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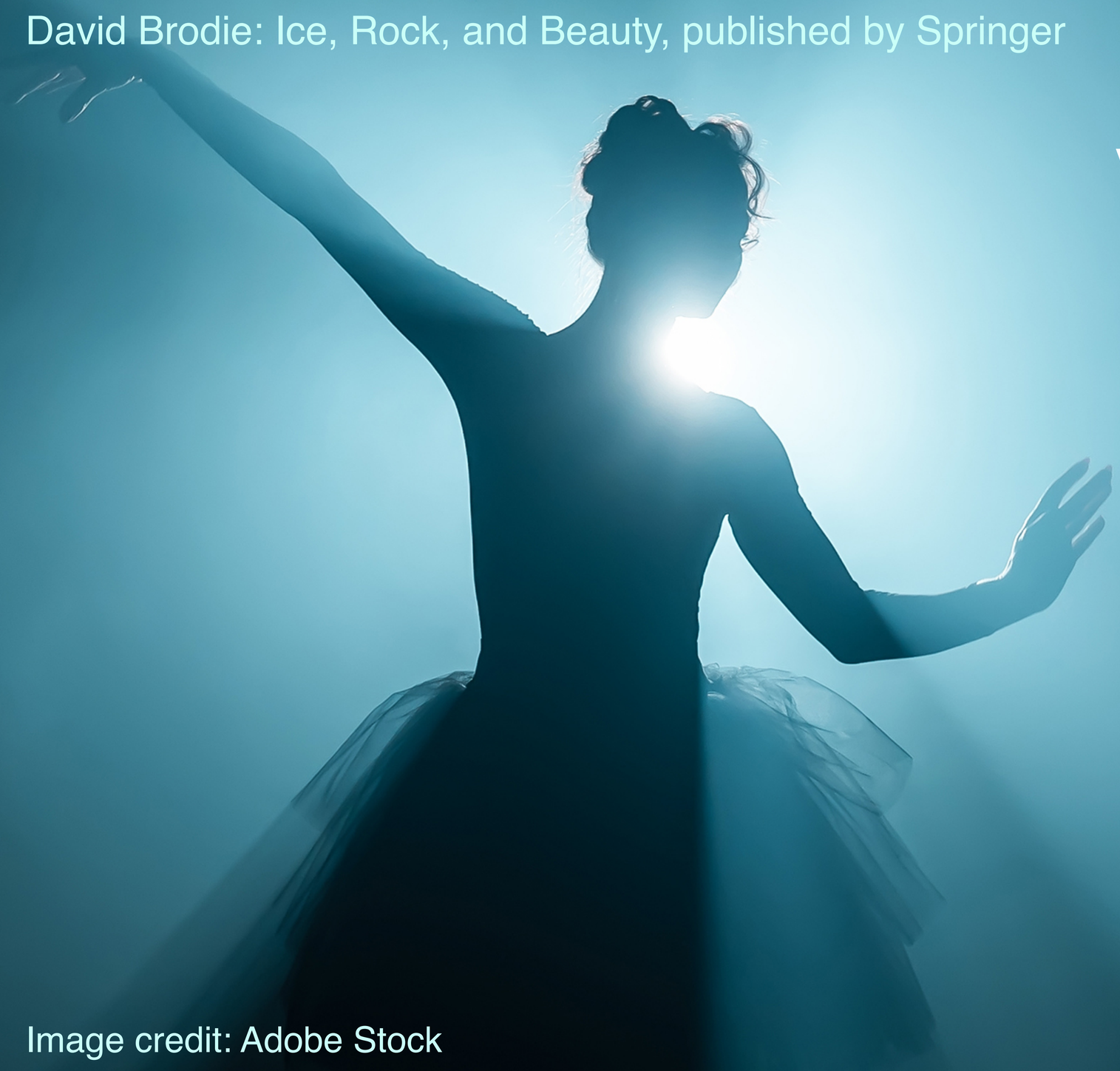

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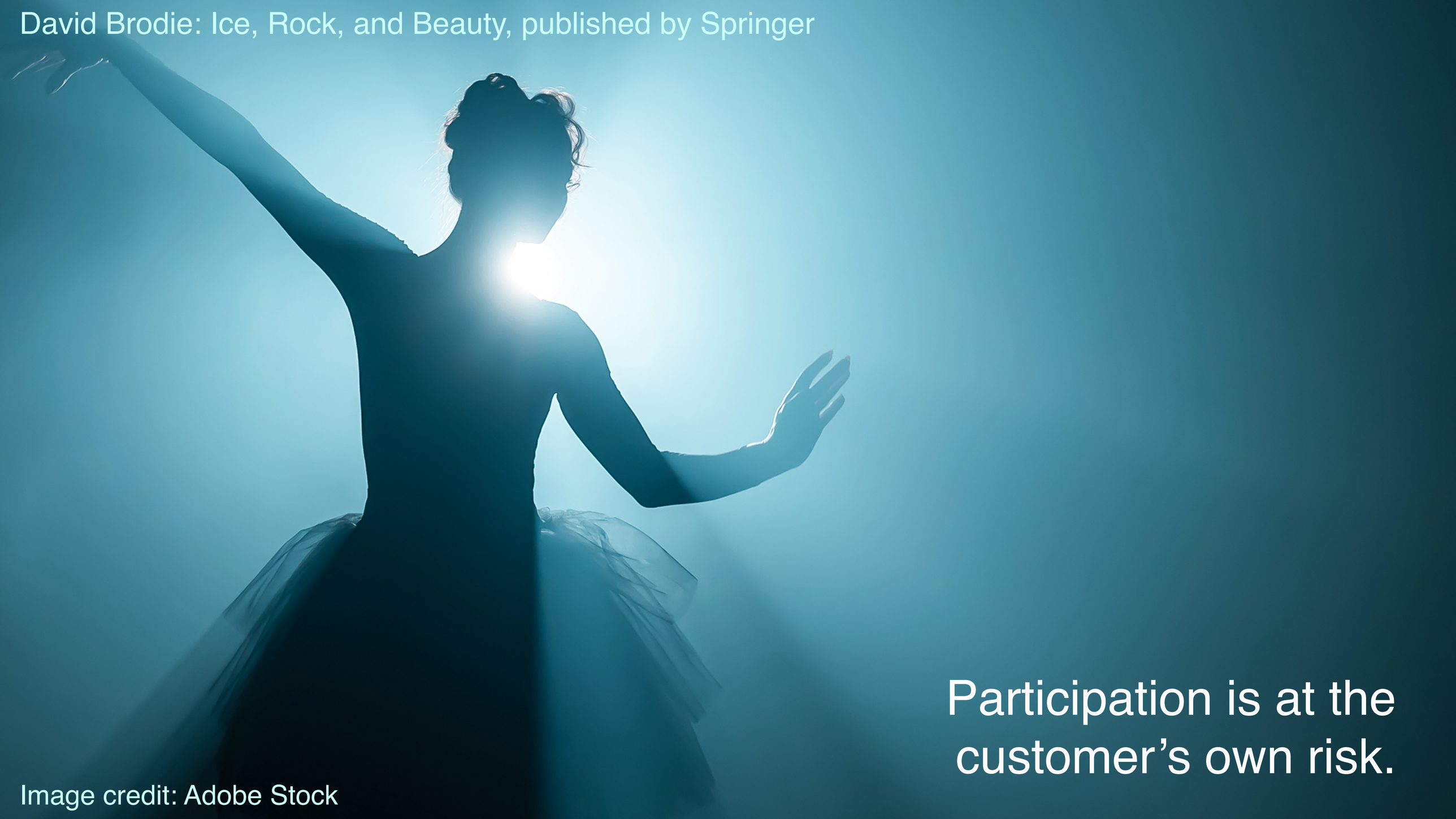

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Water, rock, air, gravity …

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Water, rock,
air, gravity …

… the great nutrient cycle called life (and death)

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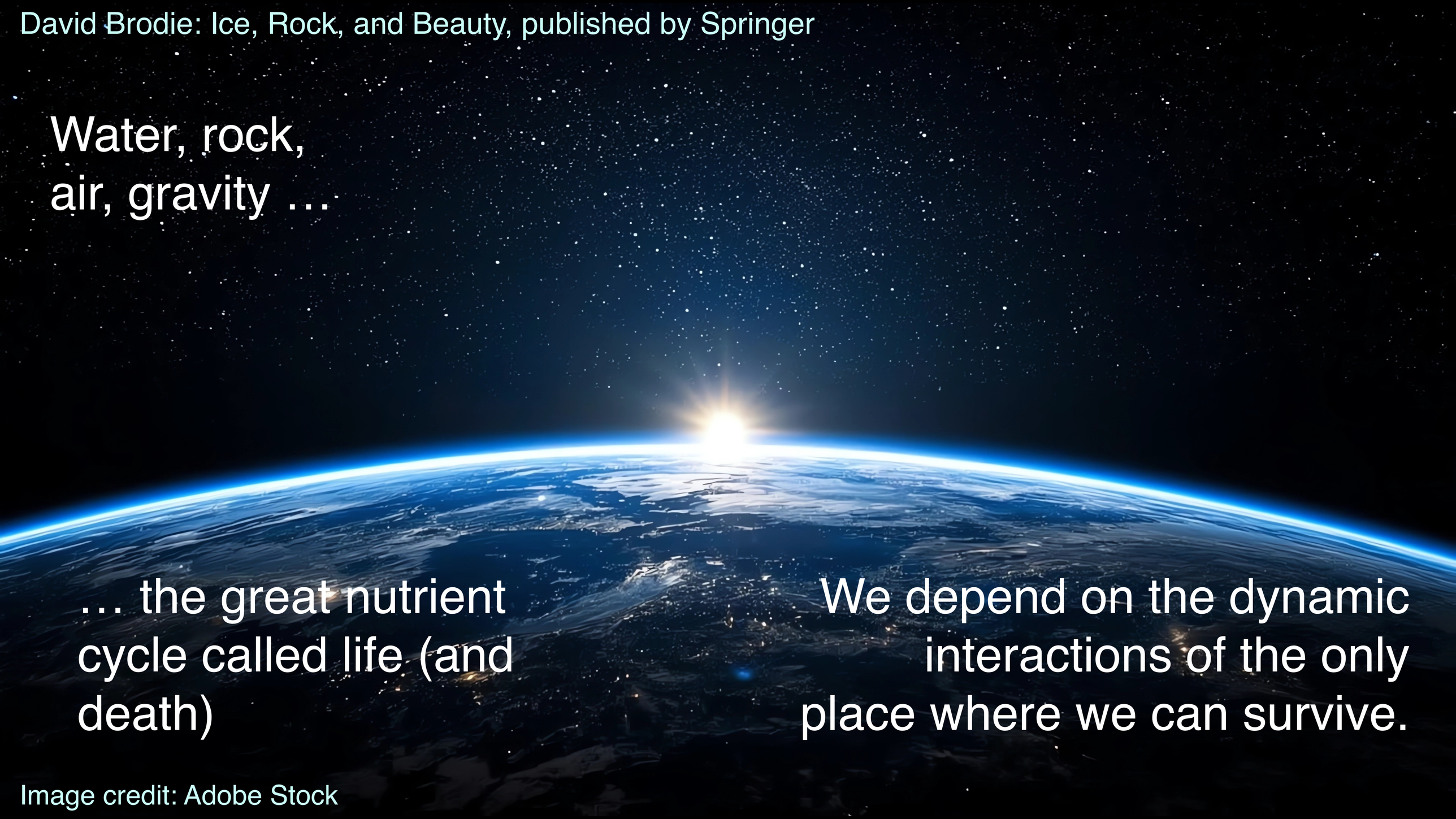

Water, rock,
air, gravity …

… the great nutrient cycle called life (and death)

We depend on the dynamic interactions of the only place where we can survive.

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There are many, many other objects out there, large and small.

Image credit: NASA, JPL-Caltech, Space Science Institute

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There are many, many other objects out there, large and small.

These are three (look carefully) moons of Saturn – Titan, Mimas and Rhea.

Image credit: NASA, JPL-Caltech, Space Science Institute

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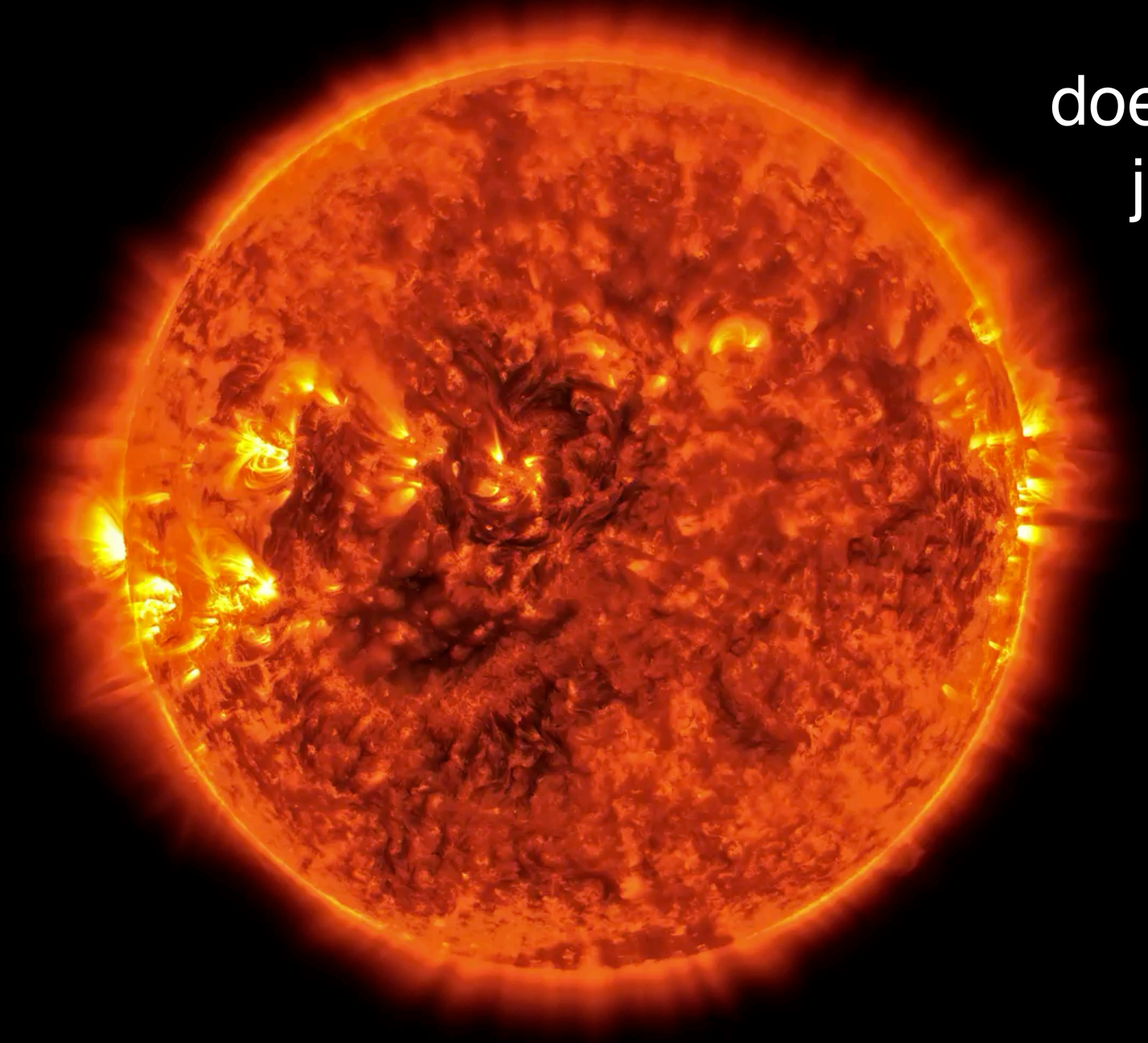
‘The environment’ doesn’t stop somewhere just above the clouds.



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Looking on the sunny side

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Looking on the sunny side

Everything moves.

Image credit: Adobe Stock

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Looking on the sunny side

Everything moves.

Stable orbit is a normal condition.

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Comets move in long elliptical orbits …

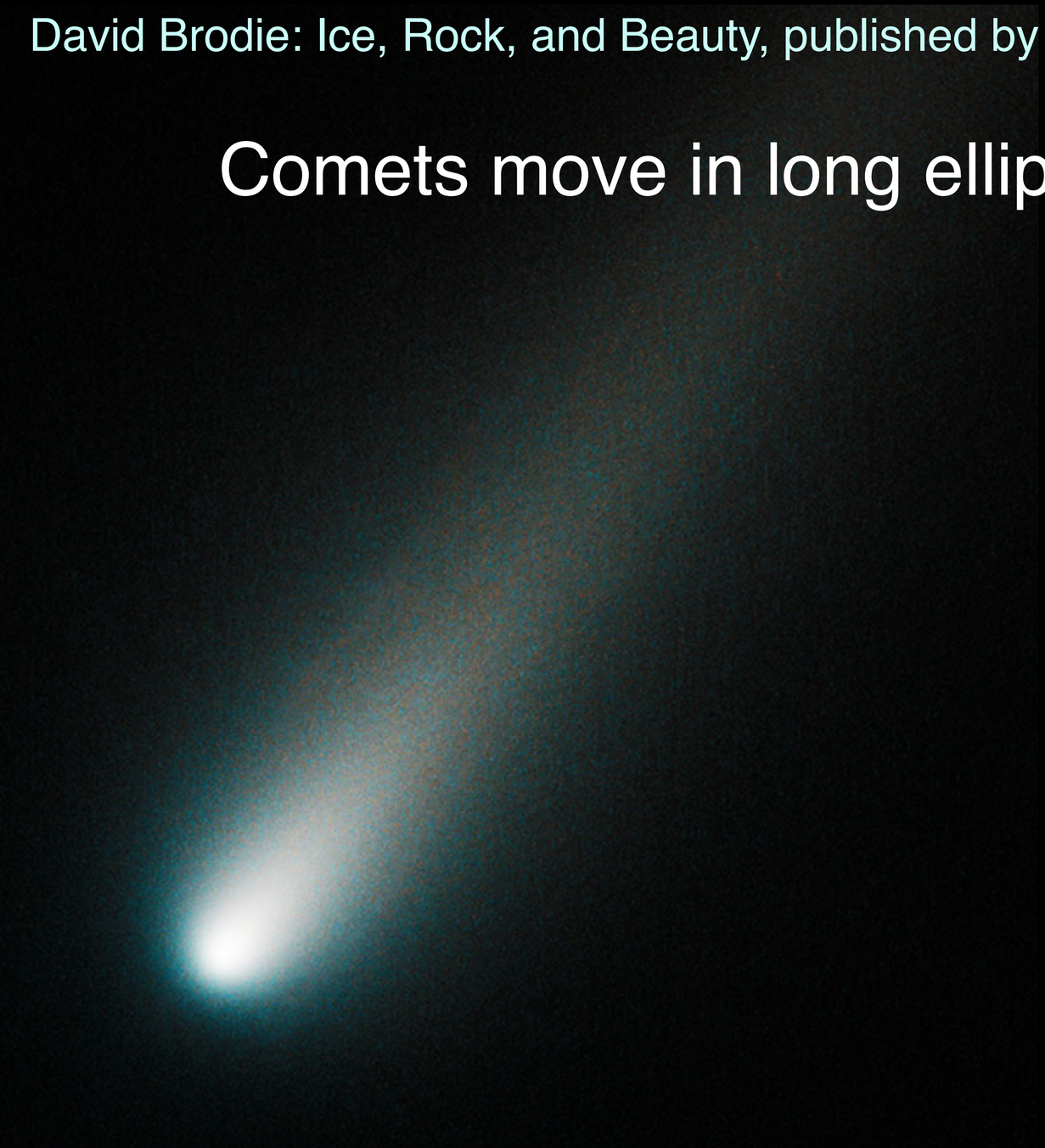

Image credit: NASA (Hubble view of comet Ison)

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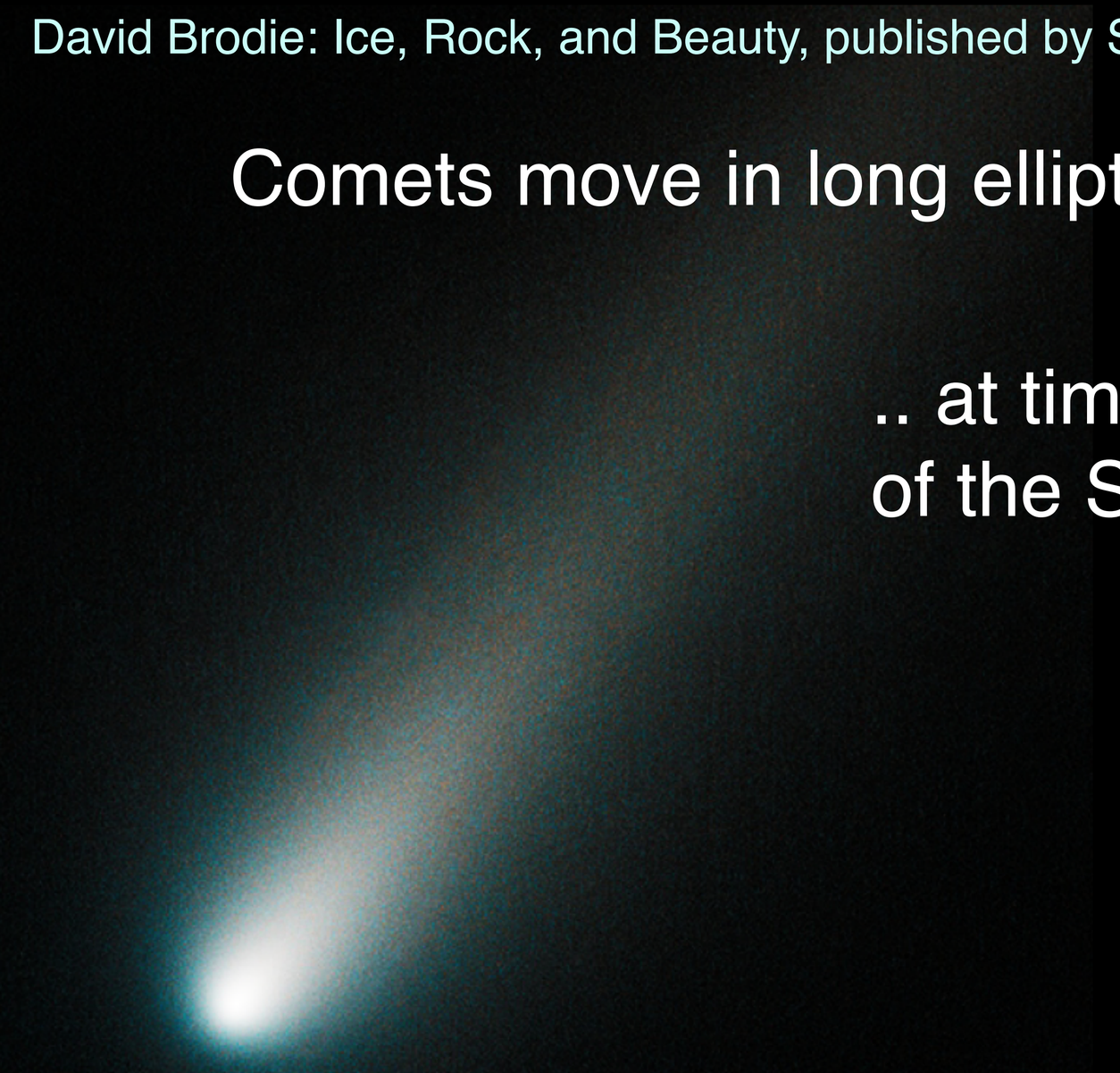
Comets move in long elliptical orbits …

.. at times with tails of debris in the heat of the Sun …



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Comets move in long elliptical orbits …

.. at times with tails of debris in the heat of the Sun …

.. before disappearing into the lonely vastness of the outer Solar System …

Image credit: NASA (Hubble view of comet Ison)

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Comets move in long elliptical orbits …

.. at times with tails of debris in the heat of the Sun …

.. before disappearing into the lonely vastness of the outer Solar System …

… some of them taking thousands of human lifetimes for one orbit of the Sun.

