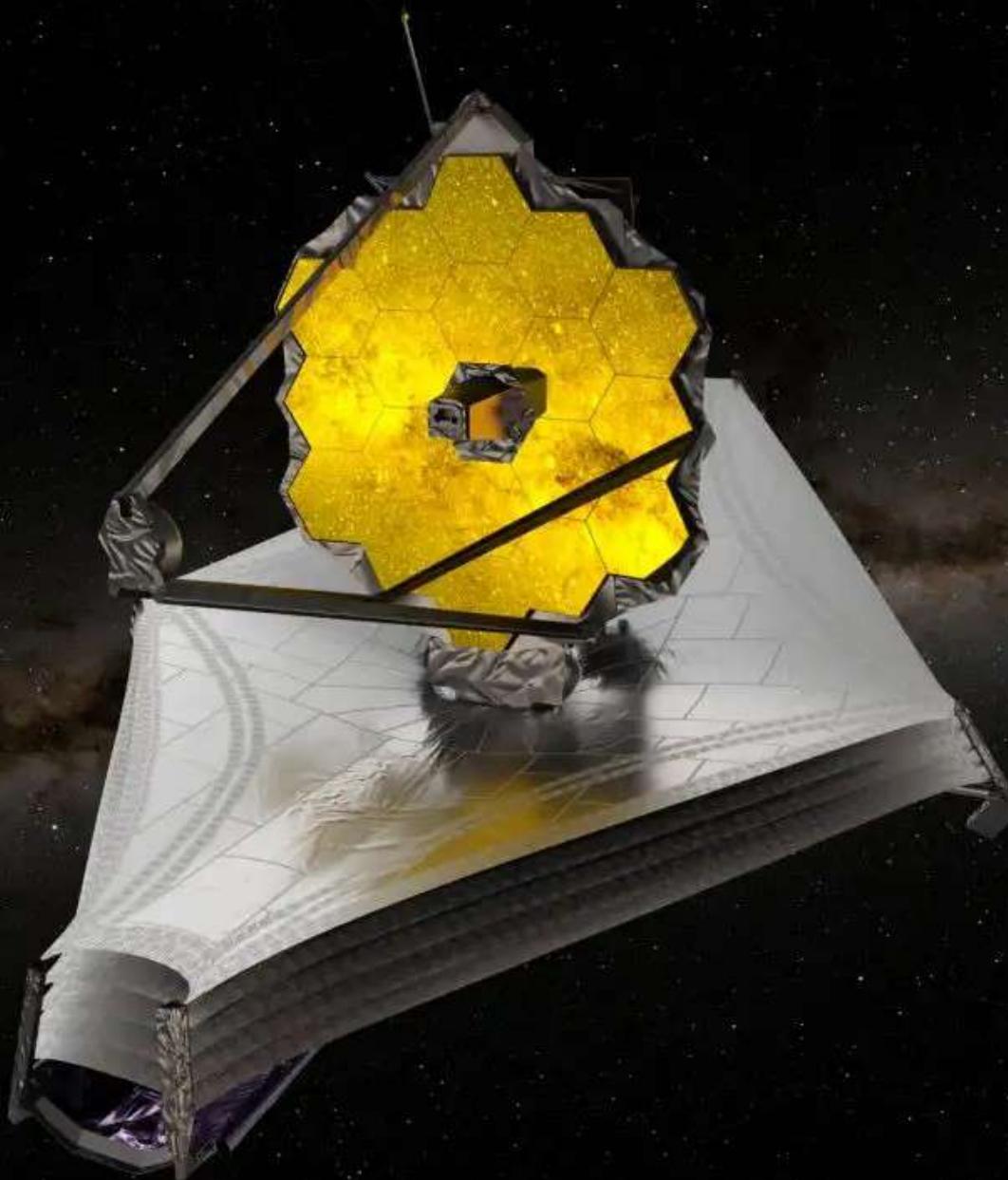


Svemirski teleskop Webb: vodeći opservatorij infracrvene astronomije

Dario Hrupec

Sastanak Županijskog stručnog vijeća Grada Zagreba
za nastavnike fizike u gimnazijama, 10. listopada 2022.

