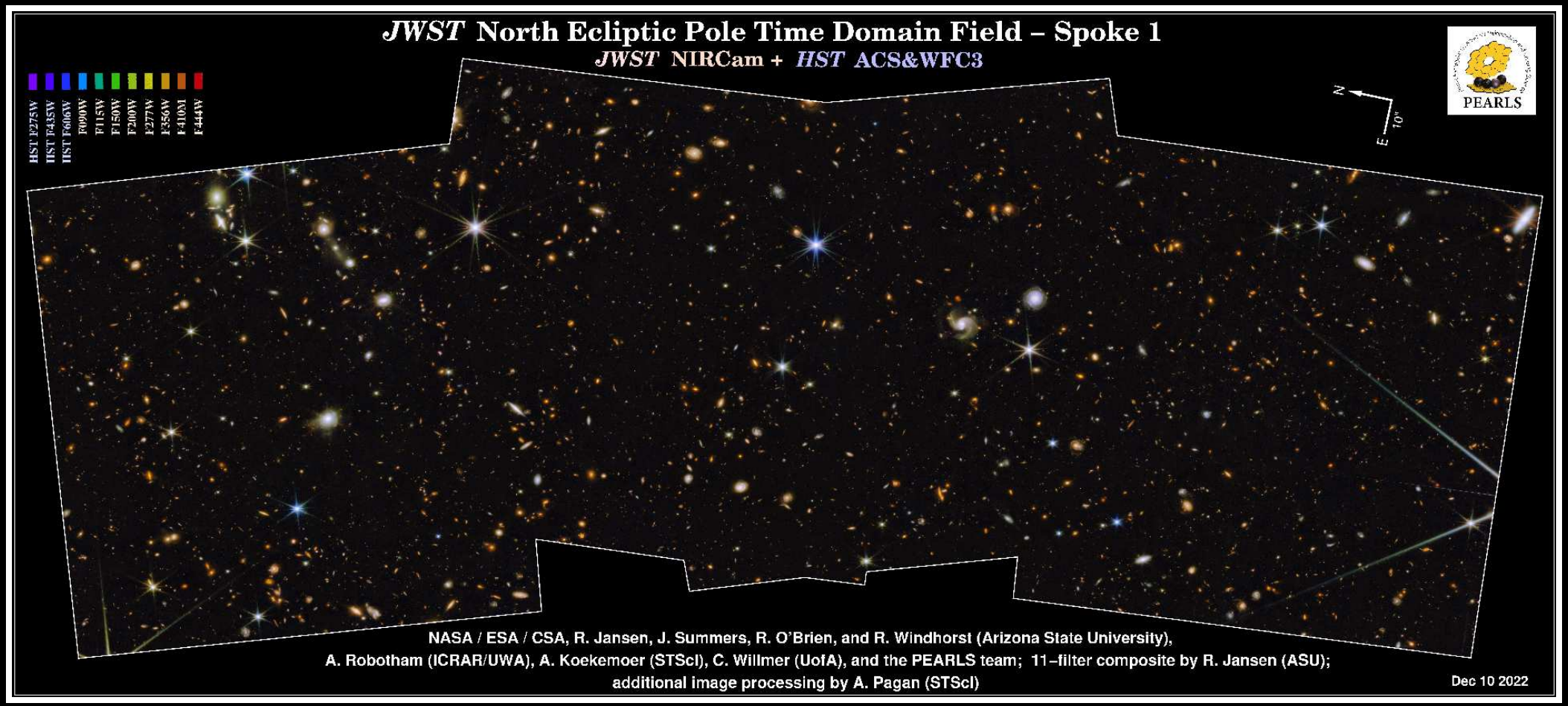
What the James Webb Space Telescope has Discovered, and What it Means: the Cosmic Circle of Life, and seeing through the Eyes of Einstein

Rogier Windhorst (ASU) — JWST Interdisciplinary Scientist

+JWST PEARLS team: T. Carleton, S. Cohen, R. Jansen, P. Kamieneski, T. Acharya, H. Archer, J. Berkheimer, D. Carter, N. Foo, R. Honor, D. Kramer, T. McCabe, I. McIntyre, R. O'Brien, R. Ortiz, J. Summers, S. Tompkins, C. Conselice, J. Diego, S. Driver, J. D'Silva, B. Frye, H. Yan, D. Coe, N. Grogin, W. Keel, A. Koekemoer, M. Marshall, N. Pirzkal, A. Robotham, R. Ryan Jr., C. Willmer + 110 more scientists over 18 time-zones



Talk at the Society for Catholic Scientists, Washington DC; June 7, 2025

Outline

- (1) Pope John Paul II and his influence on my life
- (2) Webb's first images: the "Cosmic Circle of Life"
- (3) Viewing the Universe through the Eyes of Einstein"
- (4) Summary and Conclusions

SPARE CHARTS:

- (5) Spare Science Charts
- (6) Uniquely complementary roles of Hubble and Webb

Sponsored by NASA/HST & JWST

Talk is on: `http://www.asu.edu/clas/hst/www/catholic_sc_jun25_jwst.pdf`

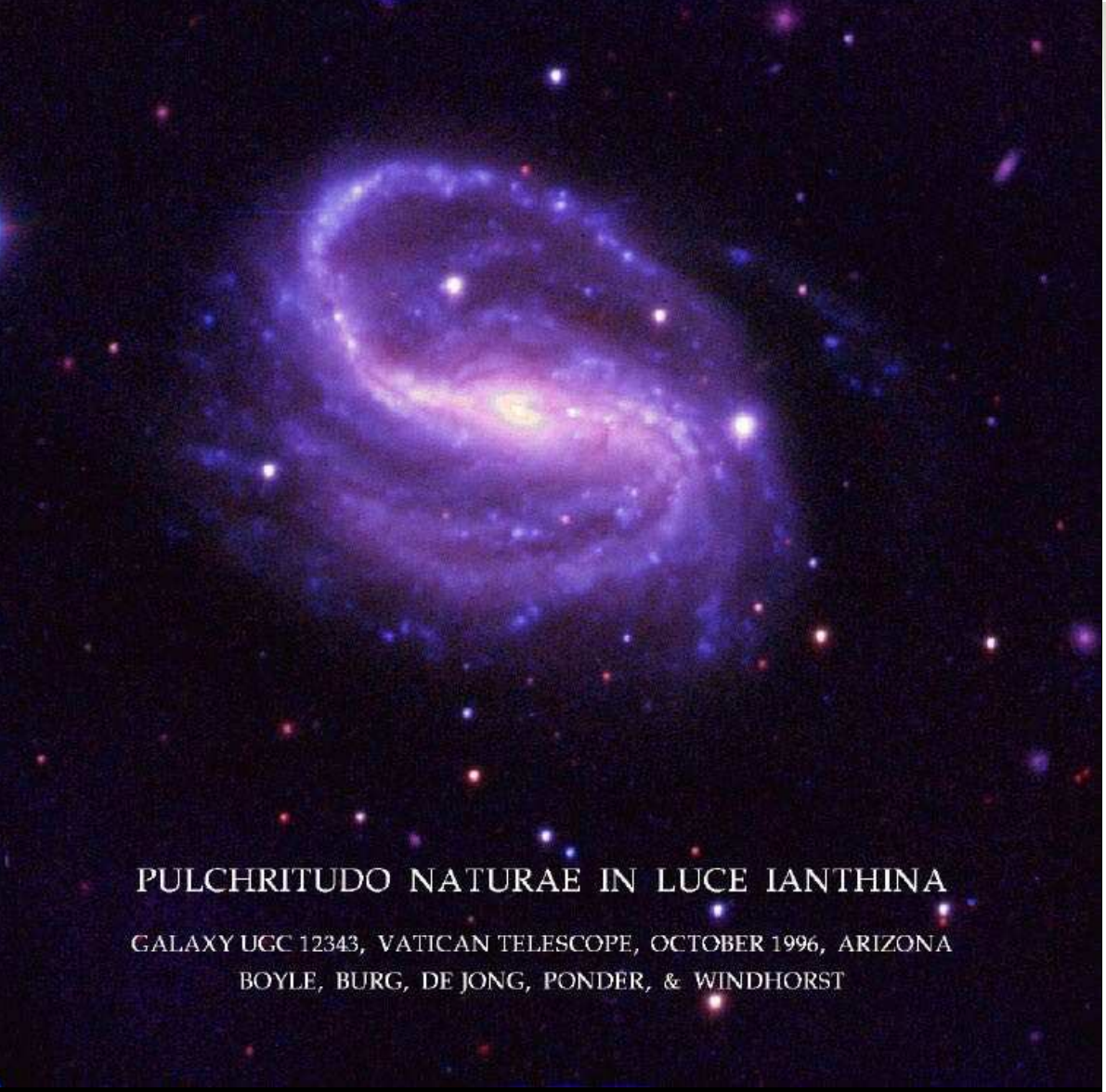
- (1) Pope John Paul II and his influence on my life

In Sept 1987, Pope John Paul II visited ASU ...

and gave Arizona funds to build the Vatican Advanced Technology Telescope!

- Unbeknownst to me, this inspired my life-long mission with Hubble and Webb:

2 Sam 7:11: " ... the LORD himself will establish a house for you ..."



SEGRETERIA DI STATO

PRIMA SEZIONE - AFFARI GENERALI

Dal Vaticano, 11 dicembre 1996

N.404.099

Reverendo Padre,

è stata mia cura presentare al Sommo Pontefice la bella fotografia di una galassia, scattata dal Prof. Rogier A. Windhorst con il Vatican Advanced Technology Telescope, collocato sul Monte Graham in Arizona.

Il Santo Padre desidera esprimere il Suo vivo ringraziamento per il devoto omaggio e per i sentimenti che l'hanno suggerito e, auspicando copiosi favori celesti per Lei e per gli astronomi che, con riconosciuta competenza, indagano i misteri dell'universo, volentieri invia la propiziatrice Benedizione Apostolica.

Profitto della circostanza per confermarmi con sensi di distinto ossequio

della Paternità Vostra Rev.da
dev.mo nel Signore

Reverendo Padre
P. GEORGE V. COYNE, S.I.
Direttore della Specola Vaticana

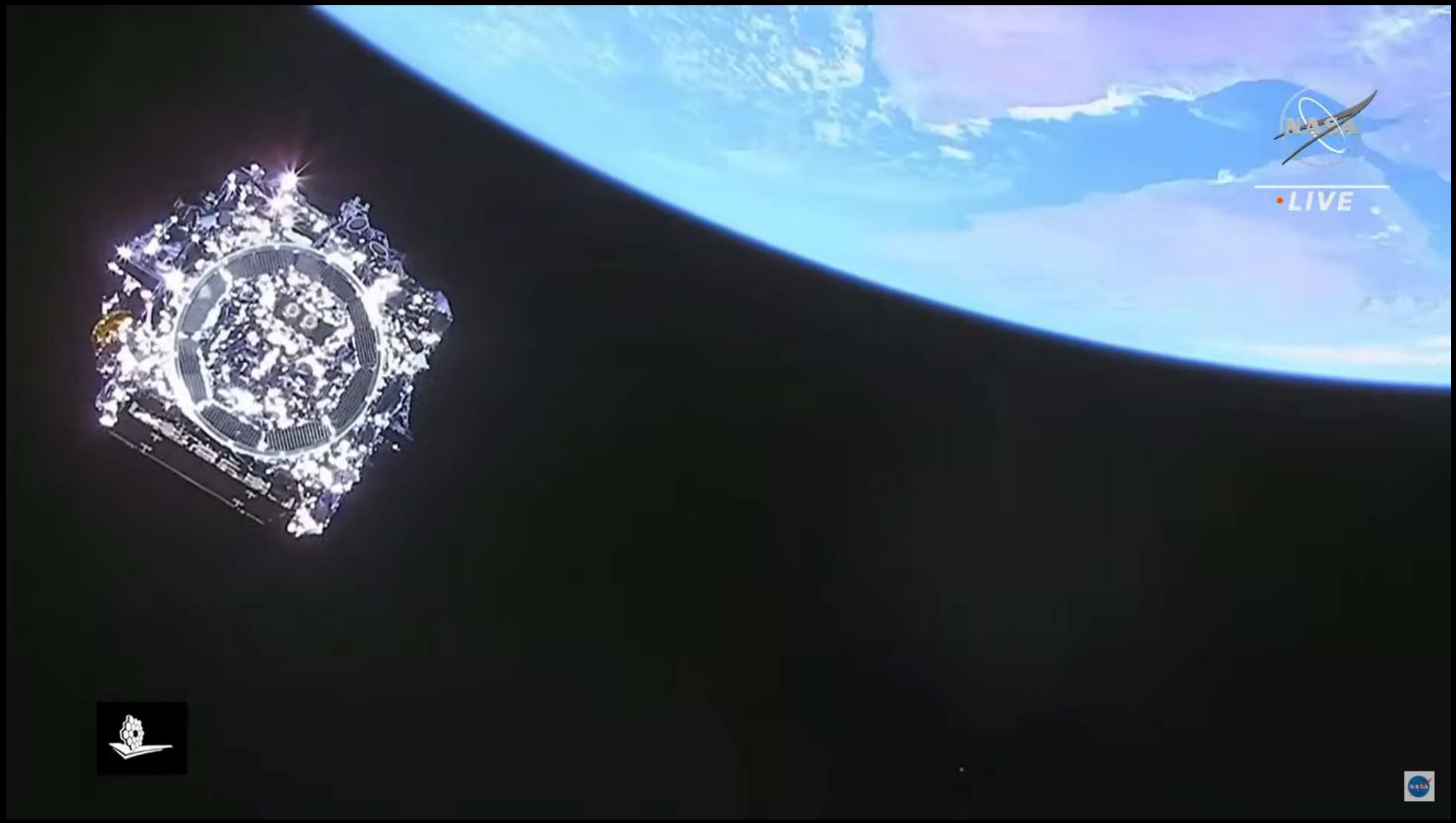
CITTA' DEL VATICANO

In Oct. 1996, we were lucky enough to take the first VATT image,

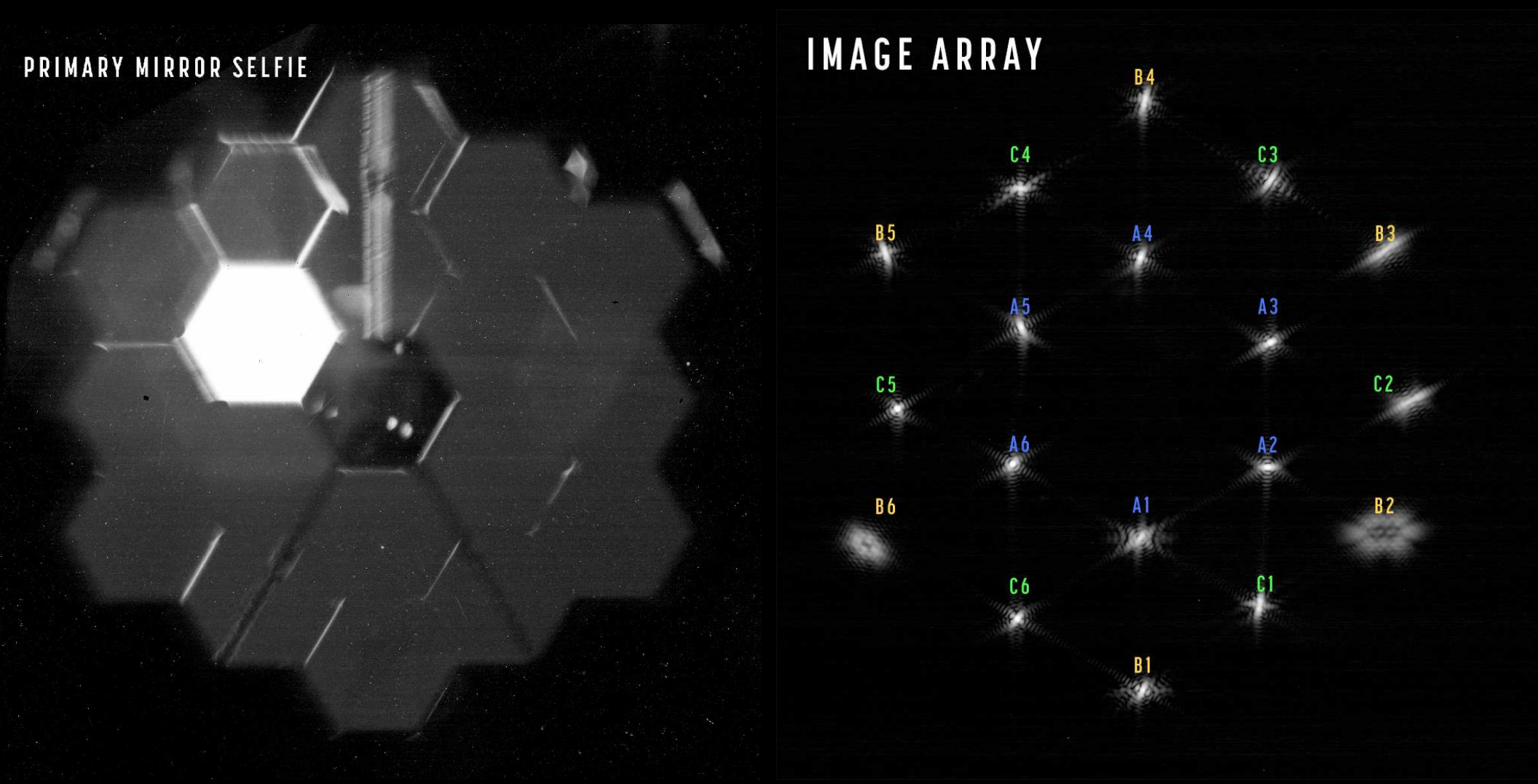
gave a copy to the Holy Father in November 1996 at the Vatican ...

and received a very kind Papal blessing in December 1996 !

Webb is finally launched from Kourou on December 25, 2021!



Dec. 25, 2021: Webb seen shortly after launch over Africa using the Ariane V on-board camera.



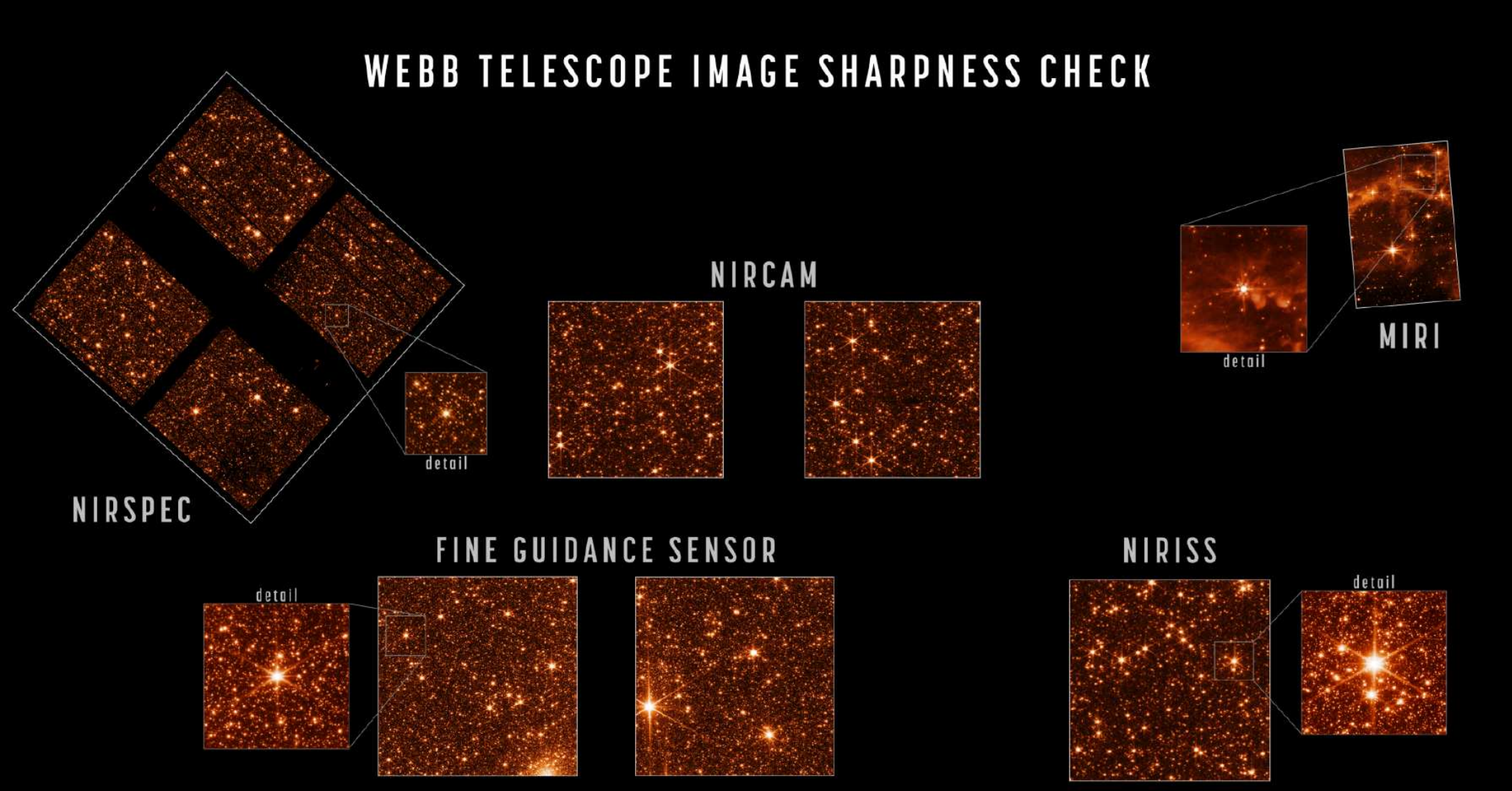
Feb. 2022: Webb's first selfie (left) and First Light raw image (right).

Webb's first segment alignment (left) and first image stack (right).

March 16, 2022: Webb's first fully focused image publicly released !!

Note the plethora of faint galaxies — Webb's looking back in time!

https://www.nasa.gov/press-release/nasa-s-webb-reaches-alignment-milestone-optics-working-successfully

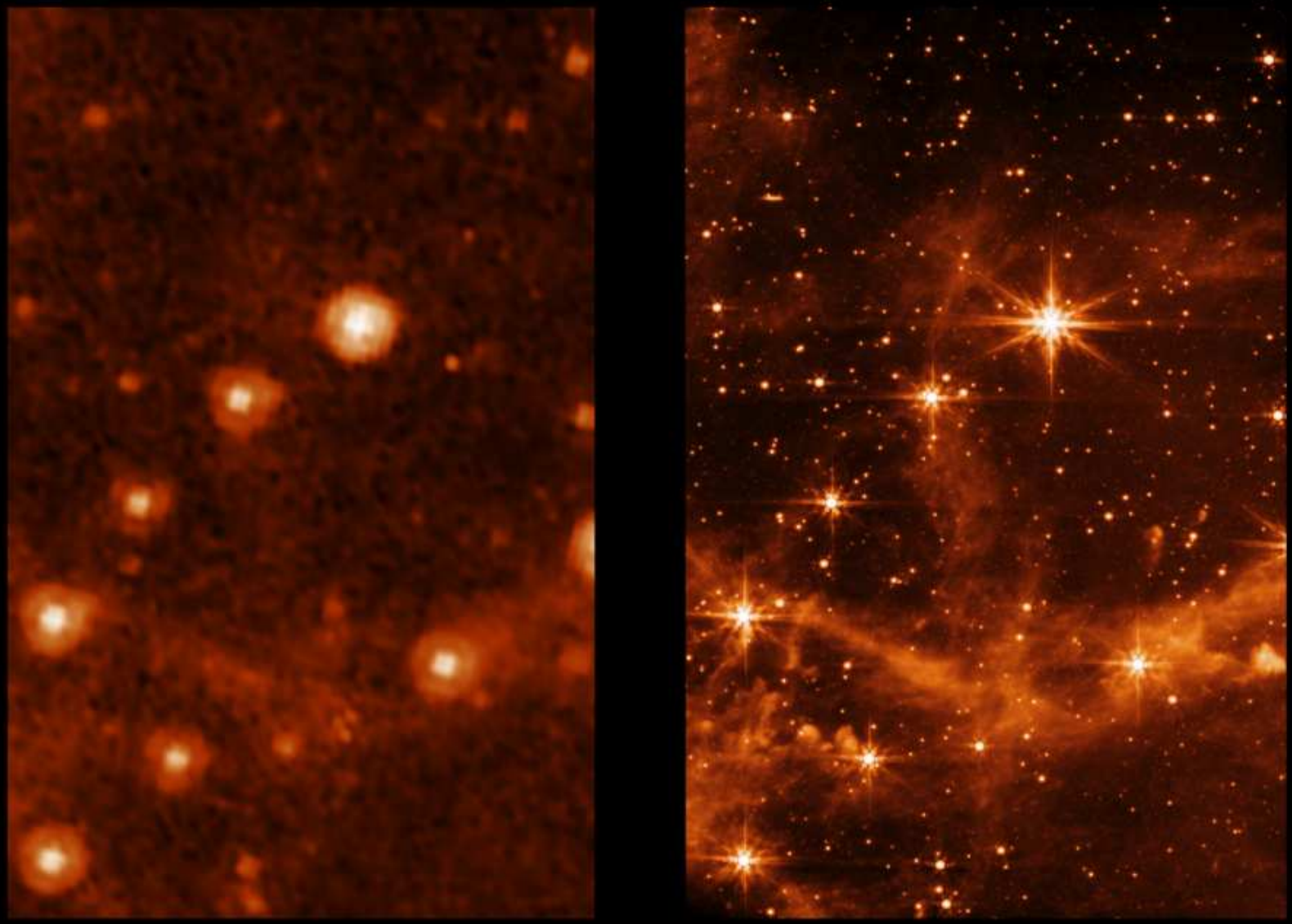


April 28, 2022: Webb's first fully focused images in all four instruments:

a dense star field in the Large Magellanic Cloud in the South Ecliptic Pole!

