

Issue
#6
2nd EDITION

ASTROBIOLOGY

The Story of our Search for Life in the Universe



Produced by the NASA
Astrobiology Program to
commemorate 50 years of
Exobiology and Astrobiology
at NASA.

Astrobiology

A History of Exobiology and Astrobiology at NASA

This is the story of life in the Universe — or at least the story as we know it so far. As scientists, we strive to understand the environment in which we live and how life relates to this environment. As astrobiologists, we study an environment that includes not just the Earth, but the entire Universe in which we live.

The year 2010 marked 50 years of Exobiology and Astrobiology research at the National Aeronautics and Space Administration (NASA). To celebrate, the Astrobiology Program commissioned this graphic history. It tells the story of some of the most important people and events that have shaped the science of Exobiology and Astrobiology. Beginning shortly after the establishment of NASA, this field is relatively young. However, as you will see, the questions that astrobiologists are trying to answer are as old as humankind.

Concept & Story

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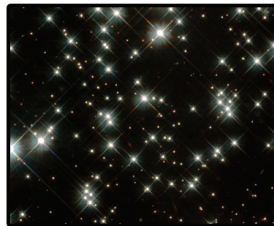
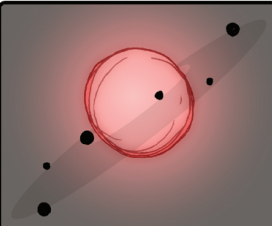
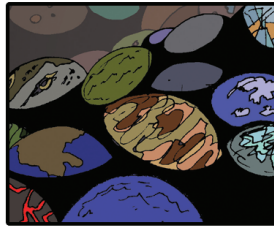
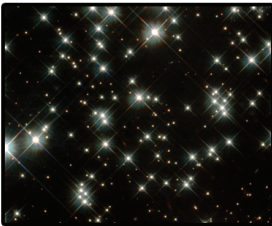
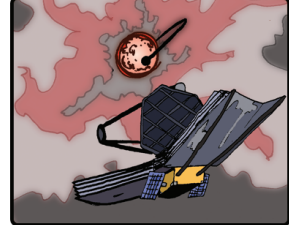
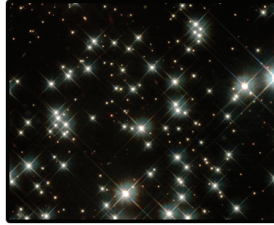
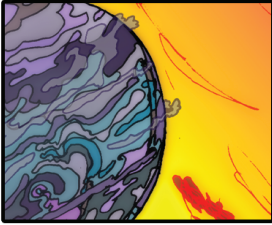
Editor

Linda Billings

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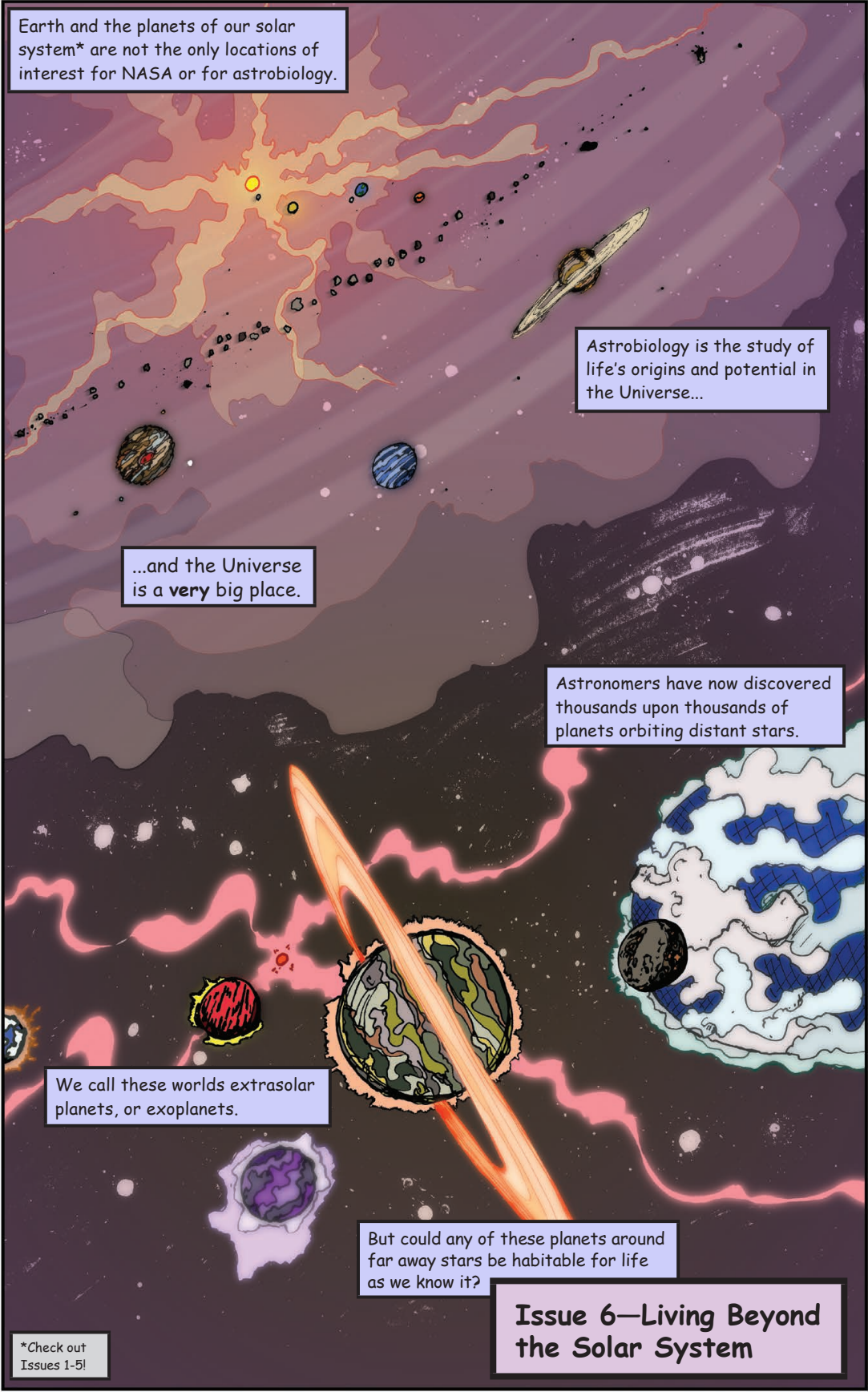
Aaron L. Gronstal
Jenny Mottar

Issue #6—Living Beyond the Solar System



The year 2010 marked the 50th anniversary of NASA's Exobiology Program, established in 1960 and expanded into a broader Astrobiology Program in the 1990s. We are telling the story of how this field developed and how the search for life elsewhere became a key component of NASA's science strategy for exploring space. This issue is the sixth in a series of graphic history books. Though not comprehensive, the series has been conceived to highlight key moments and key people in the field as it explains how Astrobiology came to be.

-Linda Billings, Editor



Earth and the planets of our solar system* are not the only locations of interest for NASA or for astrobiology.

Astrobiology is the study of life's origins and potential in the Universe...

...and the Universe is a **very** big place.

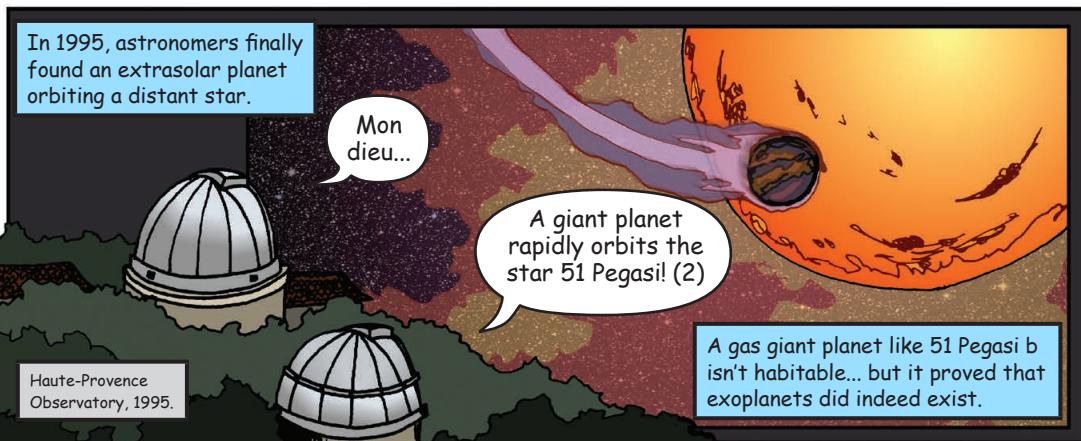
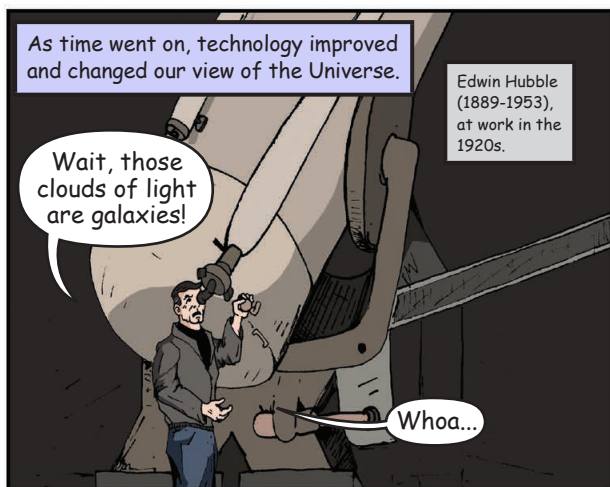
Astronomers have now discovered thousands upon thousands of planets orbiting distant stars.

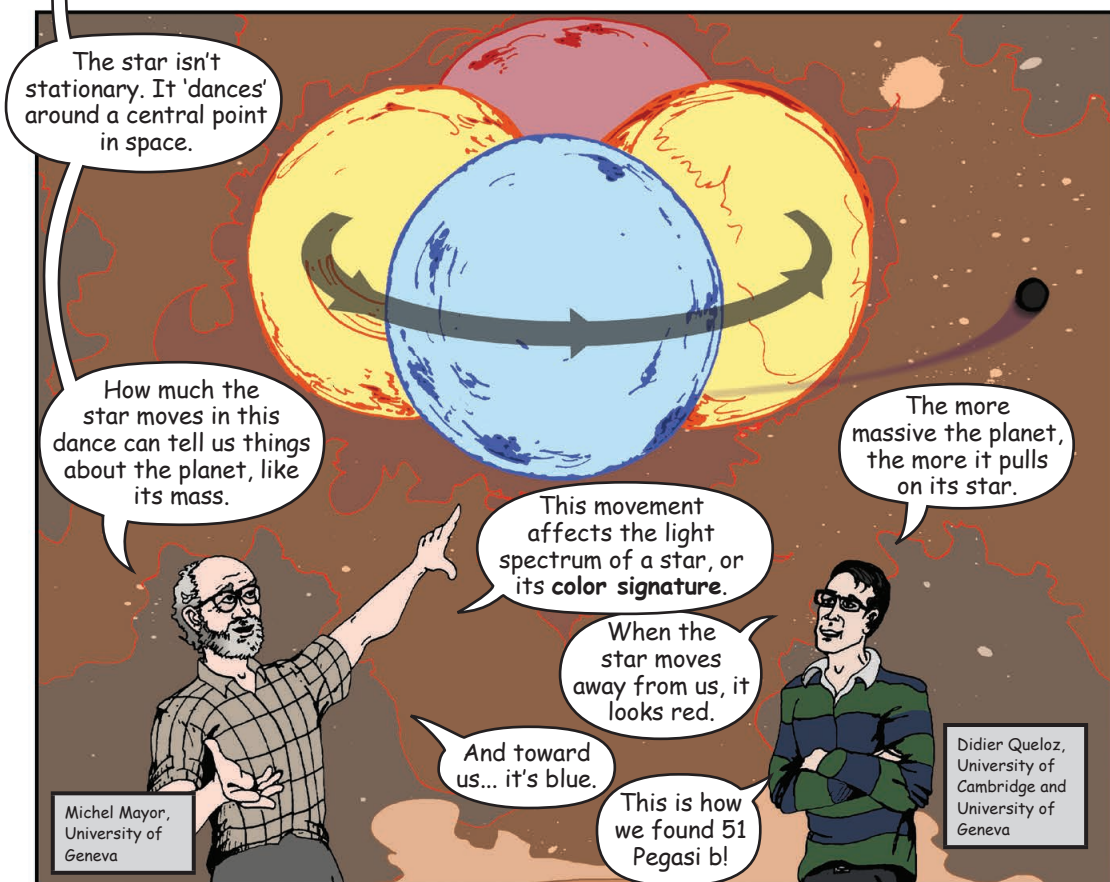
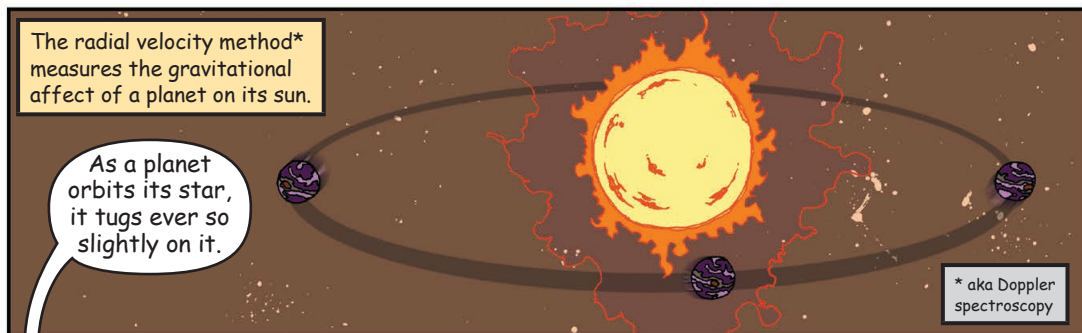
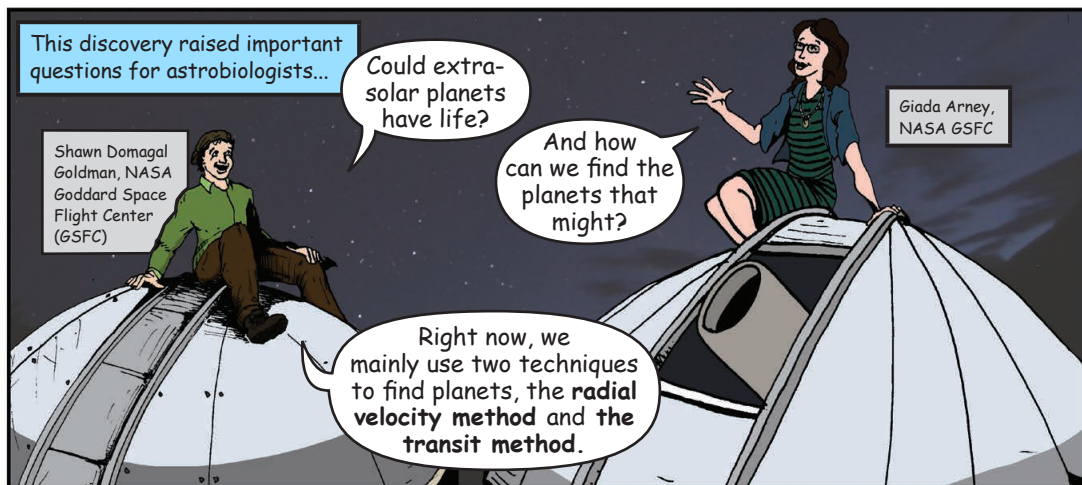
We call these worlds extrasolar planets, or exoplanets.

But could any of these planets around far away stars be habitable for life as we know it?

*Check out Issues 1-5!

Issue 6—Living Beyond the Solar System





The transit technique works when a planet passes in front of its star.

When a planet moves in front of its star, it blocks part of the light that we see.

Natalie Batalha, NASA Ames Research Center (ARC)

The amount of light blocked, and how often it happens, can tell us about the planet's size, its orbital period (or "year"), and its distance from the star.

If you know the radius of the star, that is.

Planets orbiting close to a star are easier to study, because close planets transit more often, giving us more observations to look at.

With both techniques, it's easier to spot big planets.

Bill Borucki,
NASA ARC

Gas giants similar to Jupiter have more gravity to affect their star. And they're big, so they block out more light when they transit.

Radial velocity was the first method to find exoplanets in large numbers, but now it has been overtaken by the transit method, both in the number of planets discovered and in its ability to characterize them. (3)

After the first exoplanet discovery, astronomers got to work hunting for more.

From 1995 onward, ground- and space-based telescopes were used to add to the list.

Victoria Meadows,
University of
Washington (UW)

New discoveries
flooded in, including
planets unlike any of the
planets we see in the
Solar System.

The first planets
were the easiest to
spot - huge gas giants
similar to Jupiter.

But as techniques
improved, smaller and
smaller planets were
discovered.

That's when
things started to get
very interesting for
astrobiologists.

We found
more than hot
Jupiters close to
their stars.

There were
stars with multiple
planets in orbit!

...and smaller
worlds that could be
rocky like Earth!

We now know
the most common
planets in the Universe
are mini-Neptunes and
the so-called 'Super
Earths'.

Finding small, rocky
planets raised questions
about whether or not
any could be habitable.

If we could find an inhabited planet,
it could answer so many questions
about Earth's place in the Universe.

Example of facility using:
*transit method, or
**radial velocity method

Spitzer Space
Telescope (NASA,
2003-2020)

Gaia (ESA,
2013-2025)

W.M. Keck
Observatory**,
Hawai'i

European Southern
Observatory (ESO),
Cerro Paranal

High
Accuracy
Radial velocity
Planet Searcher (HARPS)
spectrograph, ESO, La Silla Observatory**

Anglo-Australian
Planet Search (APS)**,
Australia

Convection, Rotation and
planetary Transits (CoRoT)
(CNES/ESA, 2006-2013)*

Everything we know so far about exoplanets is built on the work of some amazing technology and missions.

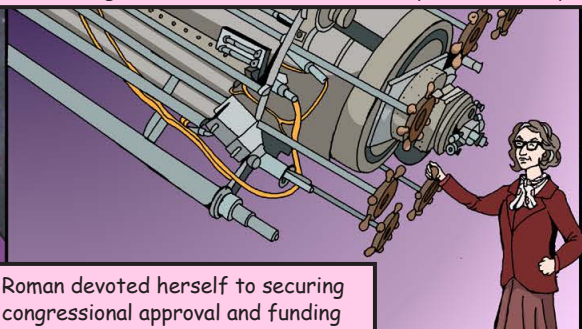
And a key figure in their development was Dr. Nancy Grace Roman (1925-2018).

When NASA was founded 1959, Roman was working as a radio astronomer at the Naval Research Laboratory.



Orbiting Solar Observatory 1
(NASA - 1962)

Six months after NASA formed, Roman was hired to help create a space-based astronomy program. By 1960, she was serving as NASA's Chief of Astronomy and Relativity.



Roman devoted herself to securing congressional approval and funding for many missions.

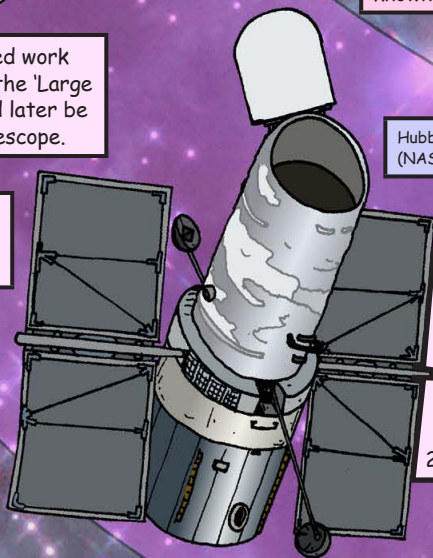
This included an ambitious mission known as the "Large Space Telescope."

