# Telescopes across the electromagnetic spectrum

# Maxwell's Equations

## Electric field

$$\oint_S \vec{E} \cdot d\vec{A} = \frac{q_{\text{enc}}}{\epsilon_0}$$

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_M}{dt}$$

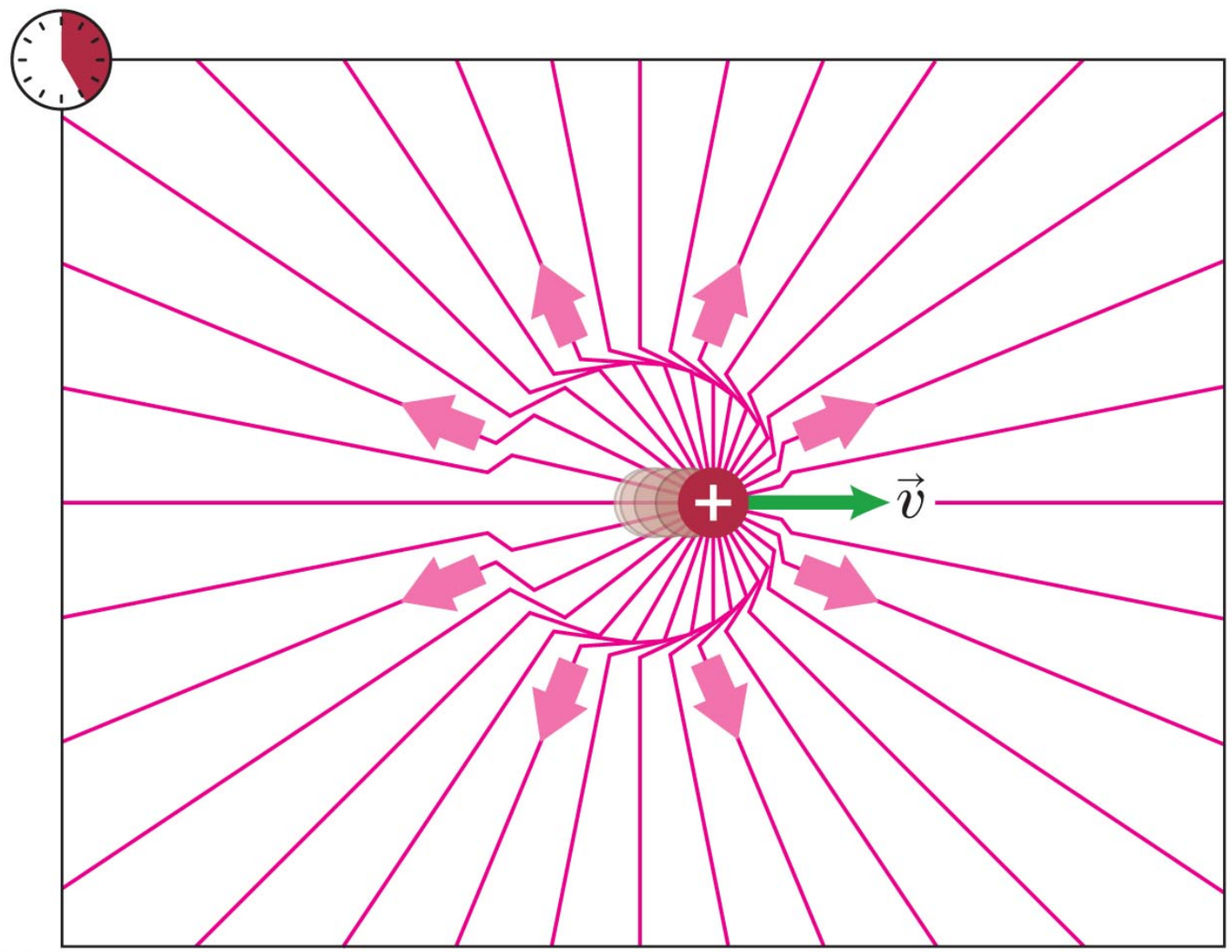
## Magnetic field

$$\oint_S \vec{B} \cdot d\vec{A} = 0$$

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{enc}} + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$$

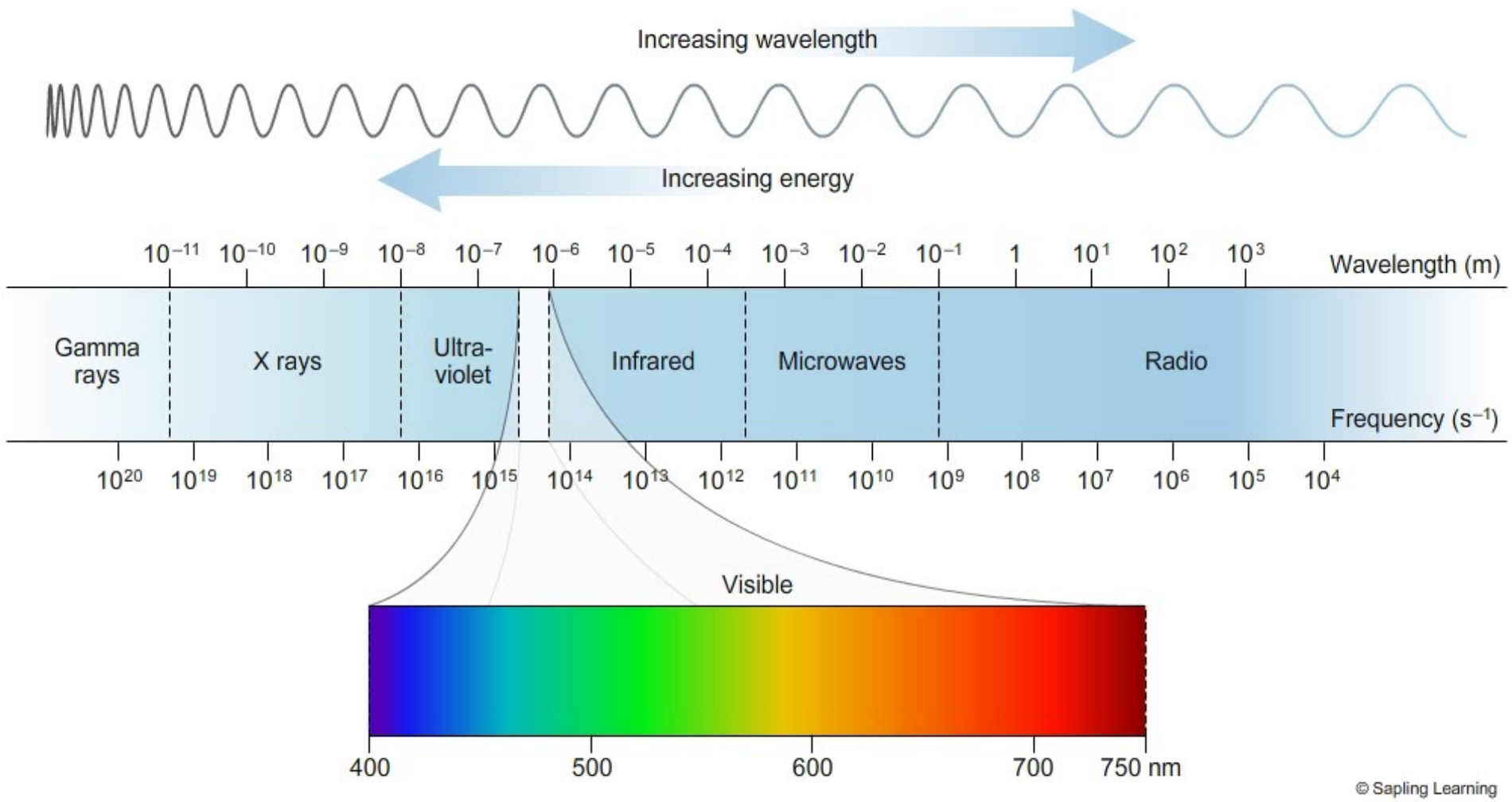
$$E \propto -\mu_0 \epsilon_0 \frac{d^2 E}{dt^2}$$

# Whenever a charge *accelerates* a kink is created

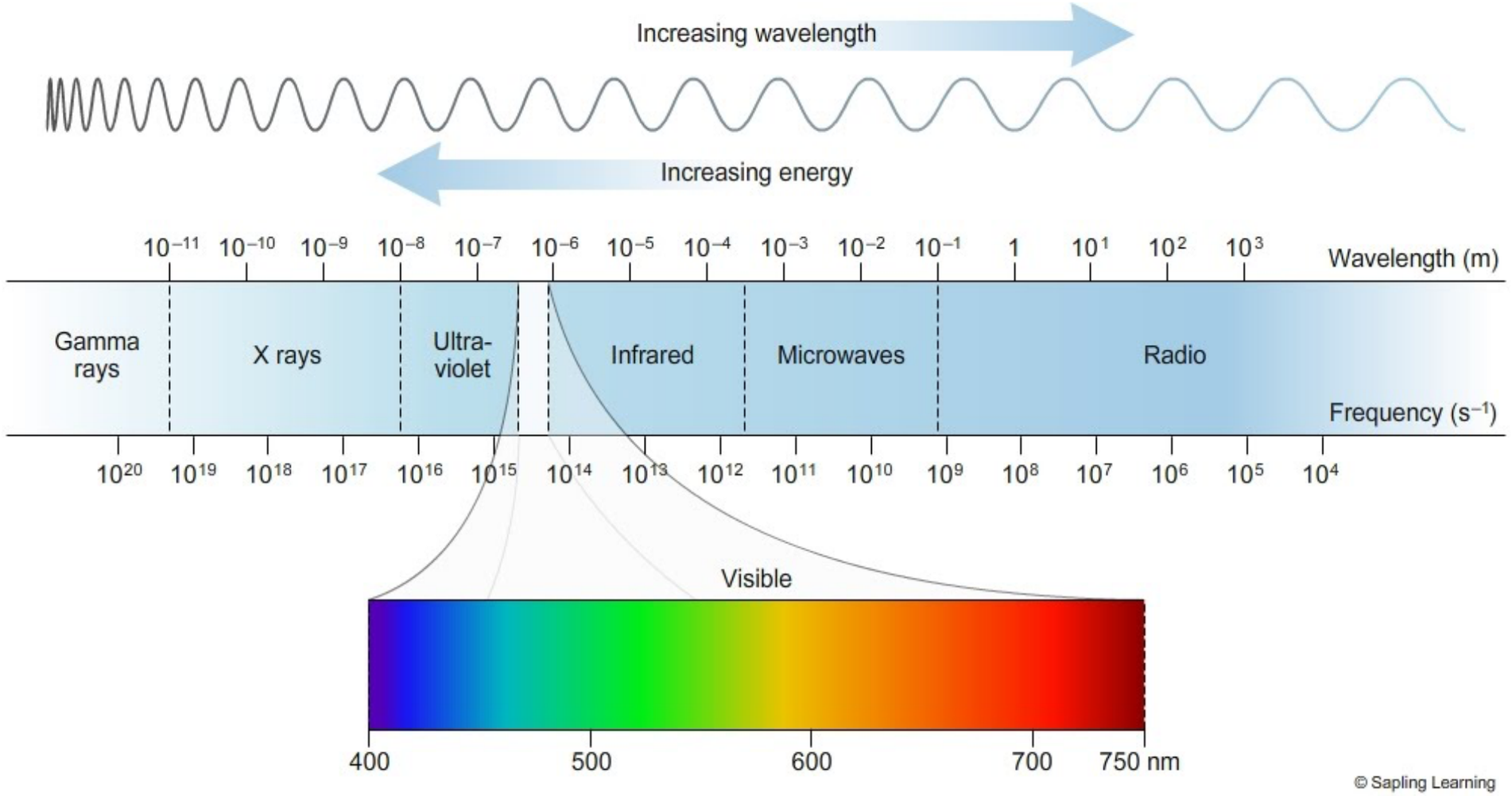


# Color

# Color


Increasing wavelength
Increasing energy
$10^{-11}$ $10^{-10}$ $10^{-9}$ $10^{-8}$ $10^{-7}$ $10^{-6}$ $10^{-5}$ $10^{-4}$ $10^{-3}$ $10^{-2}$ $10^{-1}$ 1 $10^{1}$ $10^{2}$ $10^{3}$
Wavelength (m)
Gamma rays
X rays
Ultra-violet
Infrared
Microwaves
Radio
Frequency ($s^{-1}$)
$10^{20}$ $10^{19}$ $10^{18}$ $10^{17}$ $10^{16}$ $10^{15}$ $10^{14}$ $10^{13}$ $10^{12}$ $10^{11}$ $10^{10}$ $10^{9}$ $10^{8}$ $10^{7}$ $10^{6}$ $10^{5}$ $10^{4}$
Visible
400
500
600
700
750 nm
© Sapling Learning

