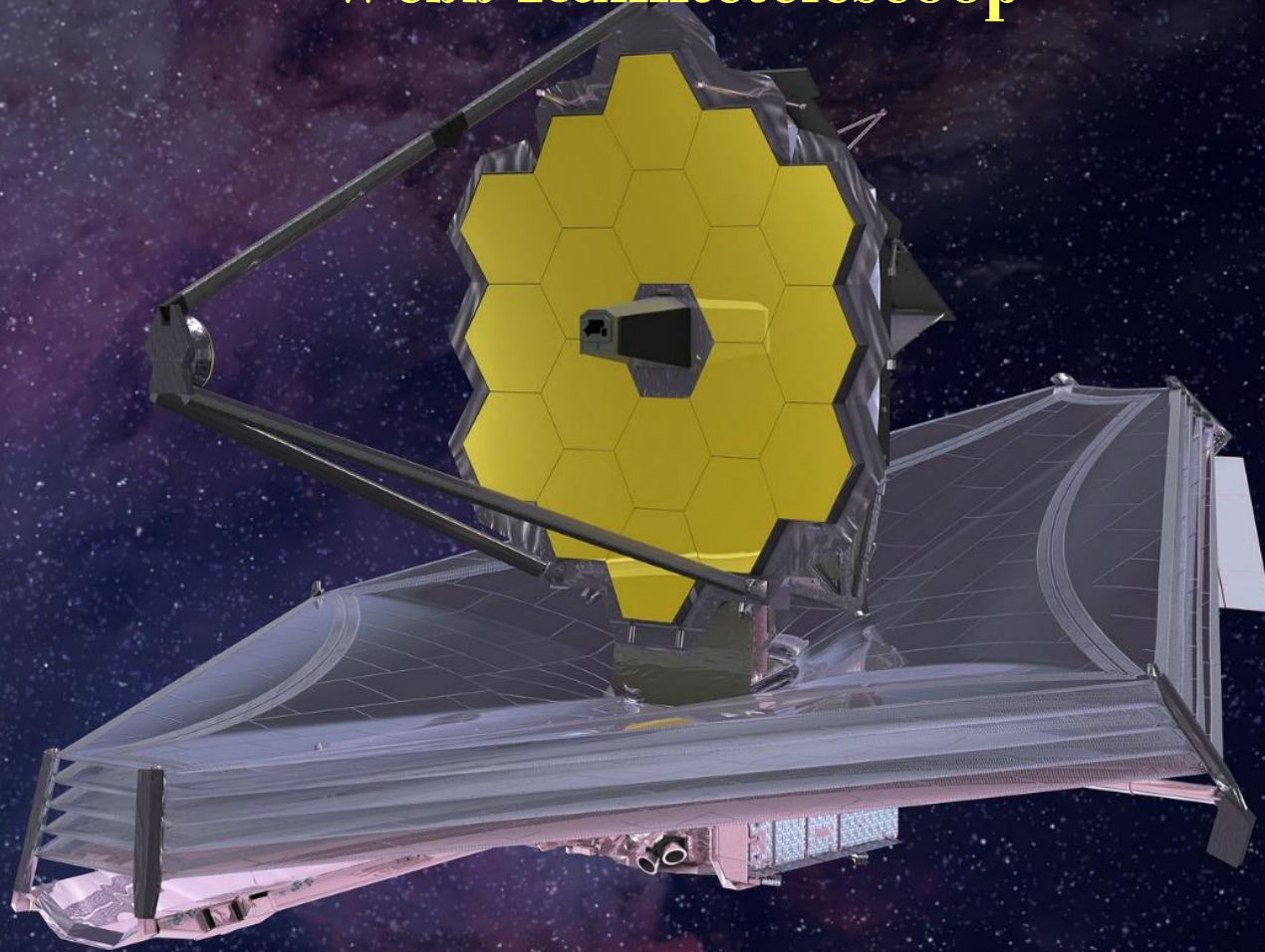


De NIRC*am* en NIRS*pec* instrumenten van de James Webb Ruimtetelescoop



Martijn van Gelder

Leidse Weer- en Sterrenkundige Kring, 17 december 2024



Mijn achtergrond: Astrochemie

De **astrochemie** is een vakgebied dat onderzoek verricht naar de abundantie van elementen, de chemische reacties die optreden in het universum en de daaruit gevormde verbindingen en ionen.

Het vormt een overlappingsgebied van de scheikunde en astronomie.

- Wikipedia

Moleculaire astrochemie

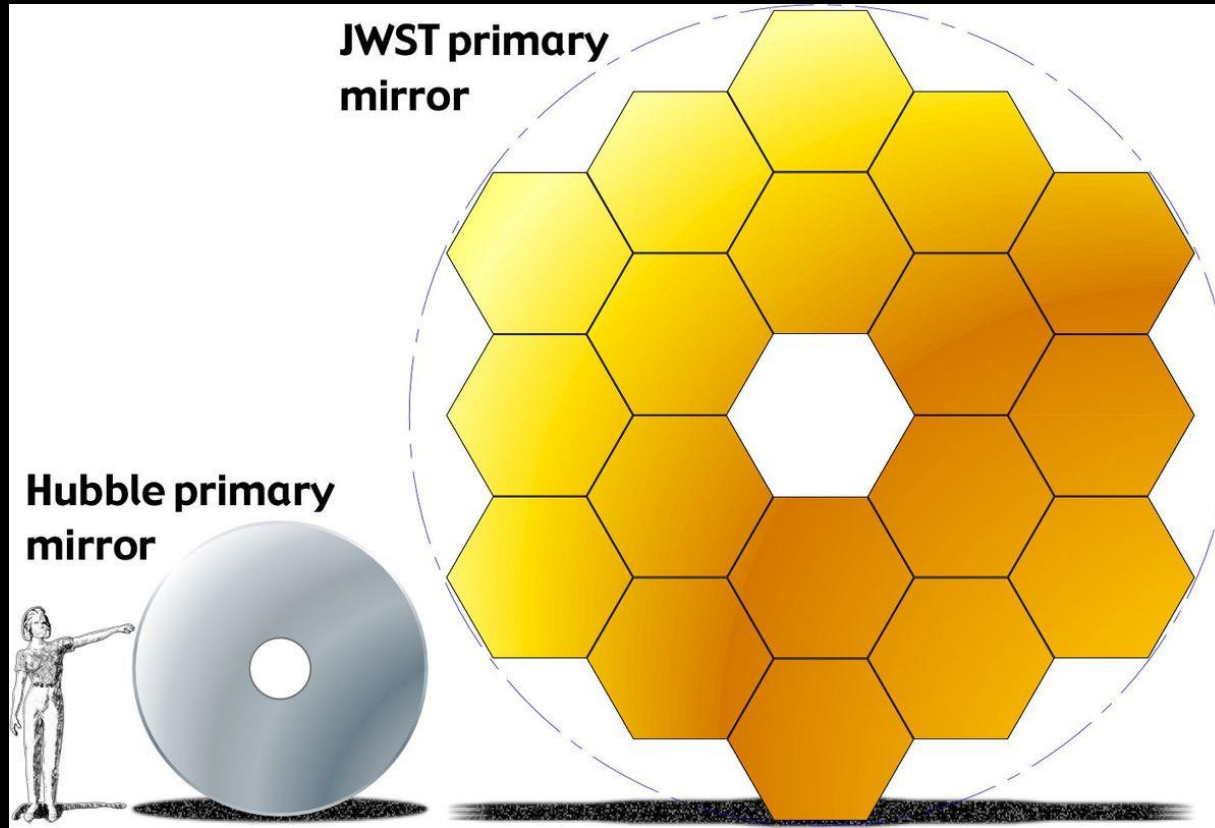
De studie van moleculen en hun chemische reacties in het universum.

Voornameijk ten tijde van het vormen van sterren en planeten en hun verdere evolutie



Diepste en scherpste opname van universum, onthuld door President Biden op 11 juli 2022

Wat maakt Webb uniek?



Webb's spiegel is groot: 6.5m!

Wat maakt Webb uniek?



Webb's zonneschild is nog groter: 14m x 21m!

Wat maakt Webb uniek?

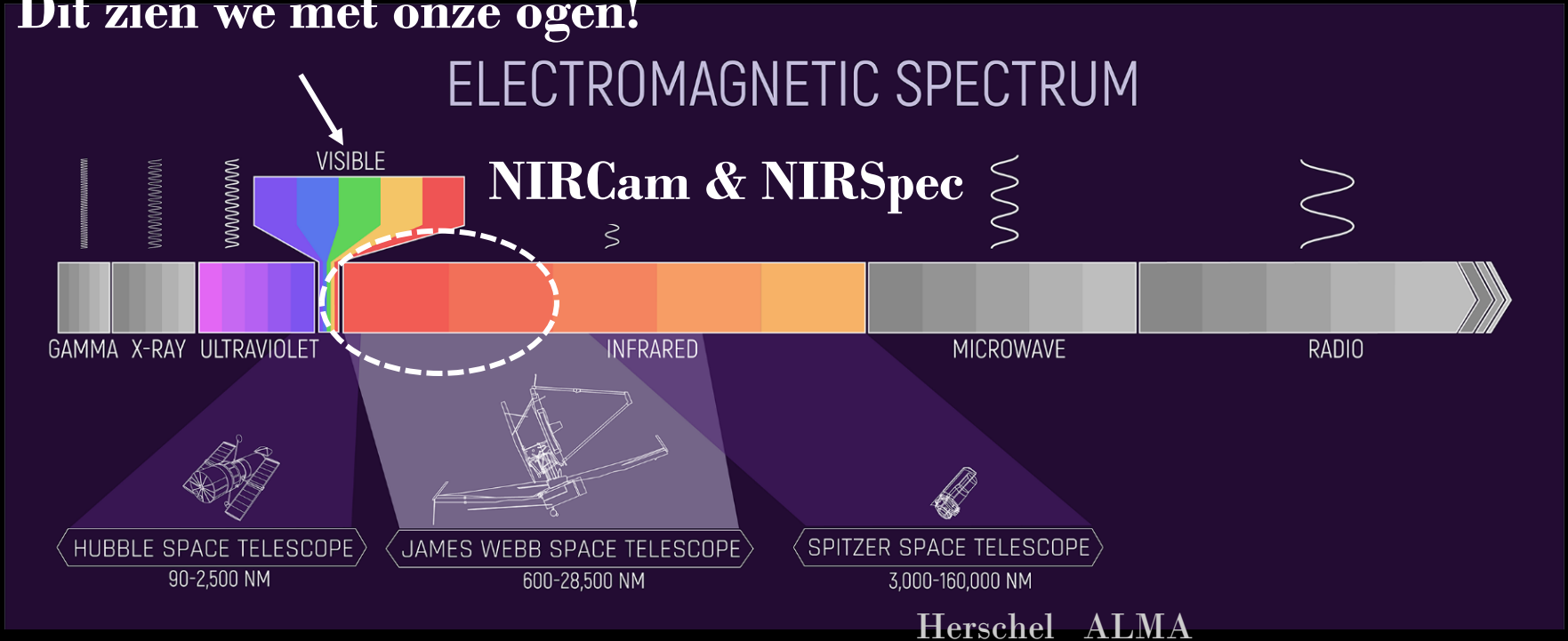


1 tennisveld!

Webb's zonnescild is nog groter: ~~14m x 97m!~~

Webb's ogen: infrarood

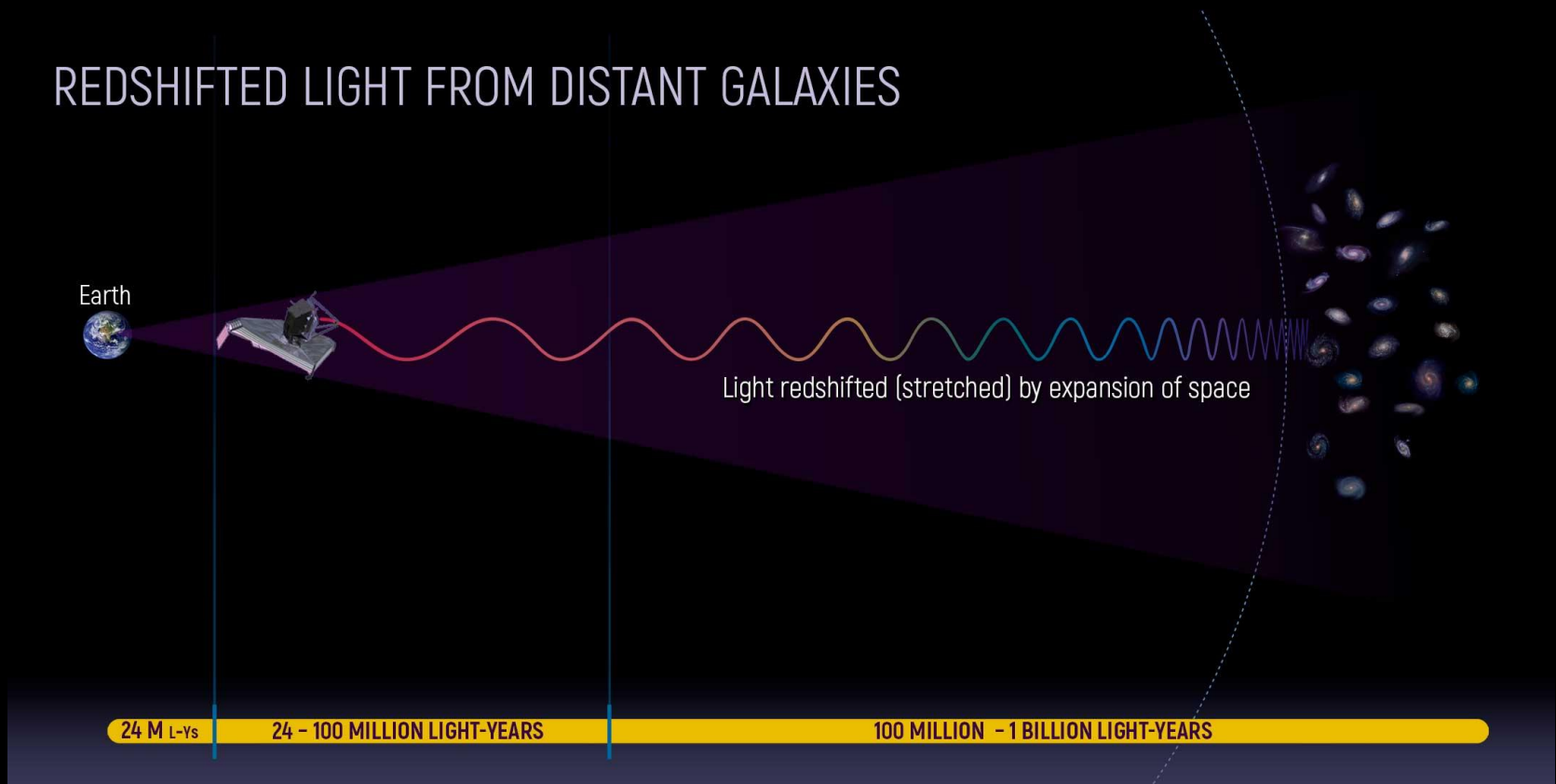
Dit zien we met onze ogen!



Aardatmosfeer blokkeert straling uit de ruimte →
ruimtetelescoop

Waarom infrarood?

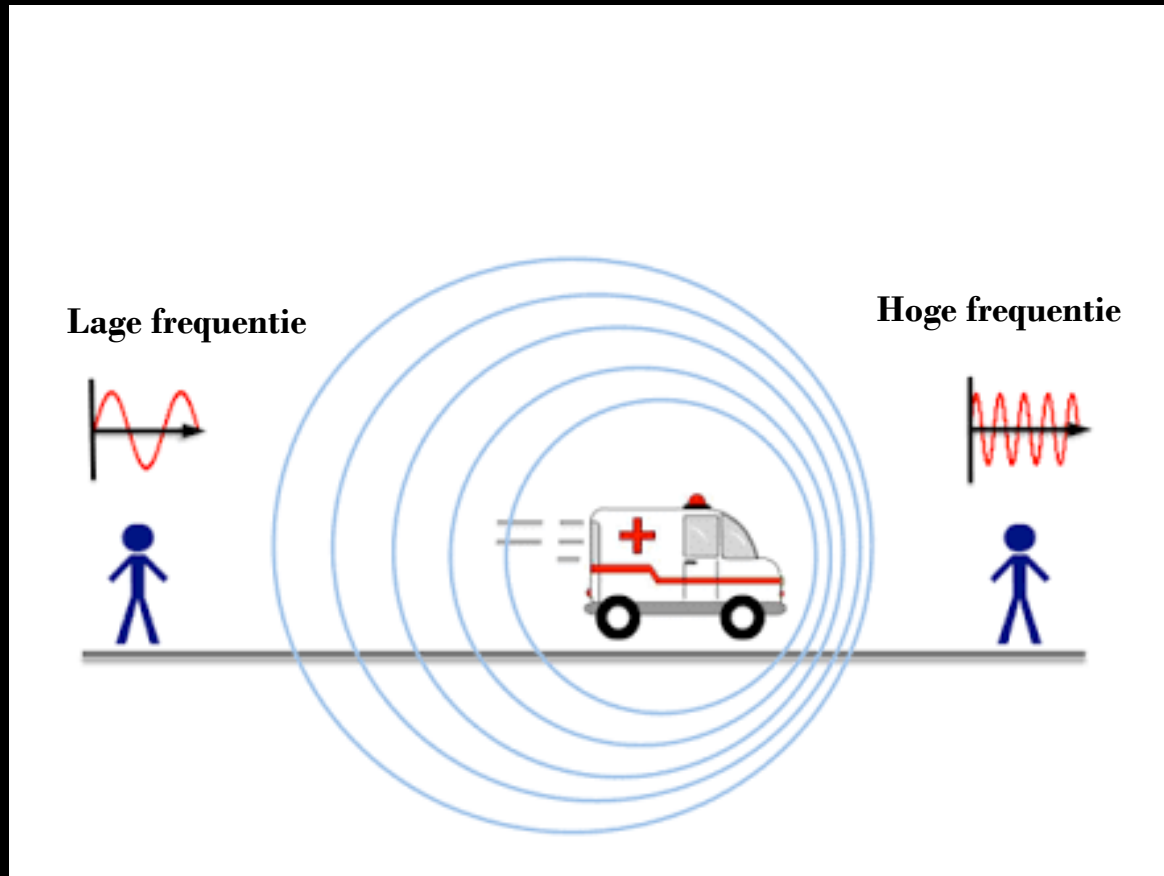
REDSHIFTED LIGHT FROM DISTANT GALAXIES



©NASA/ESA

Licht van verre sterrenstelsels is verschoven naar het rood

Vergelijk geluid ambulance



Waarom infrarood?

Penetreren donkere stoffige wolken



©NASA/ESA

Geboorte van sterrenstelsels, sterren, planeten

Webb lancering: een kerstkadoetje



25 December 2021

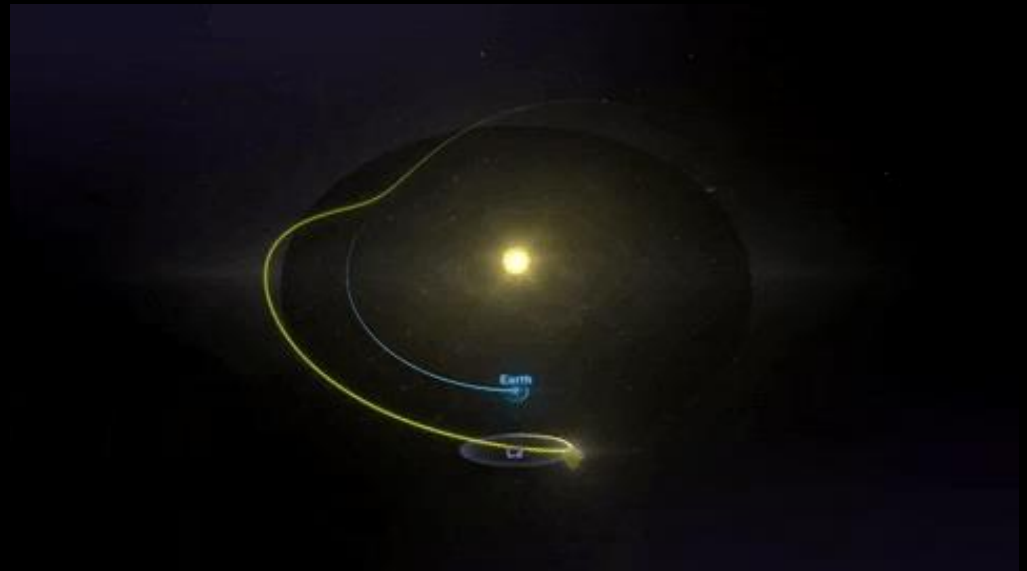
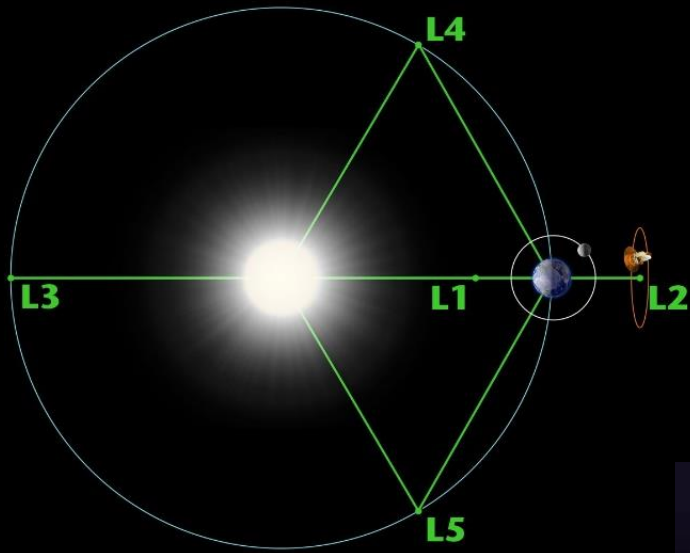
Bye Webb!



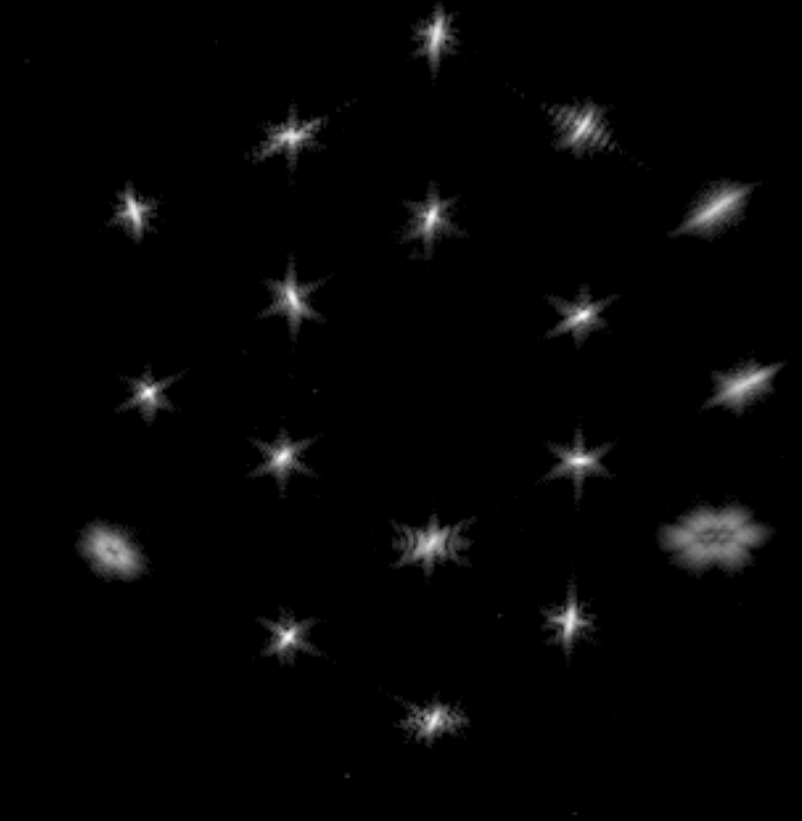
Uitvouwen van Webb



Baan van Webb

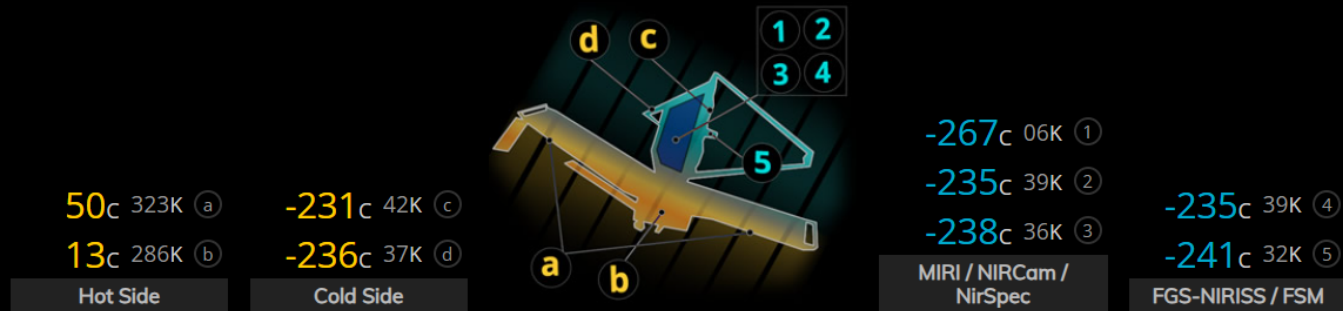


Uitlijnen spiegels



HD 84406 in Ursa Major

“Where is Webb”?



