

# OUR COMPLEX COSMOS

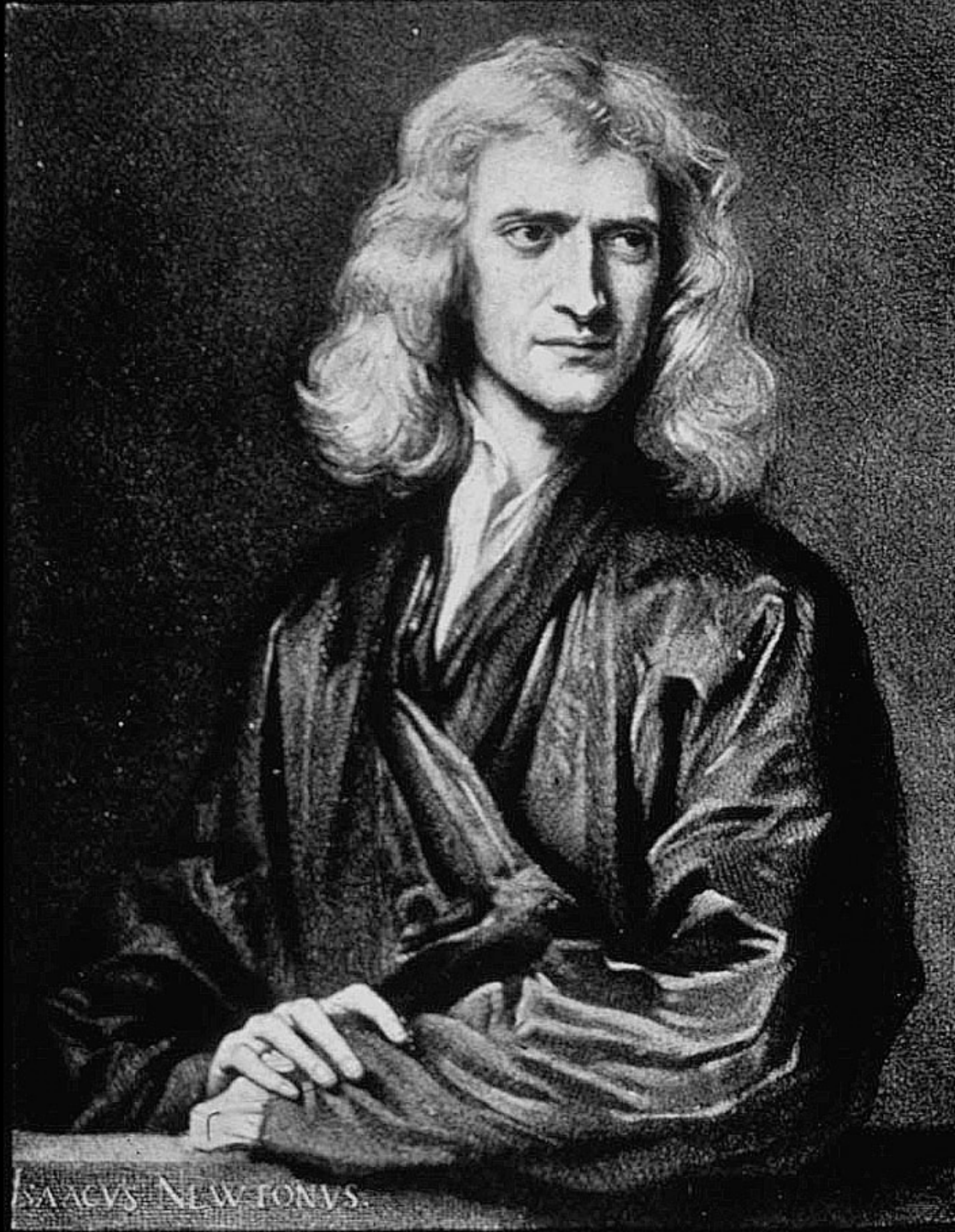
Martin Rees

Institute of Astronomy

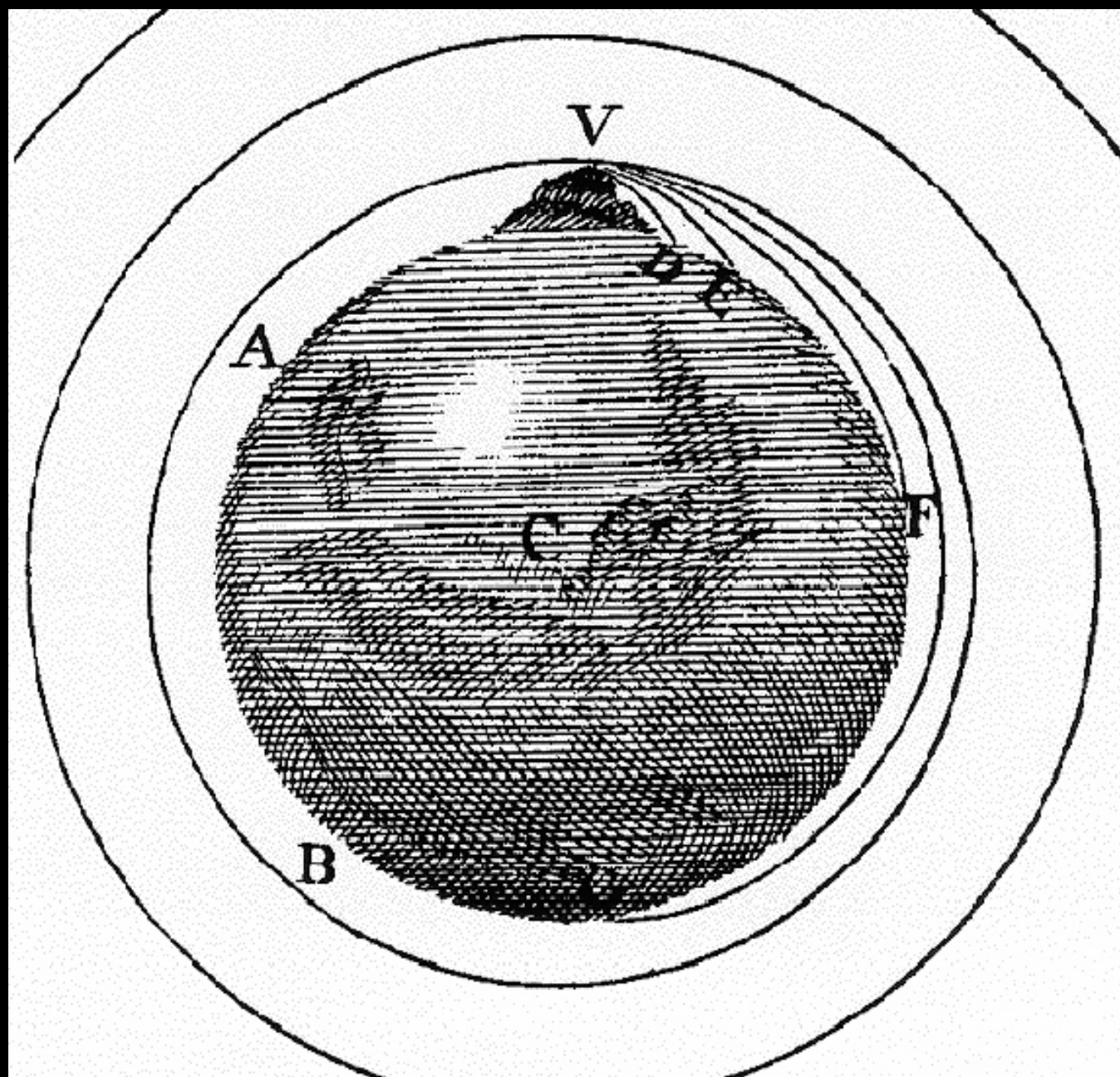


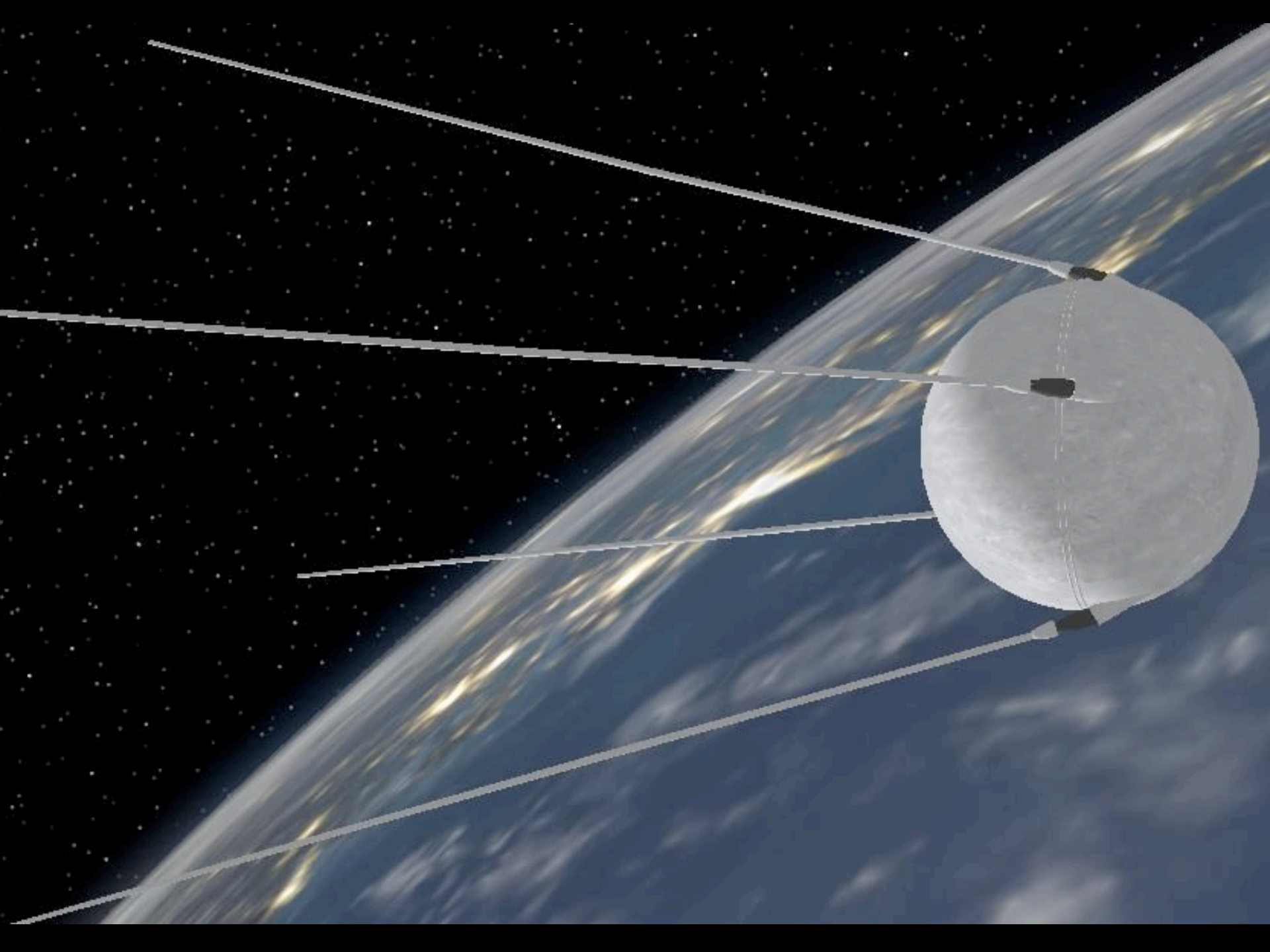
# the challenges

- What is out there? Cosmic exploration.
- Interpreting phenomena in terms of known (and perhaps 'new') physics.
- How, from a 'simple beginning', did our Universe evolve into its present complexity (stars, planets, people)?
- Can we understand, at a deeper level, why our Universe is the way it is?



ISAACUS NEWTONVS.







To Lord Rees with  
best regards,  
Dave Scott  
Apollo 9, 15

To Lord Rees,  
with thanks,  
Fred Haise  
apollo 13 LMP

TO LORD REES  
WITH THANKS  
Charlie Duke  
APOLLO 16

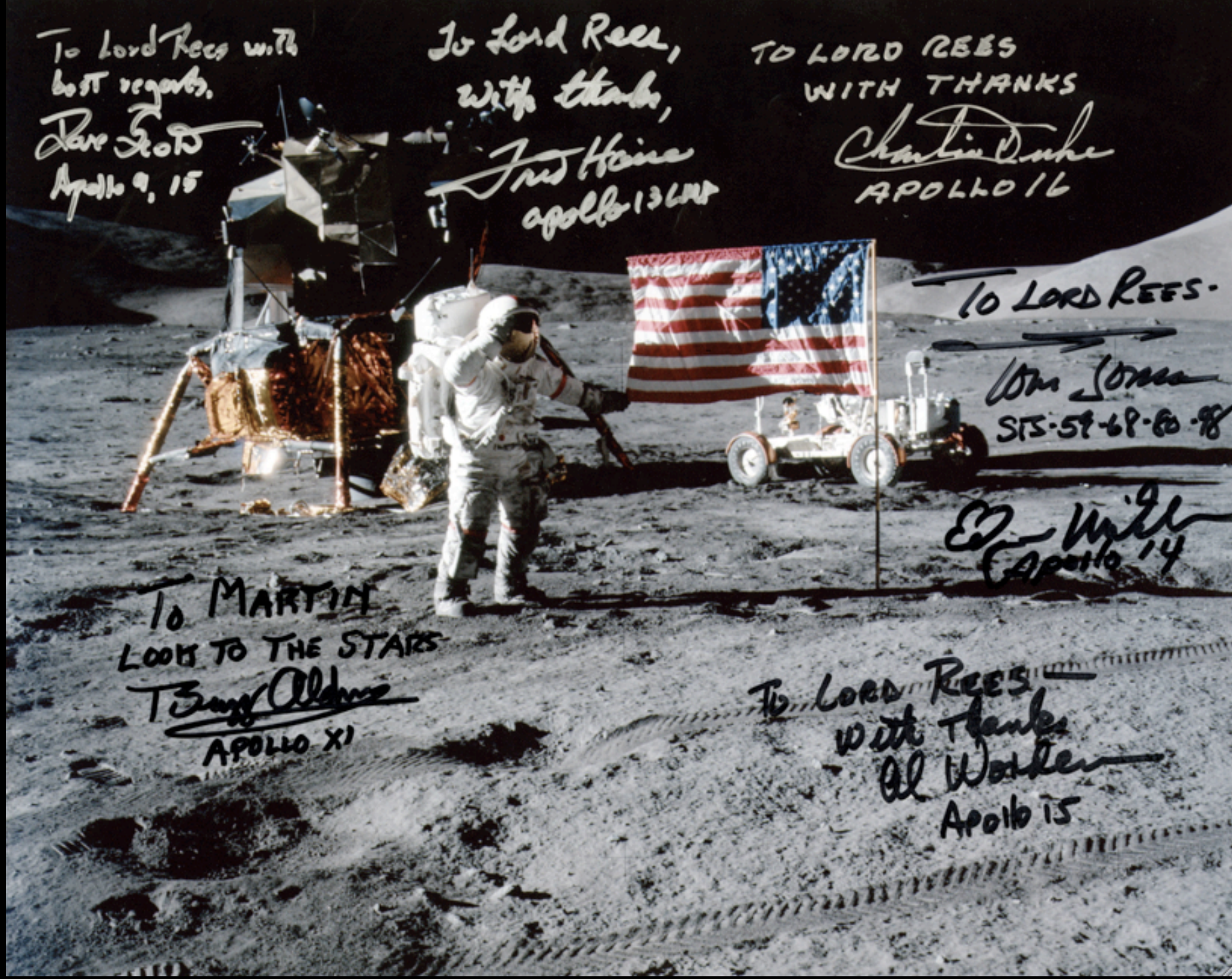
TO LORD REES.

