
Asteroids

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Review scientific paper

Željko Andreić¹;

¹University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering,
Pierottijeva 6, 10000 Zagreb, Croatia, full professor



Abstract

Asteroids are the largest minor bodies in the Solar System. Nowadays they are in the research focus due to several facts about them: first, a subclass of asteroids can collide with Earth, and consequences of such a collision are dramatic. Second, they are now seen as source of materials that are becoming scarce on Earth, and they will be needed in future space constructions anyway. Third, they are holding clues about the origin and evolution of the Solar System. In this article, a short overview of current knowledge about asteroids is presented. Last, but not least, as several Croatian scientists were recently honored by naming an asteroid after them, a short overview of the naming process is given.

Keywords

Solar System, asteroids, mining the asteroids

1. Introduction

Even today, some textbooks describe the Solar System as a quiet, highly ordered structure. The Sun is in the center and planets revolve around it on neat elliptical orbits that are assumed to be the same since the time of creation of the Solar System. The space in between (the interplanetary space) is mostly empty, permeated by a very rarefied gas called solar wind that is peppered with a few grains of dust. Asteroids may be revealed as smaller bodies contained in the so-called asteroidal belt between Mars and Jupiter. And, beyond the last planet, Pluto, there is just cold, empty, interstellar space.

The intense research of the Solar System in the last several decades draws a much more complicated picture. The current theory of the origin of the Solar System is that the Sun, together with the planets, was created from an interstellar cloud of gas and dust that went gravitationally unstable due to some external disturbance, most probably a supernova explosion, that initiated the gravitational collapse of the cloud. The originating cloud in question is usually quite large, containing enough material to create many stars. During the initial gravitational compression, such a cloud collapses into several protostellar discs (that evolve into young stars, each with, or without planets). As a final result, a so-called open star cluster containing several to several hundred newly born stars is created.

The details of star formation seem to be well understood. However, the details of how the planets are created at the same time, are still being researched and widely debated. Most scientists agree on a general outline of the process, but it is so complicated that the details are yet to be determined. Current theoretical research, observations and numerical experiments do not exclude the possibility that several mechanisms may be involved, depending on the exact conditions of the collapse (size, shape, chemical composition, density and rotation of the collapsing cloud, dust/gas ratio, external influences, etc.). Modern astronomical instrumentation allows us to observe such processes in nearby gas clouds directly, so our knowledge about planetary creation increases from day to day.

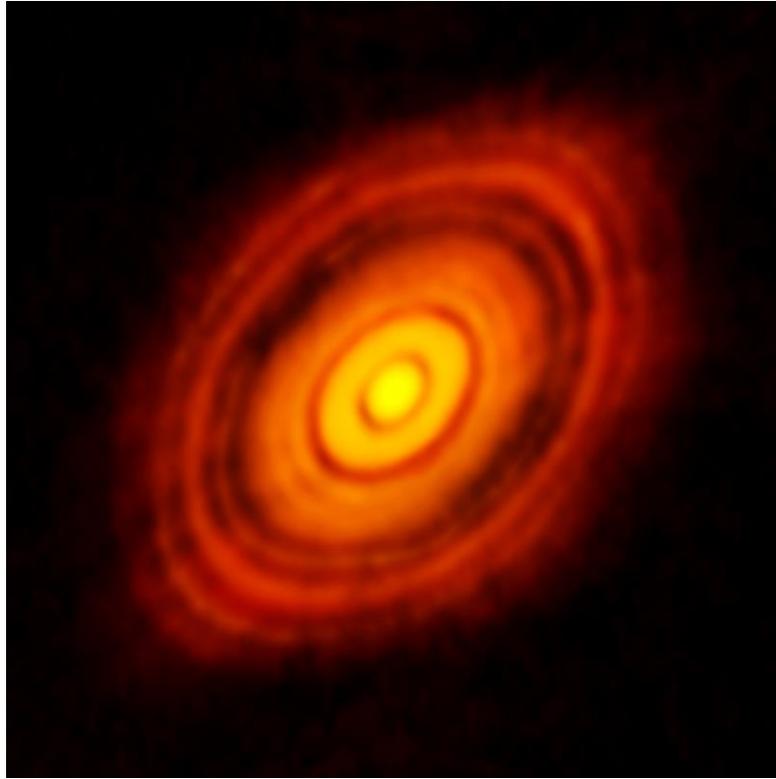


Figure 1: The protoplanetary disk (a young planetary system in forming) around the young star HL Tauri as imaged by Atacama Large Millimeter/submillimeter Array (ALMA). These new observations reveal substructures within the disc that have never been seen before and even show the possible positions of planets forming in the dark patches within the system. Image source: ALMA (ESO/NAOJ/NRAO)

The prevailing theory concerning the creation of planets starts by an agglomeration of dust particles into grains, grains into larger grains, etc. until big enough bodies are created that their gravity takes over the process, and carries it up to the bodies of planetary size. Large bodies are also capable of bonding the surrounding gas to them thus creating atmospheres around the solid cores. An atmosphere can also be created by outgassing from the hot planetary body itself during its gravitational compression and differentiation. Which of these two mechanisms is prevailing in producing the final atmosphere depends on many factors and is still an open question. The agglomeration of small particles occurs when two of them collide and stick to each other. However, at a certain size, the relative speed and the energy of collision becomes large enough to shatter both colliding bodies. How bigger bodies grow regardless of that, is still uncertain and highly debated. It seems that pure luck (or probability) plays the main role. Namely, if two large bodies (say meter to mega-meter in size) are similar in size, the collision is mostly destructive, leaving a lot of smaller debris behind. On the other hand, if one body is much smaller, there is a chance that the most of its mass will be added to the larger body, even if some debris is ejected beyond the gravitational influence of the larger body.

It is accepted that this process is quite rapid, because the strong solar wind and radiation pressure of the young star clears the cloud in about 100 000 years, first blowing the gas and then also the dust out of the newly created system, thus effectively stopping the creation process. There are a lot of smaller bodies left, so the planets can still create some material, but the resulting increase in the mass of the largest bodies is insignificant. With time, gravitational perturbations remove most of these bodies, either by collisions with newly formed planets, or by ejecting them out of the system into interstellar space. An example of a protoplanetary disc recorded by modern instrumentation around the young star HL Tauri is shown in Fig. 1.

It is also assumed that moons of planets are created at the same time by basically the same processes, but in the creation cloud around the newly formed planets. Some moons can be captured bodies that were created somewhere else in the system.

After that, the newly created planetary system evolves gravitationally, resulting in a complicated pattern of orbital changes of planets, which results in a set of orbits that are stable over large periods of time (10^9 years or more). In this process some planets may be ejected from the system, be thrown onto the central star or be destroyed by collision with another planet. It is possible that some planetary systems are eventually totally destroyed.

Returning back to our Solar System, it seems that there was a period of migration (changes in size and shape of planetary orbits) of outer gas giants that finally created the Solar System as we know it today. During that process, a lot of smaller bodies that we call asteroids ended trapped in stable orbits between Mars and Jupiter in a space we now call the asteroid belt, or the main asteroid belt, as there are some asteroids in other places in the Solar System too. The wandering of the gas giants may be the cause for a segregated asteroid belt so that today the inner portion is more rocky/iron and the outer belt is more icy (and chondritic).

