Link: Activity map **How long would it take to reach your chosen exoplanets?**

With the ongoing discovery of exoplanets, it is only a matter of time before we identify one in close proximity that exhibits signs of life. At that juncture, both manned and unmanned space missions will be essential for the exploration of extraterrestrial life.

To date, the fastest unmanned spacecraft is New Horizons, which travels at 58,540 km/h, while the fastest manned spacecraft is Apollo 10, reaching speeds of 39,900 km/h. Additionally, the fastest spacecraft ever recorded is the Parker Solar Probe, which utilizes gravity assists from Venus to navigate around the Sun, achieving astonishing speeds near the Sun's corona, surpassing 692,000 km/h in 2025, thus setting a new record as the fastest human-made object by a significant margin. Moreover, engineers are optimistic about the feasibility of constructing a spacecraft capable of traveling at speeds greater than 1000 km/s.

Recall:

- *How do you find the velocity?*

To find velocity, you take an object's displacement (the change in position in a specific direction) and divide it by the time interval taken to move, using the formula $v = \Delta s/\Delta t$, where 'v' represents velocity, 'Δs' denotes displacement, and 'Δt' signifies the change in time. Keep in mind that velocity encompasses both speed and direction.

- *How can you calculate the time interval if you know the velocity?*

To determine the time interval from velocity, you must know the distance (displacement) the object has traveled. The fundamental formula is

Time = Distance / Velocity.

1. Measures distances in the Solar system: Astronomical Unit (AU)
https://scholar.exoplanet.eu/spip.php?article635

Let us explore travel within our Solar system. Due to its vastness, astronomers find it simpler to use *astronomical units (AU)* - the average distance from the Earth to the Sun. This unit, which measures distances in our Solar System, is precisely defined as 149,597,870,691 meters, or approximately 150 million kilometers, serving as the standard 'yardstick' for nearby planets and celestial bodies.

Calculation 1: How can you determine the time it takes for the spacecraft *New Horizons*, traveling at a speed of 58,540 km/h, to journey from Earth to the Neptune, given that the average distance from the Earth to Neptune is 30 AU?

$$t1 = 30\ [AU] * 149{,}597{,}870.691\ [km/AU] / 58{,}540\ [km/h] \approx 76{,}664.4366\ [h].$$

The duration is significant when measured in hours, so it is preferable to express it in years. Astronomers use the Julian year, which is a precise duration of exactly 365.25 days, utilized for measuring time intervals rather than calendar dates, and it equates to 8766 hours (365.25

days * 24 hours/day). This standard unit guarantees uniformity in calculations, in contrast to calendar years that fluctuate, with the Julian year characterized as 365 days plus six hours.

$$t1 = 76{,}664.4366[h] / 8{,}766\ [h/Jy] \approx 8.7457\ [Jy].$$

Exercise 1. Let us explore the distance in AU in the Solar system (Fig. 1)

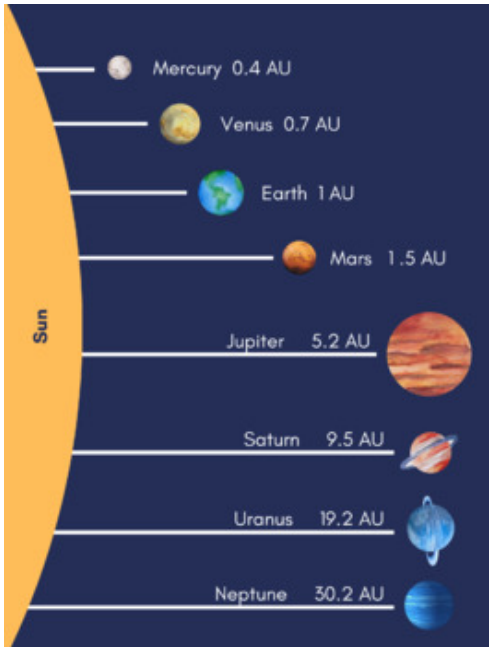

Fig. 1. Infographic of the distances (in Astronomical Units) for each planet to the Sun in our Solar system (credit: https://www.teacherspayteachers.com/Product/Planetary-Distances-AU-8762025).

Note. The instructor might request the calculation of the duration required to arrive at a specific planet within our Solar system from its distance in AU.

2. Measures distances in the Universe: light-year (ly)

A *light-year* measures vast cosmic distances, representing the distance light travels in one Earth year at a speed of 300,000 kilometers per second. A light-year is 9,460,730,472,580.8 km approximately 9.46 trillion kilometers or 63,241 AU, because space is too immense for kilometers. Astronomers use this unit to gauge distances to stars, galaxies, and beyond, essentially looking back in time as the light we see left its source long ago.