# Why can’t I see other waves?


Increasing wavelength
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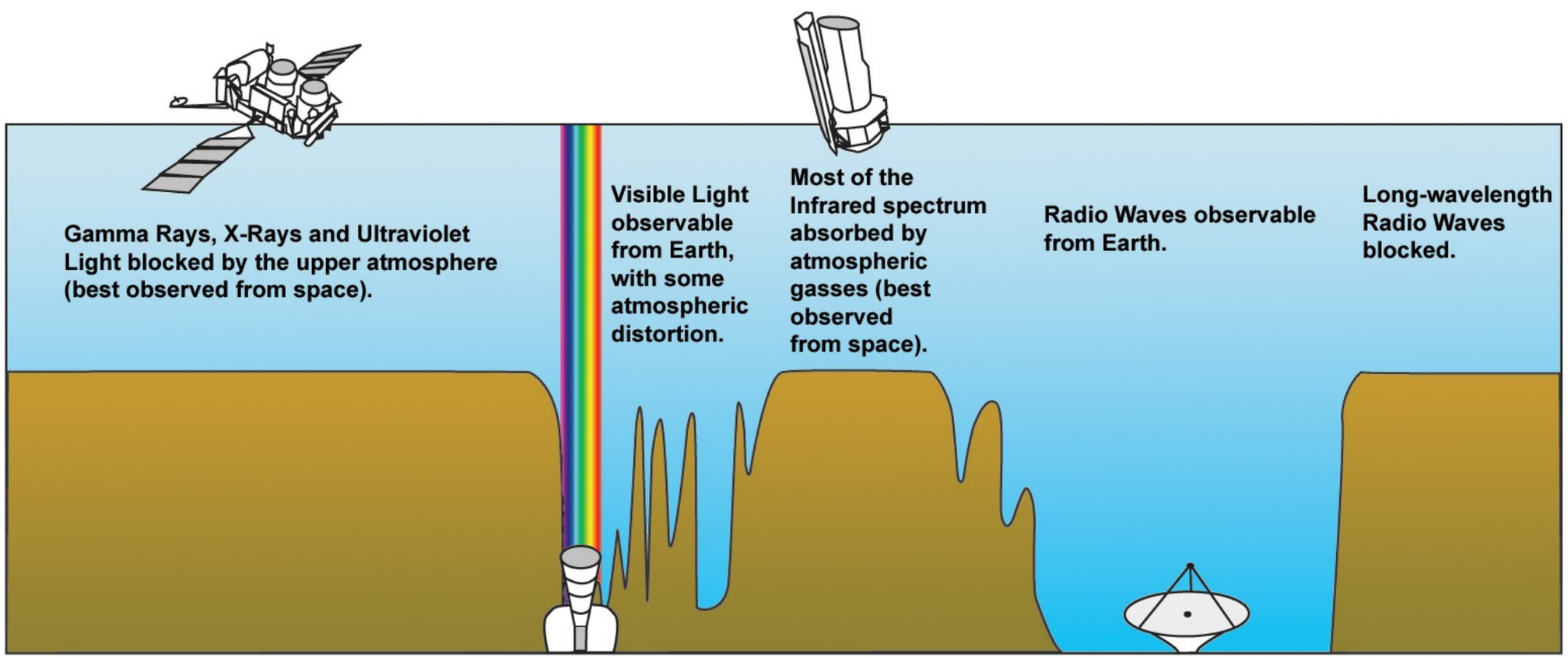
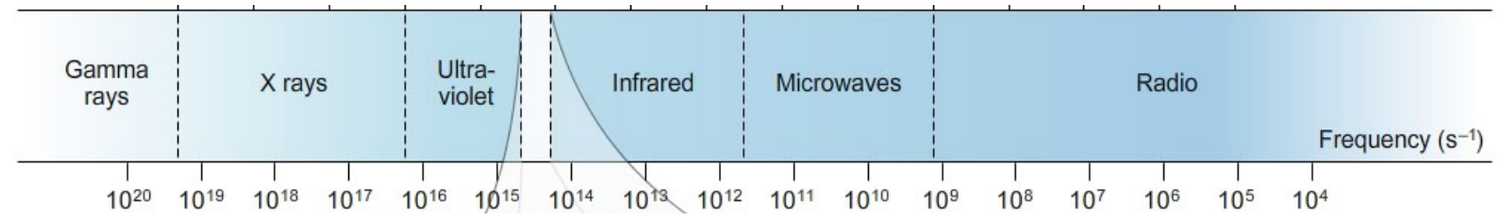
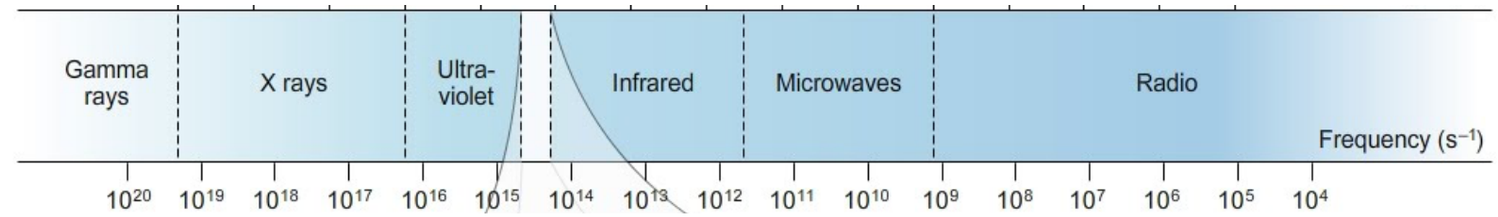
© Sapling Learning


Gamma Rays, X-Rays and Ultraviolet Light blocked by the upper atmosphere (best observed from space).
Visible Light observable from Earth, with some atmospheric distortion.
Most of the Infrared spectrum absorbed by atmospheric gasses (best observed from space).
Radio Waves observable from Earth.
Long-wavelength Radio Waves blocked.

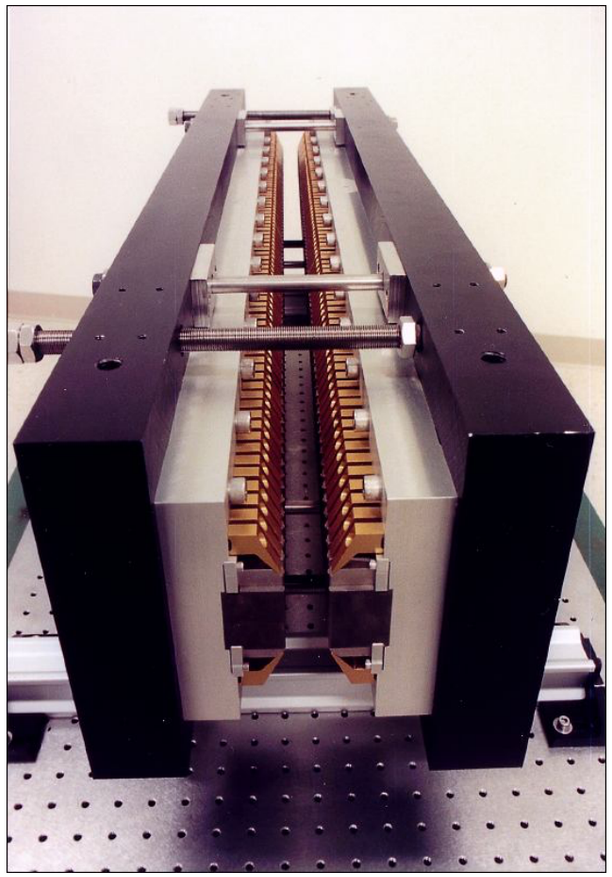
# Unnatural sources of light

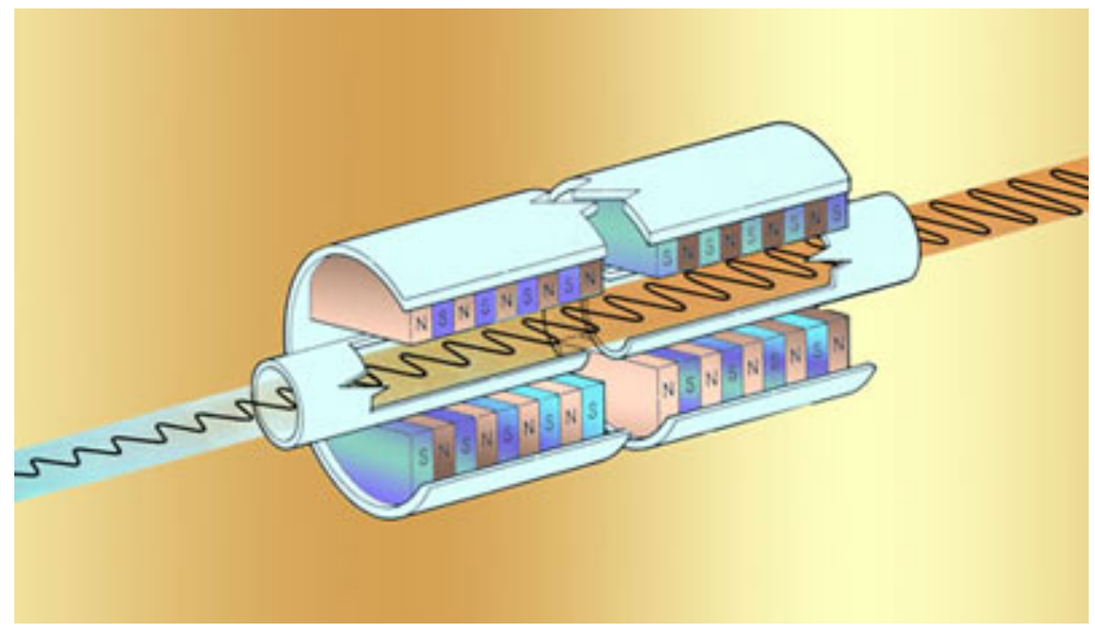

Gamma rays
X rays
Ultra-violet
Infrared
Microwaves
Radio
Frequency (s⁻¹)
10^20 10^19 10^18 10^17 10^16 10^15 10^14 10^13 10^12 10^11 10^10 10^9 10^8 10^7 10^6 10^5 10^4