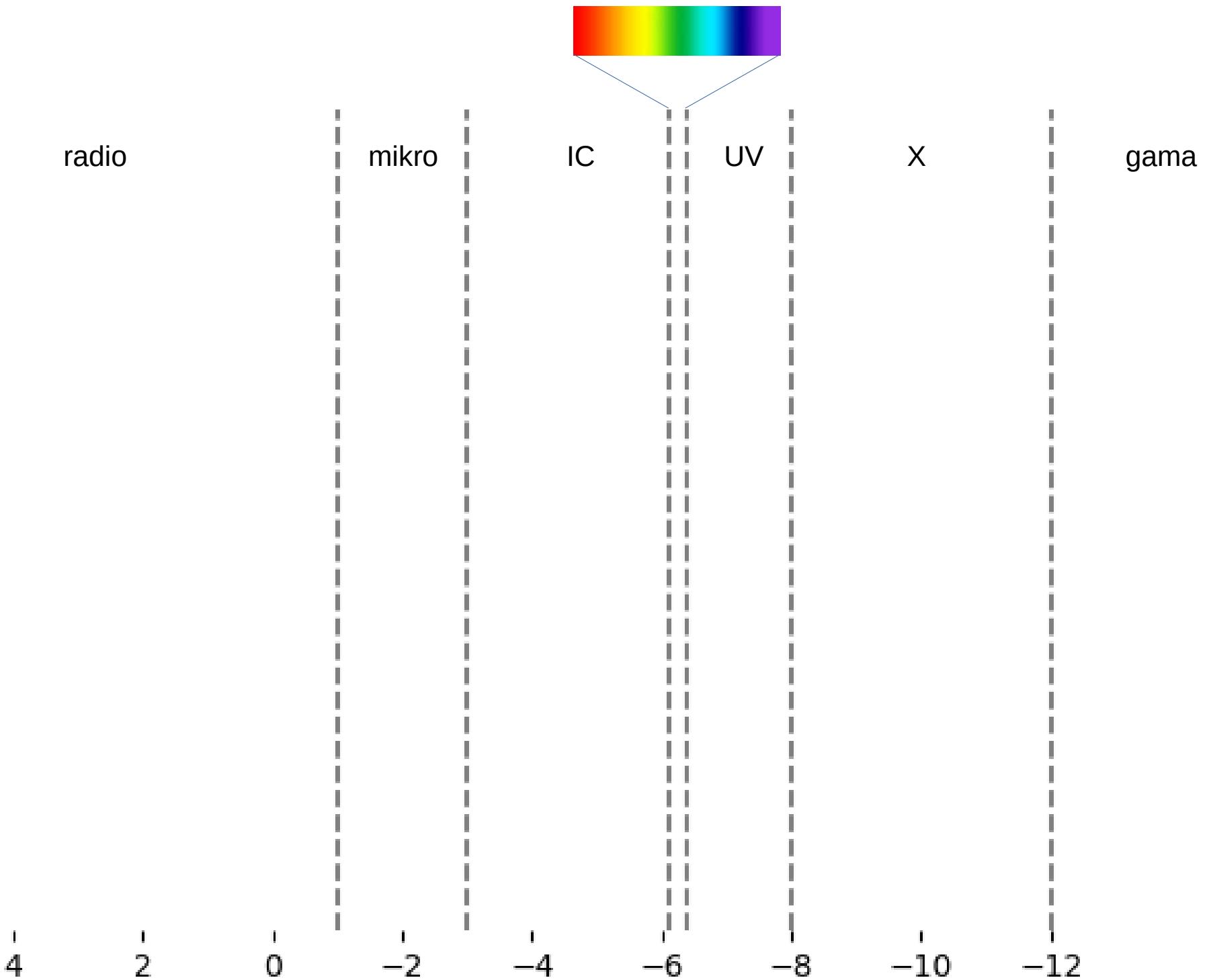


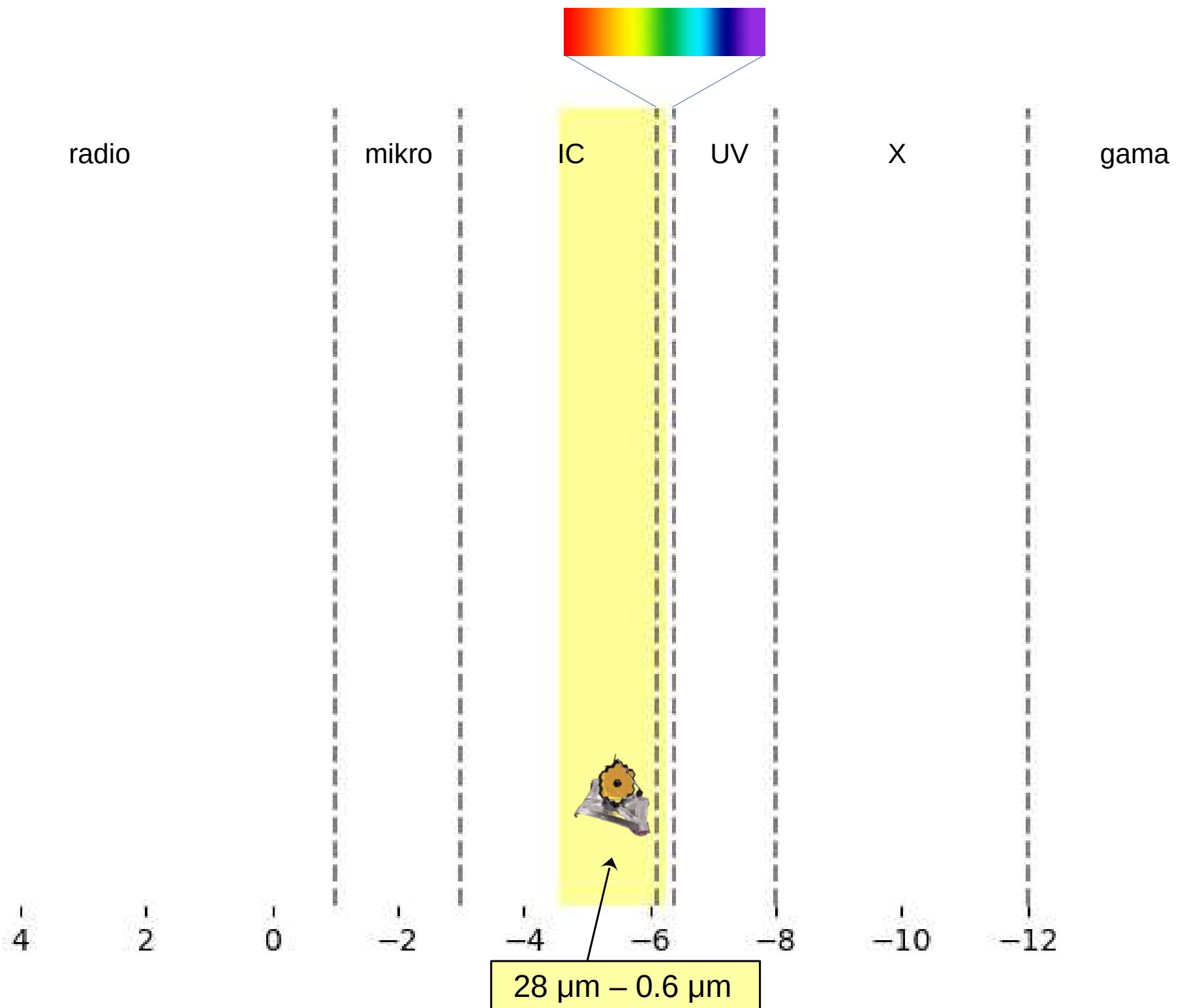
- ✓ lansiran: 25. prosinca 2021.
- ✓ počeo s radom: 12. srpnja 2022.