Final

Temperature Plots

Plots Help

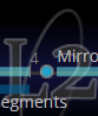
About Temps

Units: F <> C



L+WEEKS

Spacecraft Deployment



Mirror Alignment & Cooldowns

12

Instruments Commissioning

24

28

Sunshield

Mirror Segments

Step1: Segment ID

Step4: Coarse Phasing MIRI: Final Cooldown

Instruments Modes Check Out



Secondary Mirror

NIRCam Cooling & On

Step2: Segment Align

Step5: Fine Phasing

Step7: Final Correction

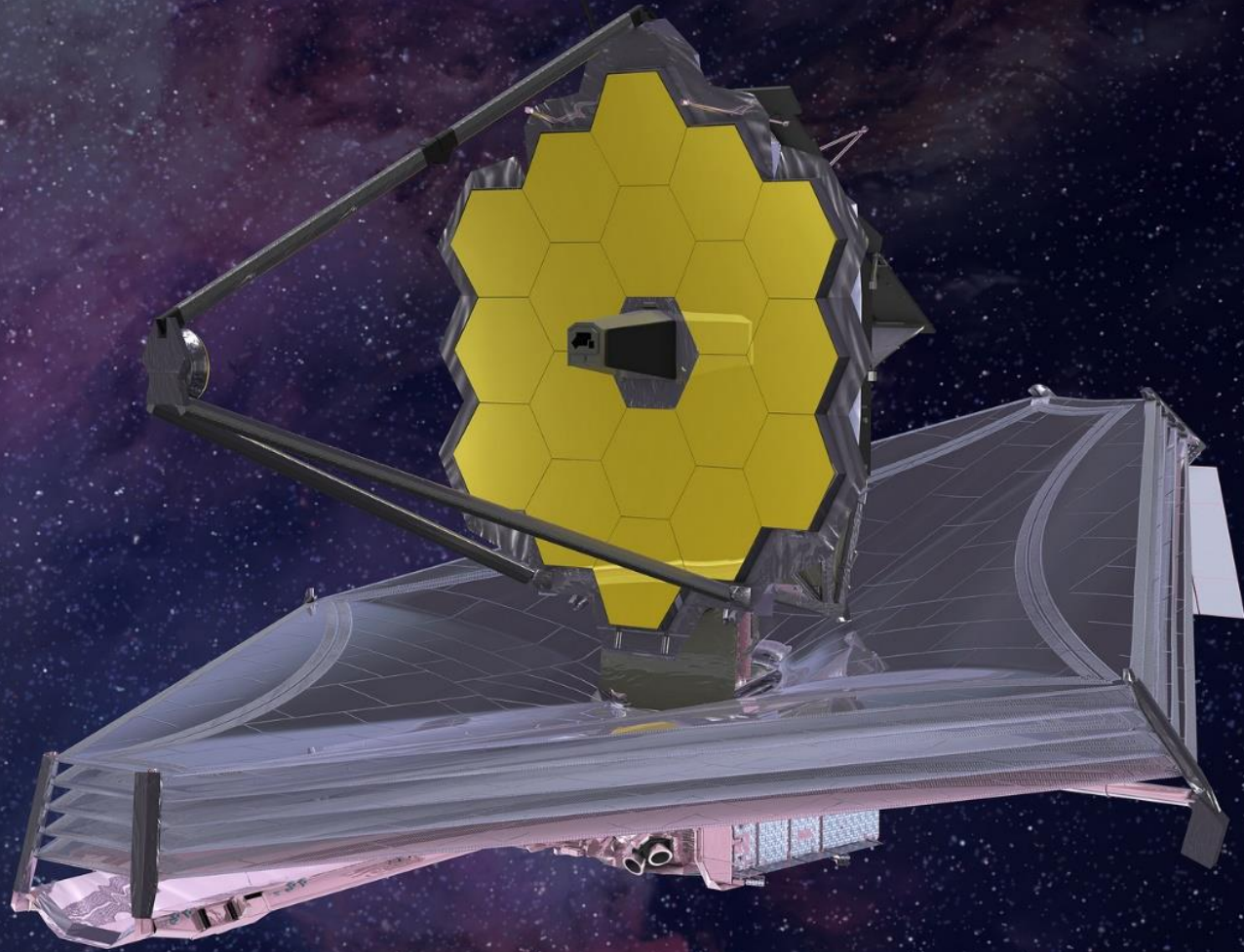
Primary Mirror

Step3: Image Stacking Step6: All Fields of View

Instruments Test, Calibration & Characterization


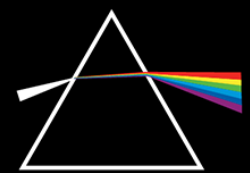

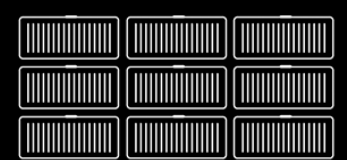


22 januari, 2024





De James Webb Ruimtetelescoop



Vier instrumenten op Webb

Maakt de mooie plaatjes

 <p>CAMERAS</p>	 <p>SPECTROGRAPHS</p>	 <p>CORONAGRAPHS</p>
 <p>MICROSHUTTER ARRAY</p>	 <p>INTEGRAL FIELD UNITS</p>	 <p>APERTURE MASK</p>

Instrument
NIRCam Univ. Az/LMATC 
NIRSpec ESA/Astrium 
MIRI ESA/Consortium /UKATC/JPL 
FGS/NIRISS CSA 

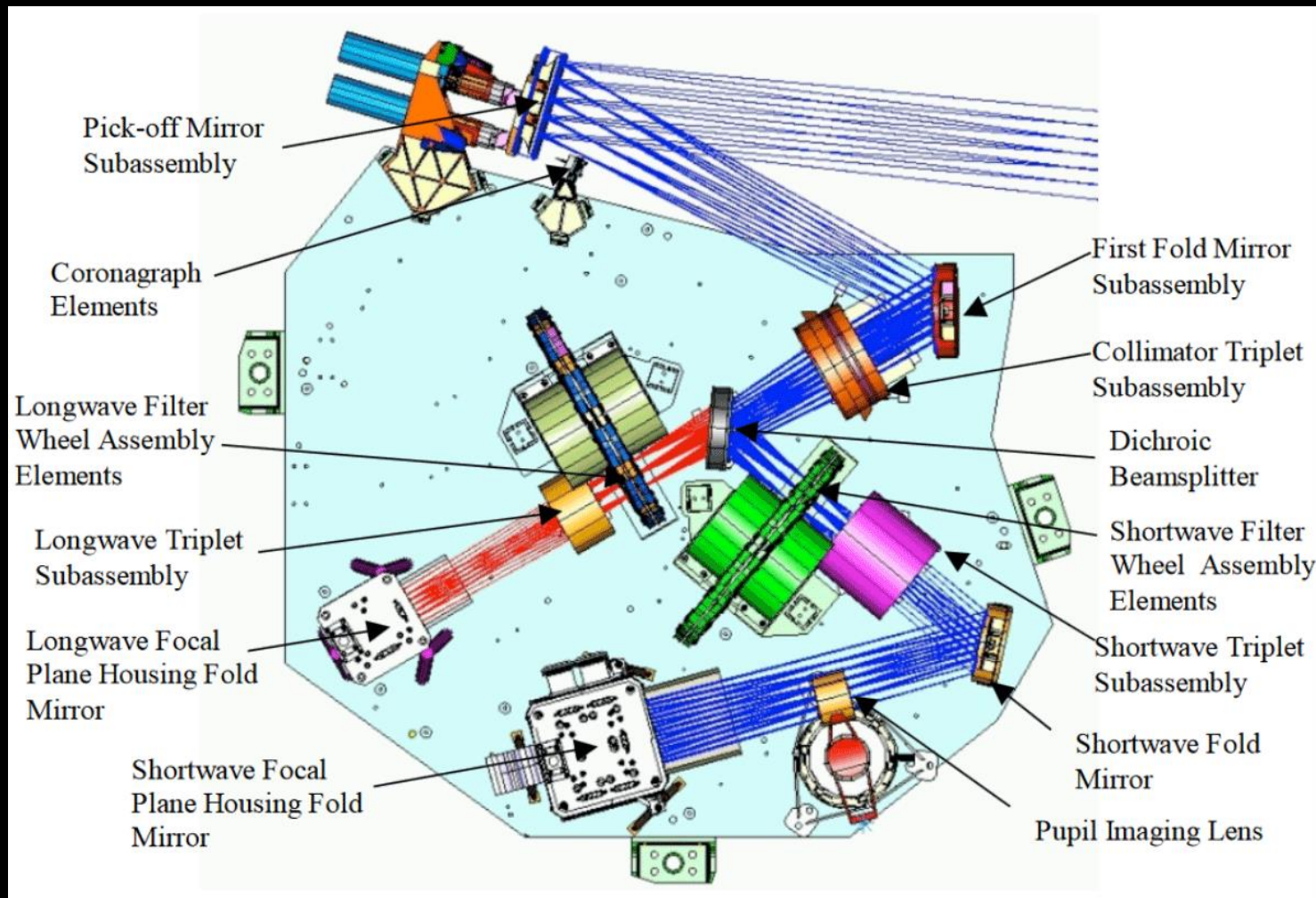
Spectrometer

Gevoeligheid factor 100-1000 beter dan eerdere instrumenten
→ Ontdekkingsreis!

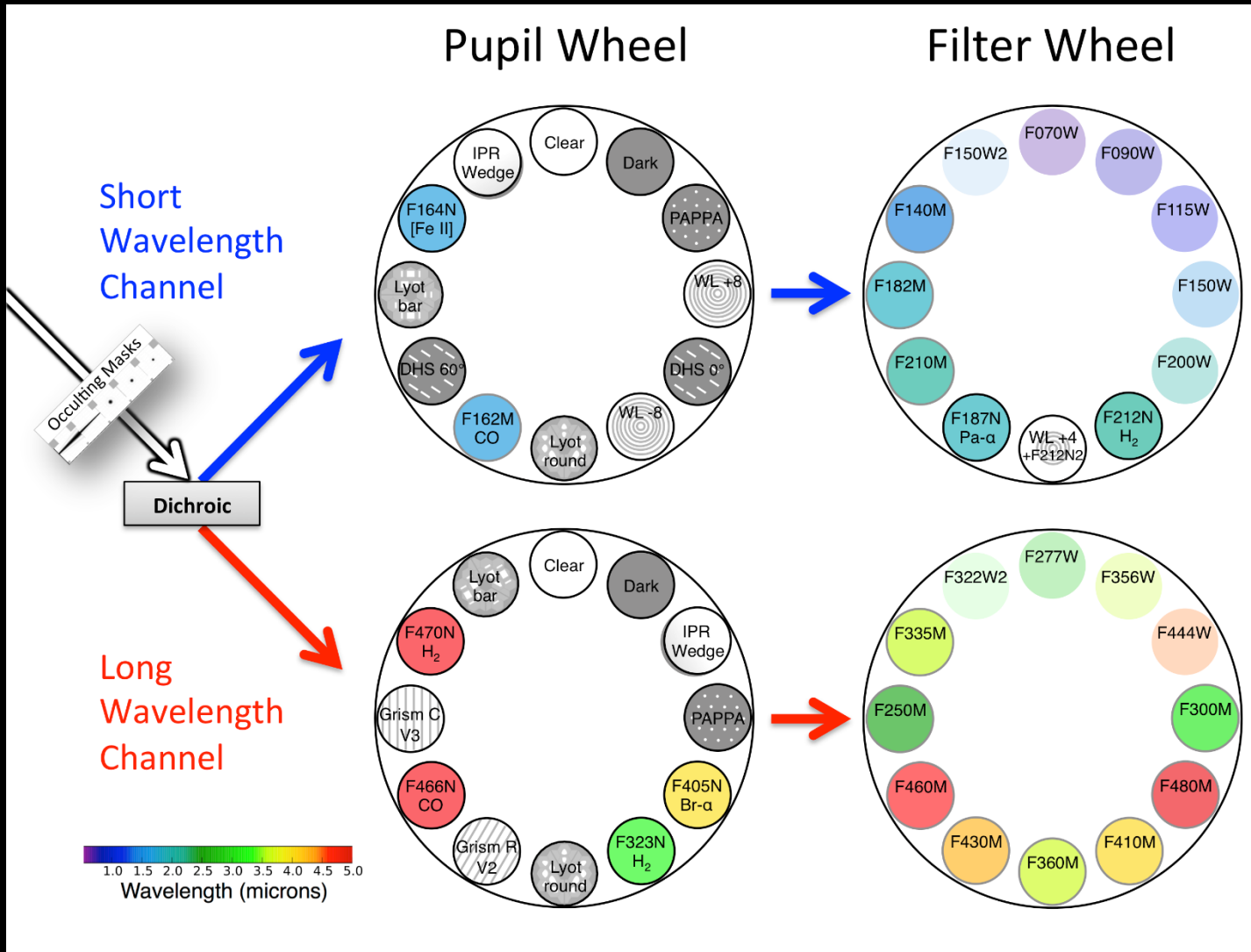
De nabij-infrarood camera: NIRCam



De nabij-infrarood camera: NIRCam



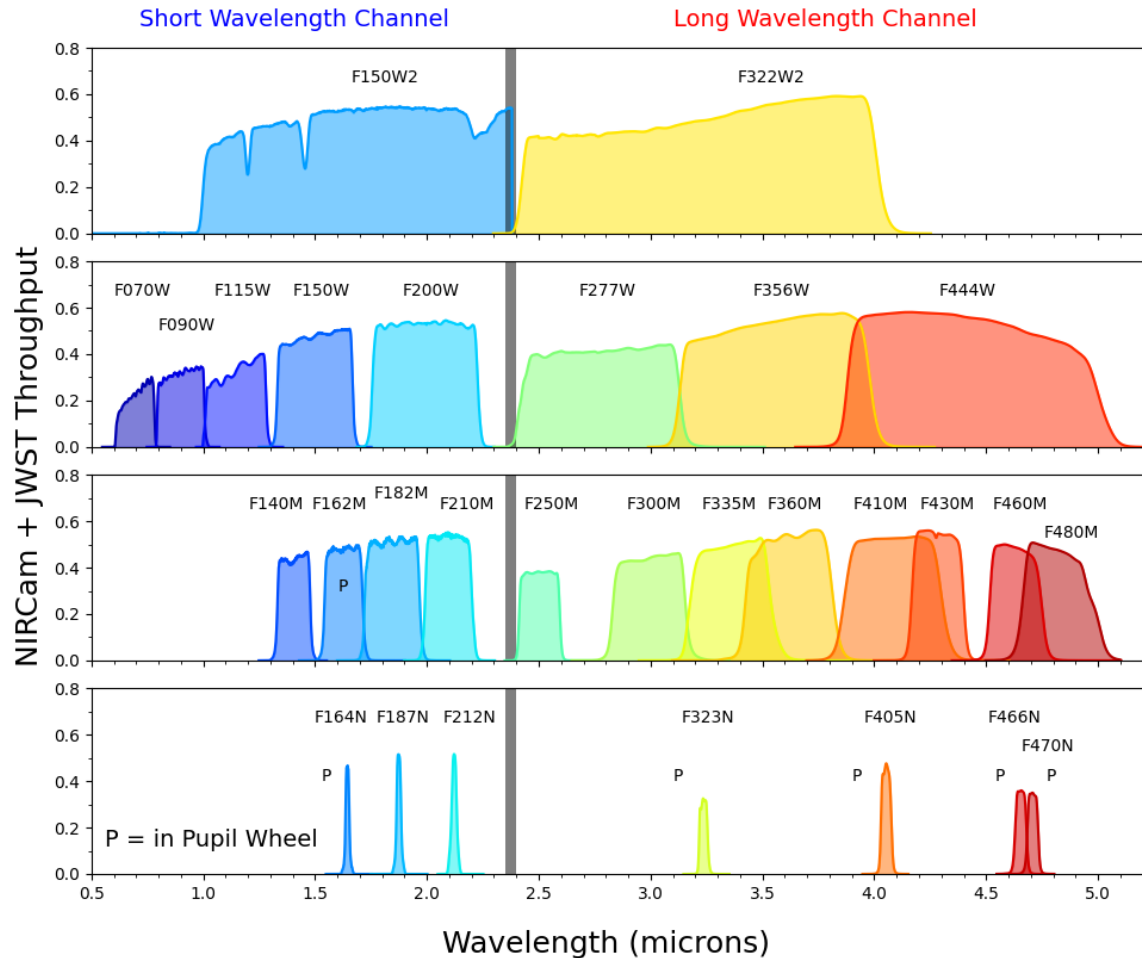
De nabij-infrarood camera: NIRC*am*



De nabij-infrarood camera: NIRC*am*



NIRC*am* Filters



Telescoop ziet scherp



TELESCOPE ALIGNMENT EVALUATION IMAGE

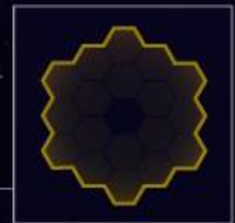


Diffractiepatroon

WEBB'S DIFFRACTION SPIKES



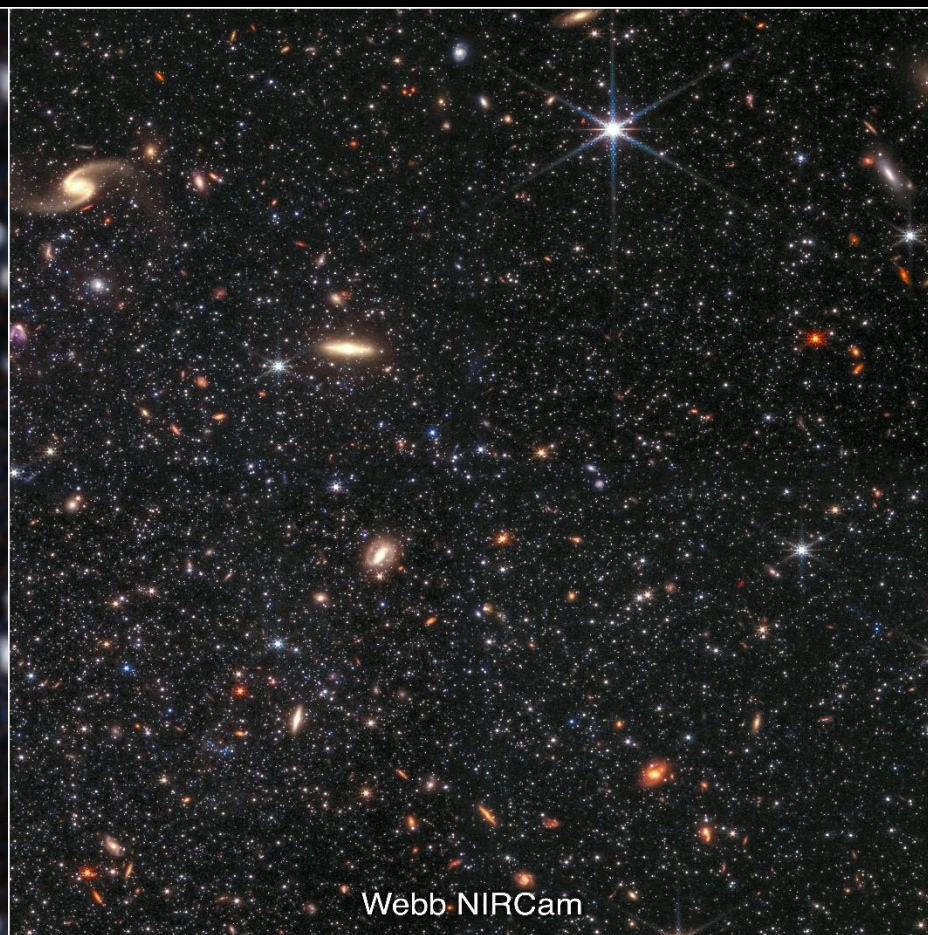
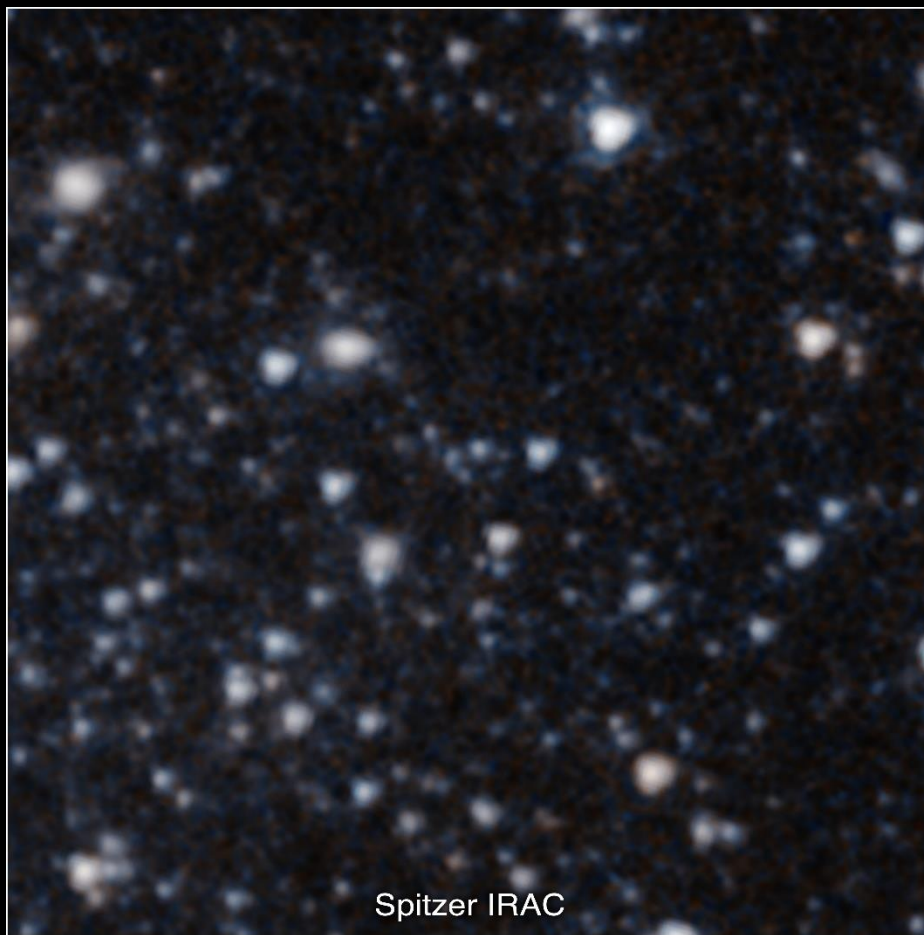
STRUT
INFLUENCE



PRIMARY MIRROR
INFLUENCE



Vergelijking *Spitzer* met JWST



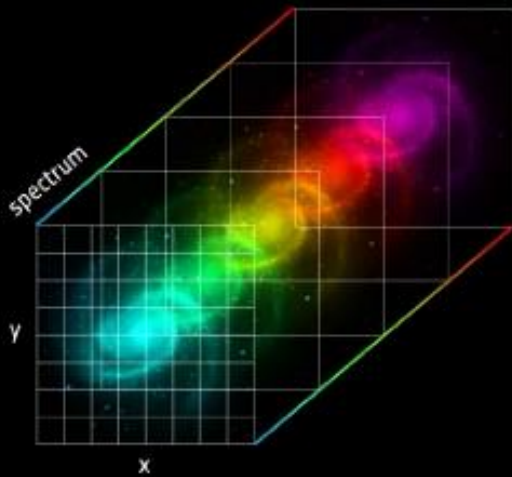
De nabij-infrarood spectrometer: NIRSpec



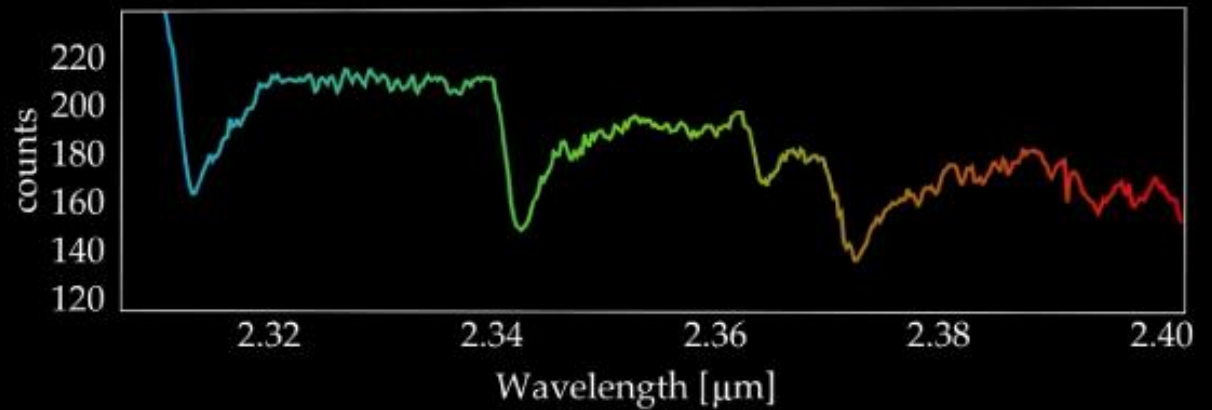
Follow the light: NIRSpec IFU



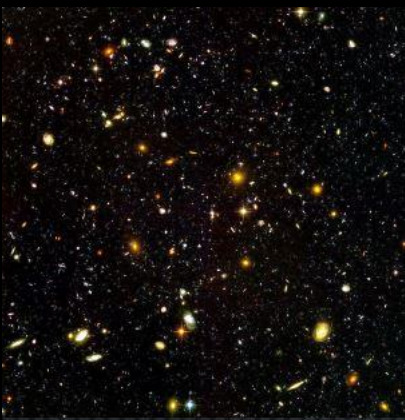
Een spectrum in elke pixel



Spectrum of each 2D spaxel



Wetenschap met JWST



Early Universe

Vroege
heelal



Galaxies Over Time

Evolutie
sterrenstelsels



Star Lifecycle

Levenscyclus
sterren



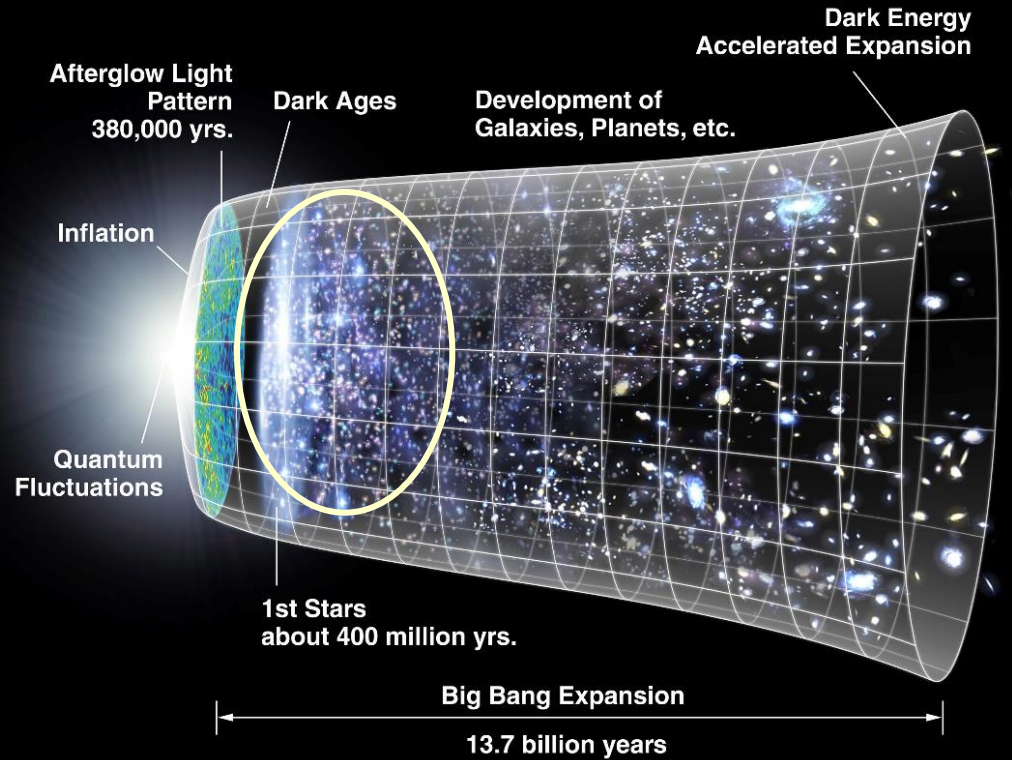
Other Worlds

Andere
werelden

“Oud, koud en stoffig”

Thema 1: “Eerste licht”?

- Eerste sterrenstelsels?
- Eerste sterren?

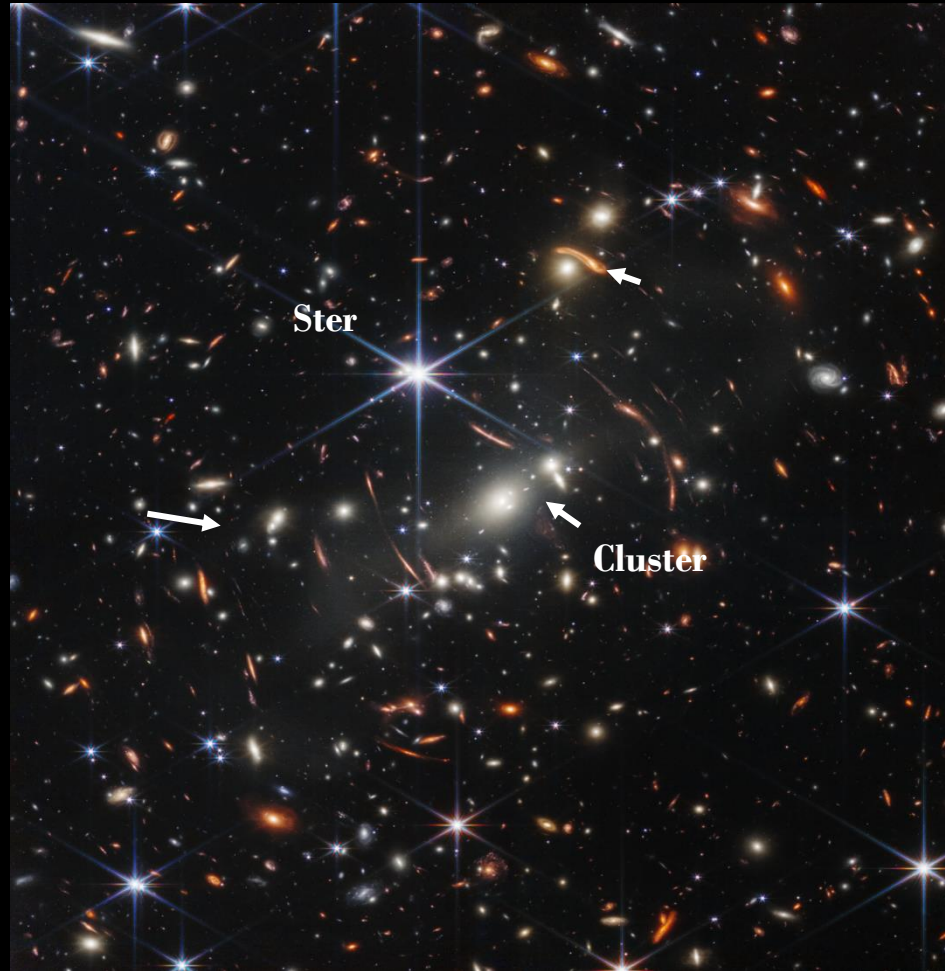


Wat bedoelen we met ‘eerste’? Geen zware elementen?

