$IO_3^- + 2H_2O_2 + H^+ \text{-------> } HIO + 2O_2 + 2H_2O$

$HIO + CH_2(CO_2H)_2 \text{ -----> } ICH(CO_2H)_2 + H_2O$

$I^- + HIO + H^+ \text{ ------> } I_2 + H_2O$

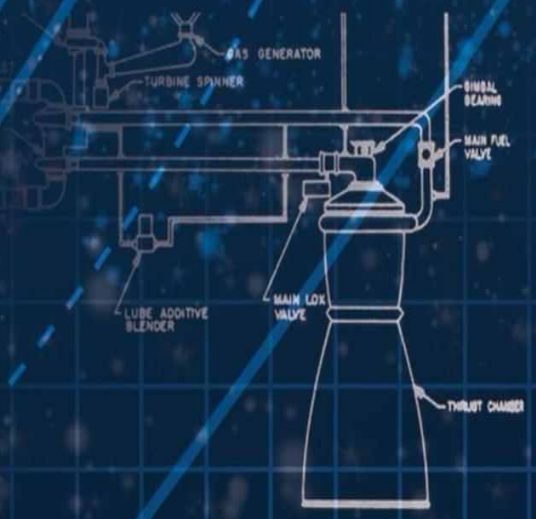
$I_2 + CH_2(CO_2H)_2 \text{ -----> } ICH(CO_2H)_2 + H^+ + I^-$

