Abstract

In a solar system far, far away... 103 light years to be exact, we find our desired exoplanet. As the name suggests, our TOI-560c is not the only exoplanet in its solar system. Although small, the system contains a second planet about twice the size, called TOI-560b. Both orbit a K-type star, TOI-560, outside the habitable zone of the solar system.

Planet Size

We first discovered the planet diameter to be 30550.62 metres with a transit depth of 0.01372 %. Now, when it comes to the radius calculation, we first took the Allesfitter multiplier of 2.395. That gave us a radius of 15 275.3 kilometres. Now with a formula of $R_{planet} = \sqrt{\frac{H}{100}q} \times R_{Star}$ with H being the light curve difference we took from Cheops light curve measurement graph, which was 99.862, meaning the difference added up to 0.137. From that we got the multiplier of 2.646, which gave us a radius of 16 752.7km, so about a 10% difference from the primary Allesfitter output.

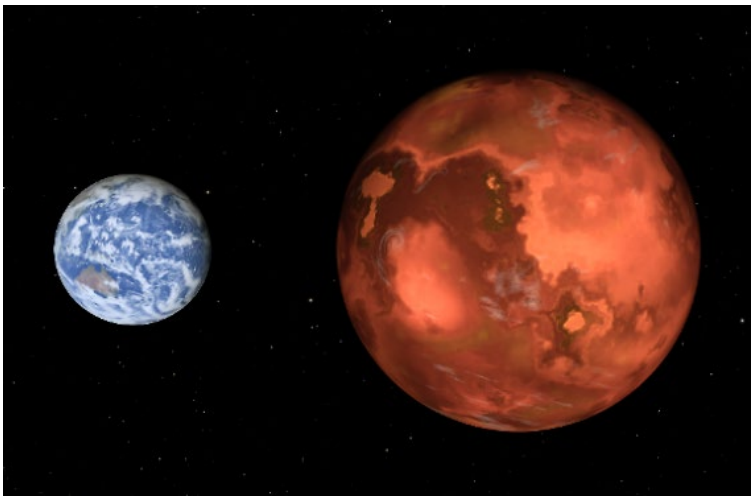

Figure 1: Earth and TOI-560c comparison

Orbit length

We know that TOI-560c has a year period of 18.87 Earth days, which makes its year much shorter than here on Earth.

In the solar system, both planets orbit very close to their star. So close in fact, that the highest orbit is much lower than the orbit of Mercury in our Solar system. Since we know the distance of TOI-560c from its star, we can calculate the orbit length to be 117,106,752.8km. And from the length, we can determine the orbital velocity as 720,958.63 m/s.

The orbit of both planets is similar in terms of inclination, which reaches only a 0.4 irregularity from 90°. Both planets B and C have a very similar orbit inclination, therefore we can say they arent traveling planets which would find their way into this solar system and stay there because of the gravitational pull, but that they were rather created at a very similar time.

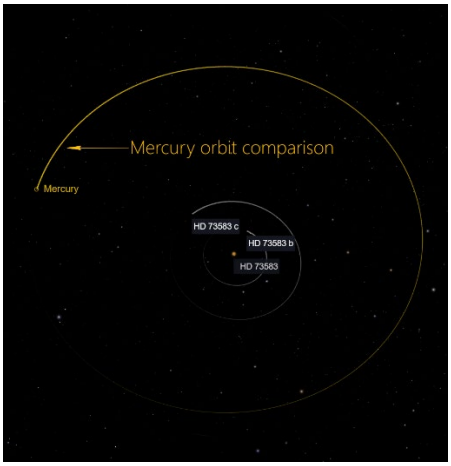

Figure 2: The layout of the TOI-560 system relative to Mercury's orbit

Solar system

TOI-560c is not the only planet in its solar system. A second planet orbits TOI-560. Both were discovered using the transition method. In addition, TOI-560b and TOI-560c have almost identical inclinations at almost 90 degrees from our point of view, further evidence that they were formed at a similar time in the past. But there are some differences. Mainly in size and orbit. TOI-560b has an orbital period of 6.39, half that of TOI-560c, according to exoplanet.eu. TOI-560b is measured to be 0.249 the size of Jupiter, while TOI-560c is only 0.23. There are also some differences in the colours. We have made hypotheses about the chemical composition of TOI-560c, which lead directly to the colour scheme, all of which are mentioned in the "Atmospheric hypotheses" tab. Both planets are also well outside the habitable zone.