Last, but not least, the numerical data presented in the article should be taken with a grain of salt, as they are changing rapidly due to research and theory both advancing rapidly. They represent the current status of our knowledge and are quite welcome for understanding the general picture, but they can not be taken for their face value.

2. The current view of the Solar System



Figure 2: One year in the Solar System. Left: inner part up to Jupiter. Right: all planets. EMB stands for Earth-Moon barycenter. In one year Mercury makes about 4.1 revolutions around the Sun, and Venus 1.6. Outer planets move increasingly slowly, as can be seen from orbital arcs covered in one year time.

In the modern nomenclature of the Solar System, we discern the Sun, the planets, and all other smaller objects. The Sun is the central star of our Solar System, a G2 dwarf roughly in the middle of its life-span. The planets are recently more strictly defined by the IAU (International Astronomical Union) as: "a planet is as a celestial body that is in orbit around the Sun, has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and has cleared the neighbourhood around its orbit" (IAU 2009), thus leaving only 8 planets on the list (Mercury to Neptune) and moving Pluto into the newly defined category of dwarf planets (A dwarf planet is in the same resolution defined as: "a body in orbit around the Sun, has sufficient mass for its self-gravity to

overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, has not cleared the neighbourhood around its orbit, and is not a satellite"). The creation of this new category was necessary after a number of large planetary-like bodies were recently discovered beyond the orbit of Neptune, a process that is far from being finished. It is expected that thousands of such objects do exist there and up to now, several hundreds have been discovered (KBO list 2015). All newly discovered large objects beyond the orbit of Neptune (collectively called trans-neptunian objects or TNOs) fall into this category, including Pluto, but also the largest asteroid, Ceres. Ceres is the only asteroid that was moved into the dwarf planets category, and is also the only dwarf planet inside the Neptune orbit. Most TNO's discovered up to now are located in the Kuiper belt, an area of space extending from the orbit of Neptune (about 30 AU) to approximately 100 AU, thus the name KBO or Kuiper Belt Objects. It is supposed that several thousand large bodies occupy the Kupier belt, with a total mass of about 30 Earth masses. The objects in the Kuiper belt are a subdivision of the TNO's and are the easiest TNO's to discover, as they are closest to the Sun and thus the brightest ones.

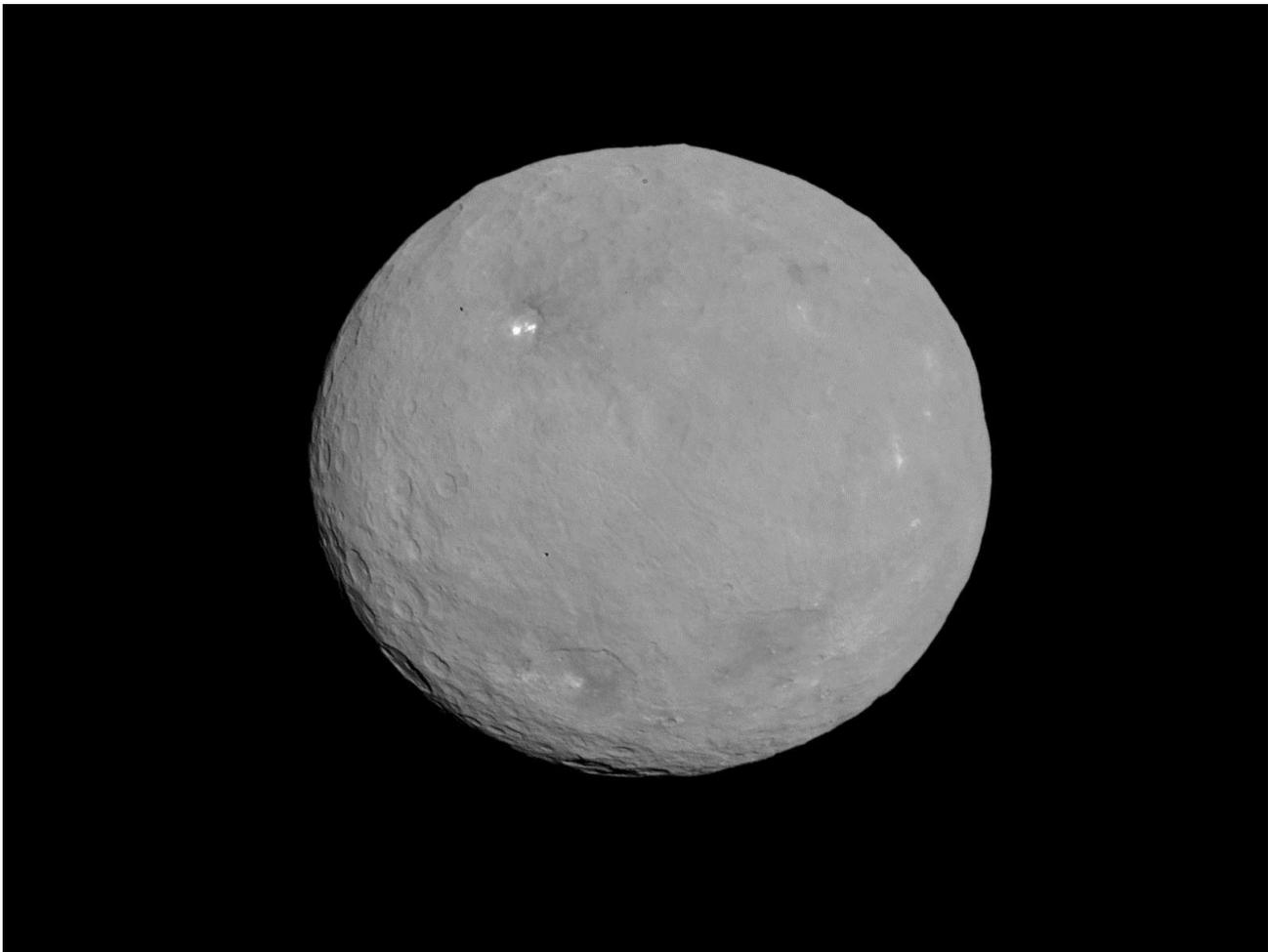


Figure 3: Ceres, up to recently the largest asteroid, now the only dwarf planet in the asteroid belt. (Image: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA, Dawn mission).

The size of the Solar System and orbital speed of planets is illustrated in Fig. 2, and an image of the dwarf planet Ceres is given in Fig. 3. Note that its shape is obviously not fully spherical indicating that it is at the lower limit of size required for a hydrostatic equilibrium to take place. The similar is true for the dwarf planets in the Kuiper belt, Pluto and its moon Charon (see Fig. 4) being the only pair visited by a space probe up to day.

All other objects in the Solar System are gathered into the small Solar System body (SSSB) group, which is defined as "all other objects, except satellites, orbiting the Sun" (IAU 2006). This group includes comets, asteroids, small TNOs and meteoroids right down to the size of interplanetary dust.