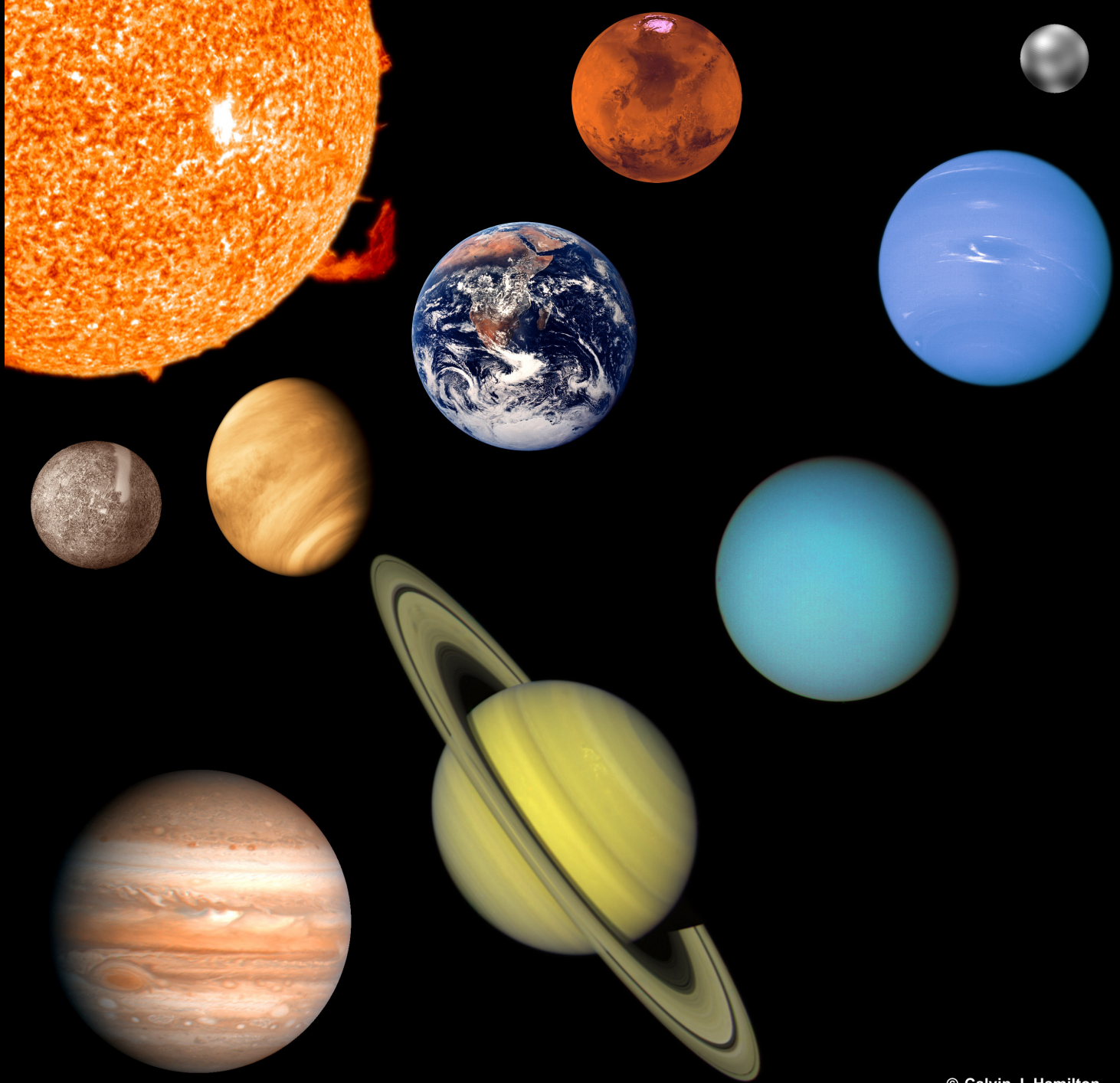
Don Jones  
STS-51-LP-60-98

Ed Will  
Apollo 14

TO MARTIN  
LOOK TO THE STARS  
T Buzz Aldrin  
APOLLO XI

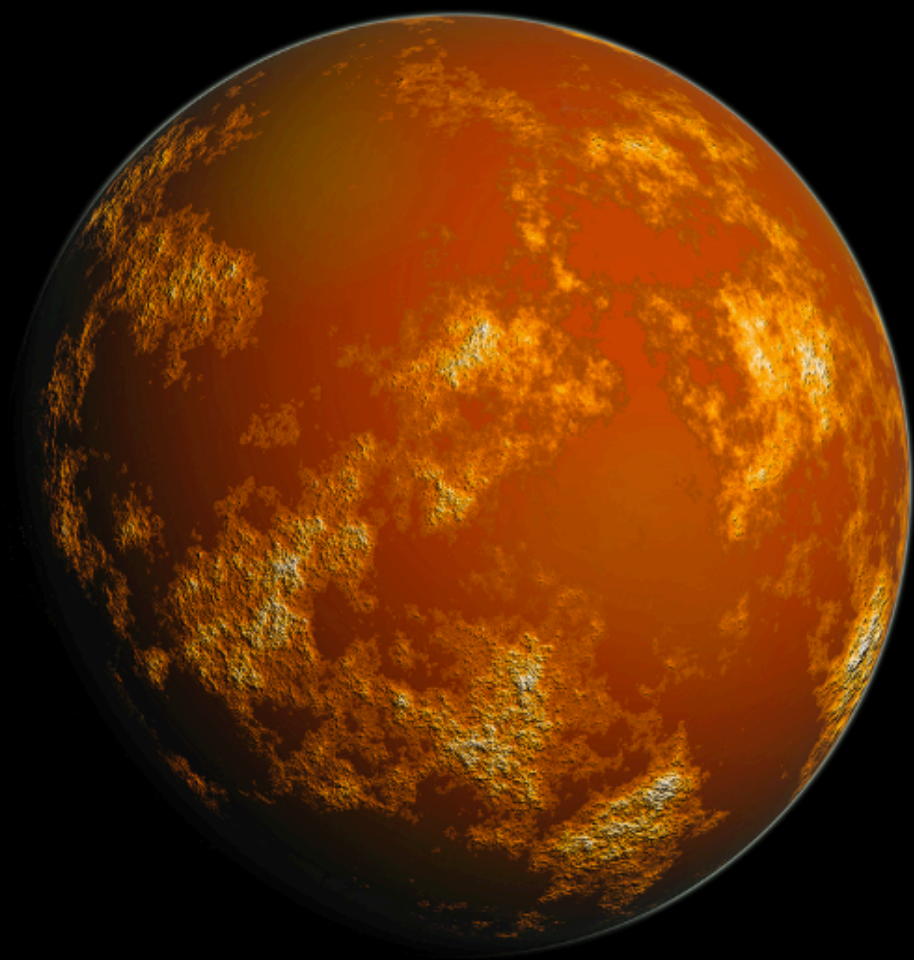
TO LORD REES —  
with thanks  
Al Walker  
Apollo 15