(NIRSpec: 1.1 μm; NIRISS: 1.5 μm; NIRCam: 2.0 μm; MIRI 7.7 μm).

https://blogs.nasa.gov/webb/2022/04/28/nasas-webb-in-full-focus-ready-for-instrument-commissioning/

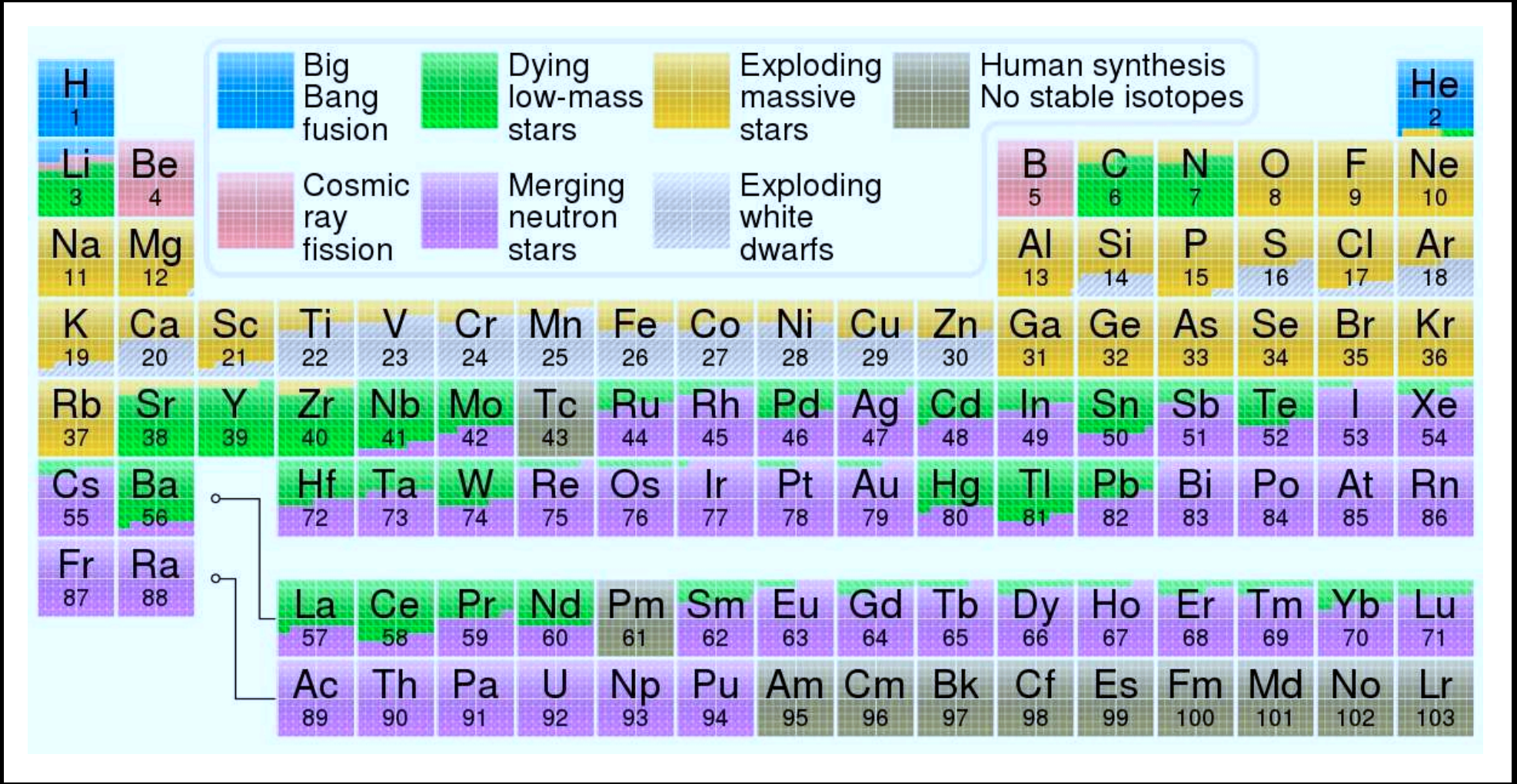


May 9, 2022: Webb's 7.7. μm MIRI image compared to Spitzer 8.0 μm:
Same dense star field in the Large Magellanic Cloud in the South Ecliptic Pole

https://blogs.nasa.gov/webb/2022/05/09/miris-sharper-view-hints-at-new-possibilities-for-science/

Before we get to the cosmic circle of life, let's get this straight:

- This Periodic Table you learned in highschool is **NOT** the real one!:



(1) Hydrogen & Helium: the *only* chemical elements made in the Big Bang!

(2) All heavier elements made by (dying) stars: • Low mass stars ejecting their outer shells; • Supernova explosions; & • neutron star mergers.

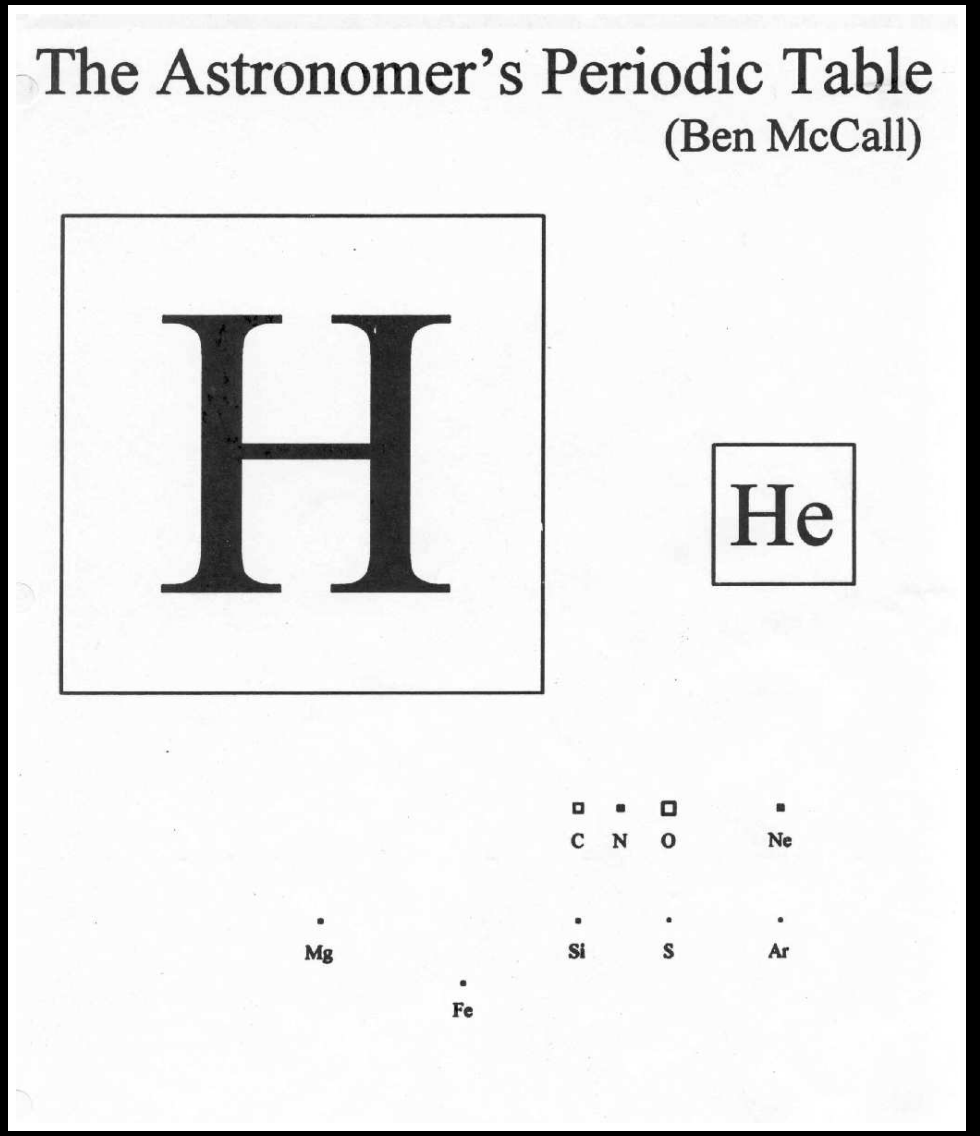
Here is the correct Astronomical Periodic Table:

(1) Hydrogen (76%) & Helium (24%) are the only chemical elements made in the Big Bang.

(2) Heavier chemical elements ($\lesssim$1%; "dust") made by (dying) stars:

- Late stages of stellar evolution, Supernova explosions & white dwarfs, and neutron star mergers distribute these throughout the universe.

$\Longrightarrow$ Planets and people are literally made from stardust!



- This is the real Periodic Table with cosmic abundance included.

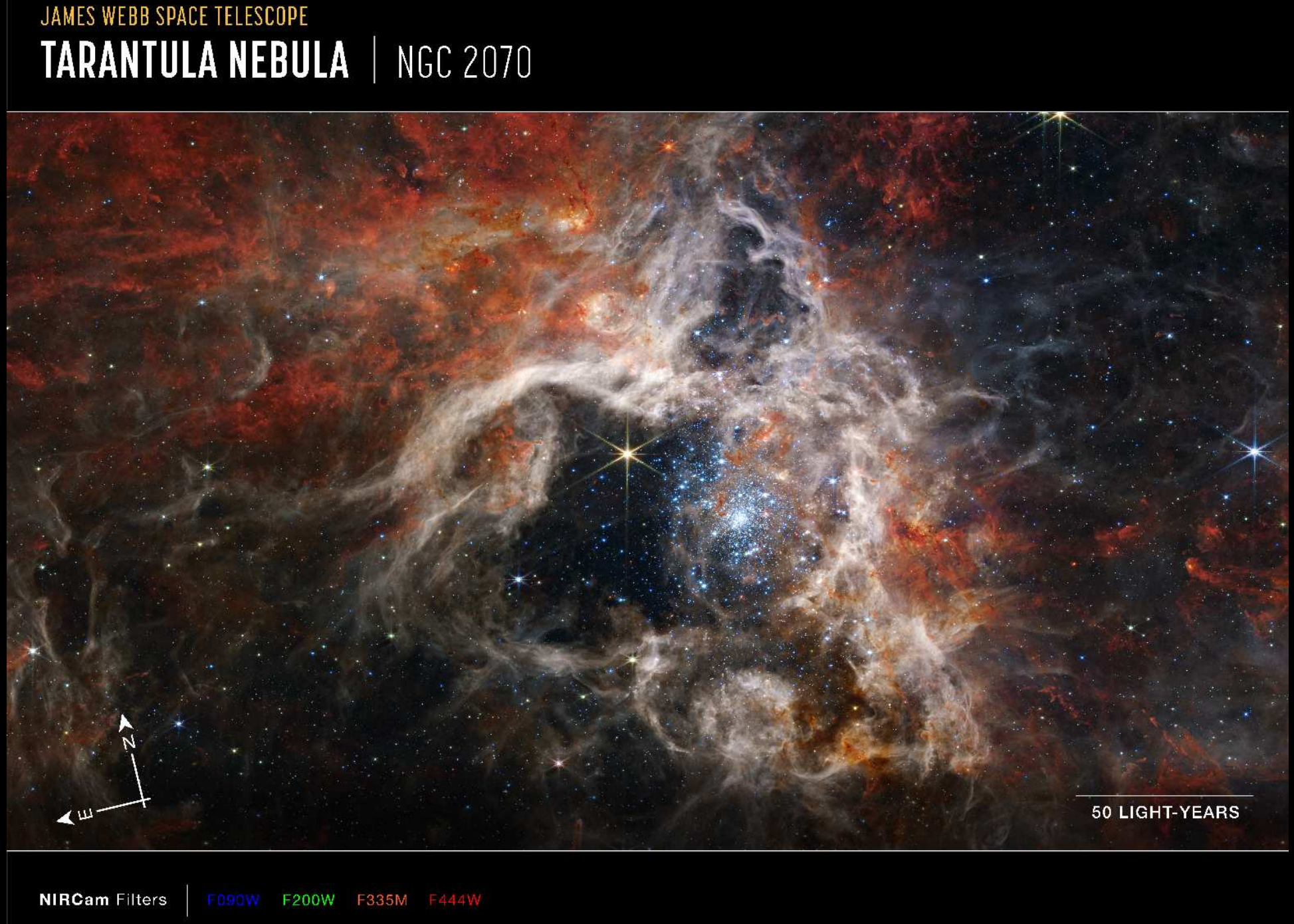
Jer. 33:25: "established my covenant with day and night and the fixed laws of heaven and earth" $\longrightarrow$ same physics/chemistry across Universe!

- (2) Webb's first images: the "Cosmic Circle of Life"

Hubble WFPC2 Eagle Nebula (1995) compared to JWST NIRCam (2022):

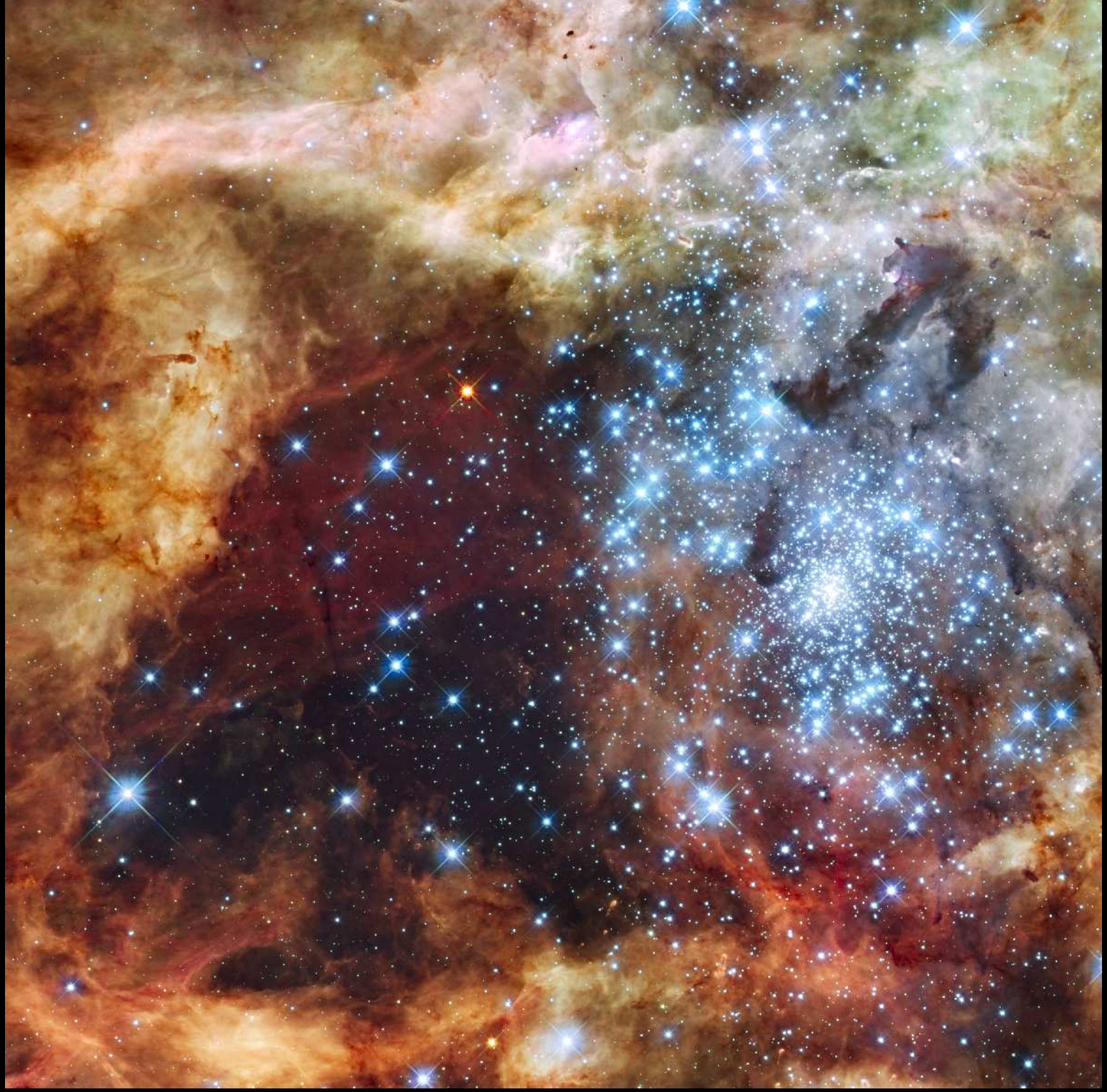
- The cradle of cosmic star-formation: NIRCam peers through the dust!
- The 1995 Hubble WFPC2 image (left) was made by Prof. Jeff Hester and Paul Scowen at ASU. It made it onto a US postage stamp!

Webb's MIRI shows the hauntingly beautiful cosmic dust pillars (8–15 μm)

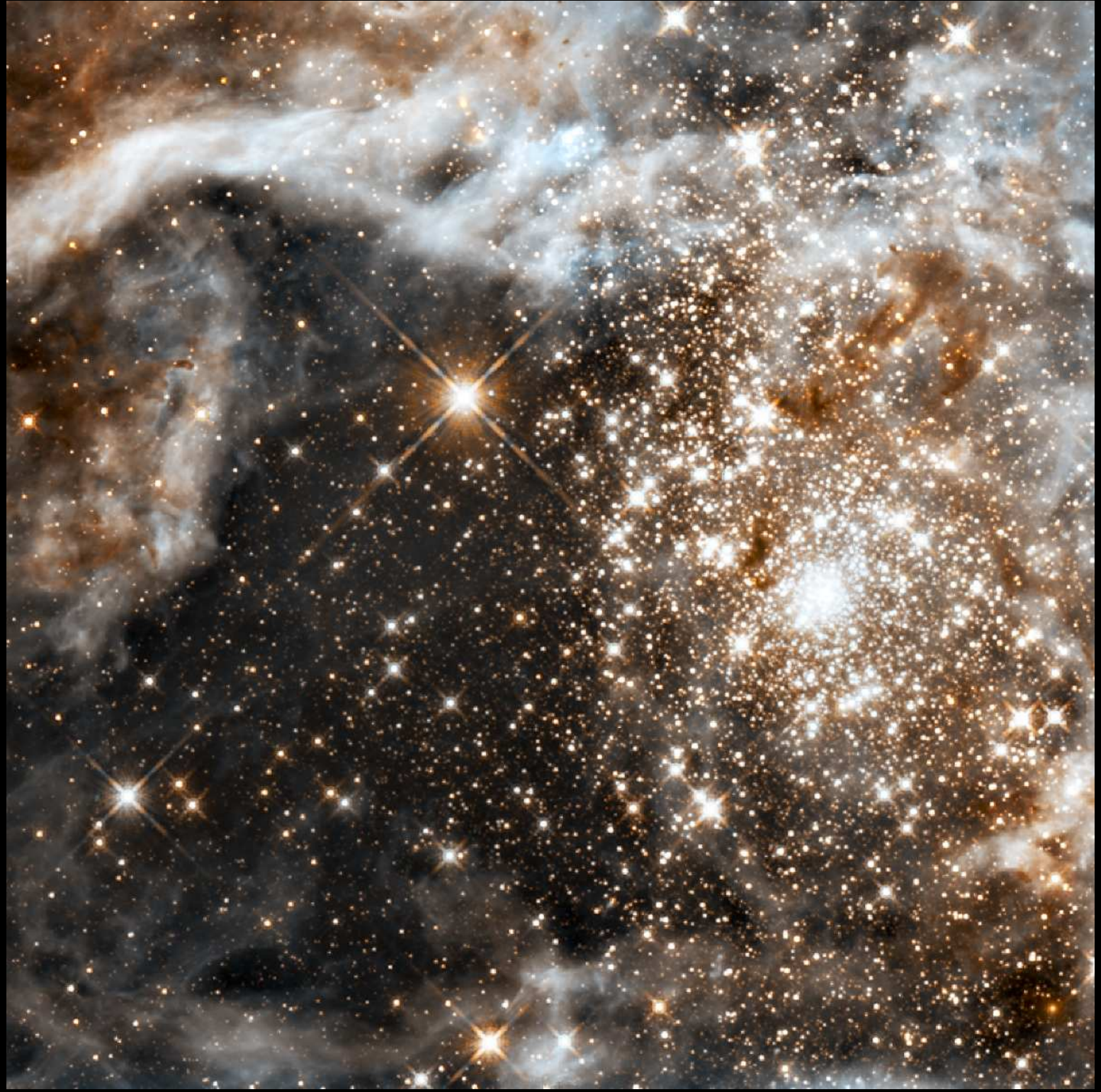


Tarantula Nebula "30 Doradus" in Large Magellanic Cloud (163,000 lyrs away)

Cradle of cosmic star-formation: massive stars trigger formation of sun-like stars



HST Wide Field Camera 3 UV–optical image of 30 Dor: hot massive stars.



HST WFC3 near-IR image of 30-Dor: massive and low-mass stars.

"Cosmic Cliffs" of star-formation in the Carina Nebula (NIR; 7600 light-years).

You will be witnessing the "Cosmic Circle of Life" ...

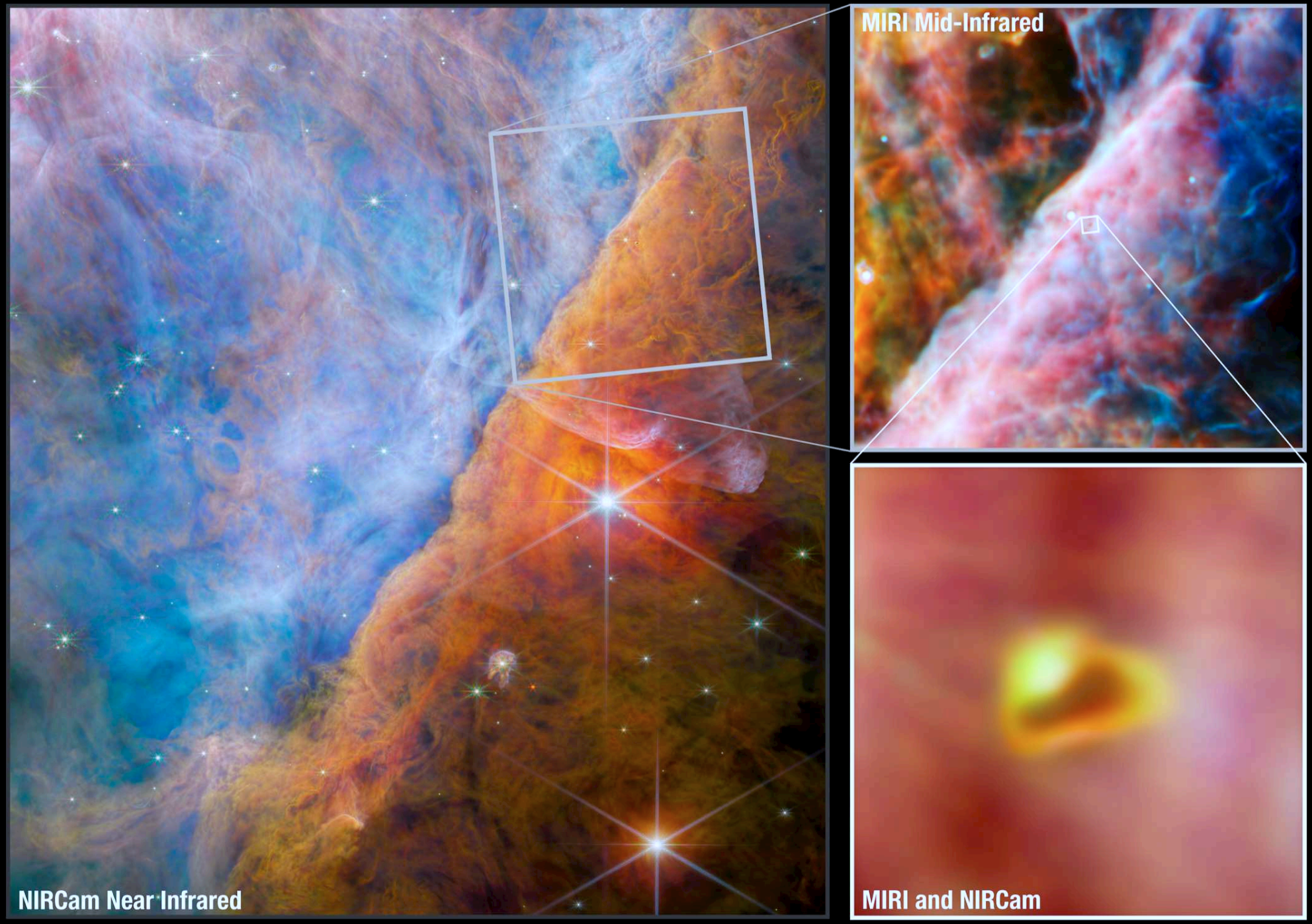
Psalm 147:4 & Isaiah 40:26: God has given a name to every star !

- That's $\sim 10^{23}$ stars in the universe ... or $\gtrsim 10^{12}$ stars for every human!

Cosmic Cliffs of Star-formation in Carina Nebula (NIR+MIR).

Compared to optical+near-IR, mid-IR sees “Cradle of Cosmic Star-formation”

Deep inside the gas and dust, mid-IR reveals birth of young Sun-like stars.



JWST NIRCam+MIRI: Cosmic Cliff-like in Orion's Trapezium (1344 lyrs):

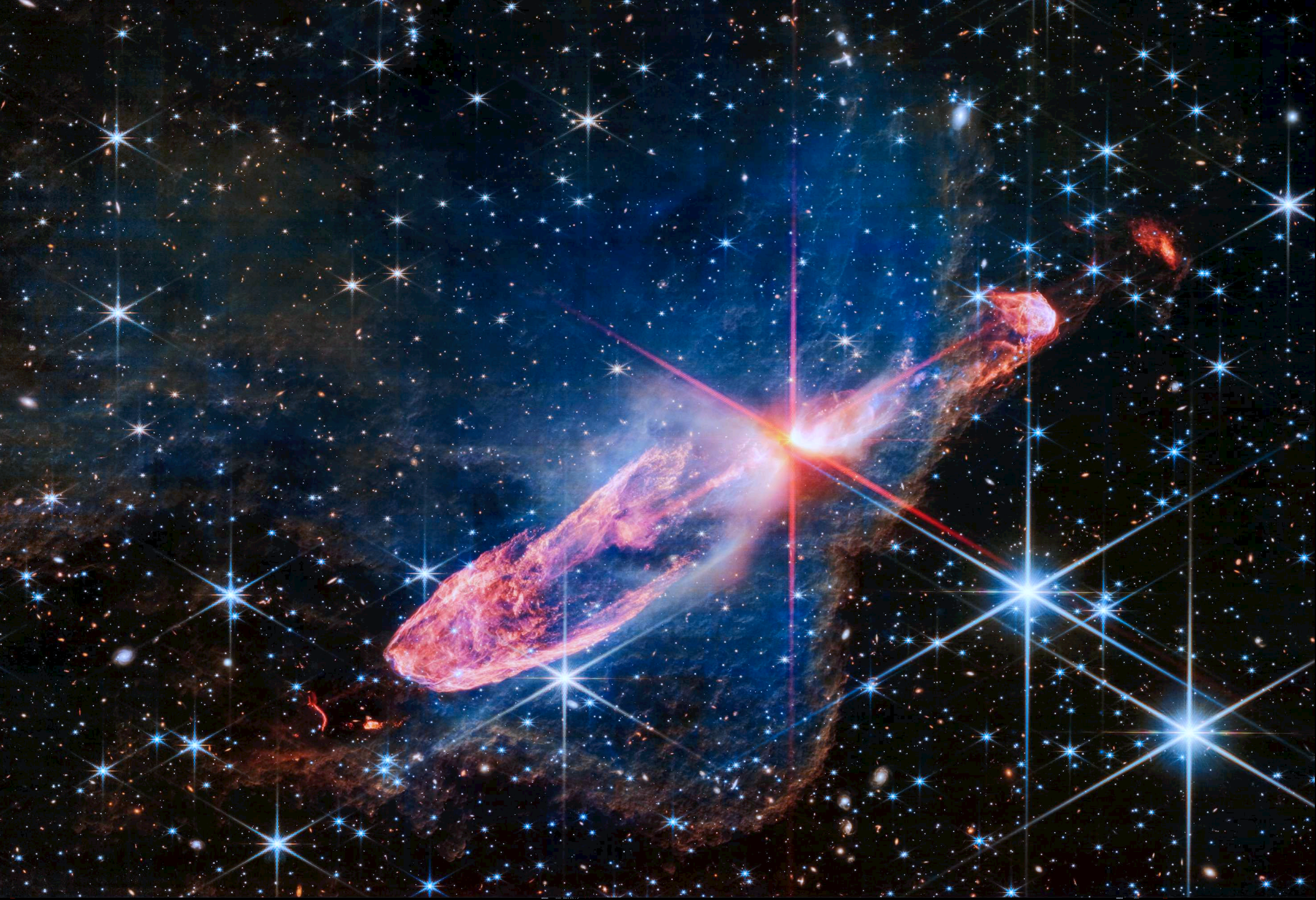
- New stars are forming containing the carbon chain "Methyl Cation"

Our birth, $e.g.$, : Protoplanetary "Hourglass Nebula" L1527 at 460 lyrs.