$$dv = -v_e \frac{dM}{M}$$

ROCKET SCIENCE

ANDREW RADER

ILLUSTRATION BY GALEN FRAZER



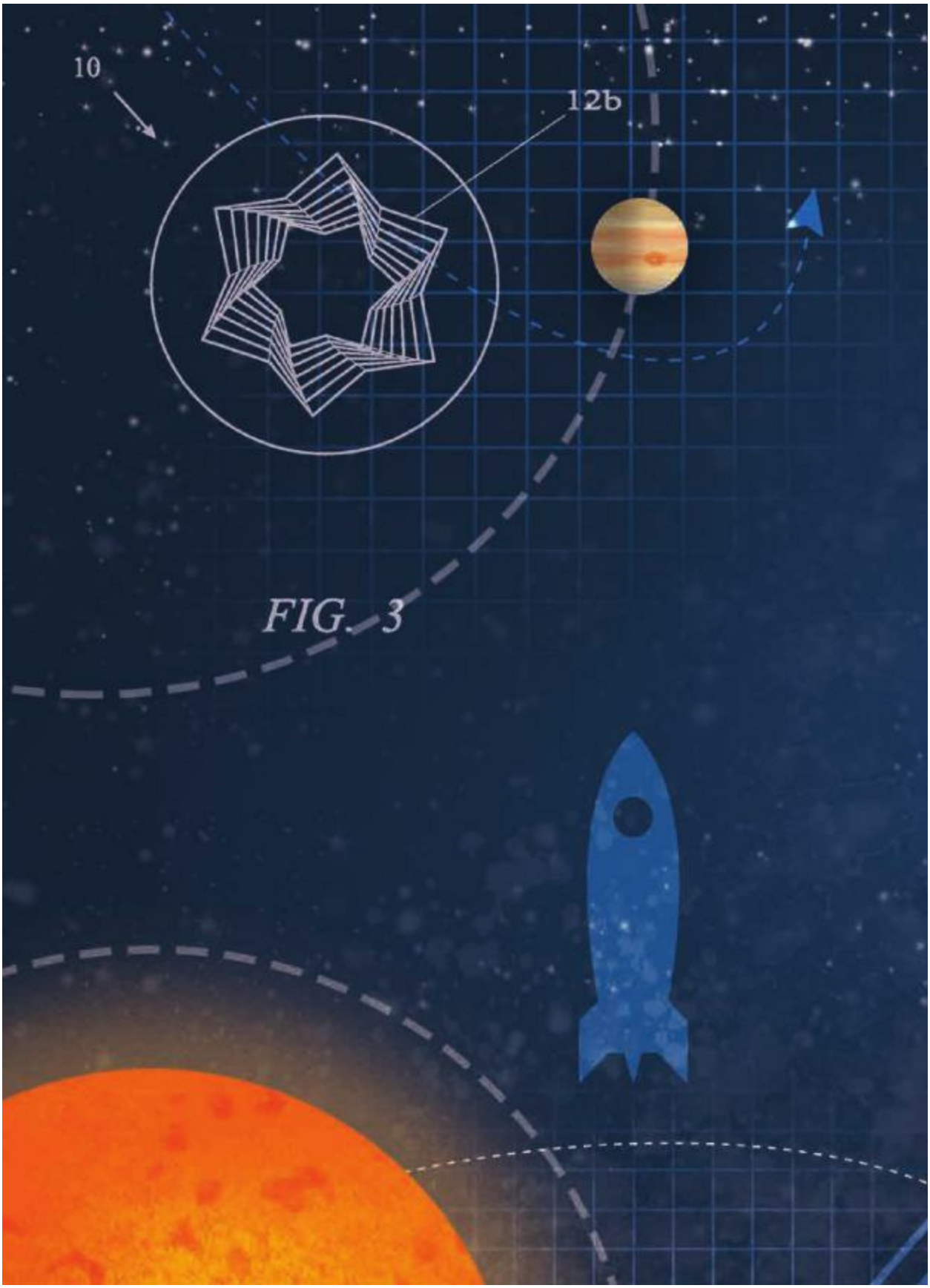


FIG. 3

