“Are We Alone in the Universe?”

Essentially a Mathematical Question

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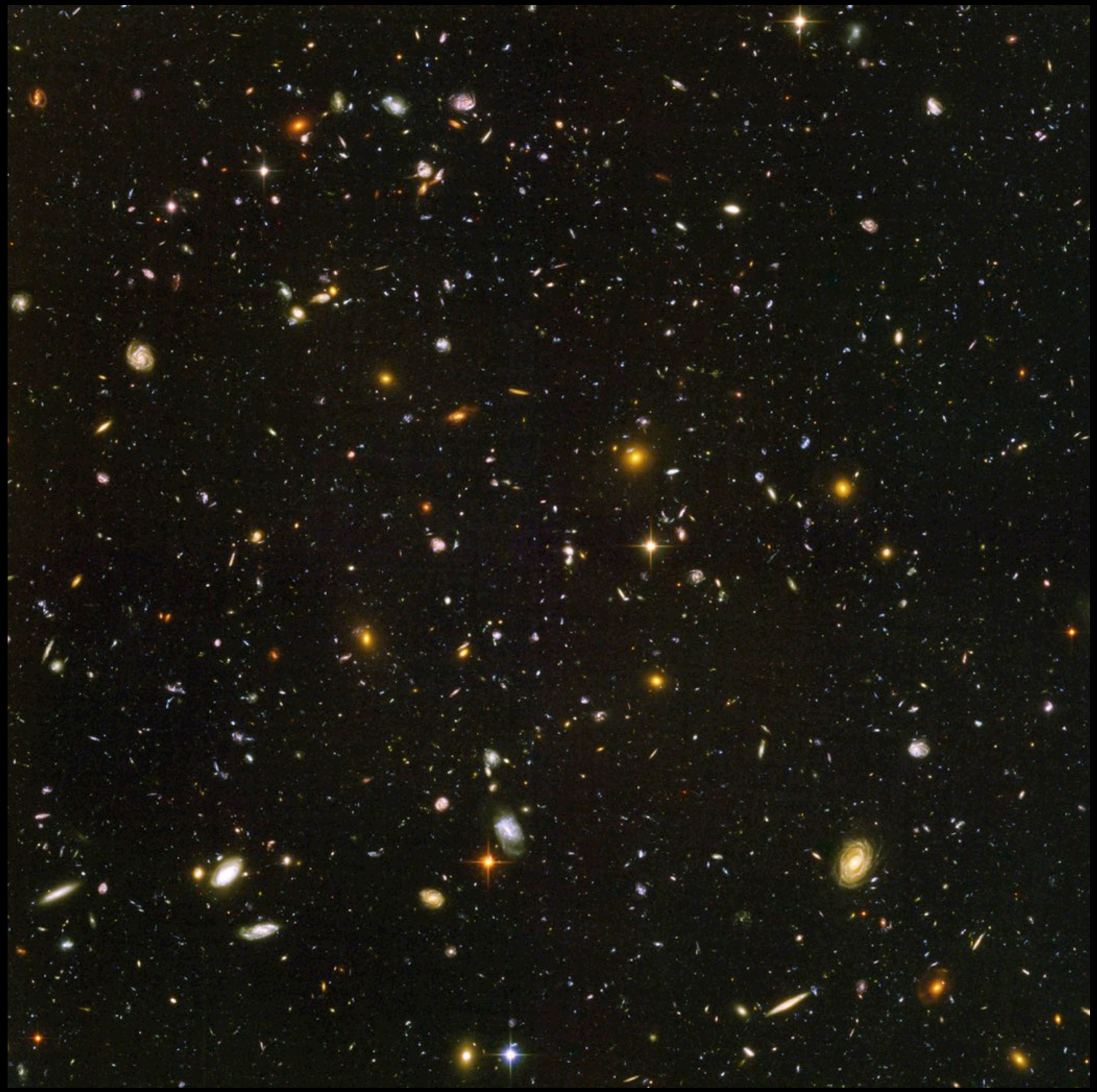
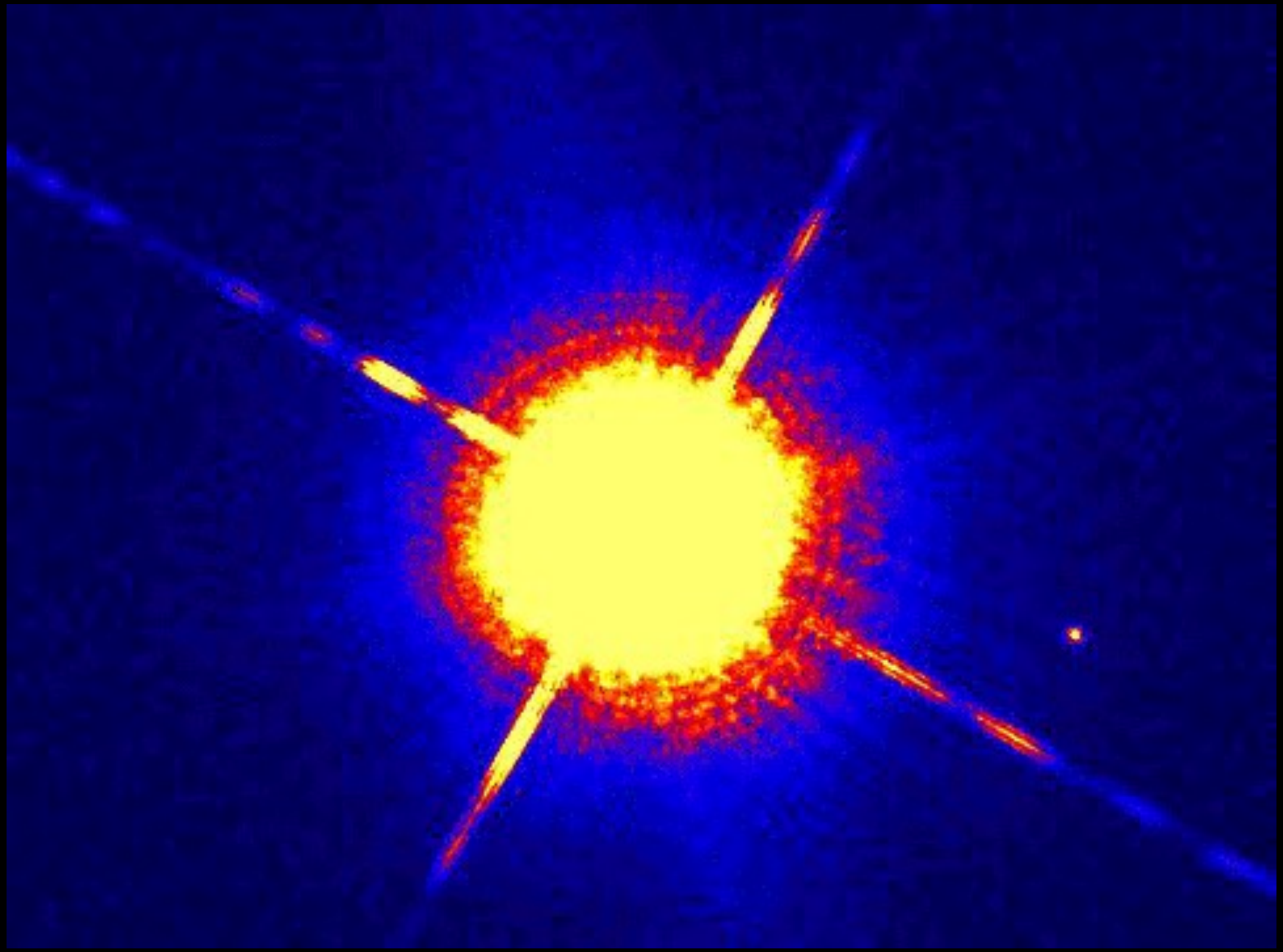
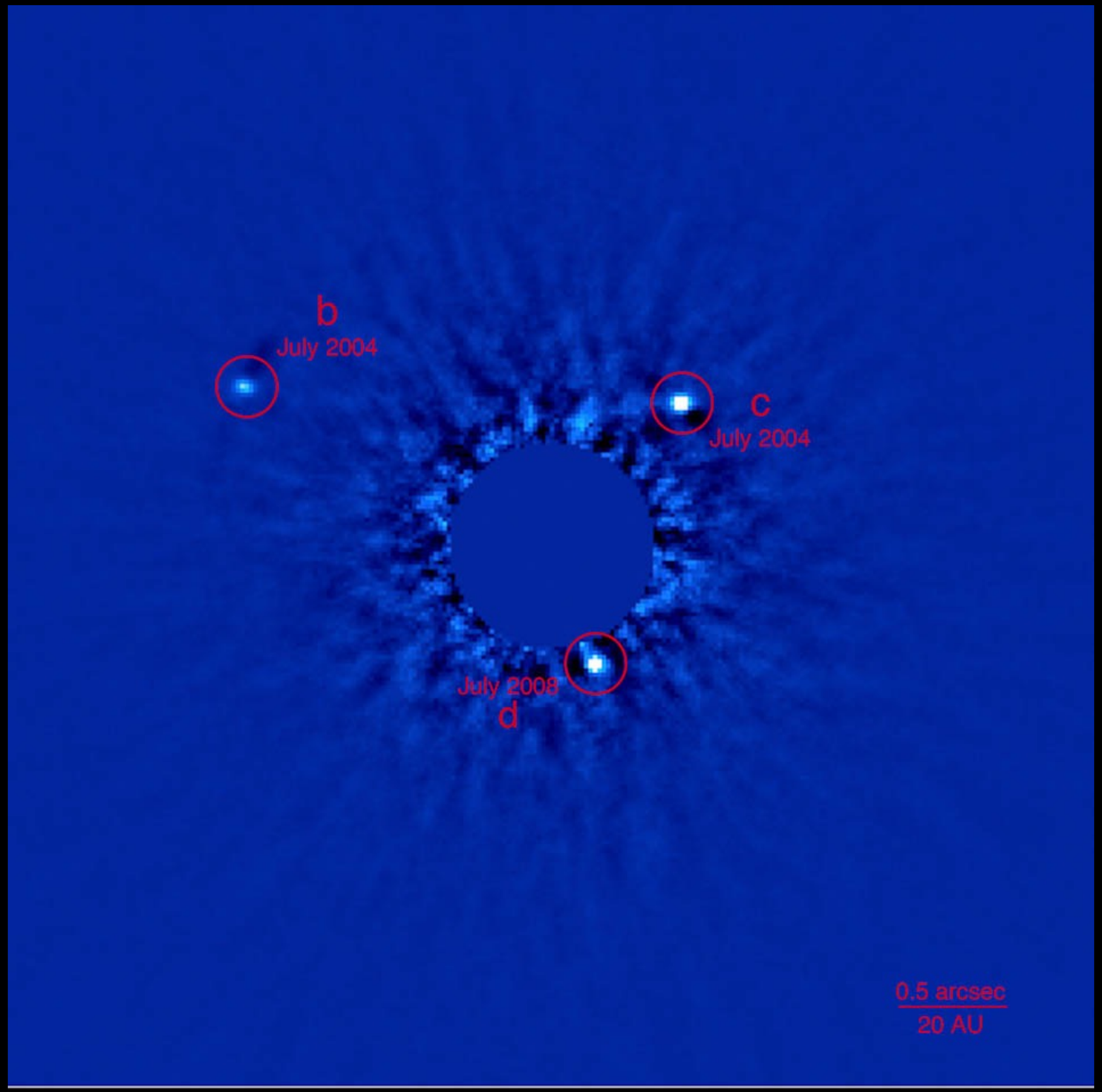
Jet Propulsion Laboratory
California Institute of Technology

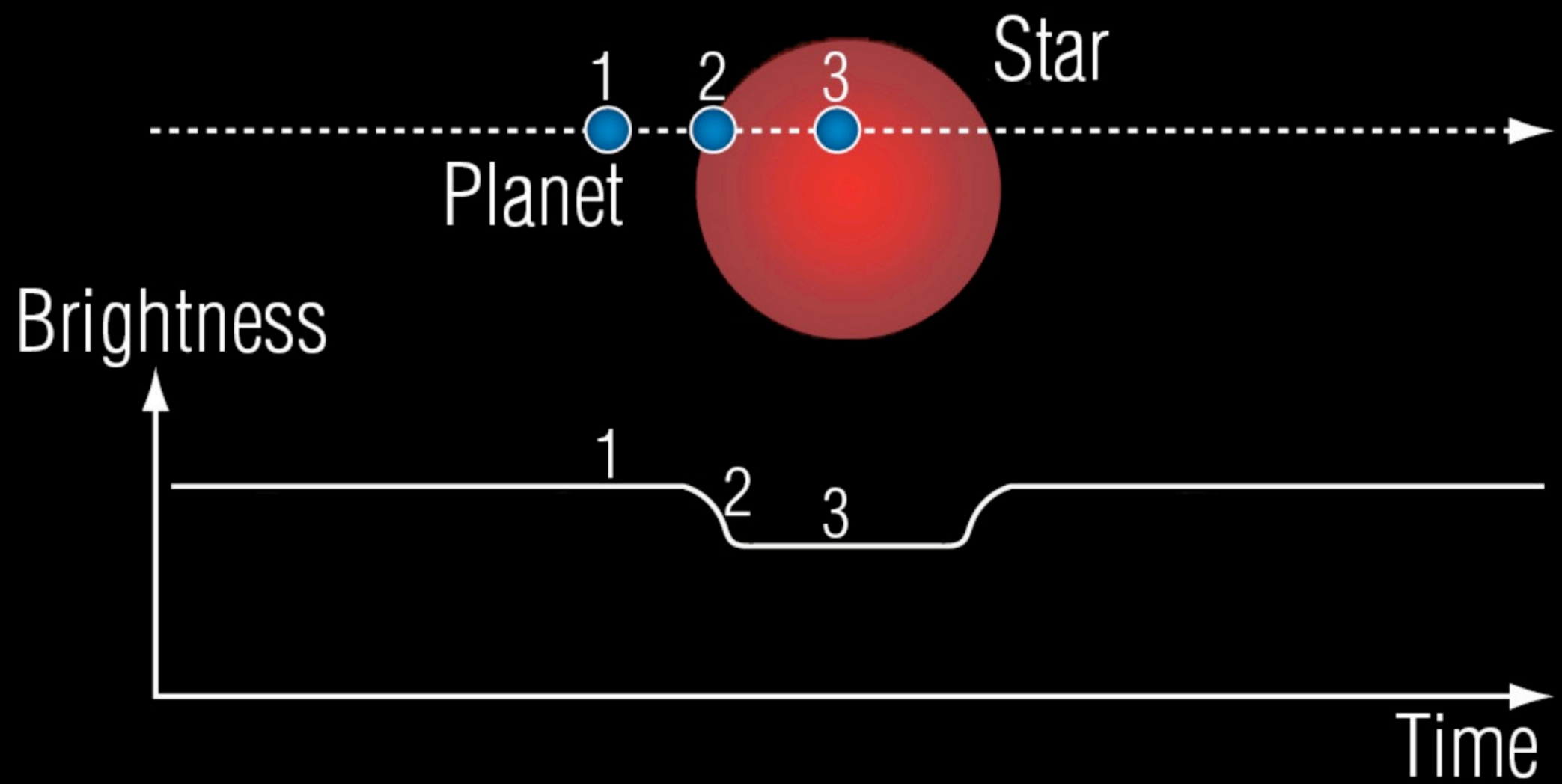






Gemini Observatory / NRC / AURA / Christian Marois, et al.

Gemini Observatory Legacy Image

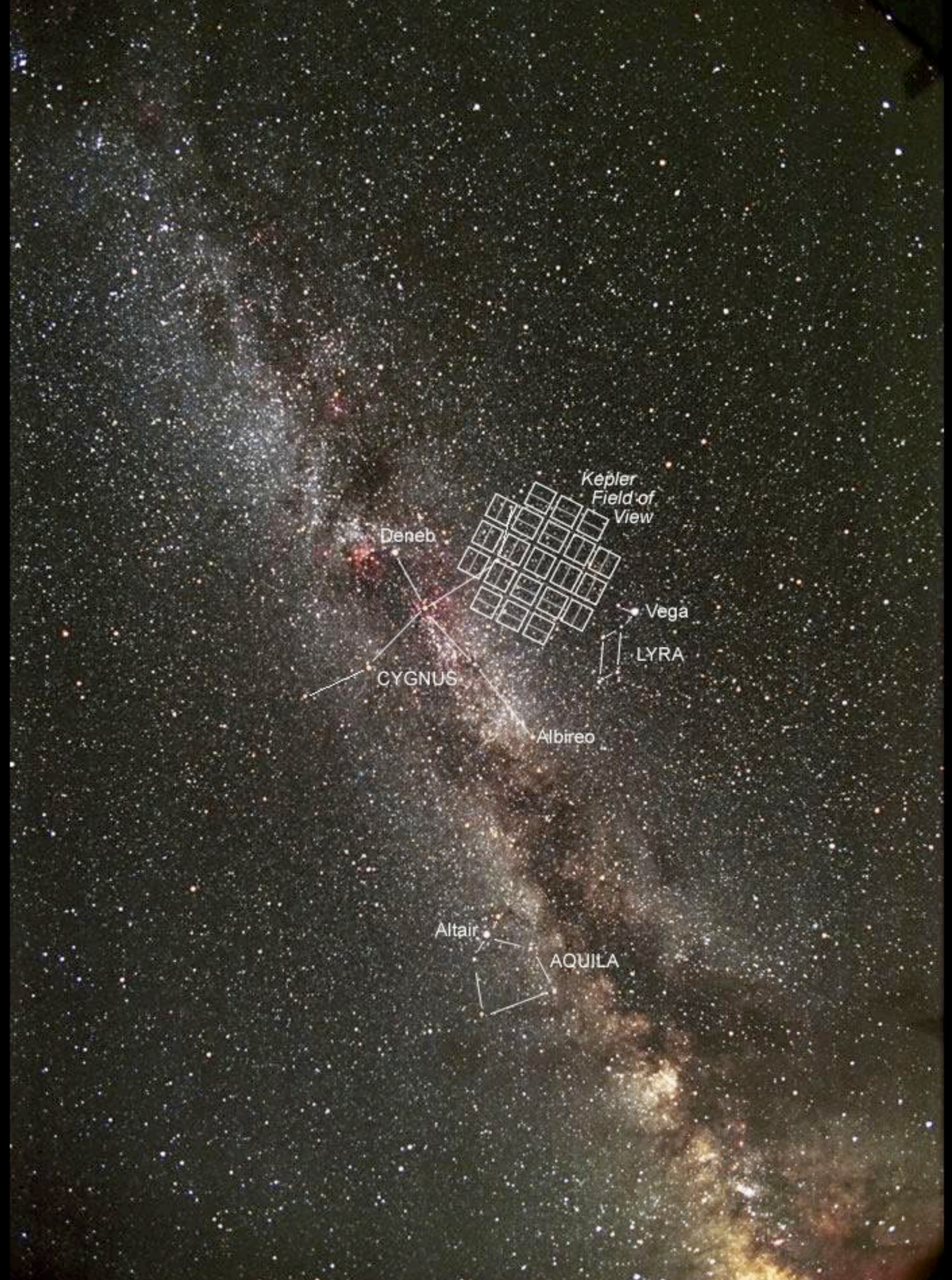

Star
1
2
3
Planet
Brightness
1
2
3
Time

Transit

$$B = \frac{\pi R_{star}^2 - \pi R_{planet}^2}{\pi R_{star}^2} = 1 - \left(\frac{R_{planet}}{R_{star}} \right)^2$$