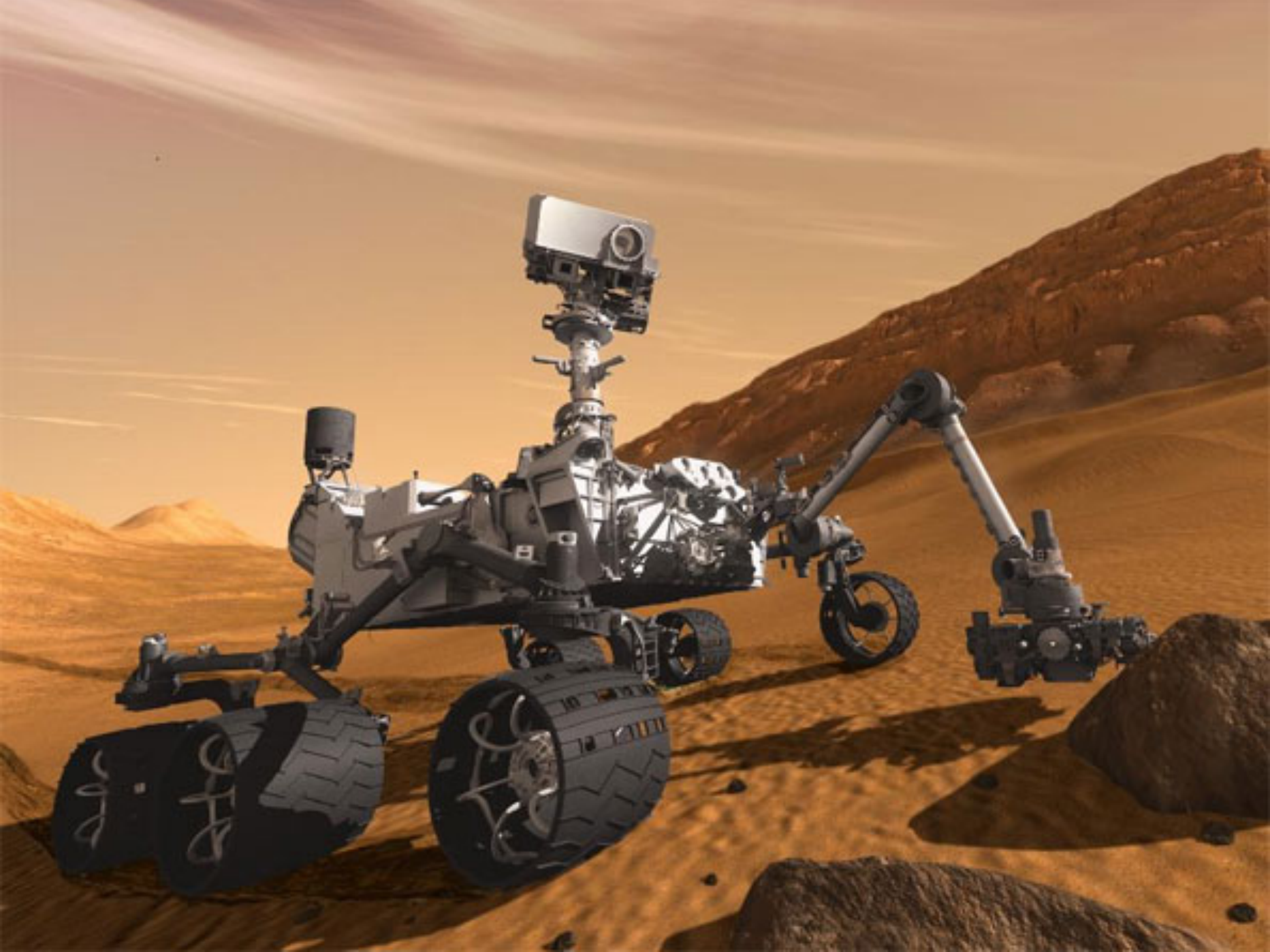


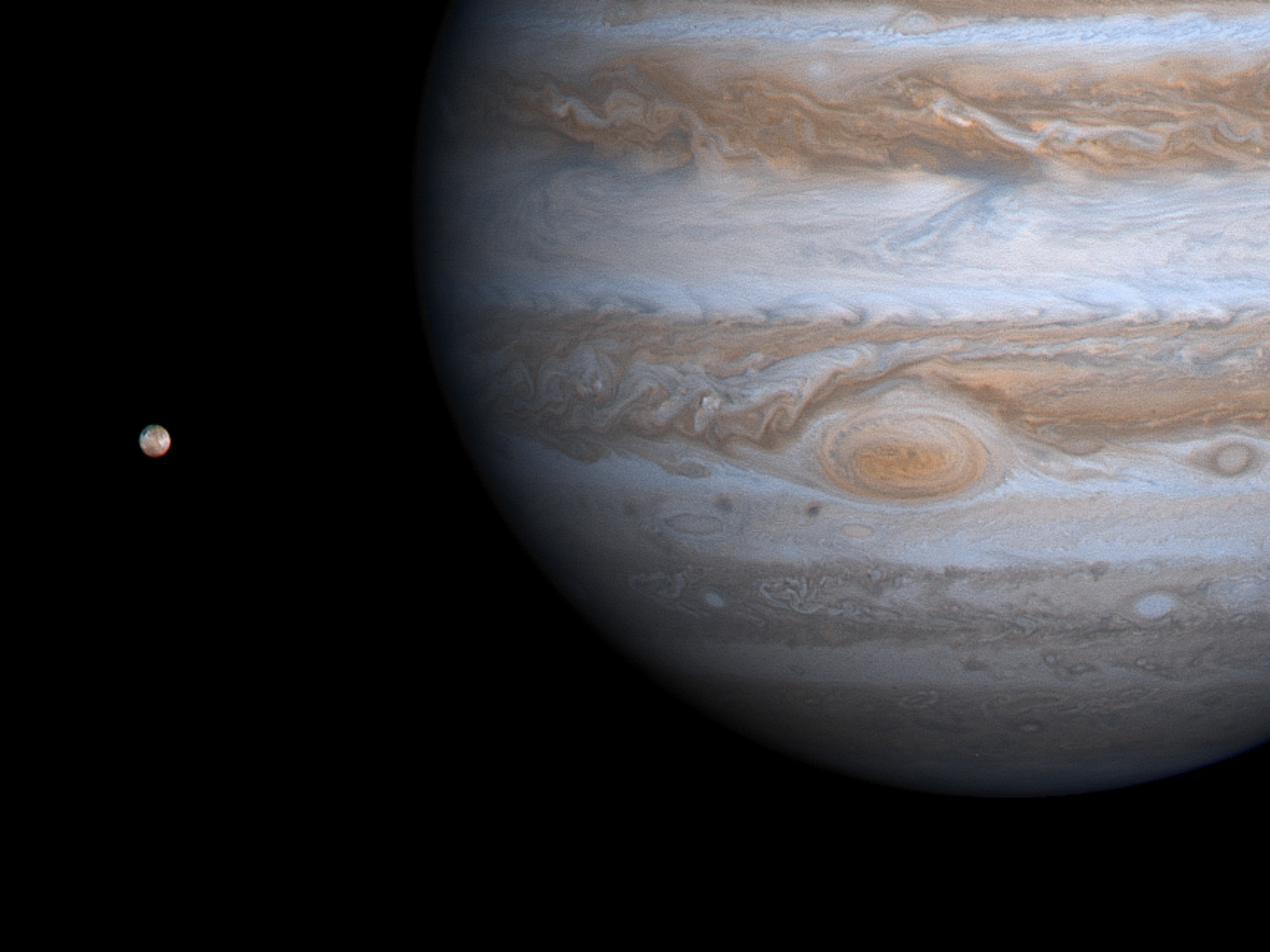


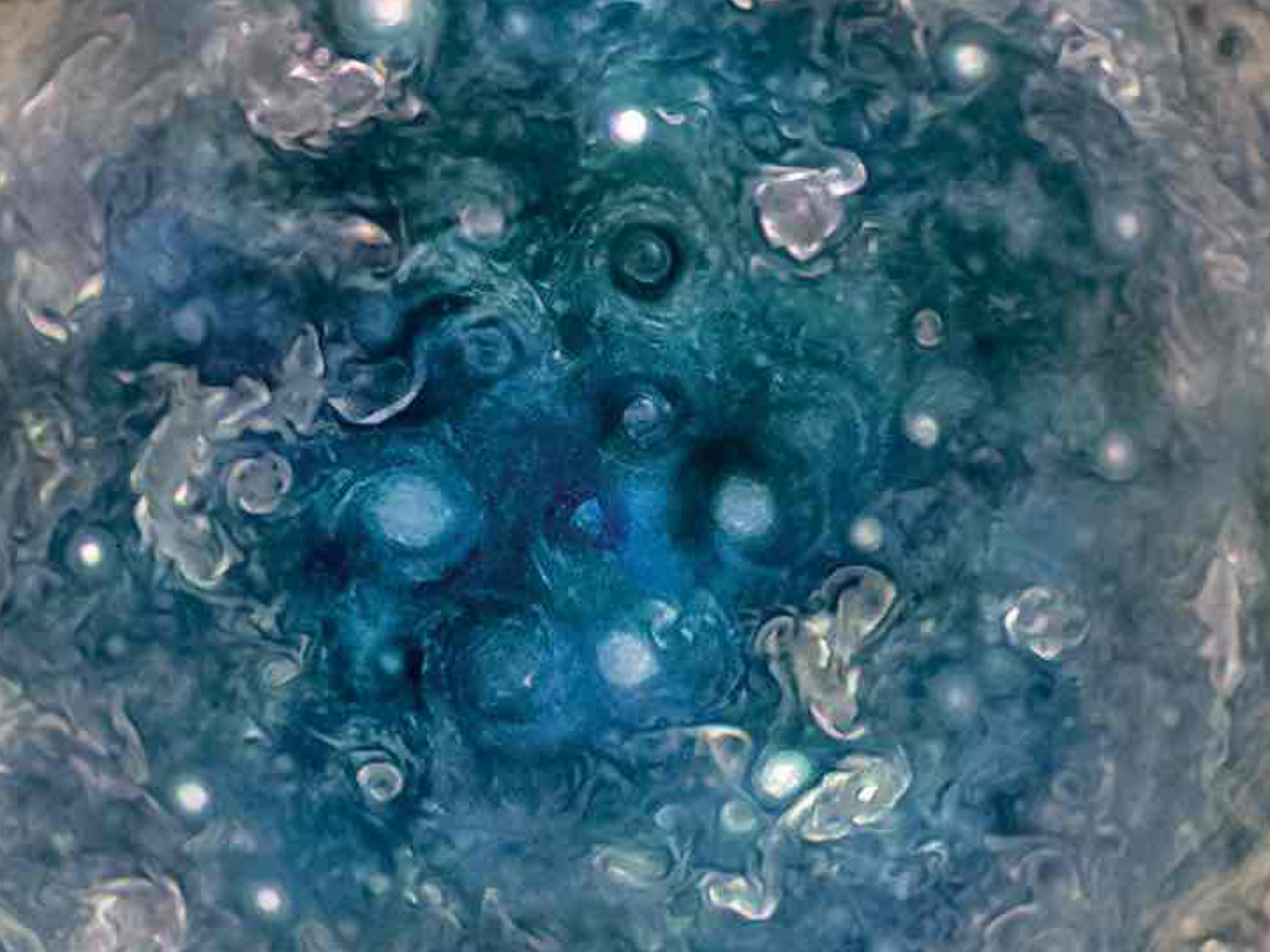




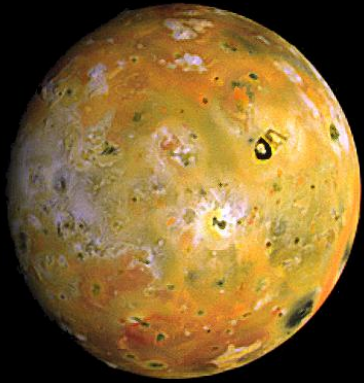




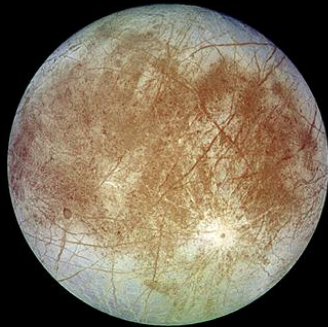




# The Satellites of Jupiter



Io



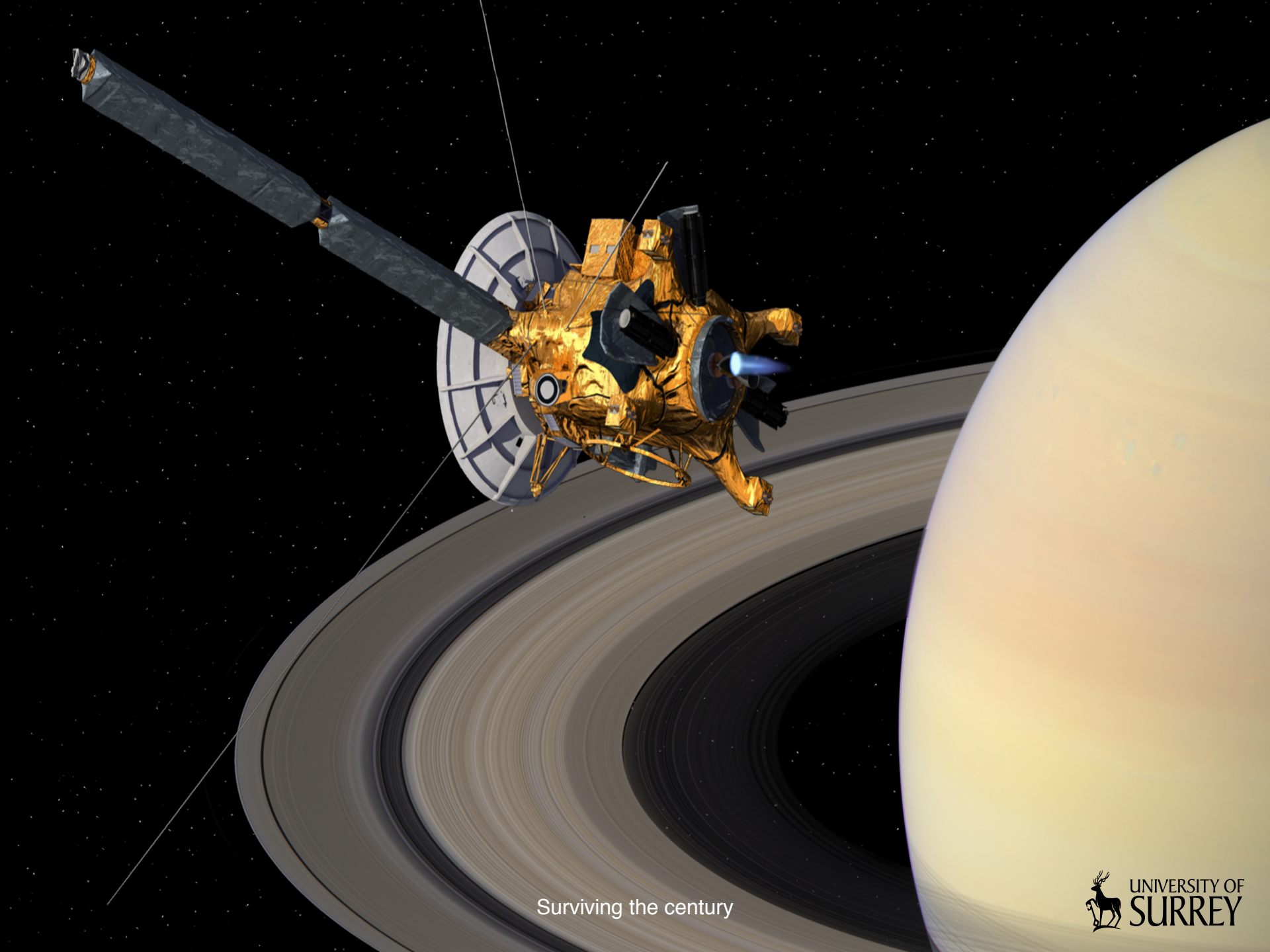
Europa



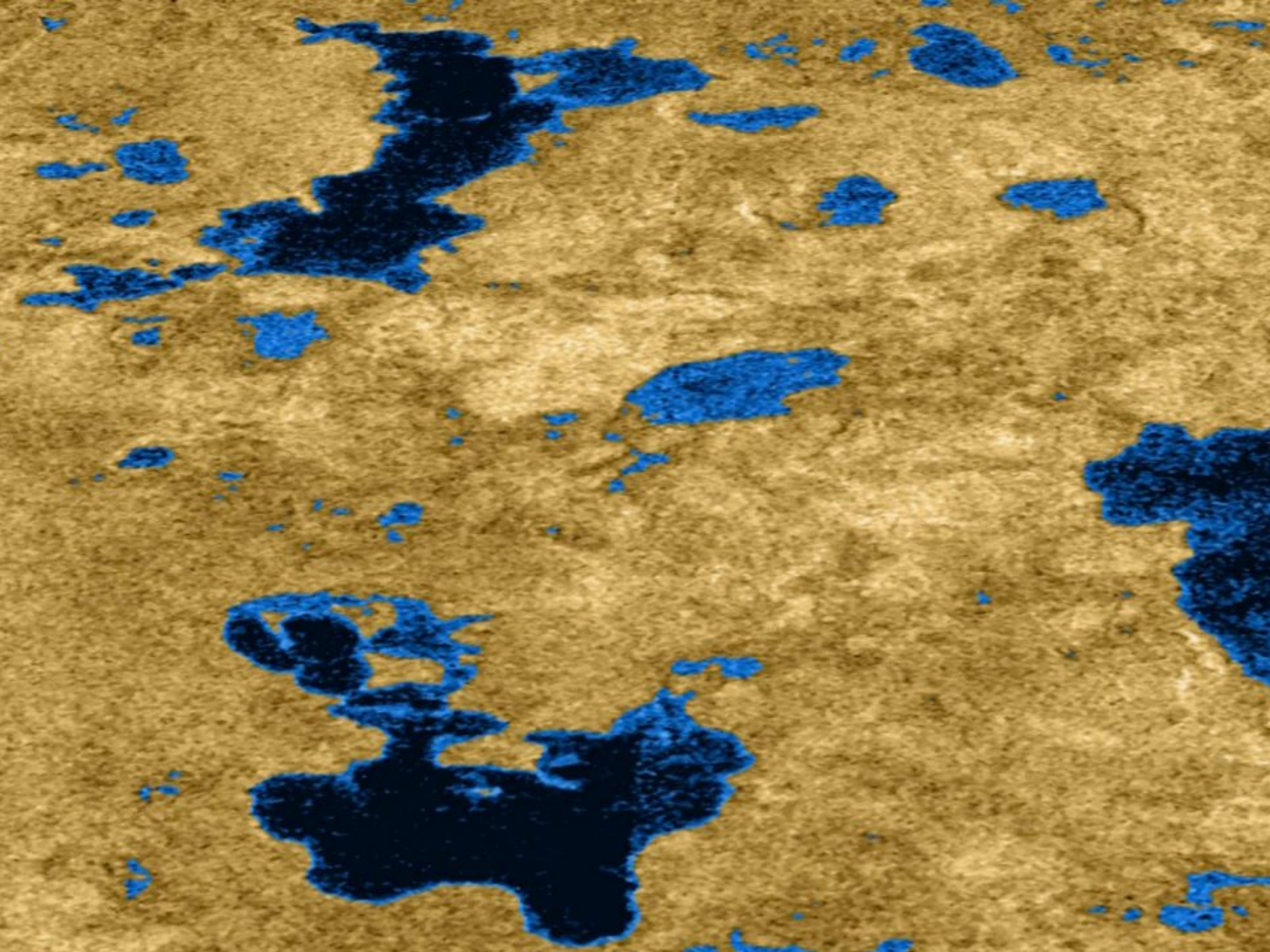
Ganymede

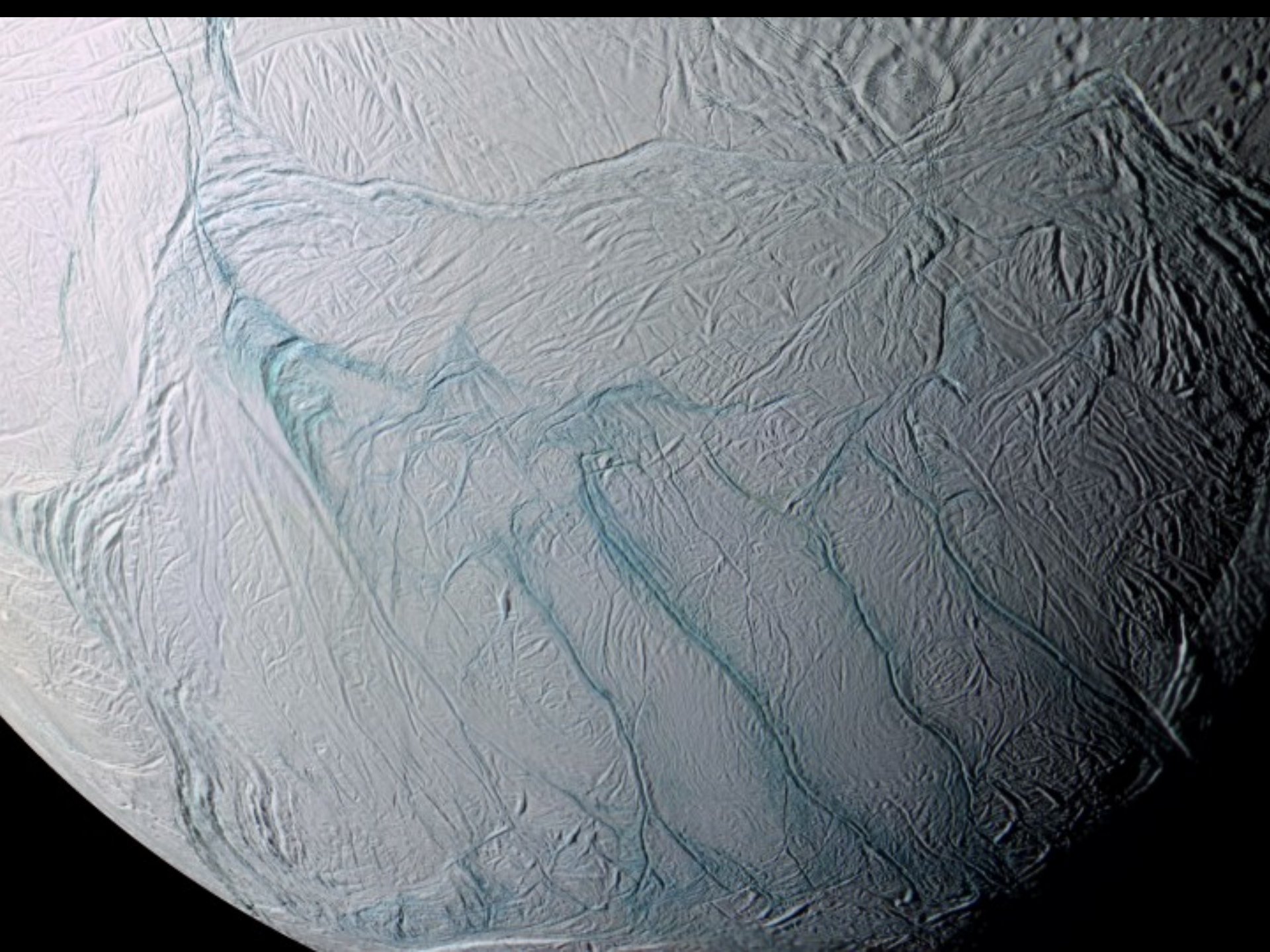


Callisto



Surviving the century







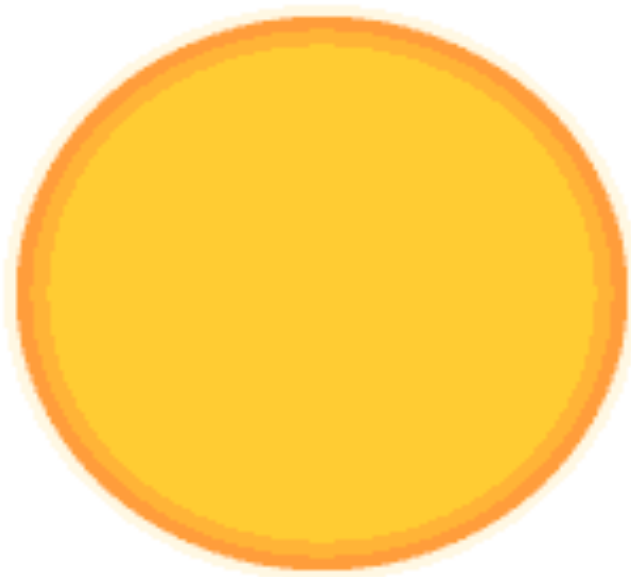
P L U T O  
80,000 KM








# Transit Detection of Exoplanets



—  
Photometric  
Light Curve

An artistic rendering of the Kepler space telescope in space. The telescope is a long, cylindrical instrument with a large, dark, circular aperture at the front. It has several blue solar panel arrays extending from its side. The background is a deep black space filled with numerous white stars. In the upper left, a yellow