Figure 4: Pluto (and its moon Charon), the first dwarf planet discovered in the Kuiper belt, and until recently considered the 9th planet of the Solar System. (Image: NASA, New Horizons mission).

Also, the outer limit of the Solar System is now thought to be at the edge of (approximately) spherical volume of space in which the gravitational attraction of the Sun is dominating over that of the galaxy (or the nearest stars, if you wish). This is much larger than the previously set limit of 100 or so AU (AU = astronomical unit or the average distance of the Earth to the Sun) and is approximately 1 light-year from the Sun (about 25 000 AU). Apart from KBOs, this space is sparsely populated by bodies of various sizes, probably down to the dust particles, but with much lower spatial

density than in the inner solar system. Altogether, it is expected that this outer space is populated with trillions of objects with a total mass of about 5 Earth masses (Wiki 2015a).

3. The discovery and naming of the first asteroids

For a long time, it was supposed that a planet between Mars and Jupiter should exist, and when Ceres was discovered on January 1st, 1801, it seemed that these expectations were justified. Soon after, it was realized that something did not fit well. First, Ceres was so small that no planetary disc was seen by instruments of that time. Also, a year later (in 1802) the second asteroid, Pallas, was found, followed by Juno (1804) and Vesta (1807). The progress was slow, as at that time only visual observations were possible, and search for a new planet/asteroid consisted of tedious looking through the eyepiece and comparing the position of stars seen with the positions drawn previously on a star map. Very often, no star map was available, so in the first step one would draw their own map, then return to the same place on the sky after some time to see if something had changed in the meantime. This was very tedious and prone to errors. It is thus no wonder that the first asteroids were considered proper planets and they were all named in the same style as the known planets (Greek or Roman deities) and even the special symbols (like the ones for the already known planets) were created for use in almanacs and tables. Especially as the next asteroid was not found until 1845, after which the rate of discovery slowly increased.

Soon it became impossible to continue in that way. In the late 19th century, the number of known asteroids was already more than 450. The names were still being given, but the list of names was expanded to include important persons from the past, or even living, land or geography-related terms, even pet names in some cases, etc. Also, the asteroids were numbered in the order of their discovery. The naming right was in the hands of the discoverer. One of them eventually used his naming right to name the newly discovered body after his benefactor, for obvious reasons, and "selling" the names was the next obvious step.

As somewhere around the beginning of 20th century photography was introduced into astronomy, the asteroid searches soon moved from visual to photographic techniques and the rate of new discoveries increased rapidly. But still, the plates had to be examined manually in a procedure that was also tedious and time consuming. When the next instrumental revolution occurred near the end of the last century when CCD detectors and electronic computers entered the scene, the discovery rates exploded. Somewhere at that time, humanity became aware of the dangers that NEO objects can present to it, and dedicated NEO search programs were initiated. Just for illustration, around 1980 about 20 000 asteroids were catalogued. Today, we are approaching the half-a-million mark, and we believe that about 95% of all NEO's 1 km or more in size are known.

4. Orbital characteristics of asteroids

About 430 000 asteroids are known today, and the number is rapidly growing on a daily basis. Most are orbiting the Sun in the space between Mars and Jupiter, in the so-called asteroid belt that lies approximately between 2 and 4 AU from the Sun (see Fig. 5). The asteroid belt has a very complex structure, produced by long term gravitational influences of the nearby planets, of which Jupiter, due to its large mass and relative proximity, is the most important. Such influences often result in resonances. In a resonance orbital or rotational period of one body there is a simple numerical relationship with the same period of the perturbing body (Murray and Dermott 1999). The most known resonances are period resonance, where orbital periods of two bodies are in fixed ratio towards each other. For example, Jupiter Trojans are in a 1:1 period resonance with Jupiter. Some resonances stabilize the orbits, while others disturb them rapidly.

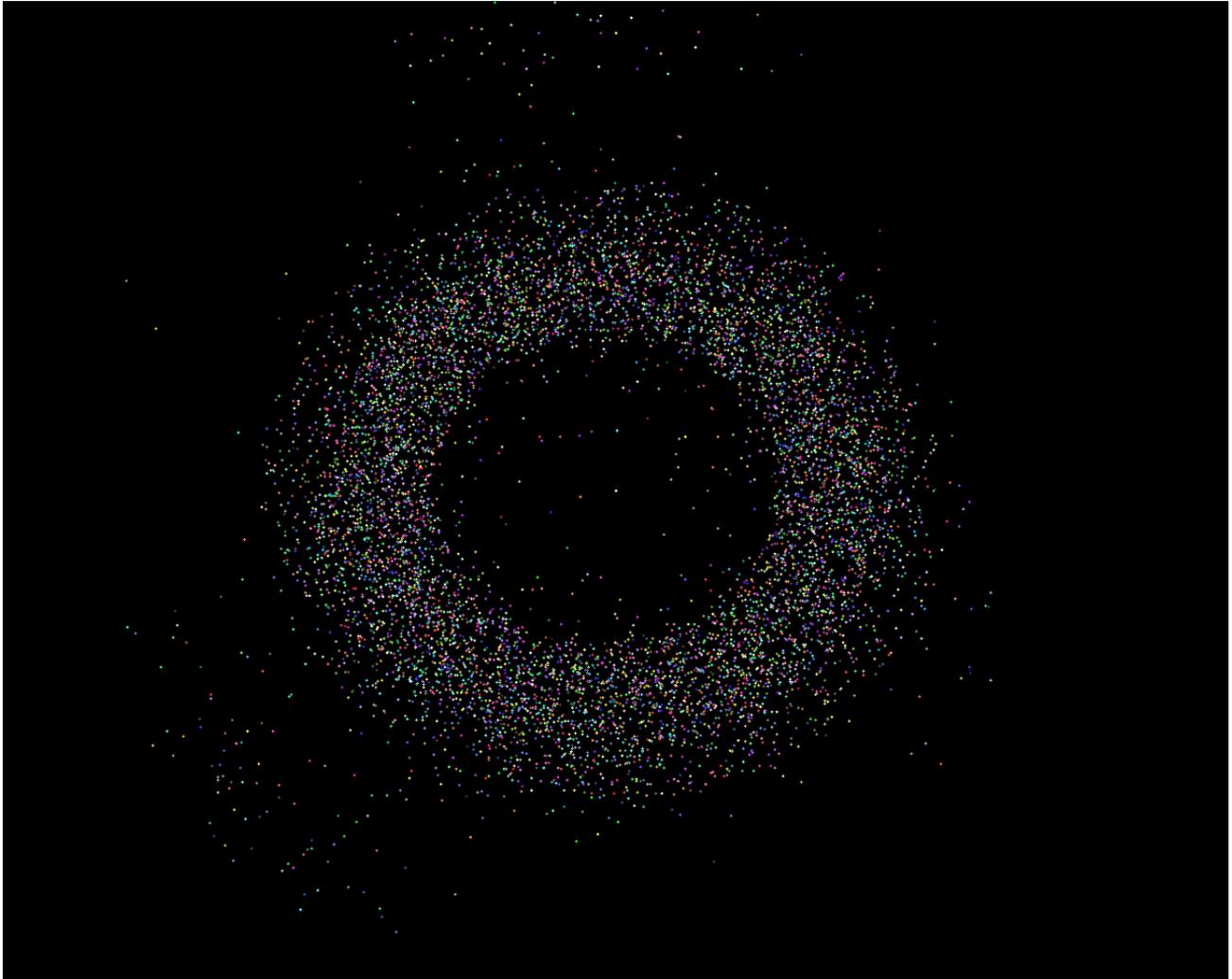


Figure 5: The positions of the first 10 000 asteroids on November 3rd, 2015. Most of them are in the asteroid belt, but Jupiter Trojans can be seen as well.