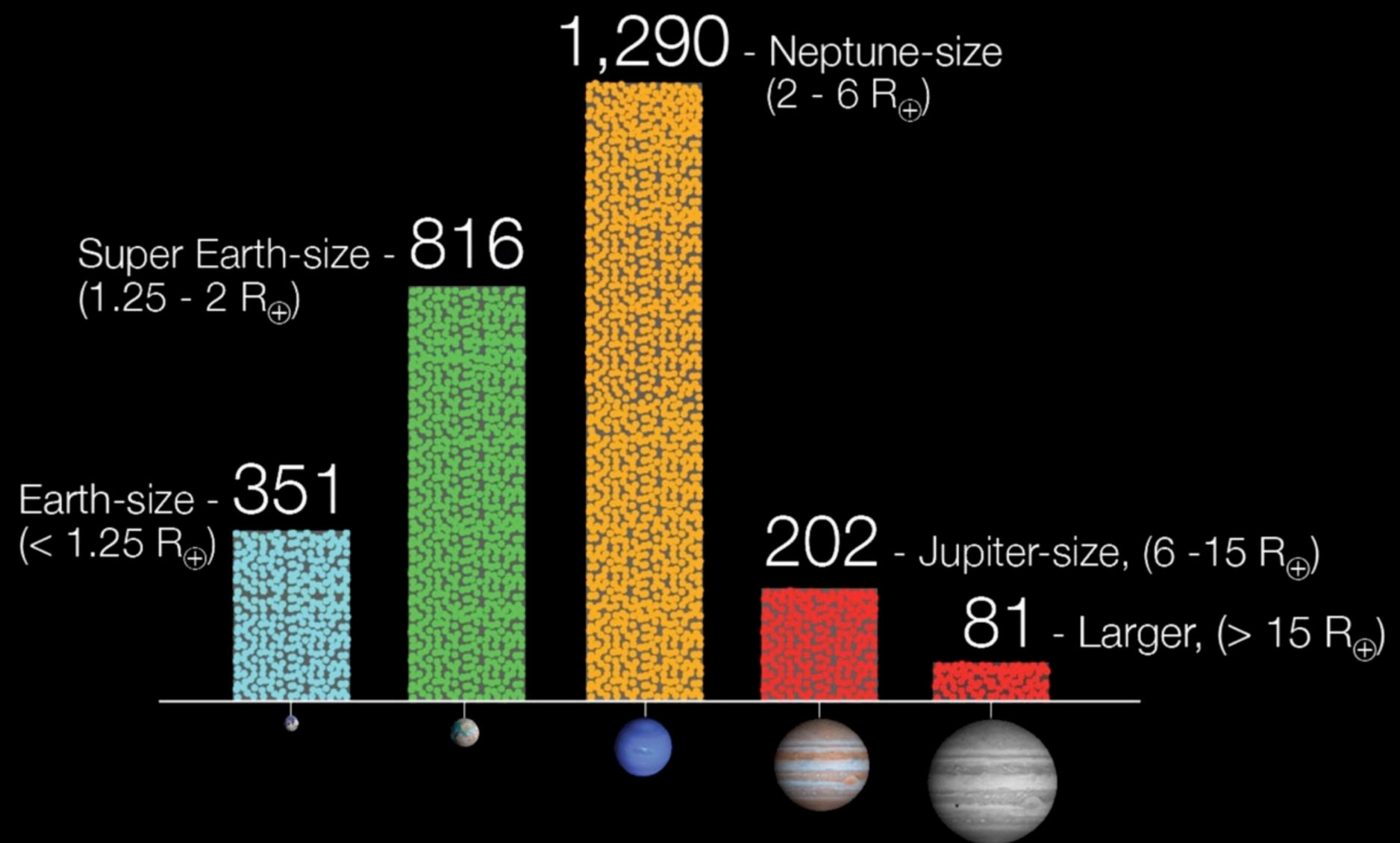
$$\Delta = \left(\frac{R_{Earth}}{R_{Sun}} \right)^2 = \left(\frac{6.37 \times 10^3 \, km}{6.96 \times 10^5 \, km} \right)^2 = 8.38 \times 10^{-5}$$

$$\Delta = \left(\frac{R_{Jupiter}}{R_{Sun}} \right)^2 = \left(\frac{6.99 \times 10^4 \, km}{6.96 \times 10^5 \, km} \right)^2 = 1.01 \times 10^{-2}$$

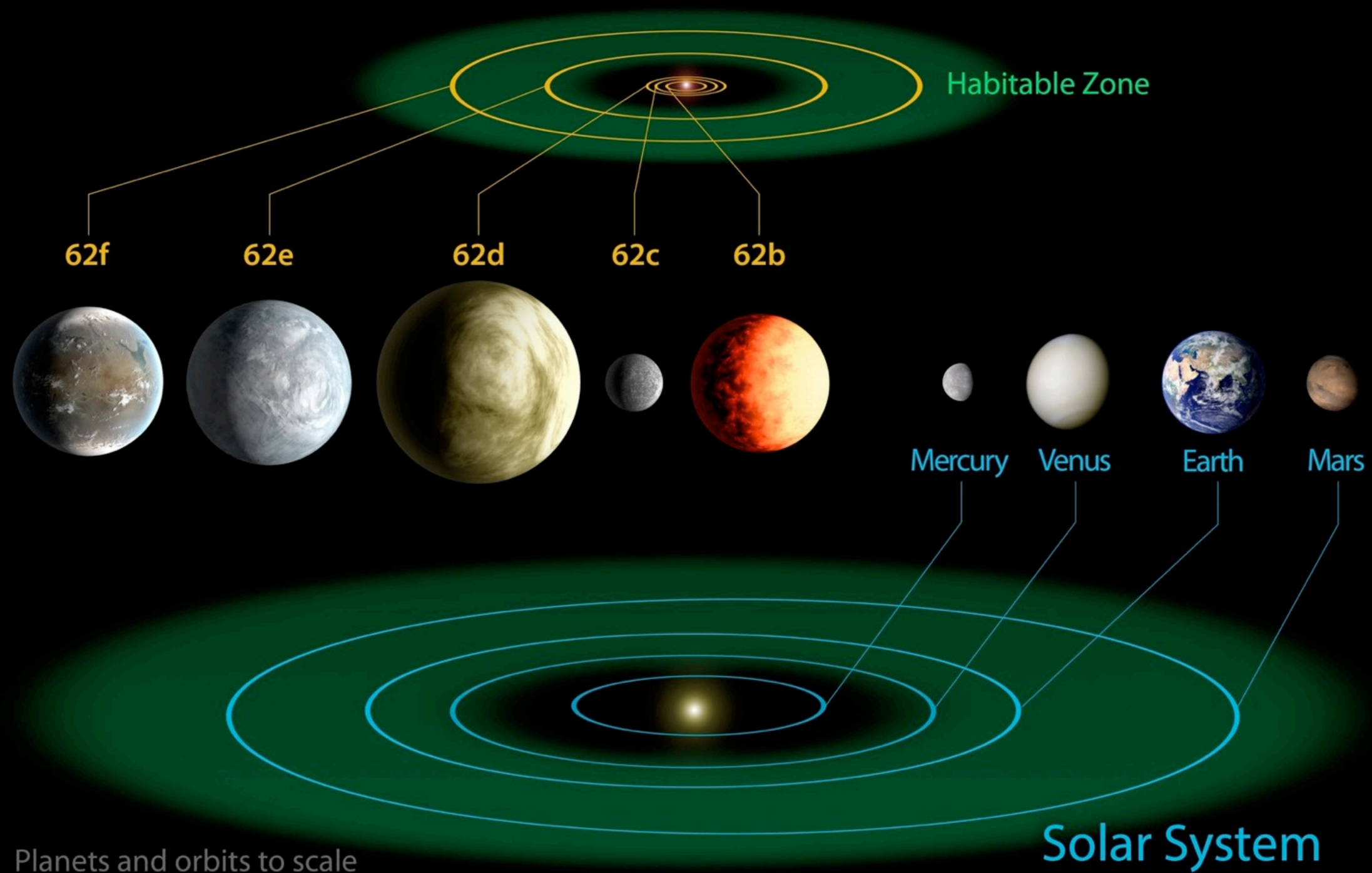

Kepler
Field of
View
Deneb
Vega
LYRA
CYGNUS
Albireo
Altair
AQUILA

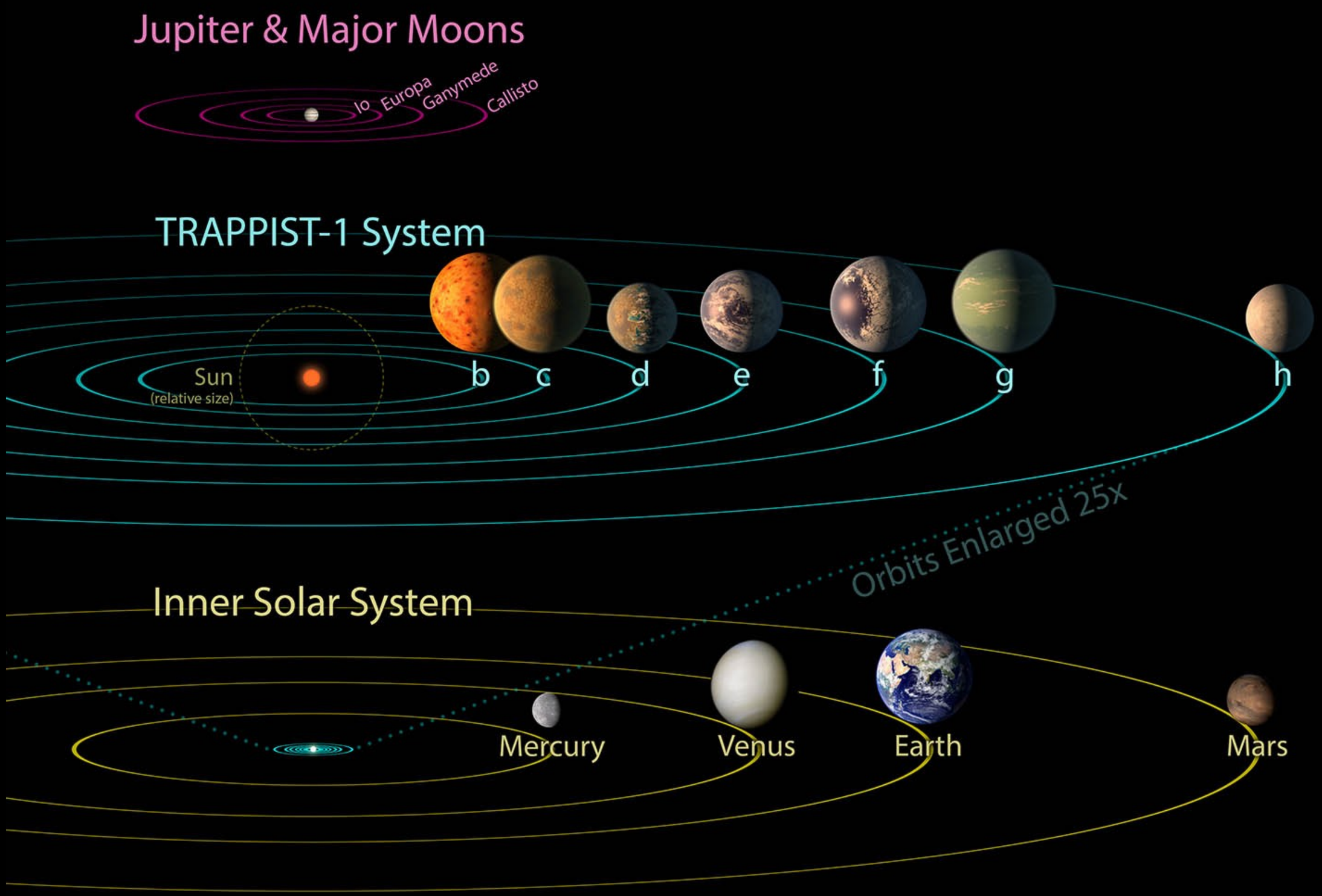
Sizes of Planet Candidates

As of January 7, 2013



Kepler-62 System




Jupiter & Major Moons
Io
Europa
Ganymede
Callisto
TRAPPIST-1 System
Sun
(relative size)
b
c
d
e
f
g
h
Orbits Enlarged 25x
Inner Solar System
Mercury
Venus
Earth
Mars

Habitable Zone

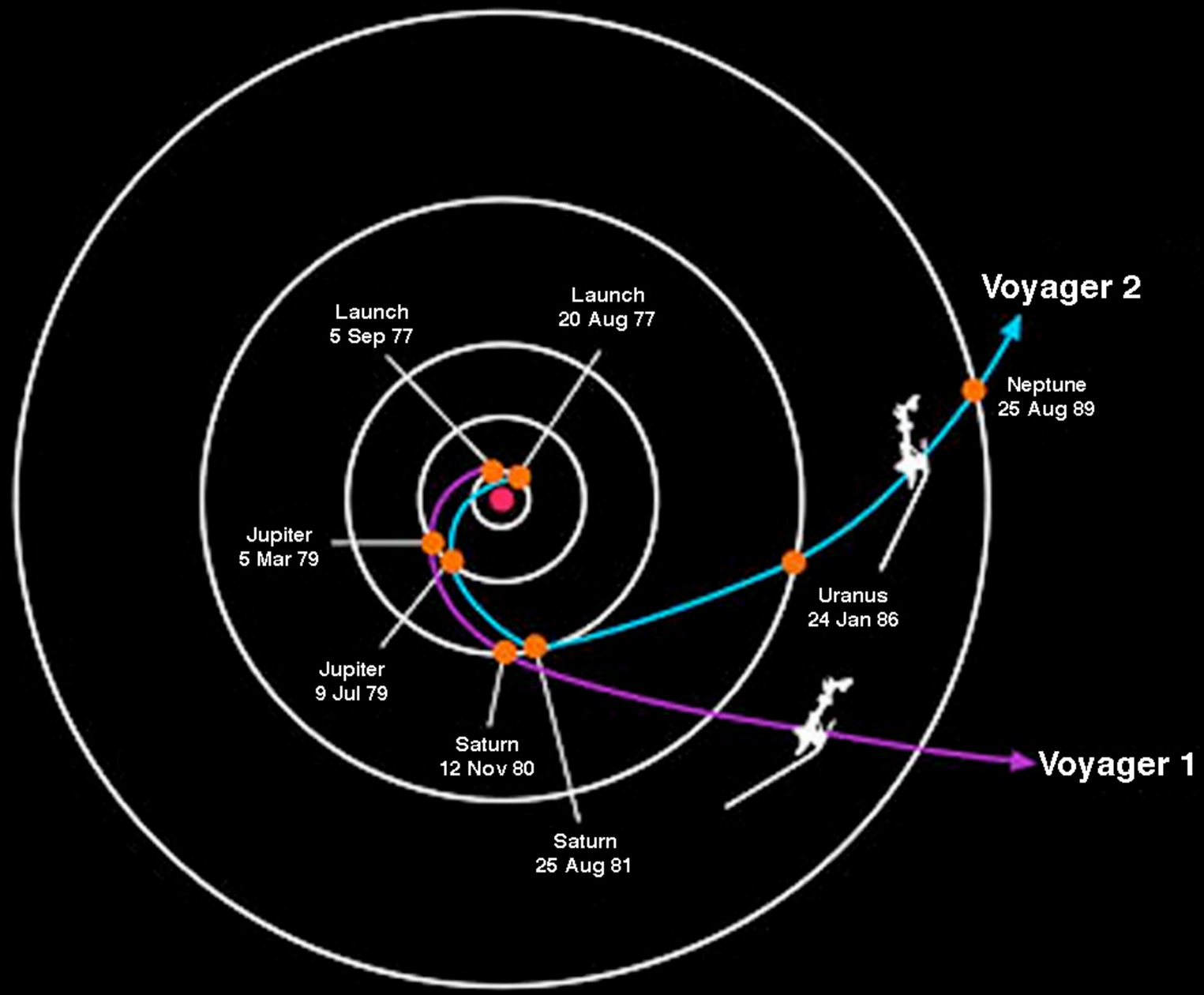
For a planet in equilibrium:

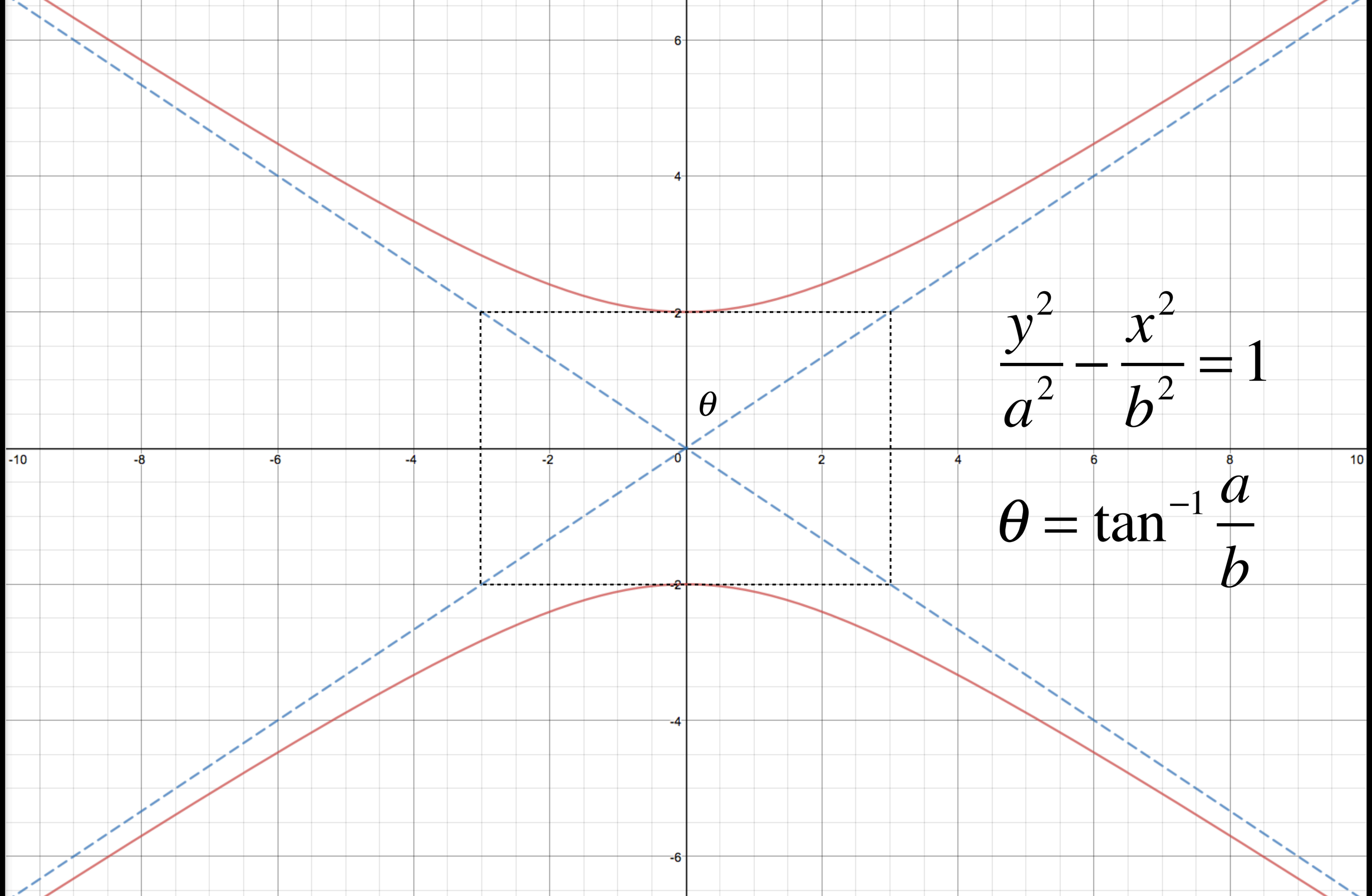
$$P_{absorbed} = P_{emitted}$$

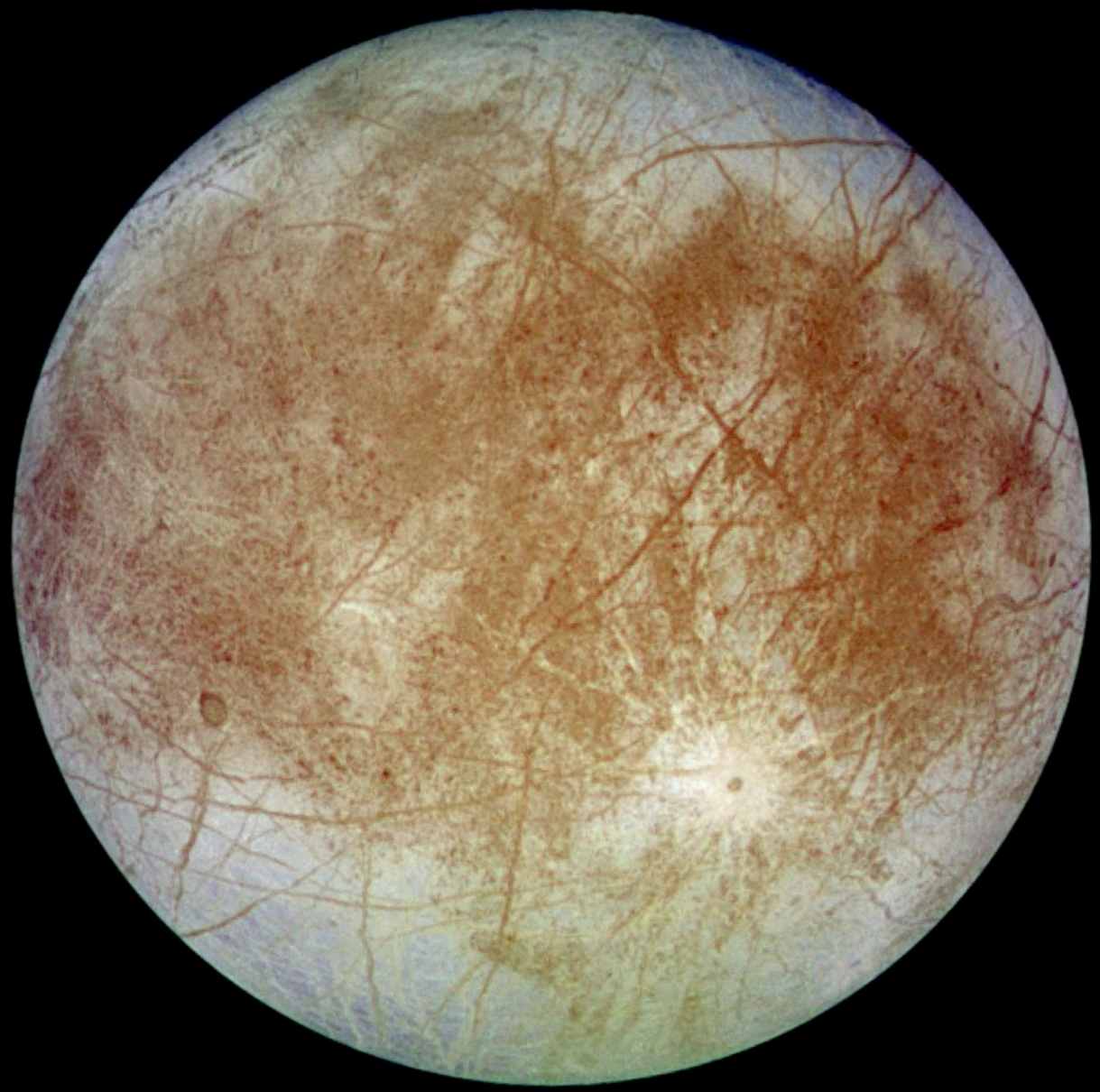
$$P_{absorbed} = \frac{P_{star}}{4\pi R^2}(1-a)\pi r^2$$

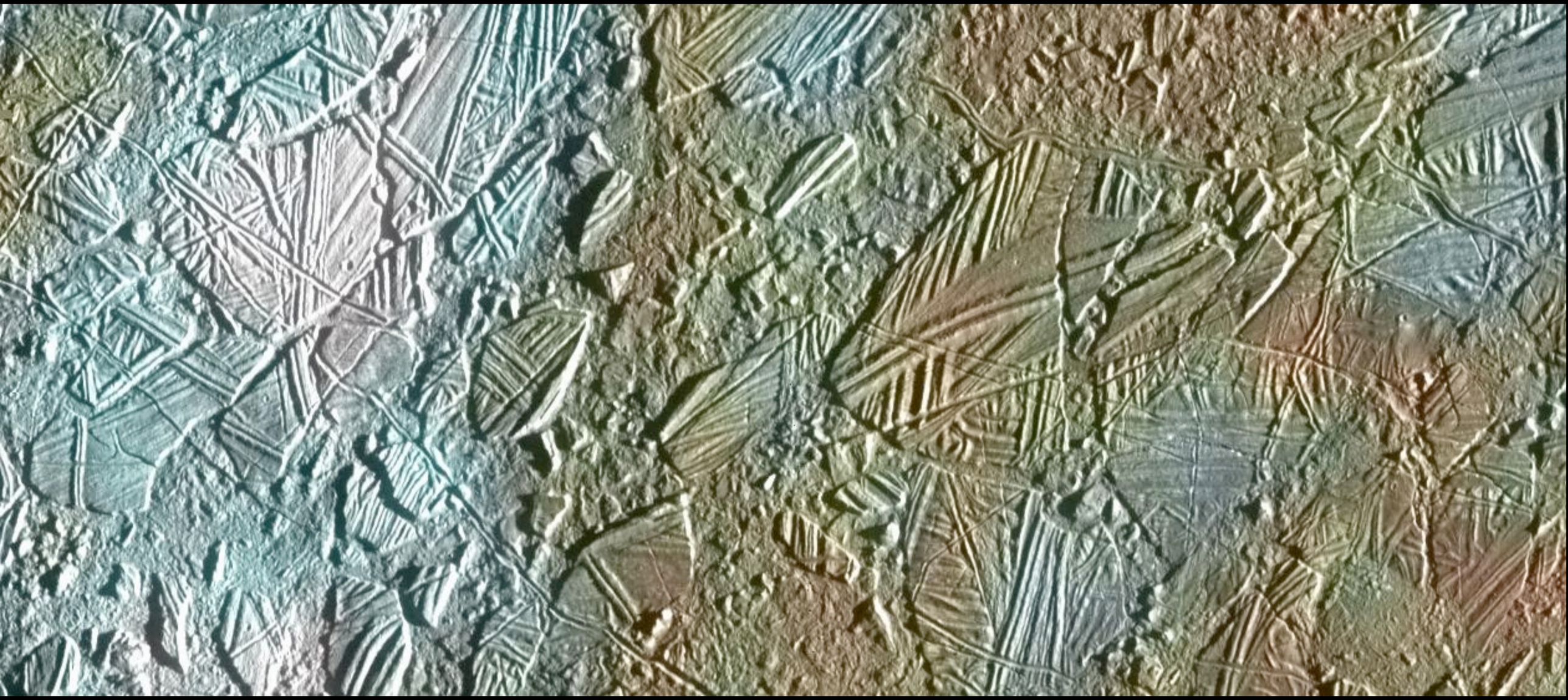
$$P_{emitted} = \varepsilon\sigma_{SB}T^4\left(4\pi r^2\right)$$

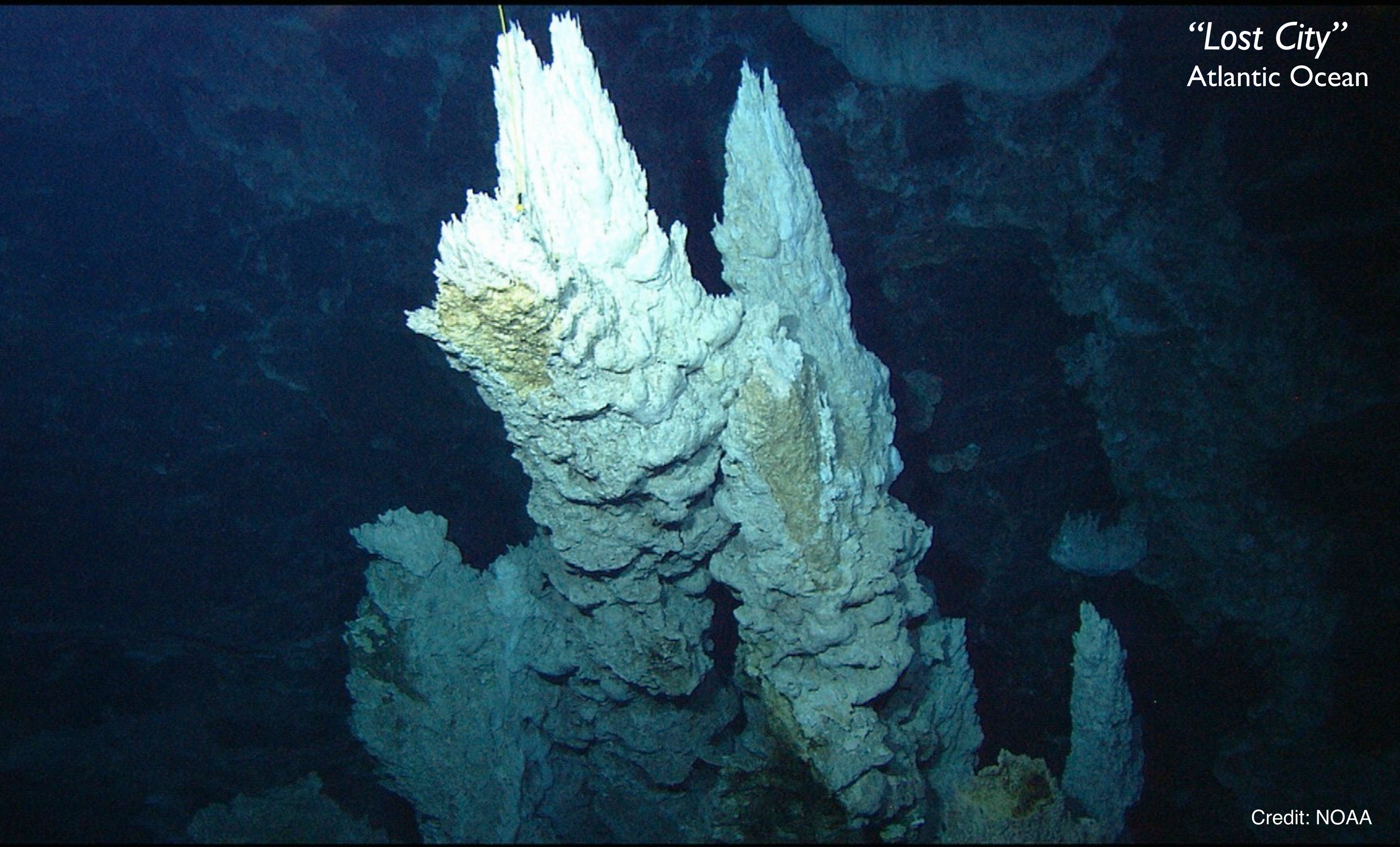
$$T = \left[\frac{1-a}{16\pi\varepsilon\sigma_{SB}}\frac{P_{star}}{R^2}\right]^{\frac{1}{4}}$$

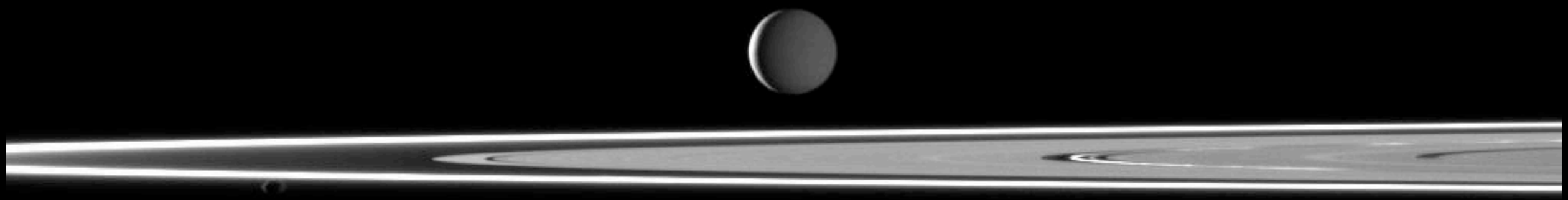

Voyager 2
Launch
5 Sep 77
Launch
20 Aug 77
Neptune
25 Aug 89
Jupiter
5 Mar 79
Uranus
24 Jan 86
Jupiter
9 Jul 79
Saturn
12 Nov 80
Voyager 1
Saturn
25 Aug 81