Diepste beeld van universum

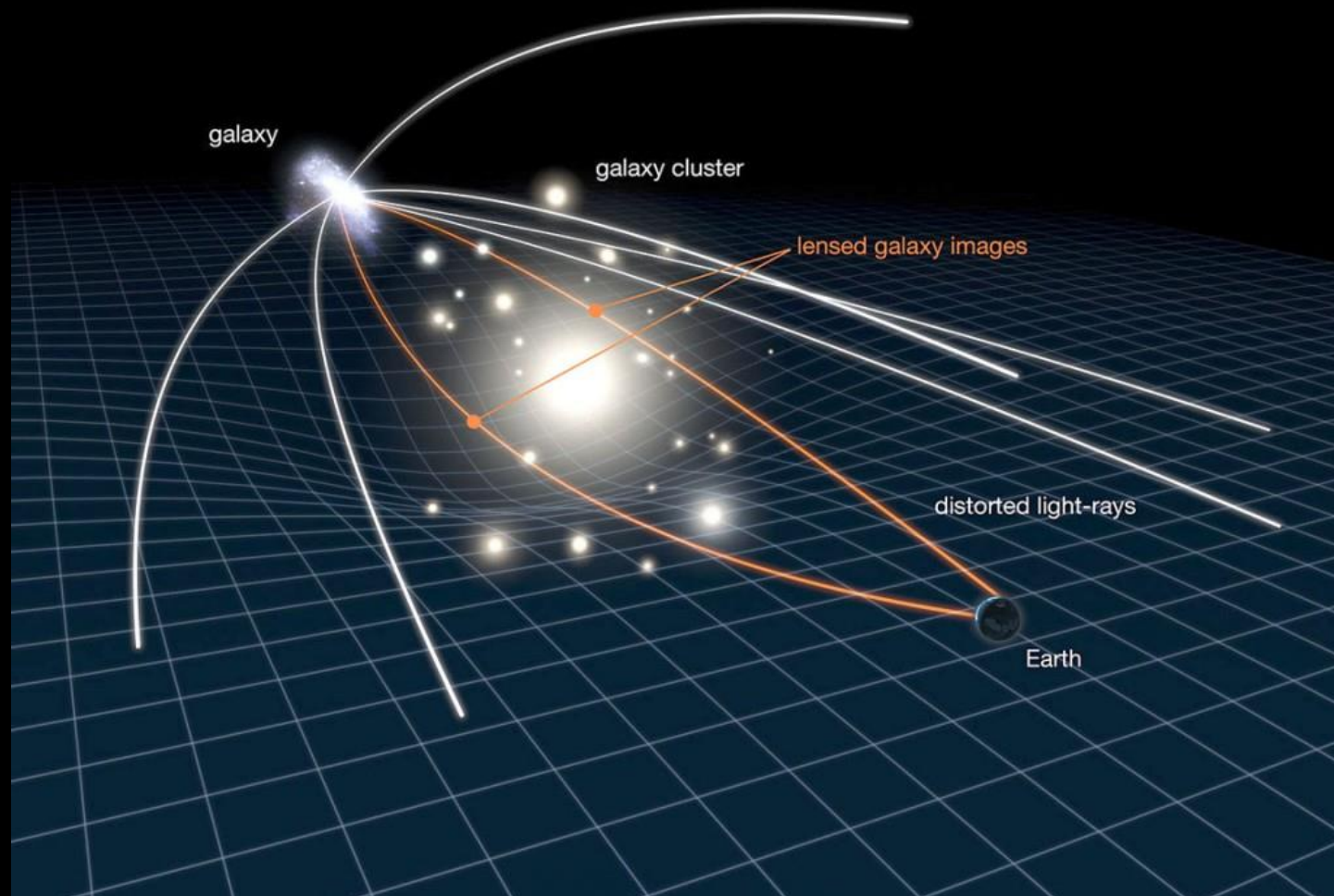


>13 miljard
Jaar oud

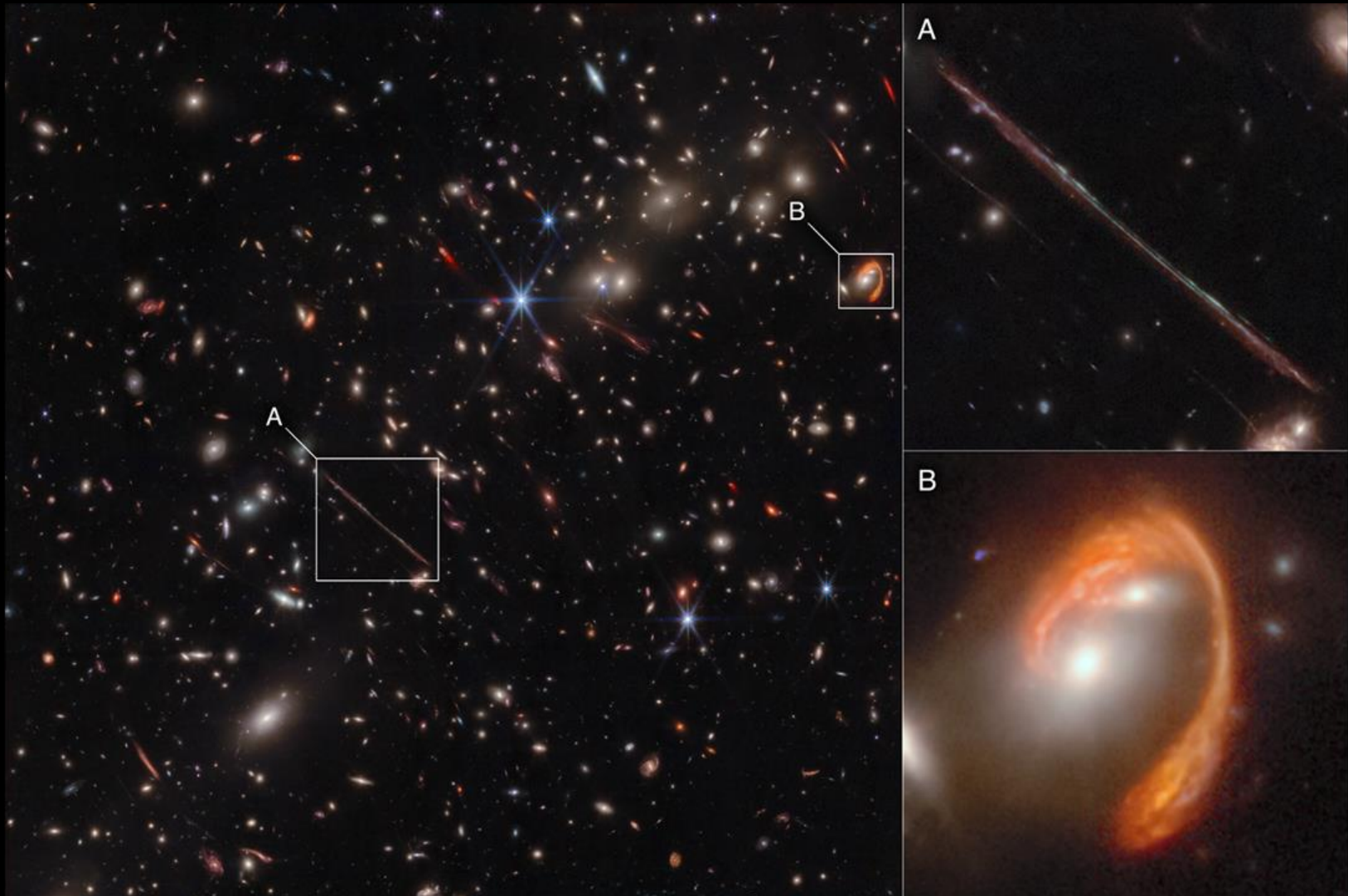


Verweg gelegen
sterrenstelsel
vervormd door lens

Kosmisch vergrootglas



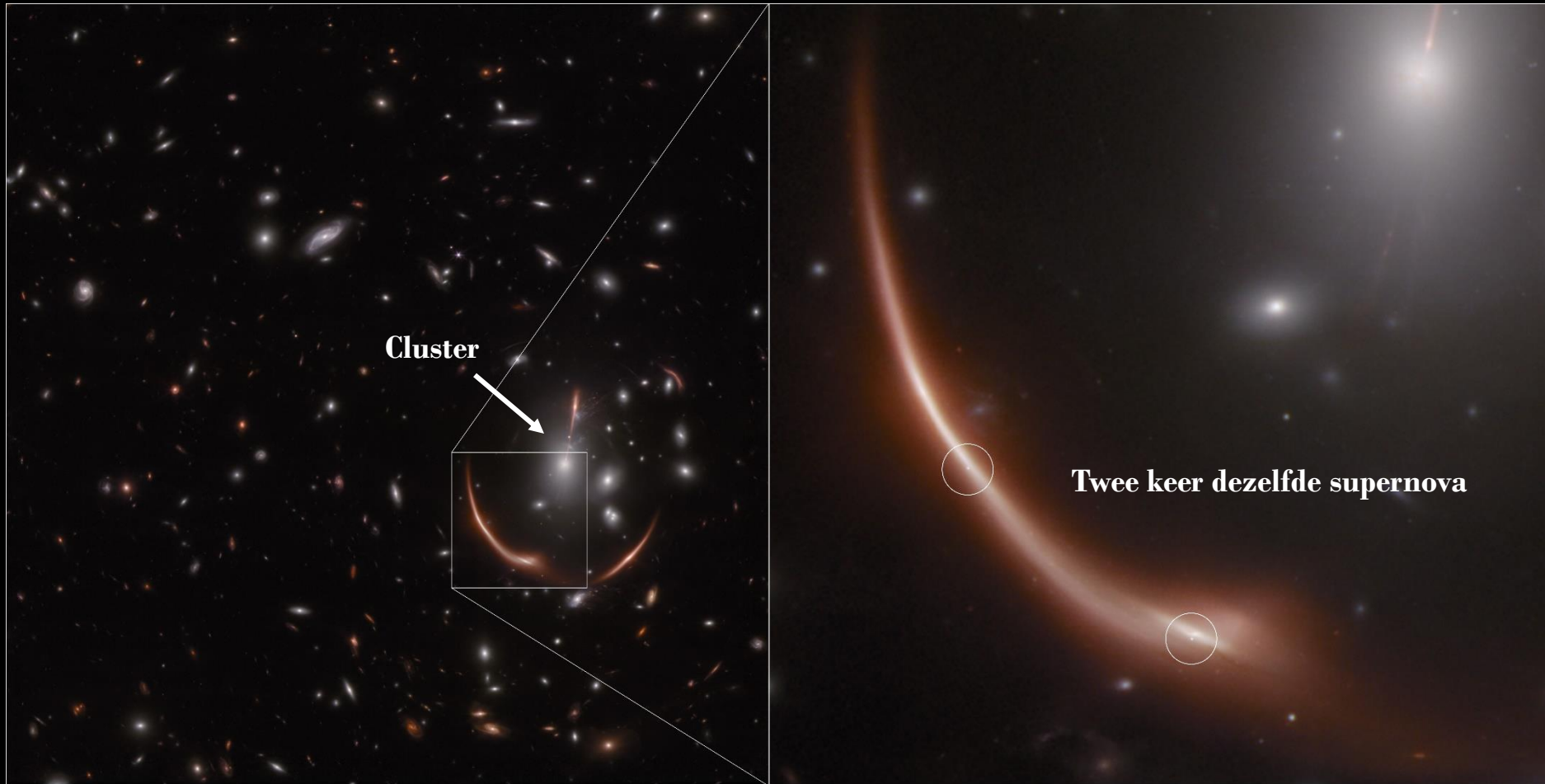
El Gordo (“De dikke”)



Supernova in een vervormd sterrenstelsel

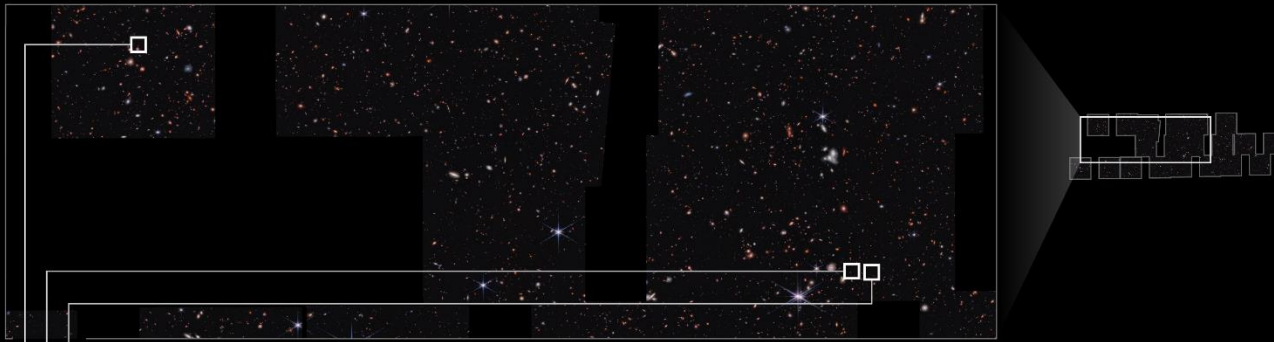


Supernova in een vervormd sterrenstelsel



Webb ziet steeds dieper in het heelal

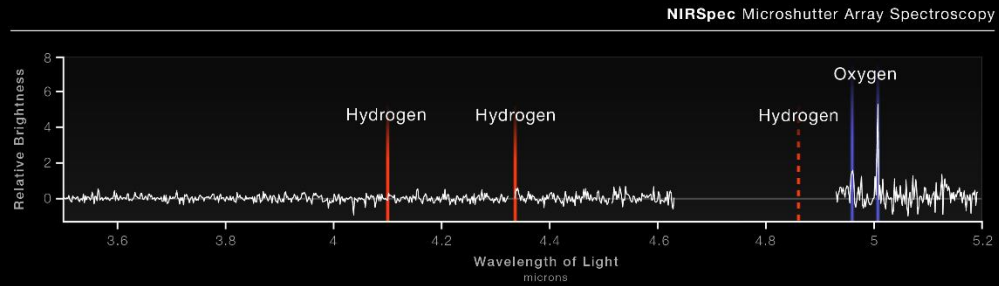
NIRCam Imaging



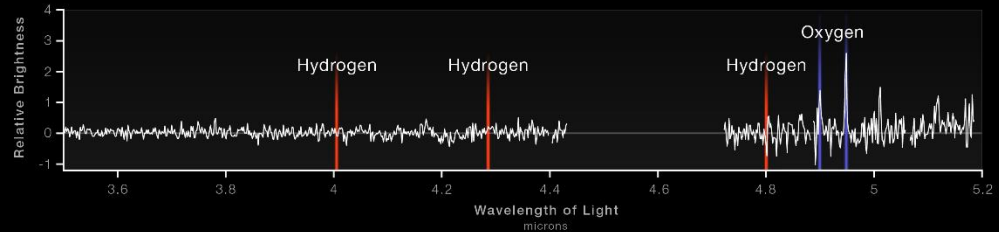
~500 miljoen
jaar na de
oerknal!