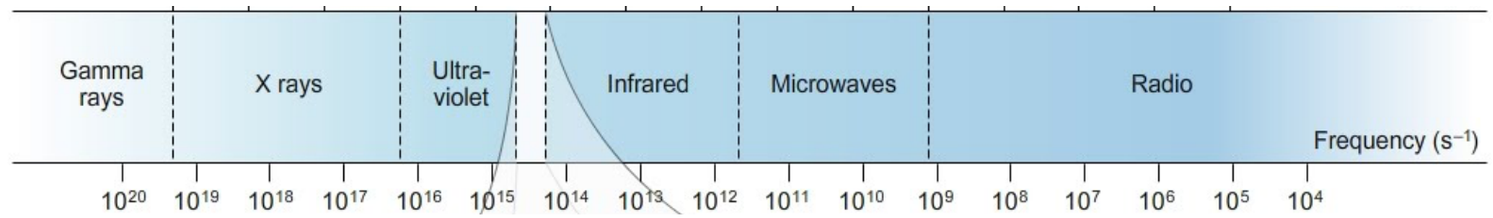
# Radio



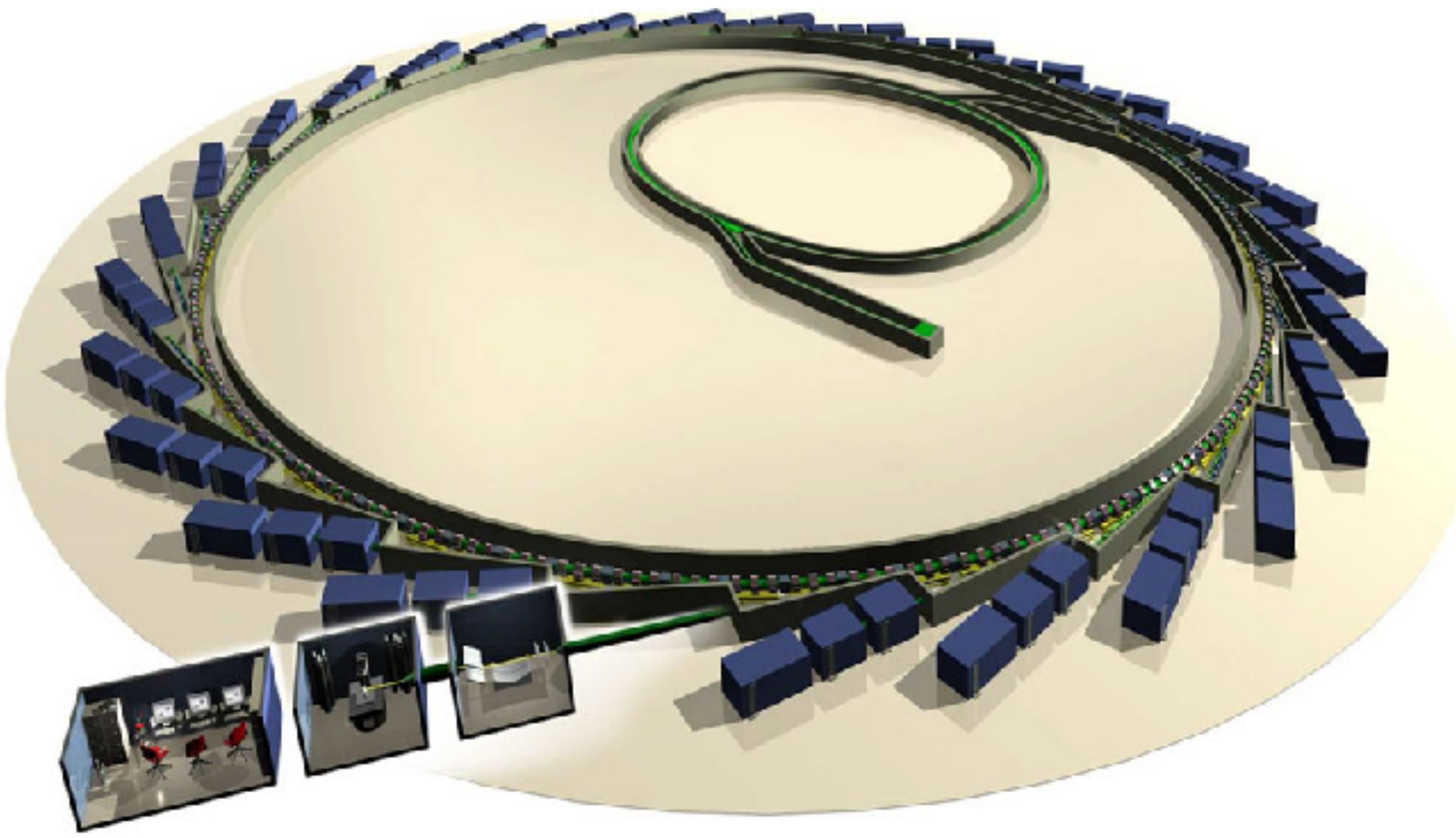

# Synchrotron light source



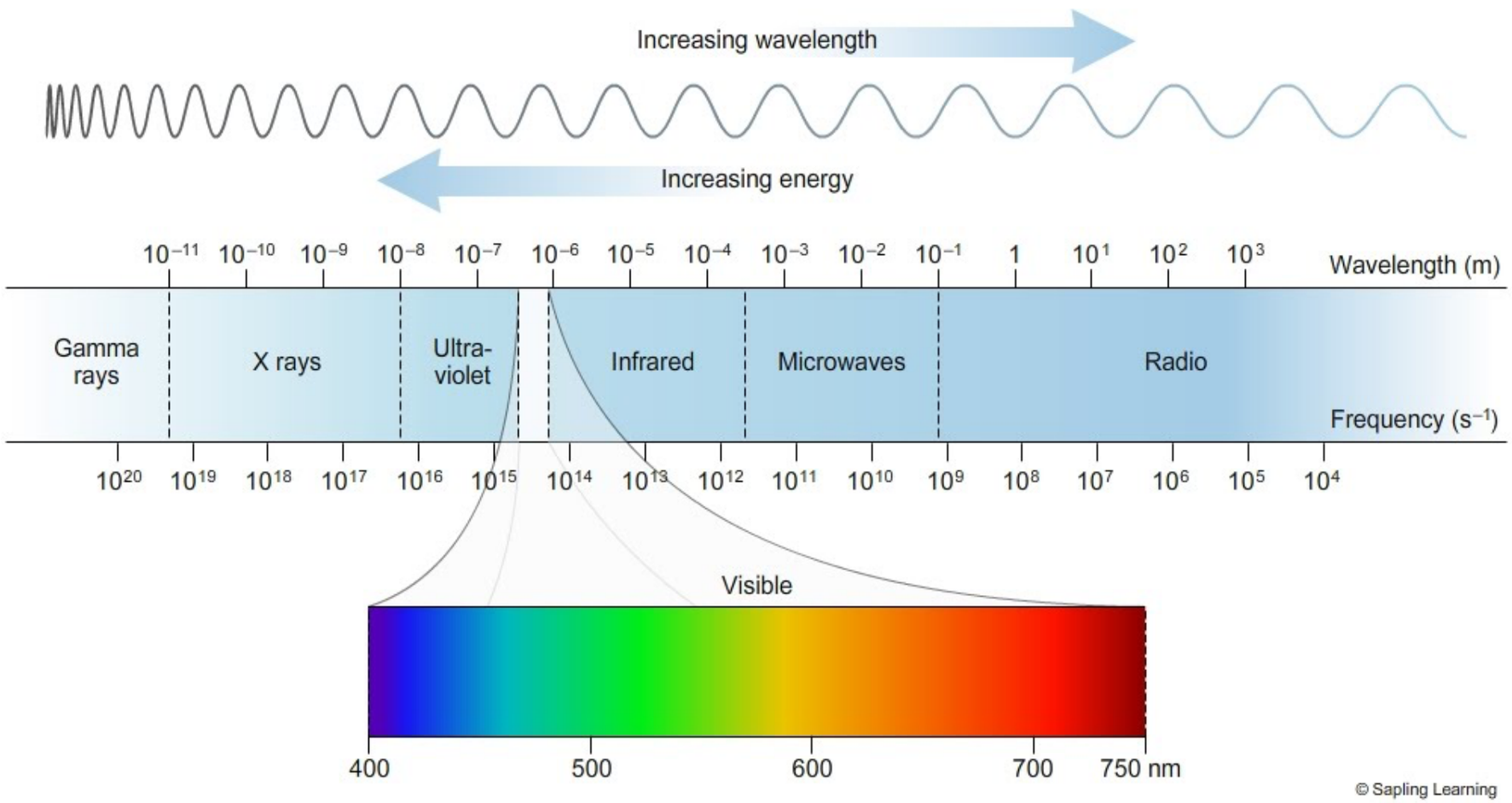




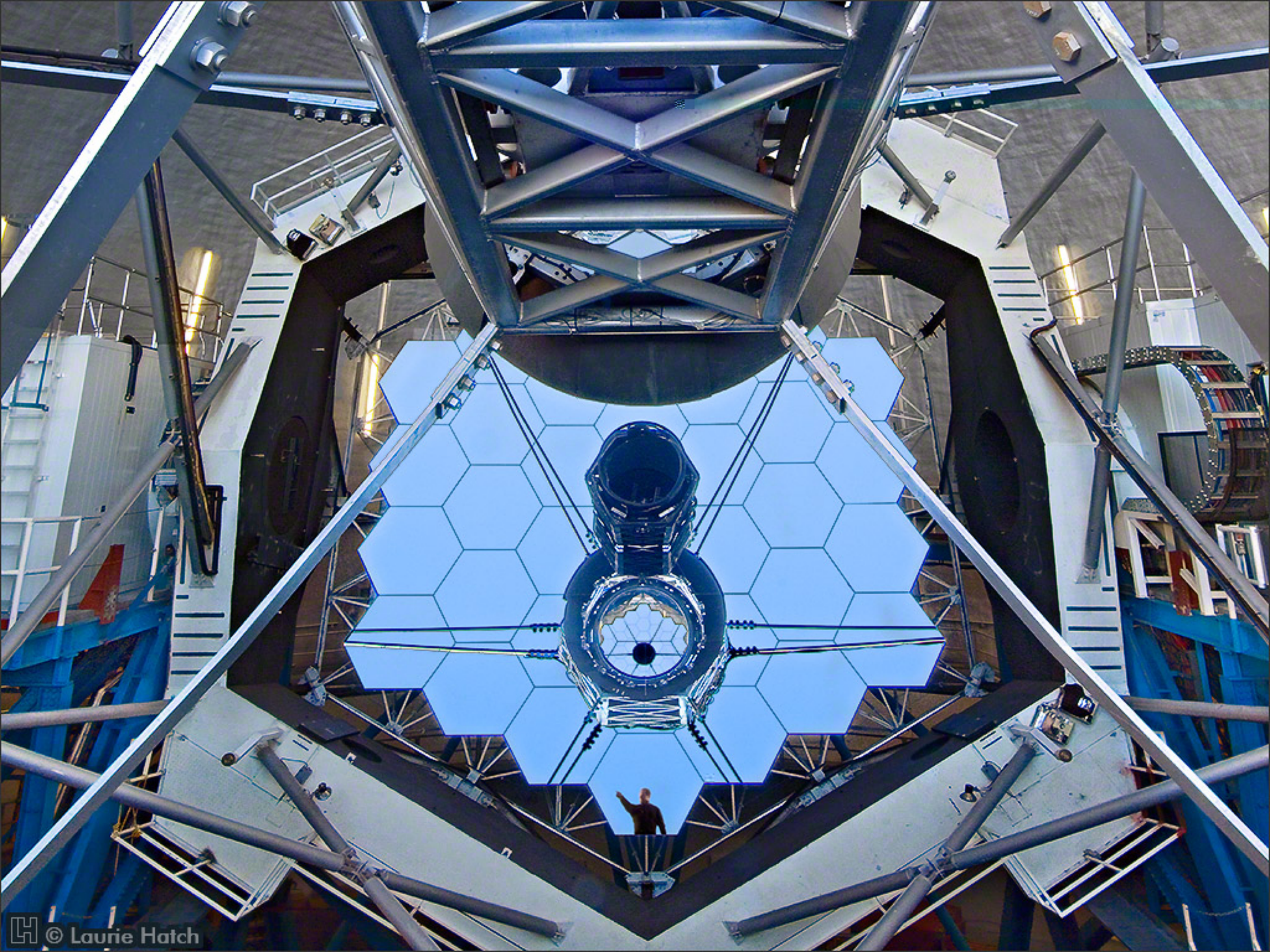

# Synchrotron light source



# Natural Light Sources

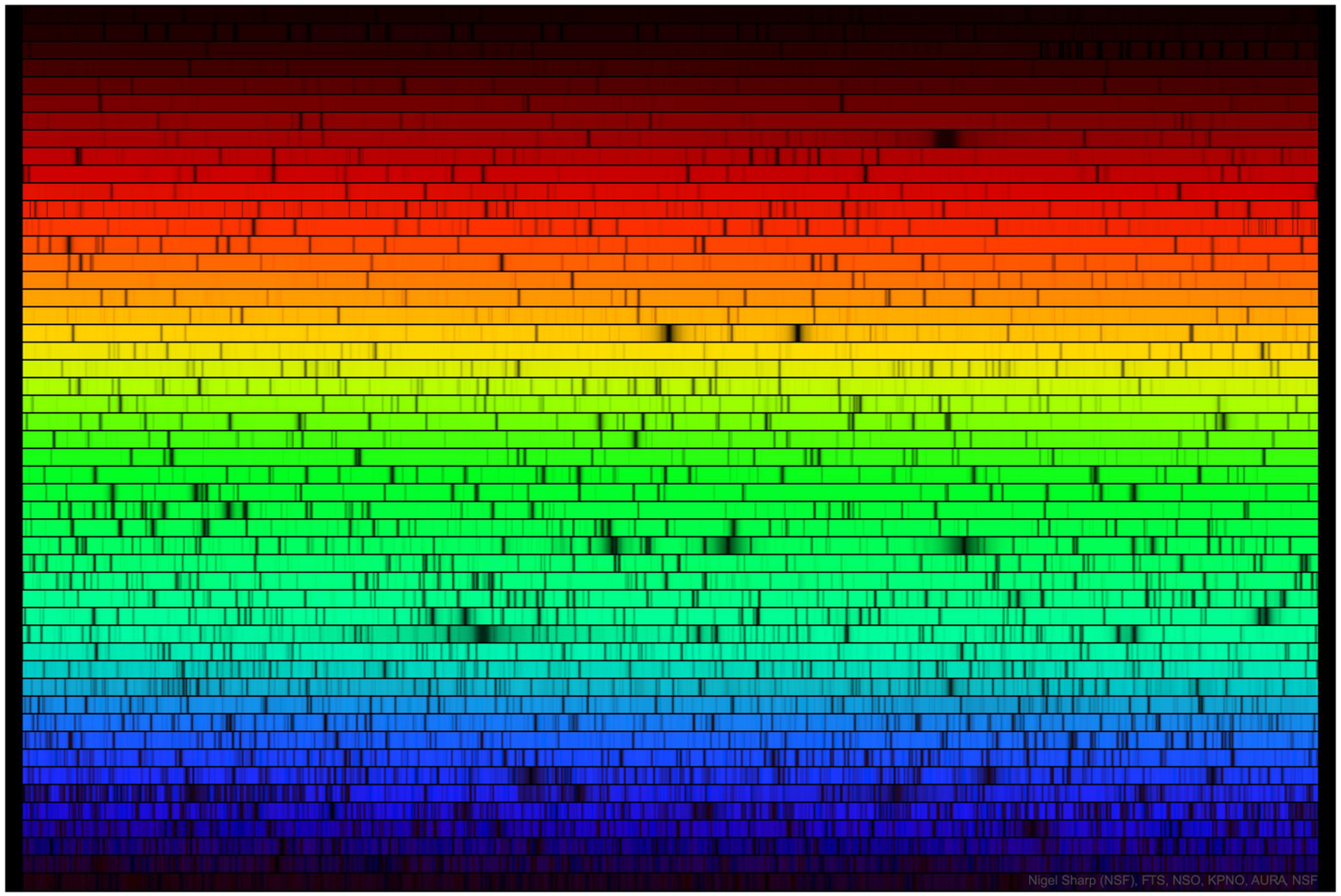


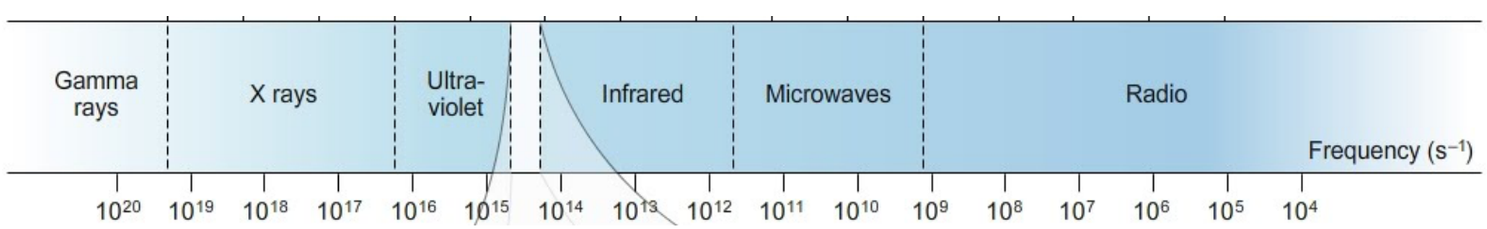

© D. Han


