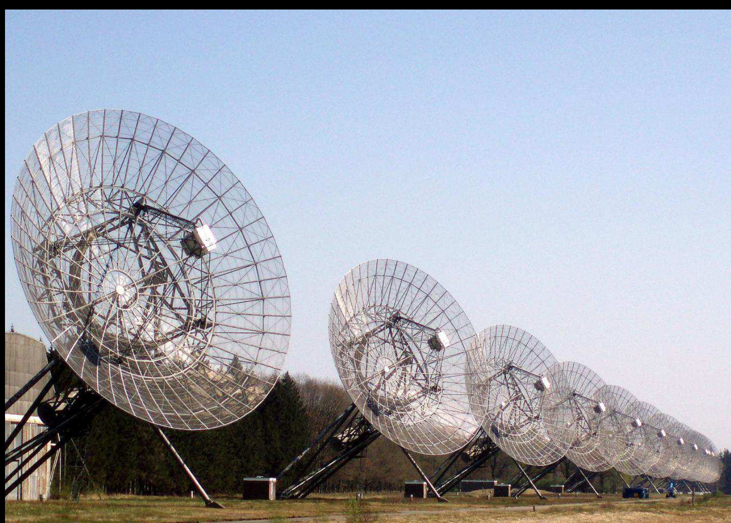
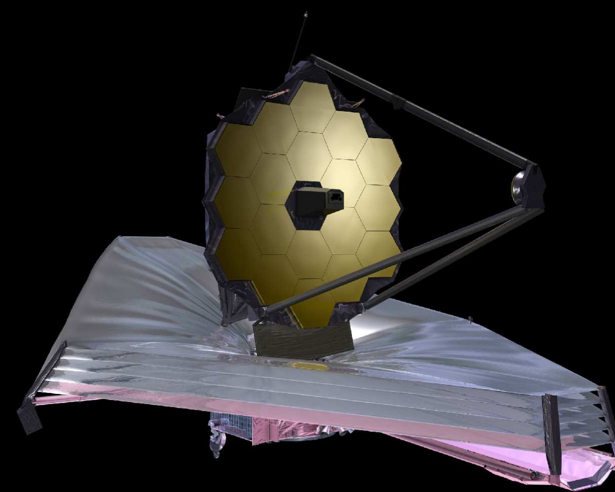
From Westerbork to the Webb Telescope: 40$^+$ years of Cosmic Star Formation & Supermassive Blackhole Growth

Rogier Windhorst (ASU) — JWST Interdisciplinary Scientist





Symposium honoring Prof. Harry van der Laan's 80th birthday

Sterrewacht Leiden; Saturday, October 8, 2016

- Harry van der Laan has been a truly outstanding mentor and teacher!
- He was “Chief Executive Officer” of Dutch astronomy for over a decade.
- He had the vision to involve NL in La Palma & Hawaii (see Jan’s talk).
- He laid the foundation of the successes of ESO/VLT (see Tim’s talk).
- Harry was always there for you when you personally needed him.

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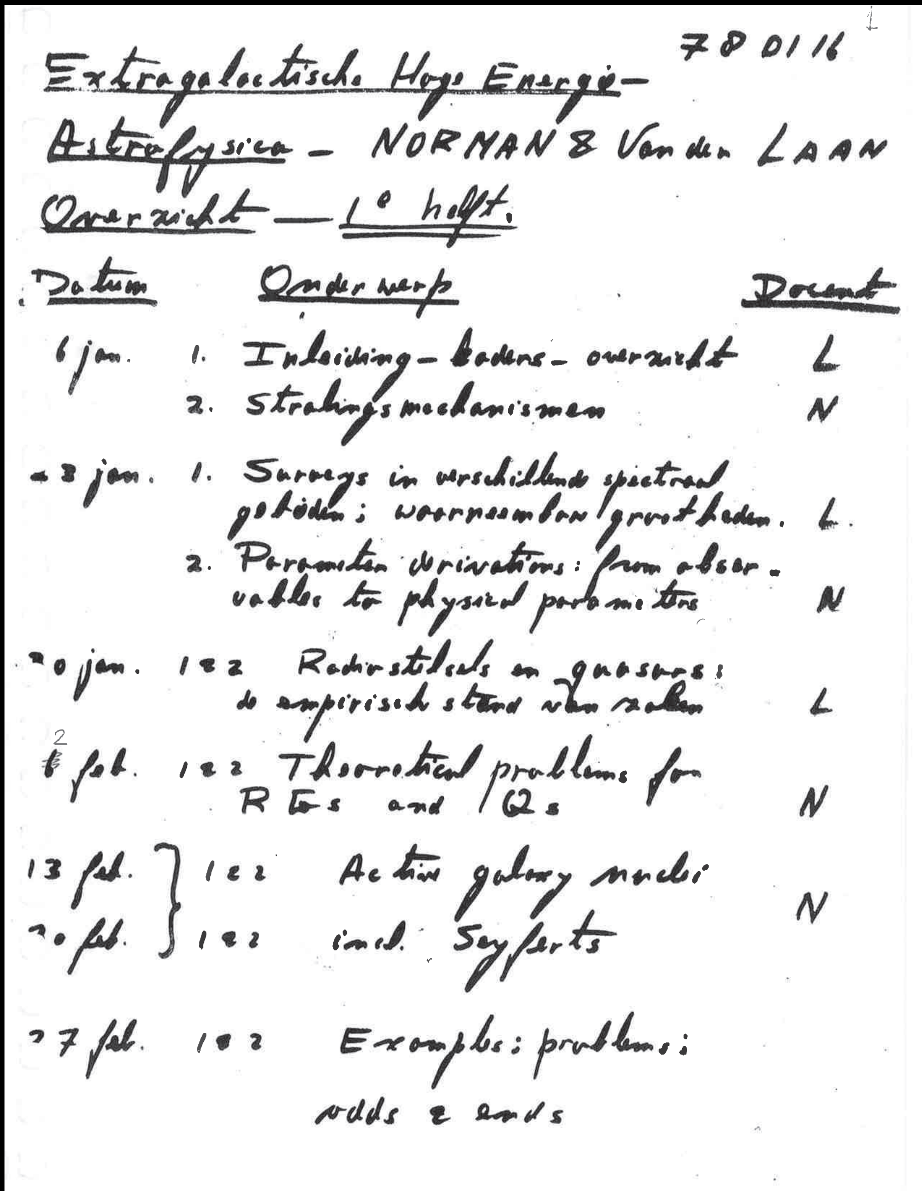
- He laid the foundation of the successes of ESO/VLT (see Tim's talk).
- Harry was always there for you when you personally needed him.
- Harry's lectures were great, once one learned how to read them:

Syllabus from Harry's 1978 course in Extragalactic High Energy Astrophysics: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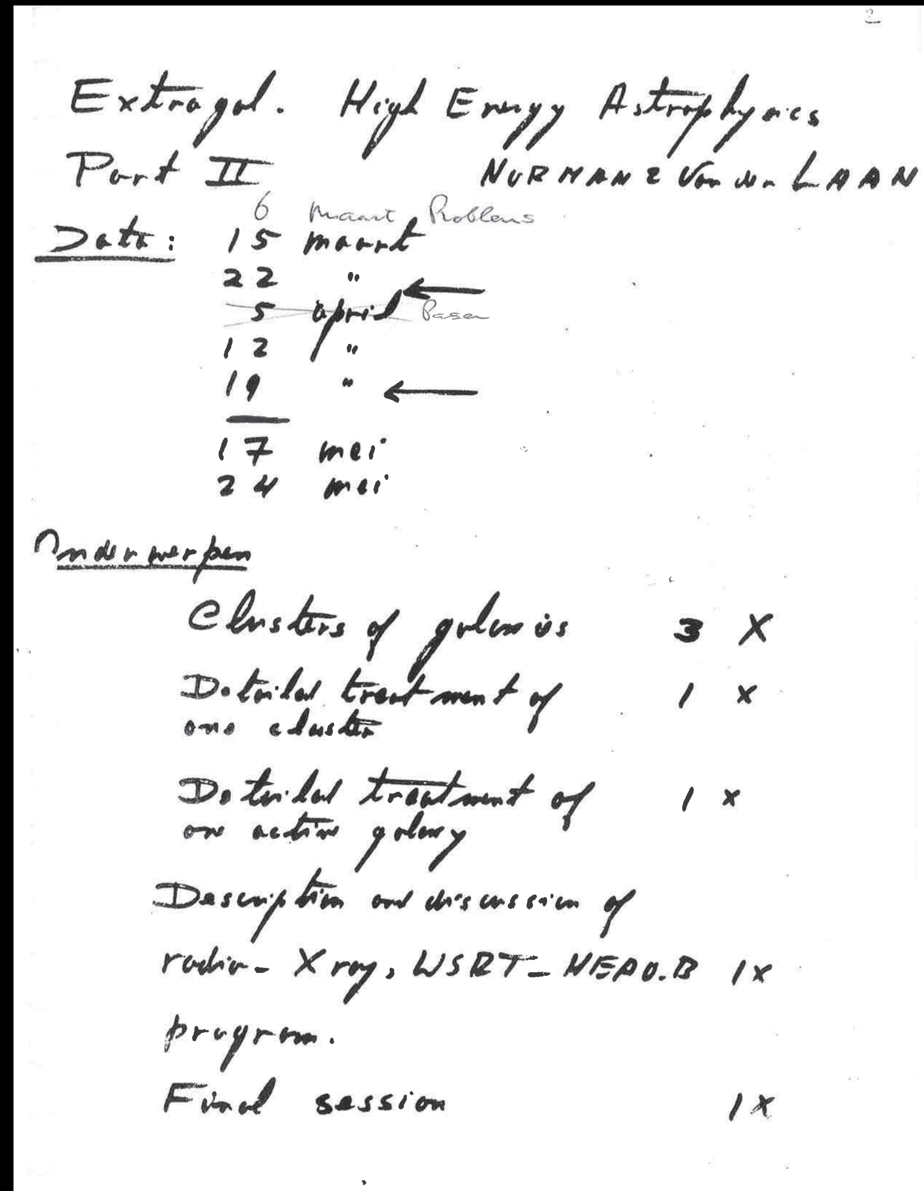
Extragalactische Hoge Energie-
Astrofysica – NORMAN & Van der LAAN
Overzicht — 1e helft.

Datum	Onderwerp	Docent
6 jan.	1. Inleiding – bodems – overzicht	L
	2. Stralingsmechanismen	N
13 jan.	1. Surveys in verschillende spectraal gebieden; waarneembare grootheden.	L.
	2. Parameter derivations: from observables to physical parameters	N
20 jan.	1 & 2 Radiostelsels en quasars: de empirische stand van zaken	L
2 feb.	1 & 2 Theoretical problems for RGs and Qs	N
13 feb.	1 & 2 Active galaxy nuclei	N
20 feb.	1 & 2 incl. Seyferts	
27 feb.	1 & 2 Examples: problems: odds & ends	