Generally, two types of orbits are possible in the asteroid belt: those that are stable for long time periods (like in geology, we speak here of periods of a billion or so years) and those that are not. A body that has a stable orbit will stay on it for a very long time. On the other hand, a body that has an unstable orbit, will suffer drastic and rapid changes of it, and be mostly either transferred into a stable orbit, or thrown out of the asteroid belt, and very often also out of the Solar System itself. It is no wonder that most asteroids we know of are in stable orbits, and those that we want to find most desperately are those in unstable orbits, as some of those can bring the asteroid to a collision with Earth (or some other planet, of course). The search for such objects is very intense, and they are collectively called NEO's (Near Earth Objects), as some comets can be in this category too.

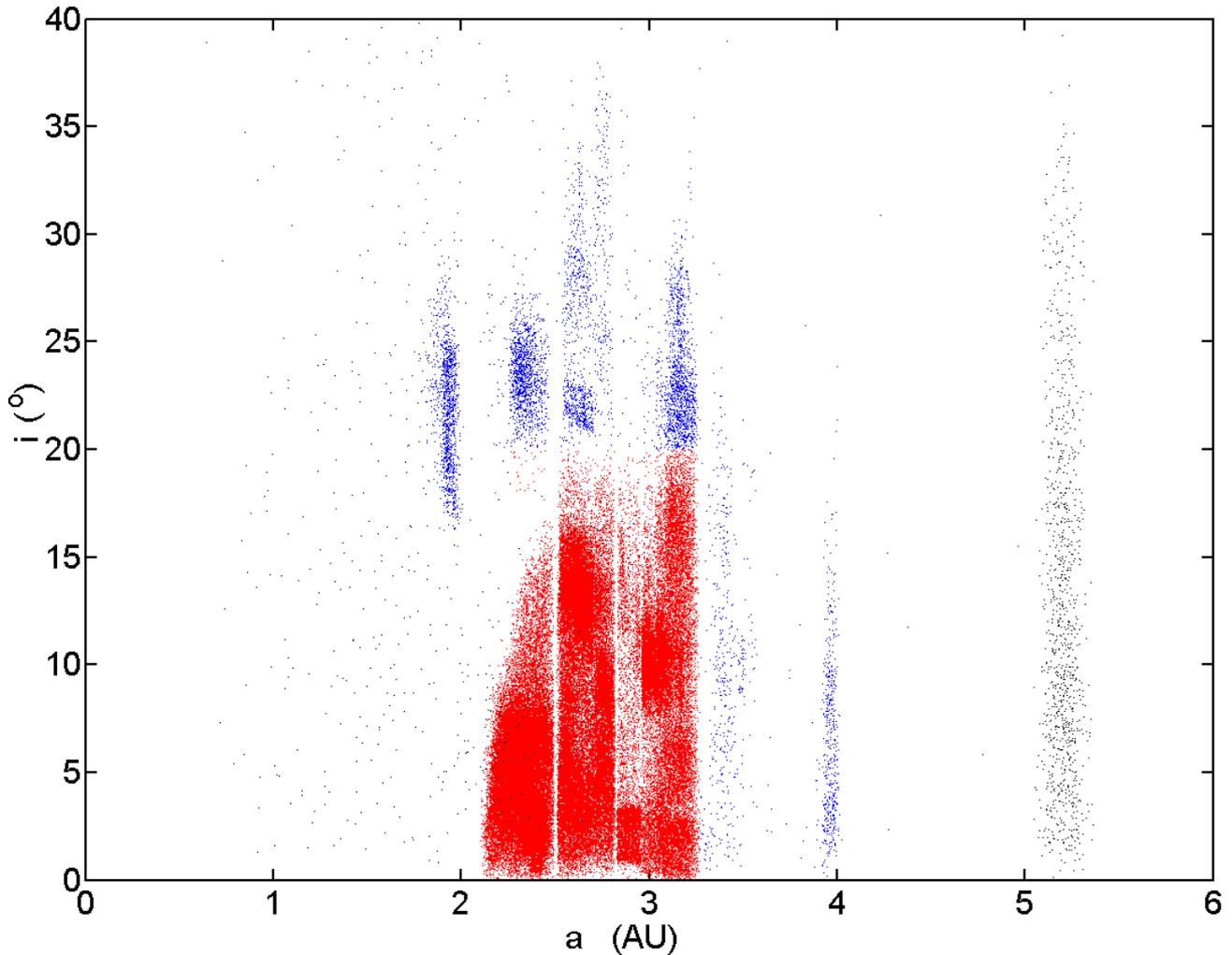


Figure 6: The plot of orbital inclinations versus distances from the Sun, with asteroids in the core region of the asteroid belt in red and other asteroids in blue (Source: Wikipedia commons). Resonance gaps can clearly be seen, as well as Jupiter Trojans at 5.2 AU.

Most asteroidal orbits in the asteroid belt are similar to planetary orbits: they are elliptical, and concentrated near the ecliptic plane (the plane of the Earth's orbit). However, the eccentricities and inclinations (inclination is the angle between an orbit and the ecliptical plane) can be quite large, in comparison with a planetary orbit. Zones of unstable orbits are empty, for obvious reasons, thus creating gaps in the distribution of asteroidal orbits (see Fig 6). If it could be seen from above, the asteroidal belt would look like the rings of Saturn in XXXL size, but with a much lower density of its "particles".

A much smaller number of asteroids populates special places in the Solar System. The most known are Trojans and Greeks, two asteroid groups which populate the so called Lagrangian points on the orbit of Jupiter. The points in question lie 60 degrees before and after Jupiter itself, and any body near such a point will be kept there for a long time due to the interplay of gravitational forces of the Sun and Jupiter. Three other Lagrangian points do exist, but bodies near them are not kept there. Instead they are slowly swept away from them unless some other force (for example a rocket motor of a space probe put there intentionally) keeps them there.

A group of asteroids with similar orbits is called a family, and it seems that some families are actually made of fragments left after a collision of two large bodies somewhere in the past. Some families are in the NEO category, like Atens (semi-major axis < 1 AU but can cross the Earth's orbit, Apollos (it can cross the Earth orbit) and Amors (orbits

outside the Earth's orbit so strictly it does not cross it but can come close). There are even a few asteroids that orbit the Sun closer than the Earth itself, never reaching it. These are called the Atiras or Apohele asteroids.