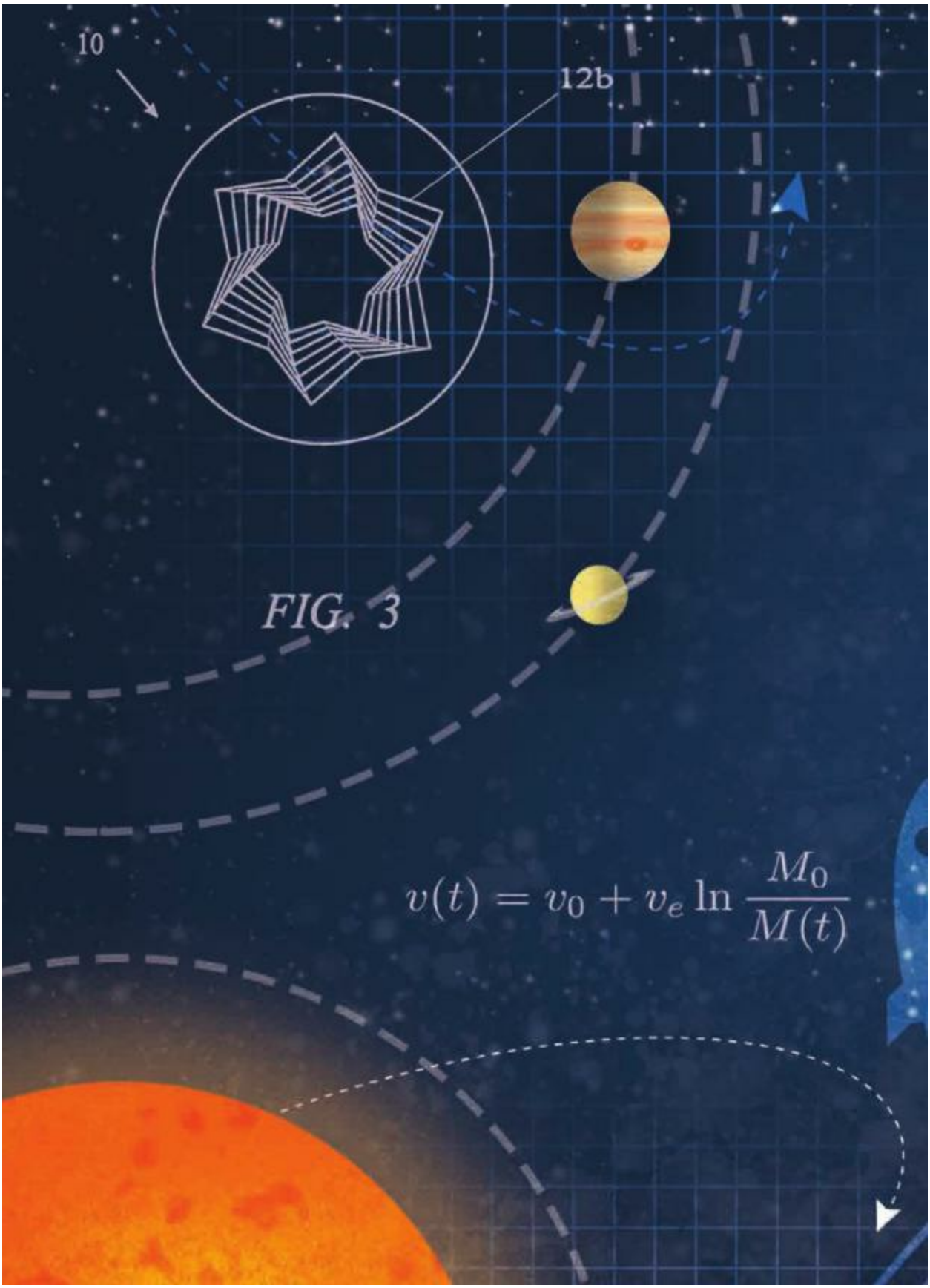
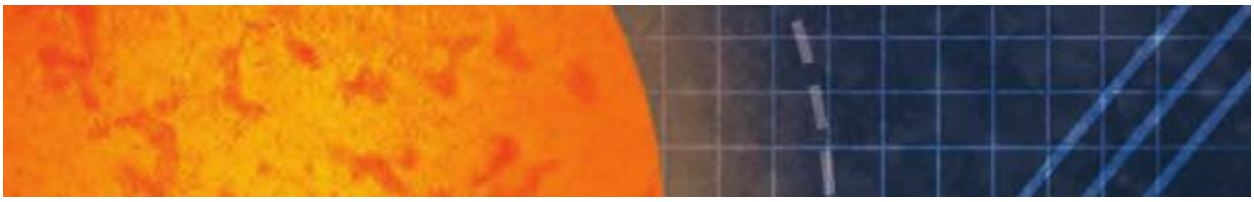
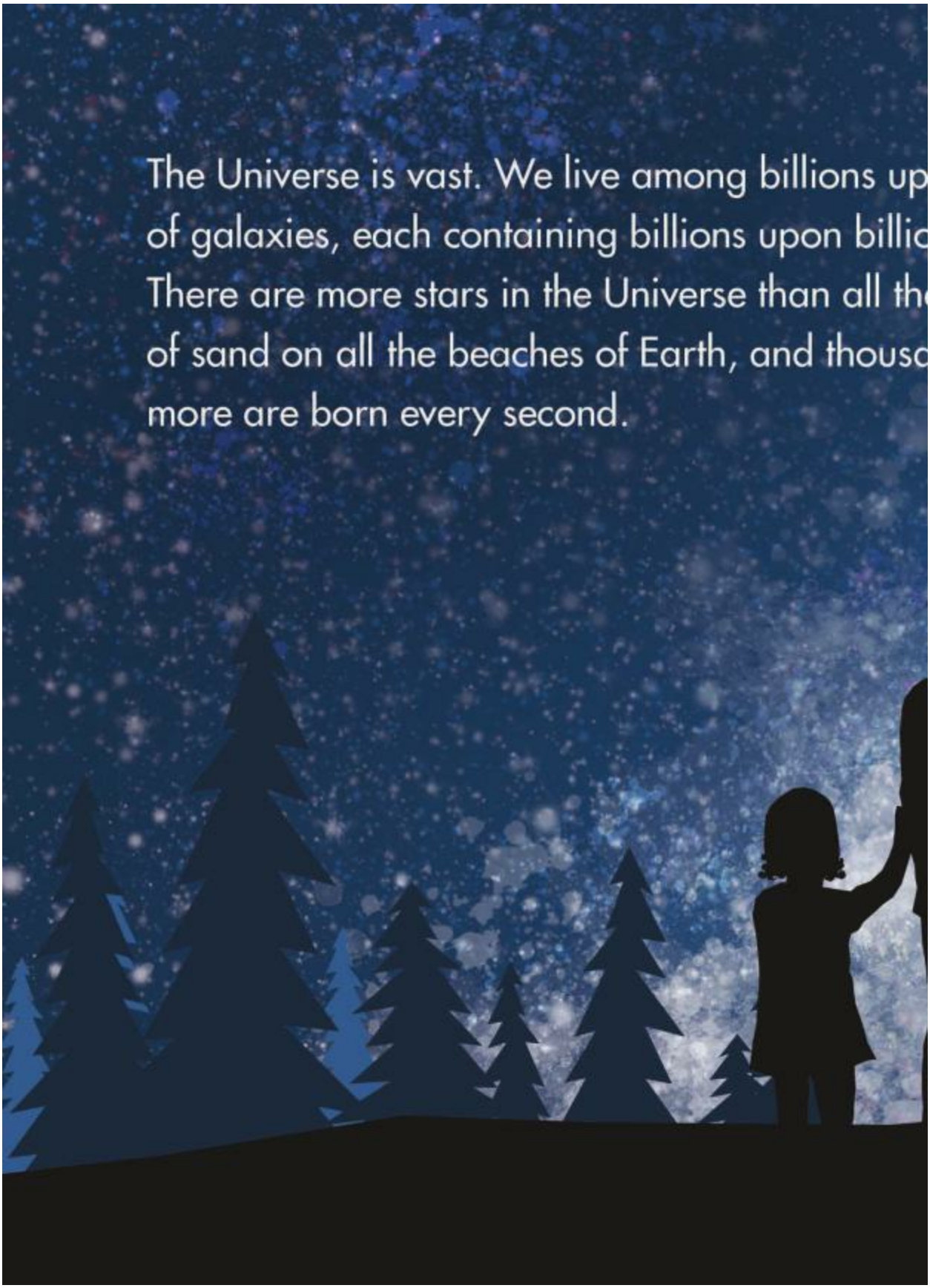
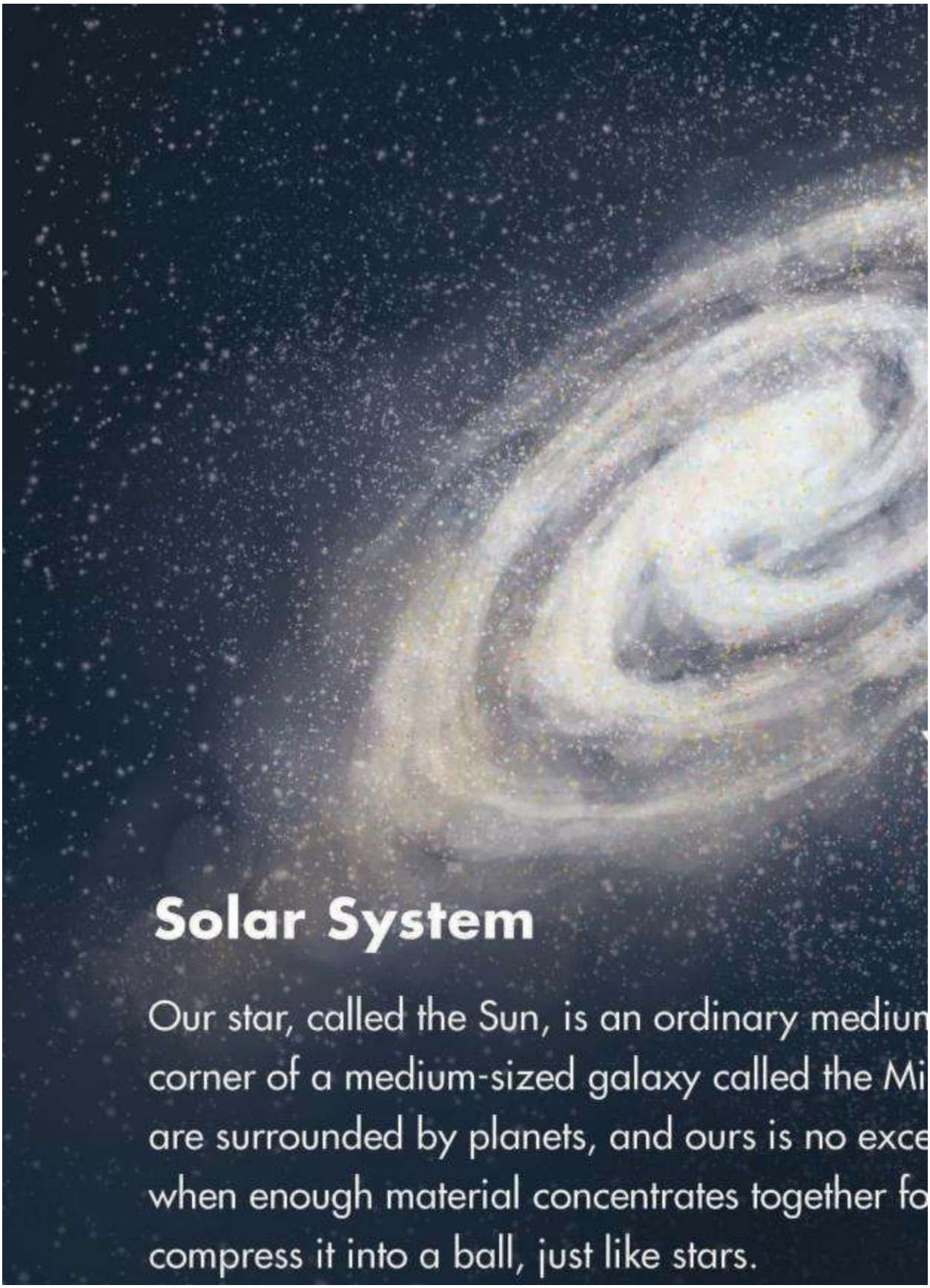


