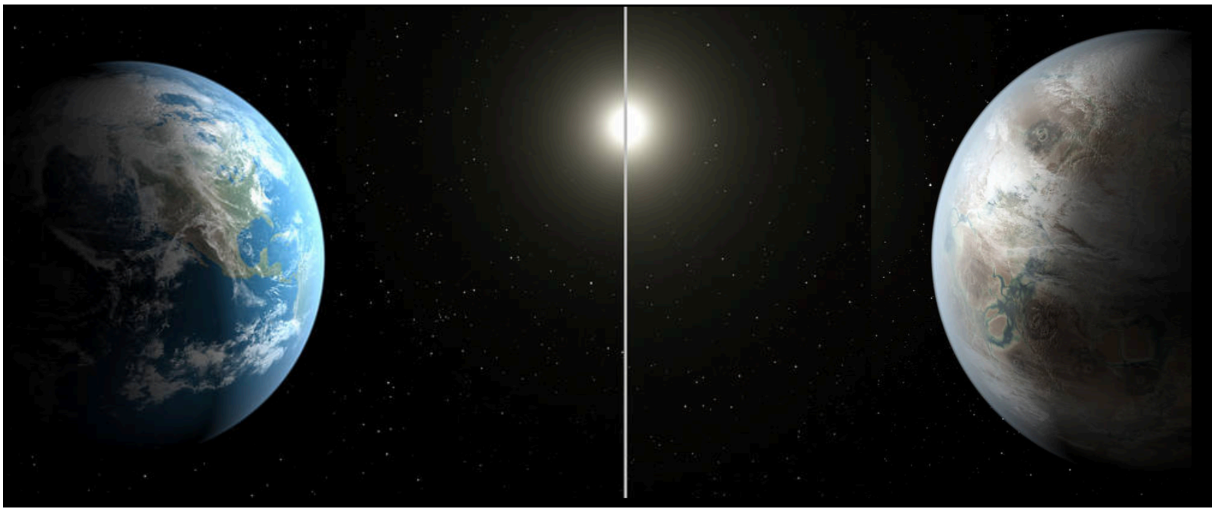

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Finding Earth 2.0 — the answer may be provided by China

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Guide: *When most people on the planet are breaking their brains for various problems such as climate warming, plastic flooding, pork prices, orange clown, Brexit, children's education, etc., a small group of people quietly Grounded their eyes on the deep space. They are committed to answering a question that does not match the reality: Is the earth lonely in this universe?*

Since ancient times, our ancestors gazed at the sky every night, and have long been familiar with the stars and the sun around the earth, rising and falling at night. But Copernicus told us five hundred years ago, no, it's not the sun orbiting the earth, but the earth orbiting the sun. After that, the sacred position of the earth has fallen again and again. Astronomers have discovered that the sun is nothing more than a star in the great Milky Way galaxy, and the Milky Way is just another galaxy in the universe. This makes us humans wonder if we are unique in this universe. Life and wisdom on earth, the technology and progress we are proud of, is it just an ordinary thing in this universe? Perhaps alien wisdom is just a river away from us?

Such an idea is just an idea. At present, not only is there no trace of extraterrestrial wisdom, even in the famous Drake equation for estimating interstellar civilization, we only know the first two: the number of stars in the galaxy, and the number of stars in the galaxy. Planet ratio. So far, we know nothing about the third term, the proportion of terrestrial planets in the habitable zone (the so-called η-Earth), because we only know the Earth in the solar system. The last few terms of the Drake formula are related to life, and we have no way to talk about it.

What this article wants to say is that with current technology, we can find Earth 2.0 and measure η Earth within a few years. What's more exciting is that China's space technology will help humans find this answer.

Earth 2.0 and the accident of life?

The origin of life on earth, and then the generation of wisdom, seems logical. But brush with philosophical terms: existence is reasonable, but not necessarily inevitable. Today's scientific research has made us realize that the emergence of life on earth may only be the accumulation of some incidents.

Let's start with the orbit of the earth. The distance of the earth from the sun is not far or near, just inside what we call the star livable zone (Figure 1). If the earth is closer to the sun and the surface temperature is slightly higher, the greenhouse effect will be so strong that the water vapor in the atmosphere will gather more and more, and the temperature will continue to rise. Suppose the earth is a little farther from the sun, and the surface temperature will drop below zero. Water vapor condenses into ice, freezes the earth, and the sun's rays are reflected back into outer space. The earth will become like Mars, and the ice will not change throughout the year.