Infracrvena astronomija

- ✓ opažanja *hladnog* svemira, najčešće u području od 1 μm do 300 μm

PODRUČJE SPEKTRA	VALNA DULJINA
gama	< 1 pm
rendgensko	10 nm – 1 pm
ultraljubičasto	400 nm – 10 nm
vidljivo	750 nm – 400 nm
infracrveno	1 mm – 750 nm
mikrovalno	10 cm – 1 mm
radio	> 10 cm





```
import numpy as np
import matplotlib.pyplot as plt

x = np.logspace(-13,4,2)
z = np.log10(x)
fig, ax = plt.subplots()

def limit(w):
    Z = np.log10(w)
    ax.axvline(Z,linestyle='dashed',color='gray')

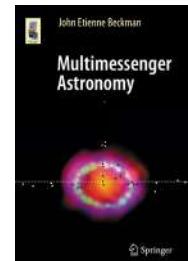
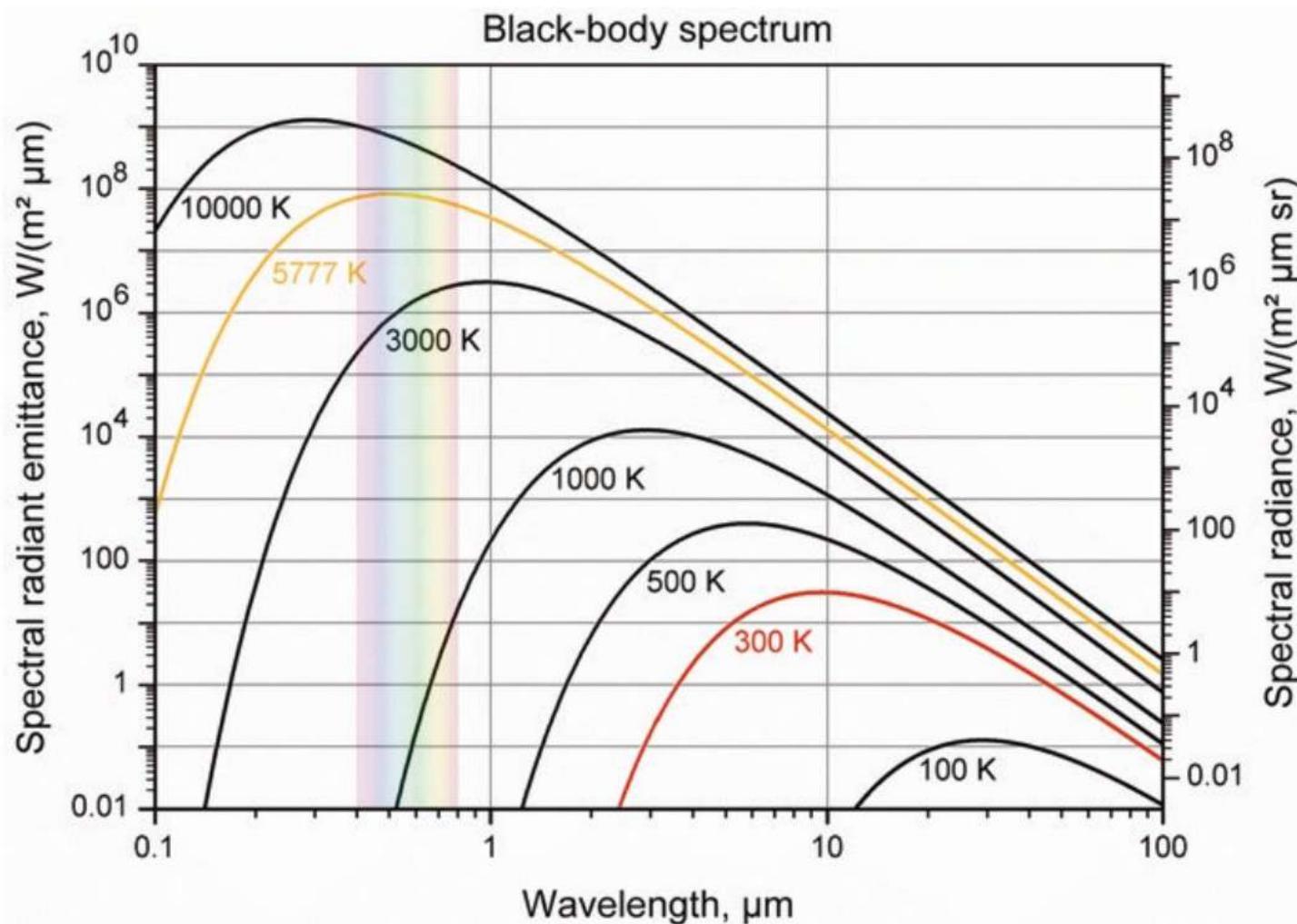
limit(1e-12) # gamma-rays
limit(10e-9) # X-rays
limit(400e-9) # ultraviolet
limit(750e-9) # visible
limit(1e-3) # infrared
limit(10e-2) # microwaves

# wavelength coverage of the James Webb Space Telescope
a = np.log10(0.6e-6) # 0.6 μm
b = np.log10(28e-6) # 28 μm
ax.axvspan(a,b,0,1, alpha=0.4, color='yellow')

plt.axis([max(z),min(z),-1,1])
plt.gca().axes.get_yaxis().set_visible(False)
plt.box(False)
plt.show()
```