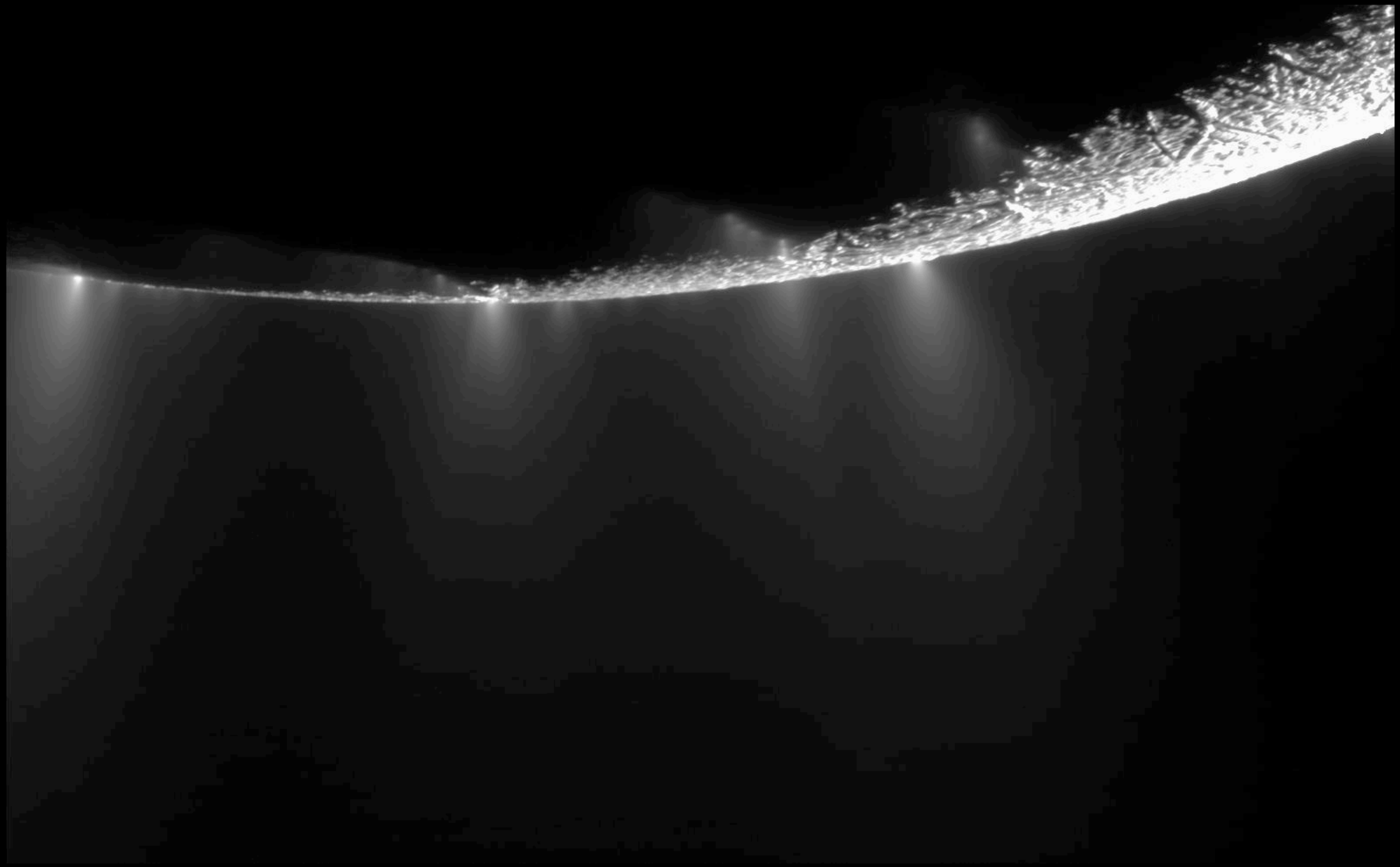

θ
$\frac{y^2}{a^2} - \frac{x^2}{b^2} = 1$
$\theta = \tan^{-1}\frac{a}{b}$

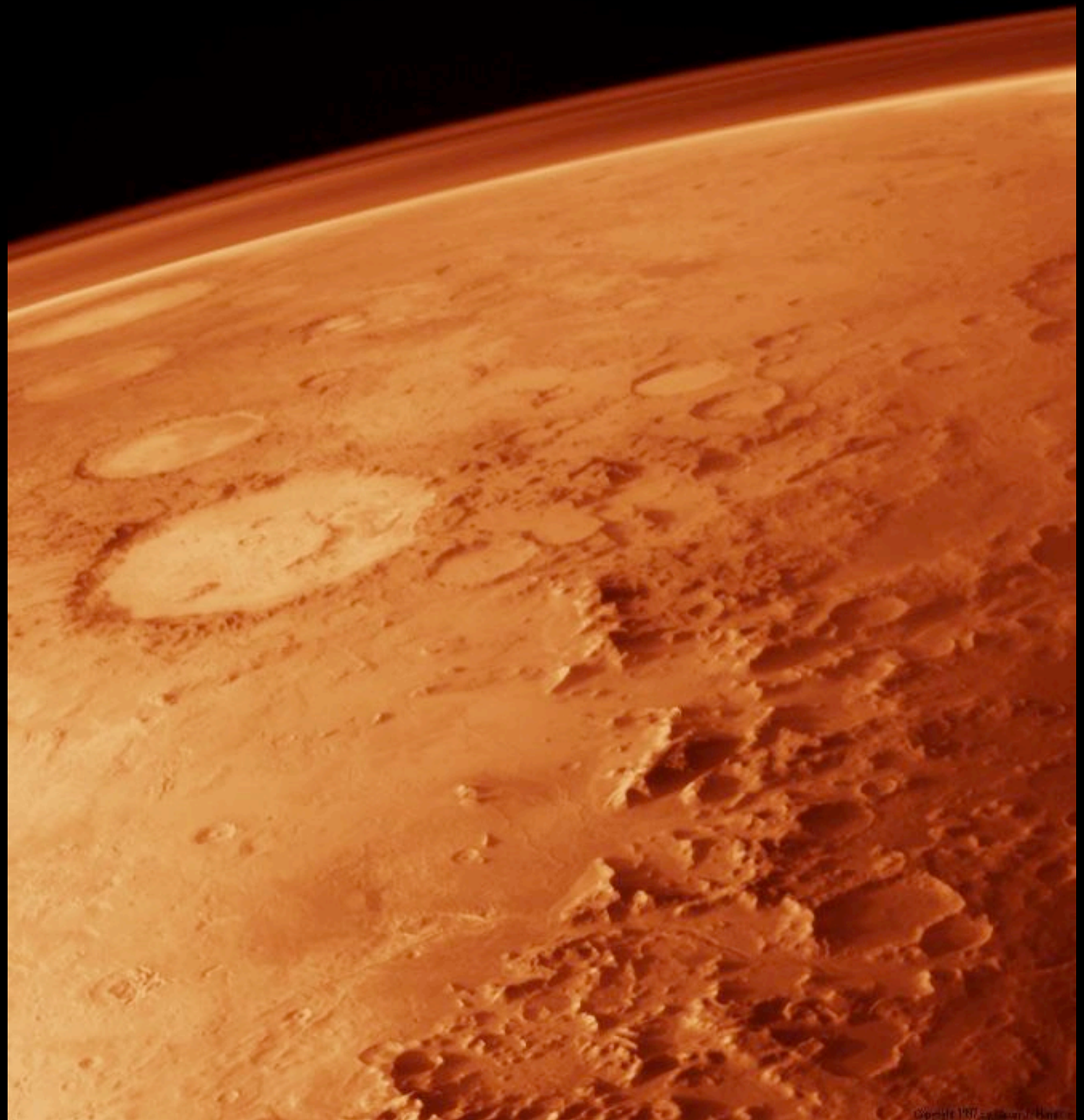


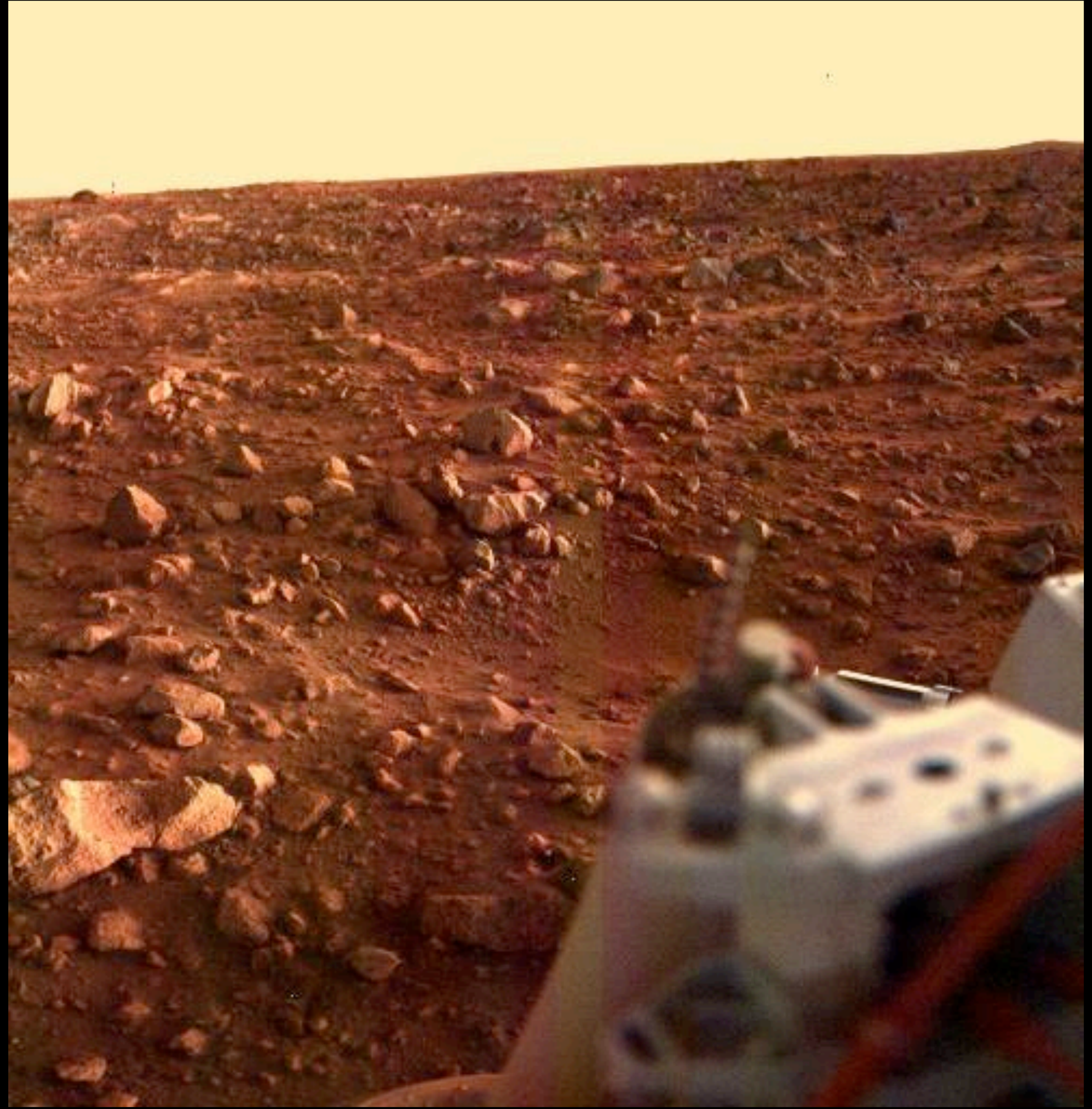



"Lost City"
Atlantic Ocean
Credit: NOAA









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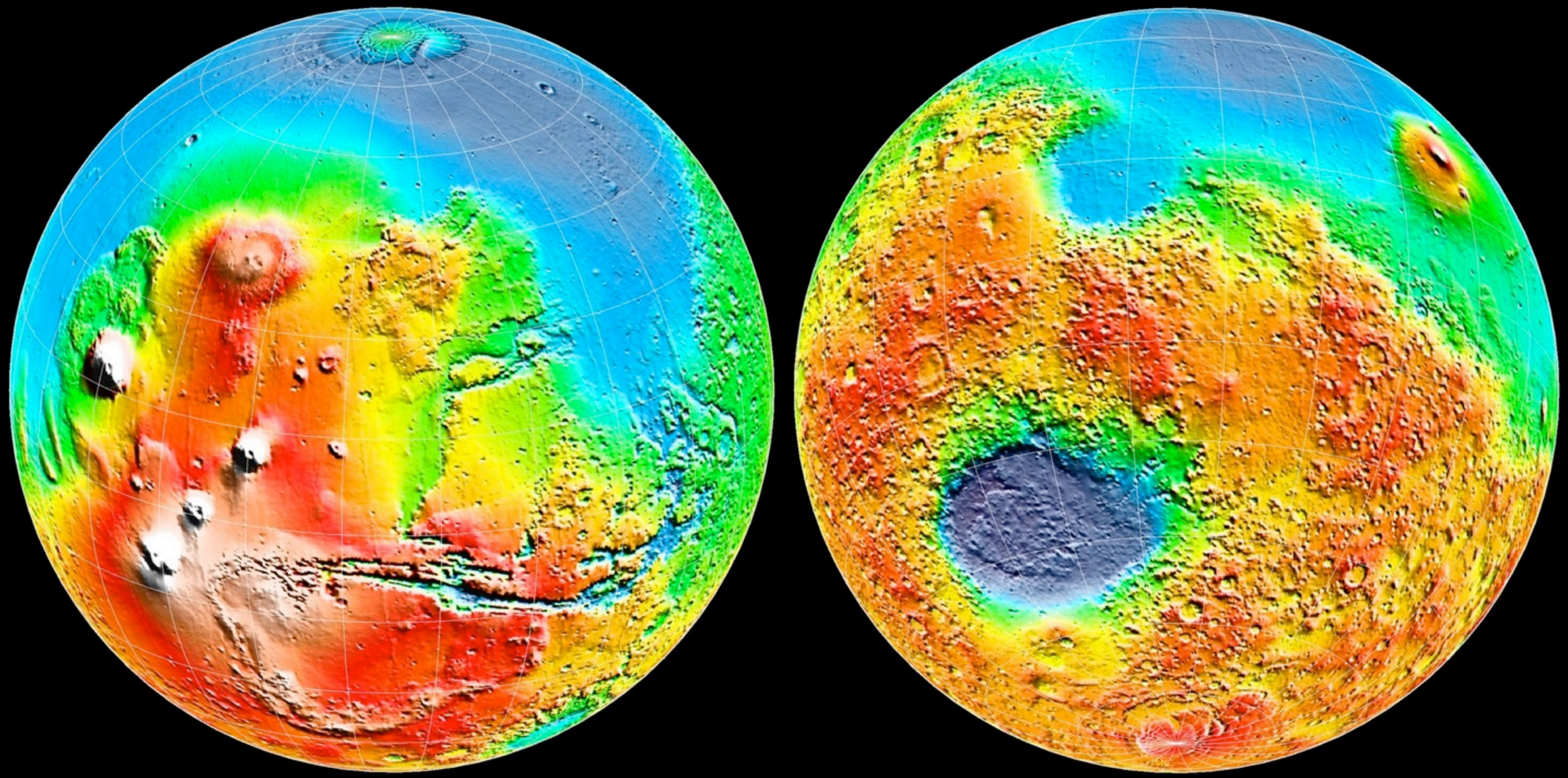
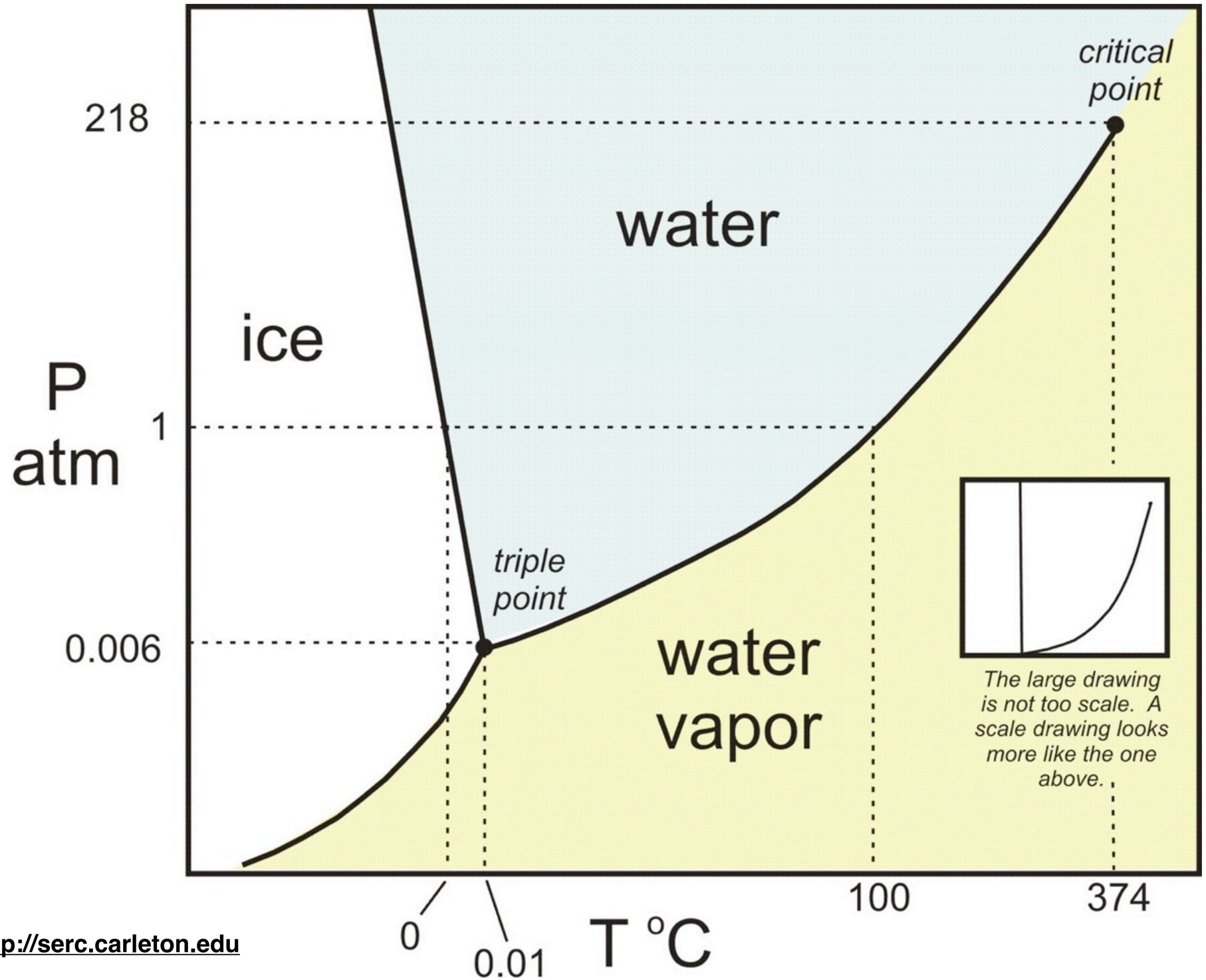
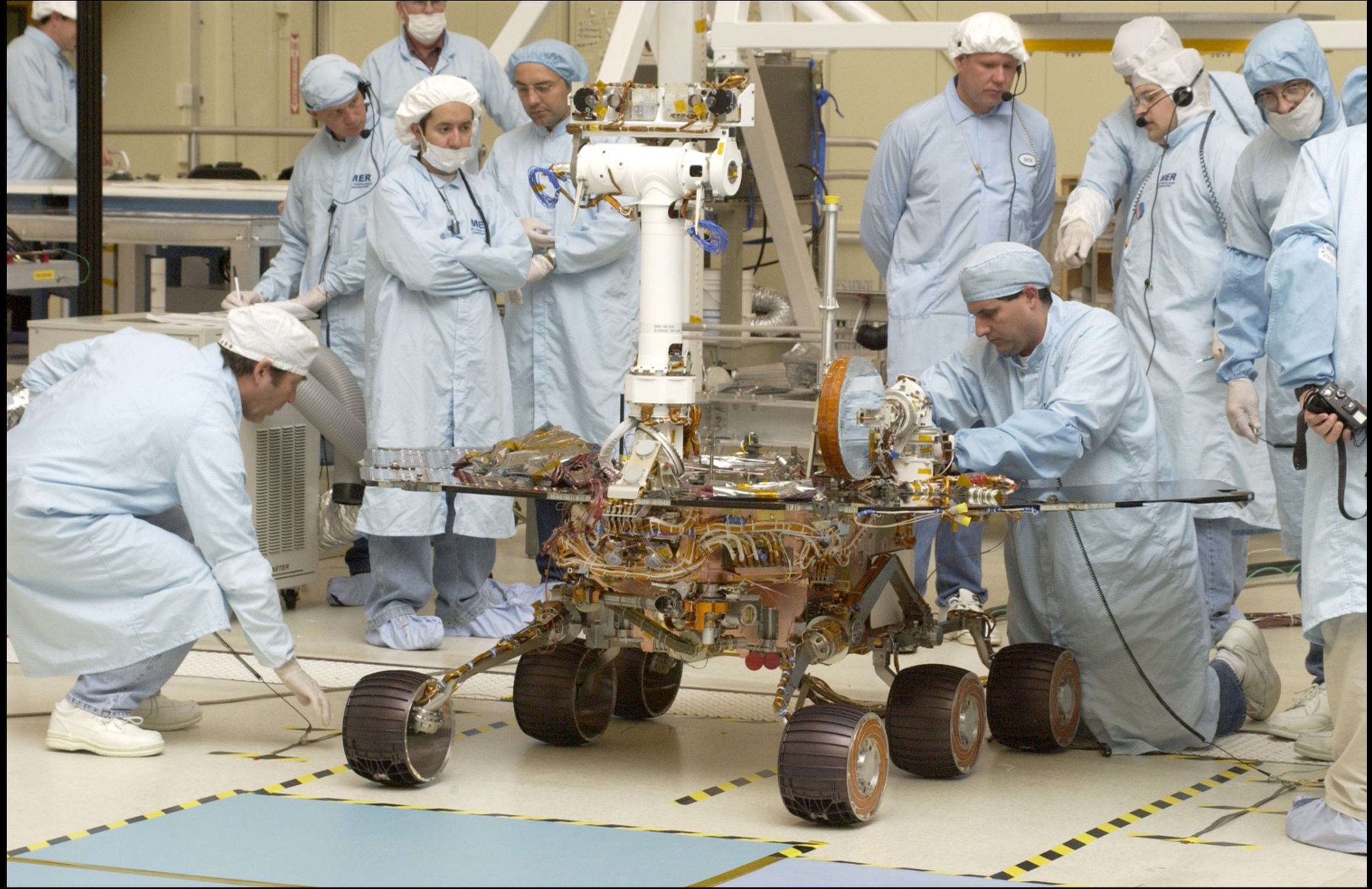
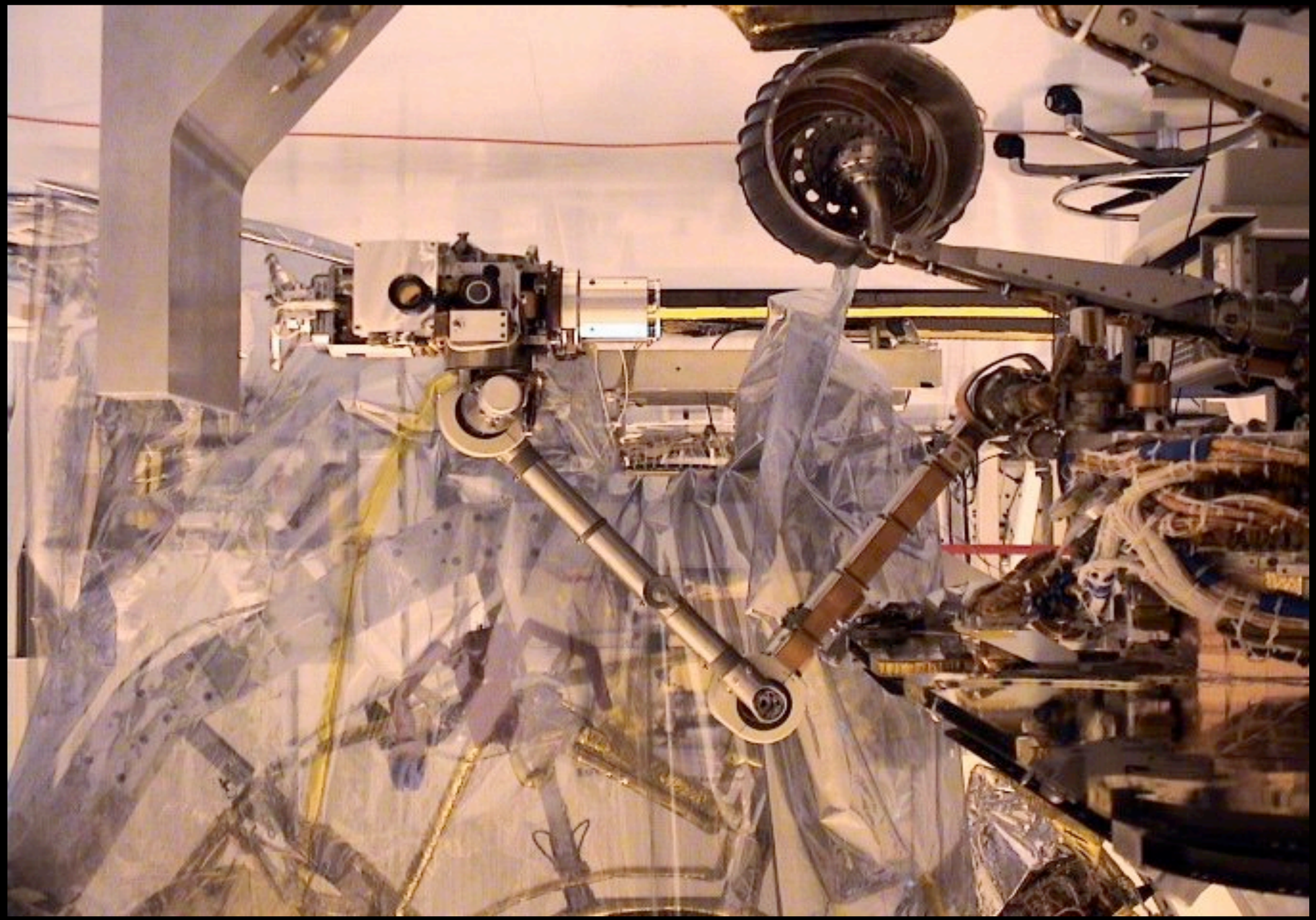