FIG. 3




The Universe is vast. We live among billions up
of galaxies, each containing billions upon billio
There are more stars in the Universe than all th
of sand on all the beaches of Earth, and thousa
more are born every second.



Solar System

Our star, called the Sun, is an ordinary mediu
corner of a medium-sized galaxy called the Mi
are surrounded by planets, and ours is no exce
when enough material concentrates together fo
compress it into a ball, just like stars.

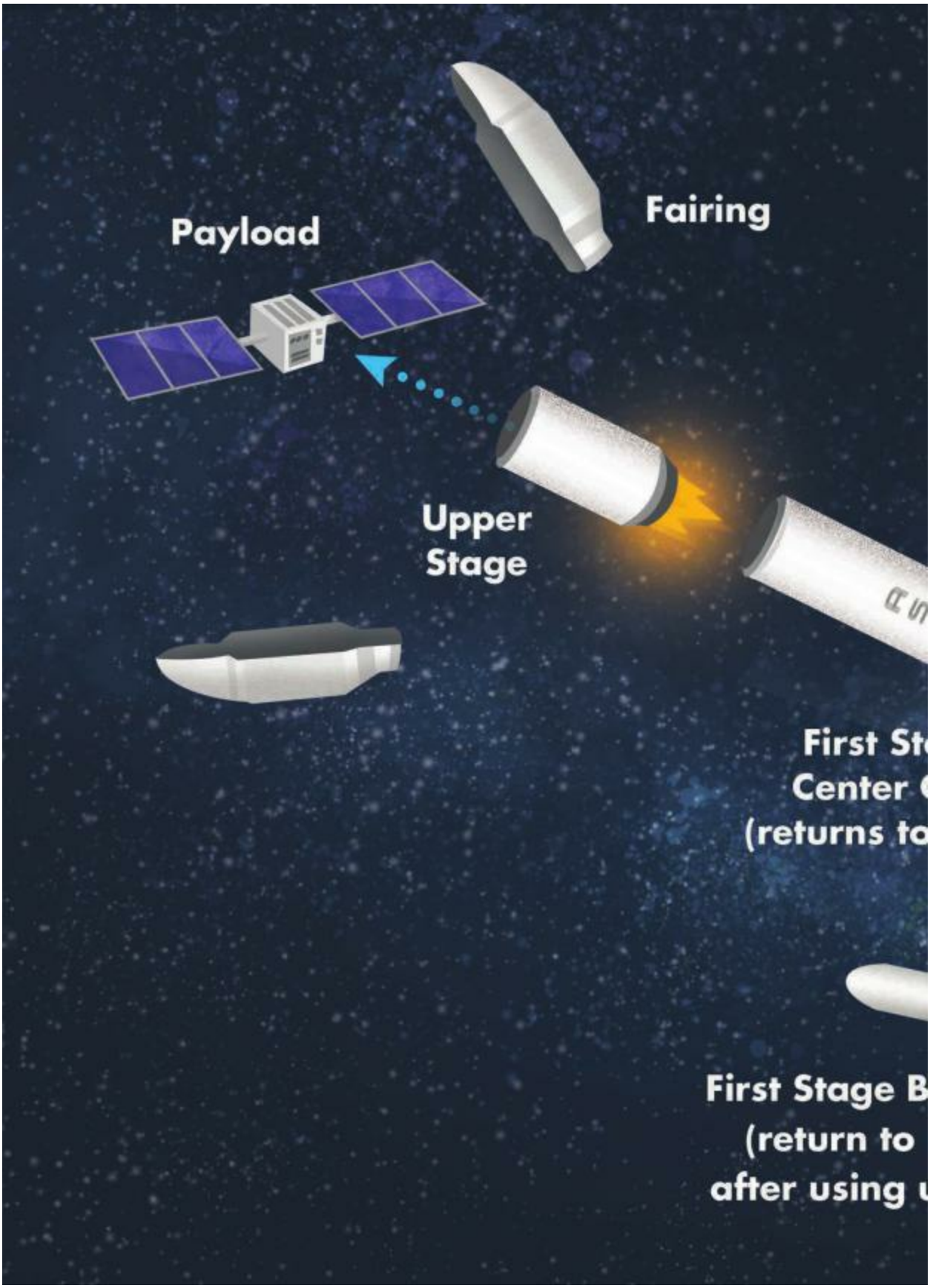
Earth and Moon

Earth is a medium-sized rocky planet, third fro
What makes Earth special is that it's close enou
stay warm, but far enough that it's not too hot.
of planets, it's just the right temperature to have
of liquid water.

How Rockets Work: Engine

There is no air in space, so we can't use propel
or balloons that float. Rockets burn mixtures of
against their own exhaust to accelerate forwar
in space to burn, rockets bring their own oxyge

Liquid F


Payload
Fairing
Upper
Stage
First St
Center
(returns to
First Stage B
(return to
after using

How Rockets Work: Landin

Since the beginning of spaceflight, most rocket
away their stages to break up in the atmospher
for simplicity and to maximize performance, bu
expensive because it means that an entirely nev
be built for each flight.

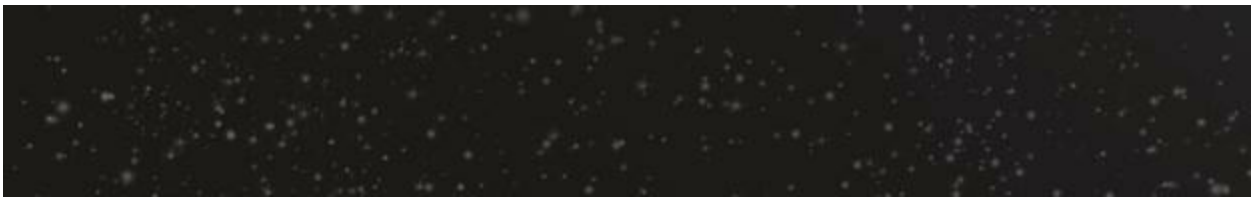
Now for the first time in history, rocket stages
with precise guidance after flight, either on a s
platform in the ocean or by turning around an
land. This allows rockets to be reused—a majo
making it easier to get to space.

Orbits

For rockets and spacecraft,
the hardest part is not getting
to space, but staying up there.
Even in space, gravity
pulls spacecraft down
toward Earth,
just like it pulls you
and other objects
toward the ground.

But if a spacecraft is
moving very, very fast,
by the time it would
normally hit the ground,
the ground is no longer there.

Orbital Path



The International Space Station

Right now there's a space station up in th
your head, orbiting our planet. People ge
traveling in a small spaceship launched c
of a giant rocket.

The astronauts floating around on the spa
lots of supplies like food, water, clothes, c
science experiments. We send supplies to
using cargo ships that are steered by com
controlled from the ground. Then astrona
space station steer the ships into a smoot
sometimes with the help of a robotic arm

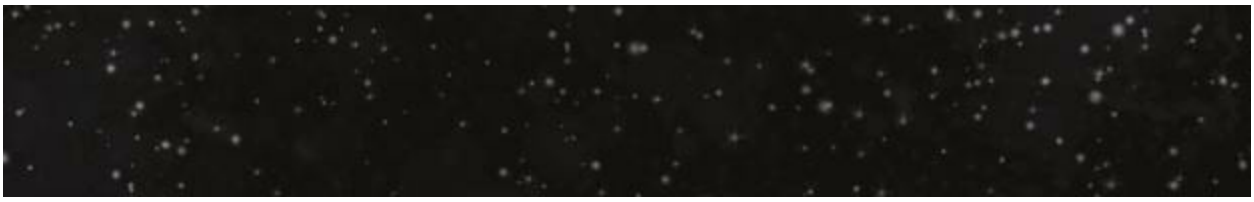
Going to the Moon

In order to send astronauts beyond Earth orbit, really big rocket. In the 1960s and 1970s, NA largest rocket ever built, Saturn V, to send 27 p Moon over 9 missions. Saturn V rockets were e as tall as skyscrapers. This was called the Apol and each flight used a series of spacecraft in o to reduce weight as much as possible in each segment of the mission.

Going to Mars

Getting to planets like Mars works the same wa
Moon, except that it takes a much longer time.
farther than the Moon—and that's at closest ap
Earth and Mars orbit the Sun, the distance and
between them varies based on their positions. E
365 days (1 year) to circle the Sun, but Mars ta

To get from Earth to Mars, first you have to get
from there, you fire your engine to escape Earth
you on a path to Mars. This is still an orbit, but
Once your spacecraft reaches Mars, you need
enter Mars orbit before you can land.