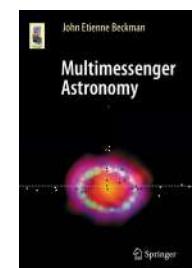
Infracrvena astronomija

- ✓ opažanja *hladnog* svemira: nastanak zvijezda, planeti, daleke galaksije



Infracrvena astronomija

- ✓ međuzvjezdana prašina *prozirnija* je u infracrvenom nego u vidljivom

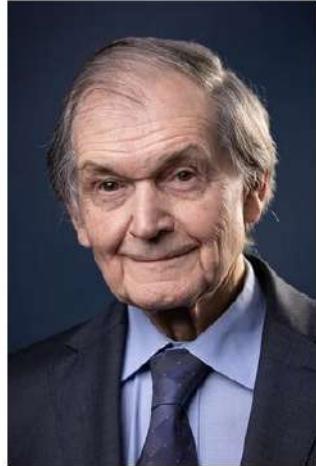


Infracrvena astronomija

- ✓ središnji dio naše galaksije zaklonjen je plinom i prašinom
- ✓ Reinhard Genzel, orbite 28 zvijezda, 16 godina: SMBH u centru



The Nobel Prize in Physics 2020



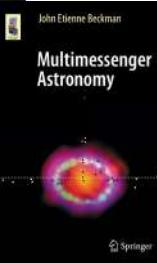
© Nobel Prize Outreach. Photo:
Fergus Kennedy
Roger Penrose
Prize share: 1/2



© Nobel Prize Outreach. Photo:
Bernhard Ludewig
Reinhard Genzel
Prize share: 1/4



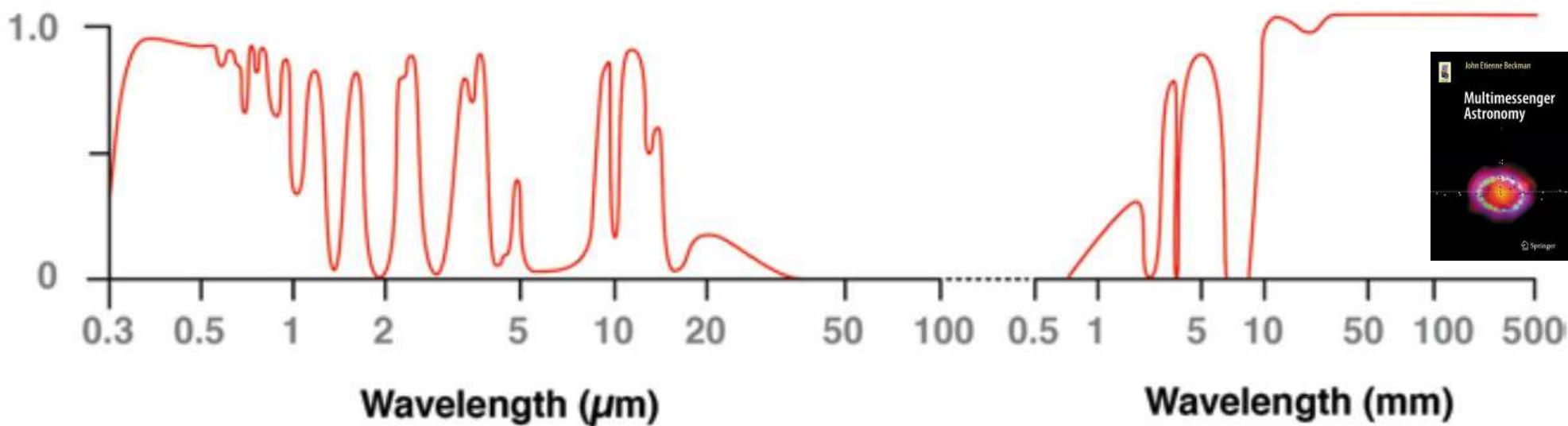
© Nobel Prize Outreach. Photo:
Annette Buhl
Andrea Ghez
Prize share: 1/4