Extragal. High Energy Astrophysics
Part II NORMAN & Van der LAAN

Date: 6 maart Robbens
15 maart
22 "
~~5 april~~ Baan
12 "
19 "
17 mei
24 mei

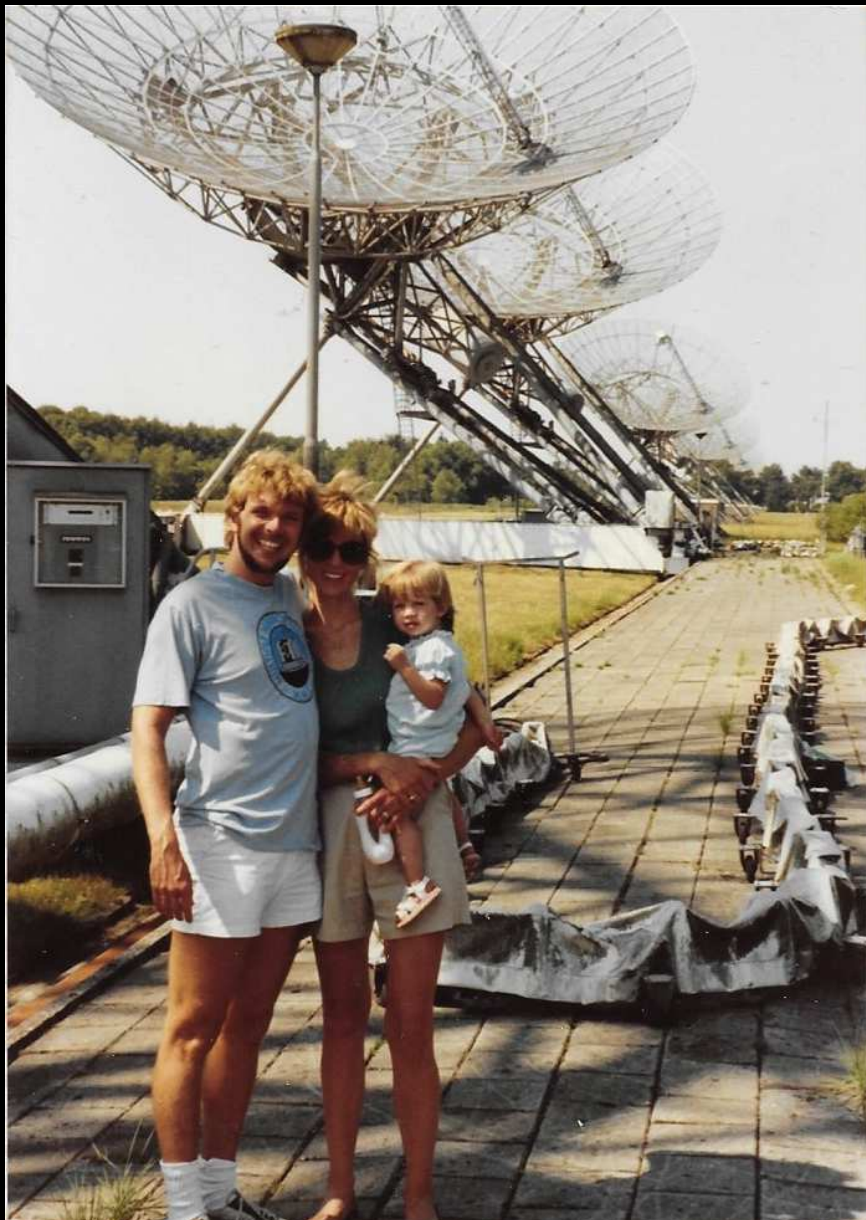
Onderwerpen

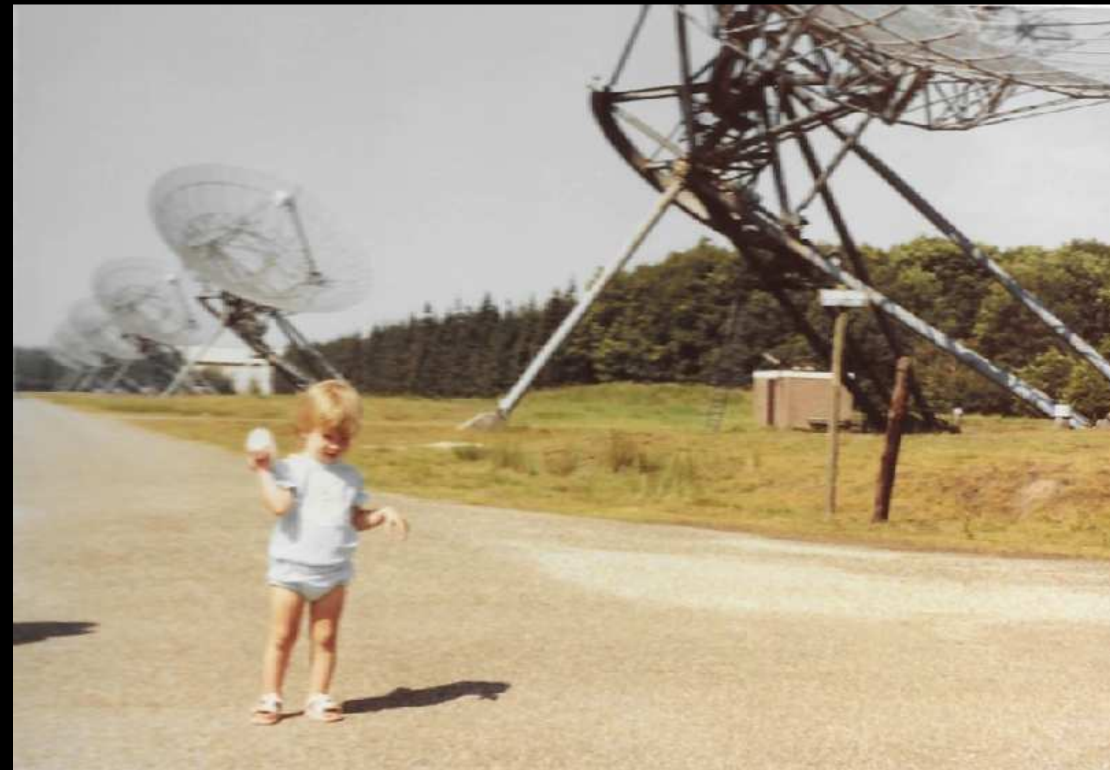
Clusters of galaxies	3 X
Detailed treatment of one cluster	1 X
Detailed treatment of one active galaxy	1 X
Description and discussion of radio- X ray, WSRT – HEAO.B program.	1X
Final session	1X

Harry's handwriting was not easy to read: we called it "Harry-oglyphics".

Harry wrote in big "Rooster-feet" or "Hane-poten"!

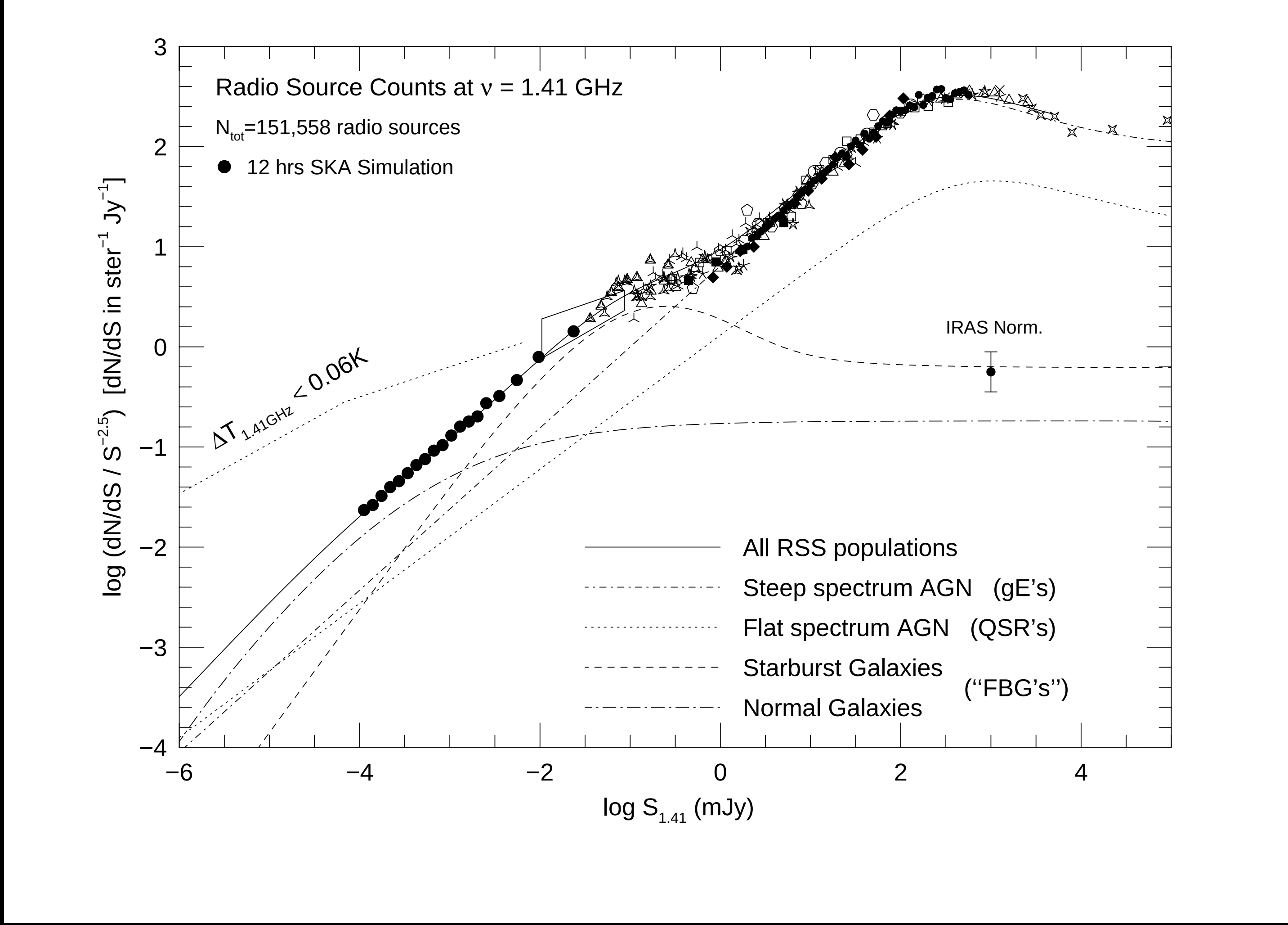
But you learned to Fourier transform and digest it. We learned a lot!





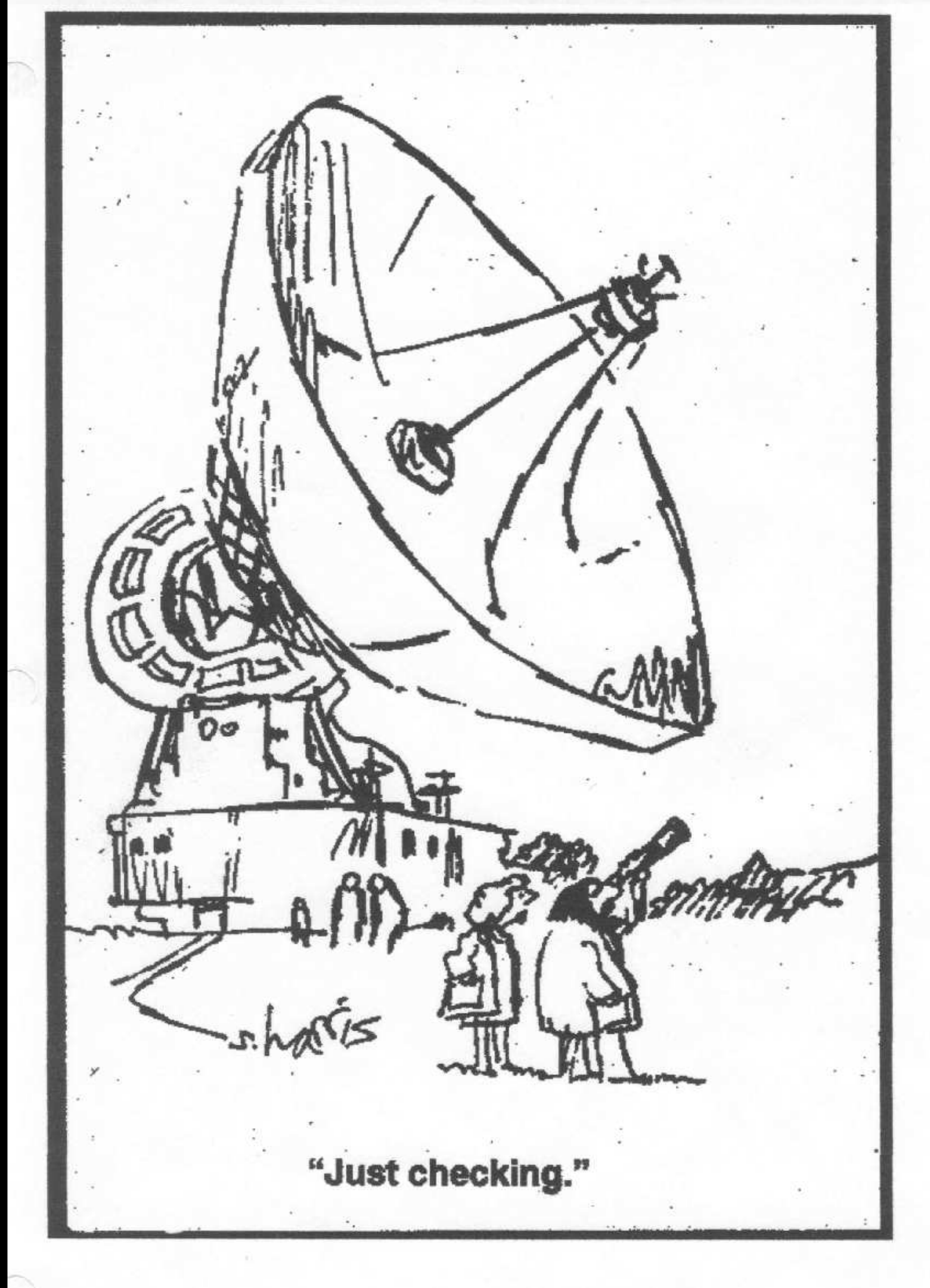
Westerbork traced Cosmic Star Formation and Actively Galactic Nuclei:

- Young Objects and Old objects with redshift, or
- Stellar Birth and Stellar Death over cosmic time.