Cosmic Background Explorer
(NASA, 1989-1993)

Twenty years after she started work at NASA, Congress approved the "Large Space Telescope," which would later be dubbed the Hubble Space Telescope.

Hubble launched in 1990 and is still returning valuable data after decades of work.

Hubble Space Telescope
(NASA, 1990)



Over its long lifetime, Hubble has made many important observations for exoplanet science. This includes the first atmospheric measurements of both a giant exoplanet (in 2001) and a super-Earth (in 2016). (4, 5, 6)

NASA's history in astronomy and the development of space-based telescopes are the result of the dedication of Roman and her colleagues.

Another incredibly important mission in the history of exoplanet science is NASA's Kepler space telescope. (7)

Kepler was approved in 2001 as NASA's first planet-hunting mission. Launched in 2009, it quickly made a huge impact on exoplanet science.

Kepler was fixed at observing a single spot in the sky. One tiny percent of the entire Universe.

In this one spot, Kepler found a HUGE number of planets, over 6000 candidates! And several hundred were Earth-sized.*

Kepler completed its extended mission in 2018, but for years to come, scientists will be combing through data to find even more.

Kepler has shown us that rocky planets are not rare, and that there are a lot of potentially habitable planets out there.

But Kepler's planets are very far away. The telescope could spot them, but wasn't powerful enough for astrobiologists to study them in enough detail. Bigger, more powerful telescopes would be needed**.

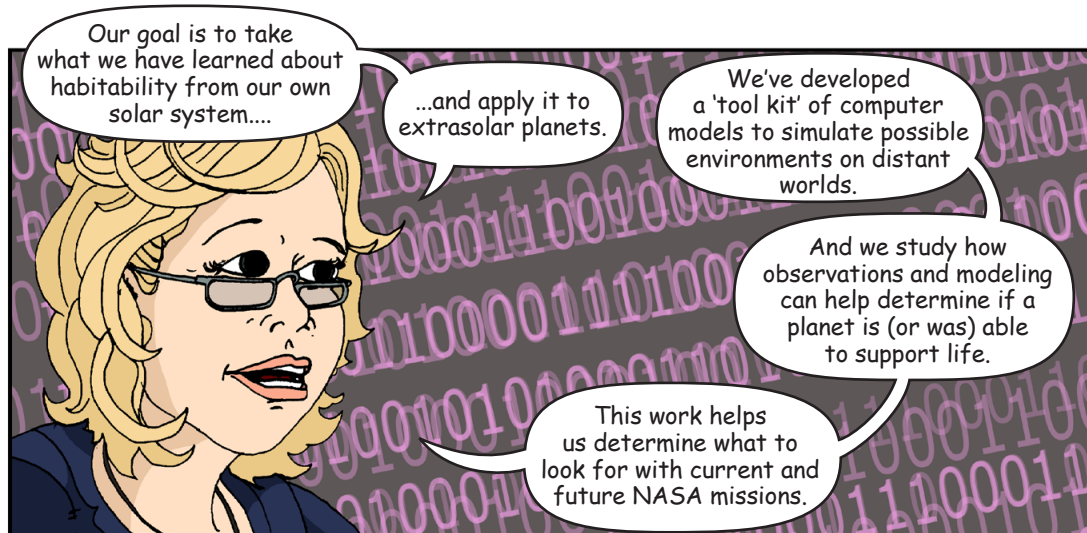
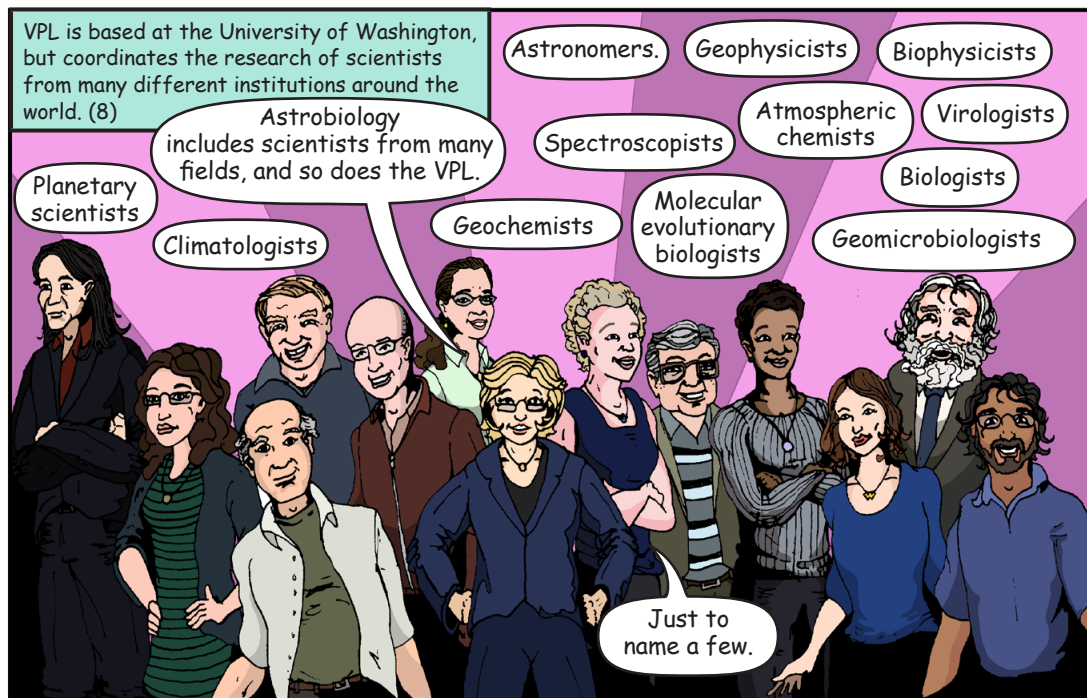
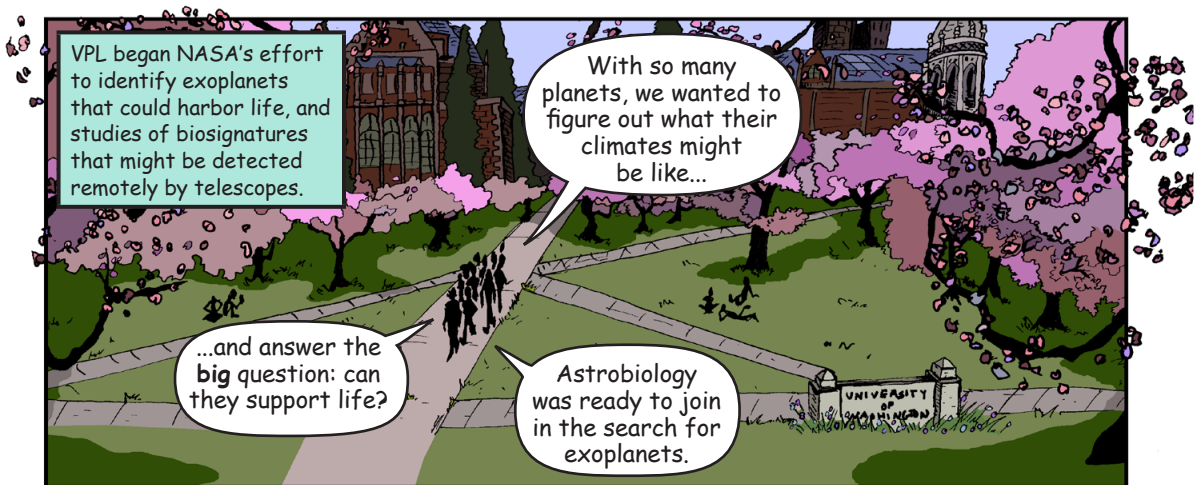
But because of Kepler, we now know that we have a good chance of finding small planets closer to home.

Astrobiologists are hoping to find such planets within 10 parsecs (roughly 32 light years) of the Earth.

At the same time NASA approved Kepler in 2001, the Virtual Planetary Laboratory (VPL) was founded with support from NASA Astrobiology.

*after a 'candidate' is found, more observations are made over time to confirm that it's actually a planet.

**More on that later.



Understanding habitable planets starts with Earth.

Analog environments on Earth help us study life's potential in the Solar System*.

* See Issue 5

But Earth, the **entire** planet, is like one giant analog for habitable worlds.

Earth science helps us predict what our telescopes might see in other planetary systems.

We also need to understand the Earth through time...

...how it formed, evolved, and became a home for life.

We start our search with **terrestrial** planets.

Mercury

Now, 'terrestrial' does not mean 'Earth-like' or habitable.

Our system has four terrestrial planets, but only one with life**.

Venus

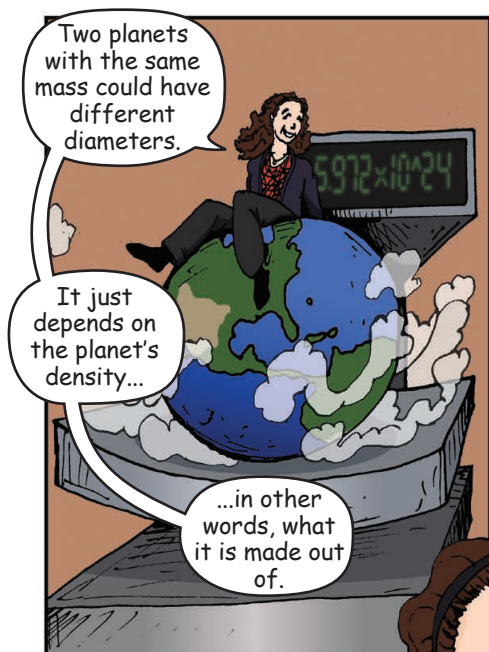
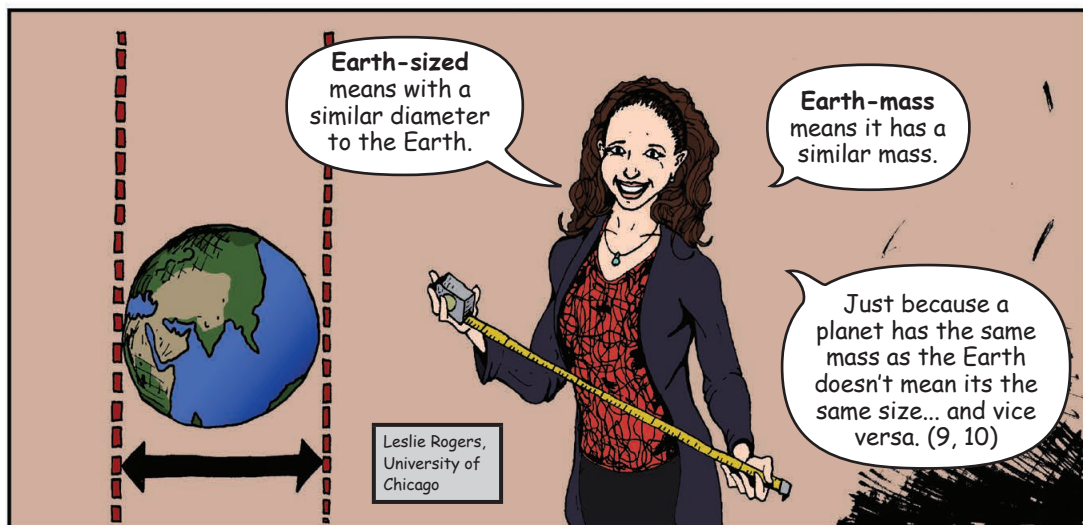
It means the planet is made of metals and rocks.

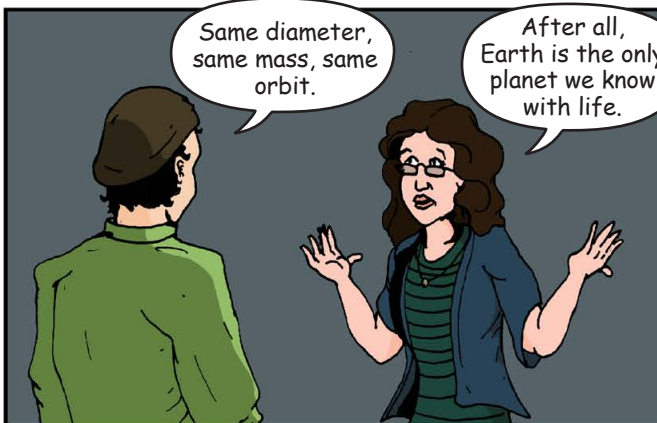
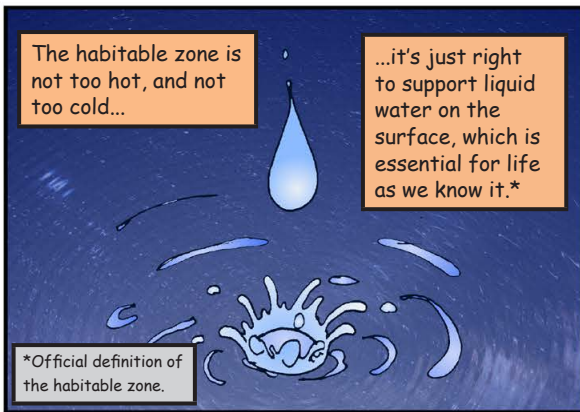
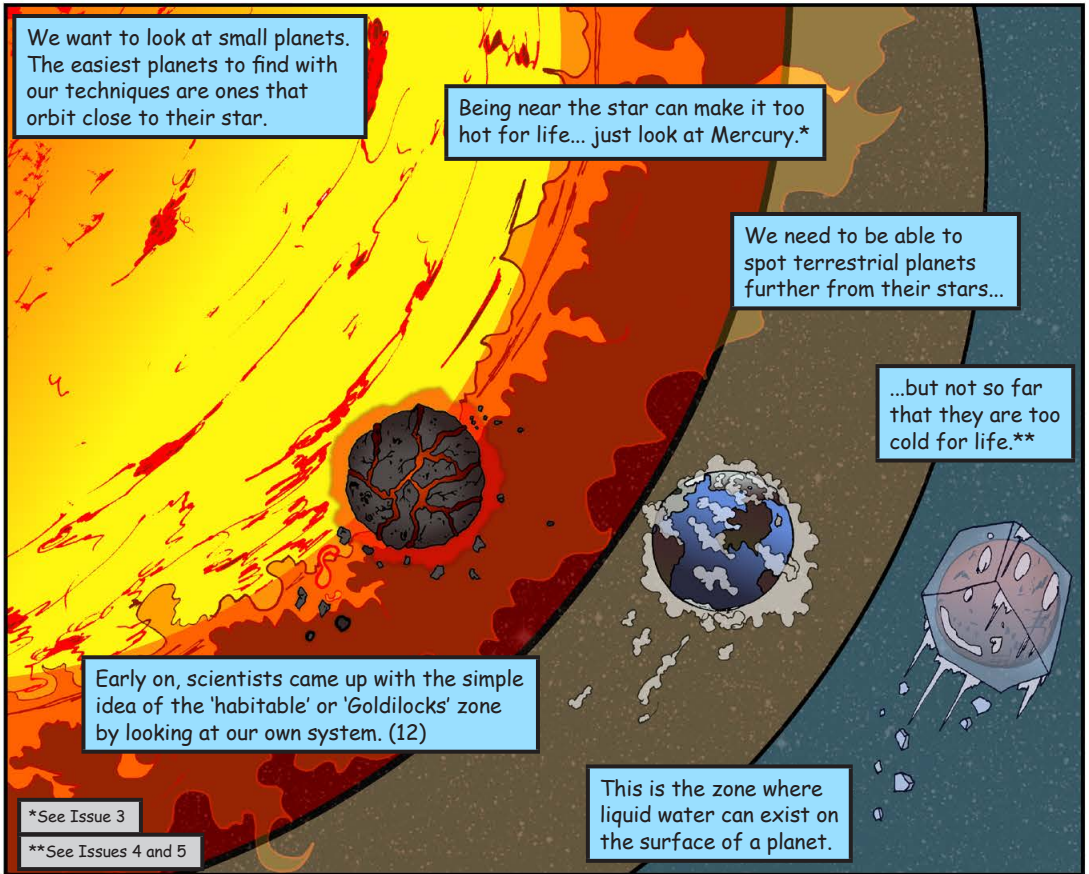
Earth

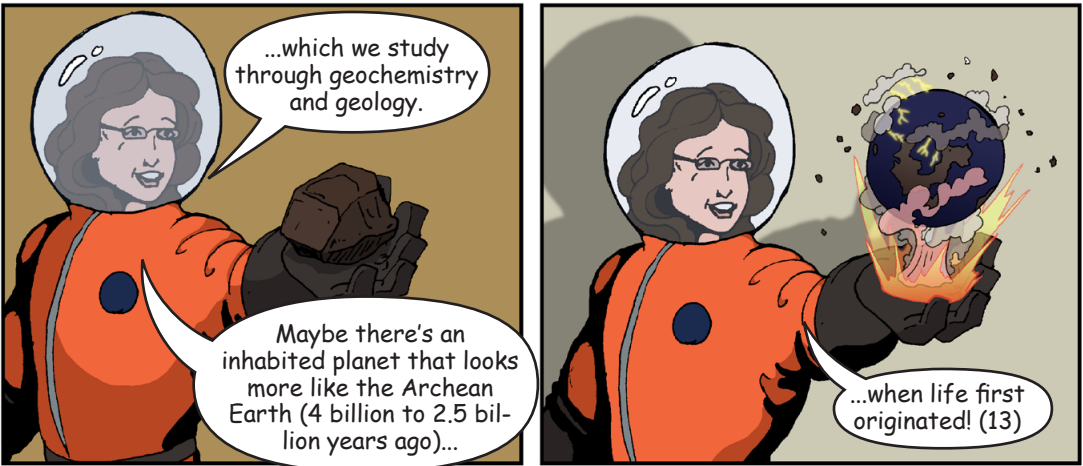
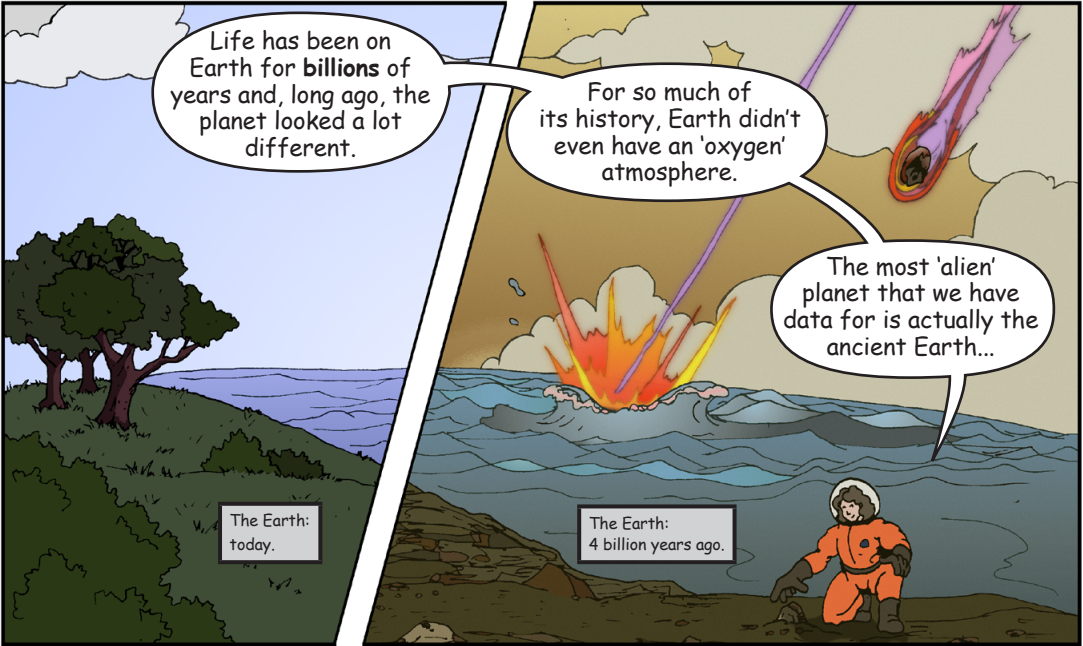
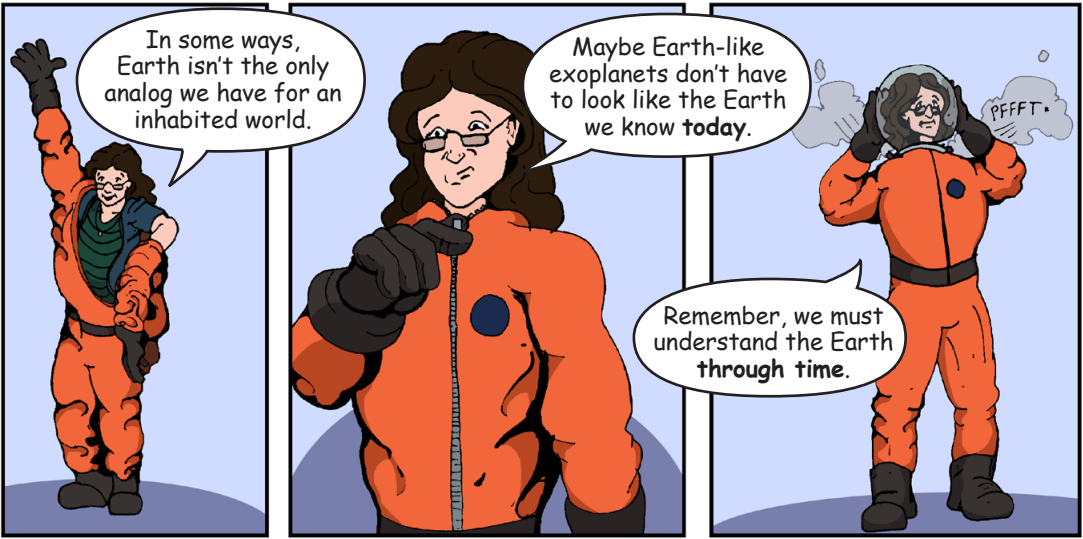
Mars