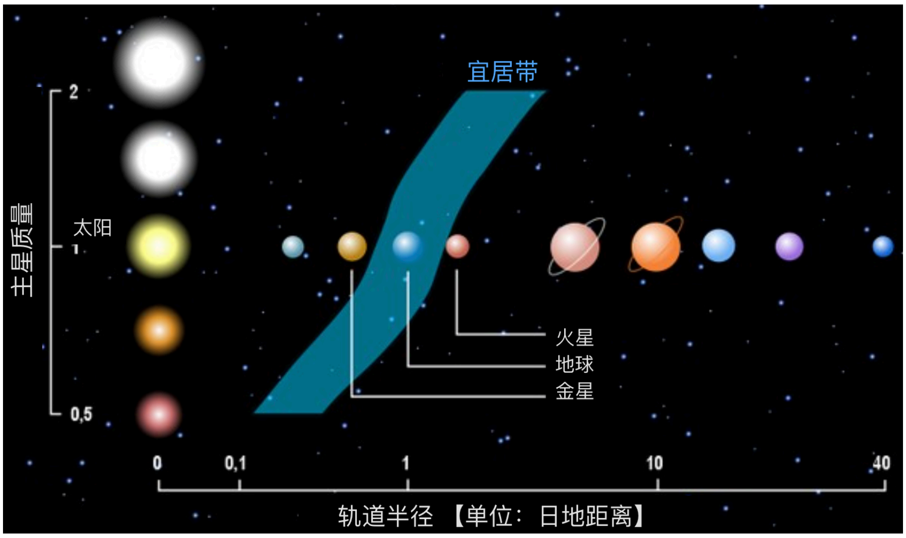

Figure 1: The Earth's orbit is in the habitable zone of a solar-like star (blue). Here, the temperature is suitable, and liquid water can exist on the planet surface. The habitable zone migrates with the size of the star: the smaller the star, the more the habitable zone depends on the host star. At present, due to technical limitations, many astronomical projects

only look for habitable planets around low-mass stars (such as NASA's TESS mission). However, these planets may be too hostile for the origin of life due to spin synchronization, stellar flares, etc. Life may prefer the habitable zone of solar-like stars. Picture source: [3]

Besides, the quality of the earth is not small or small, just right. Suppose the earth is a bit heavier and gravity is increased, and our chemical rocket is not enough to launch satellites. Unless atomic energy is available, aerospace will not come. Astronomy can only stay on the surface. Suppose the earth's mass is a bit smaller and gravity is reduced, but water molecules in the atmosphere are easily wiped away by the solar wind. As our atmosphere becomes thinner, the environment will become as harsh as Mars.

The atmosphere of the earth and the ocean are also perfectly adjusted. The concentration of carbon dioxide in the atmosphere is too high, and the global warming will be warmer than the deserts of the Arab Emirates; if the concentration is too low, the earth will turn into a frozen white planet; Composed of nitrogen and oxygen, sunlight cannot reach the ground surface, so there will be no photosynthesis. Oceans cover 70% of the Earth's surface. Life evolved successfully in the ocean before landing on land. But if the ocean is too big, without land, there will be no stove for cooking and cooking, and the evolution of human intelligence will be much delayed, of course, there will be no steam engine and integrated circuits. . .

Will these occasional events that create human wisdom reappear on exoplanets? Nobody knows. But if we can find a second earth, scientific verification will be possible.

Limited by current technology, it is impossible for us to find a planet exactly the same as Earth. So we stepped back and looked for the so-called Earth 2.0. These are planets that are similar in size to Earth, similar in orbit, and similar to the main star. Of all the exoplanets, their environment is most likely to breed life.

the Kepler Mission（2009-2013）

Even astronomical readers may know that finding exoplanets is not new. We now know more than 4,000 exoplanets. However, none of them looks like the earth!

This story should be told from 1995. This year, two Swiss (Mayor & Queloz) detected the first exoplanet with a 2-meter telescope in southern France, and the discovery was immediately confirmed by American Marcy & Butler. In 2019, the first two won the Nobel Prize in Physics, but Marcy was fired by UC Berkeley on charges of sexual harassment.

Over the past 20 years, ground-based telescopes have found nearly a thousand planets, most of which are also measured by the radial velocity method (taking Mayor & Queloz's old path), that is, observing stars swinging back and forth under the gravity of invisible planets. Most of the planets found in this way are as massive as Jupiter, far from the Earth 2.0 we are looking for.