- A forming protostar with $\sim$30% of Sun's mass only 100,000 year old!
- The protostar has surrounding accreting gas, and a circumstellar disk.
- Eventually, L1527 will start shining as a star, and have its own planets.

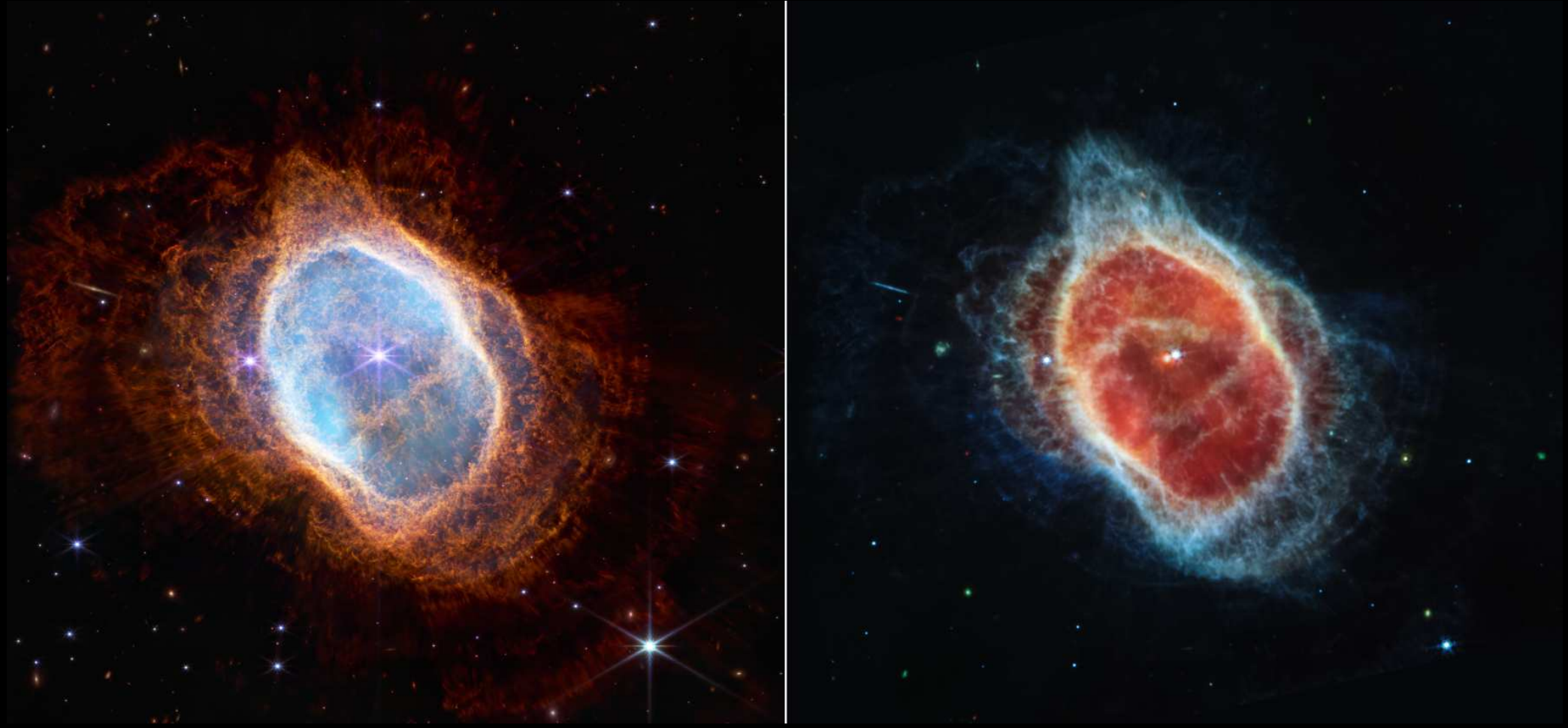
NIRCam+MIRI: ρ Ophiuchi dark cloud (closest stellar nursery at 456 lyrs):

- Cradle of star-formation contains Polycyclic Aromatic Hydrocarbons!



Newly forming stars Herbig-Haro 46/47 with jet-expelled material (1470 lyrs):

Formation of Sun-like stars is messy: inflow and outflow of gas & dust!



Southern Ring Nebula (Near-IR+Mid-IR; 2500 light-years):

- You $*are*$ witnessing the "Cosmic Circle of Life" here ...
- This is a Sun-like star expelling its outer layers in retirement ...
- It has exhausted its hydrogen and helium as nuclear fuel ...

and expanded to $>>100\times$ its current size, engulfing the Earth.

This is how our Sun *will* come to an end in 5 Billion years (near-IR).

Genesis 3:19: "... for dust thou art, and unto dust shalt thou return".

From gas expelled by previous sun-like stars, new stars are born (mid-IR).

And thanks to the dust they expelled, new stars will form with planets ...

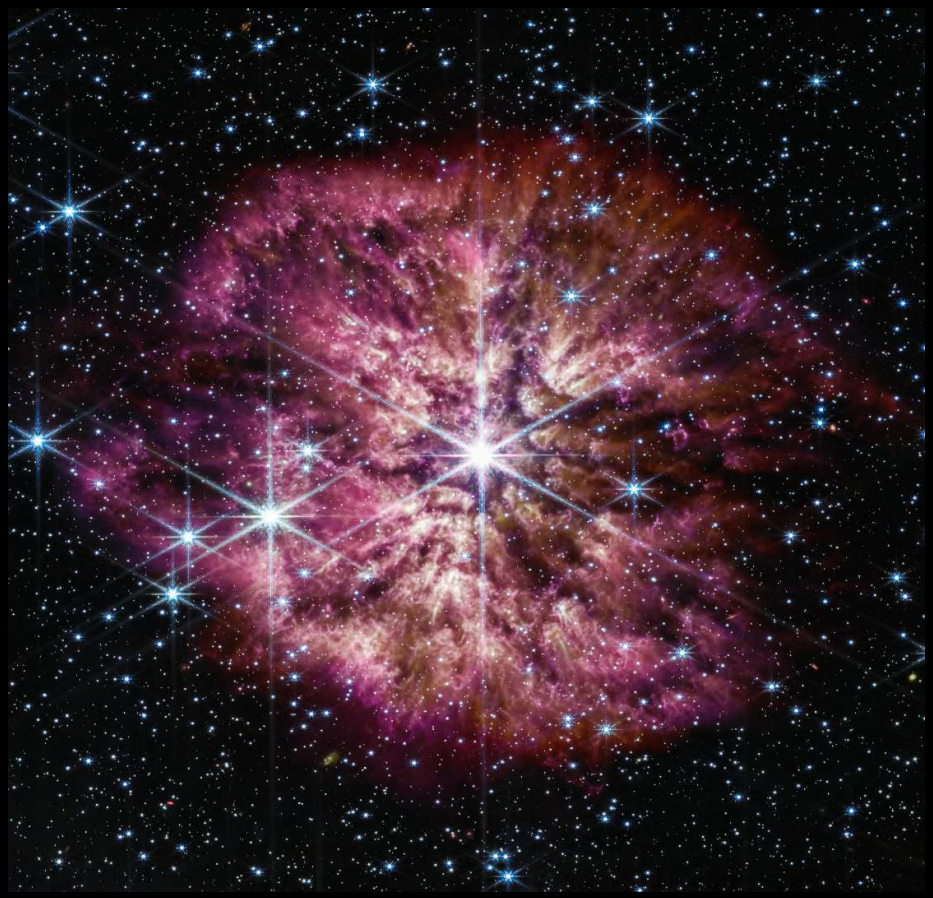
Webb images of THE Northern Ring Nebula in Lyra:

[Left] NIRCam & [Right] MIRI: mass loss in Asymptotic Giant Branch stage.

- This is how our Sun *will* come to an end in 5 Billion years ...

and leave an ultra hot dim white dwarf star behind in the center.

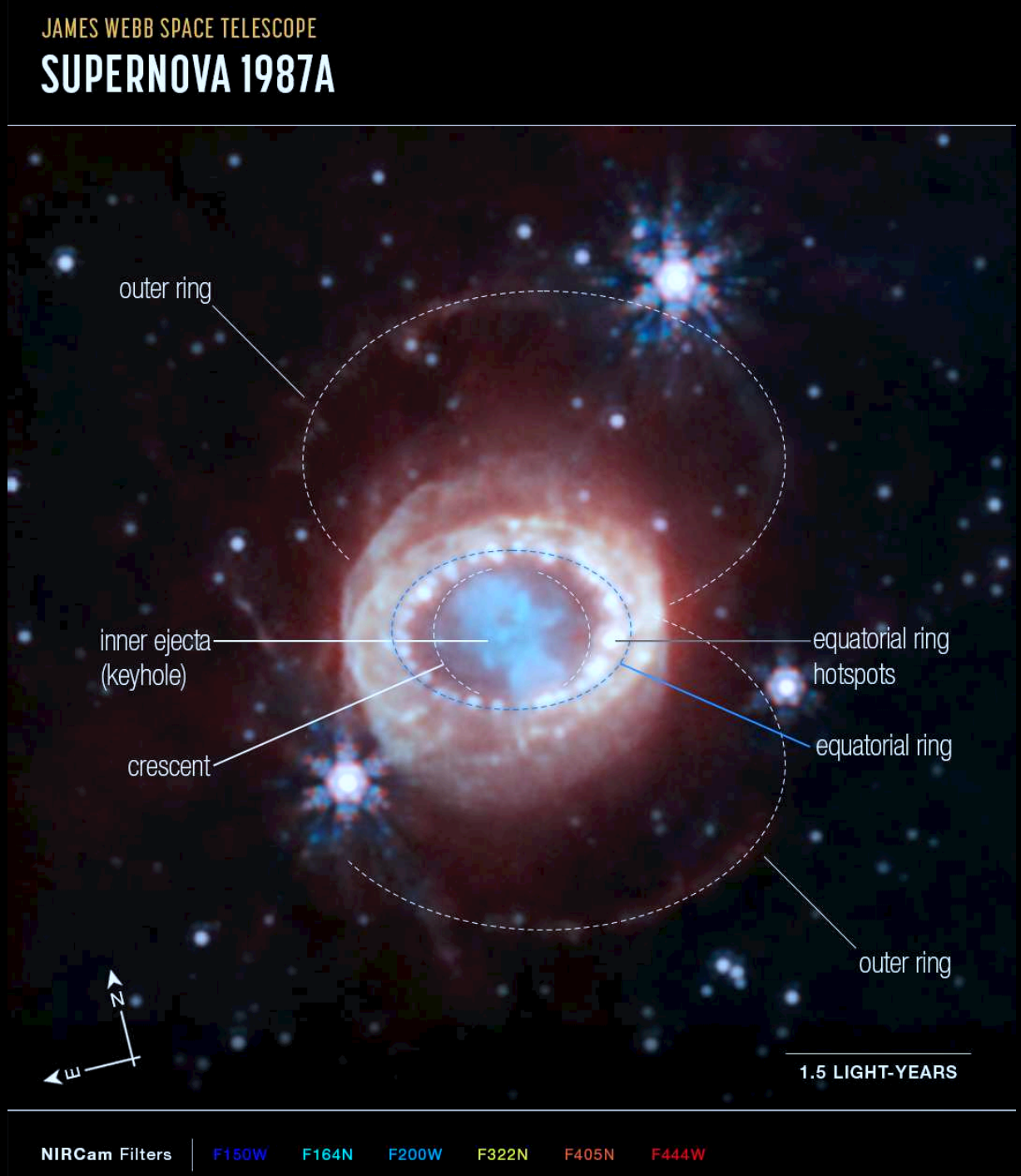
Genesis 3:19: "... for dust thou art, and unto dust shalt thou return".




30 solar mass Wolf Rayet star WR124 shortly before it turns Supernova ...

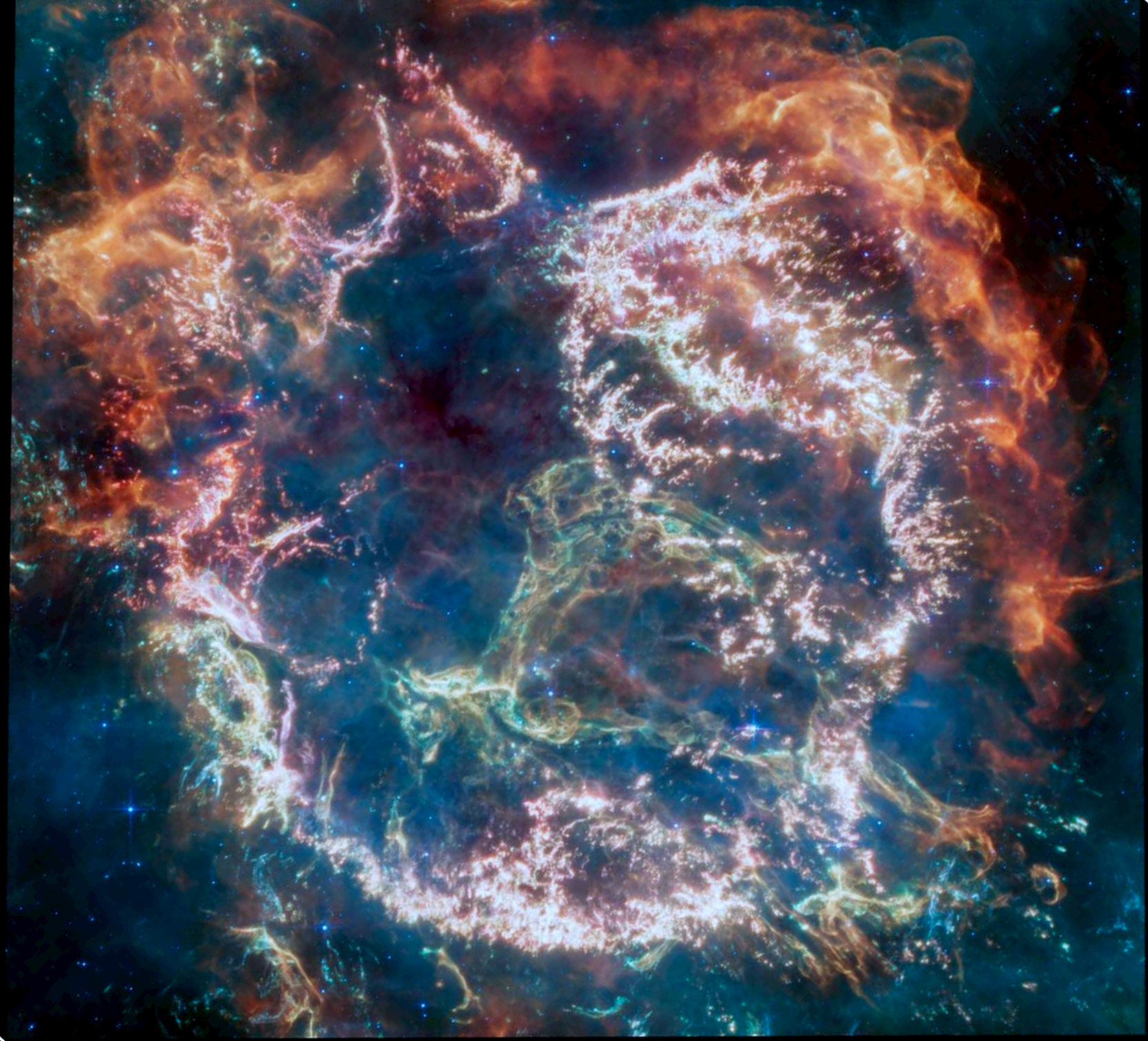
- [Left] NIRCam and [Right] MIRI — both showing recent mass loss.
- Prelude stage to Supernova also releases a lot of (dusty) mass!

Genesis 3:19: "... for dust thou art, and unto dust shalt thou return".

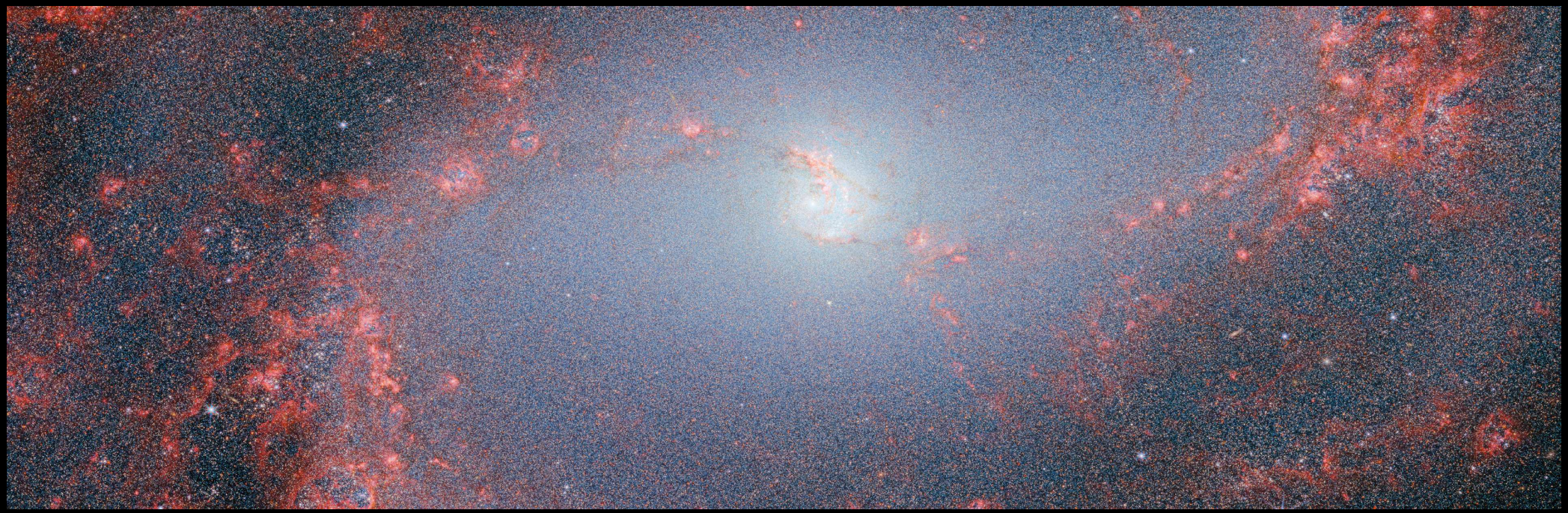


NIRCam: Remnants of Supernova 1987A seen in Large Magellanic Cloud

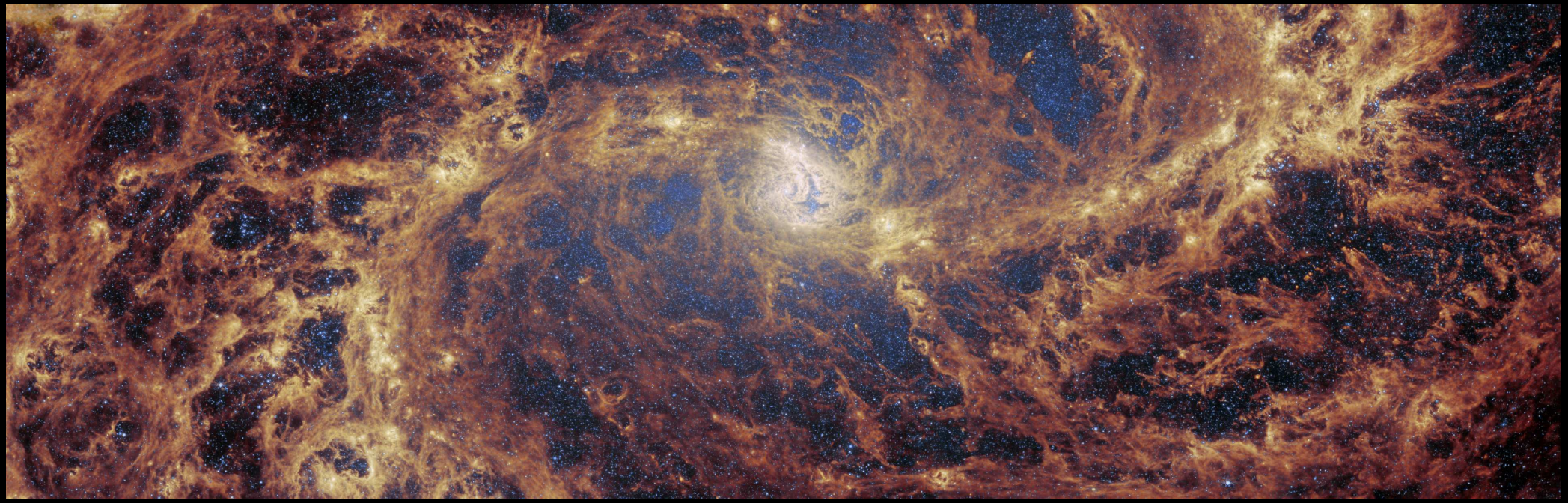
- Shells outflowing over the decades caused hour-glass shaped bubbles



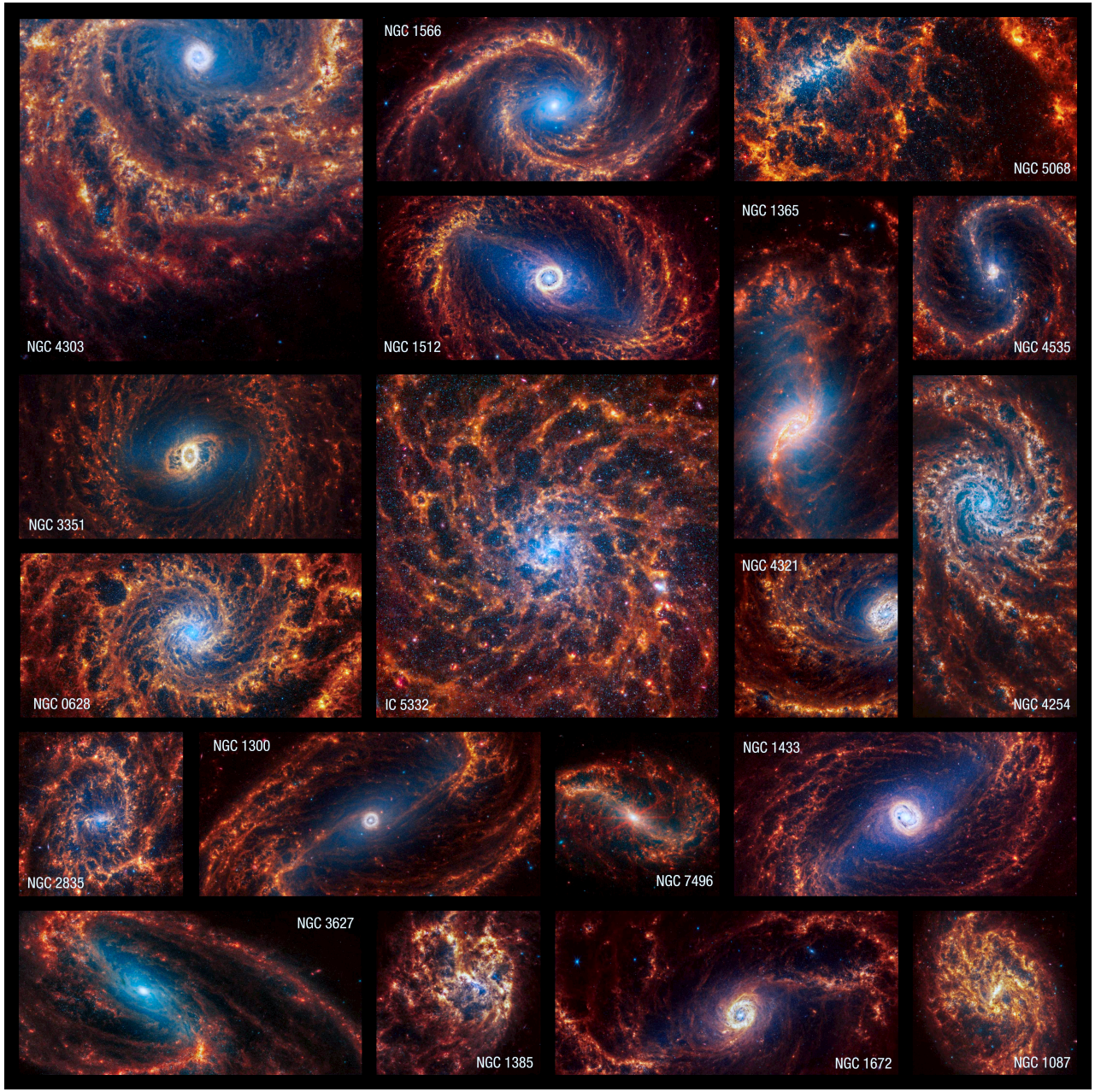
JWST MIRI: Supernova Remnant Cassiopeia-A expelling dust



M83 spiral galaxy NIRCam (near-IR): Through dust thou art made, stars!