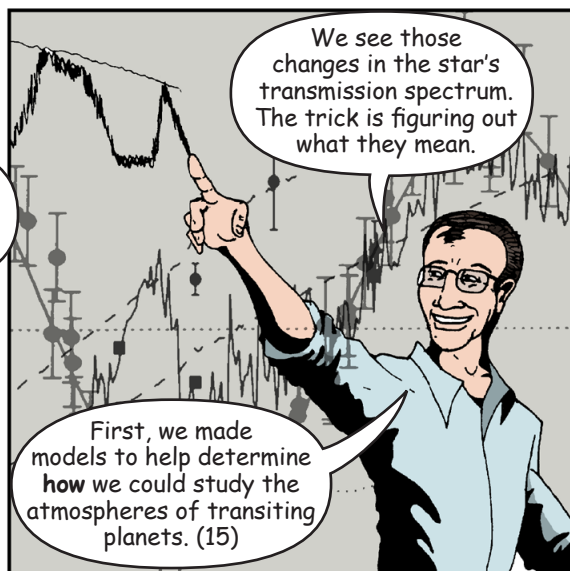
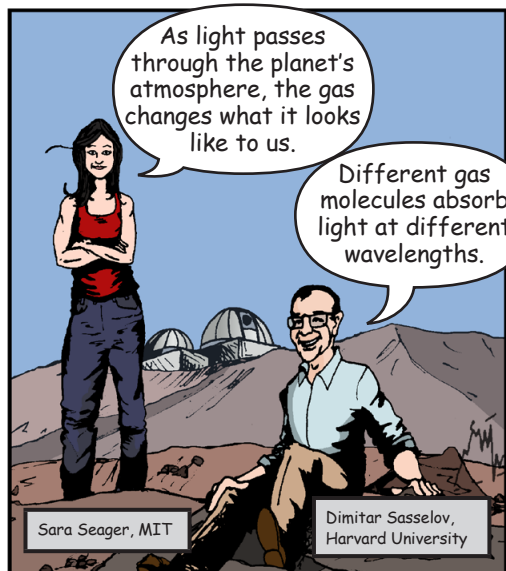
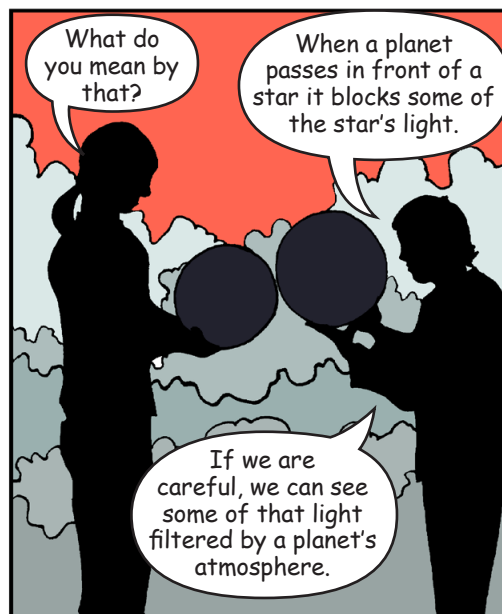
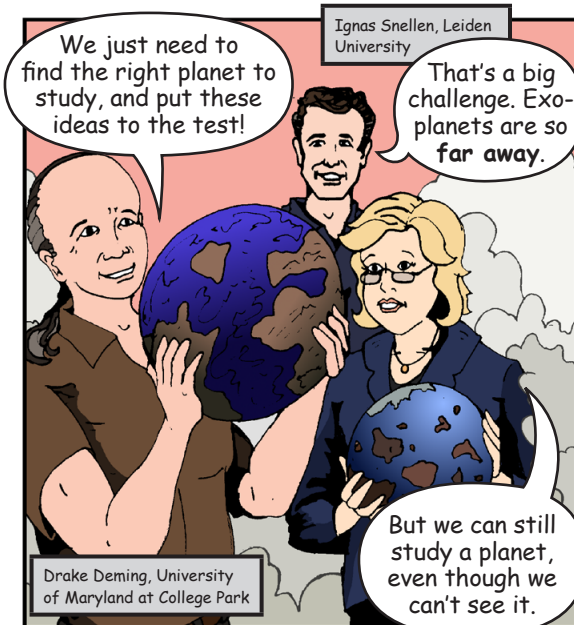
Bodies like the dwarf planet Pluto aren't terrestrial because they have so much ice and frozen material.

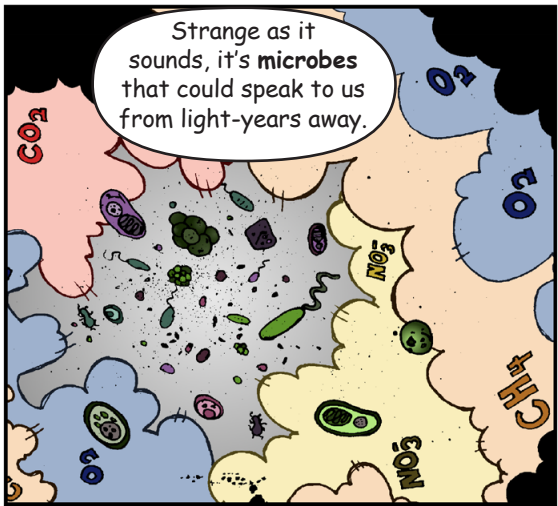
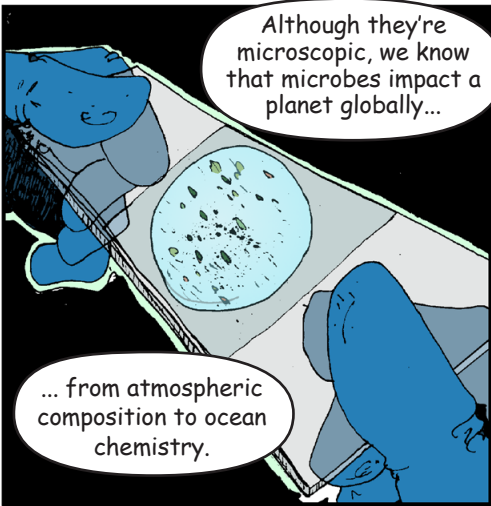
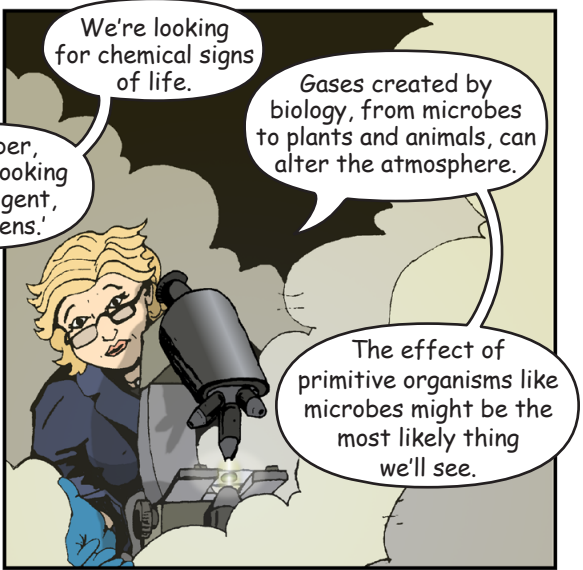
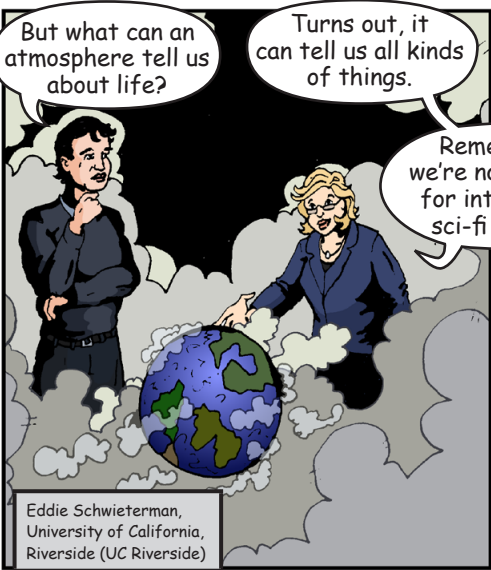
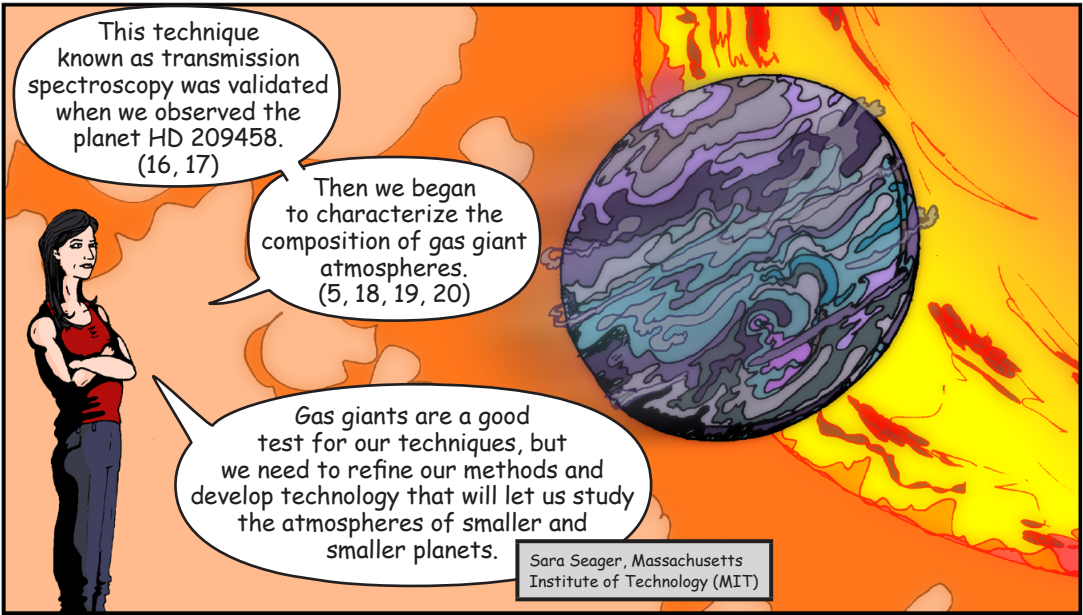
**See Issues 2,3 & 5











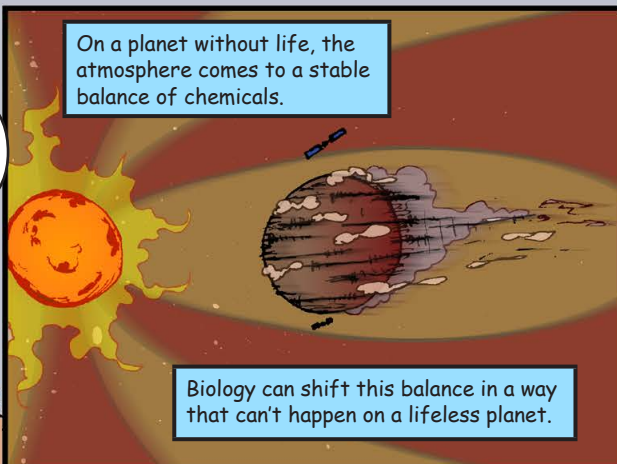
It was James Lovelock* who first suggested that biology could be detected by its effect on the atmosphere.



If Earth had no life, the atmosphere would look different. (21)

*See Issue 2

On a planet without life, the atmosphere comes to a stable balance of chemicals.



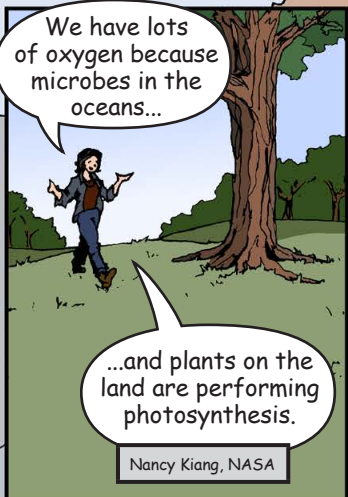
Biology can shift this balance in a way that can't happen on a lifeless planet.

Some kinds of chemicals don't co-exist easily in the atmosphere because of chemical reactions.

For example, oxygen and methane don't normally co-exist easily. But on Earth today, they do...

...because of biology!

We have lots of oxygen because microbes in the oceans...



...and plants on the land are performing photosynthesis.

Nancy Kiang, NASA

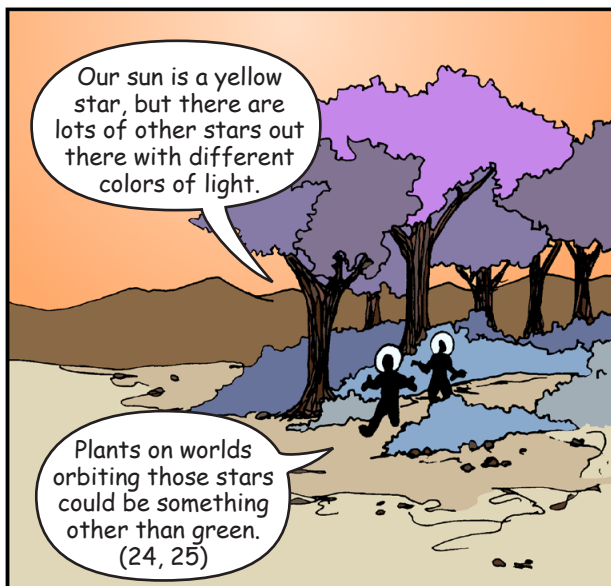
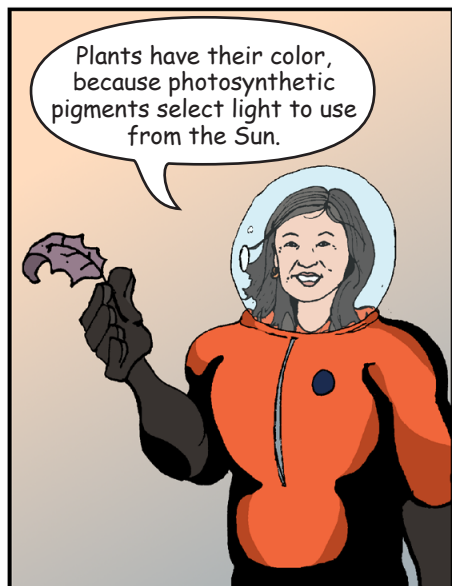
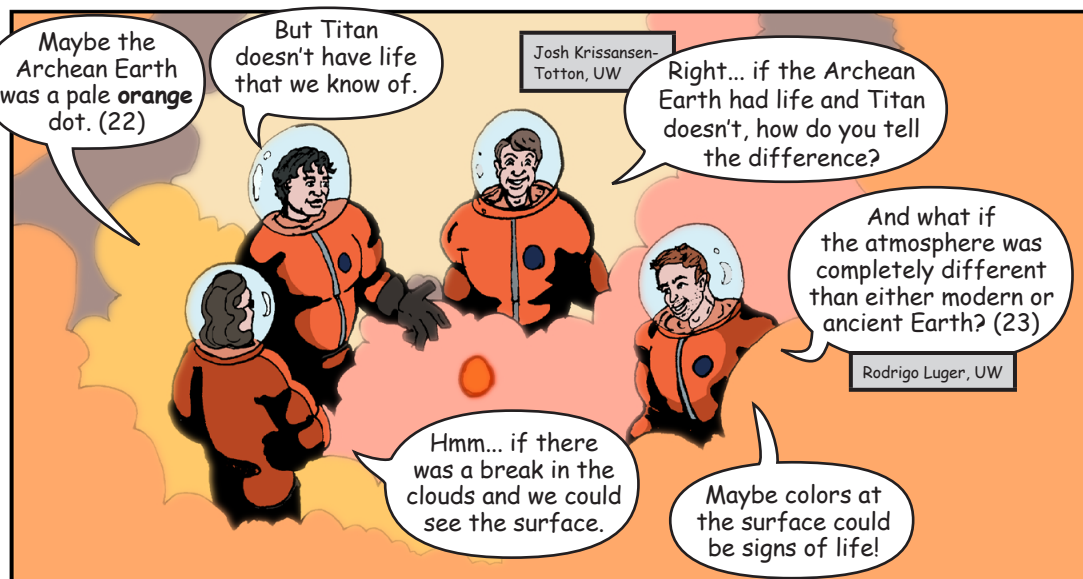
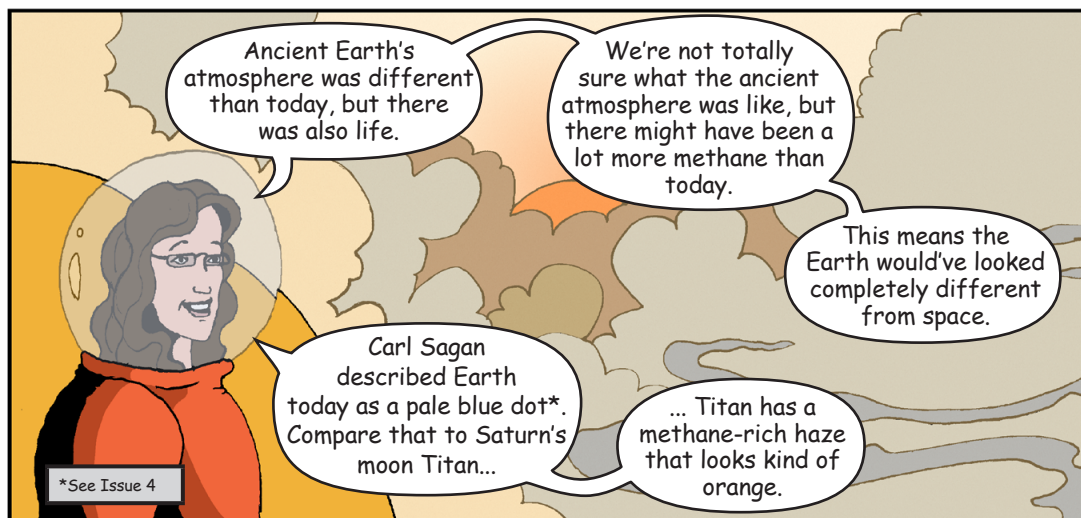
Photosynthesis makes the oxygen, and it also makes cool colors that can be seen from space!