Fortunately, this is not the only magic of human beings. Back in 1984, when we didn't know anything about extraterrestrial planets, William Borucki, a legendary man who was an NASA engineer at the time, had already propheticly planned another way. His idea is simple. Whenever Venus transits (Sun-Venus-Earth Trisomy), Venus blocks a very small part of the sun, and the sun becomes darker. A well-placed (and smart enough) alien can also discover our planet by observing the Earth's sun. Of course, the probability of a transit event is small. To find Earth 2.0, it is necessary to observe a large number of stars, and to stare for a long time (a few years) without blinking. What's more, our photometric instruments should be accurate enough: when the earth is in the sun, it only covers one ten thousandth of the solar disc (Figure 2).

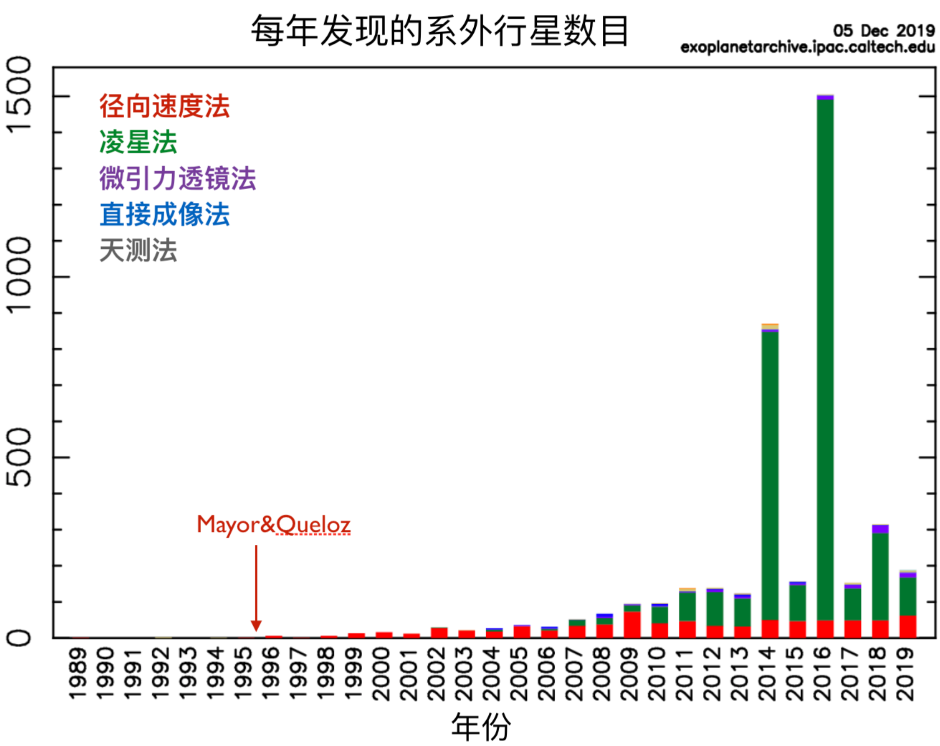

Figure 2: The number of exoplanets discovered and confirmed each year since the first record in 1995. The entry of Kepler satellite (2009) has led the Lingxing method (green) to dominate the discovery space for nearly a decade. The richness of the alien world is rapidly unfolding before our eyes. Picture source [6]

So although this method is very simple, NASA (NASA) does not buy it. Since Boroucki's first proposal in 1992, this project has been tripped up five times by NASA for reasons that the technology is not mature enough. Fortunately, William Borucki is not only a prophet, but also has more perseverance than mortals. He was discouraged, and developed a detector and detection technology on the ground. He overcame the technical difficulties one by one, and finally convinced NASA to successfully ascend to heaven in 2009-this is NASA's Kepler plan.

The Kepler satellite opened a large window for observing the universe. Within a few years, it found nearly 3,000 exoplanets alone (Figure 2), which not only increased the number of extraterrestrial planets known to mankind several times, but also Importantly, Kepler's planets have opened human eyes and subverted our understanding of the exoplanet world. Traditional radial velocity methods tell us that most of these are giant planets (similar to Jupiter and Saturn, but with some exceptions), and Kepler reveals a previously unknown but extremely common planetary population in the universe (Super Earth And Asian Neptune, see Figure 3). These small planets orbit close to about a third of the stars in the Milky Way. They are three times more common than giant planets and more exciting than the latter: their size is not far behind that of Earth.

The Kepler Project has achieved a glorious decade in the entire field of planetary science (and many have successfully obtained professorships). But in the glory, there is another unspeakable regret. Kepler's original intention was to find planets like Earth. But none of the thousands of planets it found looked like Earth!

Someone asked, how do you know if those planets look like or don't look like Earth?