sun is shown with a thin blue elliptical orbit around it. In the upper right, a blue and white Earth is visible, showing a crescent moon on its surface.

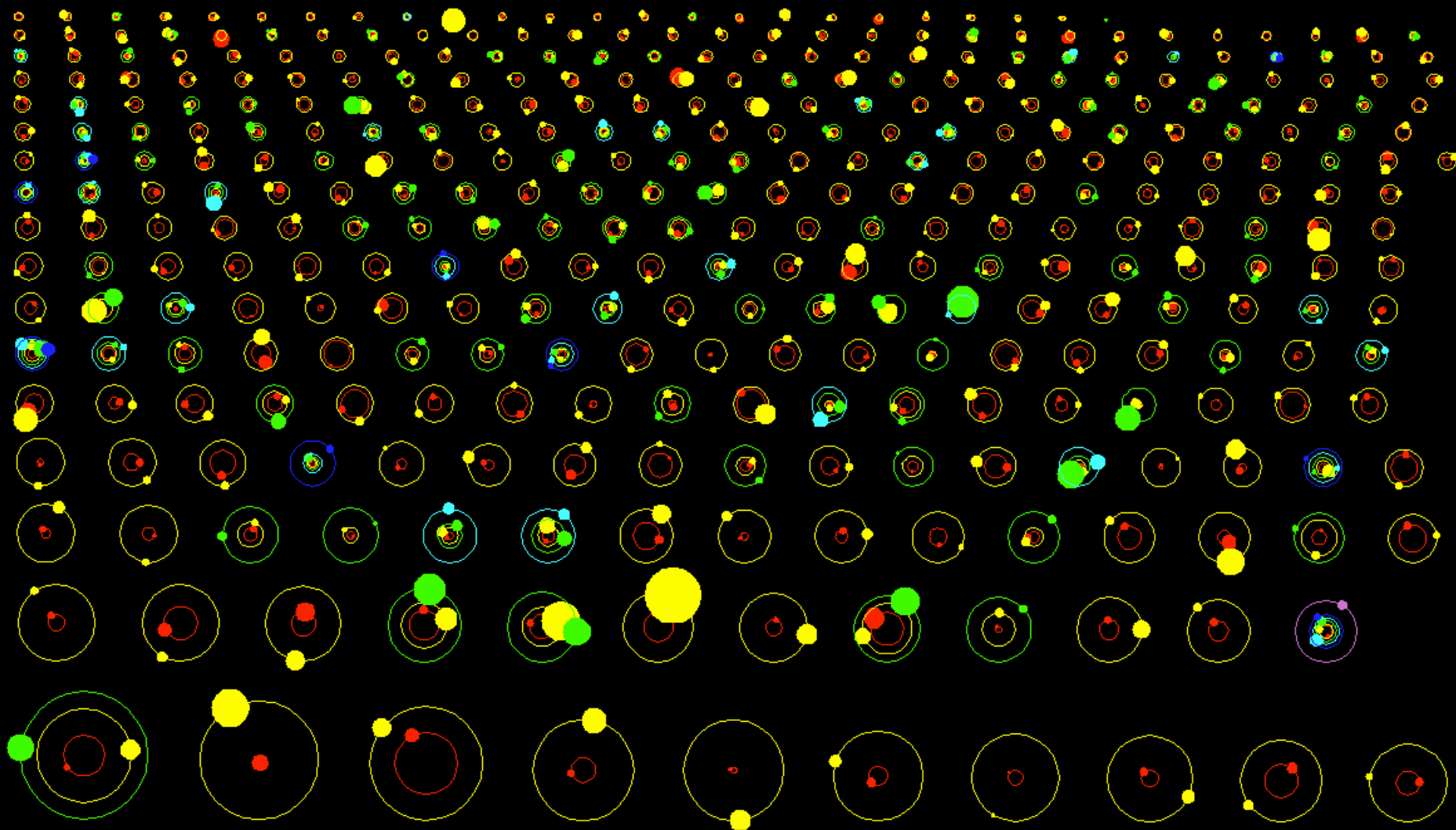
NASA's first  
mission capable  
of finding Earth-size  
and smaller planets

Launch March 09

# The Kepler Orrery II

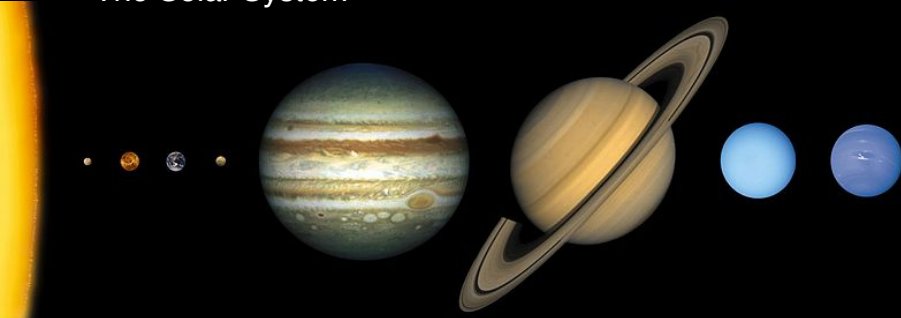
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D. Fabrycky 2012

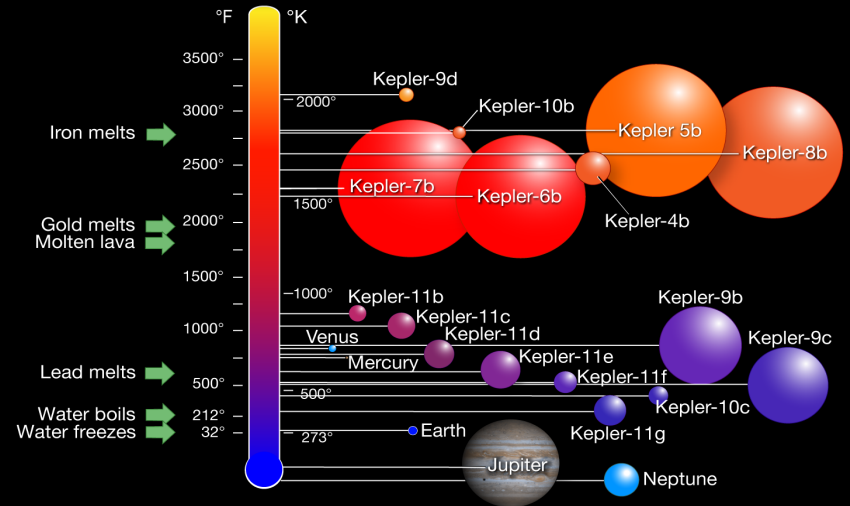


# Exoplanets are extremely diverse in their physical characteristics

The Solar System



Exoplanet Temperatures and Sizes

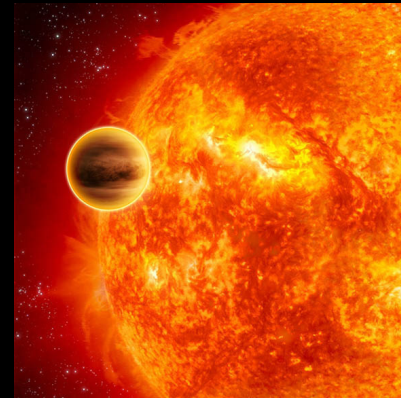
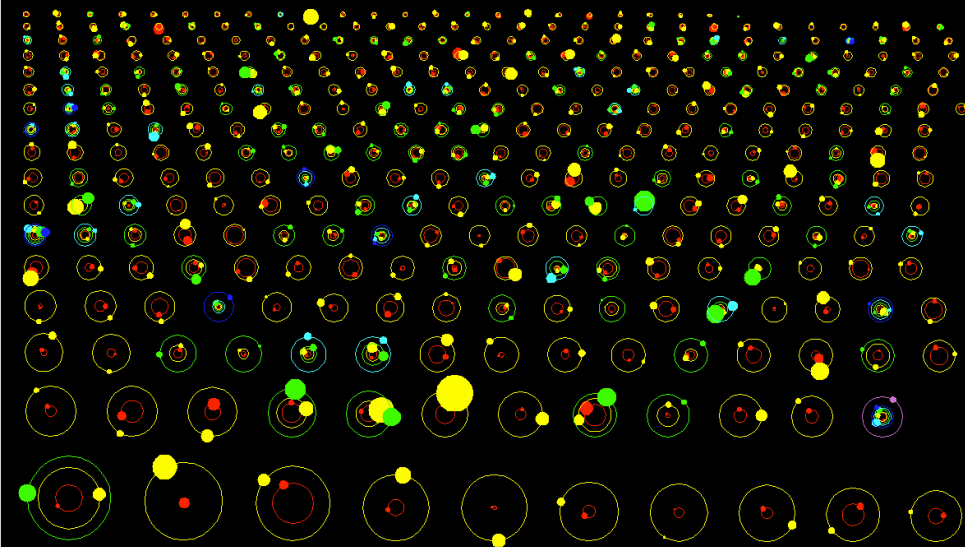


Images credits: NASA

The Kepler Orrery II

t[BJD] = 2455879

D. Fabrycky 2012



Hot Jupiter!

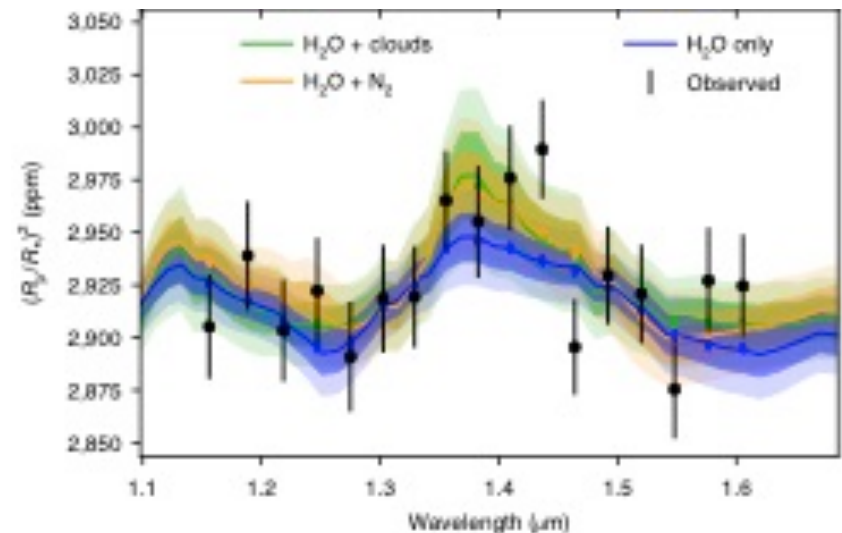
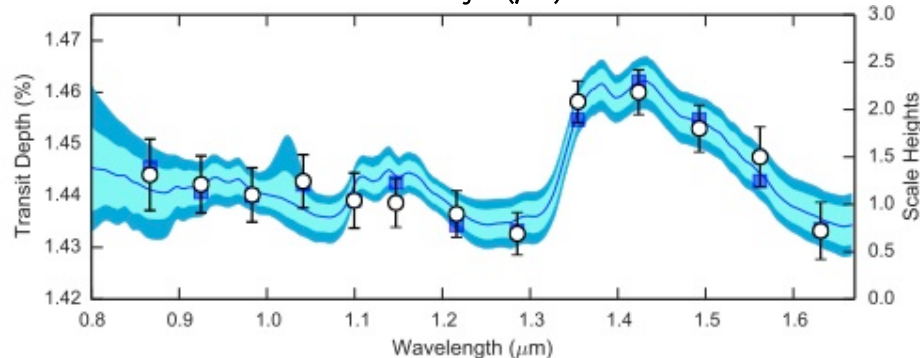
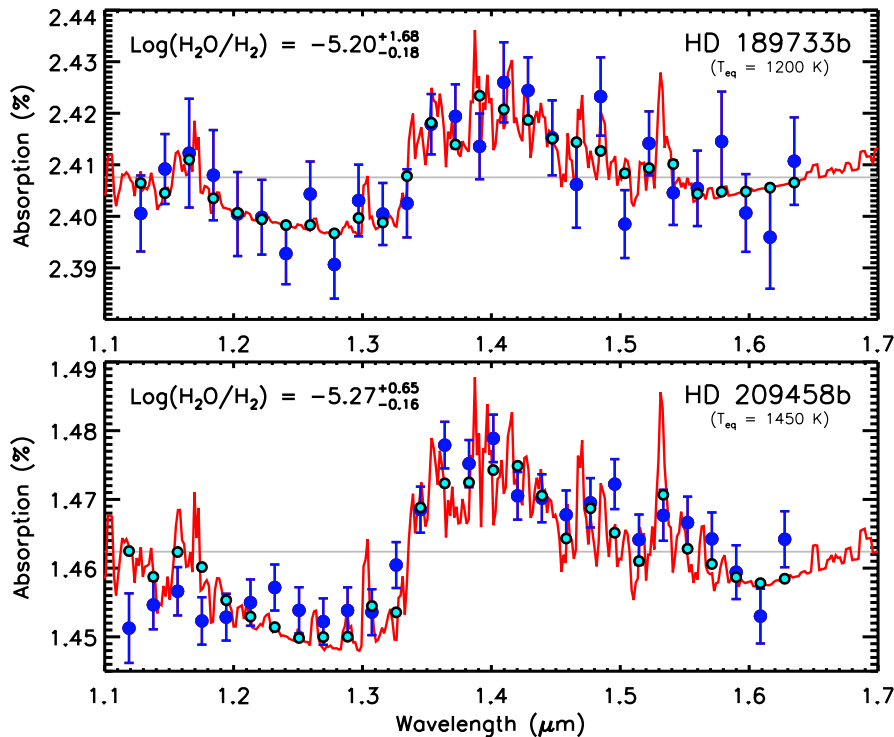


Super-Earth!