Image credit: NASA (Hubble view of comet Ison)

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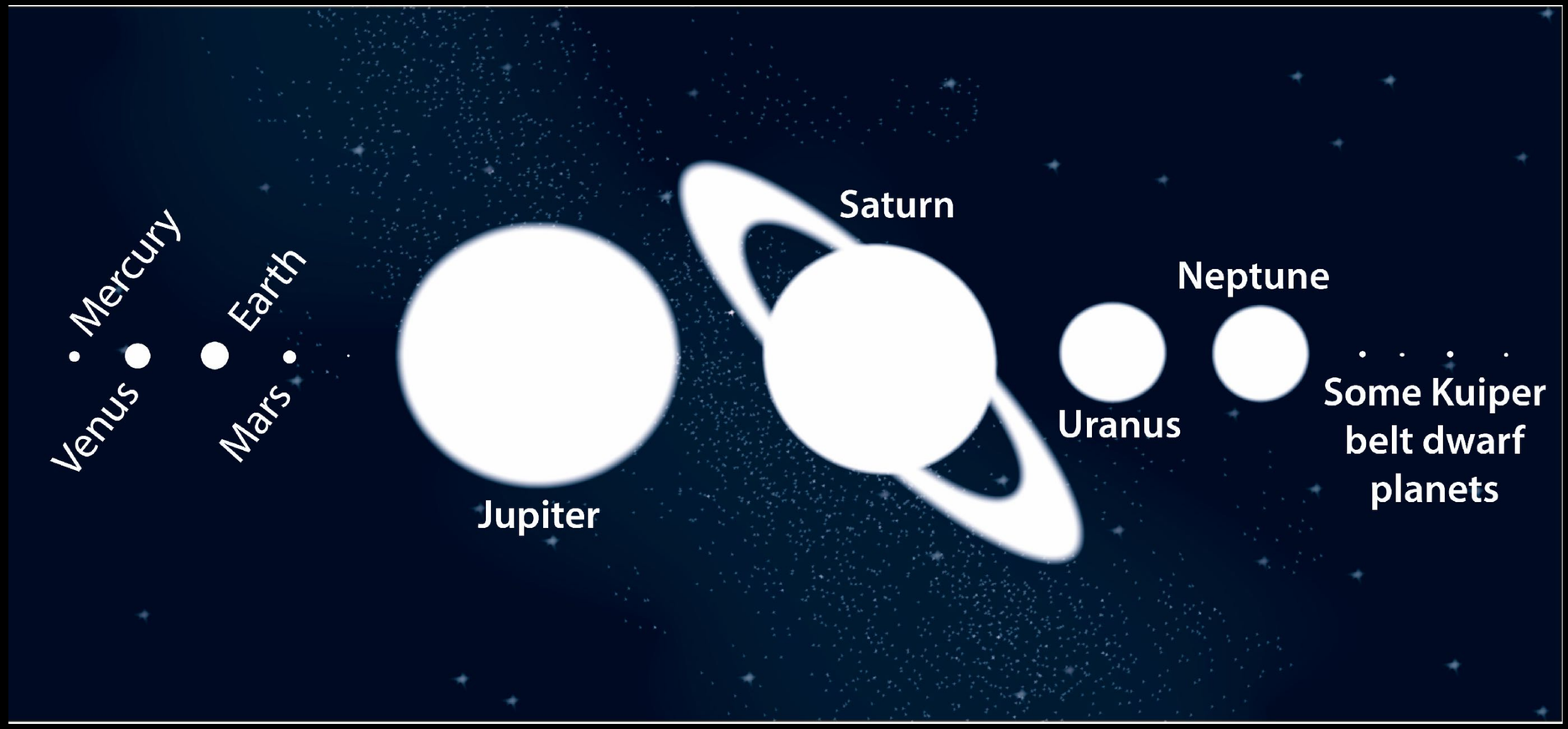
We must work with ‘models’ to make sense of it all.



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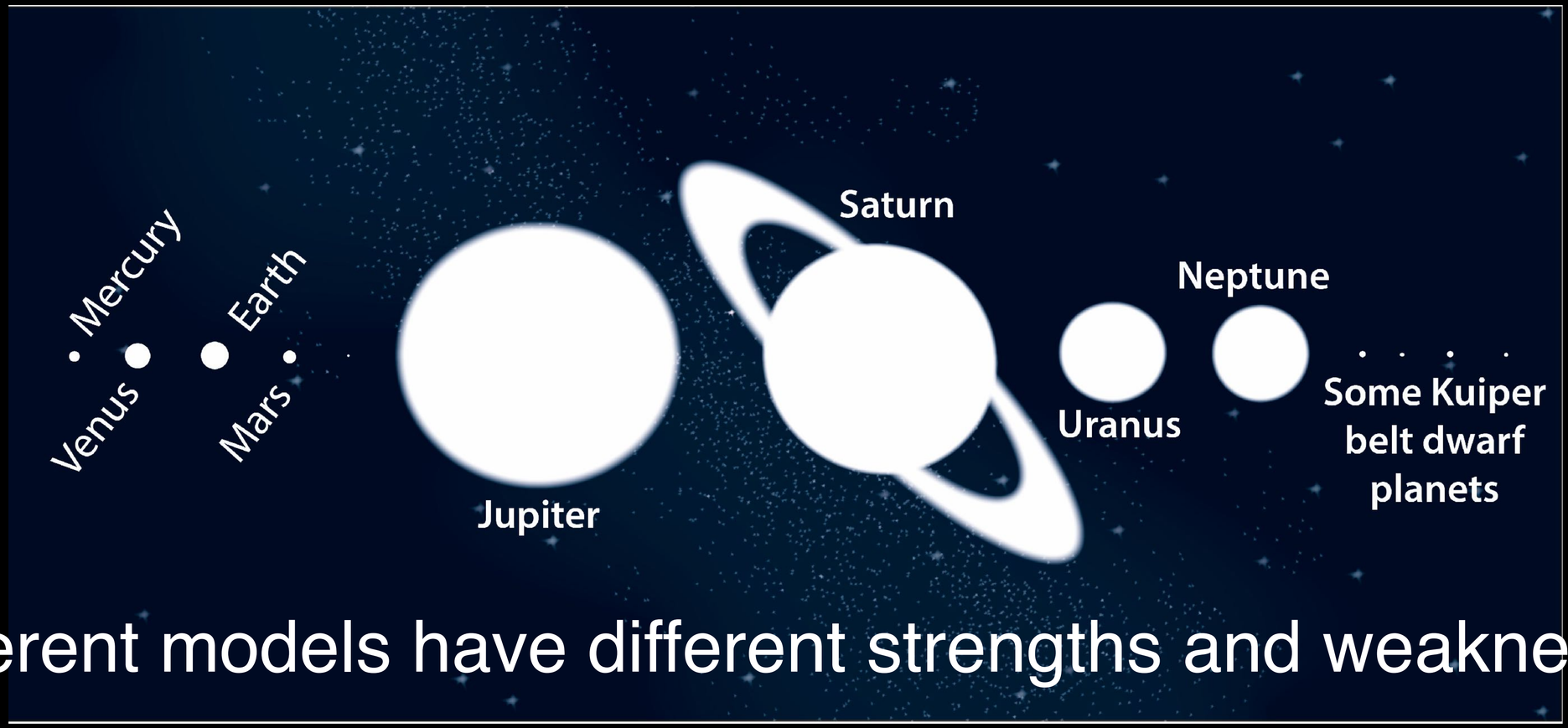

Different models have different strengths and weaknesses.

Image credit: David Brodie

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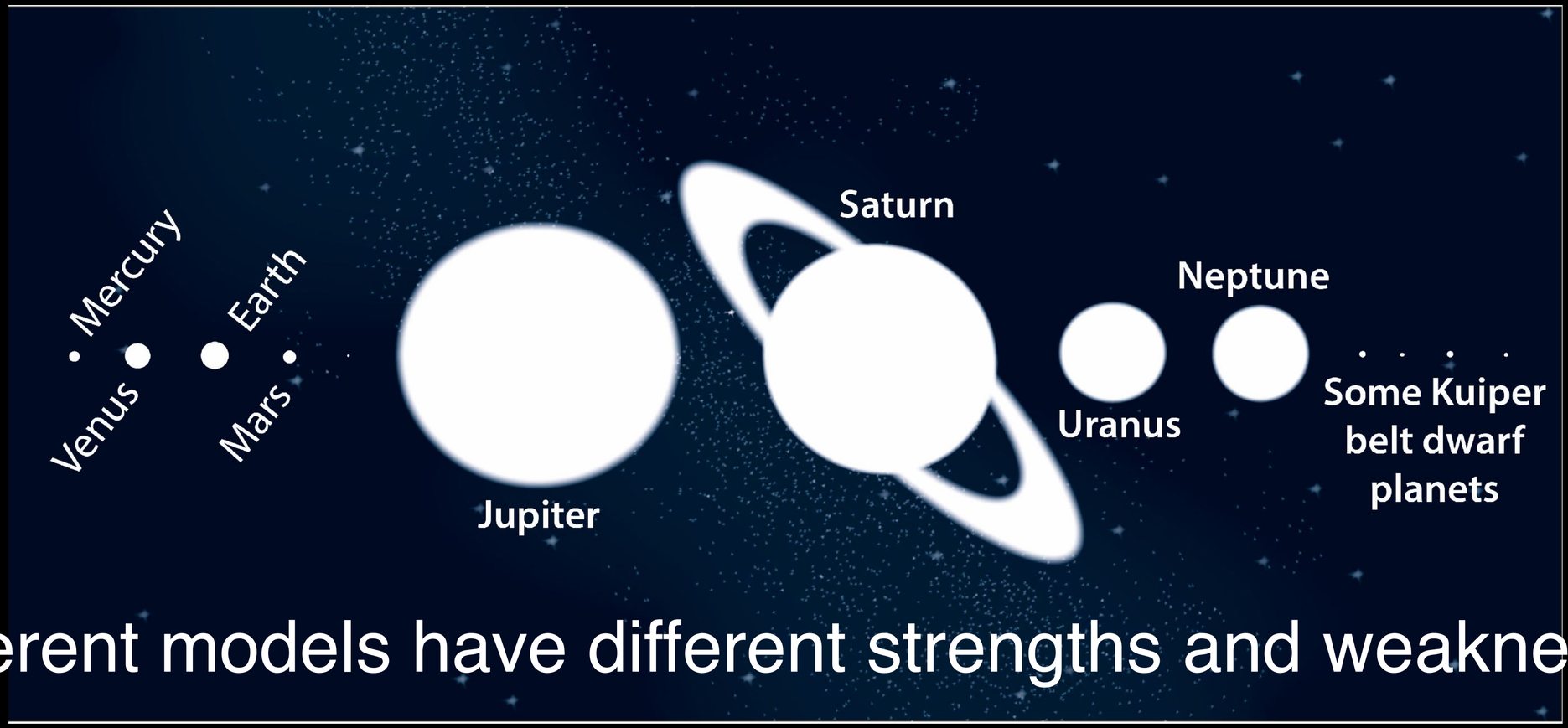
We must work with ‘models’ to make sense of it all.



Different models have different strengths and weaknesses.

The only fully ‘correct model’ of the Solar System is the Solar System itself.

Image credit: David Brodie

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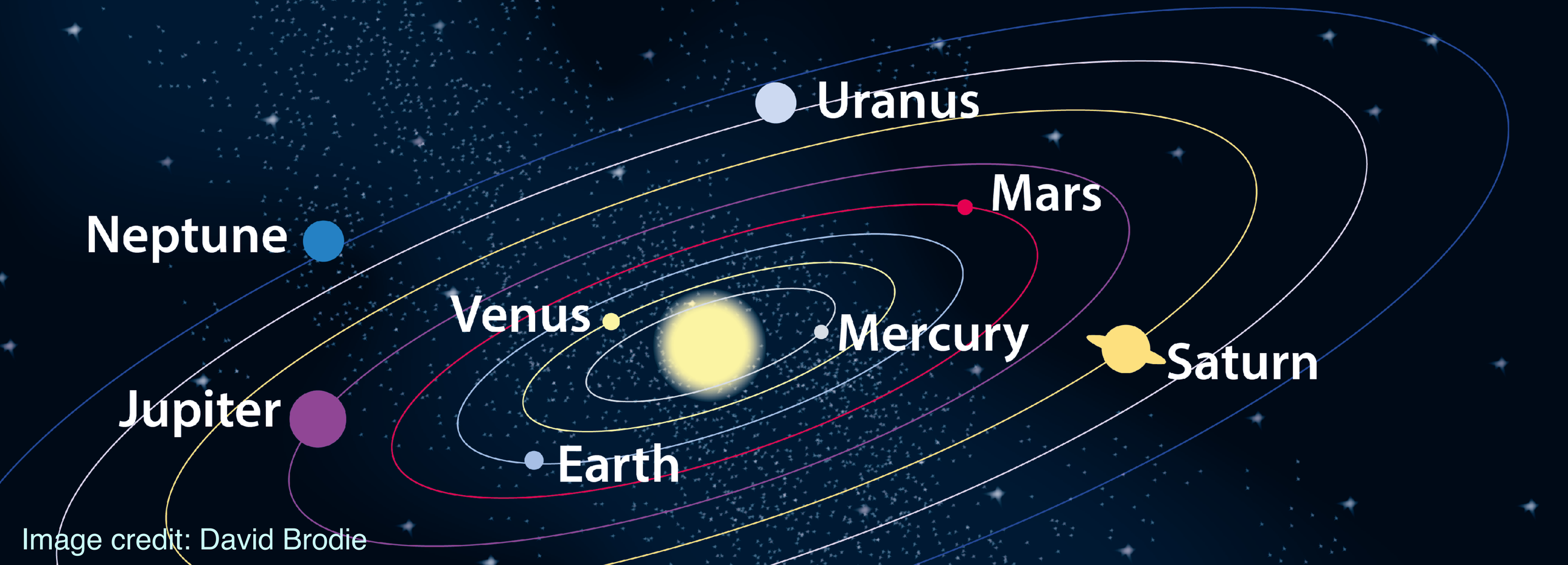
Slightly more complex models are, likewise, mere indicators of only some aspects of reality.



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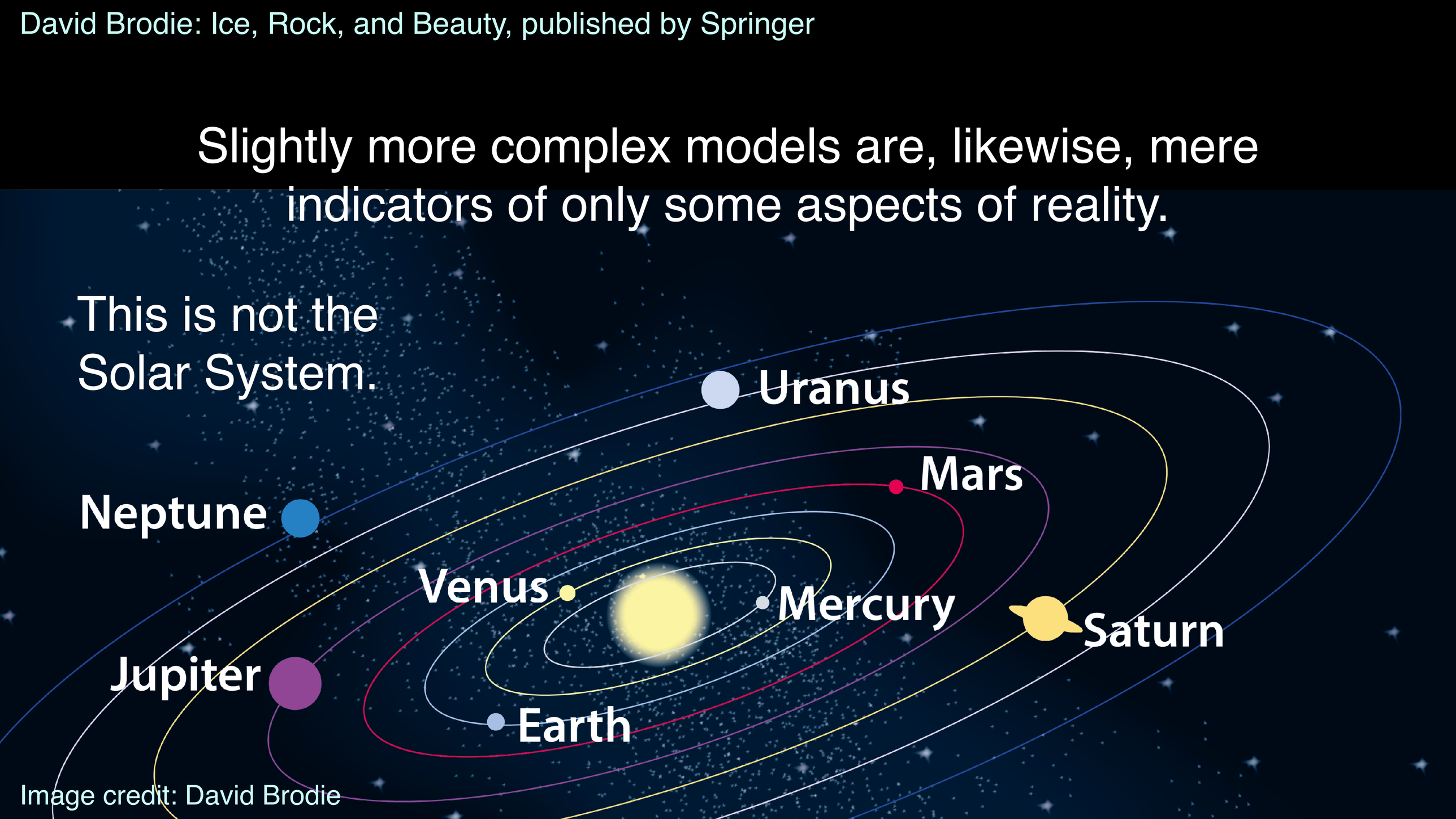

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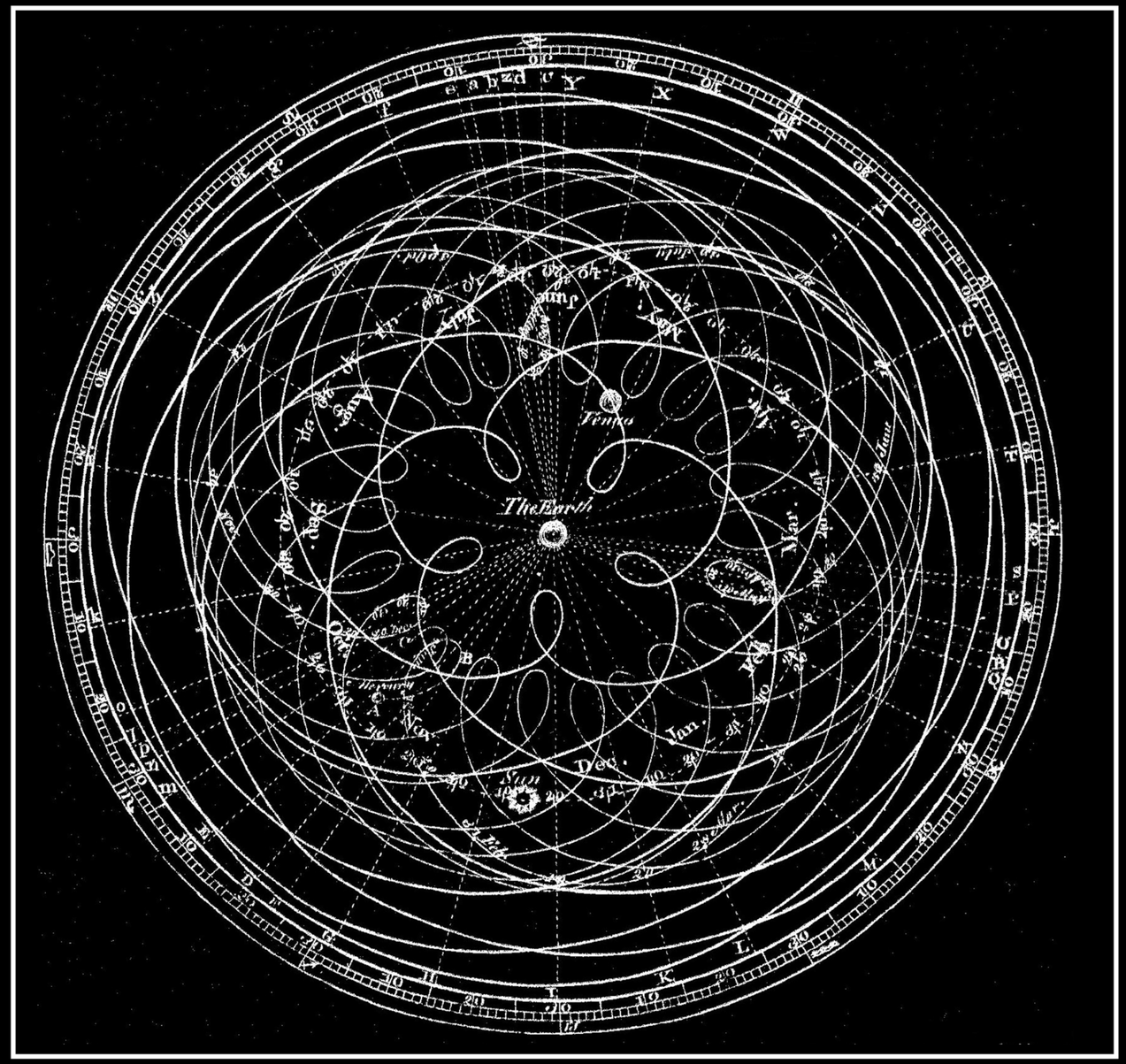

In some cases human models fail to predict further observations.