Infracrvena astronomija

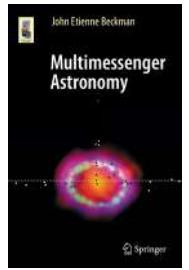
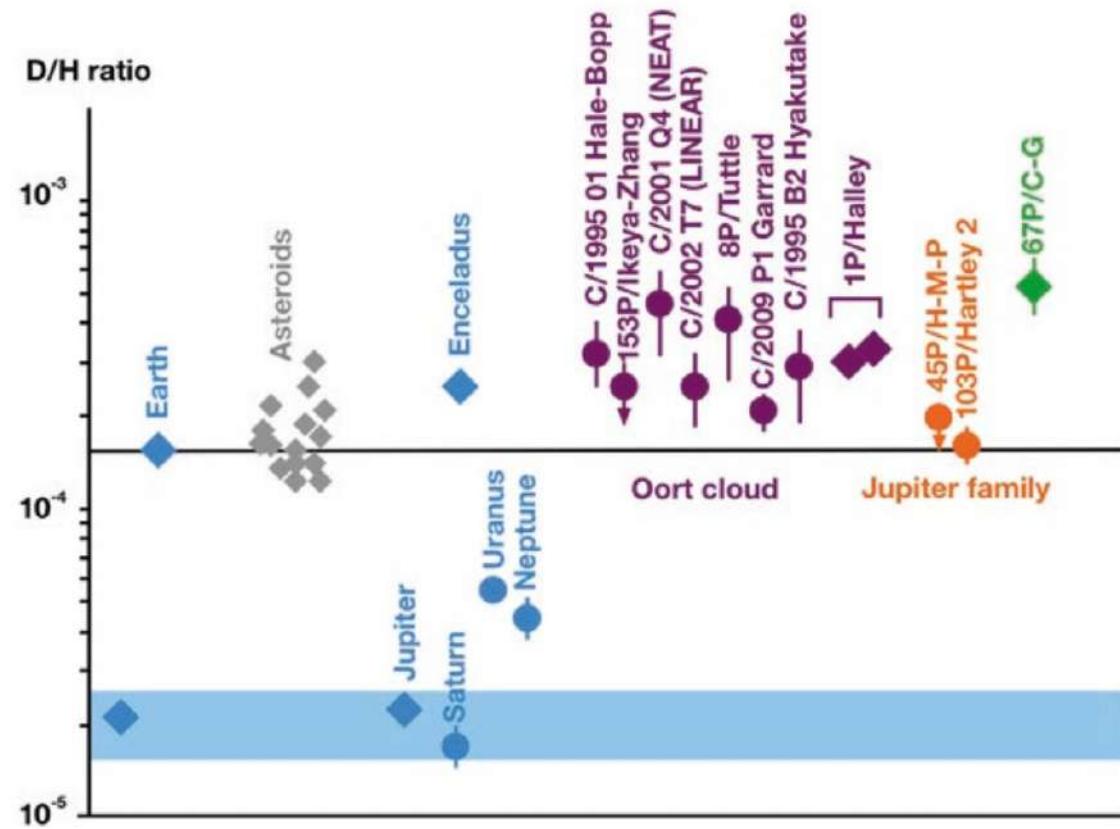
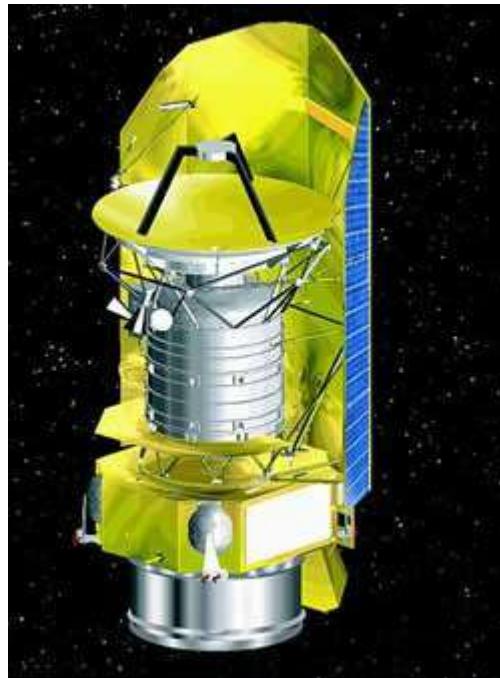
- ✓ atmosfera je propusna za vidljivu svjetlost i većinu radipodručja
- ✓ dijelovi infracrvenog spektra su djelomično ili potpuno blokirani
- ✓ potrebni su instrumenti na satelitima

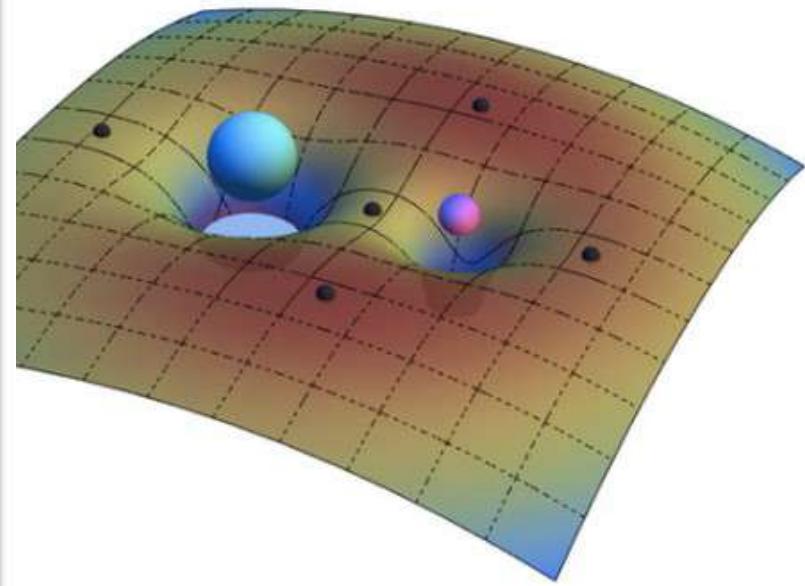
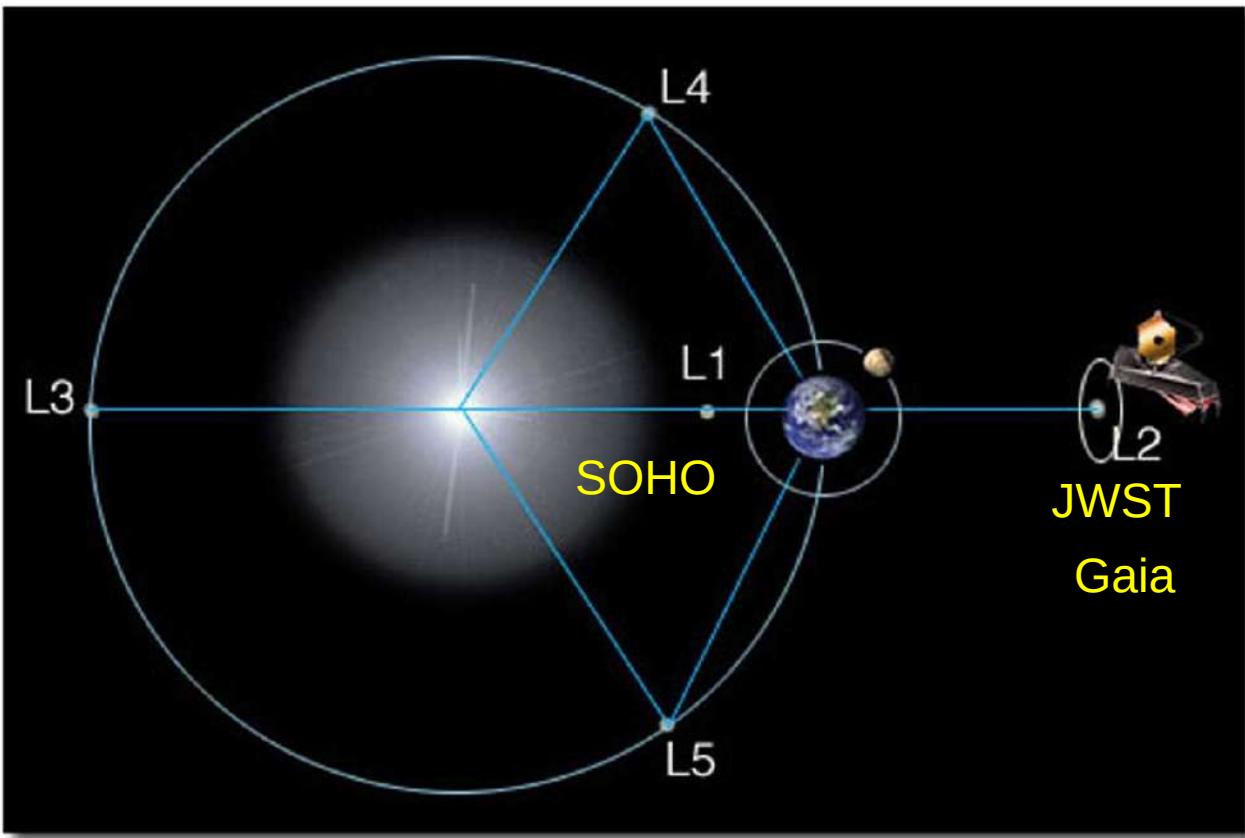
Transmittance



