"Scorched Earth Enigma" Fun Facts

A lot of real science went into making the sci-fi short feature "Goldilocks Paradox," the first episode of "The Habitable Zone" series. Here are some stories behind the story.

About the Star

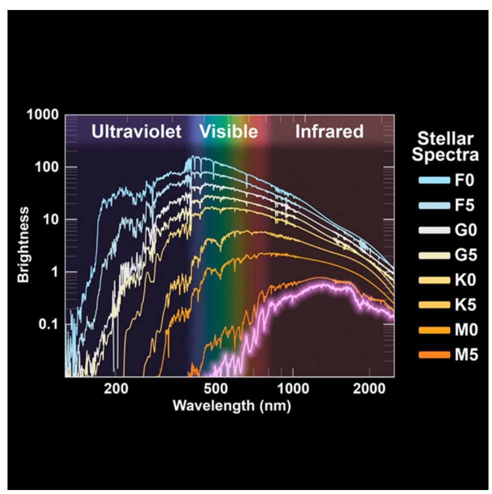
Are there really stars about the same size as Jupiter?

Strangely enough, the most common type of star in our Milky Way galaxy are also the smallest. These "red dwarfs" have masses as small as about 100 times that of Jupiter, but due to the way their interiors compress, they aren't much bigger than Jupiter. Once stars get even more massive, their size does start to swell, driven by the increased energy output in their cores

How cold can a star be?

The smallest stars in the galaxy are also the coolest and are classified by astronomers as "M dwarfs." They range in temperature from around 2,300 to 3,800 degrees Kelvin (K). While that is cold for a star, as Cas notes, it is still hotter than many hot things we experience on earth, like lava. For comparison our Sun's temperature is about 5,600 K, about twice as hot as an M dwarf.

How does Cara determine the star's type?



Cara measures the star's properties pretty much the same way astronomers do it today. The light of star is passed through an instrument similar to a prism that splits it up into a spectrum. This is seen as a squiggly line indicating how bright the star is at different wavelengths of light.

This spectrum is then compared to those from other known stars and the closest match for its overall shape and features determine the type. The spectra displayed on Cara's screen are real, taken from research archives used for this purpose.

In this case, the fictional star Arcadia-08 is represented with a magenta line, and its spectrum fits within the range of M dwarf stars. Cara categorizes it specifically as an "M6" with the number indicating just where it fits within the range of M dwarfs, slightly dimmer and cooler than the coolest template star shown on the graph.

Why aren't "red dwarf" stars actually red?

If you look at the spectrum for the M dwarf stars on the spectrum plot above you might notice a couple of interesting things. First, they are brightest in the infrared part of the spectrum, outside of the range of light seen by our eyes. This is why Cara suggests it might better be called an "infrared dwarf."

The other important factor affecting the star's color has to do with how much light it emits at different parts of the visible light spectrum. While these stars are brightest in the red part of the spectrum, they still emit light in the yellow, green, and even slightly in the blue parts. This is enough to shift its color more towards orange. In fact, the temperatures of cool stars is similar to those of low-wattage light bulbs, and their color would adopt more of that warm orange tone, rather than glowing pure red.

What is the star Proxima Centauri like?

Our Sun's nearest neighbor, about 4.24 light years away, is called "Proxima Centauri" and is very similar to the star in this video. It is categorized as an M5.5 dwarf, and we know it harbors at least one planet: Proxima Centauri b.

Another similarity between Proxima Centauri and Arcadia-08 is the strong activity. Small stars are known to have huge stellar flares that can increase their brightness by factors of two or more. One flare seen at Proxima Centauri increased its overall brightness by a factor of 10!

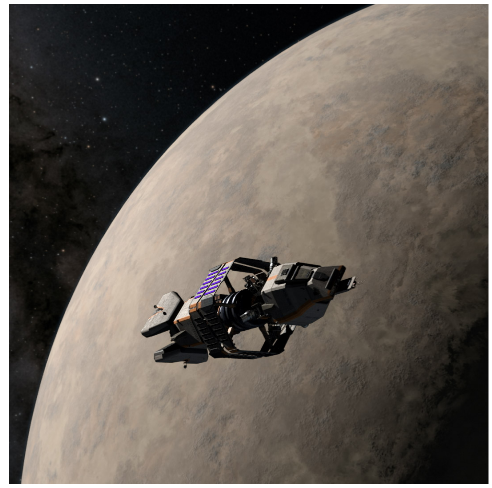
About the Planets

Do tiny stars really have orbiting planets?

While the Arcadia-08 system is fictional, it is based on many other similar stars that we know have planets. One system, known as TRAPPIST-1, is a small, cool M dwarf around which astronomers have discovered 7 Earth-sized planets. And, just like in our video, the 4th one out is located in the habitable zone of its star.

To date astronomers have found planets orbiting a whole range of stars, and quite a few small stars are known to have orbiting planets, some even smaller than the Earth.

How did Mars loose its oceans?



One leading theory is that Mars may have lost its oceans due to a long process of the Sun's solar wind scrubbing away its outer atmosphere slowly over time. Earth's strong magnetic field protects its atmosphere from such effects, but we know Mars currently has essentially no magnetic field (though it likely had one in its past). If it indeed lost its magnetic field long ago, its weaker gravity (about 1/3 that of Earth at its surface) would have made it easier to lose its air over millions, or billions, of years.

This is one of several theories that have been proposed, and NASA's Maven spacecraft is currently in orbit around Mars studying its atmosphere. The data it collects will help scientists solve the mystery of what happened to all that air.

Why were the planets named "Arcadia-05 b," "c," "d," & "e"?