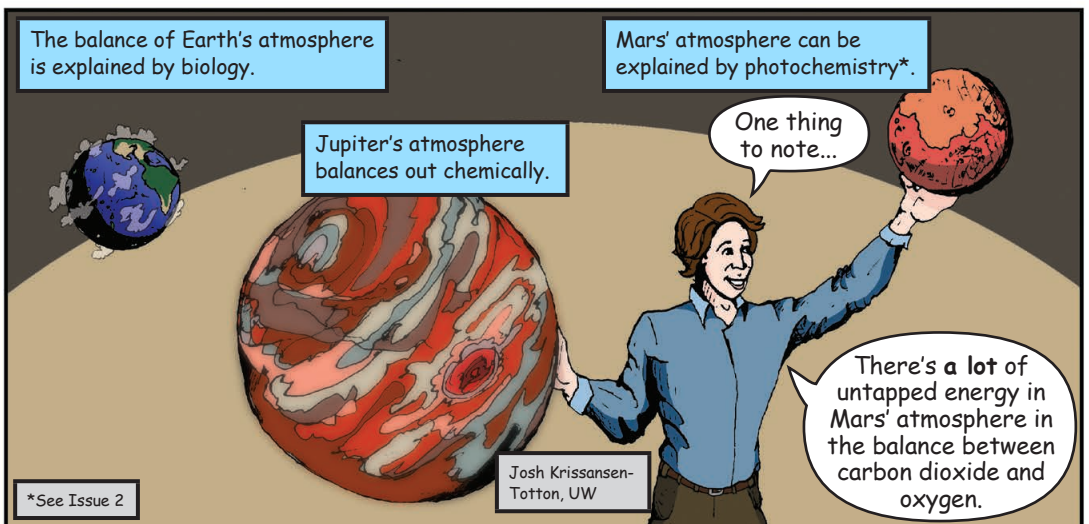
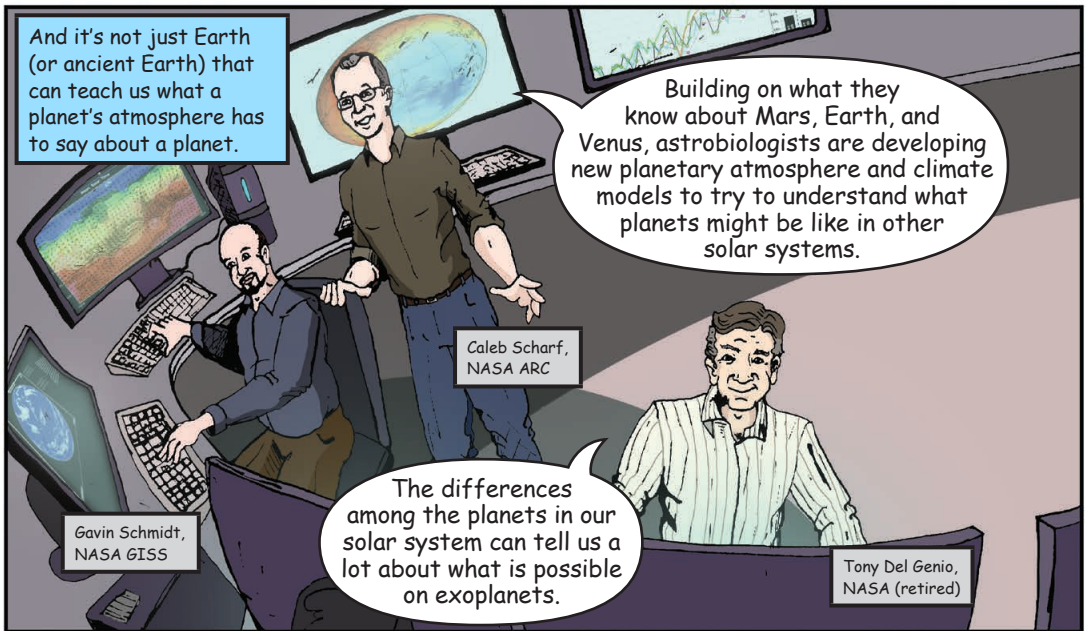
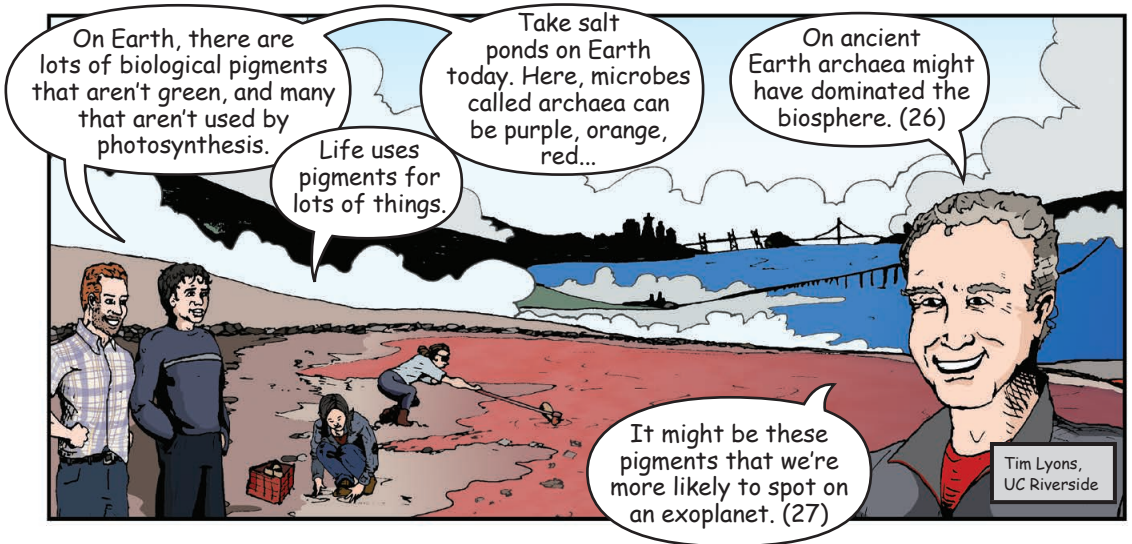


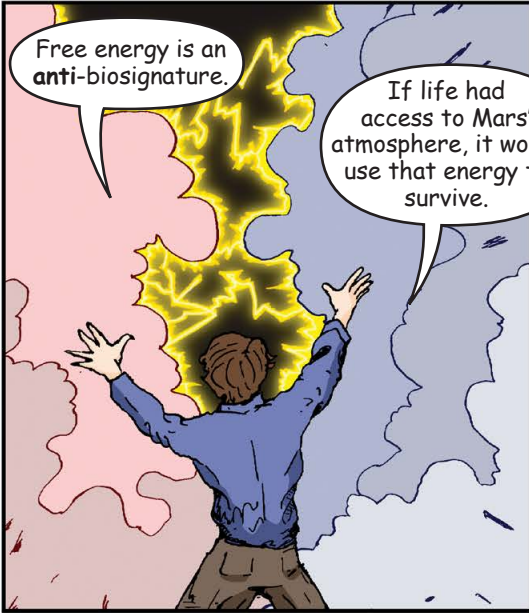
It's especially easy to see things like forests and grasslands covering the land.



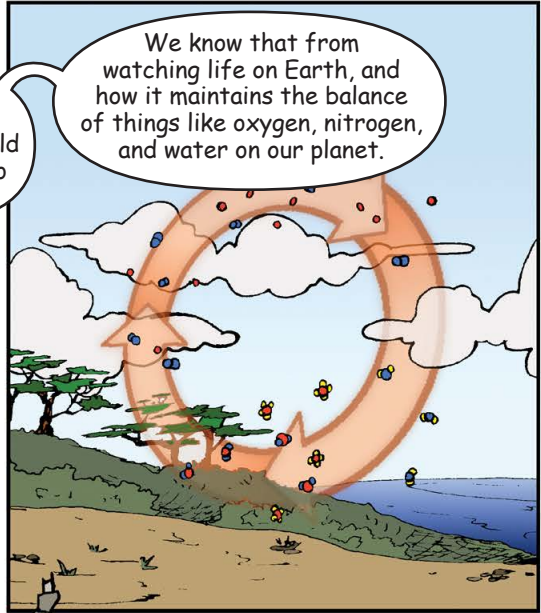
* See Issue 5







If life had access to Mars' atmosphere, it would use that energy to survive.



*See Issue 2



Ravi Kumar Kopparapu,
NASA GSFC



At a coffee shop
in Seattle, 2010...

Uh-oh!...



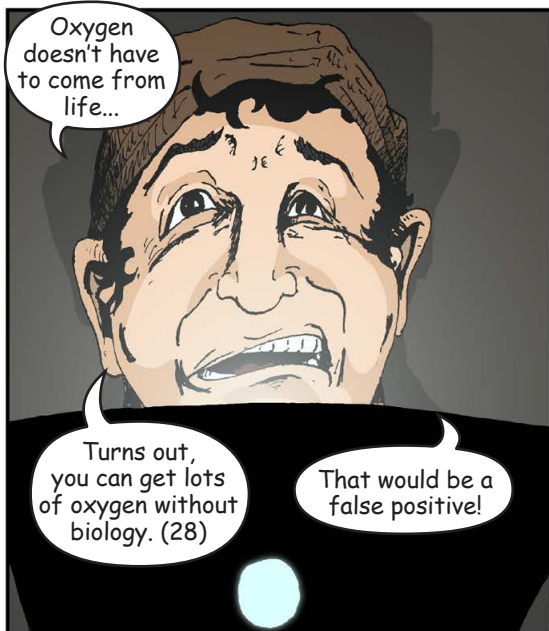
What, is
something
wrong?

Uh... yeah.

More
coffee?

No, not
that...

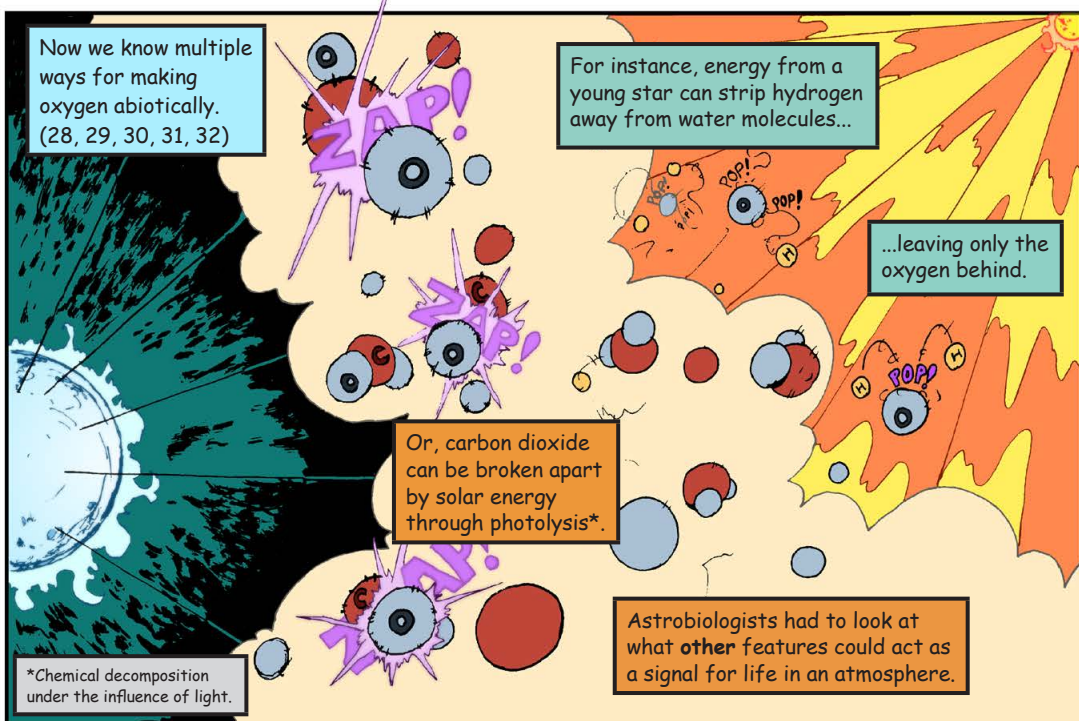
Jen Domagal-Goldman,
American Democracy Project



Oxygen
doesn't have
to come from
life...

Turns out,
you can get lots
of oxygen without
biology. (28)

That would be a
false positive!



Now we know multiple
ways for making
oxygen abiotically.
(28, 29, 30, 31, 32)

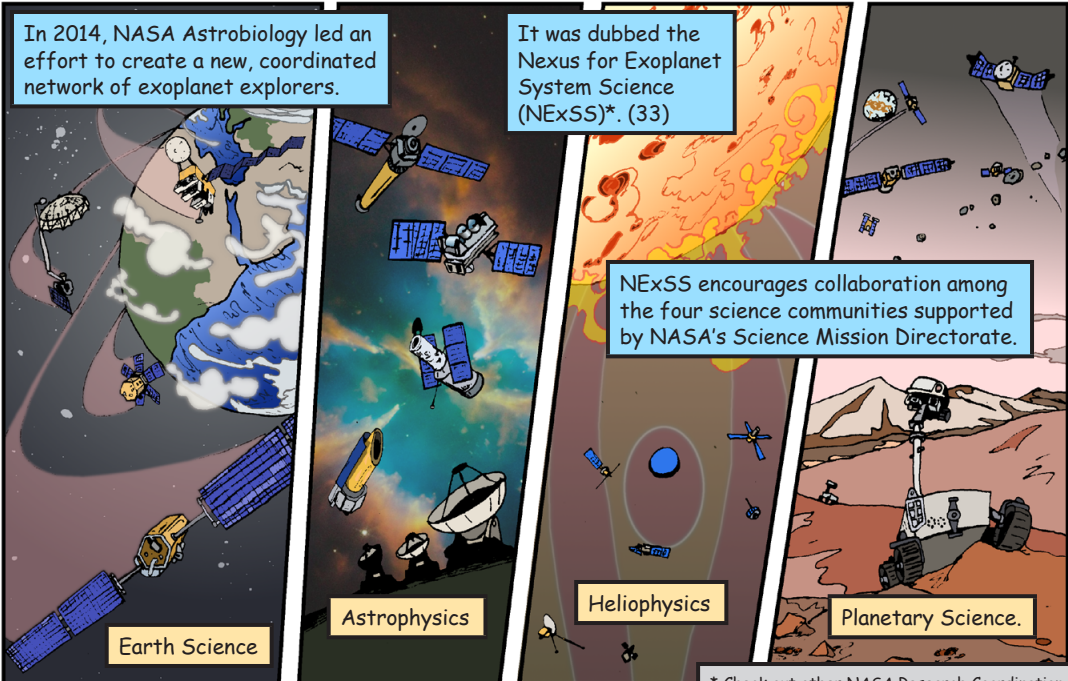
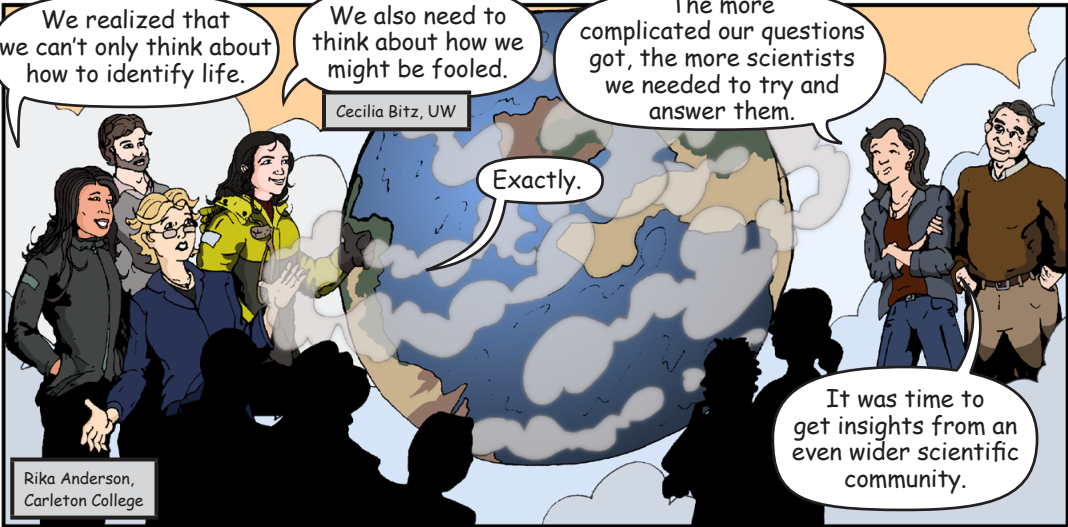
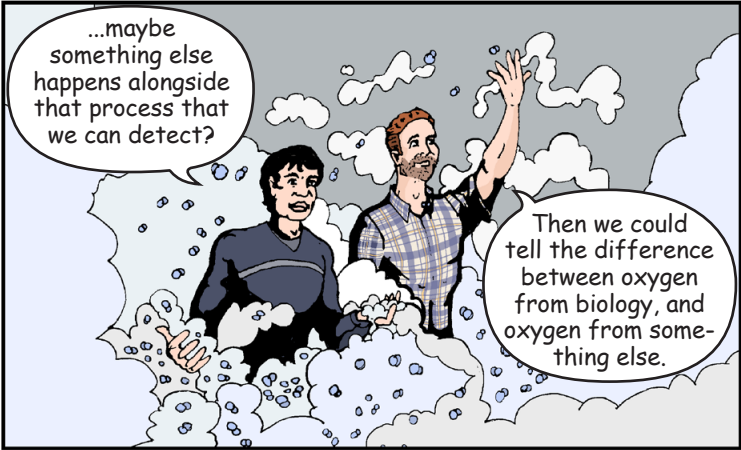
For instance, energy from a
young star can strip hydrogen
away from water molecules...

...leaving only the
oxygen behind.

Or, carbon dioxide
can be broken apart
by solar energy
through photolysis*.

Astrobiologists had to look at
what **other** features could act as
a signal for life in an atmosphere.

*Chemical decomposition
under the influence of light.



* Check out other NASA Research Coordination Networks (RCNs) in other issues!



NExSS includes several research teams, each dedicated to solving a piece of the exoplanet puzzle.



With new ideas from even more scientists, let's look again at the 'habitable zone.'



The definition of "habitable zone" is the distance from a star at which liquid water could exist on surfaces of orbiting planets. (34, 35)

The 'habitable zone' makes things sound easy. We just need a small planet with an orbit similar to the Earth.

If only it were that simple...

Antígona Segura Peralta,
Universidad Nacional
Autónoma de México



Earth sits in the middle.

Venus is outside the habitable zone, but it's close to the inner limit.



So far, we haven't found evidence of past or present life on either Mars or Venus.

Mars is at the outer edge of our system's habitable zone.



