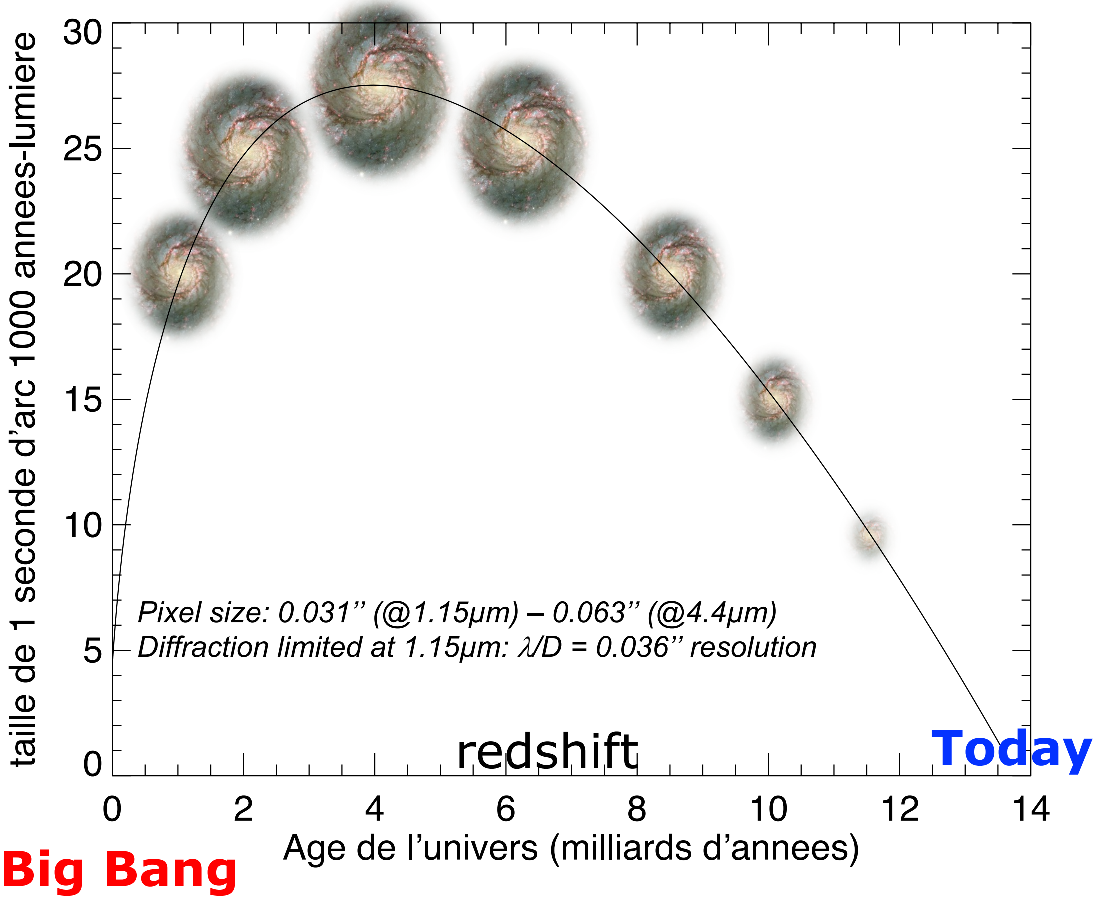
Distant ($z>7$) galaxies are ultra compact, only a few 10-100 pc !!!

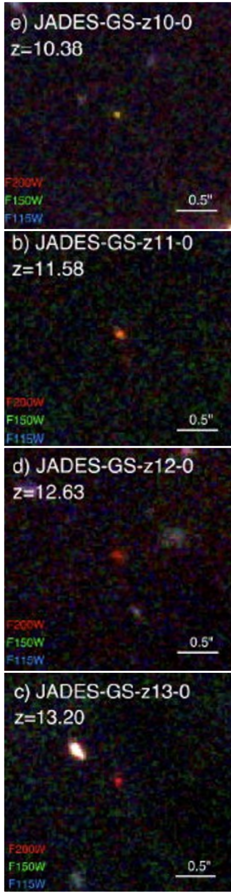
Surprise #1 : Distant galaxies are ultra-compact!

$r_{1/2} \simeq 50 - 165$ pc
$\theta_{1/2} \simeq 0.015 - 0.04''$



median half-light radius of ~500 pc

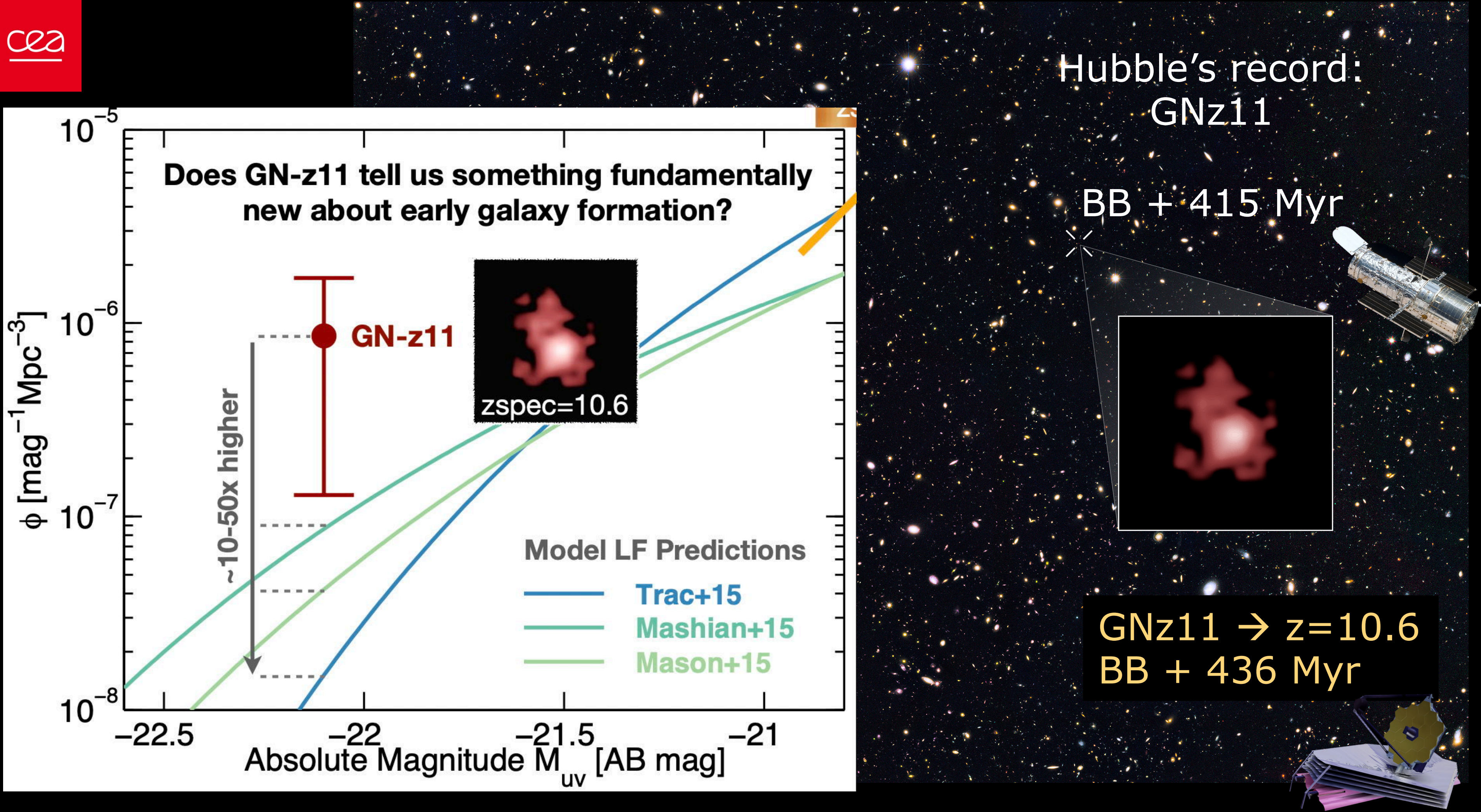




Finkelstein …Elbaz… et al. 2023

Surprise #2 :

Distant galaxies are much more"numerous/bright/massive" than "expected"...

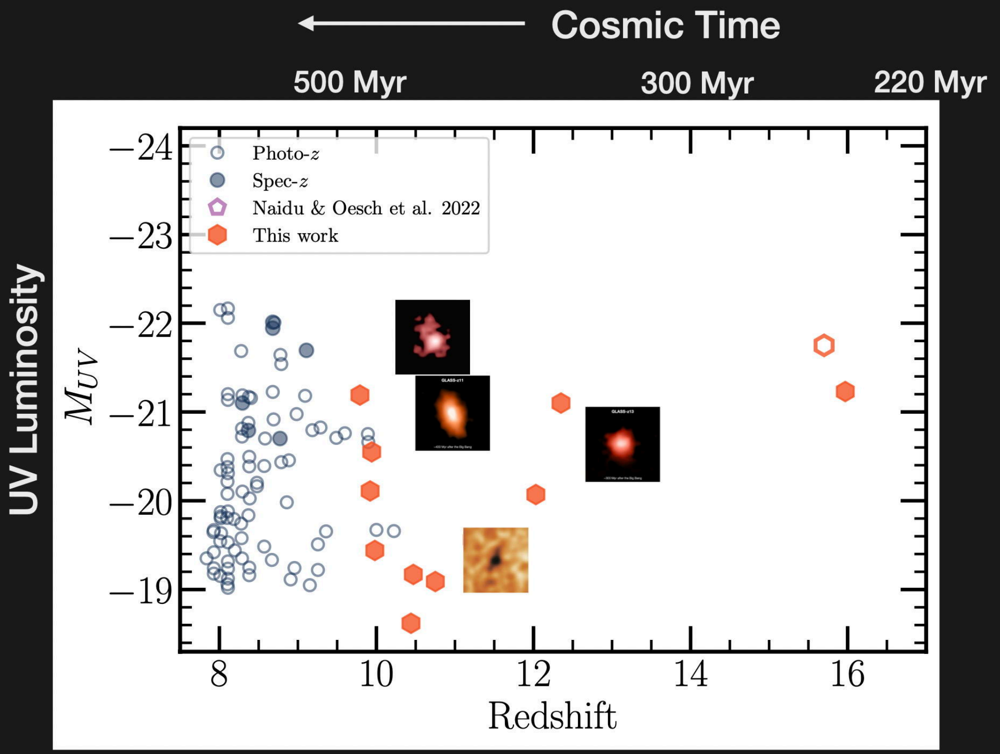

Hubble's record:
GNz11
BB + 415 Myr
GNz11 → z=10.6
BB + 436 Myr
Does GN-z11 tell us something fundamentally new about early galaxy formation?
GN-z11
zspec=10.6
~10-50x higher
Model LF Predictions
Trac+15
Mashian+15
Mason+15
ϕ [mag⁻¹Mpc⁻³]
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
−22.5
−22
−21.5
−21
Absolute Magnitude M_uv [AB mag]

Too many luminous galaxies in the first 500 Myr?

- Within first weeks already "achieved" what was expected to take a full year of JWST observations

- Expected to need >10x larger surveys to find this number of luminous galaxies

P.Oesch



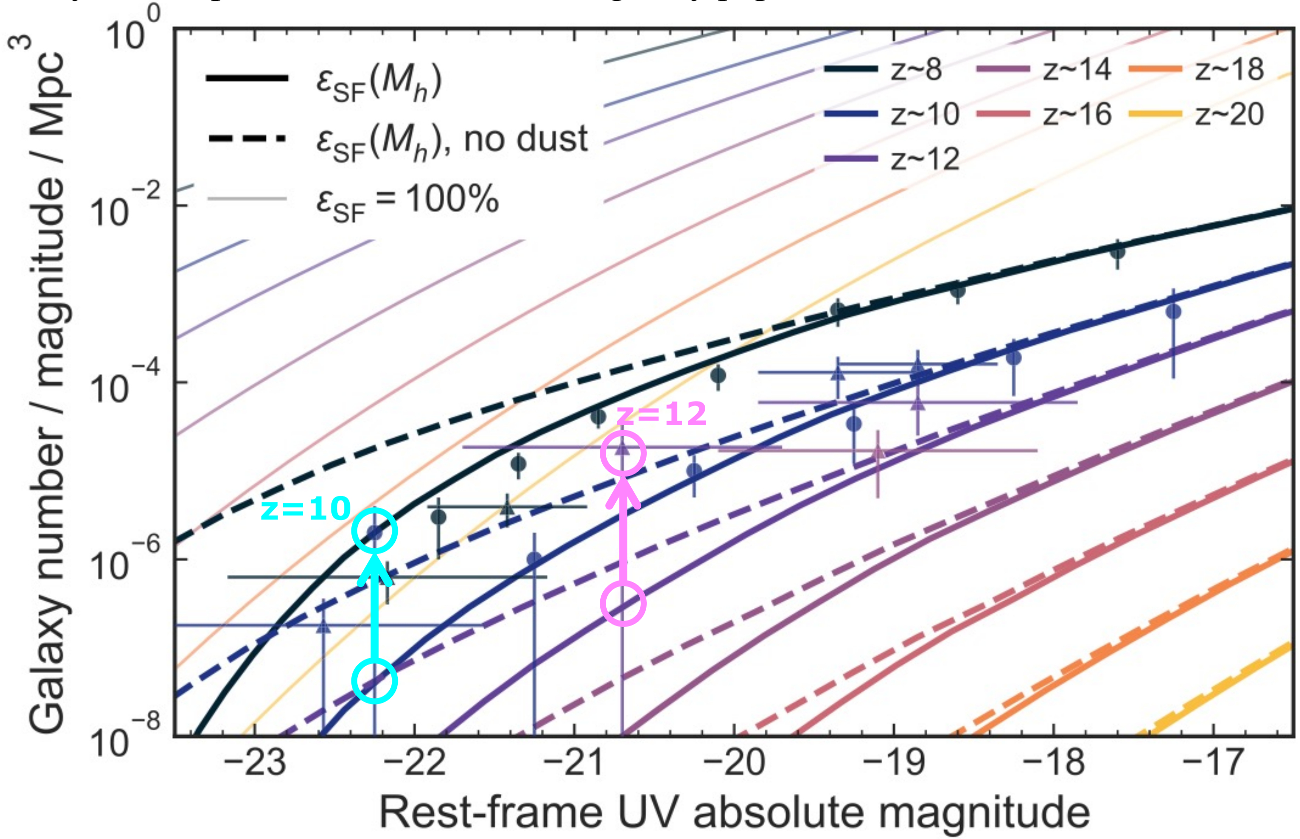
Atek+22

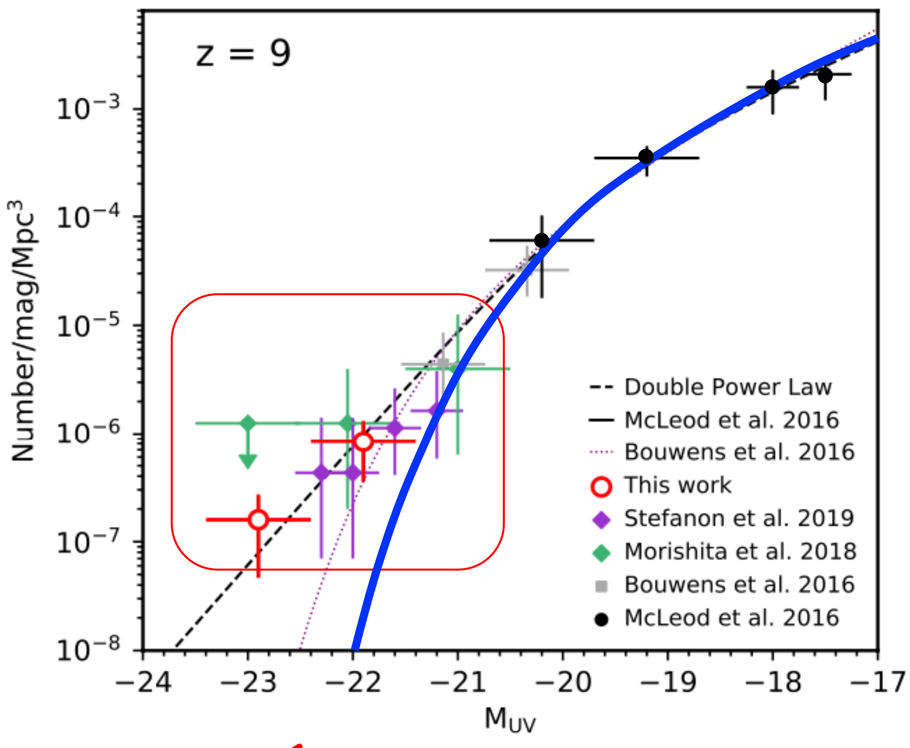
See also: Castellano+22, Adams+22, Yan+22, Finkelstein+22, Donnan+22, Labbe+22, Harikane+22, Rodighiero+22, Furtak+22, Bradley+22, Yu-Yang Hsiao+22, …

The brightest galaxies at cosmic dawn

Charlotte A. Mason[1,2]★ Michele Trenti[3,4] and Tommaso Treu[5]

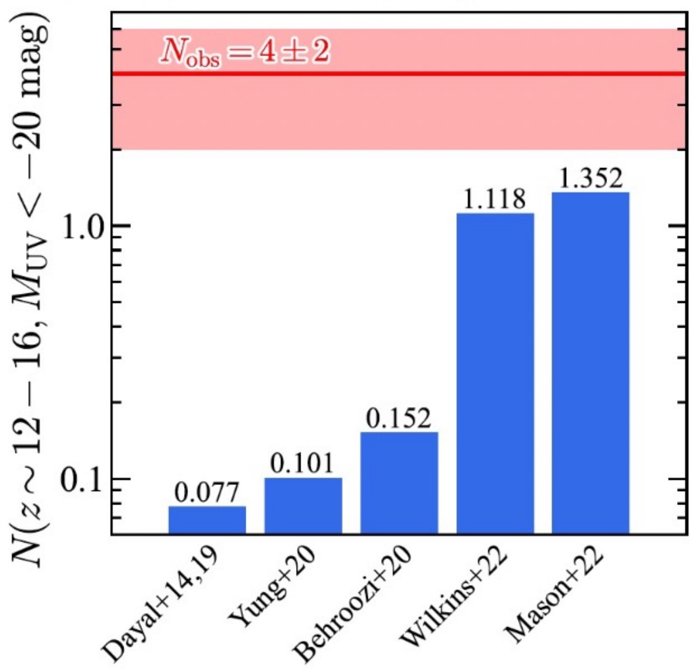
''Galaxies currently observed at $z \geq 10$ are likely to be the most extreme tip of the iceberg in terms of star formation, but are unlikely to be representative of the overall galaxy population''.