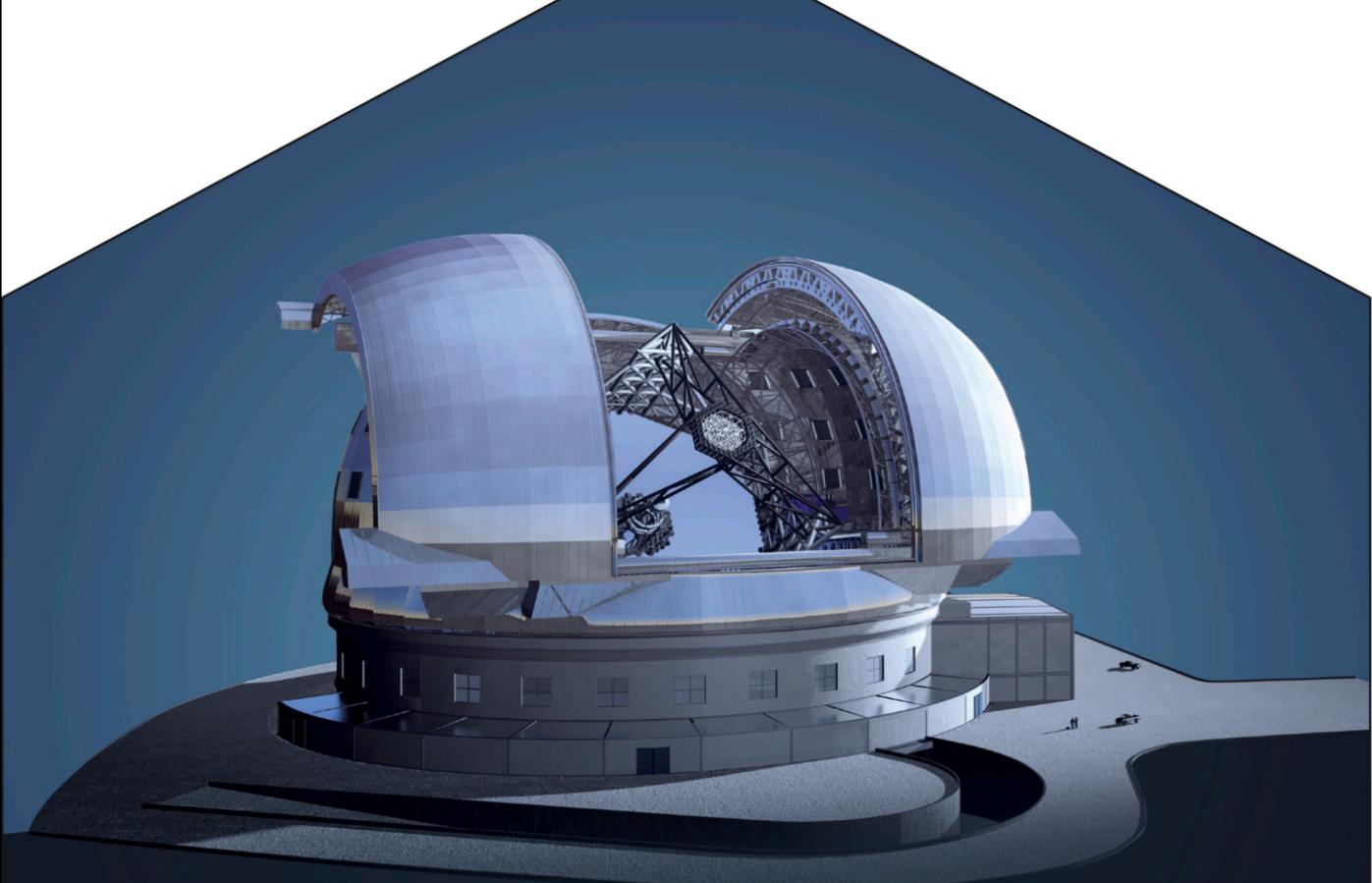
# Detections of H<sub>2</sub>O in Exoplanets



K2-18b: Tsiaras et al. 2019, Benneke et al. 2019



Deming et al. 2013, McCullough et al. 2014,  
Madhusudhan et al. 2014, Kreidberg et al. 2015,



**E-ELT** The European  
Extremely Large Telescope  
The World's Biggest Eye on the Sky

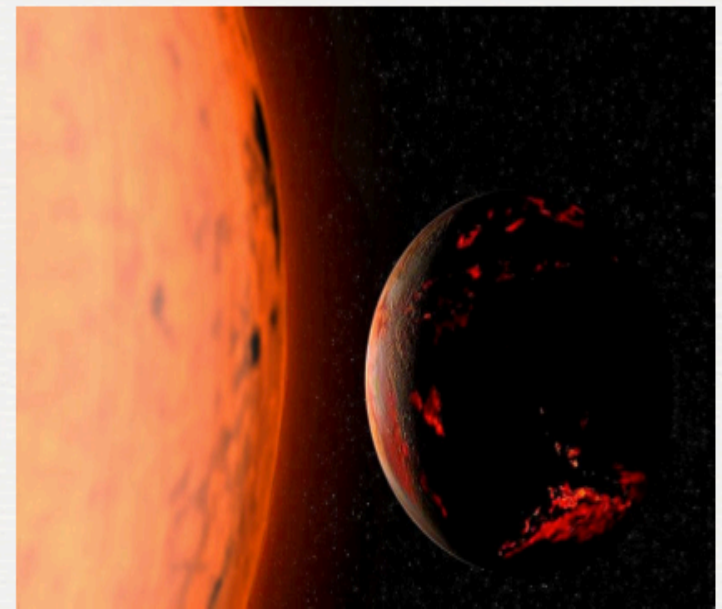
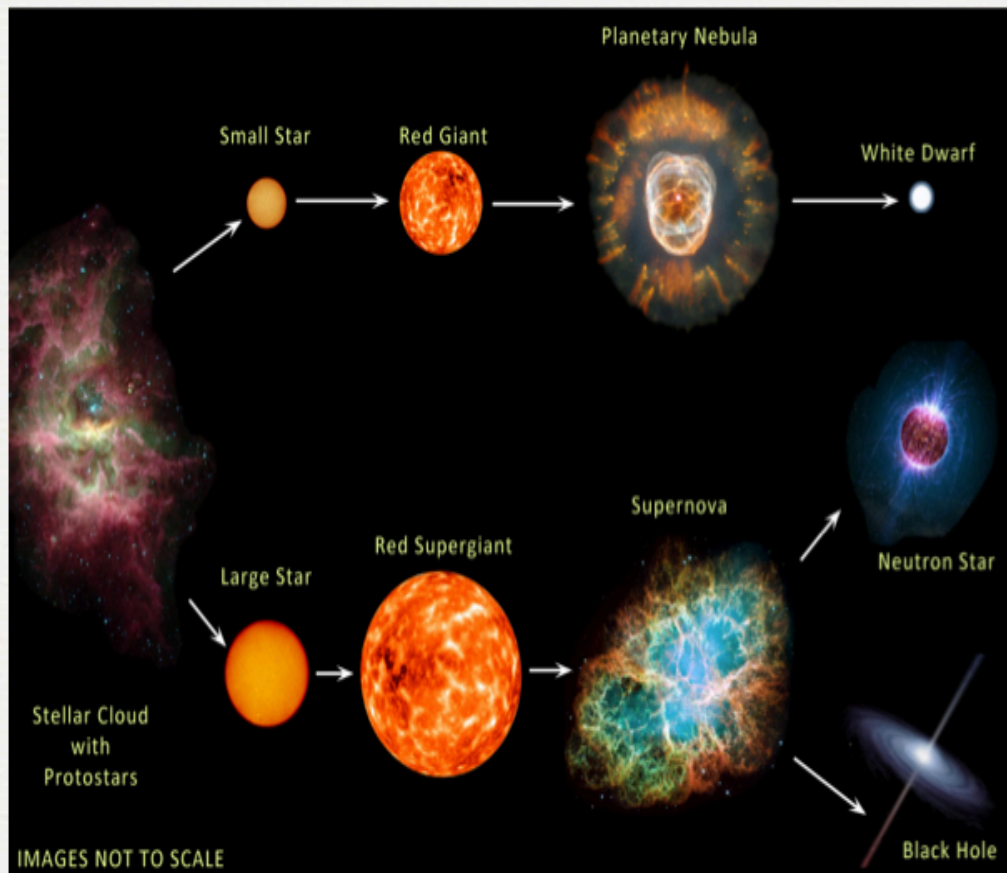
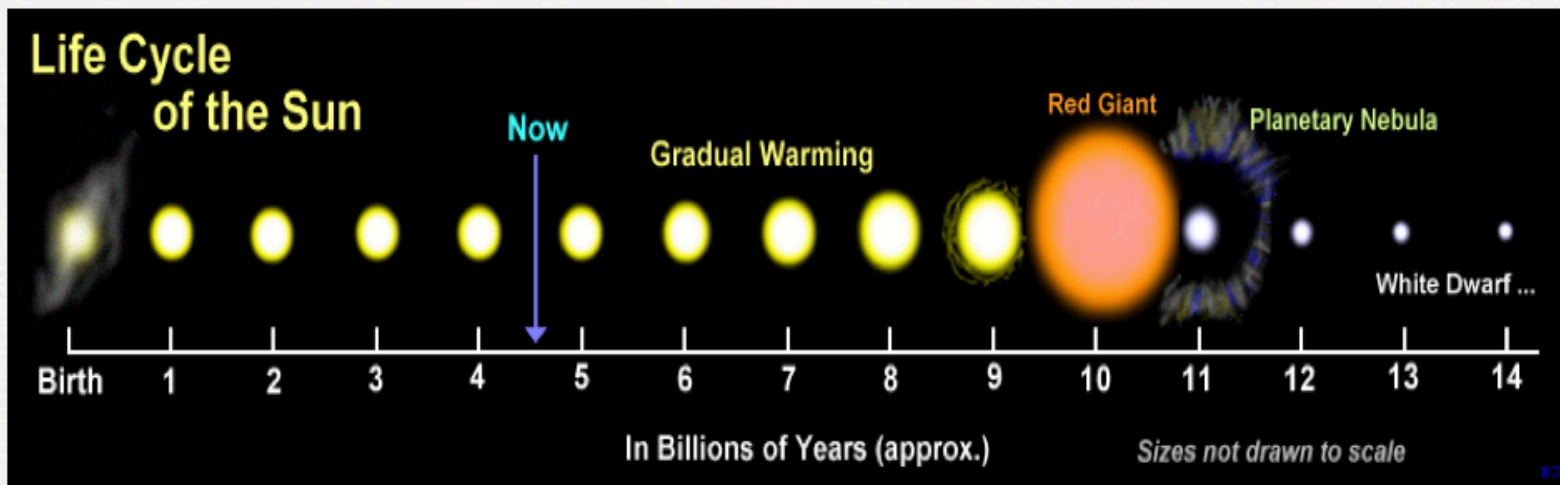