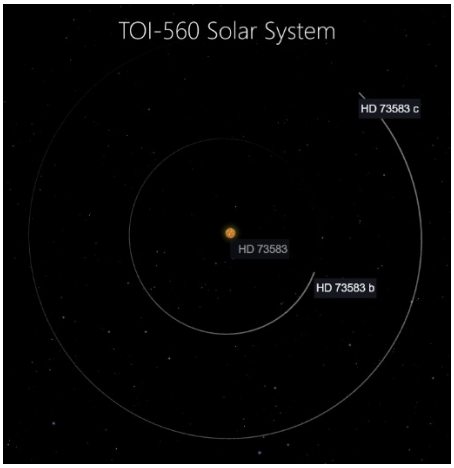

Figure 3: TOI-560 solar system

Planet Age

According to http://exoplanet.eu/ our exoplanet is rather young at 750,000,000 years. At this age Earth was still in the Precambrian era, meaning only organic clusters were forming into prokaryotic cells, from which eukaryotic cells evolved. Although during the Precambrian era the surface temperatures reached only a few degrees above 0 °C.
But what about TOI-560c? The surface temperature was measured at around 225 ℃, therefore not a very habitable environment in comparison to Earth. Although we could speculate about thermophilic cells with extra thick cell walls that have adapted to these temperatures. For example near Kavachi volcano on Earth, the water temperatures reach around 68 °C and there

still are shark species living there. But for TOI-560c we limited our suggestions to only small organisms, depending on the atmospheric contents and pressure.

Atmospheric hypotheses

The difference between a mini-neptune and a super-earth definition is at a thin border here. We made three hypotheses about how the composition of TOI-560c could look depending on the elements it is composed of and also depending on the thickness of each layer.

Hypothesis 1:

In this hypothesis, we thought of the planets core as hydrogen that acts as a solid material. The core would have a diameter of 8,000 kilometers. Could there be water? Yes. At the exact pressure of 246 MPa, which would allow for water to be in a liquid state. Now, when we would think of the upper atmosphere as identical to Neptune, that would be a viable option, but the density of TOI-560c would exceed our measured density. Therefore, we thought about a new element or compound that would be contained within the atmosphere. This chemical would be slightly denser than the hydrogen, helium, methane and ammonia that together make up Neptune's atmosphere.

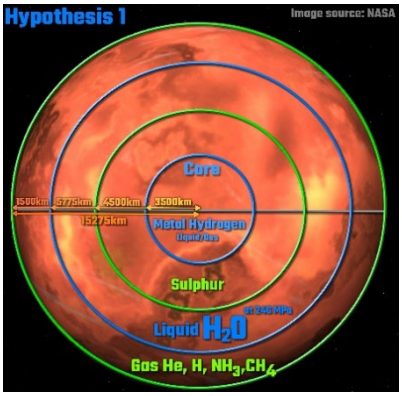

Figure 4: Hypothesis 1 visualization

Hypothesis 2:

In this hypothesis we thought of the core as of being made out of aluminum. The atmosphere would be consisting of helium and hydrogen. With a pressure of 26 MPa, we could see water there with an advantage over hypothesis 1 in this case, because the pressure would be significantly lower, therefore creating much more suitable conditions for any potential probe to be sent there. We also assumed the diameter of the radius as 5,200 km to match up with all the compounds and the density. In this case, the atmosphere could be thicker than in hypothesis 1, as the core does not take up so much space.