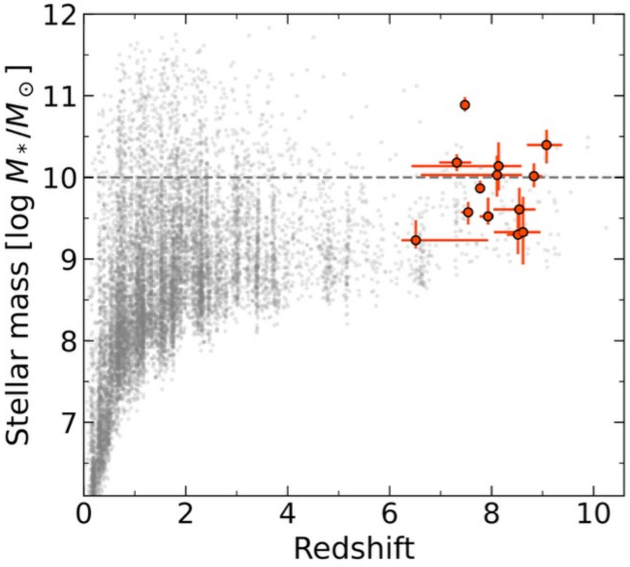


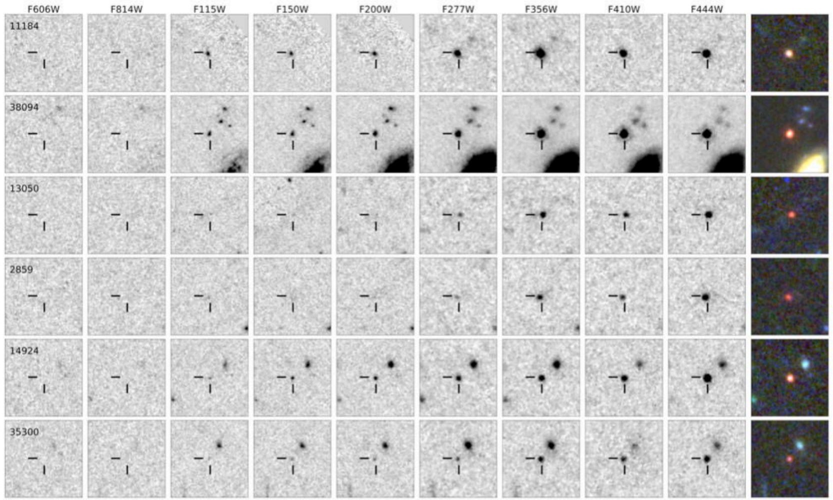
Most luminous UV galaxies

Bowler +2023

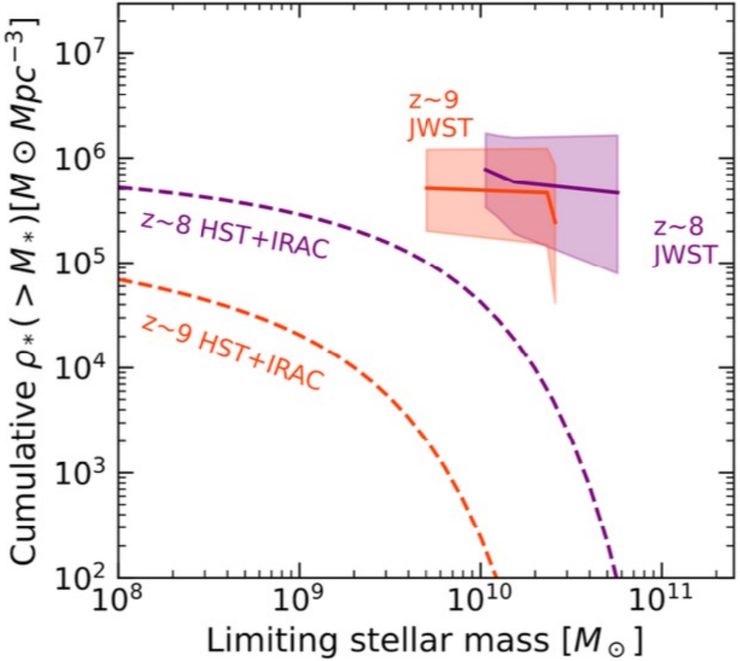


Harikane+23



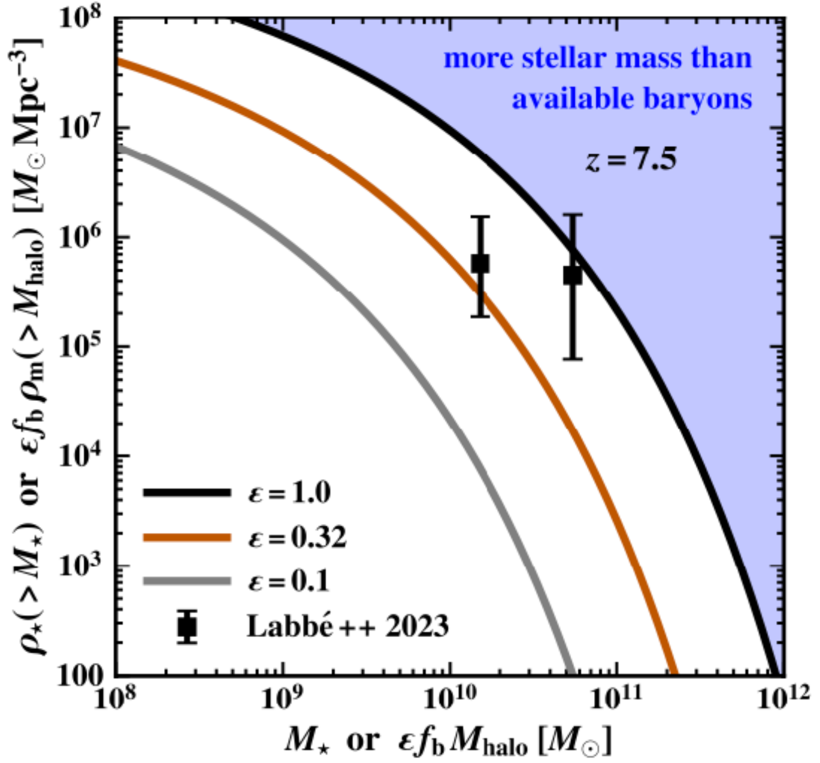


''If verified with spectroscopy, the stellar mass density in massive galaxies would be much higher than anticipated from previous studies based on rest-frame ultraviolet-selected samples.''



Labbe et al. 2023, Nature

Ruling out ΛCDM with high-redshift galaxies (?)

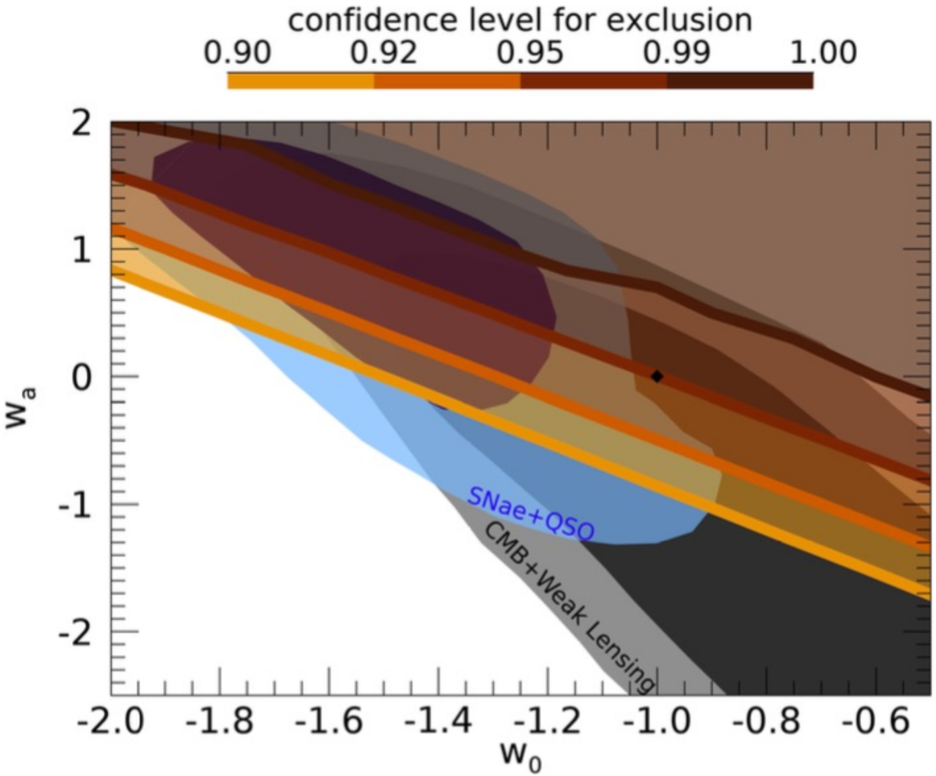


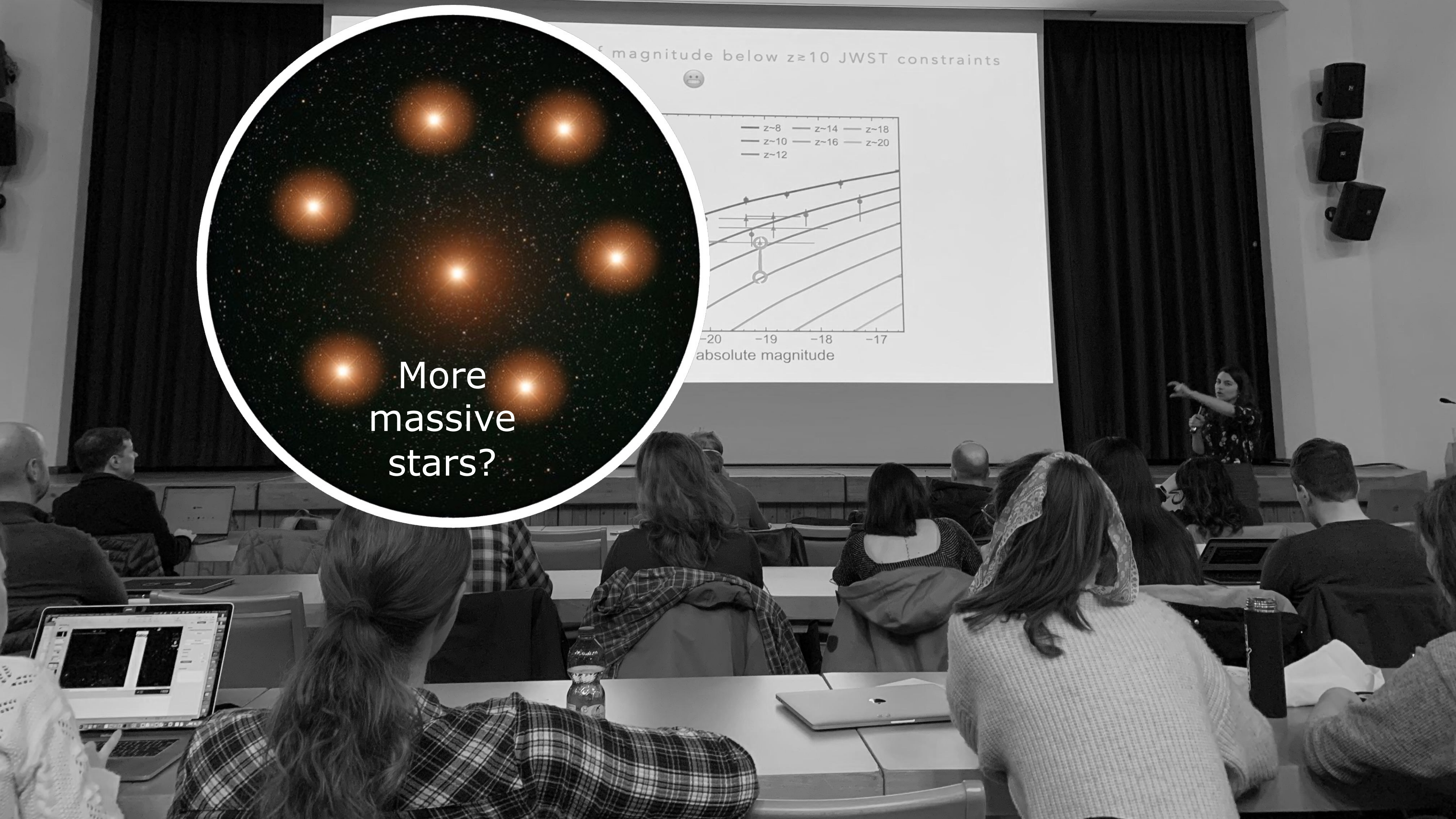
Boylan-Kolchin 2023

The Astrophysical Journal Letters, 938:L5 (4pp), 2022 October 10 https://doi.org/10.3847/2041-8213/ac96e9
© 2022. The Author(s). Published by the American Astronomical Society.
OPEN ACCESS

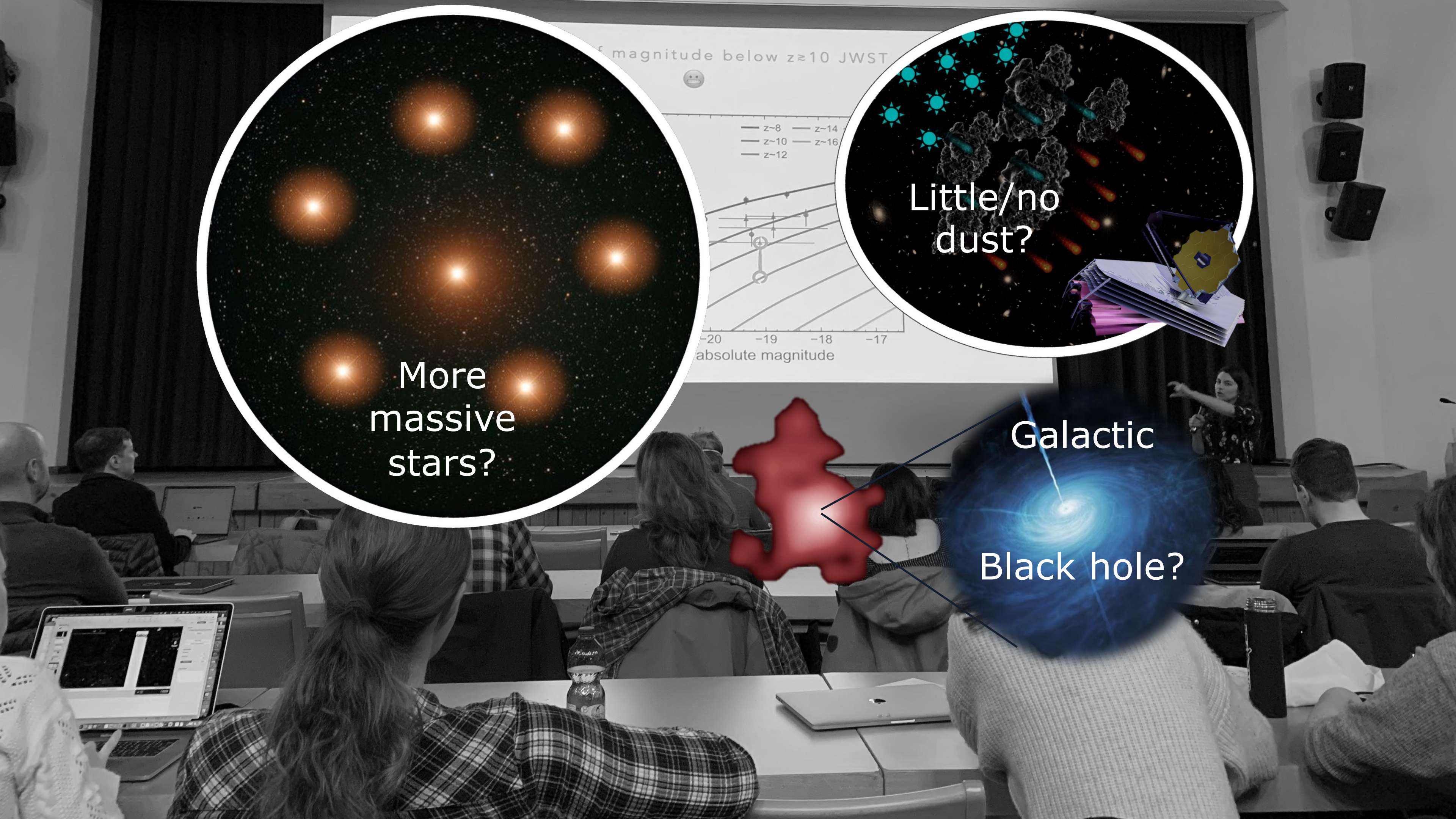
High-redshift Galaxies from Early JWST Observations: Constraints on Dark Energy Models

N. Menci[1], M. Castellano[1], P. Santini[1], E. Merlin[1], A. Fontana[1], and F. Shankar[2]





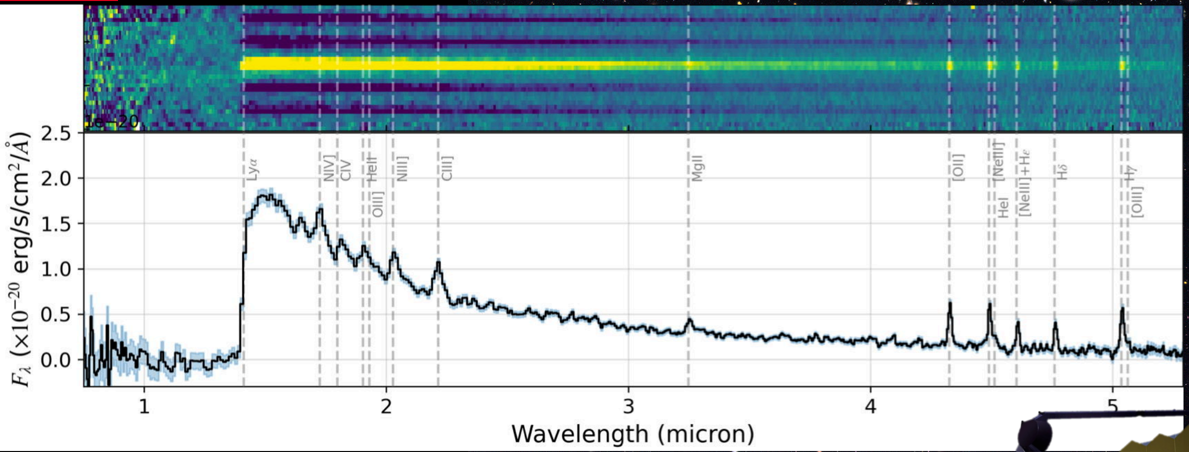
f magnitude below z≥10 JWST constraints
z~8
z~10
z~12
z~14
z~16
z~18
z~20
−20
−19
−18
−17
absolute magnitude
More massive stars?


magnitude below z≥10 JWST
z~8
z~10
z~12
z~14
z~16
-20
-19
-18
-17
absolute magnitude
More
massive
stars?
Little/no
dust?
Galactic
Black hole?