© Laurie Hatch


DANGER
HAZARDOUS
CHEMICALS
ACID
APR
6

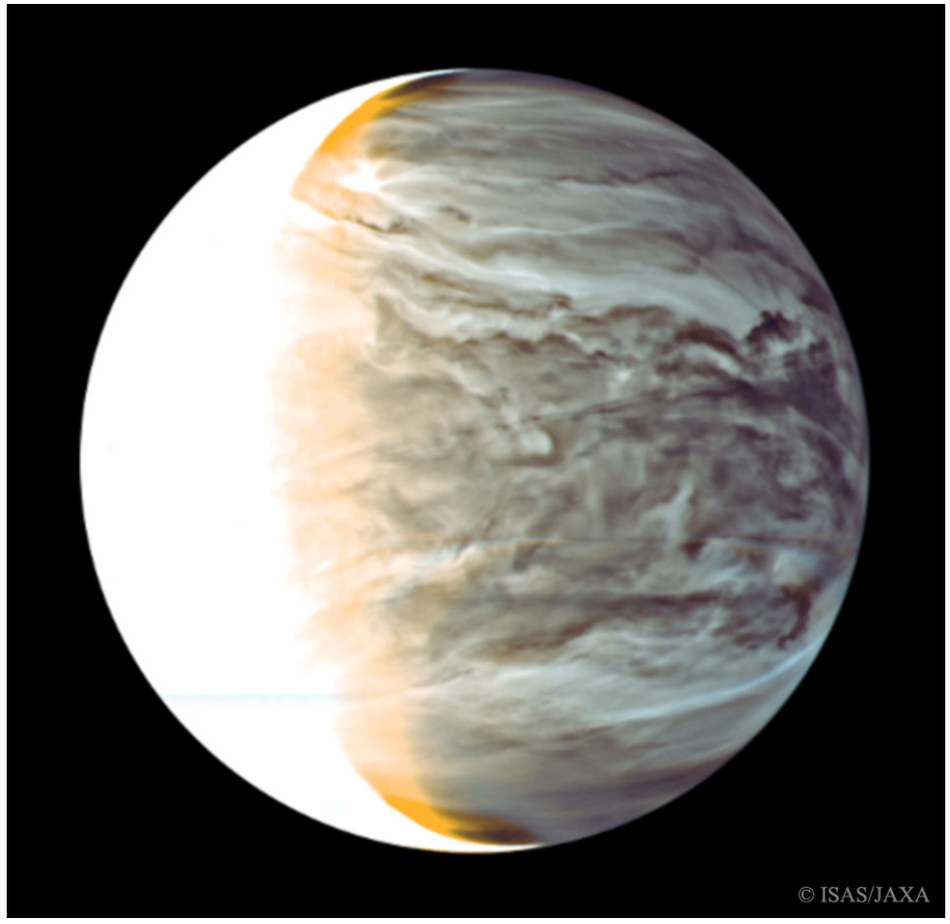
# Solar spectrum

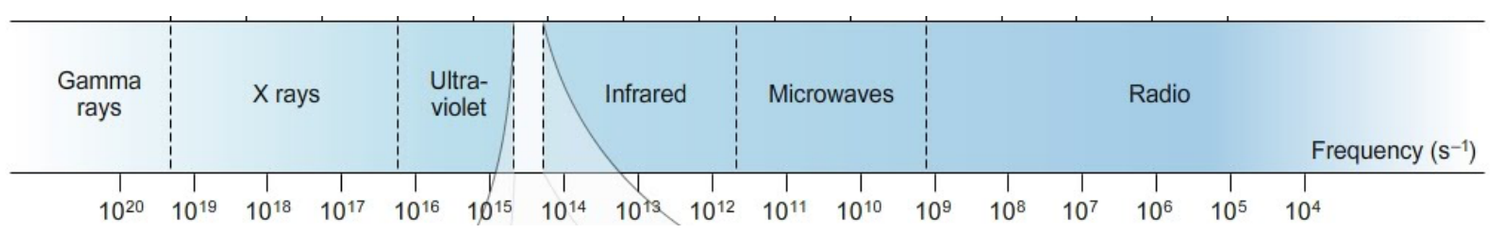


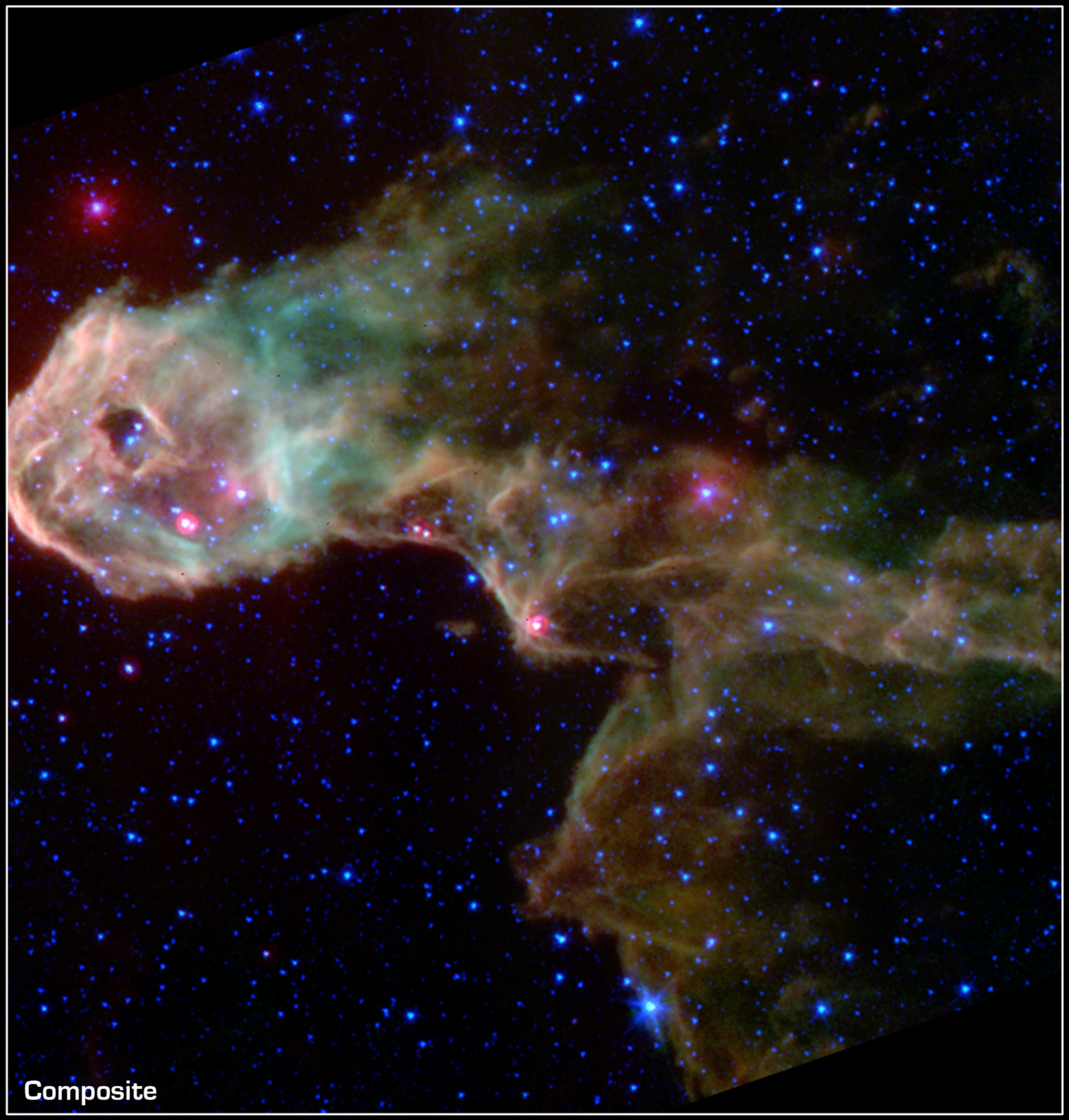



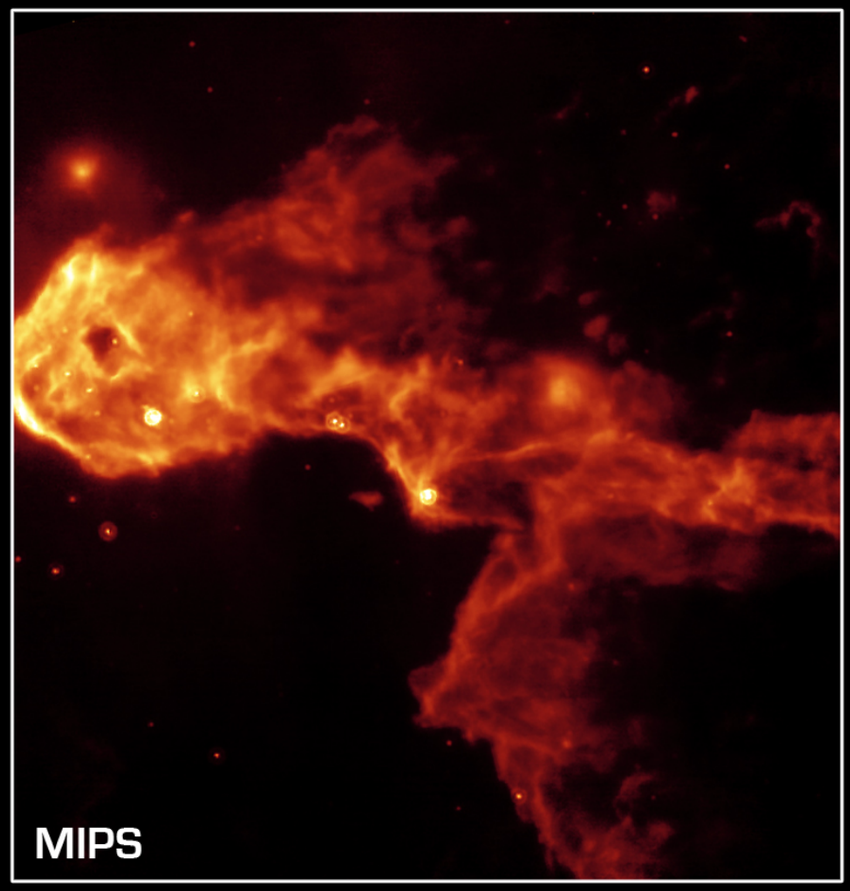
# Solar optical telescope

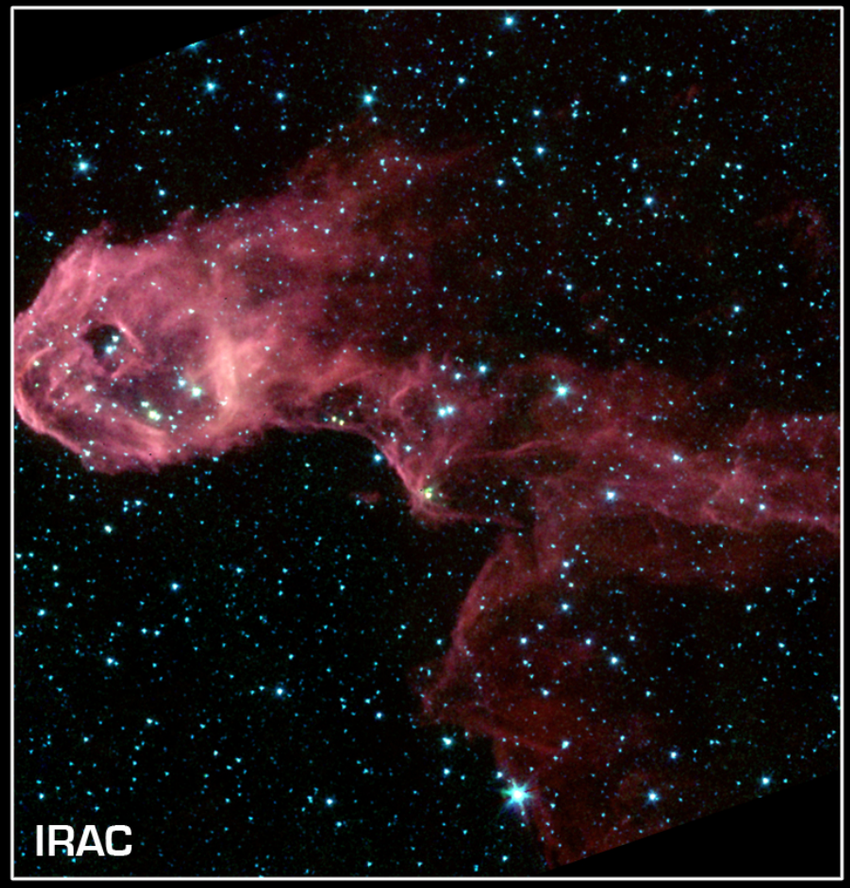
# Infrared Venus & Trifid Nebula (cold)