http://serc.carleton.edu





JPL

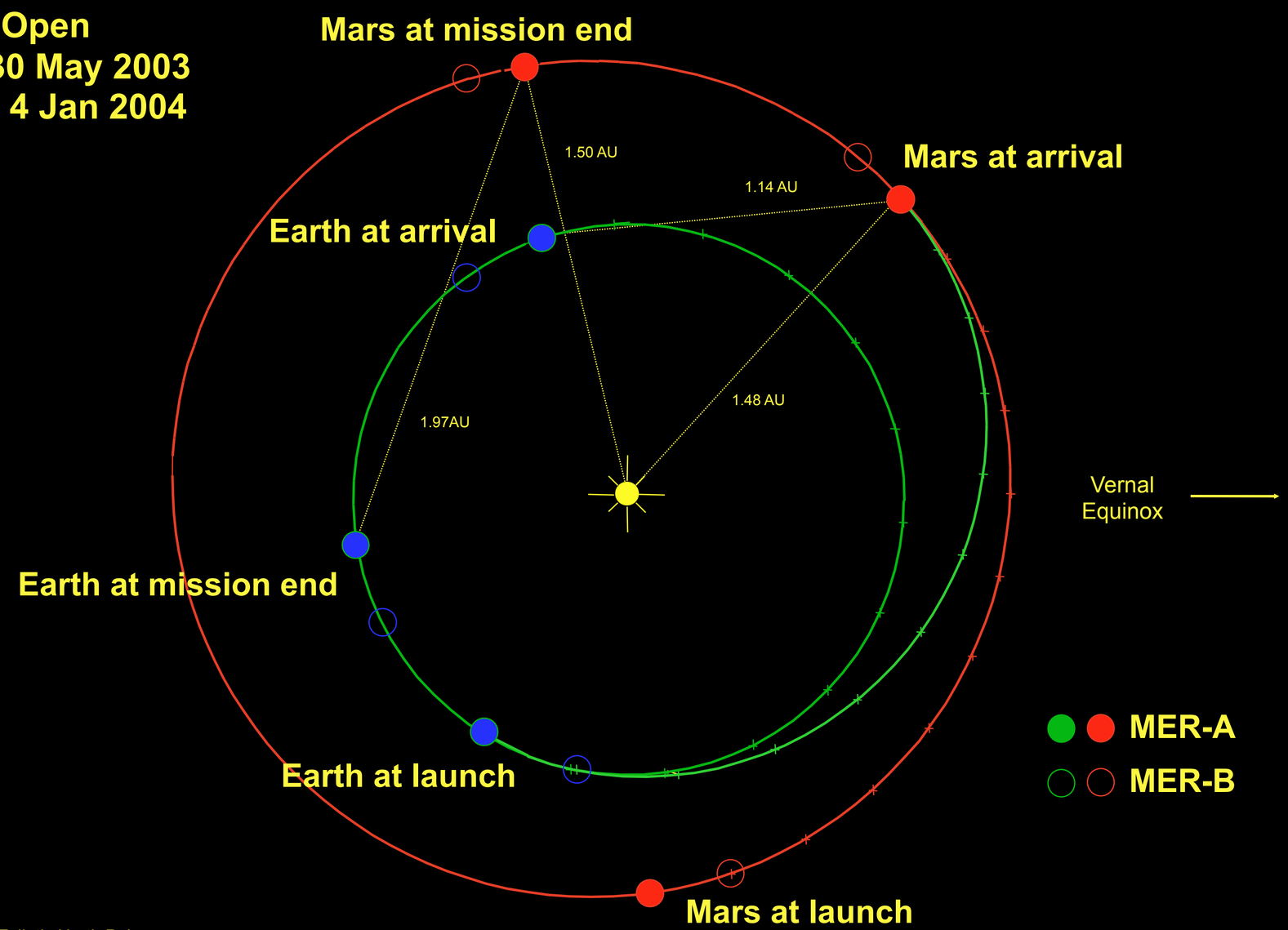
STARDUST
DEEP SPACE 1

Spirit Launch

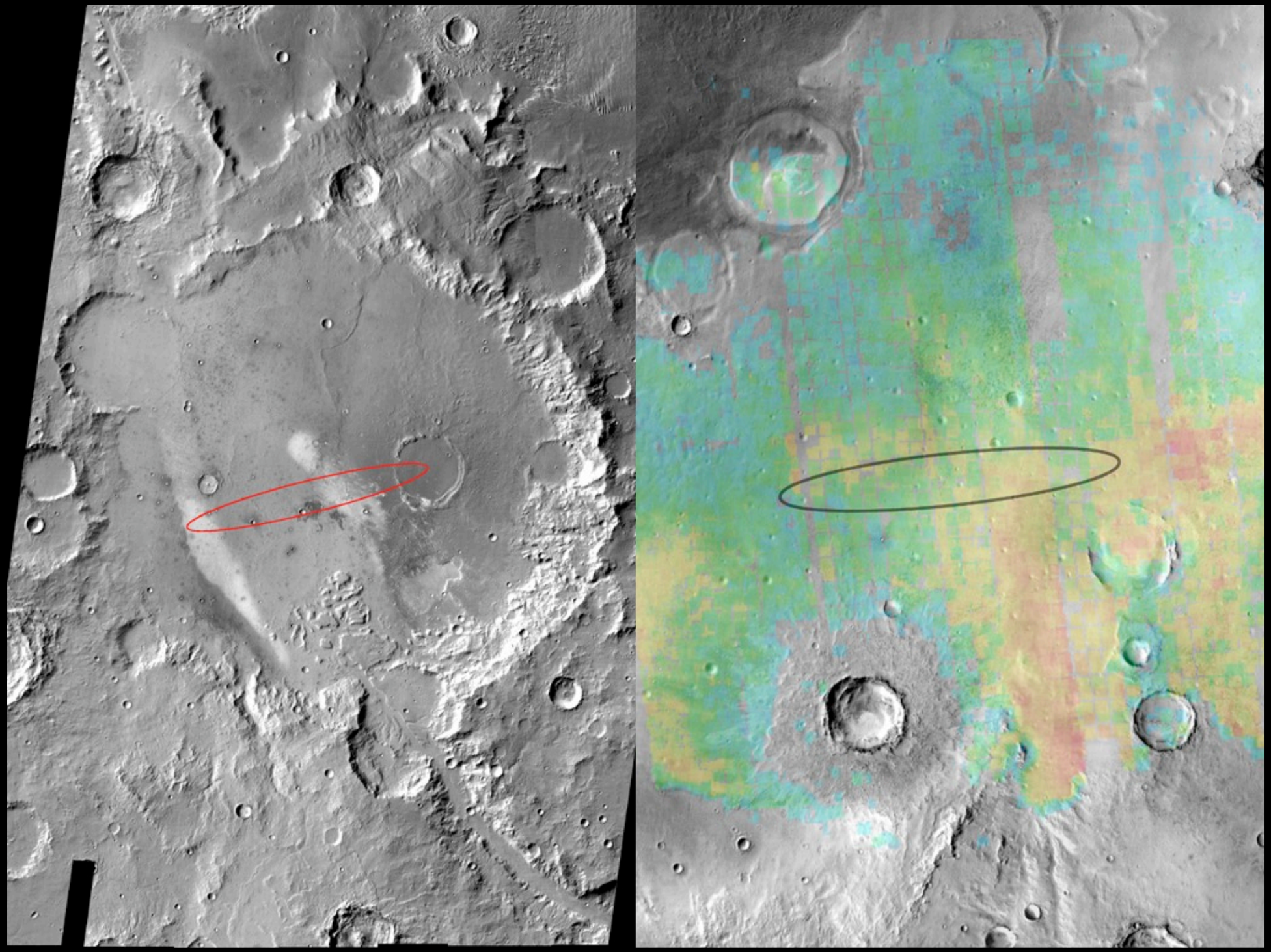
Opportunity Launch

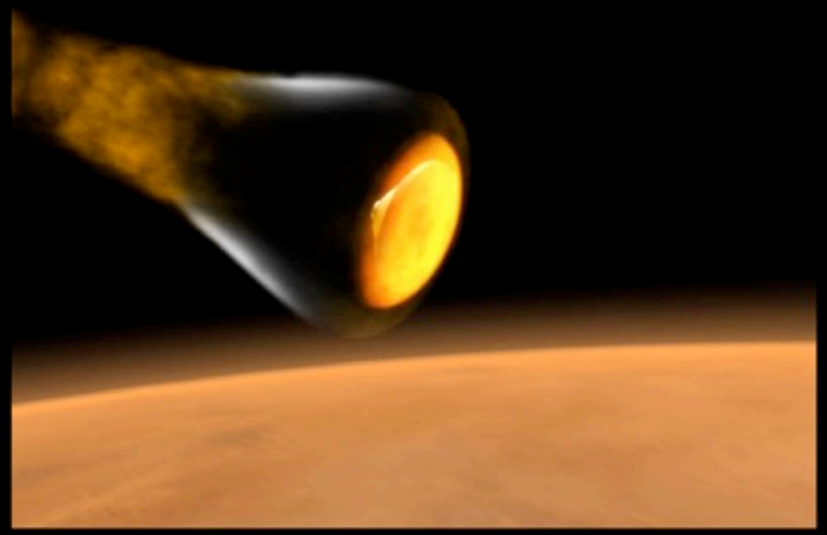
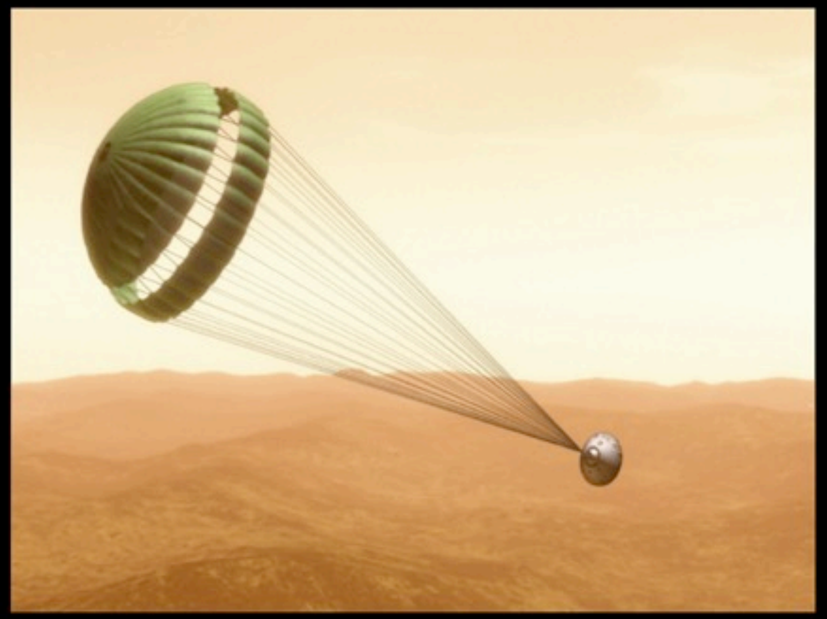
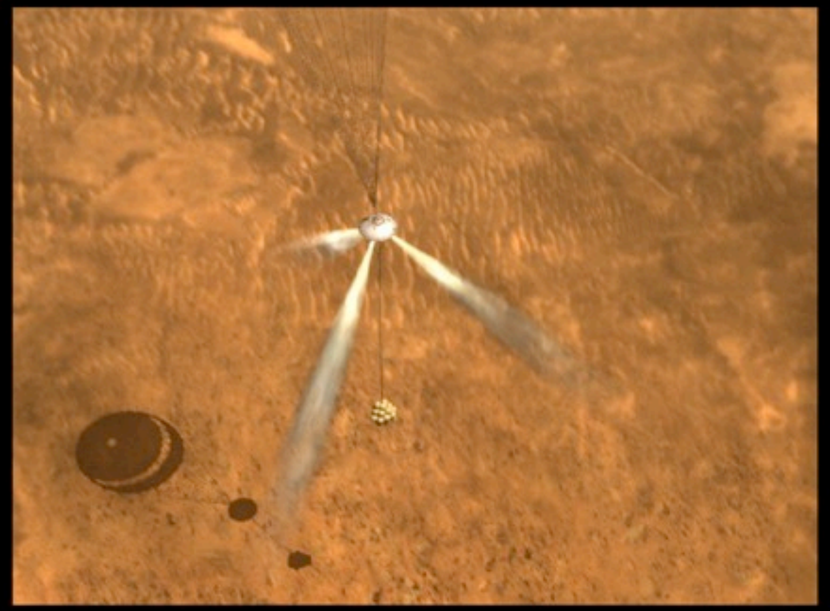
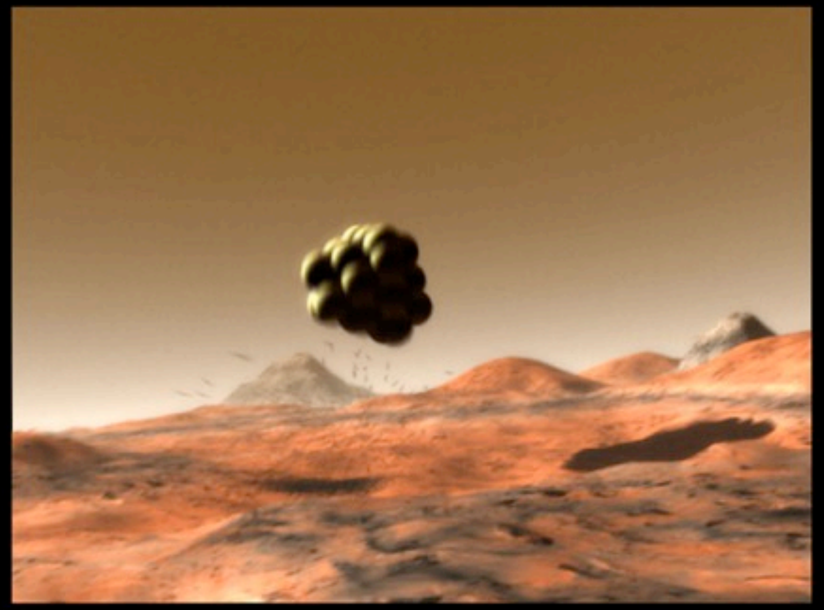
Interplanetary Trajectory

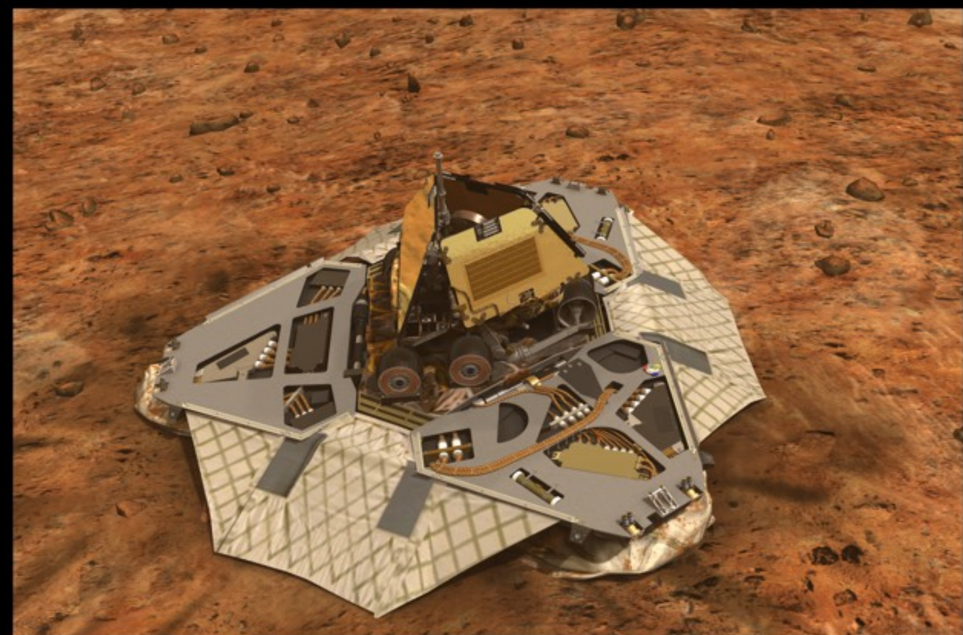
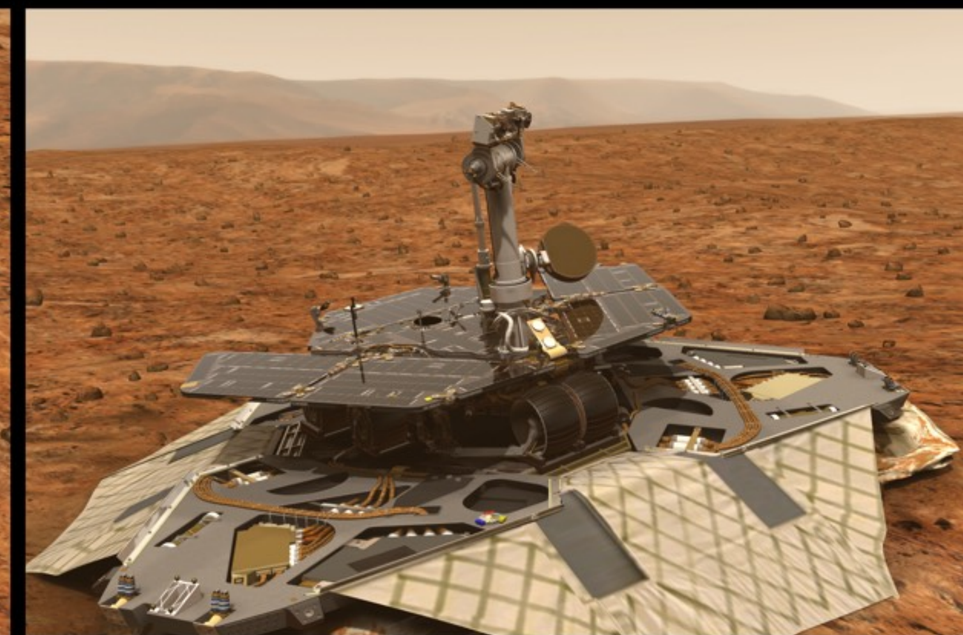
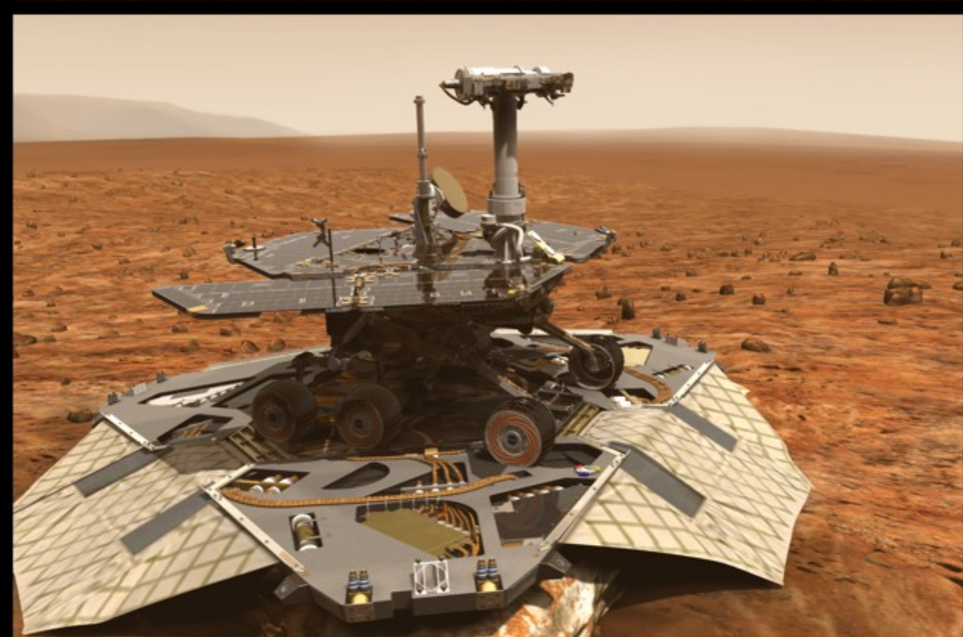
MER-A Open
Launch 30 May 2003
Arrival 4 Jan 2004

