



“Goldilocks Paradox” 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

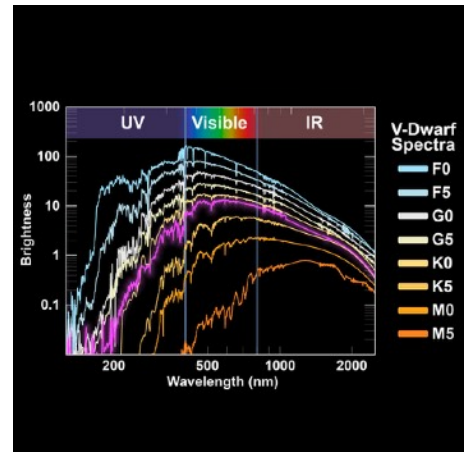
Is “Arcadia-05 A” a real star?

The star in “Goldilocks Paradox” is fictional but it was based directly on the star in the real system known as Kepler-62. The planets, however are different than those found by Kepler in this known system.

How does Cara determine the star 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.



What does Cara mean when she calls it a “K2 V” star?

Stars are categorized by both their temperature and size. Stellar temperature categories, running from hottest to coolest, are assigned letters from the sequence O, B, A, F, G, K, & M. Our sun a temperature at its visible surface of 5,770 K (9,930° F) is categorized as a G2 type star, while Arcadia-5 A (like Kepler-62) has a cooler temperature of 4,920 K (8,400 °F) corresponding to type K2. The number following the letter allows for finer subdivisions of each class.

The size of a star is indicated by a roman numeral running from “I” (supergiant) to “VII” (subdwarf). Stars like the sun, in their stable mid-life periods are considered to be category “V” (dwarfs).

About the Planets

Why were the planets named “Arcadia-05 b” & “c”?

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.

The letter following the name and number are used to both designate the star (in CAPS) and planets (in lowercase). The primary star will always be identified as “A” so in this case the star is “Arcadia-05 A.” The planet names would pick up with lowercase “b,” “c,” etc.

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

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.



How does density relate to composition?

While the ultimate goal of astronomers is to measure the chemical makeup of exoplanets from direct observations, there are still a lot of technological hurdles to overcome. However, looking around the solar system we can see that the overall density of a planet, which is simply its mass divided by its volume, can help identify general properties and composition.

A simple density measurement of a planet can be compared to simulations and models based on known physics and properties of bodies within our own solar system to give us our first estimates of which planets, for instance, are most likely to be rich in water.

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/s² or 32 ft/s²). 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 “Goldilocks Paradox”

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:

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

Watch for Episode 2, “Scorched Earth Enigma,” in early 2018!