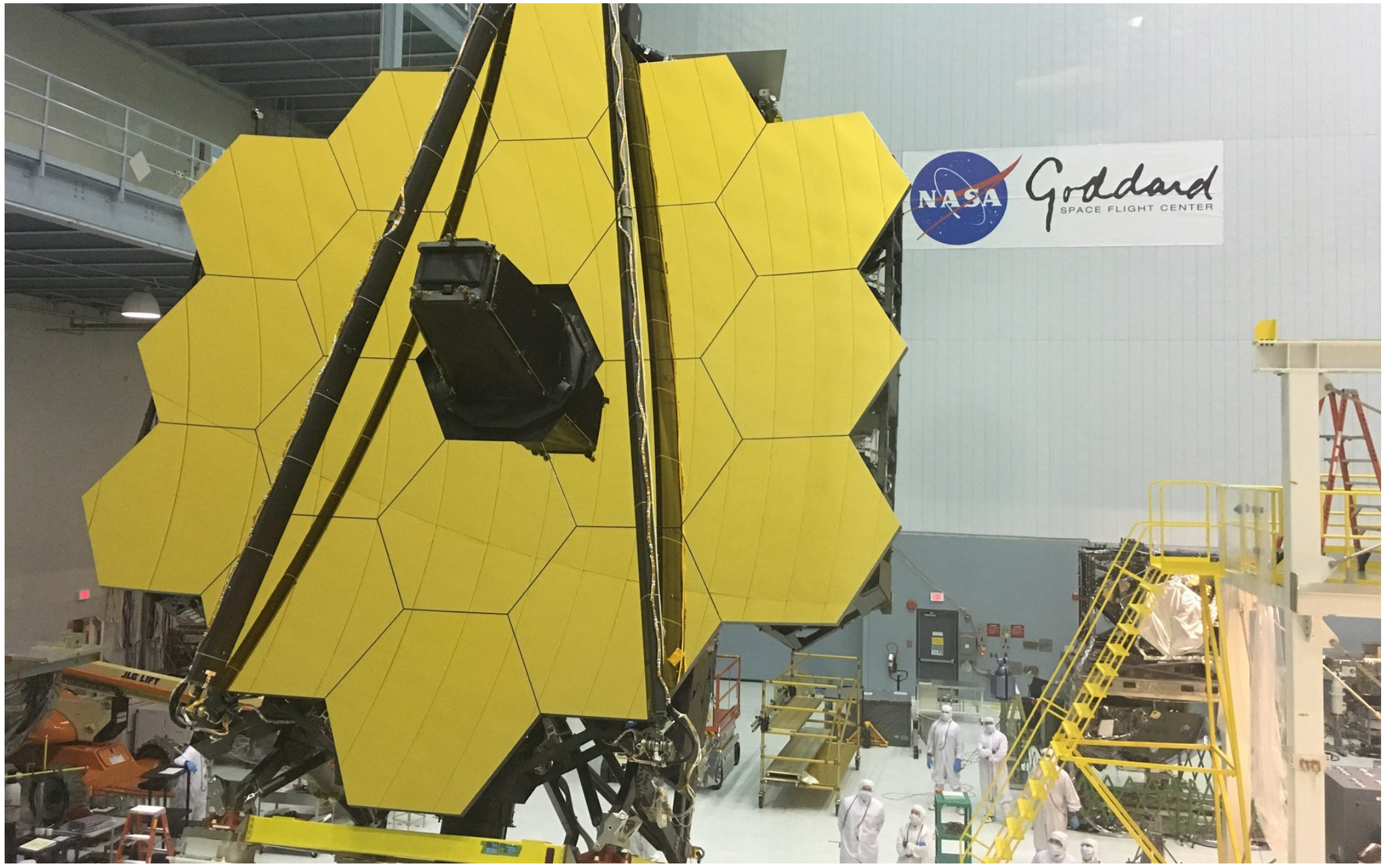




Composite


MIPS

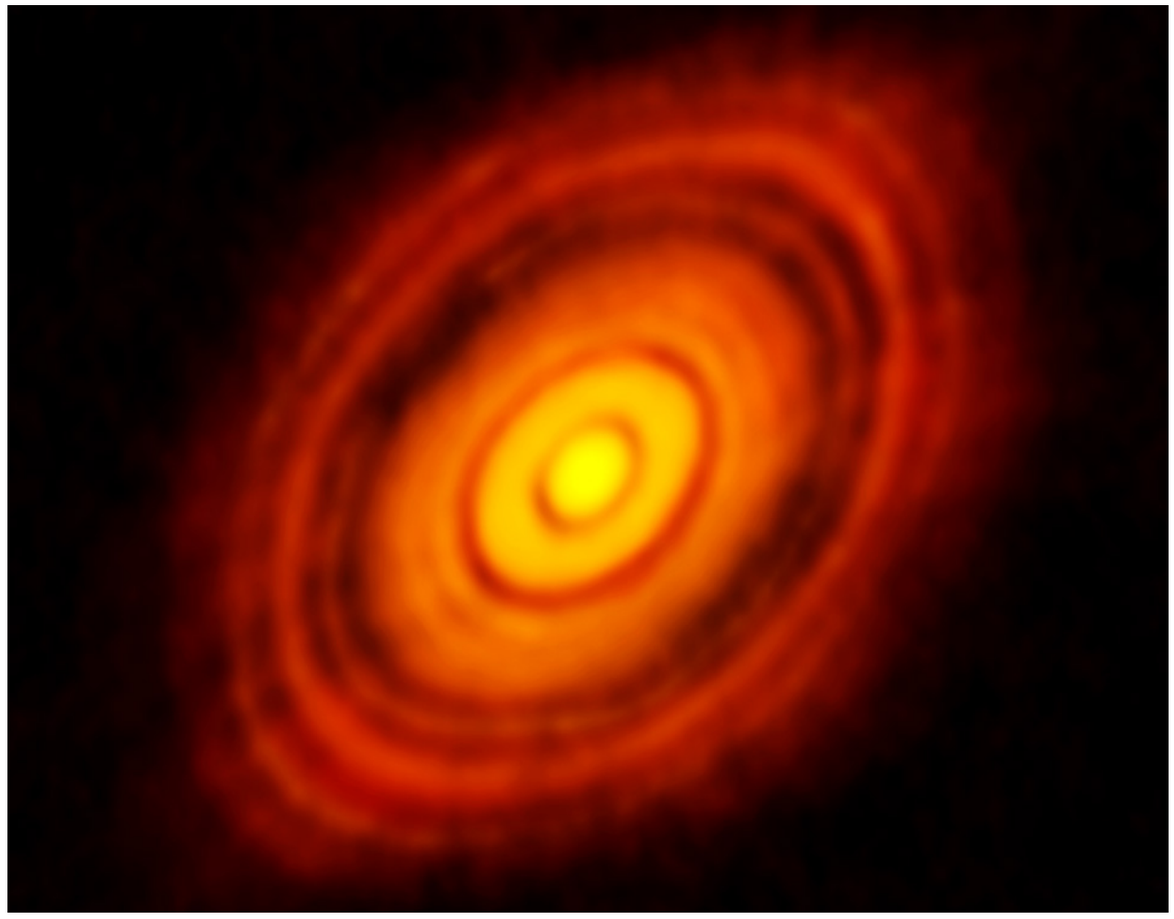

IRAC

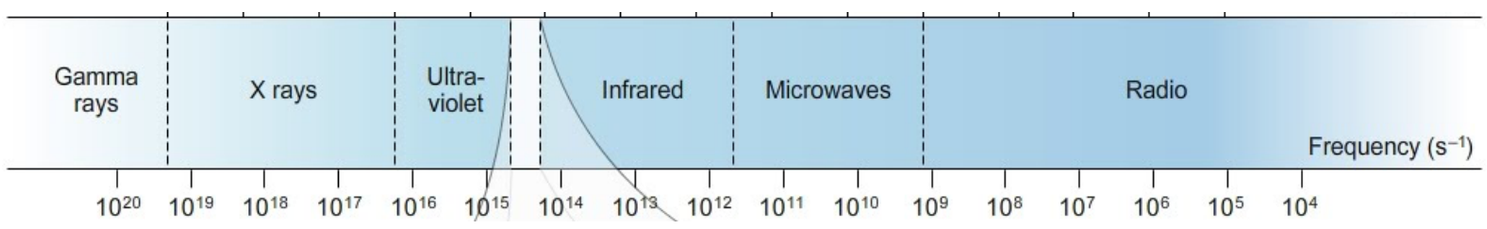
# James Web telescope



# JAMES WEBB SPACE TELESCOPE
## NOMINAL DEPLOYMENT SEQUENCE

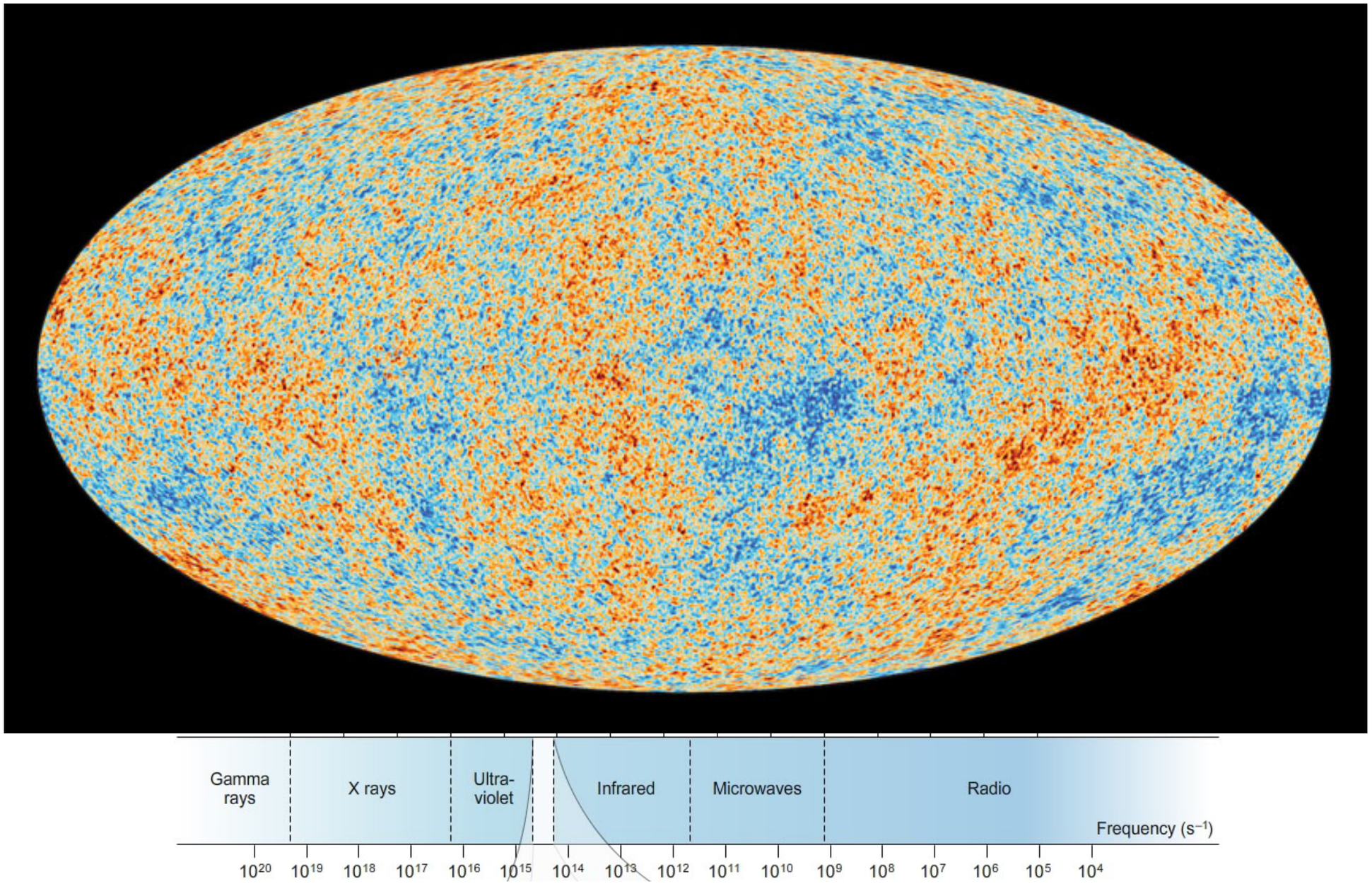
# Planetary disk (very cold)

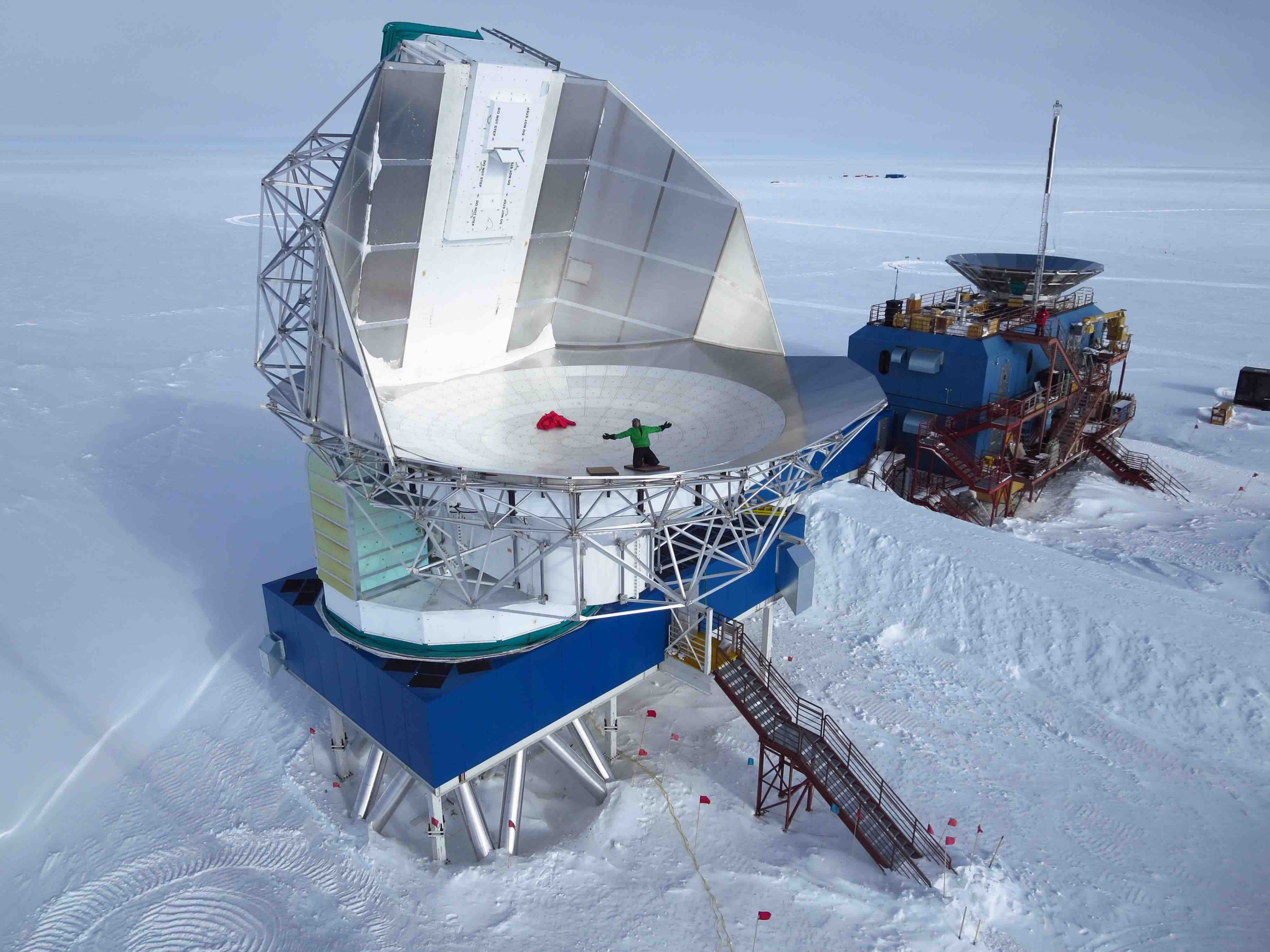


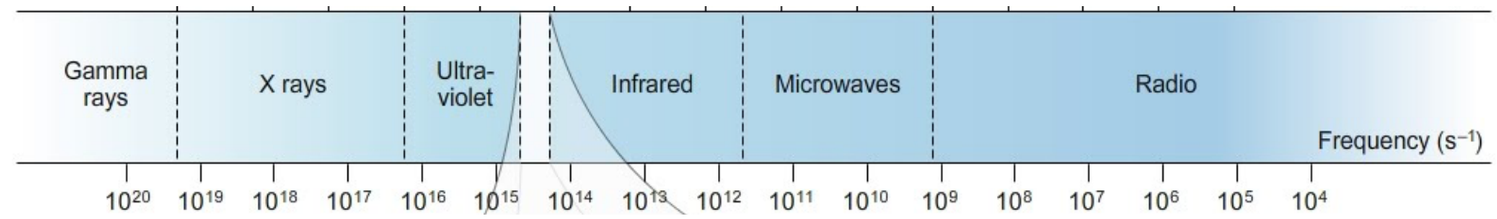


# Atacama Large Millimeter Array

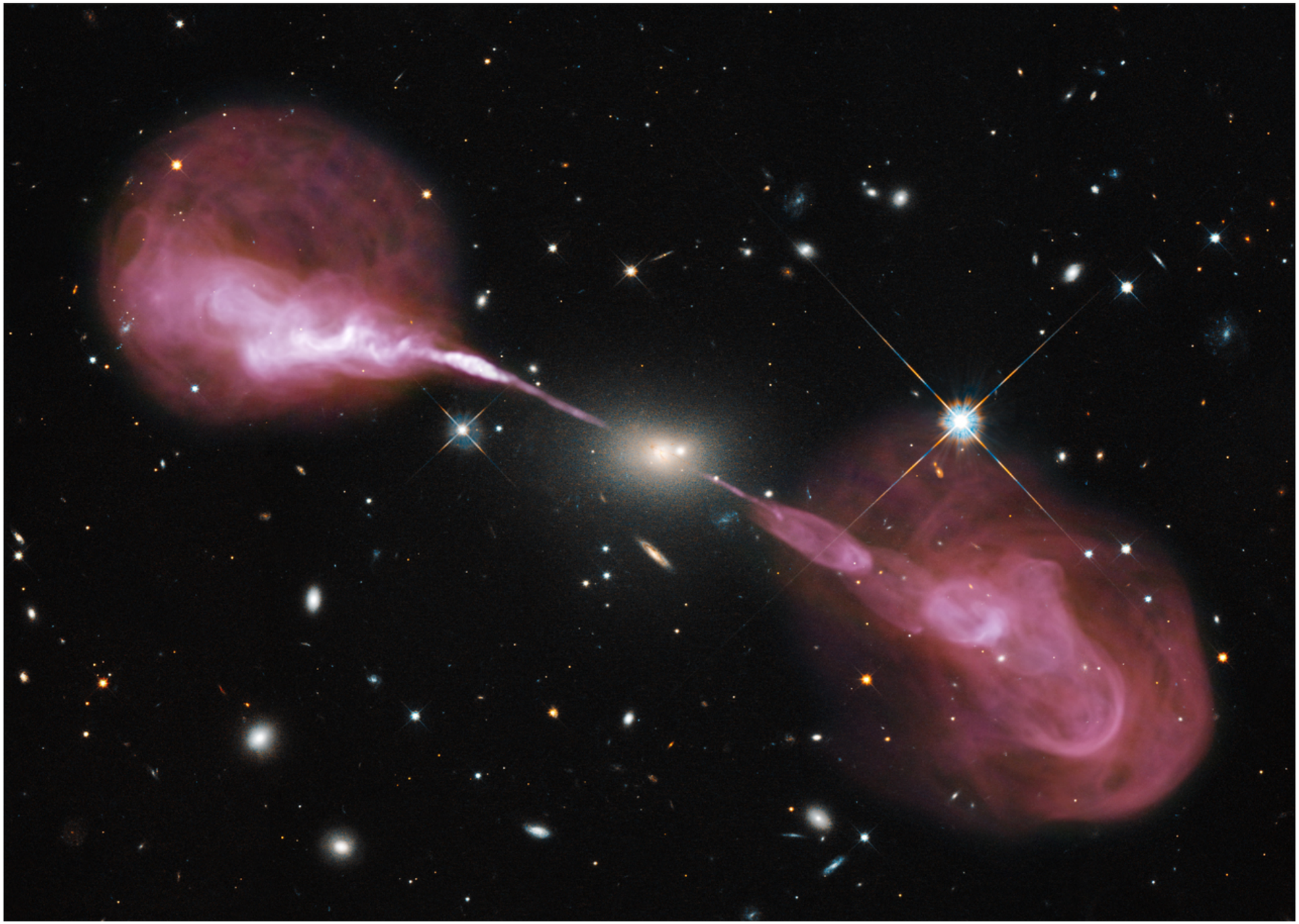
# Cosmic Microwave Background (2.7 K)