M83 spiral galaxy MIRI (mid-IR): ... and dust thou shalt return, stars!

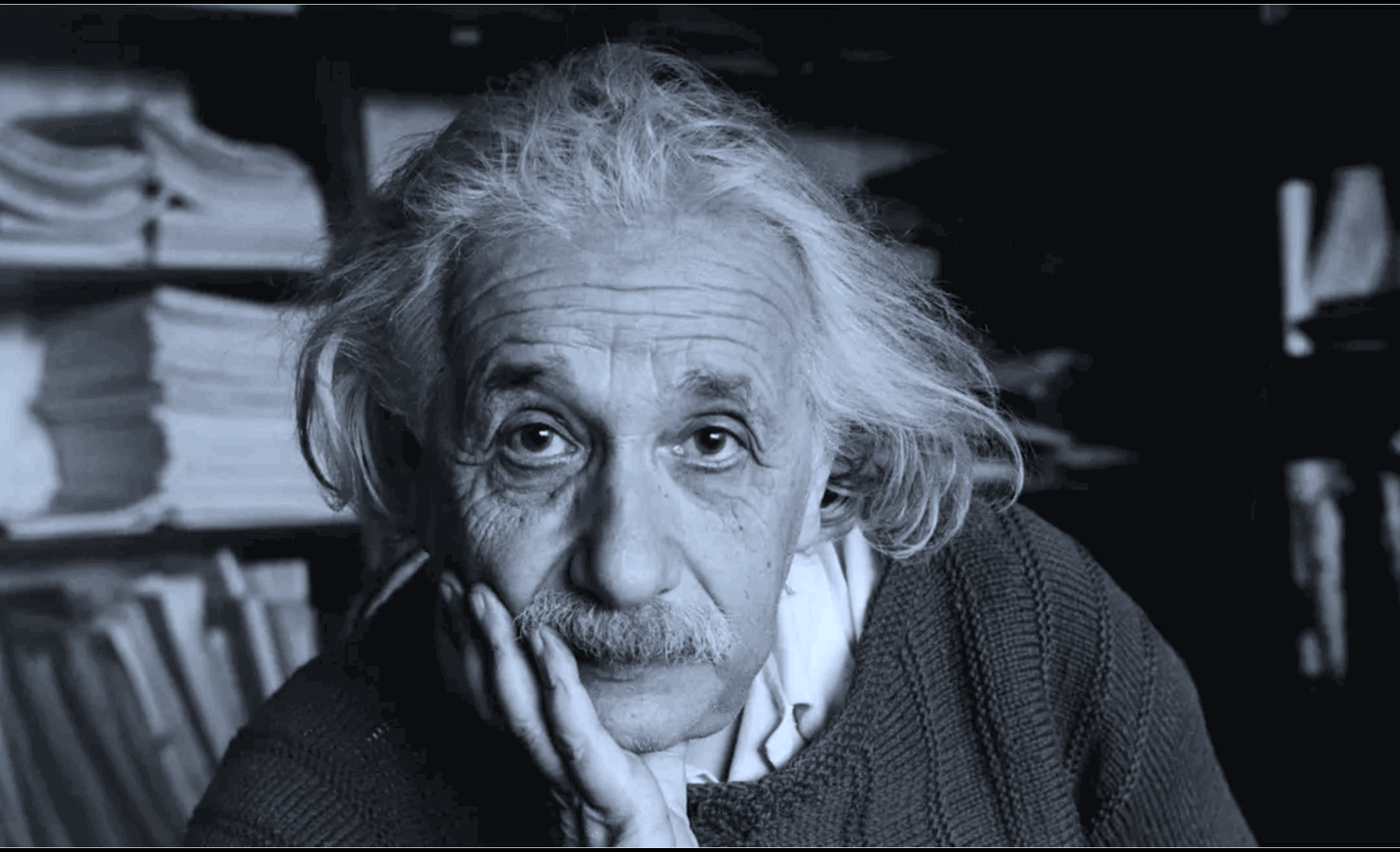


Webb NIRCam and MIRI images of nearby galaxies:

Cosmic star-formation and dust production ubiquitous throughout the universe!

The "Cosmic Circle of Life" rules throughout the universe!

- (3) Viewing the Universe through the "Eyes of Einstein"



Webb is observing many things Einstein correctly predicted, yet doubted:

Gravitational lensing, Black Holes, the Hubble Expansion, ...

Stephan's Quintet: 4 colliding galaxies (40 M-lyr; left spiral is foreground).

- These major "Cosmic Trainwrecks" are much more common in the past.
  - Sun-like stars formed in aftermath of minor "Cosmic Fender-benders".

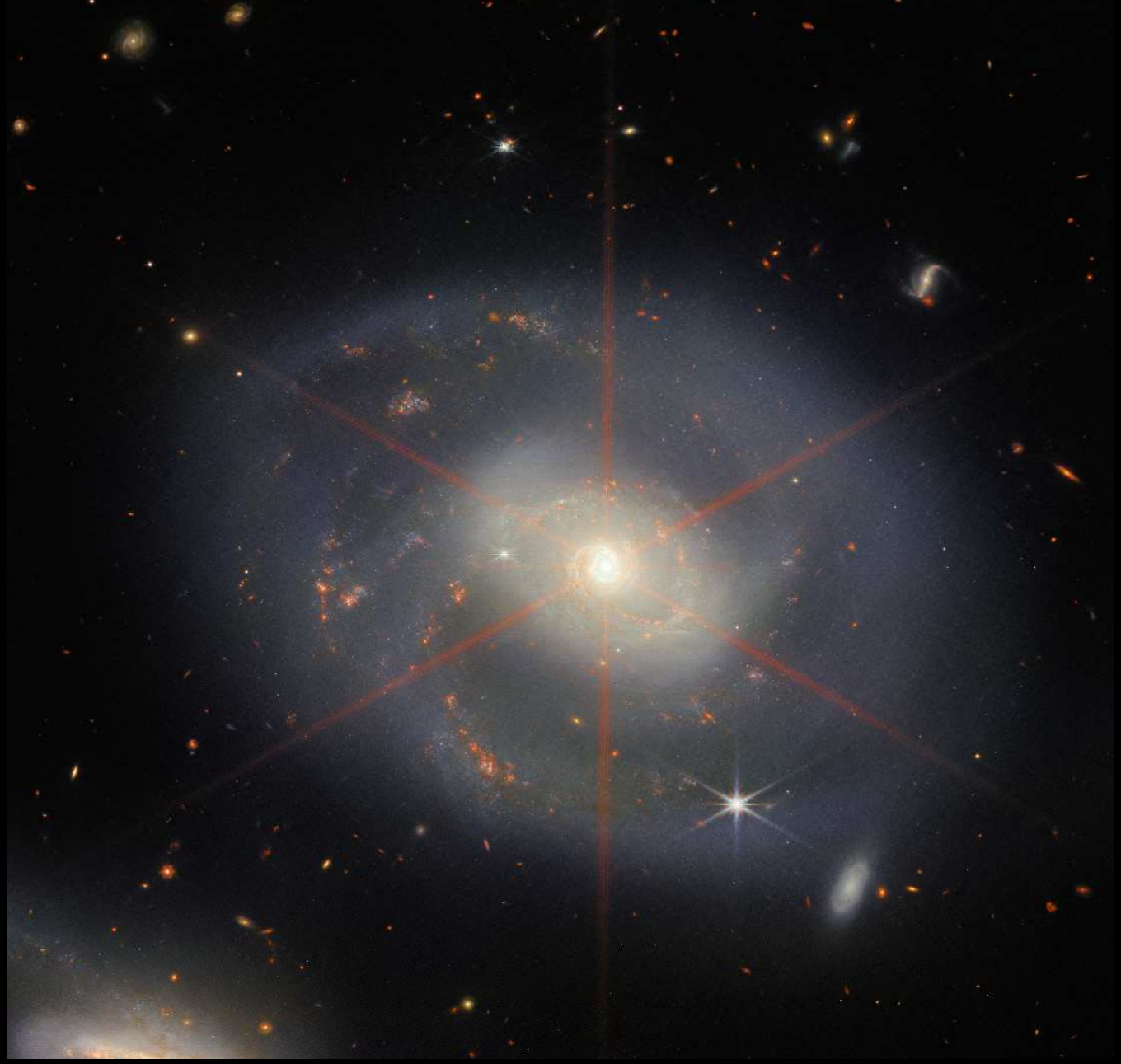
Stephan's Quintet: 4 colliding galaxies at 40 million light-years (Mid-IR):

- Mid-IR shows molecular gas being pulled out during collision.
- Gravity from collision in top galaxy feeds the Beast: central black hole!

NGC1433 a galaxy with dusty spiral arms at 48 million light-years

NGC7496 a galaxy with dusty spiral arms at 24 million light-years:

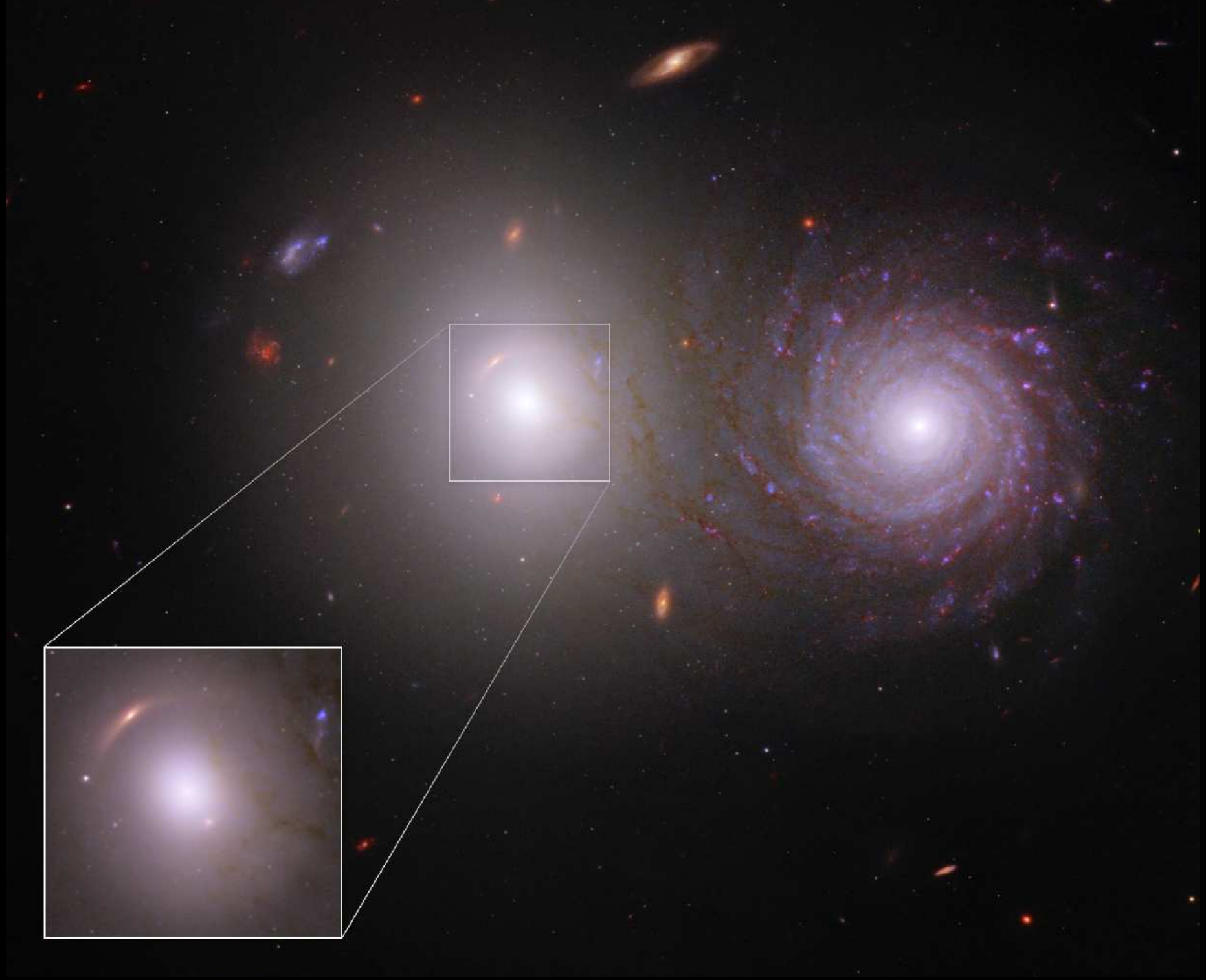
- Inner spiral arms feed the central monster (supermassive black hole!)



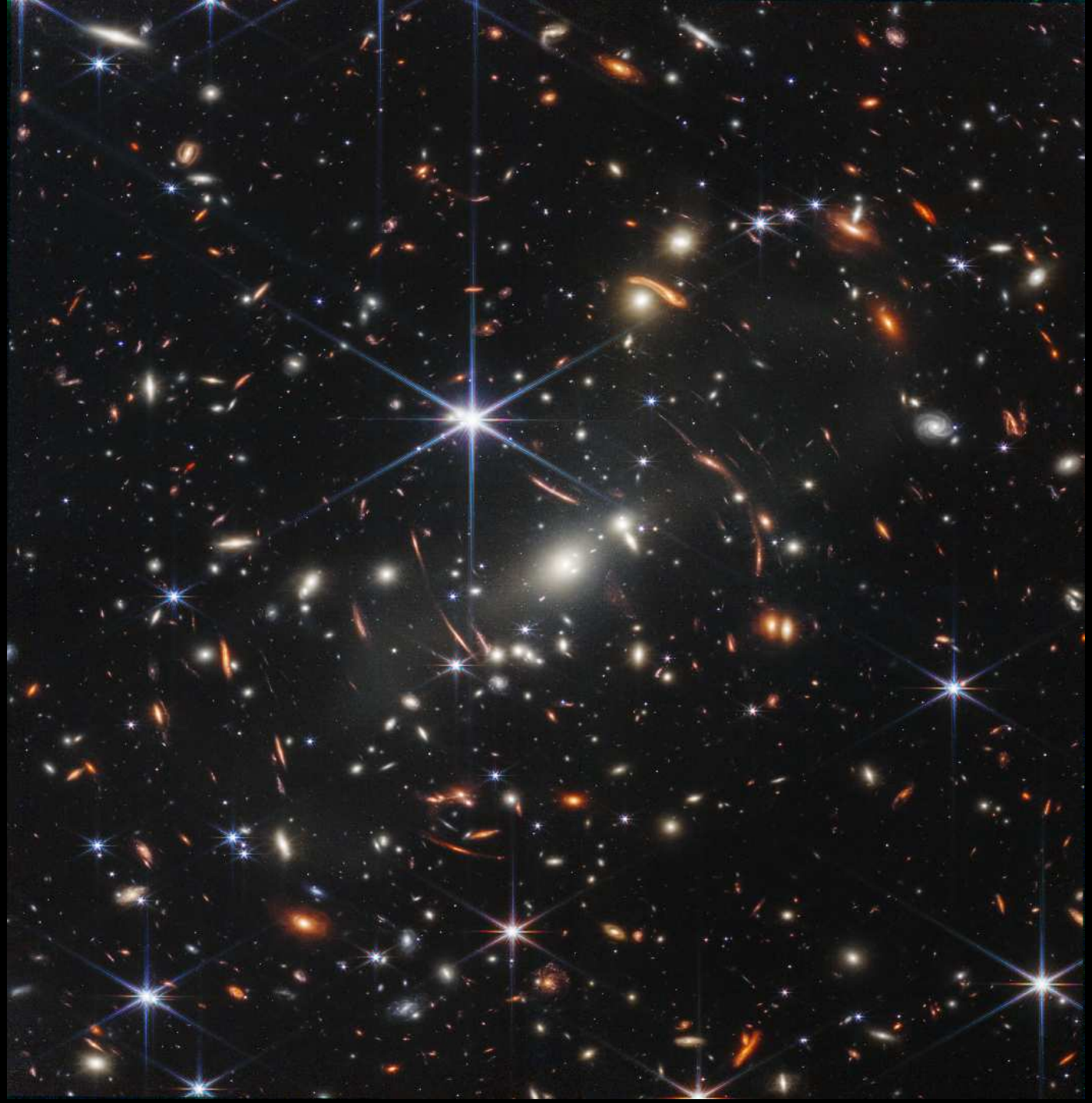
Don't feed the animals: NGC7469, a spiral galaxy at 220 million light-years:

- It has a supermassive black hole (SMBH) feasting on the in-falling gas!
- In area surrounding the SMBH, gas is expelled at very high speeds.

- Spiral overlapping Elliptical VV191: Tracing dust: small grains! (Keel^{+} 23).
  - 150 Globular Clusters in z=0.0513 Elliptical (Berkheimer^{+} 2024, ApJ, 964, L29).

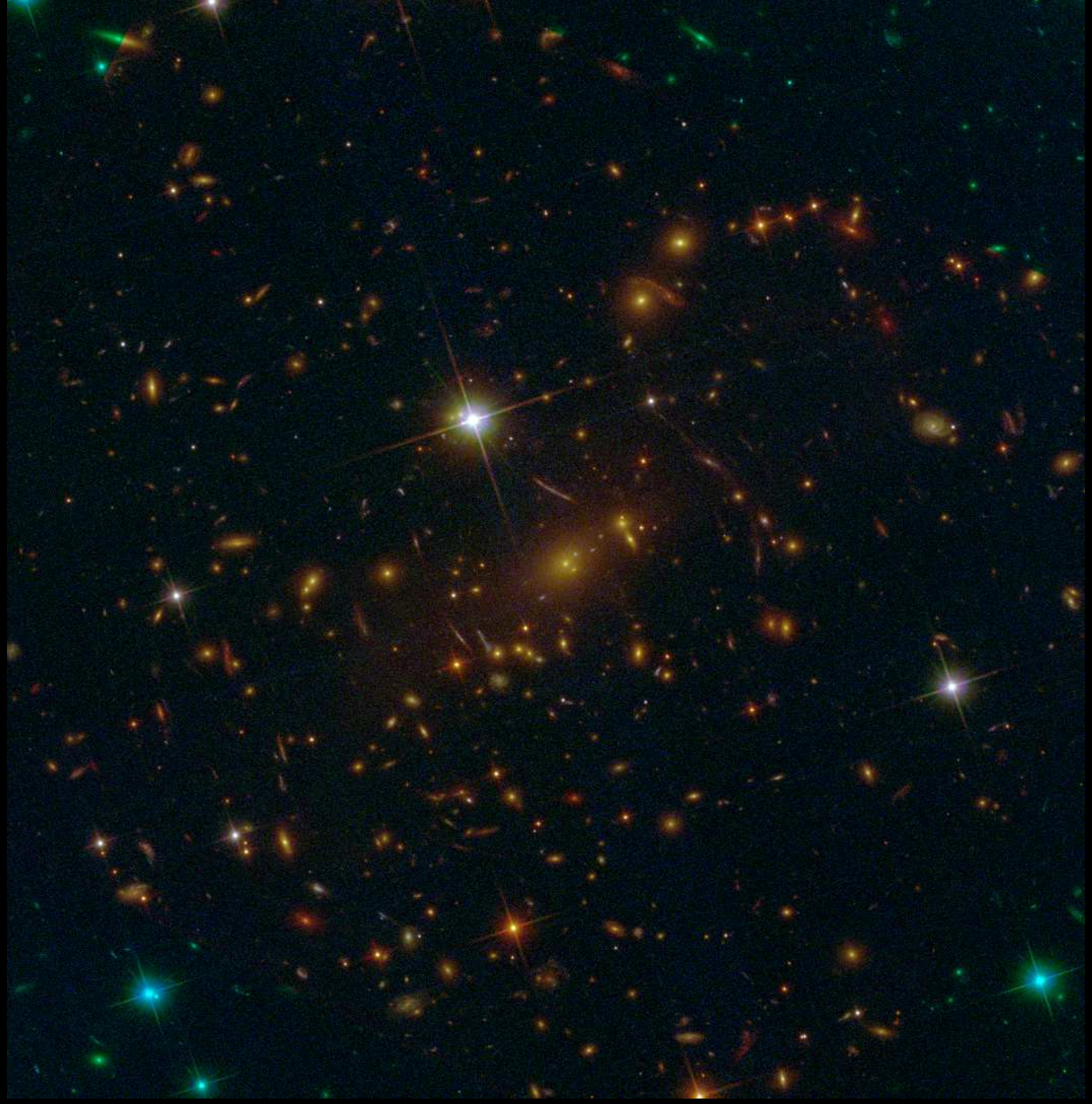


... and the z=0.0513 Elliptical also lenses a background galaxy at z∼1 (Keel^{+} 2023, AJ, 165, 16)!



July 11, 2022: 12-hr Webb Deep Field on galaxy cluster SMACS 0723

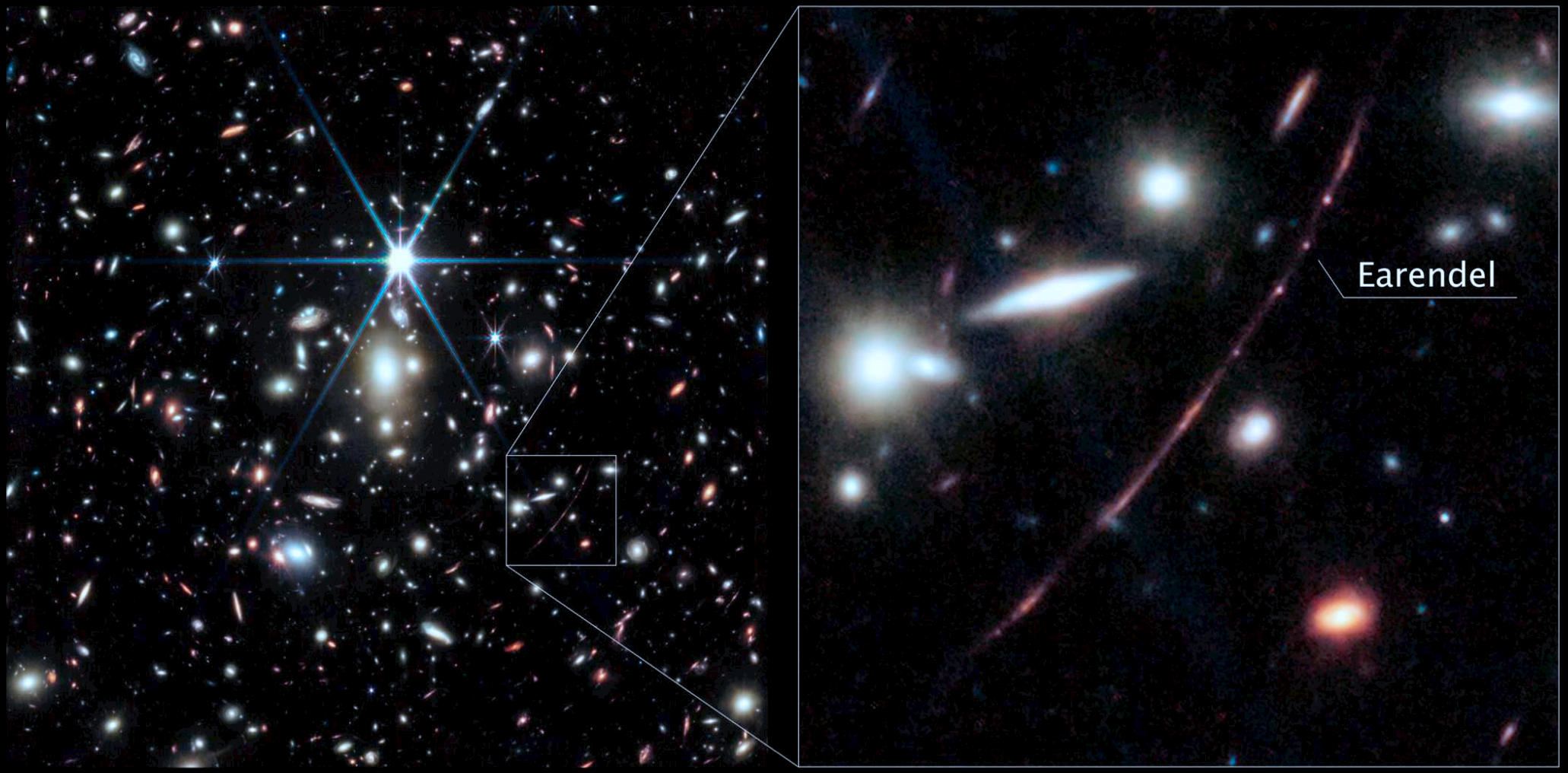
- Cluster galaxies already are $\sim$9 Byrs old, seen at 4.5 Blyr distance!



Hubble image of SMACS 0723: not the same depth and breadth as Webb!

- Cluster 3×older than the Earth today: we are cosmic late bloomers!

Cluster MACS0647 triply lensed a galaxy 0.4 Byrs after BB! (Hsiao, Coe^{+} 22)



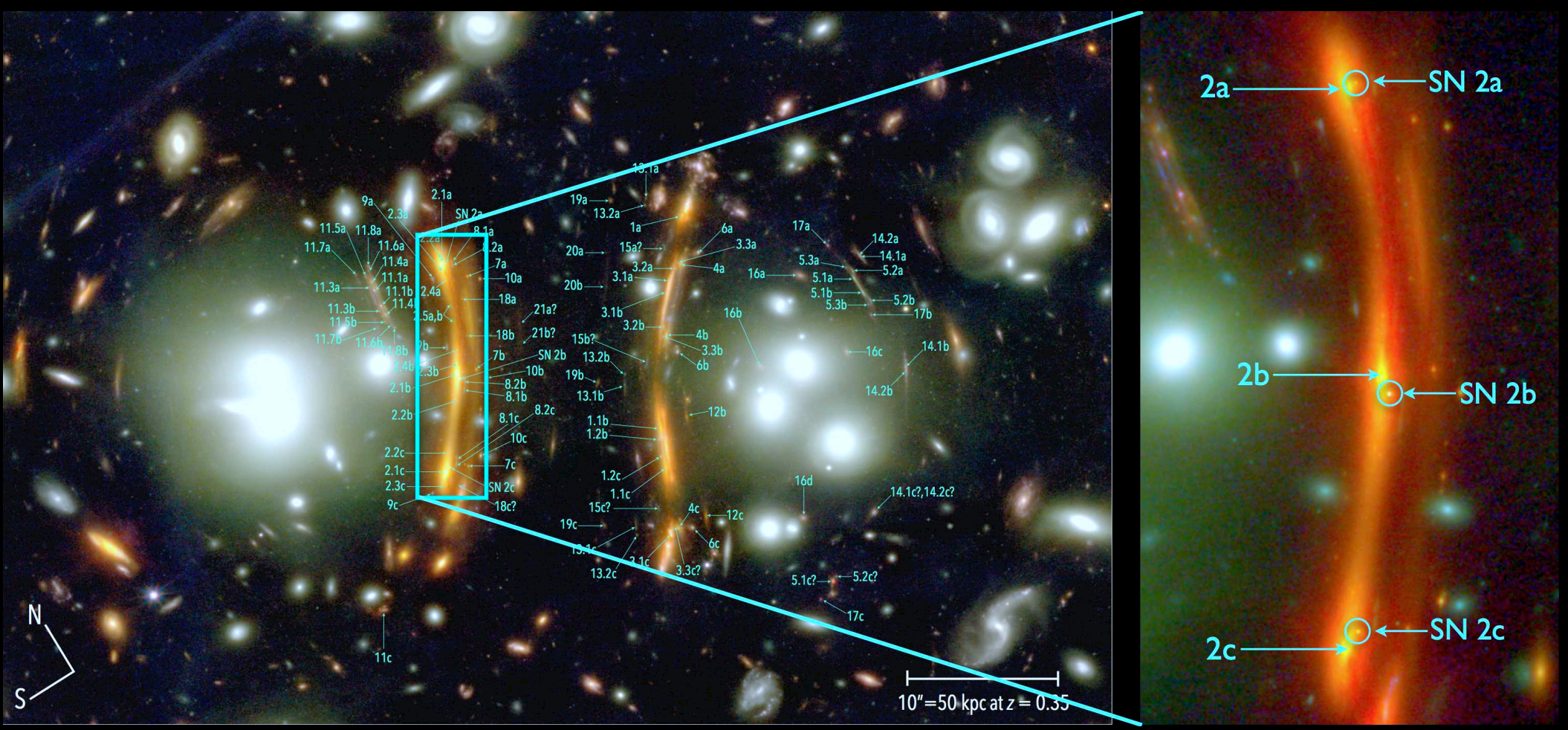
NIRCam: Cluster WHL0137-08 with highly lensed arc at z=6.2 (0.9 Byr).