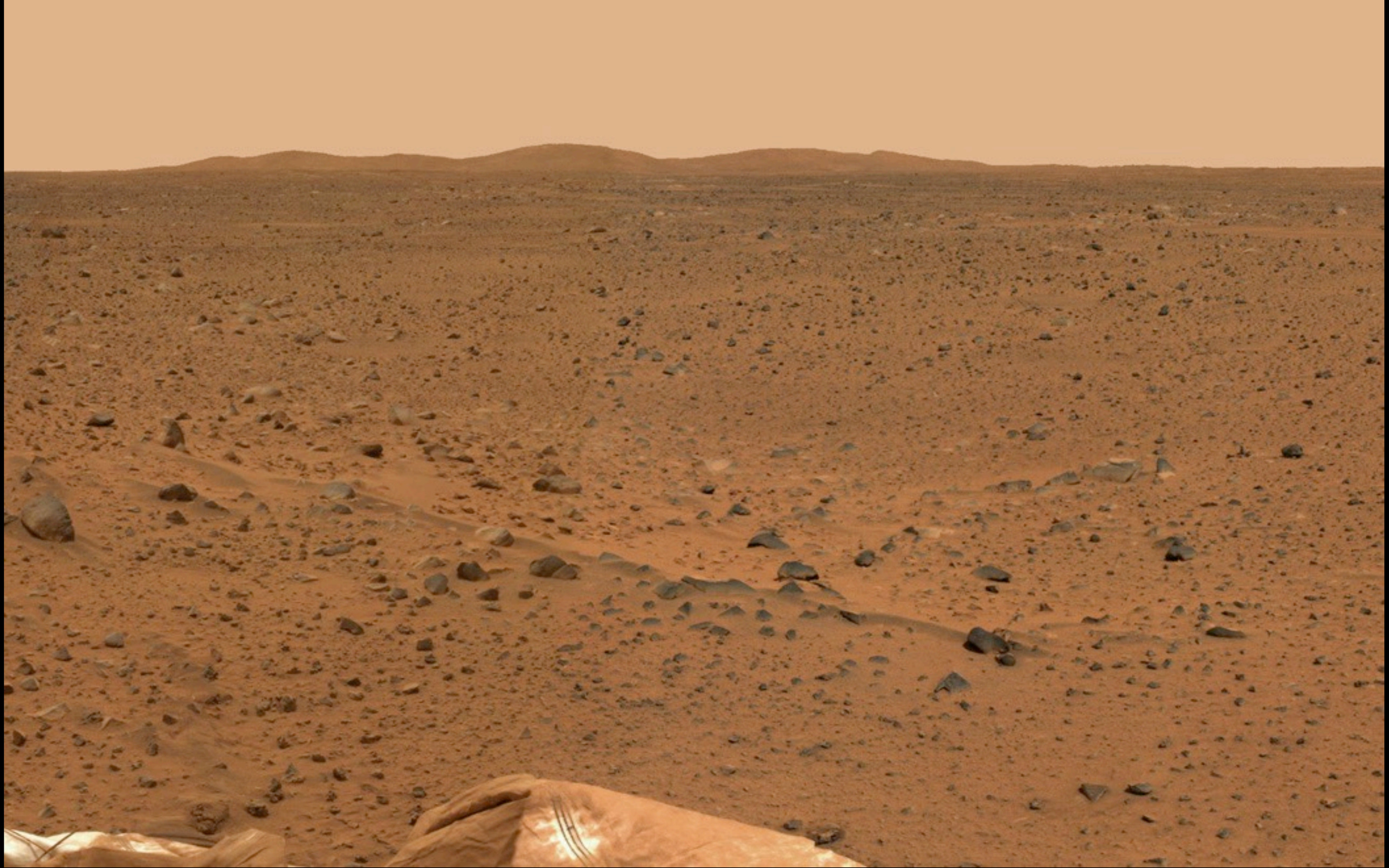


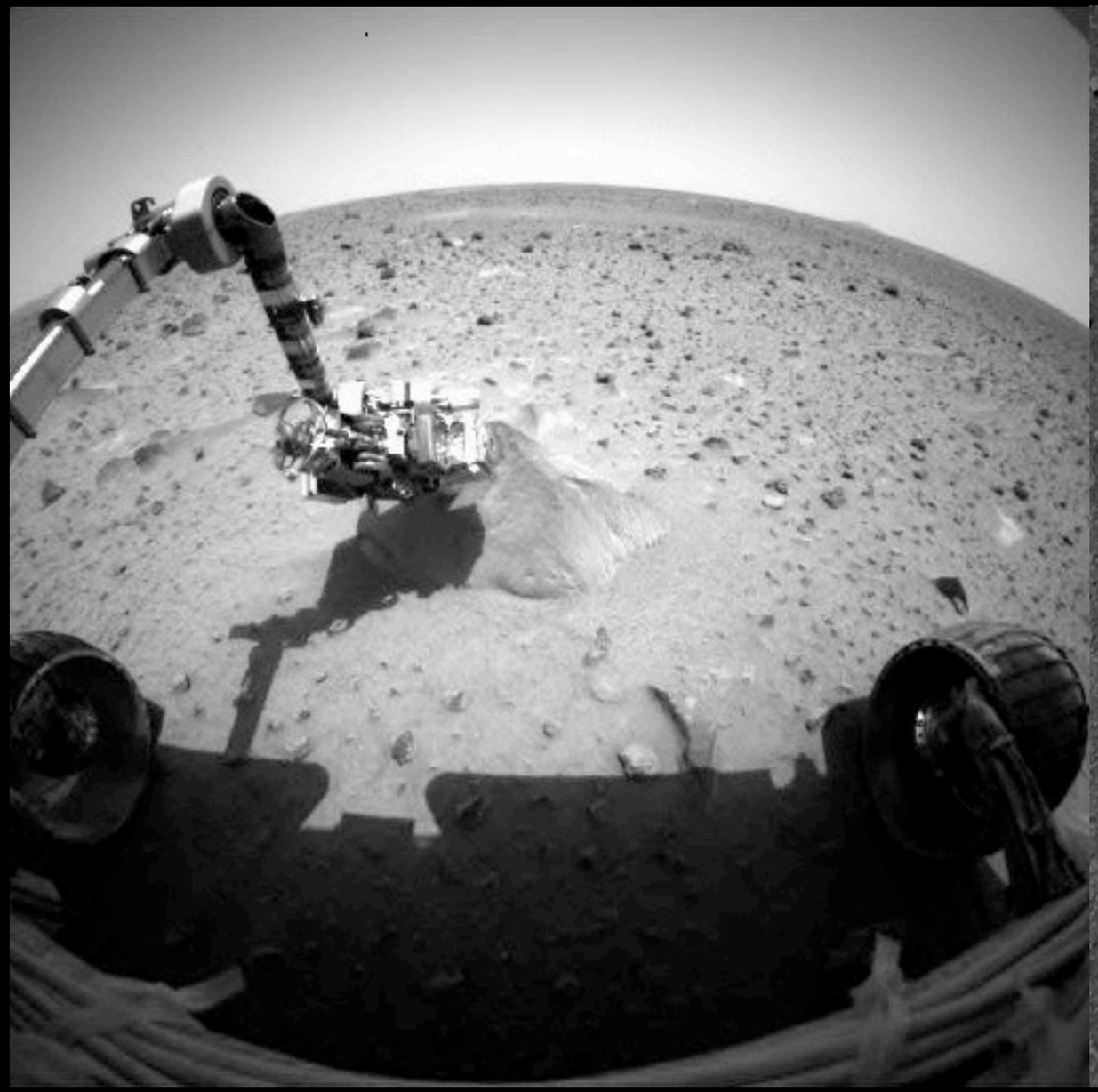
View from Ecliptic North Pole
20 day tick marks