Surprise #3 :

Supermassive black holes formed earlier than expected

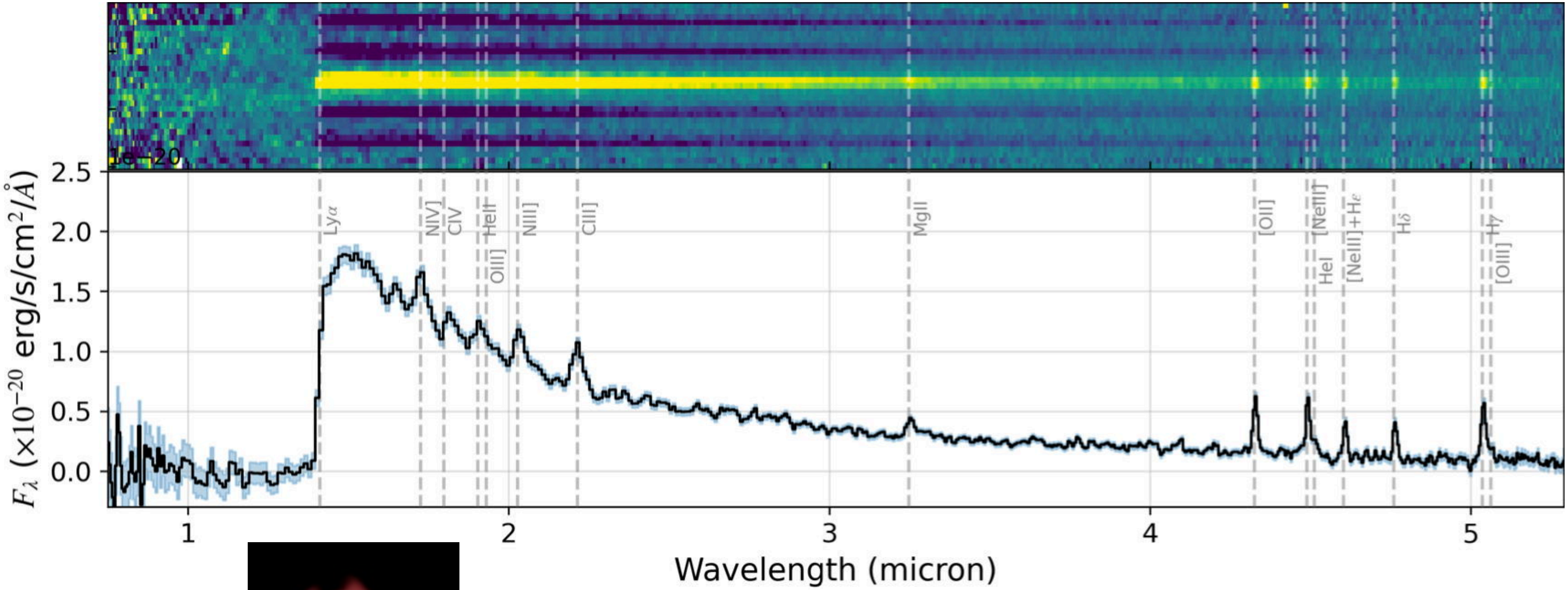
(more numerous, more massive)

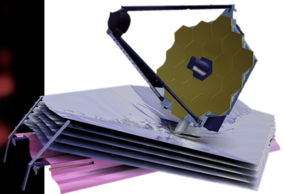


Bunker et al. 2023
JADES JWST/NIRSpec

JADES NIRSpec Spectroscopy of GN-z11: Lyman-α emission and possible enhanced nitrogen abundance in a $z = 10.60$ luminous galaxy

Bunker +2023





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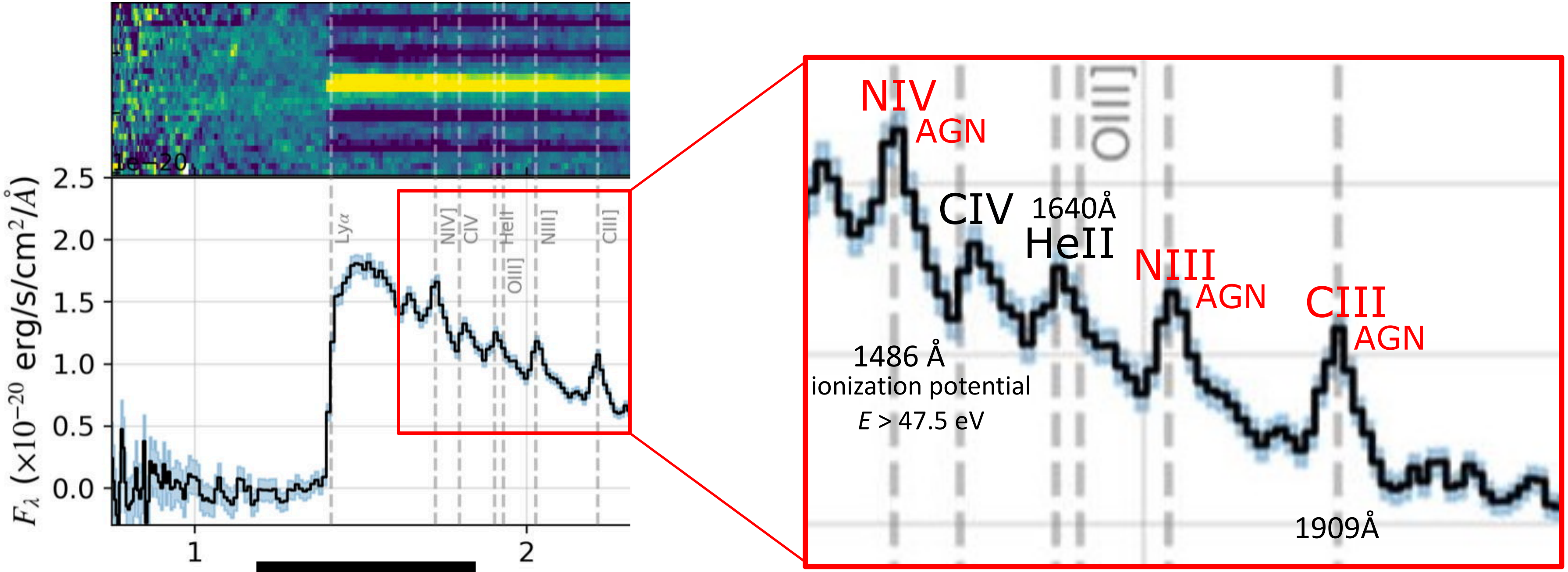
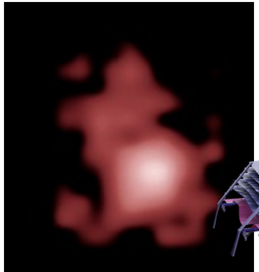
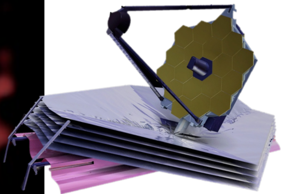


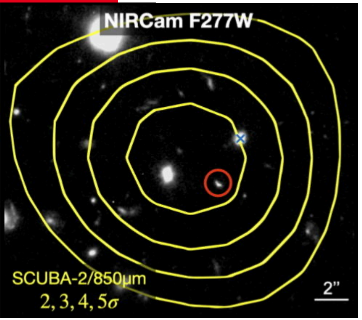
Talk Maiolino 3/2023

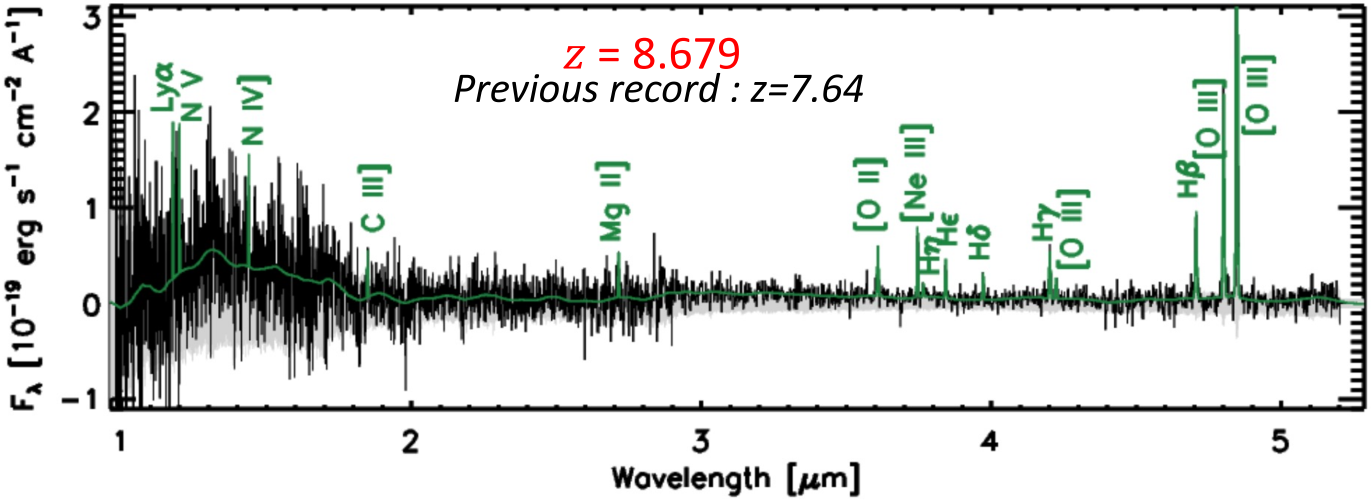




A CEERS Discovery of an Accreting Supermassive Black Hole 570 Myr after the Big Bang: Identifying a Progenitor of Massive $z > 6$ Quasars

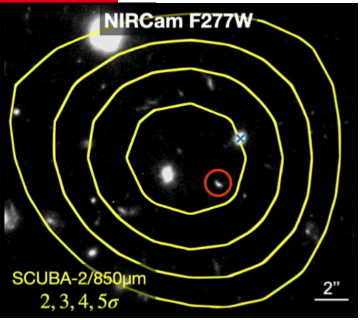
Larson +2023



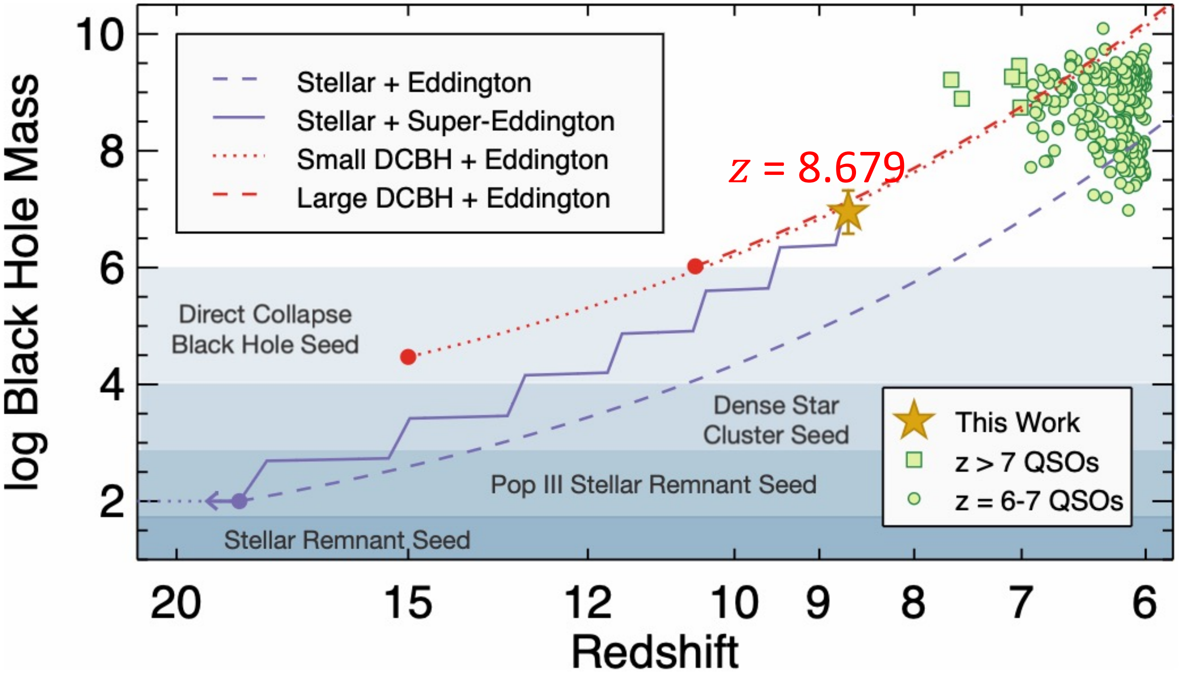


$$\log\,(M_{BH}/M_{\odot}) = 6.95 \pm 0.37$$

A CEERS Discovery of an Accreting Supermassive Black Hole 570 Myr after the Big Bang: Identifying a Progenitor of Massive $z > 6$ Quasars *Larson +2023*



log (M_{BH} /$M_{\odot}$) = 6.95 ± 0.37

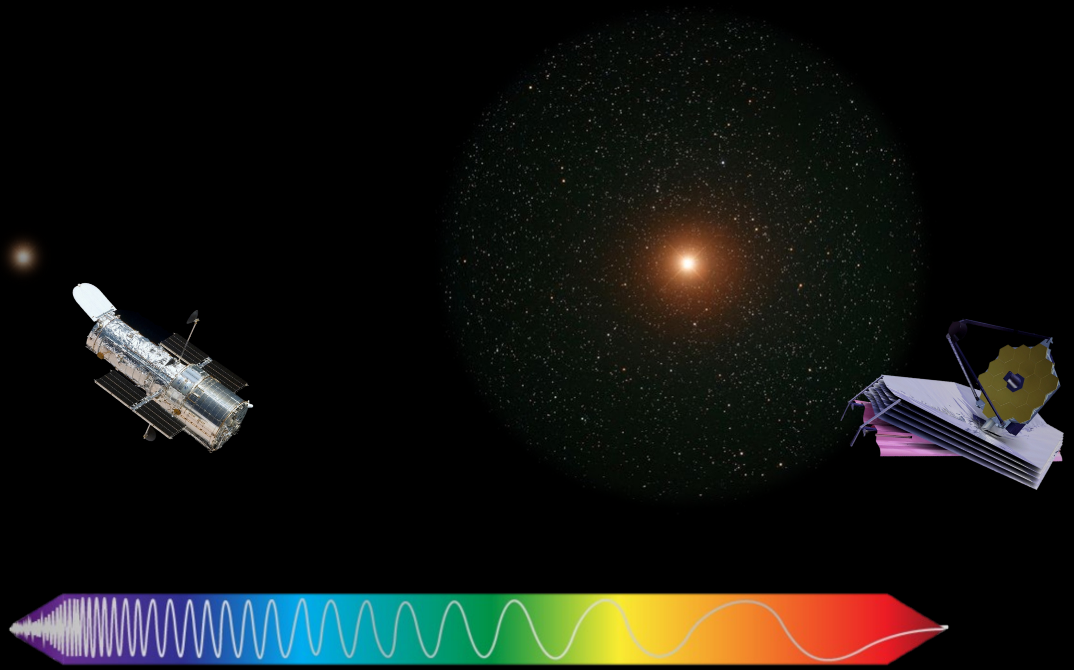


''super-Eddington accretion from stellar seeds or Eddington accretion from very massive black hole seed''

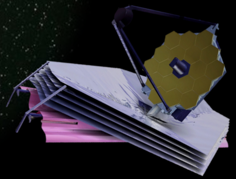
surprisingly-massive black holes in the first Gyr of cosmic history
→ alternative seeding theory: direct collapse black holes (DCBHs; Bromm & Loeb 2003)

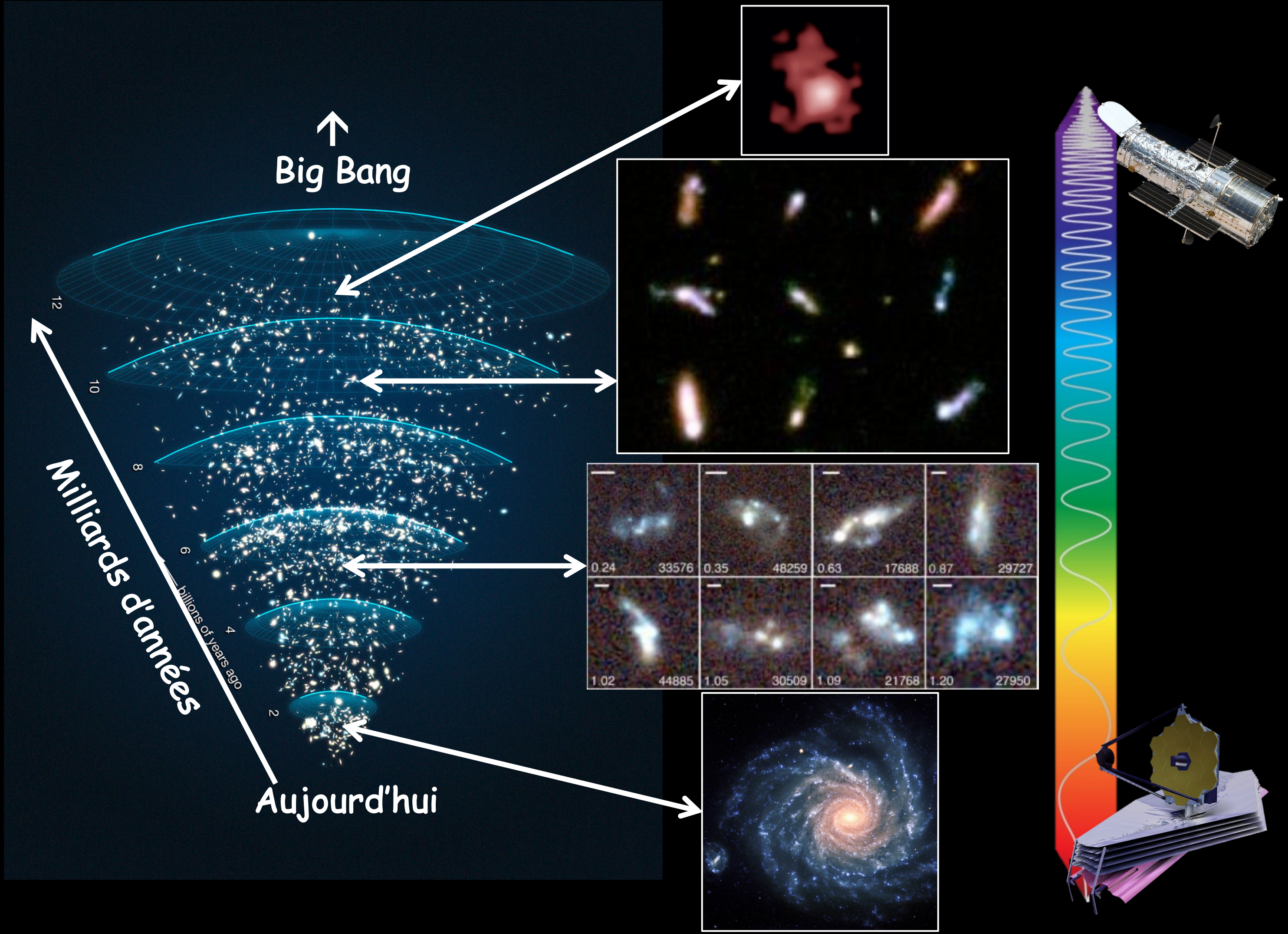
Surprise #4 :

Spiral galaxies were already in place a few 100 Myr after the Big Bang



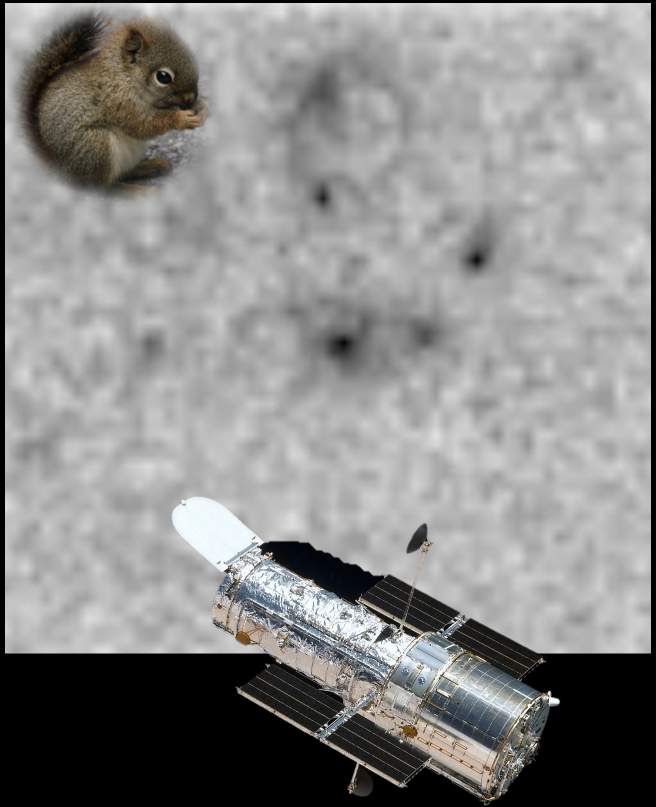
?