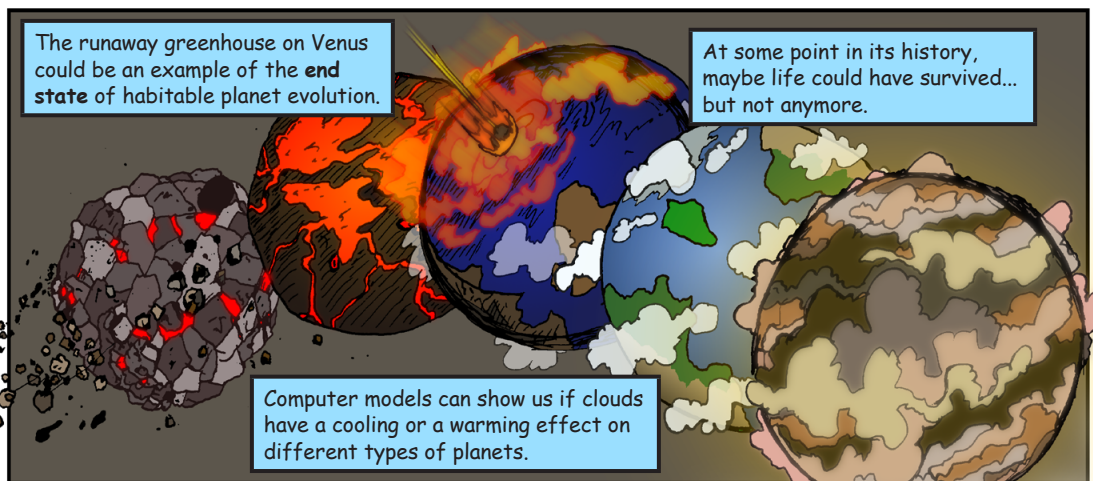
The habitable zone is based on an Earth-like planet, with an Earth-like atmosphere.

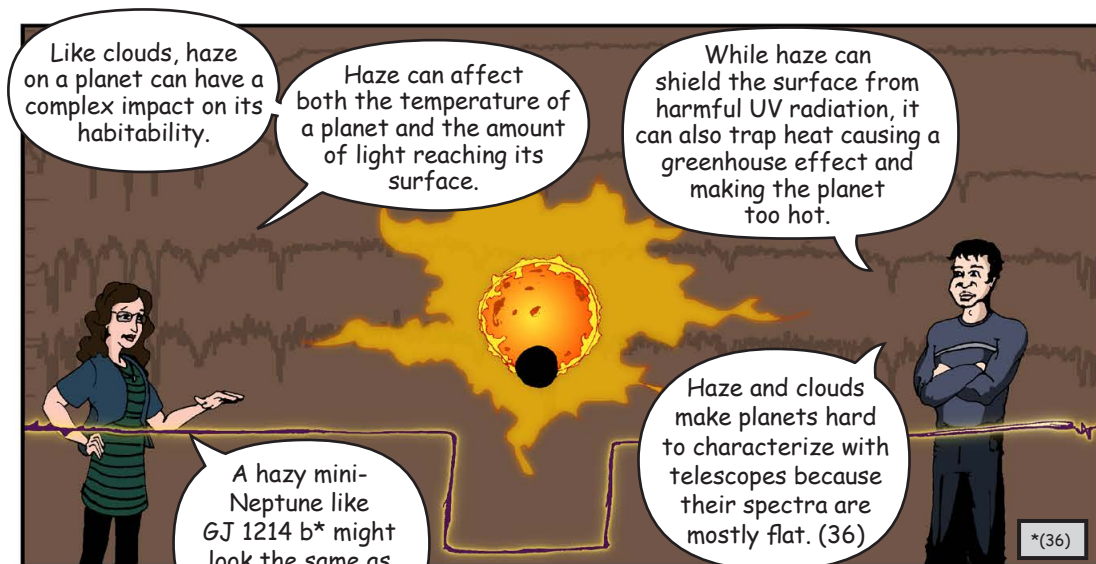
As soon as a planet deviates from that composition, it can get into trouble.

And what about the Moon? It sits within our system's habitable zone, yet it isn't habitable.

So you see, there's more to it than spotting a world in the habitable zone.







Like clouds, haze on a planet can have a complex impact on its habitability.

Haze can affect both the temperature of a planet and the amount of light reaching its surface.

While haze can shield the surface from harmful UV radiation, it can also trap heat causing a greenhouse effect and making the planet too hot.

A hazy mini-Neptune like GJ 1214 b* might look the same as a hazy terrestrial planet.

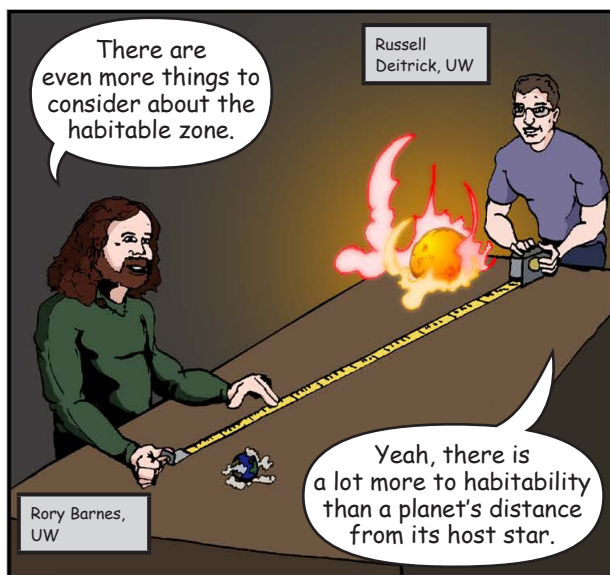
Haze and clouds make planets hard to characterize with telescopes because their spectra are mostly flat. (36)

*(36)



Haze could make it hard to identify water on exoplanets, but we can still characterize basic properties like planet colors.*

*See page 16

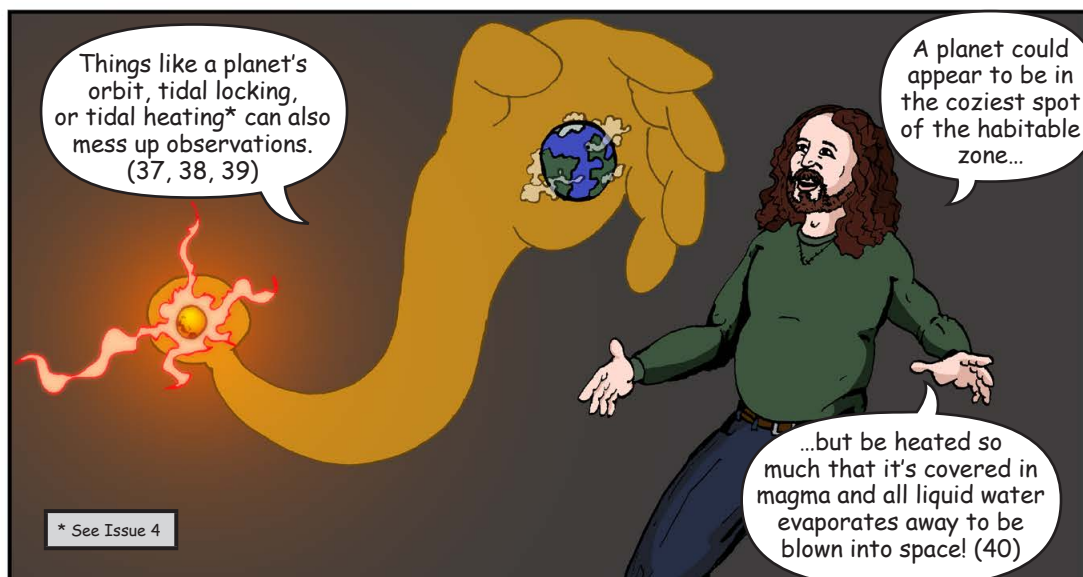


There are even more things to consider about the habitable zone.

Russell Deitrick, UW

Yeah, there is a lot more to habitability than a planet's distance from its host star.

Rory Barnes, UW

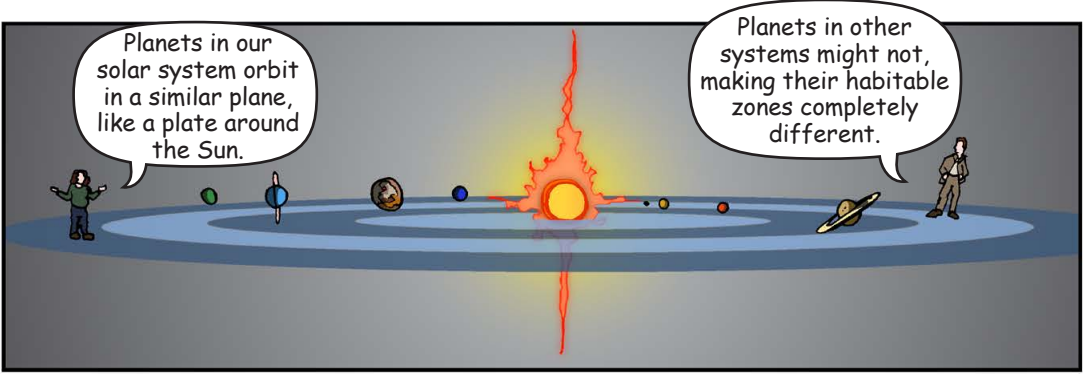


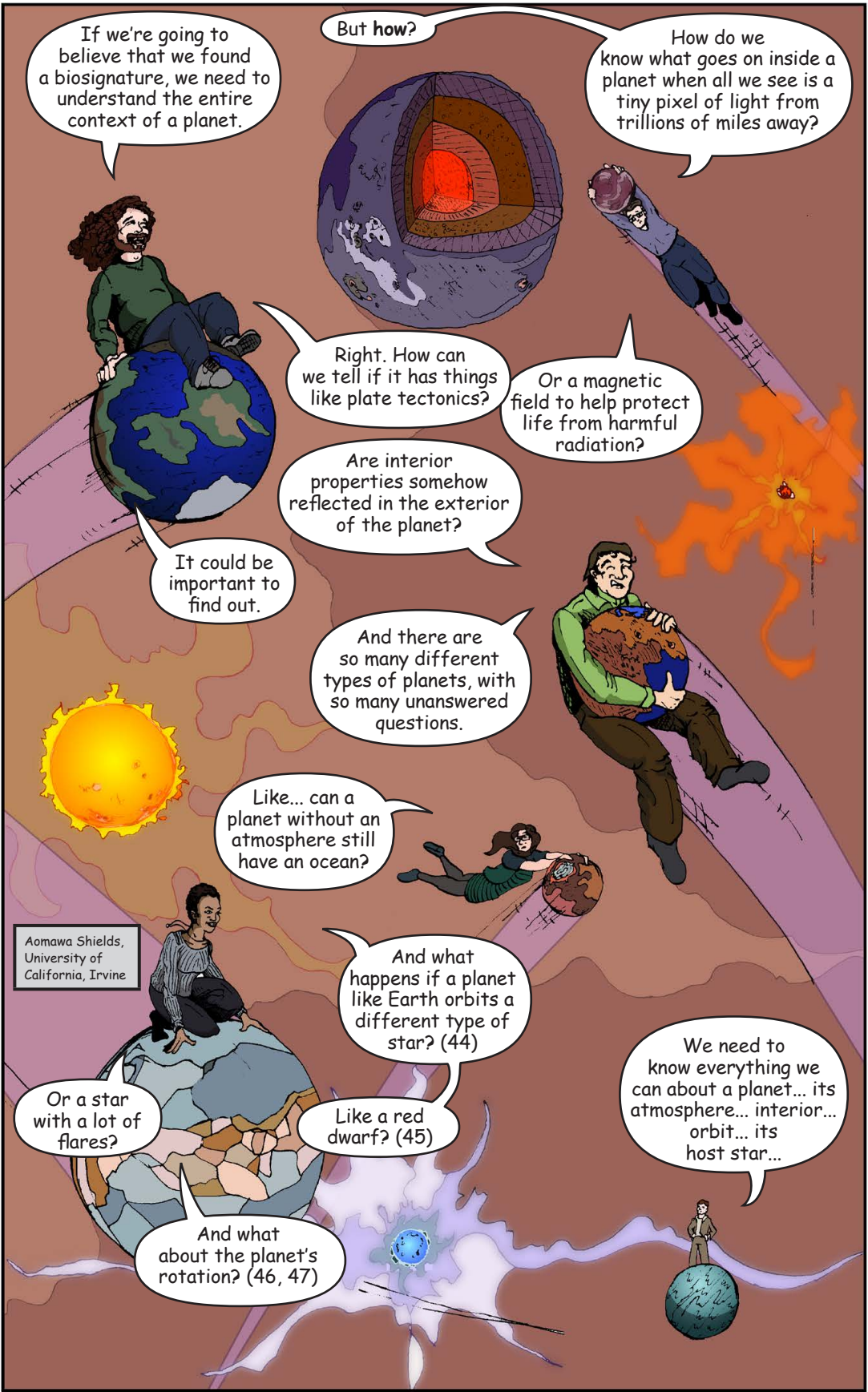
Things like a planet's orbit, tidal locking, or tidal heating* can also mess up observations. (37, 38, 39)

A planet could appear to be in the coziest spot of the habitable zone...

...but be heated so much that it's covered in magma and all liquid water evaporates away to be blown into space! (40)

* See Issue 4





Aomawa Shields,
University of
California, Irvine

Or a star
with a lot of
flares?

And what
about the planet's
rotation? (46, 47)

Like a red
dwarf? (45)

And what
happens if a planet
like Earth orbits a
different type of
star? (44)

Like... can a
planet without an
atmosphere still
have an ocean?

And there are
so many different
types of planets,
with so many
unanswered
questions.

Are interior
properties somehow
reflected in the
exterior of the
planet?

Or a magnetic
field to help protect
life from harmful
radiation?

Right. How can
we tell if it has
things like plate
tectonics?

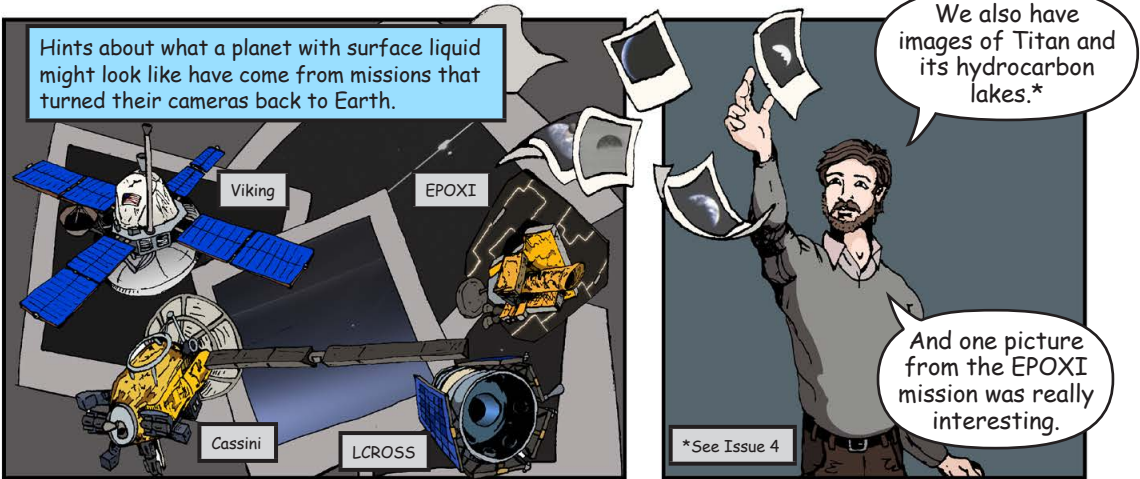
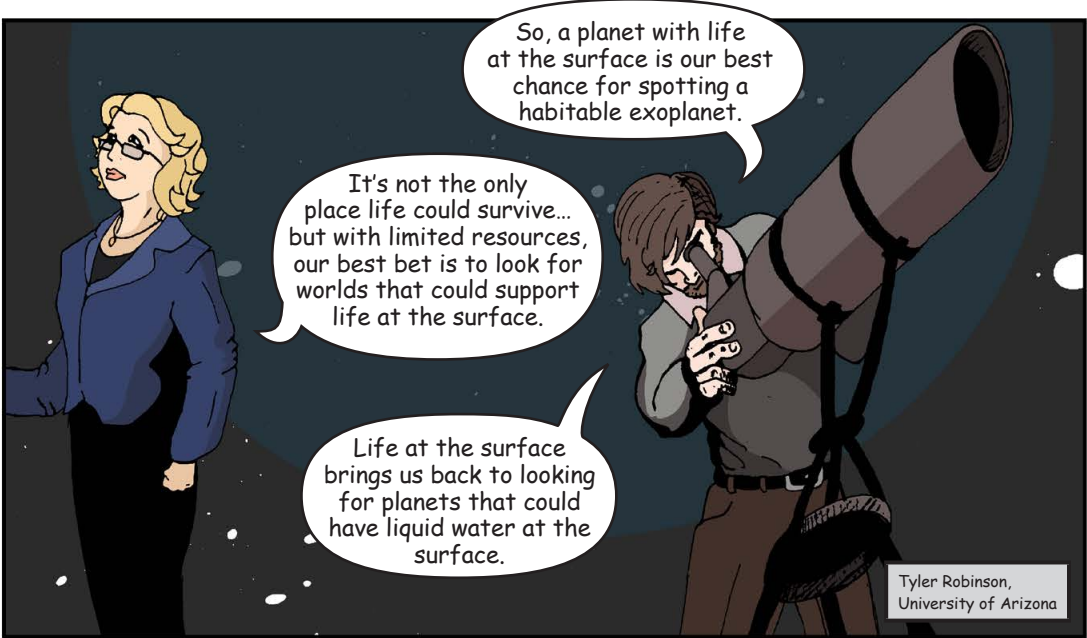
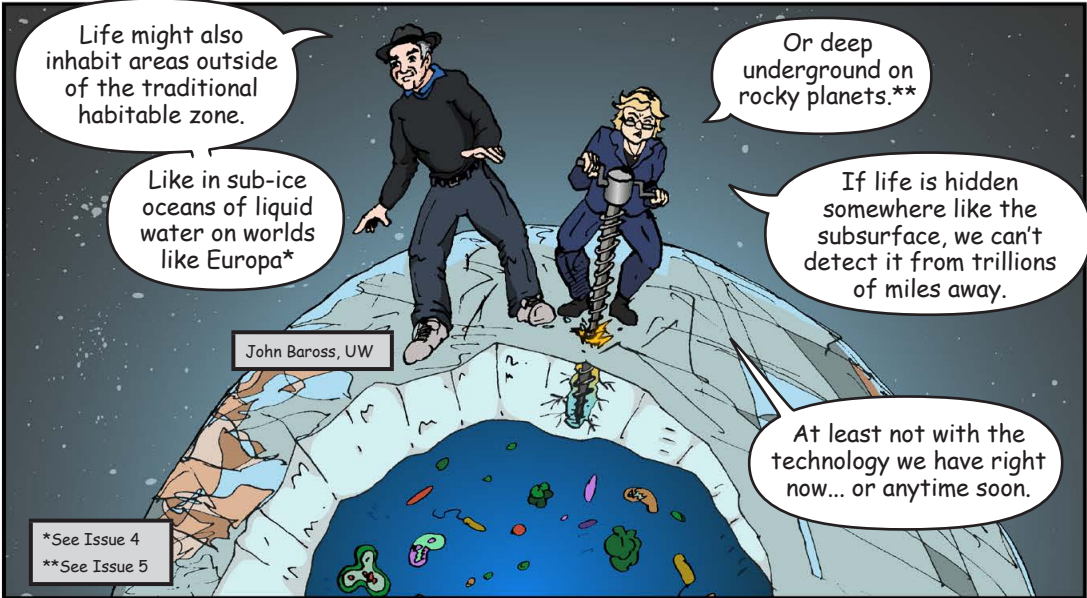
How do we
know what goes on
inside a planet
when all we see
is a tiny pixel of
light from
trillions of miles
away?