Regardless of whether it is a giant planet detected by radial velocity technology or a sub-Neptune discovered by the Kepler mission, they can be called "generation planets" (earth, earth, wood, Uranus and Neptune of the solar system are examples). Their surface is shrouded in thick hydrogen, suggesting that they formed early in the life of the star. At this time, there was also a hydrogen disk around the star, which was a waste material for star-making projects. Even the kind called super-Earth, although they have a solid surface, they are now theoretically believed to be sub-Neptunes, but because they are too close to the host star, their innate hydrogen atmosphere is stripped by the star's strong X-rays. Leaving a bare nucleus. In contrast, Earth and its little companion planets should be called "second-generation planets." They may be caused by the debris fragments that did not know where they came from after the hydrogen disk disappeared.

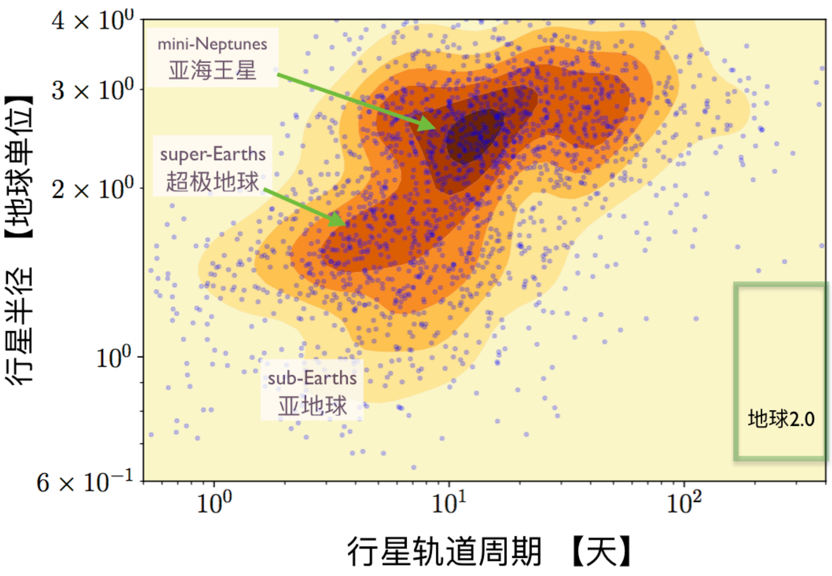

Figure 3: The distribution of small planets discovered by the Kepler mission in radius and orbital period. Most of these planets belong to the so-called "super-Earth" or "Sub-Neptune", they orbit the main star within the distance between the sun and the earth, and their size is 1 to 4 earth radii. It is now widely believed that they represent a generation of planets. Kepler did not find Earth 2.0 (green box), but found some terrestrial planets not in the habitable zone and approached the green habitable area. Figure source [9].

One generation of planets is unlikely to conceive life. Suppose you are unlucky and born on such a planet, you will slowly fall with the wind (thick hydrogen) to a soft collapsed ground-the greenhouse effect of hydrogen will keep the temperature of the planet at a few thousand degrees , Enough to melt steel; even those bare planets (super-Earth) are not much better. These super-earths are so close to the host star, and their rocky surface is not far from this temperature, even if it is not hot enough to turn into a slurry. Instead, as we have witnessed on Earth, the environment of second-generation planets is more friendly to life formation and evolution. Their underground and atmosphere may contain the chemical elements (carbon, oxygen, nitrogen, etc.) needed for life, and their atmosphere may be relatively thin, producing a proper greenhouse effect.

Unfortunately, Kepler not only failed to find Earth 2.0, it seemed that even the second-generation planets did not find a few. Could it be that something unexpected happened in the solar system that caused such a foreign body as Earth?

One possible explanation for Kepler's failure is that in the universe, the earth is really lonely. But now is not the time to give up searching. Kepler's failure has several other reasons, enough to keep us going.

First, stars are not 'constant'. The climate on the surface of stars is complex and changeable, and their brightness changes constantly. After Kepler went to heaven, he received an unpleasant gift: the flicker of the stars was much worse than we expected. In this noisy background, Kepler could not hear a weak signal of one ten thousandth.

Second, the quality of manufacturers is not enough. After 4 years of operation at Kepler, two reaction wheels failed continuously, and the entire $ 600 million spacecraft was scrapped due to the failure of these $ 200,000 gyroscopes, and it has since become a lone wild ghost wandering the solar system. .

However, of the tens of thousands of stars Kepler looks at, it is likely that Earth has begun to show signs. It's just that their sound is too low to be buried in the noise of the star and cannot be interpreted. Kepler's premature demise of his youth has made it a shortfall of success and missed the earth. Kepler's regret, can humans make up for it?