Image credit: Encyclopaedia Brittanica, 1771, James Ferguson (based on Giovanni Cassini, Roger Long), Andrew Bell

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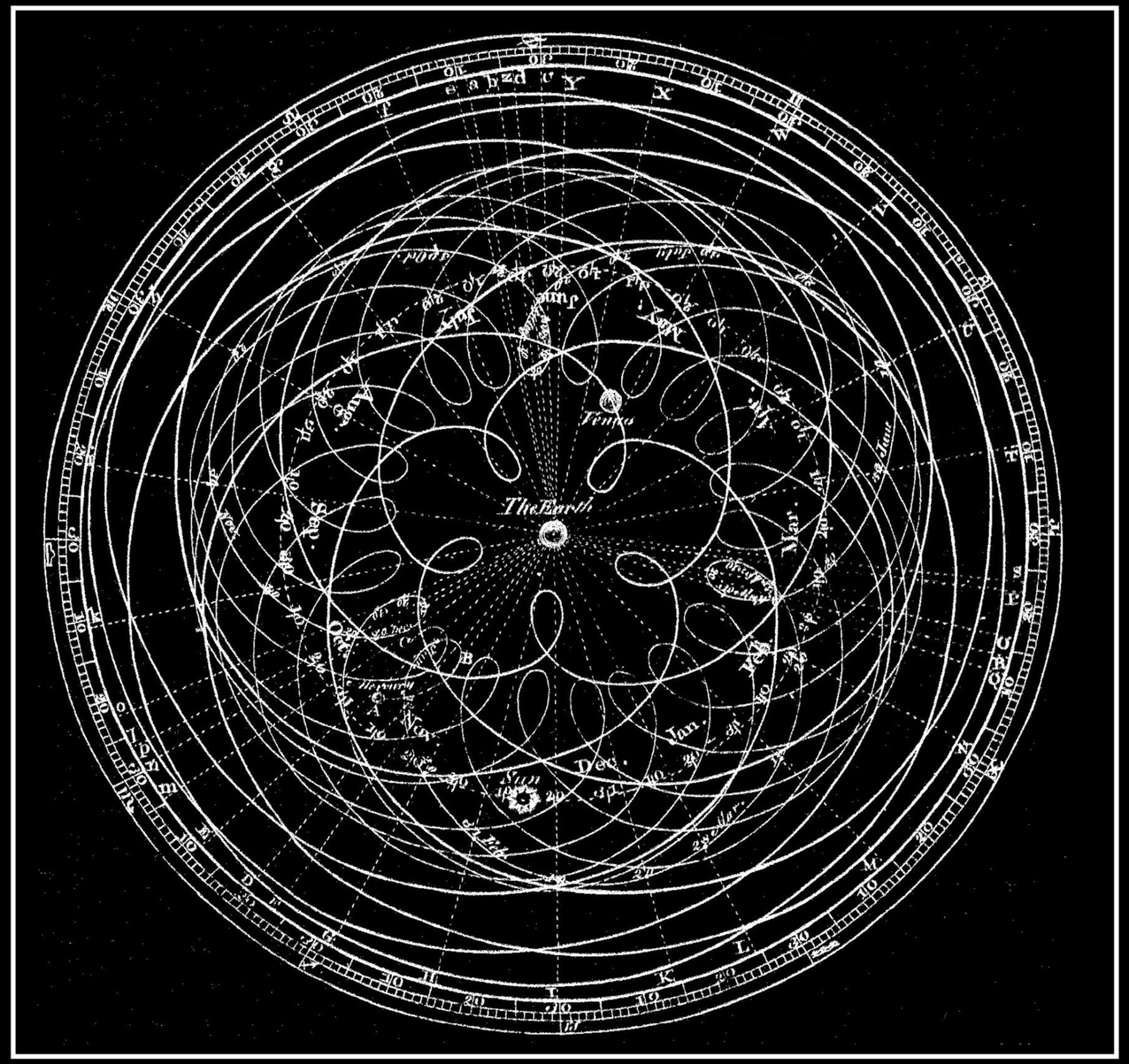

In some cases human models fail to predict further observations.

This one assumes that the home of humanity is the centre of all existence.

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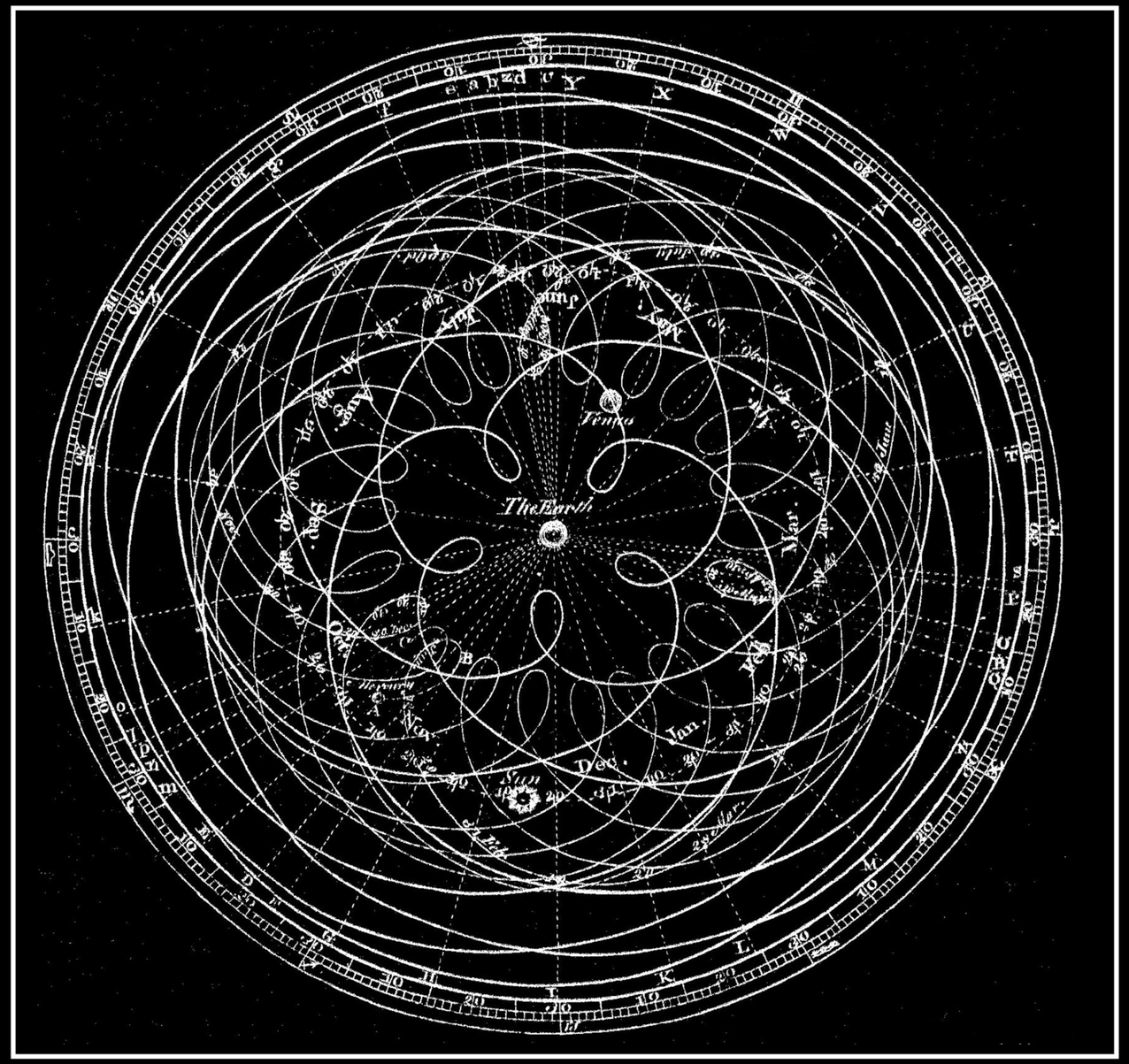

In some cases human models fail to predict further observations.

This one assumes that the home of humanity is the centre of all existence.

It takes an anthropocentric view of reality.

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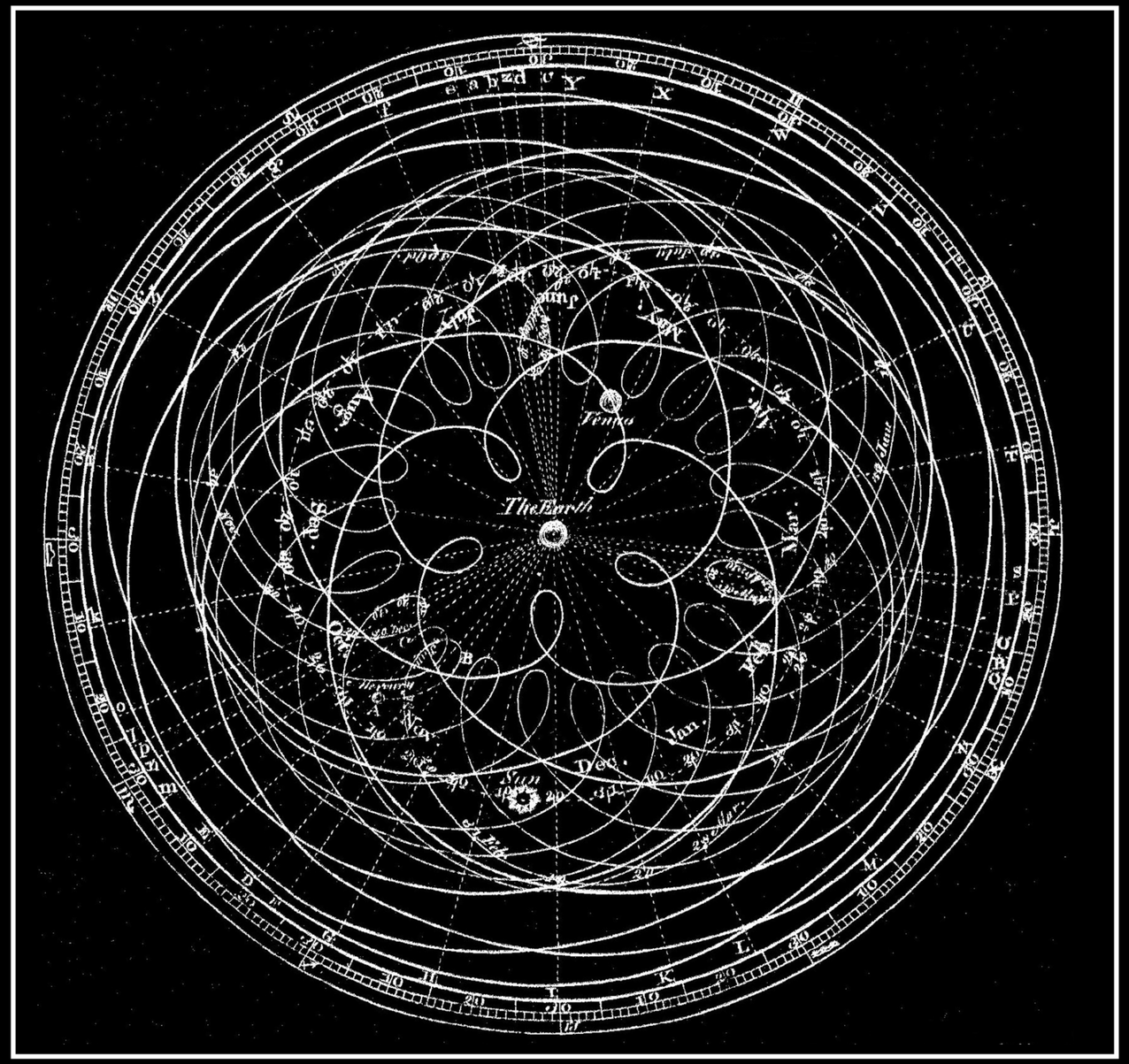

In some cases human models fail to predict further observations.

This one assumes that the home of humanity is the centre of all existence.

It takes an anthropocentric view of reality.

It’s the geocentric model.

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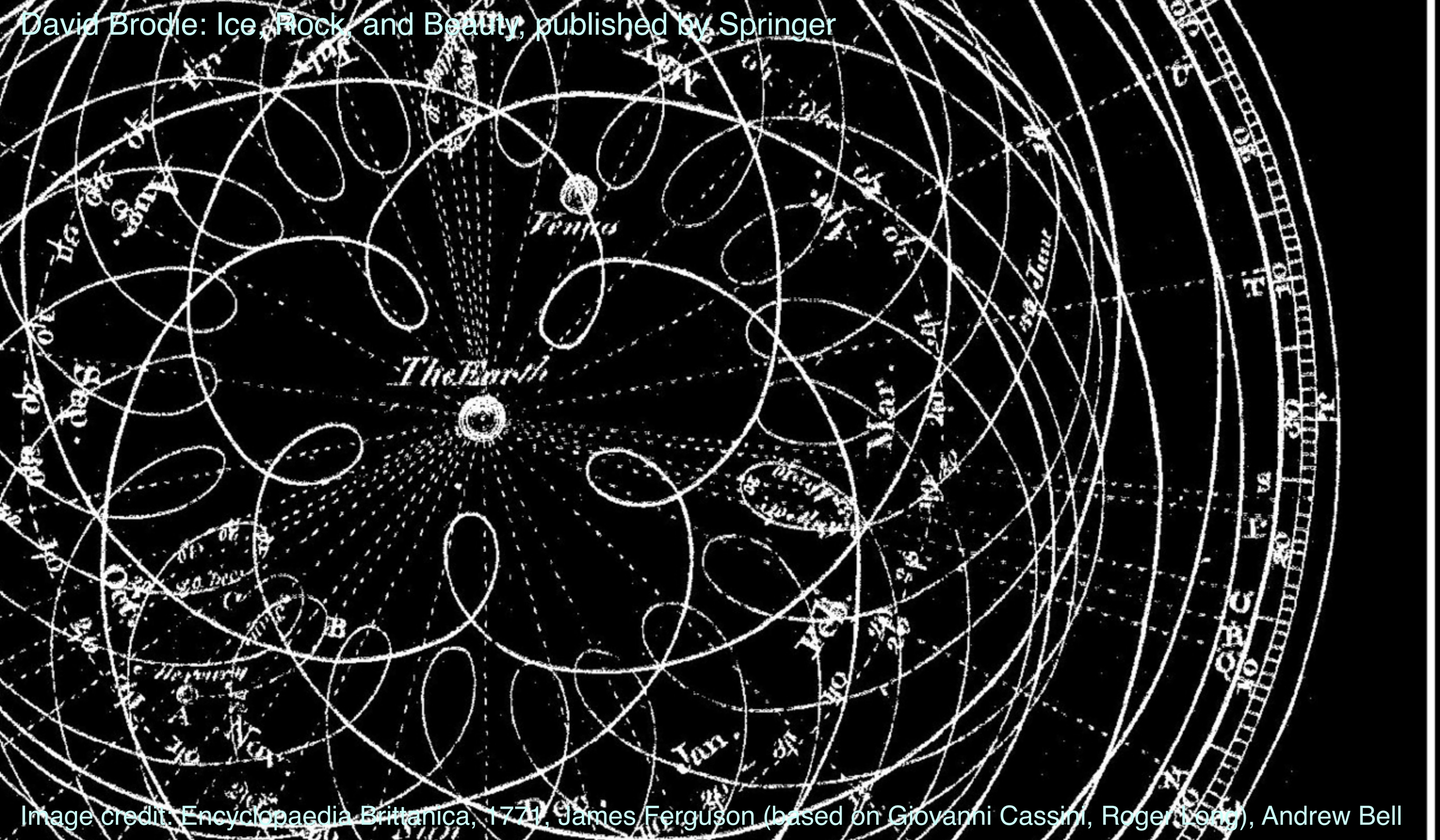

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Venus as observed from Earth, February to June 2004.

Image credit: Status Kalyvas – VT-2004 programme

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Venus as observed from Earth, February to June 2004.

The geocentric model makes incorrect predictions about the observed phases of Venus.

Image credit: Status Kalyvas – VT-2004 programme

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Venus as observed from Earth, February to June 2004.

The geocentric model makes incorrect predictions about the observed phases of Venus.

So the geocentric model is not the best available model of the reality of the Solar System.

Image credit: Status Kalyvas – VT-2004 programme

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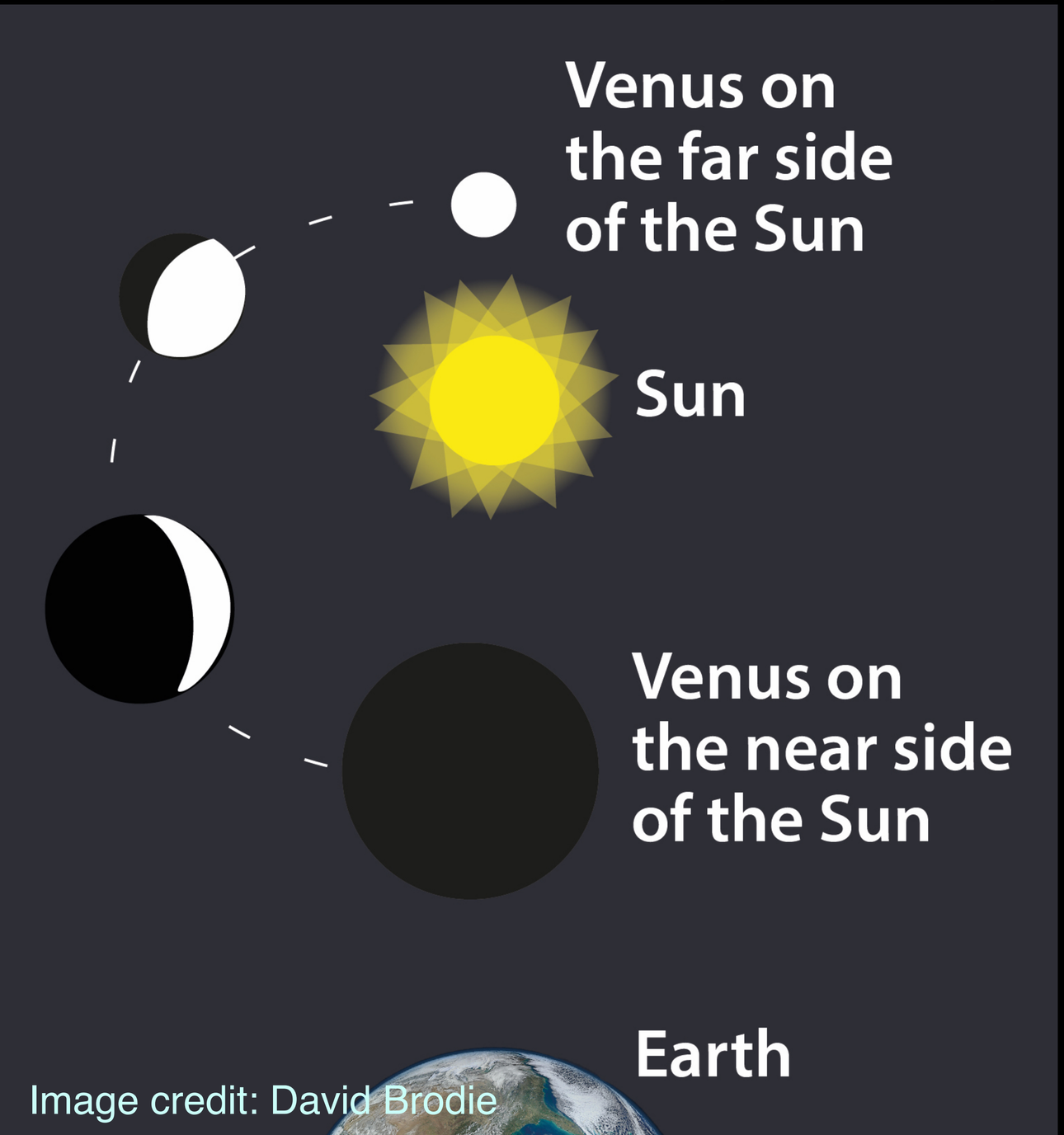

Image credit: David Brodie

A newer model places the Sun, and not the Earth, as the centre of orbits.

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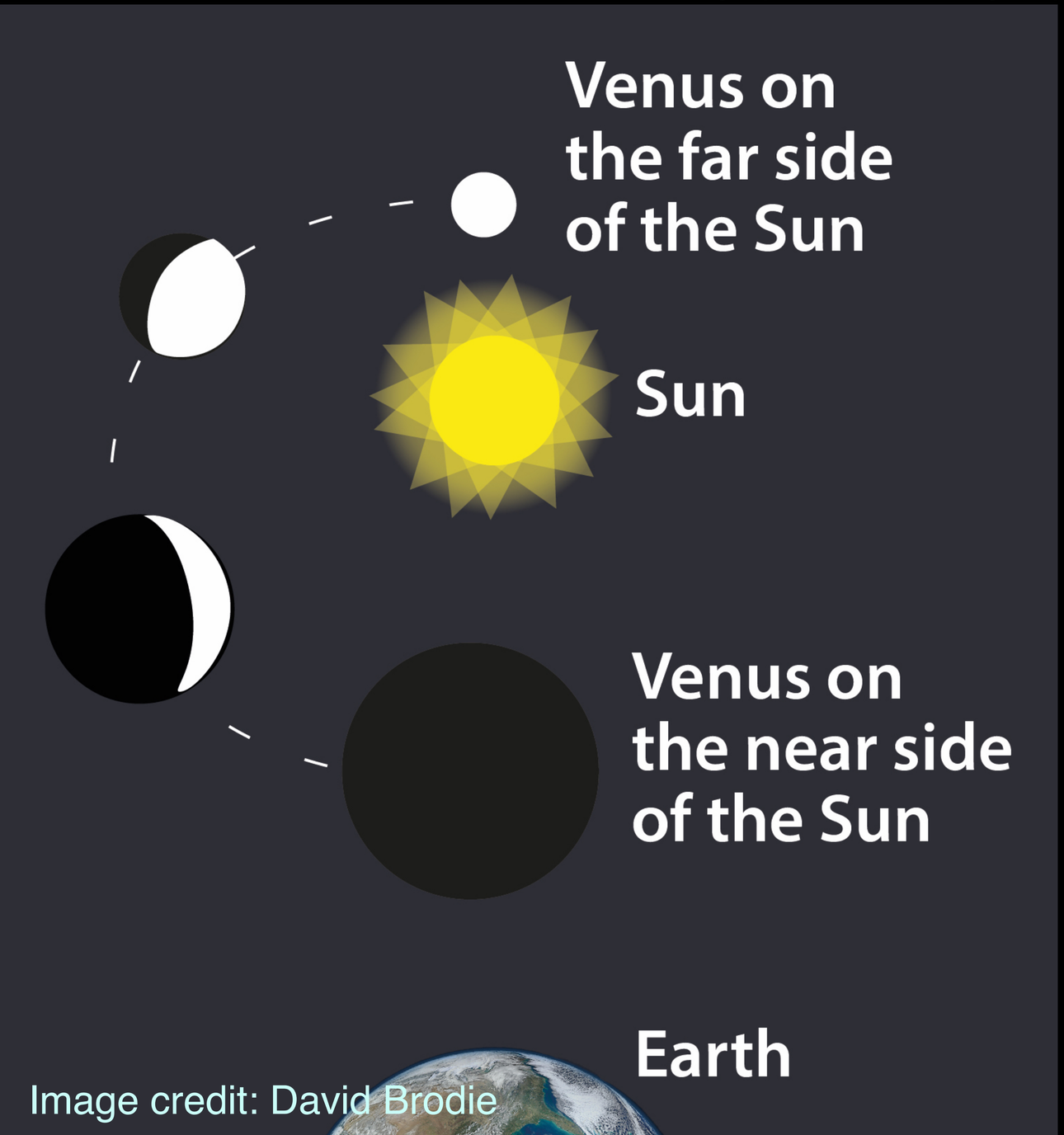

Image credit: David Brodie

A newer model places the Sun, and not the Earth, as the centre of orbits.

It removes the Earth from the centre.