# The Quest for Life in the Universe

Almost every star has a planet around it

One in every six stars has an Earth-size planet

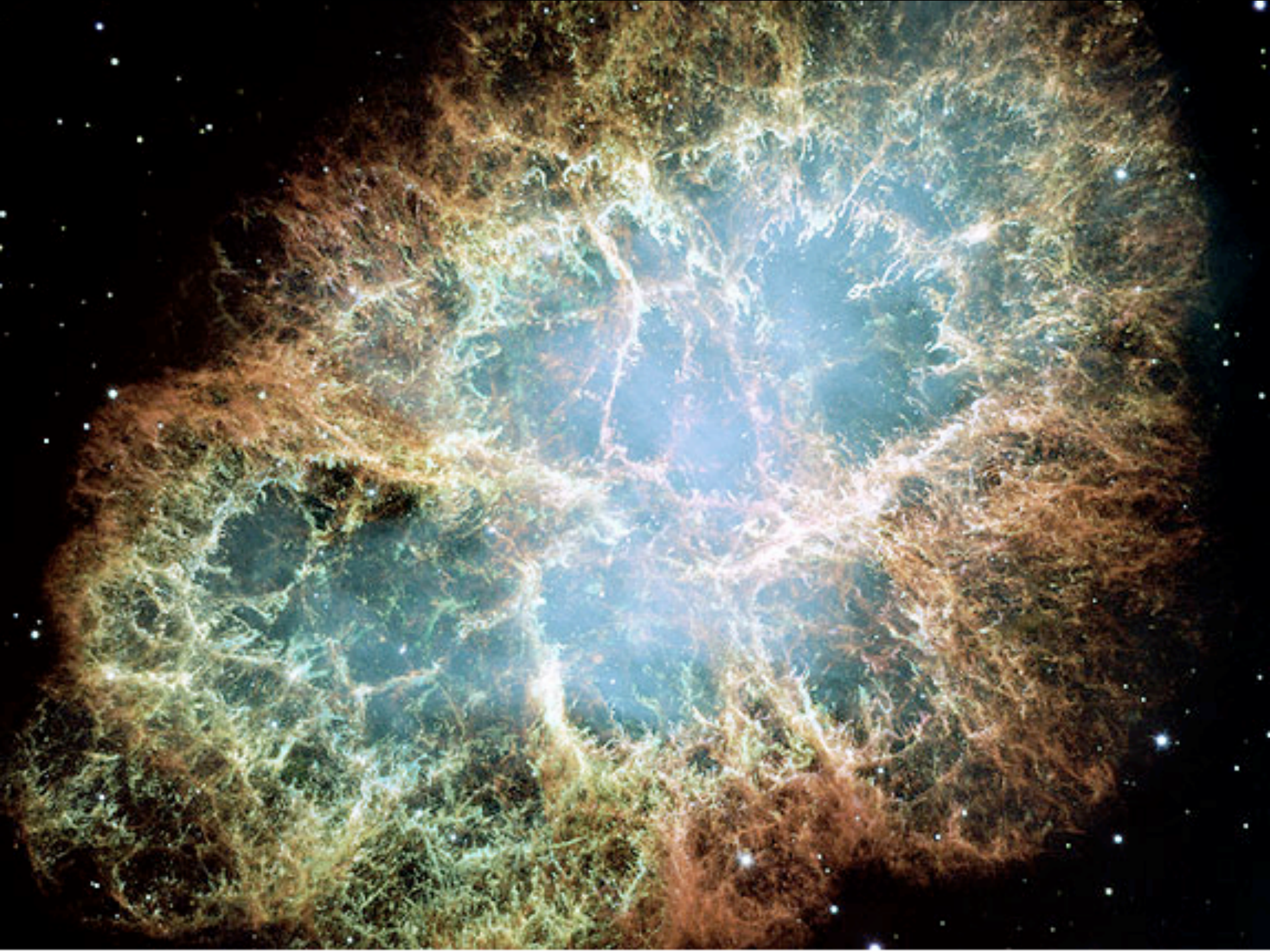




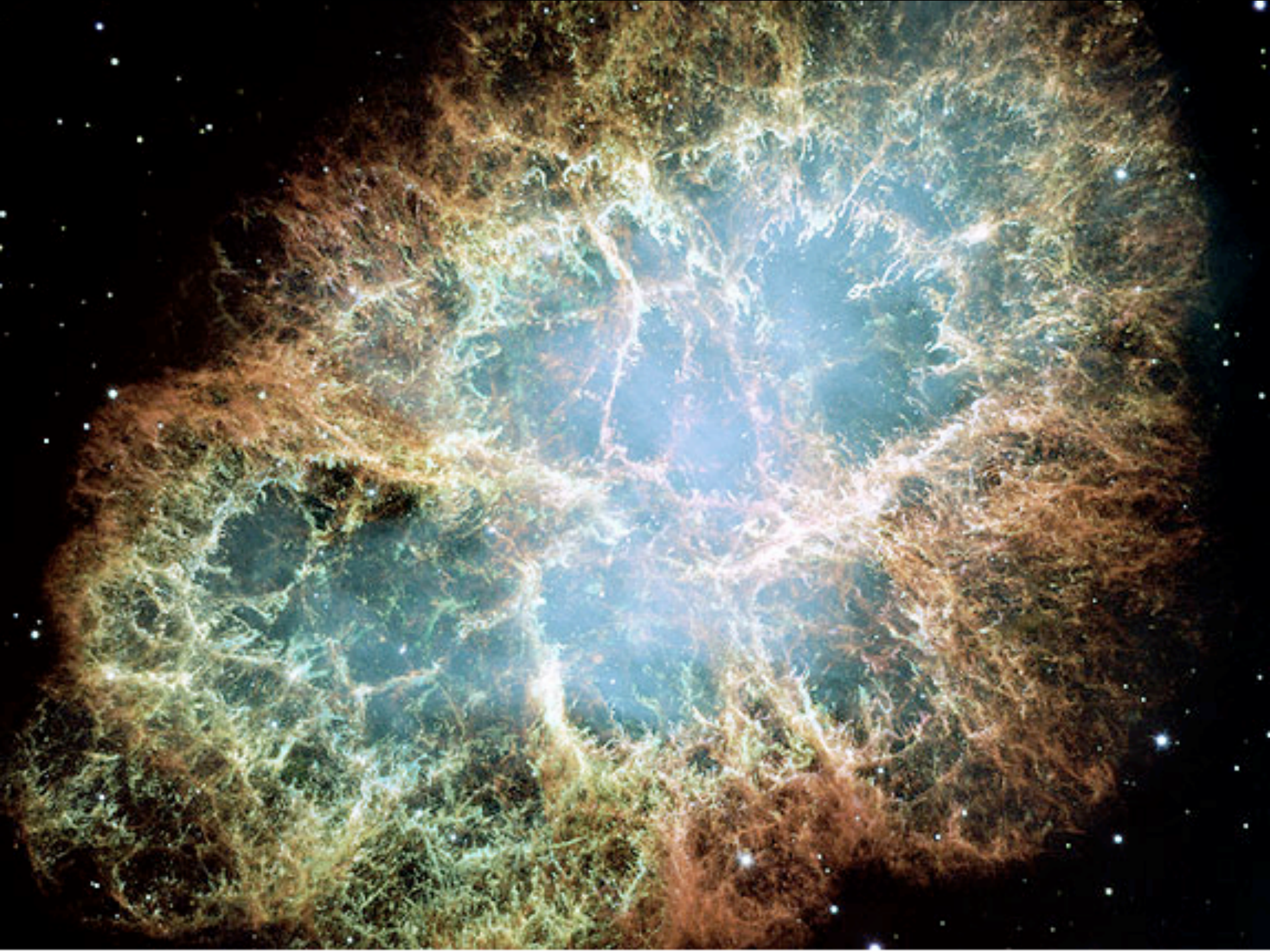
The more massive they are, the shorter their life





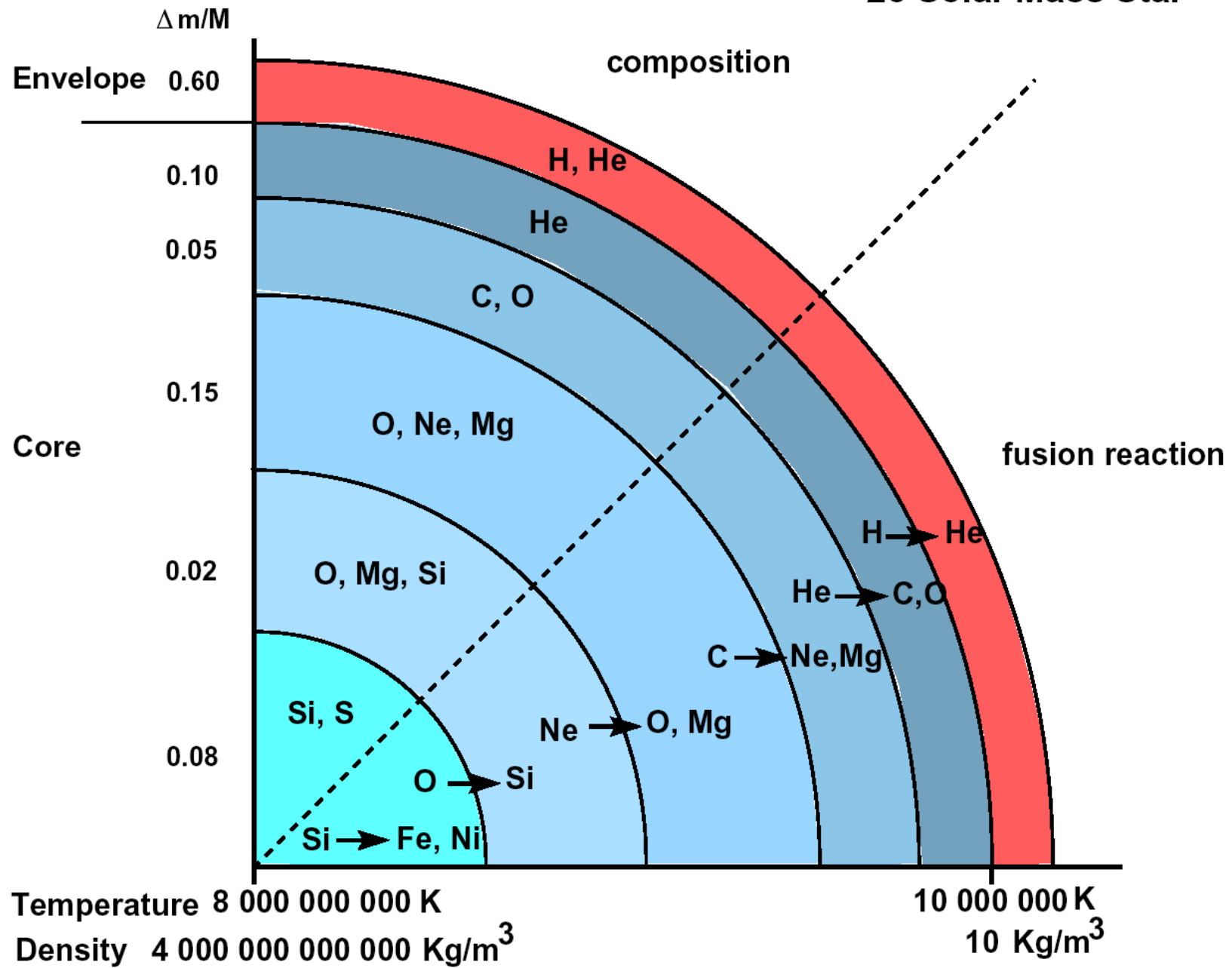


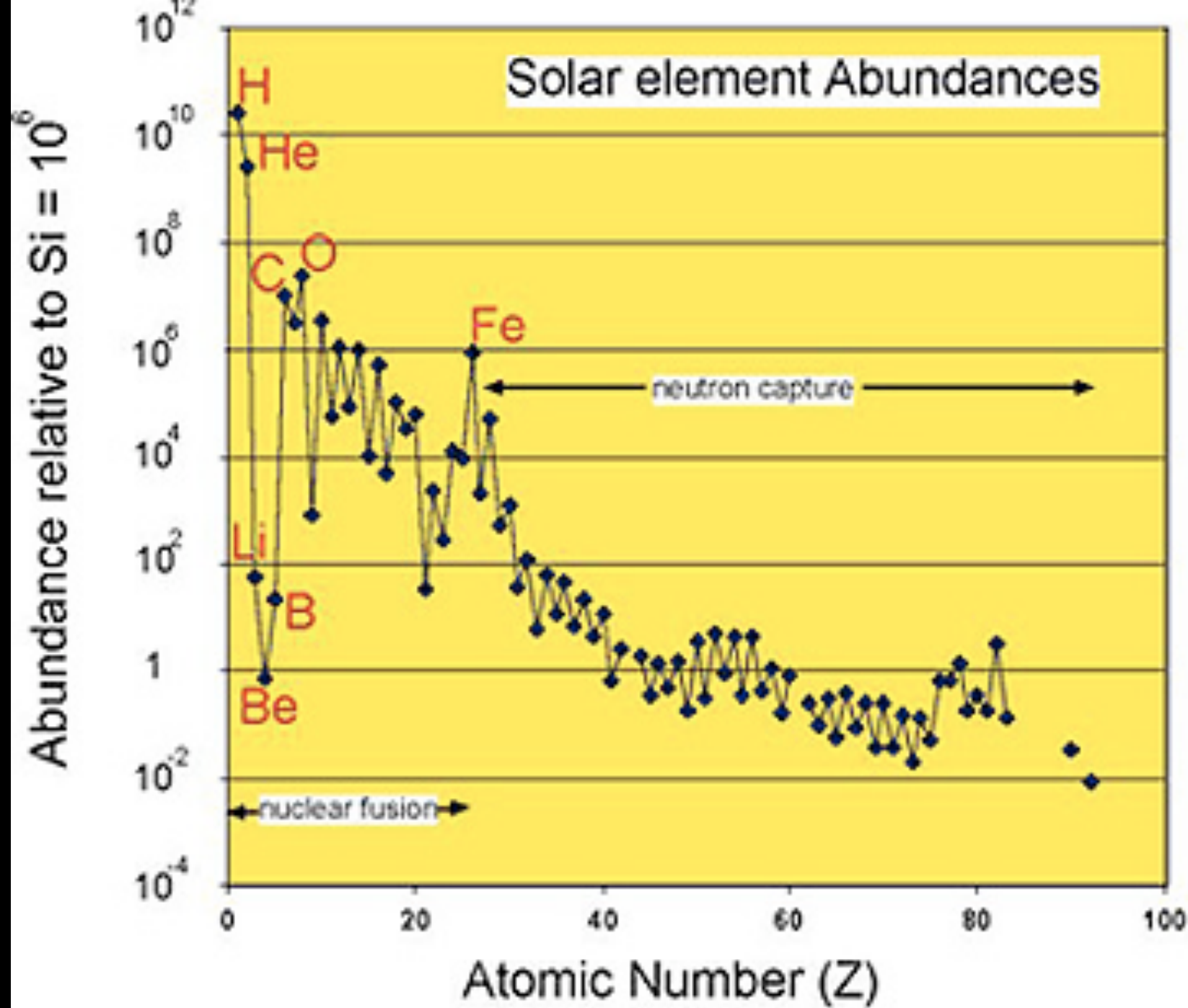
凡十一日沒三年三月乙巳出東南方大中祥符四年正月丁丑見南斗魁前天禧五年四月丙辰出軒轅前星西北大如桃連行經軒轅太星入太微垣掩右執法犯次將歷屏星西北凡七十五日入濁沒明道元年六月乙巳出東北方近濁有芒彗至丁巳凡十三日沒至和元年五月己丑出天關東南可數寸歲餘稍沒熙寧二年六月丙辰出箕度中至七月丁卯犯箕乃散三年十一月丁未出天因元祐六年十一月辛亥出參度中犯掩側星壬子犯九游星十二月癸酉入奎至七年三月辛亥乃散紹興八年五月守婁