Normalized differential 1.41 GHz source counts (Windhorst et al. 1985, 1993, 2003; Hopkins et al. 2000) from 100 Jy to 100 nJy. Filled circles below 10μJy show the 12-hr SKA simulation of Hopkins et al. (2000).

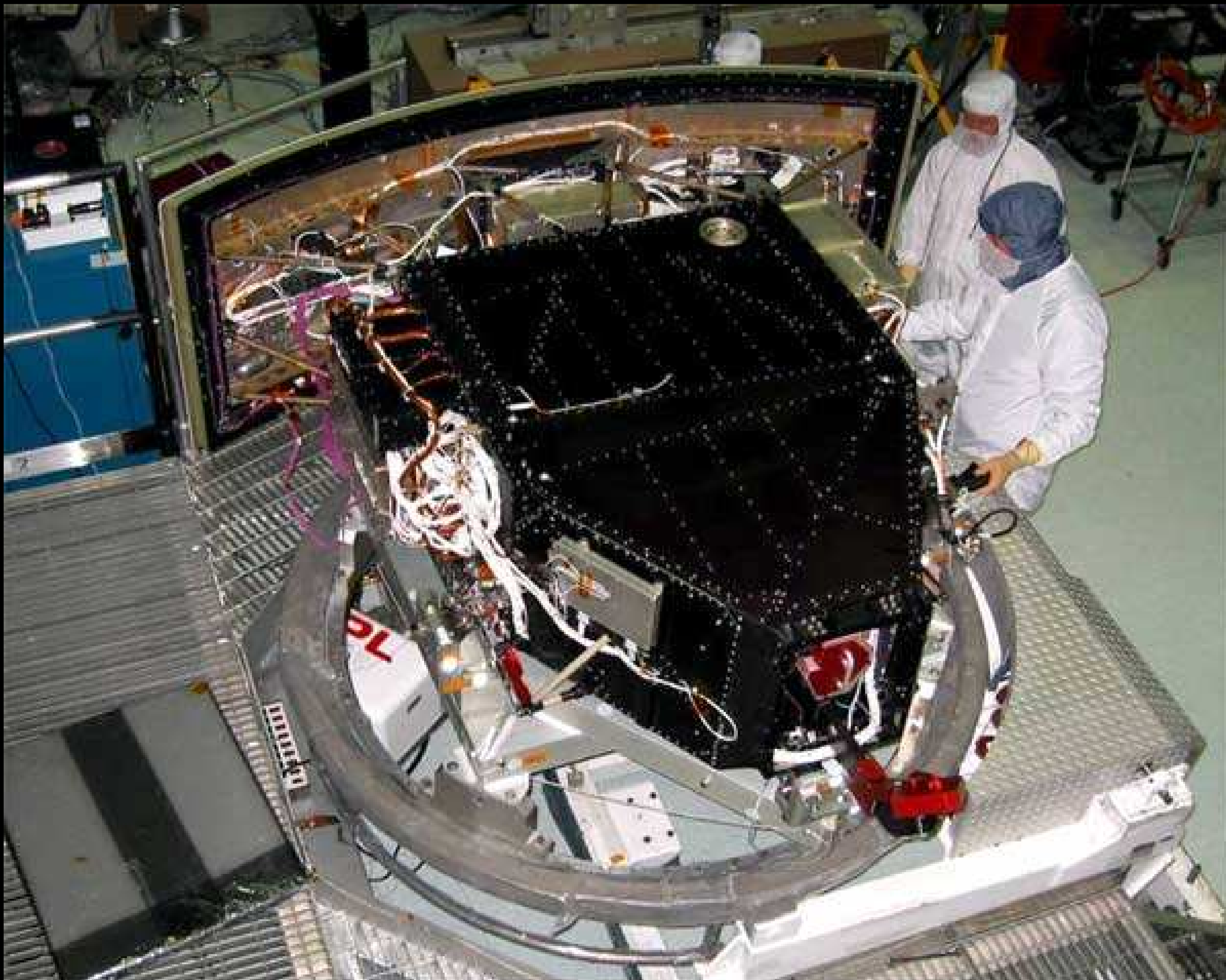
Models: giant ellipticals (dot-dash) and quasars dominate the counts to 1 mJy, starbursts (dashed) below 1 mJy. Normal spirals at cosmological distances (dot-long dash) will dominate the SKA counts below 100 nJy.



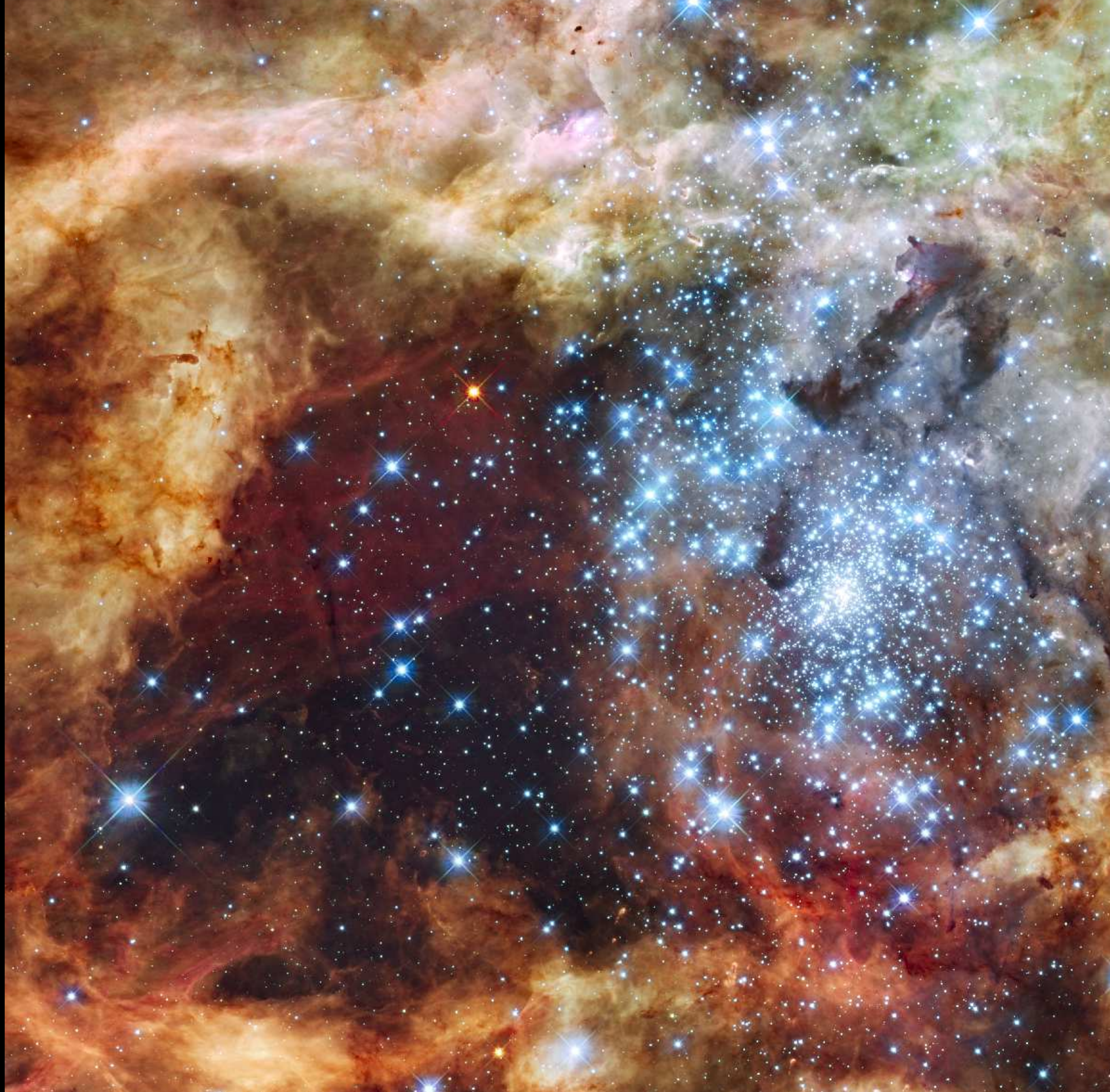
Harry whispered into my ear in June 1984: "Rogier, get involved into HST!"

HST, and JWST, changed the career of this radio astronomer ...

(2a) WFC3: Hubble's new Panchromatic High-Throughput Camera



HST WFC3 and its IR channel: a critical pathfinder for JWST science.



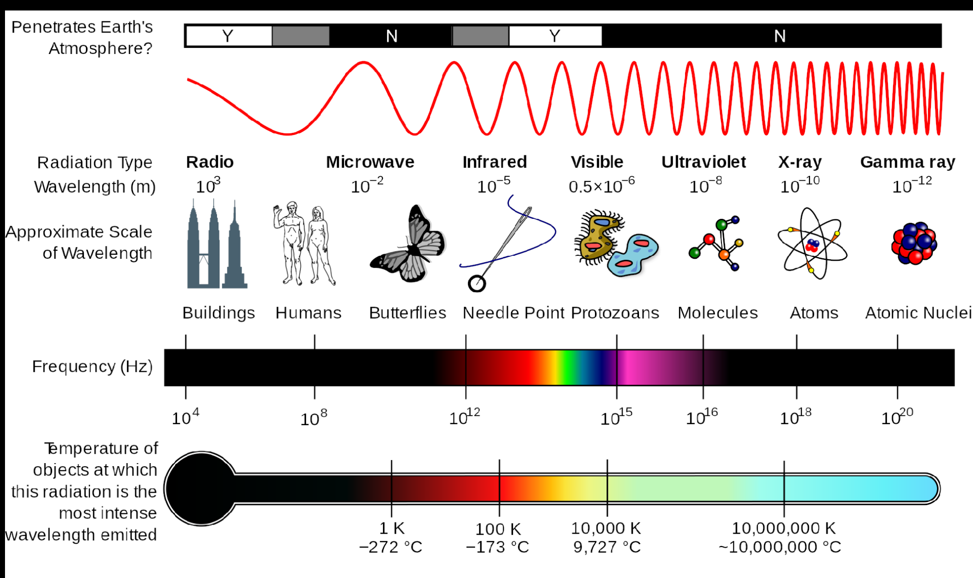
WFC3 30 Dor: Massive stars (8-30 $M_{\odot}$) leave modest blackholes (3-12 $M_{\odot}$).

Waves that happen in Nature — Sounds Waves:

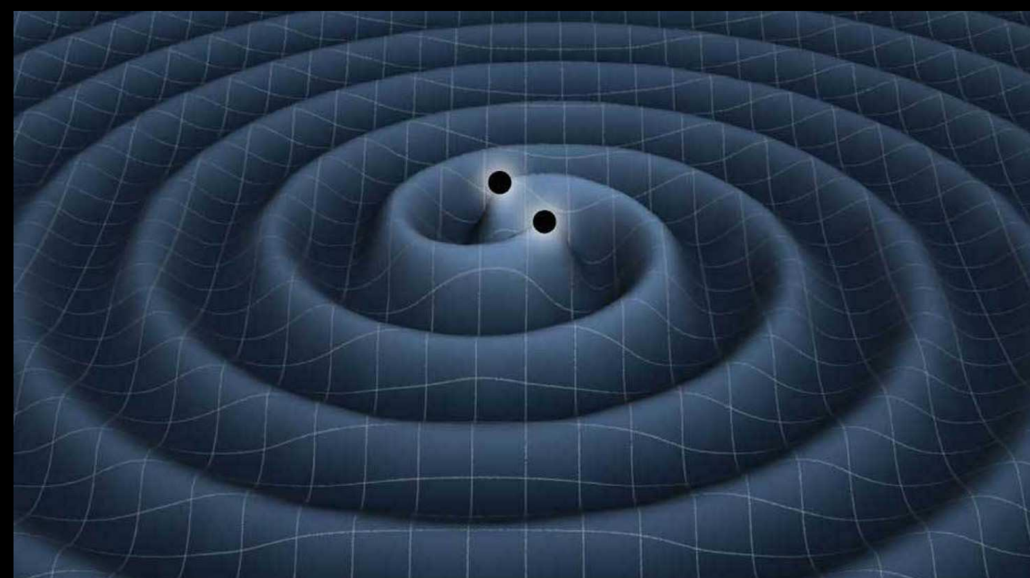
In solids: Earthquakes

In liquids: Surf!