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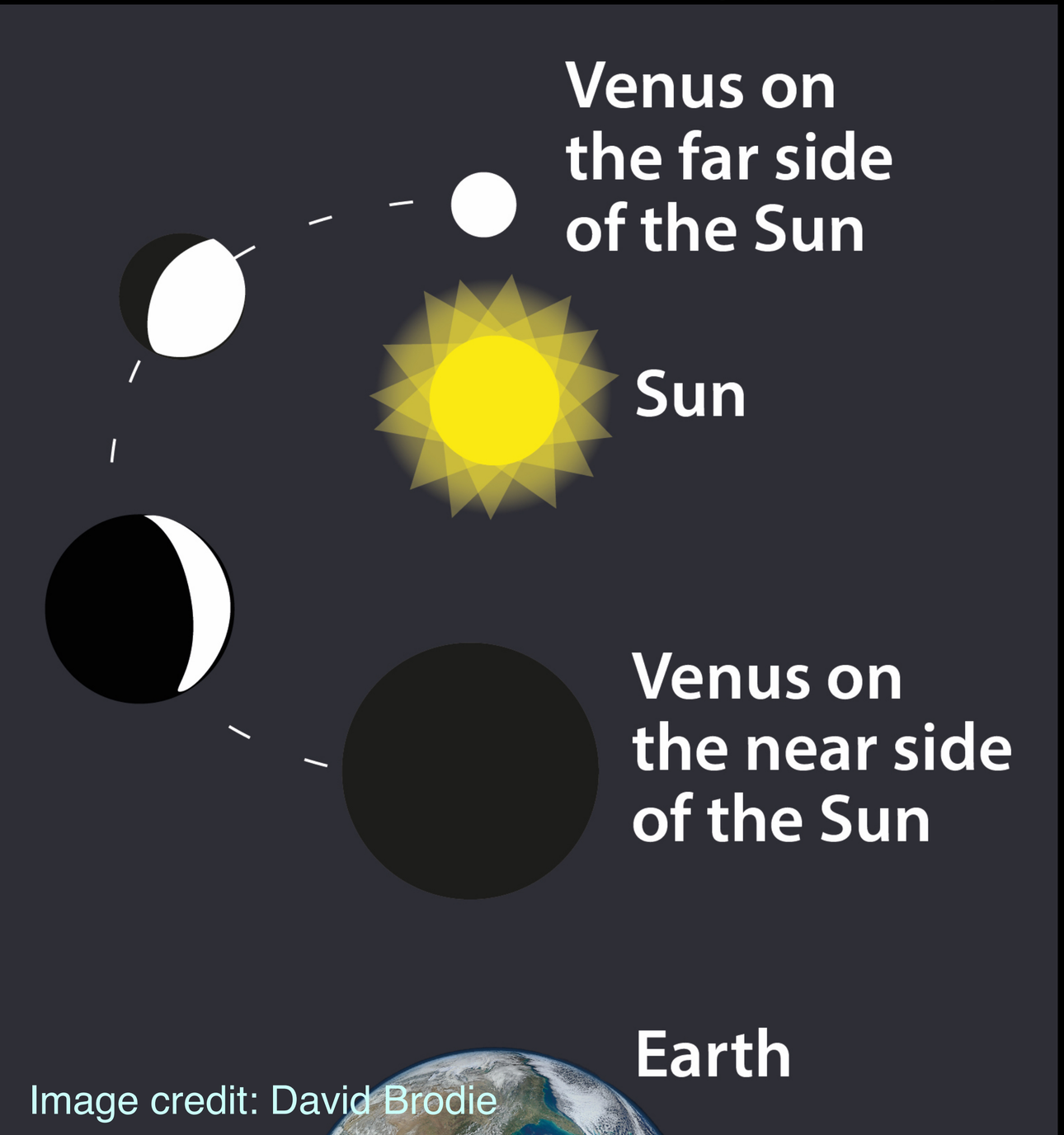

Image credit: David Brodie

A newer model places the Sun, and not the Earth, as the centre of orbits.

It removes the Earth from the centre.

It makes the Earth just one of several planets in the system.

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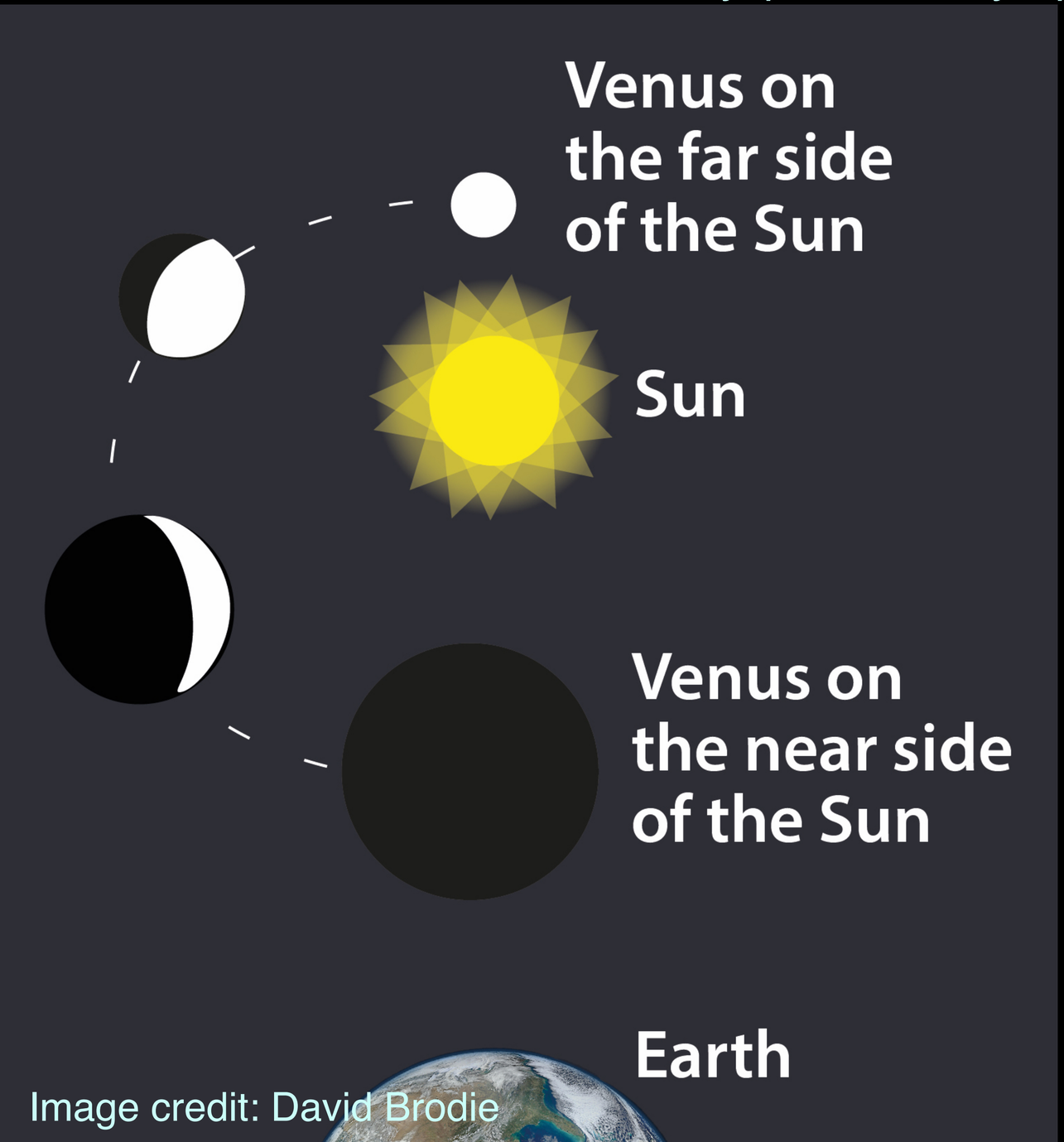

Image credit: David Brodie

The geocentric model is not the best available model of the reality of the Solar System.

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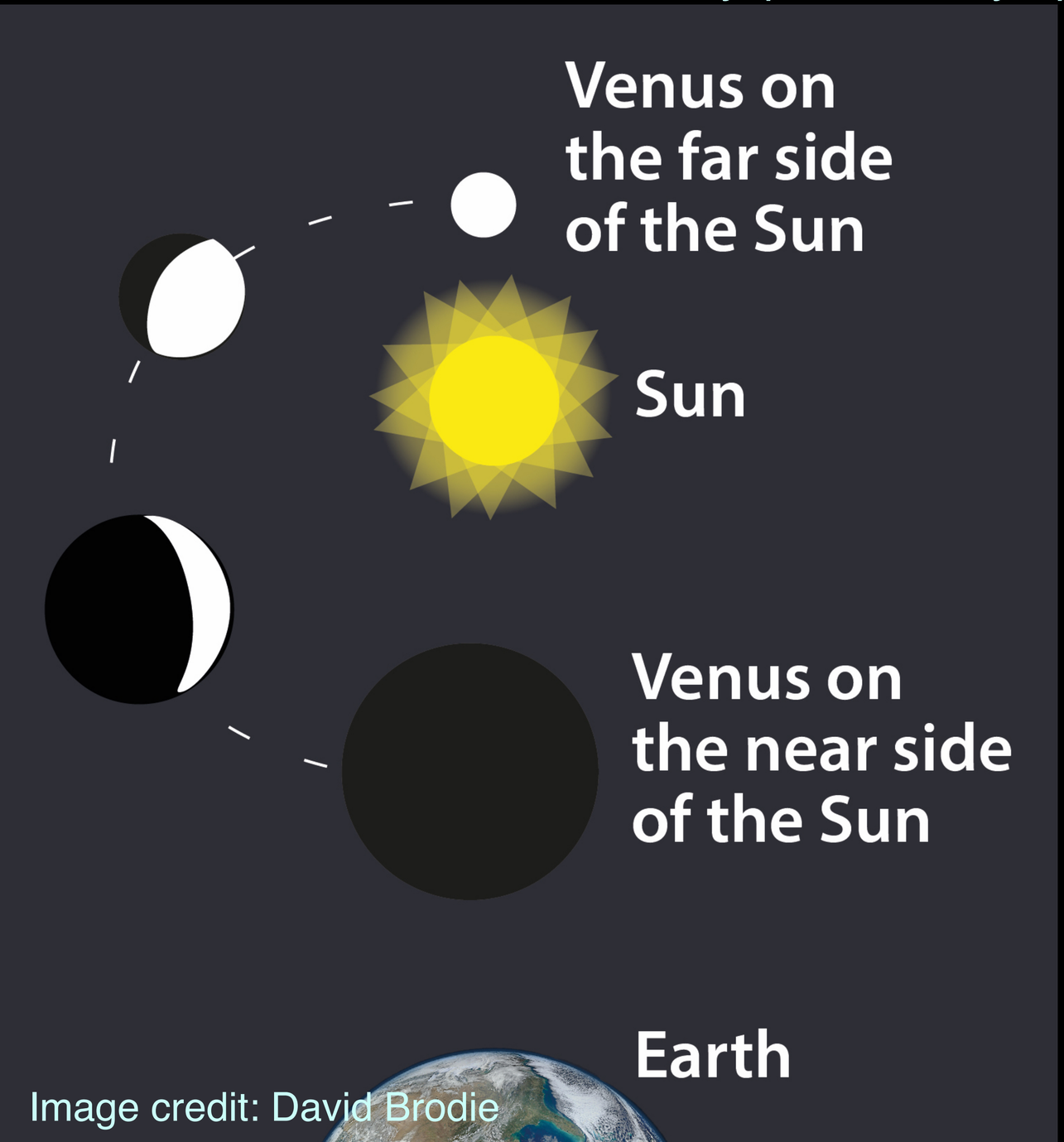

Image credit: David Brodie

The geocentric model is not the best available model of the reality of the Solar System.

A newer model makes predictions that match observations.

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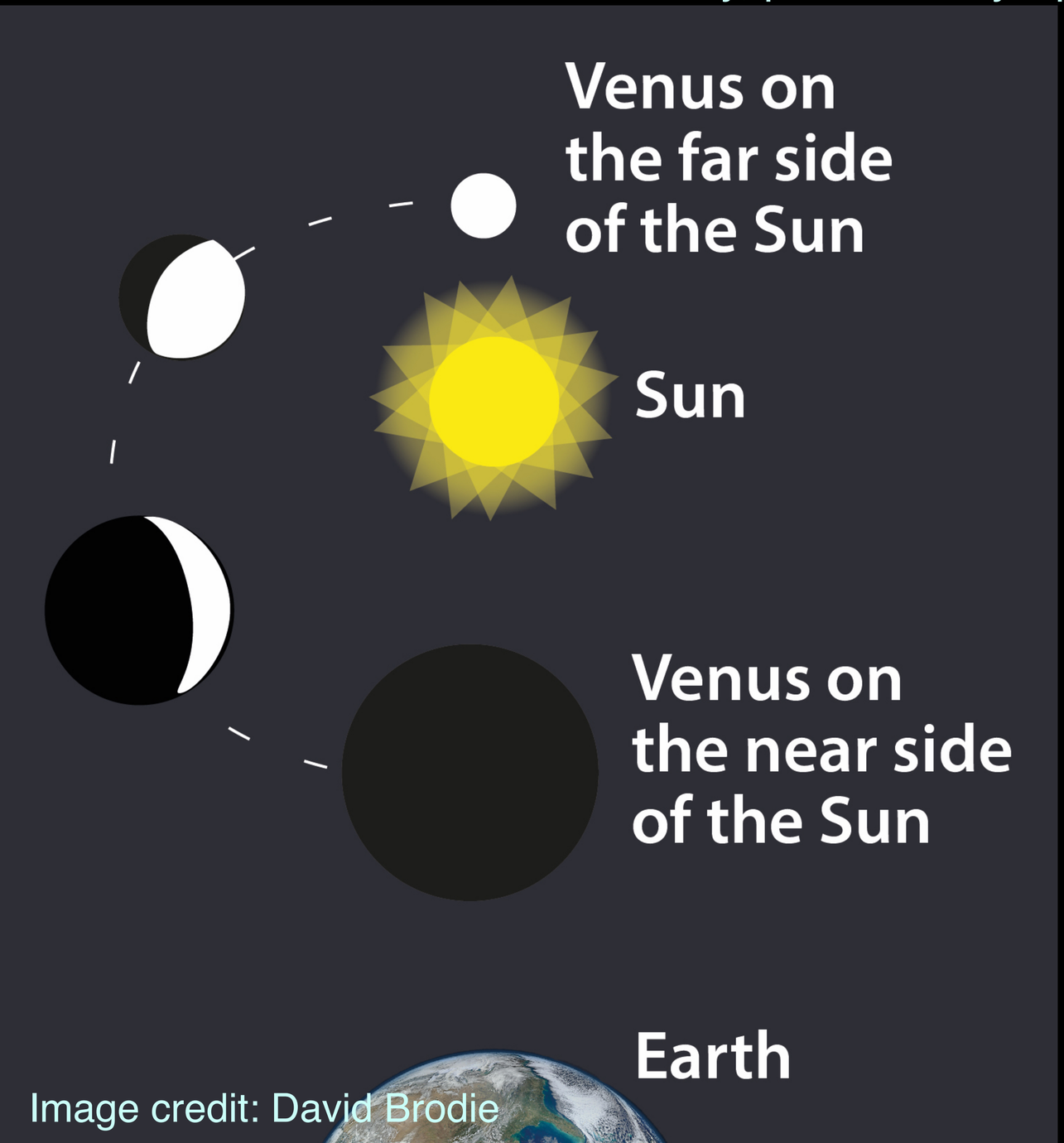

Image credit: David Brodie

The geocentric model is not the best available model of the reality of the Solar System.

A newer model makes predictions that match observations.

It's the heliocentric (Sun-centered) model,

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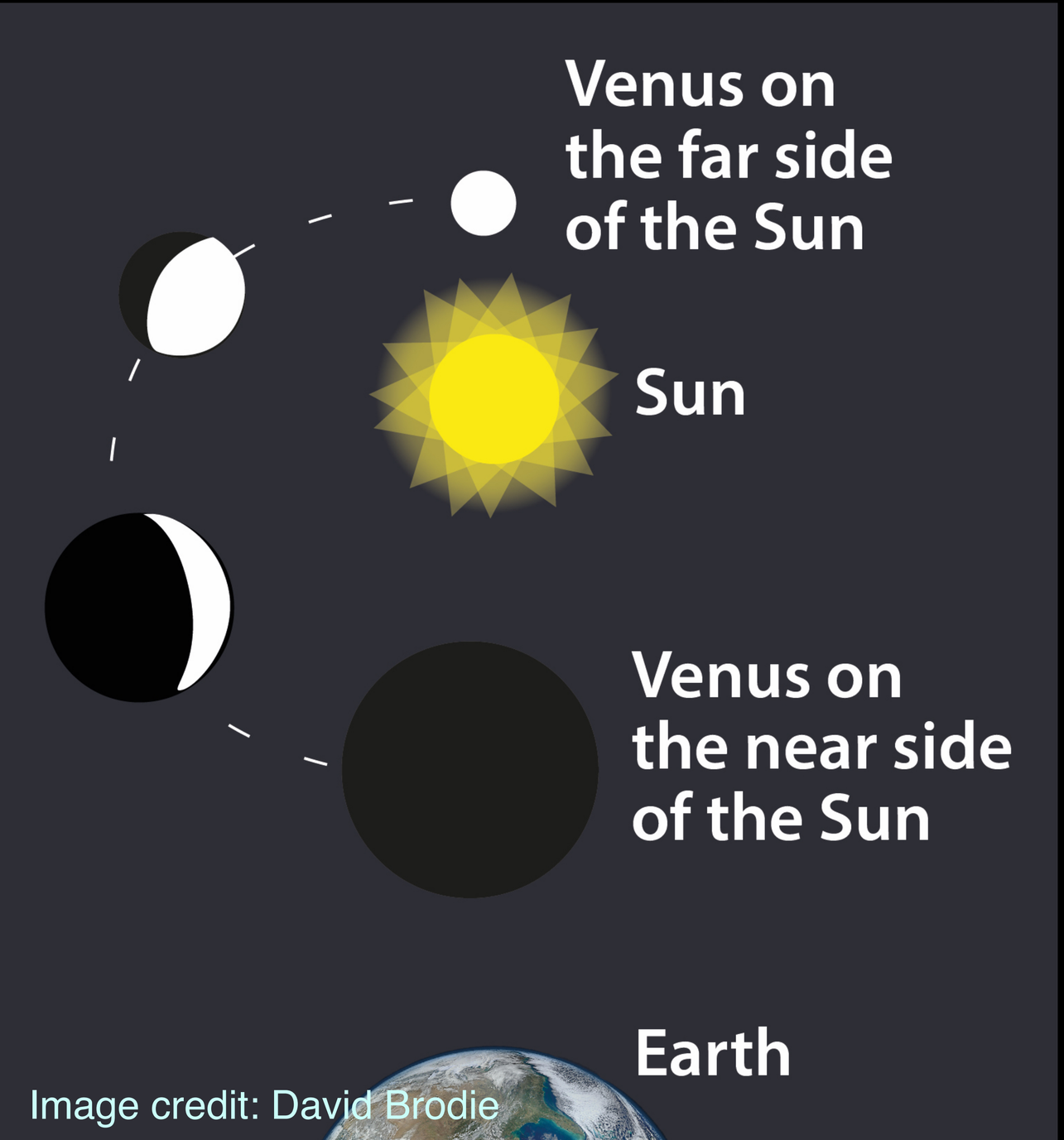

Image credit: David Brodie

The geocentric model is not the best available model of the reality of the Solar System.

A newer model makes predictions that match observations.

It's the heliocentric (Sun-centered) model,

in which the Earth also moves.

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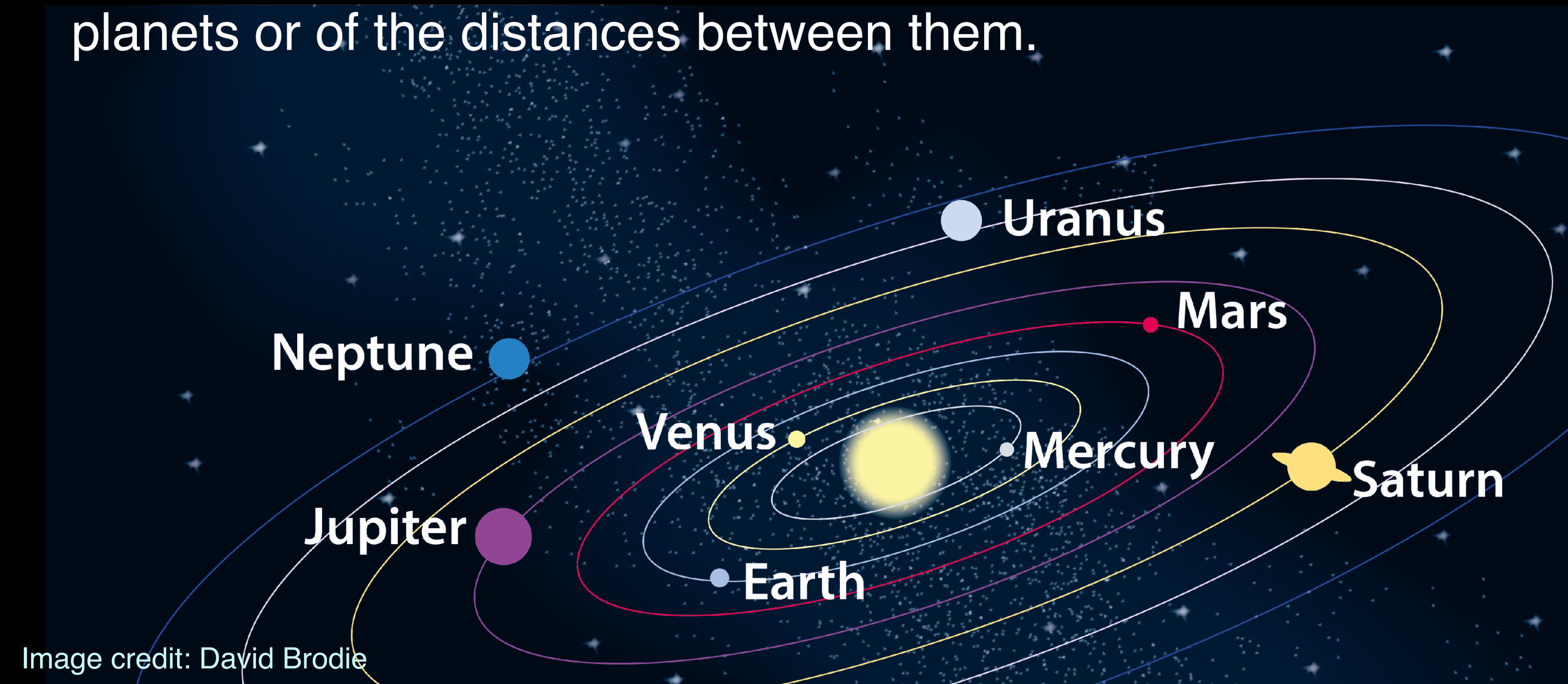
This may be a simple representation, that doesn't trouble with information about the relative sizes of planets or of the distances between them.