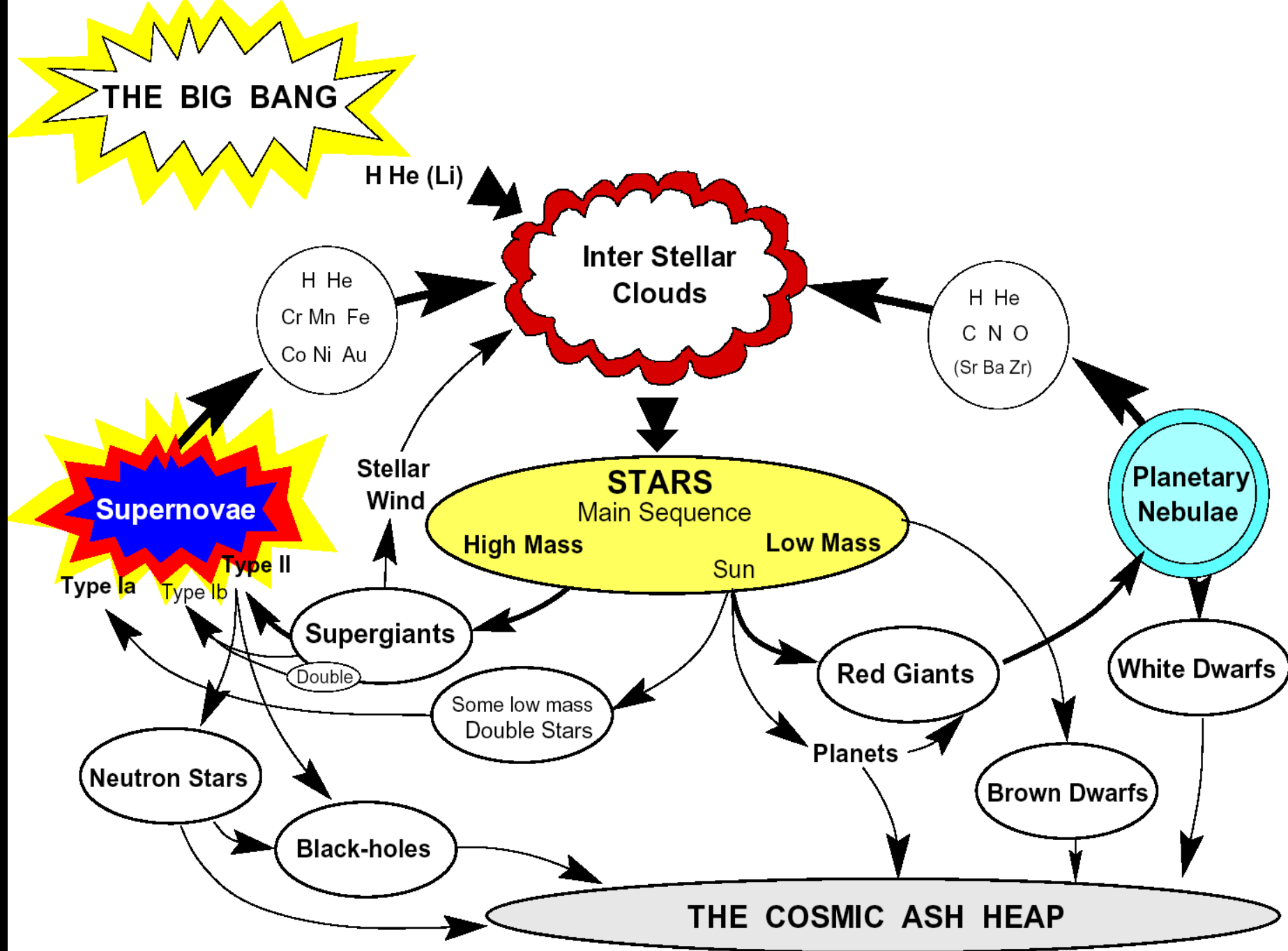


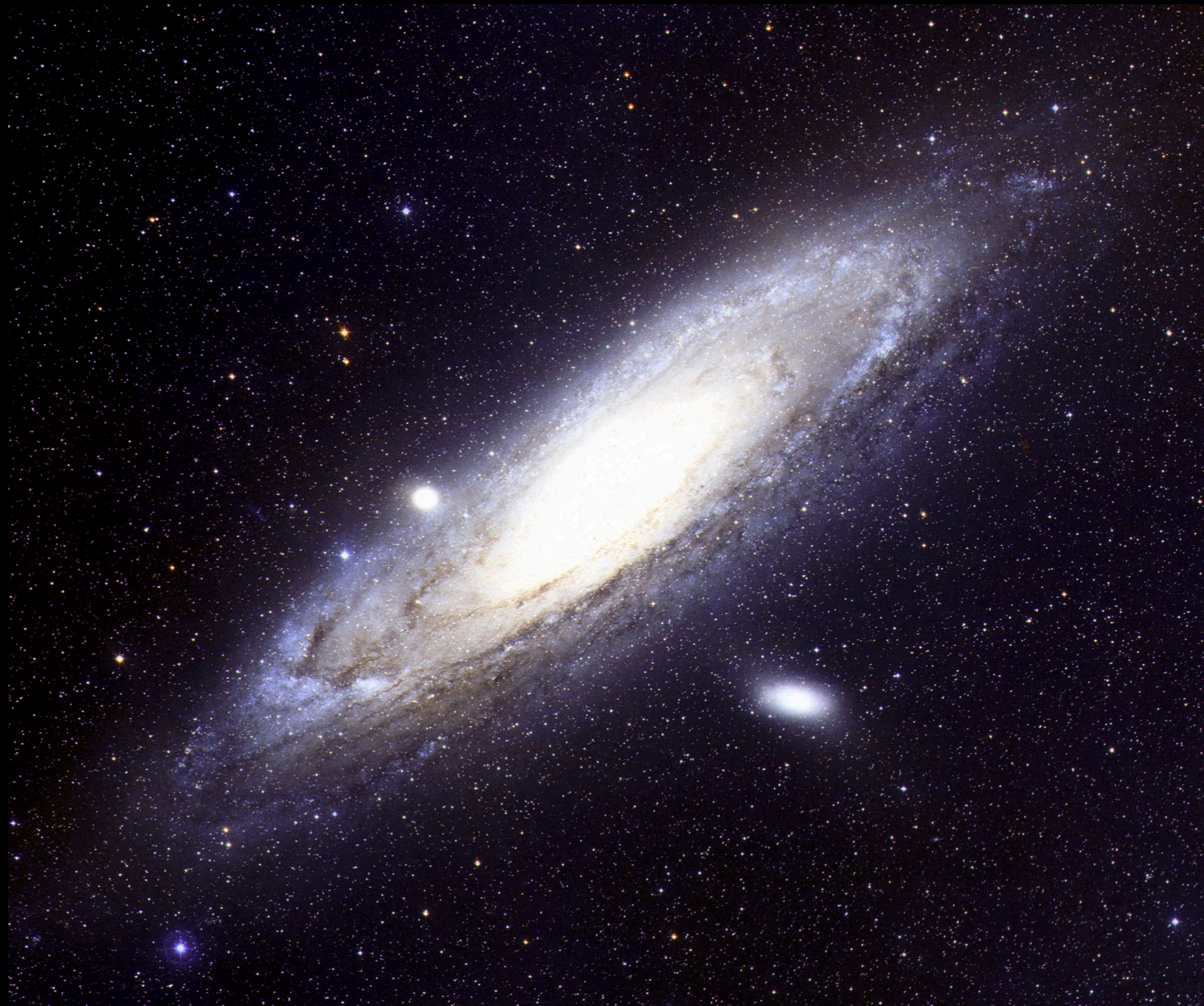


# 25 Solar Mass Star











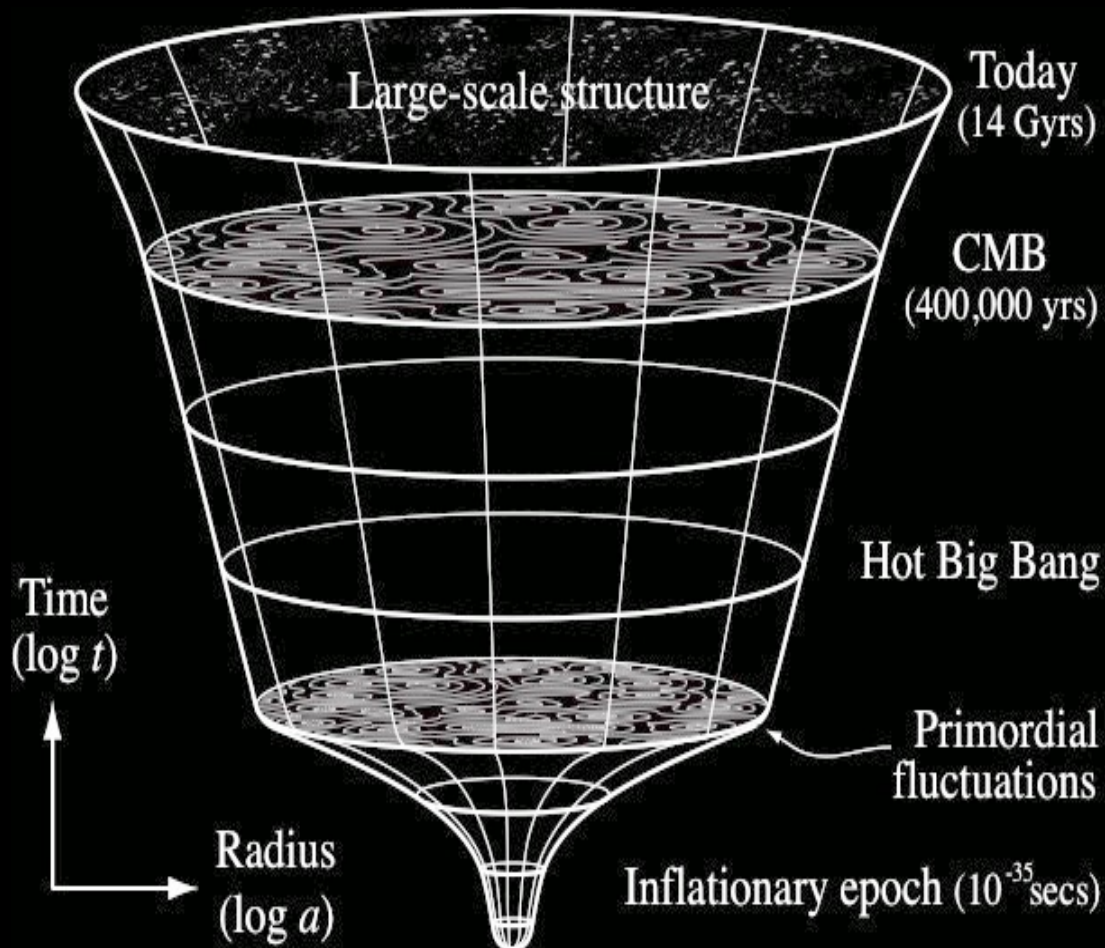






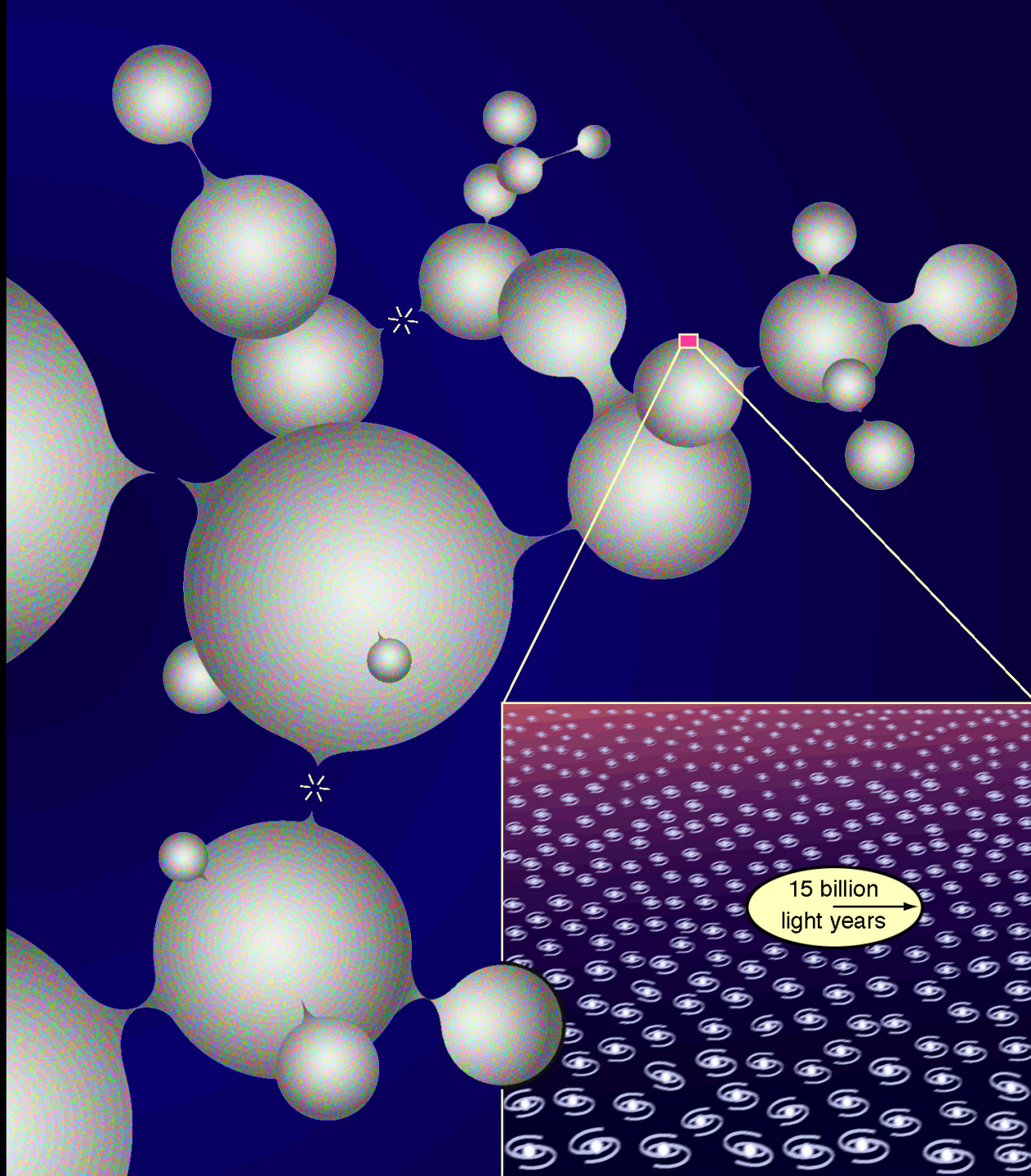


*The primordial seeds for all the structure in the universe – galaxies, stars, planets, you and I - can be generated during inflation ...*



## BEYOND THE HORIZON

How extensive is the “physical reality” that’s within the remit of science?



# THE BIG QUESTION

The physical laws and basic numbers  
are  
constant *within our horizon*.