In gasses: Sound



Electromagnetic Waves



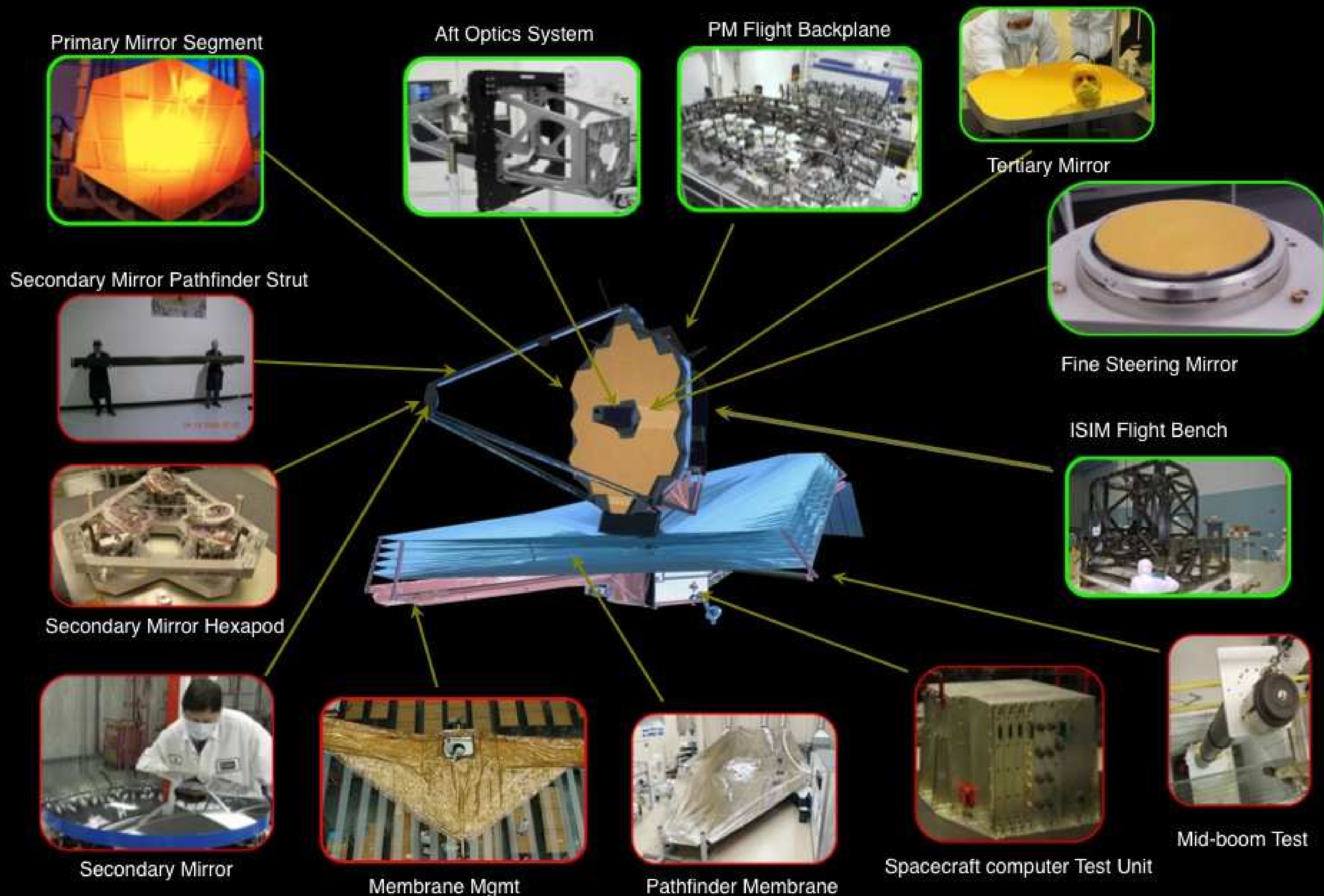
In space-time: Gravity Waves

Sept. 2015: LIGO added Gravity Waves as a new way to observe Nature!

Conclusion 1: Most low-mass blackholes today are small, slow eaters:

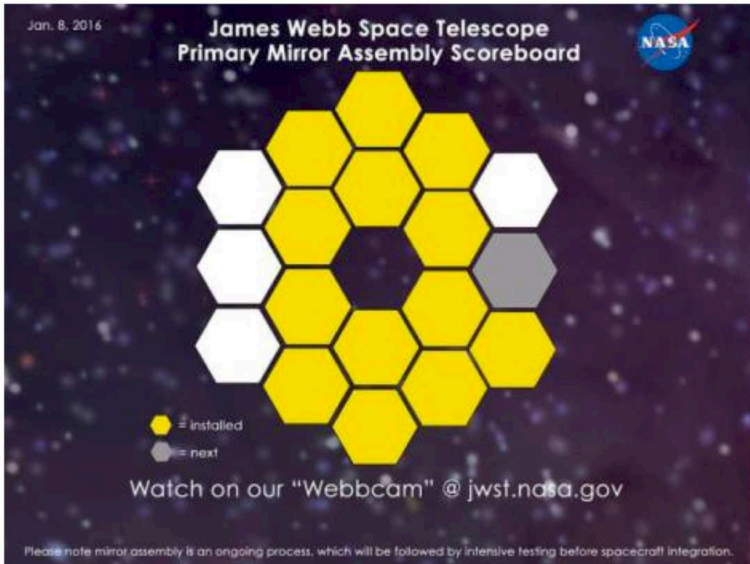
- LIGO's 29–36 $M_\odot$ blackholes: leftover from First Stars (first 500 Myr)?
- Too massive to be leftover from ordinary Supernova explosions.
- Why only seen *now* as merging by LIGO (12.5 Gyr after Big Bang)?
- They were likely not fast & efficient eaters, but slow and messy ...

JWST Hardware Status



Oct. 2016: $\gtrsim$99% of launch mass designed and built ($\gtrsim$90% weighed).

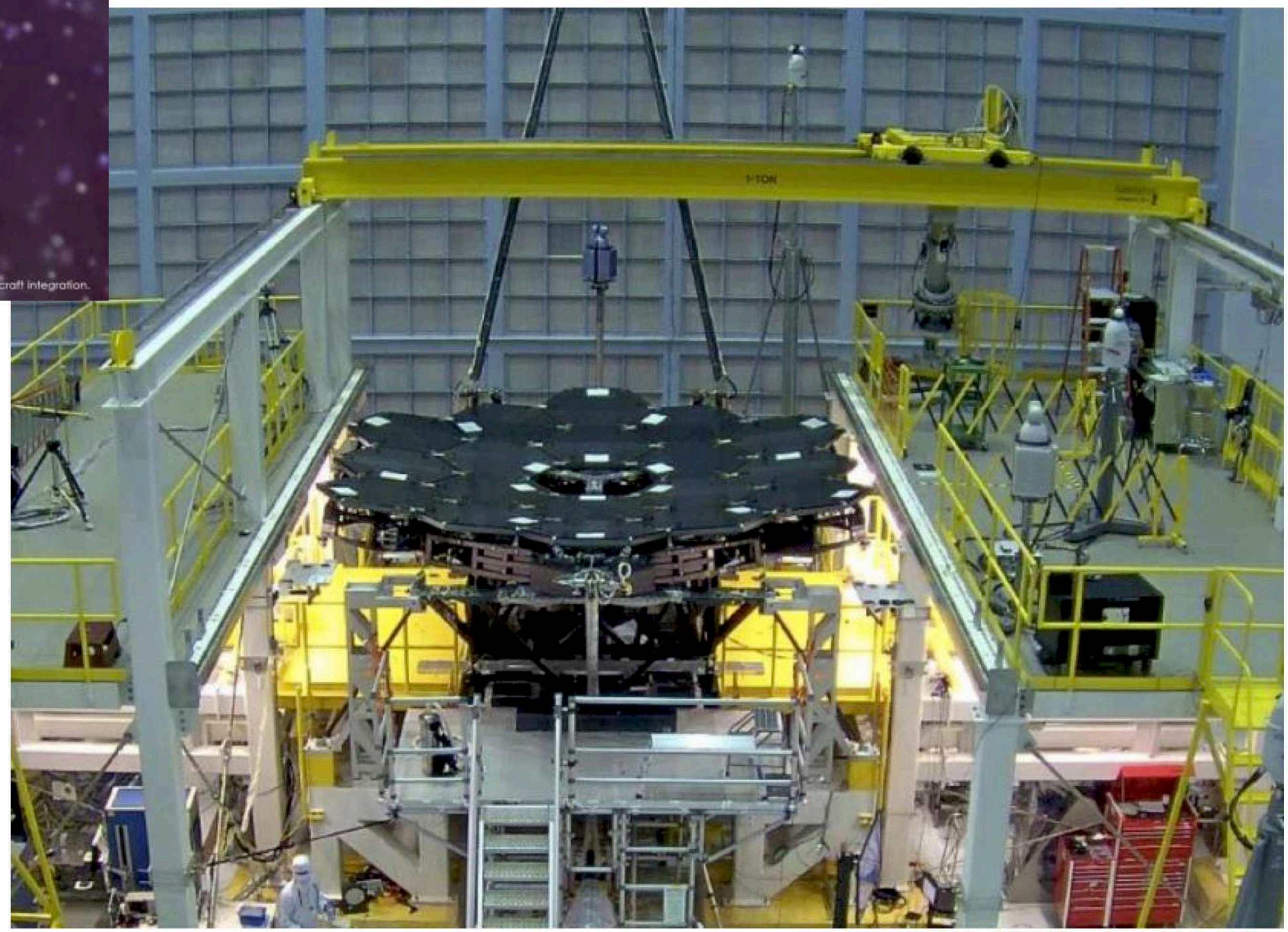
Much progress has been made in OTE integration



Where we were at last month’s call

<u>Current</u>: all 18 PMSAs installed, liquid-shim-cured, & metrologized. Alignments meet specifications, and actuator motions verified

Big milestone!