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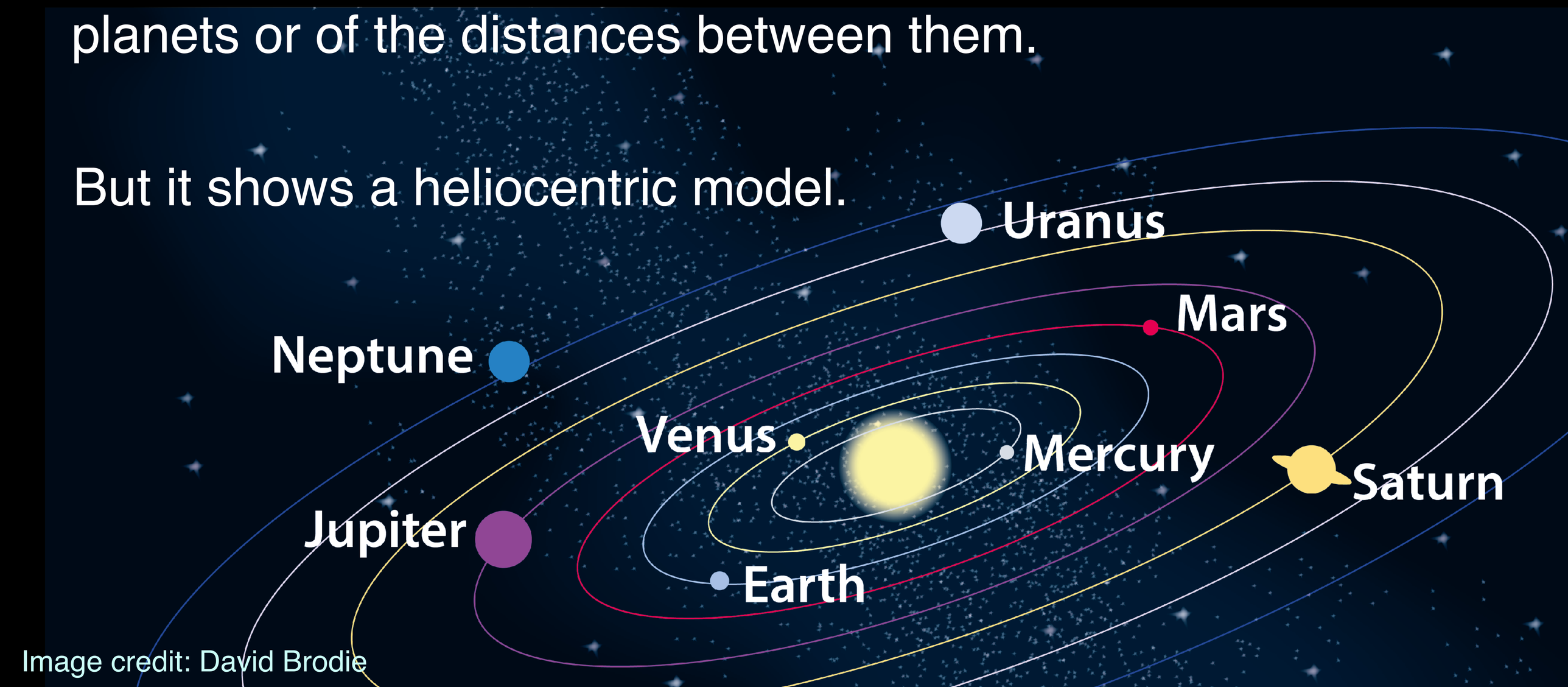
This may be a simple representation, that doesn't trouble with information about the relative sizes of planets or of the distances between them.

But it shows a heliocentric model.



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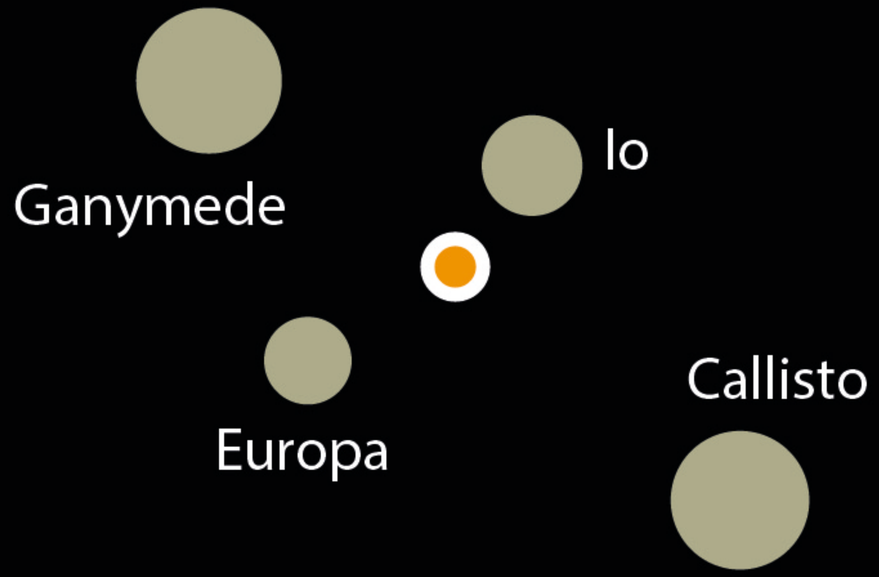
Observation of the moons of Jupiter also showed that the Earth was not the centre of all orbits.

The moons can be seen to orbit Jupiter (orange, centre, not to scale).



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The rejection of the geocentric model was the Copernican revolution …

Image credit: Derby Museums

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The rejection of the geocentric model was the Copernican revolution …

… although key observations were made after the death of Copernicus.

Image credit: Derby Museums

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Image credit: Derby Museums

It was hard for many to accept that the Universe did not revolve around humanity.

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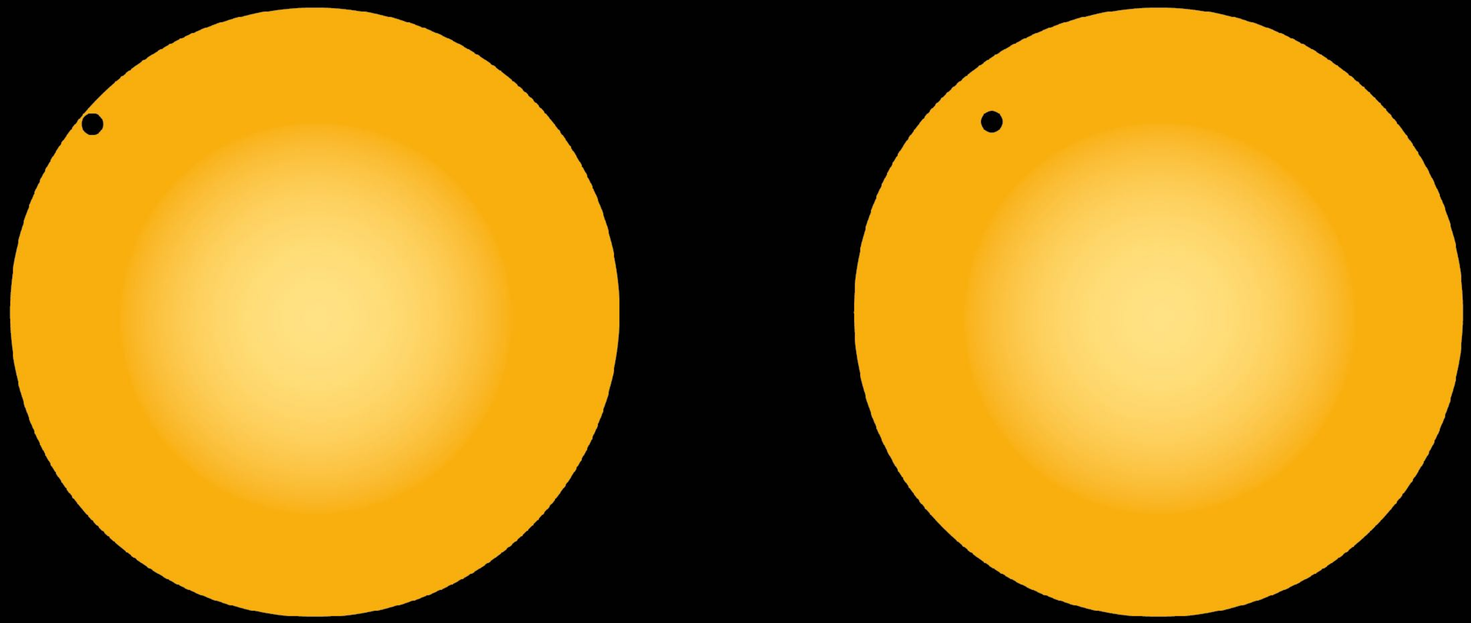
Knowing the Sun



How far is the Sun?

Image credit: David Brodie

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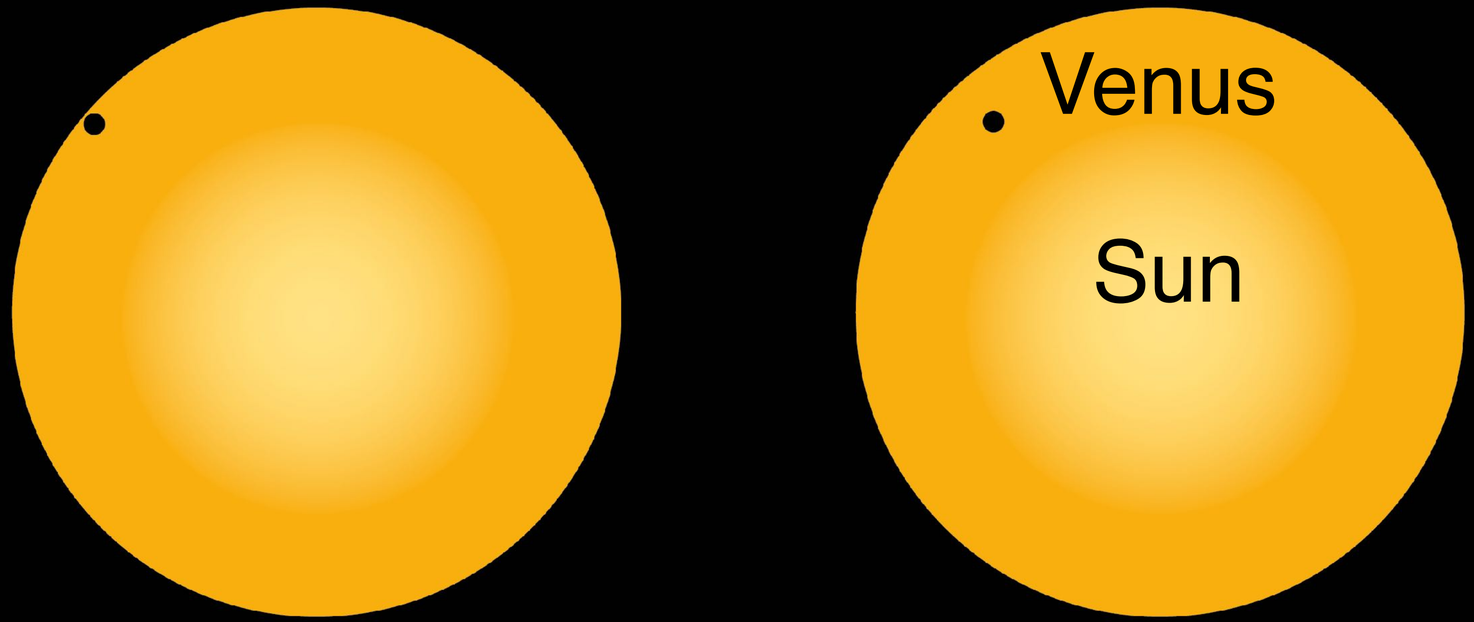

How far is the Sun?

The time taken for a ‘transit of Venus’ across the face of the Sun is observed to be slightly different from different points on Earth.

Image credit: David Brodie

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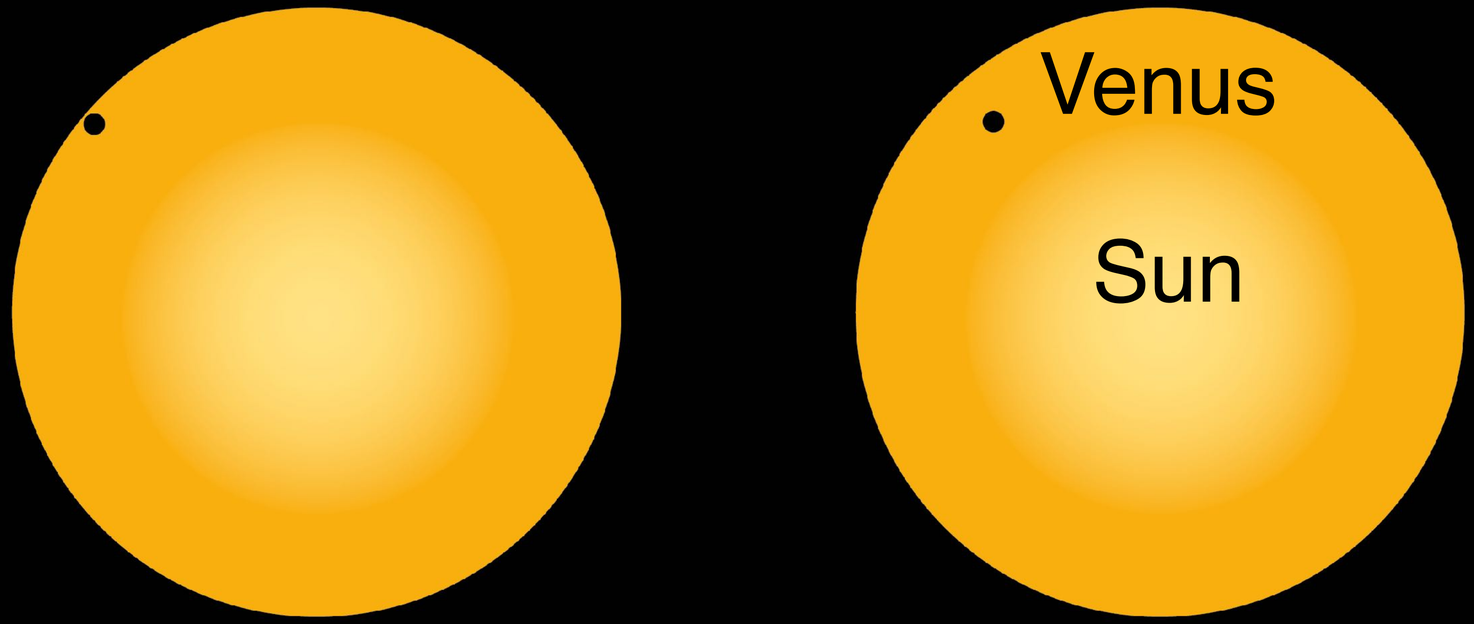

How far is the Sun?

The time taken for a ‘transit of Venus’ across the face of the Sun is observed to be slightly different from different points on Earth.

The geometry allows the distance to the Sun to be calculated.

Image credit: David Brodie

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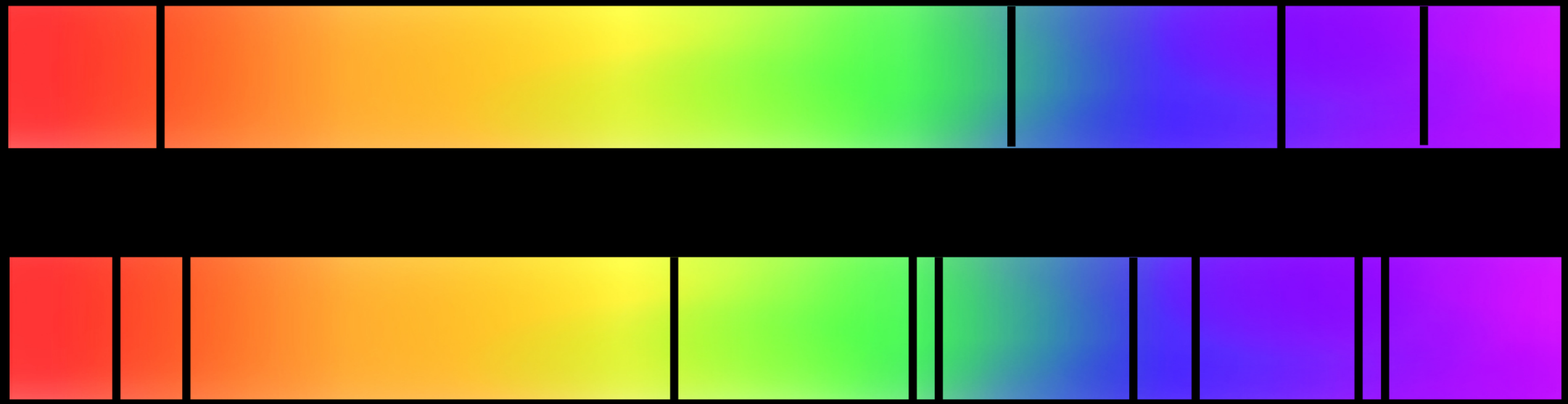
Knowing the Sun



The distinctive patterns of dark lines across the visible spectrum …

Image credit: David Brodie

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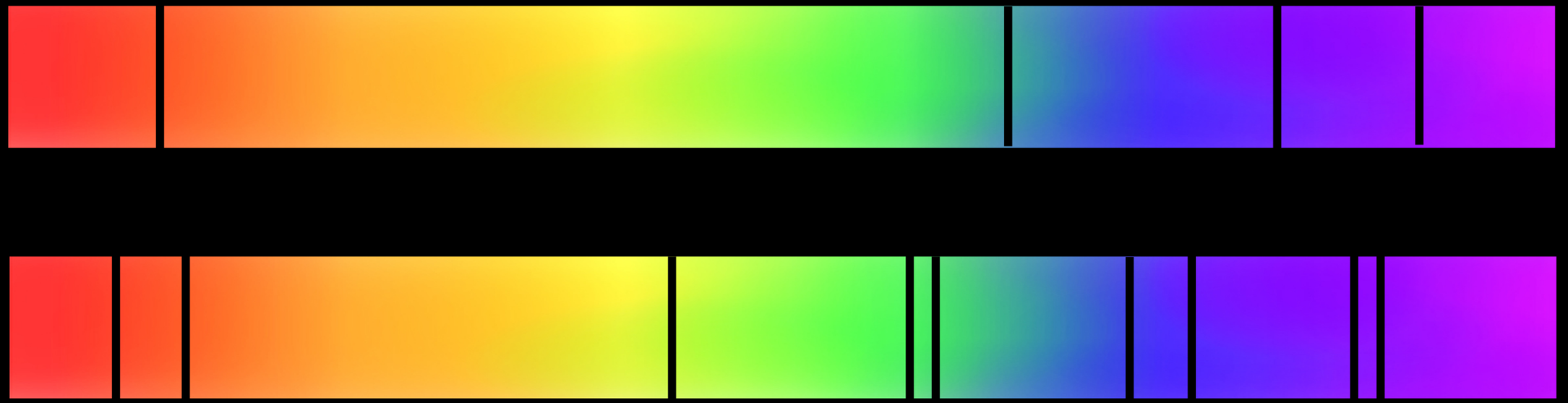
Knowing the Sun



The distinctive patterns of dark lines across the visible spectrum …

… when light has passed through different gases …

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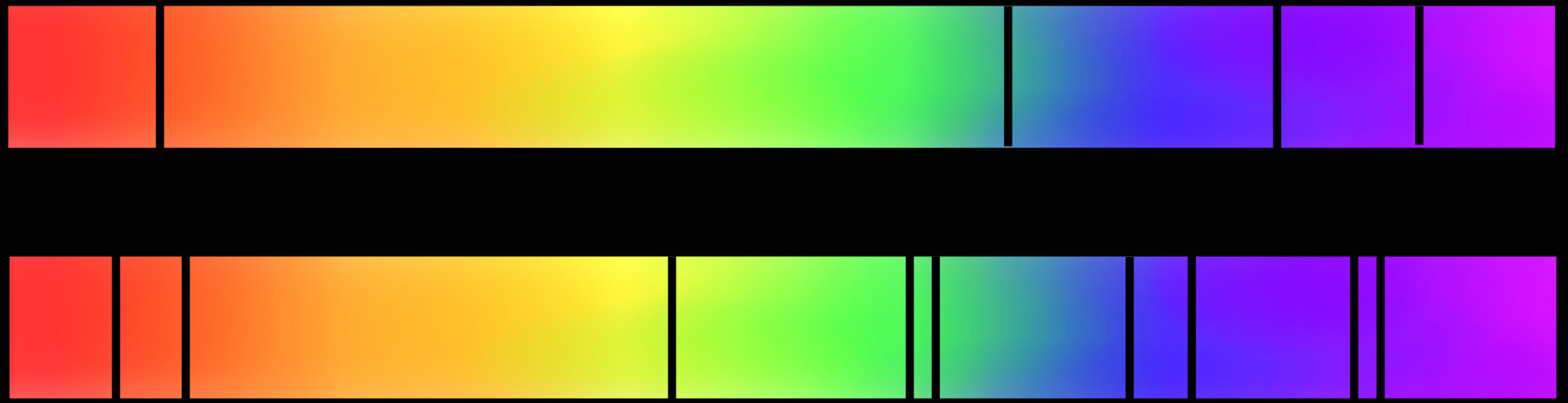

The distinctive patterns of dark lines across the visible spectrum …

… when light has passed through different gases …

… allows people to identify the gases in the outer layers of the Sun.

Image credit: David Brodie

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Much observation can be done from the ground