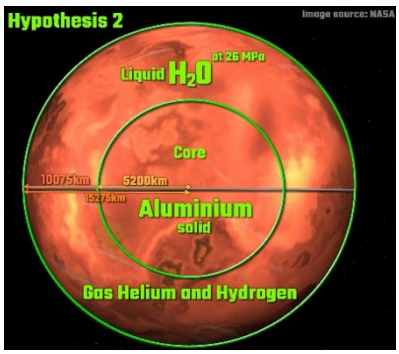

Figure 5: Hypothesis 2 visualization

Hypothesis 3:

In this last case, the atmosphere would consist of helium and hydrogen. The main difference is in the core, which would contain lithium and a phosphorus coating. This would be a great source for lithium batteries. However, we wanted to lower the pressure, so we thought about leaving water out of this hypothesis. Without any water, the pressure could be at 13,6 kPa, the lowest of all the options. After many calculations, we estimated the diameter of the core at 6202.7 km.

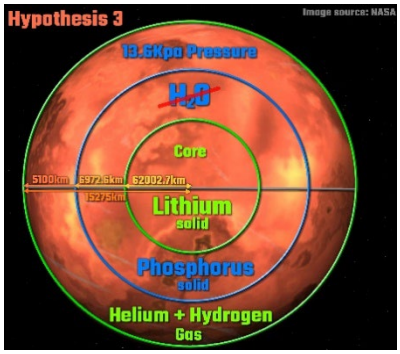

Figure 6: Hypothesis 3 visualization

Planet Color

According to www.exoplanets.nasa.gov and www.exoplanet.eu TOI-560c is portrayed as orange. However, with TOI-560 being a K4V type star and TOI-560c having a thin atmosphere, we rather think that the color may be caused from the color of the star and the light it emits. Because the TOI-560 has a vibrant orange color and therefore this color would be reflected on TOI-560c.

When will the next transit be?

We found out, that the last transit was on the 5th of June 2023 and it began at 1:28 and lasted up until 5:04. From that and allesfitter data we counted, that the next one will occur on the 23rd of June from 22:35 until 24th of June at 2:11. And on the 24th of June TOI-560C will be in the hypothetical middle of TOI-560, or at least it will look like that from our point of view.

Planet Comparison

	TOI-560c	Earth	Neptune	KELT-3b
Mass	5.793034^{25} kg	5.972^{24} kg	1.024^{26} kg	2.691364 × 10^{27} kg
Radius	15275.3 km	6,371 km	24,622 km	93,191 km
Density	2.94 g/cm^3	5.51 g/cm^3	1.64 g/cm^3	-
Gravity	13.77653981 m/s^2	9.807 m/s^2	11.15 m/s^2	3.296 m/s^2
Temperature	230 °C	15 °C	– 200 °C	-
Orbital period	18.87 days	365 days	60,265 days	2.7 days
Star distance [au]	0.124 au	1 au	30 au	0.041 au