• Earendel: a highly magnified (double-)star seen in the first billion years after the Big Bang — the most distant star ever observed directly!

Prov. 3:6: "... in all your ways acknowledge him, and he will make your paths straight." [light-paths are straight in 4D-curved space-time :)].

JWST image of most luminous far-IR Planck cluster G165 at z=0.35 found:
Lensed Supernova Ia at z=1.78 $\rightarrow$ measured H_o=$75.4^{+8.1}_{-5.5}$, 10 Byrs ago!

https://bigthink.com/starts-with-a-bang/triple-lens-supernova-jwst/ (Frye$^+$ 2023, Pascale$^+$ 2025).



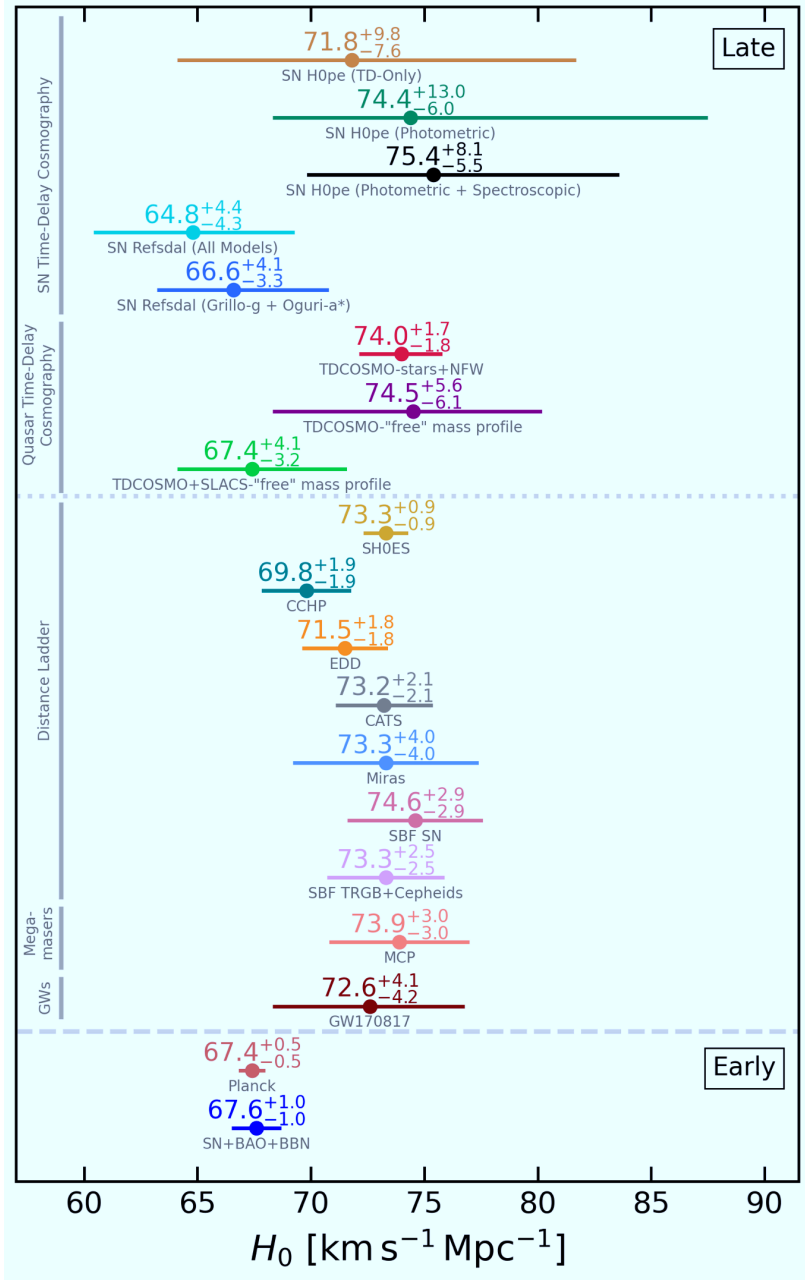
NIRCam in G165 shows: 3 bright point sources parity-flipped w.r.t. Arc-2:

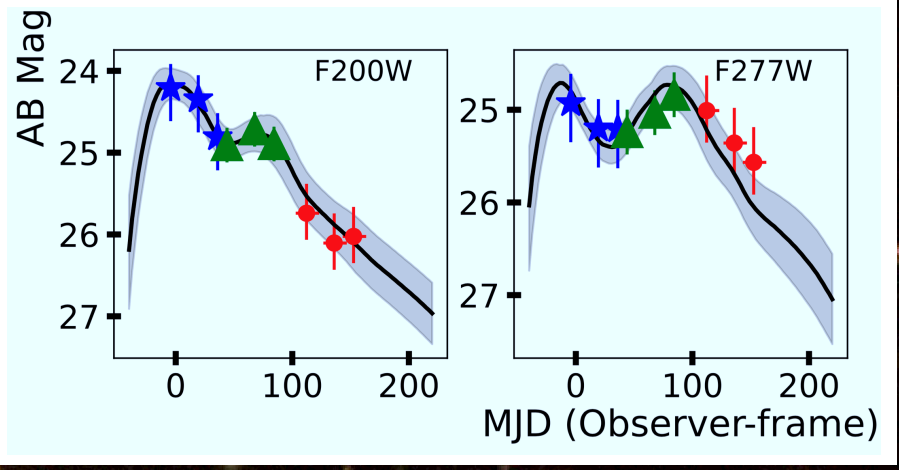
- Clearly a lensed SN Type Ia at z=1.783, seen only 3.6 Byrs after BB!
- 3-epoch 9-point light curve! $\Longrightarrow$ measure H_0 constant directly !

(Polletta$^+$ 2023, Frye$^+$ 2024, Chen$^+$ 2024, Kamieneski$^+$ 2024, Pierel$^+$ 2024, Pascale$^+$ 2025).

$\rightarrow$ Regular monitoring of clusters with extreme SF to yield more lensed SNe!

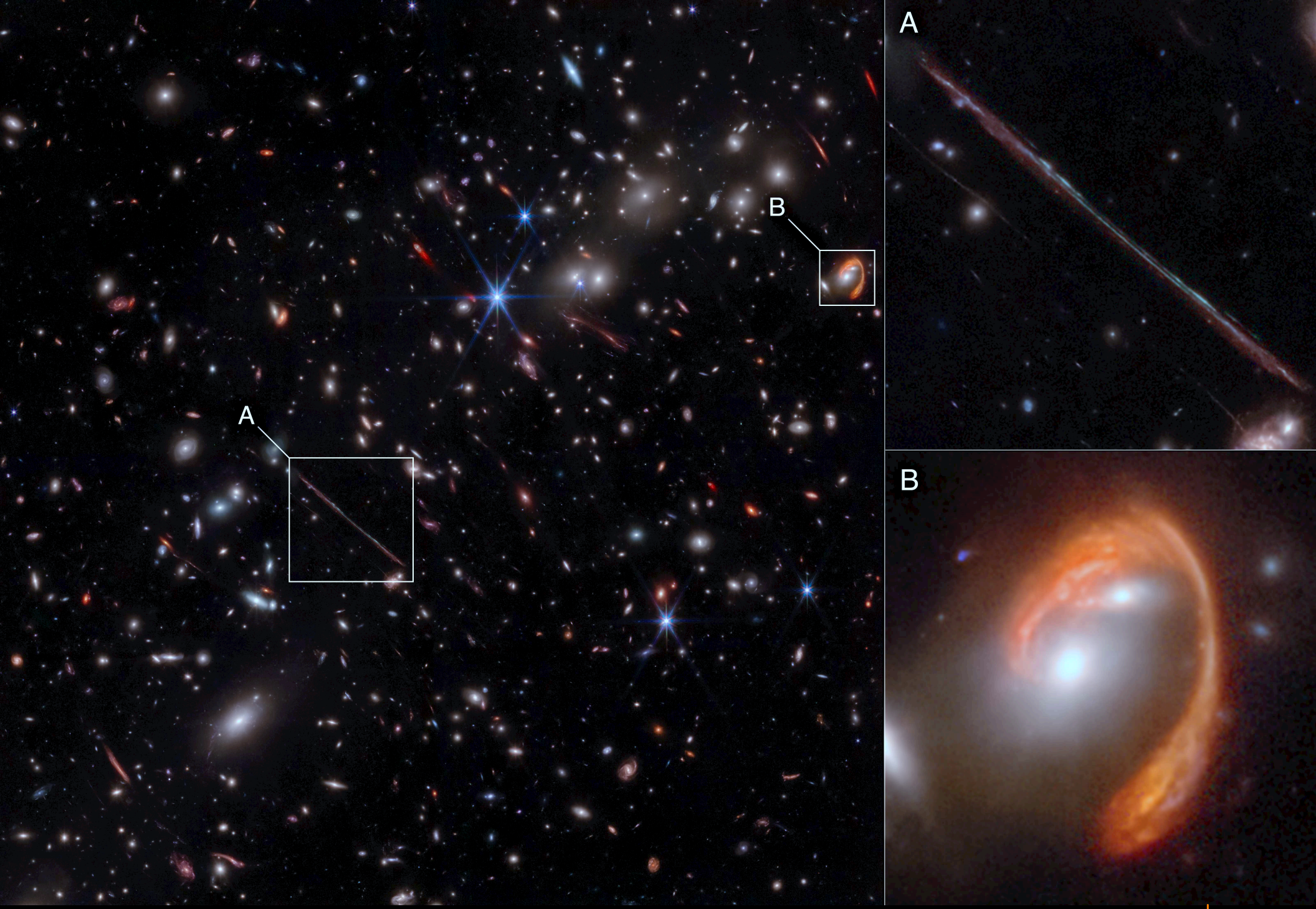
- Total SFR$\simeq$200–350 $M_\odot$/yr predicts $\gtrsim$1 lensed SN/yr (Kamieneski$^+$ arXiv/2404.08058)





Pascale^{+} (2025, ApJ, 979, 13): Photo & spectro time delay: $H_o = 75.4^{+8.1}_{-5.5}$ (at z=0.35).

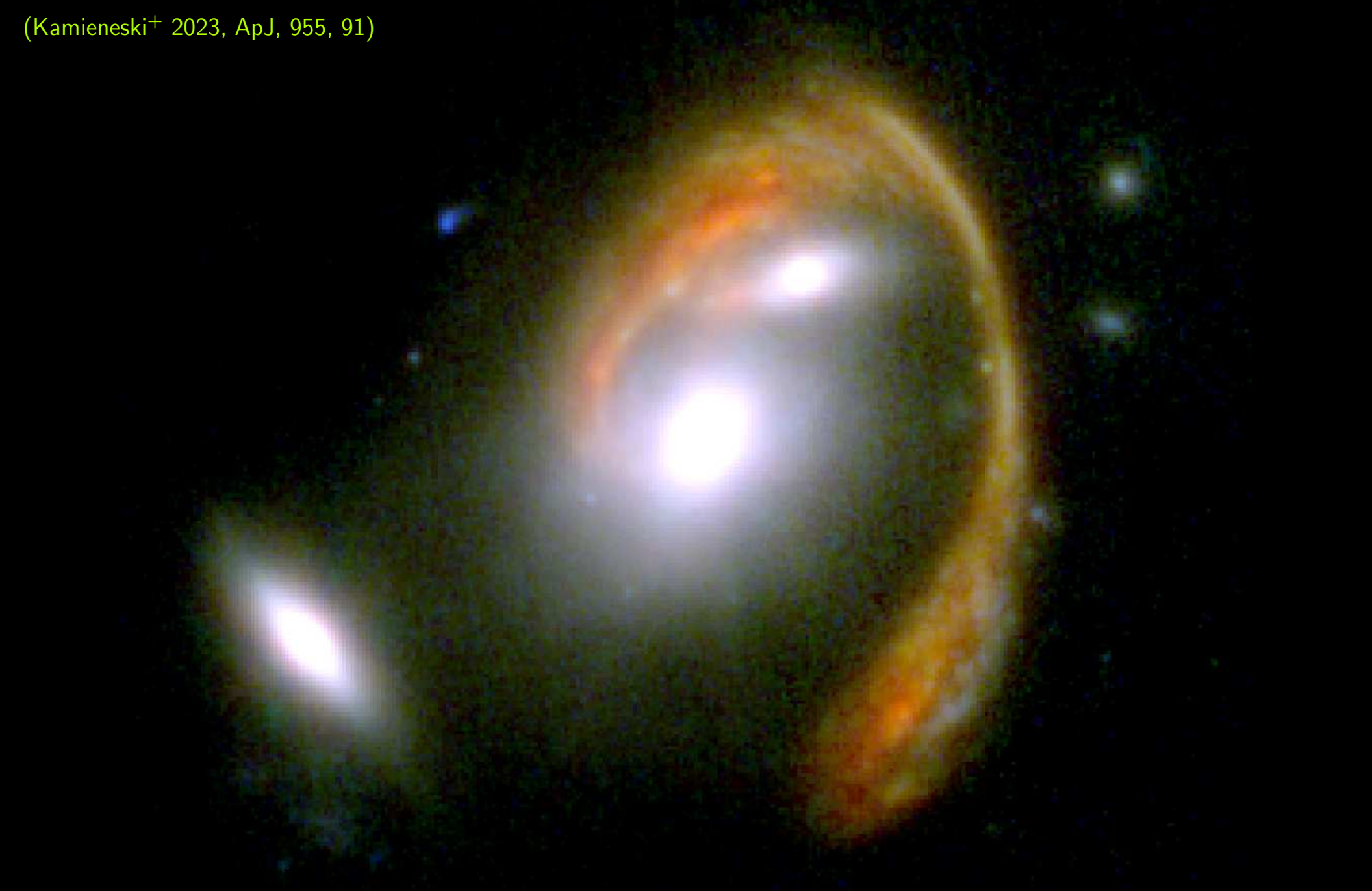
- Monitoring G165 predicts $\gtrsim$1 lensed SN-Ia/yr ! (Kamieneski^{+} 2024, ApJ, 973, 25)



Monster cluster El Gordo distorts distant galaxies into “pencils” (Diego+22)

https://news.asu.edu/20230801-jwsts-gravitational-lens-reveals-distant-objects-behind-el-gordo-galaxy-cluster

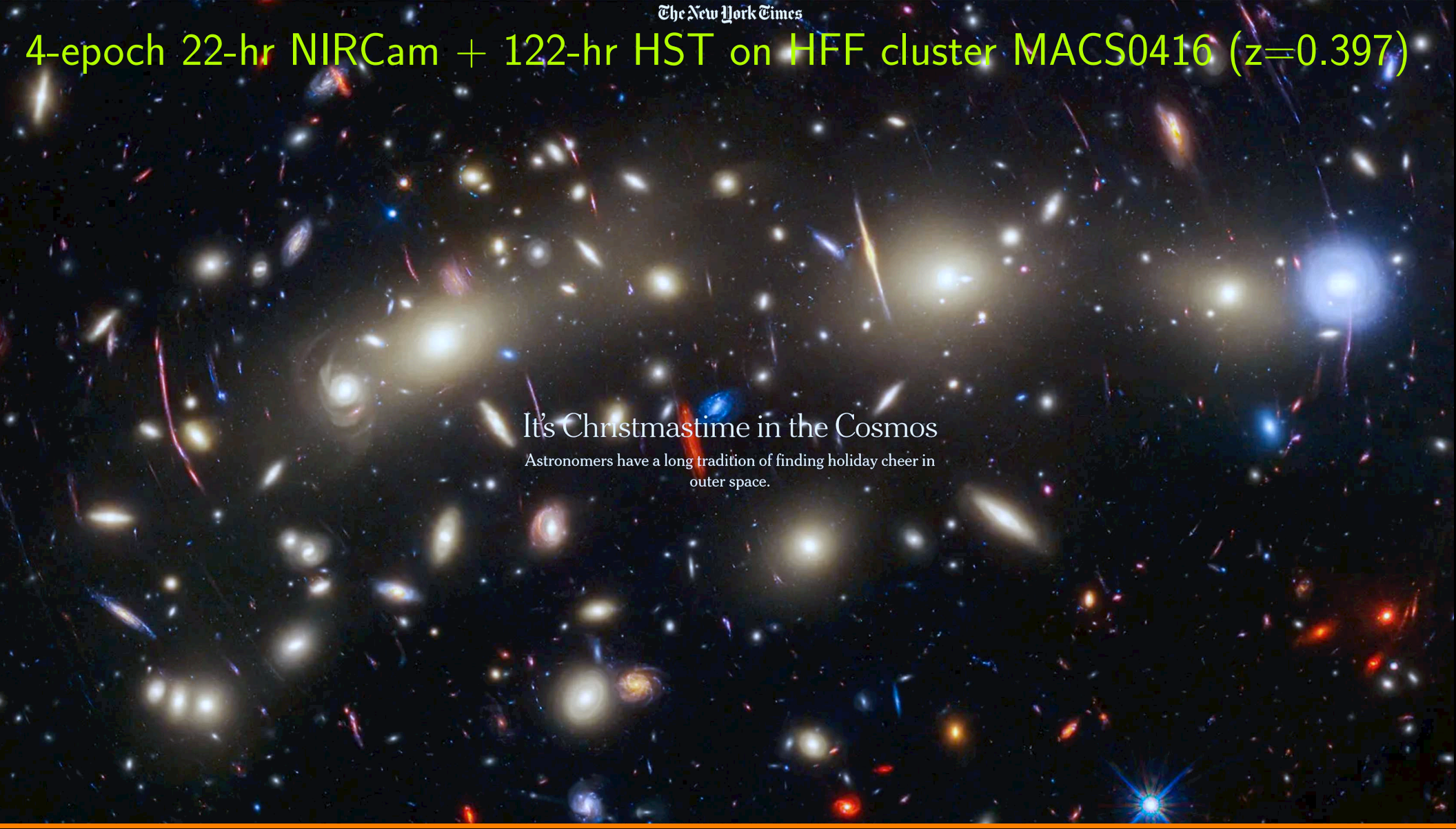
(Kamieneski+ 2023, ApJ, 955, 91)



and El Gordo makes a super-lens “El Anzuelo” — Einstein’s fishhook!

https://webbtelescope.org/contents/news-releases/2023/news-2023-119

https://news.asu.edu/20230802-global-engagement-asu-webb-telescope-einstein-werner-salinger-holocaust

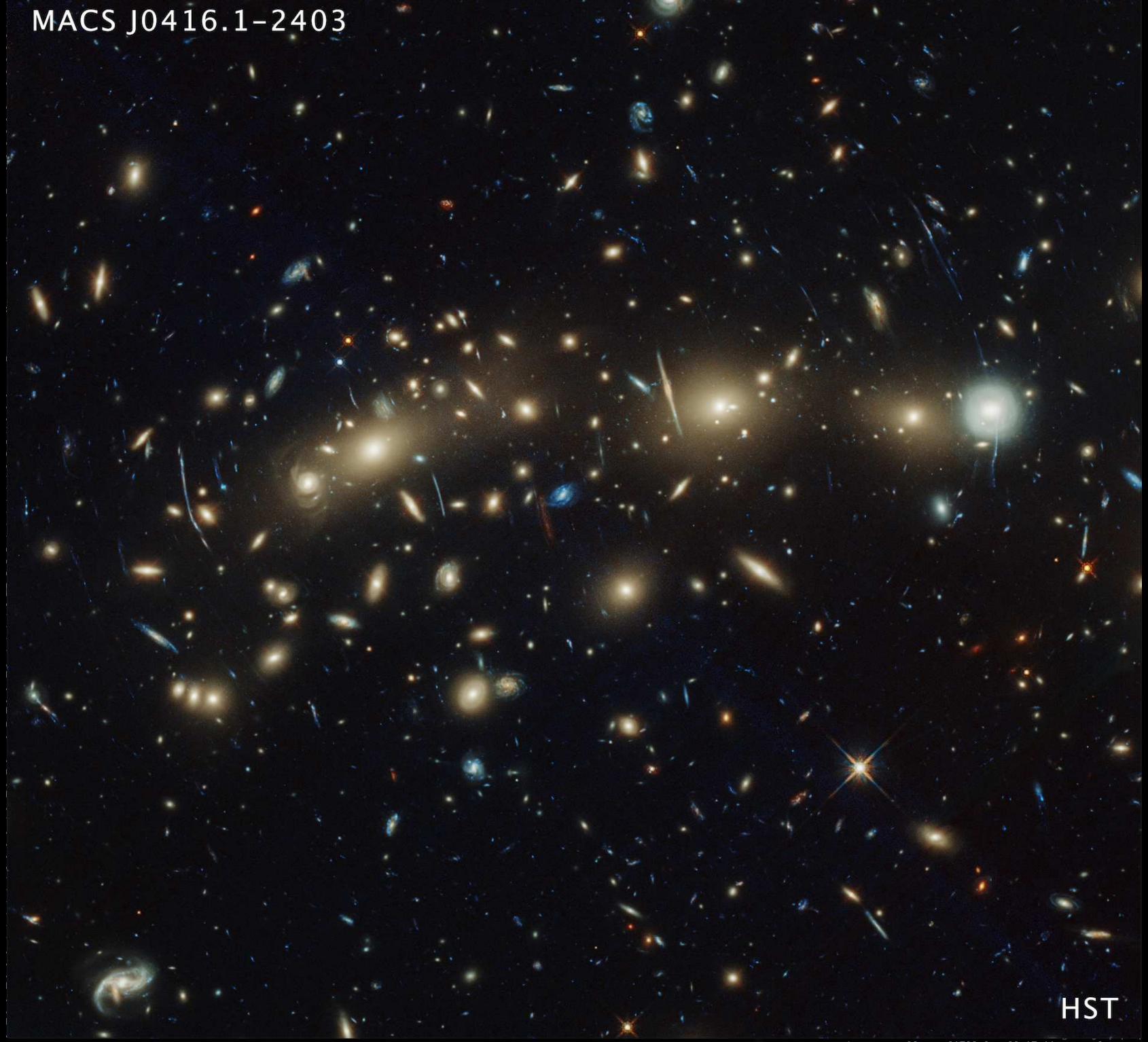


12 new caustic transits at z≃1–2 from 4 epochs! (Yan, H.+, 2023, ApJS, 269, 42)

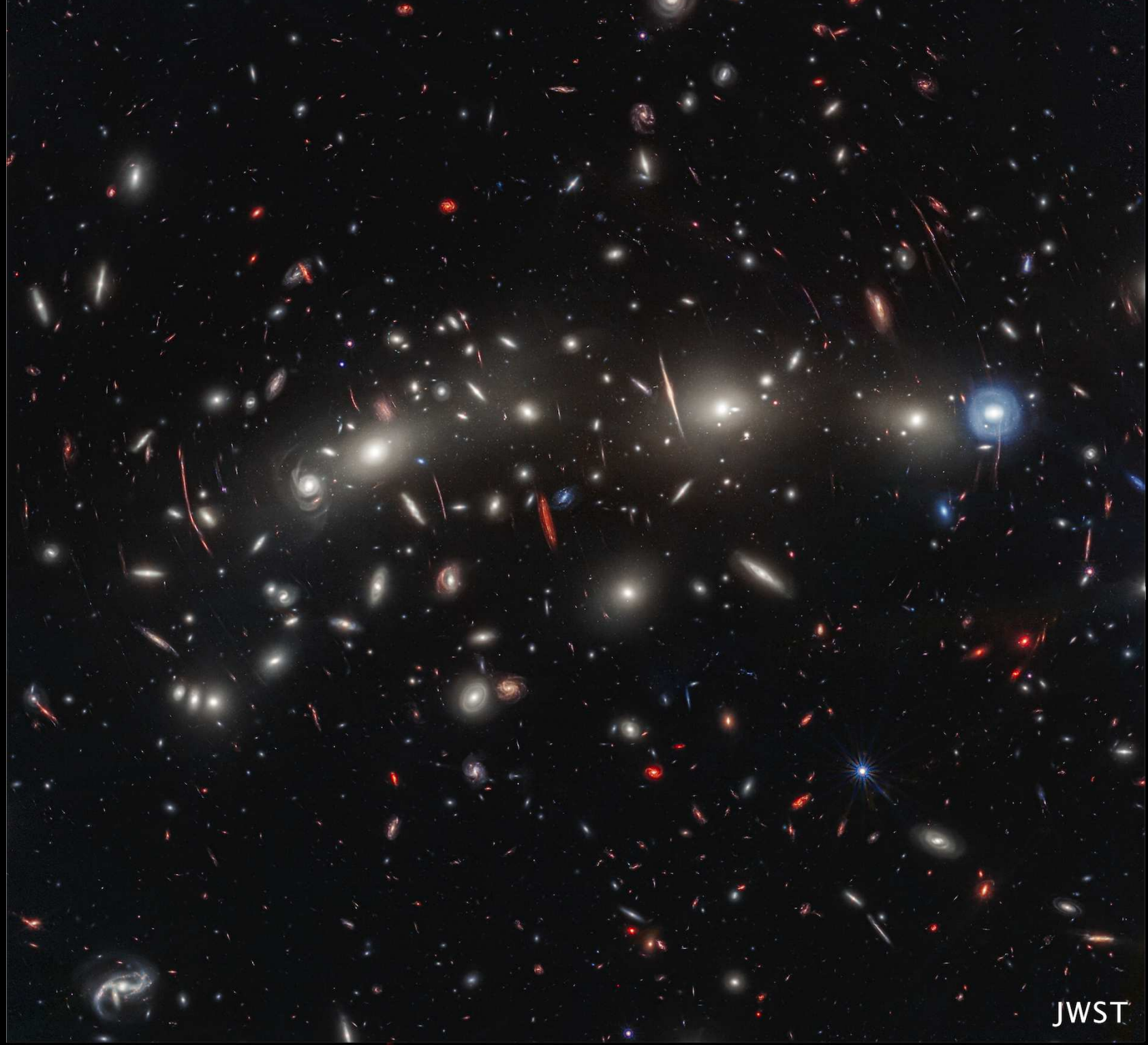
Extremely magnified binary star at z=2.091! (Diego, J.+, 2023, A&A 679, A31)

https://www.cnn.com/2023/11/09/world/webb-hubble-colorful-galaxy-cluster-scn/index.html

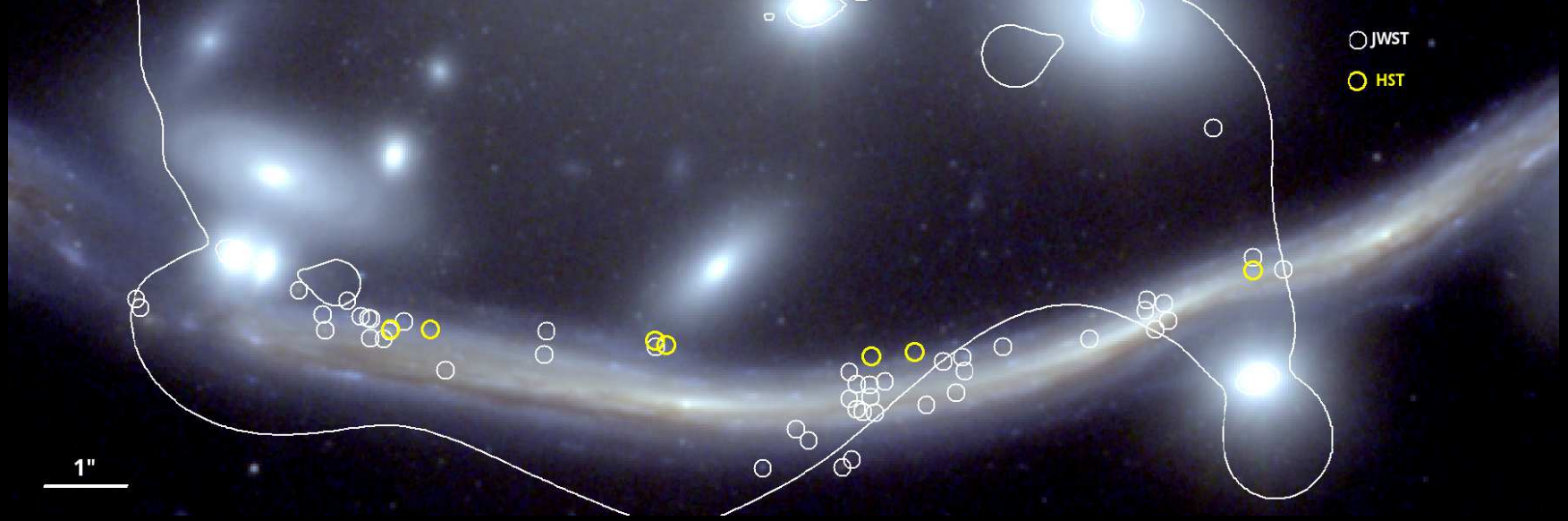
https://www.nytimes.com/2023/12/19/science/christmas-stars-galaxies-webb-nasa.html?