All other planets do have Lagrangian points too, but due to their much weaker gravity, they are not so effectively populated with asteroids. As an illustration, a small asteroid populating a Lagrangian point of Earth was discovered recently. It was effectively a small natural moon of our planet for about 18 months, after which it left the Lagrangian point and separated itself from the Earth (Wiki 2015b). As contrast, Greeks and Trojans are kept near the Lagrangian points of Jupiter for millions of years, or more.

Last, but not least, some planetary satellites are captured asteroids (asteroids that came close to a planet and were finally brought into orbit around the planet itself). The most obvious example is two Martian satellites, and it seems that some large satellites of gas giants (Jupiter to Neptune) are captured dwarf planets or asteroids.

Let us conclude this section by correcting a popular misconception: regardless of the large number of asteroids, they are so small in comparison with the size of the asteroid belt itself, that the asteroid belt is mostly empty interplanetary space. If one would sit on an asteroid, it could take eons before another one comes close enough to create some danger of a collision. It is the enormous time span in which the belt exists (which is actually close to the age of the Solar System itself), that makes such collisions happen from time to time. So the popular pictures from books or movies, that show the asteroid belt as space densely packed with asteroids and boulders of various sizes is totally wrong.

5. The size and shape of asteroids

The largest asteroid, Ceres, is about 975 km in diameter, and is now considered a dwarf planet. The next in size are Vesta and Pallas, both with a size of about 500 km. All other asteroids are much smaller. There is no fixed lower limit of asteroid size, but around the size of 10 m or so the objects are started to be called meteoroids. The somehow strange name denotes a small solid object in orbit around the Sun. If such an object enters a planetary atmosphere and ablates in it due to intense friction caused by its large relative velocity to the planet, the name changes to meteor, and if anything survives this fierce flight through the atmosphere (meteors can appear in any planetary, or satellite, atmosphere, not only in the atmosphere of the Earth), the remaining "rock" resting on the planetary surface is called a meteorite.

Concerning the shapes of asteroids, Ceres is approximately round, indicating that it is massive enough for the hydrostatic equilibrium to take place inside it. Because of that, it was moved into the dwarf planet category. Vesta has a much more irregular shape (see Fig. 7), and other asteroids have any possible shapes (see Fig. 8). The shape of an asteroid is the consequence of collisions that it had with other objects in its past. Mostly, there were many such collisions with small objects, and some asteroids were created as fragments of two large bodies that were destroyed in one gigantic mutual collision. We now have images of about a dozen asteroids gathered by space probes (see Fig. 9), and their surfaces are usually quite old, based on the fact that they are heavily cratered (each crater is the result of a collision with a small body). Apart from the few largest asteroids, all others are too small to have active geology that would modify the surface in any way, so the collisions, the solar wind and solar radiation are the only factors that are changing the surface of an asteroid. The mass distribution of asteroids is illustrated in Fig. 10.

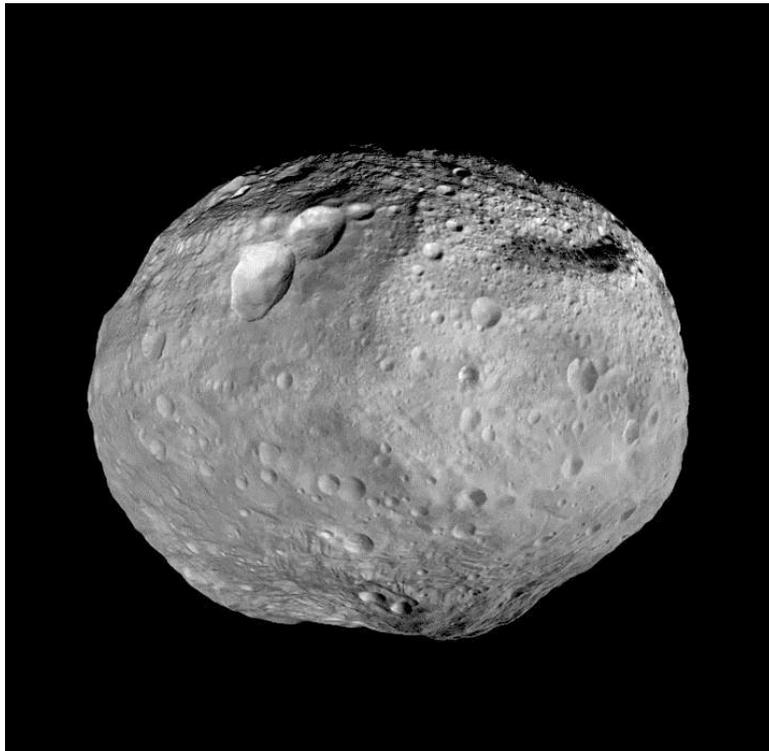


Figure 7: A closeup of Vesta, showing its non-spherical shape and complex surface. (Image: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA, Dawn mission).

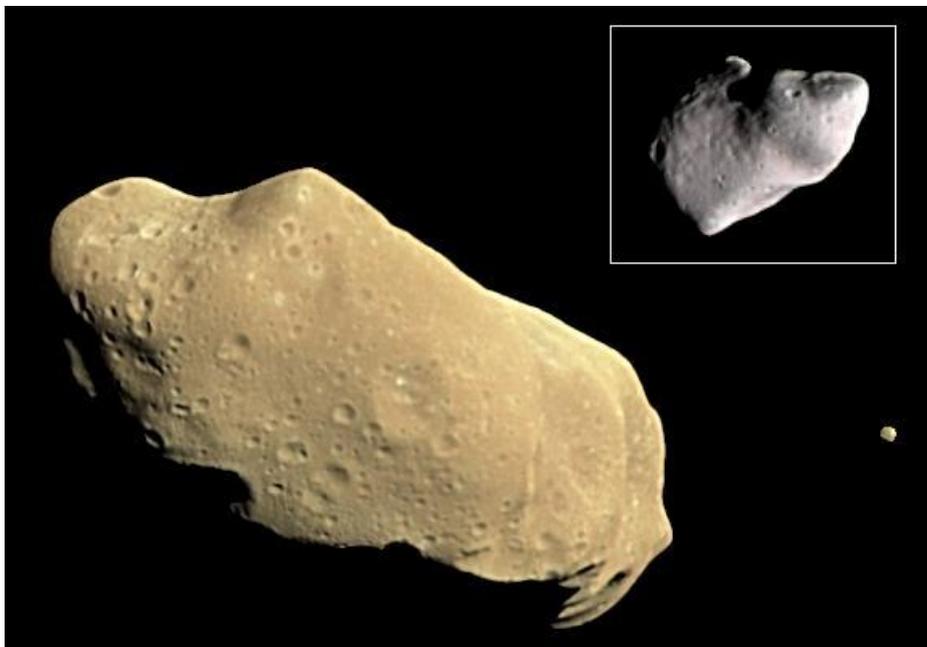


Figure 8: Asteroid Ida and its small moon Dactyl (enlarged image in inset). Ida is about 52 km long, and the size of Dactyl is about 1.5 km. (Image: NASA, Galileo mission).