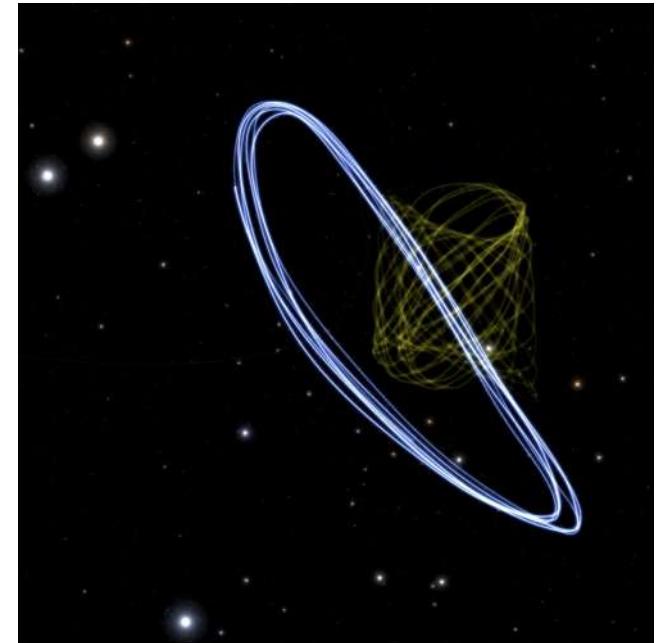
Infracrvena astronomija

- ✓ IRAS (1983.), pionirski satelit za infracrveno područje, 250000 izvora
- ✓ ISO (1995. – 1998.), kemijski sastav atmosfera planeta Sunčevog sustava
- ✓ Spitzer (2003. – 2020.), nastanak zvijezda, egoplaneti, daleke galaksije
- ✓ **Herschel (2009. – 2013.), voda u svemiru, orbita oko Lagrangeove točke**



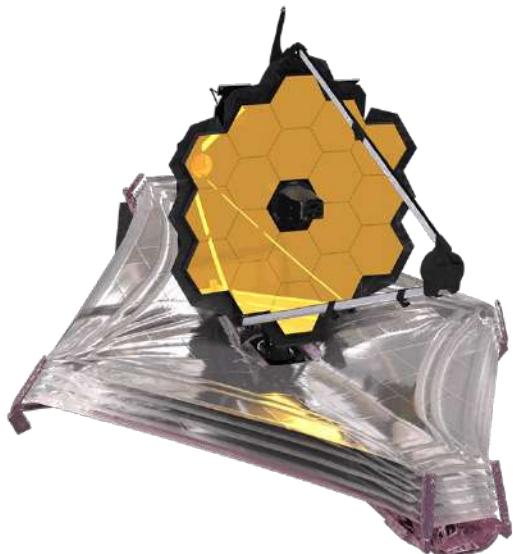


- ✓ Lagrangeove točke
- ✓ egzaktna rješenja klasičnoga problema triju tijela
- ✓ 1772. godina, Joseph Louis de Lagrange
- ✓ pet ravnotežnih položaja maloga tijela
- ✓ L_1 i L_2 nestabilne, ali...