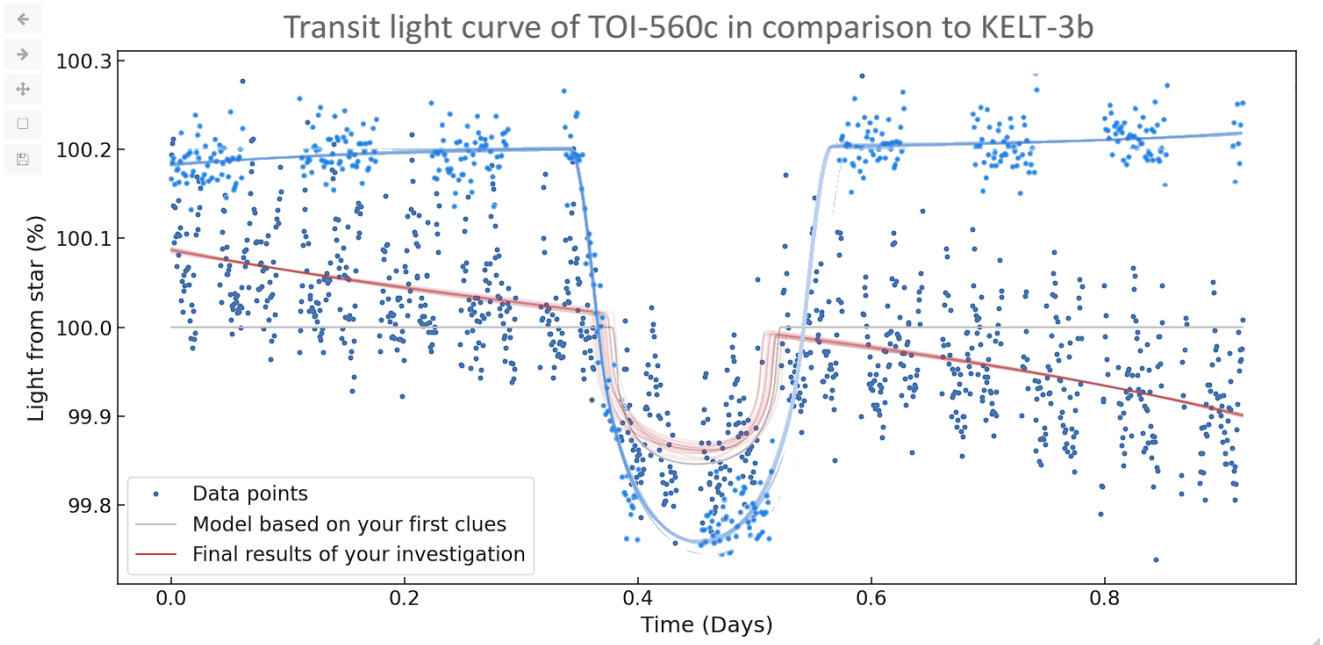

Figure 7: Transit light curve

Star Comparison

	TOI-560	Sun
Age	**750 million**	**+3,853 million**
Mass	**1.4515×10^{30}**	**+27 %**
Radius	**452,200km**	**+35 %**
Star type	**K4V**	**G2V**
Temperature	**4,240 °C**	**+30 %**
Magnitude	**9.67**	**−4.84 (therefore more luminosity)**