DO NOT STEP
DO NOT STEP
DO NOT STEP
DO NOT STEP
DO NOT STEP
DO NOT STEP

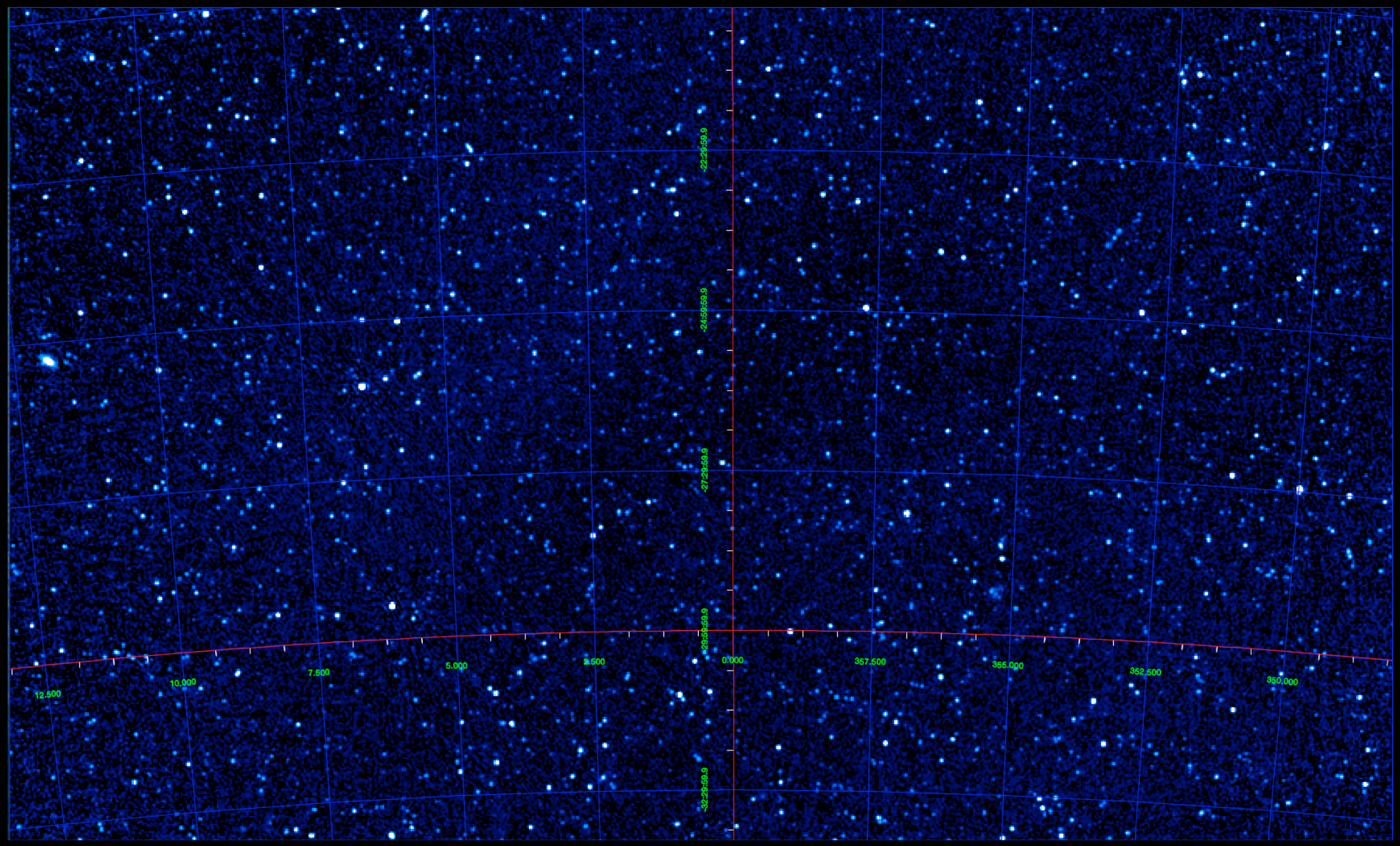



# Radio galaxy

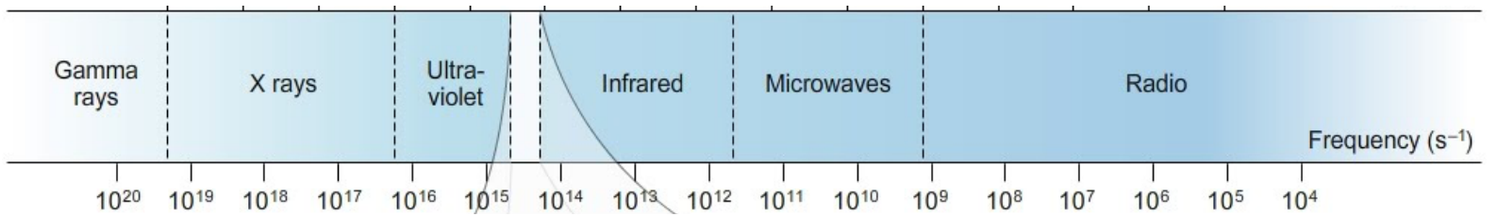


# VLA

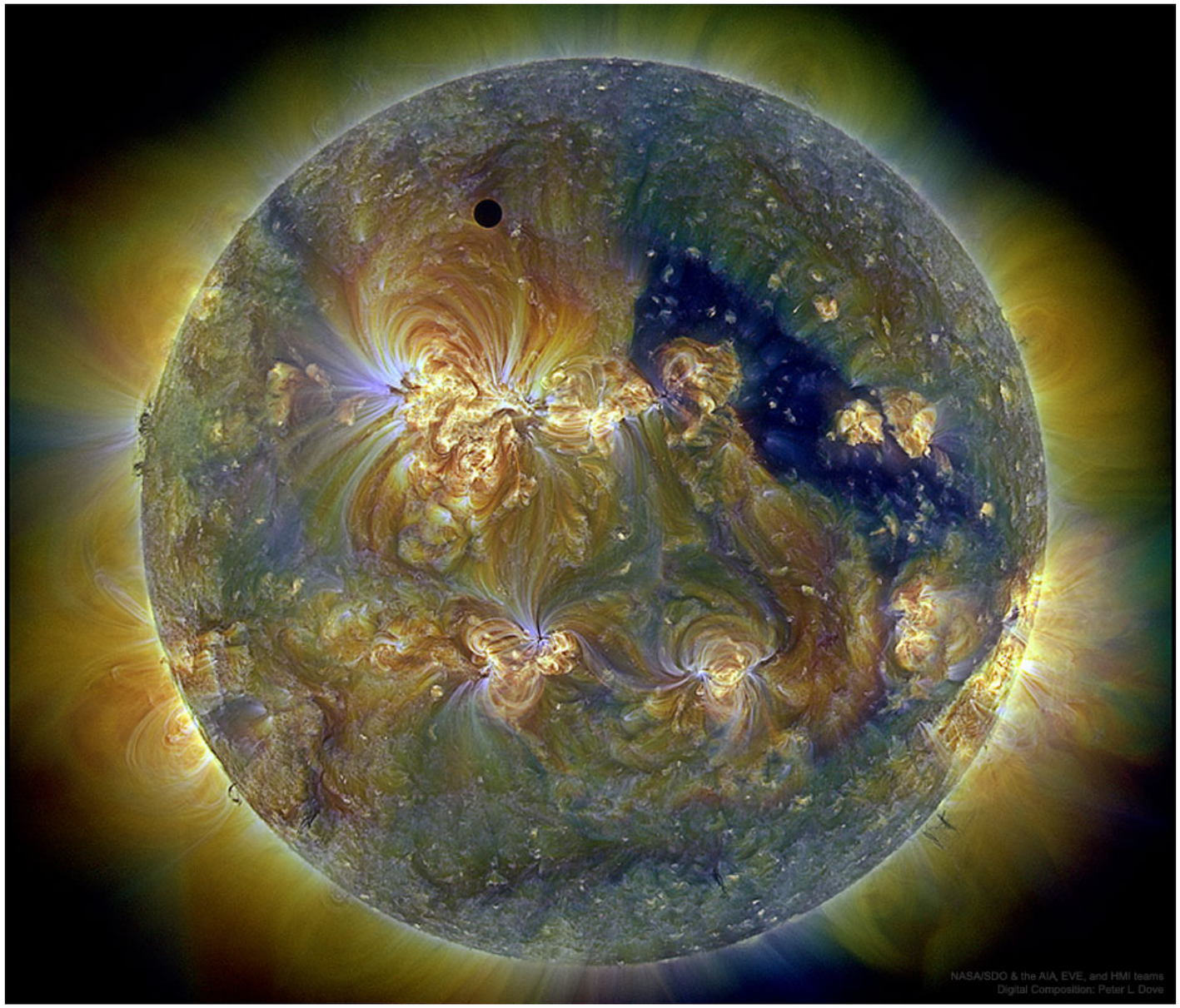
Moon to scale 

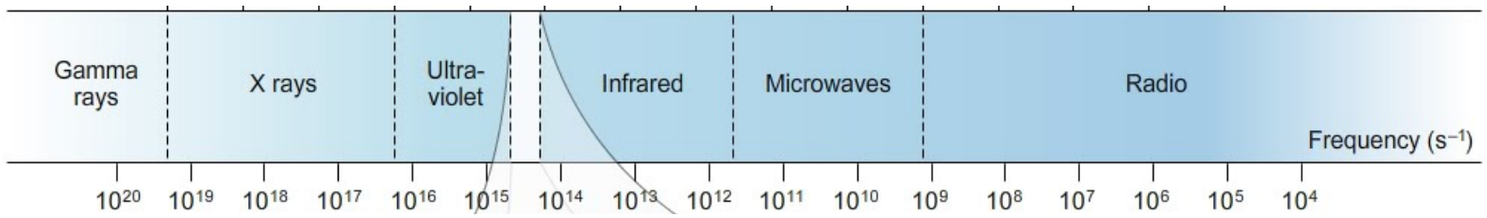



2 minutes of data, dark field, signal dominated




# Ultra-violet sun (hot)




Gamma rays
X rays