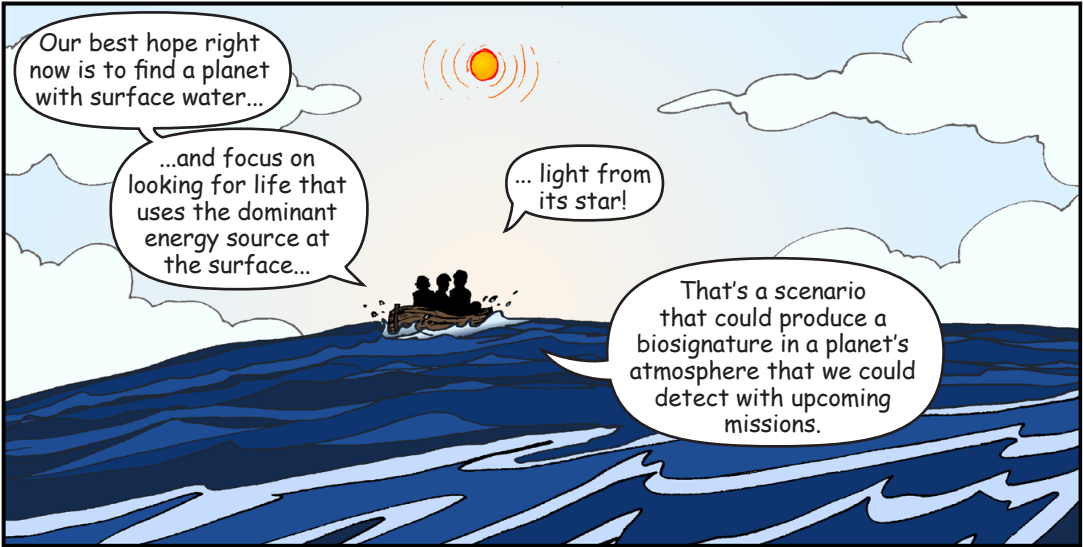
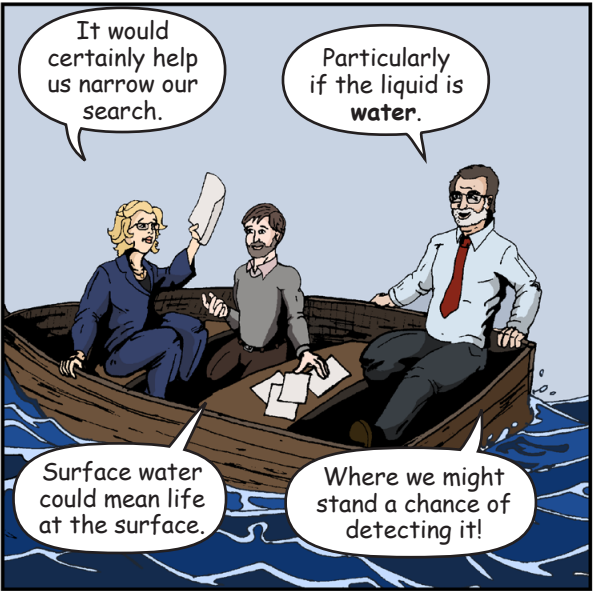
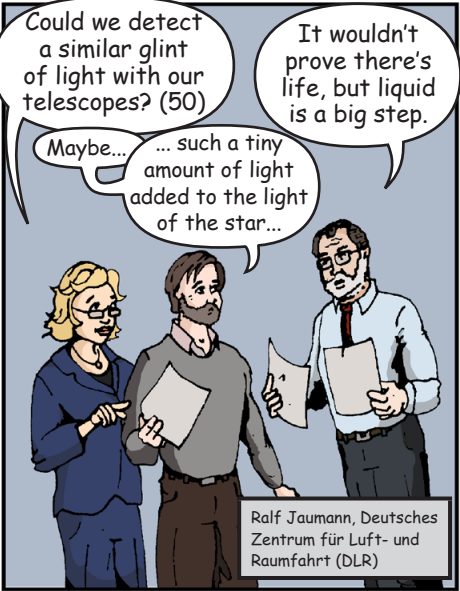
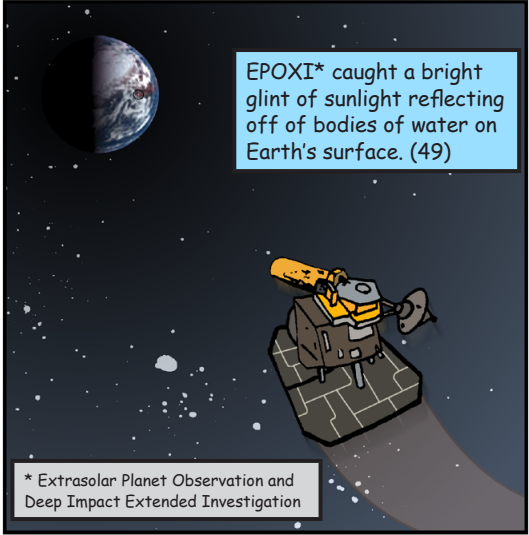
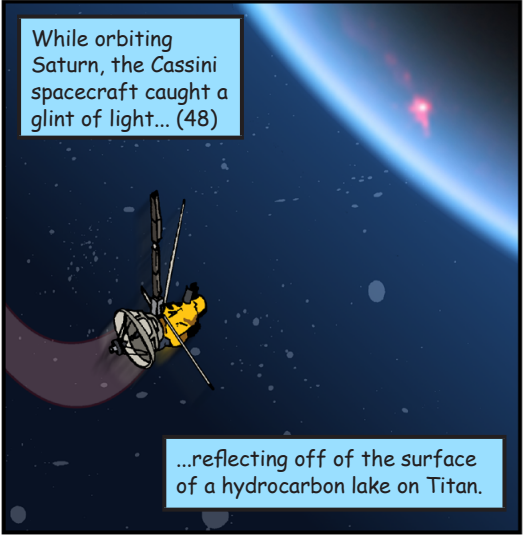
But how?

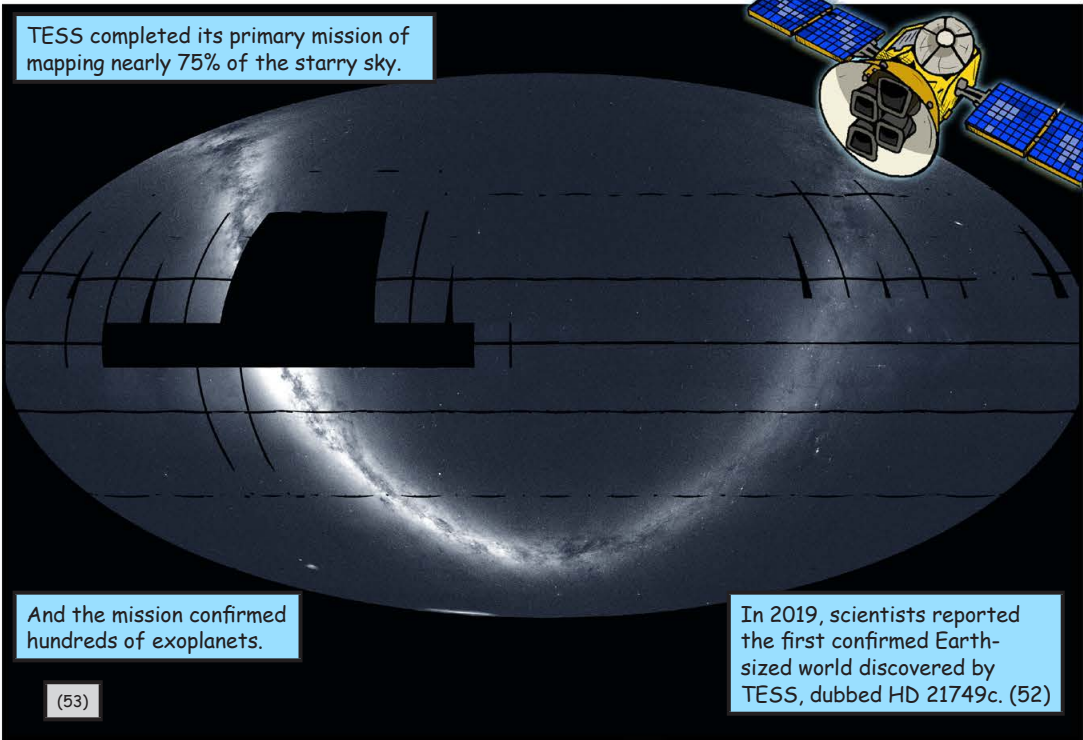
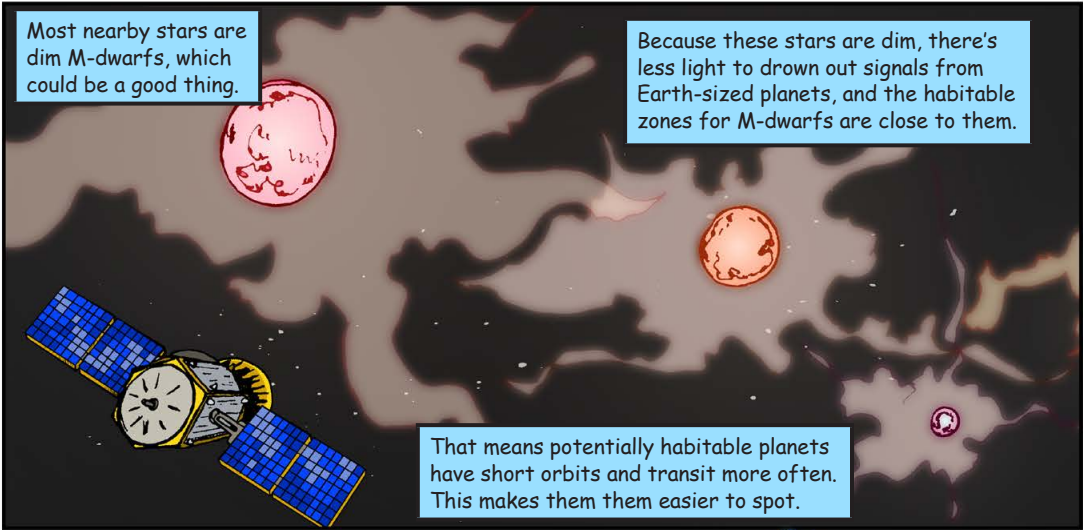
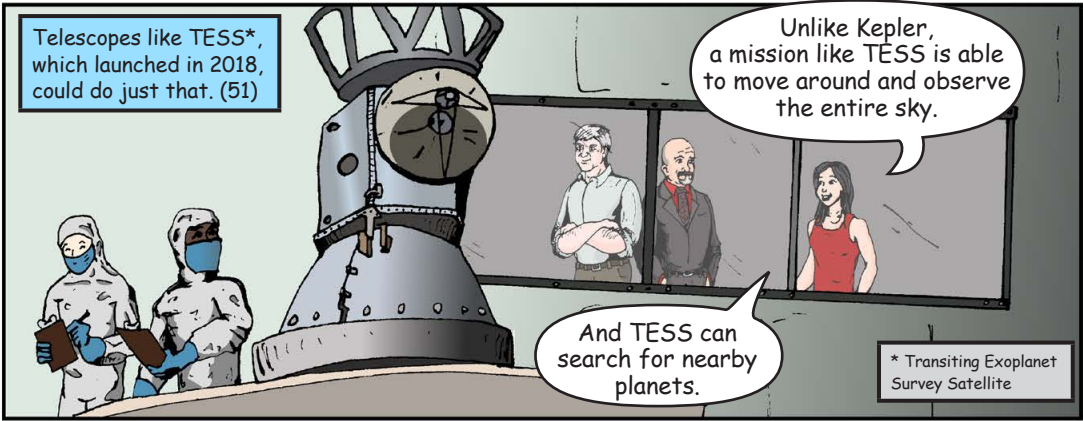
If we're going to
believe that we
found a biosignature,
we need to
understand the
entire context of
a planet.

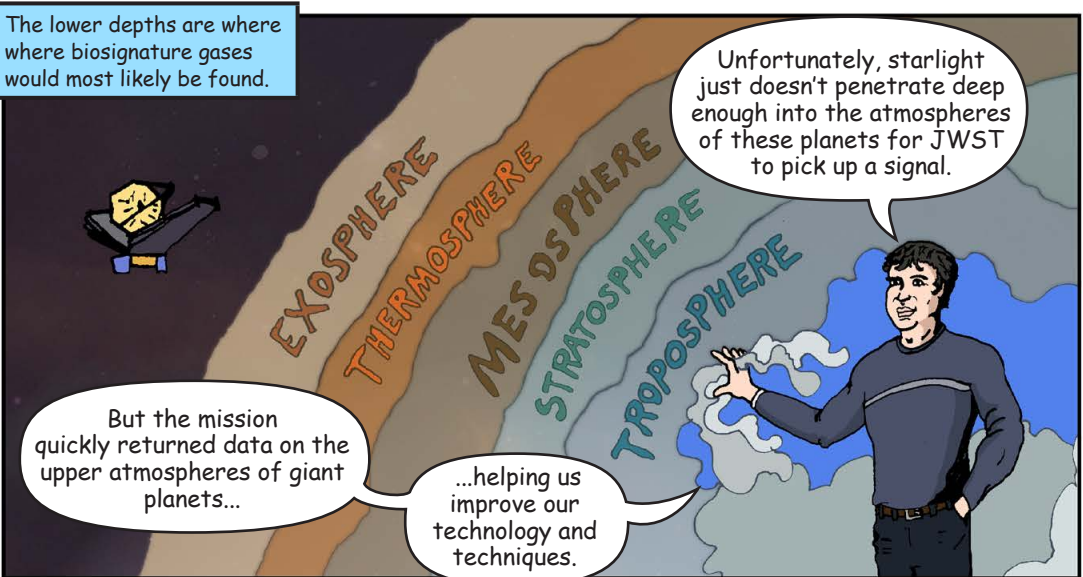
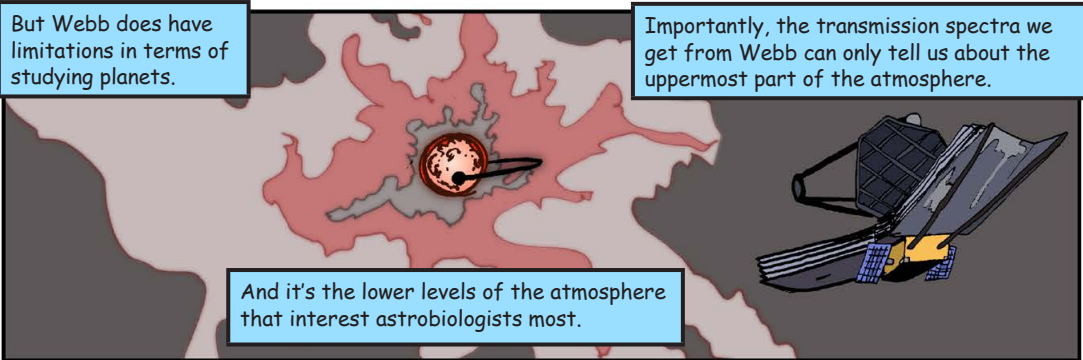
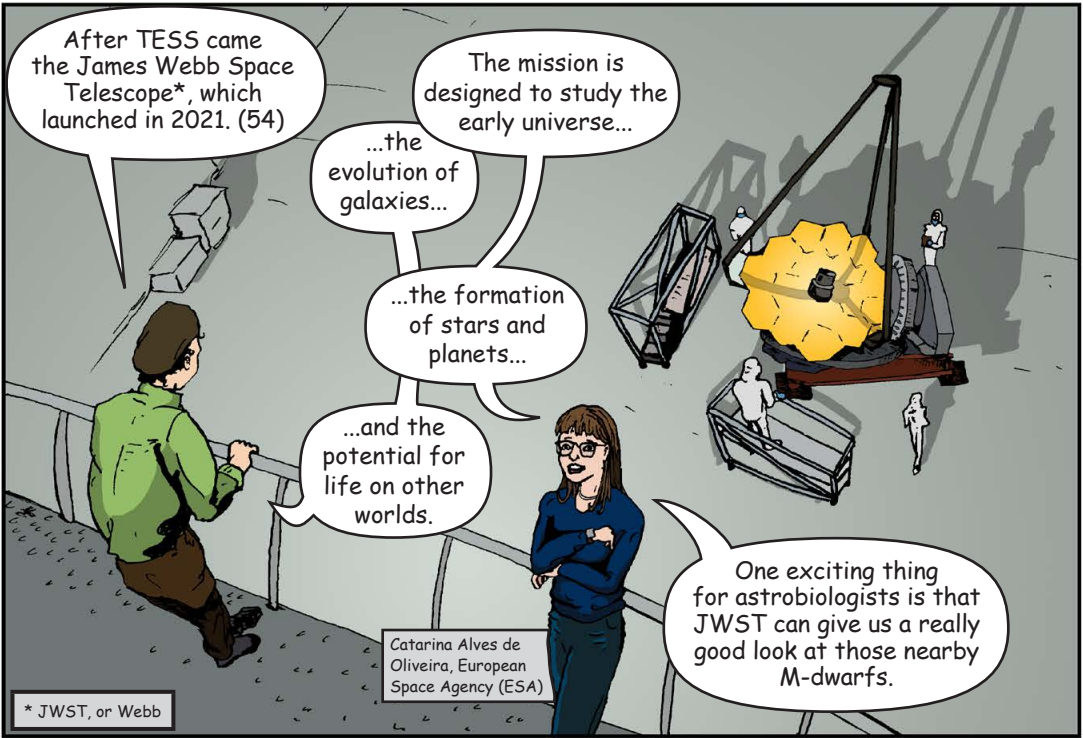
It could be
important to
find out.

We need to
know everything
we can about a
planet... its
atmosphere...
interior...
orbit... its
host star...









An example is what JWST has taught us about a group of rocky planets only 40 light years away.

Back in 2017, planets were found orbiting the nearby star TRAPPIST-1 using data from Spitzer and ground-based telescopes. (55)

This star is ultra-cool and only slightly larger than the planet Jupiter.

Scott Gaudi, Ohio State University

Because TRAPPIST-1 is so small and cool, the system's habitable zone is very close to the star.

Three of the seven Earth-sized planets orbit well within this habitable zone.

By studying the interactions of the planets, scientists were able to determine their masses.

It was the first time that scientists were able to infer masses for planets this small.

Three planets in the habitable zone, with sizes AND masses similar to Earth's...

...all orbiting close to their star, where it is easier for us to see them....

We were anxious to get a better look at these worlds...

And JWST gave us that chance in 2023 (56).

The mission was able to measure the temperature of the planet Trappist-1b based on its thermal emission. (57)

Some scientists had speculated that the planet Trappist-1c might have a thick CO₂ atmosphere, but data showed that this wasn't the case. (58)

Aki Roberge,
NASA GSFC

But other studies still leave hope for water vapor or oxygen. (59)

Michaël Gillon,
Université de Liège

To study a small planet, the telescope will have to observe the planet transiting its star many, many times.

And getting data from a single planet in this way is going to take a HUGE amount of observation time.

This is why we'll only be able to study a few planets during the mission's lifetime.