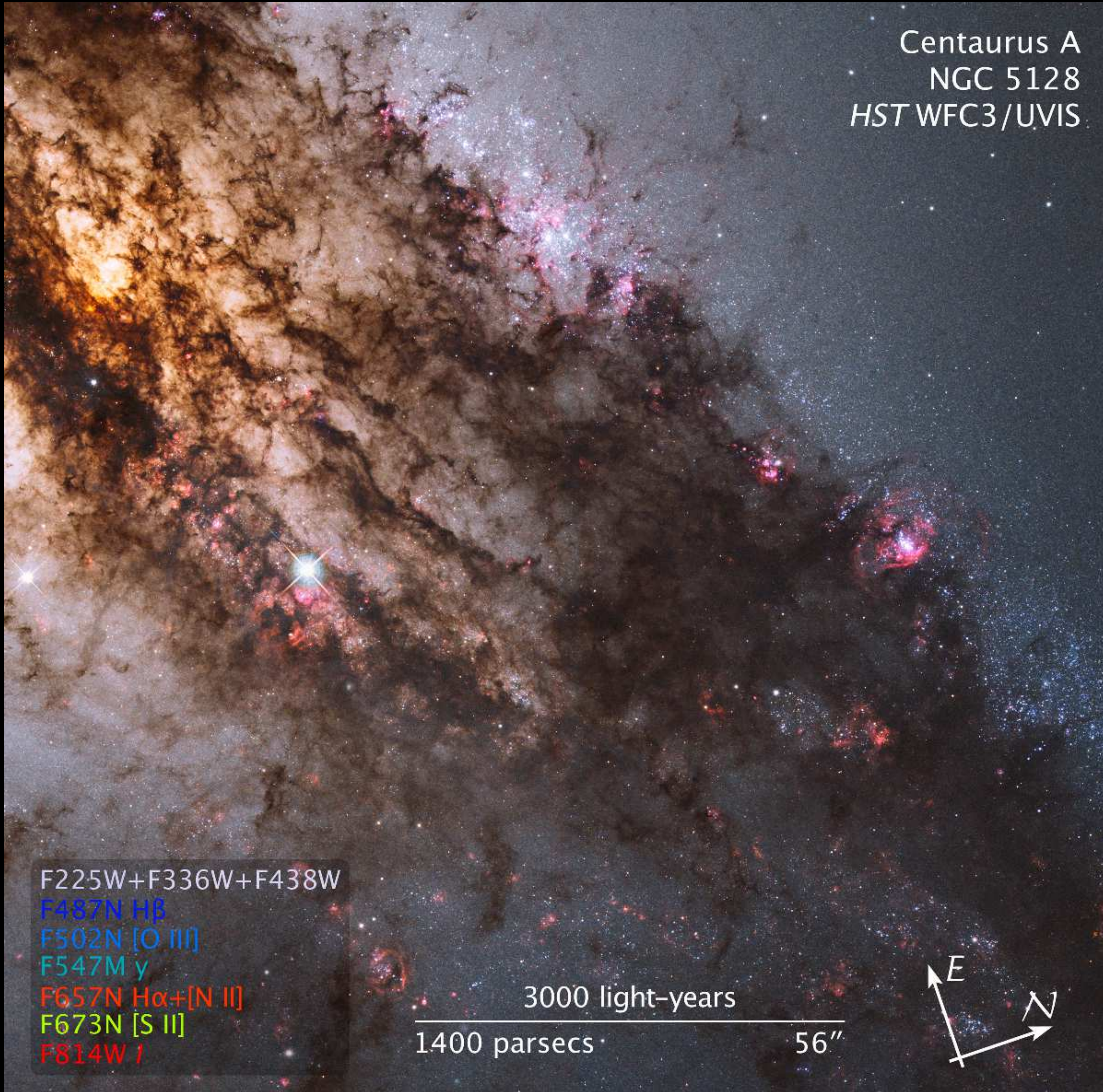
8 February 2016 JWST Monthly Telecon 8

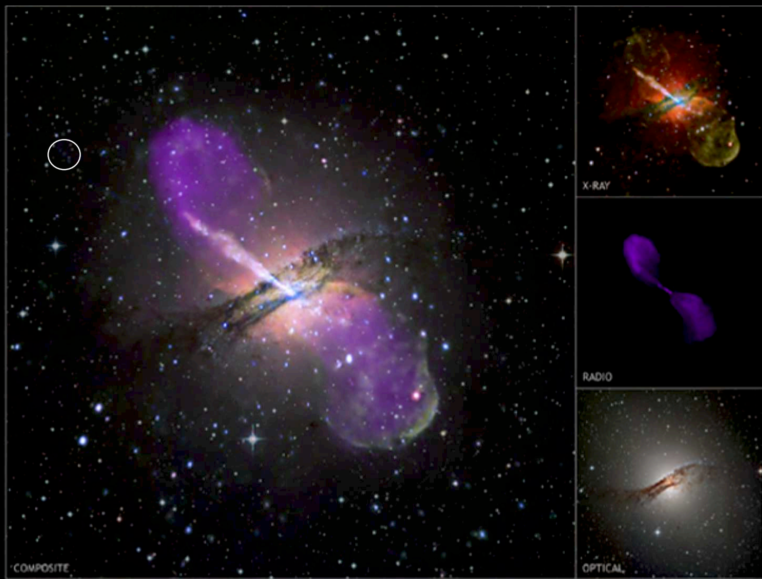
JWST lifetime: Requirement: 5 yrs; Goal: 10 yrs; Propellant: 14 yrs.

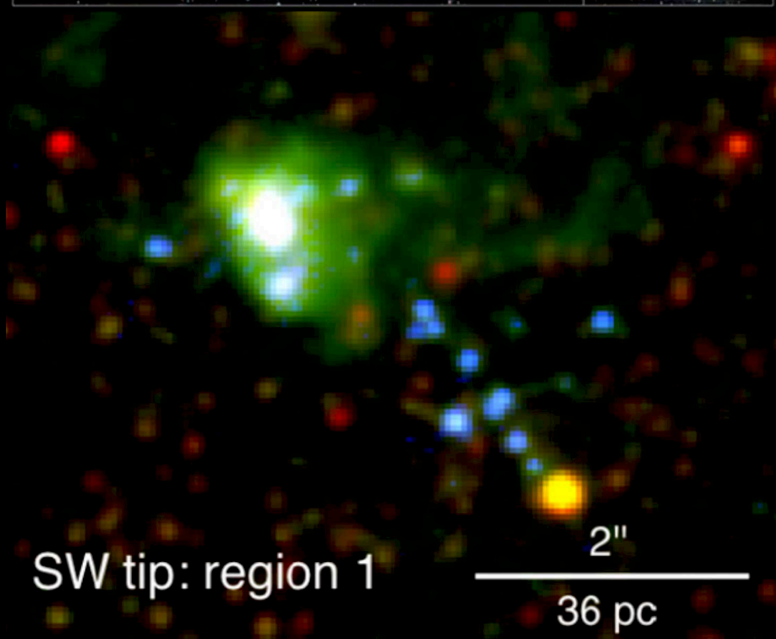
April 2016: NASA team-work to take JWST mirror covers off!

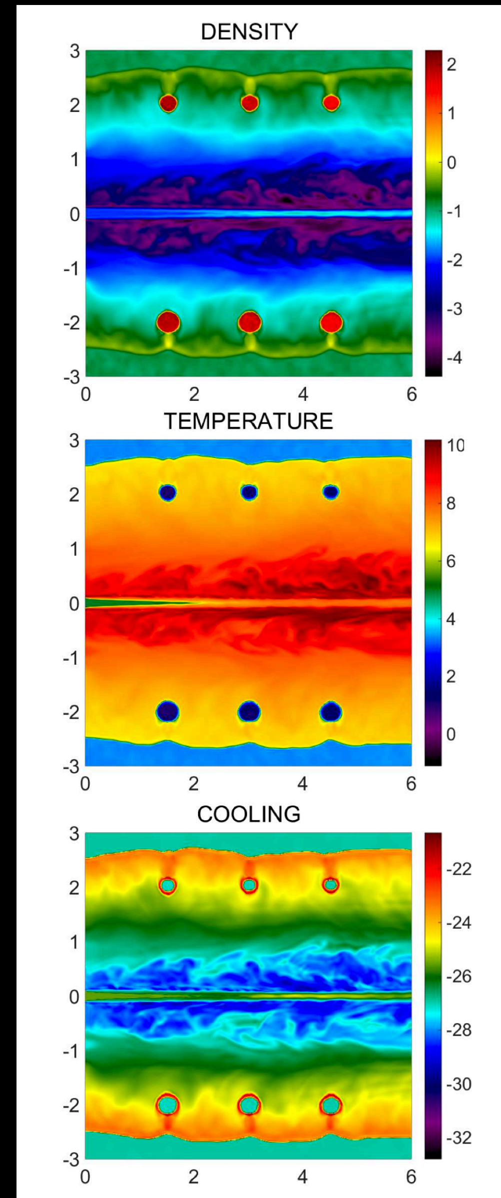
May 2016: JWST being tilted into the right position

May 2016: Webb mirrors finally mounted and ready!


Centaurus A
NGC 5128
HST WFC3/UVIS
F225W+F336W+F438W
F487N Hβ
F502N [O III]
F547M y
F657N Hα+[N II]
F673N [S II]
F814W *I*
3000 light-years
1400 parsecs
56″
E
N





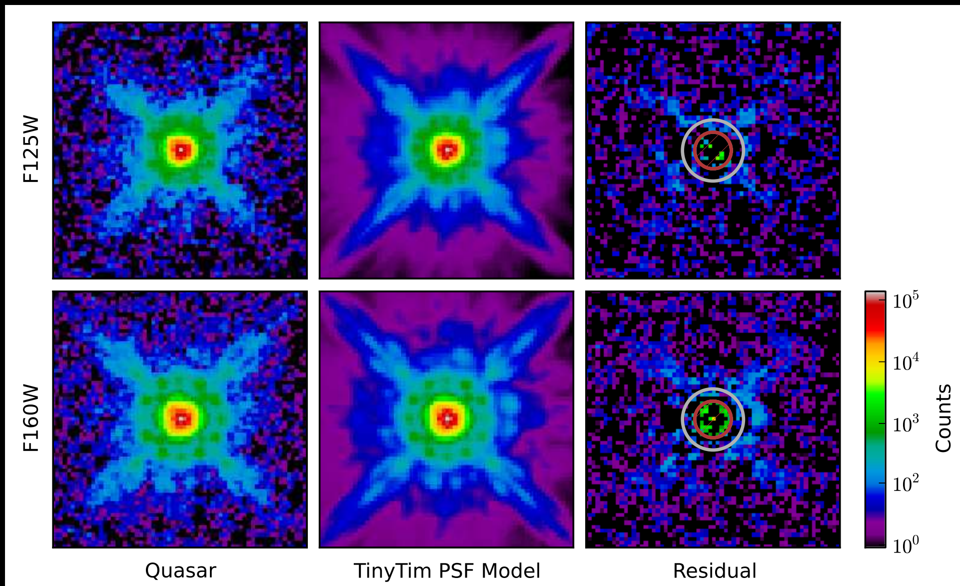


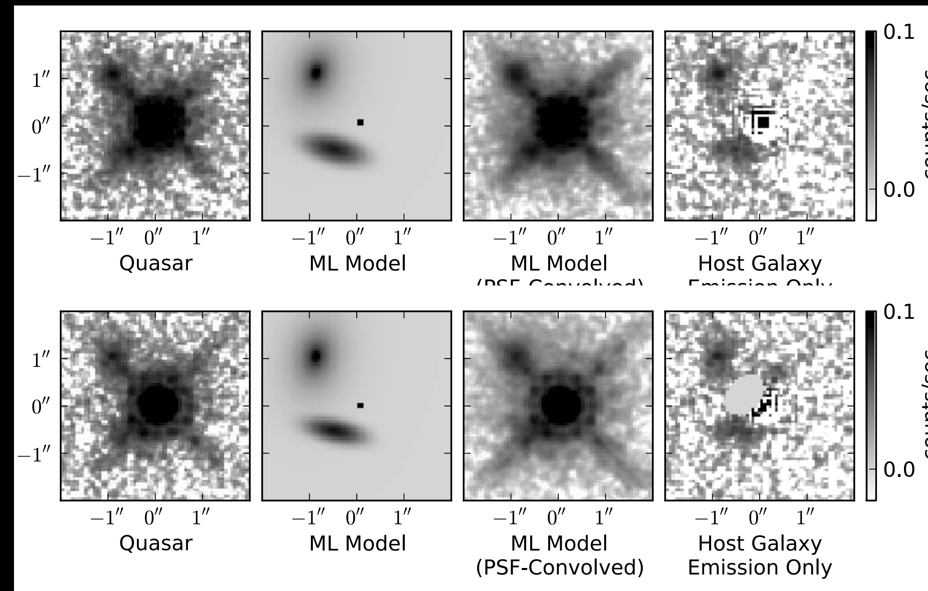
[TOP]: X-ray–Radio–Optical images of Cen A.

[BOTTOM]: WFC3: Jet-induced SF in 2-Myr starclusters (Crockett$^+$ 2009).

[RIGHT]: Hydro models of bowshock-induced SF (Gardner$^+$ astro-ph/1610).

- Quasars: Centers of galaxies with feeding supermassive blackholes:





Hubble IR-images of the most luminous Quasars known in the universe:

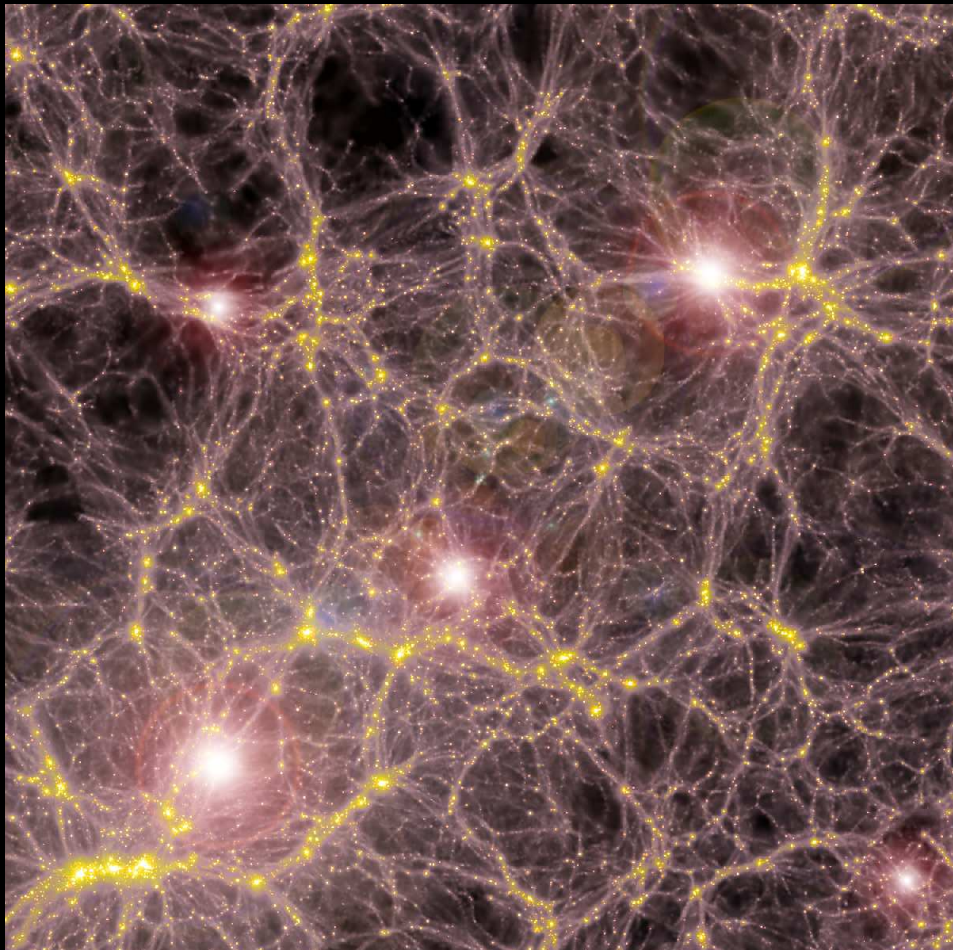
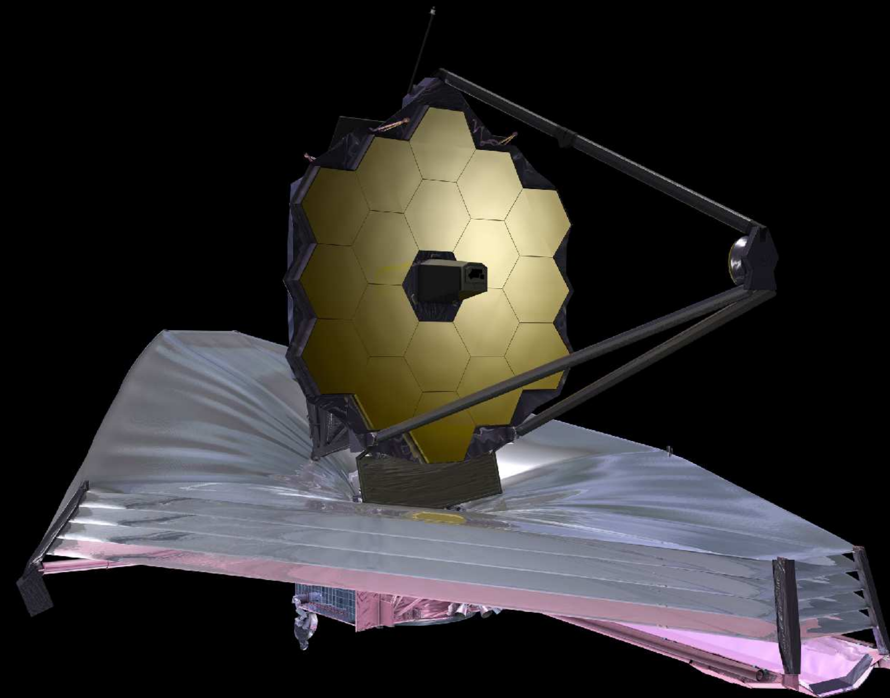
- Seen at redshift z$\simeq$6 (universe 7$\times$ smaller than today), 900 Myr old!
- Contains 10^{14} solar luminosities within a region as small as Pluto's orbit!
- Feeding monster blackholes ($>3\times10^9$ solar mass) $\sim$900 Myr after BB!

Yet, the dusty(!) host galaxies are not yet visible (Mechtley$^+$ 2012, 2016).

- Who came first: Chicken or Egg?: The supermassive blackhole!
- JWST will detect 10–100$\times$ fainter dusty hosts (for z$\lesssim$20, $\lambda\lesssim28\mu$m).

Conclusion 2: Supermassive blackholes started early & were very rapid eaters:

- All massive galaxies today contain a central super-massive blackhole.
- Masses 3×10^9 solar, leftover from the First Stars (first 500 Myr)?
- Must have fed enormously rapidly in the first 1 Gyr after the Big Bang.
- Were eating cat-astrophically (and secretly) until they ran out of food ...
- JWST will detect 10–100$\times$ fainter dusty hosts (for z$\lesssim$20, $\boldsymbol{\lambda}\lesssim28\boldsymbol{\mu}$m).

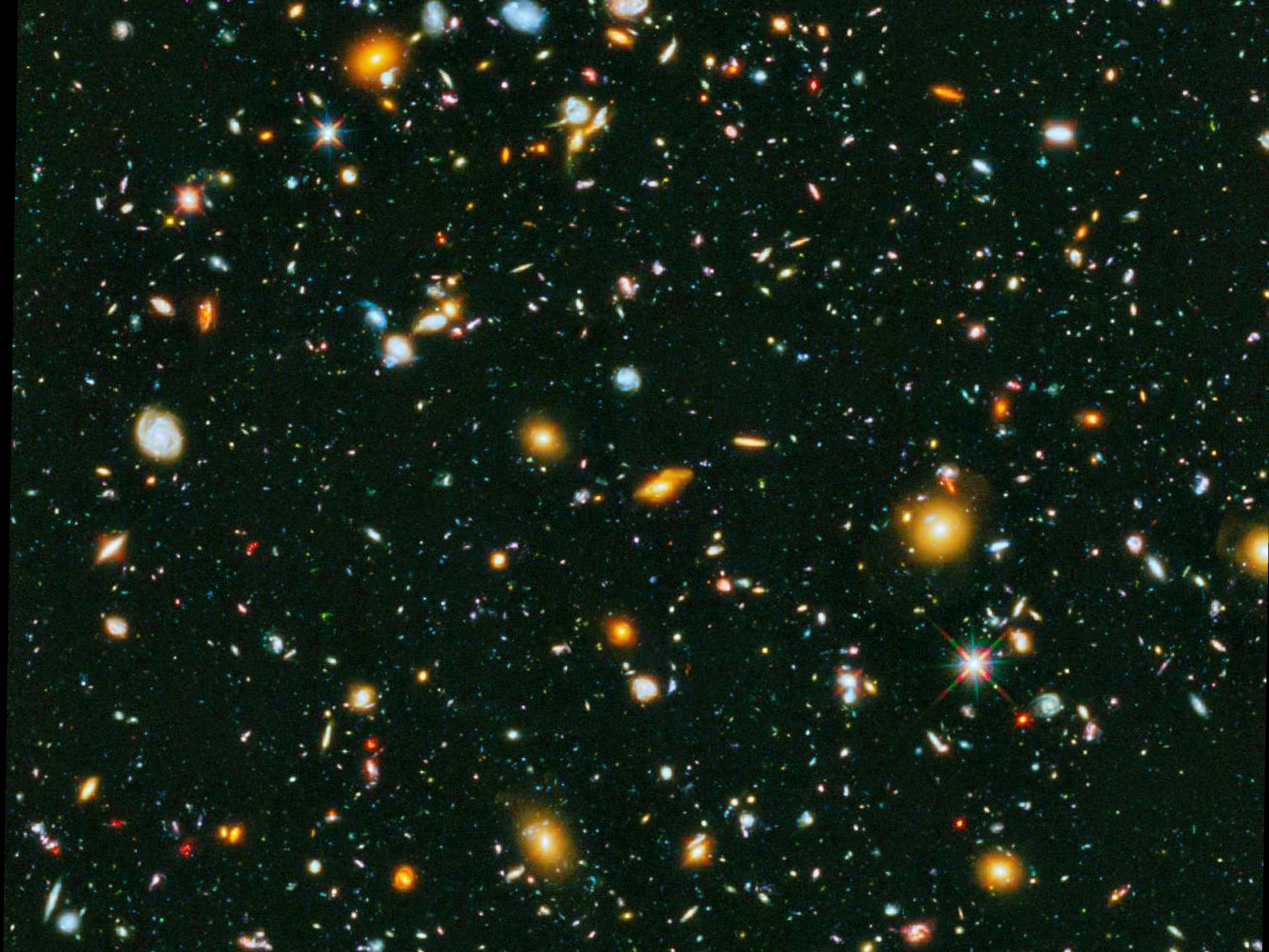
Very first stars likely born in the first 500 Myr after the Big Bang.

- They were likely 80–200 solar masses, lived fast, & died young (1 Myrs!)
- They could have left 30–80 solar mass blackholes behind, as LIGO saw.

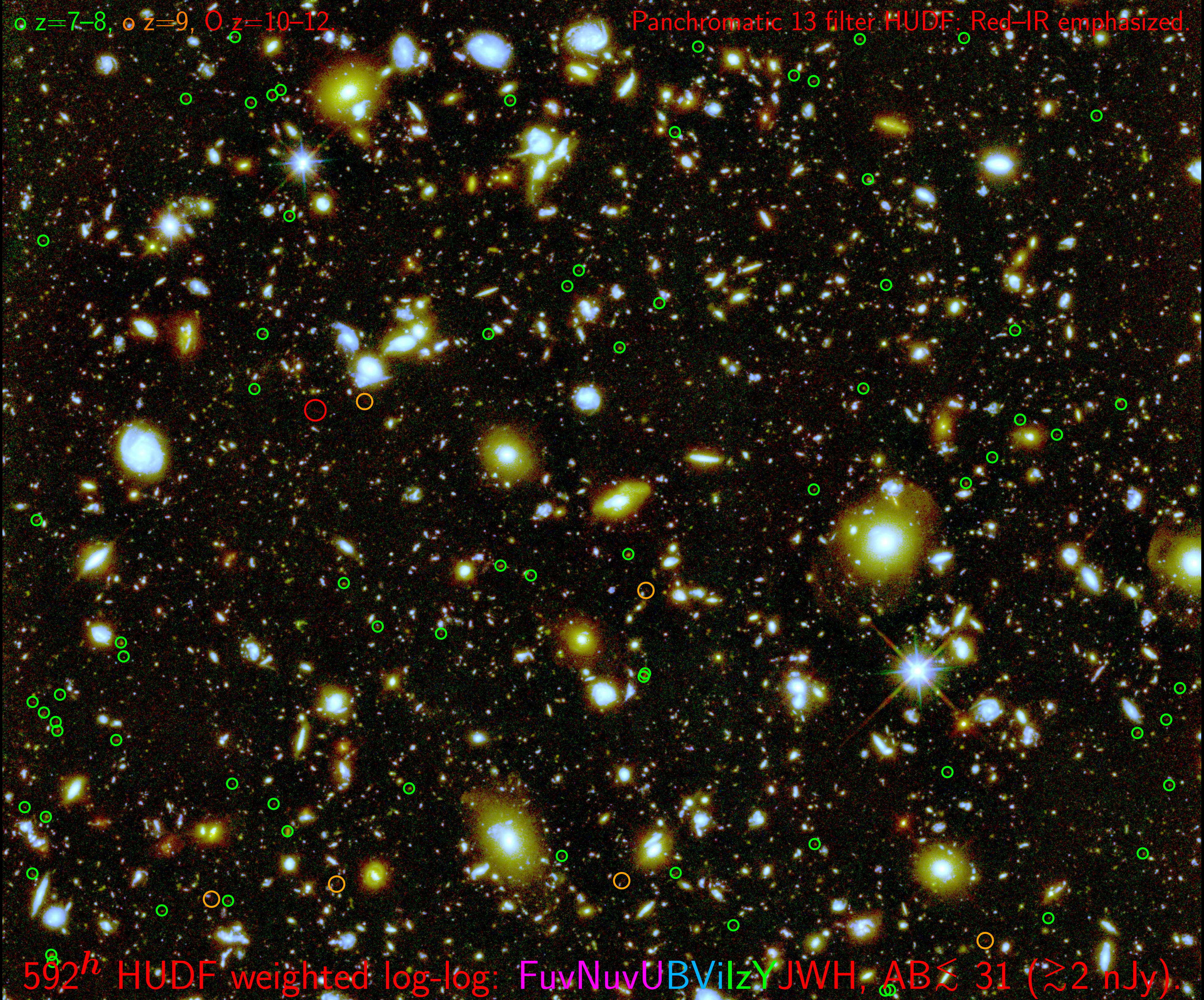
JWST will observe these First Light sources after 2018:

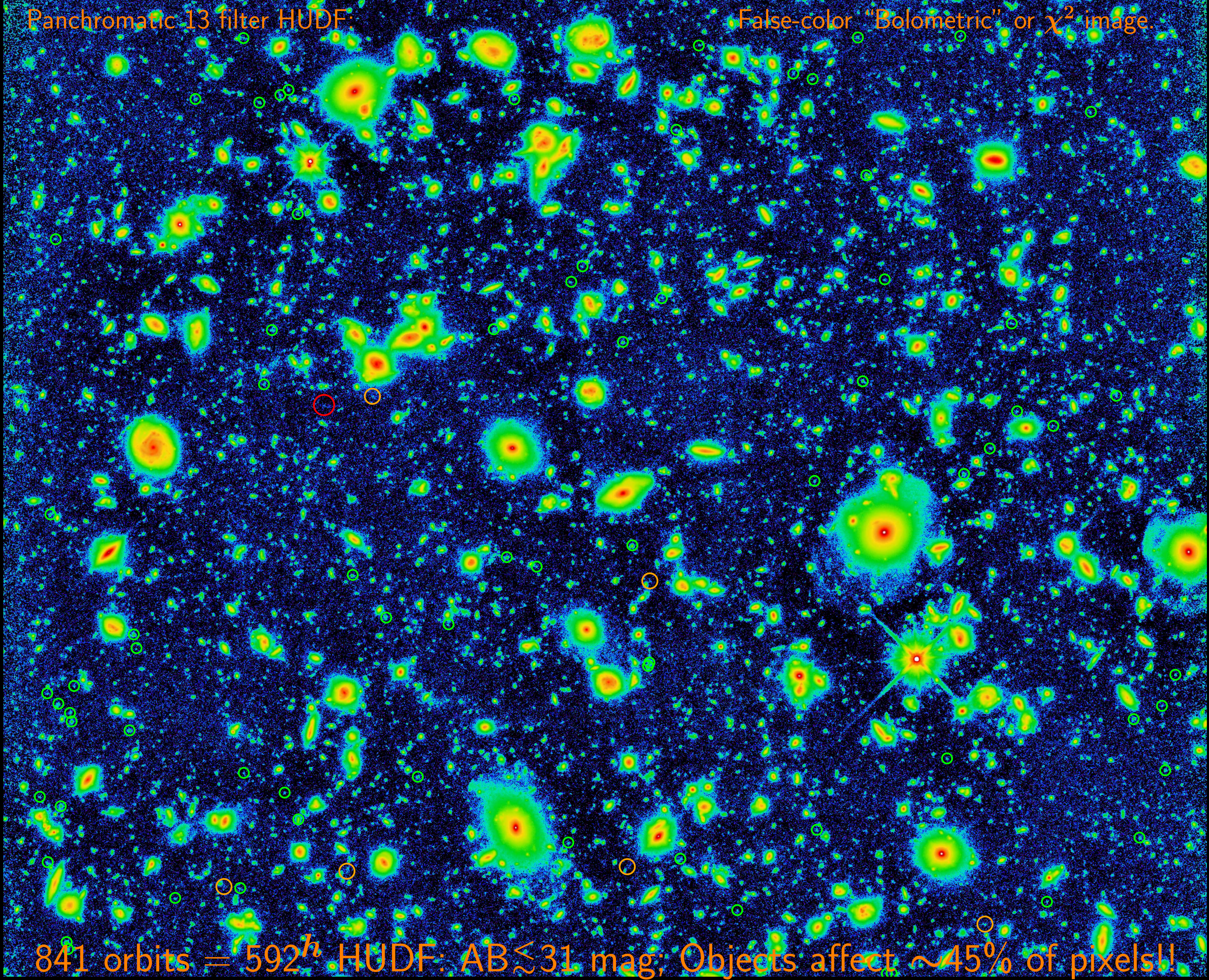
- Expected to be weekly clustered: faint signal in JWST IR background.

The HST-unique part for JWST: Panchromatic 13 filter HUDF: UV–Blue emphasized.

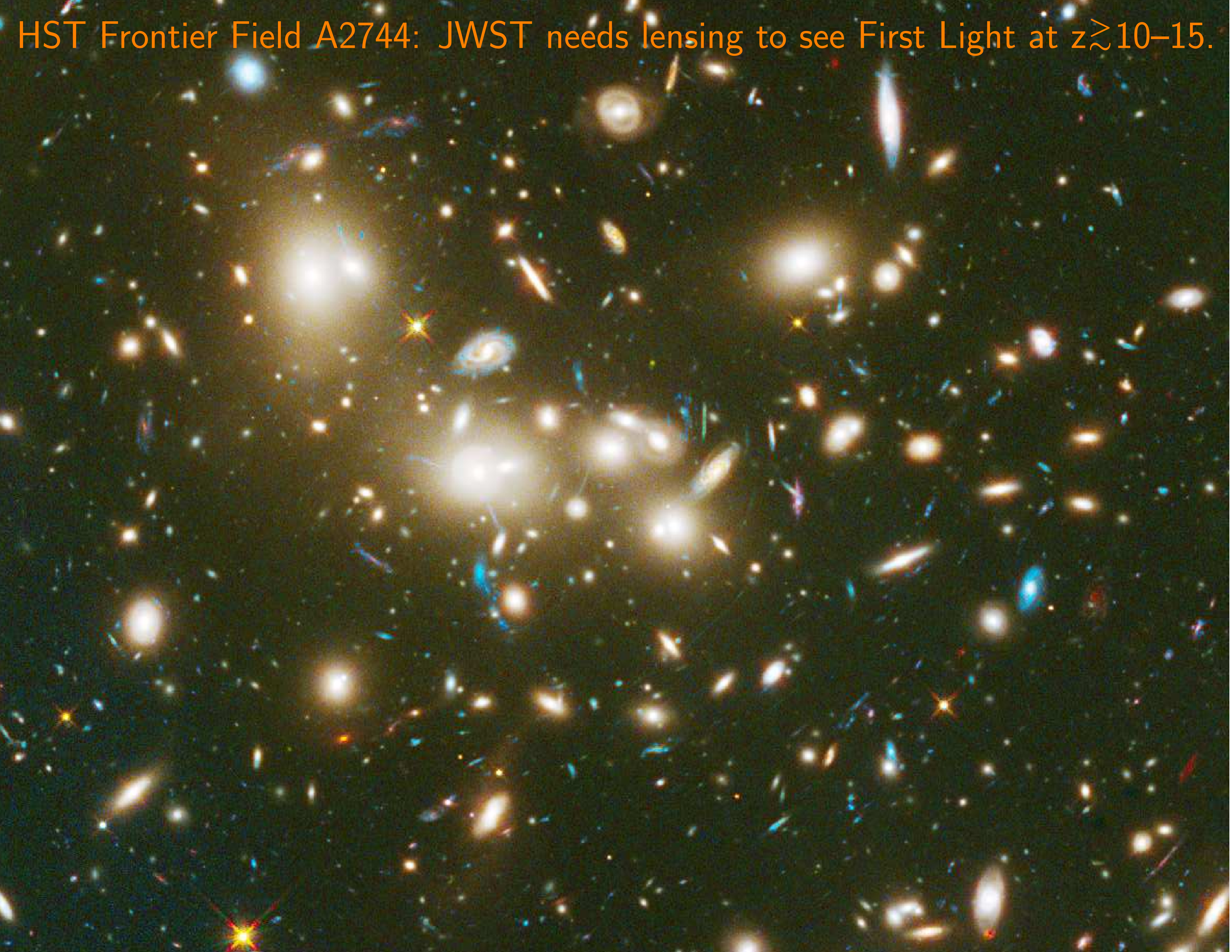


592^h HUDF weighted log-log: FuvNuvUBViIzYJWH, AB$\lesssim$28–31 ($\gtrsim$2 nJy).


o z=7–8, o z=9, O z=10–12.
Panchromatic 13 filter HUDF: Red–IR emphasized.
592^h HUDF weighted log-log: FuvNuvUBViIzYJWH, AB$\lesssim$ 31 ($\gtrsim$2 nJy).


Panchromatic 13 filter HUDF:
False-color "Bolometric" or χ^2 image.
841 orbits = 592^h HUDF: AB$\lesssim$31 mag; Objects affect ~45% of pixels!!

HST Frontier Field A2744: JWST needs lensing to see First Light at z$\gtrsim$10–15.



Conclusions: JWST First Light surveys must consider three aspects:

(1) The very rapid drop in space density (LF) for z$\gtrsim$8.

(2) Cannot-see-the-forest-for-the-trees effect ["Natural Confusion" limit]:
Background objects blend into foreground because of their own diameter.

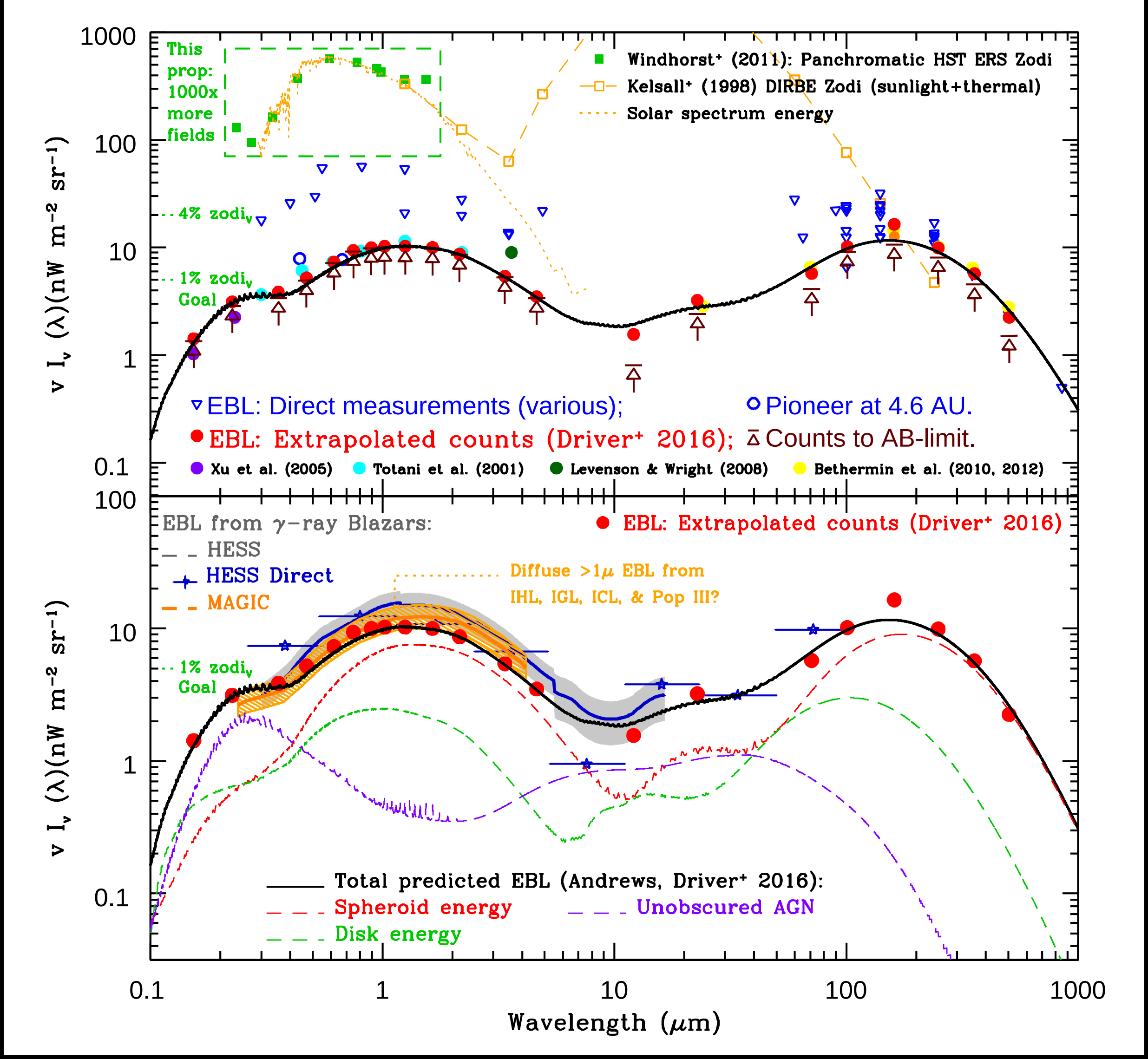
(3) House-of-mirrors effect ["Gravitational Confusion"]:

- JWST needs to find most First Light objects at z$\gtrsim$10–15 through the best cosmic lenses (making the images even more crowded):
- Lensing is needed to see what Einstein thought was impossible to observe!

Thank you, Harry, for everything you did for us:

- For your excellent mentorship!
- For your career-changing advise!
- For your friendship and understanding!
- And for constantly supporting us!