Exoplanetary systems are commonly named after the telescope or project that discovered the presence of planets around the star plus an index number indicating order of discovery. That's why so many exoplanets have names like "Kepler-452 b" since NASA's Kepler mission has found so many during its mission.

Exoplanet letters usually start with a lowercase "b" as the letter "A" (in uppercase) is reserved for the name of the star. The "A" is usually left off in the case of a single star, but if there were 2 stars orbiting one another then they would be "A" and "B" and the first known exoplanet would be "c."

Even though this is a purely fictional system, the planets were named following the real naming convention.

How do we know what the gravity is at the surface of a planet?

In the video, Cas and Cara are looking at the planet's properties and determine from its radius and mass that its surface gravity would be 85% that on earth, i.e. "things would be 15% lighter there." This is actually a simple calculation based on Newton's law of gravity that tells us that the gravitational force is proportional to a planet's mass, and inversely proportional to the square of its radius.

So if you can measure an exoplanet's size and mass, you can easily figure out just how hard it would be to climb the stairs down there!

How do we measure the masses of planets?

Mass is a tricky thing for astronomers to measure. The mass isn't obvious from a planet's appearance, any more than the weight of a suitcase can be determined by just looking at it (from the outside you can't see whether it's empty or full of lead bricks).

To measure a planet's mass you need to be able to observe how its gravity affects the motion of other objects around it. Since the I.S.V. Arcadia can fly around and orbit the planets, the crew can calculate the planets' masses directly from the properties of their spacecraft orbit (namely the size of its orbit and how long it takes to go around the planet).

It is much harder for astronomers to measure the masses of exoplanets orbiting distant stars. A small number of them have been "weighed" remotely by observing how their orbit affects the motion of their central star (causing a "wobble"), or in rare cases like the TRAPPIST-1 system, how multiple planets affect one another's orbits.

Why don't Cas and Cara visit known exoplanets?

While there are currently thousands of known exoplanets, the idea for "The Habitable Zone" was to explore new, unknown systems. This allows the story to focus on specific science topics (like how temperature and composition are connected to habitability) by visiting hypothetical worlds with very specific properties.

Our scientific understanding of known exoplanets is rapidly evolving, and basing a story on our current understanding of a specific planet might result in something that was soon outdated if new research disproved earlier ideas. Keeping the planets fictional is a way of keeping the focus on general science ideas and future-proofing the story.

About the Ship

What does the name "I.S.V. Arcadia" mean?

To renaissance artists, "Arcadia" (originally in reference to a region in ancient Greece) represented a kind of unspoiled wilderness. This seemed a good choice for the name of this "Interstellar Science Vessel" (I.S.V.) with its mission of discovering new, hopefully habitable worlds.

What are those rotating instruments behind the crew cabin?

Science fiction shows have a bad habit of allowing the characters to instantly learn about everything there is to know in a location using "sensors" that are incredibly powerful but have no visual presence on the ship.

We felt it was important to show that if you want to find planets and study them you have to have telescopes and other science instruments actively scanning the sky. The actual science instrument cluster was adapted from publicly-available 3D models of two different NASA space missions: ICESat-2, which is studying Earth's ice sheets, and WFIRST, an infrared survey telescope still under development.

Why are Cas and Cara wearing seatbelts?

Crew inside a free-floating spacecraft would be weightless and would need to strap themselves down to stay in their seats. However, when the engines are active and the ship is accelerating they would experience what effectively felt like gravity in proportion to the amount of thrust.

In the case of the Arcadia, the idea is that when the ship is moving between planets it accelerates (or decelerates) at 1 G, giving Cas and Cara the same sense of gravity that they have on Earth, but when the engines are off they are weightless. So seatbelts are the safe way to go!

Why does the ship flip around when it's flying toward a planet?

We have imagined that the I.S.V. Arcadia has incredibly efficient engines, allowing it to continuously accelerate at 1 G (9.8 m/s^2 or 32 ft/s^2). Not only would this effectively provide Earth-like gravity to Cas and Cara, but it would make moving around a stellar system much faster than what we are used to with current technology.

With this kind of engine, the fastest way to travel would be to accelerate towards your destination for about half of your trip, then flip around and decelerate for the rest. At these accelerations space travel would be much faster than current technologies, with trips to the Moon taking only hours, and trips to the planets taking days instead of months or years.

While today we do not have spacecraft engines that can maintain *high* thrust for long periods, the idea is inspired by real-life ion thruster technology. NASA's Dawn spacecraft used 3 ion thrusters which could maintain long periods of micro-thrust, allowing it to be the first space mission to orbit two different bodies beyond the Earth: the asteroids Vesta and Ceres.

Why does the ship make sound in space?

OK, yes, we really do know that there should be no sound in space, but like so many producers before us, we wanted the overall experience to be dramatic for a general audience. The sound does help to visually reinforce moments when the main engines or steering thrusters fire that might otherwise be missed. We did attempt to keep the sounds muffled, suggestive of what sounds might be heard within the ship.

How does the jump drive work?

Unfortunately it does *not* work. Current limits of science and engineering offer no way to traverse the vast distances between stars, at least within human lifetimes. The jump drive shown on the I.S.V. Arcadia is pure fantasy, used as a storytelling device to help us imagine what it would be like to visit distant exoplanets.

Viewing "Scorched Earth Enigma"

You can download this episode of The Habitable Zone and see all the related materials and links at the Universe Unplugged website:

https://universeunplugged.org

From there you can view the episode, download a copy, or subscribe to our video podcast feed. You will also find links to related materials and topics.

You can also find the video on the Universe Unplugged YouTube channel, including the previous episode “Goldilocks Paradox”:

https://www.youtube.com/c/universeunplugged