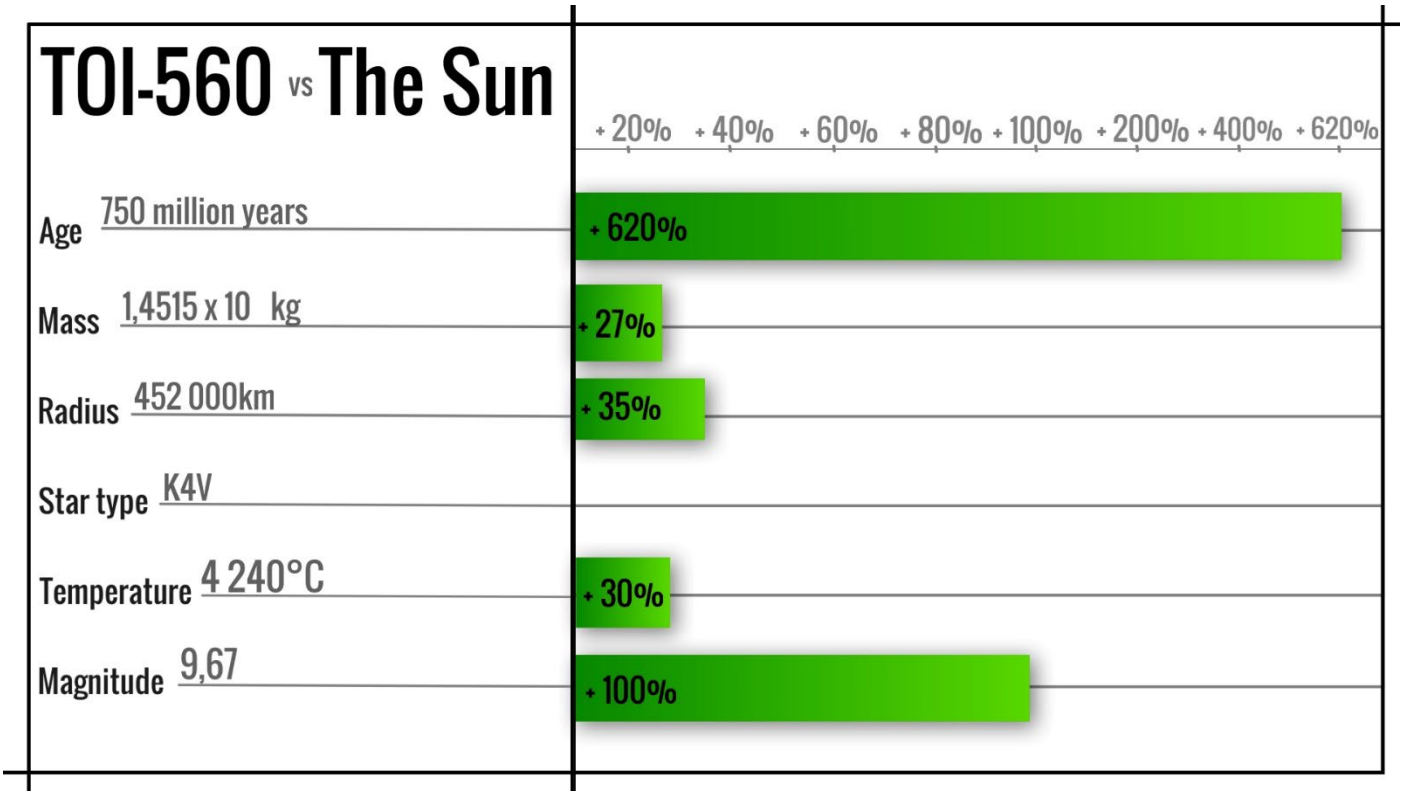

Figure 8: The TOI-560 vs the Sun

Allesfitter comparisons

The biggest difference we measured was in radius. We first tried to use the allesfitter multiplier of 2.395. But when we took the transit depth formula, we got 2.646 multiplier and therefore 16,752 km radius instead of 15,275 km.

The next difference was in distance, where we calculated it as 0.1245 au, but Allesfitter came up with only 0.124 au.

Conclusion

Finally, we think the most likely scenario for TOI-560c is that the atmosphere is quite thin, but there is enough gravity to hold it in place. High pressures also seem out of place, so we think that the absence of water is correct, as is the existence of life on the planet's surface.

Sources

About – Hack an exoplanet, [no date]. Online. Available from: https://hackanexoplanet.esa.int/about/

Exoplanet Catalog | Discovery – Exoplanet Exploration: Planets Beyond our Solar System, [no date]. *Exoplanet Exploration: Planets Beyond Our Solar System*. Online. Available from: https://exoplanets.nasa.gov/discovery/exoplanet-catalog/

MUFTI, Mohammed El, 2021. TOI 560 : Two Transiting Planets Orbiting a K Dwarf Validated with iSHELL, PFS and HIRES RVs. *arXiv.org*. Online. 26 December 2021. Available from: https://arxiv.org/abs/2112.13448

The Extrasolar Planets Encyclopaedia — Diagrams. (n.d.). http://exoplanet.eu/diagrams/

The Extrasolar Planet Encyclopaedia — HD 73583 c. (n.d.). http://exoplanet.eu/catalog/hd_73583_c/

TOI-560 c, [no date]. Online. Available from: http://www.exoplanetkyoto.org/exohtml/TOI-560_c.html

Planeterra Team from Gymnazium Brno-Bystrc / GYBY

Made by: Karel, Simon & Tomas