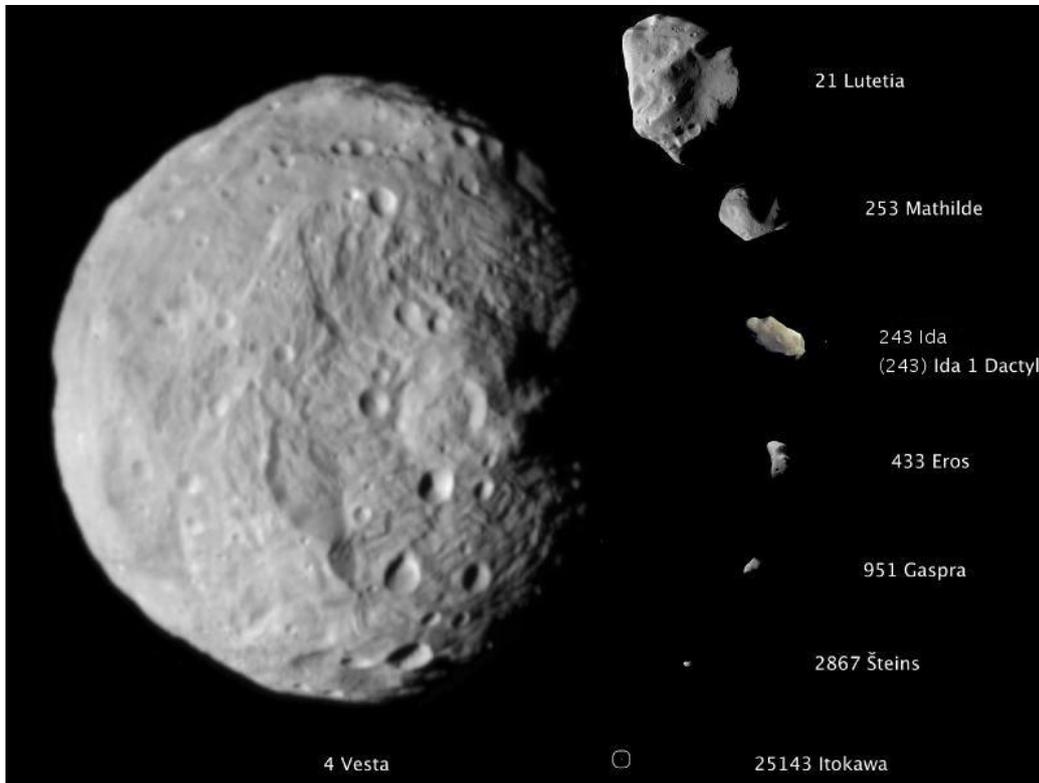


Figure 9: A comparison of the sizes of most asteroids visited by a space probe (Source: Wiki Commons).

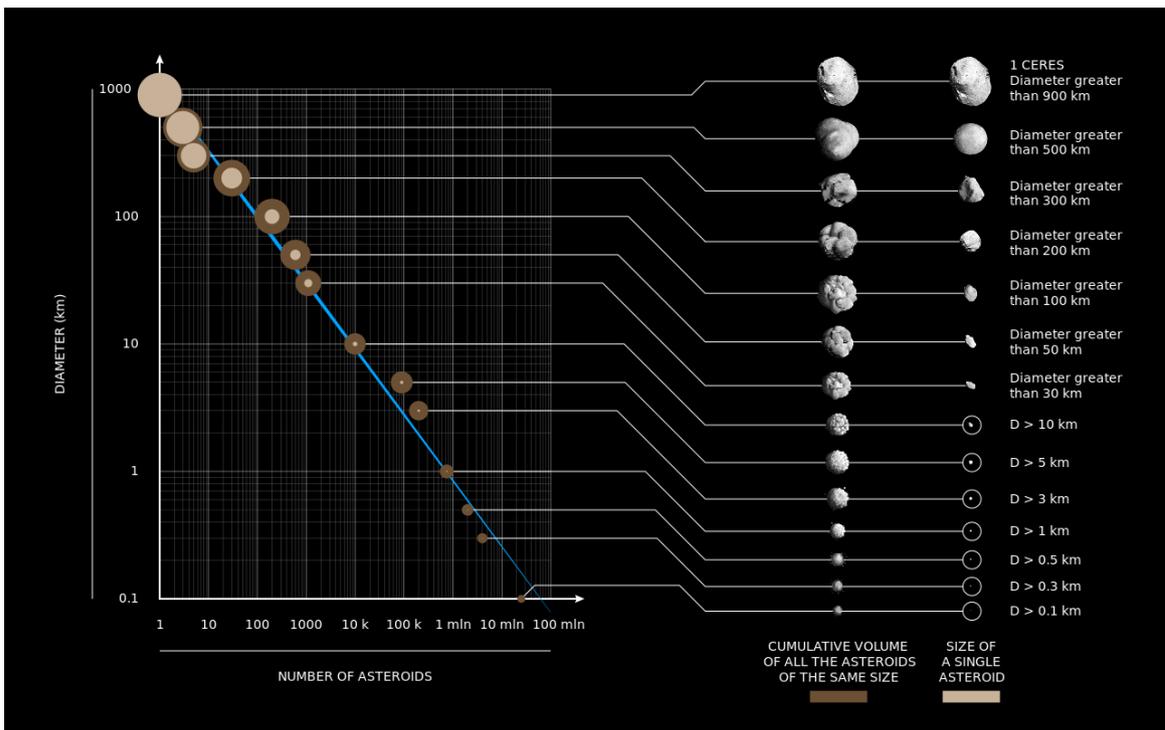


Figure 10: Mass distribution of asteroids (Source: Wiki Commons).

6. Surface and internal composition of asteroids today

Ceres is a differentiated body with a rocky core and a mantle composed mostly of ice. The surface itself is covered by a layer of dust generated by collisions with other small bodies and accumulated on the surface. The recent high resolution images of its surface indicate that it can still have an active geology.

Vesta too was studied by a space probe recently. The geological map of its surface (Fig. 11) shows many different regions. The whole surface is heavily cratered and seems to be old, with no indications of recent geological activity. The gravitational data gathered by the analysis of the probe motion indicate that Vesta also has a differentiated internal structure (see Fig 12).

Several other smaller asteroids were visited by space probes too. Some of them even have small moons, which are even smaller asteroids by themselves. They show a much larger variation in shape, but the surfaces are consistently heavily cratered and old.

Generally, the smaller asteroids can be anything from a solid chunk of rock (or even iron-rock combination), fractured rock and ice mixture to the so called pile of rubble (an agglomeration of small pieces of material held together only by the weak gravity of the asteroid in question). Accordingly, the porosity of an asteroid can be anywhere between 0% and 80%.