*BUT COULD THEY BE DIFFERENT IN  
OTHER DOMAINS IF THESE ARE FAR  
MORE EXTENSIVE ??*

# HOW MANY BIG BANGS?

one

many

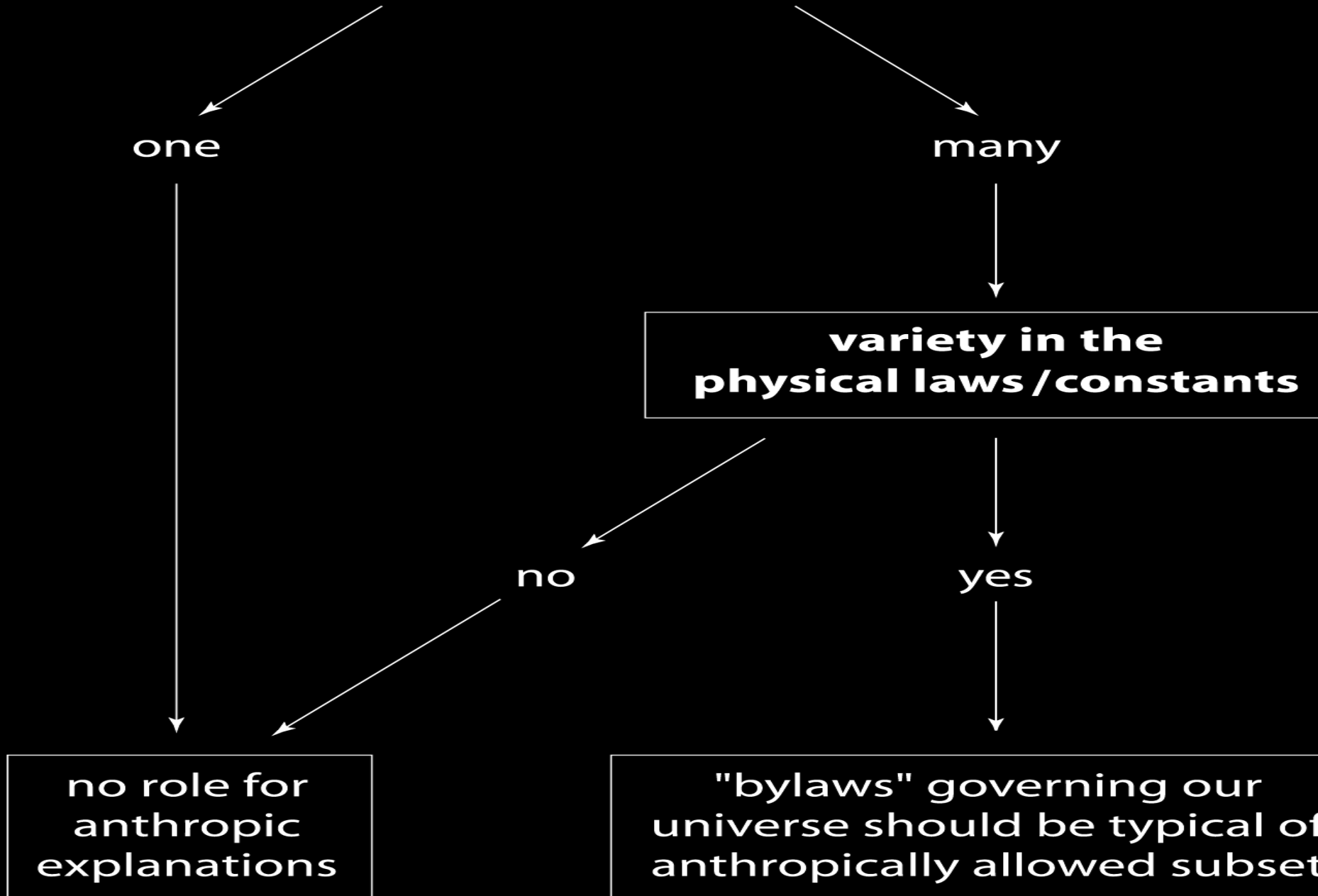
**variety in the  
physical laws / constants**

no

yes

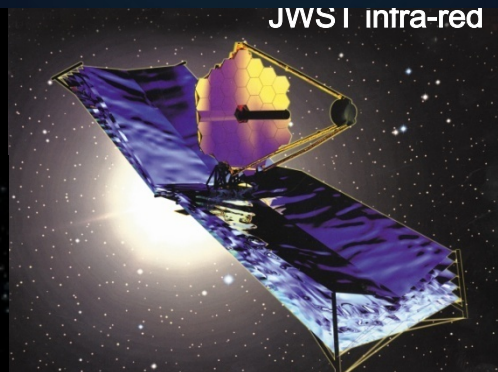
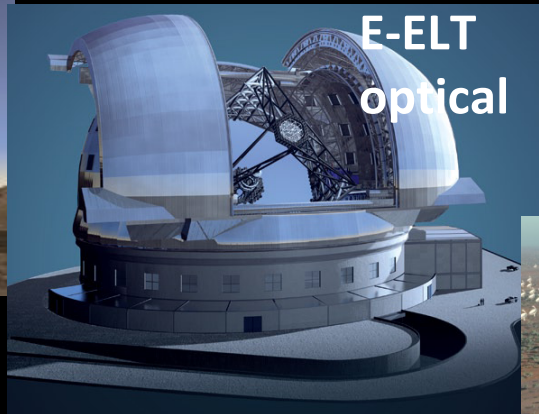
no role for  
anthropic  
explanations

"bylaws" governing our  
universe should be typical of  
anthropically allowed subset



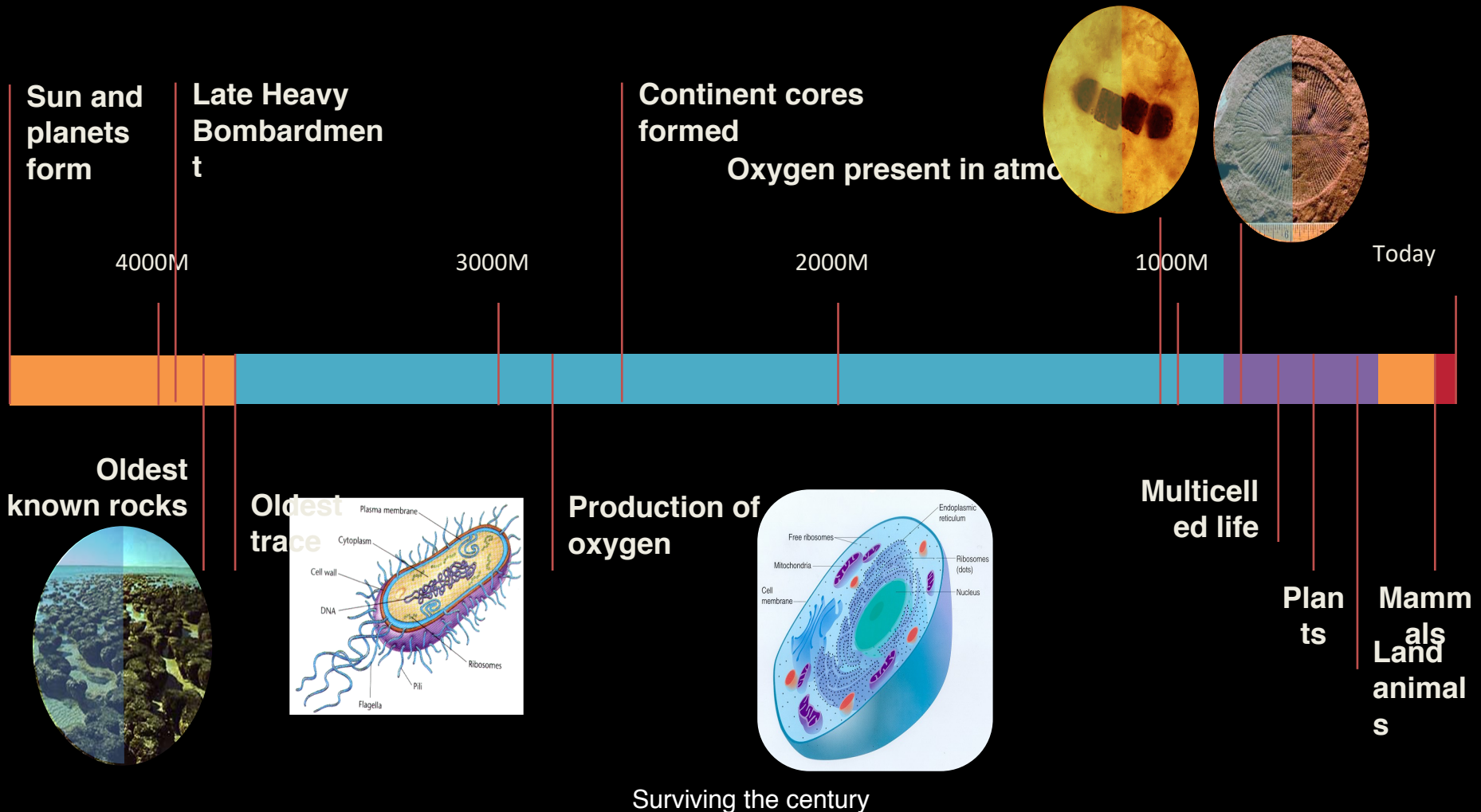


# Great Observatories for the coming decades

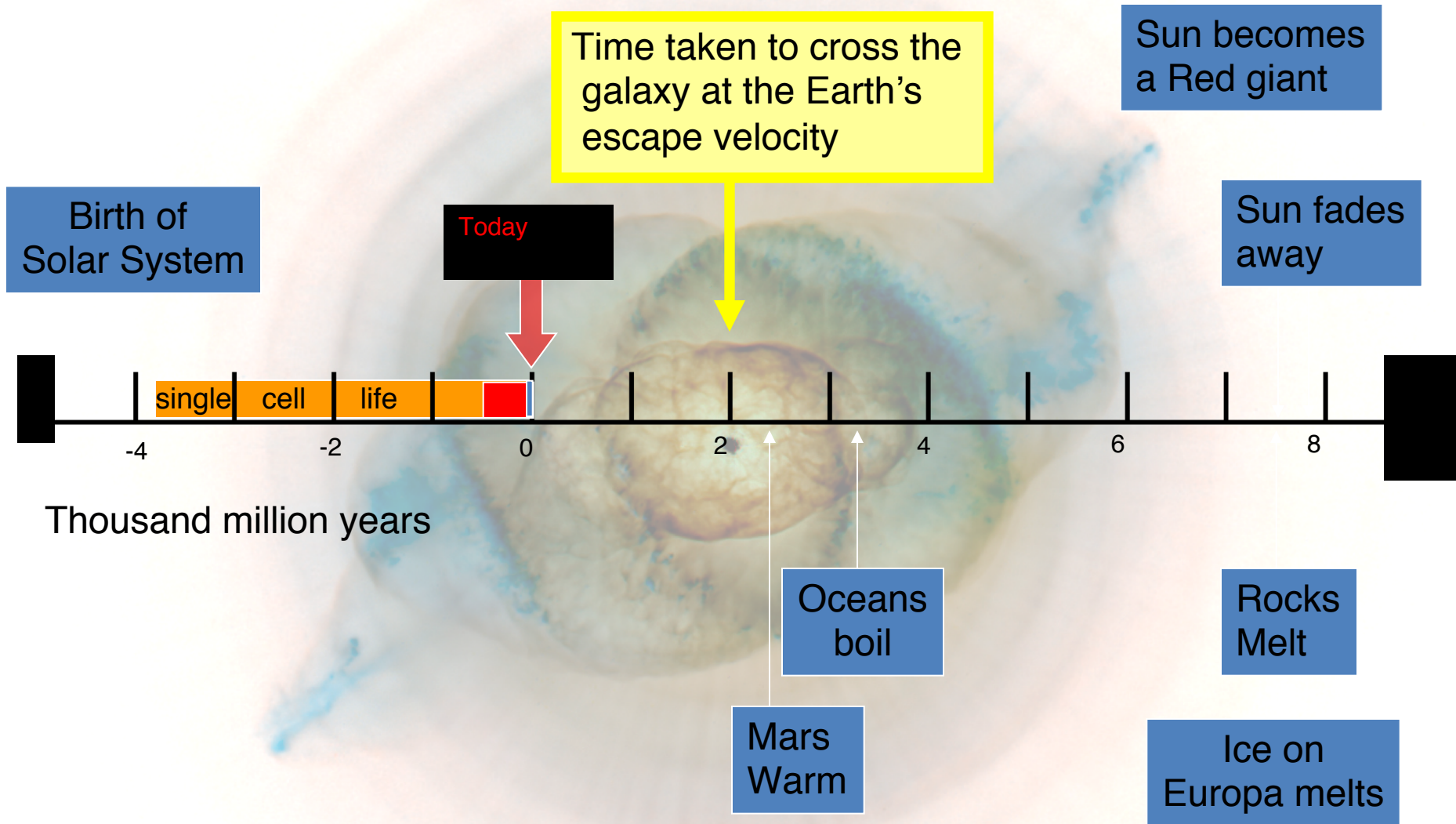




# History of Life on Earth



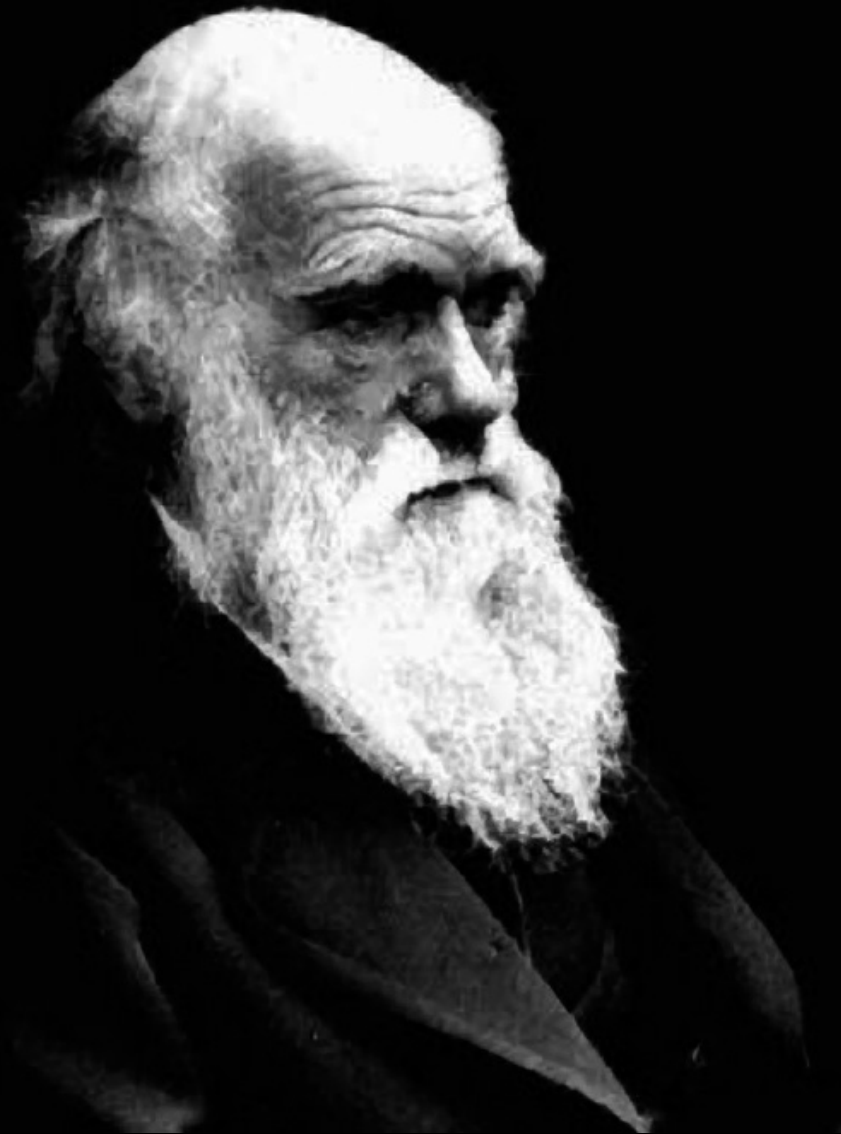
# The Past and Future of Life on Earth



# Postcard from planet Earth



we were here



**"not one living species  
will transmit its  
unaltered likeness to a  
distant futurity.... "**

**Charles Darwin**