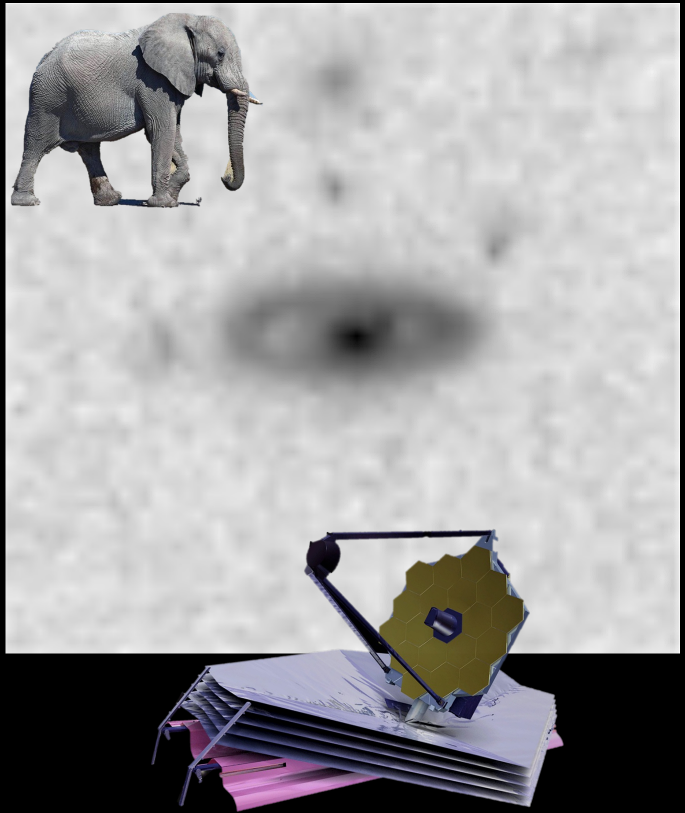




Big Bang
12
10
8
6
4
2
billions of years ago
Milliards d'années
Aujourd'hui
0.24 33576
0.35 48259
0.63 17688
0.87 29727
1.02 44885
1.05 30509
1.09 21768
1.20 27950

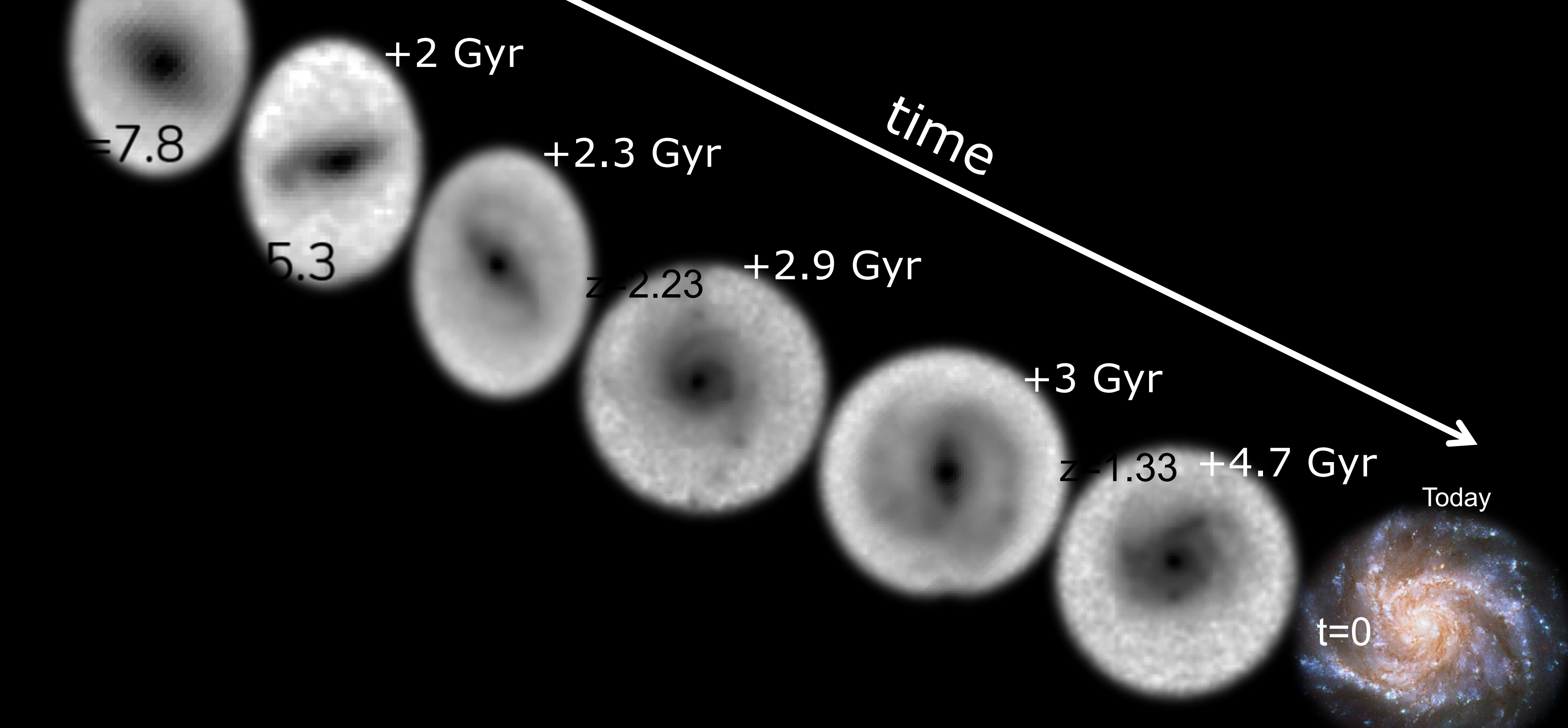
-11 billion years…





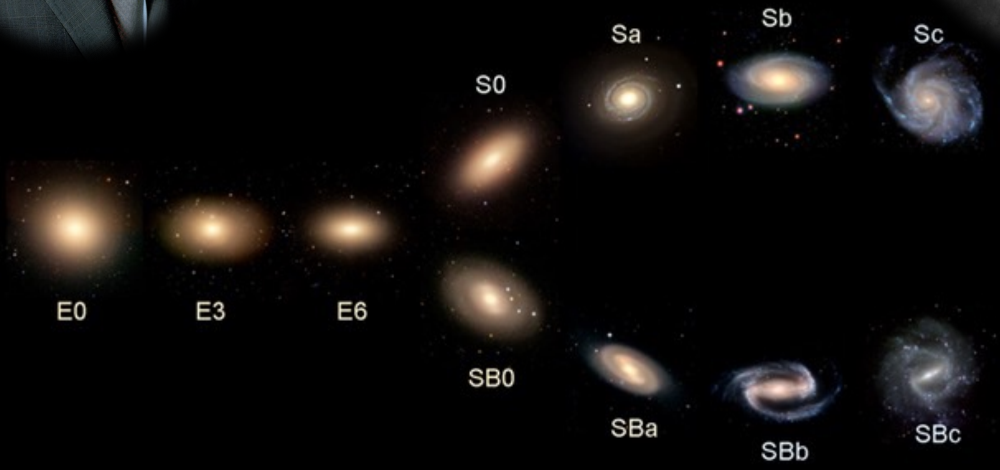
Cheng et al. 2022

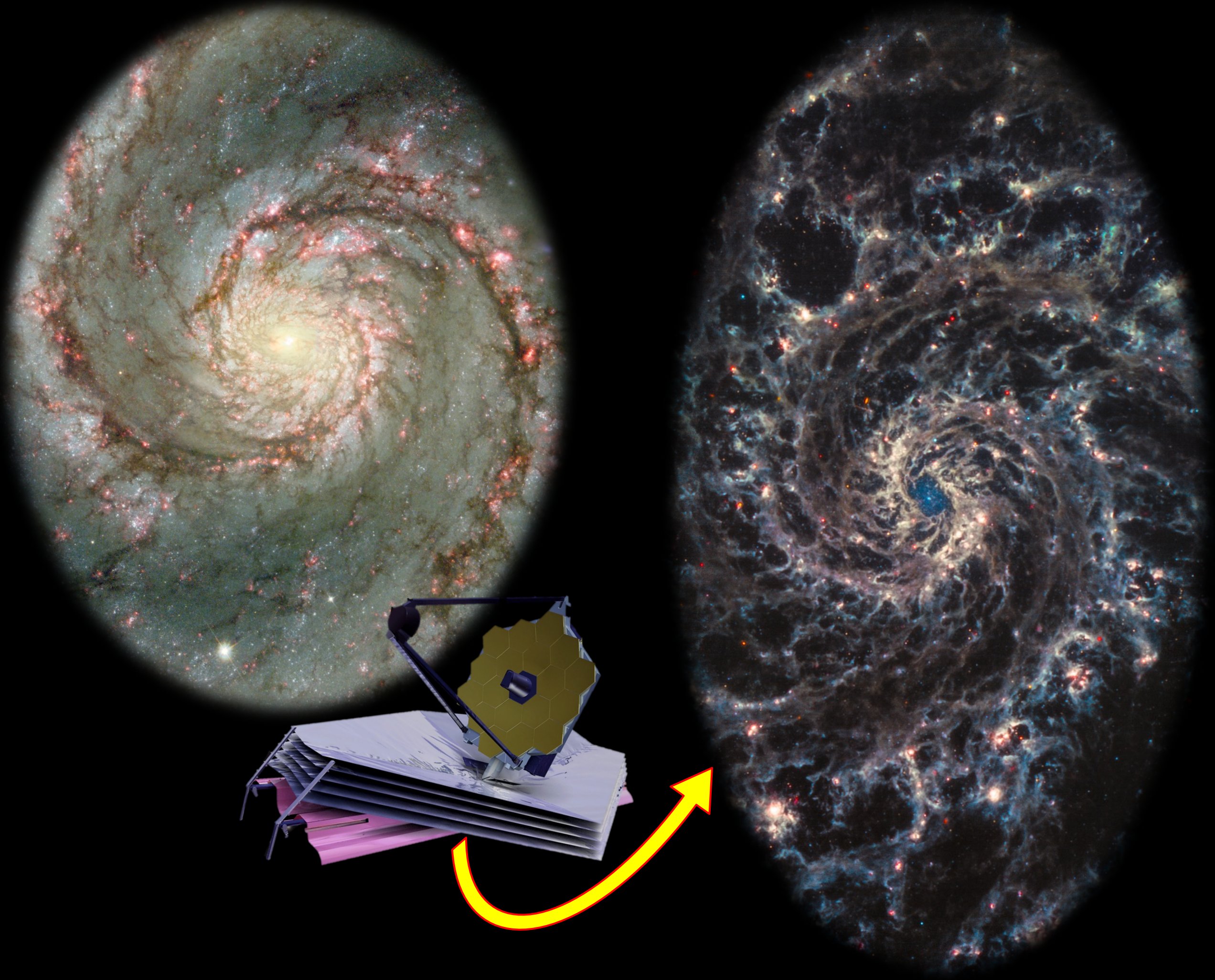
Surprise #3 : the shape of galaxies…
Spiral galaxies were in place very early on

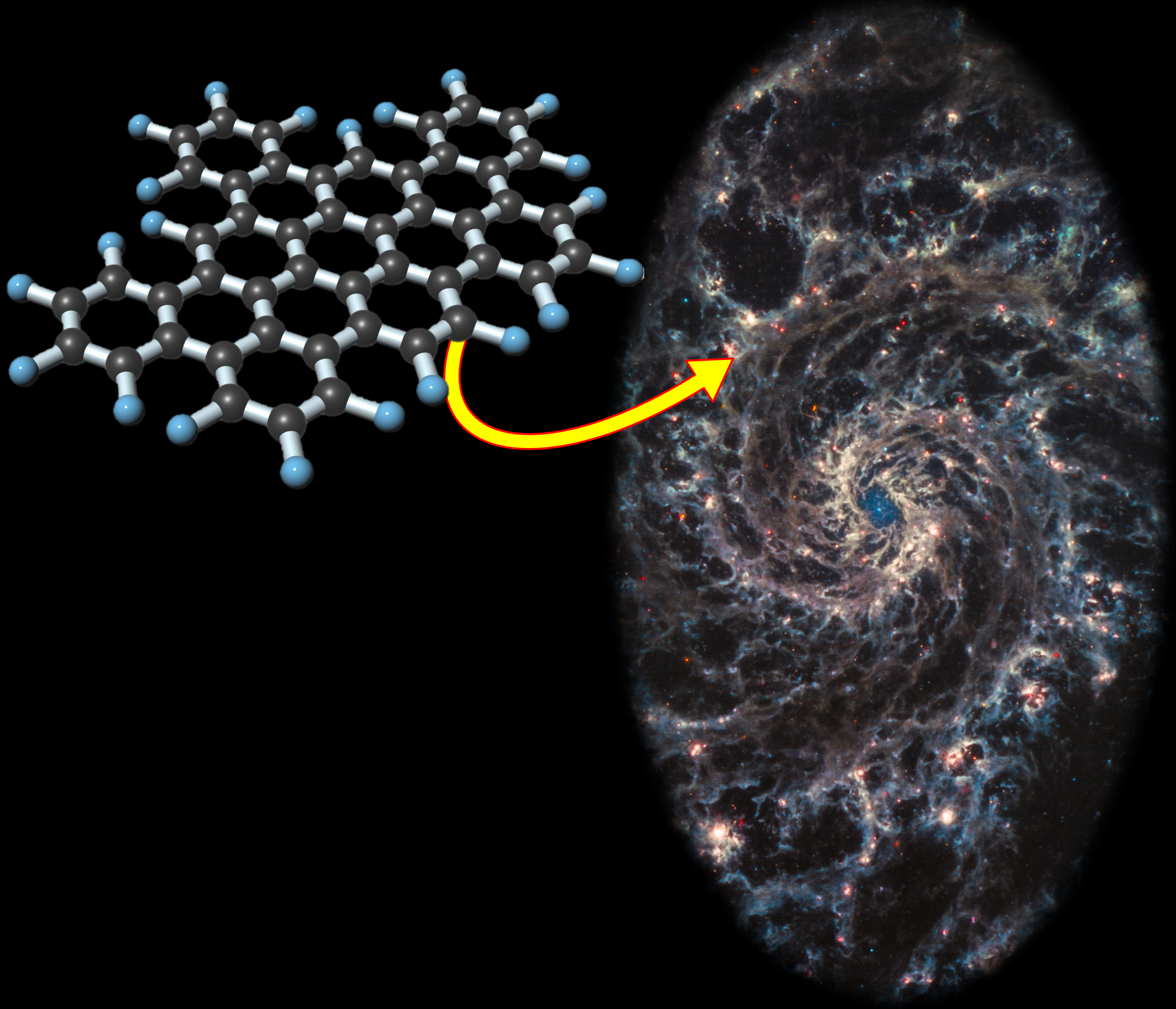


Cheng +2022, Guo +2022, Ferreira +2022

James Webb…
resurrected
Edwin Hubble’s fork







Surprise #5 :

Galaxies started to die/become passive earlier than expected

nature

A massive quiescent galaxy at redshift 4.658

215 ± 20 parsecs !!!