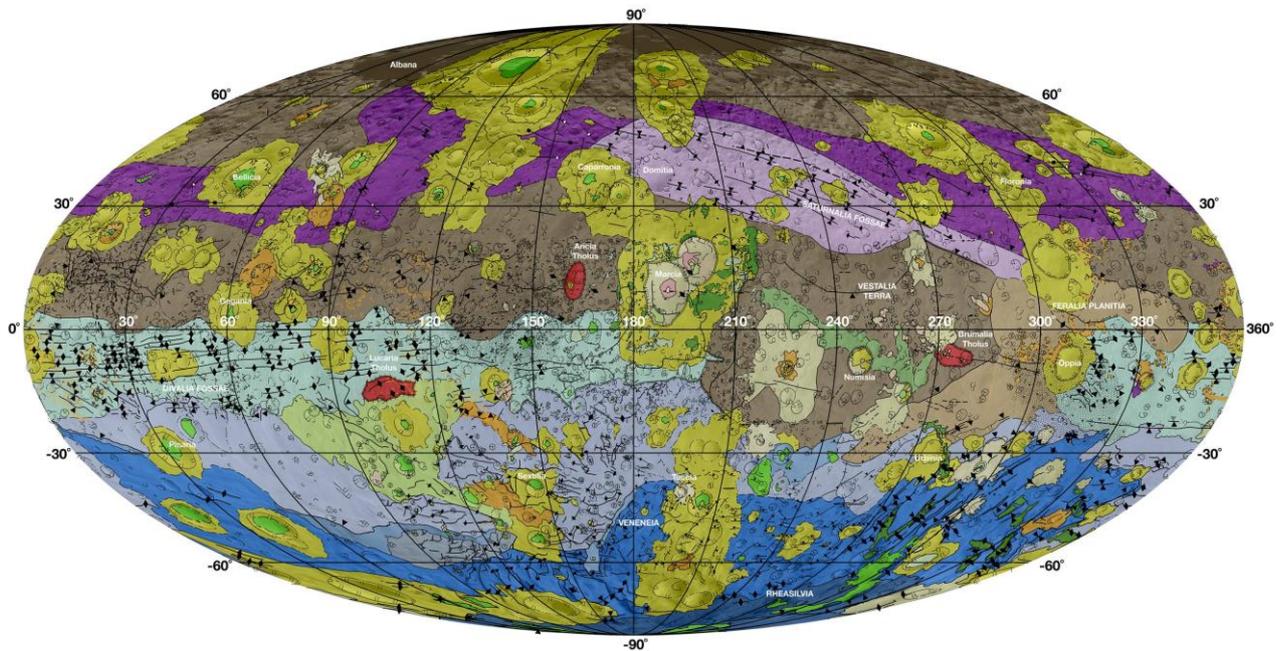


Figure 11: The geological map of Vesta. The map was produced from data about spectral reflectivity of the surface, collected by Dawn Mission. The most ancient and heavily cratered regions are brown; areas modified by the Veneneia and Rheasilvia impacts are purple (the Saturnalia Fossae Formation, in the North) and light cyan (the Divalia Fossae Formation, equatorial), respectively; the Rheasilvia impact basin interior (in the South) is dark blue, and neighboring areas of Rheasilvia ejecta (including an area within Veneneia) are light purple-blue; areas modified by more recent impacts or mass wasting are yellow/orange or green, respectively (Williams et al 2014).

From a mineralogical point of view, the asteroids can be composed of very different constituents: iron/nickel composites, often interveined with silicates (or vice-versa, depending on the relative abundance of the two classes of material), silicates or ice (water and ices of other volatile compounds). We know today that most meteorites are

asteroidal in origin and in some cases we even can relate a class of meteorites to its parent asteroid (or planet). We are today sure that we have meteorites that were part of the Moon, Mars, asteroid Vesta, etc., and there are strong indications that a few meteorites are from Mercury. Today, the only means to study the mineralogical composition of those bodies is directly.

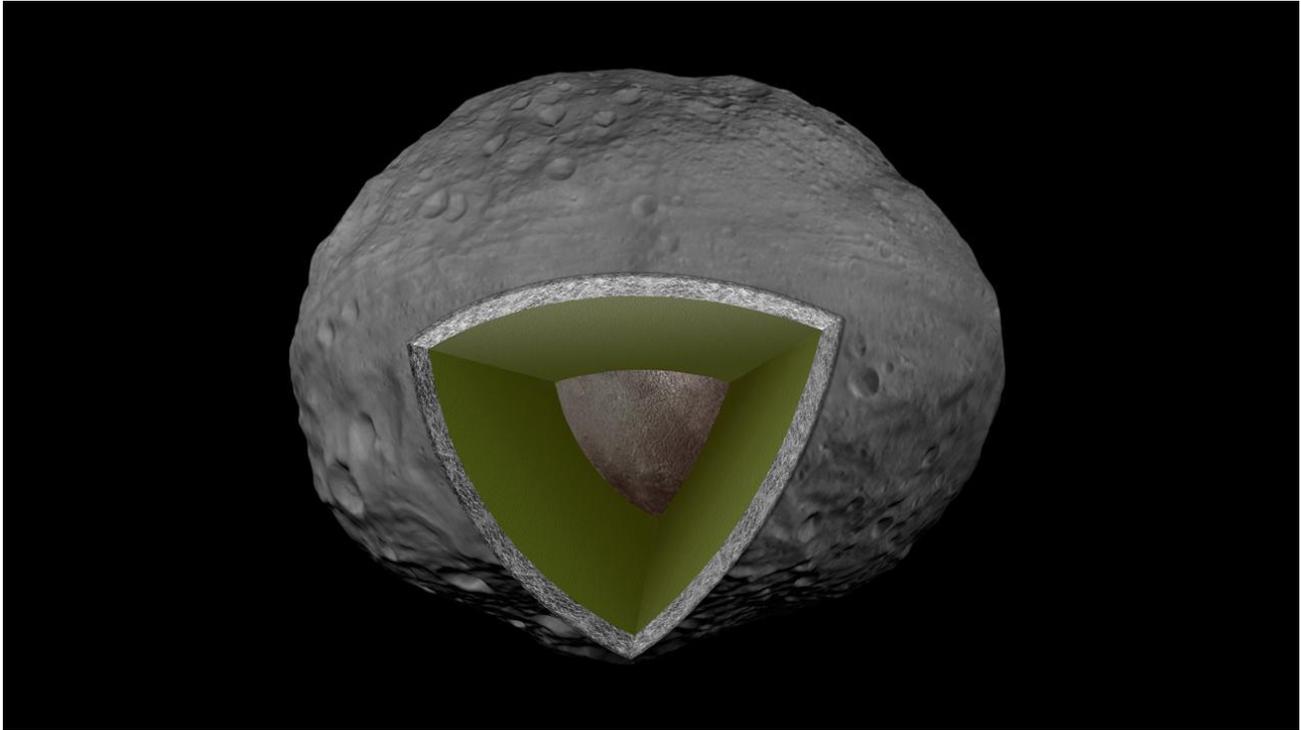


Figure 12: A model of the internal structure of Vesta. The model predicts a metallic iron–nickel core about 220 km in diameter, an overlying rocky mantle, and a relatively thin surface crust. (Image: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA, Dawn Mission).