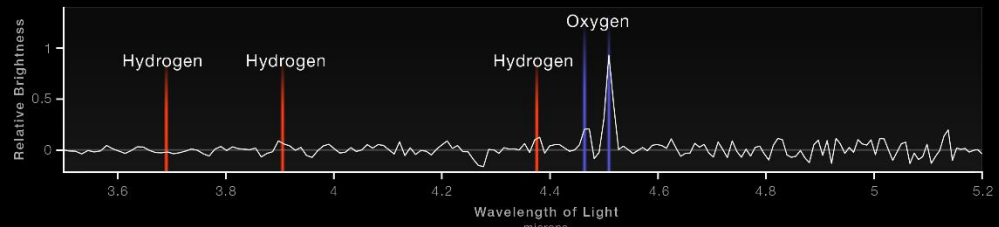
CEERS 24
13.3 billion years



CEERS 23
13.3 billion years

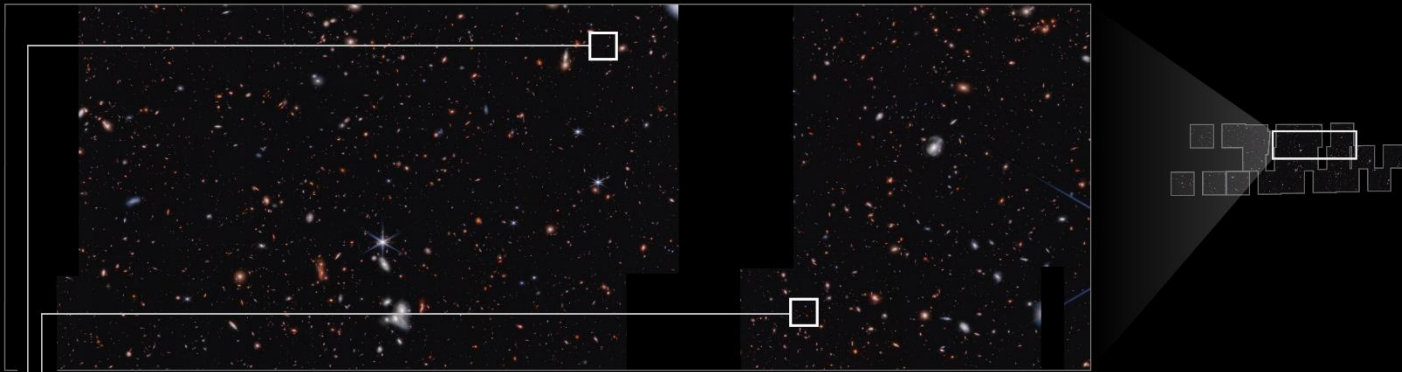


CEERS 3
13.2 billion years

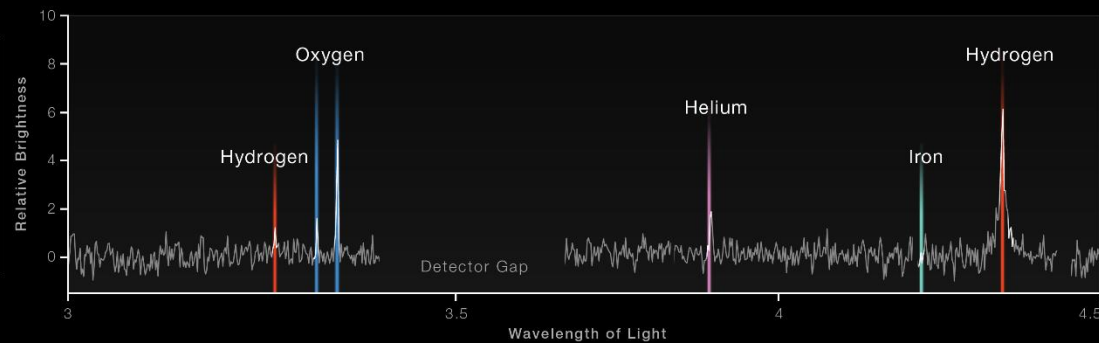


Al heel vroeg actieve super zware zwarte gaten

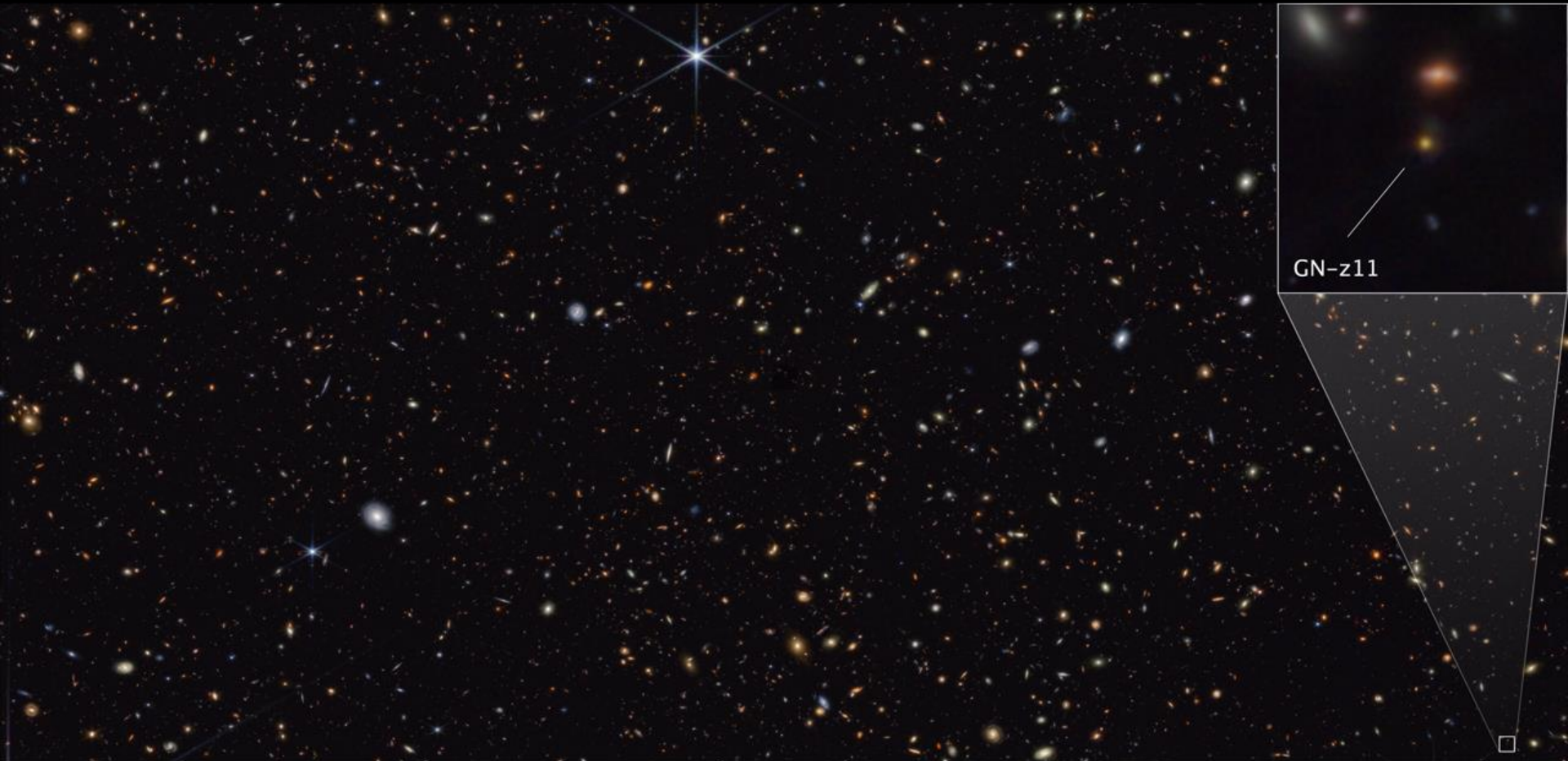
NIRCam Imaging



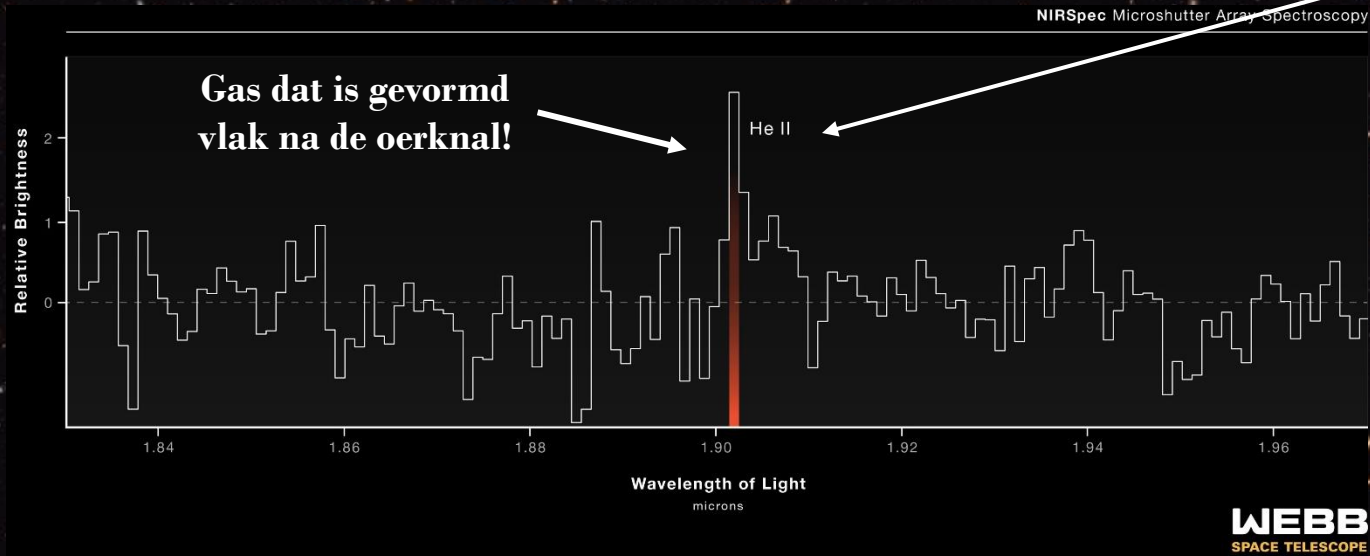
NIRSpec Microshutter Array Spectroscopy



Ongerept gas gevormd na de oerknal



Ongerept gas gevormd na de oerknal

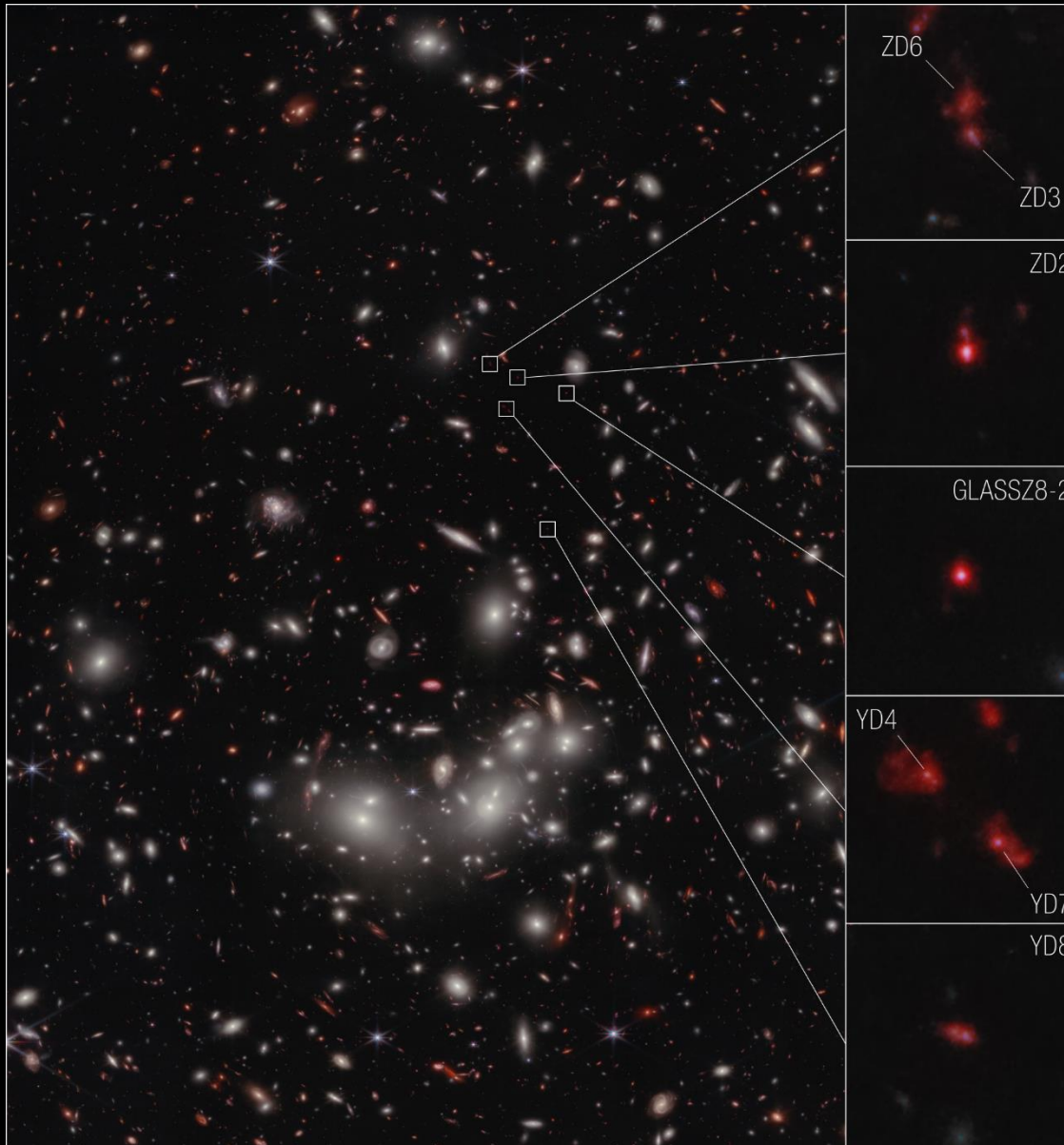


GN-z11

Sterrenstelsels in vorming



Sterrenstelsels in vorming

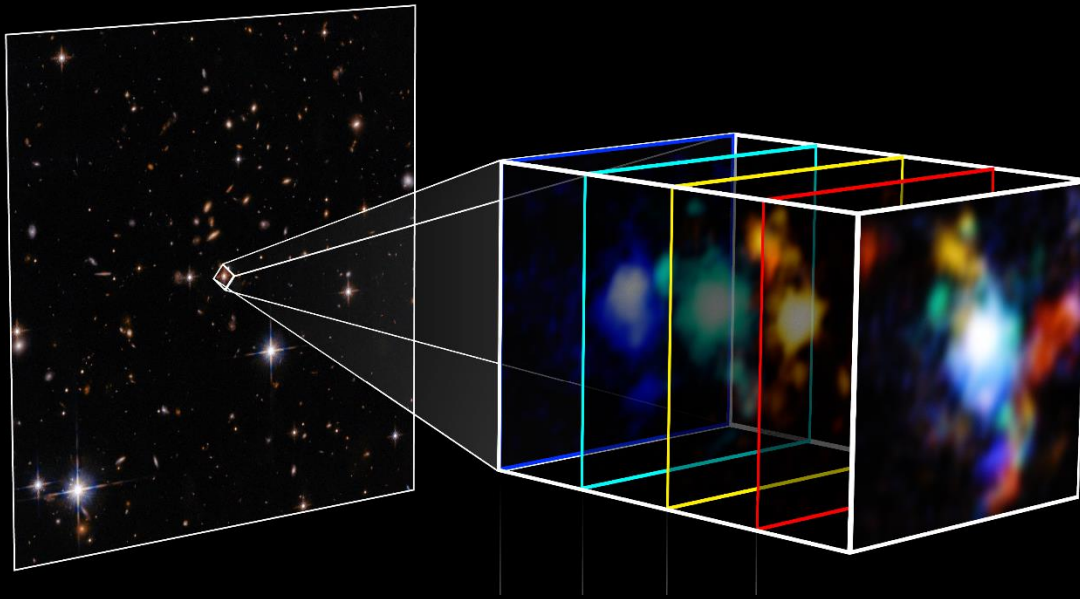


**Nieuw cluster van
sterrenstelsels ~500
miljoen jaar na oerknal**

Beweging van gas rond een Quasar

Hubble ACS + WFC3 Imaging

Webb NIRSpec IFU Spectroscopy

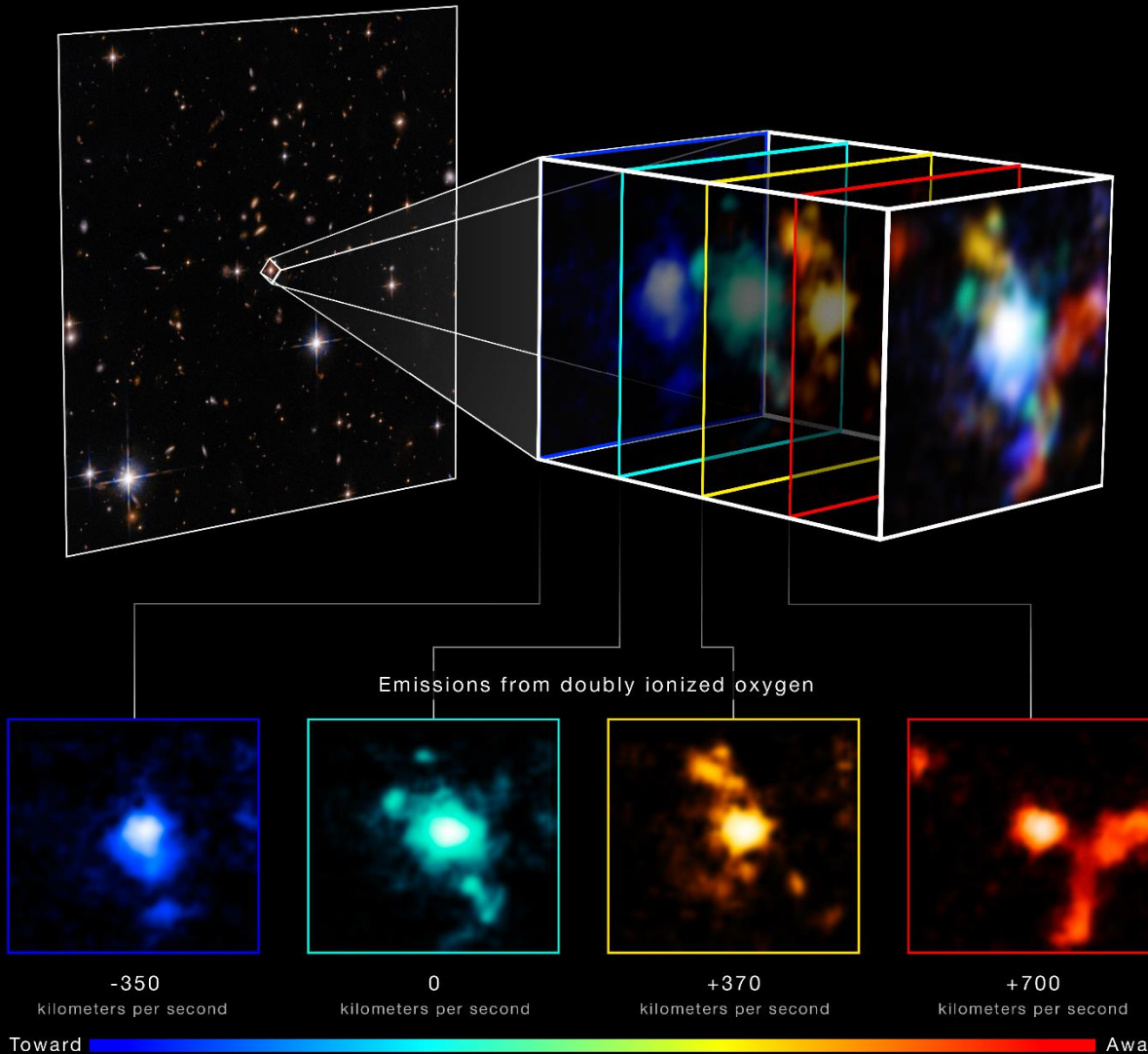


**Super zwaar zwart gat
dat materie aan het
opslokken is**

Beweging van gas rond een Quasar

Hubble ACS + WFC3 Imaging

Webb NIRSpec IFU Spectroscopy

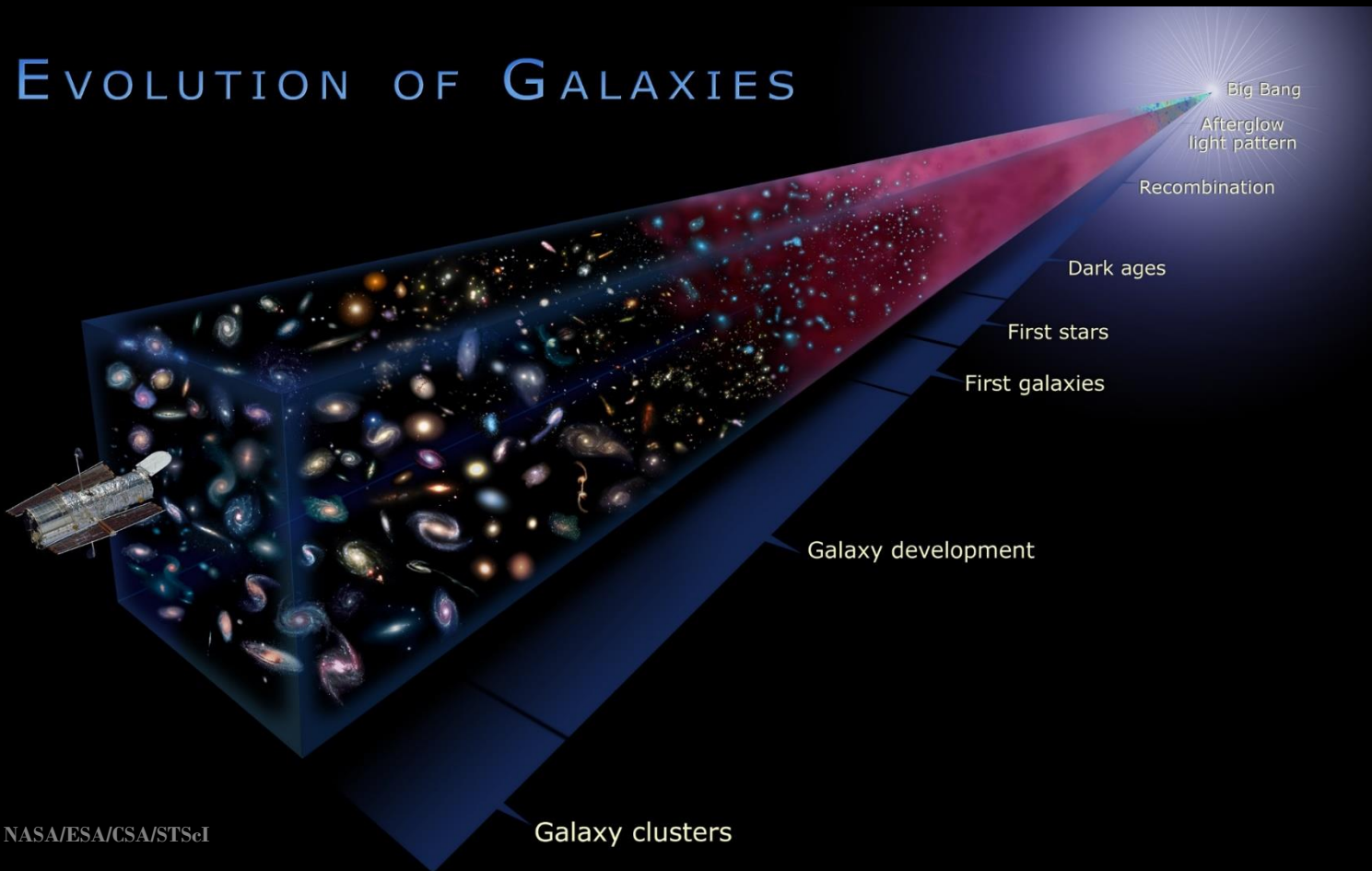


**Super zwaar zwart gat
dat materie aan het
opslokken is**

**Beweging van
geïoniseerd gas
rondom het zwarte gat**

Thema 2: Evolutie van sterrenstelsels: hoe?