Earth2.0 and Chinese Space Plans

On December 3, 2019, a defense meeting was underway at the China Space Center. Shanghai Observatory and Nanjing Purple Mountain Observatory each proposed a space plan for finding Earth 2.0. The judges are listening to reports, asking questions frequently, and deciding whether they will win or lose.

The Shanghai Station project, referred to as ET (EarthTwo) for short, consists of seven medium-sized wide-angle telescopes (Figure 4). The satellite is aimed at Kepler and several nearby sky regions, monitoring more than 200,000 bright stars for 4 years to capture the weak signal when the planet transits. It is currently estimated that about one in every ten suns has Earth 2.0 (that is, η Earth ~ 10% as mentioned above). If right, ET can find more than a dozen earths in 4 years. In addition, ET can find nearly a thousand terrestrial planets outside the habitable zone and conduct the first "census" of these second-generation planets.

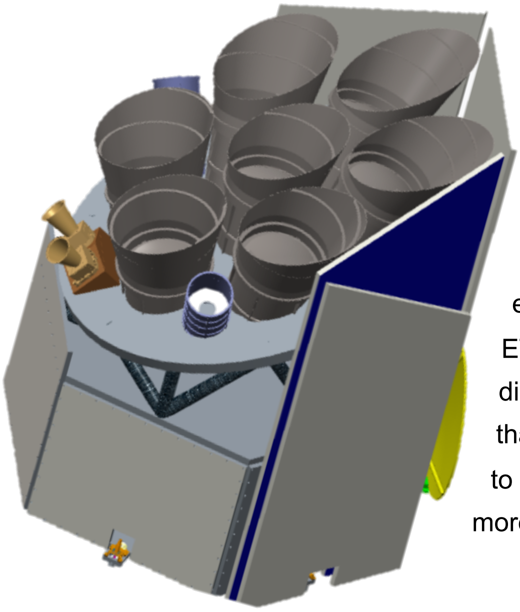

Figure 4: ET satellite program proposed by Shanghai Observatory. Seven wide-angle telescopes stared at Kepler's observed astronomical zone and its neighbors respectively. By carefully measuring the luminosity of more than 200,000 stars at each moment in four years, they captured the weak signals of the small planet transit. Even if only one in every ten suns has an earth, ET can find more than a dozen earths in 4 years. In addition, ET can find thousands of different kinds of exoplanets, including distant relatives of the Earth. Although ET is smaller and cheaper than the Kepler satellite, its scientific output is expected to be close to Kepler. Chinese astronomers also believe that the plan is even more successful than the PLATO spacecraft being built by ESA.

How can a satellite smaller than Kepler achieve Kepler's outstanding performance in four years? In addition to the technological advances of the past ten years, this can also be explained. Imagine you are chatting with someone in a noisy bar. Your voice is too low for the other party to hear. You have to say a few times before it works. The earth we are looking for may actually have traces in Kepler's vast data, and we only need to listen a few more times to catch them. What Kepler left was not regret, but a gold rush.

Zijinshantai's satellite plan is even more unique. This bold plan focused on developing another way to find planets, called ‘Sky Test’. Observe the delicate dance of stars on the sky under the influence of the planet's gravity. To detect the Earth, this technology needs to achieve unprecedented accuracy: micro-angular seconds — this is equivalent to recognizing two toothpicks that are emitted on the moon. But it is really worth calming down and working hard to solve the problem.

The process of finding Earth 2.0 has challenged human creativity to the greatest extent. The two plans of Shanghai and Zitai complement each other, sprinting from different directions with different rhythms. The proposition of whether the earth is lonely is likely to be proudly solved by Chinese space science.

Shangrila?

Finding Earth 2.0 is not counting on immigration there. These alien worlds are tens of light years away from us. However, human beings on the earth are building huge telescopes in space and on the ground, ready to patiently stare at these small planets (especially those planets that strike planets) and investigate from a long distance whether they breed life. The next play will be more exciting!

Finding Earth 2.0, the whole human is like a child who suddenly jumped from a closed ravine to a big city, and his vision suddenly widened and enriched a lot. "Vision determines achievement". Will some of the difficult problems around us be solved?

About the author: Yanqin Wu, Professor of Astronomy, University of Toronto. She studied undergraduate in the Department of Air and Space, University of Science and Technology of China, and received her Ph.D. in theoretical astrophysics from the California Institute of Technology. She also did post-doctoral research at the University of London and the University of Toronto. Currently the main research directions are planetary structure and formation, planetary disks and others. She is involved in the scientific design of the ET program.

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