Many people need to use the telescope, and it's not just exoplanets that JWST is studying. (60, 61)

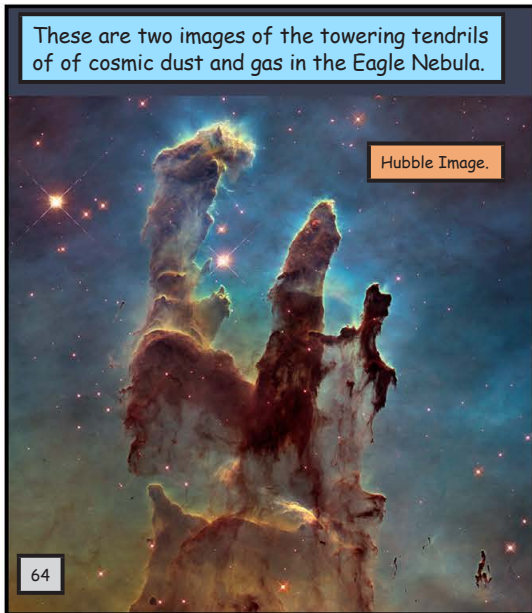
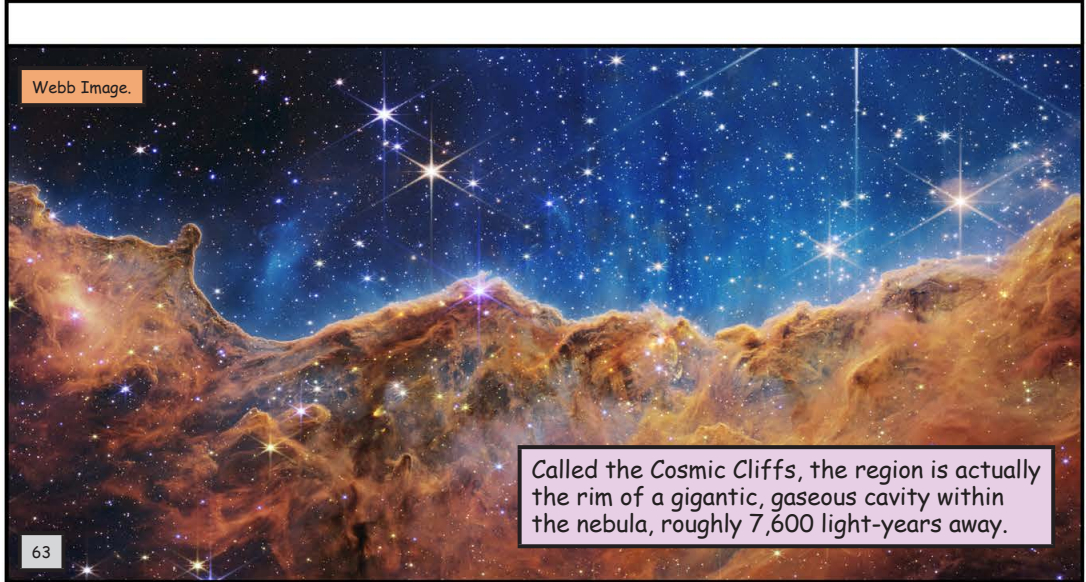
So we have to carefully choose the best planets to look at.

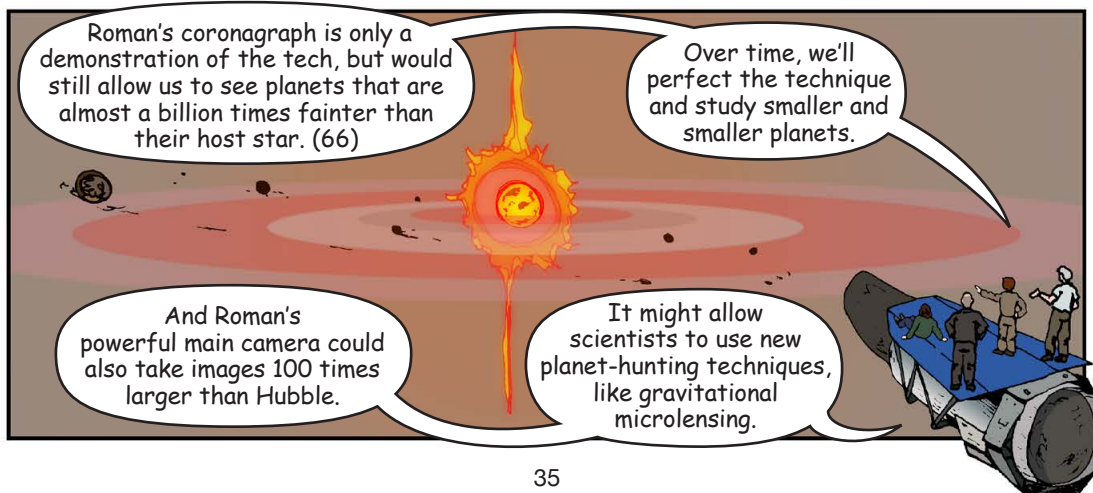
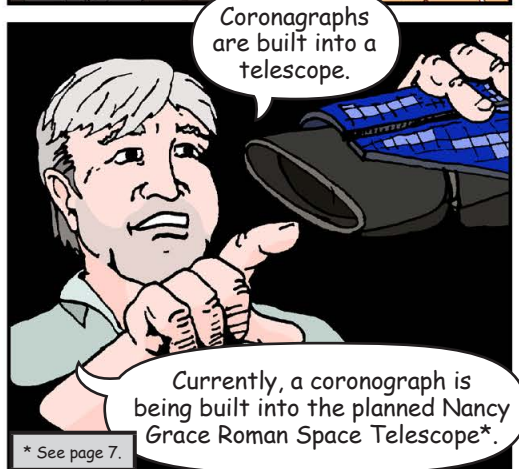
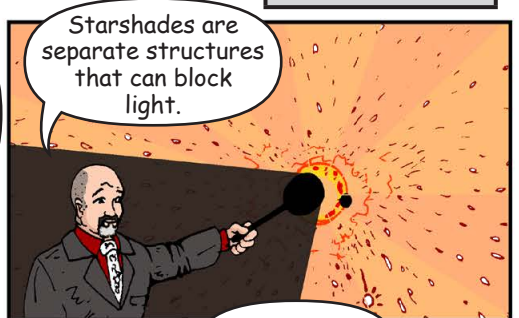
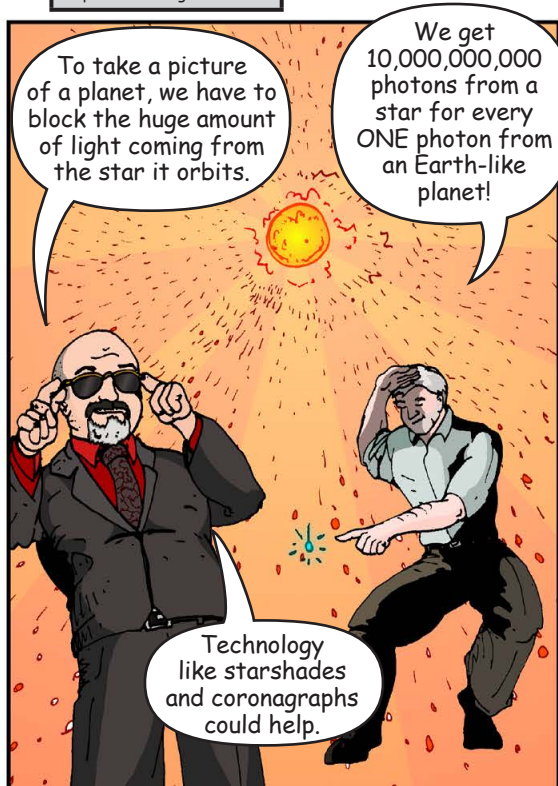
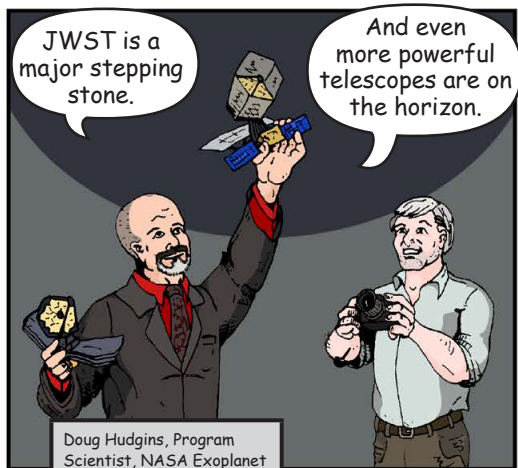
We'll only be able to study a handful of planets out of thousands of possibilities.

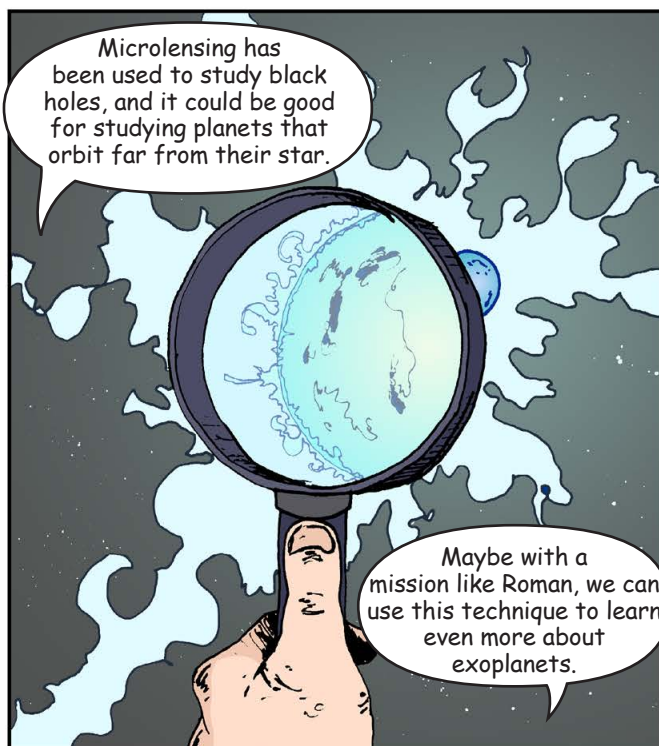
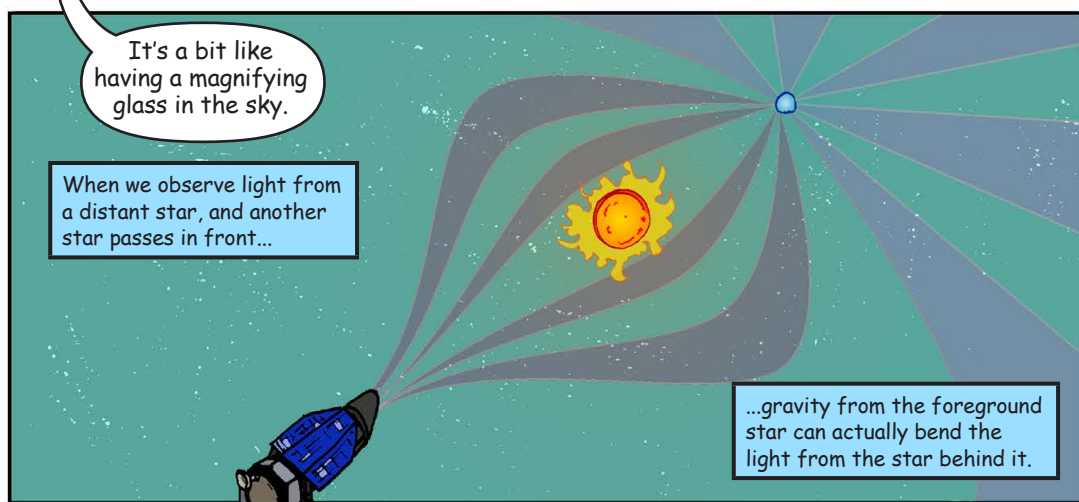
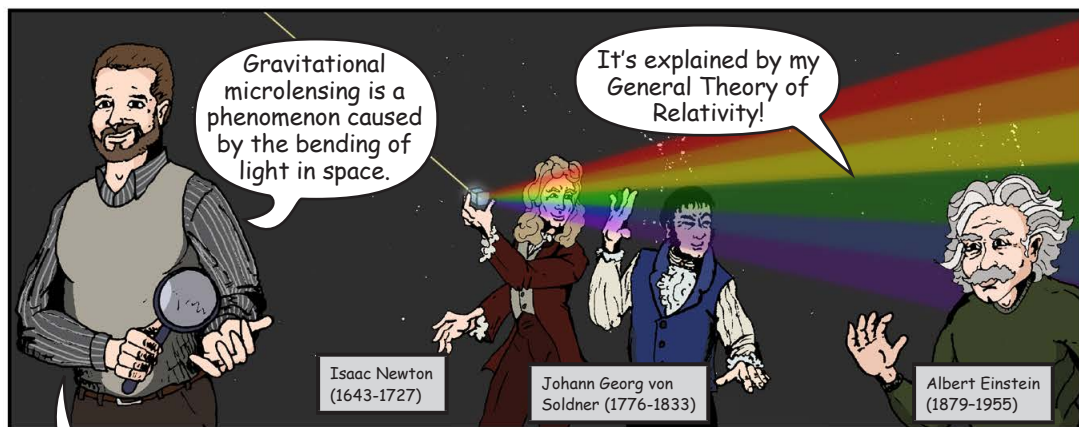
Still, JWST is a huge advancement in our capabilities. After all, it's **100 times** more powerful than Hubble!

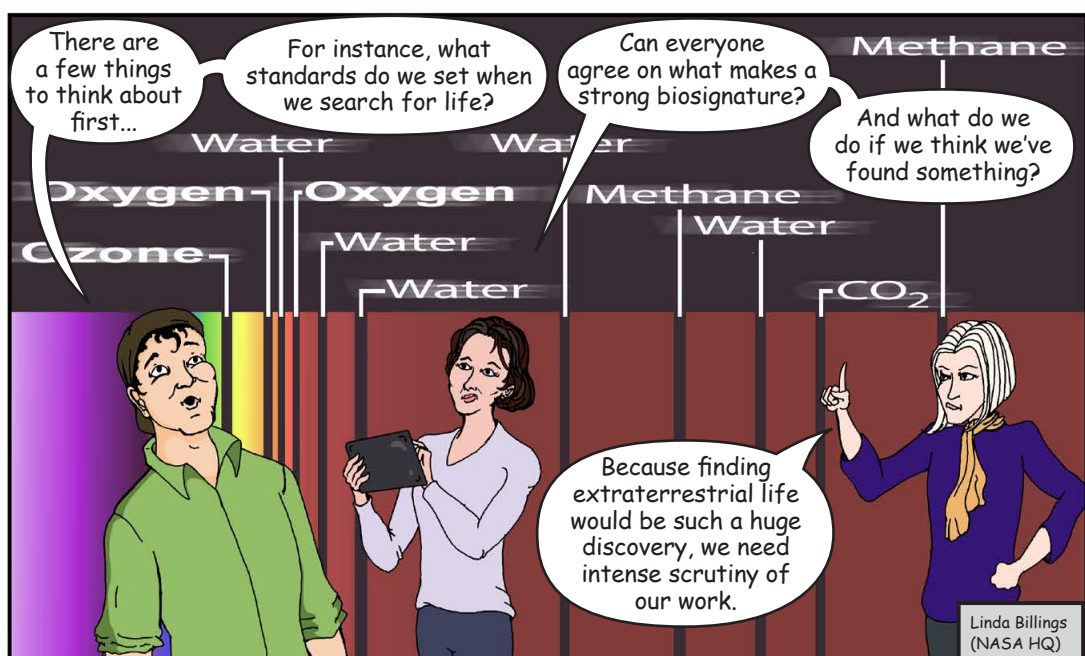
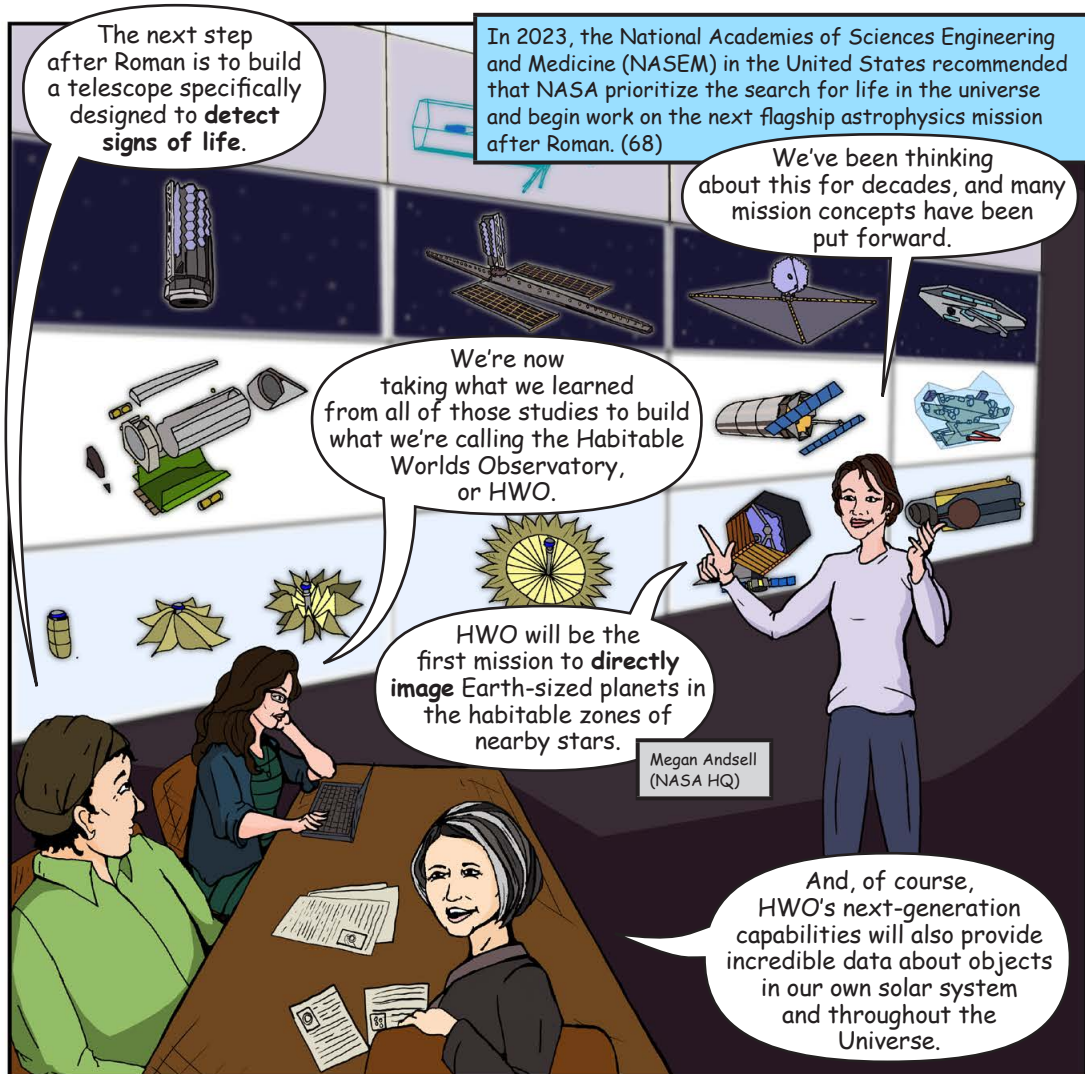
Even some of the first images that the mission sent back highlighted this advance...