SPARE CHARTS

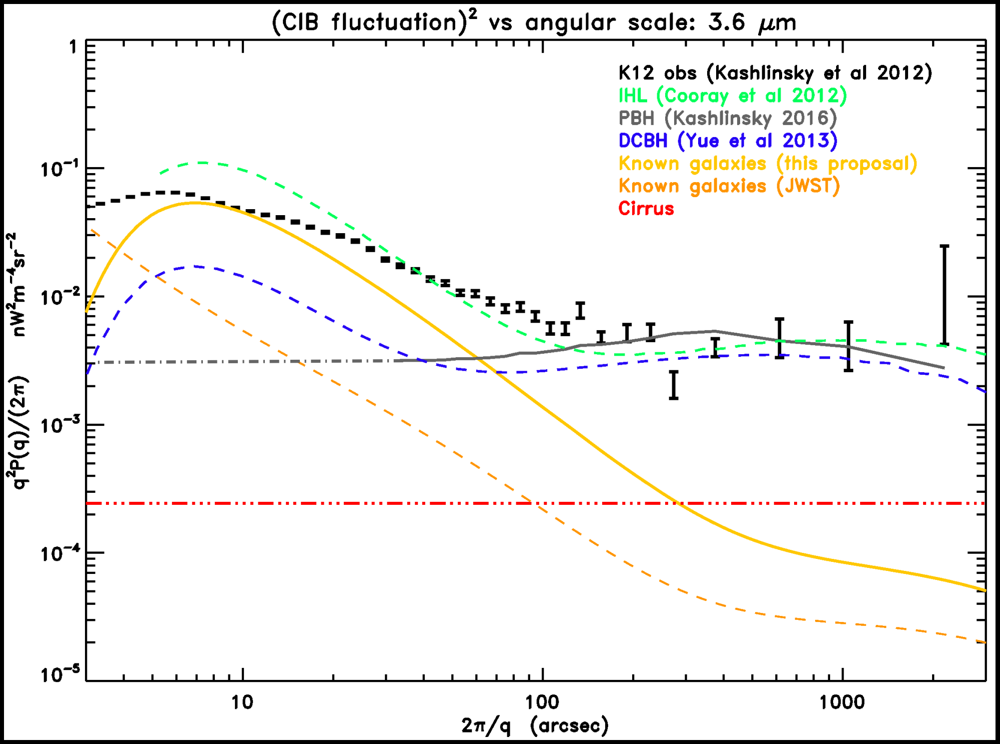


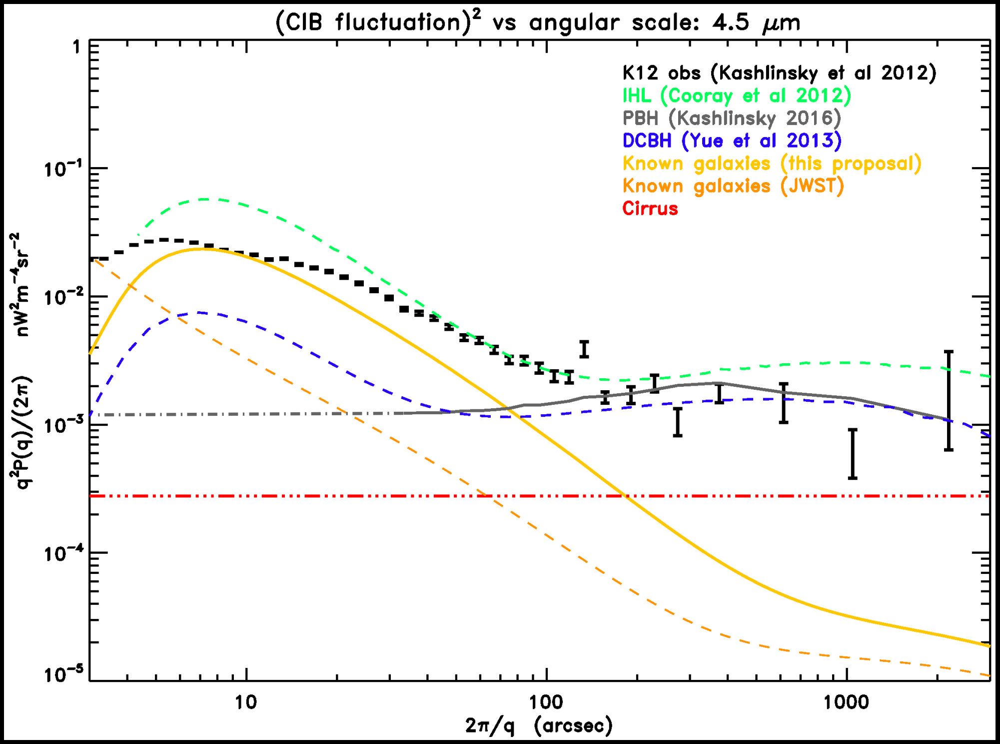
Integrated UV–IR galaxy counts converge to yield accurate Extragalactic Background Light estimates (Driver+ ApJ, 827, 108; astro-ph/1605.01523).

- Integrated starlight and dust ($z_{med} \simeq$1.5) each contribute ∼50%.

Direct γ-ray Blazar measurements may suggest dim excess at λ∼1–5μm:

- JWST will constrain *diffuse* Pop III star component at z≃10–20.





Spitzer 3–5μm power-spectrum with galaxies removed (Kashlinsky$^+$ 2012).

JWST's superior spatial resolution will substantially improve discrete galaxy light subtraction:

- JWST can detect any diffuse Pop III star excess at $\lambda \simeq 1$–5μm.

- JWST will constrain direct-collapse or primordial blackhole models (Kashlinsky 2016).

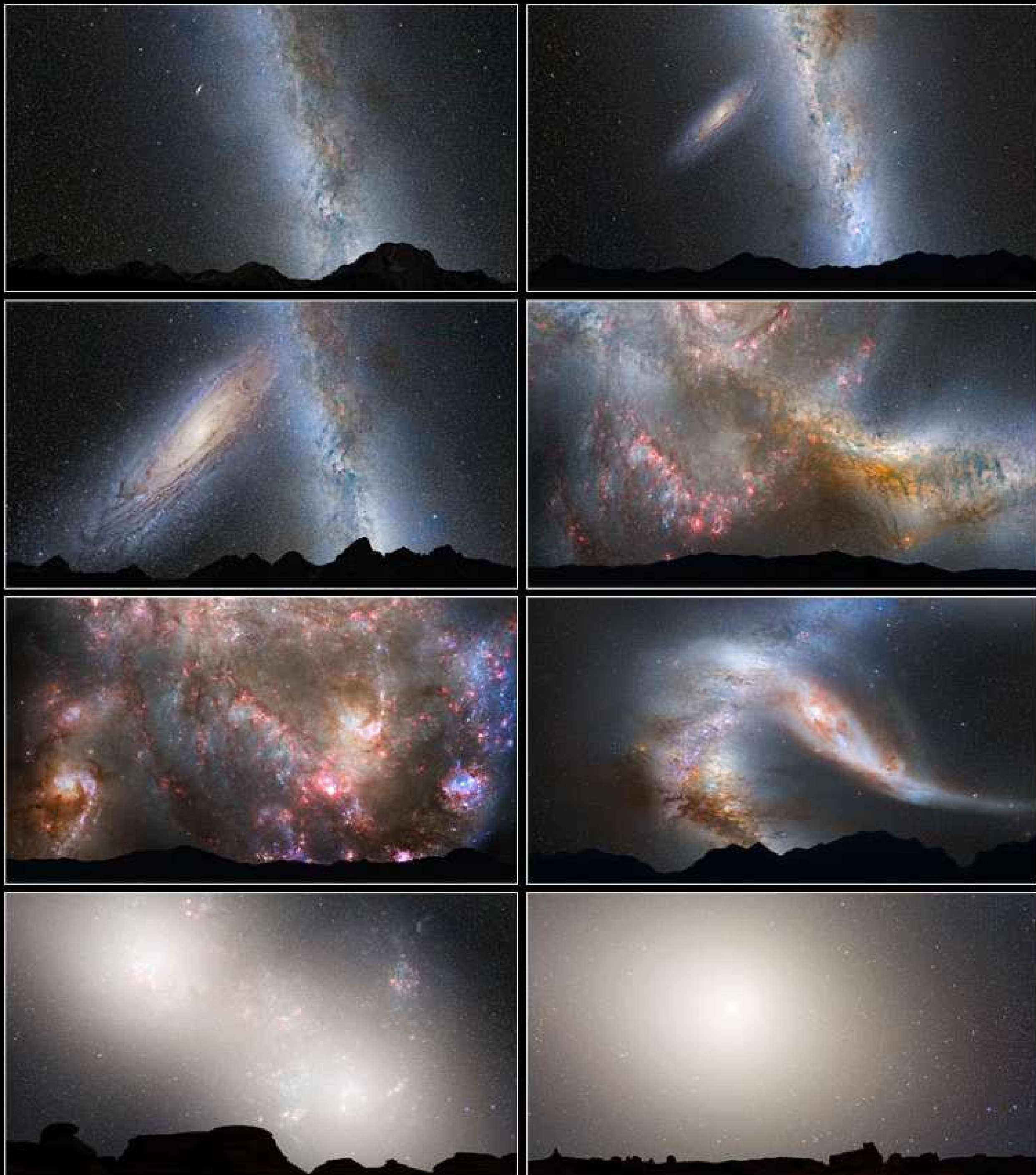


Illustration Sequence of the Milky Way
and Andromeda Galaxy Colliding

NASA, ESA, Z. Levay and R. van der Marel (STScI), T. Hallas, and A. Mellinger ▪ STScI-PRC12-20b

Will this ever happen to our own Galaxy?

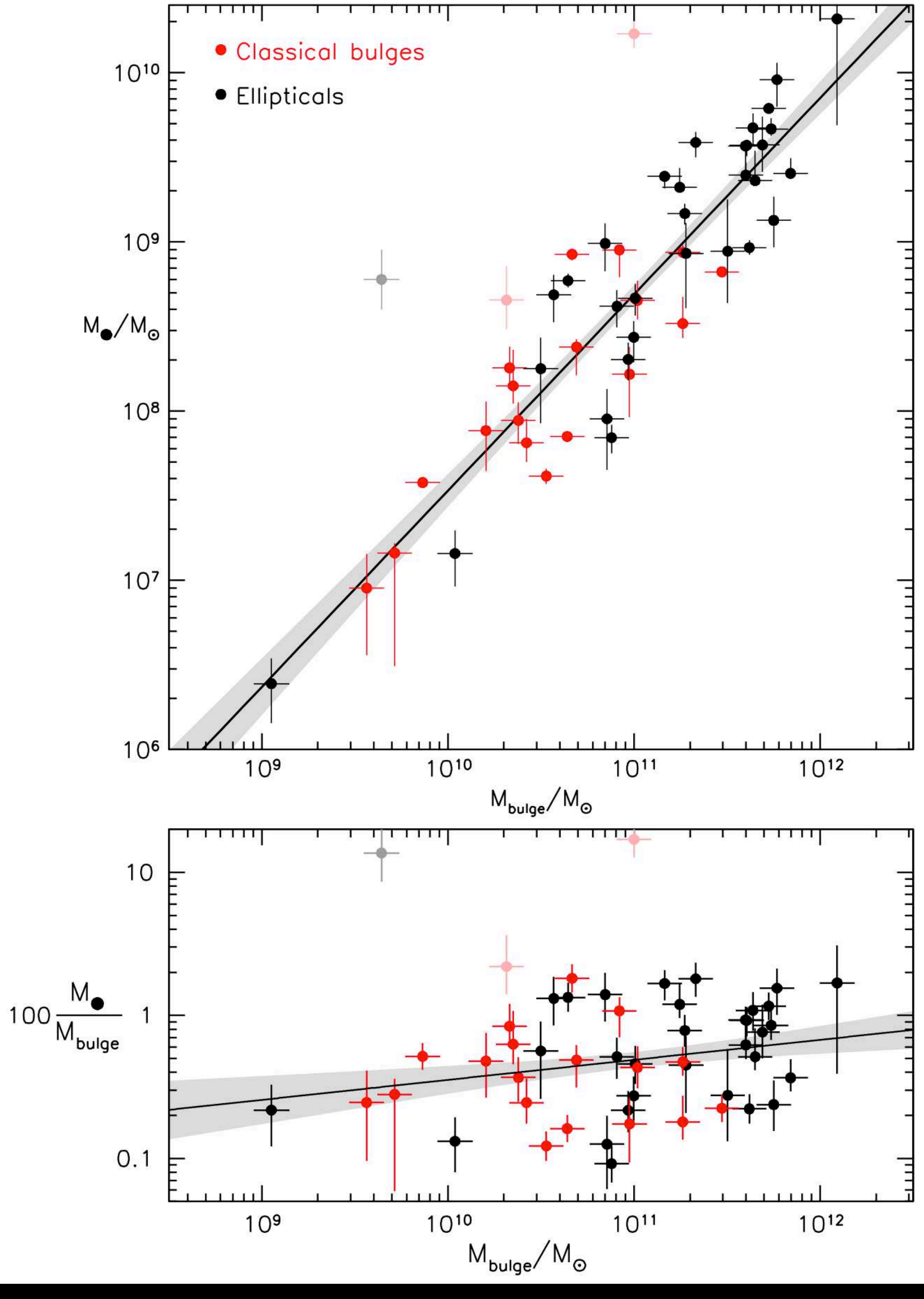
YES! Hubble showed no lateral motion:

Approaches at –110 km/s.

Hence, Andromeda will merge with Milky Way!

The two blackholes (10^6–10^7 suns) will also merge!

Not to worry: only 4–5 Gyr from today!



SuperMassive BlackHole mass vs. Galaxy Bulge Mass

(For elliptical galaxies only)

0.5% of total galaxy mass makes it into SMBH!

SMBH=cosmic garbage disposal: Messy leftover of galaxy formation!

(Kormendy & Ho, 2013 An Rev A&Ap 51, 511)