Calculation 2: Let us determine the time it takes for the spacecraft *Apollo 10*, traveling at a speed of 39,897 km/h, to journey from Earth to the closest star to Earth, after our own Sun, *Proxima Centauri*, part of the *Alpha Centauri* triple-star system, located about 4.24 light-years away?

$$t2 = 4.24\ [ly] * 9{,}460{,}730{,}472{,}580.8\ [km/ly] / 39{,}897\ [km/h]$$
$$t2 = 1{,}005{,}426{,}403.0815\ [h]$$

change the unit of t2

$$t2 \approx 1{,}005{,}426{,}403.0815 \text{ [h]} / 8{,}766 \text{ [h/Jy]} \approx 114{,}696.1445 \text{ [Jy]}.$$

Exercise 2. Let us explore the distance in light-years (light-hour and light-minutes) in the Solar system (Fig. 2)

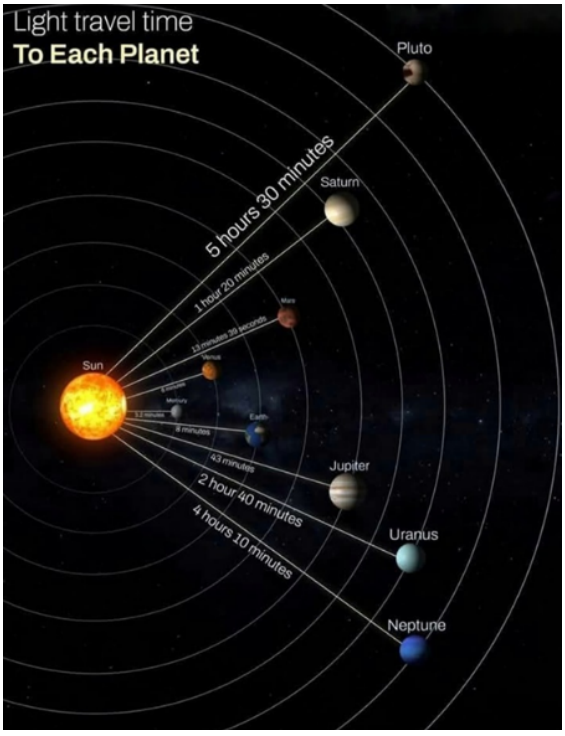

Fig. 2. Light travel time to each planet (Credit: https://www.youtube.com/shorts/W2Eq_q8HJQ8)

Note. The instructor might request the calculation of the distances of a specific planet within our Solar system in light-years [ly], light-hours [lh], light-minutes [lm], light-secundes [ls]. The conversion is:

$$1 \text{ ly} = 8{,}766 \text{ lh} = 525{,}960 \text{ lm} = 31{,}557{,}600 \text{ ls}.$$

Example: Earth-Neptune distance is 30 AU ≈ 30[AU]/63,241 [AU/ly] ≈ 0.00047438 [ly] * 8,766 [lh/ly] ≈ 4.1584 [lh] ≈ 4 [lh] + 0.1584[lh]*60 [lm/lh] ≈ 4 [lh] 10 [lm].

This means that the light takes 4 hours and 10 minutes to travel from Neptune to Earth.

3. Measures distances in the Universe: parsec (pc)

Professional astronomers use *parsec*, which is the unit for expressing distances to stars and galaxies. It represents the distance at which the radius of Earth's orbit subtends an angle of one second of arc. One parsec equals 3.26 light-years, which is approximatley to 3.09×10^{13} km.

Calculation 3. Let us determine the time it takes for the spacecraft *Parker Solar Probe*, traveling at a speed of 692,000 km/h, to journey from Earth to *Proxima Centauri* located about 1.30 parsec away?

$$t3 = 1.30\ [pc] * 3.09\times10^{13}\ [km/pc] / 692{,}000\ [km/h] \approx 5.8\times10^{7}\ [h]$$

Change the units of t3

$$t3 = 5.8\times10^{7}\ [h] / 8{,}766\ [h/Jy] \approx 6{,}622\ [Jy].$$

Exercise 3: Let us explore the distance in parsec in the Univers.

- *Proxima Centauri*, the nearest known star to Earth other than the Sun, is about 1.3 parsecs (4.24 ly) away.
- The distance to the open cluster *Pleiades* is 130±10 pc (420±30 ly) from us.
- The centre of the *Milky Way* is more than 8 kiloparsecs (8,000 pc = 26,000 ly) from the Earth and the Milky Way is roughly 34 kiloparsecs (110,000 ly) across.
- The *Andromeda Galaxy* (M31) is about 780 kpc = 0.78 Mpc (megaparsec) or 2.5 million ly away from the Earth.
- The *Virgo Cluster*, the nearest large galaxy cluster is about 16.5 Mpc (54 million ly) from the Earth.
- The galaxy filament *Hercules – Corona Borealis Great Wall*, which is the largest known structure in the Universe, is about 3 Gpc (gigaparsec) or 9.8 billion ly across.

Note. The instructor might request the calculation of the duration required to arrive at a specific star in our Milky Way galaxy in pc.

4. Assessing the time duration to reach a selected exoplanet.

How many years would it take to travel to your selected exoplanet from the exoplanet.eu database at these velocities?

Calculation 4: Choose an exoplanet https://scholar.exoplanet.eu/spip.php?rubrique24&lang=en from the database https://scholar.exoplanet.eu/spip.php?rubrique2&lang=en, and locate the distance in parsecs (pc) under Star (Basic Information). Now that you have the distance, and the velocities are provided above, you can calculate the time interval using the fundamental formula:

$$\text{Time} = \text{Distance} / \text{Velocity}$$

Note: The velocity is provided in kilometers per second (km/s), while the distance is in parsecs [pc], and you must express the time in years [Jy].

Exercise 4. I choose from the database: *Proxima Centauri b* exoplanet. The given distance is 1.295 pc. And I will use the velocity proposed by engineers, namely 1000 km/s.

Then

$$t4 = 1.295\ [pc] * 3.09\times10^{13}\ [km/pc]/\ 1{,}000\ [km/s] = 4.00155\times10^{10}\ [s]$$

change the units of t4

$$t4=4.00155\times10^{10}\ [s]/\ (3{,}600*8{,}766)\ [s/Jy] \approx 1{,}268\ [Jy].$$