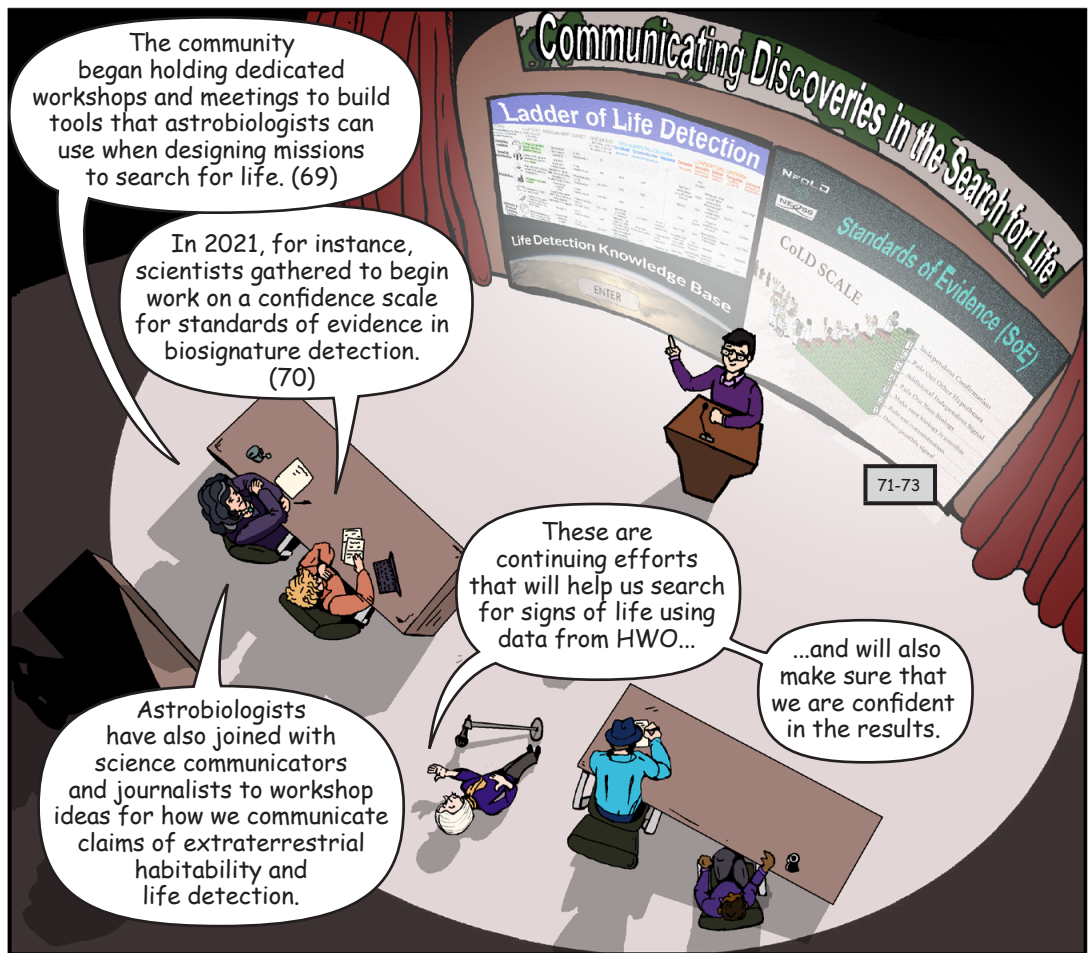
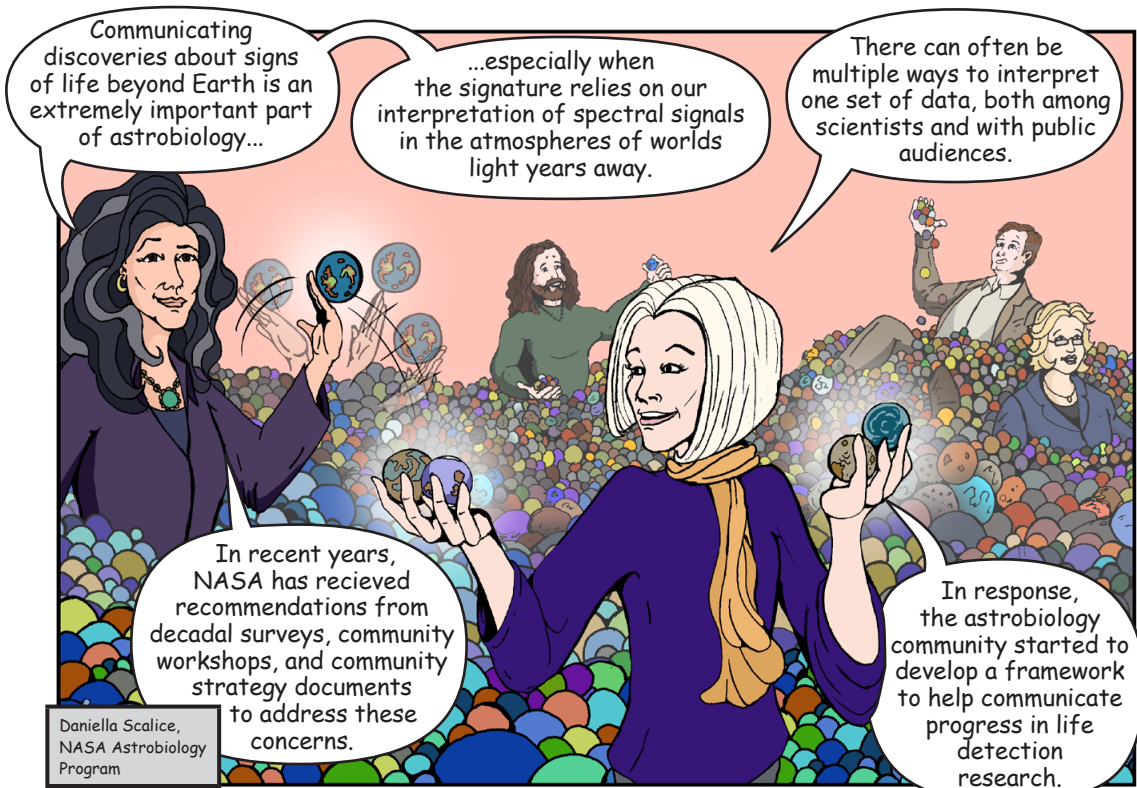
Mary Voytek, NASA
Astrobiology Program

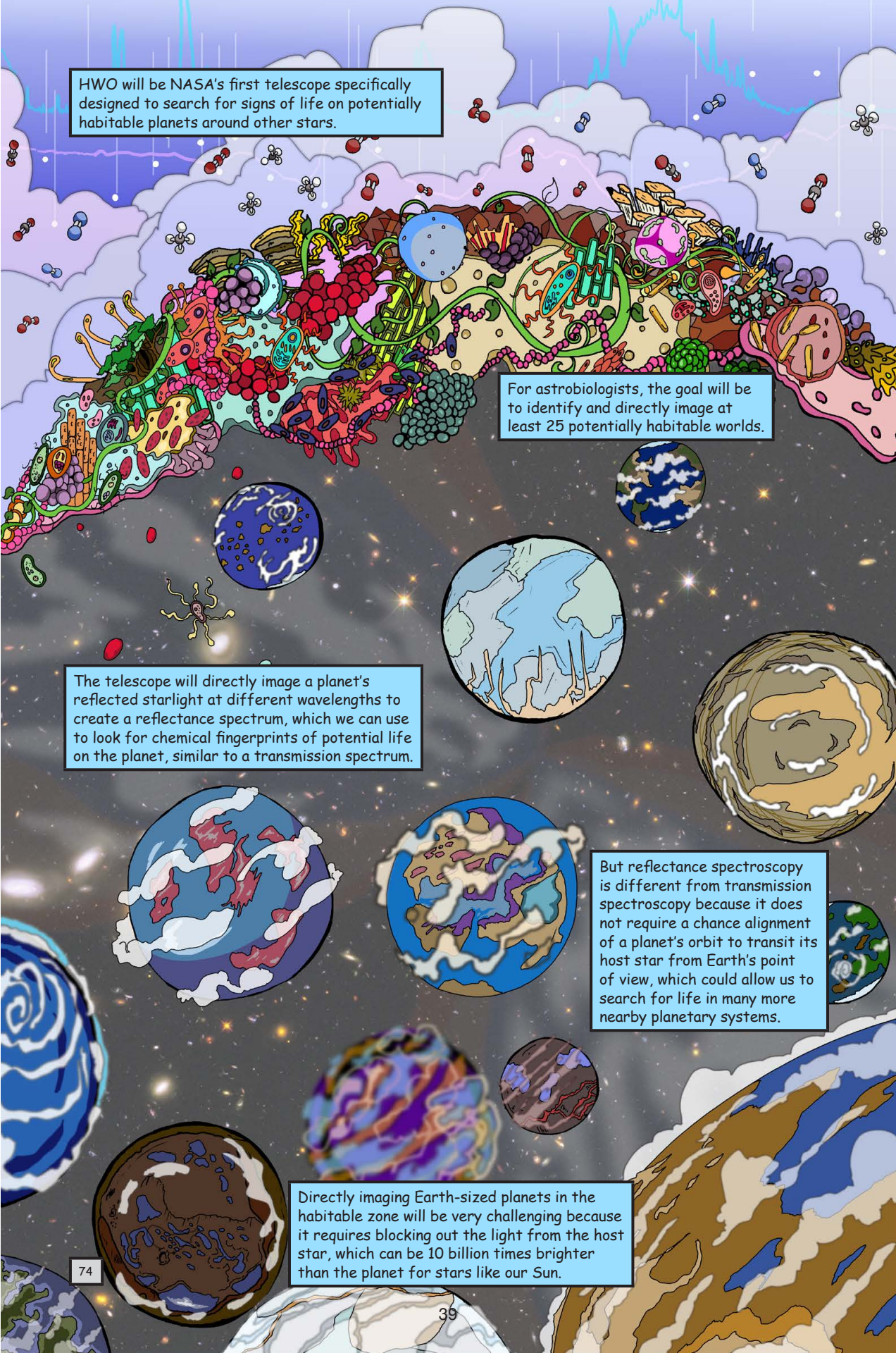












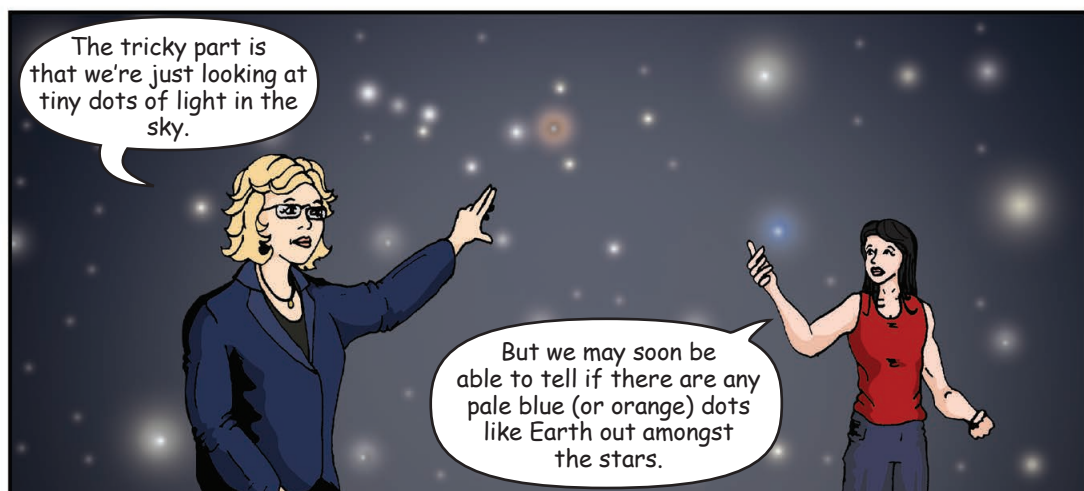
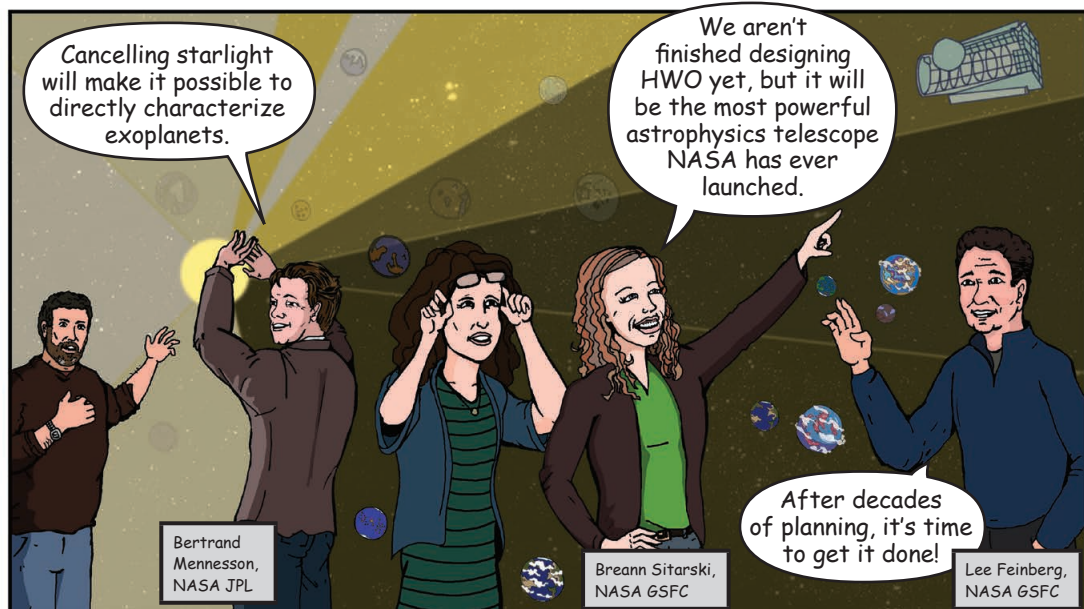
HWO will be NASA's first telescope specifically designed to search for signs of life on potentially habitable planets around other stars.

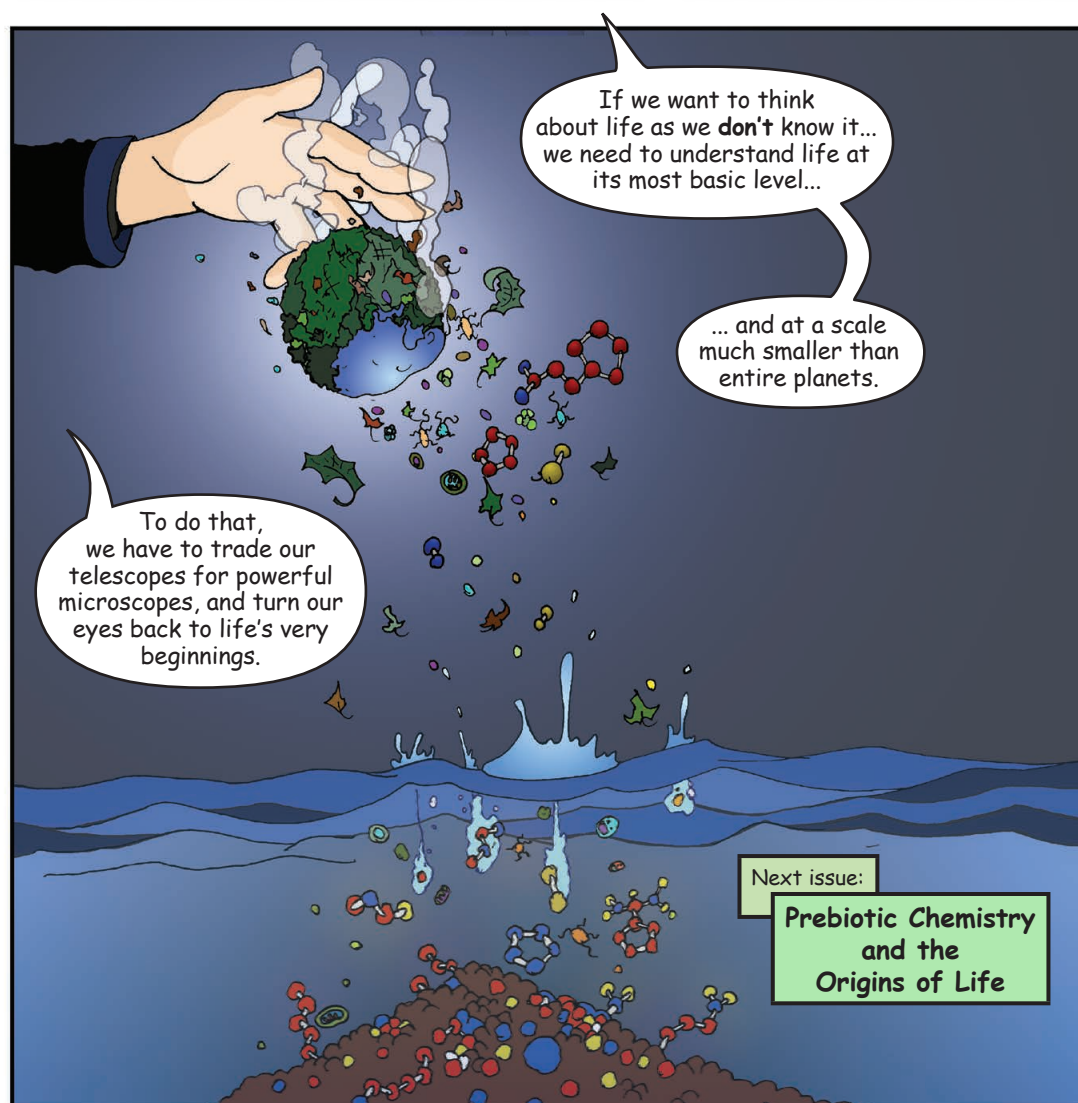
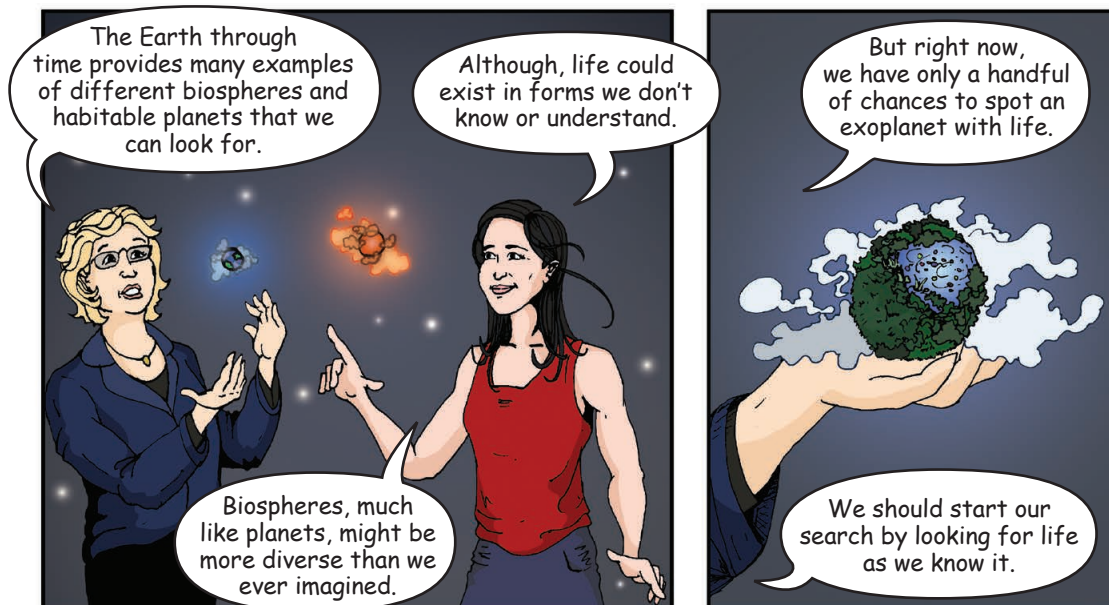
For astrobiologists, the goal will be to identify and directly image at least 25 potentially habitable worlds.

The telescope will directly image a planet's reflected starlight at different wavelengths to create a reflectance spectrum, which we can use to look for chemical fingerprints of potential life on the planet, similar to a transmission spectrum.

But reflectance spectroscopy is different from transmission spectroscopy because it does not require a chance alignment of a planet's orbit to transit its host star from Earth's point of view, which could allow us to search for life in many more nearby planetary systems.

Directly imaging Earth-sized planets in the habitable zone will be very challenging because it requires blocking out the light from the host star, which can be 10 billion times brighter than the planet for stars like our Sun.





Astrobiology

A History of Exobiology and Astrobiology at NASA

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