EVOLUTION OF GALAXIES



75% van sterren zijn gevormd in eerste 1-2.5 miljard jaar

Botsende en samensmeltende sterrenstelsels

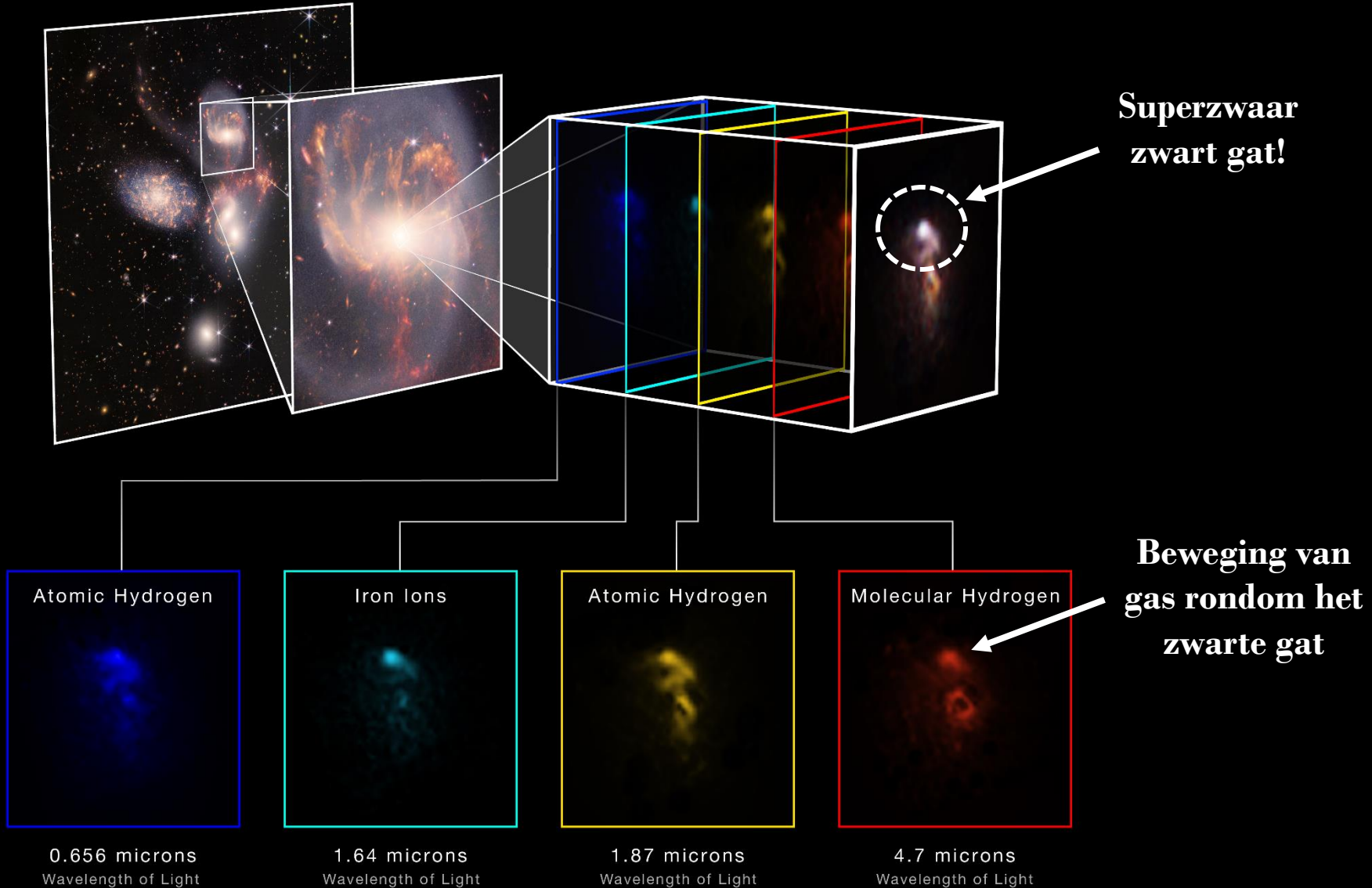


**Stephan's
Quintet
NIRCAM + MIRI**

Botsende en samensmeltende sterrenstelsels

NIRCam and MIRI Imaging

NIRSpec IFU Spectroscopy



Prachtige sterrenstelsels met Webb



**M74
Phantom
Galaxy**

Prachtige sterrenstelsels met Webb



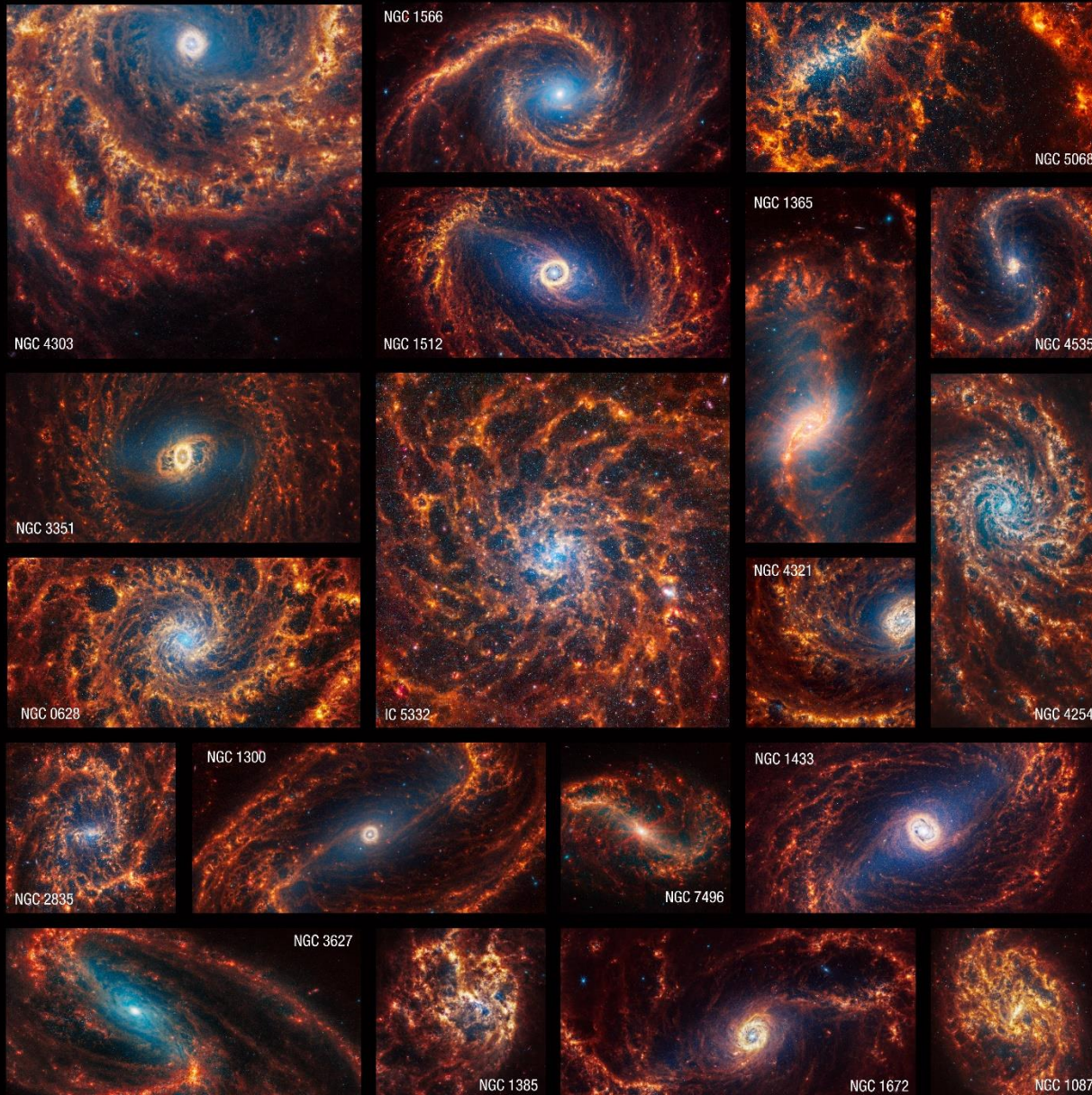
Cartwheel galaxy

Prachtige sterrenstelsels met Webb



NGC 1433

Heel veel prachtige sterrenstelsels met Webb



Botsende sterrenstelsels



Super cluster van sterrenstelsels



Pandora cluster

NASA/ESA/CSA/STScI

Kilonova: samensmelten van twee neutronensterren



Kilonova: samensmelten van twee neutronensterren

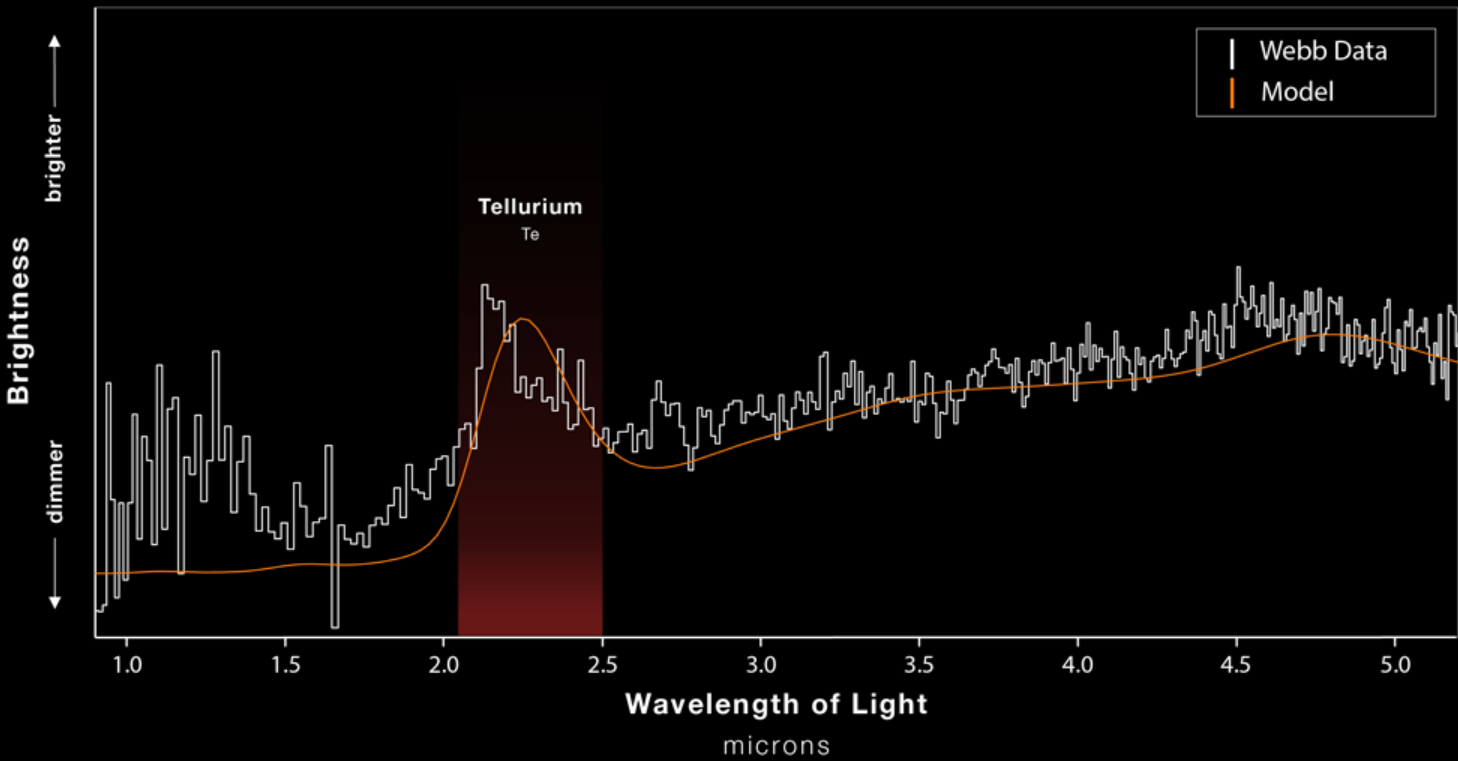


Kilonova: samensmelten van twee neutronensterren

GRB 230307A

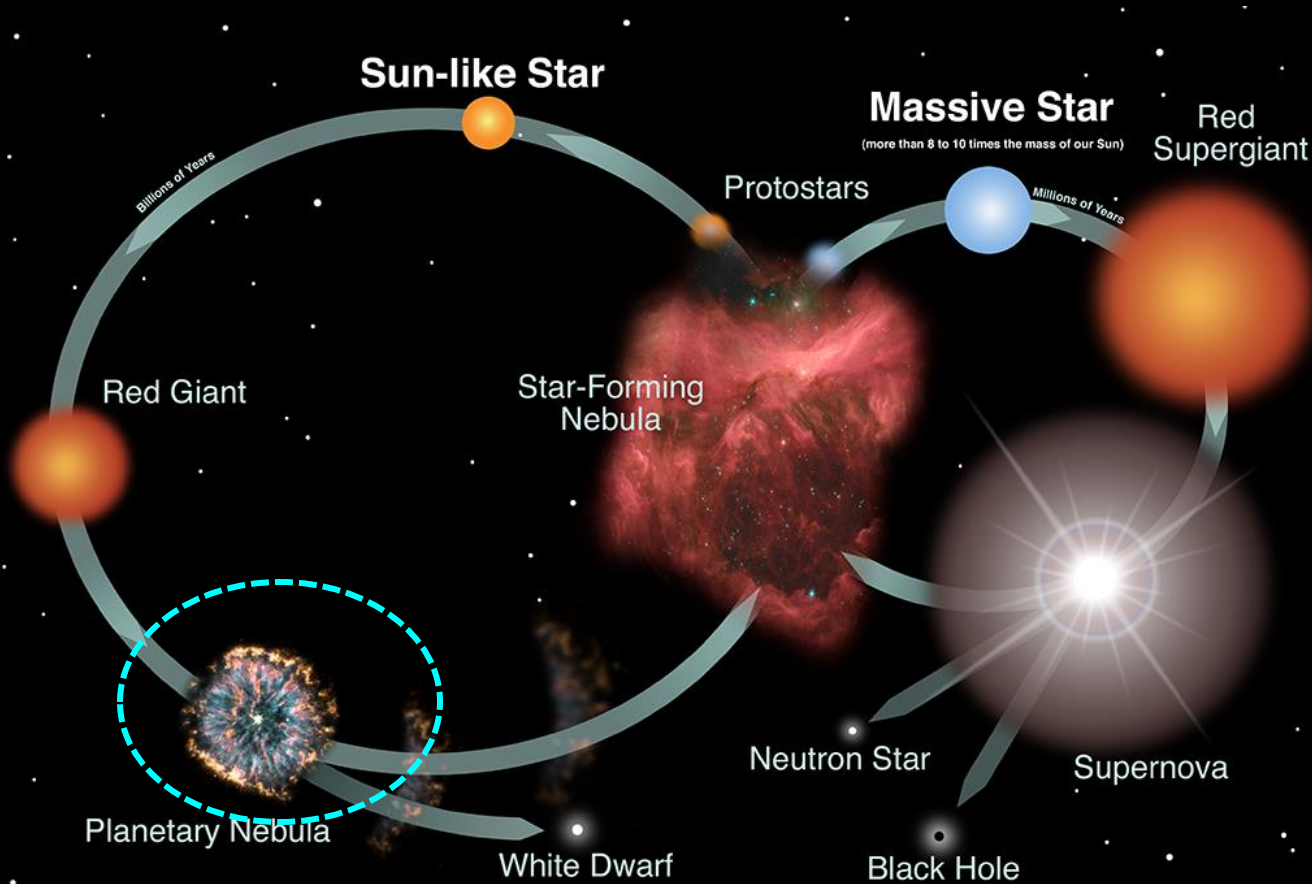
KILONOVA EMISSION SPECTRUM

NIRSpec | PRISM



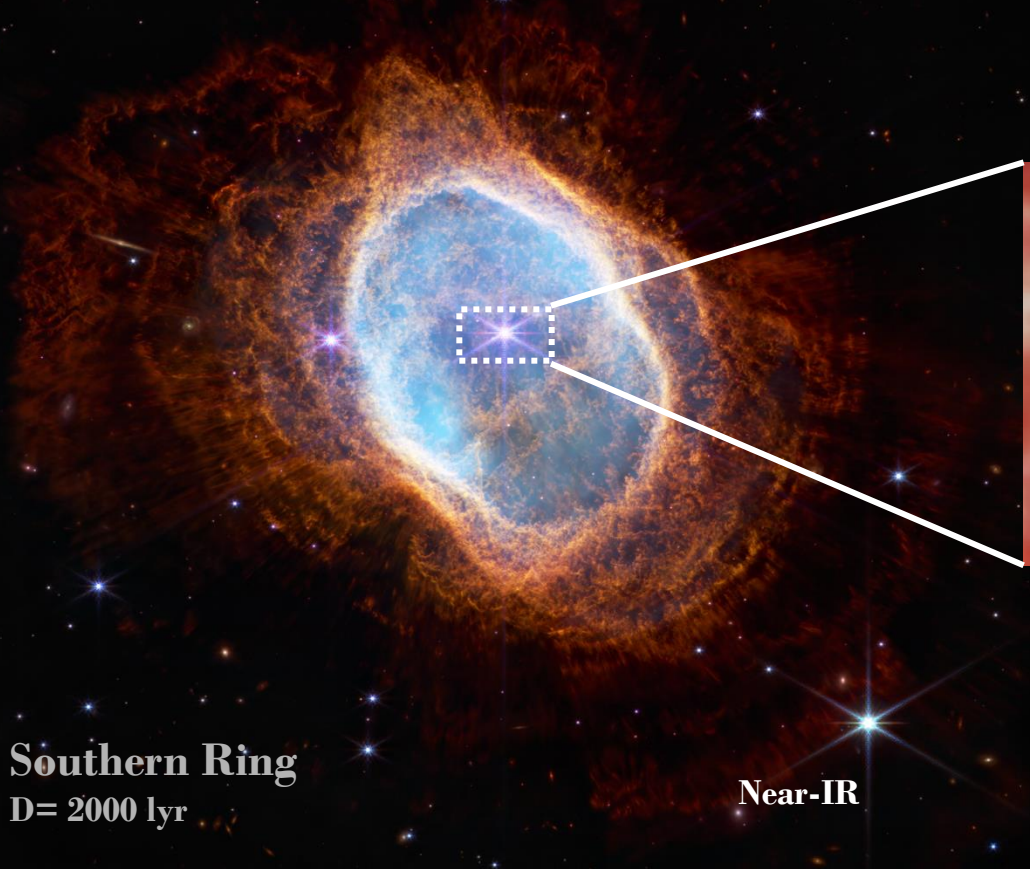
WEBB
SPACE TELESCOPE

Thema 3: Levenscyclus van sterren: van geboorte tot dood



Dood van een “normale” ster: Planetaire nevel

Vorming van stofkorrels
en aromaten



Southern Ring
D= 2000 lyr

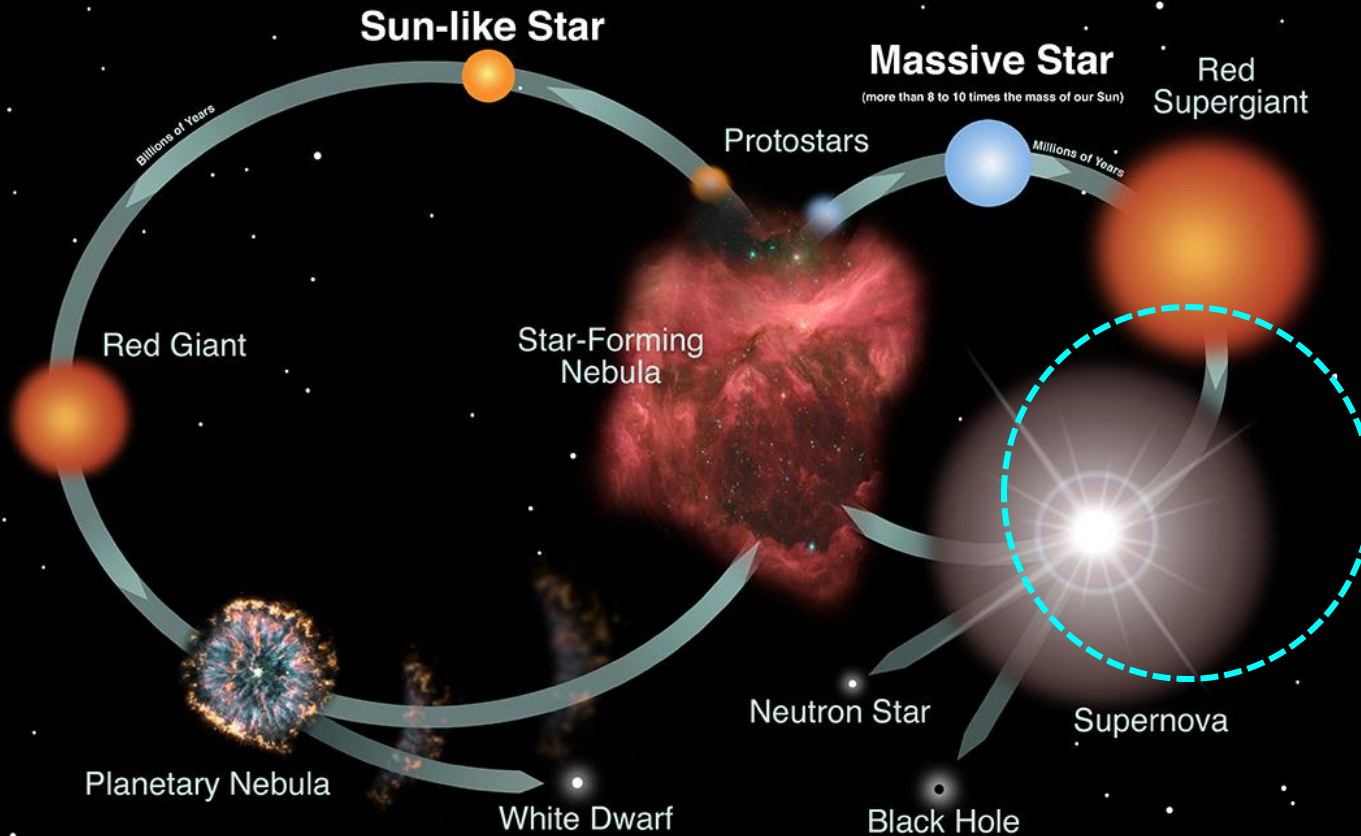
Near-IR



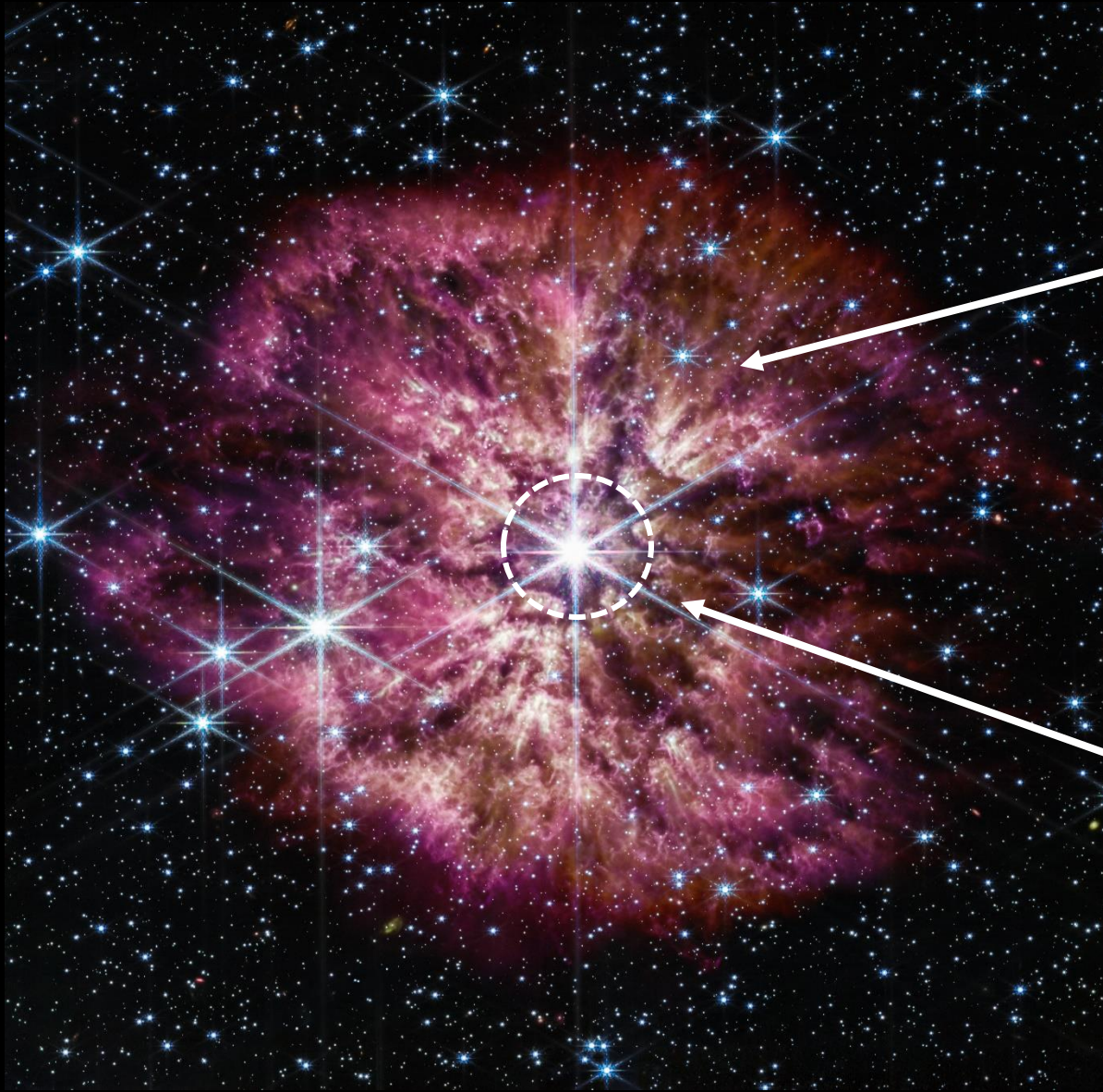
Het is een dubbelster!

Mid-IR

Thema 3: Levenscyclus van sterren: van geboorte tot dood



Wolf-Rayet ster: Dood van een zware ster

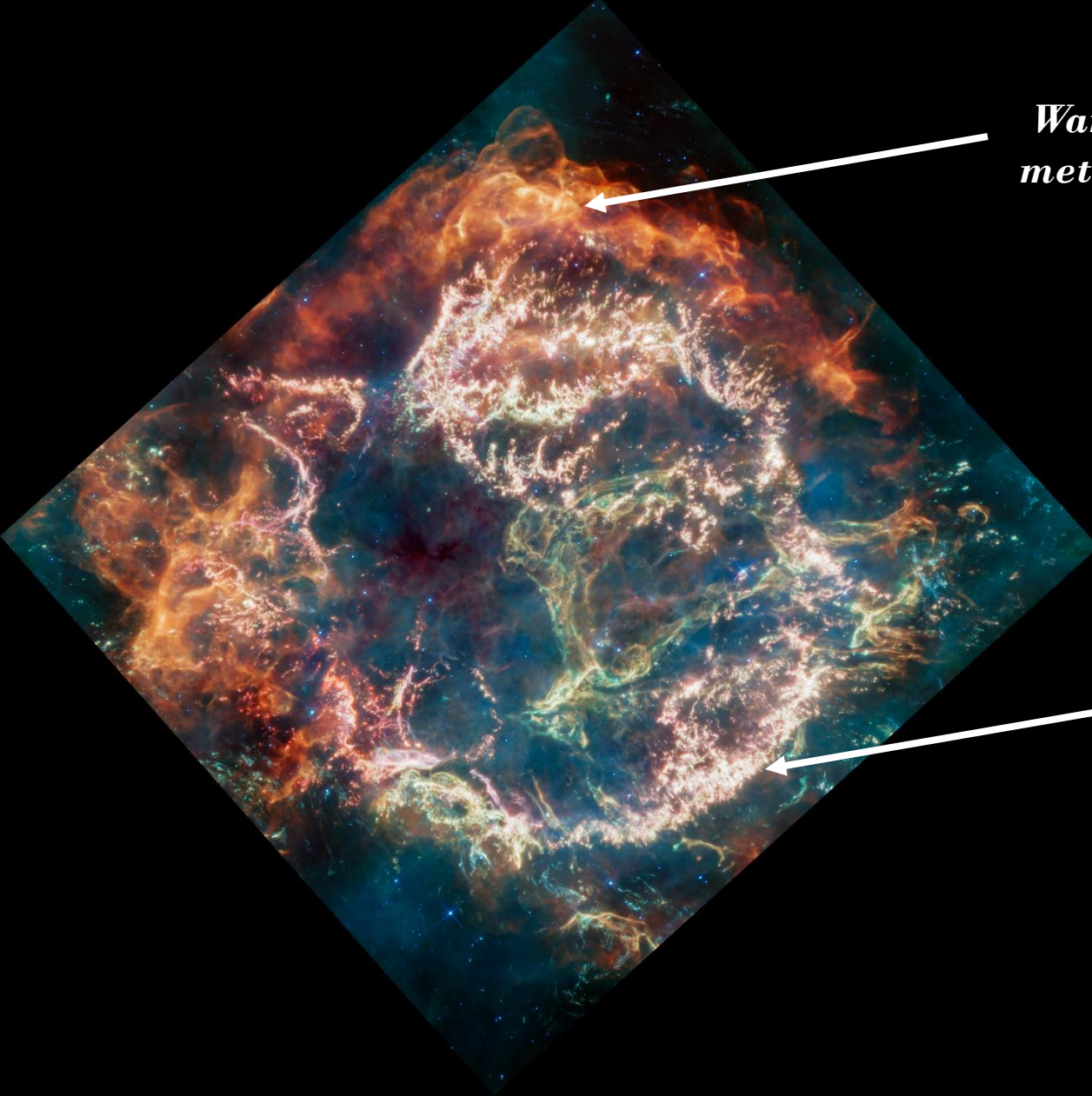


*Naar buiten gestuwd
materiaal van de ster*

*Staat op het punt om
supernova te gaan!*

WR 124

Supernovarest met MIRI

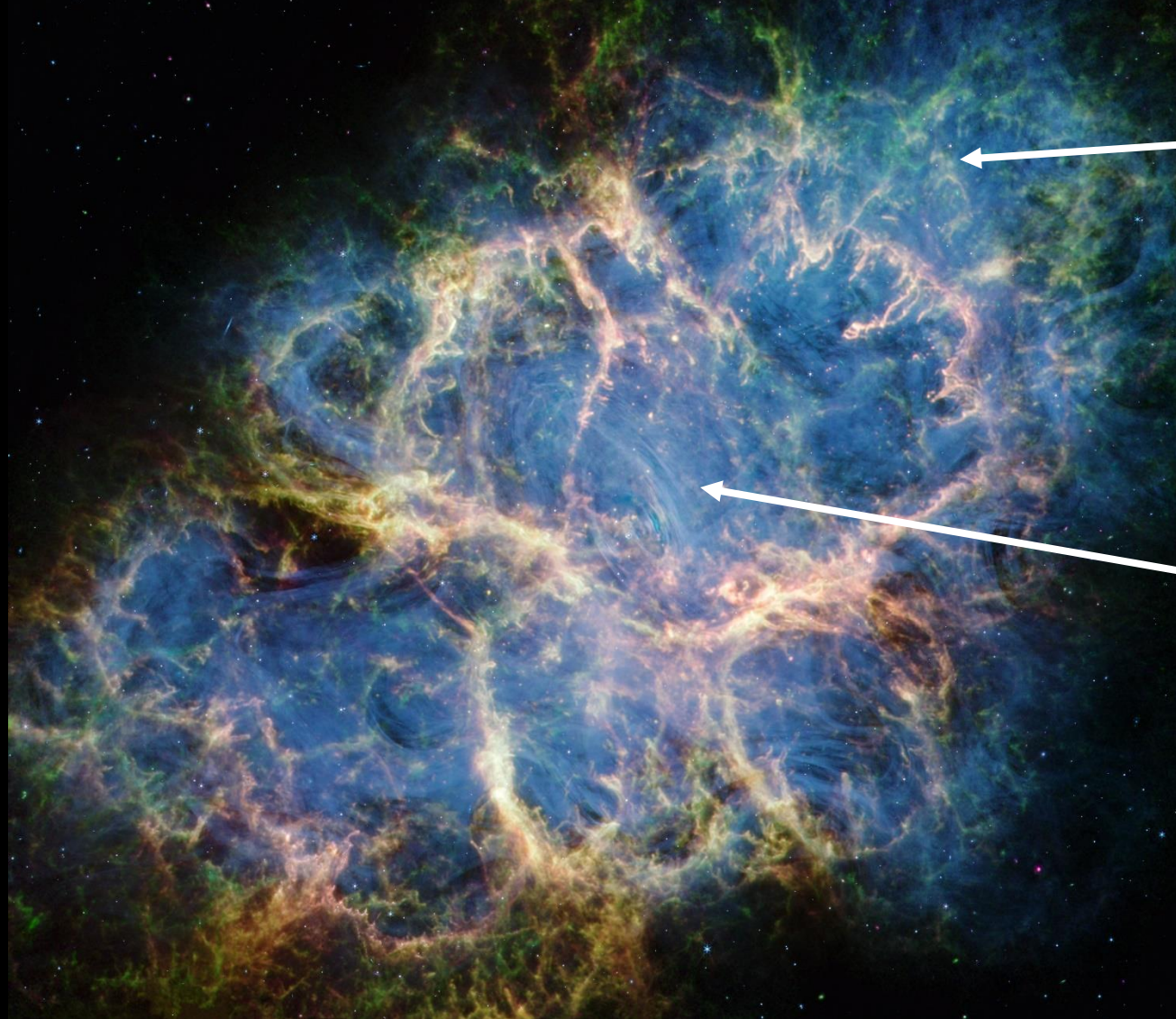


*Warm stof door botsing
met omliggend materiaal*

*Materiaal van
de ster zelf*

Cassiopeia A

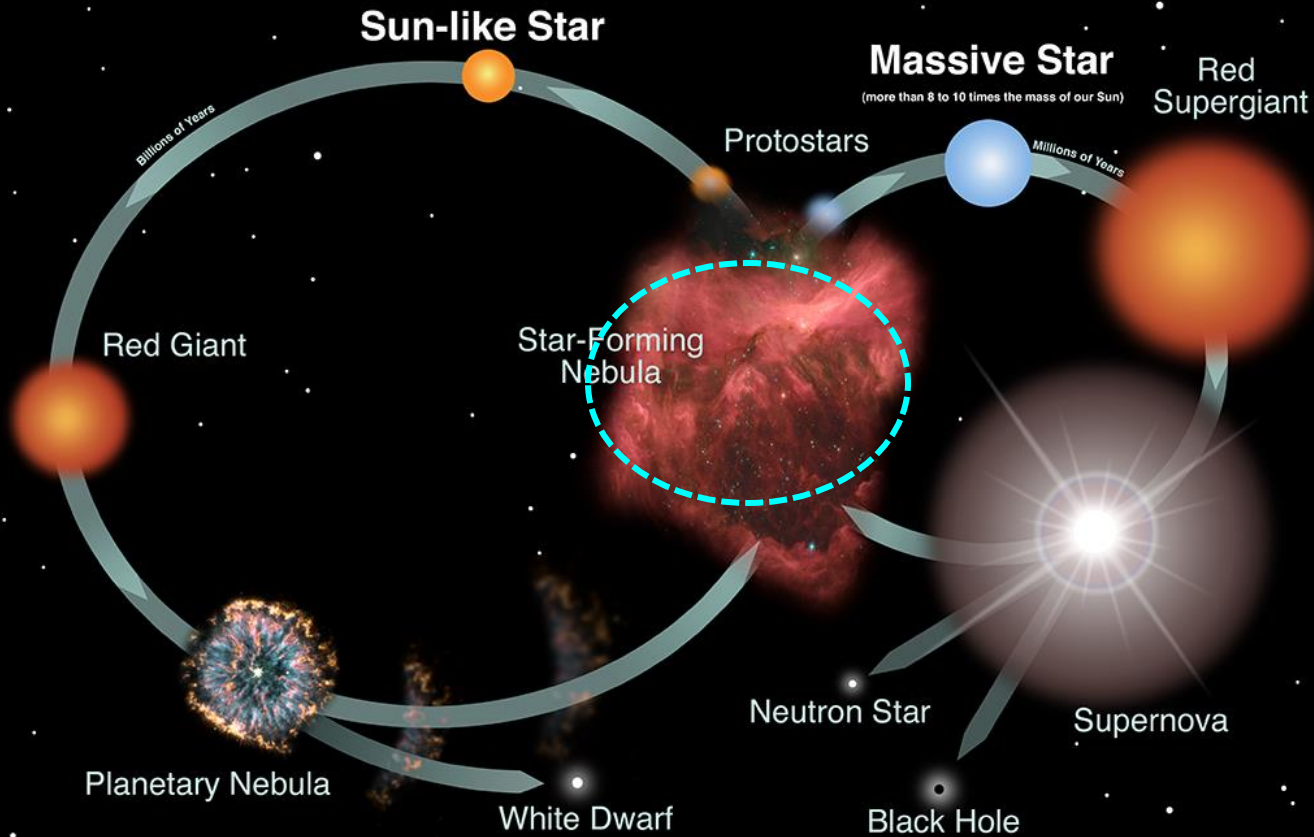
Supernovarest: de Krabnevel



*Warm stof door
botsing met
omliggend materiaal*

*Neutronenster
onzichtbaar*

Levenscyclus van sterren: van geboorte tot dood



Carina nevel met Webb



Rho Ophiuchus (slangendrager) nevel



*Jonge protosterren met
planeetvormende
schijven*

*Straalstromen van
jonge vormende
sterren*

*Zware ster die
omgeving ioniseert*

Pilaren der scheidung

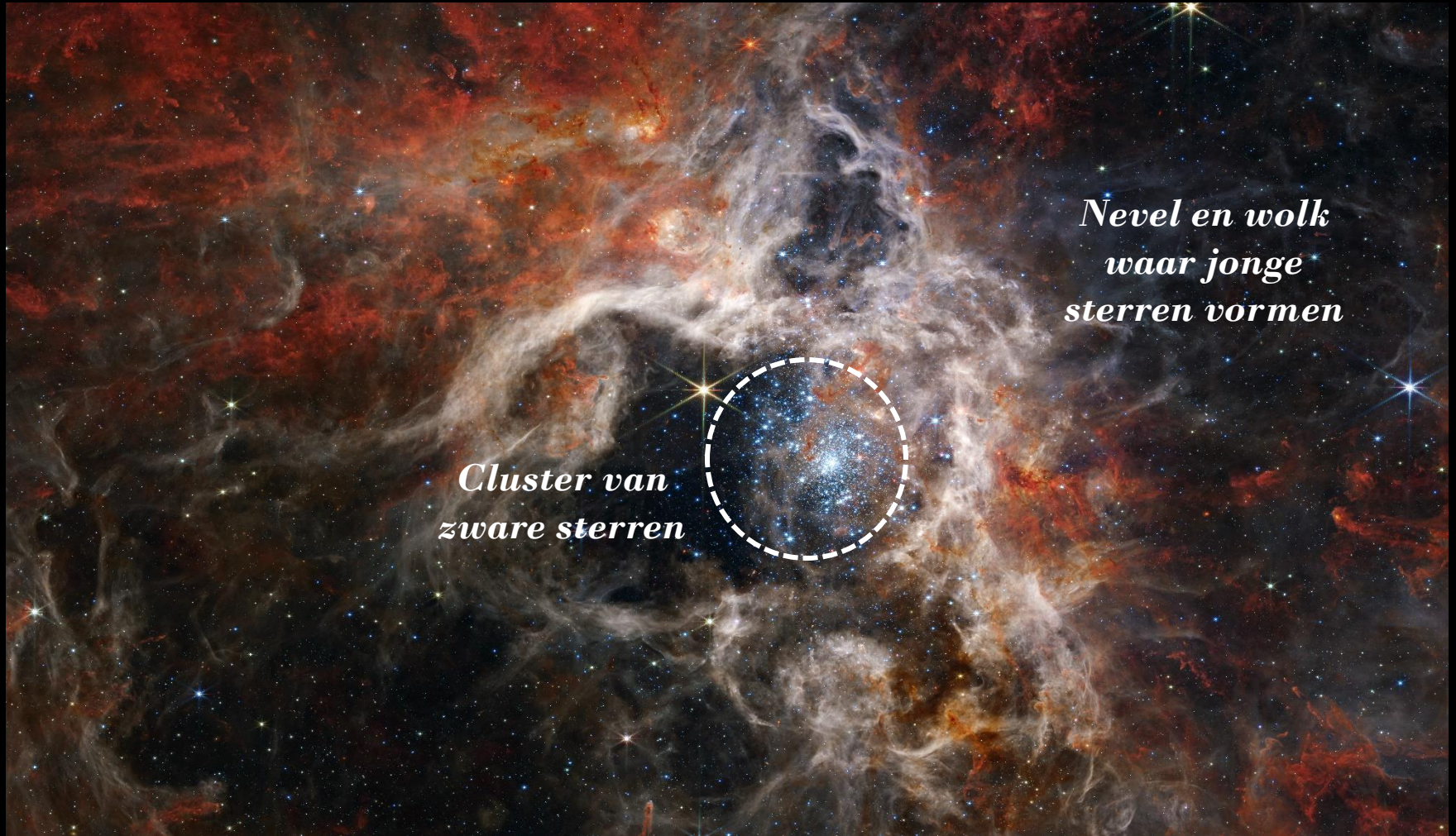
Hubble



JWST (NIRCAM)