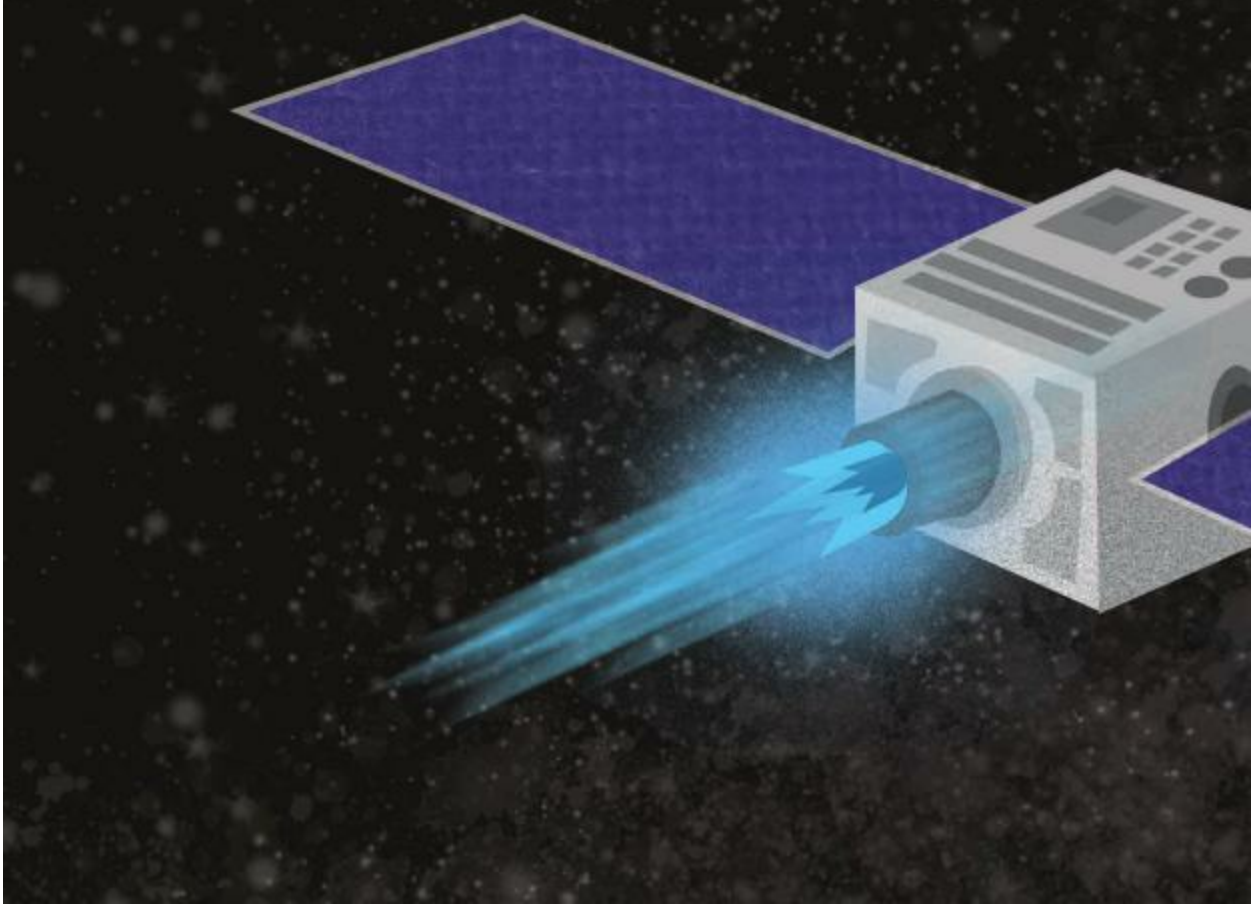


Exploring Mars

Over the years, we have sent more than 50 rob
missions to Mars, with around half of these suc
(getting to Mars is hard!). In fact, there are sev
exploring Mars right now! Some of these obser
planet from orbit, others land in place, and son
wheels to drive around.

Ion Engines

Ion engines use electricity to accelerate positi
toward a negatively charged grid at extreme
up to 90,000 miles per hour. That's more tha
than a speeding bullet! Since they use only ti
ion engines are very efficient for deep space



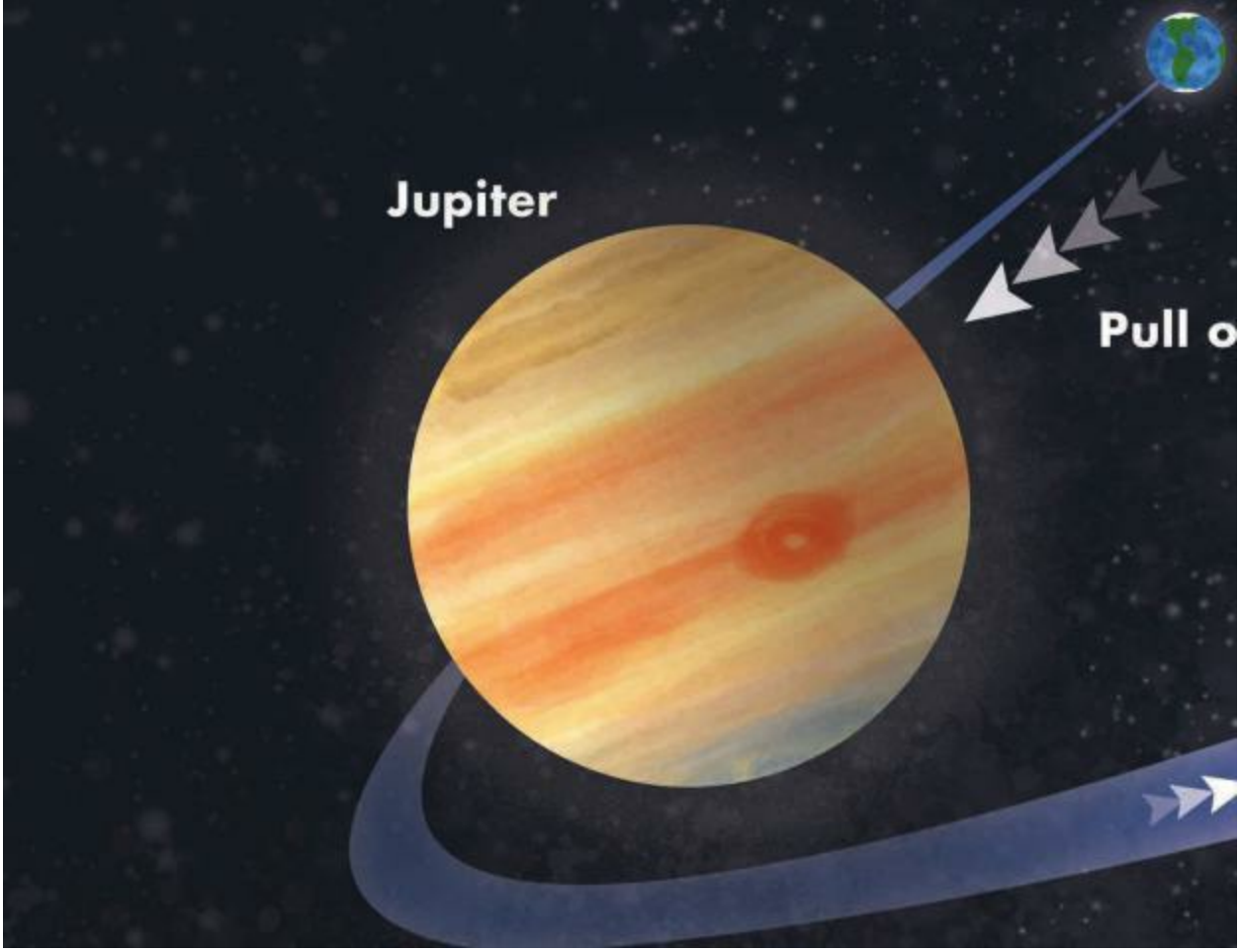
Solar Sails

The light and heat of the Sun is carried by tiny
invisible particles called "photons", and each c
a tiny push. Individually, this push is too small t
but if you collect enough photons, you can pro
A solar sail is a very large but very light surfac
capture as many photons as possible.