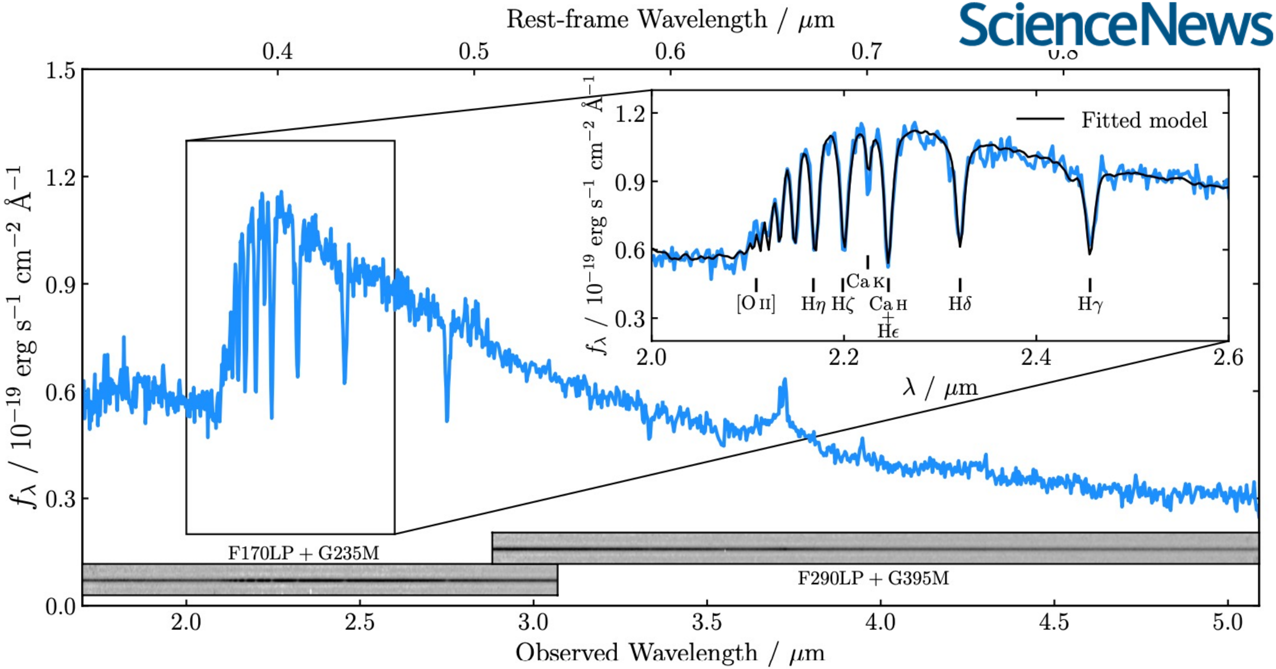
Surprise #5 :

Discovery of a galaxy already dead 1.2 Gyr after the Big Bang

The James Webb telescope spotted the earliest known 'quenched' galaxy

The galaxy may have been shut off by an actively feeding black hole

ScienceNews



Birth date : 700 million years after the Big Bang

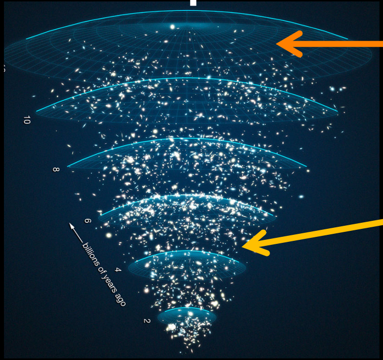
Lifespan : 200 millions years !

observed 300 millions years after its death

Surprise #6 :

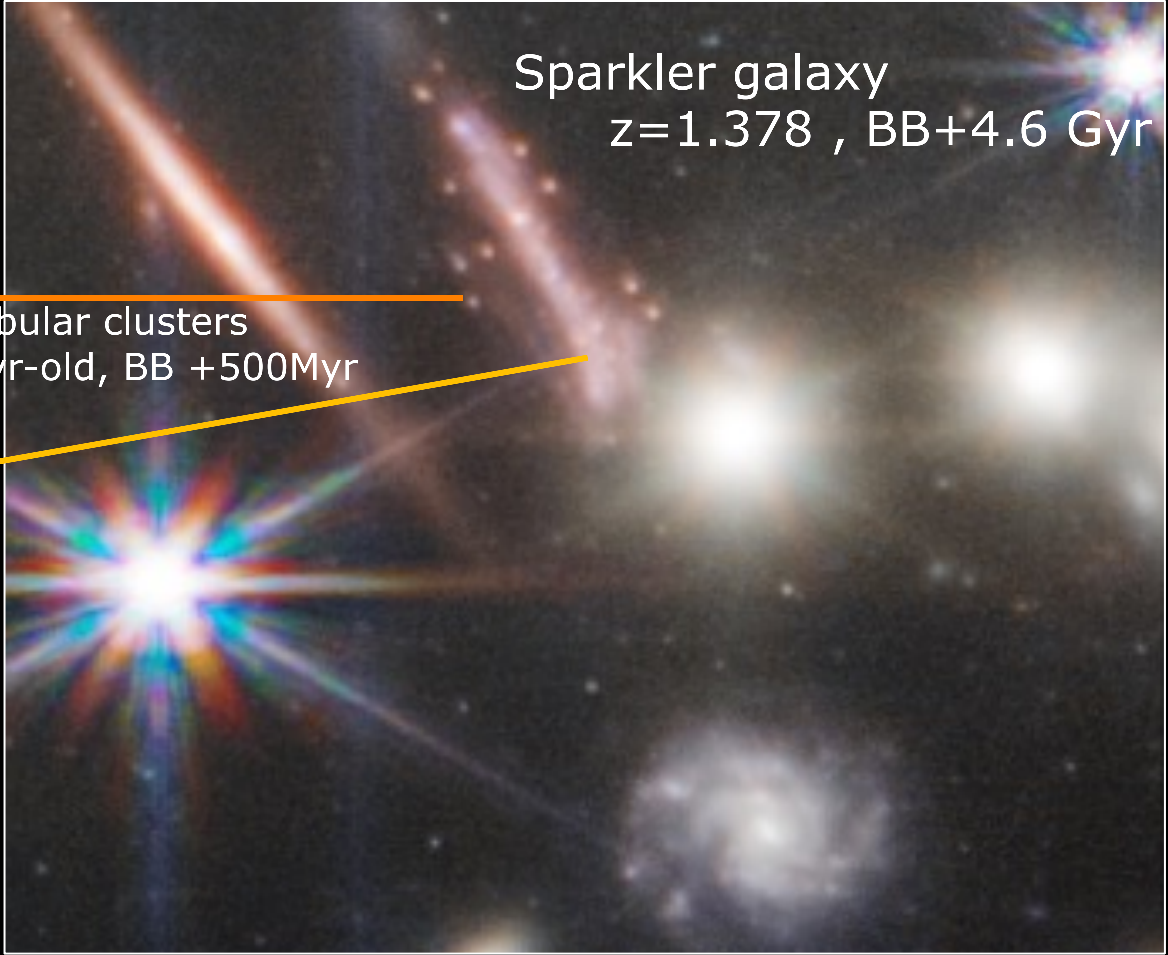
Globular clusters are very common and old… The missing link?

Big Bang



Today

Globular clusters
4Gyr-old, BB +500Myr



Mowla +2022

Surprise #7 :

Metallicity = fossil memory of past history of star formation.

How do we measure metallicities?

→ Emission line diagnostics provide the ISM metallicity

But they are calibrated on local galaxies…

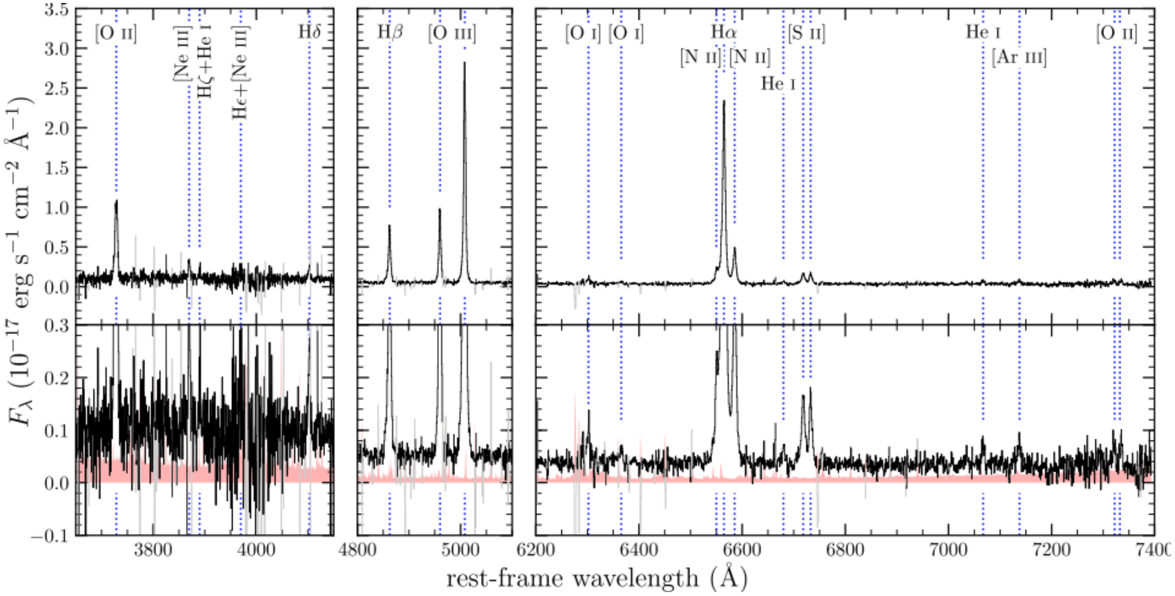
Surprise #7 :

The First Detection of Auroral lines in the early Universe

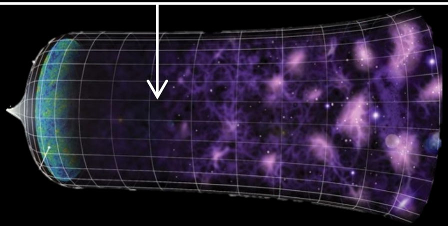
[O II]7322, 7332 Å

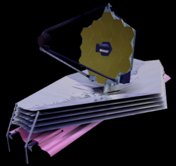
A Preview of JWST Metallicity Studies at Cosmic Noon: The First Detection of Auroral [O II] Emission at High Redshift*

Sanders +2023



Is the promise of the *dawn of the universe* kept?





First galaxies ~250 Myr post-big bang.

No sign yet of Pop.III stars/galaxies.

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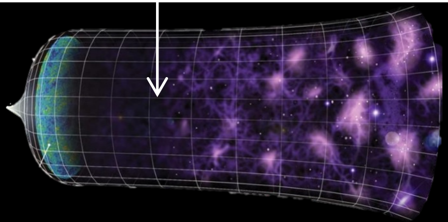

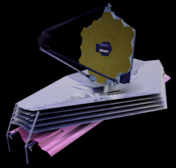

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→ the dawn of the universe may be due to the light of the first SMBH formation!

Surprise #4 : Spiral galaxies were already in place a few 100 Myr after the Big Bang

Surprise #5 : Galaxies started to die/become passive earlier than expected

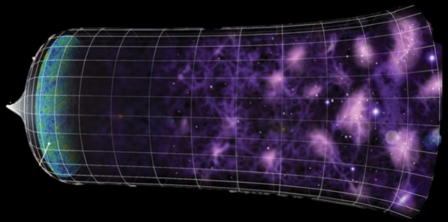
Surprise #6 : Globular clusters are very common and old… The missing link?

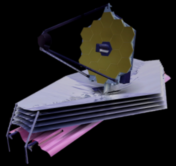
→ or maybe to the first globular cluster formation?

Surprise #7 : The First Detection of Auroral lines in the early Universe

→ high S/N JWST spectra are richer than expected → we just opened the book…

A common origin for these 6 surprises?





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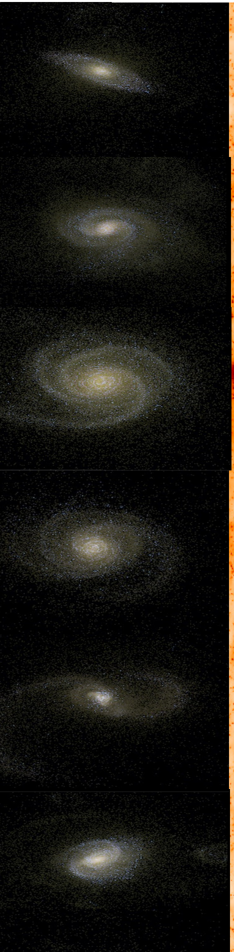
Bimodal gas accretion in the Horizon–MareNostrum galaxy formation simulation

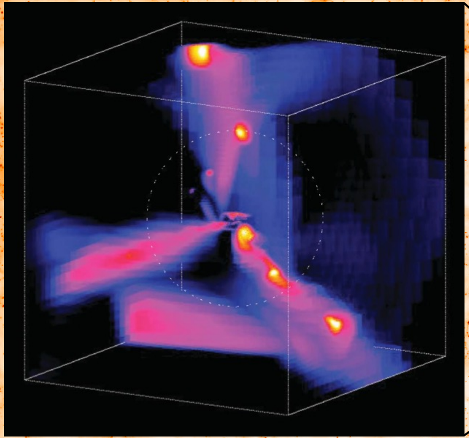
P. Ocvirk,[1,2★] C. Pichon[2,3] and R. Teyssier[2]

Mon. Not. R. Astron. Soc. **390,** 1326–1338 (2008)



A virtual image of the high redshift Universe (z=4):

Cold filaments feeding gas-rich galactic discs



HORIZON project (R.Teyssier et al.)

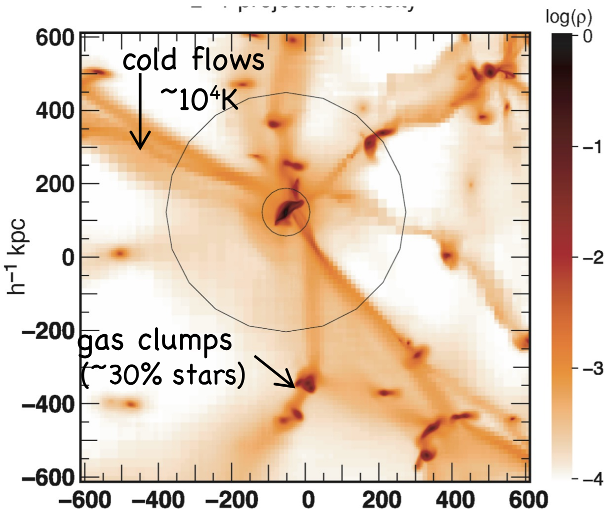
MareNostrum simulation: 94 teraflops

Cold streams in early massive hot haloes as the main mode of galaxy formation

(2009) nature 457, 451

A. Dekel[1], Y. Birnboim[1,2], G. Engel[1], J. Freundlich[1,3], T. Goerdt[1], M. Mumcuoglu[1], E. Neistein[1,4], C. Pichon[5], R. Teyssier[6,7] & E. Zinger[1]

MareNostrum simulation (AMR)
71 Mpc, res° 1.4 kpc
Ocvirk, Pichon & Teyssier 2008



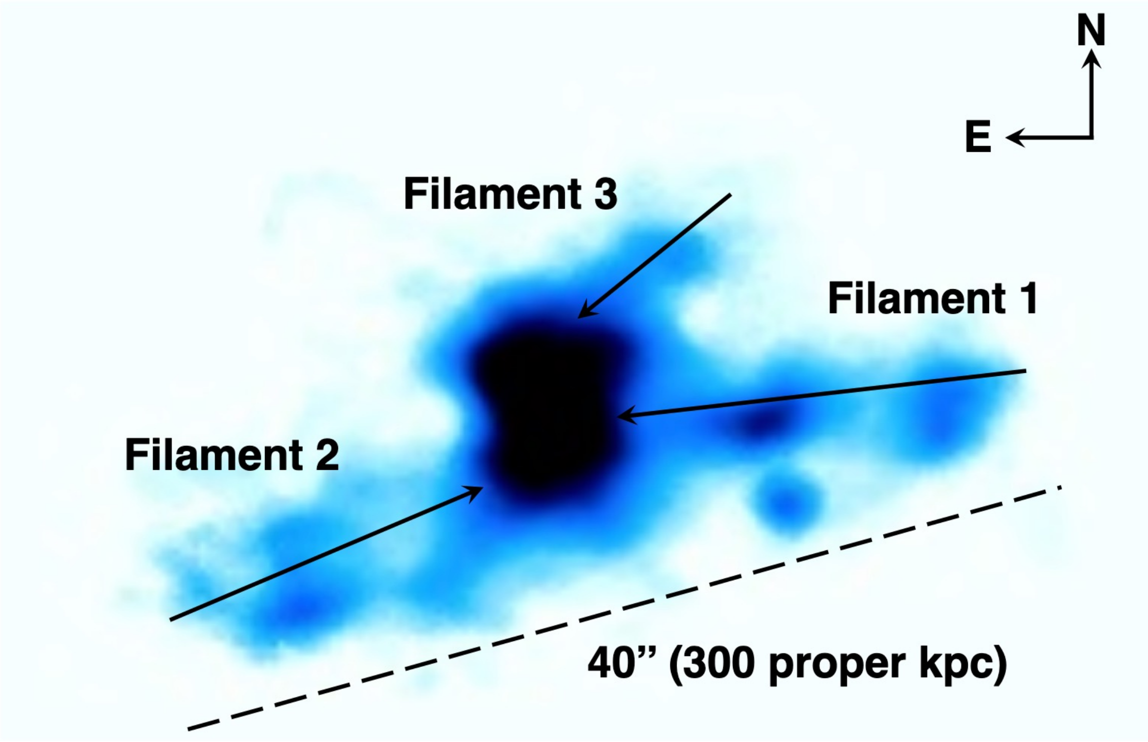
3/4 of star-formation fed by smooth streams = « cold flows »

accretion rate ~ $M_{halo}^{1.15}$ $(1+z)^{2.25}$ x 0.165 where $M_{baryons}/M_{halo}$=0.165

Three Lyman-α emitting filaments converging to a massive galaxy group at z=2.91: discussing the case for cold gas infall

2021

E. Daddi[1], F. Valentino[2,3], R. M. Rich[4], J. D. Neill[5], M. Gronke[6*], D. O'Sullivan[5], D. Elbaz[1], F. Bournaud[1], A. Finoguenov[7], A. Marchal[8], I. Delvecchio[1,9], S. Jin[10,11], D. Liu[12], V. Strazzullo[13,14,15], A. Calabro[16], R. Coogan[17], C. D'Eugenio[1], R. Gobat[18], B. S. Kalita[1], P. Laursen[19,2], D.C. Martin[5], A. Puglisi[20], E. Schinnerer[12], and T. Wang[21]