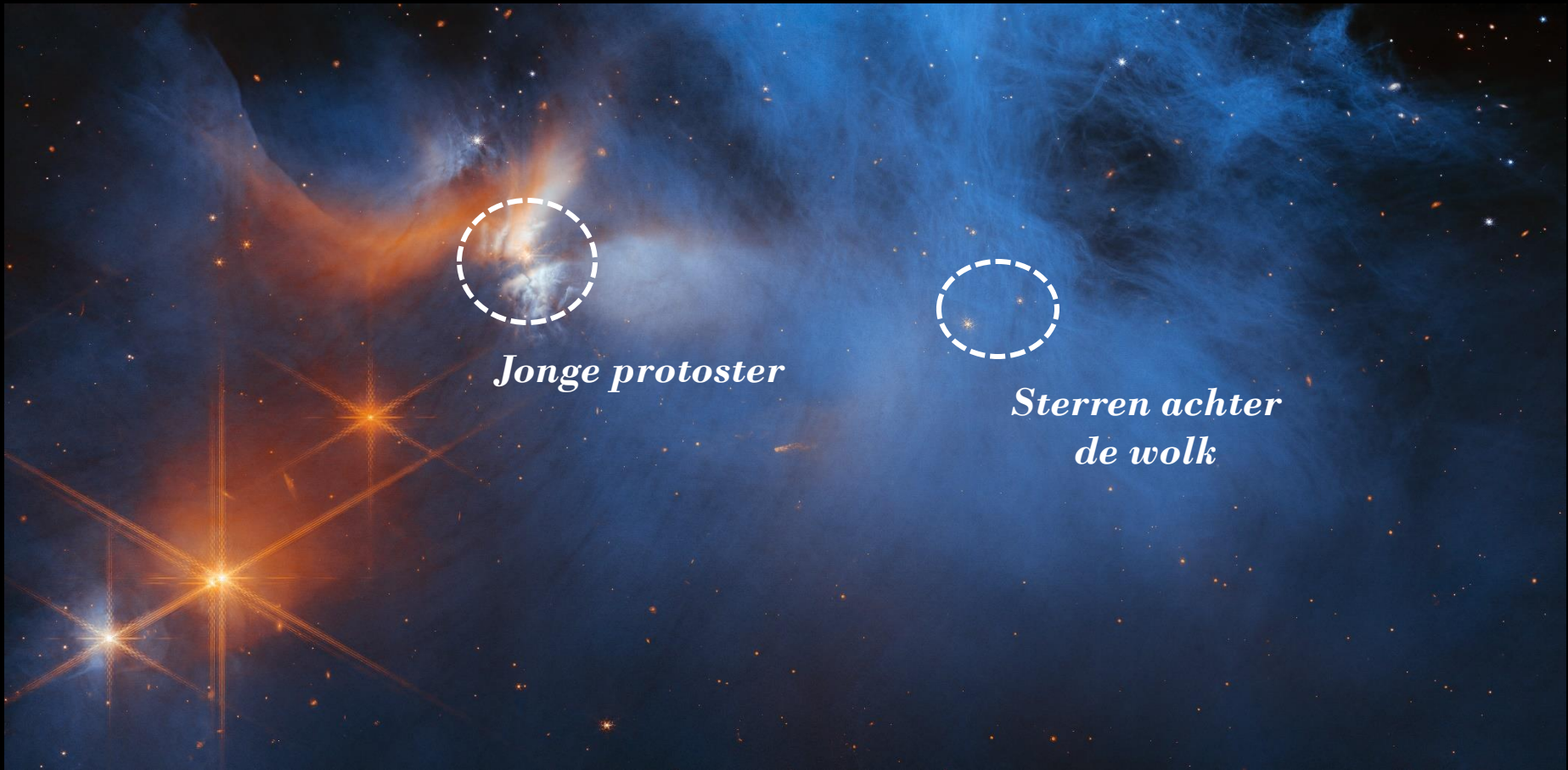
Tarantulanenevel



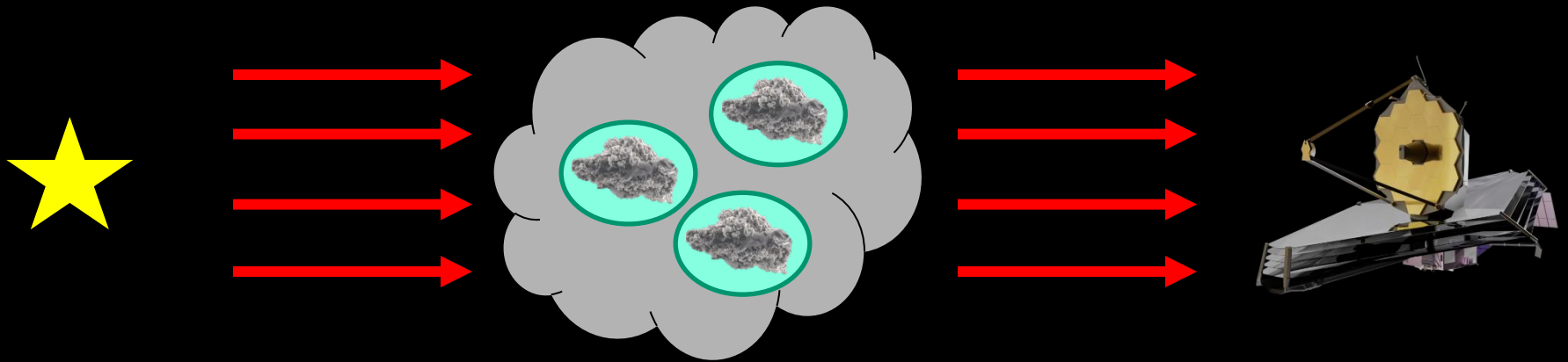
*Cluster van
zware sterren*

*Nebel en wolk
waar jonge
sterren vormen*

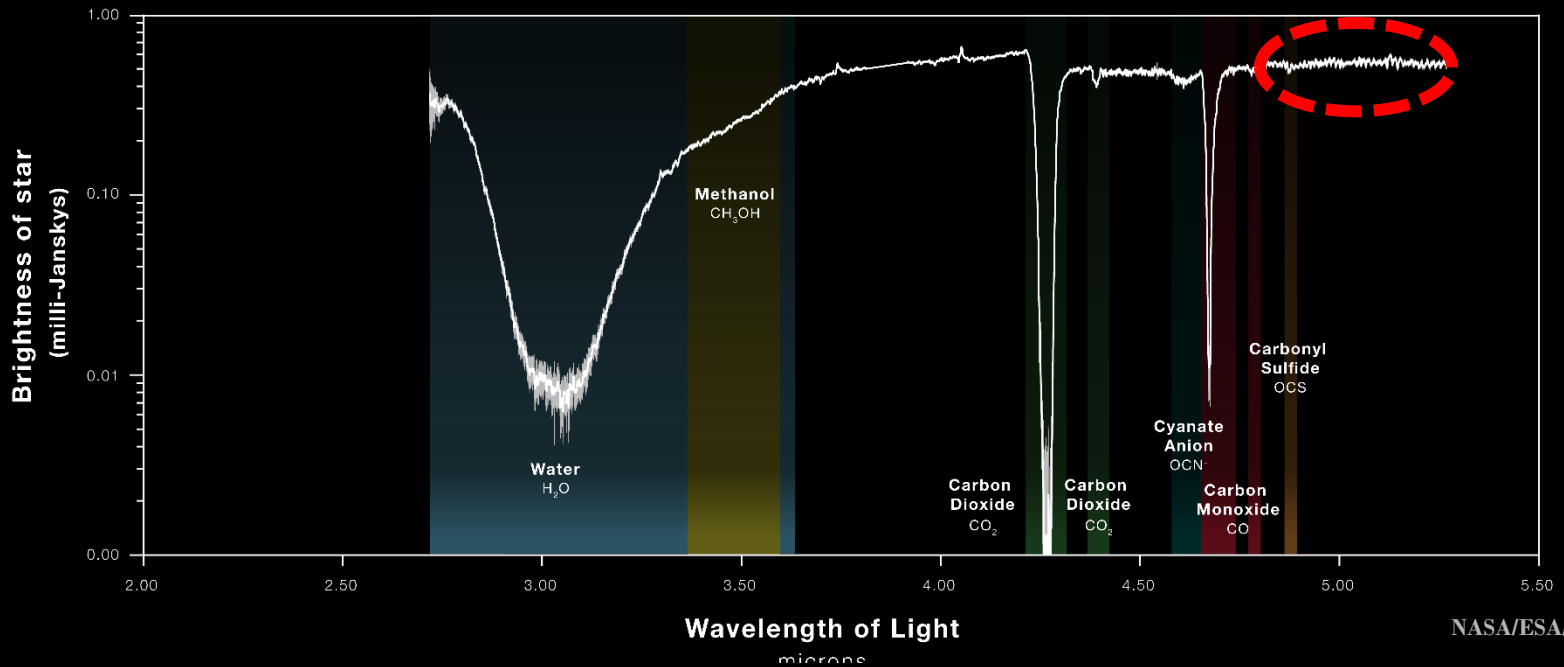
Moleculaire wolk: Chameleon 1



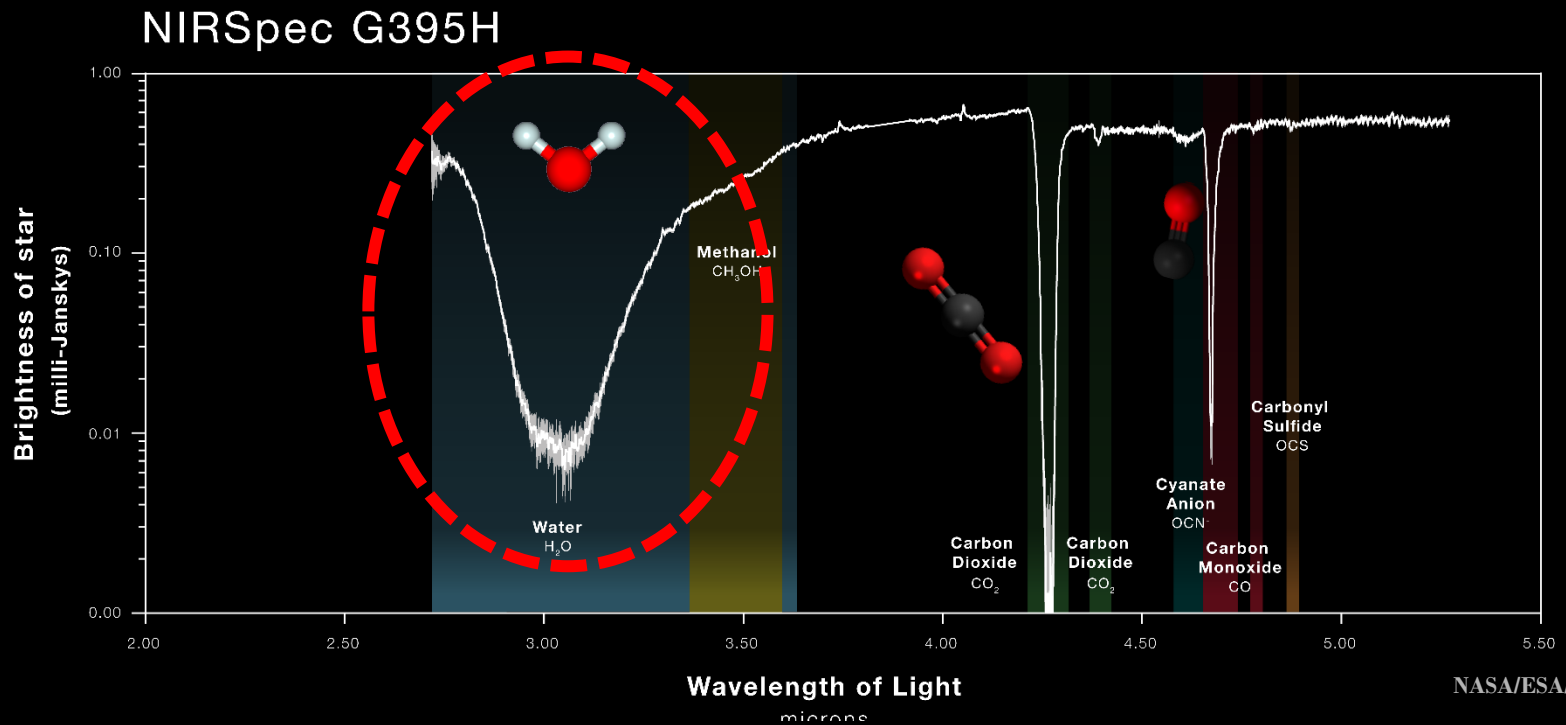
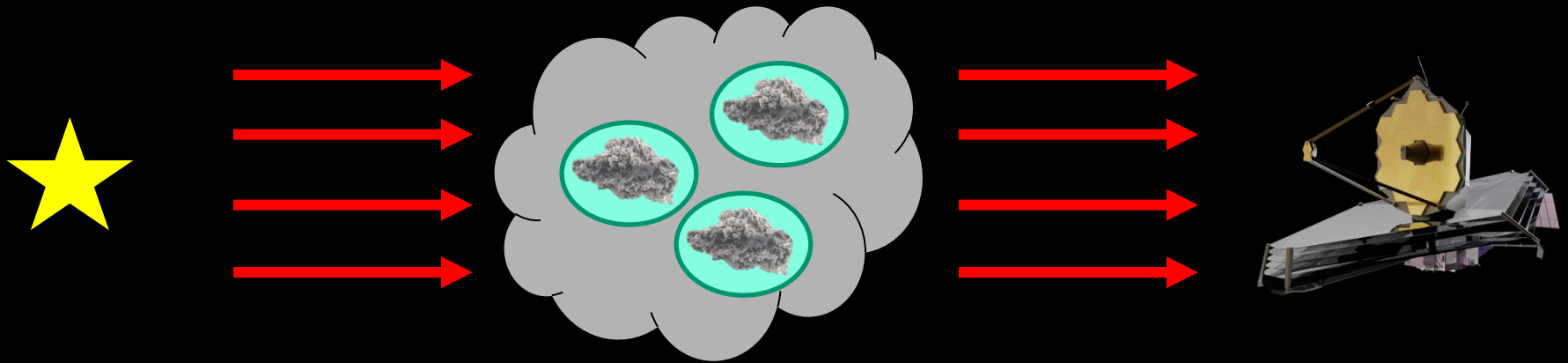
Webb ziet ijslaag op stofkorrels



NIRSpec G395H

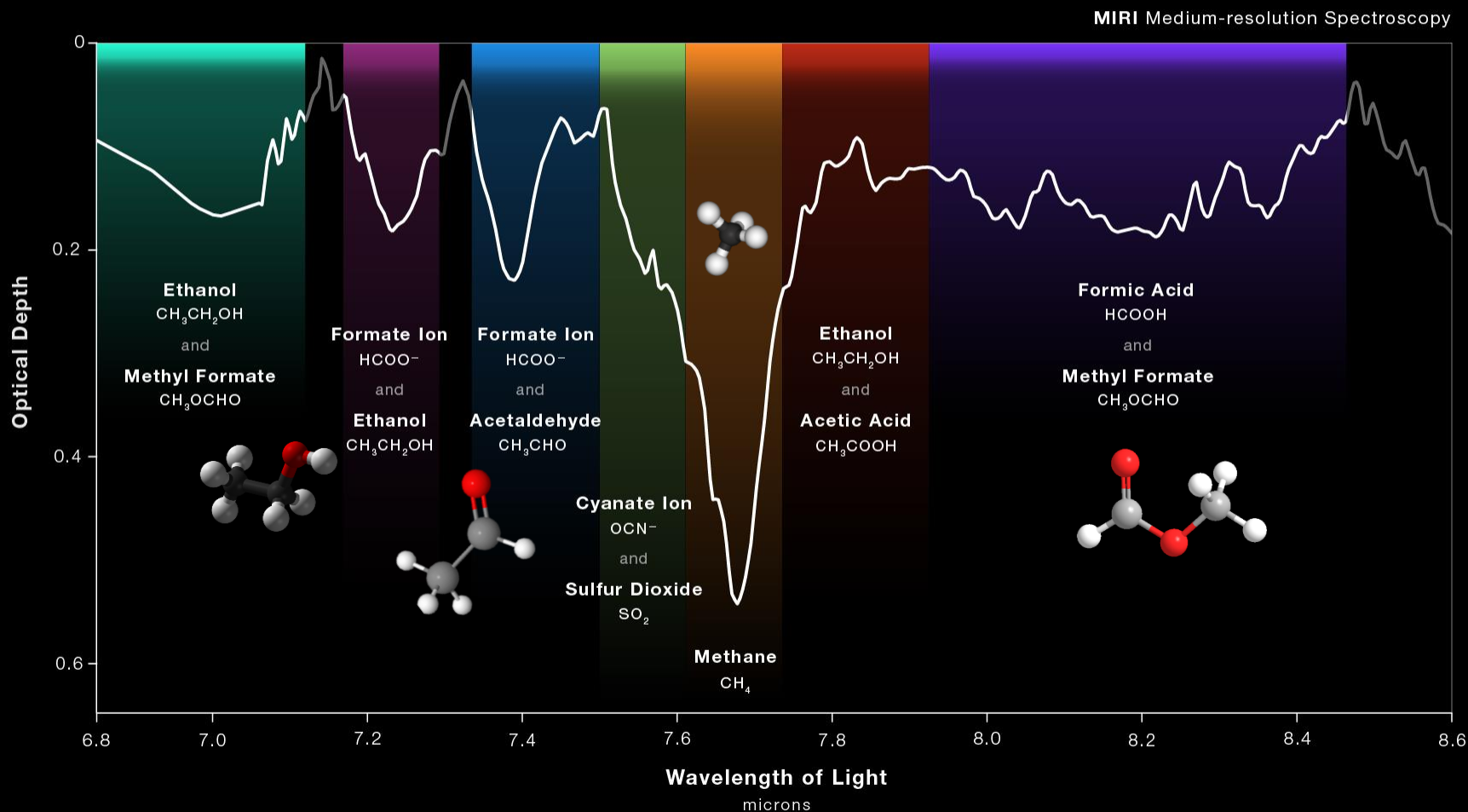


Webb ziet ijslaag op stofkorrels



NGC 1333 IRAS 2A PROTOSTAR

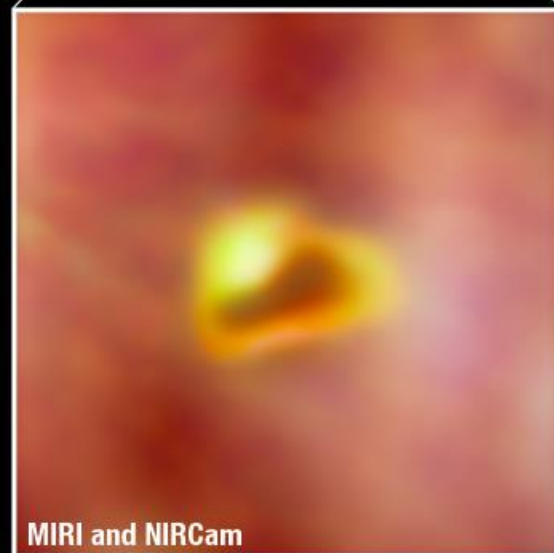
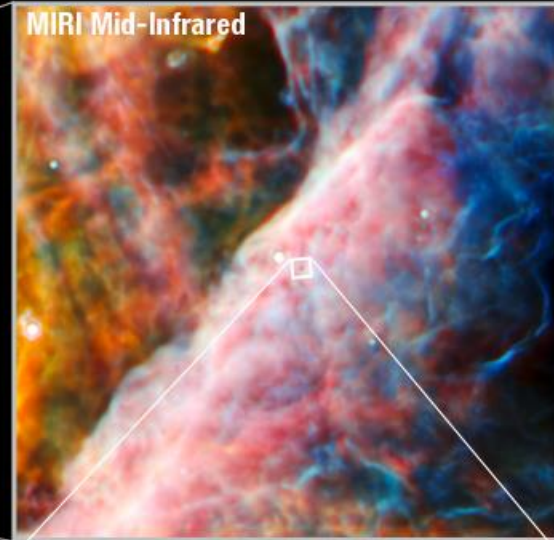
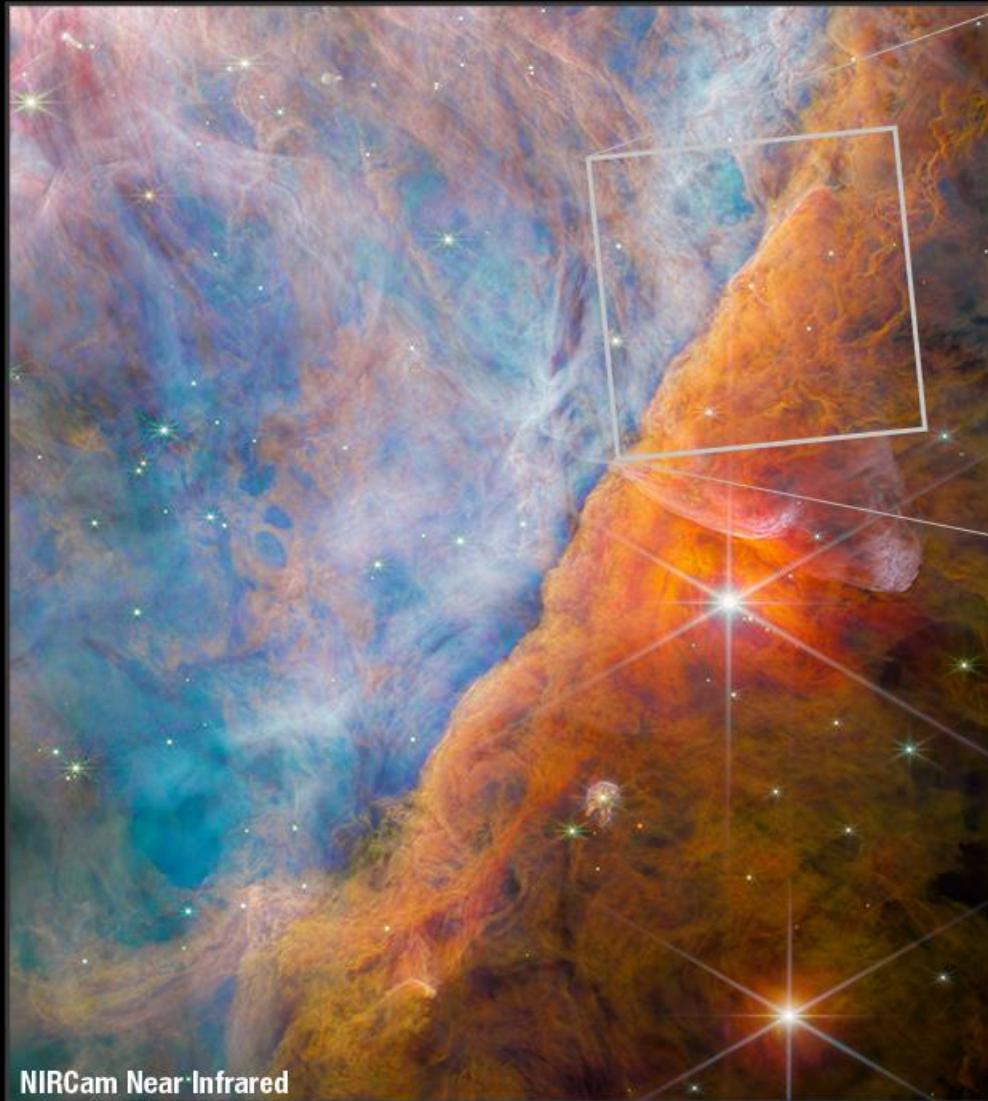
COMPLEX ORGANIC MOLECULES



WEBB
SPACE TELESCOPE

NASA/ESA/CSA/STScI

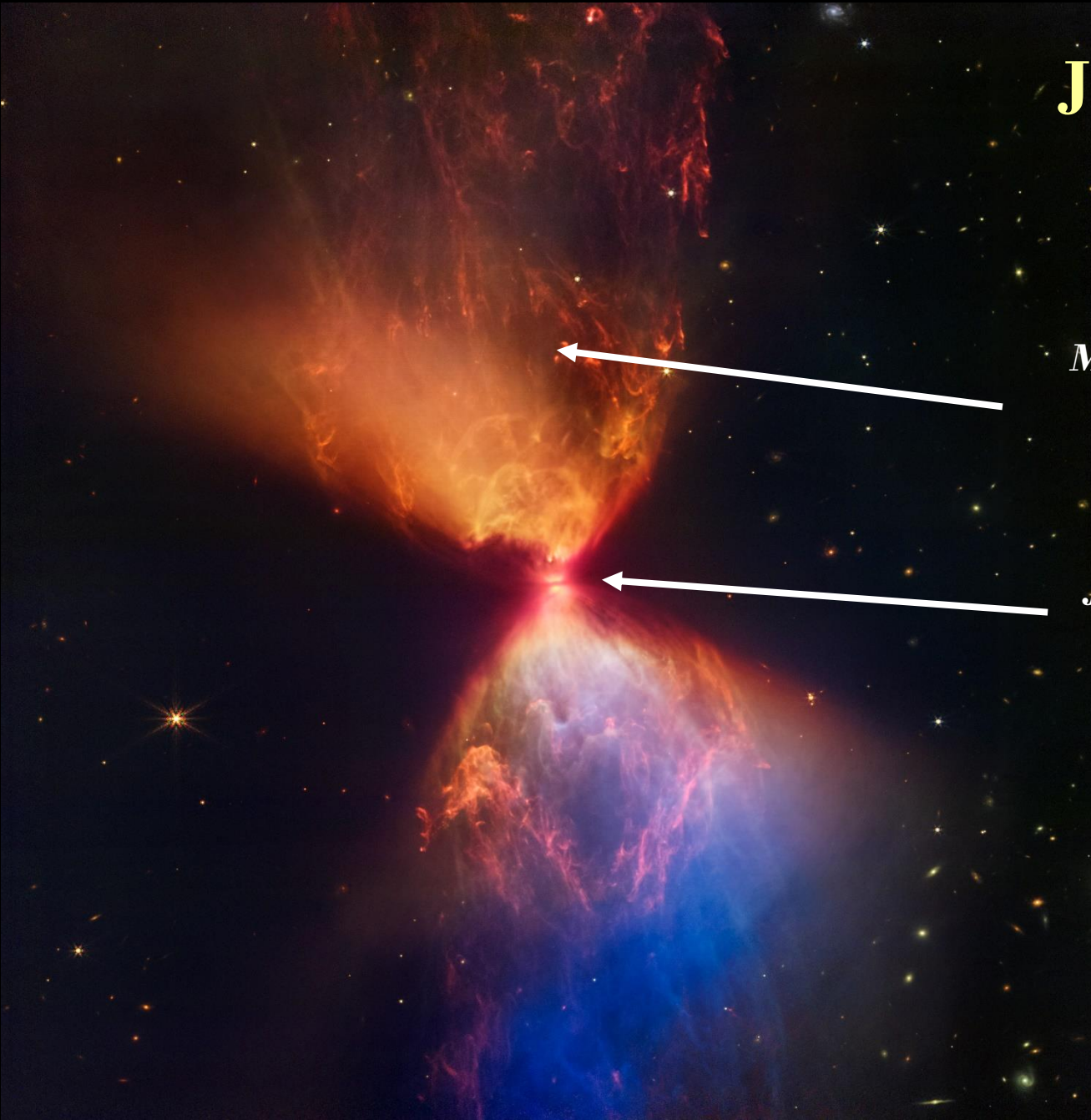
UV-Straling in een wolk: Balk van Orion



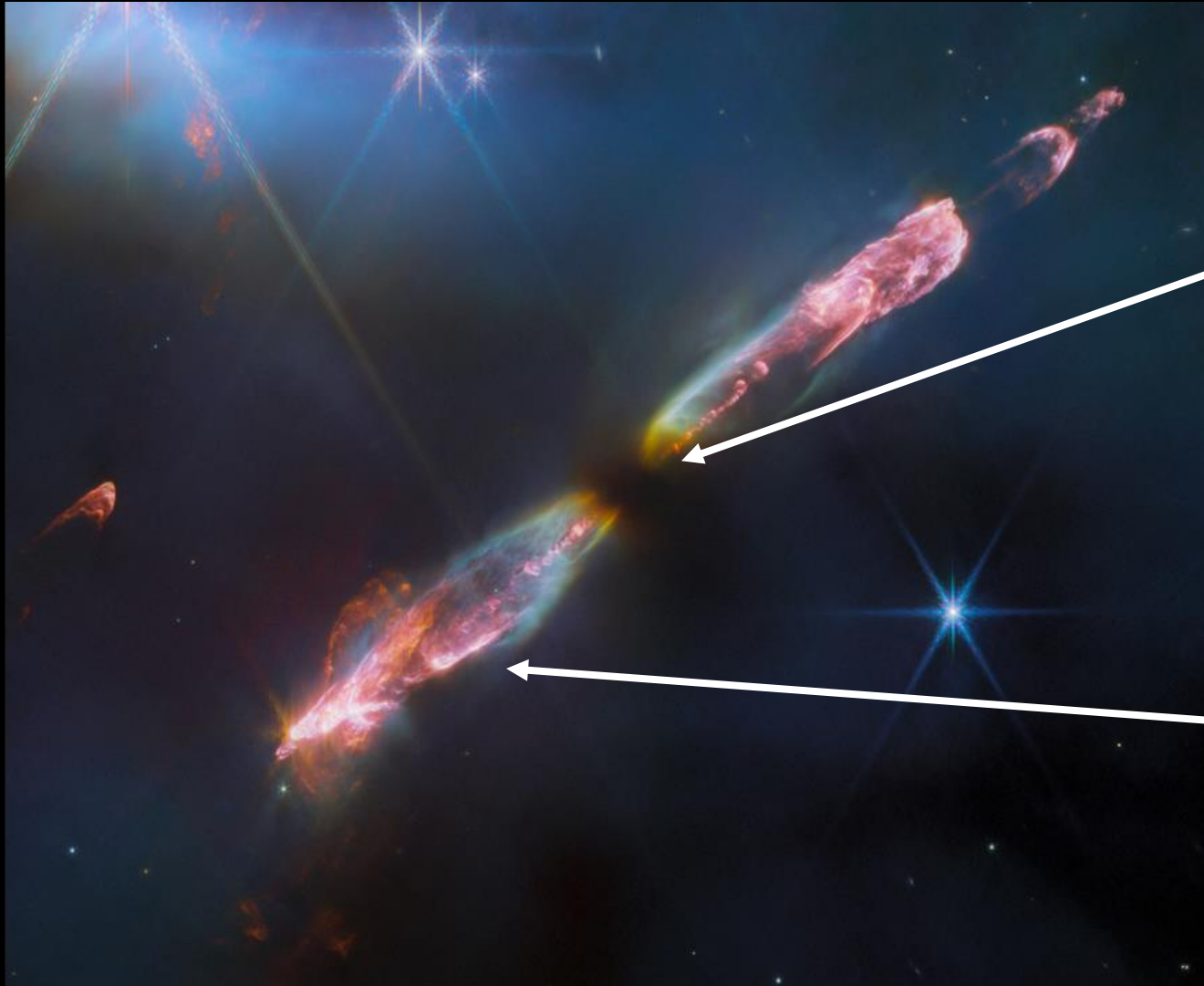
Jonge protoster

*Materiaal dat het
systeem wordt
uitgestoten*

*Jonge protoster
met schijf*



Straalstromen van jonge protoster



*Protoster zelf
niet zichtbaar*

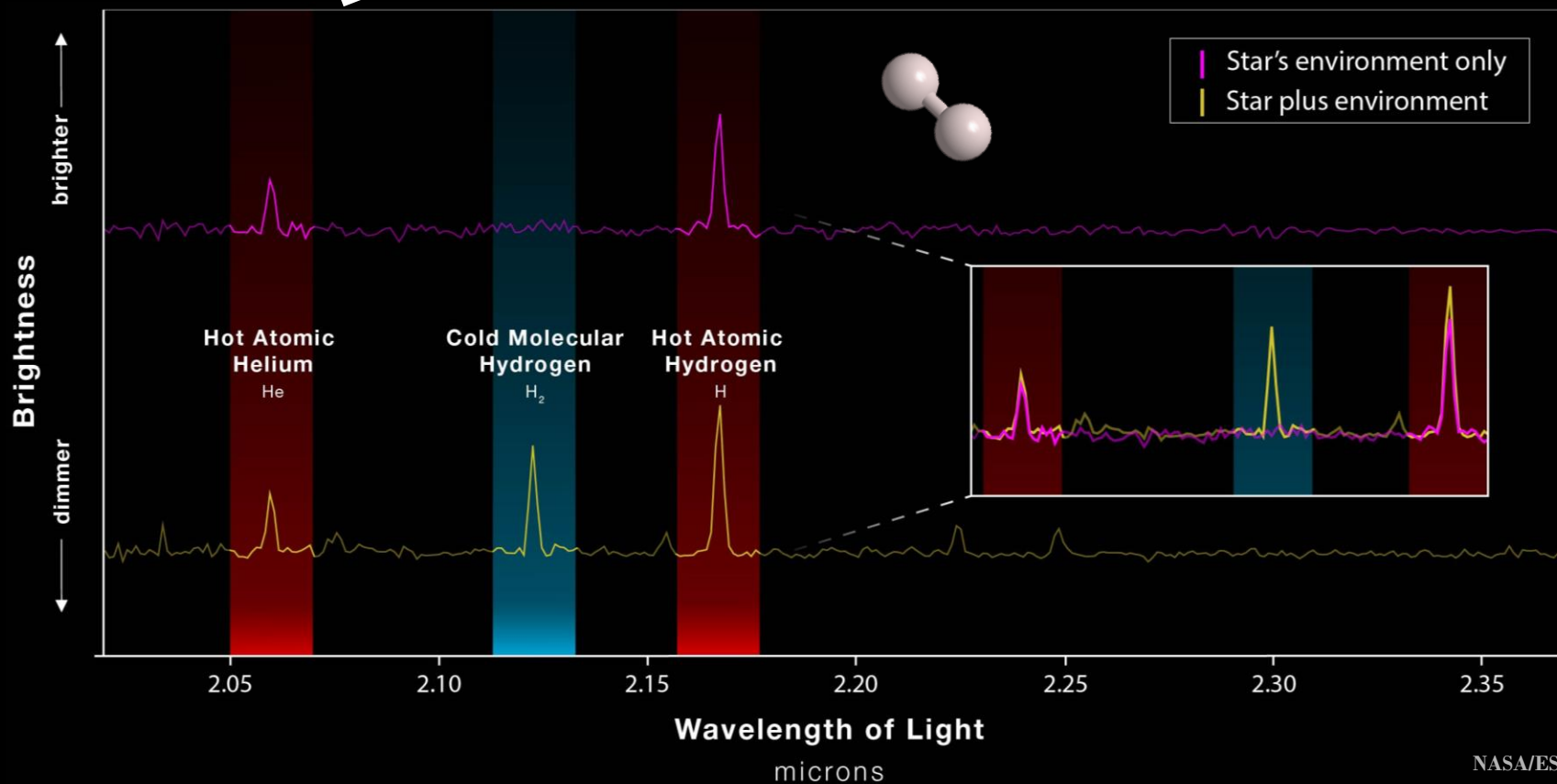
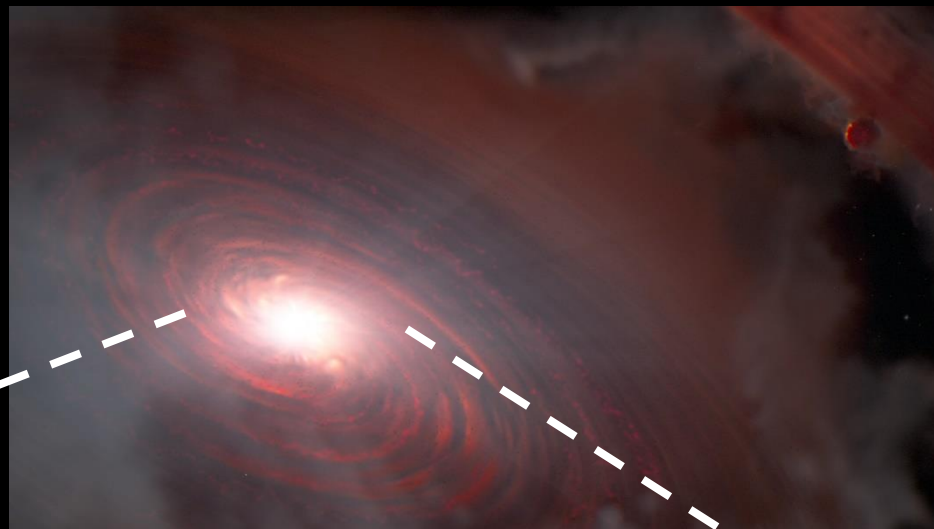
*Spectaculaire
straalstroom*