Image credit: ESO, ALMA, S.Guisard

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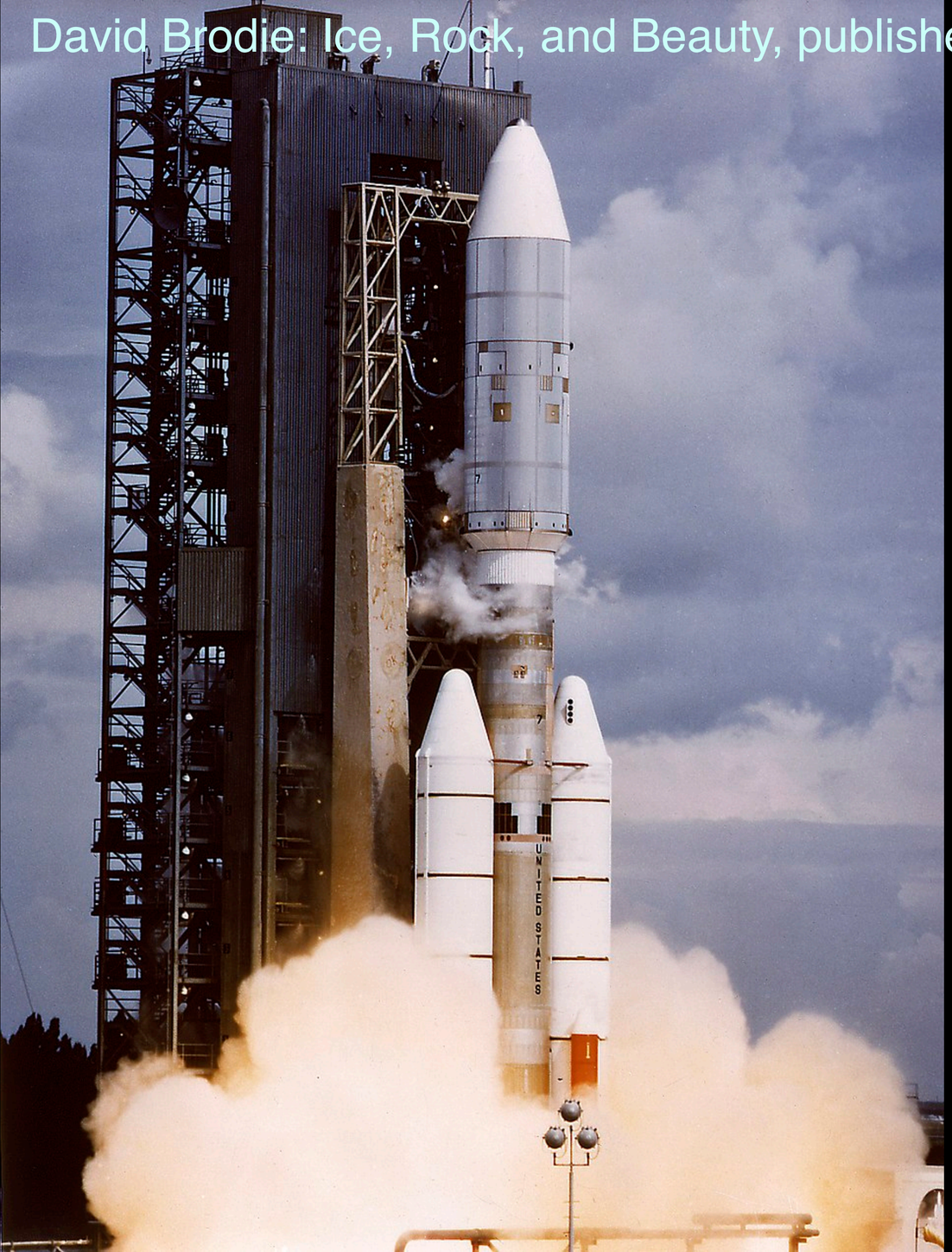
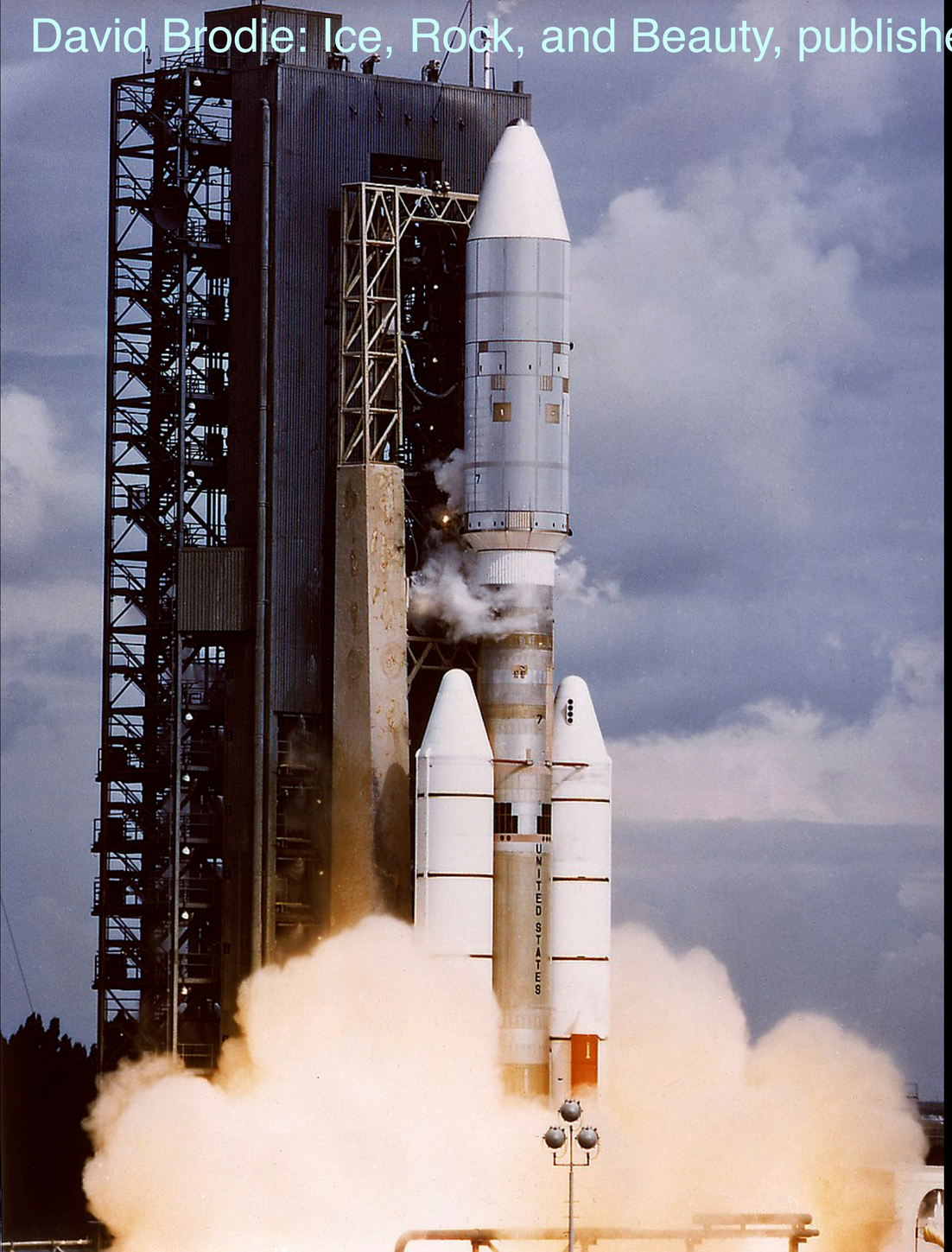


Space missions allow close-up engagement with many kinds of objects.

Image credit: NASA / MSFC (Voyager 2 launch, August 1977)



Space missions allow close-up engagement with many kinds of objects.

Voyagers 1 and 2, launched in 1977, continue their journeys away from us.

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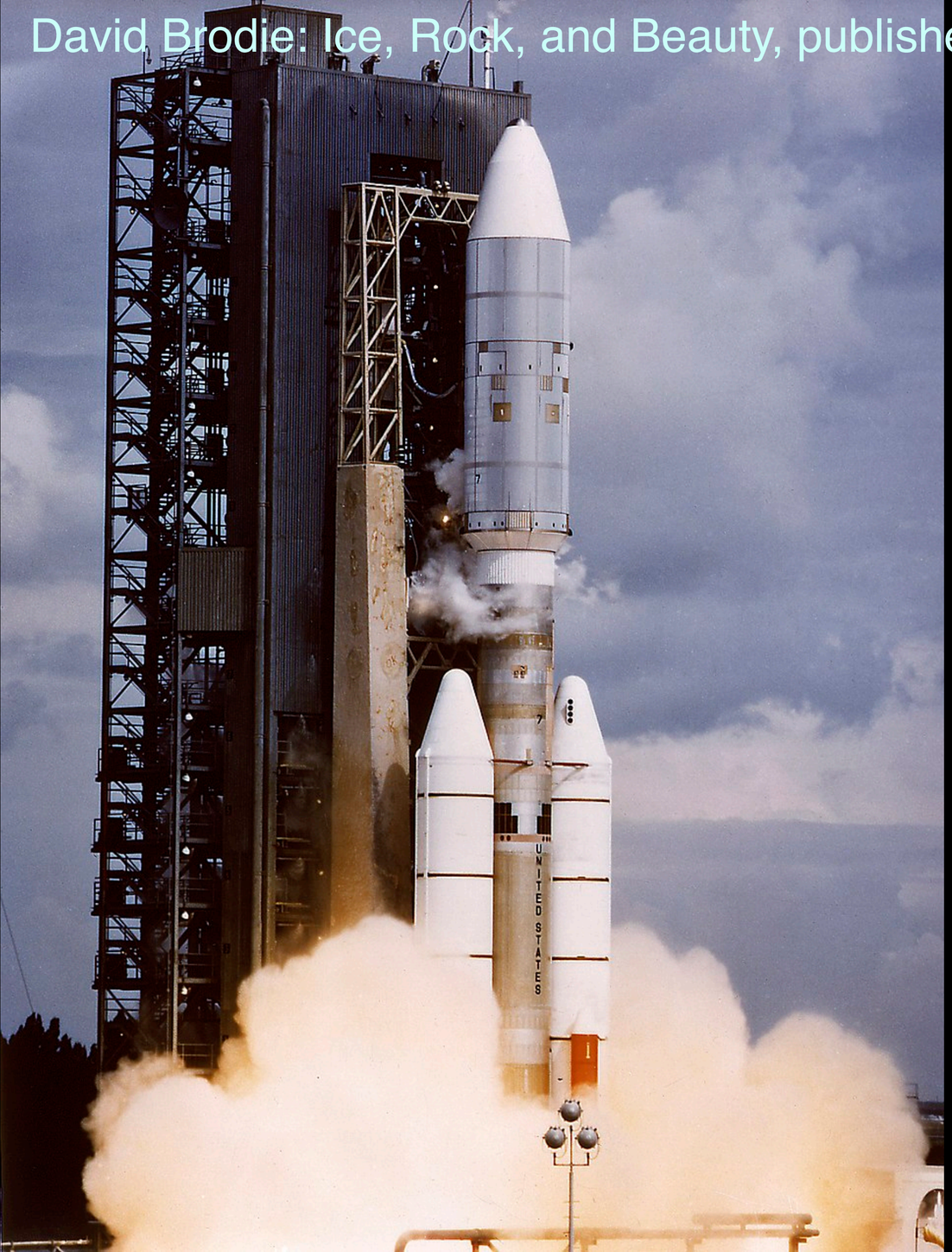

Space missions allow close-up engagement with many kinds of objects.

Voyagers 1 and 2, launched in 1977, continue their journeys away from us.

Still sending signals back home.

Image credit: NASA / MSFC (Voyager 2 launch, August 1977)

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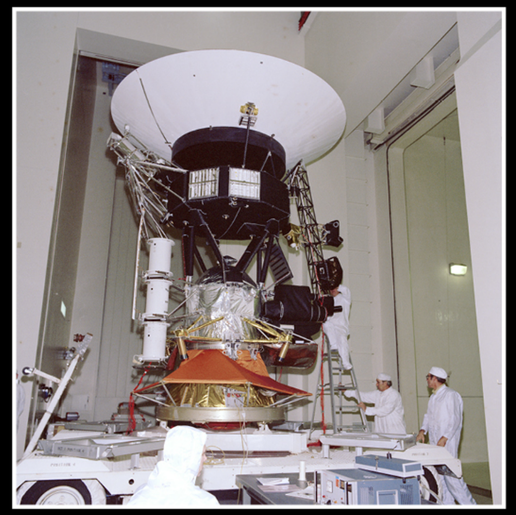
Voyager 2
before launch



A faint image
of Voyager 2,
constructed
from radio
data

Image credit: left, NASA; right NRAO, AUI, NSF

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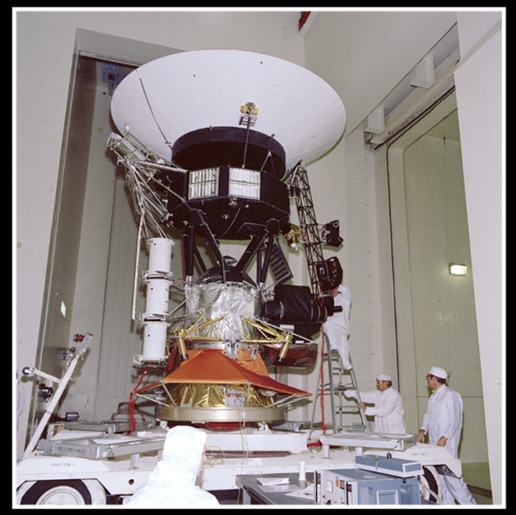
The two Voyager spacecraft have both passed through the heliopause …

Voyager X, before launch



A faint image of Voyager 2, constructed from radio data

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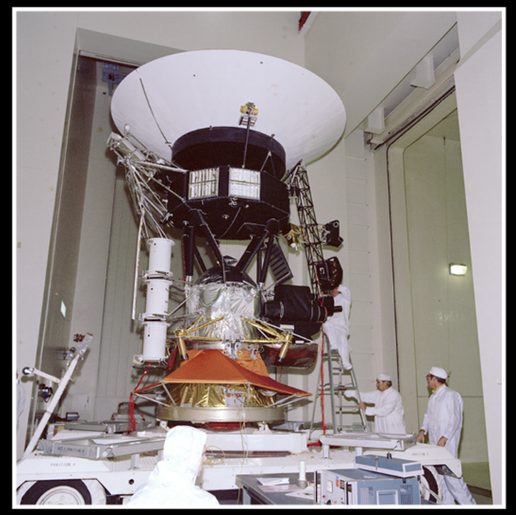
Voyager X, before launch



The two Voyager spacecraft have both passed through the heliopause …

… where the Sun’s influence is matched by the influence of instellar space …

A faint image of Voyager 2, constructed from radio data

Image credit: left, NASA; right NRAO, AUI, NSF

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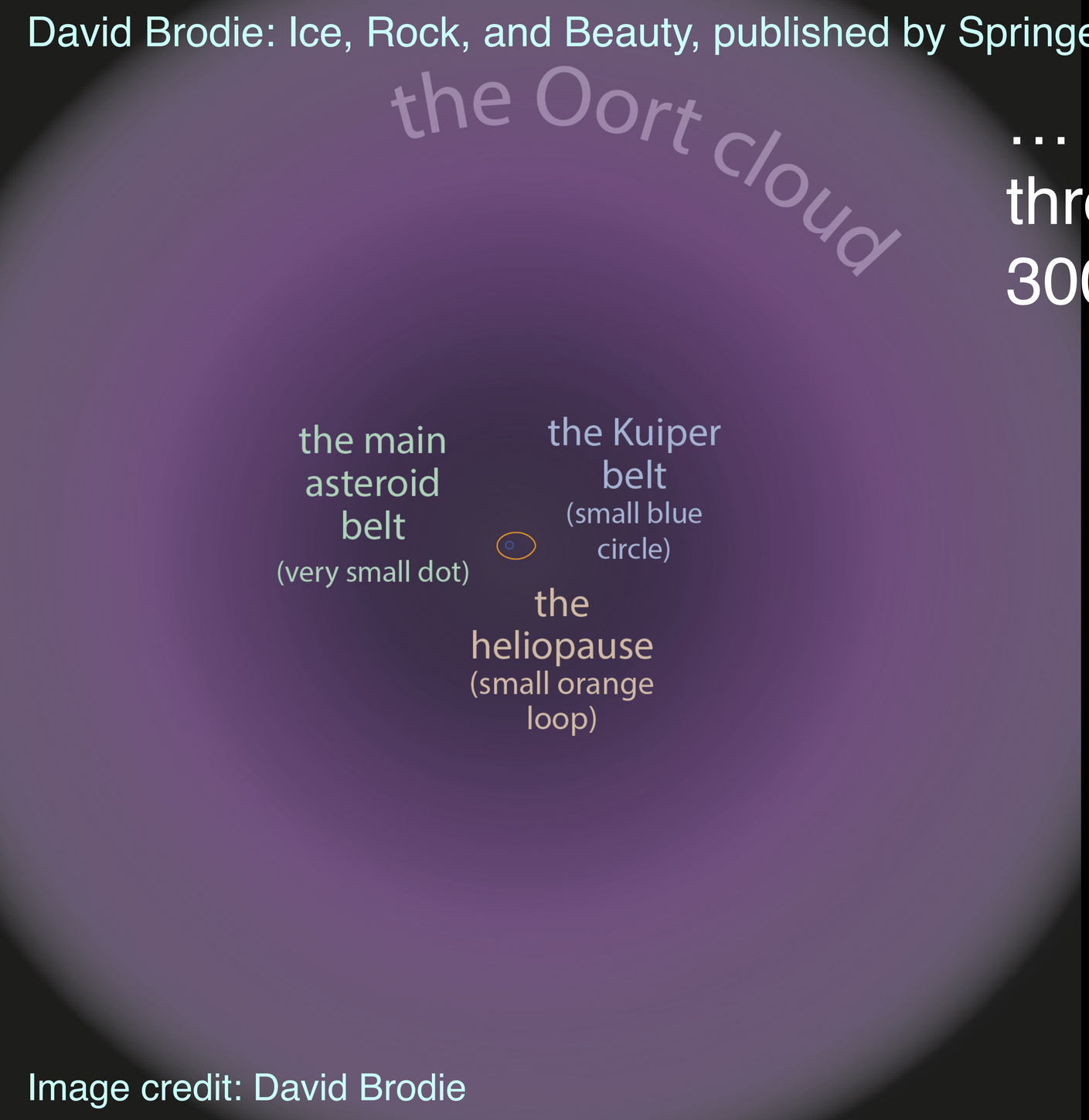

… but they must keep going, through lonely darkness, for 300 years …

Image credit: David Brodie

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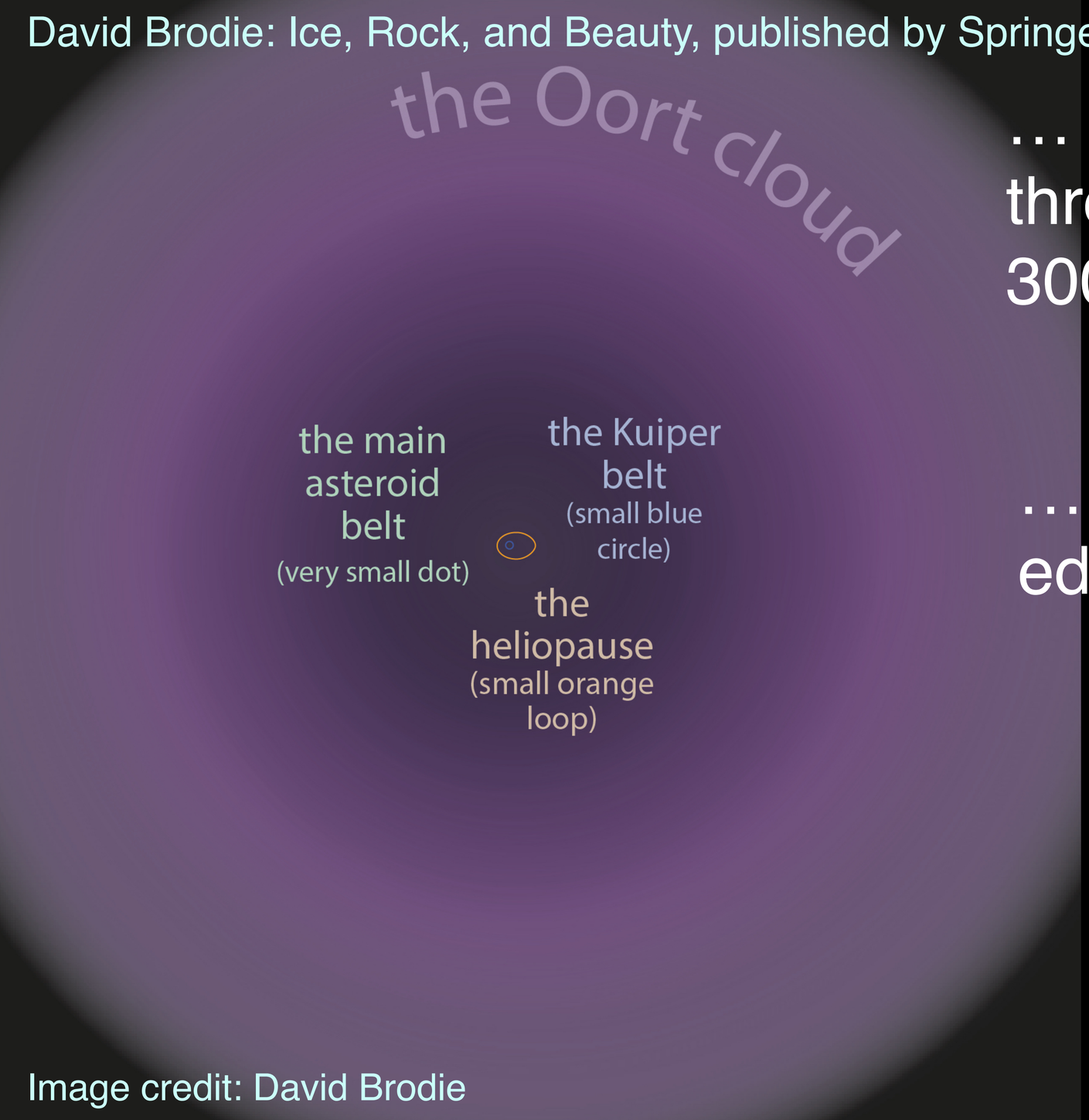

… but they must keep going, through lonely darkness, for 300 years …

… before they reach the inner edge of the Oort Cloud …

Image credit: David Brodie

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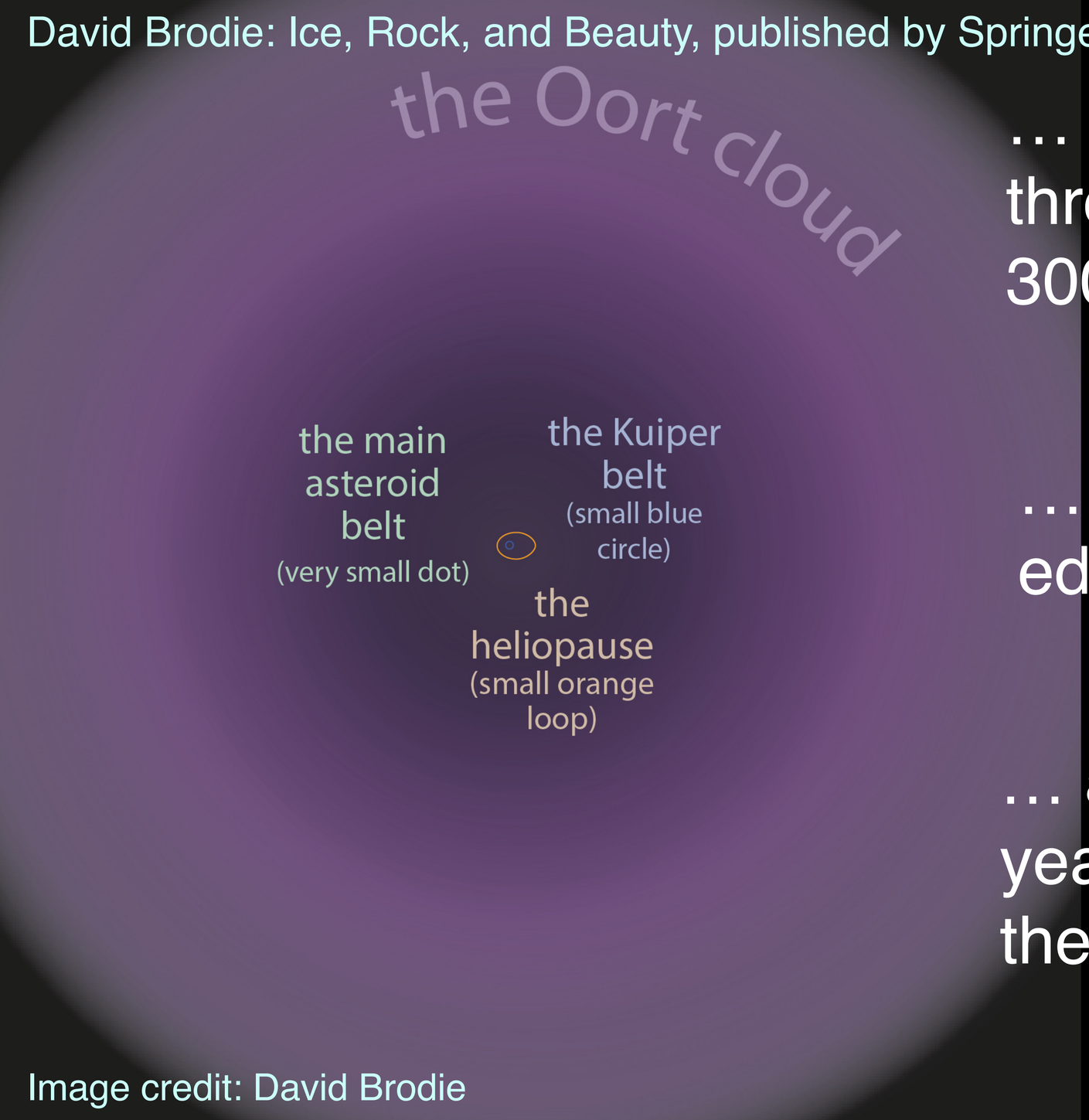

… but they must keep going, through lonely darkness, for 300 years …

… before they reach the inner edge of the Oort Cloud …

… and tens of thousands more years before they emerge at the far side.

Image credit: David Brodie

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In the meantime we can make observations from space …

Image: NASA / MSFC / imaged by a crew member, STS-105 Mission, 2001

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In the meantime we can make observations from space …

… both of our own planet …

Image: NASA / MSFC / imaged by a crew member, STS-105 Mission, 2001

In the meantime we can make observations from space …

… both of our own planet …

… and of objects very much further away.