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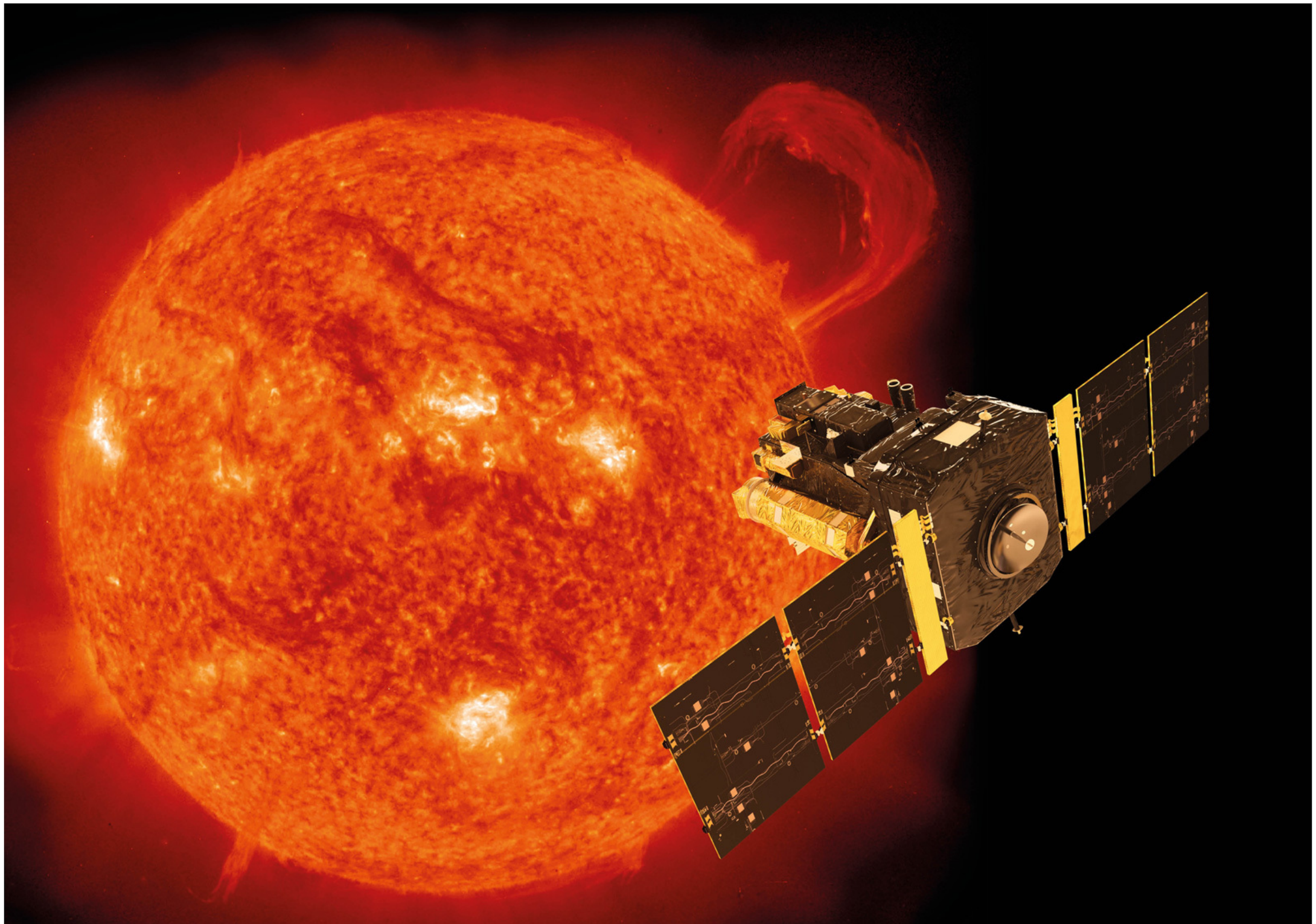
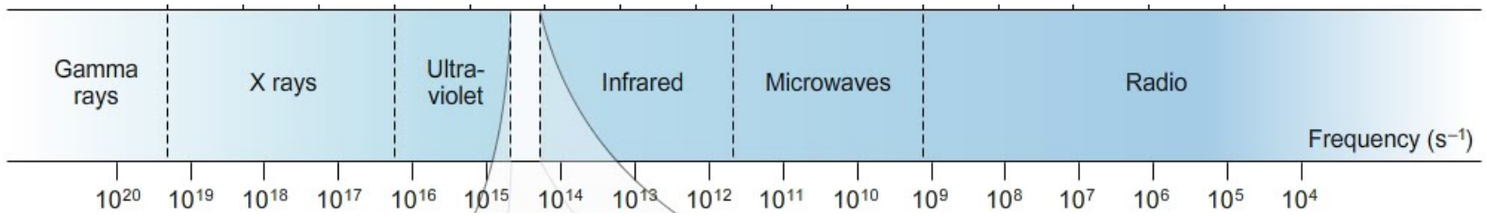
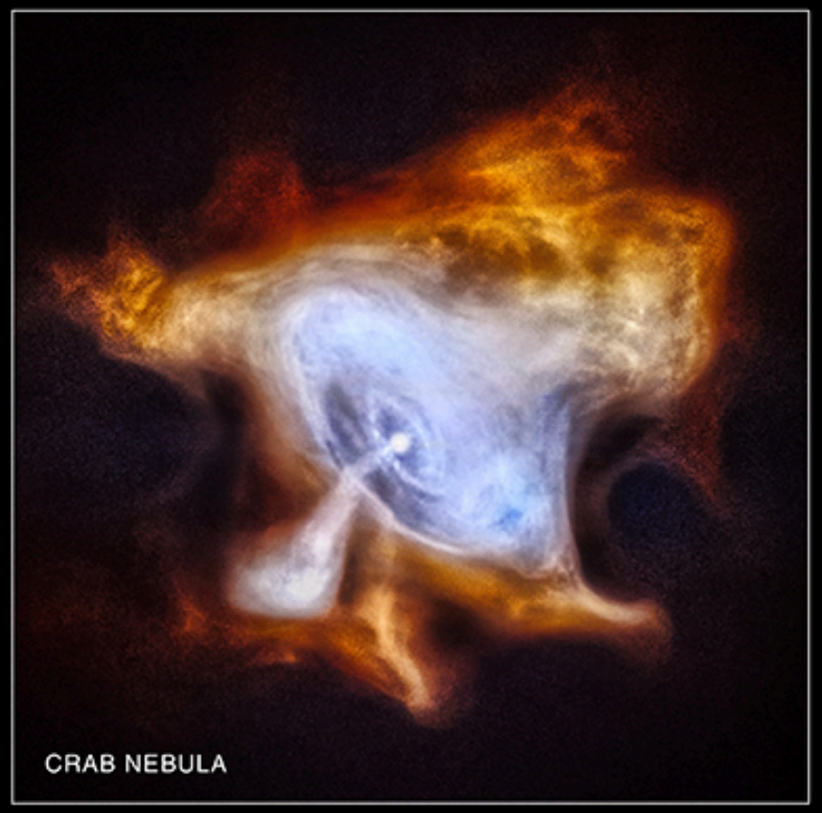
Infrared
Microwaves
Radio
Frequency (s⁻¹)
10^20 10^19 10^18 10^17 10^16 10^15 10^14 10^13 10^12 10^11 10^10 10^9 10^8 10^7 10^6 10^5 10^4

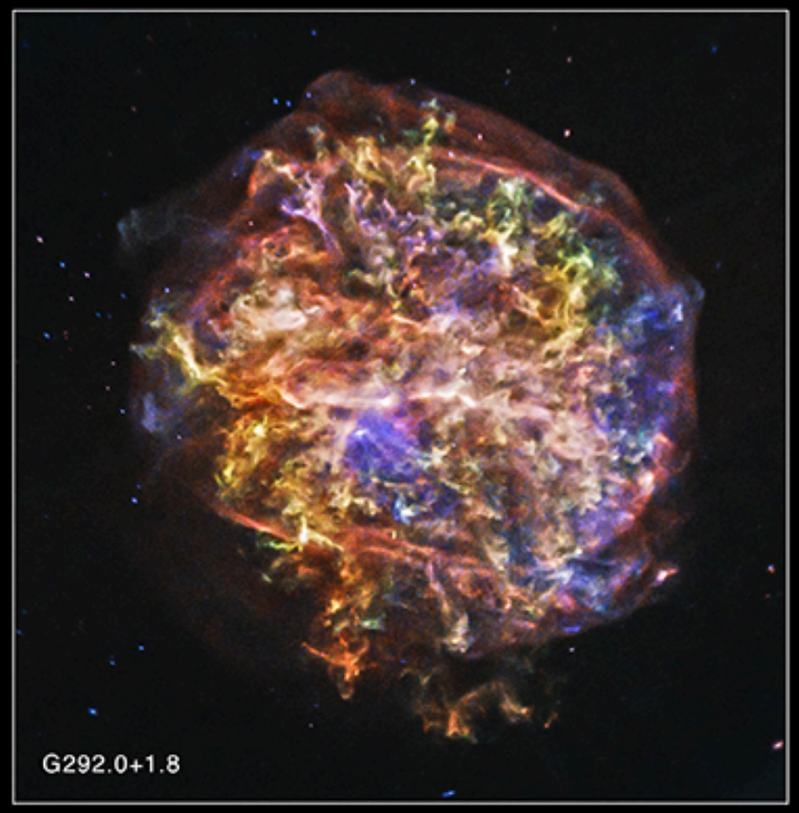
# SOHO

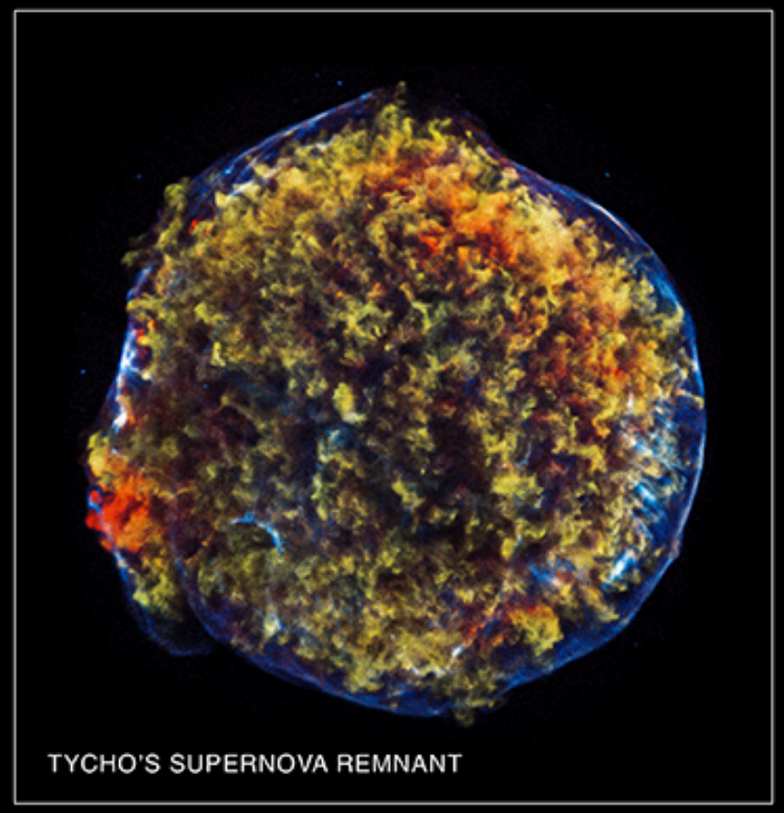


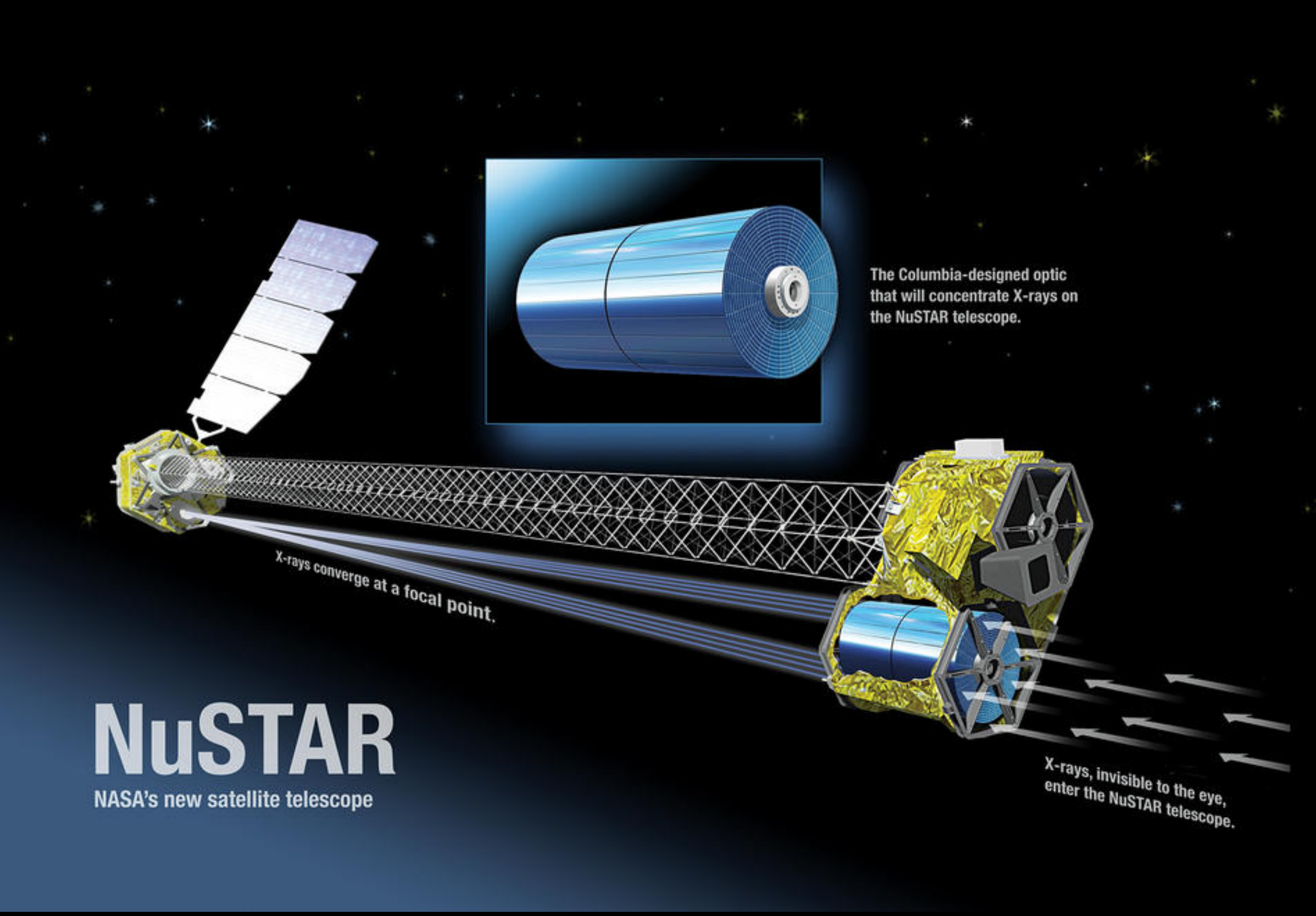
# X-rays (very hot)