Solar sails might have to be miles across to cap
photons to propel a large spacecraft, but since
space to slow you down, you could reach very
all, they use no fuel, so they never stop workin
they could someday be used to propel a space
voyage that could take hundreds of years.

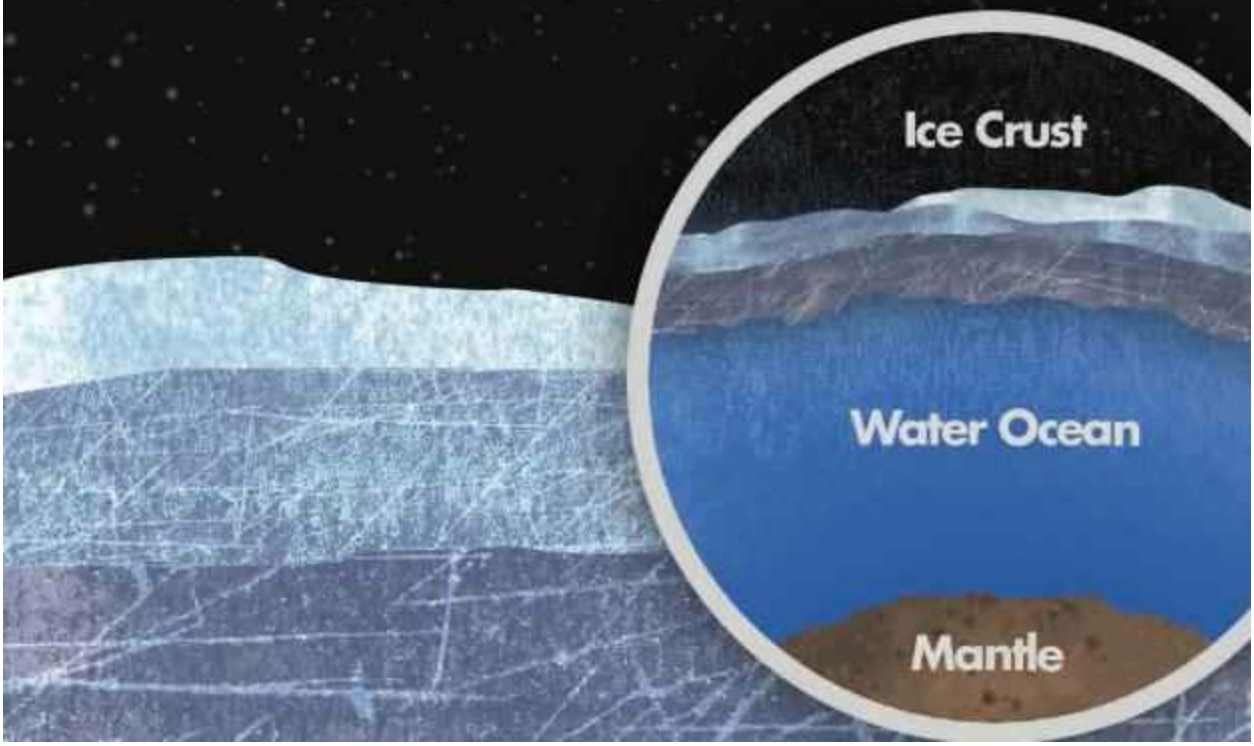
Gravity Slingshots

To get to planets far out from the Sun, we hav
really fast—even faster than a rocket. Spacec
speed by flying past a planet really close, usi
gravity to "slingshot" deep out into space. Th
heavy, so gravity tugs the spacecraft, flinging



Jupiter

Jupiter is the largest planet, almost like a miniature star. In fact, it's so large and so far from the Sun that it creates more heat than it receives. A giant ball of swirling gas, Jupiter could fit 1,300 Earths inside. It features a "Giant Red Spot", a storm the size of Earth that has lasted for more than 300 years!



Saturn

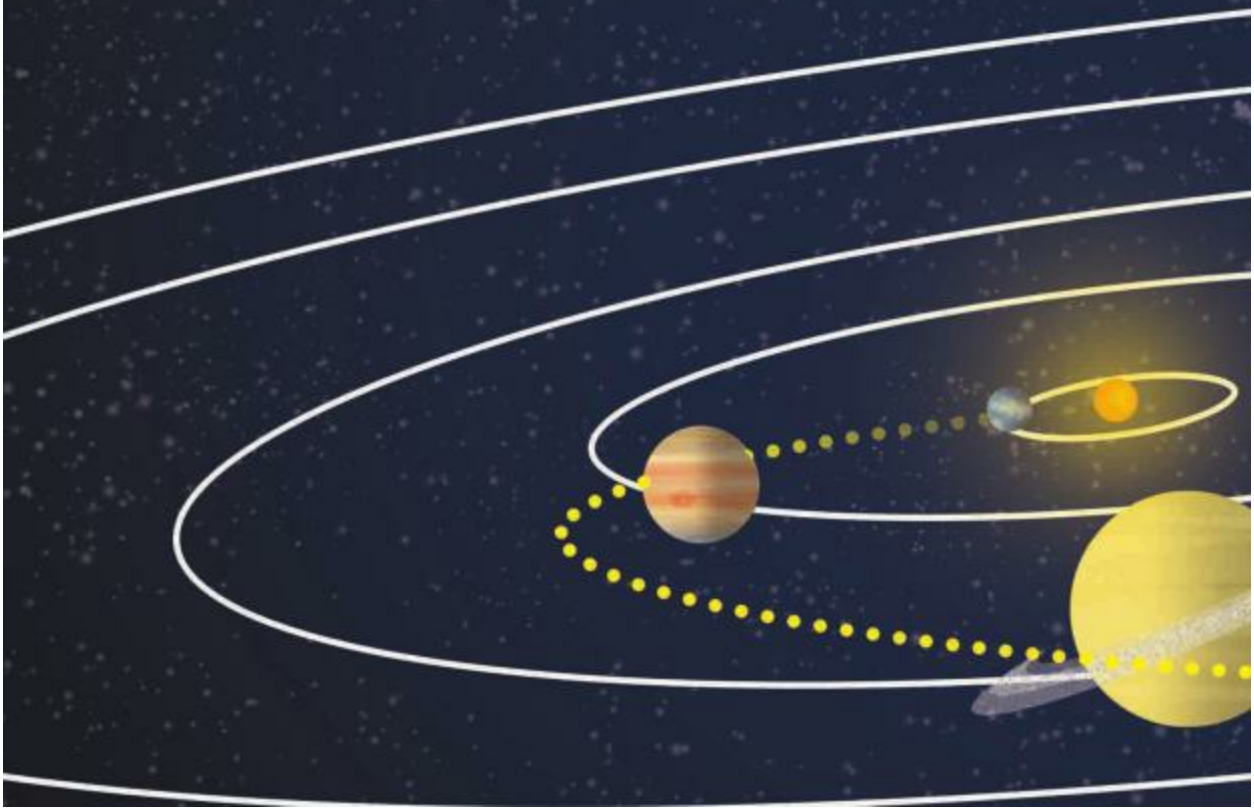
Saturn is the second largest planet in the sol
known for its giant rings. Like Jupiter, Saturn
"solar system" of its own, supporting over 5
these are especially interesting, and were ex
by the Cassini spacecraft, which orbited Satu
2004 and 2017.