7. Mining the asteroids?

Asteroids do contain a lot of different valuable materials that are of interest for space and Earth-based technologies. The idea of mining celestial bodies is almost 100 years old, and it appeared in the first books about rocket-space science even before it was taken over by science-fiction literature. A few decades ago it was again taken seriously into consideration, and was studied from all aspects of science from then on. We are today technologically capable of capturing a small asteroid (say a few tens of meters in diameter) in one of Earth's Lagrangian points, or even in a closer Earth-bound orbit, where tests of basic mining operations in space can be performed. However, the costs of such an operation are still very high, and the potential risks should be taken care of very carefully. Even such a small asteroid, if misdirected, can do a lot of harm on Earth. Remember that the Chelyabinsk meteorite was about 15 m in diameter, but the damage it caused on the ground was formidable (Popova et al 2013).

Let us conclude this short section with an estimate of the current value of raw materials contained in a 10 m diameter nickel-iron asteroid: approximately 2.5 million \$ (Lewis 1996). For sure, not enough to even cover a small fraction of the launching costs, not to speak of the whole mining mission, but consider a 100 m one: its value is already about 2.5 billion \$. With the launching costs dropping, and resources on Earth being rapidly used-up, this could soon be economically feasible. A possible mining operation on a small asteroid put into an orbit around the Earth is illustrated in Fig. 13.



Figure 13: An artist's concept of mining a small NEO asteroid (brought into a stable orbit around Earth) and using gathered materials for building solar panels for satellites. (Source: Wiki Commons).

8. Names and designations of asteroids

The system of naming asteroids was almost unchanged up to the middle of the last century, when IAU set more rigid rules. The naming right still remains in the hands of the discoverer, but the name has to be in accordance with a few basic rules (for instance, names of living politicians are not allowed anymore) and becomes official only after the naming commission, set by the IAU, approves it. Also, as the number of known asteroids exploded in the last decades, most of them do not have names, only identification numbers, which are assigned only after the orbit of the asteroid in question is known well enough to allow determining its position in the near future with enough accuracy to be able to find it with the current instrumentation. They may get a name in the future, but it is not required. Those that have names are often named after living persons of various professions and importance. Also, a lot of names from mythologies of people of the Earth are being included, thus removing the exclusive dominance of Greek and Roman mythology from the previous era. Additionally, a NEO can be only named after gods and deities from old mythologies (not restricted to Greek and Roman mythologies only).

When discovered, new asteroids receive a temporary designation that roughly identifies the time of discovery and the number of asteroids discovered in this time interval. The asteroid is followed-up, and when, and if at all, enough observations of it are gathered for its orbit to be calculated with enough precision that it could be found again in the near future based only on the orbital elements, it receives a permanent number, which is simply the ordinal number of the asteroid on the list of known asteroids. The whole procedure is carried out by the IAU but is delegated to the Minor Planet Center (MPC 2016), which acts as the world-wide clearing-house for asteroids. This secures the consistent data

quality and also removes the possibility of parallel double designations and mess that would be generated by multiple designations and very similar (but not identical) orbital elements of one and the same asteroid.

The discoverers (which nowadays are very often not single persons, but institutions or groups that run the particular search program) have the naming rights, and names are given to new asteroids at a faster rate than anytime before. However, the number of known asteroids grows so rapidly that most of them do not get named, and are referred to only by their asteroid number. As illustration, only about 19 5000 asteroids are named up to date, out of about 430 000 numbered ones.

We will conclude this text with a table of named asteroids that have some connection to Croatia (Table 1). Most of them were discovered from Croatia or by Croatians, but some were named in honor of some important person or event. We should conclude this paper with the fact that our colleague Korado Korlević, the founder of the observatory Višnjan, discovered 1283 numbered asteroids. This makes him one of the most prolific human discoverers of asteroids of all time. All modern asteroid surveys are multi-people, often also multiple-observatory projects utilizing fully automatic data gathering and analysis, resulting in tens or even hundreds of thousands of new asteroids. The discoveries of such projects are attributed to the project itself, and not to its single participants.

Last, but not least, one of the most successful camera networks for the study of meteors is active in Croatia. It encompasses a very wide range of participants, from school children, amateur astronomers, students, etc. but is coordinated by three professionals: Korado Korlević from Višnjan Science and Education Center, Damir Šegon from Astronomical Society Istra, Pula and the author. One of the large successes of this network is recorded fall and the collection of the Križevci meteorite (Borovička et al 2016), the 5th officially recognized meteorite from Croatia (Meteoritical Society 2016).

Table 1: A short list of asteroids whose names are related to Croatia or its people.

Asteroid number and name	Year and place of discovery	Discoverer
142 Polana	1875 Pula	Palisa, J.
143 Adria	1875 Pula	Palisa, J.
183 Istria	1878 Pula	Palisa, J.
589 Croatia	1906 Heidelberg	Kopff, A.
1444 Panonia	1938 Konkoly	Kulin, G.
1550 Tito	1937 Beograd	Protić, M.B.
1554 Yugoslavia	1940 Beograd	Protić, M.B.
1605 Milankovitch	1936 Uccle	Đurković, P.
2244 Tesla	1952 Beograd	Protić, M.B.
7295 Brozovic	1992 Kushiro	Ueda, S., Kaneda, H.
7364 Otonkucera	1996 Višnjan	Korlević, K.
8422 Mohorovicic	1996 Farra d'Isonzo	Farra d'Isonzo Observatory
9244 Visnjan	1998 Višnjan	Korlević, K., Radovan, P.
9429 Porec	1996 Višnjan	Višnjan
9657 Ucka	1996 Višnjan	Korlević, K., Matković, D.
9813 Rozgaj	1998 Višnjan	Korlević, K.
9814 Ivobenko	1998 Višnjan	Korlević, K.
10175 Aenona	1996 Višnjan	Korlević, K., Matković, D.
10201 Korado	1997 Farra d'Isonzo	Farra d'Isonzo Observatory
10241 Milicevic	1999 Višnjan	Korlević, K.
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Sažetak

Asteroidi

Asteroidi su najveća mala tijela Sunčeva sustava. Danas se intenzivno proučavaju iz nekoliko razloga. Kao prvo, neki asteroidi (tzv. NEA podvrsta) mogu se sudariti sa Zemljom, a posljedice takva sudara bile bi katastrofalne. Drugo, na njih se gleda kao na potencijalni izvor materijala koji na Zemlji postaju rijetki, a koji će ionako biti potrebni za svemirske konstrukcije budućnosti. I treće, oni čuvaju tajne postanka Sunčeva sustava i njegove evolucije do danas. Na kraju, kako je nekoliko hrvatskih znanstvenika nedavno počašćeno nazivanjem asteroida po njima, dan je i kratak opis postupka imenovanja i popis asteroida čija su imena povezana s našom zemljom i njezinim ljudima.

Ključne riječi: Sunčev sustav, asteroidi, rudarenje asteroida