Image: NASA / MSFC / imaged by a crew member, STS-105 Mission, 2001

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Sand dunes on Mars

Image credit: left, NASA, JPL-Caltech, University of Arizona

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Textures of the surface of Jupiter's moon, Europa



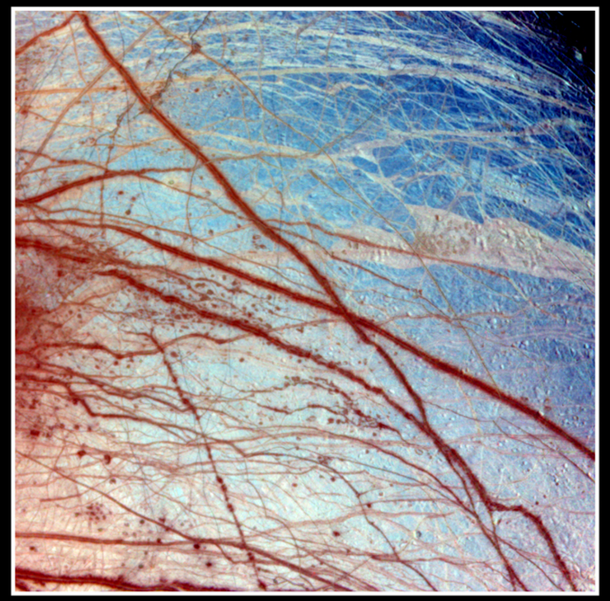
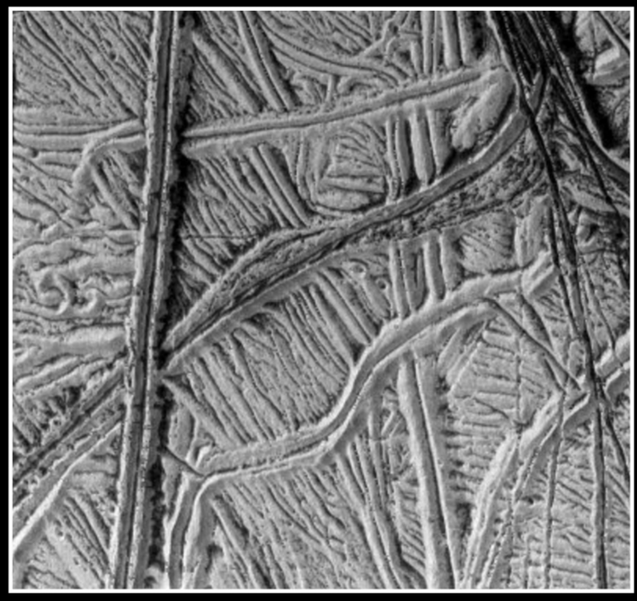

Image credit: left, NASA, JPL, University of Arizona

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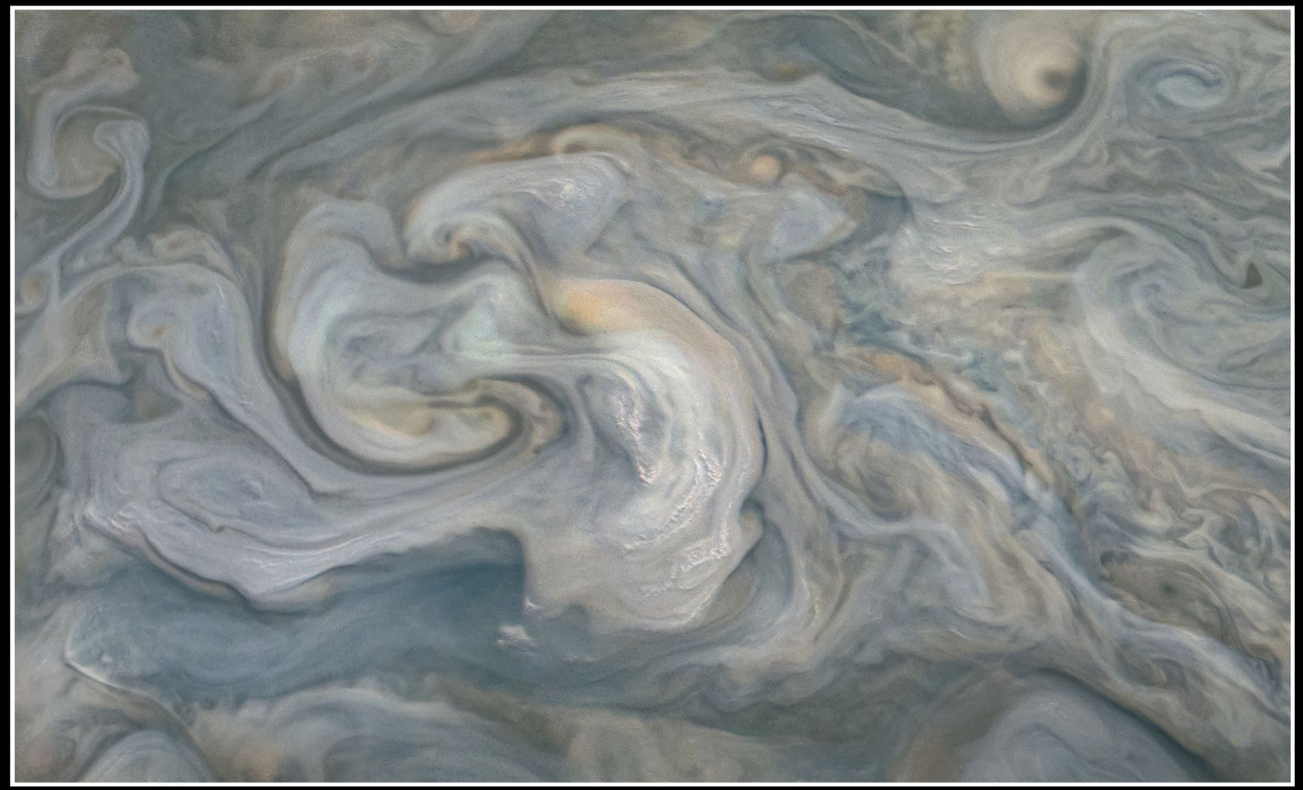


The upper clouds of Jupiter

Image credit: all, NASA, JPL-Caltch; left, Gerald Eichstadt, Sean Doran; centre Kevin M Gill; right, Roman Tkachenko

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The crescent of Saturn, with rings, and a comparatively tiny moon, Epimetheus.

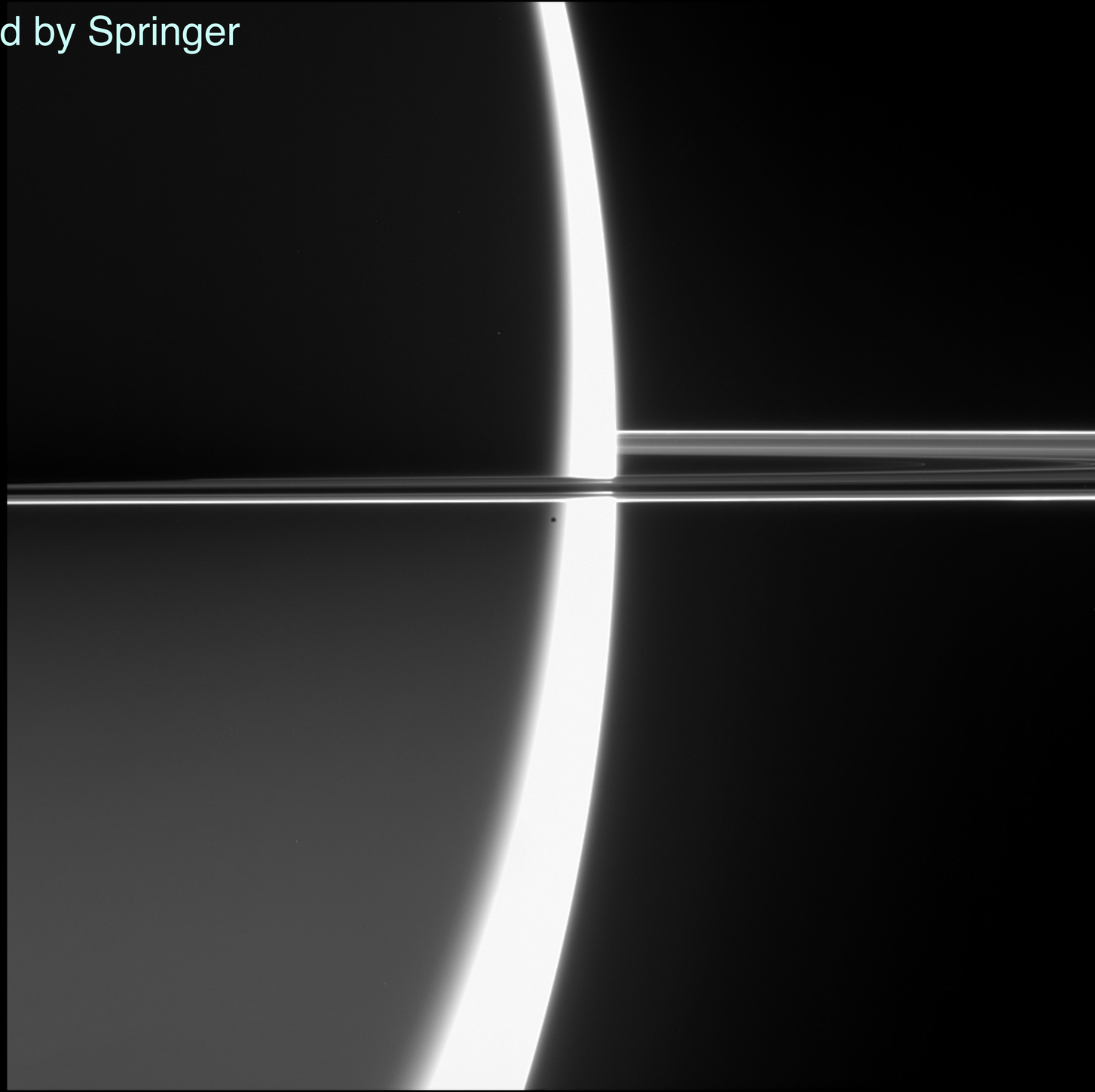

Image credit: NASA, JPL, Space Science Institute

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Saturn’s largest moon, and the second largest in the Solar System

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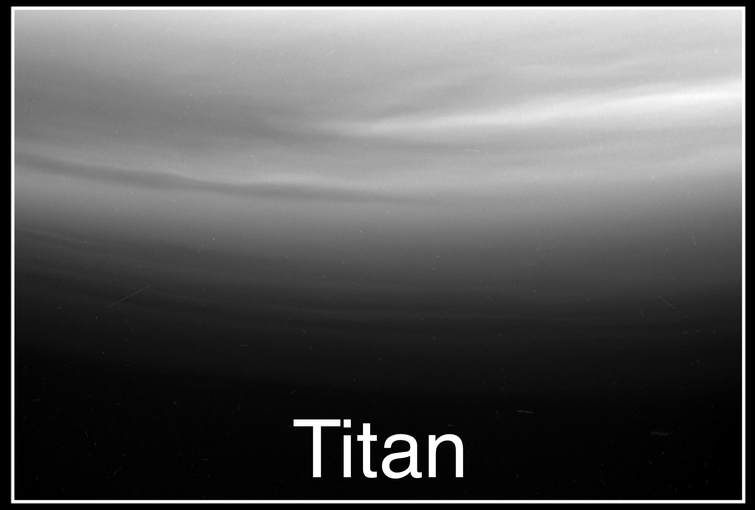

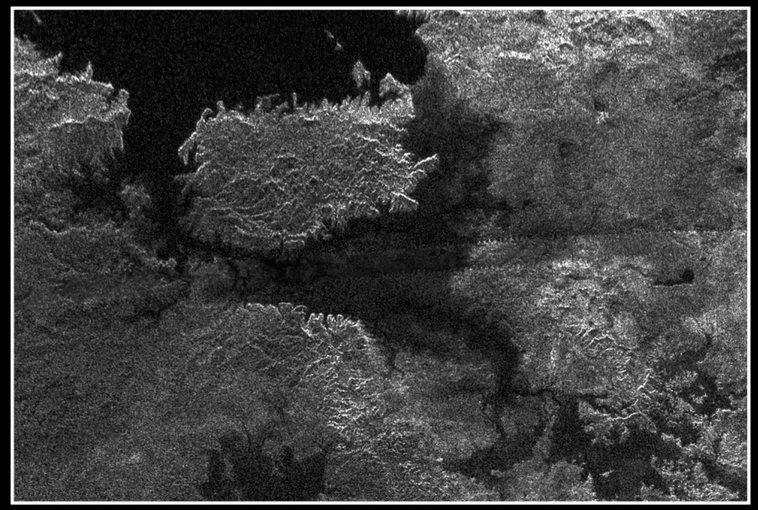

It’s far from the Sun, but explored by the Huygens lander in 2005.

Image credit: NASA, JPL, Space Science Institute

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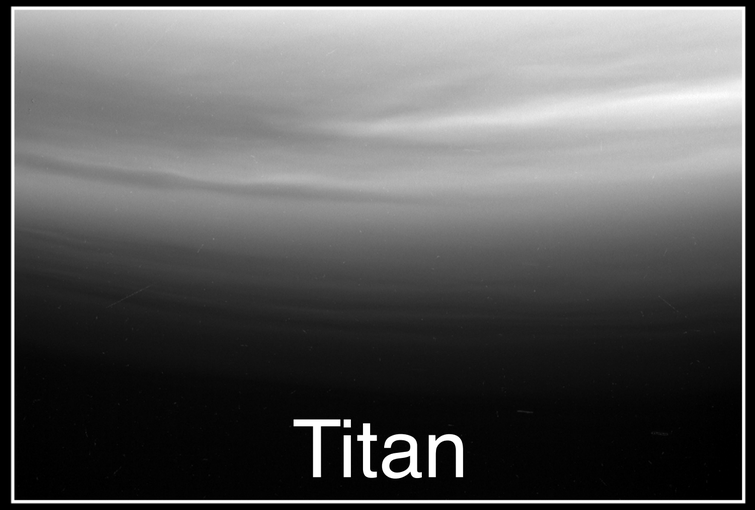
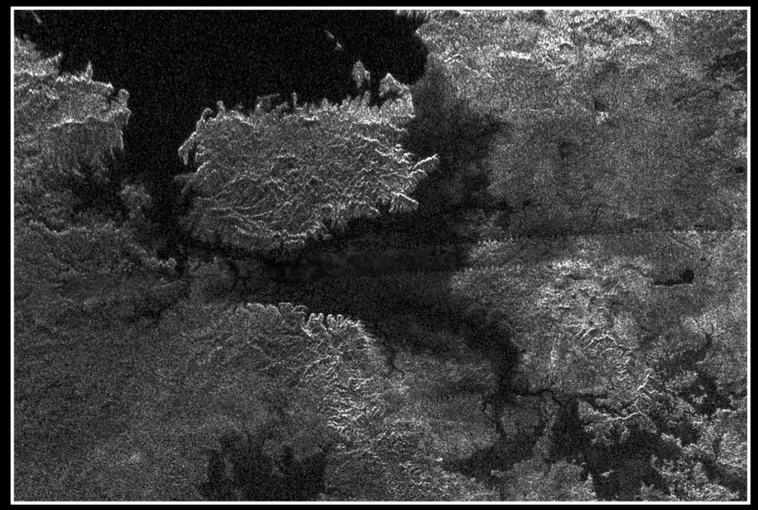
Saturn’s largest moon, and the second largest in the Solar System





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Not surprisingly, it’s cold. But it has seas of liquid hydrocarbon, with cycles of evaporation and precipitation.

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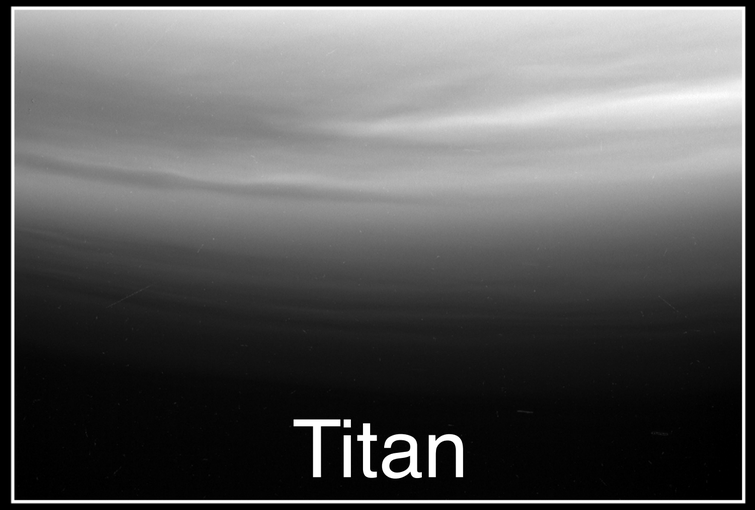

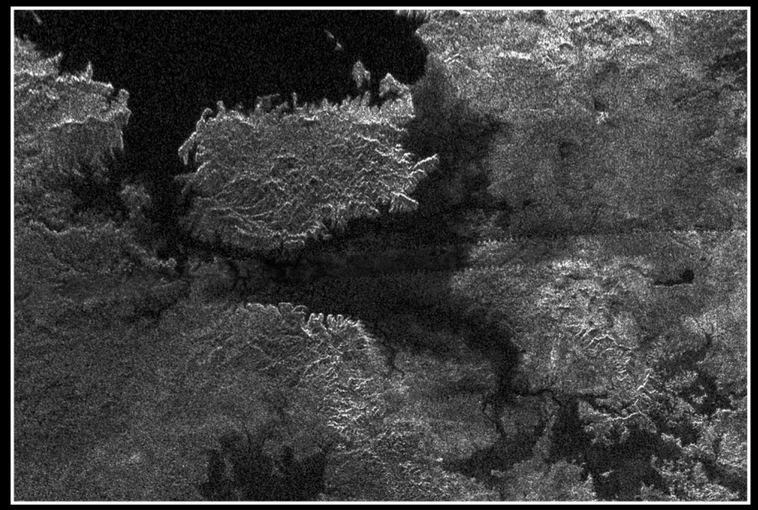

It’s far from the Sun, but explored by the Huygens lander in 2005.

Not surprisingly, it’s cold. But it has seas of liquid hydrocarbon, with cycles of evaporation and precipitation.

So it seems that there are streams there, trickling right now.

Image credit: NASA, JPL, Space Science Institute

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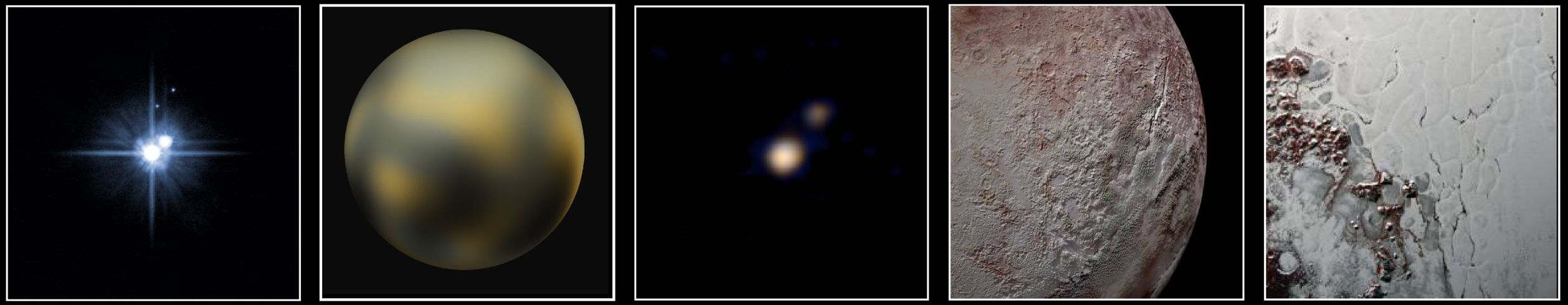
Zooming in on Pluto



Left, as seen, with Charon, by Hubble, HST, in 2005

Image credit: left, NASA, ESA, HST; centre left, NASA, ESA, SRI; centre, centre-right and rich, NASA, JHU, SRI

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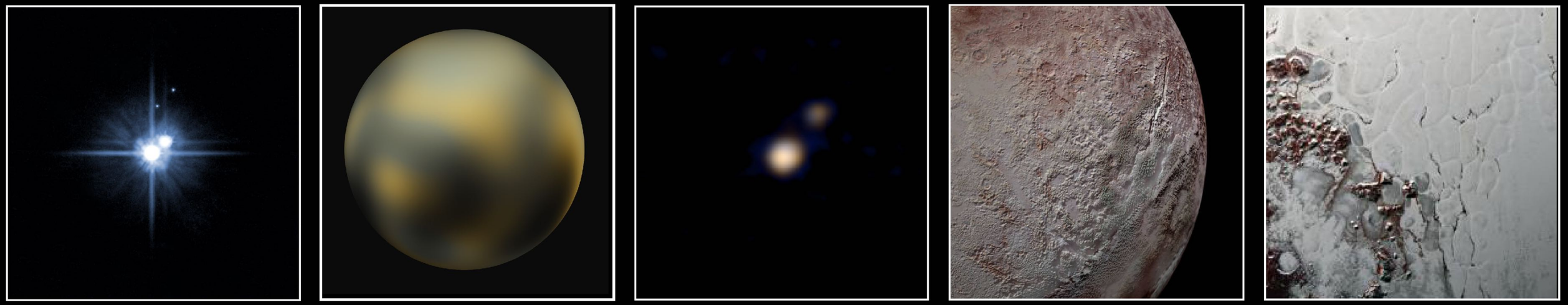

Left, as seen, with Charon, by Hubble, HST, in 2005

Centre-left, some crude texture as seen by Hubble, HST, in 2002-3

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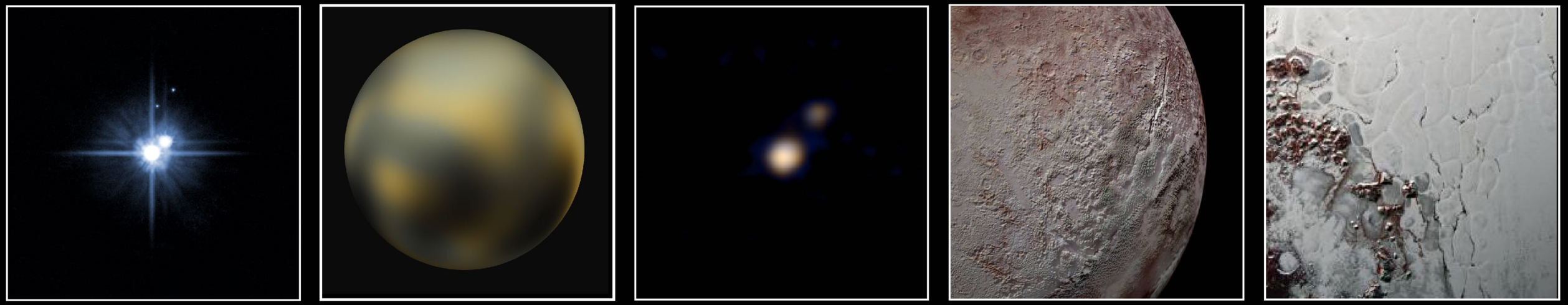

Left, as seen, with Charon, by Hubble, HST, in 2005

Centre-left, some crude texture as seen by Hubble, HST, in 2002-3

Centre, from 115 million kilometres away, as the New Horizon mission got ‘close’

Image credit: left, NASA, ESA, HST; centre left, NASA, ESA, SRI; centre, centre-right and rich, NASA, JHU, SRI