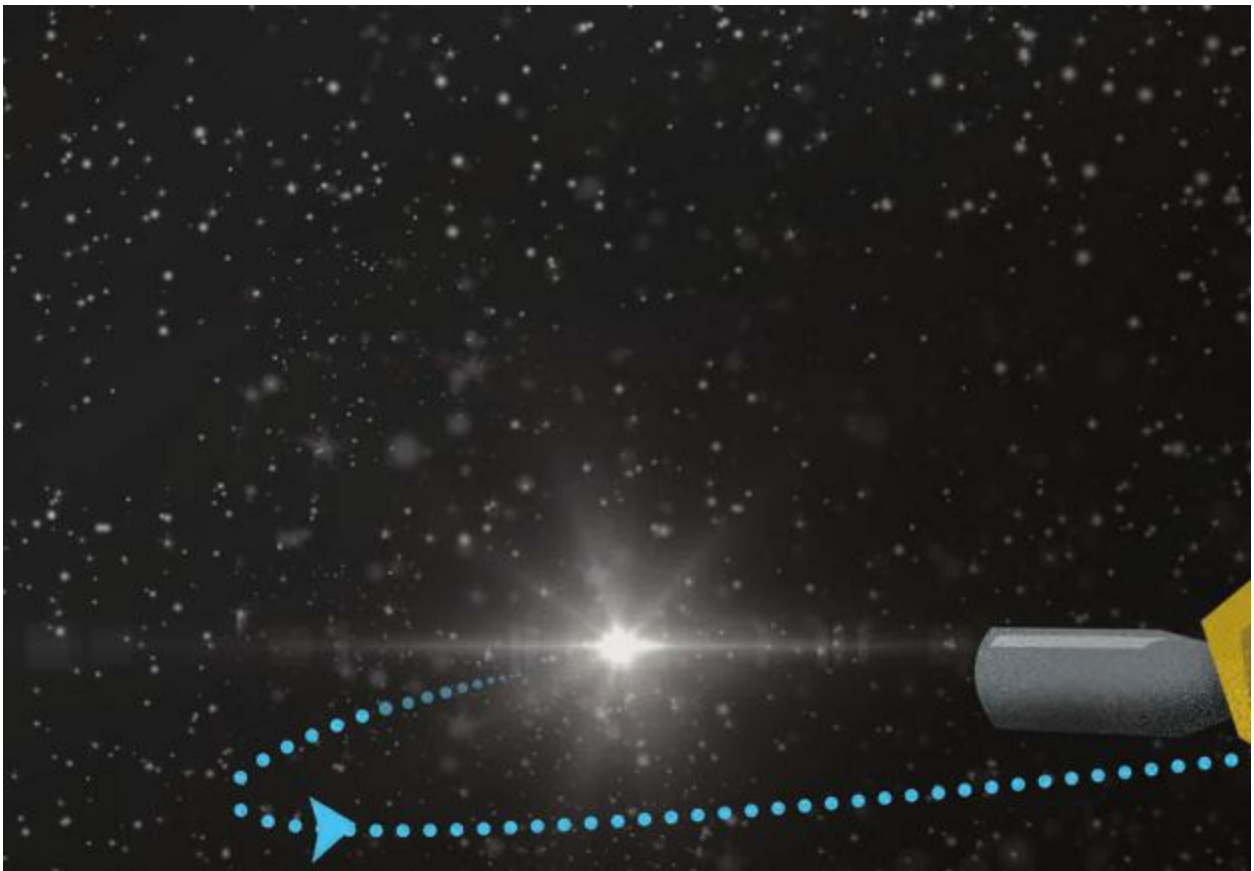
Enceladus is a small icy
subsurface liquid ocean, ge
particles trailing into sp
Saturn's large
than Earth's M
most Earthlike wor
It's the only other pl
on its surface, but Tita
liquid methane at extrer
(–290 °F/–179 °C). Titan a
very similar to Earth's in thick

Titan

Ice Giants

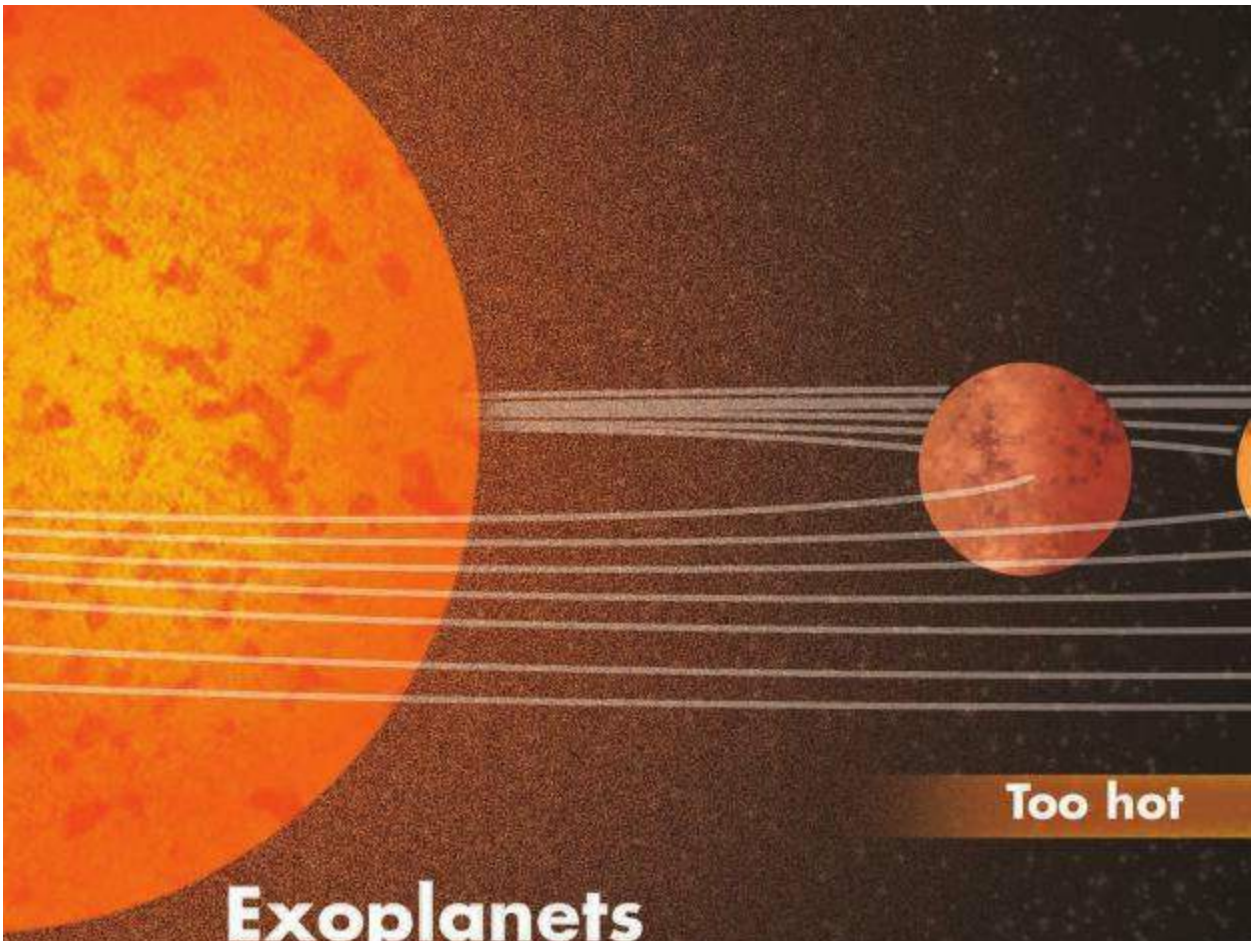
Uranus and Neptune are a bit like Jupiter an
but because they contain more water, ammor
ice, they're sometimes called "Ice Giants". Ec
moons of its own, the most interesting being
which orbits in the opposite direction of most
in the solar system.