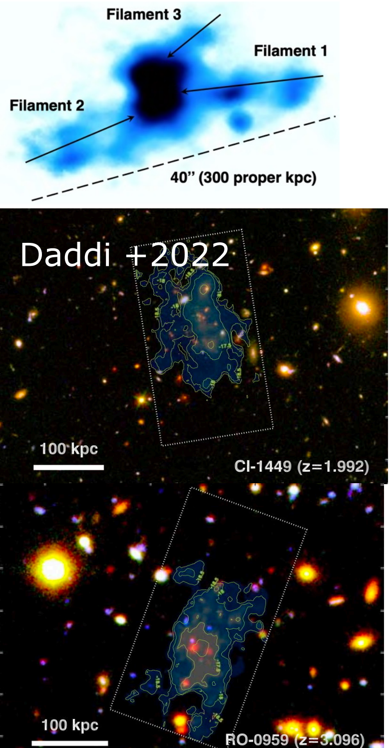
Lyα image from KCWI

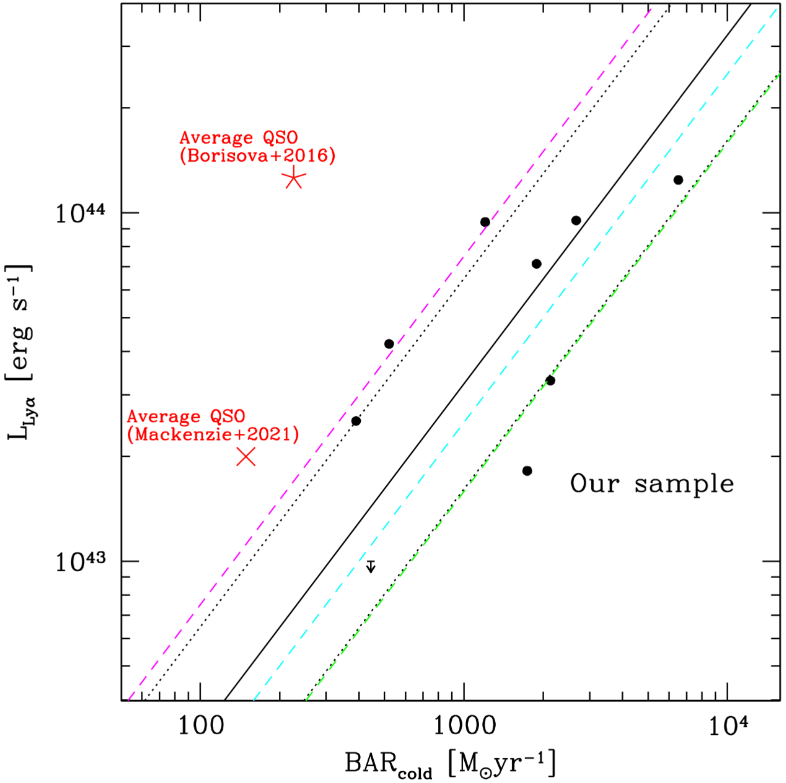
Evidence for Cold-stream to Hot-accretion Transition as Traced by Lyα Emission from Groups and Clusters at $2 < z < 3.3$

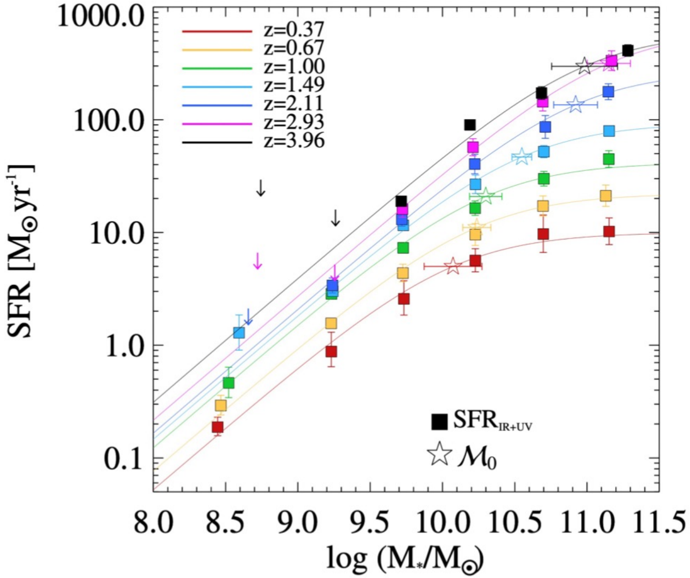
E. Daddi[1], R. M. Rich[2], F. Valentino[3,4], S. Jin[3,5], I. Delvecchio[6], D. Liu[7], V. Strazzullo[8], J. Neill[9], R. Gobat[10], A. Finoguenov[11], F. Bournaud[1], D. Elbaz[1], B. S. Kalita[1], D. O'Sullivan[9], and T. Wang[12]

Astrophysical Journal Letters, 926:L21 (7pp), 2022

Daddi +2021







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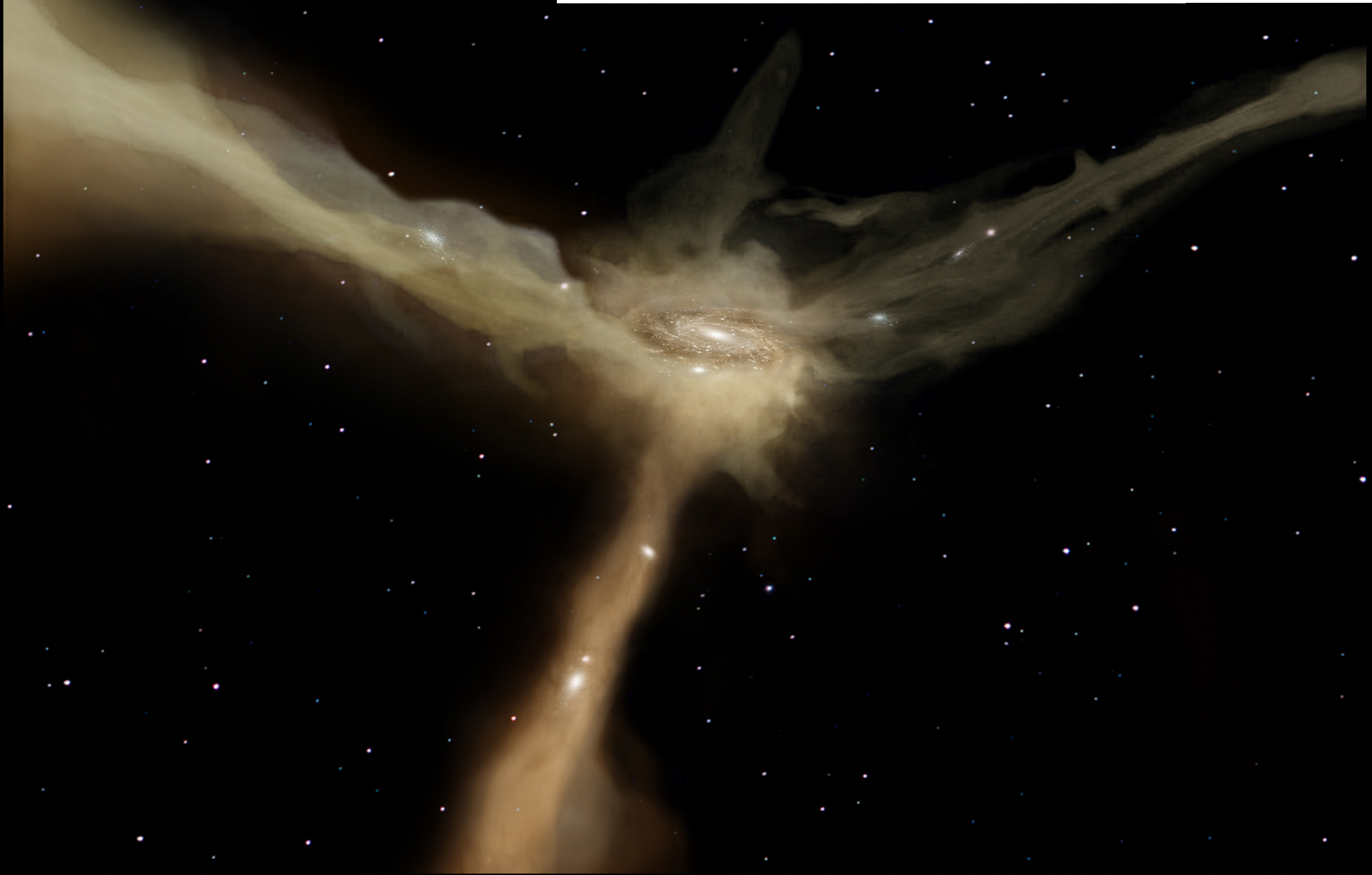
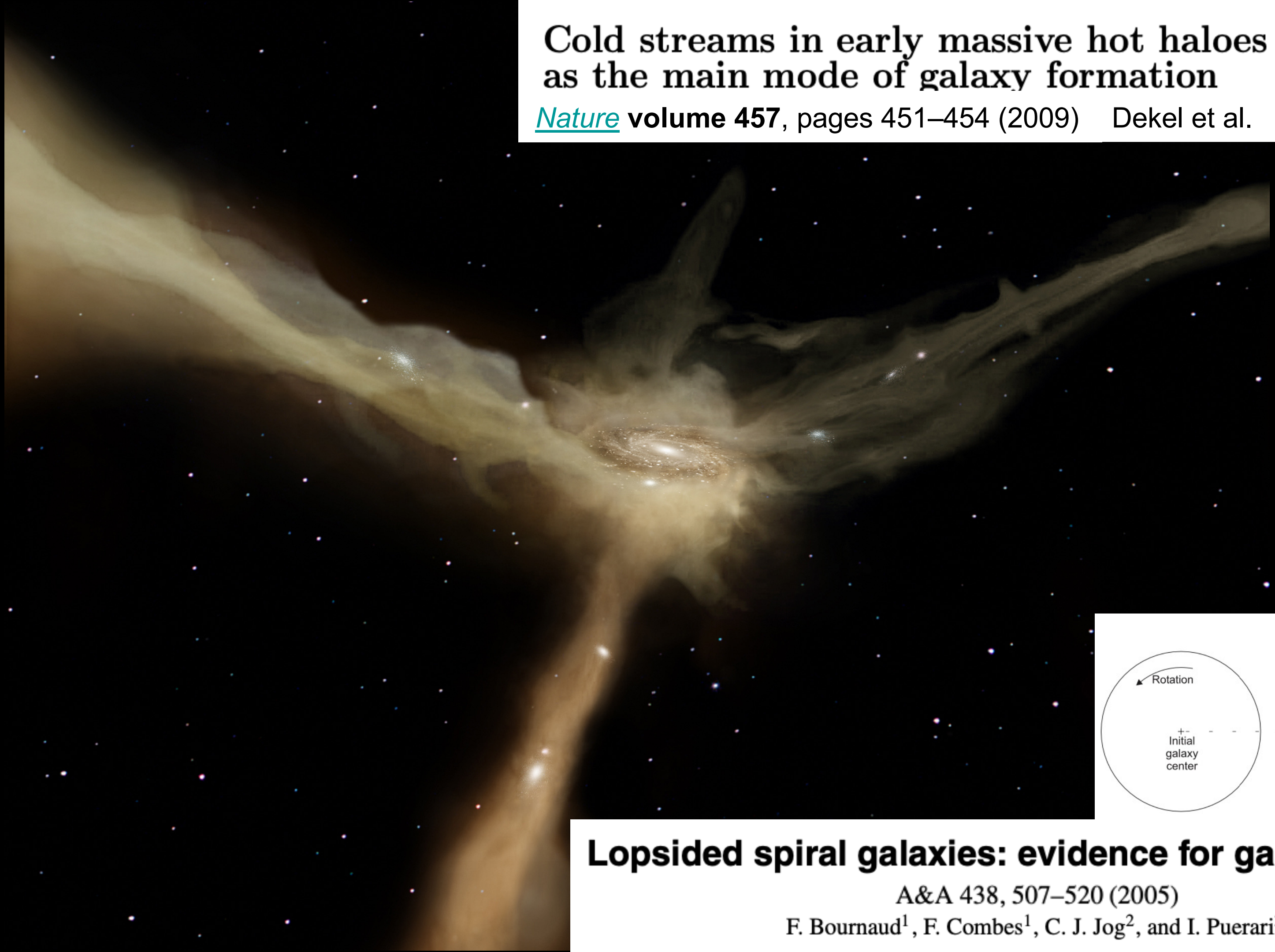
Nature **volume 457**, pages 451–454 (2009) Dekel et al.





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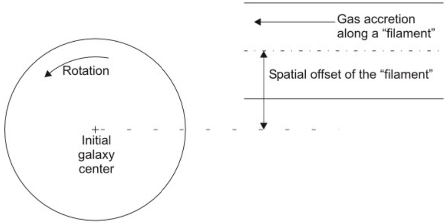
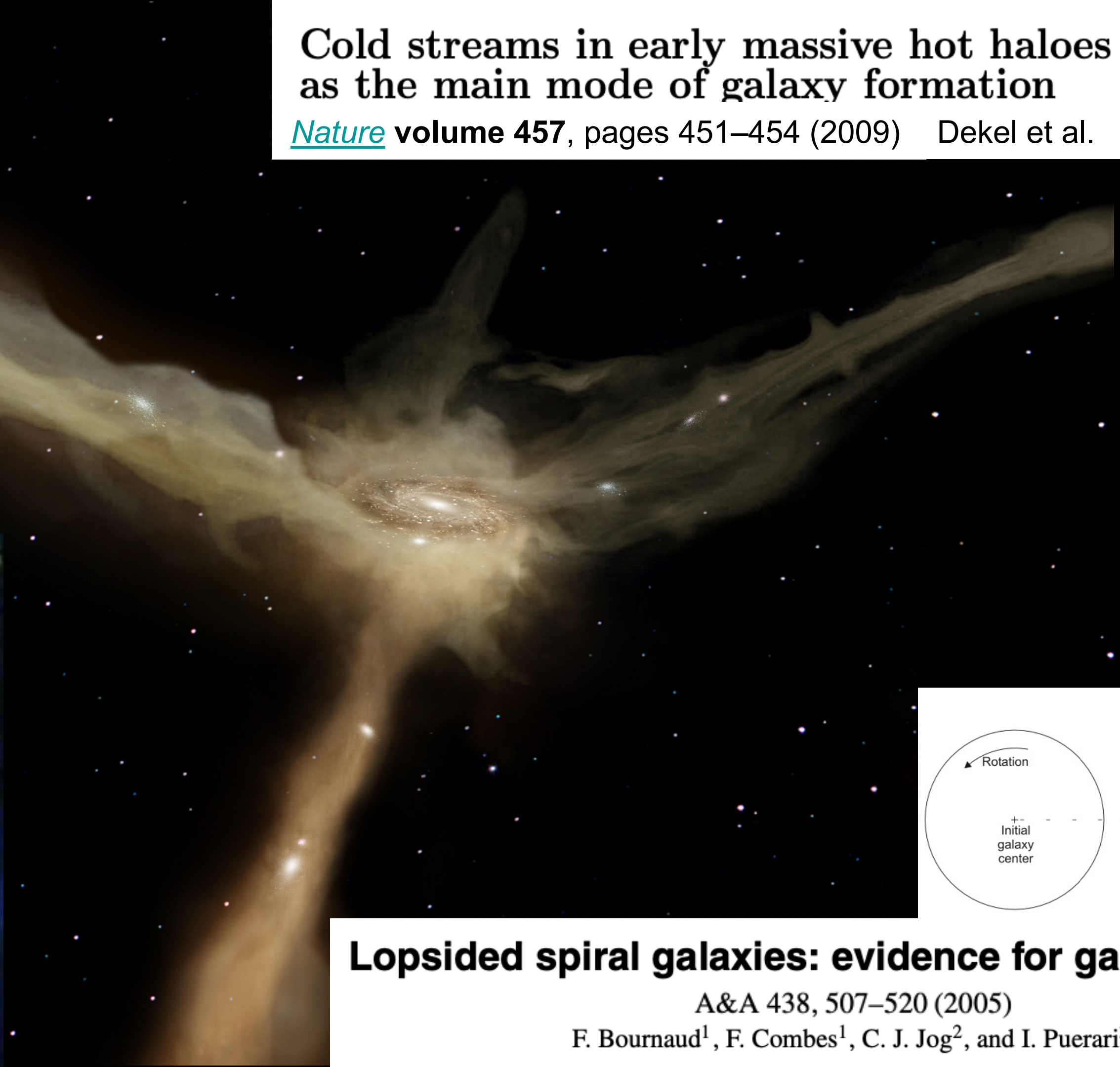


Lopsided spiral galaxies: evidence for gas accretion*

A&A 438, 507–520 (2005)
F. Bournaud[1], F. Combes[1], C. J. Jog[2], and I. Puerari[3]



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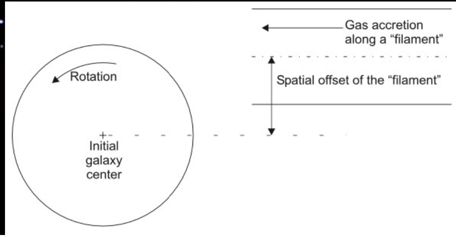
Le Bail, Daddi et al. 2023



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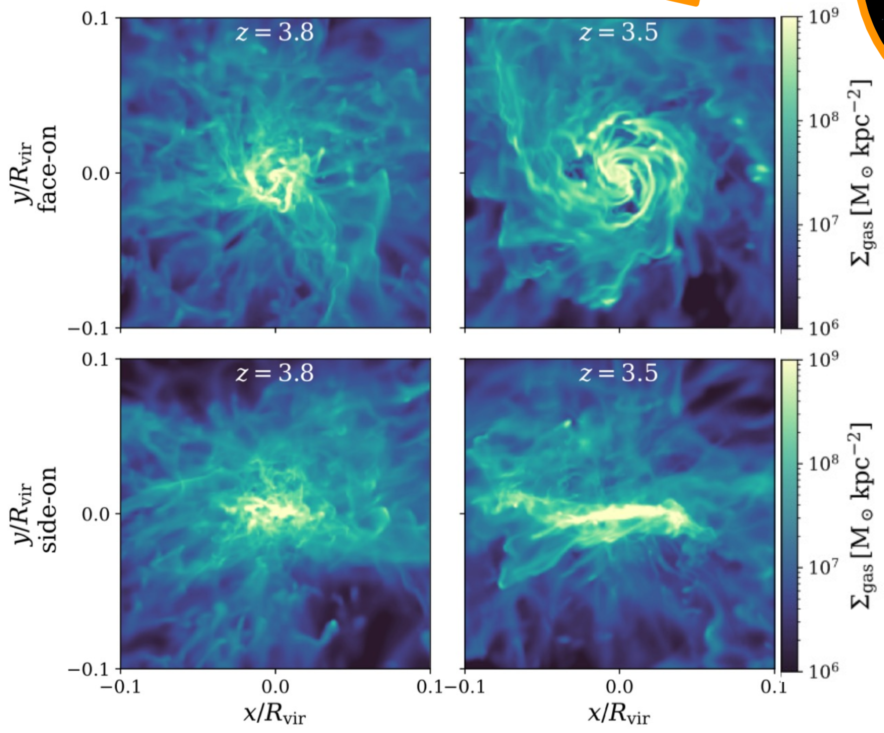
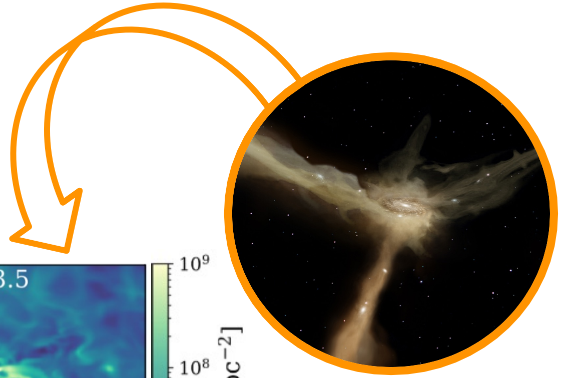