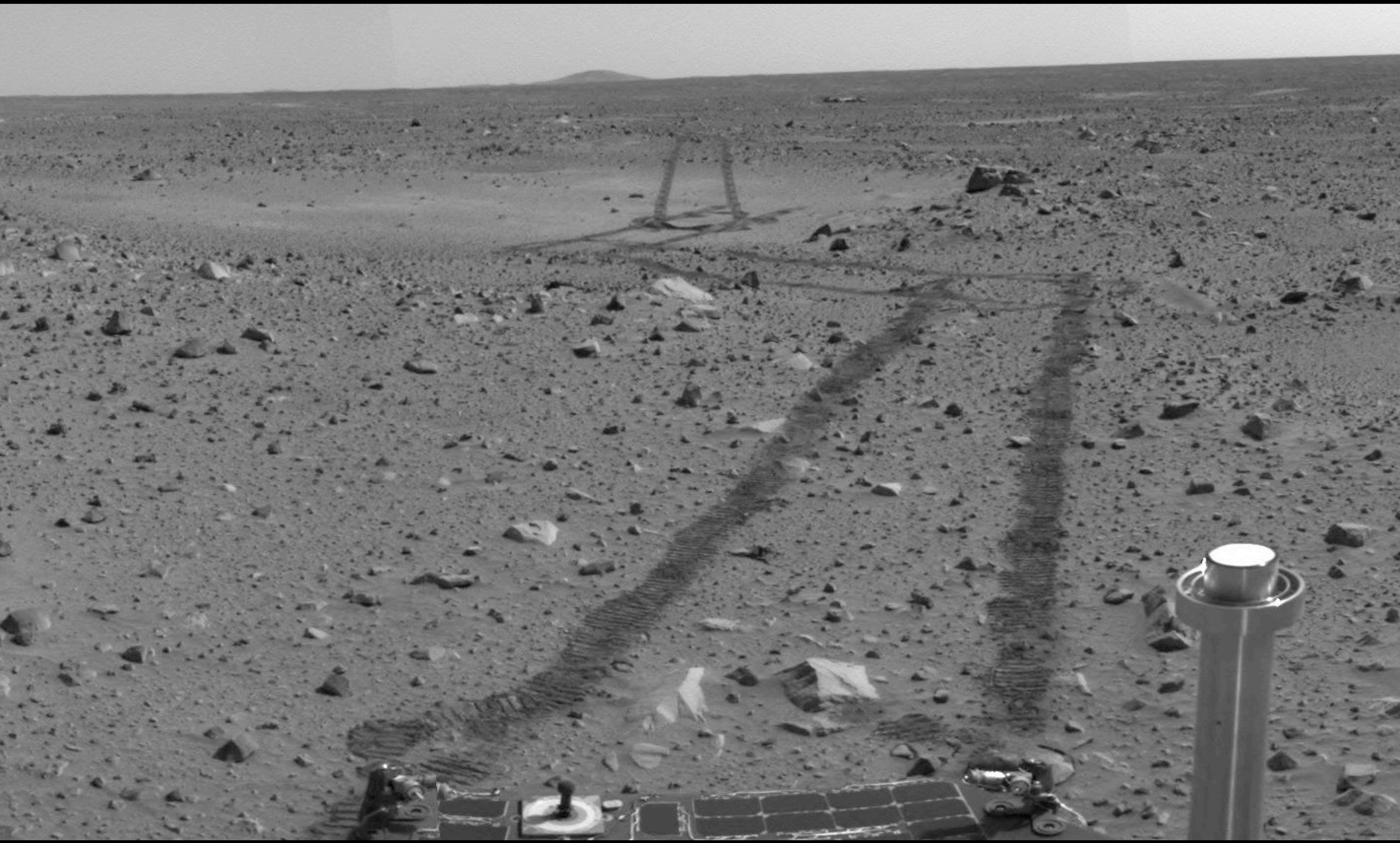


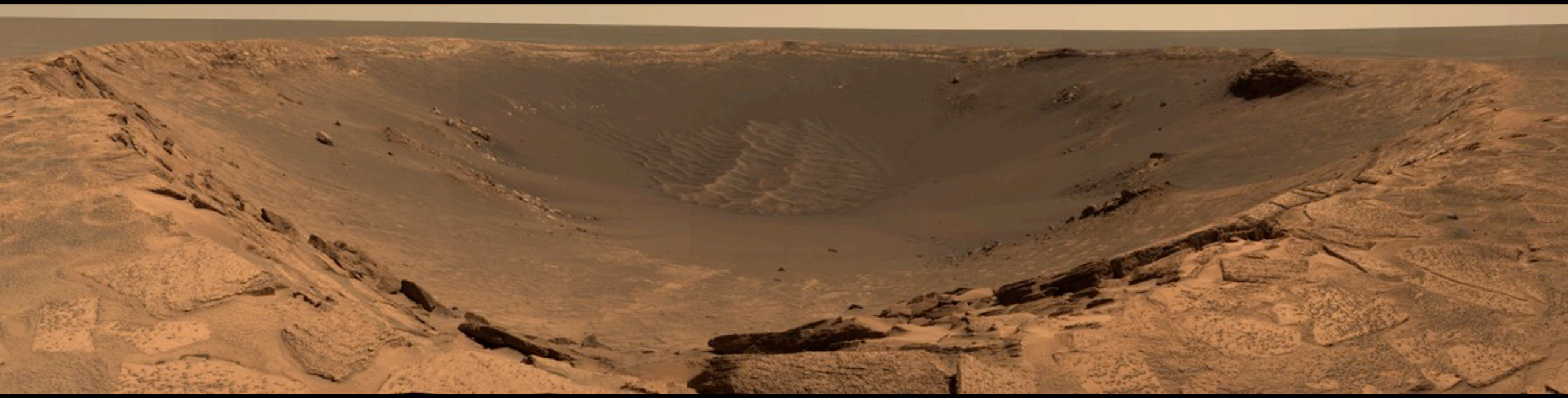





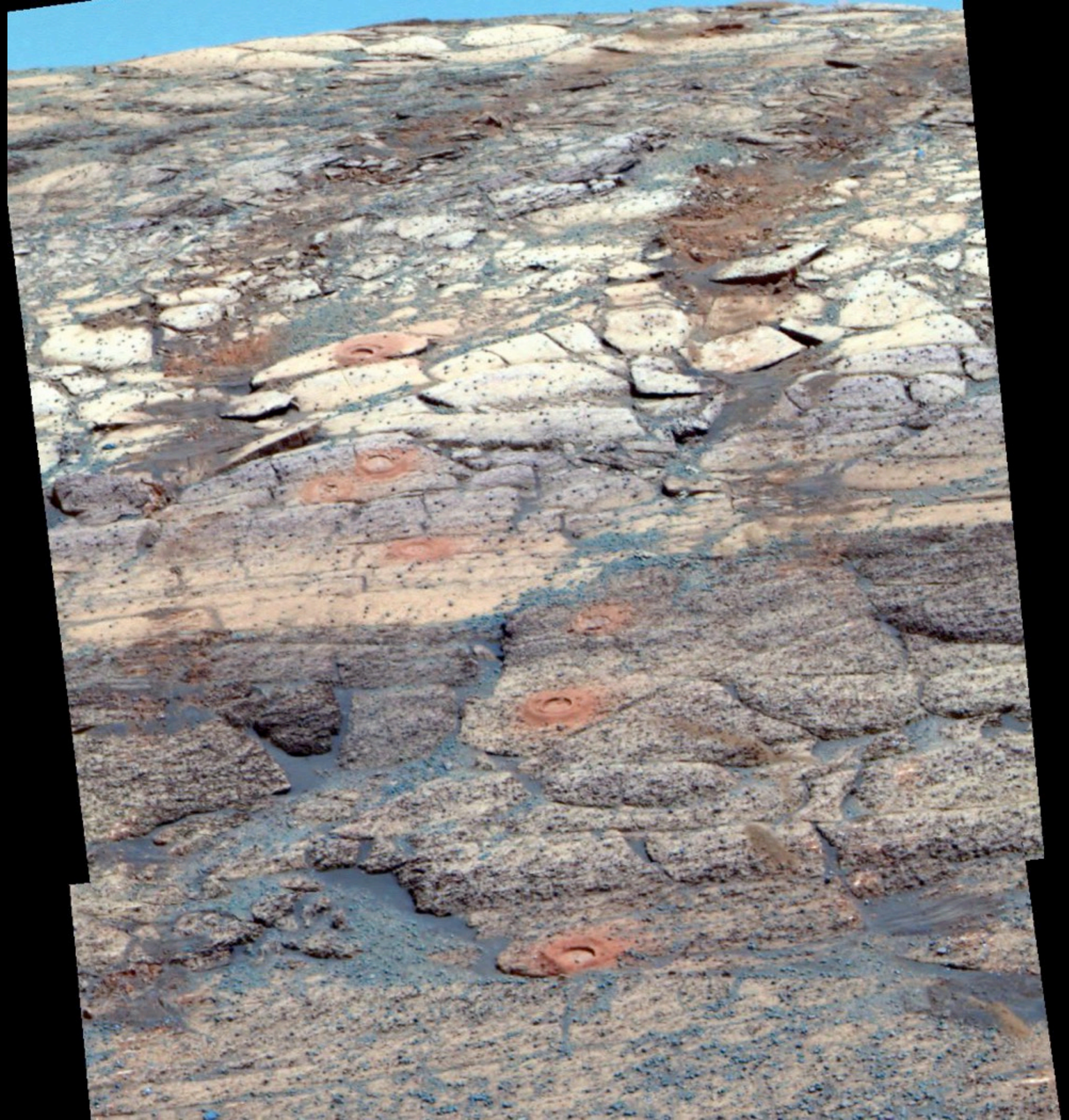




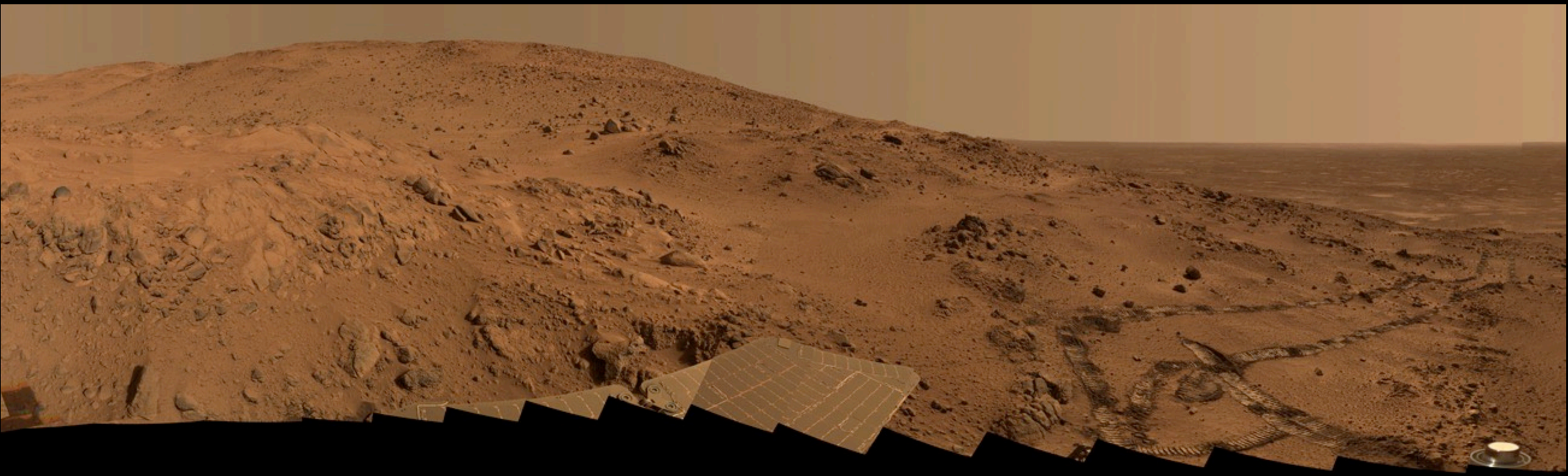


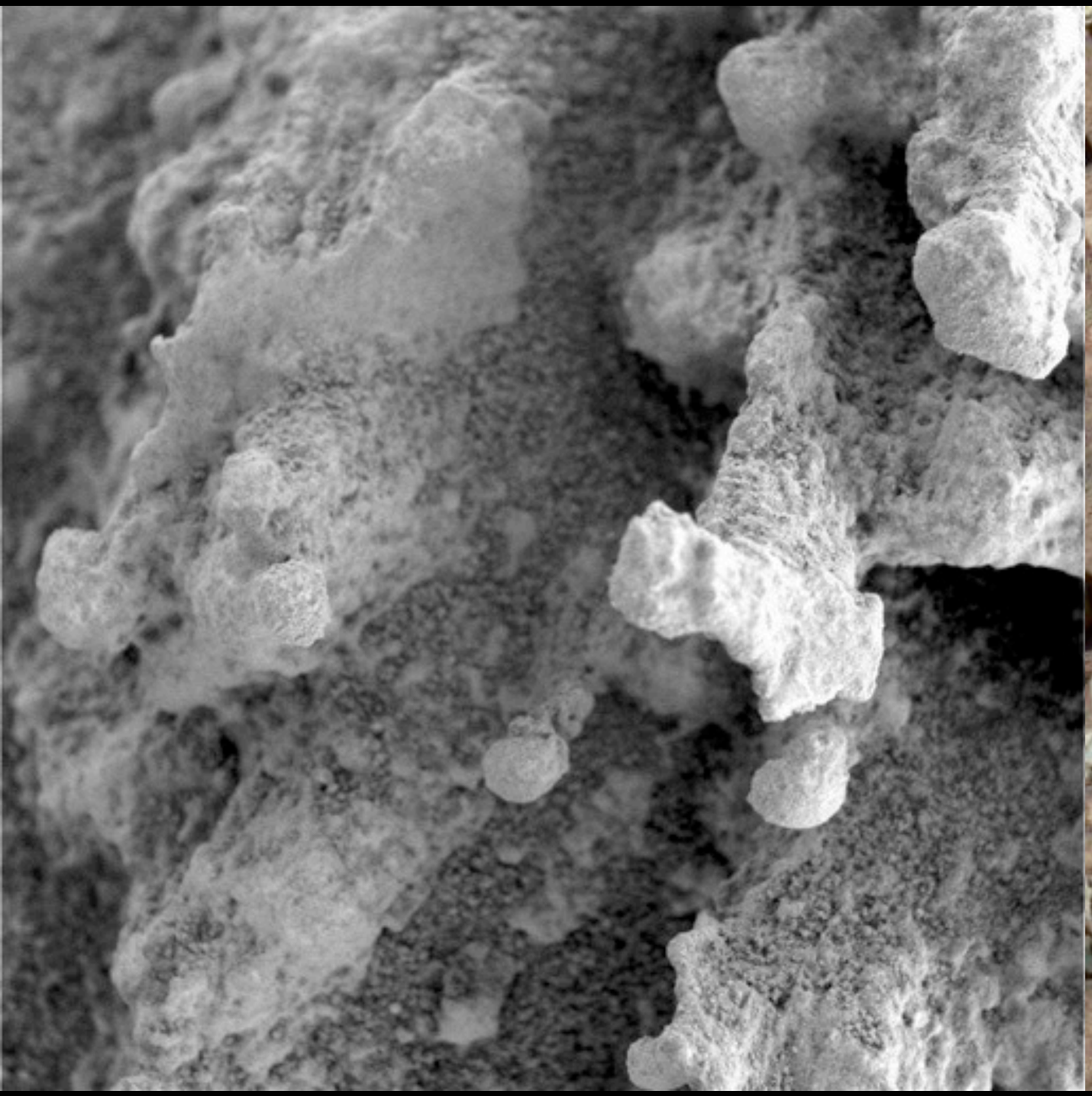


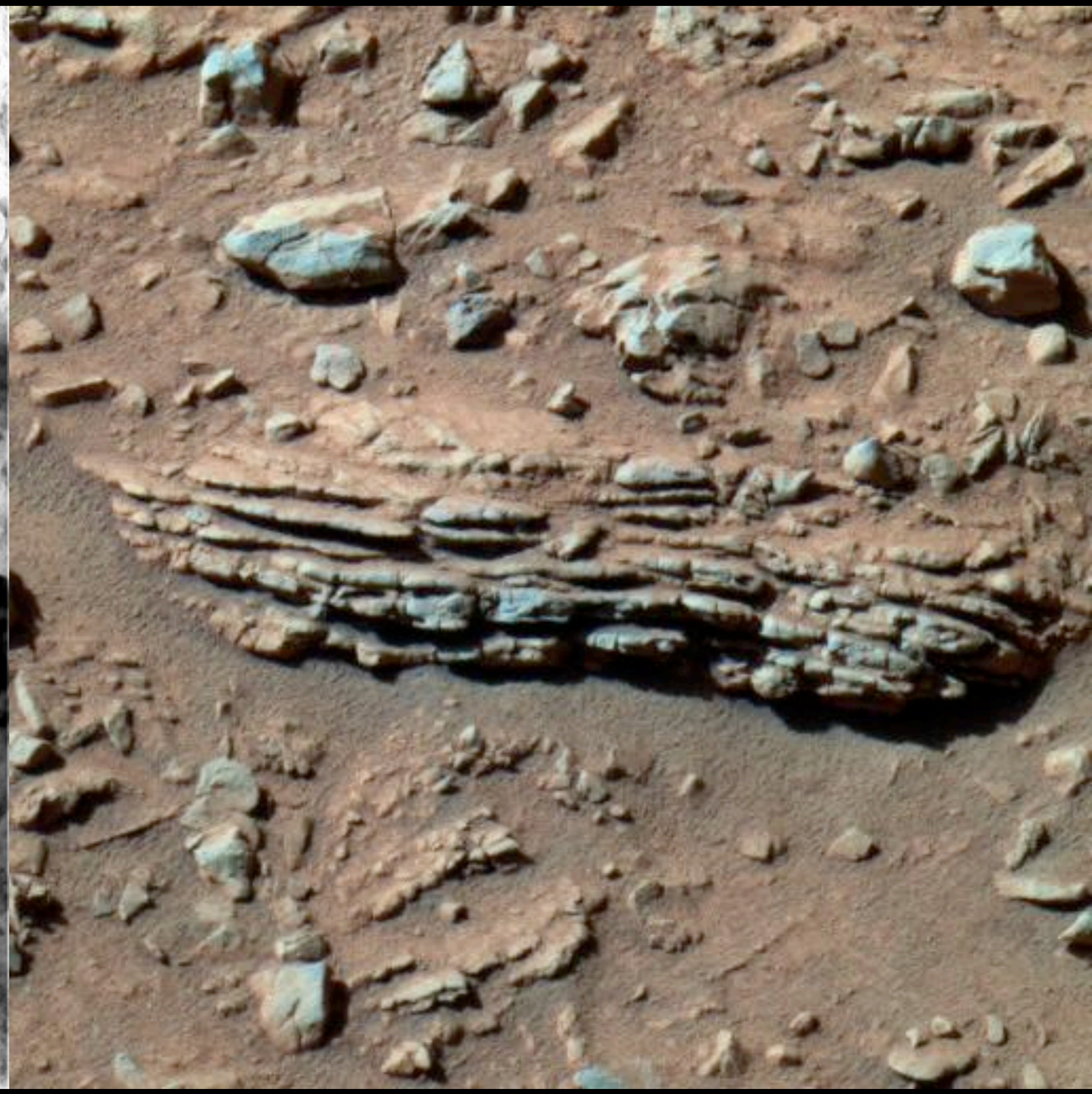


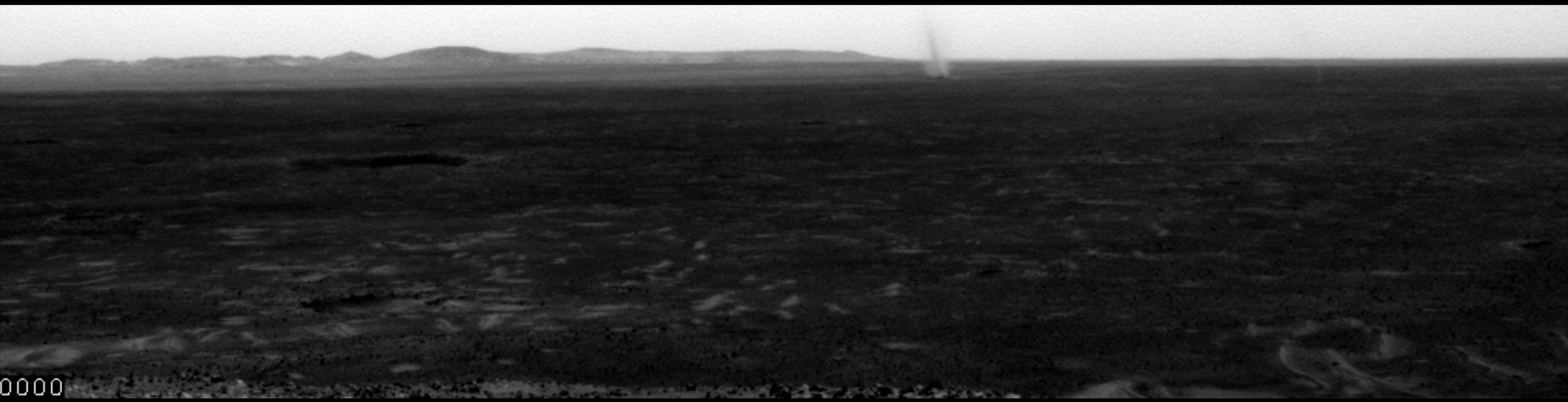








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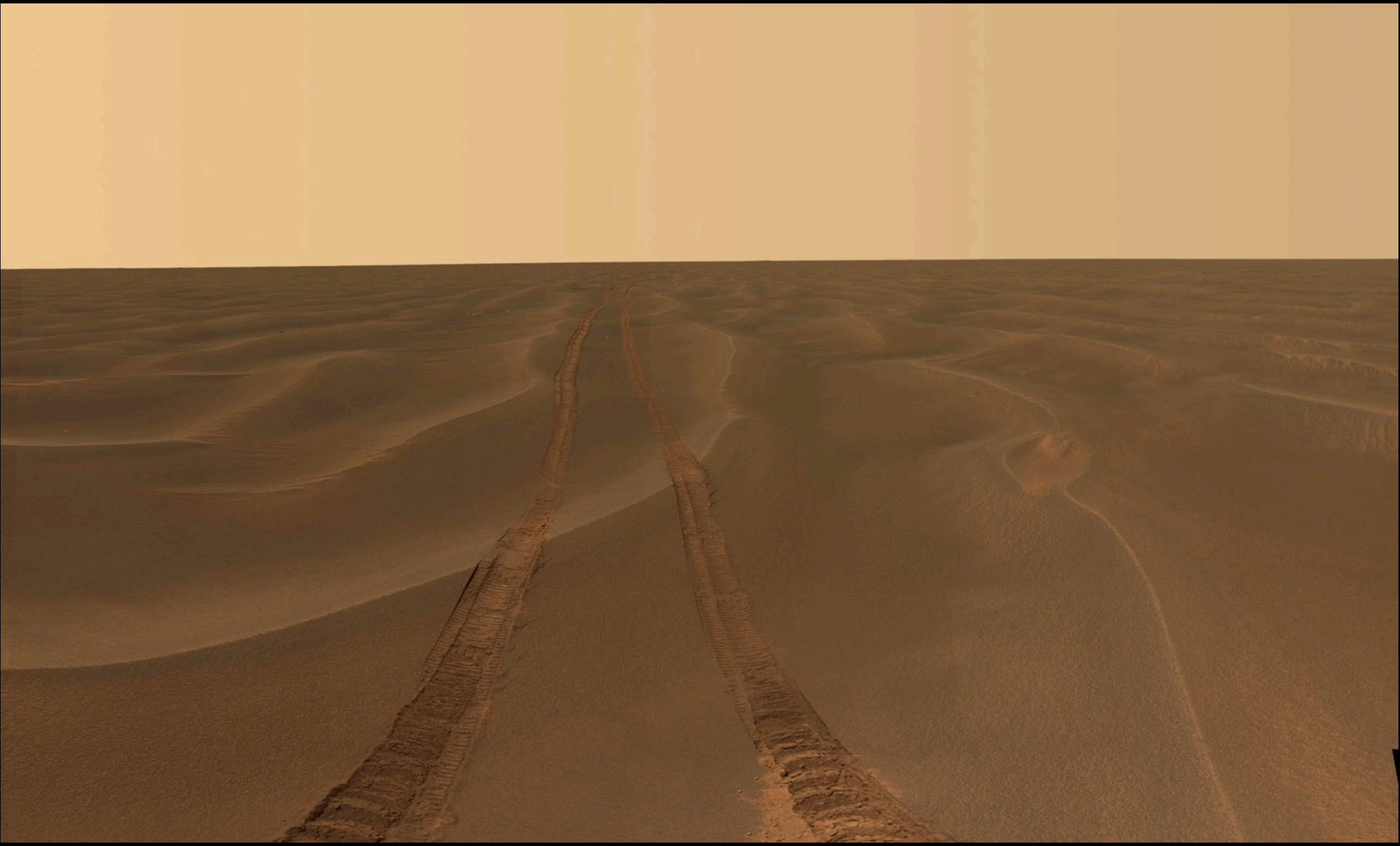