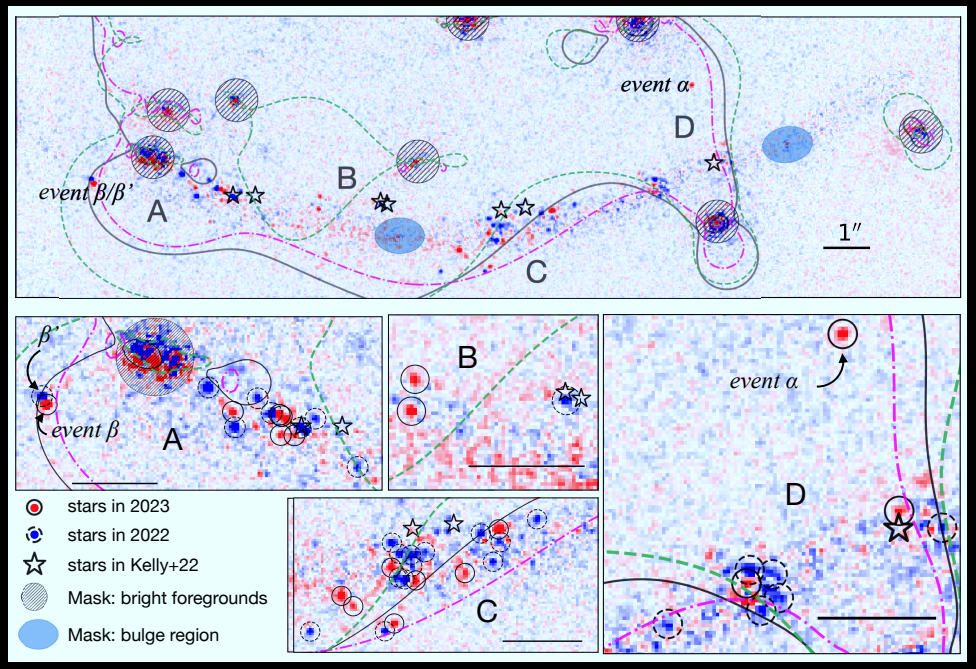


122 hr HST on Hubble Frontier Field cluster MACS0416 (z=0.397; 4.3 Blyr)



22 hrs JWST on Hubble Frontier Field cluster MACS0416 (z=0.397; 4.3 Blyr)

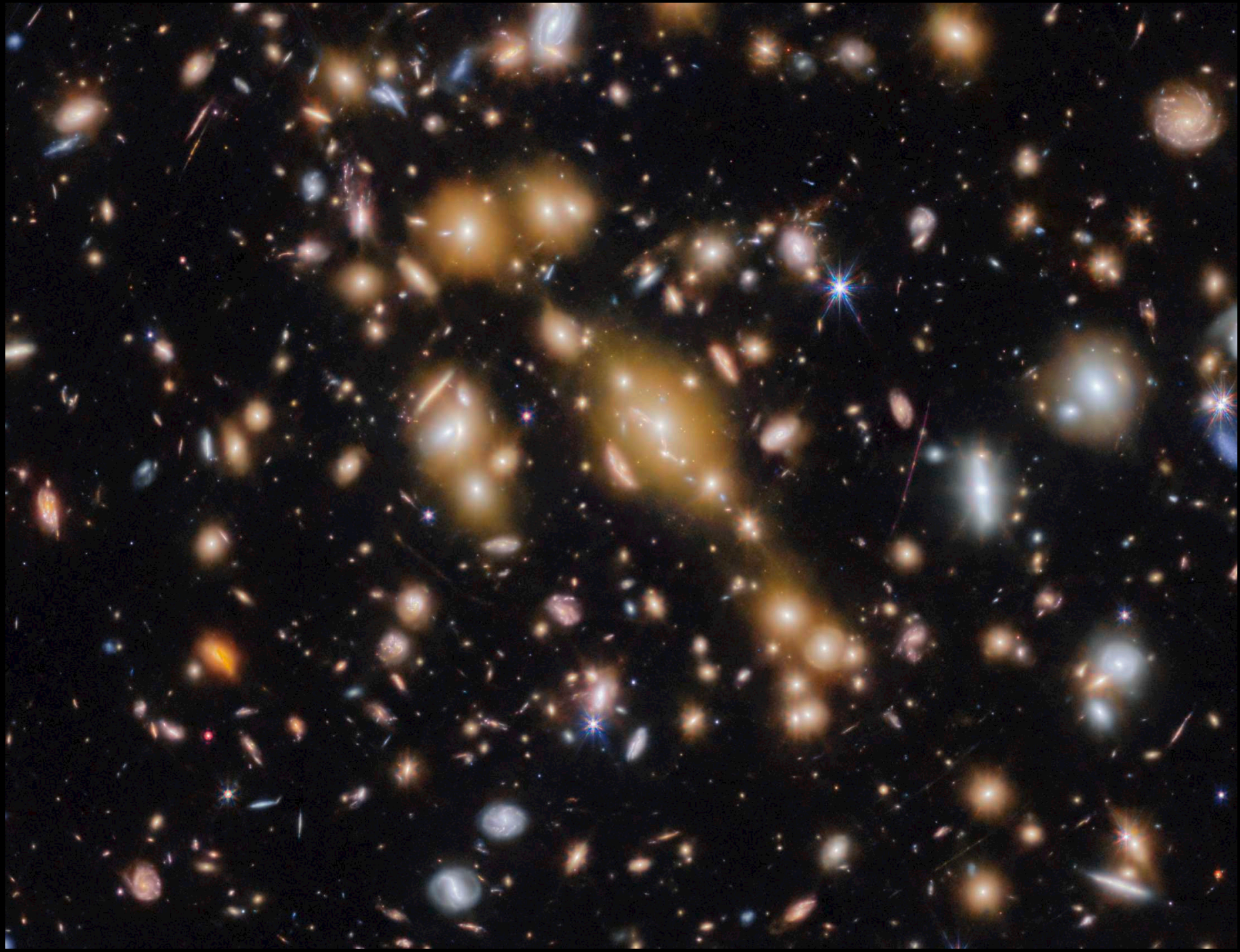




Abell 370 Dragon's arc: 44 individual caustic-transiting stars at z=0.73!

→ Detect stars at z≳0.7 directly, going across infinity lines! (Y. Fudamoto+, *Nat. Astr. 9, 428*).

1 Cor 13:12: "Now we see but a poor reflection as in a mirror; then we shall see face to face ..."



z=0.97 cluster SPT0615: lenses young globular clusters at z=10.2 !

Adamo^{+} (Nature; astro-ph/1401.03224): ∼50 Myr old, formed at z∼11! https://esawebb.org/news/weic2418/

- $z \gtrsim 1$ universe is littered with galaxy mergers and supermassive black holes!

2 Sam 7:11: " ... the LORD himself will establish a house for you ..."

Jer. 32:37: "I will bring them back to this place and let them live in safety"

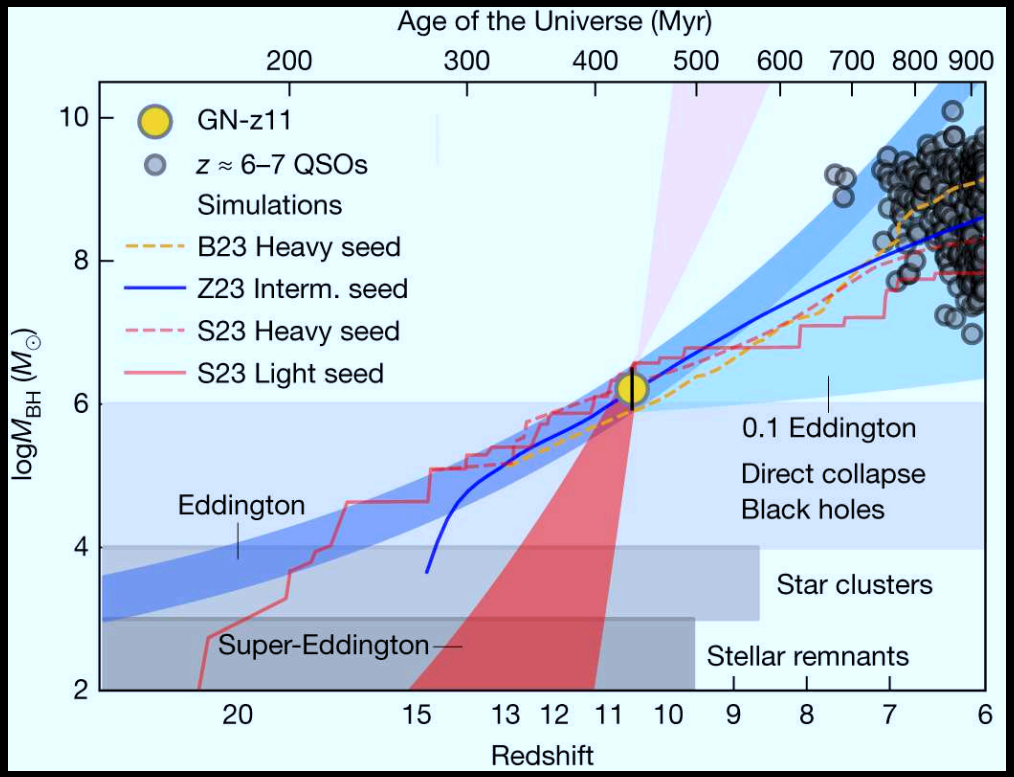
Jer. 29:11: " ... and not to harm you, plans to give you hope and a future."

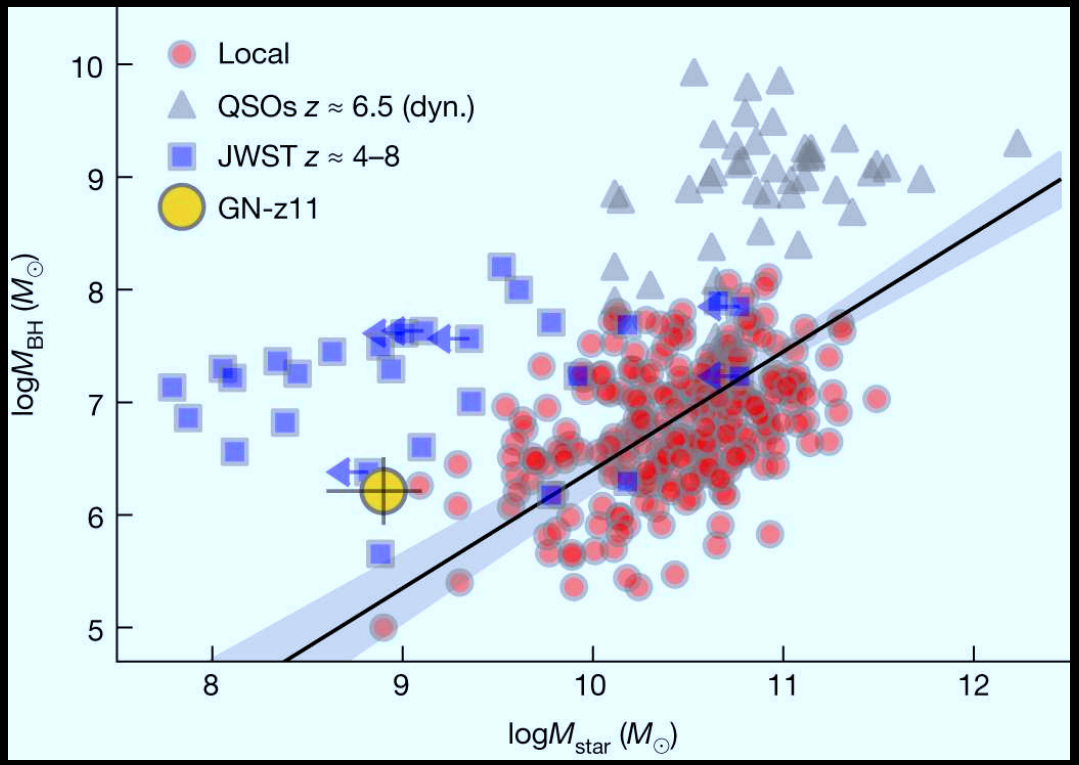
Thank God: we live in a $boring$ galaxy away from major mergers & SMBHs!

May 27, 2025: Deepest 120 hr JWST cluster image of Abell S1063 (z=0.351)!

Einstein's cosmic house of mirrors: many galaxies with supermassive black holes!

Atek+ (2025): https://www.esa.int/ESA_Multimedia/Images/2025/05/Webb_glimpses_the_distant_past





[Left] (Super Massive) Black Hole growth may start before z≃20 (175 Myr).

[Right] This results in overweight SMBHs compared to their host galaxies at z≃4–8 ($i.e.$, in the first 0.6–1.5 Byr)! (Maiolino+2024, Nature, 627, 59)

Who came first: chicken (Galaxy) or egg (SMBH)?: Most certainly the egg!

Psalm 74:20: "Have regard for your covenant, because haunts of violence fill the dark places of the land."

(3) Summary and Conclusions

(1) Webb was successfully built, tested and finally launched in Dec. 2021.

(2) Webb's first images trace the "Cosmic Circle of Life":

- Formation and evolution of stars and dust over cosmic time.
- How dust helped form exoplanets and building blocks for life.

(3) Webb is observing the epochs of First Light, Galaxy Assembly & Super Massive Black Hole-growth in detail (much through lensing):

- Formation of the first stars, star-clusters, SMBH's after 0.2 Byr.
- How galaxies formed and evolved over 13.5 Billion years.

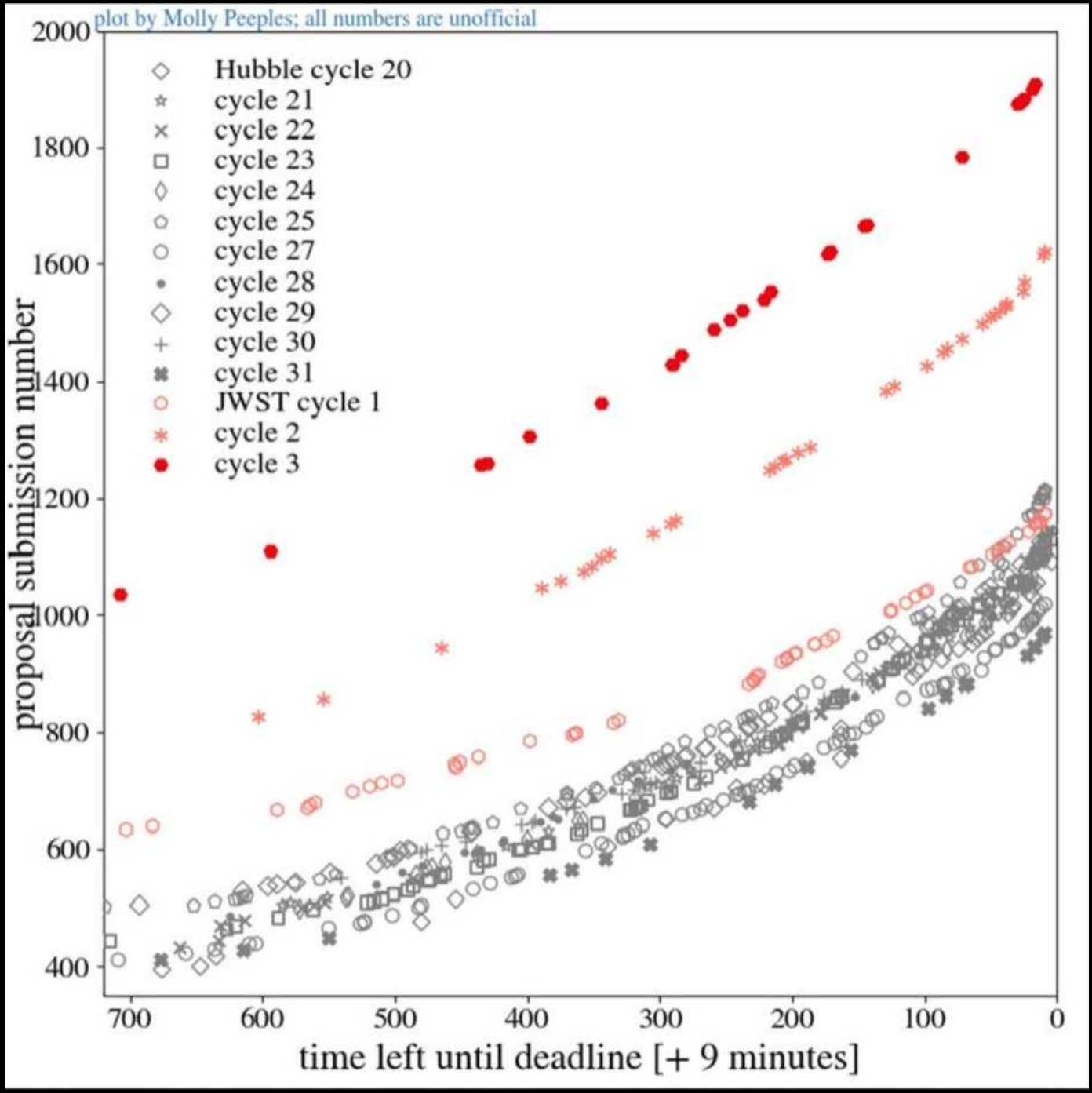
(4) Webb has shown us our proper place in the universe:

- From cosmic dust we were made, and to cosmic dust we shall return!
- We are cosmic later bloomers, and live in a cosmic quiet place !

SPARE CHARTS

With many thanks to Brad DeSandro, Jessica Berkheimer, and Rafael Ortiz for suggestions

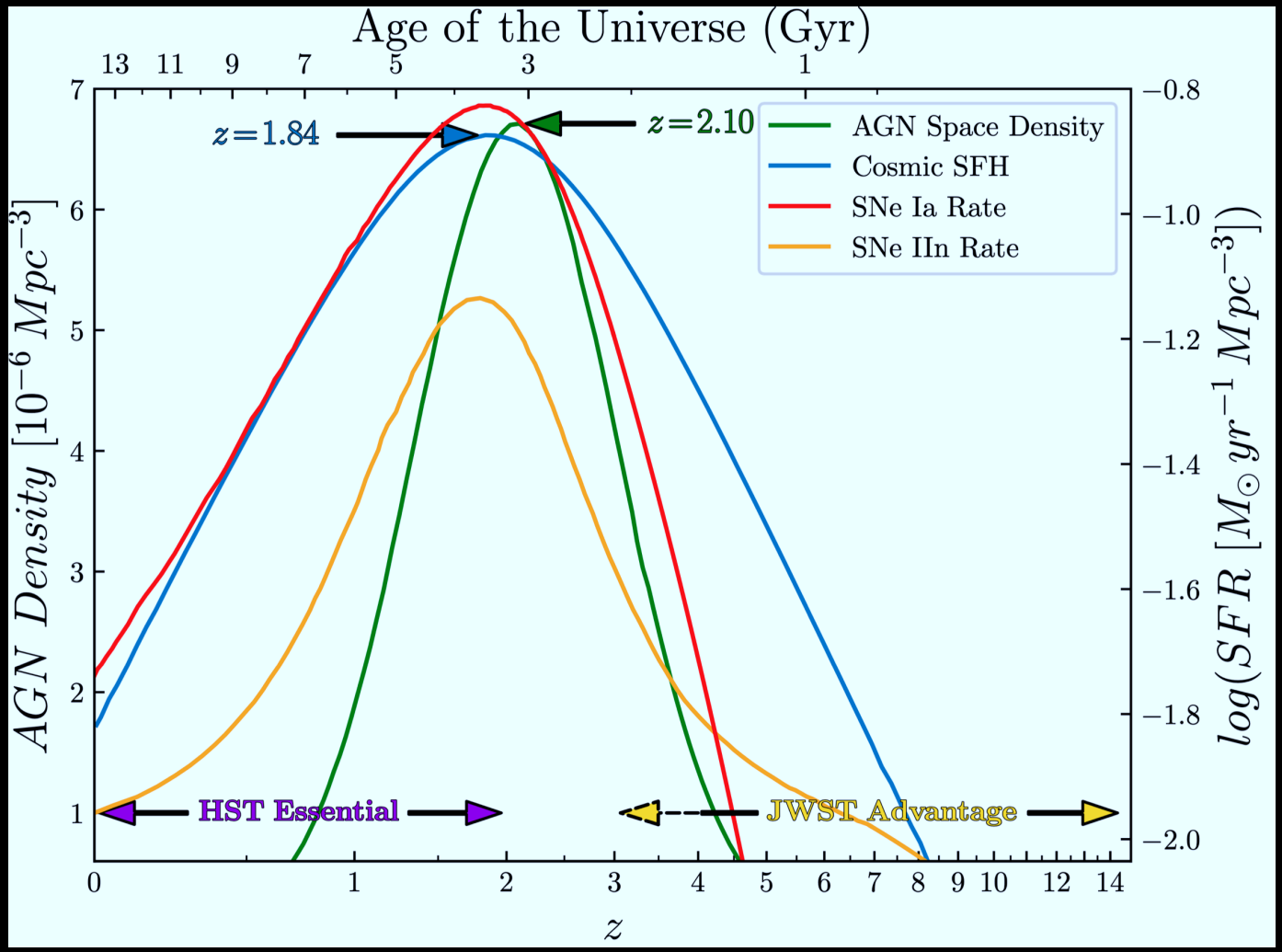
Any (space) mission is a balance between what science demands, what technology can do, and what budget & schedule allows ... (courtesy Prof. R. Ellis).



- Webb is now THE highest-in-demand NASA Flagship mission ever, but Hubble remains in at least as high a demand as it was 30 years ago!