Svemirski teleskop James Webb

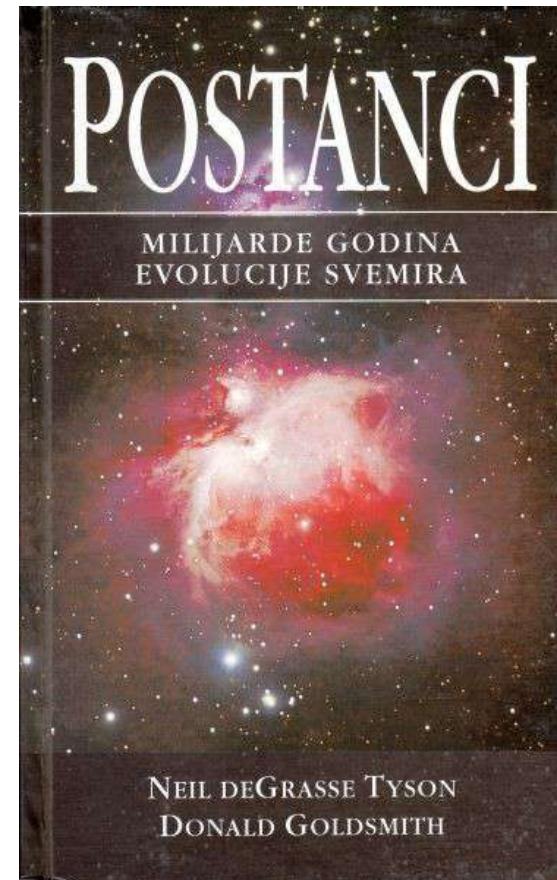
- ✓ James Webb (1906. – 1992.) zaslužni administrator u NASA-i
- ✓ u IC području opaža objekte do 100 puta manjeg sjaja HST-a
- ✓ 18 šesterokutnih segmenata od pozlaćenoga berilija, ukupni promjer 6,5 m
- ✓ održava se na 50 K (-223 °C) za zaštitu od vlastitog toplinskog zračenja
- ✓ peteroslojni štit od Sunčevog zračenja u obliku deltoida

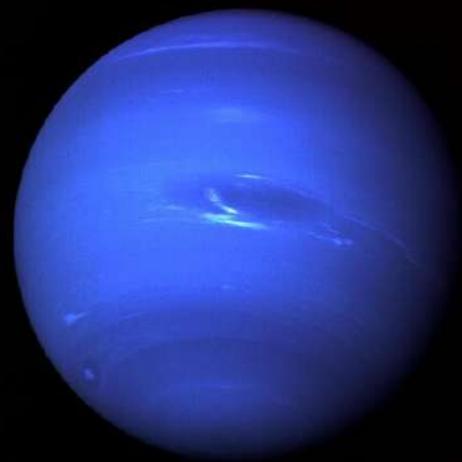


Svemirski teleskop James Webb

Četiri glavna cilja misije JWST-a:

- 1) zvijezde i galaksije nastale najranije nakon velikog praska
- 2) nastanak i razvoj galaksija općenito
- 3) nastanak zvijezda i planetarnih sustava
- 4) nastanak života





Voyager 2 (1989)



Hubble (2021)



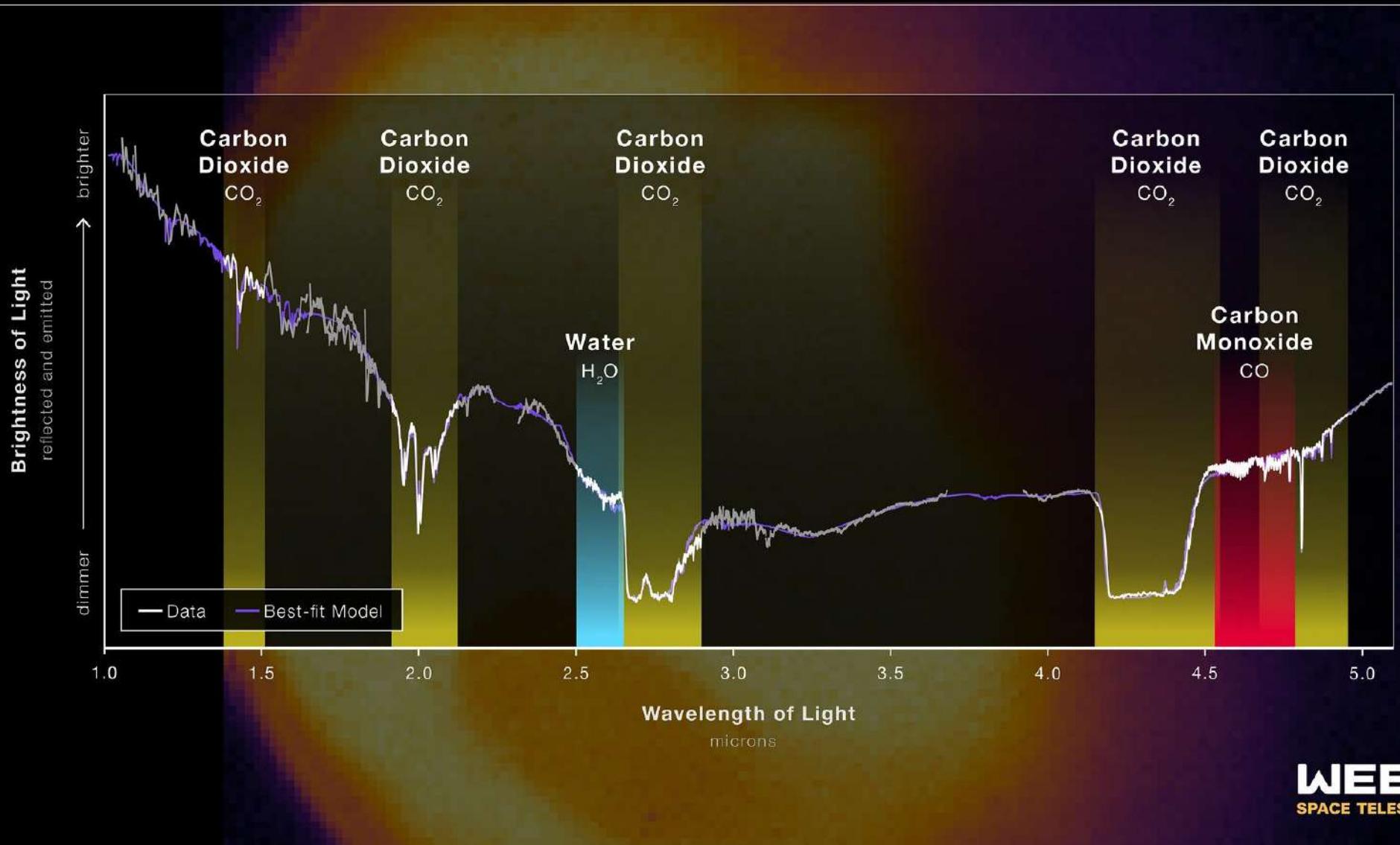
Webb (2022)