Straalstromen van jonge protoster



*Pulserende &
wiebelende
straalstroom*

Planeet- vormende schijf



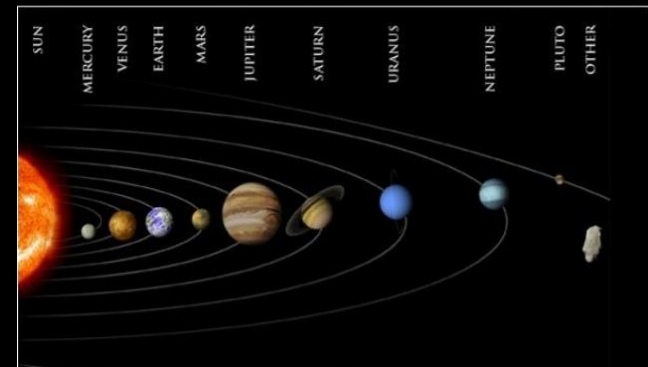
Thema 4: Andere werelden

Schijf met jonge planeet



Animation
NASA/SSC/R. Hurt

Analogie: Oernevel hypothese

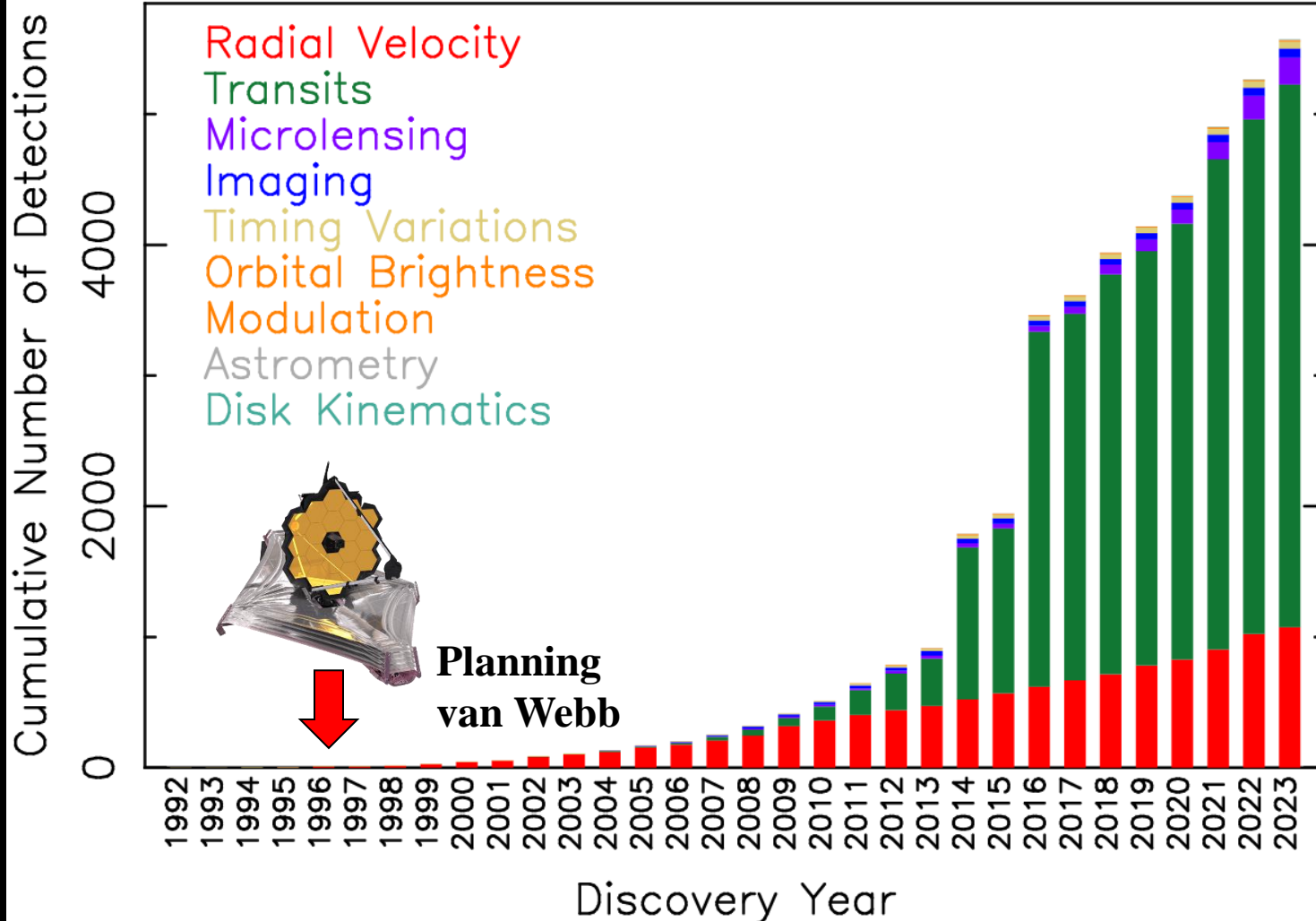


Kant 1755, Swedenborg 1734

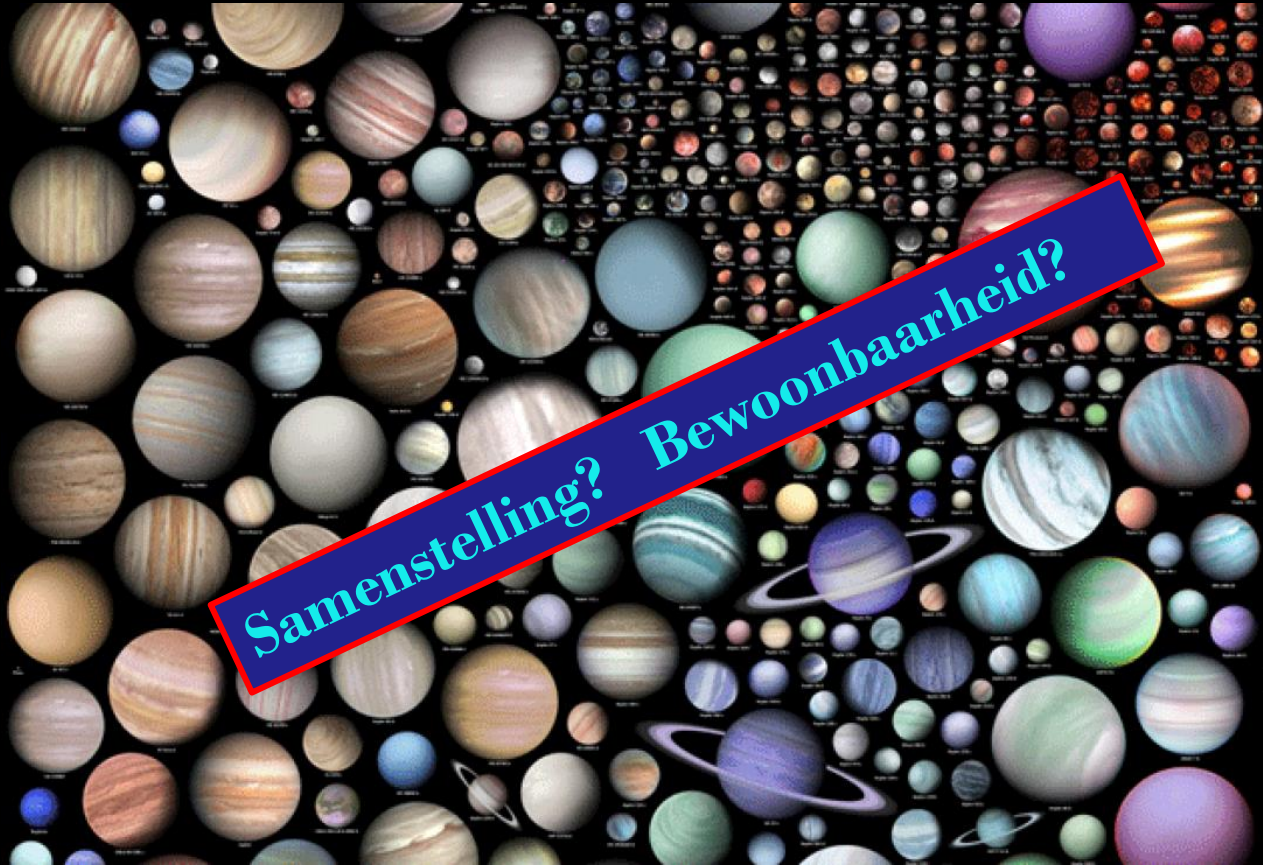
Exoplanet detections

Cumulative Detections Per Year

18 Jan 2024
exoplanetarchive.ipac.caltech.edu



Diversiteit aan exoplaneten



Artist impression

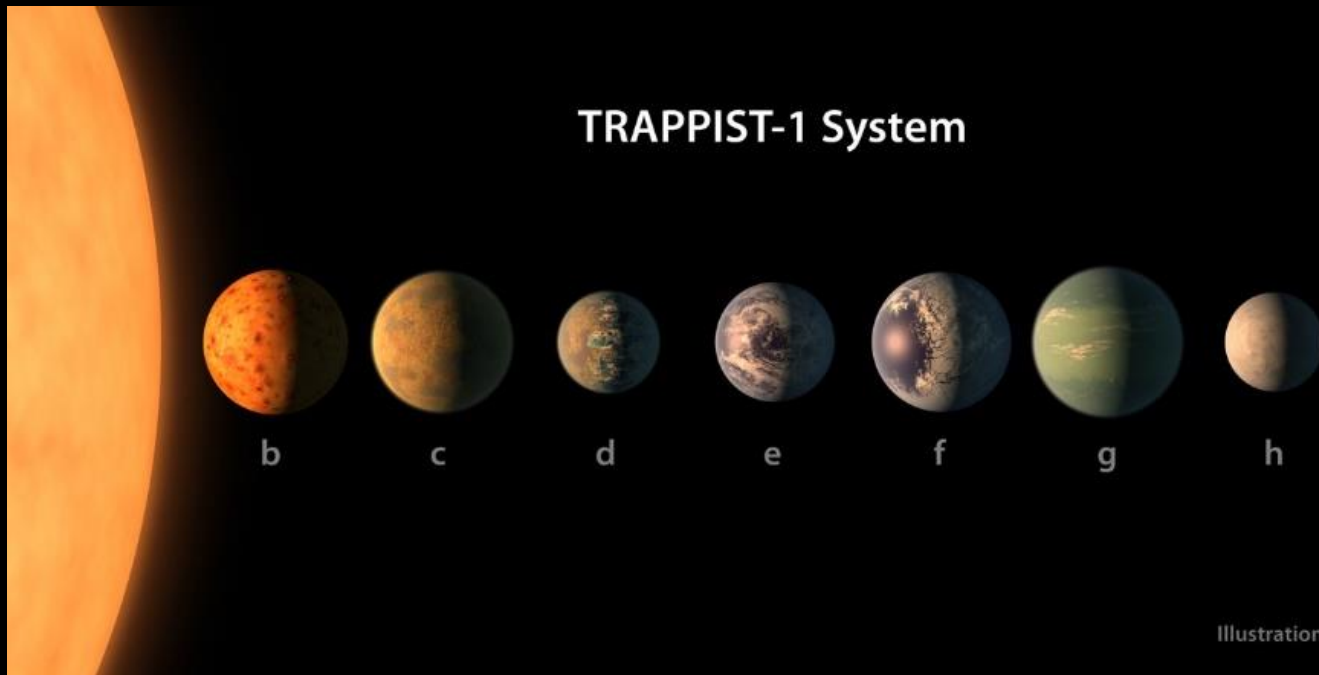
Kepler satellite: Borucki et al. 2011, Batalha et al. 2013

**Iedere ster heeft tenminste 1 planeet
Vooral super-Aardes, mini-Neptunus**



Nobel Prize 2019

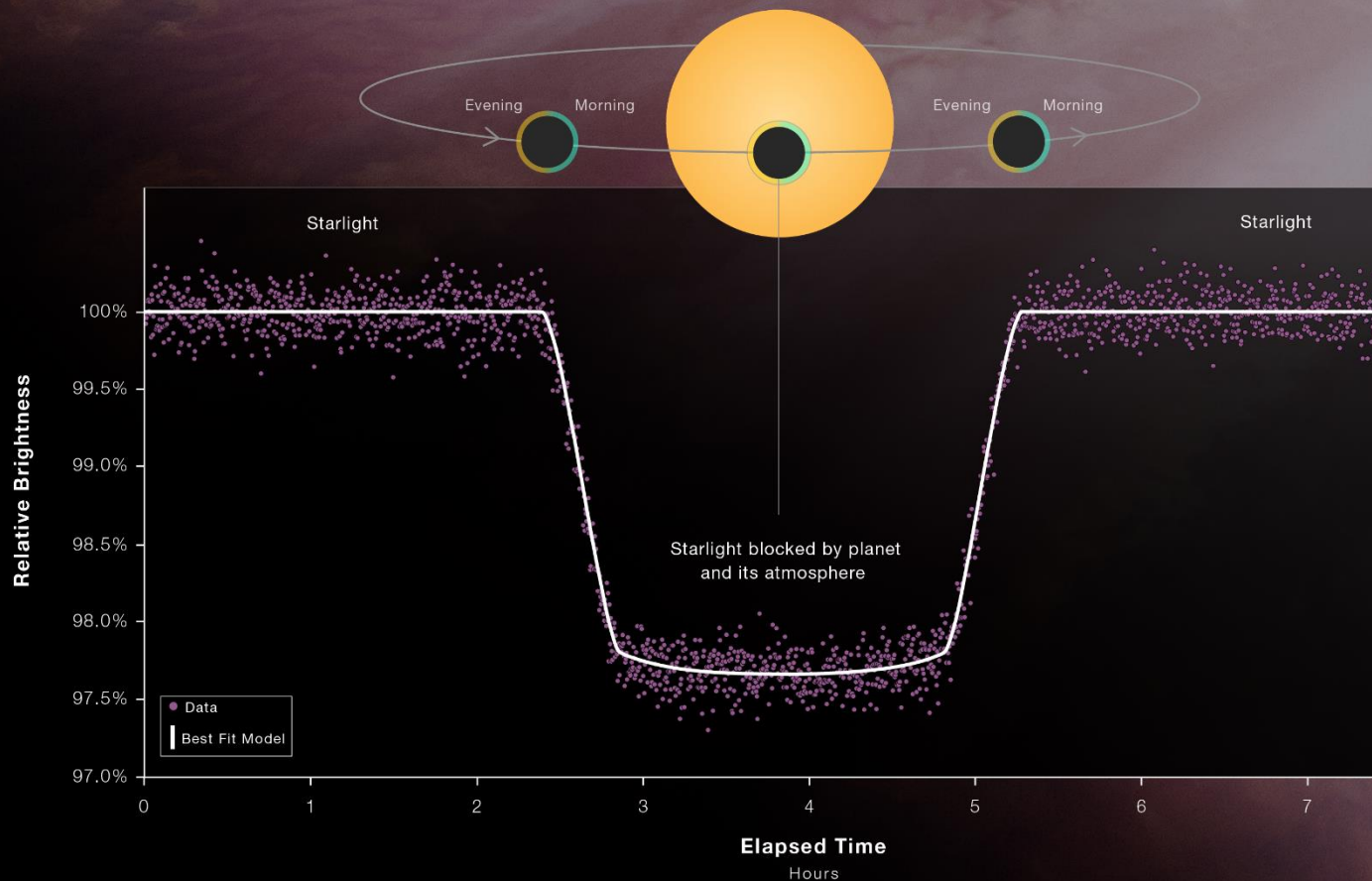
Webb: karakteriseren atmosfeer exoplaneten



Zowel gasreuzen als aardachtige planeten

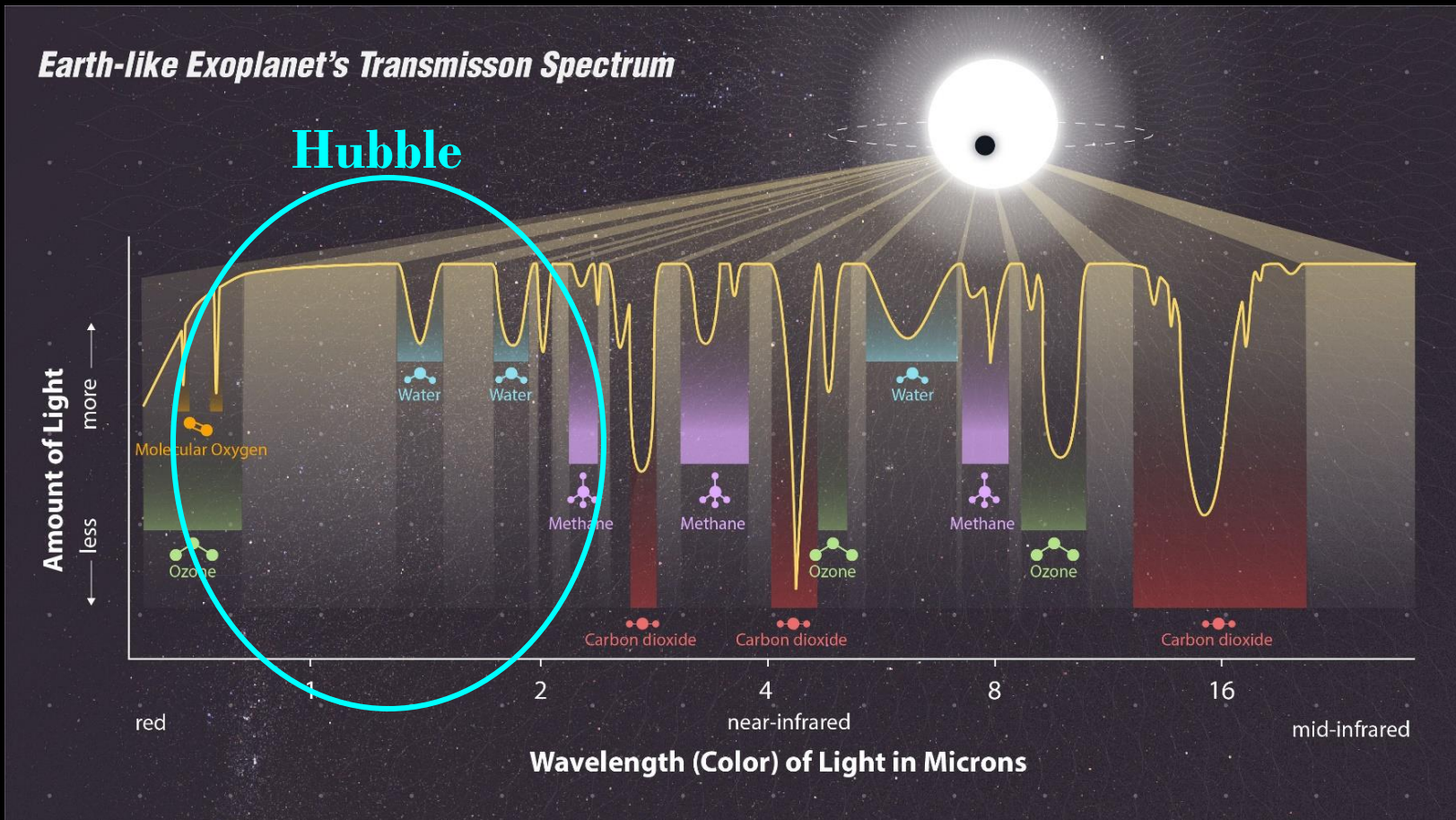
Exoplanet transit

NIRSpec | PRISM



WEBB
SPACE TELESCOPE

Vingerafdruk atmosfeer planeten



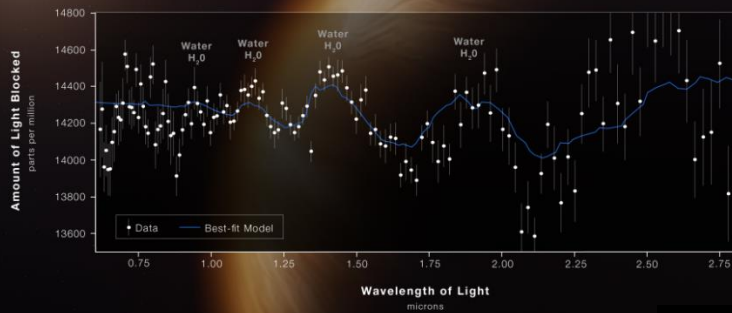
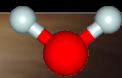
JWST heeft veel groter golflengtebereik en gevoeligheid

Water en CO₂ in de atmosfeer van exoplaneet

HOT GAS GIANT EXOPLANET WASP-96 b
ATMOSPHERE COMPOSITION



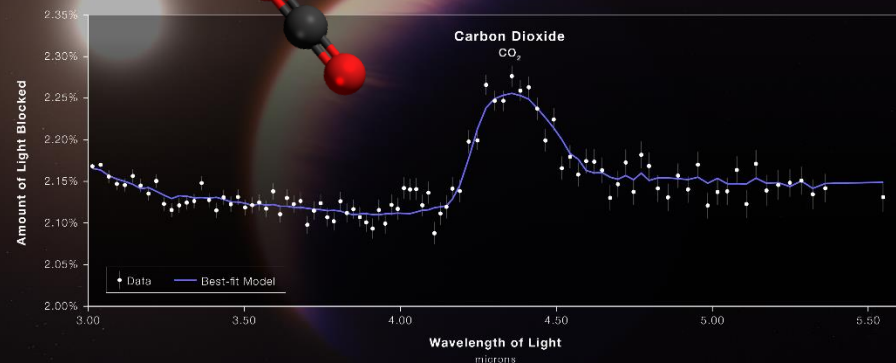
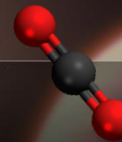
NIRISS | Single-Object Slitless Spectroscopy