Windhorst et al.

astro-ph/2410.01187



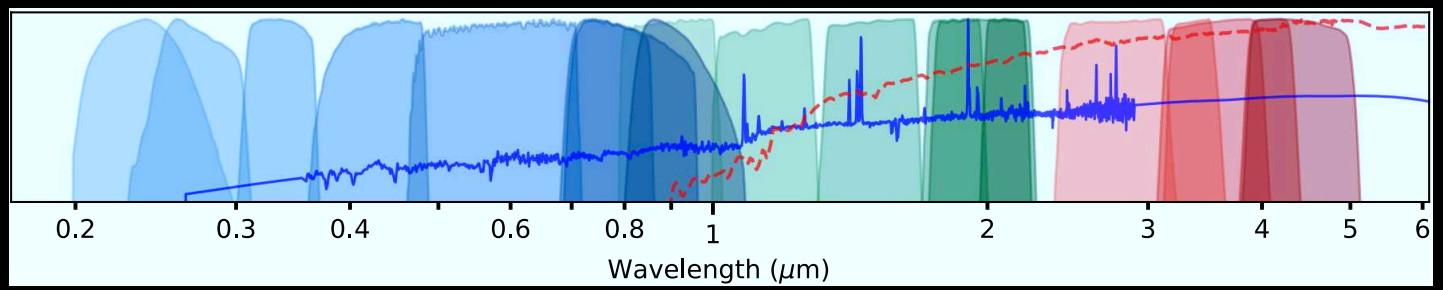
$\mathbf{Age} \sim \frac{13.8}{(1+z)} + \ldots\ \mathbf{Gyr}$

Active galactic nuclei (AGN)

$\Longleftrightarrow$ BH accretion disks

$\Longleftrightarrow$ Chandra X-ray sources

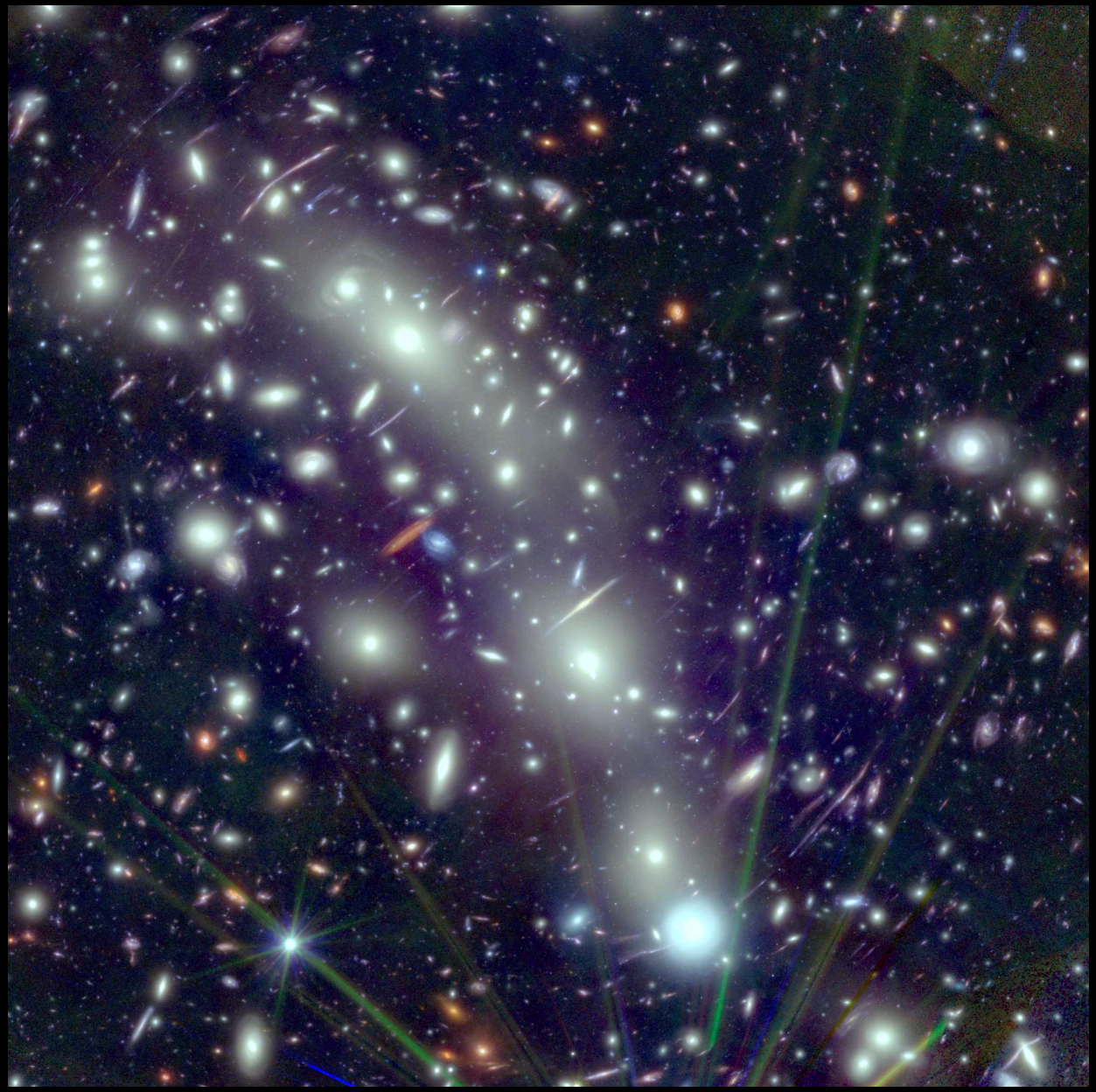
Star Formation, Supernova Rate, & Black Hole growth peak $\sim$10 Gyr ago!



$\Rightarrow$HST best samples *unobscured* SFH & BH growth in last 10 Gyr ($z \lesssim 2$),

while JWST best samples *obscured* parts, especially in first 3 Gyr ($z \gtrsim 3$).

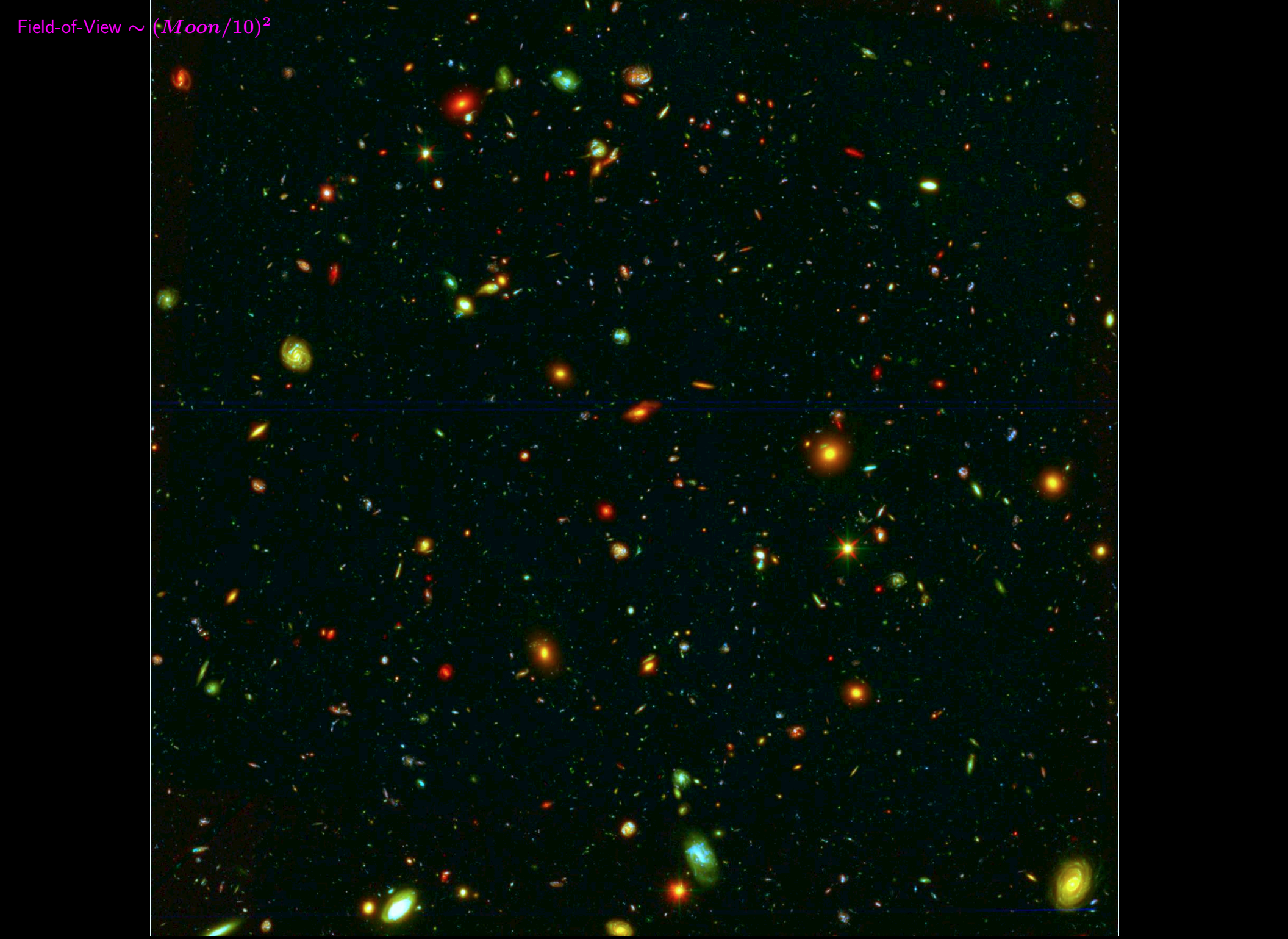
(5) Uniquely complementary roles of Hubble and Webb:



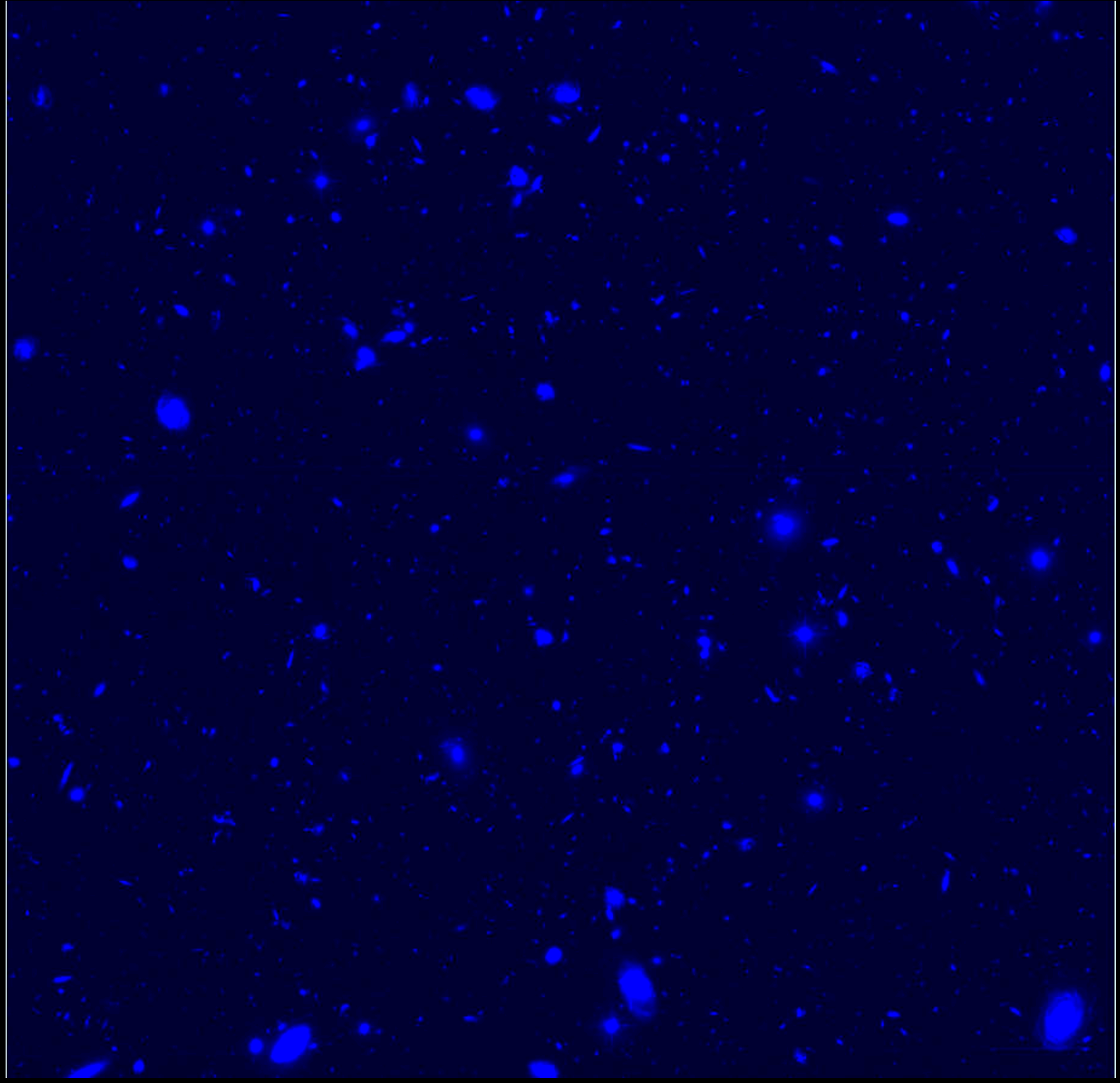
500 hrs HST+JWST: 45 filters (0.2–5.0μm), lensing cluster MACS0416:

- HST darkest skies (10-$10^3\times$ darker) + JWST's dark skies (10^3–$10^5\times$ darker than ground based):

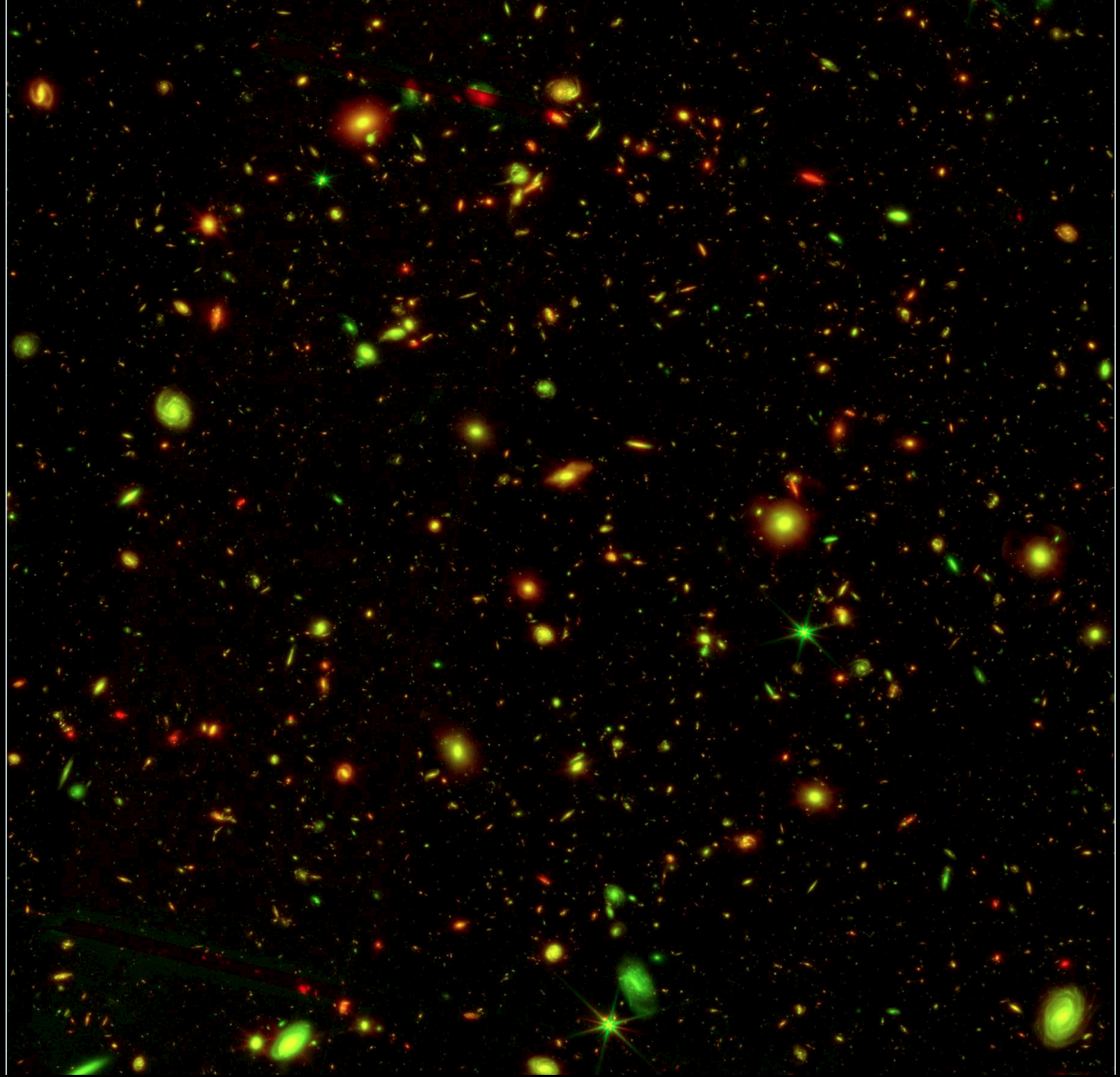
$\Longrightarrow$ HST & JWST reach 30–31 mag ($\simeq$1 nJy $\simeq$1 firefly from Moon).



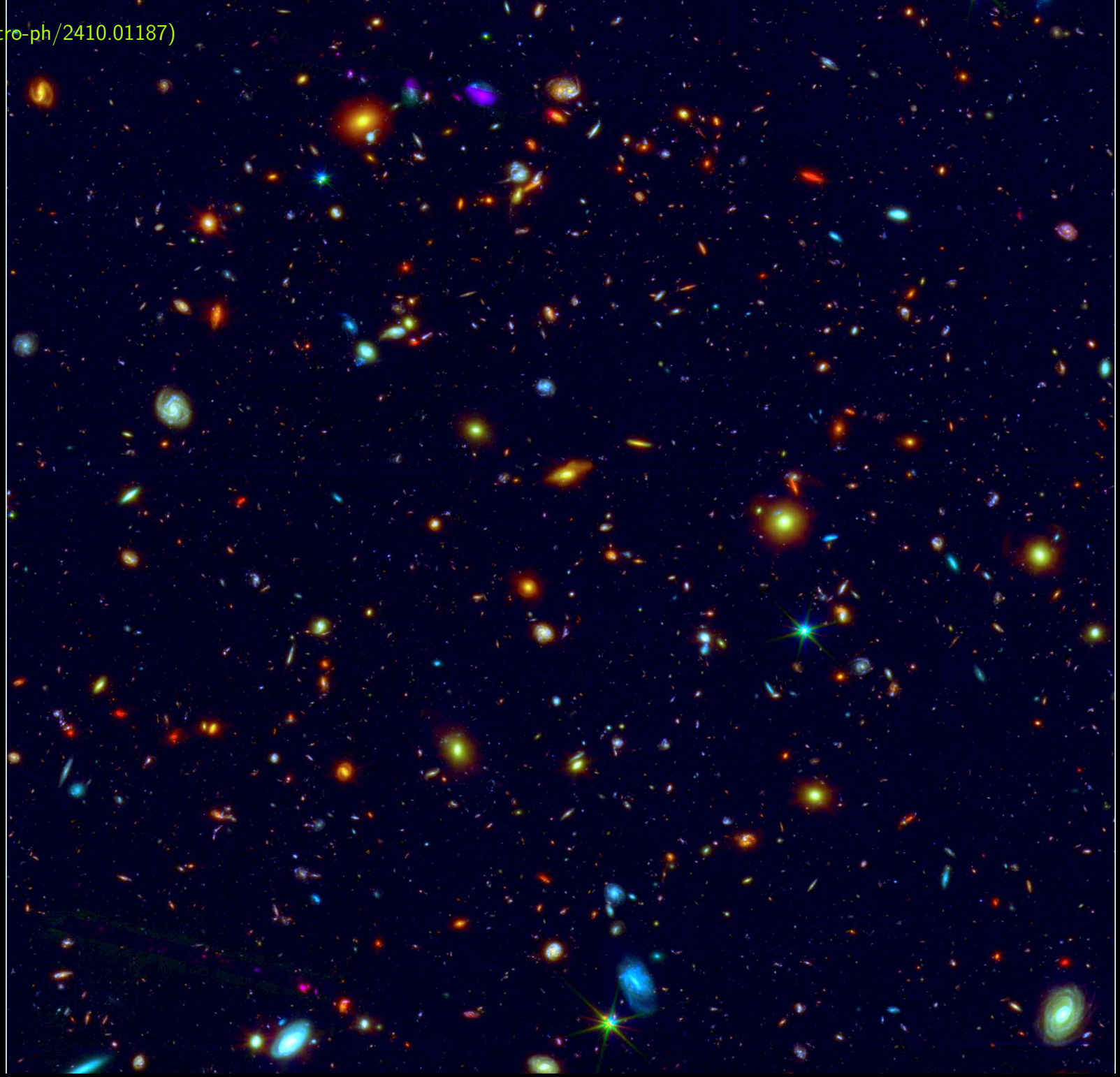
556 hr HST Hubble UltraDeep Field: 12 filters at 0.2–1.6 μm (AB$\lesssim$31 mag; $\sim$1 nJy; full BGR).



361 hr HST Hubble UltraDeep Field: 8 HST-unique filters 0.2–0.9 μm (in false color blue).

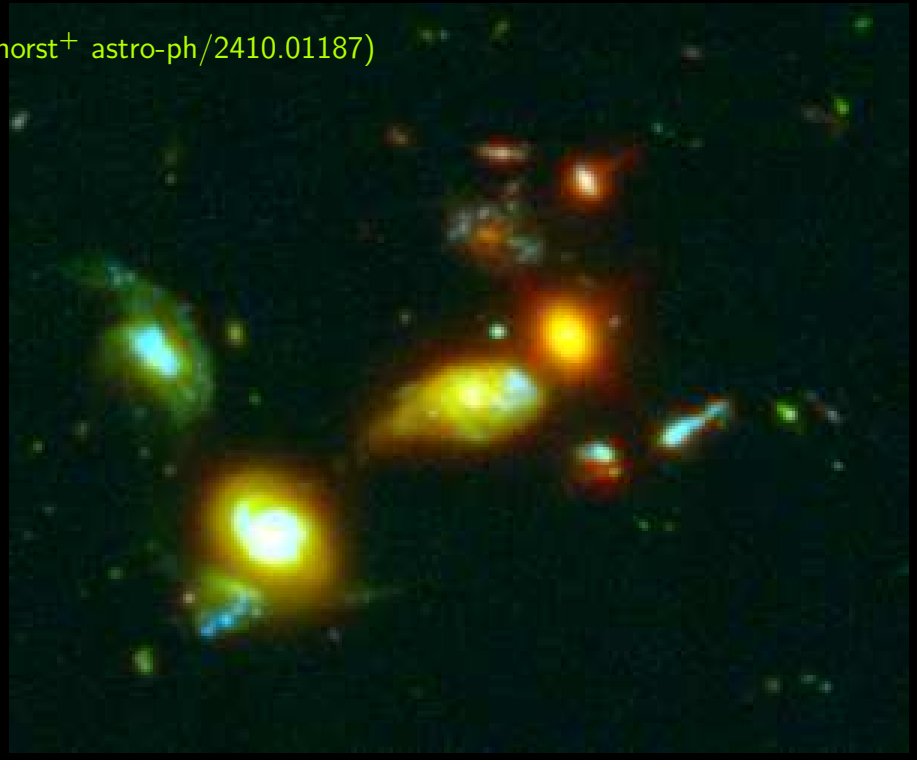


53 hr JWST/NIRCam Hubble UltraDeep Field: 12 filters at 0.9–5.0 μm (AB$\lesssim$31 mag; in green + red).

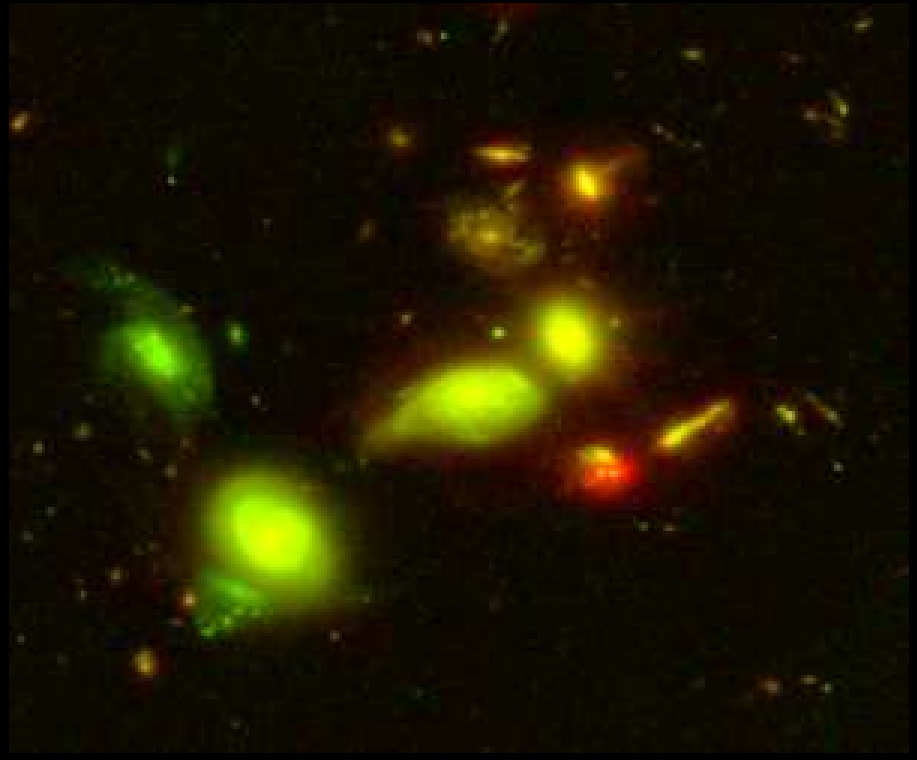


414 hr HST+JWST Hubble UltraDeep Field: 20 filters at 0.2–5.0 μm (AB$\lesssim$31.5 mag; full BGR).