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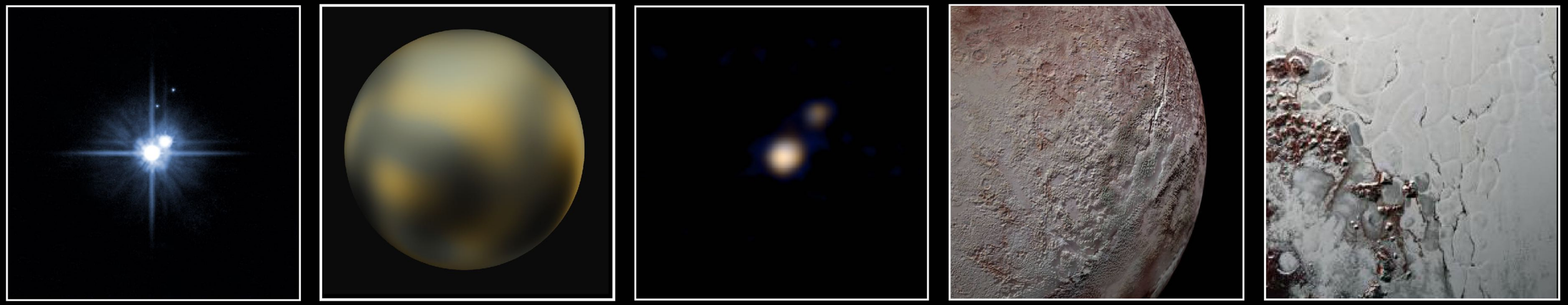

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Centre-left, some crude texture as seen by Hubble, HST, in 2002-3

Centre, from 115 million kilometres away, as the New Horizon mission got ‘close’

Centre-right and right, detail during the New Horizon flyby in 2015

Image credit: left, NASA, ESA, HST; centre left, NASA, ESA, SRI; centre, centre-right and rich, NASA, JHU, SRI

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A pair of objects in the Kuiper belt, out beyond the orbit of Neptune

Image credit: NASA, ESA, SwRI

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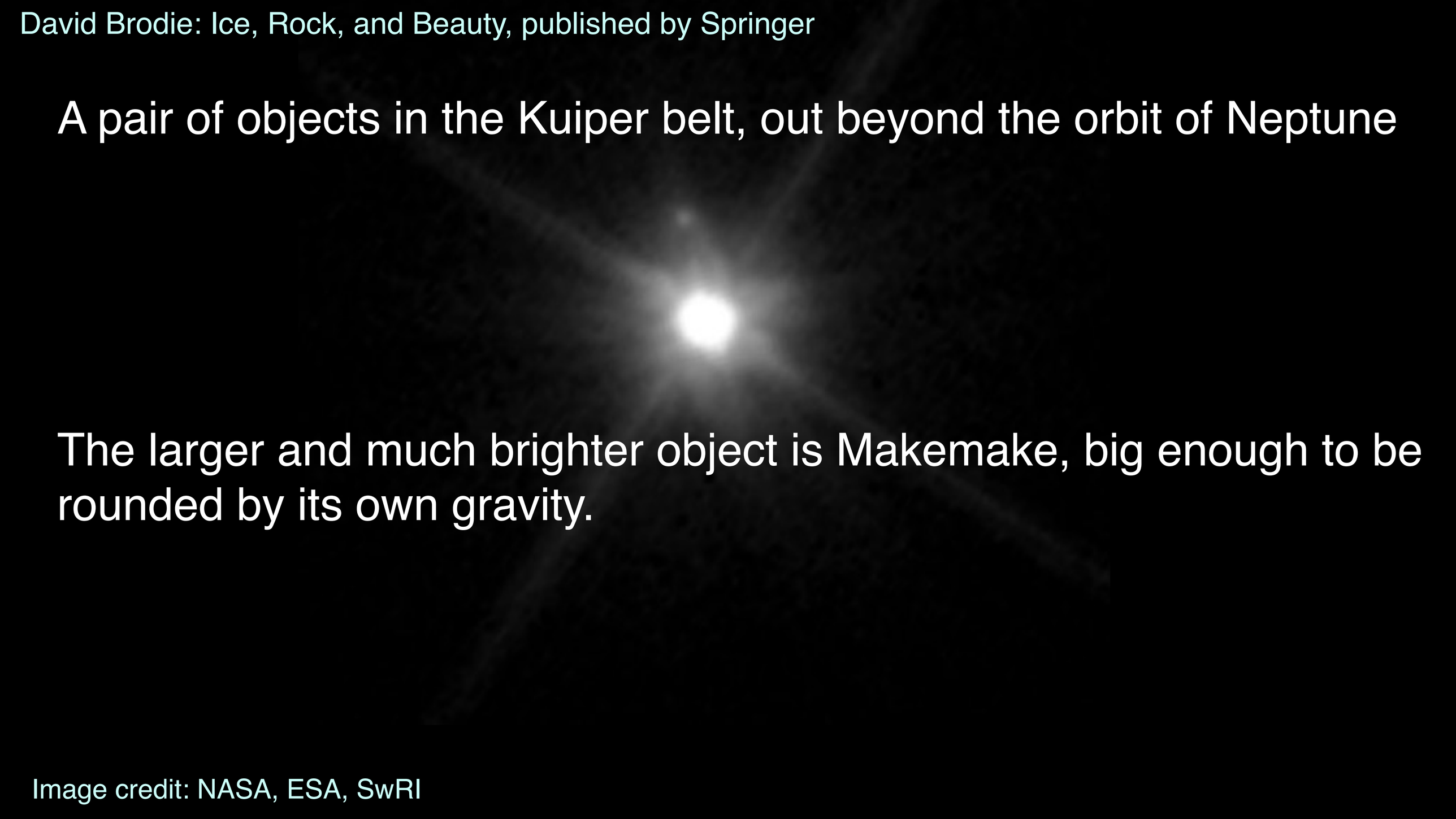

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The larger and much brighter object is Makemake, big enough to be rounded by its own gravity.

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The smaller object, top left, is its moon, currently known and Mk2.

Image credit: NASA, ESA, SwRI

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Sedna might have been discovered before Pluto.

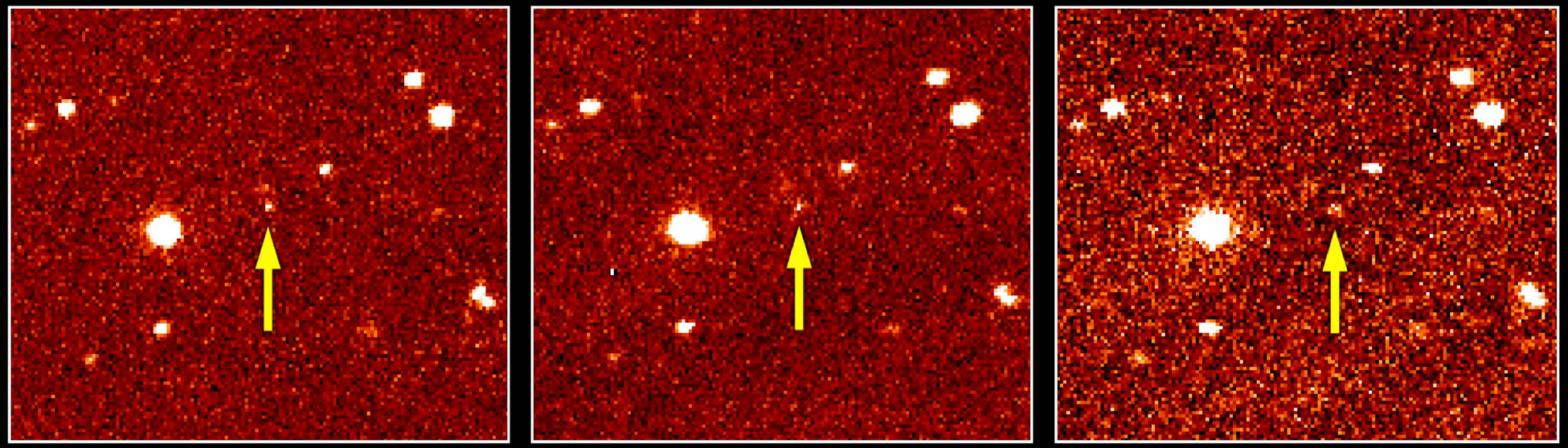

Image credit: NASA, JPL, Caltech

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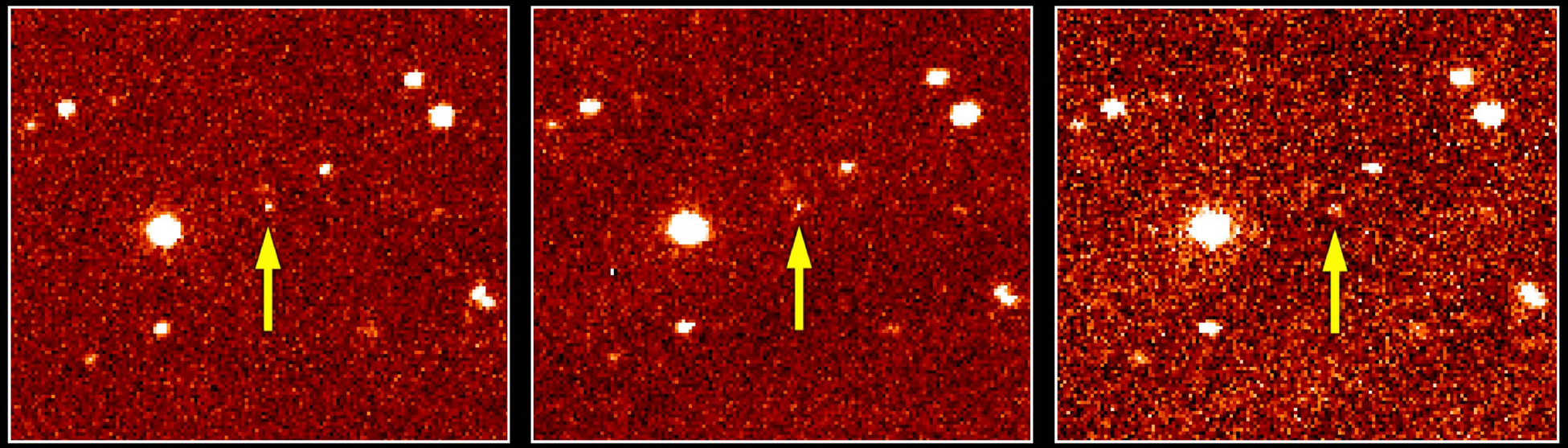

But it has an orbit that takes it out towards the Oort Cloud.

Image credit: NASA, JPL, Caltech

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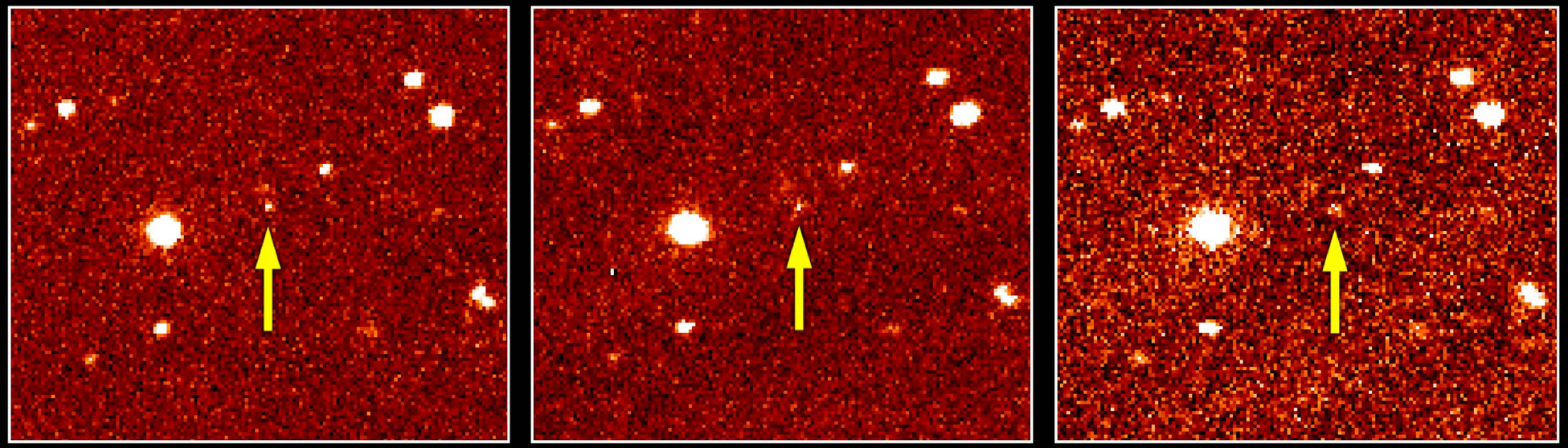

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During the 20th century it was too far away to be detectable.

Image credit: NASA, JPL, Caltech

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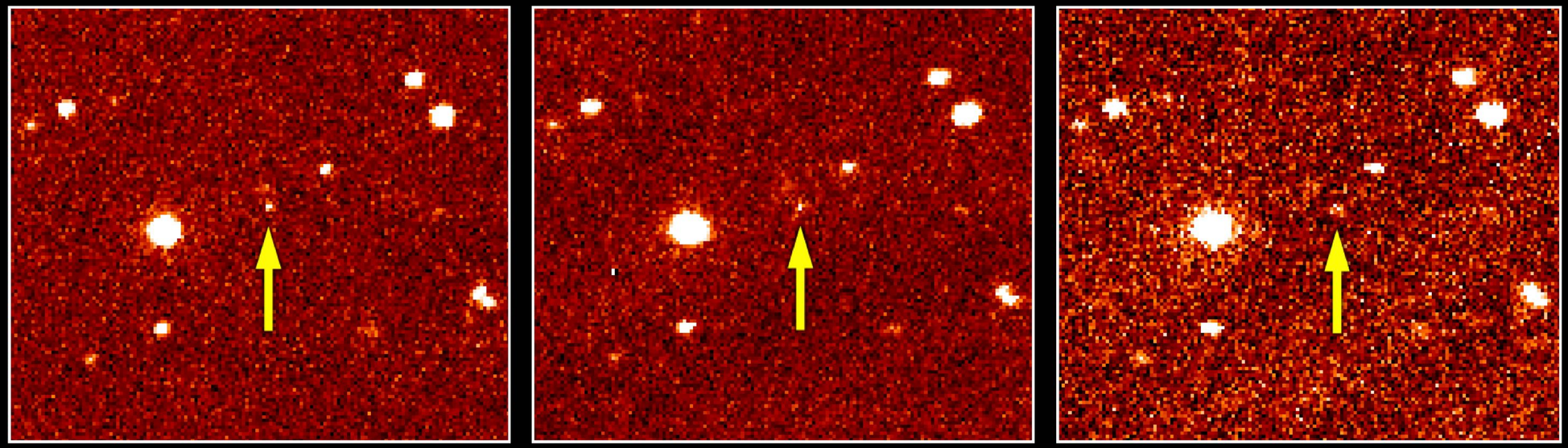

But it has an orbit that takes it out towards the Oort Cloud.

During the 20th century it was too far away to be detectable.

It’s highly elliptical and long, long orbit of the Sun takes 11,000 years.

Image credit: NASA, JPL, Caltech

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People have been engaging with our wider environment for a long time.

Image credit: Raymbertz


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This is a replica of the Nabta Playa stone circle.
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This is a replica of the Nabta Playa stone circle.
People have been engaging with our wider environment for a long time.
The original, in the Egyptian Sahara Desert, is 7000 years old.
Image credit: Raymbertz

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Stable dynamic systems survive thanks to negative feedback.

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Stable dynamic systems survive thanks to negative feedback.

How long will it be before the Earth becomes as lifeless as its neighbours?

Stable dynamic systems survive thanks to negative feedback.

How long will it be before the Earth becomes as lifeless as its neighbours?

Is there life elsewhere that might carry on after the Earth becomes a dead place?

Stable dynamic systems survive thanks to negative feedback.

How long will it be before the Earth becomes as lifeless as its neighbours?

Is there life elsewhere that might carry on after the Earth becomes a dead place?

Can the whole of nature, the Universe, ever cease to exist?

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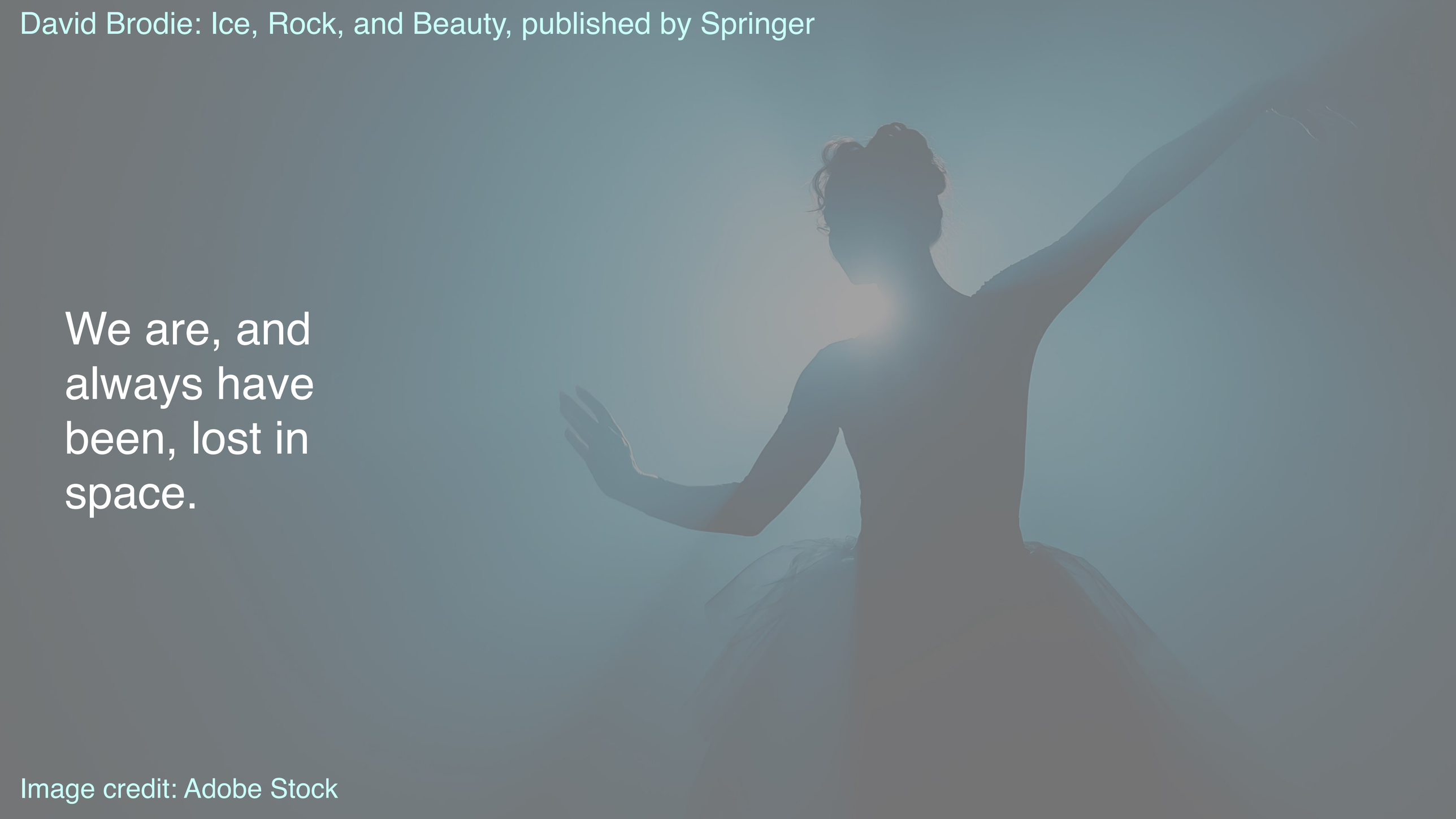

We are, and always have been, lost in space.

Image credit: Adobe Stock

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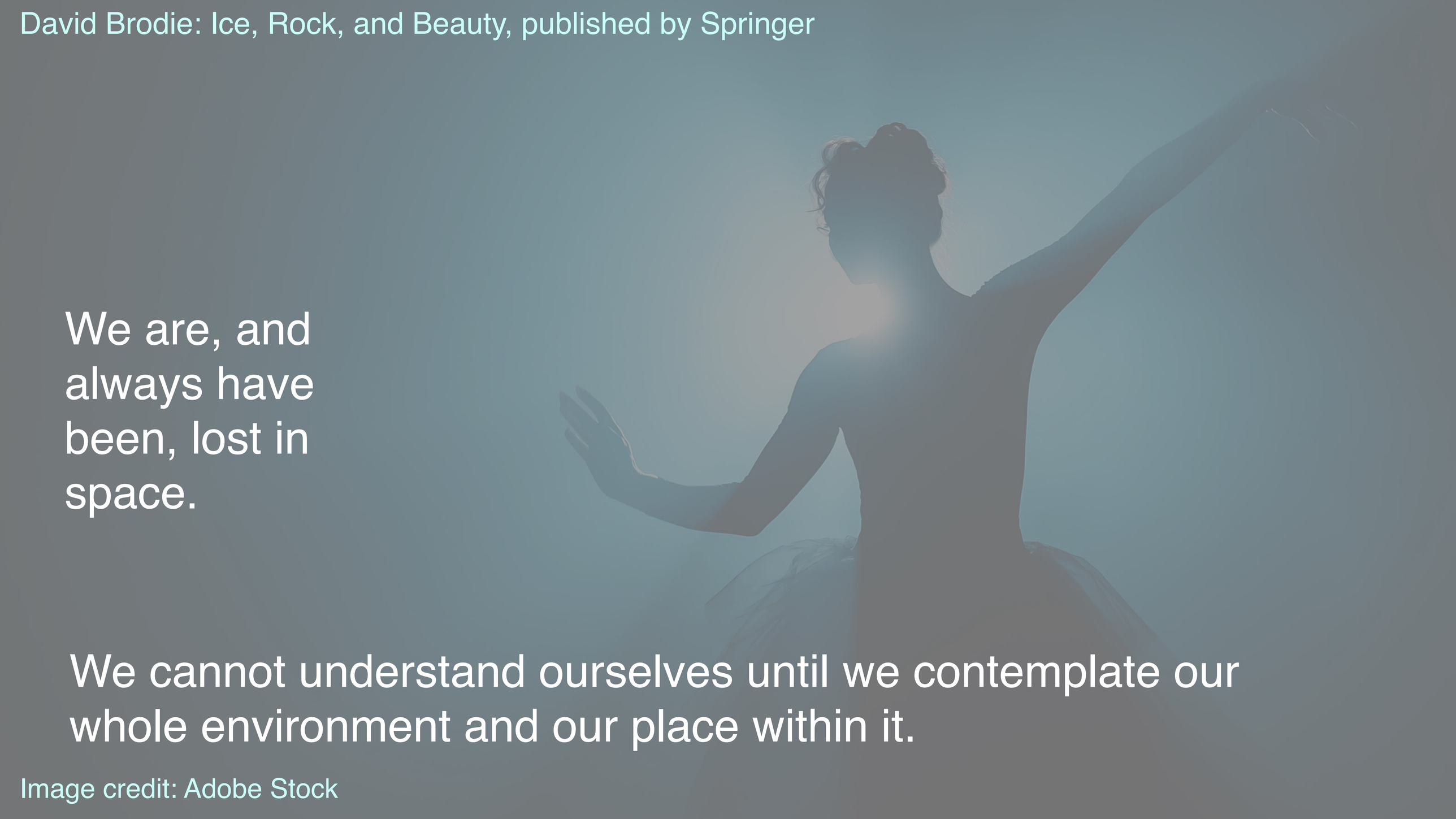

We are, and always have been, lost in space.

We cannot understand ourselves until we contemplate our whole environment and our place within it.

Image credit: Adobe Stock

PPT by David Brodie based on his book

Ice, Rock, and Beauty

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