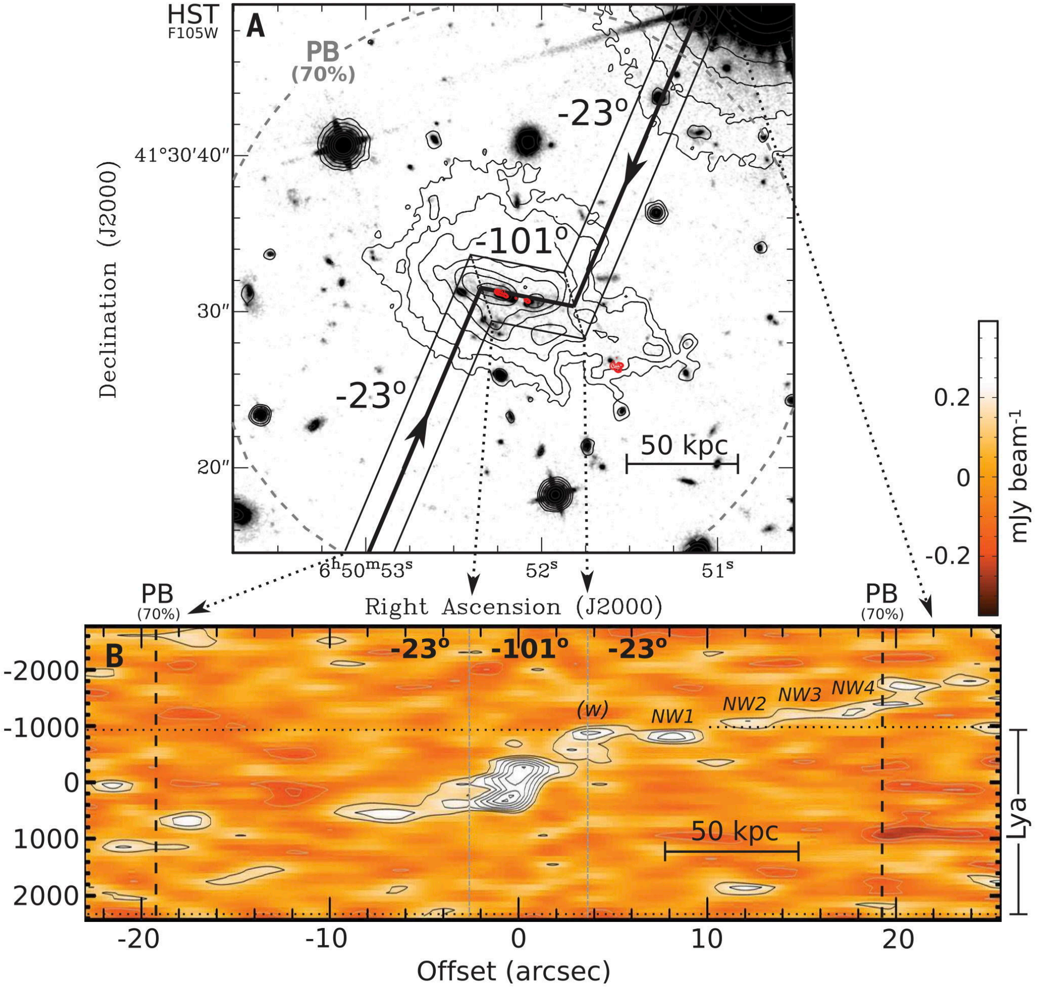


Kretschmer+2021

Before accretion During accretion

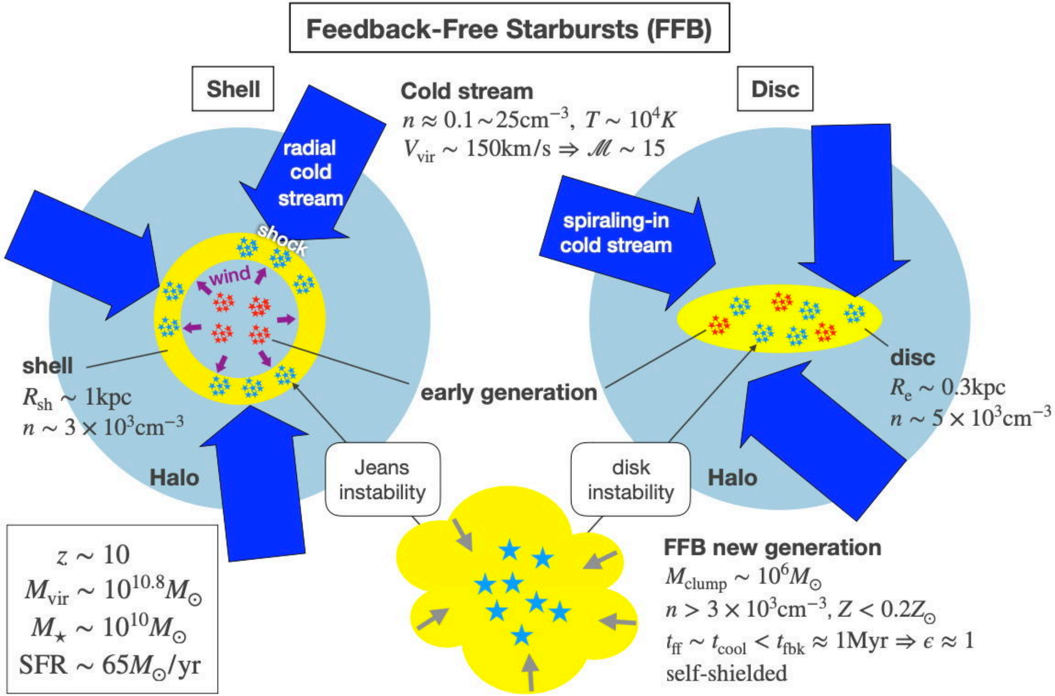
Emonts *et al.*, *Science* **379**, 1323–1326 (2023) 31 March 2023

We report a filamentary stream
of gas that extends for 100 kiloparsecs and connects to the massive radio galaxy 4C 41.17. We detected
the stream using submillimeter observations of the P_1 to P_0 emission from the [C I] line of atomic [33]
carbon, a tracer of neutral atomic or molecular hydrogen gas.



Efficient Formation of Massive Galaxies at Cosmic Dawn by Feedback-Free Starbursts

Avishai Dekel[1,2★], Kartick C. Sarkar[1,3], Yuval Birnboim[1], Nir Mandelker[1], Zhaozhou Li[1]

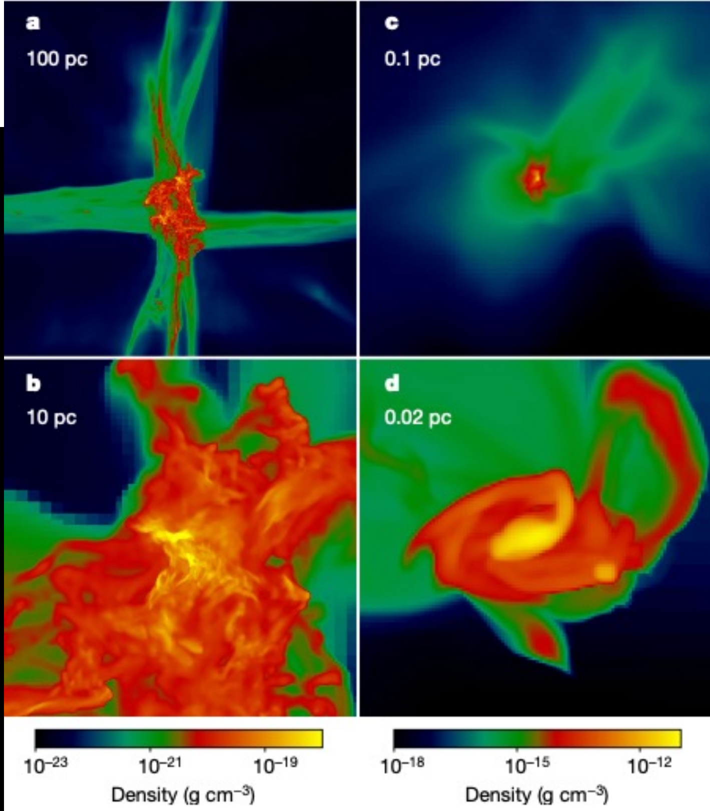


Feedback-free starbursts (FFBs) occur when the free-fall time is shorter than $\sim$ 1 Myr, below the time for low-metallicity massive stars to develop winds and supernovae. The galaxies within $\sim 10^{11} M_\odot$ haloes at $z \sim 10$ are expected to have FFB densities. The halo masses allow efficient gas supply by cold streams in a halo crossing time $\sim$ 80 Myr. The FFBs gradually turn all the accreted gas into stars in clusters of $\sim 10^{4-7.5}\ M_\odot$ within galaxies that are rotating discs or shells.

Turbulent cold flows gave birth to the first quasars

Nature, Latif et al. 2022

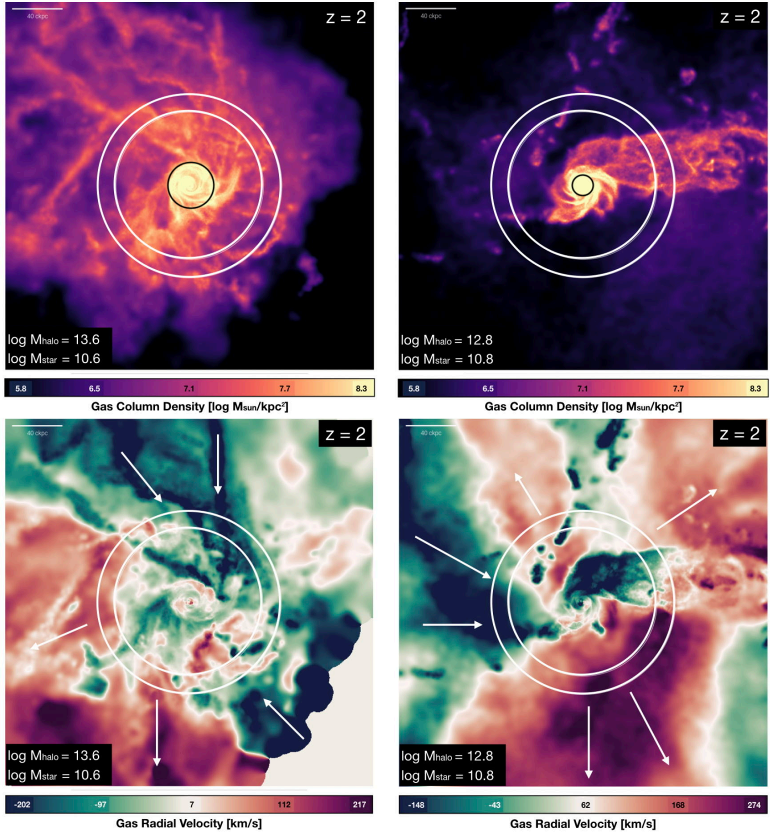
"halo at the rare **convergence of strong, cold accretion flows creates massive black holes seeds** without the need for ultraviolet backgrounds, supersonic streaming motions or even atomic cooling. Cold flows drive violent, supersonic turbulence in the halo, which prevents star formation until it reaches a mass that triggers sudden, catastrophic baryon collapse that forms **31,000 and 40,000 solar-mass stars**.



ZFIRE - The Gas Inflow Inequality for Satellite Galaxies in Cluster and Field Halos at $z = 2$

27 Mar 2023

Anishya Harshan,[1,2] Kim-Vy Tran,[1,2] Anshu Gupta[2,3] Glenn G. Kacprzak[2,4] Themiya Nanayakkara[2,4]



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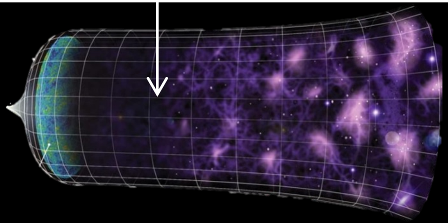

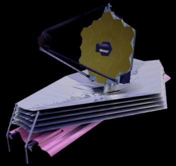

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Surprise #4 : Spiral galaxies were already in place a few 100 Myr after the Big Bang

Surprise #5 : Galaxies started to die/become passive earlier than expected

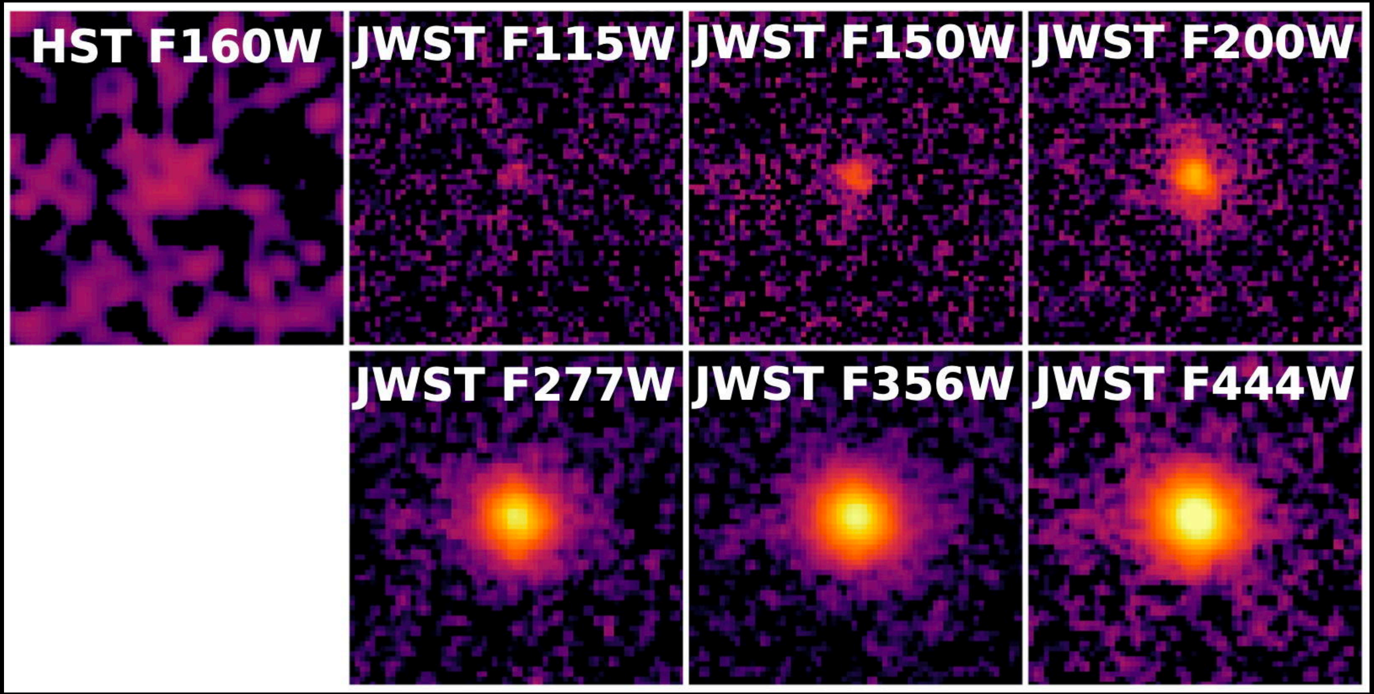
Surprise #6 : Globular clusters are very common and old... The missing link?

→ or maybe to the first globular cluster formation?

Surprise #7 : The First Detection of Auroral lines in the early Universe

→ high S/N JWST spectra are richer than expected → we just opened the book...