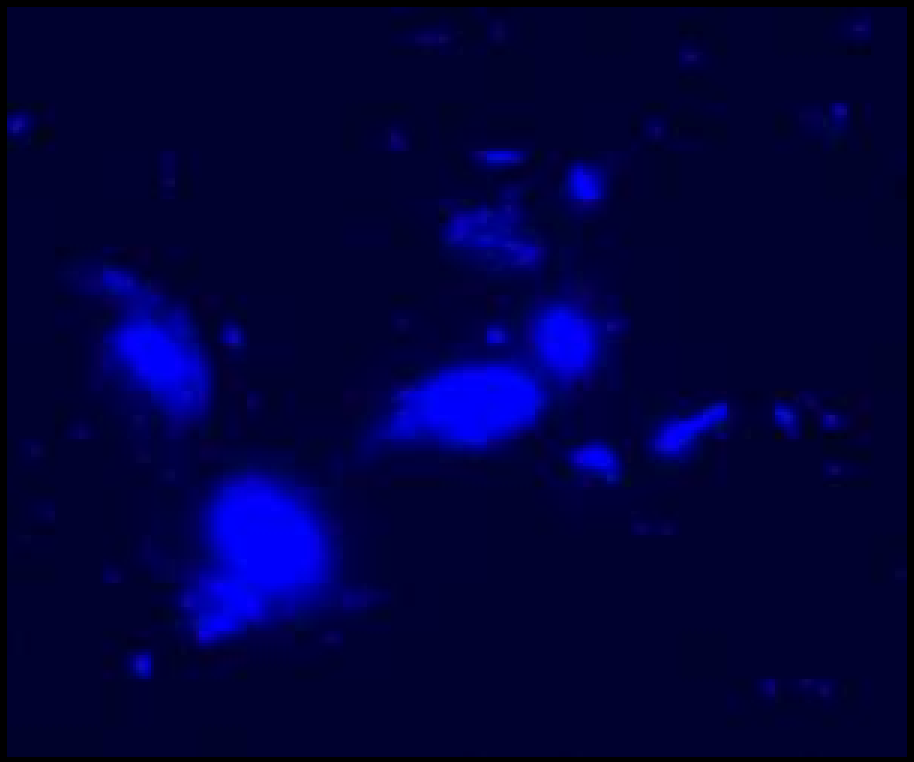
(Windhorst+ astro-ph/2410.01187)



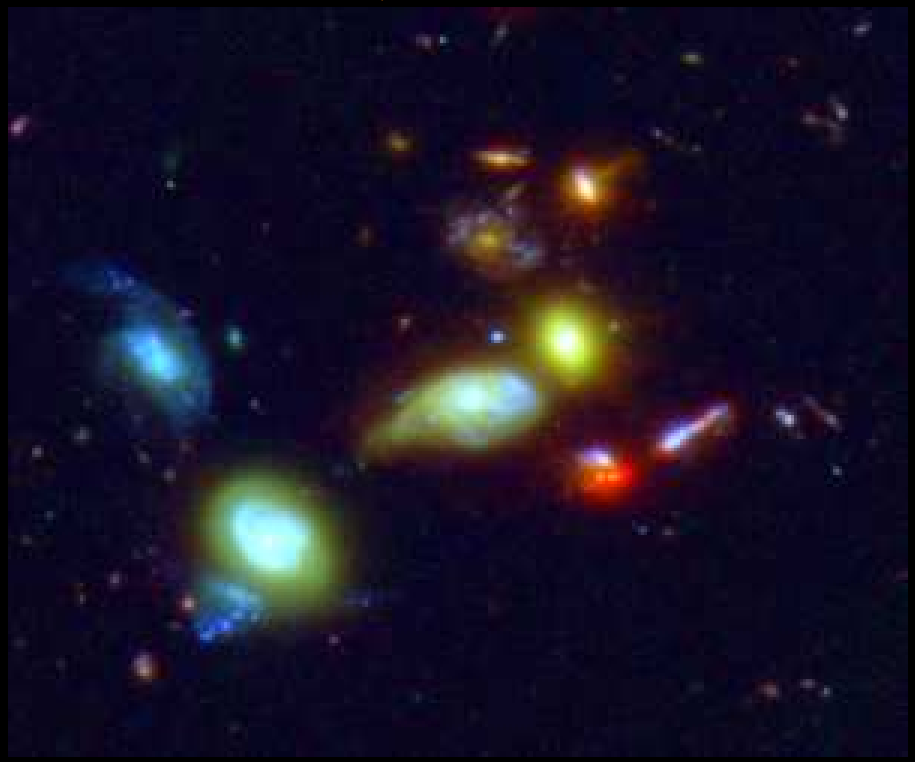
556 hr HST HUDF 12 filters



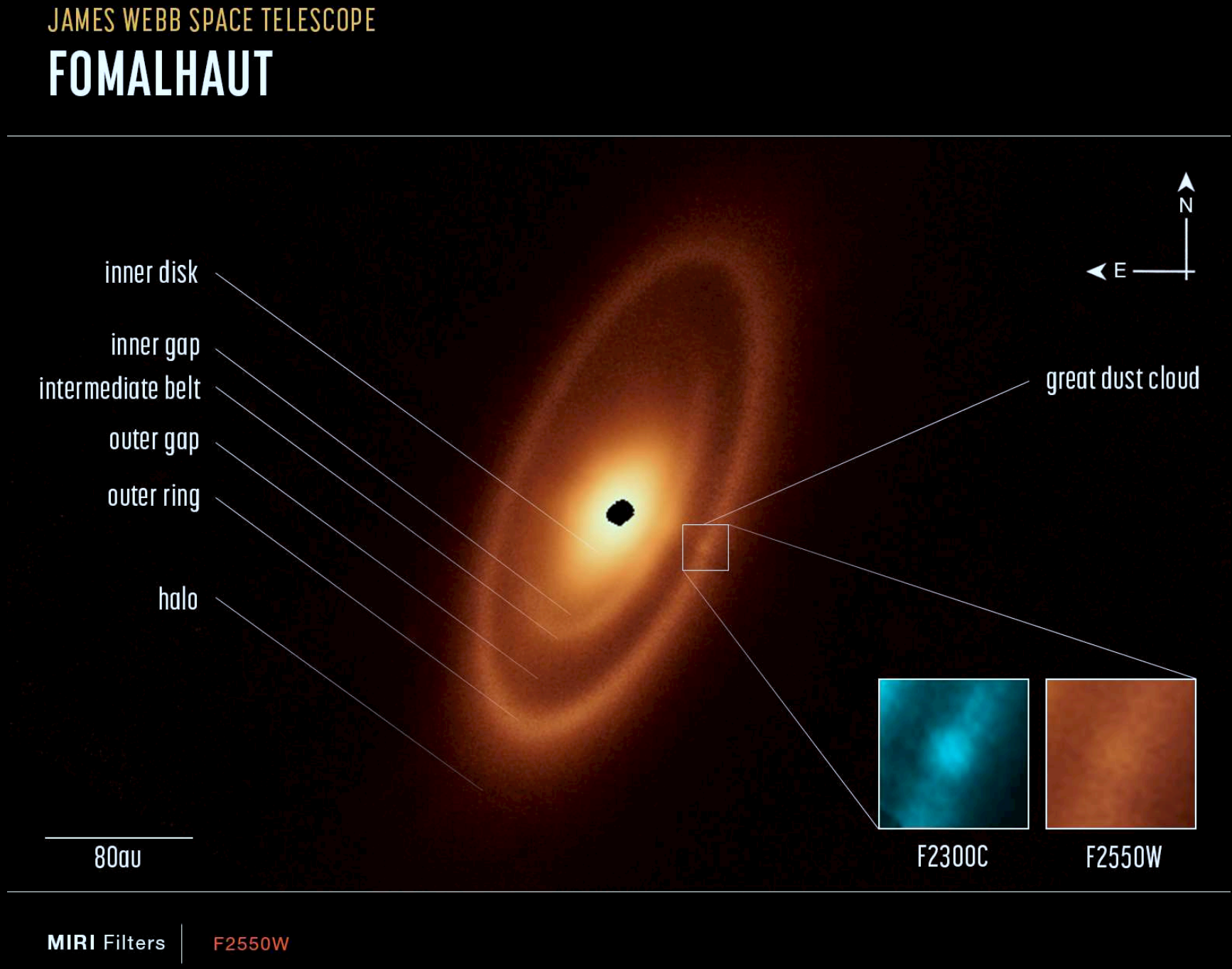
53 hr JWST/NIRCam 12 filters



361 hr 8 HST-unique filters (false-blue)

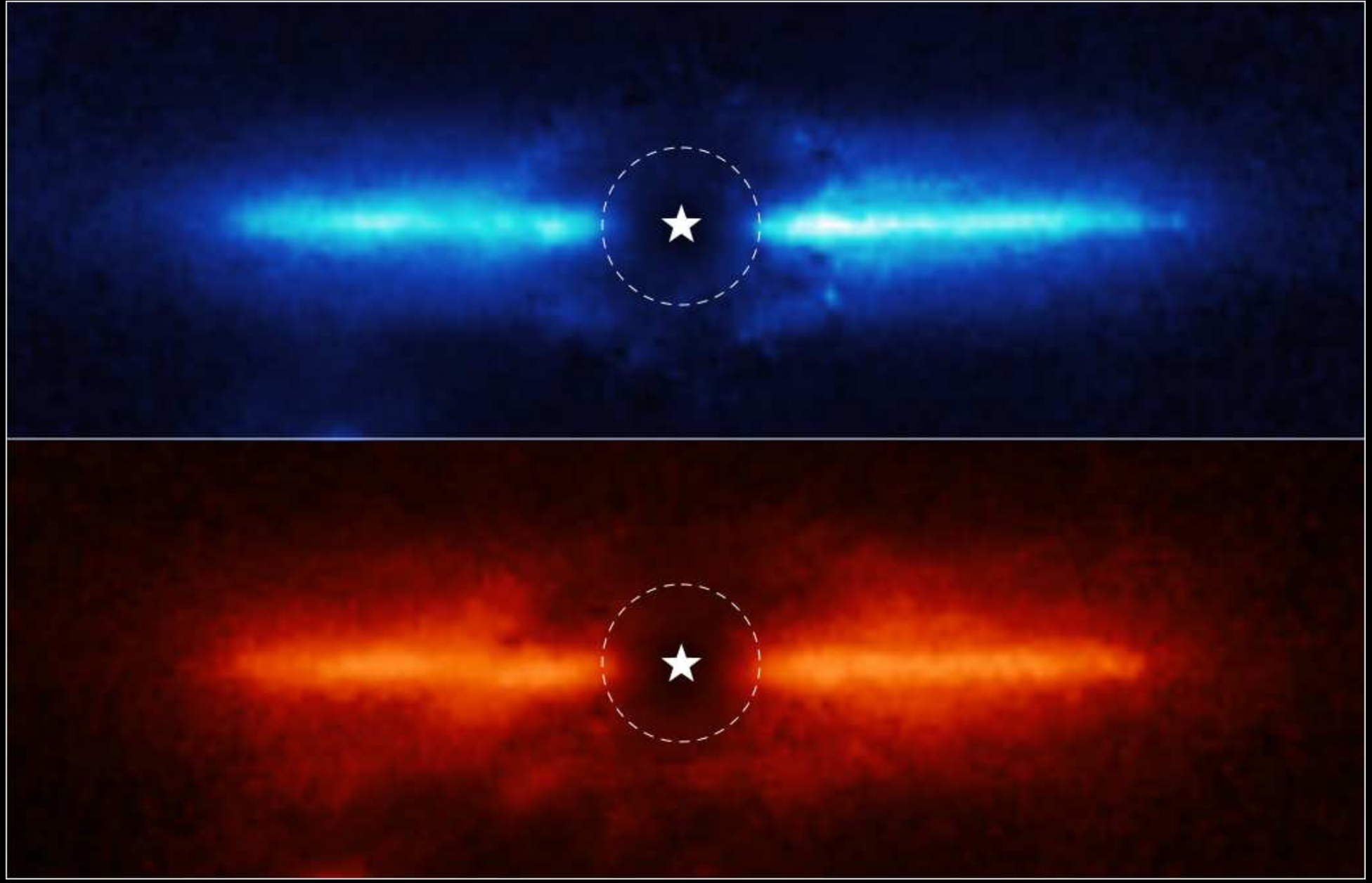


414 hr HST+JWST 20 filters



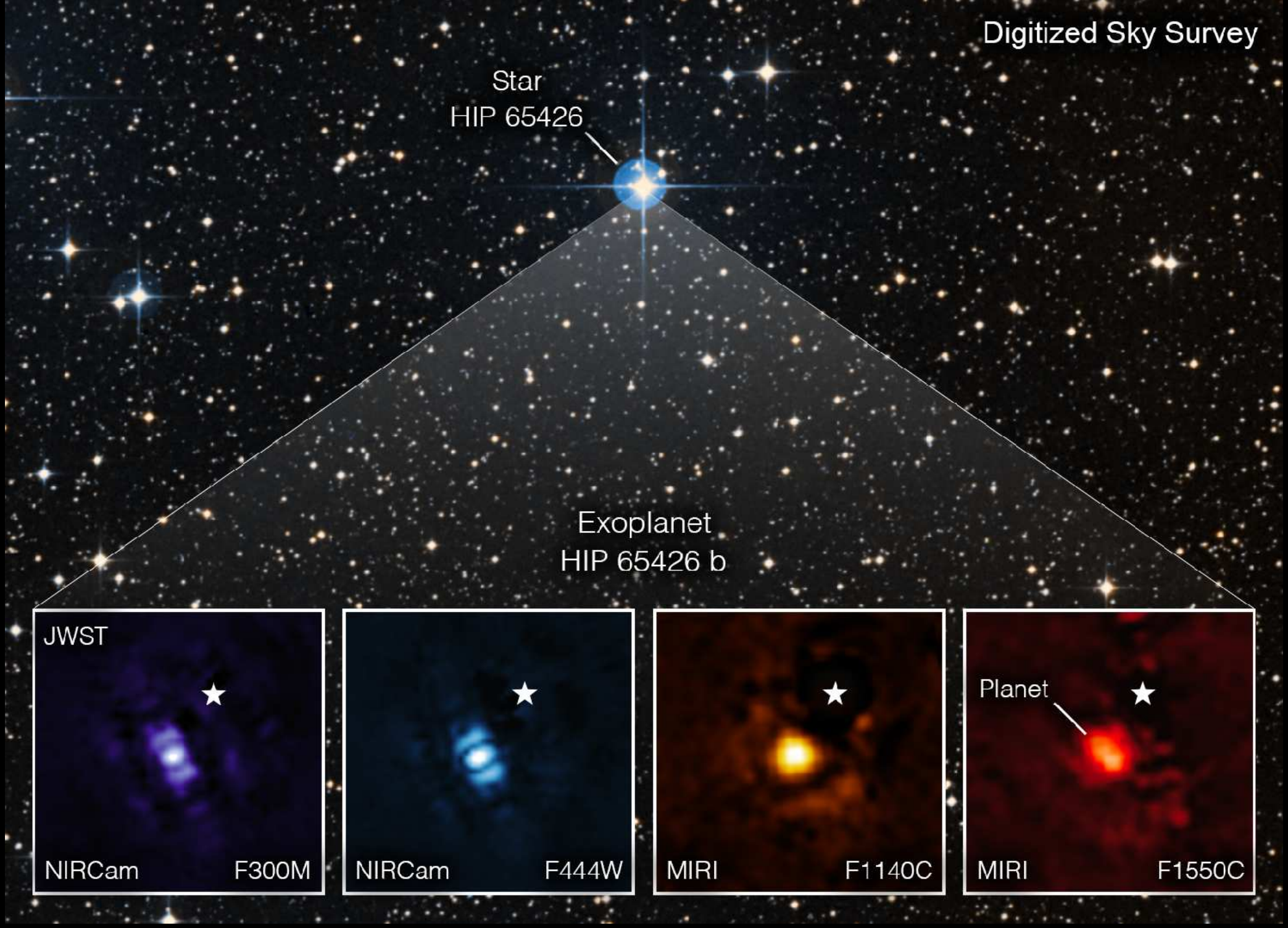
JWST MIRI Coronagraph: Debris disk around nearby star Fomalhaut:

- This is how the giant planets and terrestrial planets formed around our Sun

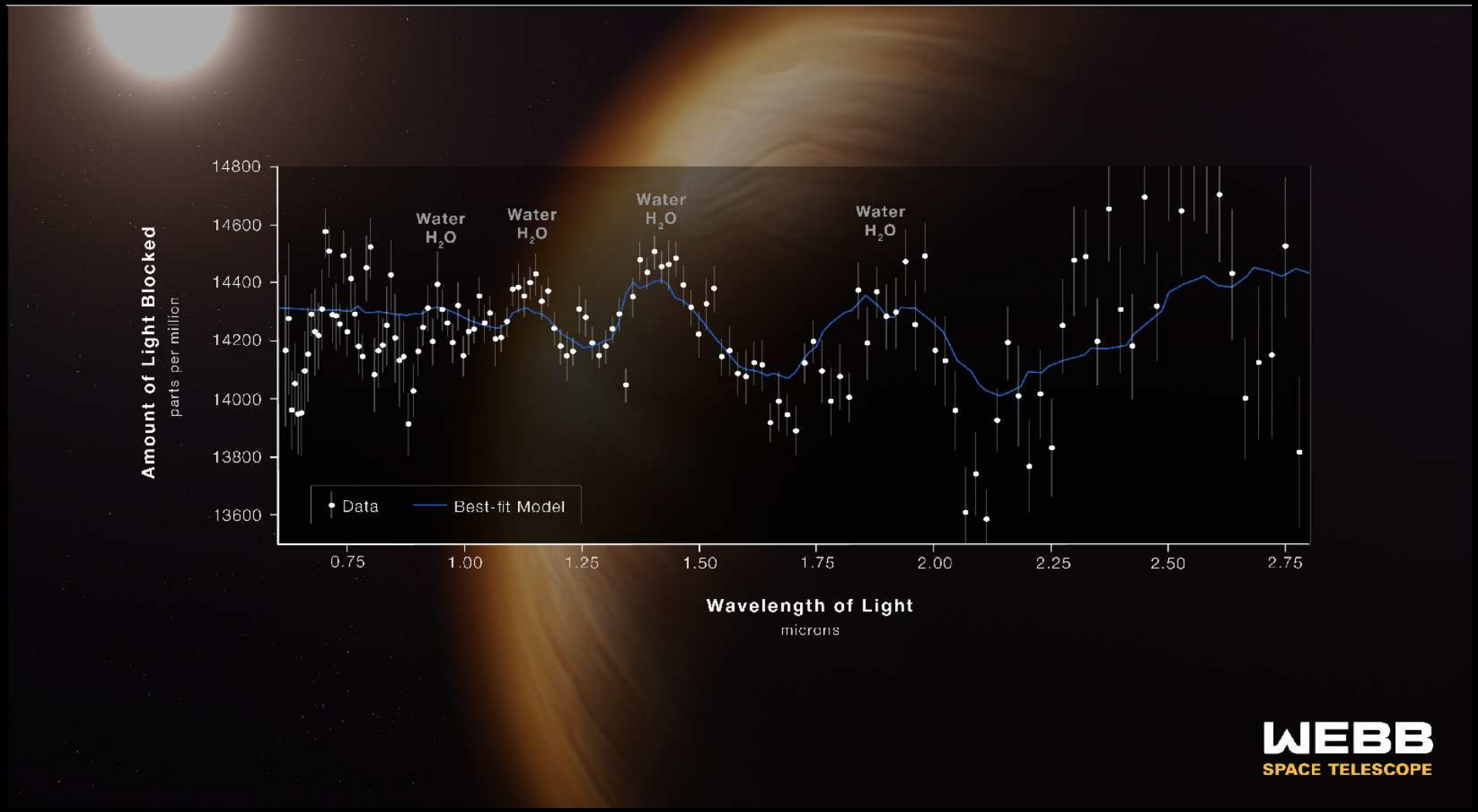


Dusty debris disk around red dwarf star AU Mic at 32 light-years:

- NIRCam's Coronagraph blocks the central star-light.
- Debris disk visible at 5–60 AU, $i.e.$, slightly larger than Solar System.



Webb 3–15 micron exoplanet images (10 Jupiter masses; 15 Myr young!)



Hot exoplanet WASP-96b orbiting a Sun-like star (1150 light-years):

- Near-IR spectrum shows characteristic features of water (steam !).
- It has a temperature of 1000 F and is half Jupiter in mass.
- Webb will scan Earth-like exoplanets for building blocks of life.

(1) SCIENCE IMPACT BY THE HST & JWST COMMUNITY (Feb. 2025):

- HST: $\gtrsim$500–1000 refereed papers/year by the community since 1990.
- 45,900 HST papers on ADS, 948,800 citations since 1990, h$_{\boldsymbol{HST}}$=322!
- JWST: over 2300 refereed papers (57k cites), since July 2022 alone!
- In year 1-3: JWST already outdoing HST's yearly production.

(2) NEWS RELEASES BY THE HST & JWST COMMUNITY (Feb 2025):

- NASA's Hubble Space Telescope (HST) had 1,100 science press releases since 1990, each with $\gtrsim$400 million readers (or impressions) worldwide.
- $\sim$480$\times10^9$ reads (or impressions) of Hubble press releases in total $\Rightarrow$
- $On\ average$ each human on Earth would have read $\gtrsim$60 Hubble stories during their lifetimes.
- HST is the most publicized space astrophysics mission in NASA history.
- JWST: $\gtrsim$170 press releases since 2022, each 0.5–1 billion readers.
- JWST is now the most-in-demand space mission in NASA history.
- ASU Cosmology: 10 billion readers from $\gtrsim$10 releases since 2022 (URL).

Related papers, press releases and other URLs

Talk: http://www.asu.edu/clas/hst/www/jwst/catholic_sc_jun25_jwst.pdf Data: https://sites.google.com/view/jwstpearls

https://hubblesite.org/contents/news-releases/2022/news-2022-050

https://blogs.nasa.gov/webb/2022/10/05/webb-hubble-team-up-to-trace-interstellar-dust-within-a-galactic-pair/

https://blogs.nasa.gov/webb/2022/12/14/webb-glimpses-field-of-extragalactic-pearls-studded-with-galactic-diamonds/

https://esawebb.org/images/pearls1/zoomable/

https://webbtelescope.org/contents/news-releases/2023/news-2023-119

https://news.asu.edu/20230801-jwsts-gravitational-lens-reveals-distant-objects-behind-el-gordo-galaxy-cluster

https://hubblesite.org/contents/news-releases/2023/news-2023-146

https://www.nytimes.com/2023/12/19/science/christmas-stars-galaxies-webb-nasa.html?

https://blogs.nasa.gov/webb/2024/10/01/ & https://bigthink.com/starts-with-a-bang/triple-lens-supernova-jwst/

Adams, N. J., Conselice, C. J., Austin, D., et al. 2024, ApJ, 965, 169 (astro-ph/2304.13721v1)

Austin, D., Conselice, C. J., Adams, et al. 2024, ApJ, submitted (astro-ph/2404.10751)

Berkheimer, J. M., Carleton, T., Windhorst, R. A., et al. 2024, ApJ, 964, L29 (astro-ph/2310.16923v2)

Carleton, T., Windhorst, R. A., O'Brien, R., et al. 2022, AJ, 164, 170 (astro-ph/2205.06347)

Carleton, T., Cohen, S. H., Frye, B., et al. 2023, ApJ, 953, 83 (astro-ph/2303.04726)

Diego, J. M., Meena, A. K., Adams, N. J., et al. 2023, A&A, 672, A3 (astro-ph/2210.06514)

Diego, J. M., Sun, B., Yan, H., et al. 2023, A&A, 679, A31 (astro-ph/2307.10363)

Diego, J. M., Adams, N. J., Willner, S., et al. 2024, A&A, 690, 114 (astro-ph/2312.11603)

Diego, J. M., Li, S. K., Amruth, A., et al. 2024, A&A, 690, A359 (astro-ph/2404.08033)

D'Silva, J. C. J., Driver, S. P., Lagos, C. D. P., et al. 2024, ApJL, 959, L18 (astro-ph/2310.03081v1)

D'Silva, J. C. J., Driver, S. P., Lagos, C. D. P., et al. 2025, A&A (astro-ph/2503.03431)

Duncan, K. J., Windhorst, R. A., et al. 2023, MNRAS, 522, 4548–4564 (astro-ph/2212.09769)

Frye, B. L., Pascale, M., Foo, N., et al. 2023, ApJ, 952, 81 (astro-ph/2303.03556)

Frye, B. L., Pascale, M., Pierel, J., Chen, W., Foo, N., et al. 2024, ApJ, 961, 171 (astro-ph/2309.07326v1)

Kamieneski, P. S., Frye, B. L., Pascale, M., et al. 2023, ApJ, 955, 91 (astro-ph/2303.05054)

Fudamoto, Y., Sun, F., Diego, J. M., et al. 2025, Nature Astron., 9, 428 (astro-ph/2404.08045)
Kamieneski, P. S., Frye, B. L., Windhorst, R. A., et al. 2024, ApJ, 973, 25 (astro-ph/2404.08058)
Keel, W. C., Windhorst, R. A., Jansen, R. A., et al. 2023, AJ, 165, 166 (astro-ph/2208.14475)
Kramer, D. M., Carleton, T., Cohen, S. H., et al. 2022, ApJL, 940, L15 (astro-ph/2208.07218v2)
O'Brien, R., Carleton, T., Windhorst, R. et al. 2023, AJ, 165, 237 (astro-ph/2210.08010)
O'Brien, R., Jansen, R. A., Grogin, N. A., et al. ApJS, 272, 19 (astro-ph/2401.04944)
Ortiz, III, R., Windhorst, R. A., Cohen, S. H., et al. 2024, ApJ, 974, 258 (astro-ph/2404.10709)
Pascale, M., Frye, B., Pierel, J., et al. 2025, ApJ, 979, 13 (astro-ph/2403.18902)
Polletta, M. del Carmen, Nonino, M., Frye, B., et al. 2023, A&AL, 675, L4 (astro-ph/2306.12385)
Robertson, C., Holwerda, B. W., Young, J., et al. 2024, AJ, 167, 263 (astro-ph/2403.15619)
Smail, I., Dudzeviciute, U., Gurwell, M., et al. 2023, ApJ, 958, 36 (astro-ph/2306.16039)
Smith, B. M., Windhorst, R. A., Jansen, R. A., et al. 2018, ApJ, 853, 191 (astro-ph/1602.01555v2)
Smith, B. M., Windhorst, R. A., Cohen, S. H., et al. 2020, ApJ, 897, 41 (astro-ph/2004.04360v2)
Smith, B. M., Windhorst, R. A., Teplitz, H., et al. 2024, ApJ, 964, 73 (astro-ph/2401.03094)
Summers, J., Windhorst, R. A., Cohen, S. H., et al. 2023, ApJ, 958, 108 (astro-ph/2306.13037)
Wang, X., Teplitz, H. I., Smith, B. M., et al. 2025, ApJ, 980, 74 (astro-ph/2308.9064v1)
Willner, S. P., Gim, H. B., Polletta, M. et al. 2023, ApJ, 958, 176 (astro-ph/2309.13008)
Windhorst, R. A., Timmes, F. X., Wyithe, J. S. B., et al. 2018, ApJS, 234, 41 (astro-ph/1801.03584)
Windhorst, R. A., Carleton, T., O'Brien, R., et al. 2022, AJ, 164, 141 (astro-ph/2205.06214)
Windhorst, R. A., Cohen, S. H., Jansen, R. A., et al. 2023, AJ, 165, 13 (astro-ph/2209.04119)
Windhorst, R. A., Summers, J., Carleton, T., et al. 2025, J. BAAS, 57, 1, in press (astro-ph/2410.01187)
Yan, H., Cohen, S. H., Windhorst, R. A., et al. 2023, ApJL, 942, L8 (astro-ph/2209.04092)
Yan, H., Ma, Z., Sun, B., et al. 2023, ApJS, 269, 43 (astro-ph/2307.07579)