HOT GAS GIANT EXOPLANET WASP-39 b
ATMOSPHERE COMPOSITION



NIRSpec | Bright Object Time-Series Spectroscopy



WEBB
SPACE TELESCOPE

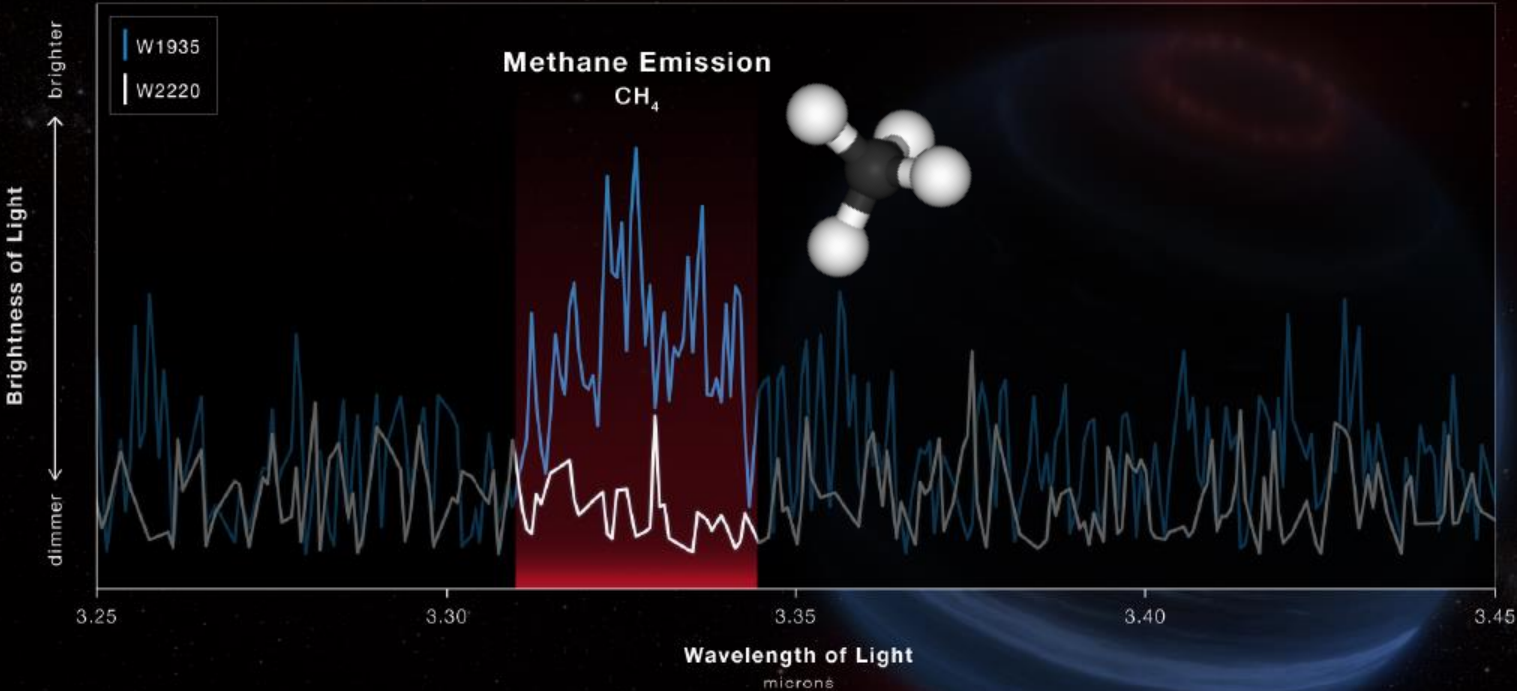
NASA/ESA/CSA/STScI

Moleculen in de atmosfeer

BROWN DWARFS W1935 AND W2220

ATMOSPHERIC METHANE

NIRSpec | Slit Spectroscopy



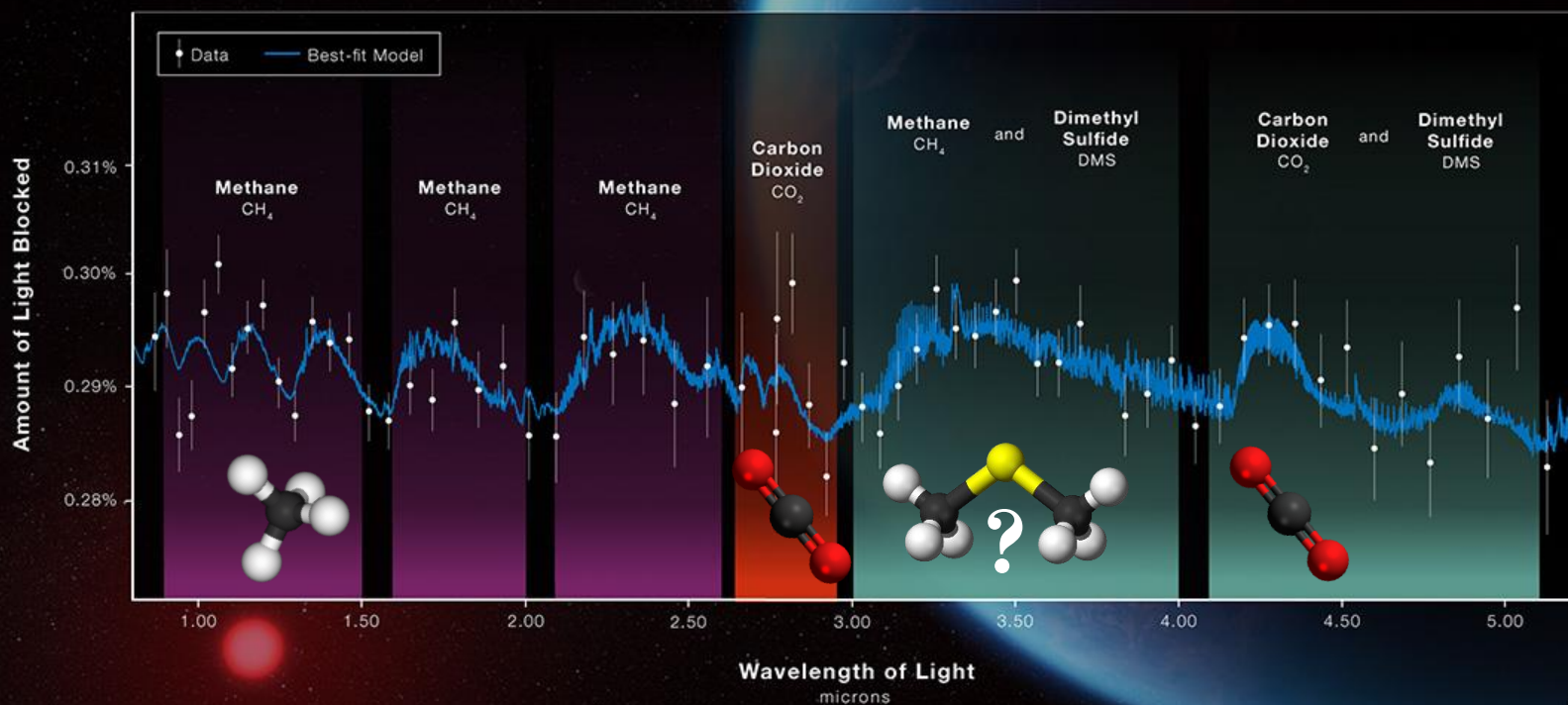
WEBB
SPACE TELESCOPE

Moleculen in de atmosfeer

EXOPLANET K2-18 b

ATMOSPHERE COMPOSITION

NIRISS and NIRSpec (G395H)



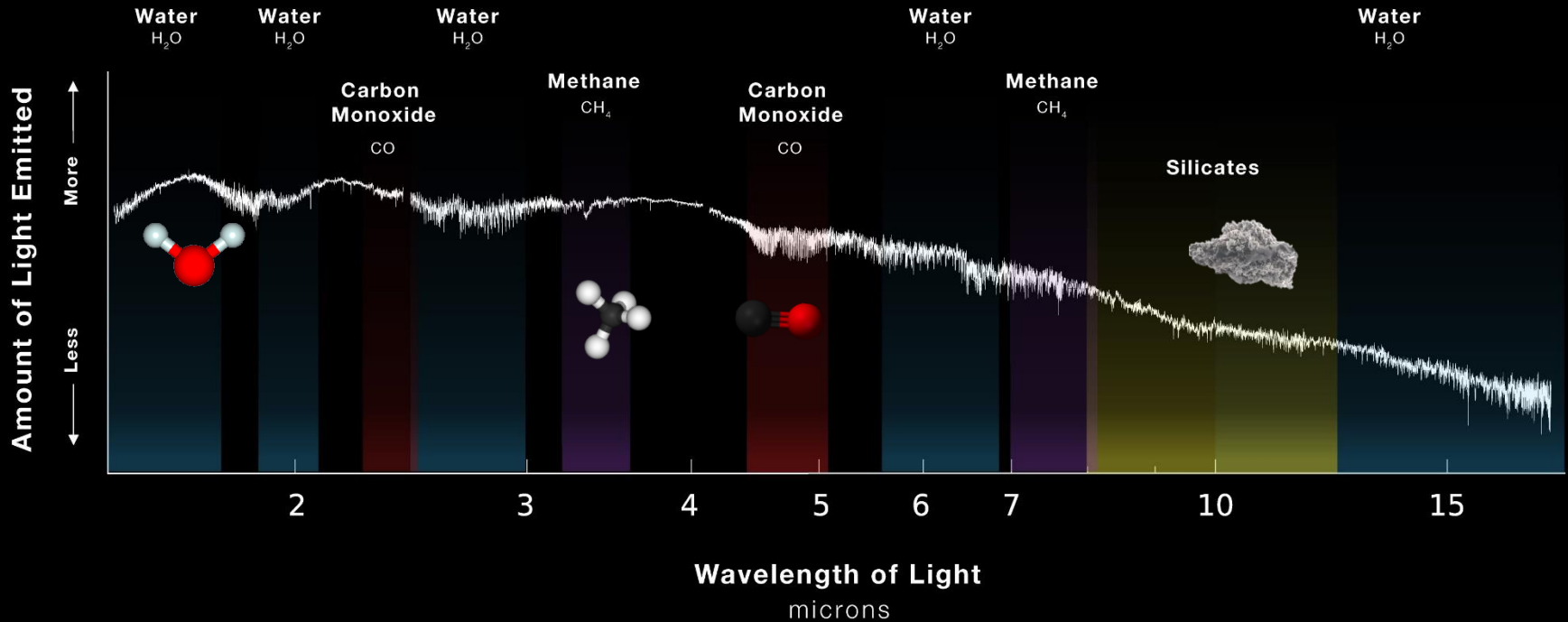
WEBB
SPACE TELESCOPE

Moleculen in de atmosfeer

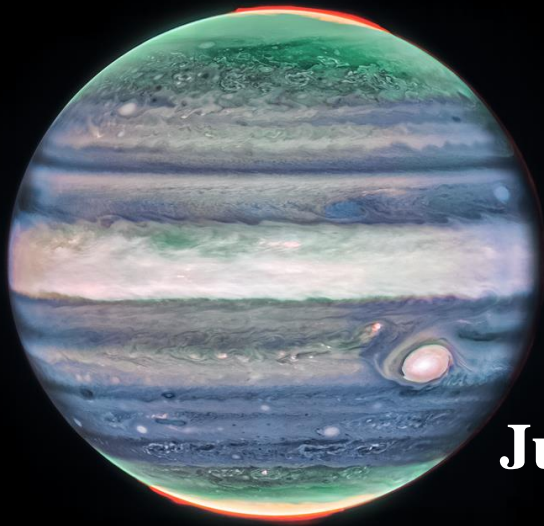
EXOPLANET VHS 1256 b

EMISSION SPECTRUM

NIRSpec and MIRI | IFU Medium-Resolution Spectroscopy



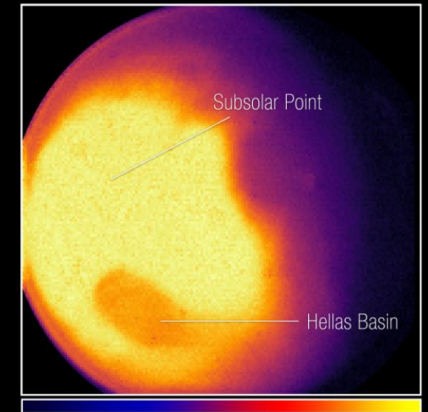
Webb en ons eigen zonnestelsel



Jupiter



Uranus



Mars



Saturnus



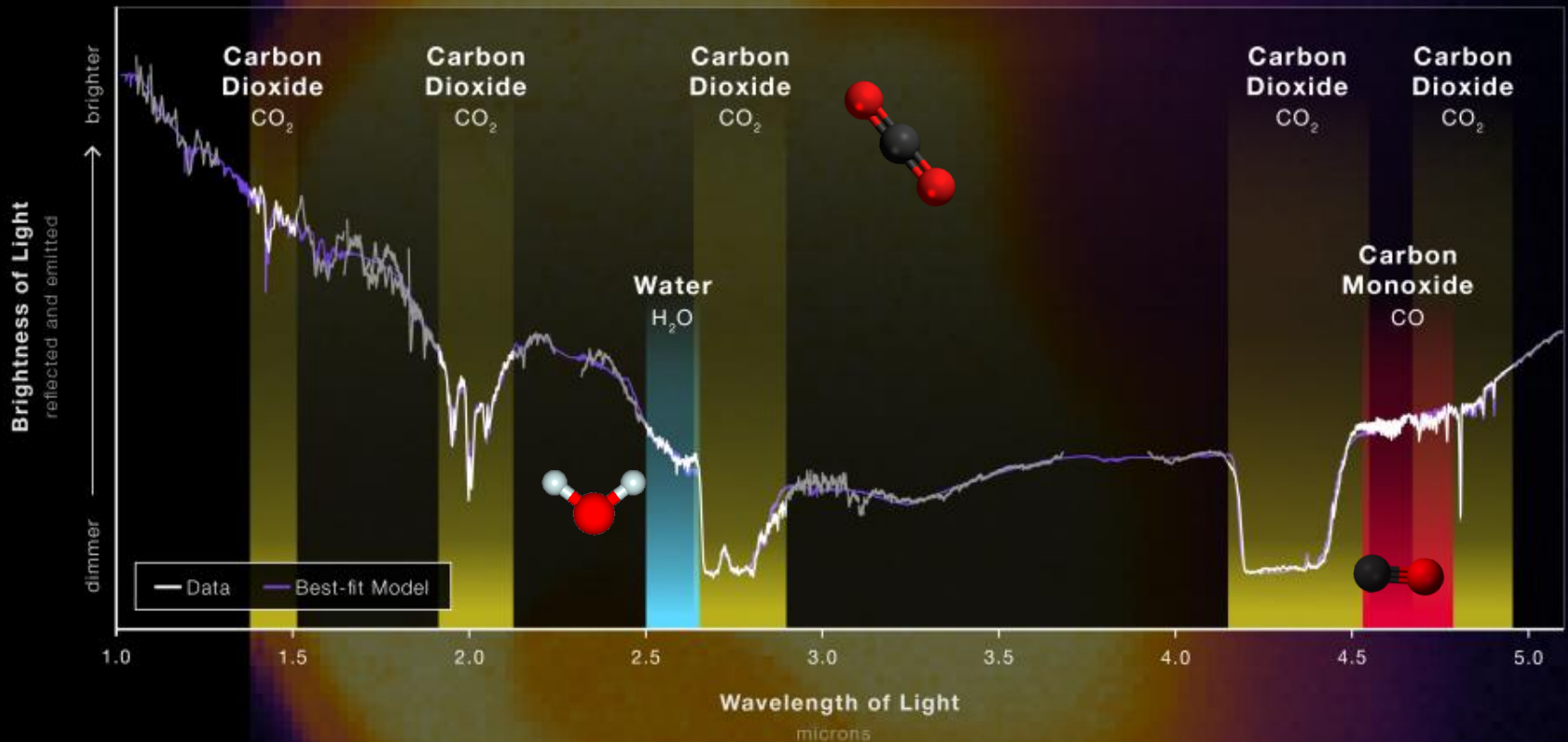
Neptunus

Webb en ons eigen zonnestelsel

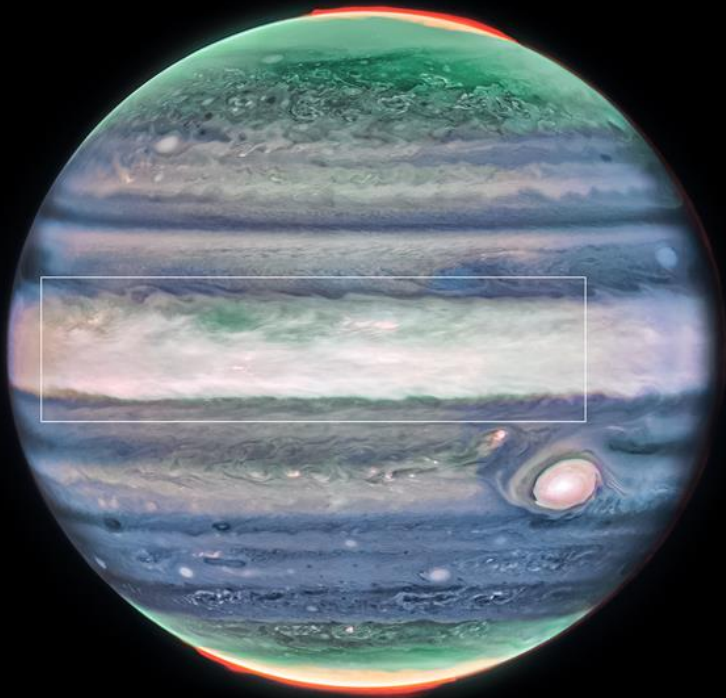
MARS

ATMOSPHERE COMPOSITION

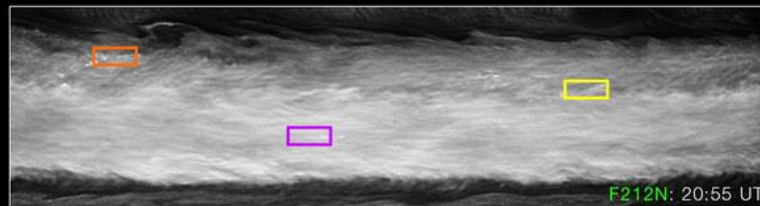
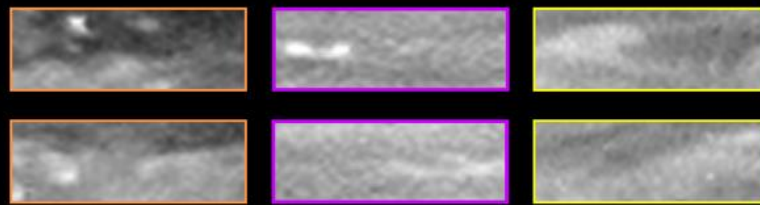
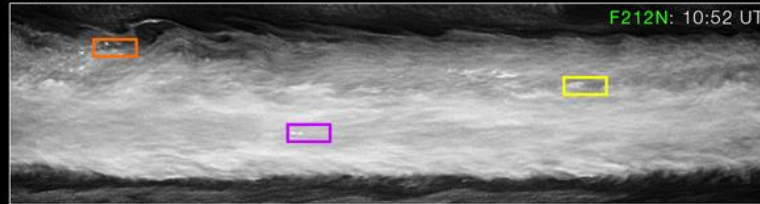
NIRSpec | Fixed Slit Spectroscopy



Webb en ons eigen zonnestelsel



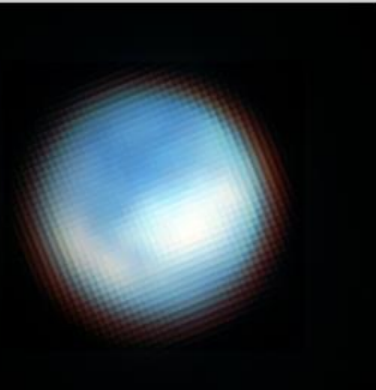
Jupiter's Equatorial Jet Stream



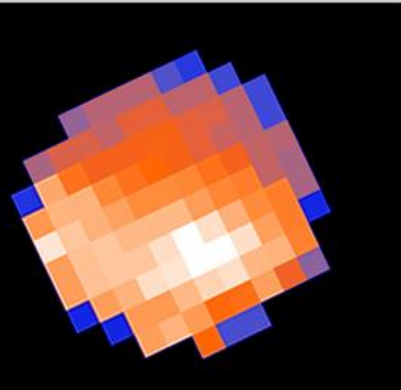
NASA/ESA/CSA/STScI

NIRCam Filters

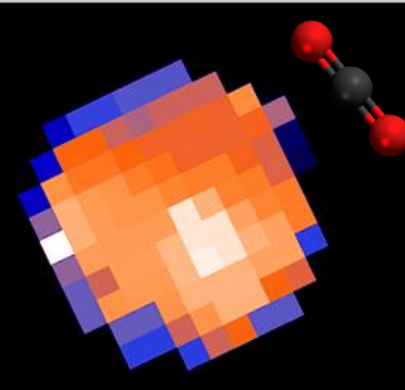
F164N F212N F360M



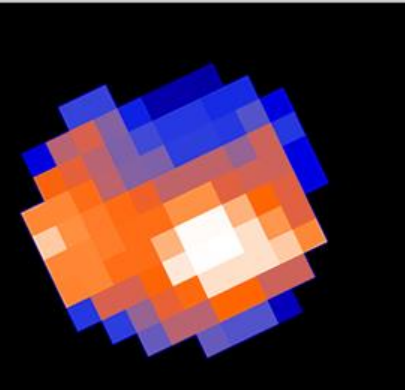
Europa (NIRCam)



Crystalline CO₂ ice at 2.7 microns



Crystalline CO₂ ice at 4.27 microns



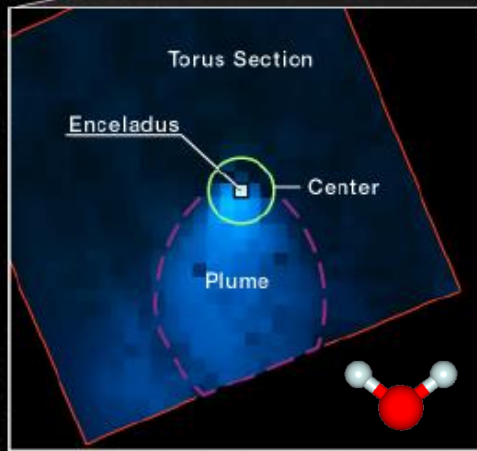
Complex CO₂ ice at 4.25 microns

Webb en ons eigen zonnestelsel

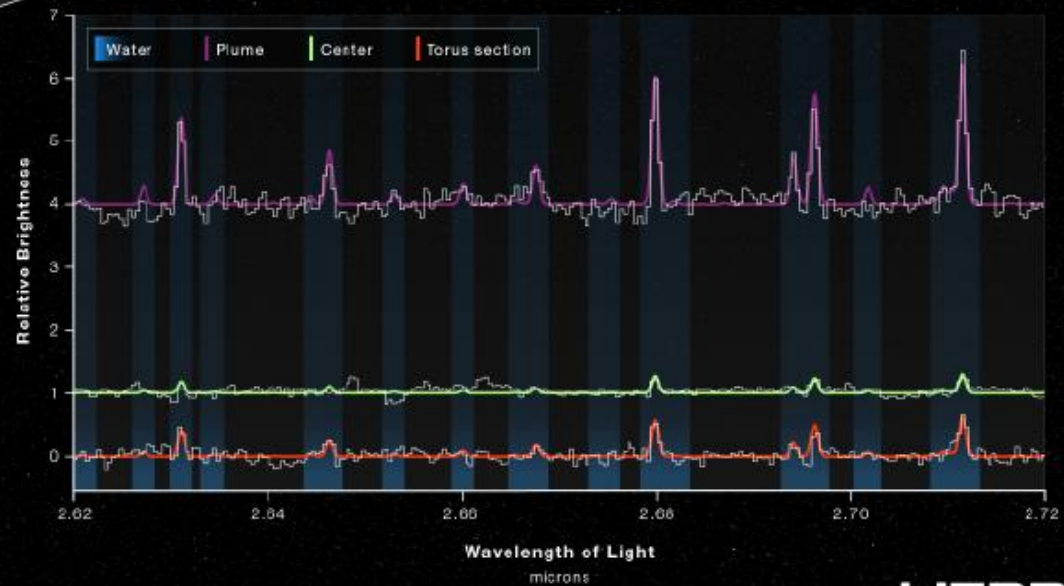
SATURN'S MOON ENCELADUS

WATER EMISSION SPECTRUM

NIRSpec | IFU Spectroscopy



Plume/Torus Model and Extracts

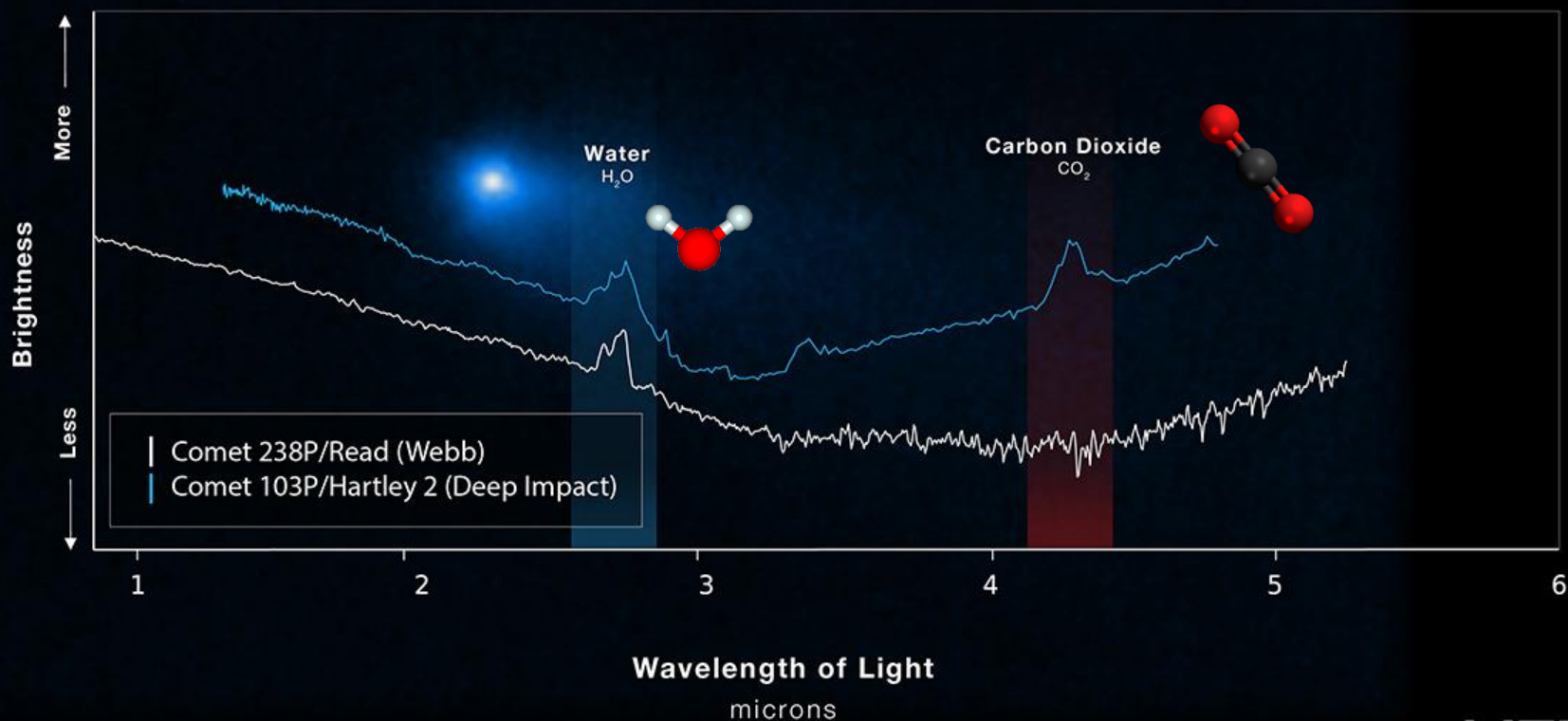


Webb en ons eigen zonnestelsel

MAIN BELT COMET 238P/READ

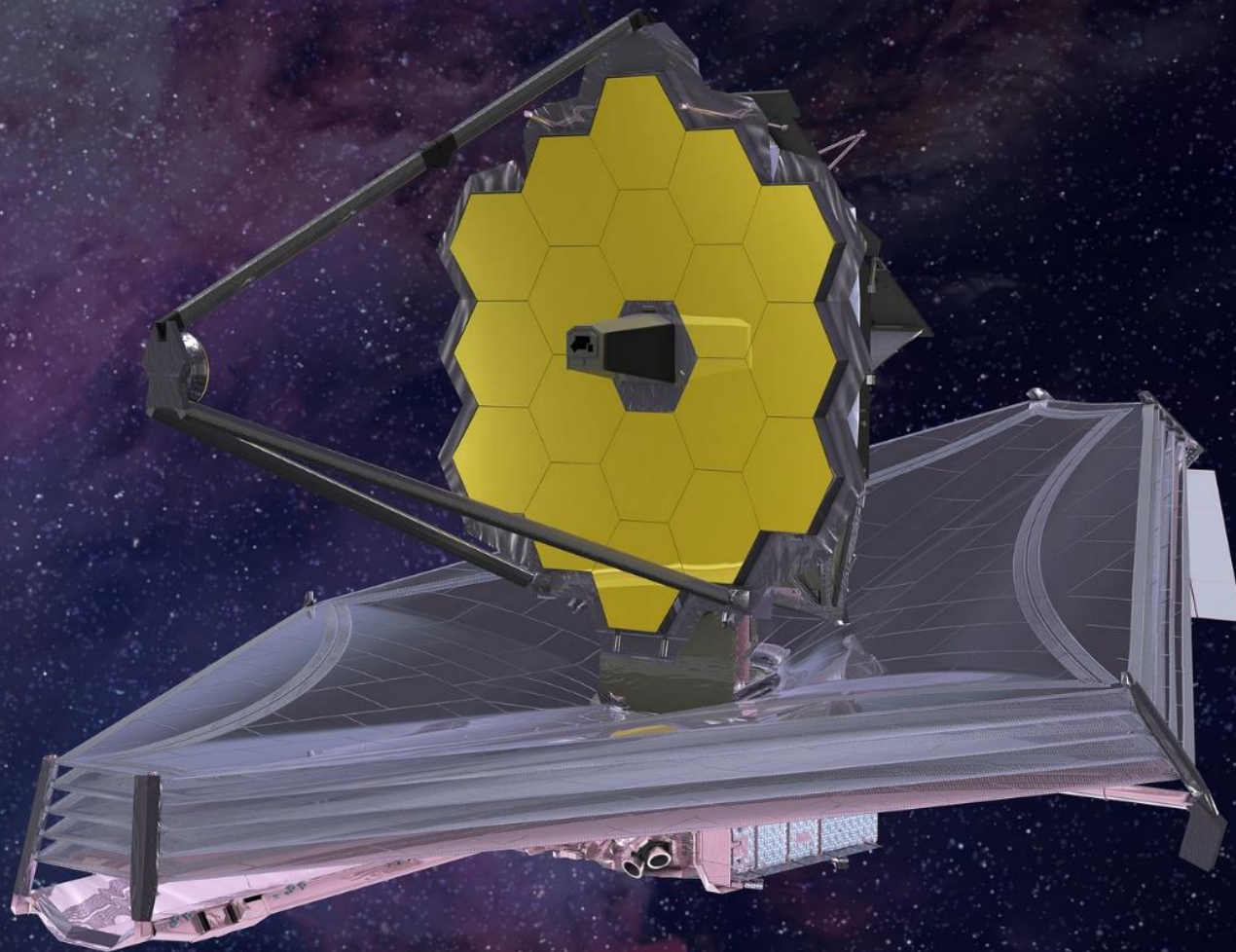
EMISSION SPECTRUM

NIRSpec | IFU Medium-Resolution Spectroscopy



WEBB
SPACE TELESCOPE

Go Webb!



Nieuw licht op het universum!