The Kuiper Belt

Beyond Neptune lies the Kuiper Belt, a regio
icy worlds so far away that the Sun provides
a full Moon on Earth. Pluto was the first Kuip
to be discovered, in 1930. Pluto is a bit smal
Moon, but has five moons of its own, includi
which is half the size of Pluto itself. In 2015,
New Horizons spacecraft became first to visit
giving us a close-up look at its shape, compo
and internal structure.



Exoplanets

Our solar system is just one of hundreds of bil
galaxy, and our galaxy is one among hundre
the Universe. We think that most stars are circ
and since these don't orbit our Sun, we call th
The main way we find exoplanets is by staring
orbit and looking for a slight wobble caused b
gravity, or by looking for a slight dimming of
planet passes in front. This is a bit like looking
in front of a searchlight on the other side of th

Extraterrestrial Life

Are we alone in the Universe? We don't know
We think that life should be able to exist on ma
out there, and simple life forms should even be
places in our solar system like Mars, Europa, o
If we found life on one of these worlds, it would
often arises when the conditions are right. This
that life is common throughout the Universe.

What about intelligent life, like the aliens of sci
It is certainly possible that there are other intelli
out there that we may someday meet. Even on
own planet there are animals that are fairly
intelligent, like chimpanzees, elephants,
dolphins, and octopuses.

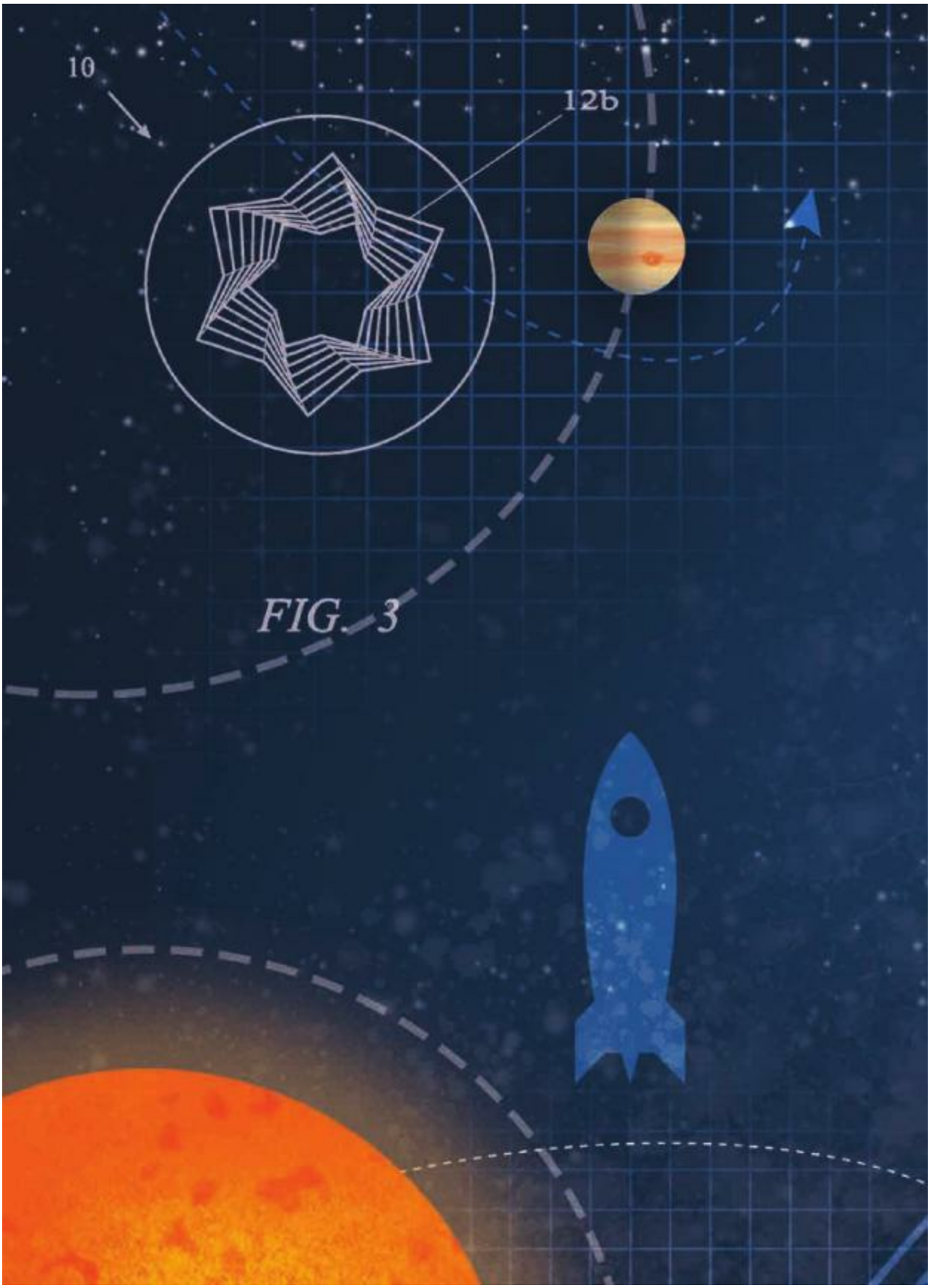


FIG. 3