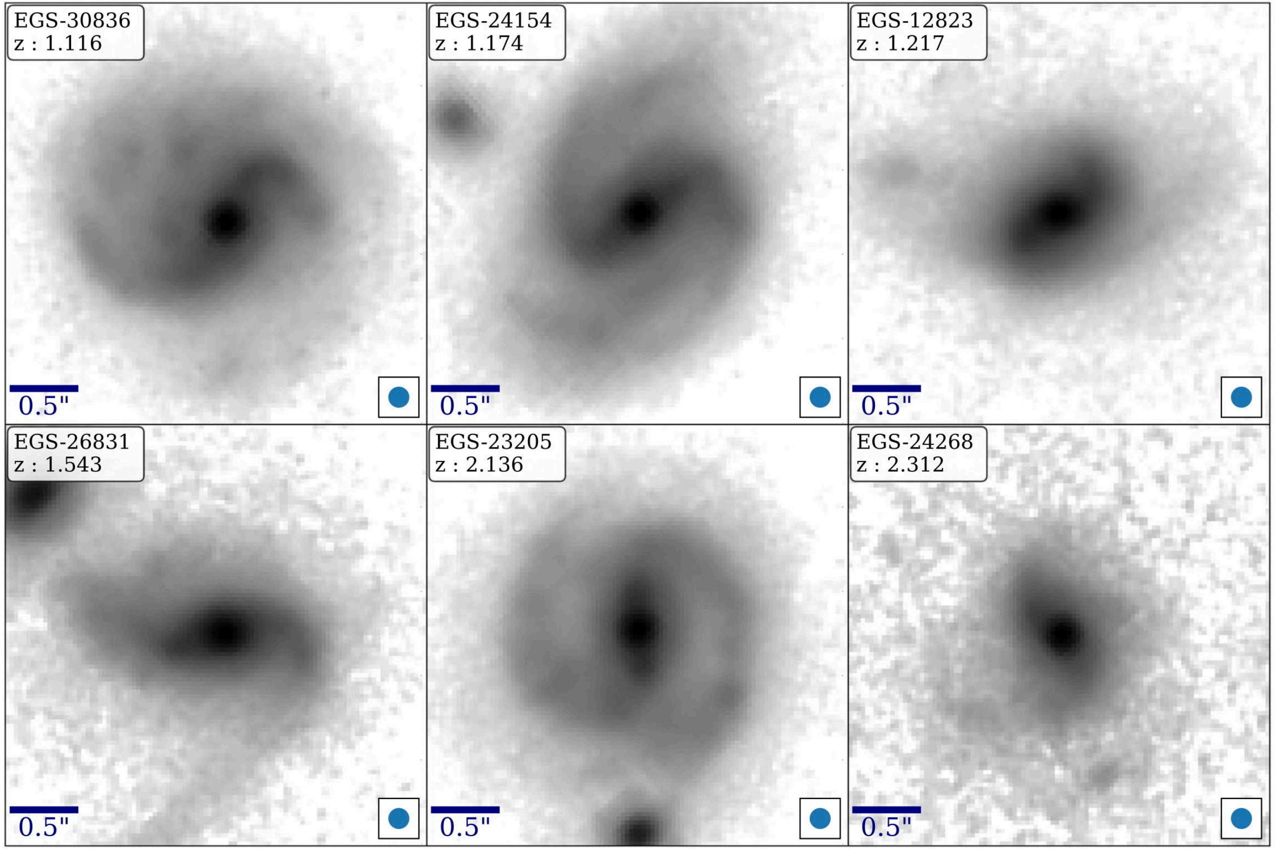
Optically-dark galaxies



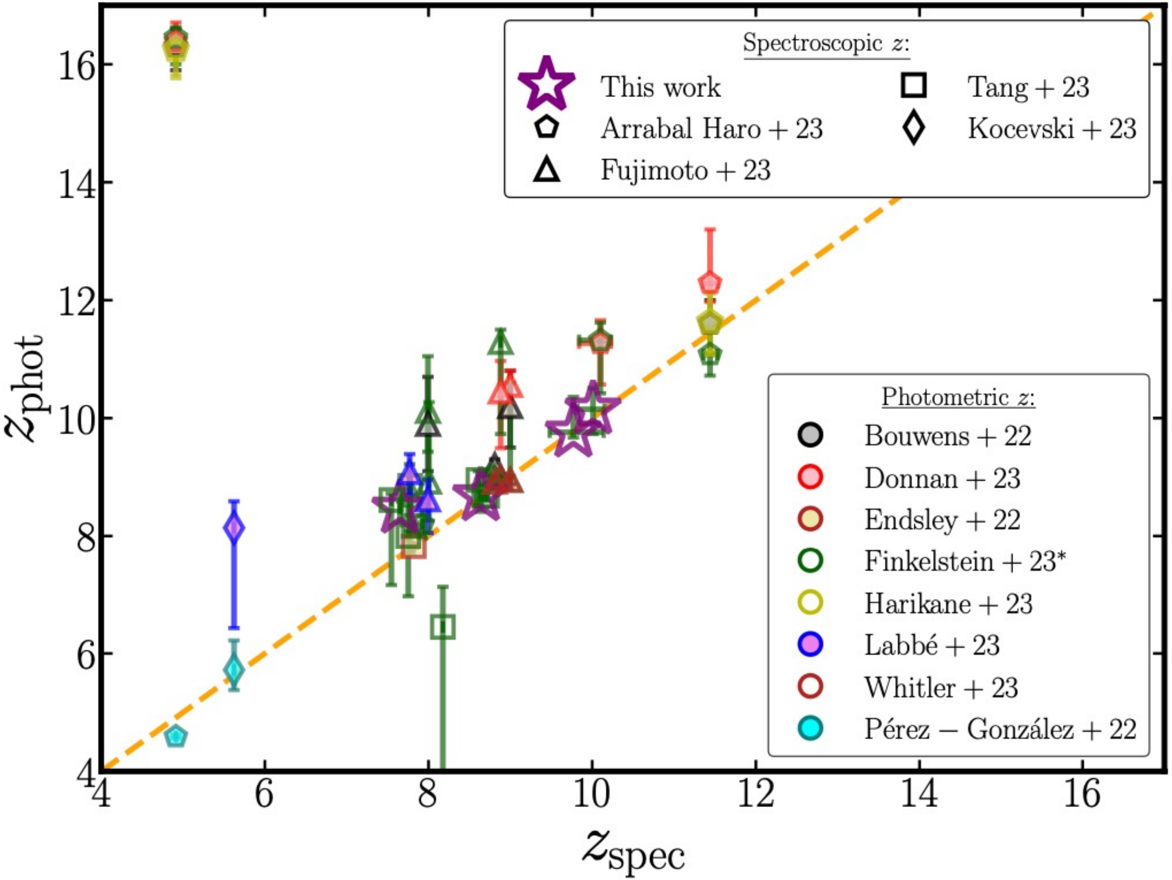
Gomez-Guijarro, Magnelli, Elbaz et al. 2023

First Look at $z > 1$ Bars in the Rest-frame Near-infrared with JWST Early CEERS Imaging

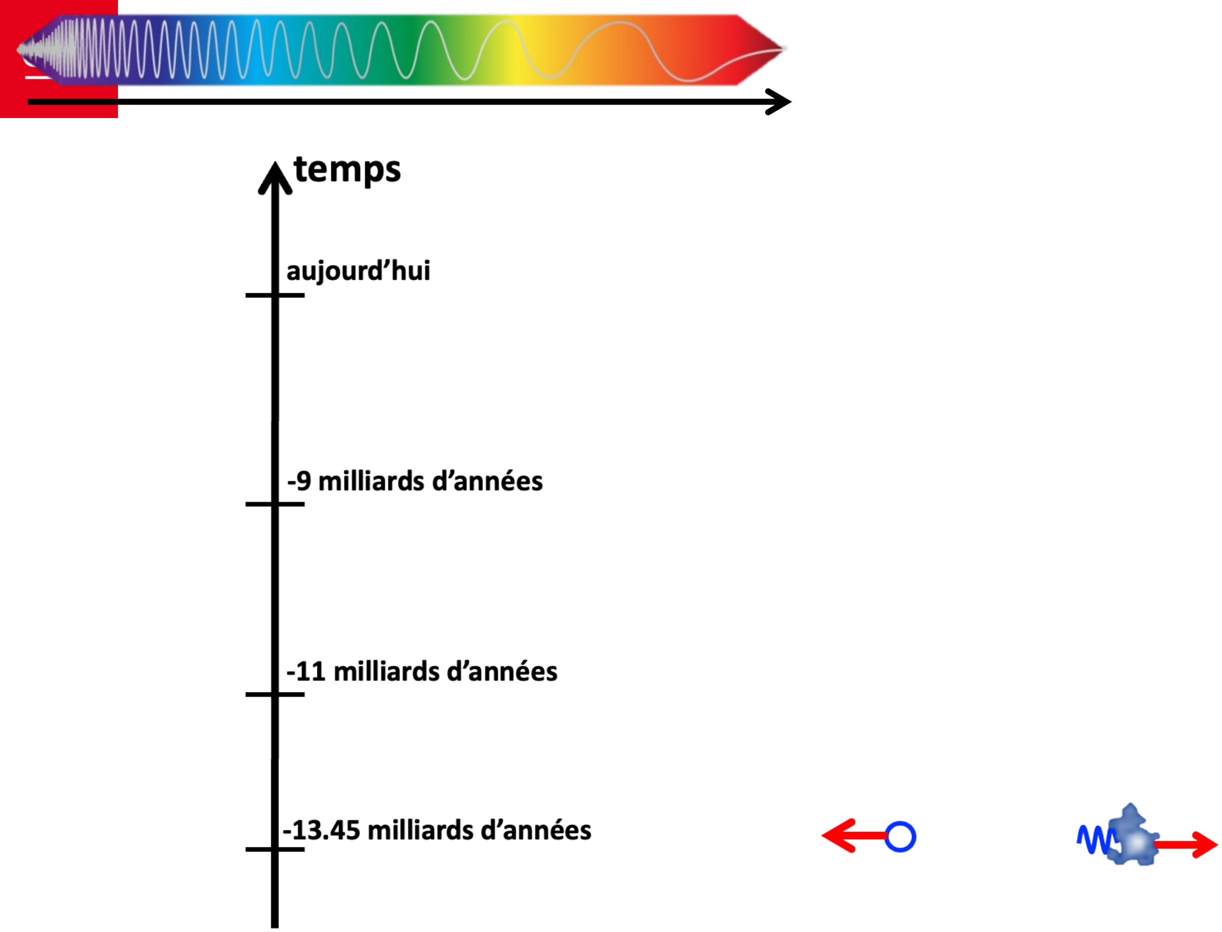
Yuchen Guo[1], Shardha Jogee[1], Steven L. Finkelstein[1], Zilei Chen[1], Eden Wise[1], Micaela B. Bagley[1], Guillermo Barro[2],



Spectroscopic confirmation of CEERS NIRCam-selected galaxies at $z \simeq 8 - 10$



Arrabal-Haro +2023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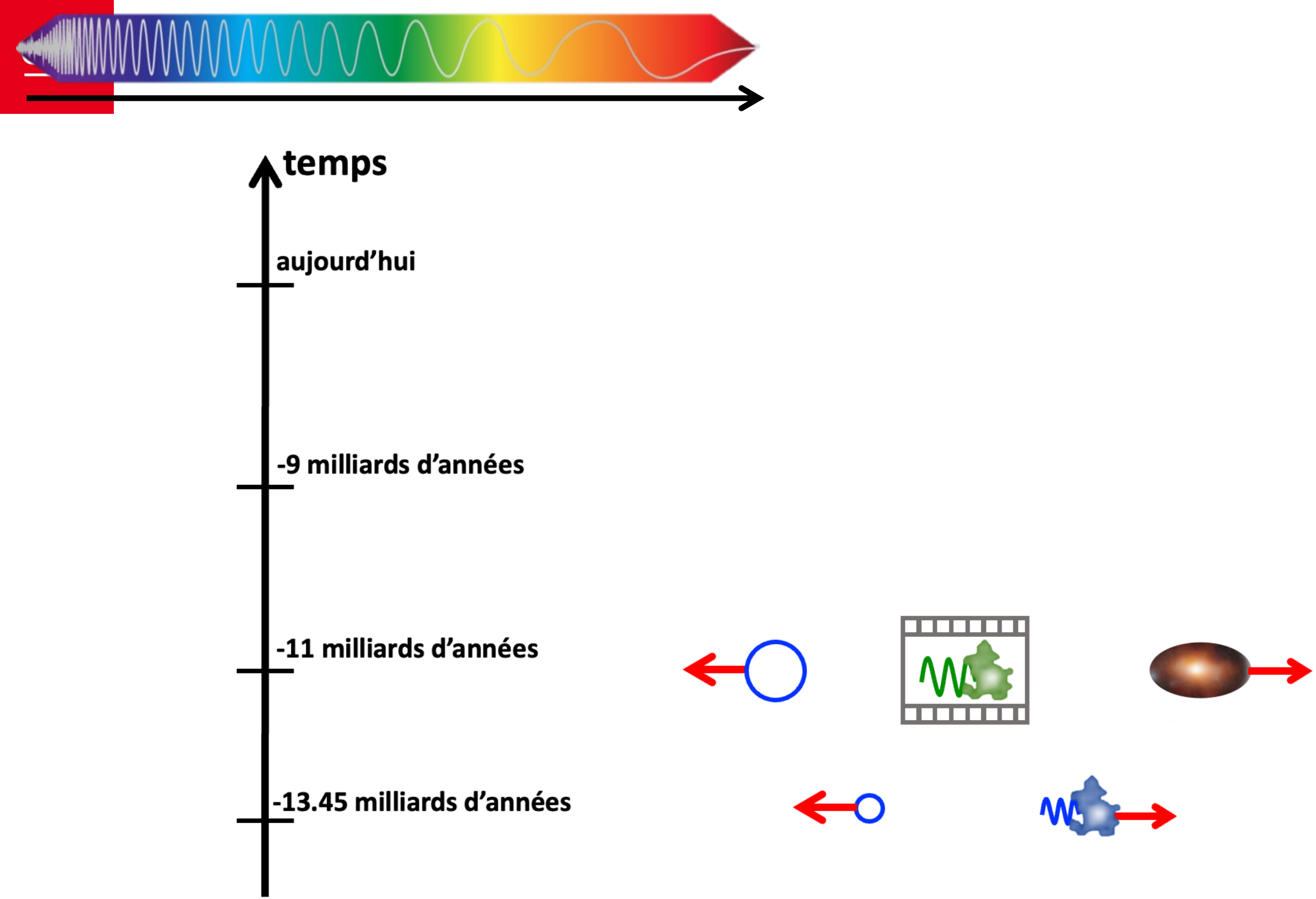
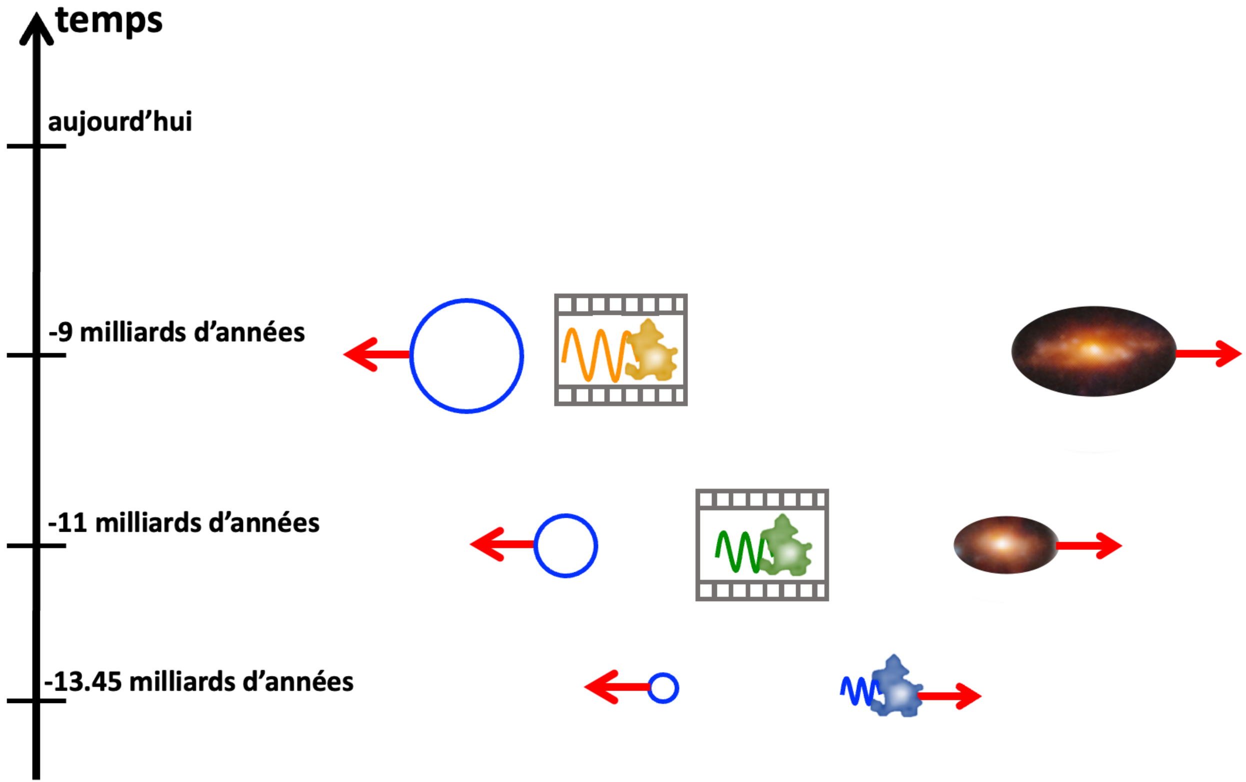
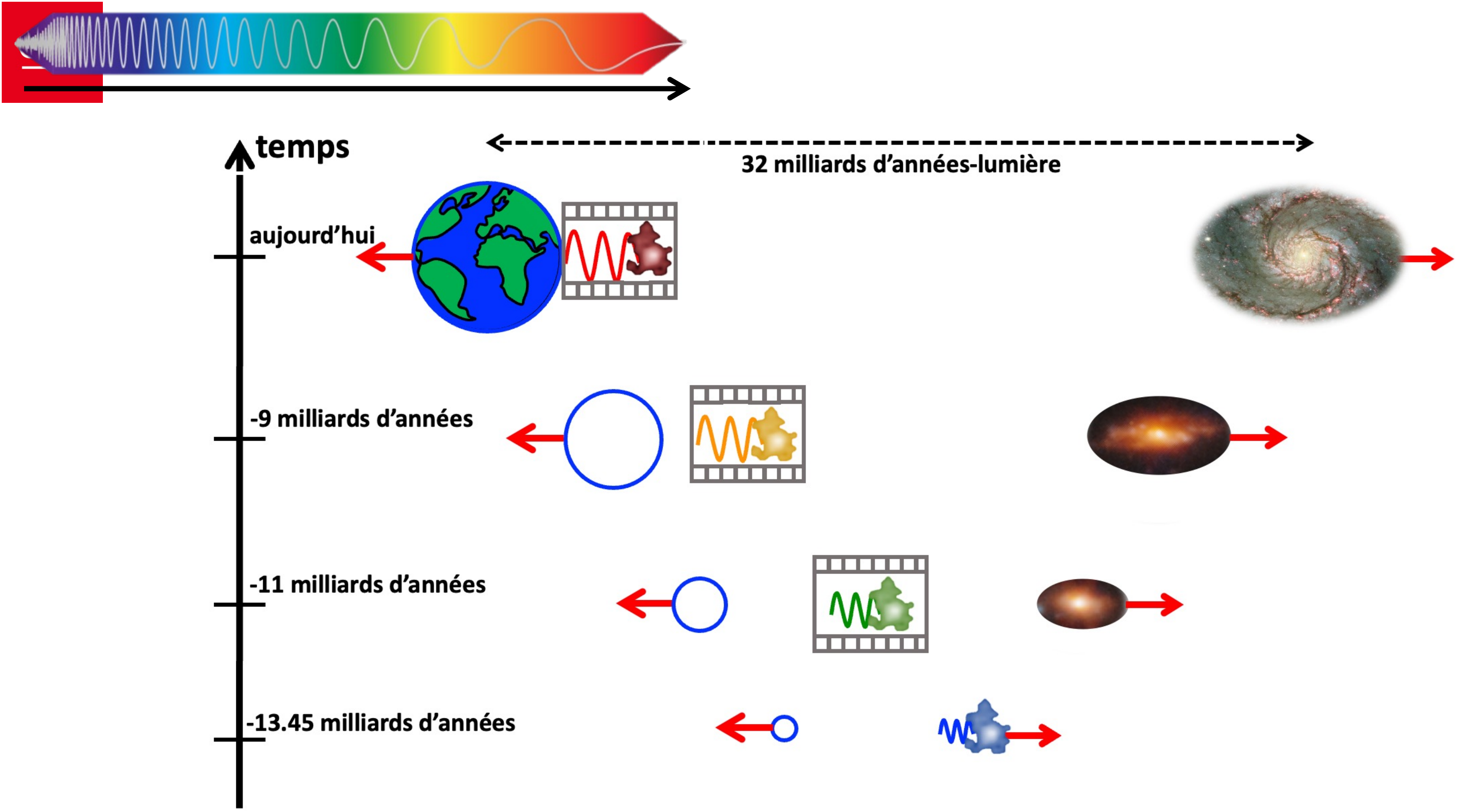
-11 milliards d'années
-13.45 milliards d'années


temps
aujourd'hui
-9 milliards d'années
-11 milliards d'années
-13.45 milliards d'années


temps
aujourd'hui
-9 milliards d'années
-11 milliards d'années
-13.45 milliards d'années


temps
32 milliards d’années-lumière
aujourd’hui
-9 milliards d’années
-11 milliards d’années
-13.45 milliards d’années

The quest for the dawn of the universe

Have we found it?

Do we go beyond Hubble?

Are we surprised by what Webb is finding?

Has the time come to change our theories of star/galaxy/BH formation?

Or even our cosmological paradigm?

In other words:

Is the promise *of the dawn of the universe* kept?

A common point between these surprises…