✓ otkriće Neptunovih prstenova

MARS

ATMOSPHERE COMPOSITION

NIRSpec | Fixed Slit Spectroscopy



✓ vrlo precizni sastav Marsove atmosfere

WEBB
SPACE TELESCOPE

Star
HIP 65426

Exoplanet
HIP 65426 b

JWST

NIRCam

F300M

NIRCam

F444W

MIRI

F1140C

MIRI

F1550C

✓ prva izravna slika jednog egzoplaneta



Hubble / Optical

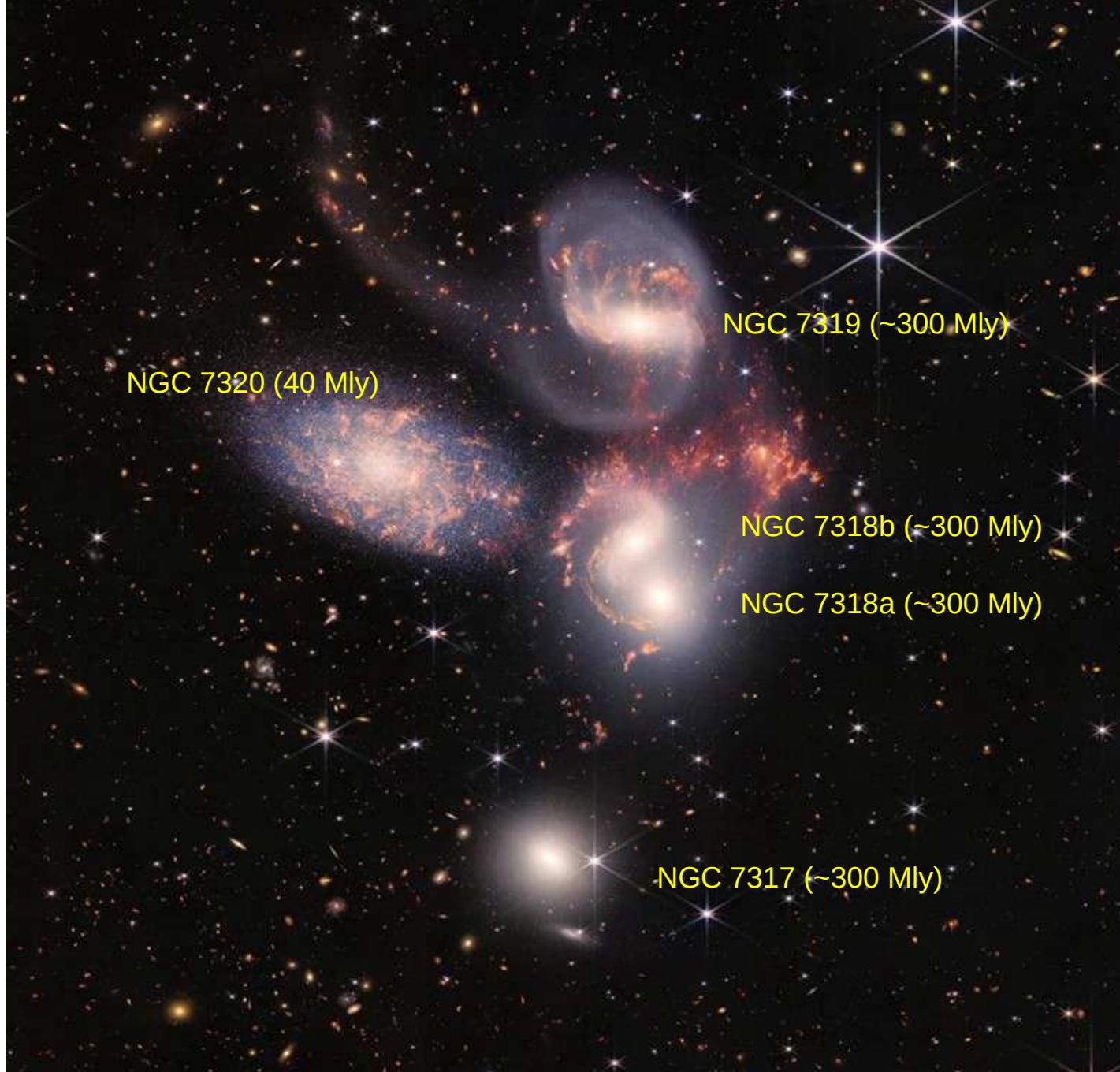


Hubble & Webb



Webb / Infrared

✓ viševalno opažanje galaksije M74



✓ Stephanov kvintet



✓ Kozmički klif (rub NGC 3324 u maglici Kobilica)