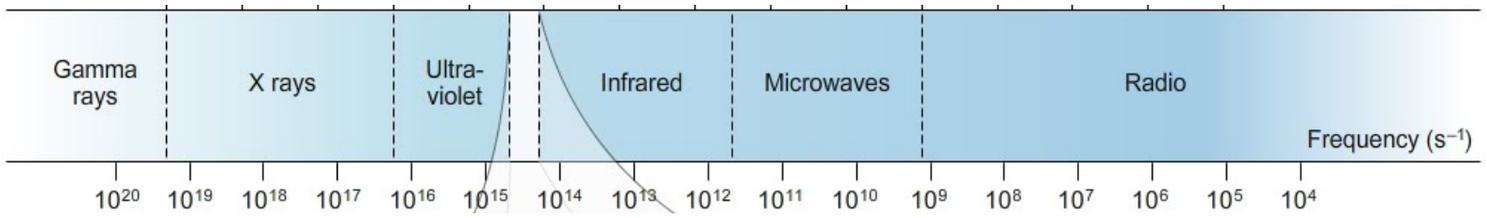



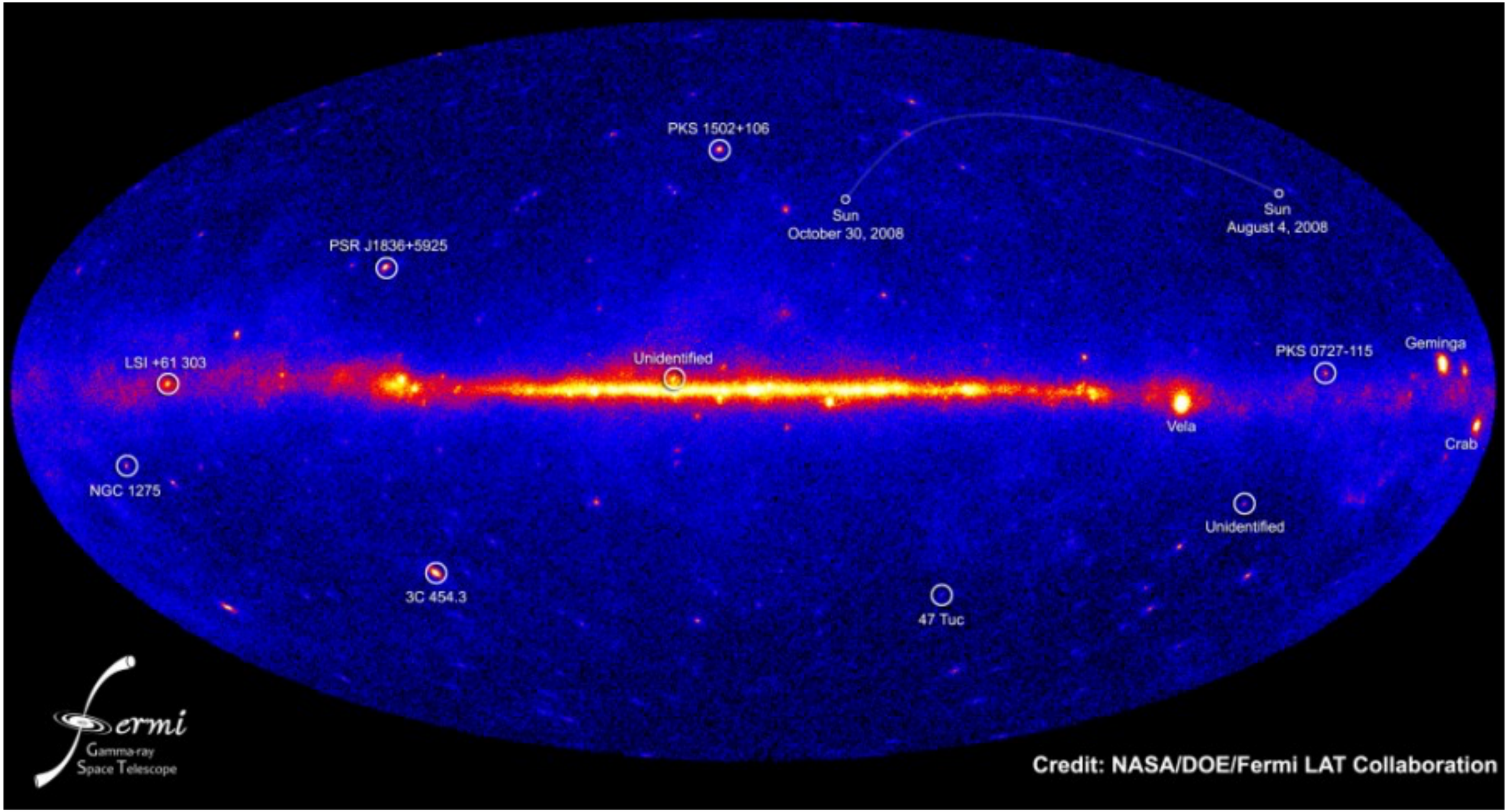




# NuSTAR

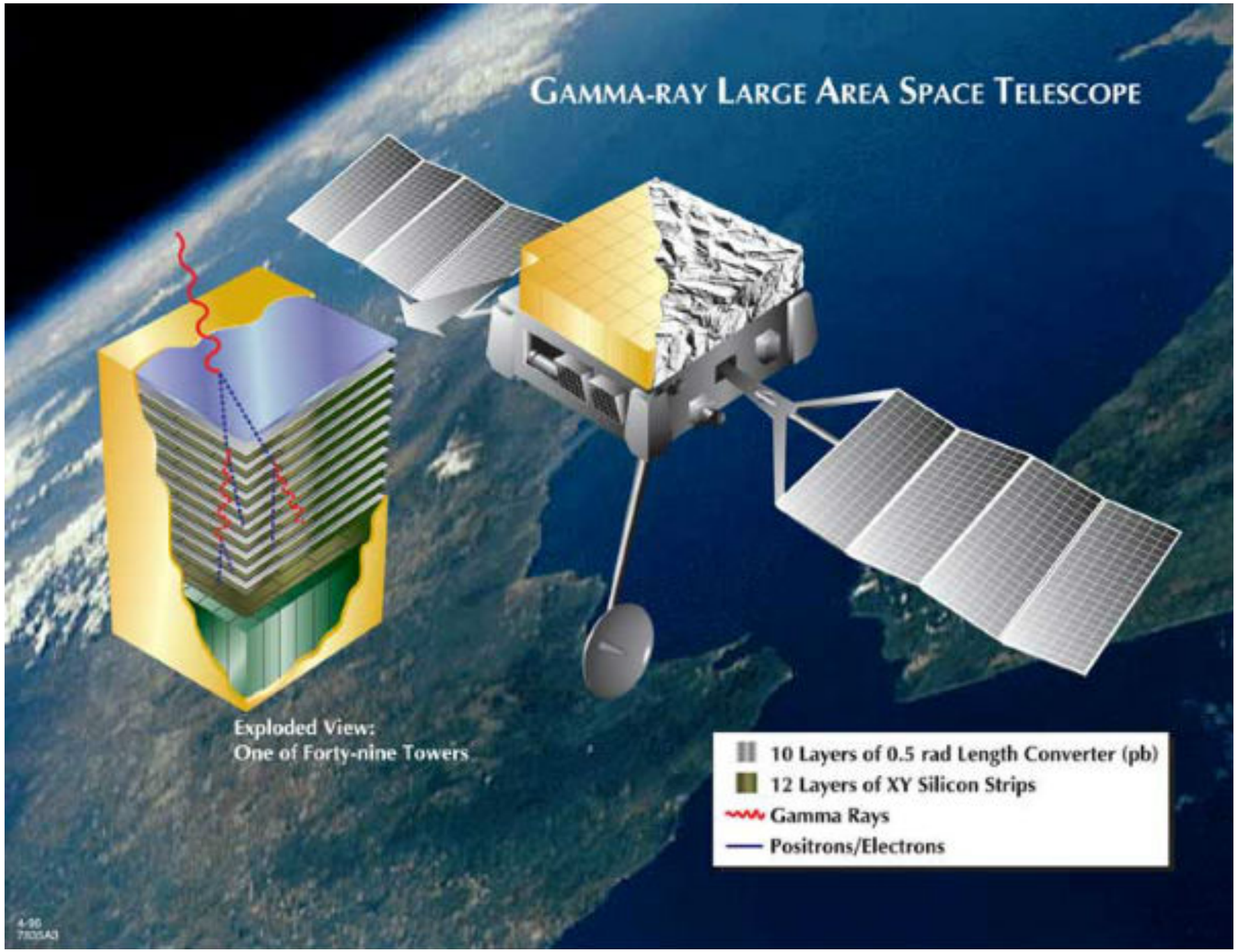
NASA's new satellite telescope

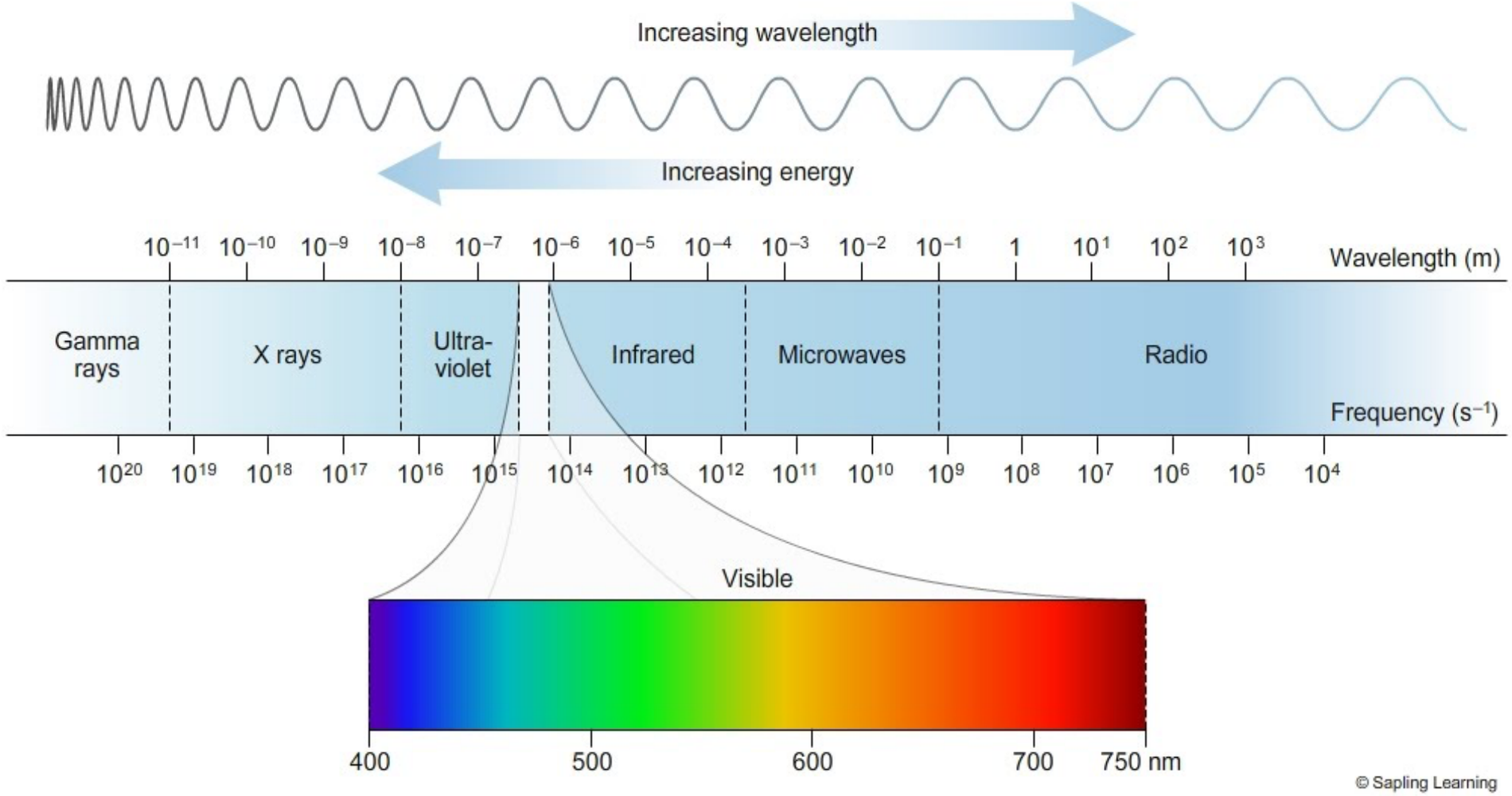



# gamma-ray sky



# Fermi telescope

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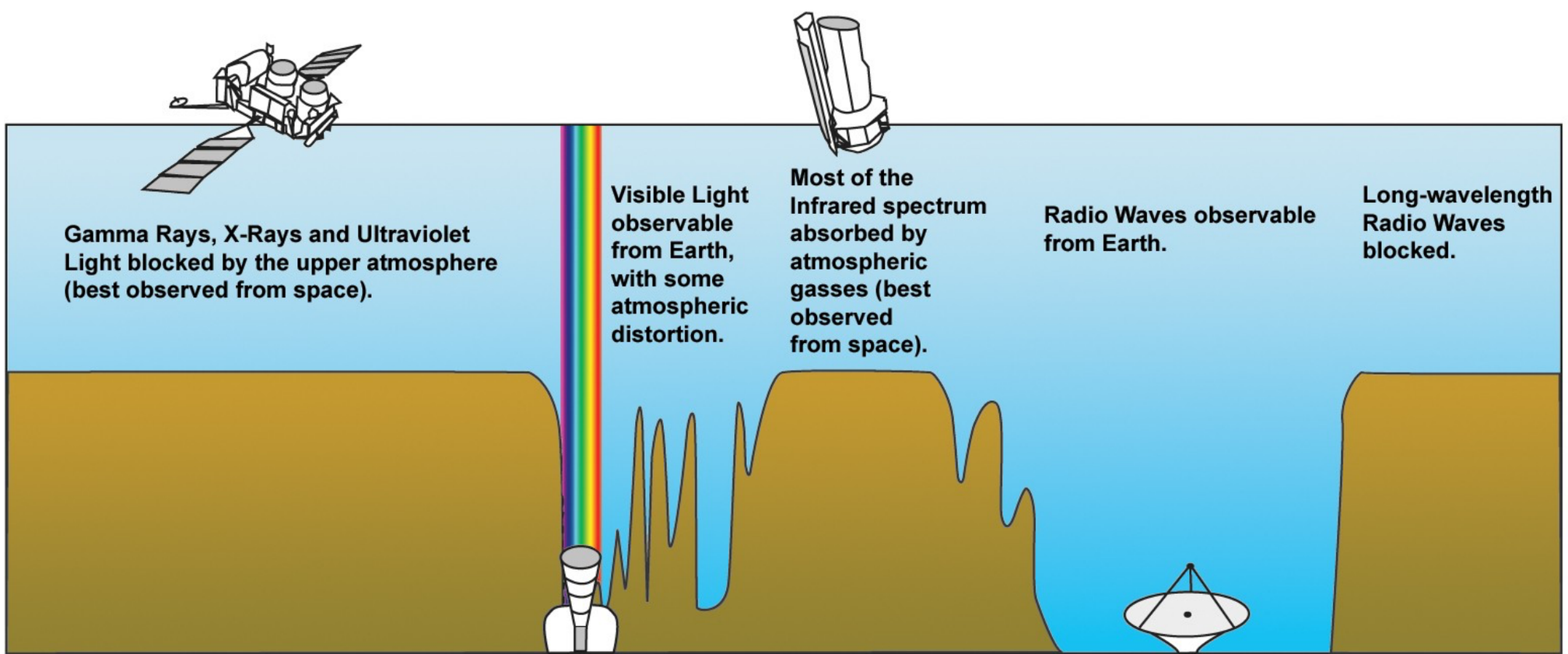
© Sapling Learning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Radio Waves observable from Earth.
Long-wavelength Radio Waves blocked.