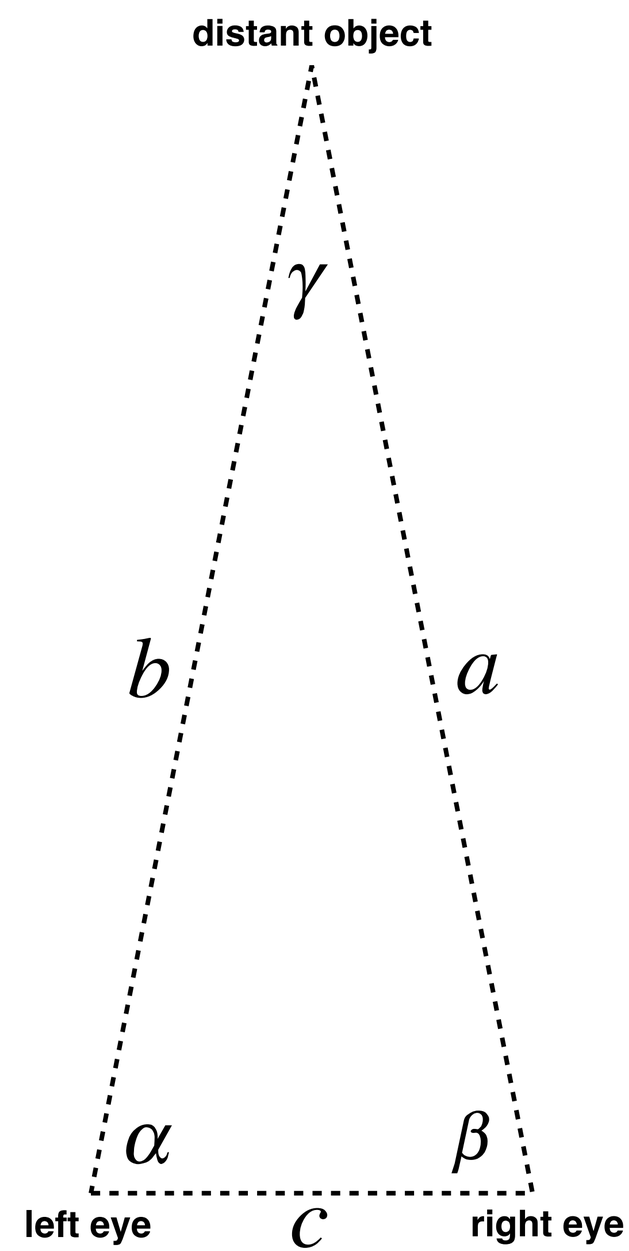
Law of Sines

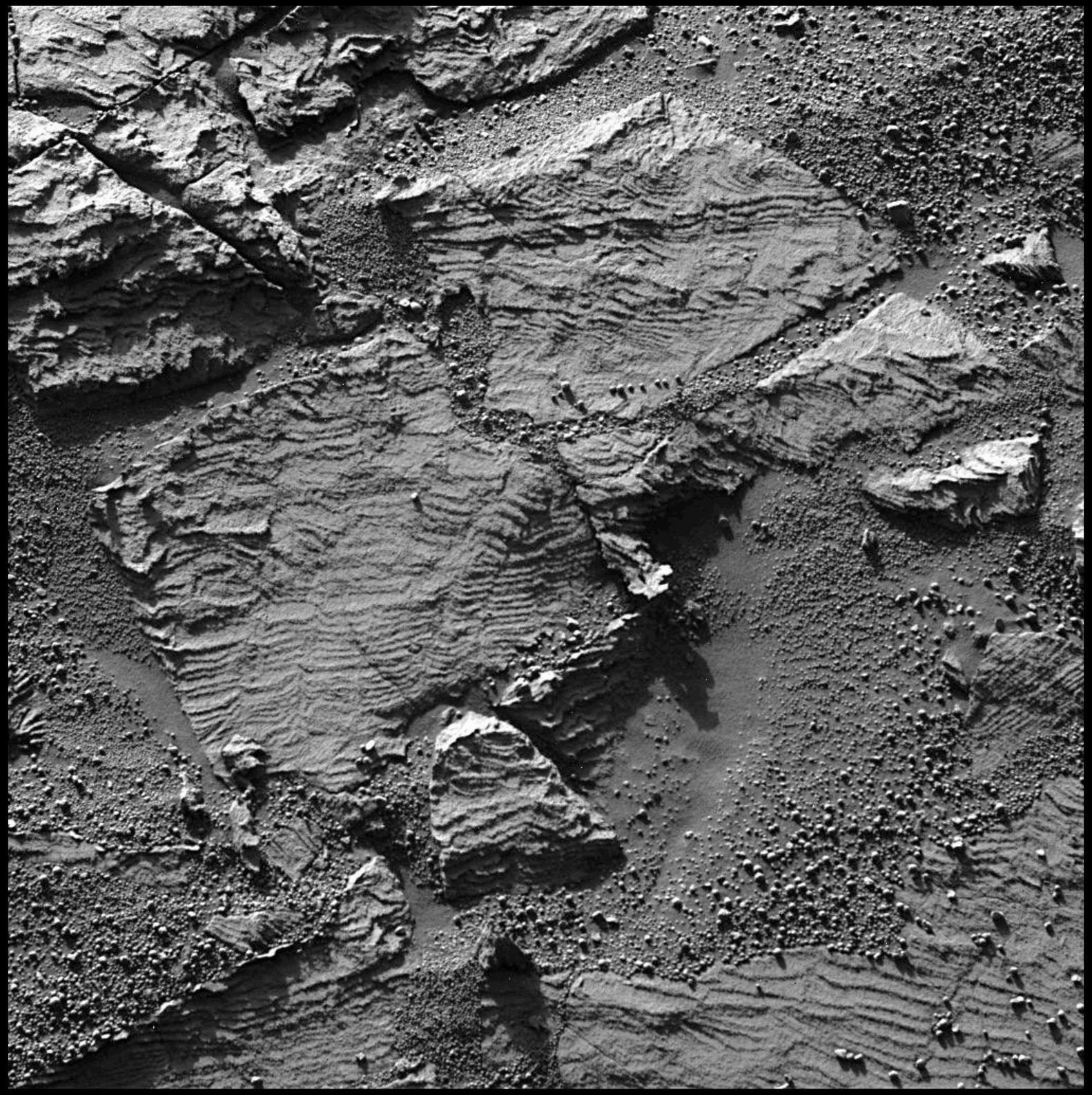
for Stereo Ranging

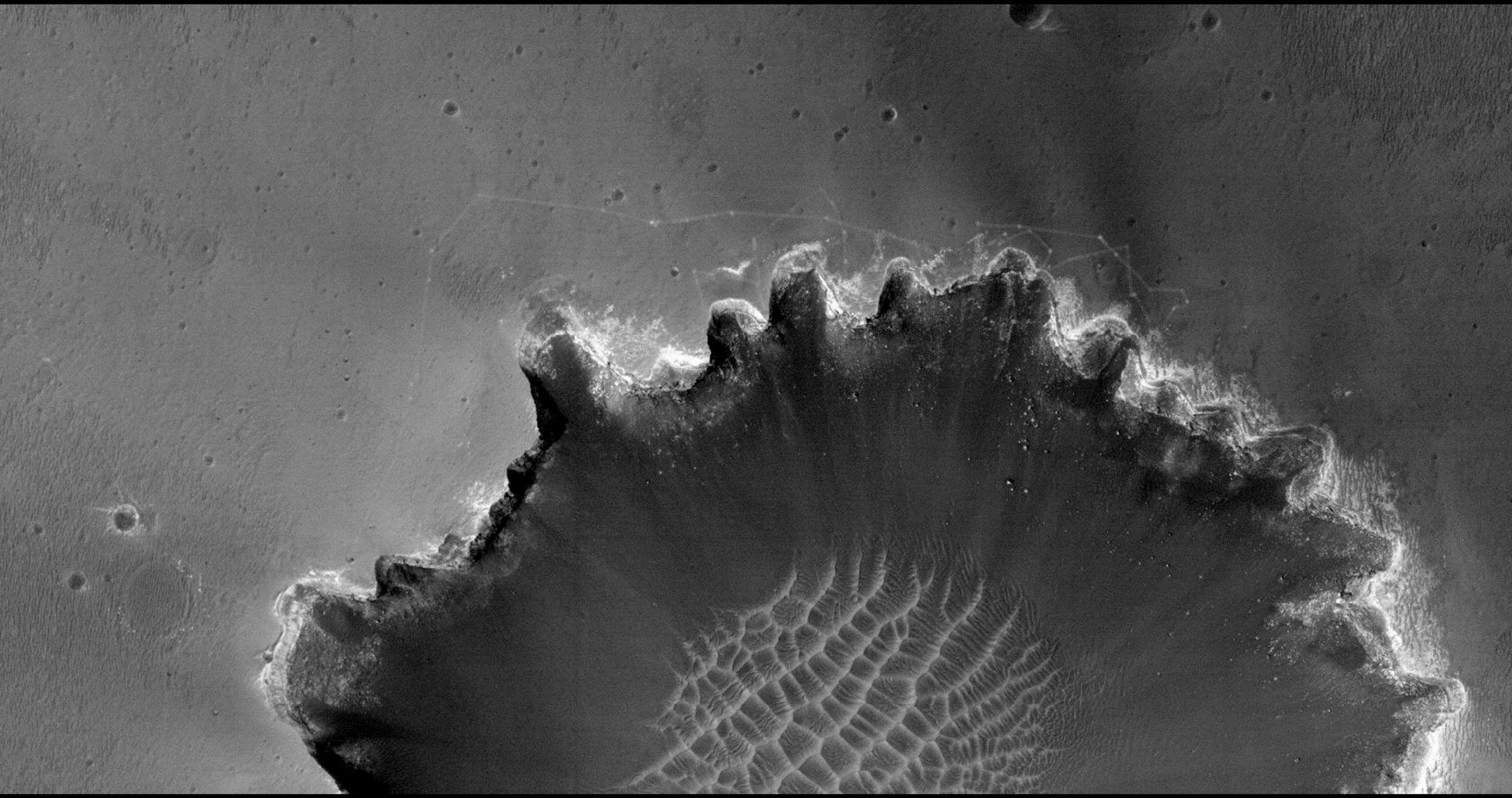
$$\frac{\sin\alpha}{a} = \frac{\sin\beta}{b} = \frac{\sin\gamma}{c}$$

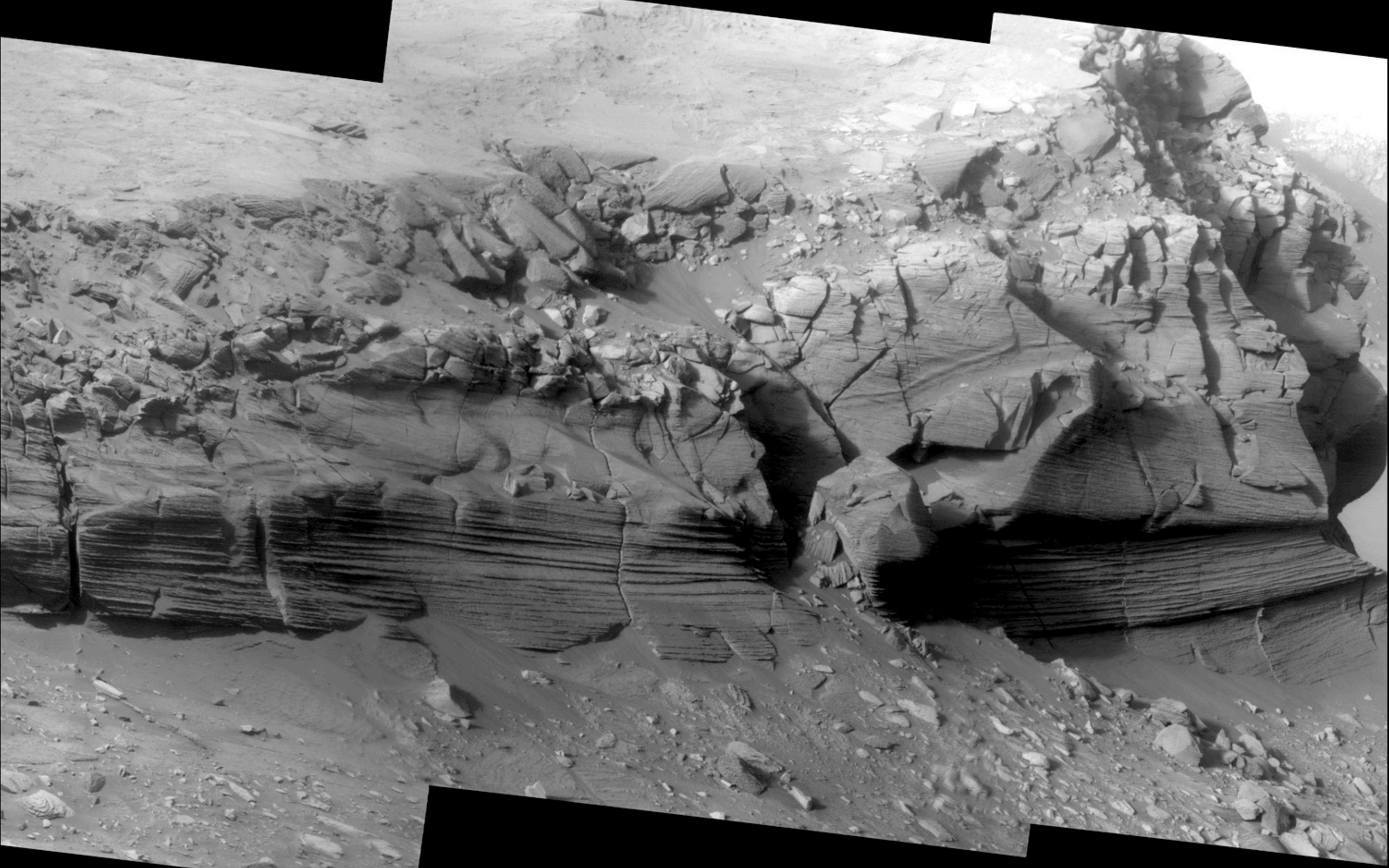
$$\alpha + \beta + \gamma = \pi \quad \text{or} \quad \gamma = \pi - \alpha - \beta$$

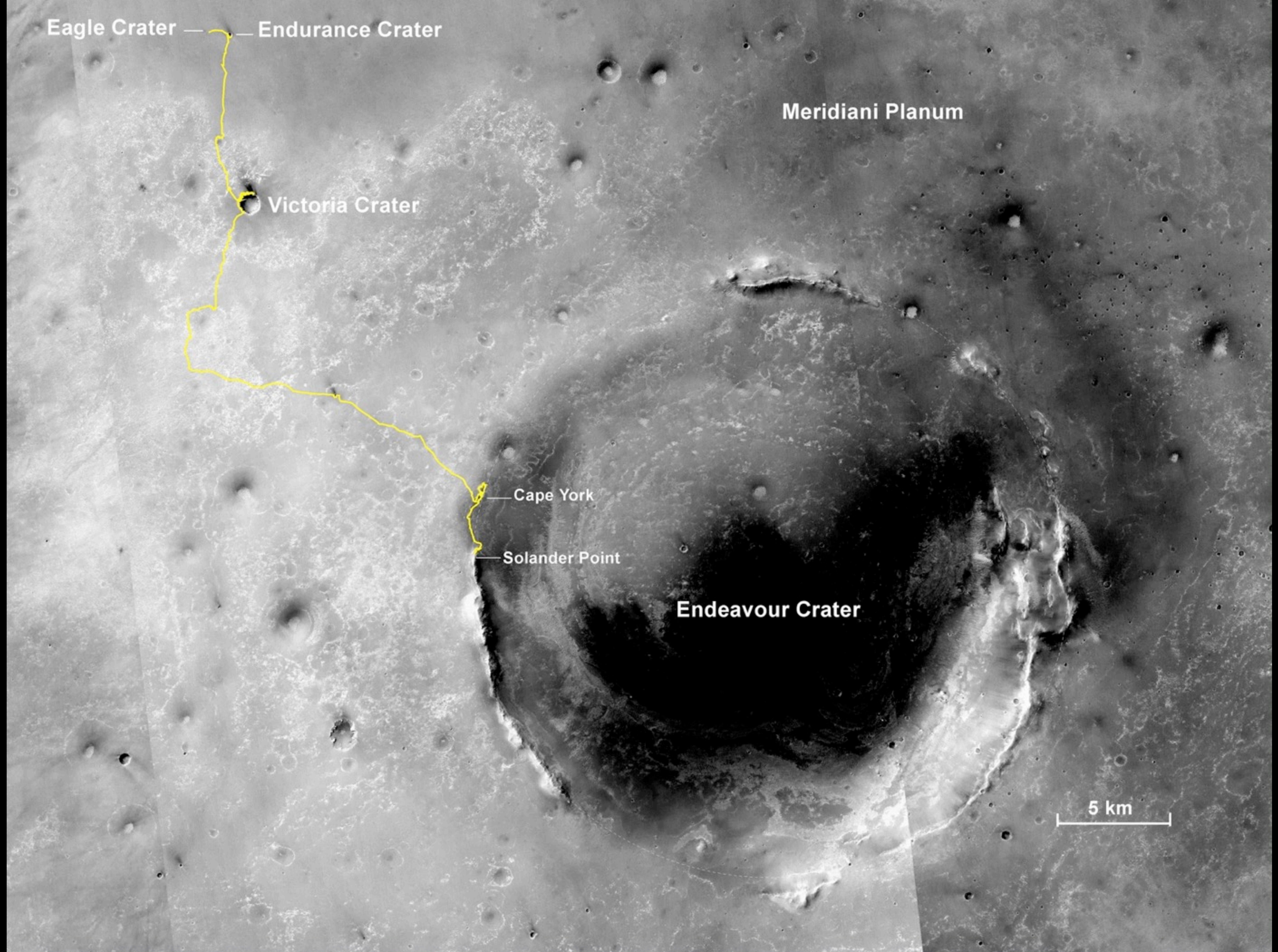
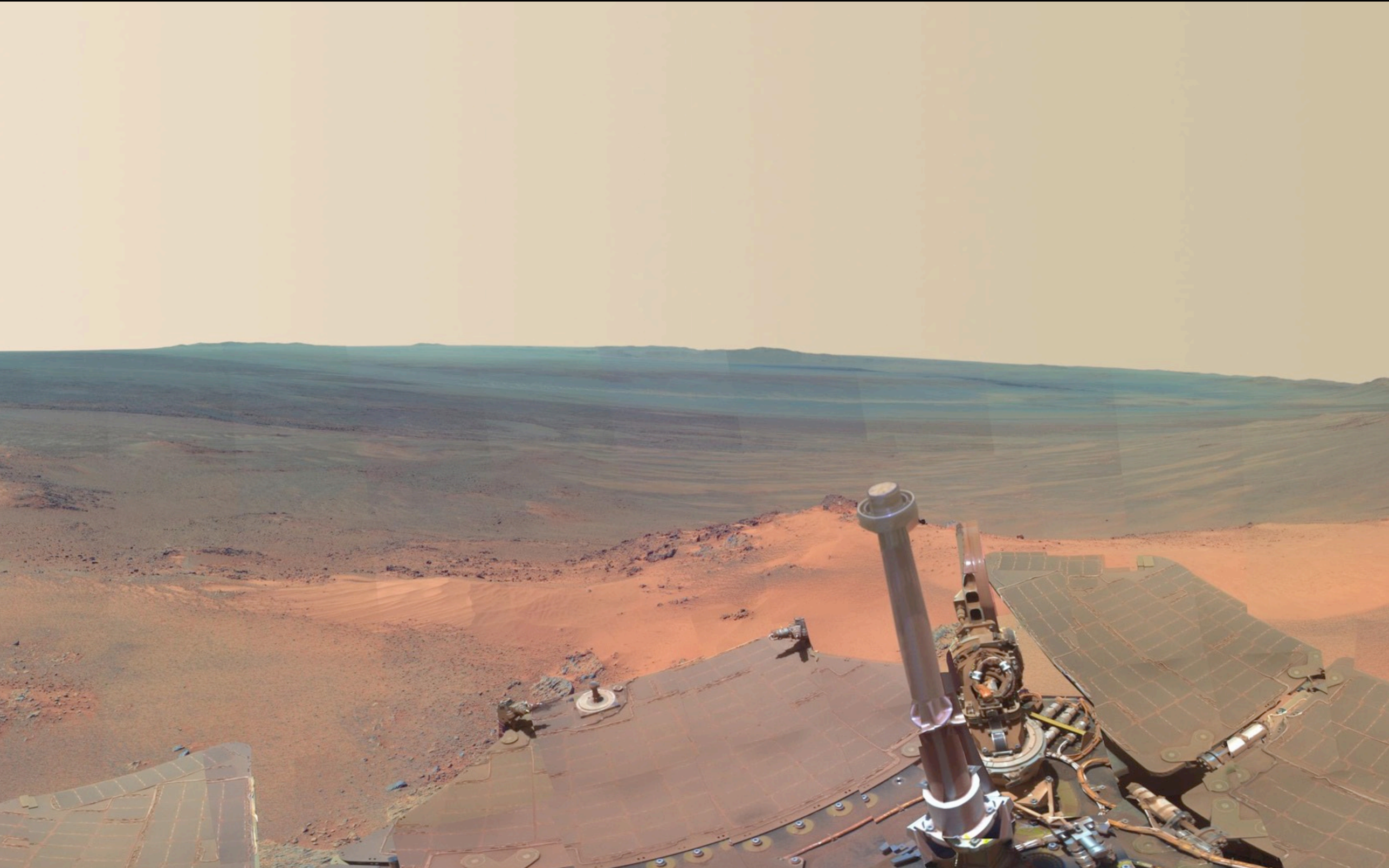
$$a = \frac{c\sin\alpha}{\sin(\pi - \alpha - \beta)} \qquad b = \frac{c\sin\beta}{\sin(\pi - \alpha - \beta)}$$










Eagle Crater
Endurance Crater
Meridiani Planum
Victoria Crater
Cape York
Solander Point
Endeavour Crater
5 km